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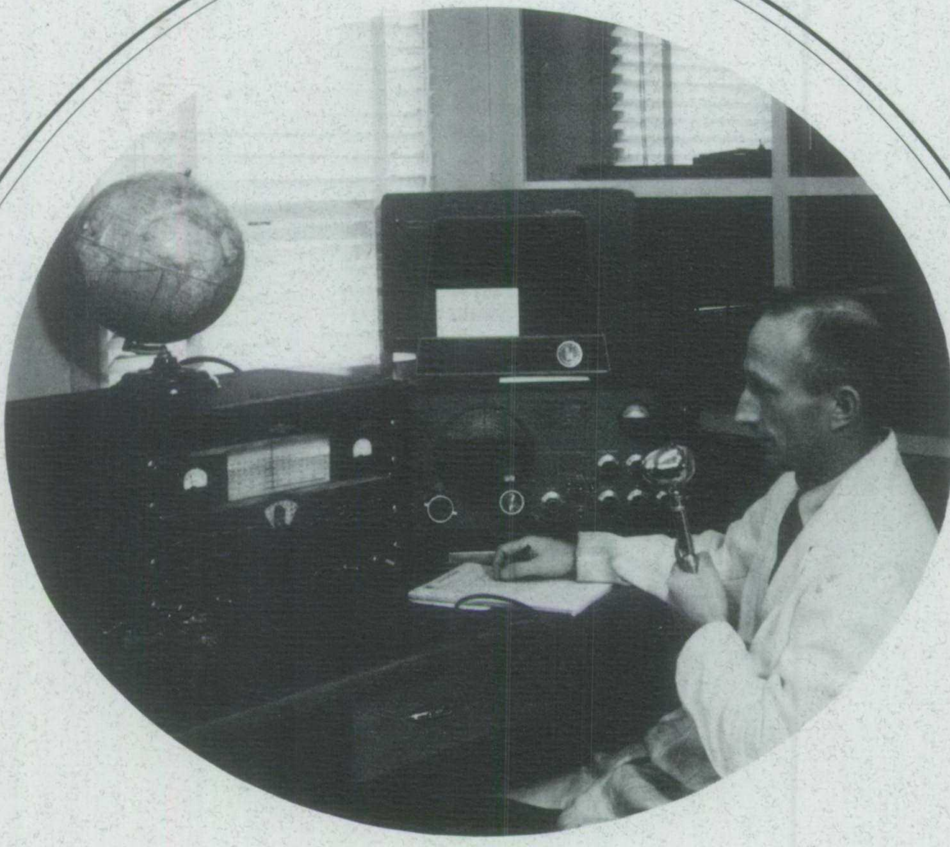

RADIO COMMUNICATION IN CANADA: AN HISTORICAL AND TECHNOLOGICAL SURVEY

Sharon A. Babaian

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Cover photo: *George Horner, chief radio engineer for the Hudson's Bay Company, 1937–1970, broadcasting from the radio laboratory in Winnipeg, c. 1948. Hudson's Bay Company Archives Provincial Archives of Manitoba, neg. no. 60-46.*

Contents

Abstract

The history of radio communication in Canada began officially in 1901, when two small federal government installations began operating across the Strait of Belle Isle at the northern tip of Newfoundland. Later that same year, Guglielmo Marconi conducted his famous transatlantic experiments between Poldhu, Cornwall and St. John's, Newfoundland. While the long distance work of Marconi and others captured the imagination of many people, the main business of radio at this time was marine communication. In the context of international economic and military competition, the ability to communicate with ships at sea was of vital importance. Thus, once it was clear that radio provided a viable, if far from perfect, means of communicating with vessels at sea, shipping interests and governments around the world began to develop extensive coastal and ship-borne radio systems. The system of marine radio stations in Canada grew rapidly after 1901 under the direction of the federal government. Development began on the east coast and St. Lawrence River and then expanded to the Pacific coast around 1908 and to the Great Lakes after 1910.

Because marine communication was the most glaring gap in the systems built around the telegraph and telephone, governments tended to concentrate their attention on it. This preoccupation was reinforced by the limitations of existing technology which severely restricted the ways in which it could be used effectively. The intense research and development that took place between 1914 and 1918 to improve radio for use in World War I expanded its capabilities to such an extent that a whole range of new applications became possible for the first time. Beginning in the 1920s, radio communication over land was used to link Canada's many remote regions and communities with the populated areas of the country and the world beyond. From the 1930s on, radio provided the only means of voice communication across the oceans (until 1957) and was increasingly used to maintain contact with moving aircraft, motor vehicles and people. Similarly important technological advances, notably microwave radar, resulted from war related research between 1939 and 1940. These further enhanced the place of radio in the emerging national and international communications networks.

Technologically, radio grew out of a series of breakthroughs in the related fields of electricity and magnetism that took place in the late 18th and early 19th centuries. Combined with a growing knowledge of electromagnetic waves and their behaviour in the mid-19th century, these advances drew the attention of many scientists and inventors. By the 1880s, various experimental systems had been devised to demonstrate the possibility of communicating using radio frequency electromagnetic waves, and by 1900, several inventors had viable installations in operation, some on a commercial basis.

The main trends in the development of radio technology from the time it was first established were: the move from spark-generated waves to continuous wave systems; the invention and application of vacuum tubes for amplification, reception and transmission; the move from the high-power, long wave formula for long distance work to short wave, lower power systems with directional antennas; the decrease in size of equipment resulting from the adoption of transistors and integrated circuits which has made possible such advances as cellular telephone.

Résumé

L'histoire des communications radio au Canada a débuté officiellement en 1901, quand deux petites installations du gouvernement fédéral sont entrées en exploitation pour assurer la liaison de part et d'autre du détroit de Belle-Isle, à l'extrémité nord de Terre-Neuve. Plus tard au cours de la même année, Guglielmo Marconi a effectué ses célèbres expériences de communication transatlantique entre Poldhu, en Cornouailles, et Saint-Jean de Terre-Neuve. Mais si les expériences de communication à grande distance menées par Marconi et d'autres ont capté l'imagination de bien des gens, à l'époque, la radio servait surtout aux communications maritimes. Dans un contexte de rivalités militaires et économiques, il était en effet d'une importance cruciale de pouvoir communiquer avec les navires en mer. Aussi, dès qu'il est devenu évident que la radio offrait un moyen viable, quoique très imparfait, d'établir la liaison avec les bâtiments en mer, les armateurs et les gouvernements du monde entier ont entrepris de monter de grands réseaux de communication radio entre les navires et la côte. Au Canada, le réseau de stations de radio maritimes s'est rapidement étendu après 1901, sous la direction du gouvernement fédéral. Il a commencé le long de la côte est et du fleuve Saint-Laurent, et s'est étendu à la côte du Pacifique vers 1908 et aux Grands lacs après 1910.

Parce que les communications maritimes représentaient la faille la plus évidente des systèmes s'articulant autour du télégraphe et du téléphone, les gouvernements ont eu tendance à leur accorder une attention particulière. Cet intérêt était avivé par le fait que les limites de la technologie existante en réduisaient les façons dont elle pouvait être utilisée avec efficacité. Les travaux de recherche et de développement intenses effectués entre 1914 et 1918, en vue d'améliorer la radio pour les besoins de la Première Guerre mondiale, en ont augmenté la capacité à un point tel que toute une gamme d'applications nouvelles sont alors devenues possibles pour la première fois. Ainsi, on a commencé au cours des années 1920 à utiliser la radio pour relier, à travers pays, les régions et collectivités isolées du Canada aux régions populeuses du pays et au monde extérieur. À compter des années 1930 (jusqu'en 1957), la radio a fourni l'unique moyen de communiquer par la voix avec les pays d'outre-mer et son usage s'est de plus en plus répandu lorsqu'il s'agissait de rester en contact avec des aéronefs, des véhicules automobiles et des personnes. D'autres percées importantes, notamment le radar hyperfréquence, ont été le résultat des recherches effectuées en 1939 et 1940 pour les besoins de la guerre. Elles ont contribué à rehausser le rôle de la radio dans les réseaux de communication nationaux et internationaux naissants.

Au plan technique, la radio est née d'une série de découvertes marquantes dans les domaines de l'électricité et du magnétisme, à la fin du XVIII^{e} et au début du XIX^{e} siècle. Ces progrès ont éveillé l'intérêt de plusieurs chercheurs et inventeurs, à mesure qu'on en apprenait davantage sur les ondes électromagnétiques et leur comportement, vers le milieu du XIX^{e} siècle. Dès les années 1880, il existait divers systèmes expérimentaux visant à démontrer la possibilité de communiquer par ondes radioélectriques. Au tournant du siècle, plusieurs inventeurs avaient mis au point des installations viables, dont certaines étaient exploitées commercialement.

Au fil du temps, la technologie de la radio a franchi les principales étapes suivantes : le passage des systèmes à éclateur aux systèmes à ondes entretenues, l'invention du tube à vide et son application à l'amplification, l'émission et la réception, le remplacement des systèmes à haute puissance et grandes ondes, servant aux communications à grande distance, par des systèmes à ondes courtes, exigeant moins de puisssance en raison de la directivité de leur antenne, et la réduction du volume du matériel, grâce à la mise au point des transistors et des circuits intégrés, qui ont permis des perfectionnements comme le téléphone cellulaire.

Foreword

Much has been written about the early pioneers of radio. The work of Maxwell and Hertz in the late 1800s and Marconi, de Forest and others around the turn of the century has been well recorded. Likewise, the development of radio broadcasting from about 1920 has been the subject of books and articles.

This has left a gap in radio history. The development of radio as a means of point-to-point communication from the early 1900s to the present is generally known only to those in the industry or to those involved in its day to day use.

When the National Museum of Science and Technology decided to produce an exhibit on the subject of communications, one of the objectives was to fill this gap with special reference to Canada.

The paper was researched and written in 1988/89 and was intended to cover the whole range of non-broadcast uses of radio. In addition to becoming the basis for one section of the proposed exhibit, it will be used to identify key developments and thereby guide the future growth of the National Collection in this area.

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Senior Curator,
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Introduction

The purpose of this paper is to outline the course of development of radio communication in Canada from the earliest days to the present, looking at some of the political, economic and commercial factors that influenced its direction as well as at the scientific and technological breakthroughs that made possible and improved and expanded its applications in society. The paper was originally written as a background report for the development of one section of an exhibit dealing with the history of communications technology in Canada. Since little, if anything, had been written on the subject of radio communication in Canada prior this report, the main objective was to establish how the technology and its uses evolved in Canada after 1901. This was best accomplished by using a narrative method and style of discourse.

As well, it should be noted at the outset that this paper relies heavily on government records, both archival and published, as sources of primary evidence. Although they do not tell the whole story of radio communication in Canada, these are by far the most comprehensive and systematic records available. The Canadian Marconi Company collection is also a valuable source, particularly of commercial information. But without comparable records from competing companies and individuals, the Marconi documents must be used with great care. Secondary sources on non-broadcast radio in Canada are virtually non-existent, though some information relating to Canada can be found in various British and American monographs and biographies. Needless to say, the author would welcome any information regarding the existence and location of sources other than those used here, not the least because this report is very much a starting point for research in the field.

The structure of this paper is quite straightforward. The first section is a lengthy discussion of the history of non-broadcast radio communication in Canada which touches upon the many different and important ways in which radio has been and is still being used in our society. Following this historical narrative is a brief description of the basic scientific principles upon which radio communication is based. This provides a foundation of understanding for the final section, which is an examination of the evolution of radio technology from the earliest mathematical equations and laboratory experiments through the rudimentary systems devised by the first inventors in the field and into the modern era of fully electronic radio technology.

1 The Early Years of Radio Communication in Canada

The history of radio communication in Canada began officially in 1901 when the federal Department of Public works established two radio or wireless (as they were called at the time) stations at Chateau Bay and on Belle Isle near the northern tip of Newfoundland. These stations were built to supplement the submarine cable connecting the north shore telegraph line with Newfoundland as it was prone to ice damage in the winter.[1] The stations communicated with one another using telegraphic code, a system which was known as wireless or radio telegraphy. This limited experiment with radio technology in typically harsh Canadian conditions laid the foundation for the adoption of radio communication as a common means of linking places and people which were inaccessible by telegraph or telephone lines.

The Canadian government's interest in radio arose from a variety of sources over the years. Of particular importance, however, were the need to promote trade through the maintenance of a safe and efficient shipping system and, later, the need to develop and to link the vast, isolated regions of the north into the economic and political framework of the nation. During the wars, strategic and defence concerns also became important motivations for expanding the use of radio.

Establishing Marine Radio on the Atlantic Coast

At the turn of the century, Canada was a young but rapidly developing nation. Its economy was largely export-based and its most important markets were in Great Britain, Europe and parts of the British empire. As a result, great significance was attached to maritime transportation and communication by Canadian businessmen and politicians. Any further developments in this field would naturally gain their attention, particularly those which promised to improve ship-to-ship and ship-to-shore communication on the North Atlantic. Thus it seems likely that Marconi's progress in Britain was followed with keen interest in certain circles in Canada.

And by 1901, when radio had its triumphant debut in Newfoundland and Canada, Marconi's progress had indeed been substantial. He had successfully demonstrated his system over increasing distances in Britain and elsewhere and his company had already secured two British government contracts for radio equipment—one with the War Office during the Boer War and the other with the Admiralty in 1900—both of which provided financial as well as public relations benefits for the fledgling organization. More importantly, in September 1901, an agreement was made with Lloyd's, the famous marine insurance company. Under the terms of the contract, the Marconi Company was to equip and operate a series of radio stations to improve communication and passage of information among their 1000 or more agents worldwide. For their part, Lloyd's agreed to use only Marconi equipment and to communicate only with other Marconi equipped vessels and stations. Given Lloyd's special dominance in the field of marine insurance and information, this contract and its exclusivity clauses not only convincingly reaffirmed the viability of the Marconi system, but also made it the obvious and sensible first choice of all shipping lines interested in acquiring radio equipment.[2]

Yet even though it had a significant headstart in the market place, the Marconi system was not the only one available at the time. There were other inventors, in other countries, working for different companies who were developing similar and sometimes better equipment for radio communication.

1. Thomas E. Appleton, *Usque ad Mare: A History of the Canadian Coast Guard and Marine Services*, (Ottawa: Department of Transport, 1968) p. 85; C.A. Hutchings, Superintendent of Lights to President, Halifax Board of Trade, 28 December 1901, Public Archives of Nova Scotia (PANS), MG 2/508 no. 1159, p. 5.

2. Hugh J. Aitken, *Syntony and Spark—The Origins of Radio*, (New York: John Wiley & Sons, 1976) pp. 232, 235–8; Susan J. Douglas, *Inventing American Broadcasting 1899–1922*, (Baltimore: Johns Hopkins University Press, 1987) pp. 70–1.

German inventors Ferdinand Braun, Adolf Slaby and George von Arco were working with two separate companies both of which were pursuing the same goal—a commercially successful radio system—in competition with one another as well as with Marconi. Their intense rivalry was ended by the intervention of the Kaiser in 1903 when they were amalgamated to form the Telefunken system which concentrated its competitive drive against Marconi and other non-German companies. With strong political support, this system quickly became an important force in the field of radio communication.[3]

Meanwhile in the United States, a different group of competitors had emerged. In 1897 the first American radio company was established—the United States Electrical Supply Company (USESCO)—by a Canadian, William Joseph Clarke. Incorporated one day before Marconi's first firm in England (19 July 1897), USESCO was manufacturing spark transmitters and receivers for sale as early as 1898. Clarke took responsibility for, among other things, demonstrating the capabilities of the company equipment at electrical shows, learned meetings and other public forums including the 1899 Canadian National Exhibition in Toronto. Together with Marconi, he reported the America's Cup yacht races of 1899 using his system in addition to Marconi's. The positive publicity arising from these and other demonstrations ultimately led to some commercial sales, to the U.S. Army Signal Corps for example.[4]

At the same time, another Canadian working in the United States, Reginald Fessenden, was employed by the U.S. Weather Bureau to develop "a network of wireless stations on the eastern seaboard for the exchange of meteorological data." After leaving there in 1902, he formed the National Electric Signalling Company with two Pittsburgh businessmen, Given and Walker, and set out to prove not only that his system could provide transatlantic radio communication just as well as Marconi's had, but also that he could accomplish feats that Marconi had not even considered, in particular wireless or radio telephony. Indeed, as early as 1901, Fessenden had patented a very high frequency alternator and, by 1904, his company was advertising radio telephone sets using a combination of high speed alternator and quenched spark gap for sale with a guaranteed range of 40 kilometres.[5]

Also at work in the United States at this time was Lee de Forest. He came into direct competition with Marconi in 1901 when they both attempted to report the international yacht races at New York by radio. Since neither could tune his apparatus, the attempted transmissions interfered with one another and the whole demonstration was a failure. De Forest, however, continued with his research despite this set back and went on to form a series of companies including the De Forest Wireless Telegraph Company which, within a few years, had won two important awards for radio, had proved the viability of long-distance radio over land under certain conditions, and had competed successfully against Fessenden and Telefunken for important U.S. Navy contracts.[6]

Marconi in Newfoundland and Canada

Nevertheless, Marconi's rapid technological progress to 1901, the contract with Lloyd's, and his close association with Britain and things British at a time when imperial sentiment was strong in Canada no doubt made a positive impression on the Canadian government and encouraged its officials to look favourably on the Marconi Company. This opinion can only have been reinforced by Marconi's decision to attempt to transmit and receive radio signals across the Atlantic, a move which, if successful, promised to expand the scope of marine radio communications on the primary shipping routes between Canada and its major trading partners. That Marconi's goals and the interests of the Canadian government were to a certain extent similar was not entirely coincidental. Marconi knew that the marine market was potentially very large and as yet only partially developed and he knew that the immediate commercial viability of his company (and therefore his ability to continue with his research) depended on its ongoing development. At the same time he was aware that development could best be accomplished by taking on new and greater challenges which would not only attract the attention of governments and other potential supporters or customers, but would

3. W. Rupert Maclaurin, *Invention and Innovation in the Radio Industry*, (New York: The Macmillan, 1949) pp. 38–9; Hugh J. Aitken, *The Continuous Wave: Technology and American Radio 1900–1932*, (Princeton: Princeton University Press, 1985) p. 179.
4. H.L. Chadbourne, "William J. Clarke and the First American Radio Company," unpublished manuscript, 5 March 1982, pages 4–6, 22–9, 31–3.
5. Aitken, *The Continuous Wave*, pages 51, 70–1, 62, 65; Maclaurin, pp. 59–60.
6. Aitken, *The Continuous Wave*, pp. 184–7; Maclaurin, p. 73.

also provide a more demanding testing ground for his equipment. The scheme to span the Atlantic met both these criteria and had the added advantage of having been widely dismissed as impossible making it that much more attractive to the determined young Italian and that much more useful as a publicity event.[7] Thus, by attempting transatlantic radio communication, Marconi was consciously appealing to governments like the British and, through it, the Canadian which he knew would have an interest in better communication on the North Atlantic for imperial and strategic as well as commercial reasons.

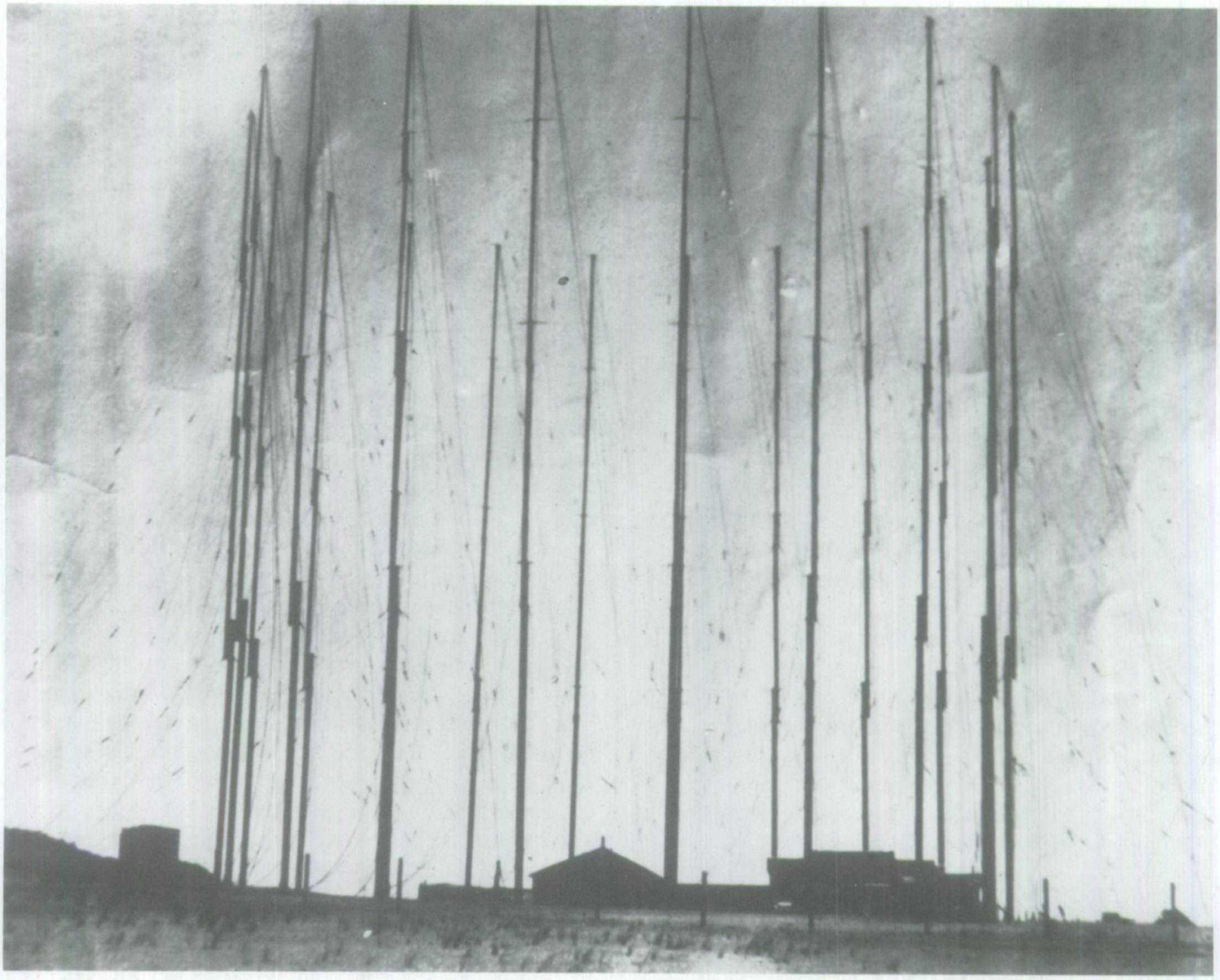
The attractiveness of Marconi's scheme was further enhanced for Canada when his original plan to undertake a two-way transmission between the stations at Poldhu, Cornwall and Cape Cod, Massachusetts had to be changed as a result of storm damage done to the elaborate aerial system which had been erected at the former site. Before leaving for North America, Marconi decided that the test should take place as planned but that, given the reduced capacity of the of the replacement aerial, a simple one-way transmission over the shortest possible distance should replace the grander original scheme. This decision was reinforced when a similar storm damaged the Cape Cod station. From Poldhu, the point of nearest landfall on the North American continent was (and is) Newfoundland, a British colony, and in December 1901, with the approval and assistance of the Newfoundland government, Marconi chose a site on Signal Hill in St. John's and immediately began to set up his temporary equipment.[8]

The receiving station at Signal Hill was a very simple arrangement made up of one on Marconi's "new syntonic receivers in conjunction with what was at the time described as a self-restoring coherer consisting of a glass tube in which a globule of mercury was retained between two iron or carbon rods" and this was attached to a telephone earpiece. It was assumed that this configuration would be more receptive to weak signals than the standard "coherer, relay and Morse inker combination." The type of aerial used was similarly basic—grounded earth plates connected to antenna wires around 150 metres in length sent and held aloft by a kite or a balloon. On December 10, 1901 after cabling instructions for transmission to Poldhu, an antenna was raised into the air but the following day, when the scheduled signals were sent, nothing resembling the letter "s" could be heard at Signal Hill. Marconi then decided to abandon the syntonic receiver because the swaying of the antenna in the gusting wind prevented proper tuning of the syntonic circuit. He replaced it with an untuned receiver only to have his experiments ended for the day by the loss of the balloon in the gale and the resulting collapse of the antenna. It was not until the following day after the loss of yet another aerial in the wind that a faint but audible series of "s" signals was heard first by Marconi and then by his colleague Kemp. The time of the first signal was recorded as 12:30 in the afternoon Newfoundland time.[9]

During the next few days, Marconi suffered a series of setbacks. When he attempted to duplicate the feat of the 12th of December, the stormy weather defeated him. The tests would have to stop until he could build a more sturdy mast-supported antenna or at least until the weather improved. This delay prompted Marconi to announce his results even though they could not be verified by any impartial observers. The announcement was greeted with scepticism not merely because of the lack of verification but also because scientists at the time were convinced that electromagnetic waves could "be expected to travel a little beyond the optical horizon, but would then travel tangentially outward into space" making a transmission of around 3200 kilometres over "a hump of ocean" more than 160 kilometres high seem impossible. As well, the announcement brought another setback for Marconi. The Anglo-American Telegraph Company which held monopoly rights in the field of transatlantic communications in Newfoundland told Marconi that they no longer considered his work experimental in nature and would take legal action to prevent any future attempts at transatlantic radio communication in the colony.[10]

Marconi, however, was undaunted and, far from allowing these problems to discourage him, he was able to use them to his benefit and continue on with his work. The scepticism of his scientific critics was, for the most part, respectful—few

7. Hugh J. Aitken, *Syntony and Spark—The Origins of Radio*, (New York: John Wiley & Sons, 1976) pages 229, 242–4.
8. R.N. Vyvyan, *Wireless Over Thirty Years*, (London: George Routledge & Sons, Ltd., 1933) pp. 25–9; W.J. Baker, *A History of the Marconi Company*, (London: Methuen & Co. Ltd., 1970) pp. 61–7; Douglas, p. 59. Both Vyvyan and Baker provide fairly detailed descriptions of the equipment used at Poldhu.
9. Vyvyan, pp. 29–30; Baker, pp. 67–9.
10. Baker, pp. 69–71; Douglas, pages 54, 59; Vyvyan pp. 30–1.



Antenna system erected at Marconi Wireless Telegraph Company station, Cape Cod, U.S.A. This system was similar to the one set up at the Marconi station at Poldhu in Britain. Both were destroyed by gales within weeks of one another in autumn 1901. Source: R.N. Vyvyan, Wireless Over Thirty Years *(London: George Routledge & Sons, 1933)* believed that Marconi had deliberately made a false claim, choosing instead to view the reported results as an unintentional mistake on his part. With his integrity and reputation intact, Marconi took this criticism as a challenge to prove what he knew to be true rather than as a bitter defeat. At the same time, the action of Anglo-American forcing Marconi to suspend his Newfoundland operations seemed petty and unfair to most observers including the Canadian and Nova Scotia governments whose officials "demonstrated their sympathy in a practical manner by inviting Marconi to visit them and state his requirements" for resuming his research in a Canadian location.[11]

The negotiations between Marconi and Canadian officials began with an exchange of letters and telegrams in the closing days of 1901. On the 20th of December, three days after Anglo-American had "served legal documents upon Marconi,"[12] the Canadian Minister of Finance, W.S. Fielding, wrote to Marconi in Newfoundland expressing his pleasure at the suggestion that the experiments might be continued in Nova Scotia and assuring him "of a cordial welcome," of "the co-operation of...Government officials" and of the absence of "difficulties" that might get in the way of his operations.[13] Marconi arrived in North Sydney on 26 December and toured a series of potential sites with G.H. Murray, Fielding's successor as premier of Nova Scotia. He spent two days with Marconi before the latter departed for Ottawa and Montreal and reported back to the Canadian finance minister that he was "satisfied an opportunity will be given Canada to participate in any benefits of [Marconi's] invention."[14]

The 1902 Agreement

By early January 1902, the Canadian government had entered into in formal negotiations with Marconi, leaving Marconi with the impression that financial support would be made available to him if he could meet certain basic requirements with respect to rates and erection and operation of stations. According to Lord Minto, Governor-General of Canada, who met and spoke with Marconi after his discussions with federal officials were concluded, Marconi proposed to establish a station in Cape Breton at an estimated cost of $60,000. He would agree to set rates no higher than ten cents/word for private messages and five cents/word for government and press messages in exchange for government financial support in setting up the Canadian station.[15] Having made his company's requirements known, Marconi left it to the government to work out the details of the agreement to their satisfaction and departed for New York and then England to continue his research and await formal approval of the arrangement from Ottawa.[16]

On the whole, Canadian officials were pleased with the proposed agreement and it received governmental approval on 29 January 1902. A week later, on 6 February 1902, the Marconi Company directors accepted the agreement and the government, at Marconi's request, prepared a formal, written version of the contract.[17] The fundamental premise of the agreement was that radio technology would reduce the cost of telegraphic communication "between Canada and other countries, especially the United Kingdom of Great Britain and Ireland," and that "such a reduction would be of great advantage to Canada." This potential advantage justified government support for Marconi's experiments in transatlantic communication and thus it was agreed that Marconi would build two stations, one in Nova Scotia and one in the U.K. The construction of the former station was to be subsidized by the Canadian government to a maximum of $80,000 with the payment schedule based on demonstrated progress at the site. Canadian "machinery, material and labour" were to be used in the construction process "as far as possible" and it was to be "understood that the assistance...provided by the Government...[would]...cover and include all charges for...patent rights or royalties," on the equipment in the initial station as well as in any future stations that the government might wish to build and equip with Marconi apparatus. Moreover the company would have to guarantee a

11. Vyvyan, p.31; Baker pp. 70–2.
12. "Wireless Telegraphy Across the Atlantic," *Electrical Review* 39, no.25 (1901) p. 766.
13. W.S. Fielding, Minister of Finance, Canada to Guglielmo Marconi, 20 December 1901, PANS, MG 2/508 no. 1163.
14. G.H. Murray, Premier of Nova Scotia to W.S. Fielding, Minister of Finance, Canada, 28 December 1901, PANS, MG 2/508 no. 1149.
15. Summary of a meeting between Marconi and Lord Minto, Governor-General of Canada, 7 January 1902, National Archives of Canada (NAC), MG 27 II B1 vol. 4, pp. 18–20.
16. Baker, p. 72; Vyvyan, pp. 31–3.
17. Marconi to W.S. Fielding, Minister of Finance, Canada, 6 February 1902, PANS, MG 2/508 no. 1155.

"fair and reasonable" price for any additional systems purchased by the government.[18]

With respect to rates, it was agreed that general transatlantic messages would cost 10 cents/word while government and press messages would cost 5 cents/word, sixty percent lower than cable rates at the time. Whatever their level, rates between Canada and the U.K. were never to exceed the rates charged between the U.K. and other points on the North American continent. The rates for marine communication were not specifically set by the agreement but it was determined that any tolls or charges levied for such messages would be collected by the company when its station or stations were involved and by the government when it owned and controlled the station receiving the message. Agents of the company or the government if and when it established its own stations would be responsible for collecting the tolls or charges due. The rates themselves and any changes to them had to be approved by the Governor in Council. The agreement further stipulated that Marconi messages once received in Nova Scotia would be transmitted on government telegraph lines at the same rate as regular telegraph messages across the country. That rate, however, was not to be less than the rate paid by Marconi to any private company providing a similar service for forwarding messages in the future.[19]

The agreement also accepted and reinforced the Marconi policy of exclusivity since it referred only to the requirement to accept and deliver messages transmitted from ships equipped with the "Marconi System." More important, from the point of view of Marconi domination of the commercial radio field in Canada, was the clause which seemed to give the company the option of building and equipping any or all of the radio stations which the Canadian government might decide were necessary in the future. Before beginning construction, the government had to give the Marconi Company one month in which to decide whether or not they were interested in taking on the project and then running the station themselves.[20] In later years, the interpretation of this section became the subject of a serious dispute between the government and the Marconi companies but at the time it seemed to reflect accurately the government's genuine confidence in the Marconi system.

Not everyone in the Liberal government of the day was happy with the arrangement made with the Marconi Wireless Telegraph Company and the Marconi International Marine Communication Company. The Minister of Public Works, Joseph Israel Tarte, expressed strong reservations almost from the outset. A strong Canadian nationalist, Tarte believed that Canada should not give anyone "the privilege of controlling...the entrance to our telegraph system." He argued that since Marconi, even at that time, was "not the only man in the world" in "control of wireless telegraphy," it would surely be possible to enter into a more limited agreement in which royalties could be paid to the company but ultimate control of the stations and the system as a whole would remain in the hands of the government. Certainly, he maintained, Canadians had a right to expect a policy that protected their interests in this important field rather than one that promoted the commercial position of Marconi and Lloyd's, or any other non-Canadian entity for that matter.[21]

It seems likely that Tarte's opposition to the agreement with the Marconi companies was based more on his instinctive resistance to any policy that might diminish Canada's ability to act independently in pursuing her own national interests than on a thorough understanding of the potential of the new technology and of the importance of developing a considered approach to dealing with it. Moreover, in this opinion and many others, Tarte was at odds with the rest of the government (he left the cabinet in 1902 because he disagreed with its anti-protectionist tariff policy)[22] and his advice had no appreciable impact on his colleagues who did not share his suspicion of Marconi or the British connection that his company represented.

18. Memorandum of Agreement [hereafter cited as MOA] between Marconi's Wireless Telegraph Company, Limited and The Marconi International Marine Communication Company Limited and the Goverment of Canada, 17 March 1902, NAC, RG 12 E4 vol. 396 file 5604-11, pages 1-2, 4.
19. MOA, pages 3, 5-6.
20. MOA, pp. 4-6.
21. Israel Tarte, Minister of Public Works, Canada to W.S. Fielding, Minister of Finance, Canada, 10 January 1902, PANS, MG 2/508 no. 1160. Tarte suggested that the government should pay Marconi royalties for the use of his equipment thereby retaining greater control over the operation of the system. This was what his department had done for the two local stations it had erected in 1901 at Chateau Bay and Belle Isle.
22. Pelham Edgar, "Joseph Israel Tarte," *The Compact Edition of the Dictionary of National Biography, Volume II*, Main DNB O'Donnell—Zuylestein and Supplement, Twentieth Century DNB 1901-1960, (Oxford: Oxford University Press, 1975) p. 2919.

On the contrary, government officials at the provincial and federal levels were enthusiastic about Marconi's proposed work in Nova Scotia and the prospects it offered for improved marine communication. Some even advised the establishment of more stations and offered suggestions for their location and for additional experimental uses for them, such as boundary surveys and defining longitude and latitude.[23]

Government Policy and the Evolving Marconi Network

The 1902 Glace Bay agreement, though technically not the first between the Canadian government and the Marconi Company (the Public Works Department had two Marconi stations already in operation by 1901 at Chateau Bay and Belle Isle),[24] was, in many ways the beginning of government involvement in the development and expansion of radio technology in Canada. The roles it assumed as a consequence of this agreement and those that followed it were essentially those of sponsor and regulator. It took the initiative in developing marine radio networks in cooperation with commercial manufacturers. At the same time it controlled use of the new technology through its licensing power. No radio communication facility, whether amateur, commercial or government sponsored, could operate without a license from the federal government. Licenses were not easy to obtain, especially in the first few years, and, once granted, they usually contained strict guidelines for location, power levels, type of use and operating frequencies and times of each station. The government clearly expected research and development to take place on a continuing basis and was determined to take full advantage of any progress made, but government officials for the most part did not concern themselves with the details of technological advances in the field. Practical considerations dominated their approach to radio policy—demonstrated results, low cost, and access to an established network.

In the early years of the century, until about 1906, the Marconi companies were clearly the best equipped to meet the government's requirements. Indeed, during this period, both the commercial goals of Marconi and his associates and their methods of achieving them coincided well with what the Laurier administration wanted to accomplish in the radio field. Each of the parties to the agreement of 1902 sought to improve marine communication, particularly on the North Atlantic, as a means of enhancing their economic prospects. At the same time, both welcomed the opportunity to promote this goal by undertaking a grand experimental project which, because it claimed a more ambitious and appealing purpose—competition with the cables for transatlantic communication—was sure to command wide public attention and support. The fact that the proposed stations "were not well located for interconnection with the domestic landline telegraph networks, as they should have been if intercontinental signaling had been the prime objective" would no doubt go unnoticed by all but the most informed observers. Meanwhile the tests aimed at achieving full "radio coverage of the North Atlantic shipping lanes" could, it was hoped, be carried to a successful conclusion.[25]

In general, then, the Marconi companies were in an enviable position in early 1902 and other companies and inventors faced an uphill struggle, at least initially, in challenging their emerging network of radio stations, operators and equipment. The focal point of the Marconi system in Canada was the transatlantic station at Glace Bay, Nova Scotia. Completed late in the fall of 1902, the Glace Bay station was originally equipped with a second-hand 75 kw alternator powered by a steam engine. To the established spark technology of the day was added Marconi's latest invention, the magnetic detector. This detector was based on Rutherford's "discovery that electrical oscillations passed through a coil surrounding a magnetised iron wire will demagnetise the wire," and it proved to be an important advance on the coherer since it was both more sensitive and more stable than its predecessor. It quickly became standard equipment in most Marconi stations. The new station at Glace Bay, like its sister station at Poldhu, Cornwall, also had an elaborate new aerial system consisting of "four wooden towers, 210 feet [63.6 metres] high" which were "erected to form a square with the building so placed that the aerial insulator leading into the building came exactly in the centre of the square."

23. Department of the Interior official to W.S. Fielding, Minister of Finance, Canada, 14 March 1902, PANS, MG 2/508 no. 1164; C.A. Hutchings, Superintendent of Lights to President, Halifax Board of Trade, 28 December 1901, PANS, MG 2/508 no. 1159.
24. Canada, Department of Public Works, *Annual Report for 1902*, (Ottawa: King's Printer, 1903) p. 8.

25. Aitken, *The Continuous Wave*, pp. 243–4.

This structure supported 400 wires which formed a double inverted cone directly above the building.[26]

Yet despite all of these grand preparations, initial results from the two stations were disappointing. Transmitting from east to west in early November, the signals received in Nova Scotia were "very weak and unintelligible." After some unsuccessful adjustments to the aerials were attempted, the transmitting direction was changed, but Poldhu received no signals during the first experiment on 19 November 1902. Further changes were made which resulted in some improvement, however, there was still no consistency of performance. Marconi, characteristically, was discouraged but undaunted and decided to attempt to send the first transatlantic message from Canada to the U.K. via the *Times* correspondent, Dr. Parkin, on 15 December 1902. On the third try the attempt proved successful and, while it was held back for a few days because Marconi wanted the first messages to go to the kings of England and Italy, this was, in fact, the first radio message sent and received across the Atlantic. Thus, after a momentary false start, the Glace Bay station assumed the dual role that its promoters had intended: it quickly gained worldwide publicity and at the same time it provided an extremely challenging testing ground for new techniques and equipment.[27]

Meanwhile, as national and international interest became focused on the transatlantic experiments which "made good newspaper copy,"[28] Marconi's men and Canadian government officials could get on with the more mundane but equally important task of building and equipping a series of radio stations along Canada's east coast. On 13 May 1904, a further agreement was reached between the Marconi interests and the Canadian government. The initial contract was for the construction of five stations, three on or near the coasts of Newfoundland and Labrador—Belle Isle, Point Amour and Cape Race—and two in the Gulf of St. Lawrence—Fame Point and Heath Point. In August the terms of the contract were extended to include an additional Newfoundland station at Cape Ray.[29] These stations, which were all completed before the end of November of 1904 and which had efficient ranges of between 160 and 208 kilometres,[30] were owned by the government but operated by the company which received payments from the government of $5000 per station for construction costs and $2500 per station per year to meet maintenance, operation and repair costs. Like the agreement of 1902, this contract made provision for the setting of rates and collection of tolls and for the re-equipping of the stations with the latest inventions at "a reasonable cost to the government." Unlike the earlier arrangement, however, this one contained an escape clause for the government allowing it to withdraw from the contract one year after giving notice of its intention to the company if "the Marconi system of wireless telegraphy becomes superseded in utility by another system in general use." As well, the government reinforced its position vis-a-vis the company and perhaps also quieted some critics of its radio policy by declaring that "neither this contract nor any other heretofore entered into, shall be construed as giving to the Marconi Company an exclusive license for wireless in Canada or any part thereof."[31]

Despite the government's pronouncement to the contrary, however, it must have seemed to many observers that, for all intents and purposes, the Marconi Company did have a practical monopoly in Canada. By the end of 1905, the Department of Marine and Fisheries reported "13 wireless telegraph stations established for the benefit of navigation and commercial purposes" as well as three government ships equipped to receive messages. All were in the east coast/St. Lawrence region and all were built, equipped and operated "under contract with the Marconi Wireless Telegraph Company of Canada" which was licensed by the Minister of Marine and Fisheries. By 1907 the number had risen to 15 "consisting of nine high power stations, which have a normal range of about one hundred and twenty-five miles [200 kilometres], and six low power stations, which have a normal

26. G.E.C. Wedlake, *SOS: The Story of Radio-Communication*, (Newton Abbot, Devon: David & Charles Ltd., 1973) p. 35; Vyvyan, pp. 34–6.
27. Vyvyan, pp. 36–46. These pages provide a fairly detailed description of some of the early experiments carried out at Glace Bay between 1902 and around 1910.
28. Aitken, *Syntony and Spark*, p. 244.
29. Agreement [hereafter cited as Agreement] between Marconi's Wireless Telegraph Company, Limited and The Marconi International Marine Communication Company, Limited and the Government of Canada, 13 May 1904, NAC, RG 12 vol. 391 file 5604-1.
30. Canada, Department of Marine and Fisheries, *Annual Report for 1904*, (Ottawa: King's Printer, 1905) pp. 114–5.
31. Agreement, 13 May 1904, NAC, RG 12 vol. 391 file 5604-1.

Marconi and his staff outside the transatlantic station at Glace Bay, Nova Scotia. The men are standing in front of an antenna brought down by a heavy coating of ice, 6 April 1903. Source: R.N. Vyvyan, Wireless Over Thirty Years *(London: George Routledge & Sons, 1933)* range of about sixty miles [96 kilometres]."[32] At the same time, other companies and other inventors were lobbying the government in an attempt to obtain experimental and/or commercial licenses to operate in Canada; in most instances they met with little or no success.[33]

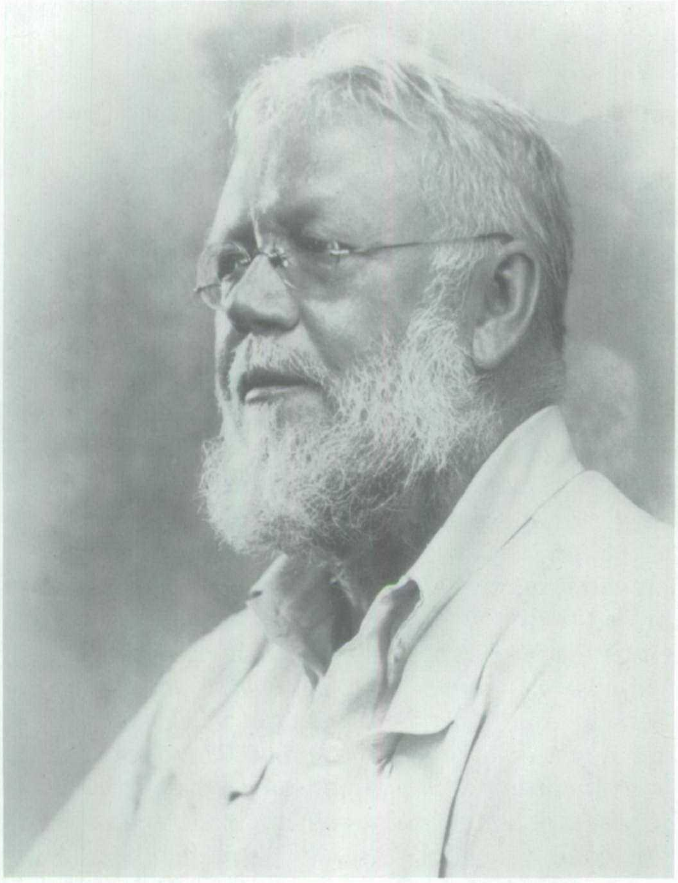
It cannot be said that the government was unaware of the existence of other viable radio systems. Indeed, as early as 1903, the Public Works Department had some equipment made by the American De Forest Wireless Telegraph Company in at least one of its stations and, by the following year, the Canadian branch of the company, Dominion De Forest, claimed to have two commercial operations in Toronto and Hamilton.[34] Moreover, in 1905, three years after Drs. Rutherford and Barnes had shown that wireless could be used to communicate with a moving train,[35] the Railway Commission sought government approval for a proposed system of stations along the transcontinental railway route using De Forest equipment. Two tenders were received to establish the series of stations in northeastern Ontario and De Forest significantly underbid the Marconi Company. A deal was struck between the Railway Commission and De Forest which included the stipulation that the stations must never be sold to the Marconi interests.[36]

As well, beginning in 1904, Reginald Fessenden, who was not without influential Canadian contacts, asked the government for permission to build a station at Sable Island. It was only the first of many such requests made by him between 1904 and 1910 and all of them were turned down.[37] John Stone Stone's company also approached Canadian officials in 1905 in an unsuccessful attempt to interest them in purchasing some of his equipment.[38] Finally, the fact that the first International Wireless Telegraphy Conference held in Berlin in 1903 recommended obligatory intercommunication between all coastal and ship stations and a free exchange of technological information towards this end, clearly demonstrated the existence of more than one active and viable system of radio in the shipping world.[39]

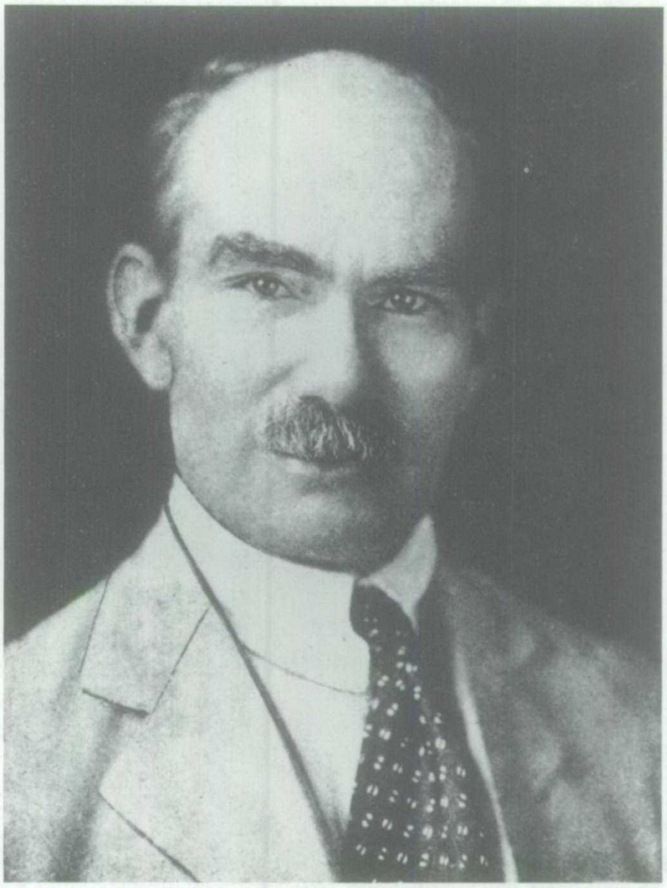
Nevertheless, the Canadian government remained reluctant to alter its approach to radio policy. There were two important reasons for this stance. Until 1906, the government was almost exclusively preoccupied with covering the North Atlantic shipping routes, an area in which Marconi was still overwhelmingly dominant. The obligatory intercommunication recommendation of the Berlin Conference was just that, a recommendation with no legal force[40] and, in any event, much of the traffic using routes served by the Canadian stations was already Marconi-equipped as a consequence of the company's early start in the field and this was not likely to change overnight since substantial investments had already been made.[41]

At the same time, Canadian officials were worried about the problem of interference between stations. This was a common concern at the time—

32. Canada, Department of Marine and Fisheries, *Annual Report for 1905*, (Ottawa: King's Printer, 1906) p. 12 and *Annual Report for 1907*, (Ottawa: King's Printer, 1908) p. 11.
33. For general information on the various applications made to the government for wireless licenses see the Department of Marine and Fisheries records in NAC, RG 42 vols. 491–4, 1037 and 1042. Information on De Forest can be found in the Laurier Papers, NAC, MG 26 G III pp. 112058–66. Also in the Laurier collection are papers relating to John Stone Stone, pp. 98570–603. The record of Fessenden's applications can be found in NAC, RG 97 vol. 85 file 6209-113.
34. Department of Public Works, station log book, NAC, RG 11 vol. 2001; Dominion De Forest Company official to Sir Wilfred Laurier, NAC, MG 26 G III vol. 266 pp. 73715–22.
35. Arthur S. Eve, *Being the Life and Letters of the Rt. Hon. Lord Rutherford, O.M.*, (Cambridge: Cambridge University Press, 1939) pp. 82–3.
36. Proposal and related correspondence in Laurier Papers, NAC, MG 26 G III vol 381 pp. 101448–478.
37. Fessenden made at least four formal applications for licenses during this period, one of which involved several stations. He also made requests for Canadian officials to visit his Brant Rock station in the U.S. and witness his system at work. These too were turned down. See NAC, RG 97 vol. 85 file 6209-113 for the official record.
38. Laurier Papers, NAC, MG 26 G III vol. 370 pp. 98570–603.
39. Baker, p. 96.
40. In 1903, no convention was signed by the participating nations. Instead "a final protocol was drafted and signed" by all delegations except the British and Italian and it was suggested that this form "a basis for discussion at a future conference." John D. Tomlinson, *The International Control of Radiocommunications*, [1938] (New York: Kraus Reprint Co., 1972) pp. 14–7; Canada, Department of the Naval Service, *Annual Report for 1912–13*, (Ottawa: King's Printer, 1914) p. 119.
41. The issue of intercommunication, which became an important concern in equipping the west coast stations in 1907–8, was not raised in connection with the east coast/St. Lawrence system of Marconi-operated stations even though the Marconi companies did not officially accept the policy until around 1912–13. See Naval Service annual reports for these years.



Reginald Aubrey Fessenden. Source: Department of Archives and History, Raleigh, North Carolina, neg. no. 50.



Lee de Forest. Source: Ellison Hawks, Pioneers of Wireless *(London: Methuen & Co. Ltd., 1927)*

Operating position in Fessenden's National Electric Signalling Company transatlantic station at Brant Rock, Massachusetts, 1906. Source: Department of Archives and History, Raleigh, North Carolina.

the Berlin Conference had discussed it at length—because, despite the development of syntonic apparatus, spark-generated waves did not lend themselves well to precise tuning. Although inventors like Reginald Fessenden were working relentlessly to replace spark technology with a continuous wave system that would solve the tuning problem (among others), regulators at the national and international level chose to pursue a more immediate solution. The Berlin Conference recommended that stations not be placed too close together.[42] The Canadian government agreed with this approach and maintained careful control through its licensing power. In addition it sought to achieve consistency in the type of station and equipment used in each region, believing that this would also help to limit interference.

This policy naturally favoured the status quo in Canada, that is, the emerging network of Marconi built, equipped and operated stations on the east coast. Even as new and better technology was developed (Fessenden had a continuous wave system working, though not for sale, by 1906)[43] the Canadian government stood firm in its policy because of the investment required to replace the whole Marconi system with a new one which was what its officials suggested it would have to do. (O.G.V. Spain and Ray Prefontaine both promoted the idea that one system should be used throughout Canada to prevent interference.)[44] Many companies, inventors and scientists no doubt disputed this interpretation and the restrictive policy which was based on it and at least one, Dominion De Forest, offered to prove, at its own expense, that interference was not a necessary consequence of using different types of equipment. In 1906, the president of Dominion De Forest requested permission to build a station on the Magdalen Islands stating that his company would take the station down if it was found to interfere with the existing stations in the region.[45] Apparently even this type of appeal did not move the government and, when a station was built on the islands in 1910, it was operated by Marconi.

Nor did the De Forest company or any other competitor in the field achieve much by moving the focus of their lobbying away from the east coast/St. Lawrence region to inland areas. De Forest's proposed contract with the Railway Commission was challenged not only because of the tendency of Marine and Fisheries officials to favour one system throughout Canada, but also because radio communication over land, though possible, was not as reliable as telegraph or telephone lines. That precisely the same criticism could, with justification, have been levelled at the Glace Bay transatlantic project might well have escaped men like O.G.V. Spain, Commander Canadian Marine Service, and Ray Prefontaine, Minister of Marine and Fisheries. On the other hand, the government's preoccupation with improving marine communication probably led them to view the latter experiment as being of greater value than the former. In any event the Railway Commission's plans were apparently abandoned and, despite later attempts by men such as Fessenden and Marconi to convince the government to develop a land-based system to link the major regional centres of Canada, the national radio communications network remained largely a marine system until after World War I.[46]

A Changing Government Approach to Radio

Though the general purpose of the radio network in Canada did not change substantially before 1918, the government's approach to achieving that purpose did shift discernably around 1906. In that year it became apparent that the Canadian government's goals and interests in the field were not necessarily the same as those of the Marconi companies and strains began to appear in relations between the two. Marconi officials at the time suggested that the cause of the problem was a change in personnel at the Department of Marine

42. Sir Robert Borden Papers, NAC, MG 26 H vol. 315 file 111; Tomlinson, p. 16.
43. Aitken, *The Continuous Wave*, pp. 72–5.
44. Department of Transport records, NAC, RG 12 E4 vol. 389; Laurier Papers, NAC, MG 26 G III vol. 381 p. 101606–8.
45. Laurier Papers, NAC, MG 26 G III vol. 420 p. 112058–66.
46. In the Department of the Naval Service, *Annual Report for 1911–12*, (Ottawa: King's Printer, 1913) p. 64, the importance of marine radio was made very clear. "It should be borne in mind that the wireless service is primarily intended for communication with ships at sea, as an aid to their navigation, and should the stations be loaded up to their capacity with inter-station business the real object of their maintenance would be defeated." It was not until 1920 that the government acknowledged that a land-based network might be worth developing. In that year, according to the Naval Service Annual Report, Marconi was issued licenses for stations at Winnipeg, Montreal, Toronto and Glace Bay. Canada, Department of the Naval Service, *Annual Report for 1919–20*, (Ottawa: King's Printer, 1921) p. 25.

and Fisheries[47] where two strong Marconi advocates had been lost—Ray Prefontaine died in December 1905 and O.G.V. Spain's name disappears from the annual radio reports around the same time. There may have been some truth to this claim but, at best, it provides only a partial explanation of the changes that took place because it ignores the larger issues that clearly influenced officials in Ottawa.

Regulating Radio: Berlin, 1906

By 1906 most well-informed observers at both the national and international levels were convinced of the great importance and future potential of radio communication. There was no longer any doubt about the immediate practical viability of the system; coastal stations were being established on most of the major shipping routes around the world, more and more ships were radio-equipped and the variety and effectiveness of systems on the market were growing steadily. In Canada specifically, ship owners, captains and the travelling public showed enthusiastic support for the services provided by the Marconi stations on the east coast and in the Gulf of St. Lawrence such that plans for upgrading and expanding the network were almost constantly being considered. Of the Canadian Marconi stations only Glace Bay remained experimental in character while all the others quickly became working and revenue-generating components of the international marine communications system.[48]

The obvious and increasing importance of this new technology led many governments to take a more active interest and role in determining its use. Even those countries which were not caught up in the industrial and imperial rivalry of the time saw radio as a vital commercial and strategic tool requiring vigilant regulation and control. On the international level, this led to the calling of a second international conference on radio in fall of 1906. The Berlin Convention, as it was called, ratified and gave legal force to the earlier recommendations of the Berlin Conference of 1903 including compulsory intercommunication.[49] In Canada, a set of national guidelines and regulations were also implemented in 1906 as part of the provisions of the Telegraph Act. The commercial license granted under the terms of this act contained some 17 conditions and restrictions most of which were intended to reaffirm and extend the government's jurisdiction over the development and use of radio. Among other things, these conditions demanded adherence to any international agreements signed by Canada and recognised the right of the government to use any system of radio wherever and whenever it chose.[50]

Creating a Canadian Regulatory Framework

These legislative changes were quickly translated into real policy changes in Canada. Some time in 1906 it was decided that the government would "take over absolute control of the wireless service on board government vessels" because the Marconi operators who had been responsible for it were not providing "satisfactory service" and "the apparatus on board the ships was in a most unsatisfactory condition, due to the fact that the department had no control over same."[51] Similar complaints were reported after an inspection of the government stations operated by Marconi which revealed the use of "very crude" apparatus, but in this instance the problem was corrected by the company and no further intervention was required. That same year, the Department of Marine and Fisheries also announced its intention to build a series of stations on the Pacific coast "to serve as aids to navigation, as well as a means of communication along the west coast of Vancouver island."[52] Despite the best efforts of the Marconi interests to obtain the

47. Department of Transport records, NAC, RG 12 E4 vol. 391 file 5600-1; Borden Papers, NAC, MG 26 H vol. 315 file 111.
48. The evidence of this evolving attitude can be found in various sources but for Canadian information the annual reports of the Departments of Marine and Fisheries and the Naval Service provide a fairly clear picture of the growing importance of radio. Over the years the reports become longer and more detailed, combining statistical data, photographs and maps with written descriptions of everything from construction work to shipwrecks. The NMST and National Libraries both have some of these reports.
49. Tomlinson, pp. 17–27.
50. Canada, Revised Statutes, 1906, Chapter 126, *An Act respecting Telegraphs*, and "License to use Wireless Telegraphy for Commercial Purposes," issued in accordance with the provisions of paragraph 4 of the Telegraph Act, R.S.C., 1906, Chapter 126, in G.J. Desbarats (Deputy Minister, Marine and Fisheries and, later, Naval Service) Papers, NAC, MG 30 E89 vol. 2. In the latter document see items 12 and 16 especially.
51. Canada, Department of Marine and Fisheries, *Annual Report for 1907*, (Ottawa: King's Printer, 1908) pp. 95–6.
52. Marine and Fisheries, *Annual Report for 1907*, p. 11.

contracts to build, equip and operate these stations,[53] the government chose to take direct responsibility for the operation of these stations including deciding to install a different make of equipment, produced by Shoemaker. Officials of the department argued in defence of this new approach that intercommunication had become a more pressing general concern since the ratification of the Berlin Convention and that it was absolutely essential on the Pacific coast because "several boats calling at British Columbia ports... [were] equipped with the Massie system." Moreover, they added, the system chosen was not only "more up-to-date and better than that in use in the gulf stations" but also significantly less costly both in terms of original price and maintenance cost than that currently offered by Marconi.[54]

Despite continued protests by Marconi officials over the west coast decision and legal action contesting the validity of the licensing requirements of the Telegraph Act which, they maintained, were prejudicial to the rights established in the 1902 agreement, the government was undeterred.[55] It went ahead with the construction of the five stations in B.C. and they were equipped as planned and in operation by 1908. The following year, plans were made for another two stations in the region and these too were to be owned and operated directly by the government. At the same time, it retained strict licensing control and issued only a few licenses to various radio companies for experimental and private, as well as commercial purposes in various parts of Canada. By 1910–11, when the Department of the Naval Service took over responsibility for radio in Canada, it was clear that the government intended "to control all coastal stations as a monopoly."[56]

Expanding the Marine Radio Network in Canada

The increasingly rigorous restrictions placed on the use of radio in Canada, however, did not prevent the expansion of the marine communication network. On the contrary, it continued at a steady pace. The litigation between Marconi and the Canadian government had by no means put an end to the domination of this company in the east. Not only did it receive contracts to build and operate new stations in the Gulf of St. Lawrence/Atlantic coast region, but it also was called upon to expand this network up the St. Lawrence River by establishing stations at Grosse Isle, Quebec, Three Rivers and Montreal and to construct the first in a series of Great Lakes stations at Port Arthur, Ontario. All were completed in 1910 and arrangements were made for all to placed under Naval Service control although the Port Arthur station was owned by Marconi until 1912. By that time four of the proposed eight stations in the Great Lakes system were finished and it was decided that the Marconi company which equipped and operated the stations should continue to do so but that the government would own them.[57]

During the same period, the government also decided to expand the transatlantic radio service in an attempt to compete with both Marconi and the cable companies thereby bringing prices for such communication down. Marconi's Glace Bay station had been open for business off and on since mid October 1907 but according to the Naval Service was still only operating at half of its message-sending capacity in 1911.[58] In spite of this apparent lack of business, the Postmaster General gained parliamentary approval in 1913 for an agreement with the Universal Radio Syndicate to build two additional transatlantic stations in Canada and Great Britain. The Syndicate which was built around the Poulsen arc system and its related patents was chosen over Marconi because the Postmaster General was convinced that it was unwise to allow the latter company to retain its near monopoly position in the field in Canada. Elaborate financial arrangements were made to insure the speedy completion of the two stations and by the end of the 1914 fiscal year substantial progress had been made on the Newcastle, N.B. station. It was reported to have a power plant consisting of "two 225-horse power Diesel engines directly connected to two D.C. generators." It had "an umbrella type" aerial "covering approximately

53. Department of Transport records, NAC, RG 12 E4 vol. 391 file 5600-1.
54. Marine and Fisheries, *Annual Report for 1907*, p. 96.
55. Department of Transport records, NAC, RG 12 E4 vol. 391 file 5600-1 and vol. 1631 files 6800-31 and 6800-126.
56. Canada, Department of Marine and Fisheries, *Annual Report for 1909*, (Ottawa: King's Printer, 1910) p. 209; Post Office Department records, NAC, RG 3 vol. 621 file 6209-113; Department of Marine and Fisheries records, NAC, RG 42 vol. 491 files 209-6-5, 209-6-56 and 209-6-37.
57. Canada, Department of the Naval Service, *Annual Report for 1911*, (Ottawa: King's Printer, 1912) p. 55; Canada, Department of the Naval Service, *Annual Report for 1912*, (Ottawa: King's Printer, 1913) pages 58, 62, 67–8.
58. Naval Service, *Annual Report for 1911*, p. 51.

20 acres [8 hectares], supported by six 400-foot [121 metres] wooden and one 500-foot [152 metres] steel tower."[59] In the end, the station was not completed until 1915 by which time, after suffering a series of financial setbacks, the URS had folded and the Postmaster General had been replaced. The act which formalized the agreement, the Ocean Telegraph Act, was eventually repealed and Marconi took over the stations.[60]

On the west coast development was also continuing. By early 1913 there were ten stations in the region acting as navigational aids, providing information of "the utmost value to the public and shipping interests."[61] Three of the stations—Dead Tree Point, Ikeda Head and Alert Bay—had an additional function since they provided the only "telegraphic" connections between these communities and the outside world. The successful inter-station communication carried out between these establishments and the other land stations in the region demonstrated the great value of radio in such isolated areas where land lines could "only be maintained at a prohibitive expense through the mountainous and heavily timbered country encountered." The effectiveness and reliability of this form of communication along the rugged B.C. coast was also apparent to private business interests and in 1912 and 1913 the amount of paid business between land stations increased dramatically. Though concerned that this added function might eventually come into conflict with the original and primary purpose of the stations, the government nevertheless granted two licenses to private companies to communicate with its west coast chain and its officials believed that there would be "numerous applications for further licenses" as development and settlement continued.[62]

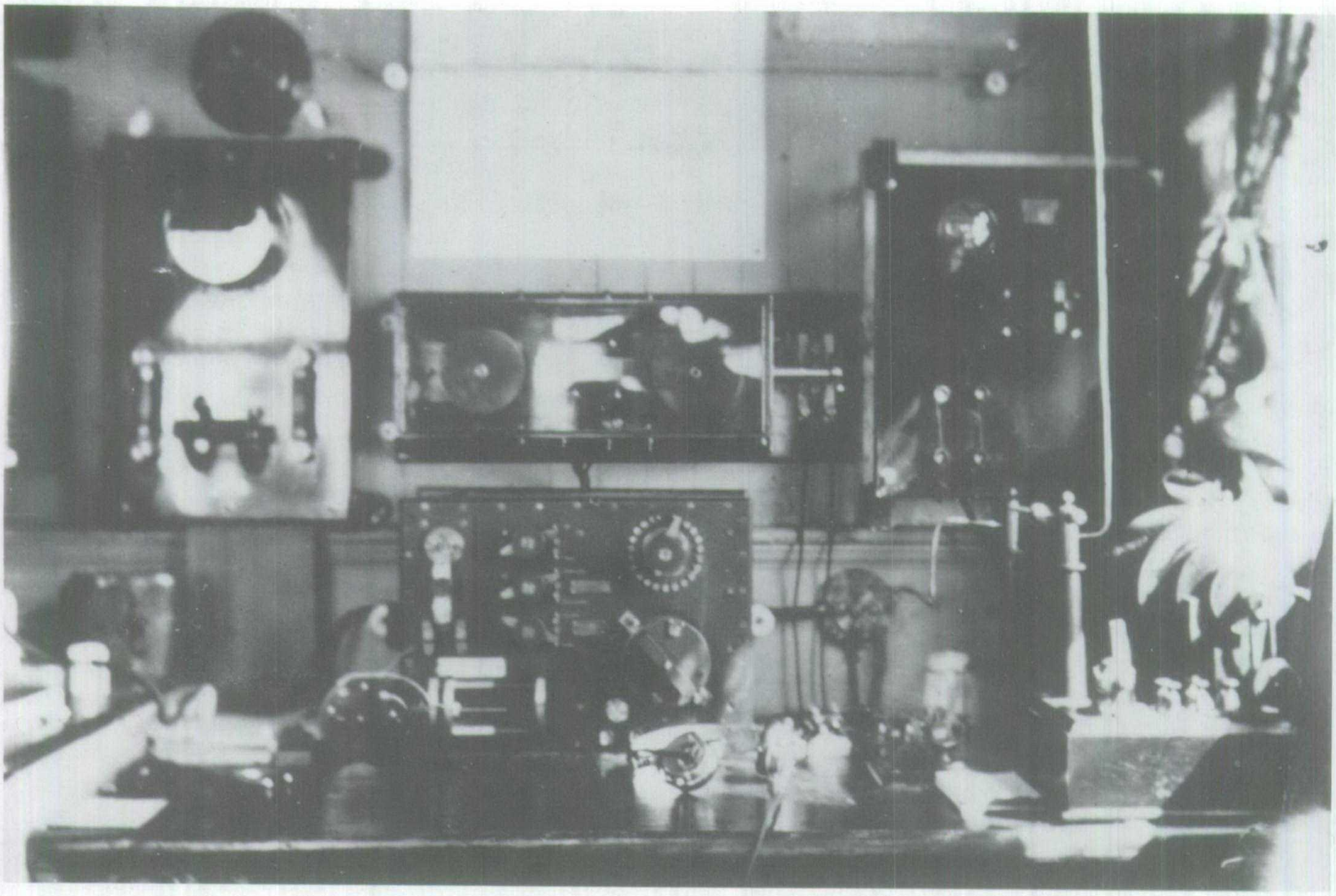
By the end of March, 1913, the Department of the Naval Service reported a total of 123 stations in operation in Canada and on Canadian ships. Of these 37 were coast stations, four were licensed commercial stations, two were licensed private stations, 28 were amateur and experimental stations, 16 were government ship stations and 36 were licensed ship stations. The coast installations handled a total of 272,087 messages containing some 4,275,759 words and took in revenue amounting to $10,420. The annual maintenance cost for these stations was just under $120,000. The greatest revenue-producers were the government owned and operated stations on the west coast but even these were far from profitable since it cost nearly $50,000 to run them and they generated something less than $10,000.[63]

Although the fact that the government-operated stations were more economical than those run by Marconi on its behalf was undoubtedly of interest to the advocates of direct government control of radio, the level of profitability of the stations was not the primary concern of either the Department of the Naval Service or of the government. As an active participant in the international shipping system, Canada had a responsibility to make her shipping routes as safe as possible for all traffic. The development of an effective radio network along these routes was an essential component of that responsibility, and one which the Canadian government had taken seriously for some time. Indeed, as early as 1910, a British newspaper article called on "various colonial governments to bring their wireless facilities to the level attained several years ago by Canada."[64]

The Titanic *Disaster and the London Conference*

Before April 1912, facts such as these might not have persuaded the average Canadian that the substantial and ongoing investment in radio technology was justified especially since in a developing nation there were many valuable inventions and innovations competing for such political and financial support. When the *Titanic* went down after striking an iceberg off the coast of Newfoundland on 14 April, however, all but the most intransigent critics must have recognized the absolute necessity of actively developing and extending the use of this technology. Had it not been for the use of radio during the night of the 14th, the disaster would have been much worse. The initial distress signal was sent out by radio and was received by

59. Canada, Department of the Naval Service, *Annual Report for 1914*, (Ottawa: King's Printer, 1915) pp. 77–8.
60. The record of the Universal Radio Syndicate and its dealings with the government can be found in the Post Office Department records, NAC, RG 3 vol 621 file 26969. It is an important and interesting story that needs to be told in more detail than can be provided in the context of this general report.
61. Naval Service, *Annual Report for 1912*, p. 64.
62. Naval Service, Annual Report 1912, pp. 64–5; Canada, Department of the Naval Service, *Annual Report for 1913*, (Ottawa: King's Printer, 1914) pp. 111–13.
63. Naval Service, *Annual Report for 1913*, pp. 104–8.
64. Department of Transport records, NAC, RG 12 E4 vol. 389.



Wireless room on SS Kingston, *circa 1910. Source: W. Harold Reid* two liners, the *Virginian* and the *Carpathia*, which were 480 and 30 kilometres away respectively. The operator on the *Titanic* stayed in touch with these ships throughout the ordeal using his regular equipment and when the power failed, an emergency generating source. In the end the *Carpathia* was only able to rescue those who had made it into the life boats but even these people might well have perished in the harsh spring conditions on the North Atlantic had it not been for her speedy arrival.[65]

The first news of the disaster and the list of survivors were relayed from the ships that went to the scene to the station at Cape Race, Newfoundland. An attempt was also made to send information through the installation at Sable Island but the equipment there was not up to the task and some confusion arose over the authenticity of the reports which reached New York before the arrival of the *Carpathia*. Once the sequence of events was clearly established, it became apparent that more stringent radio regulations for large ships might well have reduced the extent of the disaster significantly. The radio operator on the *Carpathia* was in fact off duty for the night when the distress call of the *Titanic* came in on his set which was still switched on. The operator on the *Californian* which at the time was much closer to the scene of the catastrophe, had unfortunately closed down for the night and thus, although it was alleged at the time that the *Titanic*'s distress rockets could have been seen from the *Californian*, no one on board knew of the sinking until the next day.[66]

The loss of the unsinkable *Titanic* raised many questions concerning safety at sea including how to insure more consistent transmission and reception of emergency information between ships and between ship and shore stations. More importantly, it did not merely raise the questions but also produced the necessary collective political will to find some immediate answers to them. Convinced that they could command the support of their people, who were shocked and outraged by the disaster, no matter how strong the measures they implemented or how determined the opposition to them by shipping interests, the nations involved in international shipping made a concerted effort to prevent another, similar tragedy from happening. At the third international conference on radio held in London in June of 1912, a series of international regulations were formulated towards this end. The conference, at which the term radiotelegraphy replaced wireless as the recognized label for communication by electromagnetic waves and which was attended by some 36 nations (Canada sat independently of Great Britain), produced a regulatory framework which each country was expected to implement in accordance with its own legal and administrative systems.[67]

The primary recommendations of the London Convention included: "compulsory intercommunication between ship stations and between ship and shore stations, irrespective of the systems employed"; systematic classification of ships equipped with radio apparatus establishing the watches to be kept, the level of proficiency of the operator or operators and the minimum endurance and range of emergency installations where required; two essential standard working wave lengths for shore stations and ship stations (600 and 300 metres); application of strict limitations to long distance transmissions from ship to shore; and the addition of a second class operator classification based on similar qualifications but demanding less speed than the original first class operator level. Once adopted by the Convention, it was the responsibility of the delegates to report to their respective governments and initiate the legislative process which would give these principles the force of law. Canada's representative was G.J. Desbarats, Deputy Minister of the Naval Service and he wasted no time in producing the required bill.[68]

The Radiotelegraph Act was presented to the House of Commons for the first time on 12 December 1912 and received royal assent on 6 June 1913. The act itself was only eleven pages long and, as expected, it reaffirmed and extended the

65. Most of the general secondary sources on the early years of radio contain accounts of the Titanic disaster. The basic facts concerning what happened after the ship struck the ice-berg are seldom disputed though some of the details about transmission of information sometimes are. The account used here comes from the Naval Service, *Annual Report for 1913*, pp. 114–5. Published in 1914, it is an official-style report containing no personal anecdotes and no speculation which attempts to answer questions such as who, if anyone, on the Californian actually saw the Titanic's rockets why they did not respond in some way.

66. Naval Service, *Annual Report for 1913*, pp. 114–5.

67. Naval Service, *Annual for Report 1913*, pp. 119–20; Tomlinson, pp. 29–31.

68. Naval Service, *Annual Report for 1913*, pp. 121–4; see also Tomlinson, pp. 30–44, for a more detailed discussion of the London Convention proceedings from an international point of view.

principle of government control of the use of radio technology. The government's licensing power was increased by adding a series of specific regulations stipulating the form and content of application for, and the various classes and duration of, radio station licenses. Each class was allocated certain wavelengths as well as being provided with some general rules defining the type of transmission and reception permitted. In addition, there were some 24 provisions governing experimental and amateur experimental licenses which applied strict government control to a growing and potentially problematic field. Only the conditions for licensing ship stations were more meticulous and thorough, for obvious reasons. Of the 17 pages of licensing provisions, 10 dealt specifically with ship stations, dividing them into three main classes based on where the ship travelled and how many people it carried, and then determining from this the general characteristics of the regular and emergency equipment required and the watches to be kept on it. Other regulations set out the classification levels for operators—three for ship station operators and six for the operators of the various types of land and coast stations. The examination procedure by which the proficiency certificates for each class were obtained were described in some detail particularly for the higher levels of proficiency such as Extra First-class coast or land station operator. All regulations were supported by penalties involving fines or imprisonment for noncompliance.[69]

69. Canada, Department of the Naval Service, Radiotelegraph Branch, *The Radiotelegraph Act and Regulations Issued Thereunder*, Statutes 1913, Chapter 43, (Ottawa: King's Printer, 1914) pp. 5–39.

2 Radio During World War I

In addition to the provisions dealing with normal day-to-day operation of radiotelegraph stations, the Radiotelegraph Act also included provisions and regulations giving the government special powers in times of war or other emergencies. Section 10(c) gave the government the power to censor and control signals and messages from any or all stations under its jurisdiction and section 13 allowed the authorities to take temporary possession of stations, apparatus and operators at any time with a guarantee of fair compensation to the owner and nothing more. Parts 4 and 5 of the appended regulations provided for government control of stations in cases of emergency as defined by the minister. When war broke out in Europe less than 14 months after the Act had received royal assent, the government used the powers given it insure that radio technology was used to the benefit of the imperial war effort.[70]

Immediately upon the declaration of war, the Canadian government placed "all the radiotelegraph stations in the Dominion...on a war basis."[71] The precise meaning of this status is not made clear in the annual reports of the Department of the Naval Service but it seems that, in addition to the complete closure of all amateur stations for the duration of the war, certain of the eastern coastal stations run by Marconi were taken over by the government after the war began while others were provided with guards. All radiotelegraph installations in the country were undoubtedly subjected to much stricter controls insuring top priority to government messages and systematic censorship of content. As well, in 1916, the government granted licenses to two radiotelegraph schools, the Dominion Telegraph and Wireless Institute in Vancouver and the Columbia College of Wireless in Victoria, presumably to meet the growing need for trained operators resulting from the war.[72]

Yet despite these changes, most private stations remained in the hands of their operators and/or owners throughout the war. Indeed, during 1915 and 1916 eleven new licenses were granted for private stations in Alberta.[73] This is not surprising since the primary goal of the government's wartime domestic radio policy was to maintain and protect Canada's inland and coastal shipping routes. The supplies that passed along these routes were essential to the imperial war effort and, with the increased traffic resulting from that effort, the network of radiotelegraph stations and the increased efficiency and security they could provide for shipping became that much more important. As long as the private operators accepted the stricter regulations and continued to do their work effectively, it made sense for the government to use its human and financial resources in other ways.

The place of radiotelegraphy on the international stage during the war, posed more difficult and immediate problems for the Canadian government, both on the North Atlantic and on the battlefields of France and Belgium. There was concern from the start of the war that the transatlantic submarine cables connecting Europe, Great Britain and North America would be cut; the German cables had been cut the morning after the ultimatum expired and diverted to British use.[74] The government would have had to have made preparations to cope with the demands which then would have

70. *The Radiotelegraph Act*, pages 9, 11.
71. Canada, Department of the Naval Service, *Annual Report for 1915*, (Ottawa: King's Printer, 1916) p. 125.
72. What little reliable information there is on war time regulation of radiotelegraphy can be found in the Naval Service annual reports for 1915–1918 usually under the sub-heading "Annual Report of the Radiotelegraph Branch".
73. Department of Transport records, NAC, RG 12 E4 vol. 1631; Naval Service, *Annual Report for 1914–15*, p. 119; Canada, Department of the Naval Service, *Annual Report for 1915–6*, (Ottawa: King's Printer, 1917) p. 86.
74. G.R.M. Garratt, *One Hundred Years of Submarine Cables*, (London: His Majesty's Stationery Office, 1950) p. 33.

been placed on the two transatlantic radiotelegraph stations at Glace Bay and Newcastle. Would the increased use of these stations interfere with reliable marine communications which had become some much more important since the oceans were now invaded by hostile naval forces determined to prevent the passage of supply ships as well as military ones? In the end the problem never arose since the Germans were only able to damage the Pacific cable and then only for a short period of time.[75] Nevertheless, the threat clearly existed and might well have contributed to the decision to reallocate Canadian resources from the Royal Navy back to the east coast during the U-boat scare in the western Atlantic in 1917–18.[76]

Radio in the War at Sea

The Canadian government was also preoccupied with expanding the military uses of radiotelegraphy. The recently created Royal Canadian Navy had two ships in 1914, the *Rainbow* and the *Niobe*, both of which were radio-equipped. Moreover, the great value of this form of communication had long been accepted by Britain's Royal Navy into which most of Canada's naval contribution was integrated and it played an integral role in several important battles as well as in the protection of supply convoys travelling in treacherous international waters. Until the war radio had been used largely for communication "between a fixed point and a moving point" though "general calls were made and messages were transmitted simultaneously from one station to a number of others in the vicinity " in certain situations. The requirements of the war at sea demonstrated not only the possibility of simultaneous communication between a headquarters and many reception points but also its remarkable value. Both sides had the technology and thus were forced to use cypher but the British were obtained a German cypher book and were able to use it to predict and to counteract German raiding activities for several months in both the Atlantic and the Pacific theatres.[77]

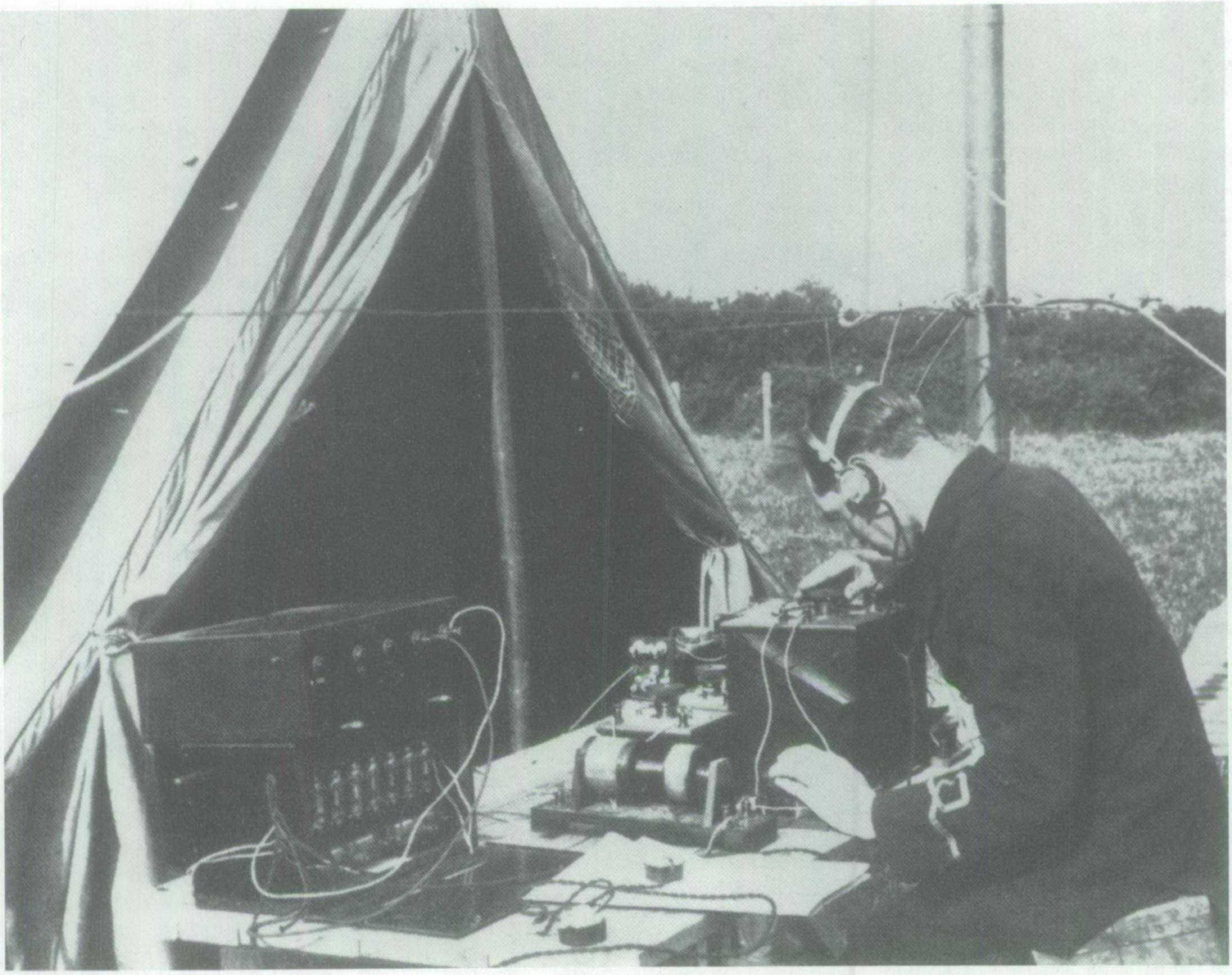
The Royal Navy also made profitable use of one of the latest developments in radio technology at the time—the radio direction finder. In this regard, the British were ahead of the Germans (who for some unknown reason did not use this new system) and this became readily apparent during the Battle of Jutland in May 1916. With this technology, housed in a group of stations along the south east coast of England, the Royal Navy was able "not only to determine the position of any German ship that left harbour and was indiscreet enough to use its wireless, which...it was very likely to do, but by making a series of observations was able to track her course across the North Sea." Thus when the German fleet left port, the Royal Navy knew and was well prepared to meet it.[78] Afterwards, it became clear that great care would have to be taken by all ships and aircraft equipped with radio wherever an efficient direction finding system existed since any communication could betray their presence and their position.[79]

Radio in the Land War (Air and Ground Forces)

The contribution that radiotelegraphy made to the allied victory at sea was clear to all observers both at the time and since. The role it played in the land war was much more ambiguous. At the outbreak of hostilities both the British and the German armies had radio sets but knowledge and use of the equipment was limited. In the whole British army there were only ten sets and these quickly proved to be of little use.[80] Even as late as 1916 during the Battle of the Somme, British brigade headquarters and their units had radio sets some of which were kept open during the fighting "but few of them passed a single message."[81] The 1st Divisional Signal Company of the Canadian army had only two "French Pack" sets in 1914 and these were left in Canada when they departed for Europe.[82] It was not until 1916–17 that Canadian military authorities began to establish experimental stations presumably, in part, for the purpose of training the troops to use radiotelegraphy.[83]

There were several reasons for this early lack of enthusiasm for a technology that, in theory at

75. Garratt, p. 33.
76. R.H. Roy, "Vimy Ridge," in *The Canadian Encyclopedia*, Volume III, Pat-Z and Index, (Edmonton: Hurtig Publishers Ltd., 1985) p. 1910.
77. Wedlake, pp. 107–10.
78. Wedlake, p. 111.
79. Wedlake, p. 112.
80. Wedlake, p. 116.
81. Shelford Bidwell and Dominick Graham, *Fire-Power British Army Weapons and Theories of War 1904–1945*, (London: George Allen and Unwin, 1982) p. 141.
82. John S. Moir (ed.), *History of the Royal Canadian Corps of Signals, 1903–1961*, (Ottawa: Royal Canadian Corps of Signals, 1962) p. 12.
83. Naval Service, *Annual Report for 1915–16*, p. 86; Canada, Department of the Naval Service, *Annual Report for 1916–17*, (Ottawa: King's Printer, 1918) p. 73.



This was considered a small, portable radio direction finding unit at the time this photograph was taken, probably around 1913. Source: G.E.C. Wedlake, SOS The Story of Radio-Communication, *(Newton Abbot, Devon, GB: David & Charles, 1973)* least, had the capability to improve immensely the quality of ground-based and air to ground communications. In 1914 the available equipment was not well suited to the needs of the army or its newly formed reconnaissance section, the Royal Flying Corps. Sets were both large and heavy, some ground models weighing up to two tons and some aircraft ones up to 90 kilograms. When the army was on the move the time required to take down these sets and put them up in a new location made rapid transmission of urgent messages almost impossible and, when stationary, the masts securing the aerials often presented easy targets for the enemy. Once a set light enough for aircraft was produced, it was still so large that it had to take the place of the observer leaving the pilot to operate the set to pass on information to his ground unit in addition to flying the plane. The noise of the engine also posed a significant problem since it meant that the planes could transmit information but could not effectively receive it. Moreover, in both ground and air situations, spark technology was all that was available at the time and thus interference plagued operations making it necessary for stations to be spread widely apart and to limit their transmission times according to an established schedule. This lack of flexibility was exacerbated by the need to encode messages since radio signals were easily intercepted, especially near the front lines.[84]

In this context, the initial reluctance of the military to embrace radiotelegraphy wholeheartedly is perhaps understandable. As improvements were made in equipment and in the training of personnel and as experience was gained in action, however, radio began to play a more significant role in the land war, and Canadians were among the first to put it to profitable use. In March 1916, Major van Den Berg, a machine-gun officer with the Princess Patricia's Canadian Light Infantry, used spark radio in the forward area "to control the indirect fire of his guns." Using "a crossword puzzle code over a phone" van Den Berg gave the necessary information "to his wireless signaller who transmitted [it] to the guns." The signals were overheard by a staff officer and van Den Berg and his team were arrested, but this combination of radio and telephone ultimately "became the normal practice." As well, during the Ypres Salient, "in the Canadian Corps, an FOO [forward observation officer] from a 9.2-inch howitzer battery sent fire orders over six thousand yards [5400 metres],"[85] and by late 1916 the Canadian Corps Wireless Section had come into being reflecting the emerging recognition among Canadian authorities of the potential value of radiotelegraphy in the war.[86]

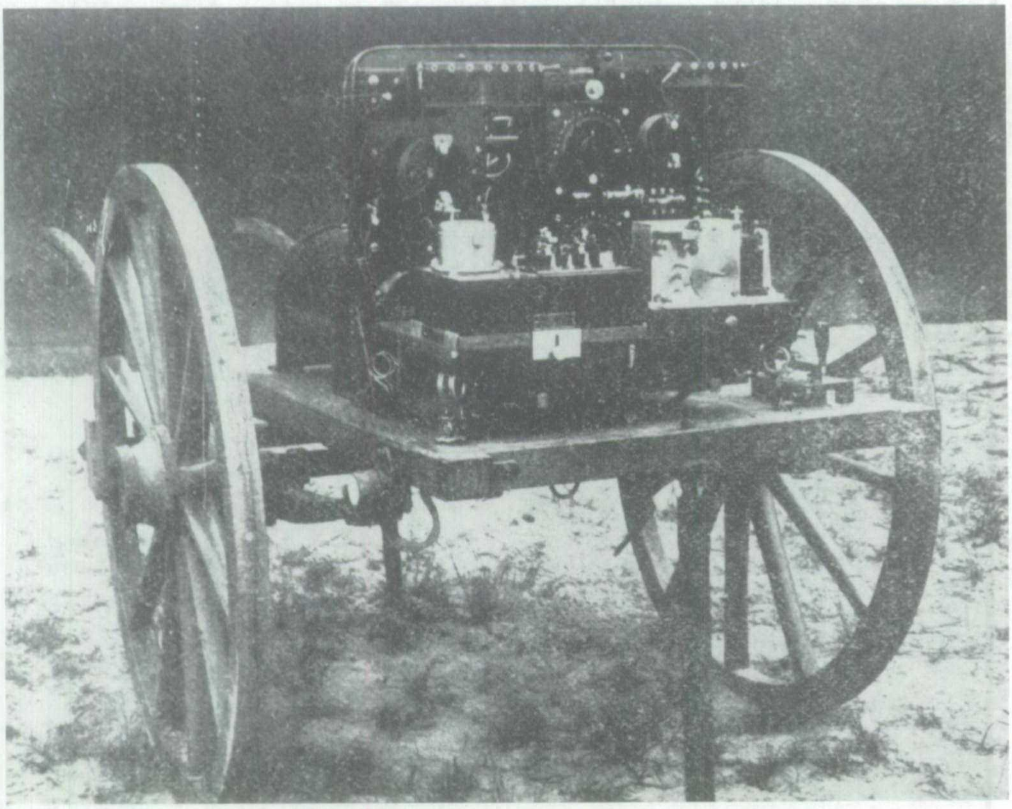
The Royal Flying Corps (RFC) also welcomed technological improvements which promised to enhance the ability of its pilots to report the location of enemy targets back to the artillery. In 1914, "no British aircraft was equipped with even one-way wireless," but by late 1915 the Sterling transmitter "weighing only twenty pounds [9 kilograms] with a range of eight to ten miles [13 to 16 kilometres]" became available. Combined with the development of a gridded reference system which permitted accurate and consistent identification of the targets and the emergence of a class of artillery officers determined to make the system work, this made air to ground radio a crucial factor in the battle of the Somme. In that battle fought in the summer and fall of 1916, 316 aircraft were fitted with radio sets and were able to communicate with some 542 ground stations. The artillery observer in the plane "could communicate with any battery via a telephone exchange and rapidly engage any target that he could identify in pre-arranged zones of the front." Interference, however, remained a problem and "it was still only possible to use one plane per 2000 yd [1800 metres] of front."[87]

The early problems experienced by the military in using radio clearly inspired inventors and manufacturers to produce new types of sets that better suited battlefield requirements. This creative process ultimately led to the development of reliable continuous wave equipment which, by 1917, was increasingly replacing the existing spark sets, especially in sensitive areas. Continuous wave radiotelegraphy had been demonstrated by Reginald Fessenden in 1906 but had remained largely experimental until the war, overshadowed by the remarkable success of the spark system pioneered and promoted by Marconi and others. The inadequate performance of the spark system in combat produced a willingness to try something new and, when tested, continuous wave sets proved much more useful than their spark predecessors. CW, as the military called it, achieved "greater range for less power so that the batteries

84. Wedlake, pp. 116–125; Bidwell and Graham, pages 102, 141.

85. Bidwell and Graham, pp. 141–2.
86. Moir, p. 29.
87. Bidwell and Graham, pp. 101–2; Wedlake, pp. 123–4.

This bicycle power unit was used to generate the power to operate a radio station in the field in World War I. Source: G.E.C. Wedlake, SOS The Story of Radio-Communication, *(Newton Abbot, Devon, GB: David & Charles, 1973)*



A German radio unit (receiving apparatus) built by Telefunken for use in World War I. Source: Alfred P. Morgan, Wireless Telegraphy and Telephony, *(New York: The Norman W. Hensley Publishing Company, 1920).*

and sets were lighter and the aerials shorter." As well, tuning was greatly improved such "that four times the number of sets could operate in an area without interference and enemy interception was more difficult."[88] It was especially well-suited to the needs of the artillery "with their intricate network of long range communications with aircraft, ground observers and computing centres, and their system of coded fire orders."[89]

The Canadian Corps was quick to take advantage of the new technology. At Vimy Ridge in April 1917, CW sets were used and "operated at a range of 8000 yards [7200 metres] with only five foot [1.5 metre] aerials at the forward set."[90] Later that year, in August, at "Hill 70 the first registration of guns by wireless was carried out by the Canadian Corps, all messages and corrections being sent by wireless to the artillery exchange, though from there they were passed to the batteries by telephone."[91] During the fighting at Passchendaele, CW signalling was tested against carrier pigeon and was found to take "less time than it took to get the bird into the air." These positive experiences led not only to the purchase and distribution of more CW sets and thus to the ongoing development of the technology, but also to the establishment of schools devoted to the training of personnel in both the artillery and the signals units of the Canadian Corps.[92]

When the Allied offensive began on the 8th of August 1918 marking the beginning of the Hundred Days, CW was an established element of the overall plan. On the first day of battle at Amiens, "the Canadian Independent Force of armoured cars, machine-guns in trucks and mortars penetrated at least six miles [10 kilometres] beyond the corps objectives and maintained communication to Corps Headquarters with Mk III Continuous Wave wireless sets. Its bulletins were listened to by the French divisions on the Canadian right flank and by the Australians on the left." Throughout the battle, CW was used "extensively" and in Flanders, the Canadian Corps' movement into battle was aided by the passage of "deception traffic" over radio.[93] In general, during the final offensive of the war, the Canadian Corps relied more heavily on radio than the British, using it "throughout the advance as an auxiliary system to take surplus traffic" rather than "only when the advance had outrun line communications" as in British practice. Between "26 August and 10 September, for example, Canadian Corps wireless traffic amounted to 2523 messages" and heavy artillery use was "extremely prevalent, especially where brigades were decentralized," and it was "impossible to lay lines between them in the time available." In such cases, "wireless supplied the direct communication required, with as many as 30 to 40 messages passed by continuous wave each day." Radio was also used by the artillery for directing fire onto fast-moving enemy targets and for general observation purposes.[94]

Following the long and rapid march to the Rhine and the signing of the armistice on 11 November 1918, it was clear that radiotelegraphy had become an accepted form of strategic communication. So significant was the use of radio on the march that Army Headquarters had established "a general scheme" the main points of which were: "Continuous Wave sets were to be used as much as possible to minimize interference and to cover the distance required; each corps was to be equipped with one long range C.W. set for work back to army; lateral communication was to be carried out on C.W., the calling station adjusting its transmitter to coincide with the wavelength on which the other station was listening." Within this general plan, the Canadians operated their own CW communication system, connecting each division to corps and corps to Army Headquarters. To meet the long range requirements, they used "a new-type British set, the Tyrell H.W. No. 1, which was stated to have a range of 60 to 75 miles [96 to 120 kilometres] under all conditions." A large set, it was moved on a Crossley box truck supplied for the purpose. For communications over shorter distances, C. Mk. III CW sets were employed and were reported to have covered over 52 kilometres. The Canadians also had a Crossley Spark Lorry Set which was found to be "extremely useful in controlling the spark transmitters within the 2nd Division." Using these and whatever other sets they possessed, the Canadian operators handled over 5000 messages within the Corps between 12 November and 22 December 1918.[95]

88. Bidwell and Graham, p. 142; Moir, p. 29.
89. Bidwell and Graham, p. 142.
90. Bidwell and Graham, p. 142.
91. Moir, p. 29; Bidwell and Graham, p. 142.
92. Moir, p. 29.
93. Bidwell and Graham, p. 142.
94. Moir, p. 37.
95. Moir, pp. 40–1.

The use of radio in the RFC had also progressed rapidly during the last two years of the war. By 1917, airmen were responsible for 90 per cent of observation of enemy artillery positions and as a consequence "the success of the artillery battle had come to depend...on wireless reception and on a network of telephones from the receivers to the users of the airmen's information." During the Hundred Days, "highly organised fire direction centres" were able to function as a result of effective air to ground radio communication between some 600 radio-equipped aircraft and 1000 ground stations, and, by the end of the war, it was abundantly clear that, together, the RFC and radiotelegraphy had made an "invaluable contribution...to the ground victory."[96]

96. Bidwell and Graham, pp. 143–5; Wedlake, pp. 123–5.

3 Radio in Canada after 1920

Although many of the promoters of radio technology made extravagant claims about its contribution to the allied victory in World War I, its application in battle was far from uniformly successful particularly in the early years. Nevertheless, the uses to which radio was put in the conflict and the adaptations that were attempted to improve its performance opened the door to new and hitherto unexplored avenues of development in the field. Methods of marine communication for navigational and other purposes were refined and diversified as a result of wartime experiences. As well, though overland radio communication had long been considered a technically difficult and unprofitable objective by the government, the war proved that for all its flaws radio had great potential for mobile land communication and for communication with remote or otherwise isolated areas. The use of aircraft in battle also provided radio with another unique role since, like ships at sea, once out of sight of home port, an aircraft's only possible method of receiving or giving complex information was by radio. Finally, the war gave indirect impetus to long distance radio communication by demonstrating the strategic importance of efficient international communication. Among other things this helped to generate the political will to proceed with the long-delayed Imperial chain of radio stations contributing to the creation of a better and more comprehensive international long distance radio network.

Marine Radio in Canada After 1918

Radio Aids to Marine Navigation

The system of marine radio stations established by the Canadian government before World War I to improve navigation on the east and west coasts and the Great Lakes and along the St. Lawrence River was maintained throughout the war and in some cases improvements were made to the system. For example, during the latter years of the war the government added four direction finding stations to its east coast network—at Chebucto Head and Canso, Nova Scotia, St. John, New Brunswick and Cape Race, Newfoundland. These stations which could determine the direction of incoming signals not only had an obvious military role, but also were very useful devices for navigation in reduced visibility. The bearings given by these stations were reliable "up to within two degrees" and the government was so pleased with their performance during the war that it decided to retain them. By modern standards this was a rudimentary system which was most useful only where cross bearings from two stations could be obtained and yet those who used the system were favourably impressed and petitioned the government to extend the system.

After the war, the marine network was not greatly expanded (in 1936 there were only 30 coast stations compared to the 47 that were listed in 1919) but important and extensive improvements were undertaken that made navigation easier and safer. One of the first developments was the expansion of the direction finding services. A new type of radio direction finding apparatus, the radio beacon, was developed and used increasingly on the major shipping routes. Radio beacon stations were established to serve the needs of those ships which carried on board direction finding apparatus. In their earliest form, these radio beacons were linked to the sound fog alarm and came on automatically with it, giving off a radio alarm signal which had a range of about 80 kilometres. According to departmental assessment, the ship board instruments did not, "by any means equal the accuracy of a properly organized and well run station ashore," but their quality was improving. Because of this, official encouragement was given to their on-going development and by 1928 an improved type of beacon had been designed which gave off a regular signal even when there was no fog and a constant signal when there was. These new beacons, which were supplied by the Marconi Company, also had a range of 120 kilometres. Based on the signal given off by these beacons DF-equipped ships could determine their own bearings without the assistance of the station operator and could navigate accordingly.

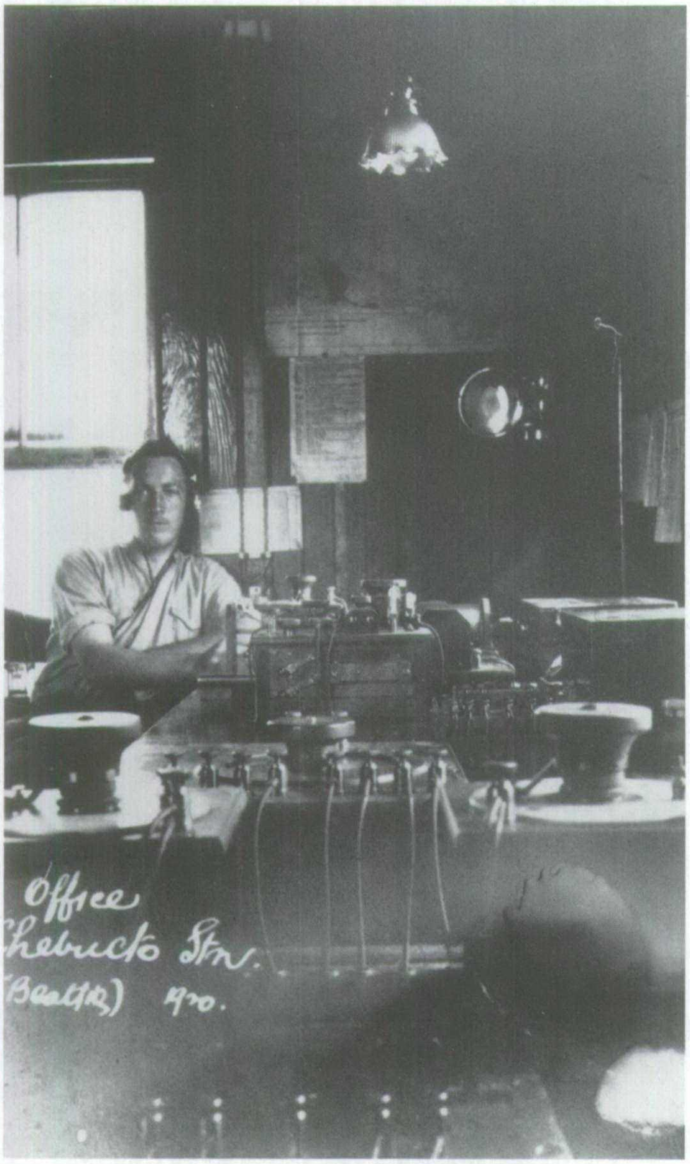
Throughout the twenties, ship-based DF apparatus became increasingly common and, as a result, the Department of Marine and Fisheries which had regained responsibility for the Radio Branch from the Department of the Naval Service in 1922, expanded this network of stations. In 1936 there were some 24 radio beacons operating on the east and west coasts, on the Great Lakes and in the Gulf of St. Lawrence. These were supplemented by thirteen direction finding stations (up from the four original installations) which served all ships equipped with radio including those which did not have DF apparatus on board. Of these, 7 were in the Atlantic region, 1 was in B.C. and 5 were in the north, along Hudson Bay and Hudson Strait. Together with the original network of coastal radio stations, these DF-equipped outposts were intended "to provide radio facilities whereby any ship within 500 miles [800 kilometres] of the Canadian coast can establish instant touch with the shore." The services provided by this system were free of charge and they appear to have been used to great advantage. The Imperial Shipping Committee was sufficiently impressed with the performance of the DF equipment in and around Saint John harbour that it stated in 1929 that no additional insurance premium should be charged for vessels calling there.

In the forties the Department of Marine and Fisheries continued to stress improvement as opposed to dramatic expansion of the radio aids to navigation network. The number of radio beacons grew significantly (by 1951–52 there were 35), but most other additions to the system were in the form of more advanced technology. Full advantage was taken of new developments made during or as a result of World War II. Immediately following the war, tests were begun to estimate "the value of radar as an aid to navigation for merchant shipping," using Type 268 radar sets designed by the National Research Council's Radio Branch and manufactured by Research Enterprises Limited for the British Navy. The success of these tests led to the expanded use of radar by Merchant Marine and other Canadian ships and to the decision to design a radar set specially suited to the needs of these vessels. Around the same time, the Research Council, in cooperation with the Department of Transport (which took over responsibility for radio from Marine and Fisheries in 1937), began design work on a shore-based radar system for harbours. Other radio technology advances that were incorporated into the aids to navigation system in Canada during this period included high frequency direction finding apparatus to supplement the existing low frequency system and LORAN (long range aid to navigation) which provided accurate position readings for ships at much greater distances from shore.[97]

Radio and Safety at Sea

Radio also played an important role in other advances in marine safety after the war. The established practice of broadcasting information useful to mariners at specified times each day was carried on by the department. These broadcasts included weather reports and forecasts, notices of the "position and nature of any danger to navigation, such as ice, derelicts, etc., in that area, and any changes in aids to navigation." Warnings of severe weather were broadcast immediately rather than in the specified time slot. Before 1924, this service was carried out using radiotelegraphy and could only reach those ships that carried radio operators trained in the use of telegraphic code. The movement to continuous wave technology during and after the war, however, soon made the reliable transmission of voice possible. Radio then became a much less complex and expensive method of communication which was of particular use to smaller vessels such as fishing boats. Recognizing this, Marine and Fisheries decided to set up a small trial program involving some of its west coast stations in 1924–25. The experimental system worked on a wavelength of 200 metres to prevent

97. Department of the Naval Service, *Annual Report for 1918–19*, (Ottawa: King's Printer, 1920) p. 48; Department of Marine and Fisheries, *Annual Report for 1922–23*, (Ottawa: King's Printer, 1924) p. 140; Department of Marine and Fisheries, *Annual Report for 1924–25*, (Ottawa: King's Printer, 1926) p. 132; Department of Marine and Fisheries, *Annual Report for 1928–29*, (Ottawa: King's Printer, 1930) pp. 7, 163; Department of Marine and Fisheries, *Annual Report for 1935–36*, (Ottawa: King's Printer, 1937) p. 6; Department of Transport, *Annual Report for 1945–46*, (Ottawa: King's Printer, 1947) p. 187; Department of Transport, *Annual Report for 1946-47*, (Ottawa: King's Printer, 1948) pp. 185, 195; Department of Transport, *Annual Report for 1947-8*, (Ottawa: King's Printer, 1949) pp. 200–1. Reports from subsequent years reveal the continuing use of such radio techniques and their ongoing improvement.



Earl Beattie operating Chebucto or Chedabucto marine radio station, 1920. Source: S.G. Roscoe.

interference with other marine radio services and the department undertook to train one member of the crew of smaller vessels "to adjust and operate" the radiotelephone. The system was used by tugs and other small craft working along the Pacific coast.

Within three years of beginning its radiotelephone broadcast experiment on the west coast, the government "decided to inaugurate a radiotelephone service to fishermen on the East coast." Encouraged by the success of the Pacific system and by the apparent willingness of fishermen to use this new technology, the Radio Branch equipped three Atlantic coast stations to communicate with such vessels. Weather and other useful information such as market prices for fish was to be broadcast from the stations at Louisburg, Halifax and Saint John on wavelengths ranging from 322.4 to 434.5 metres. The Louisburg station was powerful enough to ensure that the messages could be heard as far east as the Grand Banks. The other stations had shorter ranges but, taken together, these stations were supposed to "provide reception at any point along the Atlantic seaboard."

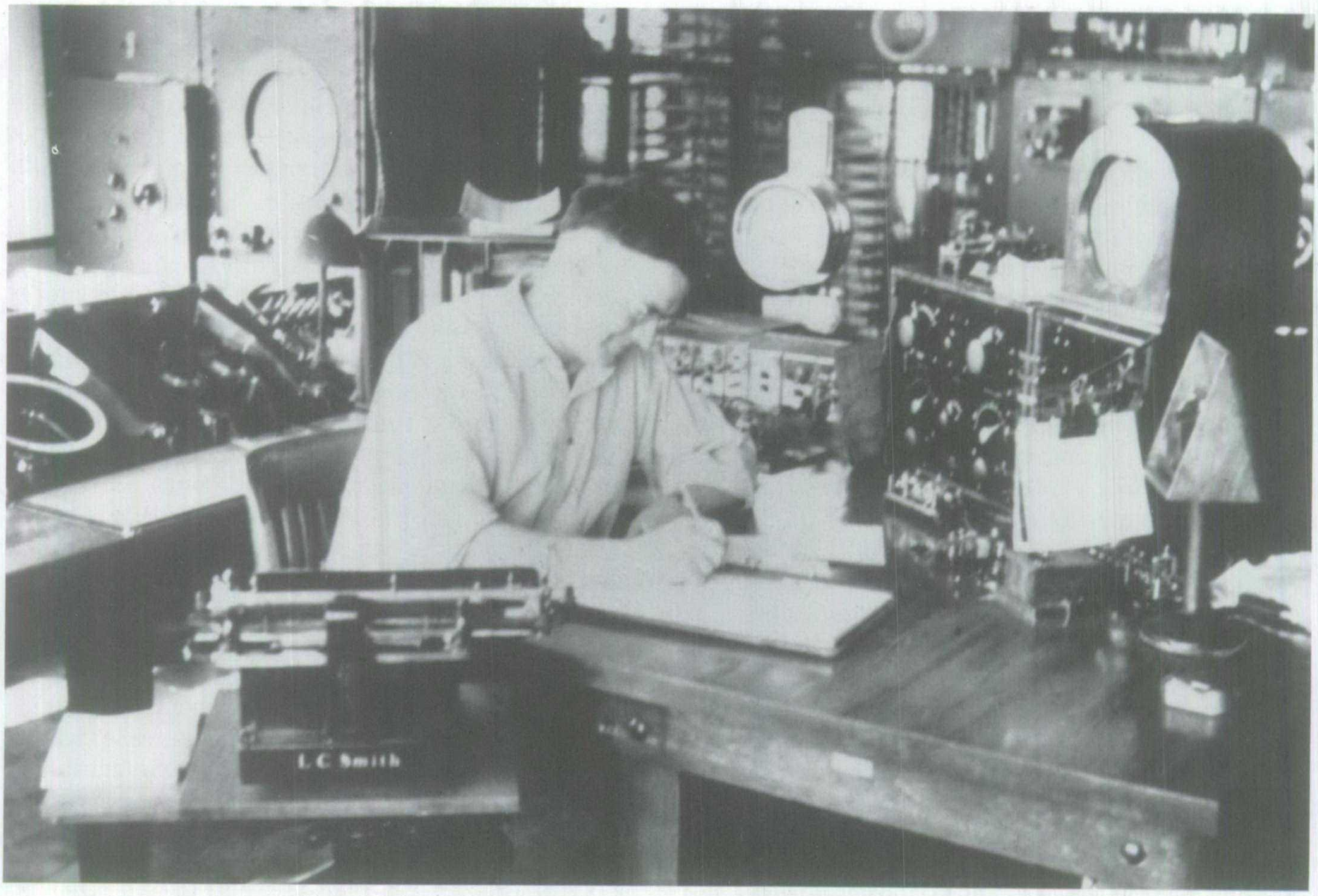
Also around 1924, the Department of Marine and Fisheries began using radio to report ice conditions in the Gulf of St. Lawrence. During the spring of each year, the department sent an icebreaker into this area to locate the ice and determine the best and safest navigational route for ships in the area to follow. The radio station on the ship collected the latest information from the various stations along the Gulf as well as from ships in the area. Added to the observations collected by the icebreaker's crew, this data was broadcast every four hours, every day until the season was over. A summary of this information was re-broadcast by certain coast stations and any vessels that called in could be provided with specific information on ice conditions along their charted course and could make changes accordingly. The Canadian ice patrol worked in cooperation with the International Ice Patrol and this too was facilitated by radio.

Safety at sea was further enhanced by the development of auto alarm devices. Presumably there were a variety of such devices available by the mid 1930s—officials of the Radio Branch inspected some 652 ships fitted with auto alarms in 1935–36—but the one approved by the Canadian government consisted "of a valve receiver sharply tuned to 500 Kc/s (600 metres)" which could pick out the auto alarm signal from all others. That signal activated a series of bells on the ship which warned the crew that a ship was in distress. In effect, this allowed a continuous radio watch to be maintained on certain ships in accordance with international regulations without the operator being on duty 24 hours a day thereby reducing the day to day costs incurred by shipping companies.[98]

Commercial Long Range Marine Communication

One final aspect of marine radio which is worth mentioning. Although the "primary aim" of the coastal stations organization was to provide navigational assistance to vessels in the area, a limited commercial service was carried on in conjunction with this. Ships, whether passenger or cargo vessels, were isolated places when far out at sea and from the first days of marine radio there had been a demand for the passage of information not necessarily related to navigation or safety at sea. Officials on the ships and in the coastal stations attempted to accommodate these demands without jeopardizing the efficiency of essential communication. The Marconi Company's production of a shipboard newspaper in the early years is one example of this attempt. The supremacy of spark technology before WWI, however, made it difficult to reconcile the conflicting demands placed on the ship to shore radio system since interference was a constant problem. Indeed, after the sinking of the *Titanic* in 1912, international regulations had placed more stringent limitations on the use of radio for conveying non-essential information such as press despatches for shore to ship and radiotelegrams from ship to shore.

98. Department of Marine and Fisheries, *Annual Report for 1923–24*, (Ottawa: King's Printer, 1925) p. 133; Department of Marine and Fisheries, *Annual Report for 1927–28*, (Ottawa: King's Printer, 1929) p. 4; Department of Marine and Fisheries, *Annual Report for 1929–30*, (Ottawa: King's Printer) p. 139; *Annual Report 1935–36*, p. 11; Department of Transport, *Annual Report for 1944-45*, (Ottawa: King's Printer, 1946) p. 11; Department of Transport, *Annual Report for 1946–7*, (Ottawa: King's Printer, 1948) p. 187; Department of Transport, *Annual Report for 1946–47*, (Ottawa: King's Printer, 1949) p. 195; Department of Transport, *Annual Report for 1947–48*, (Ottawa: King's Printer, 1949) p. 202; Department of Transport, *Annual Report for 1948–49*, (Ottawa: King's Printer, 1950) pp. 234–5; Department of Transport, *Annual Report for 1949-50*, (Ottawa: King's Printer, 1951) p. 165; Department of Transport, *Annual Report for 1950–51*, (Ottawa: King's Printer, 1952) p. 146; Department of Transport, *Annual Report for 1951–52*, (Ottawa: King's Printer, 1953) p. 155.



Bill Baker operating Camperdown marine radio station, 1938. Source: S.G. Roscoe.

After the war the situation was improved by the spread of continuous wave radio systems. These new systems produced purer radio waves which allowed for finer tuning of equipment and thus caused much less interference. The new equipment also tended to be more powerful. The government took advantage of these developments to relieve the over-used "short range aid to navigation stations" (the services of which were essential to controlling and directing marine traffic in a safe and efficient manner) by setting up a series of coast stations equipped with long range, high-power equipment to take over commercial long distance ship to shore and shore to ship traffic.

On the east coast, three Marconi-run stations at Louisburg, N.S. handled long range commercial service. The Pacific service was provided by the government owned and operated station at Estevan Point on Vancouver Island. In fulfilling its commercial role, the west coast system achieved some remarkable ranges (8800 to 9800 kilometres on three occasions in 1924–5) despite its "comparatively low power transmitter (2,000 watts)."

It is not altogether clear from the available statistics to what extent and at what rate this particular service grew over the years after World War I. It seems likely that this type of communication has remained part of the service provided by the coastal marine radio stations even though it ceased to be mentioned specifically in the annual reports after the mid 1930s. Modern demands are probably much smaller given the reduction in passenger liner traffic and what radio communication is required is no doubt handled increasingly by satellite links which by-pass the coastal stations altogether.[99]

99. *Annual Report for 1924-25*, pp. 131–3; Department of Marine and Fisheries, *Annual Report for 1925–26*, (Ottawa: King's Printer, 1927) p. 5; Department of Marine and Fisheries, *Annual Report for 1926–27*, (Ottawa: King's Printer, 1928) p. 6; *Annual Report for 1927–28*, p. 6; *Annual Report for 1928–29*, p. 7; *Annual Report for 1929-30*, pp. 6–7; Department of Marine and Fisheries, *Annual Report for 1930–31*, (Ottawa: King's Printer, 1932) p. 126; Department of Marine and Fisheries, *Annual Report for 1931–32*, (Ottawa: King's Printer, 1933) p. 134; Department of Marine and Fisheries, *Annual Report for 1932–33*, (Ottawa: King's Printer, 1934) p. 95; *Annual Report for 1935–36*, p. 6.

Radio Communication over Land

Early Uses of Radio for Land Communication

The employment of radio as a means of communicating between land locations was accepted only as a last resort, in the years before WWI. When proven methods such as telegraph and telephone lines had been tried and failed or clearly were not feasible, radio became an option. Although the first two radio stations erected by the Canadian government were established in just such a context to supplement the submarine cable connecting the north shore telegraph line (at Chateau Bay) with Newfoundland (at Belle Isle) because it was prone to ice damage, the marine bias of government radio policy became and remained very strong until the 1920s. Certain of the Pacific coast stations were allowed to do some interstation work on behalf of residents of isolated communities but before 1914, the government issued only a handful of non-marine licenses two of which went to another government department—Railways and Canals—for communication along the construction route of the Hudson Bay Railway in northern Manitoba. In 1917 a series of licenses were issued to the Department of the Militia allowing it to erect land stations for training and experimentation.[100]

During this same period the government received repeated requests from various private citizens, businesses, community and other interest groups to establish stations in isolated communities especially in the north. As early as 1911 the Commissioner of the Yukon wrote to the Governor General asking that a radio station be established at Dawson to replace or to supplement the telegraph line linking that community to the south which frequently broke down. This specific request was reinforced by a general suggestion made the following year by an official of the Anglican Church in the Yukon that a government radio network linking the far-flung settlements of the territory was badly needed. Also in 1912, C.A. Magrath, a member of an International Joint Commission, began to lobby the government in an attempt to interest it in setting up a series of radio stations throughout the north and the northwest. Arguing that radio could provide a very effective means for carrying out and collecting research in these iso-

100. *Annual Report for 1913*, p. 111; Department of the Naval Service, *Annual Report for 1916–17*, (Ottawa: King's Printer, 1918) see section entitled 'Radiotelegraph Service'.

lated and largely unknown regions, he proposed that six stations be established each manned by a young university agriculture graduate who would gather data on a variety of subjects including the local flora and fauna. This research would ultimately form the basis for the informed and enlightened development of this vast and rich area. According to Magrath, the Royal Society, the Chief Astronomer and the Director of the Meteorological Service also advocated the use of radio for research purposes in the north.

A concerted effort was made by some of the residents of northern Alberta to establish some kind of communication link with the south around the time of World War I. In 1914–15 licenses were issued by the Radio Branch to M.S. Berkley for stations at Edmonton, Calgary, Fort MacKay, Fort Chipewyan and Fort Vermillion but the stations were never built and the licenses expired. This apparent failure of private enterprise seems to have shifted attention to the possibility of government intervention and from 1916 through to the 1920s letters and petitions urging support for such a project were frequently received at the Radio Branch. Similar lobbying campaigns were undertaken by various promoters of northern development in other areas such as the Mackenzie River district and Mayo Landing, Yukon Territory throughout the late teens and early twenties.[101]

The Radio Branch of the Department of the Naval Service and later the Department of Marine and Fisheries was not overly responsive to these requests to build radio stations. There were probably several reasons for this. Most importantly, apart from its regulatory role as licenser and inspector of all radio stations in the country, the "primary object" of the Branch was to operate and maintain an effective system of marine communication with a view to improving safety at sea. Only "incidentally" did the radio service provide for the passage of commercial messages to and from ships and for the linking of certain remote communities in the area of existing stations with land lines or other established communication networks. As well, with the advent and rapid development of radio broadcasting after 1919, the regulatory demands placed on the Branch became increasingly onerous. In this context, it is perhaps understandable that the officials of the Radio Branch resisted taking on the added responsibilities of research and development agency for the north and other promising but remote regions.[102]

The federal government was certainly not unsympathetic to the notion that radio could provide an invaluable form of communication in all kinds of situations unrelated to marine navigation, but the role of the Radio Branch remained limited to issuing licenses and offering cooperative encouragement to private interests and other governments or government departments in their efforts to extend radio networks to isolated communities. During the war several radiotelephone stations were licensed including a private one for Shawinigan Water and Power and a provincial government system for the British Columbia forestry service. Licenses were also awarded in 1919–20 for various land radio stations including a proposed chain of Marconi-owned and operated ones linking Winnipeg, Toronto and Montreal to the transatlantic station at Glace Bay. Moreover, throughout the twenties and into the thirties, radio licenses were issued to numerous private companies and individuals as well as to public utilities and power companies in remote areas to allow them to meet both their daily and emergency communication needs. The Branch was pleased by this growing awareness on the part of "private enterprise" of the "utility of radio as a means of communication with isolated points not reached by telegraph and telephone lines," and no doubt sought to encourage it.[103]

There was also an attempt made to accommodate the needs of those isolated communities that were near existing or proposed marine radio stations. This was already established policy for certain stations on the west coast which had, for a number of years, been allowed to carry private and commercial interstation messages from the Queen Charlotte Islands and other communities without telegraph or telephone links to the outside world. Around 1919–20 the Branch had increased the demands placed on this service by issuing licenses to several pulp and saw mill operations and agree-

101. These and many other examples of requests for radio stations in the north can be found in NAC, RG 12 vol. 2159 file 6700-8 pts. 1-3.

102. Department of the Naval Service, *Annual Report for 1919–20*, (Ottawa: King's Printer, 1921) p. 24. The growing concern with regulating broadcasting can be seen in the annual reports after 1920 where longer and more detailed discussions of the Radio Branch's activities in this field appear yearly.

103. *Annual Report for 1919–20*, p. 25; *Annual Report for 1927–28*, p. 11; *Annual Report for 1930–31*, p. 131; *Annual Report for 1932–33*, p. 92.

ing to carry their traffic for a toll charge. This combined with the general increase in settlement in the region led to a reorganization of the west coast network. The ten existing stations were divided into two groups, one to do ship to shore work and the other to do interstation work. It had to reroute some traffic, rearrange its equipment to meet the new needs, and build one entirely new station near Vancouver to handle just the interstation work, but with these changes, it became possible to do commercial marine work and interstation work without conflicting with essential marine communications.[104]

A similar policy was pursued later in the twenties and thirties, when the Hudson Bay Railway project was reactivated by the Department of Railways and Canals. Delayed by the war and other problems, the railway was intended to transport prairie grain to the new port at Churchill from where it would be shipped to markets all over the world. The remoteness of the line itself as well as of the shipping route through the Hudson Strait and Bay into Churchill made radio indispensable during both construction and operation of this project. In 1927, the Radio Branch reopened the existing Department of Railways and Canals station at Port Nelson and erected a temporary station at Fort Churchill to assist in the construction of the rail line. As well, a group of stations were set up along the Hudson Strait. Initially intended to communicate with the government sponsored Hudson Strait Expedition which was charged with exploring the region and collecting navigational and other information on it in 1927, these stations evolved into the coastal system protecting ships moving in and out of Churchill. The original temporary stations were located at Port Burwell, Wakeham Bay and Nottingham Island but within two years the Wakeham Bay and Port Burwell installations had been moved to Cape Hopes Advance and Resolution Island respectively where they were used to set up permanent direction finding stations.

In 1930–31 two additional northern stations were erected by the Branch at Chesterfield Inlet and at the mouth of the Coppermine River. The latter establishment was "to act as an observation post for the collection of meteorological data" rather than as an aid to navigation but it was an integral part of the northern network because the information supplied by it to the Meteorological Office in Toronto was "used in the compilation of daily weather reports" which were essential to improving safety at sea. As well, starting in 1931, day-to-day conditions (ice and other) in the Strait were reported by radio (telegraph and telephone) from a government steamer to the various coast stations as well as to Ottawa via a short wave transmitter.[105]

Yet while marine communication was without a doubt the primary purpose of the northern network, like the other coastal station systems, allowances were made for other uses as long as these did not interfere with safety at sea. One such allowance which was very welcome to residents within range of the three most western stations (Churchill, Chesterfield, and Coppermine) and the radio equipped RCMP schooner *St. Roch*, was the broadcast of personal and press messages beginning at Christmas 1930. A great many "trading posts, settlers, miners, missions, etc.," took part in this program. The transmission was done by voice on a prearranged schedule depending on location. For some Northerners, these special broadcasts quickly became an established form of communication with the outside world that made life in the Arctic that much more enjoyable. For others, however, who wanted a more direct connection with the south, they may well have reinforced the conviction that the isolation of their communities in the age of radio was unnecessary and unfair.[106]

Northwest Territories and Yukon Radio System 1923–1960

Although the Radio Branch itself did not take on the development of land based radio systems for the north in other than an incidental way, the federal government eventually was pressured into providing some form of communication for the region beginning in the mid 1920s. Instead of turning to the Radio Branch which was clearly preoccupied with its marine and regulatory functions, the government, in this instance the Department of the Interior, called upon the Royal Canadian Corps of Signals to develop and operate an effective system of northern land communication. Having recently returned from the war, members of the Signal Corps were experienced in radio operation and maintenance. Their commanders were no

104. *Annual Report for 1919-20*, pp. 25–6.

105. *Annual Report for 1927-28*, pp. 24–6; *Annual Report for 1928-29*, pp. 27–8; *Annual Report for 1929-30*, p. 23; *Annual Report for 1930-31*, p. 140.

106. *Annual Report for 1932-33*, p. 89; *Annual Report for 1935-36*, p. 9.

doubt pleased with being given the opportunity to keep their men working and thus expand their knowledge and experience of this new technology. Those in charge of the Canadian Army also promoted the scheme as part of a plan to find peacetime roles that would justify the continued existence of the army and allow it to maintain a workable level of staffing and training.

In its initial stages, the project was quite limited and there was no master plan outlining in detail where and when stations would be built. Accepting the idea of an extensive network in principle, the Department of the Interior and the Signal Corps approached the actual development of it pragmatically. A variety of factors determined where and when a station would be built, what its role would be and how it would be equipped. A primary consideration was need and in the government's eyes this usually meant some kind of resource development and settlement potential. With mineral and oil exploration taking place all over the northwest in this period, tiny communities of engineers, surveyors and workers were appearing regularly. Some of these became established and grew into small settlements while others remained little more than work camps or disappeared altogether sometimes almost overnight as finances, the deposit itself or the market for the resource dried up.

Other definitions of need grew out of the ongoing development of the north. Exploration and exploitation of the region's resources required both people and supplies and these, in turn, required some form of transportation to the north. Thus there was a need for navigational aids on rivers, lakes and along the arctic coastline and, eventually, for air travel. These aids included the gathering of detailed and regular weather information from a variety of locations and its distribution throughout the region. The evolution of the system was also influenced by the varied and changing administrative and military needs of the government from 1923 to 1960. The system does not seem to have been aimed at improving communication between the many small native communities throughout the northwest, though these communities probably were allowed access to the system when a station happened to be located in or near their settlement.

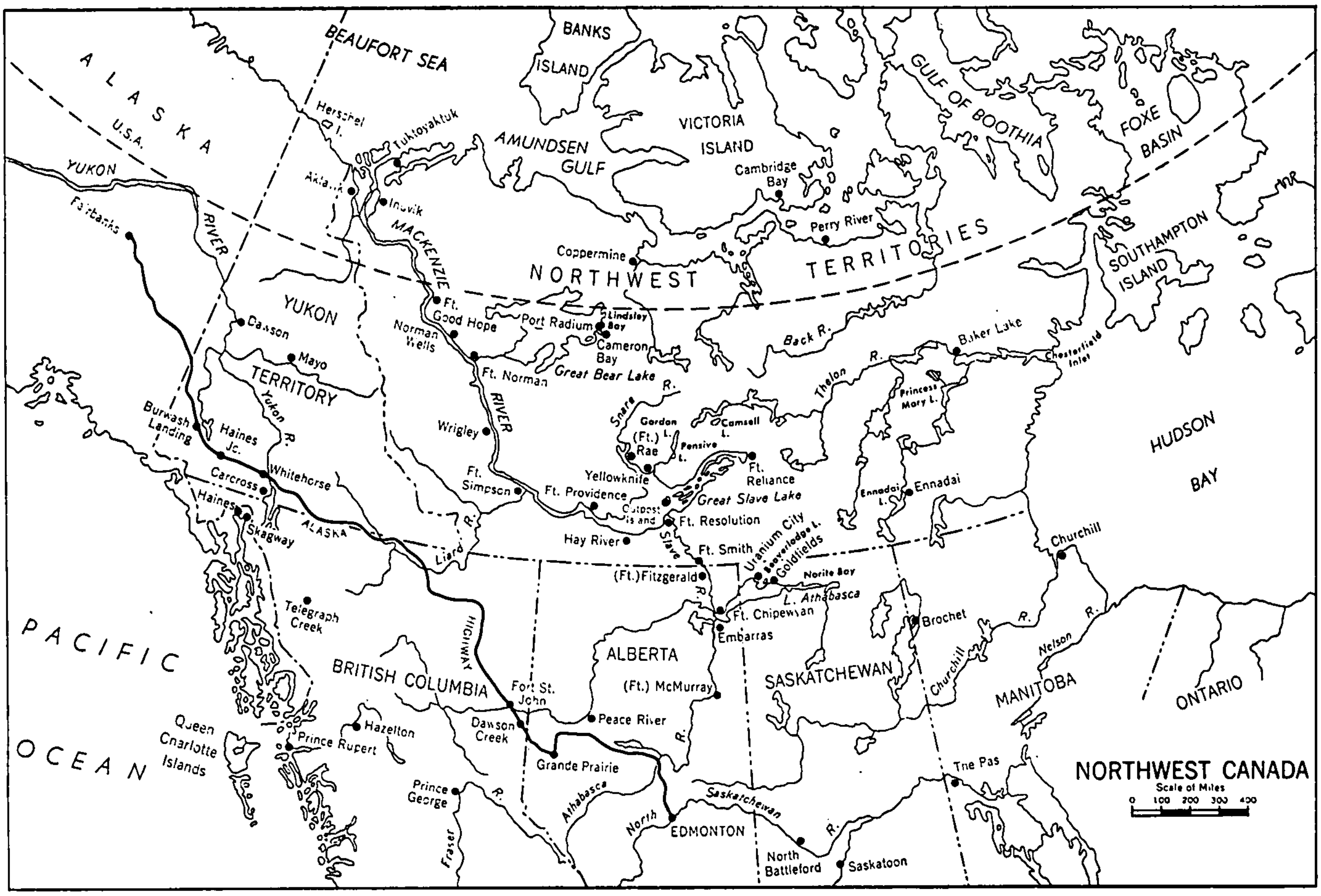
The first link in the system was established in 1923 between Dawson City, Yukon, "the northern terminus of the Government Telegraph Line [through B.C.], and Mayo Landing [Yukon], because it was the centre of a rich mining area and headquarters of such Government officers as the Gold Commissioner, Mining Recorder and RCMP Commissioner." In the seven years following, the system was expanded to cover crucial supply routes such as the mouth of the MacKenzie River (Herschel Island, Aklavik), Great Slave Lake (Fort Resolution) and the MacKenzie River between the mouth and Great Slave Lake (Fort Norman) and established trading centres such as Fort Simpson and government centres such as Fort Smith. A station was set up at Edmonton as an additional connection with the telegraph and telephone lines to the south.[107]

Similar types of requirements determined the Department of the Interior's approach to expansion in the thirties. At least six stations were established in the Northwest Territories and northern Saskatchewan to serve the needs of mining camps, though some of these did not last long. Two installations were created along important supply routes and yet another link to the south was set up at North Battleford, Saskatchewan to relay government traffic from such departments as Health, Natural Resources, Indian Affairs, and the RCMP to and from the north. This relieved the increasing pressure on the station at Edmonton and improved the efficiency of the system as a whole.[108]

The thirties also saw the emergence of new tasks for the Northwest Territories and Yukon Radio System. Air traffic was becoming more and more common in the north, in part because resource development was spreading to areas inaccessible by land or water. Until 1936, "air-ground communications had been practically all of an emergency nature, with the aircraft carrying very low powered equipment which could not be operated while in flight." Despite this fact, the government saw fit to set up three stations to service air routes from Fort McMurray north and Whitehorse west in 1933 and 1935 respectively. Presumably these were used to help the airline companies keep track of the whereabouts of their planes a little more effectively. With the advent of reliable two-way radio communication around 1936, stations along primary air routes became even more valuable and, in recognition of this, the government established one at Yellowknife in 1937 to assist with the rise in air

107. Royal Canadian Corps of Signals, *A Short History of the Northwest Territories and Yukon Radio System, RC Sigs*, (Edmonton: Royal Canadian Corps of Signals, 1960) pp. 2–5.

108. Royal Canadian Corps of Signals, pp. 5–16.



Map of the stations that made up the Northwest Territories and Yukon Radio System. Source: John S. Moir, History of the Royal Canadian Corps of Signals 1903-1961, *(Ottawa: Corps Committee, 1962)* traffic in that area and one at Fort Providence to serve the Canol Pipeline project.[109]

Two other new services were provided by the government network. For a short period in the late thirties a radiotelephone link with the Alberta Government Telephones system in Edmonton was maintained. Phone booths were installed in stations at Fort McMurray, Fort Smith, Yellowknife and Goldfields, Sask. and residents of the area could place long distance calls to anywhere in the western provinces. This service enjoyed great popularity not only among business people but also among the general public in the communities but due to the war it lasted only four years. The government system also made an effort to assist those organizations and interests in the north that had taken the initiative and set up their own radio stations. The Hudson Bay Company, the RCMP, airline companies and even religious missions were among those who installed radio equipment in places that did not warrant a government station. They were allowed to link up with the government network and thereby keep in regular touch with the outside world.[110]

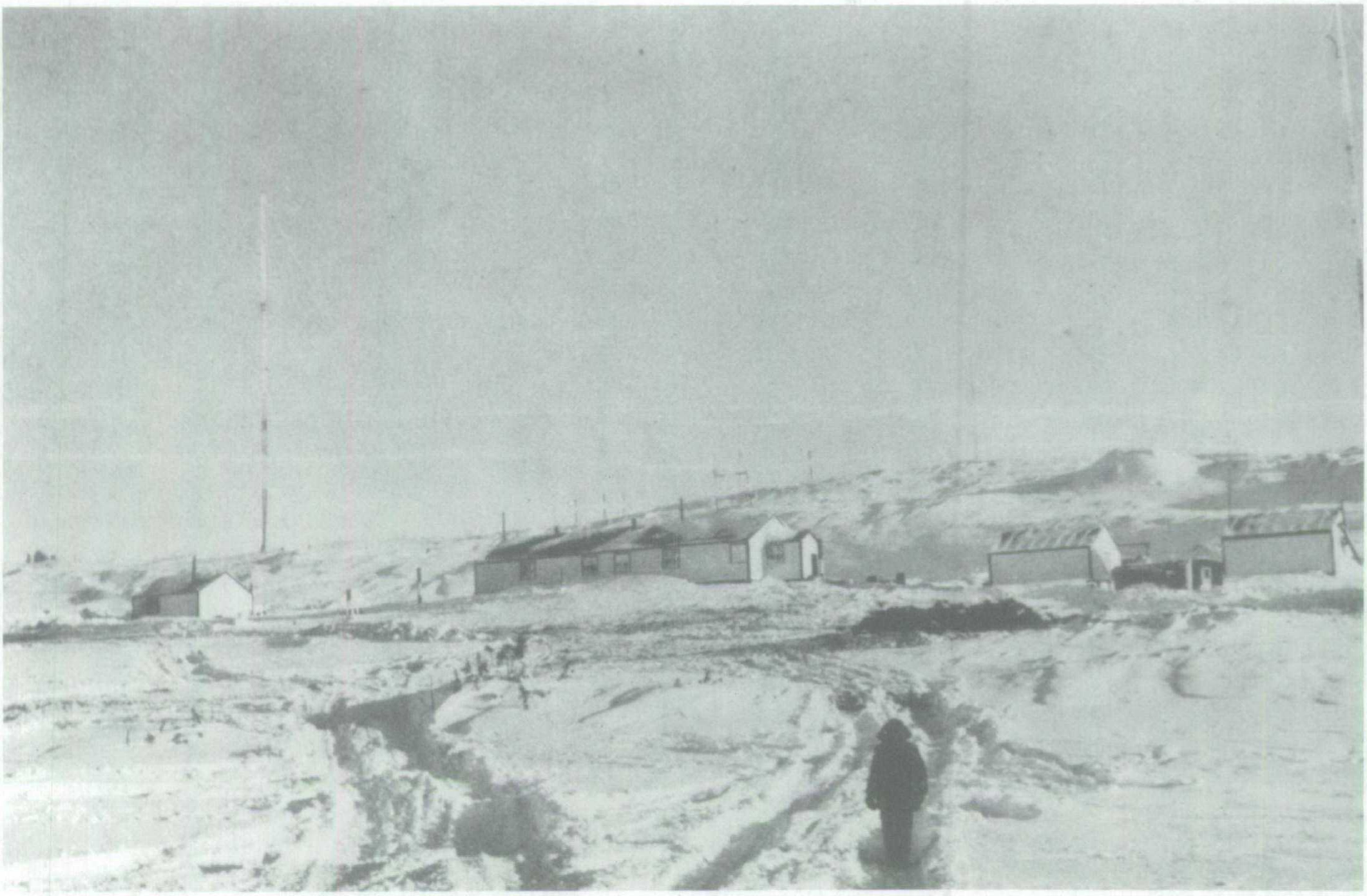
The declaration of war in September 1939 had a profound effect on the Northwest Territories and Yukon Radio System. Projects were cancelled, stations were closed, staff was depleted and services were reduced as both Signal Corps personnel and government funds were channelled into the war effort. By 1940 there were 12 stations operating at a severely diminished capacity compared to the 19 fully operational ones that existed before the war, not to mention those that were in the planning stage of development. Moreover, the military needs of the day took precedence over the radio requirements of the civilian population in the region. After the attack on Pearl Harbour and the entrance of the Americans into the war, the U.S. Army became very involved in the north, building defense installations and the roads and landing strips necessary to supply these. Both commercial and military aircraft were flying into the north 24 hours a day with personnel and supplies for these projects and the Canadian government radio network was called upon to provide communications support including detailed and current weather information. This led to an eventual expansion of the system back to its pre-war level of 19 by the end of 1944, but all of these new installations were military in origin.[111]

The influence of the war on the NWT&Y Radio System was not, in the long run, negative. The military involvement in the north had opened up and developed previously inaccessible areas and had given direct impetus to oil and uranium exploration in the region. As well, with the war over, stations built and used for military purposes could be retained for civilian purposes. Thus by 1949, the system was larger than ever before with 24 stations carrying out a wide variety of services.[112]

Collecting and conveying meteorological and weather information had become an important component of the system and members of the Corps were often sent to extremely remote places to fulfill this rôle. The personnel at one such station, Ennadai Lake, NWT, had only a small group of Inuit for neighbours. The data gathered by this station and others like it was absolutely essential to safe flying in the north even though the specific locations themselves did not attract any air traffic to speak of. This role was significantly expanded in 1955 when construction of the Distant Early Warning system or DEW line began. Equipment and supplies were airlifted to the various sites all day and night requiring constant weather information and increased air-ground-air radio coverage. The NWT&Y Radio System was responsible for providing these services from Cambridge Bay in the east to the Alaska boundary in the west. As well, radio stations were set up on the local building sites. Equipped and operated by the Marconi Company (subcontractor to Western Electric), these stations filed hourly weather reports which were passed through the government network to the forecast office in Edmonton.[113]

The increased traffic resulting from uranium mining, the DEW line and other special projects, such as the Duke of Edinburgh's aerial tour of the north in 1954 (during which the system had to handle massive air communication and press traffic), was handled with remarkable efficiency. This was, at least in part, the result of a technological shift away from hand-keyed Morse code equipment and towards automatic radioteletype equipment. First tested in 1946 between the stations at Edmonton and Yellowknife, the system had required a lot of adjustment and refinement

109. Royal Canadian Corps of Signals, pp. 11–15.
110. Royal Canadian Corps of Signals, pp. 9–11, 15–16. See also "Radio Stations in Northern Canada," 1 April 1940, NAC, RG 12 vol. 1631 file 6800-30 vol. 4.
111. Royal Canadian Corps of Signals, pp. 18–24.
112. Royal Canadian Corps of Signals, pp. 24–34.
113. Royal Canadian Corps of Signals, pp. 28, 32–4, 43–4.



The Northwest Territories and Yukon Radio System station at Ennadai Lake. Typical of the isolated stations which made up the system, Ennadai Lake was the last station established by the Signal Corps and one of the first to be transferred to the Department of Transport. Source: John S. Moir, History of the Royal Canadian Corps of Signals 1903-1961, *(Ottawa: Corps Committee, 1962)* before it was considered ready for general use. By 1954, several of the major stations along the Edmonton-Yellowknife-MacKenzie River route were equipped or in the process of being equipped with both high and low frequency RTT systems allowing them to receive and transmit messages at a rate of 60 words/minute. The advocates of the manual system grudgingly accepted the overall superiority of the new system but still enjoyed gloating "on many occasions in the summer months when high frequency blackouts and extremely heavy atmospherics on low frequencies rendered the RTT circuits utterly useless for hours at a time and sometimes for several days on end." When this happened, the Morse operators were able to pass on urgent messages by using the old CW circuits while the keyboard operators sat idle.[114]

As the system continued to evolve after 1955, it became clear that the services it was providing were becoming increasingly specialized. It was no longer filling a general void in northern communications but was expected to provide detailed and technical meteorological data, complex air traffic control information and classified military intelligence in addition to general communication links between isolated communities and the outside world. The difficulties and inefficiencies inherent in maintaining such services first became apparent in 1950 when the Korean conflict again reduced the number of experienced staff available. As a result of the immediate problems caused by the war, the officials of the Department of National Defence (which now administered the system) began the process of transferring responsibility for certain NWT&Y Radio System stations to other departments. This process was to continue until 1960 when the last stations were handed over.

The first station to go was Dawson in 1951 and it went to the Canadian Army Signal System which was by far its heaviest user. The remainder of the network was handed over to the Department of Transport in stages over the course of five years. Transport had been given responsibility for the Radio Branch and aviation in 1937 and since more and more of the work being done by the NWT&Y Radio System involved air traffic control and weather reporting in support of air safety, it made sense that this department should gradually take over these responsibilities and eventually the system as a whole. Thus after providing 37 years of service to many northern residents the Royal Canadian Corps of Signals relinquished control of the Northwest Territories and Yukon Radio System and of government radio in the north to the Radio Branch which, by its successful resistance to anything but an incidental involvement in providing general radio service to isolated communities, had indirectly encouraged its formation in 1923.[115]

The Hudson Bay Company Radio System 1937–1970

The private radio network of the Hudson Bay Company was established in response to a perceived commercial and social need for better communications between the many remote fur trade posts in the north and the Canadian headquarters of the company in Winnipeg. The early thirties had not been profitable years for the company for a number of reasons and radio communication (along with air transportation) was instrumental in the reduction of administrative costs. As well, post-World War I commerce, in general, was becoming more and more dependent on rapid and reliable communication on a local, national and international scale.

At the same time, radio helped to relieve some of the social isolation felt by the residents of these posts, many of whom saw the supply and mail ship only once a year and sometimes not at all if weather conditions turned unexpectedly. This made life very difficult for post residents especially since by the 1930s most were used to enjoying some of the comforts of modern society.

These and other issues related to the possible use of radio by the HBC were first discussed by company officials in 1934. While visiting some of the posts on the supply ship *Nascopie*, Fur Trade Commissioner Ralph Parsons, Governor of the Company Sir Ashley Cooper and the summer student radio operator on the ship, George Horner, exchanged ideas on the subject and decided to conduct a limited trial. Two company apprentices with amateur radio licences used their low-power sets from their posts at Norway House, Manitoba and in the Western Arctic "to communicate with other amateurs all over the world." More systematic tests were carried out in the summer months of 1935 and 1936 by George Horner to determine the special characteristics of radio transmission

114. Royal Canadian Corps of Signals, pp. 30–2, 39, 41–2.

115. Royal Canadian Corps of Signals, pp. 34, 36, 37–60. A similar account of the NWT&Y Radio System can be found in Moir, pp. 276–87.

and reception in the arctic. The results of these tests convinced the company to establish a network of stations and they were aided in this by the cooperation of the government Radio Branch which issued the necessary licences.[116]

Horner became the HBC radio engineer with an office and radio lab in Winnipeg where equipment was assembled and operators trained. Recognizing the special problems associated with the transportation, storage and maintenance of radio equipment in the north, Horner stressed smallness and simplicity in creating systems for the posts. The primary technical problem to be overcome was how to supply the power required to run the transmitters. Horner devised a system based on wet-cell accumulators charged by windmill generators, thereby avoiding dependence on the precious and at times uncertain coal supply needed to heat the posts. He used a voltage inverter to provide the two separate voltages used by the electronic tubes of the time. Both the receiver and the transmitter were each "about the size of a toaster" and together with the batteries could fit neatly into a corner of one room. The wind-powered generator was erected somewhere on or near the building housing the radio.

The four stations set up in 1937 were not particularly powerful and messages had to be relayed to the south via the nearest government station to insure their reception. As well, voice communication was not possible and only those trained in telegraphic code could use these radio facilities. But these were minor disadvantages to a company cut off from its employees and to people who had no other means of regular contact with the world beyond their tiny posts. As a consequence, the network expanded to 54 stations in the space of two years and fulfilled its dual role admirably facilitating the passage of business information such as world fur prices or supply orders and personal messages including a marriage proposal to points south. The popularity of the radios was such that many wives and other residents learned code so that they too could use the sets.[117]

The HBC radio system was especially valuable in emergency situations which arose all too frequently in the harsh and remote northern environment. The Canadian government doctor at the Chesterfield Inlet station was called upon regularly to provide medical advice and assistance over the radio and when extreme cases had to be evacuated, the HBC radio operator often provided air-ground-air communications support. In 1943, a dramatic air rescue of stranded HBC employees was coordinated using radio. Fort Ross was isolated even by HBC standards and pack ice had prevented the supply ship from reaching the post for two consecutive summers. Without the necessary food and supplies to survive another winter, the manager, his wife and the clerk of the post had to be evacuated. A large US Air Force transport, flying to the limit of its range for a return flight first dropped supplies and a skilled worker to prepare a landing site and then flew in to pick up the residents and a handful of their belongings. The whole rescue was made possible by the use of the post radio equipment to guide the plane in and out of the area.

This extensive radio network was used to great advantage by the government during World War II, as well. Employees at certain posts were trained to detect and report strange aircraft, while others collected meteorological data used to assist in transatlantic flights. The company posts also provided support for radio research personnel sent to the arctic to investigate the ionosphere and its effects on radio transmissions.[118]

By the end of the war, the value of radio in the north was so obvious to the officials of the HBC that all of its "101 northern trading posts were equipped with radio transmitters and receivers." Moreover rather than abandoning radio when, in the late 1940s, it became too time-consuming to train personnel to use code, the company readily switched its stations over to voice equipment. Similarly, in the fifties, it attacked the growing problem of interference head-on by supporting a new series of experiments undertaken by George Horner and re-equipping according to his advice with a completely new single side-band radio system—the largest and most northerly such system in the world when it was completed in 1959.

In just over a decade, however, this system too was being eclipsed by newer and more advanced telecommunications systems as the pace of technological change in this and other fields continued at an incredible rate. Telephone communication using microwave and satellite technology was becoming

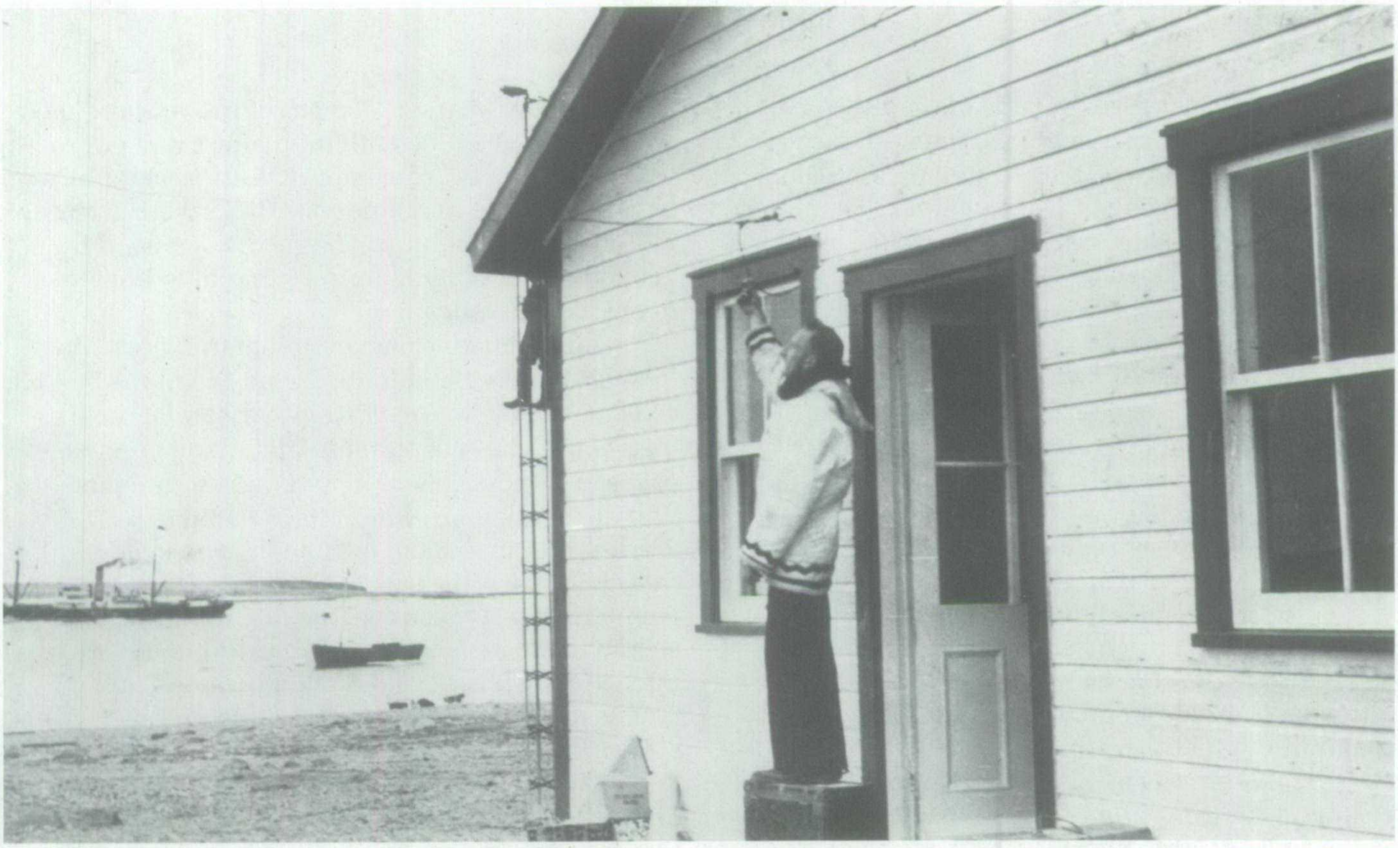
116. Thomas R. Roach, "The Saga of Northern Radio," *The Beaver*, 5 (Summer, 1984) pp. 19–21; Morris Zaslow, *The Northward Expansion of Canada, 1914–1967*, (Toronto: McClelland and Stewart, 1988) p. 137.

117. Roach, pp. 21–3, 25.

118. Roach, pp. 23–4.

G.C.M. Collins, an amateur radio operator and one the Company's apprentices, is pictured here using his set from the post at Norway House, Manitoba 1935. He helped to show that radio was a viable means of communicating in the north. Source: Hudson's Bay Company Archives Provincial Archives of Manitoba, neg. no. 84-69.

Station CY8Q in the Hudson's Bay Company post at Little Grand Rapids, 1940. Note the large batteries under the desk. Source: Hudson's Bay Company Archives Provincial Archives of Manitoba, neg. no. 84-71.



S.G.L. Horner installing station CY7L at Fort Ross post. At the left corner of the building the windcharger is visible and is being adjusted by another person. The company's supply ship Nascopie *can be seen in the background. Source: Hudson's Bay Company Archives Provincial Archives of Manitoba, neg. no. 84-70C.*

available to northerners outside of the major communities. As a consequence, the number of radio stations in HBC posts declined rapidly in the late sixties and the seventies. There were 72 remaining in 1970 and now there are only a handful, no doubt kept as back-up systems, as a hobby or as a sentimental reminder of an earlier era in the north when the radio was the only link with the outside world.[119]

Other Land-based Radio Systems and Uses

Amateur Radio in Canada

The roots of amateur radio in Canada go at least as far back as Marconi's famous transatlantic signal in 1901 which inspired many to become radio experimenters. Though some developed a professional interest in the field, most remained amateur enthusiasts. Their amateur status, however, far from limiting their contribution to technological change and advancement, provided the inspiration for important innovations which shaped the evolution of radio science after World War I.

With the proliferation of radio stations both commercial and government in the years before 1914 and the increased interference resulting from them, amateurs were forced to work outside of those areas of the spectrum which at the time were considered the most useful for reliable long distance communication. International regulators gave them wavelengths shorter than 200 metres to work with in much the same way that an adult would "give a toy to a child." This did not deter them in the least, however, and, with equipment much simpler and less powerful than the big companies were using, the amateurs began to achieve some impressive distances. Despite being shut down altogether during the war, by the early twenties, North American amateurs had set up traffic nets "which covered the area between the Mexican border and parts of Canada" and in 1921, "amateurs spanned the Atlantic" in a series of coordinated tests in which thirty or more North American stations were heard in Britain. One of those recorded was spark station 3BP, Newmarket, Ontario. During this same period "Canadian and American amateurs were able to establish frequent contacts with Africa, Asia, and Australia."

119. Roach, pp. 24–5. For a similar account of these developments see also Thomas R. Roach, "Brass Pounders of the North," unpublished paper, 30 October 1983, pp. 1–16.

Within four years of the end of the war, radio amateurs were sufficiently numerous and enthusiastic to organize a convention. With "several hundred" adherents in attendance, talks were given by well-informed amateurs and professionals in the field on topics ranging from technical to business to regulatory issues.

Also in attendance were Canadian representatives of the American Radio Relay League (A.R.R.L.) which formally linked North American amateurs together in chain of stations that made possible the passage of messages over vast distances. Alone, Canadian amateurs would have had difficulty forming and financing a viable relay network especially given the size of Canada and its sparse population, but as part of the A.R.R.L., they had access to a large and established group of like-minded individuals who could provide them with access to a reliable long distance communication system.[120]

The accomplishments of amateur radio operators were quite remarkable especially given the fact that for many years much of their equipment was built out of household items and bits and pieces from the local hardware store. Yet while their unique contribution to the progress of the art was generally praised by commercial and government leaders in the field, they constantly had to defend their spectrum allocation against the intrusions of those who believed that they had a more serious claim to spectrum space. Amateur officials lobbied the government in Ottawa to protect their interests on both a national and international level (since spectrum allocation was quickly becoming a global issue) by reminding them of the important role amateurs played in filling in the communication gaps in the north and other isolated regions of Canada and in providing expertise and innovative ideas in what was still a relatively new technological field. They also made up a pool of well-trained personnel willing and able to assist their government in times of war or other emergencies.[121]

The efforts of amateurs to defend their legitimate place in the radio field met with qualified success

120. Aitken, *Syntony and Spark*, p. 272; Saskatoon Amateur Radio Club, *From Spark to Space The Story of Amateur Radio in Canada*, (Saskatoon: Saskatoon Amateur Radio Club VE5AA, 1968) pp. 15, 24; Clinton B. DeSoto, *Two Hundred Meters and Down The Story of Amateur Radio*, (West Hartford, Connecticut: The American Radio Relay League, 1936) pp. 29–30.

121. "Canadian amateurs make their views known prior to international conference 1927," NAC, RG 97 vol. 123 file 4003-4-1 pt. 2.

over the years. Some band widths were reduced, some new space allocated but overall the movement has prospered and grown despite being shut down for a second time between 1939 and 1945. In part this is because radio amateurs have an insatiable appetite for experimentation and thus have always made the best use of whatever parts of the spectrum they were allocated. Also governments and society generally could not fail to recognize the valuable service radio amateurs have rendered to their country and their fellow citizens. During natural disasters such the Winnipeg flood of 1950, the Alaska earthquake of 1964 and, most recently, the hurricanes in the Caribbean, crucial communications have been maintained with the outside and relief efforts coordinated through radio amateurs. As well, Canadian amateurs have played a special role in establishing radio links with various expeditions and research teams working in the arctic. Government systems have now taken over much of the formal communications work for these arctic projects but amateurs still listen in with great interest as many did during the joint Soviet-Canadian polar expedition of 1988. This kind of dedication and this level of interest insure that amateur radio will continue to exist for many years to come in Canada and all around the world.[122]

Mobile Radio on Land

Before the development of mobile land-based radio systems, it was impossible for people on the move to keep in direct touch with their headquarters to coordinate their actions. In urban areas telephone networks made communication rapid in some contexts, but certainly not immediate. In rural and remote areas such as forest reserves, telephones were of even less value if they existed at all. Emergency services found it particularly difficult to fulfill their responsibilities without direct and immediate intercommunication. With the advent and spread of marine radio (which was essentially mobile), the prospect of developing a similar land communication system must have occurred to some inventive minds. Indeed, as early as 1912, communication between a moving train and a fixed radio transmitter was successfully established in a series of experiments. But early radio was not as reliable over land as it was over water and the training required to familiarize all emergency personnel with telegraphic code and keying was probably considered too great an investment in both time and money to make such a project worthwhile. As well, there was no such thing as a truly portable set for the use of workers alone and on foot while carrying out their duties.

By the mid twenties, voice radio or radiotelephone as it was then called, was available and was used for short distance marine communication. It appears to have been some time, however, before this technology was adapted for use on land. In the meantime urban emergency personnel presumably used streetside telephone call boxes where they existed while their rural counterparts such as the RCMP used the government radio network in the north and in the south depended on messages broadcast over the local radio station at prearranged times each day which they listened to in the local store or restaurant or wherever there was a receiver. It was not until 1937 that the use of radio for emergency services was mentioned in the Department of Transport Annual Report and the description provided little precise information on how and when it was used and to what advantage, if any.[123]

World War II gave great impetus to the development and refinement of mobile radio. The walkie-talkie which had been developed by a Canadian named Donald Hings in 1937 for use by a mining company in British Columbia, attracted significant attention after the outbreak of war. The infantry in particular saw the value of a communications system that the individual soldier not only could operate with relative ease but also could carry by himself. By the end of the war, the walkie-talkie and other forms of mobile radio had become a familiar and integral part of military communication networks.[124]

This wartime experience eventually led to the widespread use of mobile radio by police, ambulance and fire services throughout North America. By 1944, the Department of Transport reported that 73 municipalities across Canada had licensed police radio stations which communicated with radio-equipped police vehicles. These systems were generally controlled by a central headquarters dispatcher responsible for collecting and distributing all the essential information. Such mobile networks were intended for the exclusive use of the particular organization operating them, although people with the right kind of receiver could and did

122. Saskatoon Amateur Radio Club, pp. 126–7.

123. See Department of Transport, *Annual Report for 1936–37*, (Ottawa: King's Printer, 1938).

124. "B.C. exhibit fetes walkie-talkie inventor," *The Ottawa Citizen*, 27 August 1988, p. F7.

listen in. The walkie-talkie was also used by police forces and others who patrolled without a radio-equipped vehicle.

In the years following the war, the use of mobile radio spread beyond emergency services. Many businesses saw improved communication as a way to improve efficiency in delivering their goods and services. Fleets of vehicles could be coordinated so that they would be in use virtually all the time instead of running empty. Any company moving large amounts of goods or large numbers of people around a sizeable urban community was likely to profit from such a system and many did.

As well, by 1946, Bell Telephone was testing a radio system that would link into the local telephone exchanges in major Canadian cities allowing its users to phone from their vehicles in much the same way that they would from their homes or offices. First established in Montreal in the same year as the tests, this system spread rapidly to other cities in the late forties and also grew to include service along certain busy highways outside of urban areas. Calls made to or from vehicles were handled by an operator until the mid 1960s when the first limited use of a direct dial system was begun by the Quebec Provincial Police (1964). This system in which switching was controlled automatically by computer, was developed and produced by Bell Canada. It was refined and its use expanded by the force over the course of the next 13 years and its success in this role was such by 1977 that Bell introduced it (calling it Access 450) to the public as an alternative to the established operator-based system.

Eight years after the introduction of direct dial mobile telephone, an even more sophisticated system of mobile communication was introduced in Canada—cellular radio or telephone. First developed in the U.S. in the 1960s and 1970s (though not tested until 1980 in Chicago), the primary goal of cellular technology was to relieve the congestion of mobile frequencies in some of the large American cities. It accomplished this goal in two ways. First, the system used higher frequencies (between 806 and 890 MHz) and thus could accommodate many more channels than the existing mobile networks which used frequencies between 150 to 174 and 450 to 470 MHz. Second, instead of striving for coverage of the largest possible area by the smallest number of base stations, the cellular system divided urban communities into many small districts (1.6 to 16 kilometres wide) called cells. Each cell operates on one frequency and contains a number of cellular antennas, transmitters and receivers which relay calls to and from mobile units in the cell over conventional telephone lines to a computer-controlled central switching system linked to the established telephone network. As the mobile unit moves from one cell to another the computer automatically switches the call over to the frequency of that cell without interruption. His elaborate framework (along with the higher frequencies) means that lower powered transmitting equipment can be used and so frequencies can be reused in the same urban area without risk of interference.

The use of higher frequencies alone promised to increase the number of channels available for mobile radio communication from 24 to over 600. With the added advantage of reusing frequencies in a large urban area, the practical effect in a city the size of Toronto would be substantial. It was predicted at the time the system was announced in 1983, that several hundred mobile units would be able to communicate reliably at one time instead of the 12 that could do so using the existing technology.

After two years of such glowing predictions and intense promotion, the cellular system was introduced by Bell and Cantel on a limited scale in the Montreal and Toronto-Hamilton regions in July 1985. As well, plans were made for expansion to many other urban centres across Canada by the beginning of 1986. Coverage was extended within a year to include most of southern Ontario and the whole Toronto-Ottawa-Montreal corridor. By late 1987, there were some 80,000 cellular subscribers across the country (an estimated 30,000 of which were in the Toronto area) and the market was growing at a greater rate than even the companies themselves had anticipated. Moreover, as the market for cellular grows, the cost of the equipment ($1800 to $2500 in Oct. 1987) and the service itself should, according to the companies, come down making the system more attractive.[125]

One other form of mobile land radio is worth mentioning here. General Radio Service (GRS) was set up by the Canadian government to give ordi-

125. All the information on the evolution of Bell's mobile radio system and on the development of cellular radio in Canada can be found in a clippings file entitled "Mobile and Cellular Radio 1945–1987," held by Collections and Research. The articles are from a variety of periodicals including *Bell News*, *The Globe and Mail*, *The Financial Post*, and Telecom Canada's *News Monitor*.

nary Canadians access to mobile radio communication for private use. This service, which is known to most Canadians by its American name, Citizens' Band radio, provides spectrum space in the high frequency band and licenses individuals to communicate on the assigned frequencies using low-powered equipment. At the height of its popularity in North America in the 1970s, GRS was exploited by a very large number of people, many of whom did not comply with the rules and regulations governing its use. As a result of this misuse, the assigned frequencies were often congested and could not provide a reliable medium for communication. This problem diminished as the CB fad passed but the use of GRS is, like all other forms of radio communication, still regulated by the federal government to insure efficient and, in this particular case, equitable use of the allocated spectrum space.[126]

Radio and Aviation

Instant radio communication is today considered an essential component of aviation. The large numbers of aircraft in the air at all times could not function safely or efficiently without such things as automatic signals that define their course and frequent traffic and weather reports all provided by various forms of radio technology. Similarly, in emergencies, airborne craft need to communicate their status and location to the nearest airport and in forest fire fighting or search and rescue operations, observations and information must be exchanged constantly between aircraft and the base of operations on the ground.

Yet this type of rapid and reliable air-ground-air radio communication did not exist for many years after the development of manned aircraft. The first extensive use of airborne radio occurred during World War I when aircraft were used to observe and report on enemy positions and activities. The radio equipment on board these planes consisted of transmitters only, however, and consequently pilots could send information to the ground stations but could not receive any. Even this limited form of radio contact with the ground was far superior to the existing systems of communication such as visual signalling and over the course of the war more and more aircraft were equipped with radio transmitters.

In the years following the war, many non-military aviation services took shape in Europe and North America and the use of radio was perpetuated by these organizations despite the fact that reliable two-way radio equipment was not generally available until the early 1930s. Aerial observation continued to be an important role particularly for government aviation services such as forestry patrols and for this purpose airborne transmitters were as irreplaceable as ever. As well, information passed from aircraft to a well developed ground system of airport and aviation company radio stations provided the basis for a rudimentary air traffic control system which could be used to keep track of the location and status of flights whether on busy or remote routes. The ground system could also be used to collect current meteorological data and to distribute it to pilots before takeoff. Since most early aircraft had to land regularly to refuel this system worked reasonably well and it benefited from the increased range and reliability of ground-based radio which grew out of the war effort. When similar advances in aviation and airborne radio technology made two-way aircraft radio feasible, aerial observation, aids to navigation and traffic coordination and basic safety and emergency communication continued to be the primary roles of radio in support of aviation, but the level of effectiveness in performing these tasks rose dramatically.

Radio and Aerial Observation

Canadians were quick to apply the experience gained in aerial observation during the war to peacetime requirements especially in the remoter regions of the country. As early as the 1920s, the government used aerial observation for at least three tasks—forestry patrols, collecting geographical and meteorological information in isolated areas and in search and rescue operations—all of which benefited from the availability of radio communication.

Forestry Patrols

This was the first aerial observation task assigned to the air force and it grew out of the need to conserve the one million square miles of forests throughout Canada. In 1920 alone forest production accounted for "more than $300 million" and the protection of this profitable resource, particularly from fire, required the development and

126. Canada, Department of Communications, *The Spectrum*, (Ottawa: Department of Communcations, n.d.) pp. 11–12.

implementation of effective methods of observation and intervention. Until the 1920s, the forestry industry and the various branches of both the provincial and federal governments had been forced to rely on such methods as foot, horse and canoe patrols, lookout towers, telephone networks, fire lanes, guards and prepositioned equipment and pumps which at best were "marginally effective." According to one forester, with these types of methods "up to 75 per cent of the forest fires in his area of responsibility remained unobserved or unreported."[127]

Many in the forestry field believed that aerial observation was a much more promising means of detecting and fighting forest fires in the vast Canadian wilderness. During 1919 and 1920, this belief was confirmed by a series of experimental patrols made over forests in Quebec and Alberta. The success of these "convinced the dominion forestry branch to dispense with the construction of a ground lookout system and to rely on air patrols instead." Others in the field arrived at the same conclusion and a handful of experimental flights rapidly evolved into an extensive system of stations and patrols throughout the country operated on behalf of various levels and branches of government.[128]

The effectiveness of these systems even in the absence of radio would almost certainly have been greater than traditional ground-based surveillance methods since the occupants of the aircraft were able to observe so much more territory and report back fairly quickly to their headquarters via message drop or other means. By adding radio to this combination of air and ground observation and intervention, reaction time could be further reduced. Aircraft could report their findings immediately to the station and ground crews could be dispatched to the area without delay. Despite the cost involved in setting up radio-equipped bases and fitting the aircraft themselves with transmitters, the radio linked system was definitely the preferred one, and those governments that could afford it were quick to set one up.

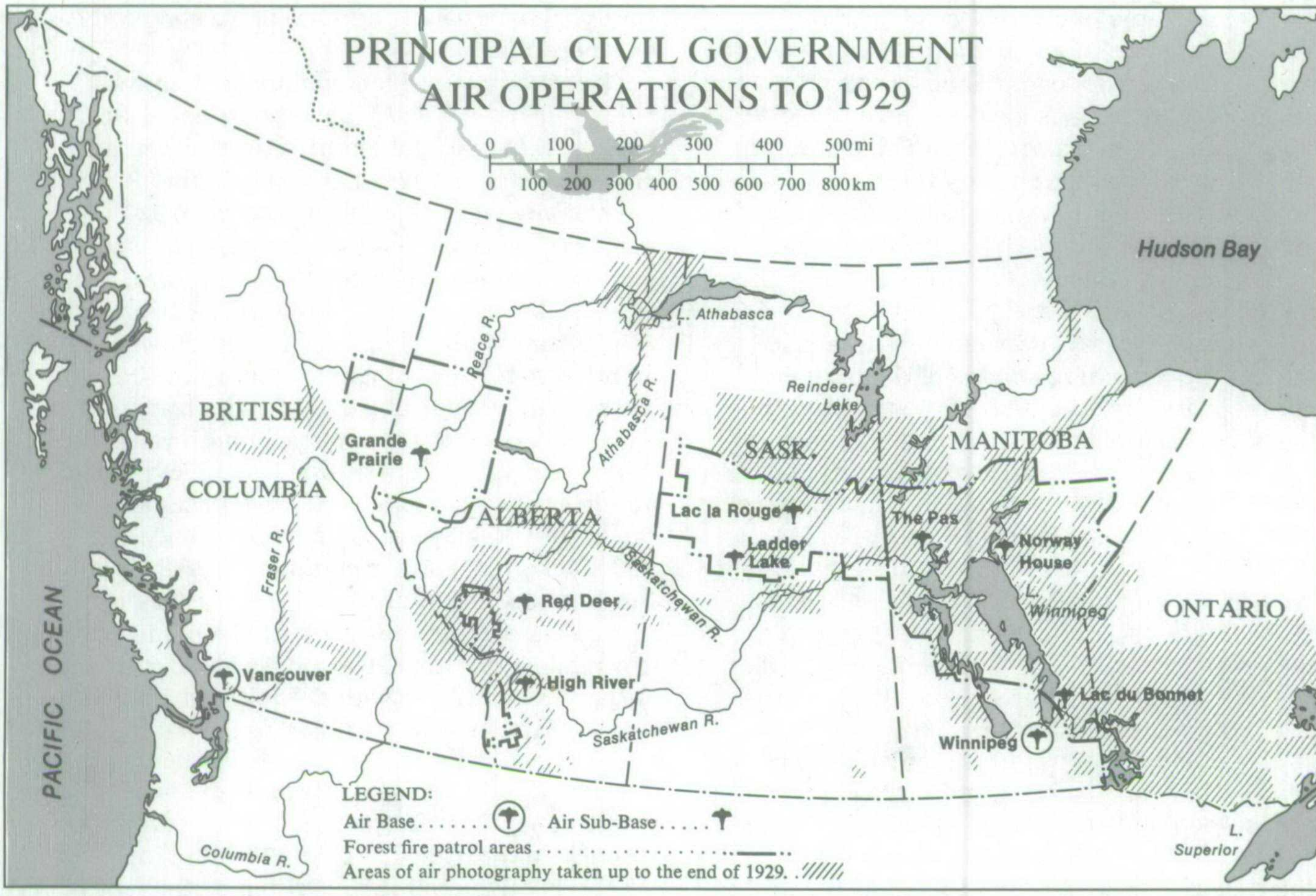
One of the most extensive air to ground radio networks in support of aerial forest observation was established beginning in 1921 by the federal government to protect the forests under its control. Contained mainly in the three prairie provinces and the territories to the north, these vast tracts of woodland had to be patrolled regularly in the fire season. This required that a number of radio-equipped base stations be built across the region. The first of these were set up in 1921 at Sioux Lookout in northwest Ontario, Victoria Beach, Norway House and The Pas in Manitoba and High River, Alberta near the foothills of the Rocky Mountains. In the next ten years the system, which was operated jointly by the Department of National Defence and the Department of the Interior using personnel from the Royal Canadian Air Force (RCAF) and the Royal Canadian Corps of Signals (RCCS), expanded to 15 stations divided into three networks.

The established method of operation for the stations in the prairie network was quite simple and straightforward. Each spring aircraft and crews were stationed at the various bases and sub-bases and, working from the weather and fire hazard evaluations of local forestry officials, would be assigned specific areas to patrol. If, in the course of those patrols, a fire was spotted, the pilot would transmit a message describing the location and status of the fire to the base station and firefighters and equipment would be dispatched immediately by various means including aircraft when they were available. For the most part, the radio apparatus used in these operations was not very sophisticated. The aircraft were fitted with "T-21 (RAF) transmitters which were rebuilt to reduce weight and simplify operation," and the ground stations "began with 120-watt sets of wartime vintage" but soon had 500-watt sets built by the Signals Inspection and Test Department which provided better range.

In some cases forestry officials using these patrol and communication methods were able to stop fires in the very early stages with a minimum of effort and expense. In 1924 a fire was spotted from a patrol craft returning to the base at Victoria Beach, Manitoba. A crew, a pump and 182 metres of hose were sent out immediately upon receipt of the pilot's call for assistance and were placed in the best position according to the observer's instructions. With the help of some rain the blaze was extinguished in two days. Sometimes, however, the use of radio had an impact at a much later stage in the process. When a large fire broke out on the western side of the Rocky Mountains outside of the patrol area in the summer of 1921, it burned for several days before being detected and

127. W.A.B. Douglas, *The Creation of a National Air Force The Official History of the Royal Canadian Air Force, Volume II*, (Toronto: University of Toronto Press, 1986) pp. 93–5.

128. Douglas, pp. 67–8.



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Map of the principal civil government air operations to 1929, showing areas of forest fire patrols. Source: Directorate of History, Department of National Defence.

reported by a radio-equipped patrol aircraft. Coordination of the week-long firefighting effort was carried out using the "comprehensive reports of the fire's advance" sent back over "extreme range" to the headquarters by patrol pilots. Though not the ideal role envisioned for patrol aircraft, this emergency communication system turned out to be of great value all the same, especially when there were large crews and a lot of equipment committed to a fire.[129]

In 1931, the federal government relinquished control of the natural resources of the prairie provinces (with the exception of those within the national parks) and the responsibility for forestry patrols fell to the provincial governments concerned as it had earlier in the 1920s in the cases of Ontario and Quebec. This signalled the end of the RCAF and RCCS patrol and communication network. Aerial forest observation continued to be employed in forestry but the networks tended to follow provincial lines and thus were on a smaller scale. Yet regardless of how limited the systems were or whether the government owned any aircraft or had to contract out to commercial aviation concerns, the use of aircraft and radio to protect valuable woodlands continued to be the preferred approach. Today, though the equipment employed is much more specialized and sophisticated, forest fire prevention and fighting is still based on sound coordination and rapid, reliable communication with mobile units, both of which depend heavily on the use of various forms of radio technology.

Geographical and Meteorological Study

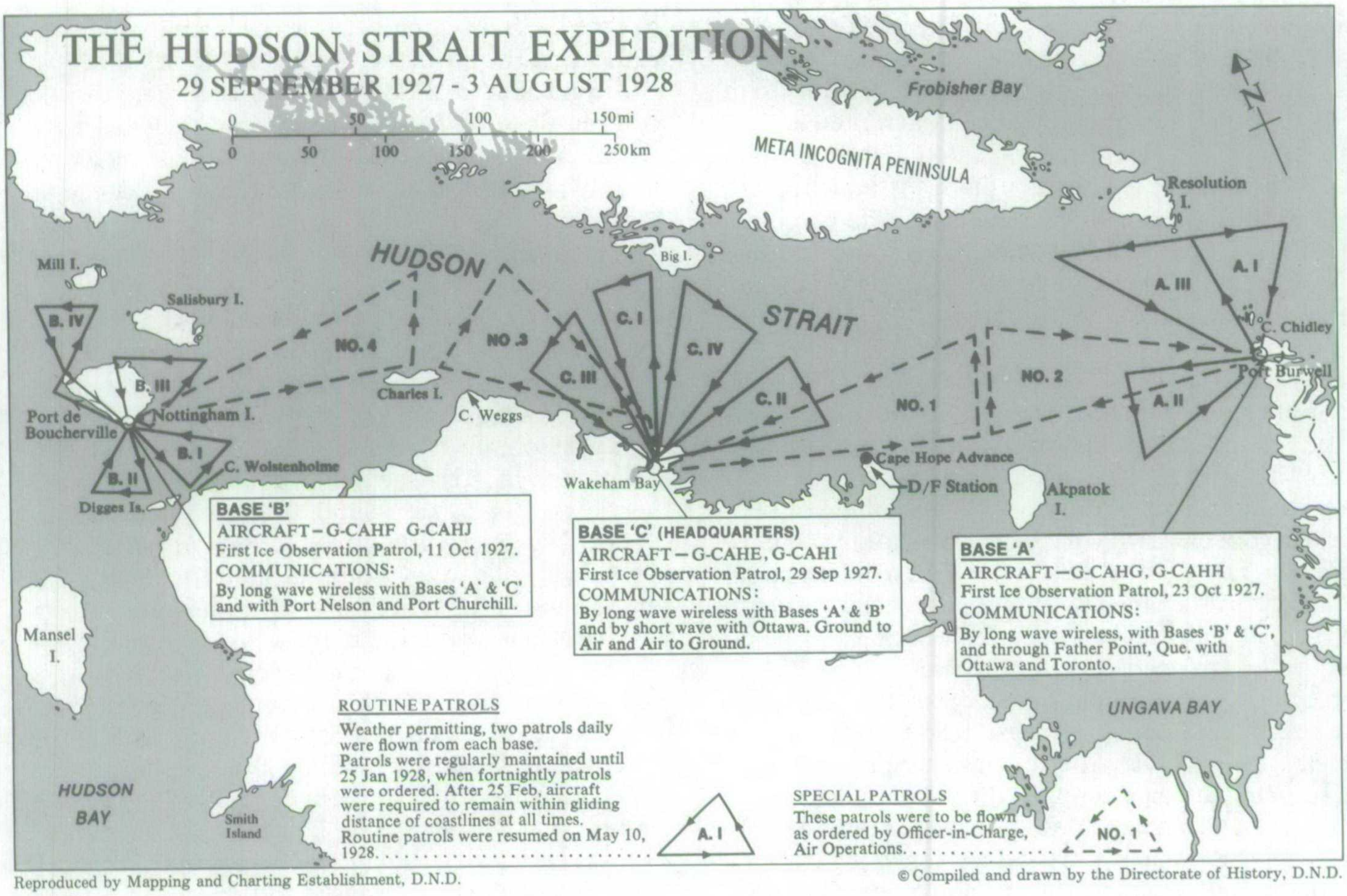
Air to ground radio soon came to be an integral component of other types of aerial observation as well. The Hudson Strait Expedition was sent north in 1927 by the federal government to establish the "seasonal limitation of ocean-going traffic" using the proposed port at Churchill, Manitoba. Existing estimates varied widely and so the government decided that "an extended monitoring of ice conditions was crucial." They further determined that the most effective way of carrying this out was through a systematic aerial survey. Given the isolated character and harsh climatic conditions of the region, as well as the limited range of the aircraft of the time, it was necessary to set up well-equipped base camps and a reliable communication network.

The expedition, which comprised 7 aircraft, 6 RCAF pilots, 12 RCAF mechanics and 4 RCCS personnel to man the ground stations, were transported by ship from Halifax to Wakeham Bay near the midway point of the strait in July 1927. The main base was set up at Wakeham upon arrival and two secondary bases were set up soon after close to the east and west ends of the strait at Port Burwell and Nottingham Island respectively. In addition to being equipped to communicate with the aircraft which carried T-21 radio transmitters with trailing antennae capable of both voice and code transmission, the bases were linked to one another through a long wave system capable of ranges of 160 kilometres using telephony and 480 kilometres using telegraphy. This allowed the western base to connect with the government system via the stations at Port Nelson and Port Churchill, while the eastern base could, through Father Point, link up with Ottawa and Toronto. The main station at Wakeham had short wave equipment and communicated directly with Ottawa.

Daily patrols were flown from these bases beginning on the 29th of September and continuing through to the 3rd of August 1928, weather and ice conditions permitting. (During certain seasonal periods such as freeze-up no patrols were carried out because ice conditions did not allow the safe use of either skis or floats for take offs and landings.) While in the air monitoring ice conditions and taking photographs to document their observations, the crews remained in constant contact with their home bases via radio. Transmissions were sent every 5 minutes and were always duplicated. First a telegraphic message was sent by key and then the same message was confirmed by voice.

Overall the system of aerial patrols was a success. A great deal of valuable information about the area was collected and, of 167 patrols flown, less than 5% were failures despite the incredibly harsh and unpredictable conditions with which the participants were faced. The radio communication network was an integral factor in that success since it not only made the dangerous work of flying in the north safer, but also by its very presence increased the confidence of the pilots and crew members. In general the radio links were reliable—only three flights experienced communications failures and some remarkable distances were achieved as transmissions from Nottingham Island

129. Moir, pp. 53–4; Douglas, pp. 93-5; Group Captain E.J. Gauthier, "The Evolution of RCAF Telecommunications," *Roundel*, (November, 1964) pp. 5–6.



Map of the Hudson Strait expedition, patrols and communications. Source: Directorate of History, Department of National Defence.

were recorded at Port Burwell, far outside the established reception range. (see map) As well the short wave link with Ottawa made it possible to alter plans when circumstances warranted and this increased efficiency and safety. When the permanent radio stations were finally established along the Hudson Strait, the people who operated them benefited from the knowledge gained during the expedition about both the navigation route and the use of radio in the arctic.[130]

Search and Rescue

Aerial observation also proved very useful in search and rescue operations especially those involving aircraft downed in remote regions such as the north. Large scale ground searches could not be conducted effectively in these areas and thus officials working in the field come to depend on aerial reconnaissance for covering the necessary territory systematically. As early as 1929, radio-equipped aircraft were used as part of a search and rescue operation in the arctic. In that year, the two planes of the MacAlpine party were forced to land near Melbourne Island. An extensive search was organized using aircraft tied into the government radio system at Churchill, Manitoba and Ottawa and the private stations of Dominion Explorers at Stoney Rapids, Bathurst and Baker Lake to which the pilots or observers reported their findings. After two months, the group was located by Inuit and taken to Cambridge Bay where the news of the rescue was conveyed via the radio on board the Hudson Bay Company ship *Baymaud* through the government stations to the outside world.[131]

In the MacAlpine case, aerial search techniques did not contribute much to the eventual rescue of the group, but this did not lead to their rejection by authorities. On the contrary, as the use of aircraft in the north expanded throughout the thirties, forties and fifties, aerial search and rescue operations became increasingly common. Improvements in airborne and ground-based radio equipment made swift and accurate location of some aircraft possible but planes still had to be sent up to check the location established by the bearings obtained since these were almost invariably inaccessible by land. Moreover, even with improved direction finding capabilities, bearings were not always accurate and, in these cases, the radio-assisted aerial search became the primary method of locating the stranded people and their craft.

An incident in 1956 amply demonstrated the continuing importance of aerial reconnaissance for search and rescue in isolated and remote regions. In May of that year the Norseman aircraft of C. Crossley was forced down near Cape Welsford. The distress signals sent out by Crossley on his "Gibson Girl" transmitter were weak and garbled when received at the government stations at Chesterfield Inlet, Nottingham Island and Churchill. Repeated attempts were made to obtain direction finding bearings based on these signals but those that were obtained—many were too weak to be of use in this regard—seemed to contradict the location suggested by the signal message. A check of the D.F. system at the three stations revealed no obvious problem that would explain the apparent inaccuracy of the readings and yet, it was Crossley's garbled radio message relayed to the search aircraft that ultimately provided the best indication of where the plane had gone down. The site was located by aerial patrol and the RCMP Otter CFMPP rescued Crossley. Radio communication continued until "all aircraft had left the search area."

It was later suggested that the poor D.F. readings derived from Crossley's radio transmissions were the result of the combined effects of a weak signal and the substantial distance from Cape Welsford. The ground stations were probably basing their readings not on the necessary direct wave but on a "skip wave."[132] Whatever the explanation, these events reinforced the need for more than method of search and more than one role for radio in that context. Even today with such equipment as emergency locator devices which send out automatic radio signals from a downed plane and search and rescue satellites, the importance of radio coordinated aerial observation for search and rescue operations is disputed by few, if any, in the field.

Radio Aids to Air Navigation and Traffic Control

With the growth of non-military aviation services after World War I, improving the safety and efficiency of air navigation became a major concern of many governments, including the Canadian. A

130. Douglas, pp. 105–12; Moir, pp. 54–5; Gauthier, pp. 4–5.
131. *Annual Report for 1929–30*, p. 148.
132. Department of Transport intra-departmental correspondence 8–10 June 1956, NAC RG 12 vol. 1631 file 6800-30 vol. 4.

variety of means were used to accomplish this goal of which radio communication was perhaps the most important. It fulfilled several roles including providing current and accurate weather information, systematic traffic control at airports and along flight paths, and more effective communication in extraordinary situations such as inclement weather conditions or an emergency landing or a crash in a remote area.

Weather Information

The provision of weather information was the first aviation communication problem addressed by the Canadian government and the reasons for its priority are obvious. First of all, the vulnerability of early aircraft to adverse weather conditions was great, perhaps even greater than that of ships which could wait out fog by slowing or stopping completely out at sea. Planes either had to fly around the bad weather if they had sufficient fuel or land in spite of it and hope for the best. In Canada, where extreme weather conditions were more often the rule than the exception, the need for current and detailed meteorological information was that much more important.

The government took the first steps toward fulfilling this need in 1928 when, at the request of the RCAF pilots working on forestry patrols in the west as well as of the commercial pilots in the area, the personnel at the western stations began sending out regular weather reports. These reports were prepared twice a day by radio operators (due to the nature of forestry patrol work, many had been trained as weather observers) "in a form most useful for aviation" and "were broadcast from High River, Edmonton, Prince Albert, Cormorant Lake." The forecasts were combined and then "passed by the stations to local newspapers, flying clubs and aircraft companies" which disseminated the information to aviators and others such as the forestry service headquarters in Winnipeg which used it to plan the daily round of patrols.

Later in 1928, a similar service was coordinated on an experimental basis at St. Hubert near Montreal. A small station was set up there "to assist in the air mail flights for the Post Office Department" in the Montreal-Ottawa-Toronto area. The St. Hubert station received (probably by telephone) and compiled weather data "from all the Canadian and American stations in the eastern half of the continent" and produced a weather forecast for the principal air routes used by the mail planes which it broadcast to the air fields just before the scheduled takeoff times.[133]

The value of the information provided by these stations seems to have been significant and they were only the first in an extensive network that evolved as advances in aircraft and radio design made airborne as well as ground-based radio much more versatile. Because of the limitations of the early aircraft radios, weather information had to be supplied to the pilots before they took off. By 1931, however, the new stations erected by National Defence Civil Aviation Branch (also intended to assist in air mail operations) across the prairies were equipped "to supply weather information to planes in flight by radiotelephone." The extent to which this particular service was used immediately following its introduction is unclear since in 1936 there were only 4 aircraft radio stations licensed by the government and there is no indication of whether these were transmit only or radiotelephone units. Nevertheless, it is probably safe to assume that of the 91 licenses issued two years later for aircraft radios, a good number were capable of receiving voice communications from the ground.

By the beginning of the 1950s there were weather reporting stations all across the country in both uninhabited and populated areas. The variety of locations made possible the collection of comprehensive data which was used by internal and trans-oceanic flights. Some of the northern stations were especially important in this regard and it would have been expensive and difficult to link these outposts to the network by any means other than radio. Obviously, any communication with aircraft in flight was similarly dependent on radio technology. Today, these weather reporting tasks remain as essential as ever but have been taken over by satellites which relay radio signals carrying meteorological data (including photographs) from one ground station to another as well as to aircraft in flight.[134]

Air Traffic Direction and Control

The idea that radio could be used to monitor and control the movements of aircraft was probably inspired by the experience of World War I but it did not receive much governmental attention (except

133. Gauthier, pp. 6–7.

134. *Annual Report for 1935–36*, p. 5; *Annual Report for 1937–38*, p. 27; *Annual Report for 1949–50*, p. 169.

perhaps in military circles) until the emergence of civil aviation services after 1918. It then became obvious that some form of communication between the air and the ground, however rudimentary, would assist both the pilots of aircraft and the airport crews in determining the best time and place to land. This, it was believed, would greatly improve the efficiency and safety of transporting goods and people by air.

In Canada immediately following the war, though flying was not yet an established, reliable form of transportation and non-military flights were few and far between in most areas, radio played an important role in experimental long distance flights. For example, from the late twenties through to at least 1936, a variety of aircraft from several nations communicated with the Canadian government marine stations in the north and on the east coast during the course of their journeys. Some of these craft, such as the Untin Bowler (a trimotored Sikorsky Amphibian) carried receiving apparatus and thus could be given information and instructions while airborne as well as simply sending status and location reports. Those craft that carried only transmitters on board also benefited from making contact with the marine stations since the government operators could keep track of their route and progress by comparing data with other ground stations and this information could be passed on during refuelling or other stops. Due to the limited fuel-carrying capacity of many early planes such stops were made regularly and thus even this limited radio service could be of real value.[135]

Moreover, as aircraft and radio design advances were made through the twenties, thirties and forties, more sophisticated communication methods were developed to improve the direction and control of air traffic in Canada. The first step in this process was taken by the government around 1930 when a series of directive beacon type radio stations were introduced at various locations across the country. They worked on the same basic principle as their marine counterparts, sending out radio signals which DF-equipped aircraft could use "to obtain relative directional bearings." Initially, the network was small, the equipment quite simple and the information it provided not always dependable. But in under twenty-five years, the number of stations grew from 6 to 19 and the reliability of the radio system increased dramatically.[136]

By 1937–8, the service provided by the radio beacons was augmented by the addition of two new advances in radio-based aviation aids—radio range stations and short wave radio. Radio ranges send out a radio beam which pilots can track and be guided along to their destination. First used in the late thirties, radio ranges soon became the "principal aid to air navigation provided by the Department [of Transport]." By the mid fifties there were some 94 of these stations spaced about 160 kilometres apart along Canadian airways and pilots could be guided by these beams across the country. These signals could also be used "for the purpose of obtaining direction finding bearings," and the range stations themselves were equipped to communicate with aircraft in flight via radiotelephone. As well, by 1945, many of these ranges included station location markers which sent an inverted cone of energy straight up from the ground indicating to the pilot by means of a light on the instrument panel when the plane was directly above the range. By 1949 all but two ranges in the country had this capability.[137]

Short wave radio had its roots in amateur experimentation before and after World War I. The success of these experiments led to the adoption of short waves for long distance radio communication during the twenties and thirties. By the thirties, these techniques were also being applied to aviation. At the time, most commercial flights travelled over fairly short, established routes and, for these purposes, medium wave transmitters and receivers had sufficient range. On very long flights, however, it was found that atmospherics interfered with this type of communication. To overcome this problem, certain aircraft and ground stations were equipped with short wave apparatus which allowed radio contact to be maintained over substantial distances such as from Cairo to South Africa.[138]

135. *Annual Report for 1929–30*, p. 148; *Annual Report for 1930–31*, p. 30; *Annual Report for 1931–32*, p. 41; *Annual Report for 1932–33*, p. 97; *Annual Report for 1935–36*, p. 15.

136. Moir, p. 55; *Annual Report for 1930–31*, p. 130; Department of Transport, *Annual Report for 1953–54*, (Ottawa: King's Printer, 1955) p. 180.

137. Department of Transport, *Annual Report for 1937–8*, (Ottawa: King's Printer, 1939) pp. 27–8; Department of Transport *Annual Report for 1941–42*, (Ottawa: King's Printer, 1943) p. 133; Department of Transport, *Annual Report for 1945–46*, (Ottawa: King's Printer, 1947) p. 190; *Annual Report of 1949–50*, pp. 167–9; *Annual Report for 1953–54*, pp. 179–81.

138. Vyvyan, pp. 160–1.

In Canada, short wave radio was introduced to the field of aviation by the federal government in the mid 1930s and it was used to fulfill a variety of communication needs. The Department of Transport set up a series of short wave stations to communicate with its aircraft along one east-west route. A combination of short and long wave radio techniques was also used for intercommunication between a group of stations established in 1941 at eight locations in the northwest. Important aviation-related information was exchanged between ground stations, and as aviation services expanded the network of ground stations grew until parts of it were beyond the reach of telephone and teletype lines. Since it was "not practicable to install teletype lines" between these stations, the essential links were established via radio.[139]

Throughout the 1940s the use of short wave radio for communication between aircraft and the ground was extended to include high frequency (HF) radio ranges. But this band of the radio spectrum quickly became congested and government aviation officials began to look further up the spectrum to the very high frequency (VHF) band for a solution. By 1949 there were some 60 VHF-equipped radio ranges and towers located across the country. Much of the interference which plagued the lower frequencies was eliminated and despite the fact that this type of communication was limited to "line of sight, thus making necessary more frequent installations than are required in the HF band," the government continued to expand its use of VHF radio.

Several other important additions were made to the government air navigation and communication system during the forties. In 1941 fan markers were introduced for the first time. Established at locations along the airway, these use a vertically-directed VHF signal to indicate to a pilot when the aircraft is passing over a specific point on the ground. These markers tell the pilot that altitude may safely be reduced on approaching an airport or that the aircraft is a certain distance from the next airport.

The problem of simultaneous operation of voice and range signal equipment was also addressed during this period. Although government officials had been aware of the need to reconcile the operation of these two systems since 1937, it was not until the mid forties that significant progress was made towards this goal. By 1945 over 40 stations had been or were in the process of being converted to allow voice communication to be carried on without shutting off the course signals or beams. This provided the crew of the aircraft with the most comprehensive and current information available.[140]

139. *Annual Report for 1937-38*, p. 27; Department of Transport, *Annual Report for 1941–42*, (Ottawa: King's Printer, 1943) p. 133.

Radio and Special Safety Procedures

In addition to its everyday use in aviation, radio also played a crucial role in extraordinary circumstances. The most common of these was inclement weather along the flight path or, more importantly, at the landing site. In the early years when aircraft had limited fuel-carrying capacity, the ability to fly around the disturbance was restricted. At the same time, landing assistance was almost non-existent and so pilots took their chances and landed as best they could. The evolution of weather forecasting services improved the situation by helping pilots to avoid bad weather where possible but where it was not possible the outcome remained the same—a dangerous blind landing.

With the ongoing development and installation of more reliable radio aids to air navigation and traffic control, pilots were able to depend on more help from the ground. The signals received from radio beacons, ranges, station location markers, and fan markers provided a good deal of information about the position of the aircraft relative to the airport and all of this could make a landing in reduced visibility safer.

It was not until after World War II, however, that a radio system was introduced specifically to cope with blind landings. The instrument landing system, as it was called, consisted of

> *a localizer which provides a beam down the centre of the runway; a glide path transmitter which provides an inclined beam which meets the runway at the approach end; two markers at four miles and 3,500 ft. from the approach end of the runway which indicate to the pilot by means of lights on his instrument panel the exact distance he is from the runway; and, compass locator stations to assist in holding procedures and in tracking the localizer course.*

140. *Annual Report for 1937-38*, p. 27; *Annual Report for 1941–42*, p. 133; *Annual Report for 1945–46*, pp. 189–90; *Annual Report for 1948–49*, p. 237; *Annual Report for 1949–50*, pp. 168–9; *Annual Report for 1953–54*, pp. 180–1.

The compass locator stations operated on low and medium frequencies, the localizer and markers on very high frequencies, and the glide path on ultra high frequencies. The process of installing this type of equipment began in 1945–6 at a handful of the most important airports in the country including Goose Bay, Dorval, Toronto, Winnipeg and Ottawa. In less than ten years, there were twenty-five instrument landing systems in operation across the country and at least one other was under construction.[141] Though these stations could not eliminate the risk involved in landing in bad weather, they significantly reduced it and made flying in Canada that much safer as a result.

Radio technology has also helped to improve emergency safety for those pilots who travel in remote regions of the country and whose small planes have less capacity for carrying elaborate equipment even if they could afford to buy it. As early as the 1920s, bush pilots ventured into isolated areas for a variety of reasons including aerial surveying and photography, search and rescue operations and medical evacuations. Initially many of these planes carried no radio equipment at all or only transmitters with limited range. As equipment and aircraft design advanced, more reliable and sophisticated radios became increasingly common and in emergency situations this improved the pilot's chances of being found quickly, assuming of course that the radio equipment was still intact and that the pilot was not severely injured or unconscious. To cope with situations when radio equipment can not be used to indicate location, an automatic radio transmitter called an emergency locator device is now installed in aircraft. Activated upon impact, it sends out a signal that can be received over long distances and provides a specific area of focus for search and rescue operations. Though certainly not foolproof, these ELDs fill a notable gap in the emergency safety equipment of both small and large aircraft and clearly demonstrate just how far aviation radio has come in less than seventy years.

Long Distance Radio Communication

Radio's proponents had long been convinced that this technology could provide a reliable means of long distance communication and in the years before World War I a number of commercial transoceanic circuits were successfully established including the one between Glace Bay, Nova Scotia and Clifden, Ireland. These successes were limited, however, in as much as they failed to convince the governments of the industrialized nations to adopt radio as a primary component of their international communication networks. Their reluctance was due, in part, to the supremacy of line telegraph systems which had a good reputation after years of reliable operation. Long distance radio, on the other hand, had been a commercial reality for about seven years when war broke out and the service had not been dependable 24 hours a day at least until 1910 and probably even later than this.

It is perhaps not so surprising then that the various international network schemes put forward by Marconi, Fessenden and others met with limited success. Of all of these, Marconi's came the closest to realization since it had the political support of some very influential people in Britain. First proposed in 1910, the Imperial Wireless Scheme foundered amidst a political scandal over the negotiation of the contracts and was abandoned in 1914. Fessenden's All Red Route, first proposed in 1910, was even less fortunate with little or nothing to show for a very elaborate proposal and a good deal of lobbying in Canada and elsewhere.[142]

The idea of using radio technology as the basis for international communication networks was not revived again until after 1918. The war had focussed attention on strategic and defence concerns and improved communication systems were among these. Equally important, technological advances made during the war promised to expand the capabilities of radio beyond those of the line telegraph to include reliable commercial-quality voice communication. Together, these factors provided the necessary impetus for the development of a series of international radio networks including one linking the far-flung countries and colonies of the British Empire.

Glace Bay

When war broke out in 1914, the commercial transatlantic service between Glace Bay and Clifden was closed down, although the Canadian station continued to be used for military purposes. The station was returned to its original status on

141. *Annual Report for 1945–46*, p. 189; *Annual Report for 1949–50*, pp. 168–9; *Annual Report for 1953–54*, p. 180.

142. For information on these various schemes see NAC collections RG 97 vol. 85 file 6209-113 and MG 30 E89 vol. 2.

3 December 1918 and remained the single long distance commercial station operating in Canada until the mid twenties. (Newcastle was still not operating commercially in 1920 and was eventually abandoned altogether.) Before the war, with the rebuilding and upgrading that had taken place since fire destroyed the station in 1909, Glace Bay had become a leading example of the high power, long wave stations that dominated long distance radio at the time. In the years immediately following the war, Glace Bay continued to be viewed in this light and, along with other Marconi stations of this kind, was seen as a model for new long distance stations.[143]

These stations, which were originally planned as part of a new Imperial wireless scheme proposed by the Marconi Company in Britain in 1919, were to be built around the emerging vacuum tube technology rather than the old spark system. At the same time, however, they were to perpetuate the established long distance formula of very high power, large antenna systems and long waves. As late as 1923, work was begun on an Australian "super-station" which was "to be of 1,000 kW power, with an antenna system supported on twenty steel masts each 800 ft. in height," and a South African station on a similar scale was also being planned. In Canada, by 1923, licences had been granted to the Canadian Marconi Company by the Department of Marine and Fisheries "for the installation of super high-power stations at Montreal and Vancouver, the Vancouver station to work with Australia and the Orient, and Montreal with Europe." Moreover, despite the massive size of these planned installations, messages were still to be telegraphic as they were at Glace Bay. Voice or telephonic transmission and reception were apparently still not considered commercially feasible by Marconi officials despite the advances in continuous wave technology that had taken place since 1914.[144]

Work on these long distance stations was delayed by the debate over a series of proposals and counter-proposals put forward by the Marconi Company and the government through the Post Office. The governments of several colonial nations were also involved and the negotiations dragged on through several government committees for about five years. Colonial officials in South Africa and Australia wanted a reliable form of radio communication established as quickly as possible. They went ahead and awarded contracts to Marconi to build stations that would place them on an equal footing with the senior dominion, Canada, whose very successful long distance installation had been built and was operated by Marconi. Canada, for its part, wanted to improve its long distance capabilities by the addition of two bigger and better long wave stations one of which, that at Vancouver, would make Canada a crucial radio link between the Great Britain and Australia. Canadian officials believed that, with adequate licensing and regulatory control, the task could be effectively carried out by commercial interests, in this case Marconi. The British government was concerned with retaining public control of the proposed network and the company, predictably, rejected this. In the end the government settled for the Post Office owning and operating the British stations of the Imperial network, leaving the rest of the field, including communication with countries outside the Empire, open to private interests such as Marconi.[145]

But in the five years that elapsed between the Marconi Company's original post-war proposal and signing of the final agreement in 1924 a very important technological breakthrough had been made which changed the fundamental premise of long distance radio communication. The short wave beam system developed by Marconi researchers beginning in 1916 was, in many respects, still experimental in 1924. Yet it clearly had the potential to equal and surpass the performance (while using much less power) of the established long wave system of which the Glace Bay station was an integral part. Indeed, when Marconi officials announced the breakthrough, South Africa, Australia, and Canada all expressed interest in the new technology despite its experimental nature and despite the fact that each had a long wave, long distance facility under construction or, in Canada's case, already in operation. The British government was more hesitant but eventually gave its approval to use the beam system as the basis for the Imperial network.[146]

It took two years to establish the first link in the new beam system and during that period, Glace Bay continued to function as the transatlantic/

143. Gilbert Norman Tucker, *The Naval Service of Canada Its Official History Volume I Origins and Early Years*, (Ottawa: King's Printer, 1952) p. 241; *Annual Report for 1919–20*, p. 25.
144. Baker, pp. 207–13; *Annual Report for 1922–23*, p. 140.

145. *Annual Report for 1922–23*, p. 140; Vyvyan, pp. 73–7; Baker, pp. 206–15.
146. Vyvyan, pp. 74–7.

A bank of vacuum tubes at the Glace Bay station. Source: NMST

Imperial station connecting Canada with Britain. On 25 October 1926, however, this service was taken over by the newly opened beam stations at Drummondville and Yamachiche, Quebec. From this time forward, the Glace Bay installation, the first and once the only transatlantic radio station in the Americas, ceased to be a major focus of experimental attention. It continued to carry out long distance work for marine traffic and it was re-equipped with the latest vacuum tube technology. But it lost its importance as the symbol of the great transatlantic experiment, becoming just one of the many marine radio stations along Canada's Atlantic coast.[147]

Drummondville and the Imperial Chain

The decision to go ahead with the development of the beam system for Imperial communication was announced on 2 July 1924 and the construction of the Canadian link became an immediate priority. Because the system was still experimental, C.S. Franklin was faced with challenge of producing a commercial form of transmitter based on the one used in the tests by the company. He also had to design "antenna systems to radiate on the various wavelengths demand," and to devise a method "to convey the energy from the transmitter into the antenna system without undue loss." And all of this had to be accomplished in a very short time in order to fulfill the stringent terms of the agreement with the British Post Office. The problem of producing receiving equipment for the beam system fell to G.A. Mathieu while the man responsible for supervising the manufacture of the finished units and the construction of the stations to meet the specialized requirements for creating and reflecting the beam was R.N. Vyvyan. All of these men and those working with and for them had "an almost impossibly rigorous time schedule" to meet.

Despite the difficulty of the situation, the Canadian circuit progressed rapidly. Sites at Drummondville and Yamachiche, Quebec were chosen as the locations for the transmitter and receiver stations. They were to communicate with "the British terminals of the Canadian circuit at Bodmin and Bridgwater." These latter stations were "officially handed over to the Post Office for test purposes and for communication with the Canadian transmitting and receiving stations" on 18 October 1926 and, according to the official history of the Marconi Company, the "circuit passed its preliminary acceptance easily, proving conclusively that it was possessed of a greater traffic-handling capacity than any other long-distance wireless telegraph circuit in the world."[148]

The Canadian stations were opened for regular commercial business on the 25 October 1926 offering five different forms of message delivery and payment ranging from fully paid at 18c./word to post letter messages at 60c. for 20 words and 3c. for each additional word. In less than two years a similar, transpacific circuit was opened from Drummondville to Victoria, Australia. The original plan to use Vancouver as the site for the Pacific station had obviously been abandoned though the reasons for this are not clear. In any event, the beam system was found to be sufficiently powerful to ensure reliable commercial service from the eastern location. The rates were about double those for the transatlantic circuit.[149]

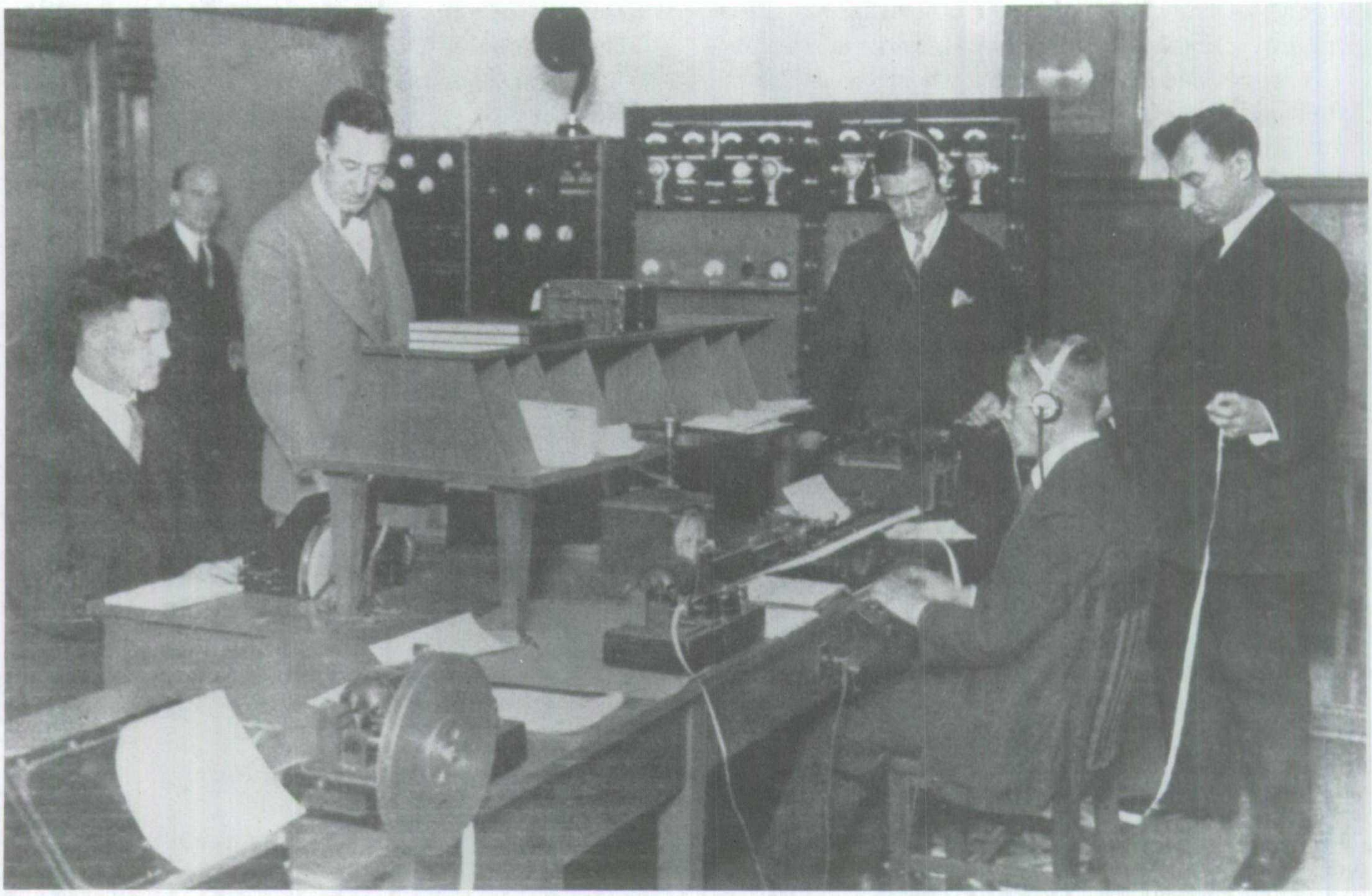
Moreover, the development of the beam system did not end with opening of the various telegraphic circuits connecting Australia, South Africa and India in 1927 and 1928. Beginning in 1926, while the British government was carrying out a series of radiotelephone tests using American Telephone and Telegraph's short wave station near New York and its own station at Rugby, the Marconi Company was doing similar experimental work with its beam stations at London, Drummondville and Yamachiche. By June 1927 the details of an agreement between the Post Office and AT&T, linking Canada to Great Britain via the line network through New York and by radiotelephone across the Atlantic had already been worked out, but Marconi officials did not give up the fight. Instead, the Canadian branch of the company adopted a strongly nationalistic posture and lobbied for a direct Anglo-Canadian route rather than a perpetuation of the near monopoly of transatlantic radiotelephone currently held by AT&T.

In October 1928, after two years of tests the managing director of the Canadian Marconi Company, H.M. Short wrote to F.W. Phillips of the British Post Office to suggest that the beam system should be used to provide a direct commercial telephone link between Canada and Great Britain. These tests had established that "Beam can be multiplexed and provide channels for the simultaneous transmission of both telegraph and tel-

147 *Annual Report for 1919–20*, p. 25; Glace Bay information sheets circa 1931 in Ernie Decoste's Marconi file.

148. Baker, pp. 215, 221, 224.

149. *Annual Report for 1929–30*, p. 147.



Opening the the transoceanic beam service, Montreal (Drummondville), August 1926.
Source: S.G. Roscoe.

ephone signals" and that, as a result, the same stations with a few alterations and additions could be used for both types of work. The current Imperial beam radiotelegraph network could therefore be adapted to become an international radiotelephone system.

The British government was not convinced by the Marconi test results and maintained that given the rapid pace of change in the radio field, it was not clear that beam would prove to be "the most efficient and economical means of conducting a direct commercial link between Great Britain and Canada." The Canadian government, for its part, showed greater interest in the idea of a direct Anglo-Canadian link and conducted a thorough investigation of the options open to it. Based on two series of tests—one conducted by the Canadian Marconi Company between April and June of 1928 and the other by the Company in conjunction with the British Post Office during the summer of 1929—it was determined that beam system by itself could not provide the same level of reliability currently offered by the short and long wave system used by AT&T and the British Post Office. During periods of atmospheric disturbance, most short wave systems were unworkable and without a backup long wave transmitter/receiver installation, the circuit could not function. Since AT&T had denied Marconi access to its long wave circuit in these circumstances, the proposed direct Anglo-Canadian link could not promise full and dependable service and as a result, the Canadian government rejected the Marconi proposal for the time being.

Despite this setback, negotiations and lobbying continued on all fronts. AT&T eventually softened its stand on allowing its long wave circuit to be used as an alternative in the event of atmospheric disturbances shutting down the beam link. In return it insisted that rates for the Canadian circuit be equal to those on the American one. The British Post Office retained control of the installations on its side of the Atlantic while the Canadian Marconi Company owned and operated the Canadian stations. Bell Canada provided the necessary line connections from those places which were to be part on the new transatlantic system to the stations at Drummondville and Yamachiche. By the end of 1932, the system was operating and it provided the only commercial voice link between Canada and Great Britain until the advent of submarine telephone cables in the late 1950s.[150]

In 1950 the Canadian Marconi beam installations were taken over by the government to be administered by the newly formed Canadian Overseas Telecommunications Corporation which took control of all Canadian international communication. The COTC thus became responsible for the long distance radiotelegraph circuits between Drummondville and Great Britain, Australia, Bermuda and Jamaica and the radiotelephone circuits between Drummondville and Great Britain and St. John's, Newfoundland. It also gained control of the overseas telegraph cables connecting Canada to other continents. But these responsibilities were soon eclipsed by those which emerged with the development submarine telephone cables.

The first transatlantic submarine telephone cable was laid between Oban, Scotland and Clarenville, Newfoundland in 1956. Owned and administered jointly by the British Post Office, AT&T, and COTC, it provided "excellent service" and proved to be just the first of many submarine cable enterprises entered into by the Canadian government between 1956 and 1974. The success of these cables along with the increasing use of satellites significantly reduced the role of the beam stations in international telecommunications. As late as 1974, the Drummondville and Yamachiche stations were still used to link Canada with certain remote countries or regions of the world such as Peru and Greenland, but almost all long distance work was done by cable or satellite. The two radio stations ceased operations in June 1975.[151]

150. Department of Transport, miscellaneous records and correspondence 21 May 1926 to 4 June 1929, NAC RG 12 vol. 603 file 6715-5 pts 2, 3.

151. For information on post-1950 long distance communication see COTC information file held by Ernie Decoste.

4 Radio in World War II

It has been suggested that at the outbreak of World War I, "it was almost possible to grasp the relative warmaking potentials of most countries simply by glancing at a diagram depicting annual coal and steel production." In 1939, while these figures remained significant, their importance "had been overshadowed by another and more modern set: the number of automobiles made, the quantity of aluminum (for aircraft) extracted, and the quantity and quality of electronic products assembled." One of the main targets of electronics production on both sides was the manufacture of reliable and durable radio equipment to be used at all levels of the war on land, at sea and in the air. Since radio had, in the interwar years, become "robust, simple to operate, and portable," it had clearly achieved the tactical and strategic importance that its promoters had claimed but which it had never really attained in World War I.[152]

Radio technology was adapted and used in a great many different roles in the war, on the home front, in preparation for battle and during battle. In general, though, the uses to which radio was put can be placed into three basic categories: communication, aids to navigation, and detection/intelligence. These uses were not entirely new—during World War I some radio work was done in each of these areas—but the extent and variety of the use was new, and it shaped the conduct of the war in ways that were not always anticipated by those who were leading it.

Communication by Radio

Basic radio communication is undoubtedly the first task which springs to mind when considering the possible applications of radio technology to warfare. The variety of ways in which it was used in this field and their significant impact on the war are probably less obvious. Radio was absolutely essential in the day to day coordination of the war efforts on both sides of the conflict. It was used to maintain contact between various types of active units in the field, whether that field was a beach in Sicily or a coastal observation post in British Columbia. Also, these units always had a base of operations or headquarters with which they had to exchange information and orders on a regular basis.

One of the most romanticized contexts in which radio was used for unit to headquarters communication was in intelligence work behind enemy lines. The image of the underground agent hiding in a barn in northern France, frantically sending out coded telegraphic signals containing information essential to the war effort and trying not to be detected by the Germans, is a common one. And there is some truth in this view. Agents were sent in by both sides—in some cases the allied agents were Canadians—and they were either trained to use a radio or had a trained operator with them. As well, each side had an elaborate system of codes and special signals that were supposed to confirm the identity of the agent and the reliability of the information being sent.

In some instances these various agents actually acquired important information or were successful in organizing and supplying an underground network in enemy-controlled territory using radio to inform headquarters of their activities and requirements. In others, however, the results were far from positive. On several occasions, captured Allied agents and their radios were used by the Germans to communicate orders for supplies and more agents to headquarters in Britain. And despite the numerous codes and security checks in place, these orders were often accepted as genuine. Three Canadian agents and several other British and American ones, as well as thousands of dollars worth of supplies were dropped into the arms of the waiting Germans in the spring of 1944 following these radio orders.

It is possible that the Germans gained access to the correct signals through interrogation of cap-

152. Martin Van Creveld, *Command in War*, (Cambridge, Massachusetts: Harvard University Press, 1985) p. 189.

tured agents, but it is also possible that overworked radio operators at the British end, "burdened with coding and decoding thousands of messages, occasionally failed to notice that the agreed security checks were missing from a message which, in any case, might well arrive so garbled as to make meaningless the rigid application of such tests." The German ploy was eventually discovered and new precautions were employed to insure the agents' absolute dependence on radio communication would not be used against them and against Allied underground operations as a whole. By the end of the war, the record of successful clandestine activities using radio communication—finding and evacuating downed pilots and ordering, collecting and hiding dropped supplies in preparation for D-day—probably outweighed the earlier failures. But in the context of the larger war effort, these operations were of much less importance than the more widespread use of radio communication between battle units in the field.[153]

Radio communication was used by air, sea and land forces throughout the war to link mobile units together and to connect those in the field with the command post. In general, it improved the speed and efficiency of mobile operations from the unit level up to the battle group level. The air forces and navies involved in the war had long been aware of the value of reliable radio communication in fulfilling the two essential requirements of battle, command and control. Land forces had often been more hesitant in embracing the new technology but the dramatic increase in the mobility of these forces brought about by the extensive use of motorized vehicles, especially tanks, and improvements in radio technology changed all this. As a consequence, radio became an essential component of the land war and its use ultimately had a profound impact on how this war and the wars that followed it were fought.

Radio's new importance for armies arose from the fact that increased mobility resulted in ground forces being spread over much larger spaces. A tank commander was thus "forced to decentralize the chain of command and rely on intelligent initiative at every rank, beginning with lowest, in order to seize every fleeting opportunity and exploit it to the hilt." But this decentralization could easily deteriorate into confusion in the absence of some form of central control. Radio, provided the means for exercising that control since it alone among existing communications techniques, "came close to making reliable, instantaneous two-way communication between mobile forces possible, regardless of the relative positions and speed of the forces and regardless also of the weather, time of day, and terrain."

The rapid adoption of radio technology by land forces "revolutionized" command in at least two ways. It led to the development of a series of principles of radio-based command which stressed the importance of quantity as opposed to quality of equipment, a systematic distribution plan taking into account performance characteristics required by each commander, and sound training and operating procedures that deal with the limitations of radio as well as its strengths and that address all levels of the army. These principles soon became a cornerstone of modern land warfare especially where large numbers of tanks were involved. Radio also altered the physical position of commanders during battle. For years, commanders had been forced to move further and further behind the front lines in order to maintain overall control of the battle. There, line communication to the rear and from there out to the flanks could be protected against enemy fire thus, preserving the chain of command. With radio-equipped vehicles, however, commanders could move "far forward" again without giving up control.[154]

Radio Aids to Navigation

Prior to the outbreak of World War II, radio aids to air and sea navigation were perhaps the single most important application of radio communication in Canada. The original coastal system of radio stations was built to improve navigation along Canada's main waterways. As well, the extensive network of air beacons, ranges and other radio devices constructed to mark the primary flight paths across the country fulfilled the same role for air traffic. There were also numerous weather stations built in remote areas of the country to supply, by radio, the accurate and detailed weather information that was so critical to shipping on the North Atlantic and to flying in general.

All of these systems were used extensively during the war and many of them were further refined and developed to meet the specialized needs of the military effort. Moreover, new devices were added

153. Roy MacLaren, *Canadians Behind Enemy Lines 1939–1945*, (Vancouver: University of British Columbia Press, 1981) pp. 57–64, 272–86.

154. Van Creveld, pp. 191–3.

A World War II signalman reports via radio to his rear headquarters. Source: John S. Moir, History of the Royal Canadian Corps of Signals 1903-1961, *(Ottawa: Corps Committee, 1962)*

A signaller carrying a heavy No. 18 set lies in a ditch in northwestern Germany to avoid stray shells while transmitting a message. Source: John S. Moir, History of the Royal Canadian Corps of Signals 1903-1961, *(Ottawa: Corps Committee, 1962)* to the existing collection of radio navigation devices. For example, the Germans used radio beams (a similar concept to the locator beams later used for civil air navigation) to direct their bombers to targets in Britain. The allies also used this technique for their bombing raids. Later in the war, the British Marconi Company was called upon to develop a supersonic buoy which sent out radio signals at specific times and on specific frequencies each day. These signals were used to "for the guidance and transport and beach-landing craft" during several invasions including Sicily, Anzio and Normandy.[155]

Many other remarkable strides were made in the technological development of radio navigation aids as a result of the pressures of war. Of these, one of the most astonishing was the portable German weather station that was set up on the northern coast of Labrador in 1943 to obtain crucial weather information for the northwest Atlantic that could best be acquired in the Canadian north. Carried by a U-boat which eluded detection both going into and leaving the site, the weather station was a very sophisticated unmanned system that could automatically collect and transmit the temperature, barometric pressure, wind force and direction. A timing device was used to turn on the transmitter "every three hours for about three minutes: one minute for warming, and two minutes for transmission of coded weather information." Although the system was low power, it used the high frequency band and thus its signals could be received at stations in Europe.

Despite its sophistication this particular station was not really a success. It transmitted weather information for two weeks but then the signal was jammed, possibly by a Canadian intercept station but more likely by another German radio source. But the weather data was considered so important especially for the U-boat war on the Atlantic, that another station was sent out by U-boat in 1944. This time the vessel was sunk before unloading its equipment. It would be around twenty years before the Canadian government established similar unmanned weather stations in the north.[156]

155. Baker, pp. 317–320; Wedlake pp. 135–6, 195–6.
156. Alec Douglas, "The Nazi Weather Station in Labrador," *Canadian Geographic*, vol. 101 no. 6, December 1981/ January 1982, pp. 42–7.

Radio and Radar in Intelligence and Detection

Many different forms of radio technology were used to fulfill intelligence and detection requirements during World War II. These requirements were numerous but, for the most part, they fell into three main types of tasks: listening in to enemy radio signals, interfering with enemy signals of all kinds, and using radio signals in the form of radar to detect and establish the course, speed and range of enemy aircraft and ships. All of these tasks were carried out at home in Canada as well as in the theatres of battle.

The widespread use of radio communication by both sides in World War II led to the rapid evolution of radio interception networks which monitored enemy traffic in all of its forms. Within Canada, radio stations in various locations listened for submarine traffic, especially off the east coast where the war against the deadly U-boats was a constant preoccupation. As well, the Army had stations at Ottawa, Grande Prairie, Alberta and Victoria, B.C. which were operated by Special Wireless or "Y" units of the Signal Corps. For these stations, the primary listening targets "were subversive activity, South American commercial and political events...[involving] the Axis countries, and Japanese operations in general."[157]

This domestic radio interception system did some important intelligence work but its contribution was overshadowed by the far more conspicuous role played by the field units of the Special Wireless Section which collected intelligence very near the various fronts before, during and after battles. These Y units were first located in England but then moved into Normandy, Belgium, Holland and eventually Germany following the Allied offensive which began on D-Day. On the surface, their role was much the same as that of the domestic listening installations, that is, intercepting enemy radio transmissions that might be of value to the war effort. The manner in which this role was fulfilled, however, was quite different for the field units because of the immediacy of the situations in which they were frequently involved.

Information obtained by field Y units was often relevant to Allied battle plans and thus had to be passed on very quickly especially when a military

157. Douglas, p. 46; Captain Norman A. Weir, CD, (ed.), *Second World War Army Experiences of Major R.S. Grant, MBE, CD*, (Ottawa: National Defence, 1986) pp. 2–6.

action was already in progress. But speed alone was not sufficient. Precautions had to be taken to prevent the enemy from connecting the military response too closely with the related radio communication since this would encourage the use of false intelligence. Other measures were employed to insure that any false intelligence that was passed by the enemy was not accepted as genuine, including attempting to confirm the information received from Y units using other intelligence sources. The time lag created by this latter requirement helped to separate the listening activities of the Y units from the eventual military action taken by the Allies.

The operating procedures used by the Y units varied according to the German divisions assigned them. For example, "parachute divisions used the low end of the Very High Frequency (VHF) spectrum around 28,000 to 30,000 kilohertz" while most other work was done between 1500 and 4000 kilohertz "in the low HF range." The Y units recorded the content of messages sent on these and other frequencies as well as obtaining direction finding bearings on the transmissions themselves. Much of the German traffic was sent in morse code which made it easier for non-German speakers to copy the messages and the VHF messages were often sent in plain language instead of code, since the Germans seemed to believe that transmissions at these frequencies were immune to Allied interception techniques.

Even those messages that were carefully encoded before being sent were useful to the interceptors since the codes used on both sides could be broken by the numerous specialists working in the field. Moreover, attempts to obscure the source and destination of messages in order to reduce the value of the content to the interceptor were often not entirely successful either. During the period between the German occupation of France and D-Day, Allied intelligence groups were able to piece together a German Army call-sign book which allowed them to keep track of the daily changes made in the call-signs of every German unit. Once one transmitter was identified with its sign from the day before, the identity of all the units could be established. Many methods were used to obtain the essential first identification including listening for the "peculiarities of the equipment or operators" which an experienced interceptor could often associate with a particular unit with which he was familiar from an earlier series of transmissions.[158]

Allied radio transmissions were also subject to interception and decoding by the German and Japanese intelligence networks. Though it is not clear just how successful these operations were, it seems likely that, given the Allies' heavy dependence on radio and its inherent insecurity, they too obtained a significant amount of sensitive information despite the elaborate methods used to keep it from them.

Radio interception work did not always involve listening in to enemy transmissions. Sometimes radio systems would be used to jam or interfere with the transmissions or even, where possible, to alter the content of the message. The main defensive targets of these jamming systems tended to be radio navigation and location transmissions emitted from enemy installations. These installations sent out signals which directed aircraft or self-propelled bombs to predetermined targets in enemy-controlled territory.

Both sides used this type of radio location system and both, in turn, devised ways to disrupt each other's signals. When the signals were successfully jammed, the next step was to find a way "to work through the jamming signals." For example, early in the war the Germans used "a modified Lorenz beam system" to direct their aircraft to British targets. Once aware of this operation, the British set up a jamming system using "modified medical diathermy equipment" at first and then more powerful transmitters. The Germans countered with "a more complex navigational system (X-Gerat)" and the British, in turn, developed a more sophisticated jamming system. Eventually, this technical contest produced methods by which navigational signals could be altered to provide feasible instructions which were sufficiently inaccurate to insure that the planes were taken off their course and the bombs were dropped well away from their targets.[159]

Radio interference techniques were also used for offensive purposes. The rapid development and spread of radar-based defence installations which warned of the imminent arrival of enemy aircraft, ships or self-propelled bombs led to the production and use of specialized radar-jamming devices. Once locked on to the frequency and location of the

158. Weir, pp. 11–13. A similar group served in Australia 1944–45. See Moir, pp. 223-4.
159. Baker, pp. 317–18; Wedlake, pp. 135–6.

targeted radar installations, the signal given off by this equipment would interfere with the radar transmissions. The defensive weapons that were linked to the radar readings would, as a consequence, be aimed inaccurately and a greater number of attackers could successfully penetrate into the area. This type of offensive jamming was particularly important in the D-Day invasions.[160]

Radar itself evolved primarily as a defensive tool during the war. It had been known since Hertz's time that radio waves of certain frequencies could, like light waves, be reflected by objects in their path. In the twenties and thirties, it was shown that these reflected radio waves could be used to measure the distance of the object off which they were being reflected from the site of transmission and reception. E.V. Appleton proved the existence and determined the approximate height of the Kennelly-Heaviside layer of the ionosphere in 1924 by employing this reflective principle and recording the amount of time required for the echo of the waves to return to earth.

By the mid 1930s, the idea of applying these same techniques as a defence against the growing threat of German air power had taken root in military research circles in Britain. Prior to this time, defence against air and naval attack was based on a combination of "optical direction-finding" and "auditory sound-ranging" techniques. Information on the speed, direction, range, etc. of the approaching targets was obtained from these sources and fed to the anti-aircraft batteries which then aimed their guns accordingly. Yet both of these detection and ranging systems had serious flaws. The optical observations were too easily thrown off by atmospheric conditions such as fog and by darkness. Sound ranging was more dependable but was limited by the fact that aircraft were steadily becoming faster and approaching the speed of sound which obviously reduced the effectiveness of this type of equipment when quick responses were required.

Radio waves, because they moved at the speed of light and could penetrate many obstacles including fog and darkness, promised to provide a more efficient basis for rapid detection and ranging of enemy attackers. In 1935 the Committee for the Scientific Study of Air Defence (or the Tizard Committee as it came to be known) was set up and quickly determined that such a radio-based system was the most fruitful avenue for their research.

160. Baker, p. 321.

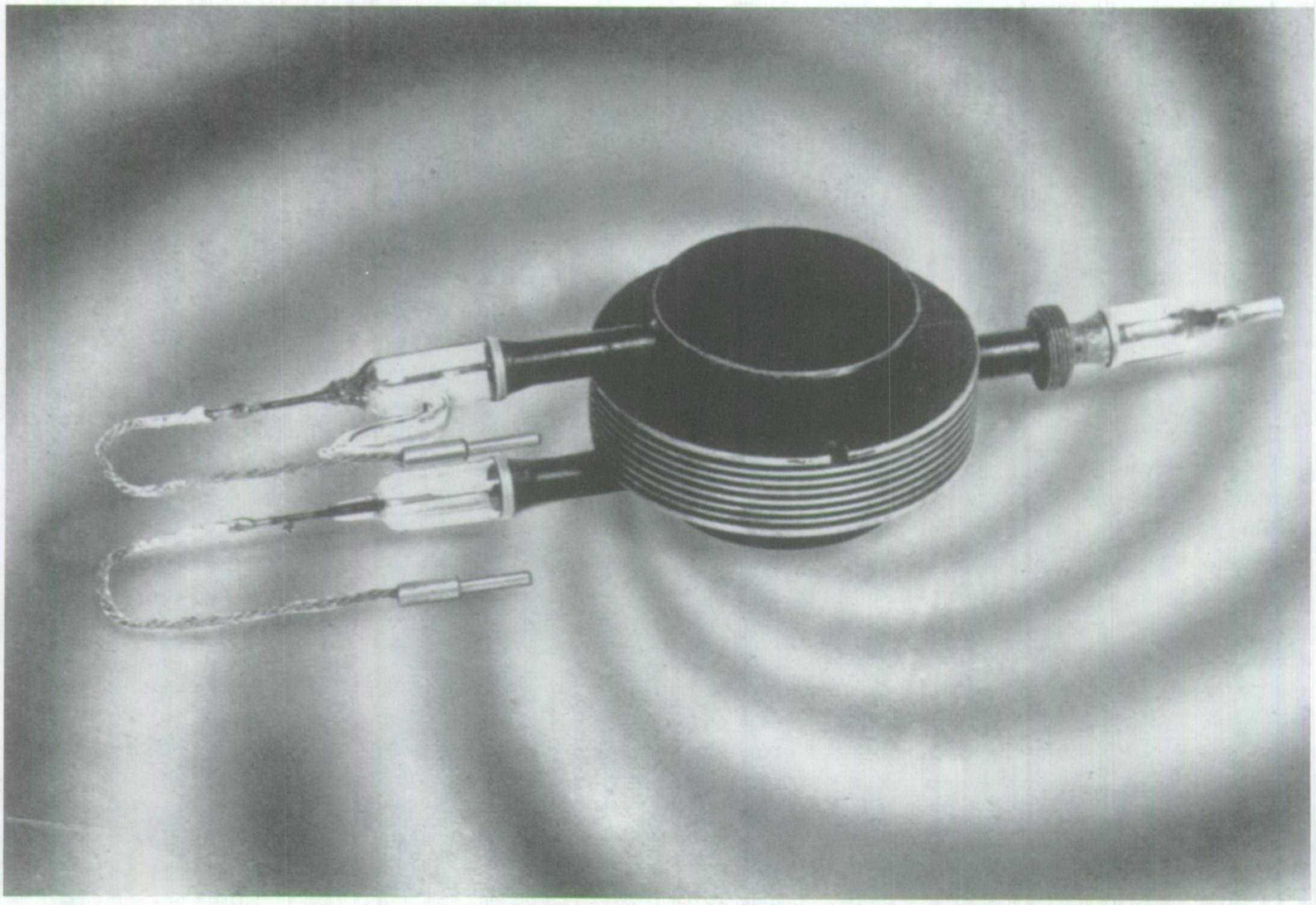
Between 1935 and 1939, this British committee directed intensive research, development and testing efforts which led to the successful installation of a chain of twenty stations capable of measuring the range, bearing and elevation of aircraft. Other stations supplied similar information on enemy shipping.

The potential of radio detection and ranging systems was also being explored at this time by scientists in other countries including Germany, France and the United States. The Germans had, by 1939, developed early warning systems which detected both aircraft and shipping. A year later, they had a radar system linked to anti-aircraft guns which proved "more effective than its Allied counterpart." The Americans also had an early warning set that went into large scale production in 1940.[161]

Yet while radar began as a fairly simple defensive system, it evolved rapidly into a complex, sophisticated technology designed to fulfill increasingly specialized tasks. In the early stages of the conflict, the basic technology was adapted as quickly as possible to meet as many different needs as possible, from simply warning defenders of the enemies activities to aiming guns and fighter aircraft at identified airborne and naval targets. It quickly became apparent, however, that the simpler the equipment was, the easier it was for the enemy to find ways to interfere with the signals. This led to the development of more powerful and far more elaborate systems that could either overcome or evade interfering signals.

Canadian scientists and military personnel both contributed to and took advantage of the development of radar. In cooperation with British and American scientists, the National Research Council scientists made a significant contribution to the development and manufacture of a microwave radar-activated gun-laying (aiming) set later called G.L. Mark III C in 1940–41. The basis of this and other microwave radars was the newly developed cavity magnetron which produced powerful pulses of ultrahigh frequency radio waves. This type of radar had certain important advantages which longer wave radar lacked. Microwaves are not

161. J.G. Crowther and R. Whiddington, *Science at War*, (London: His Majesty's Stationery Office, 1947) pp. 1–7, 11–12; C.P. Snow, *Science and Government*, (Cambridge, Massachusetts: Harvard University Press, 1961) pp. 24–7; Wilfrid Eggleston, *Scientists at War*, (Toronto: Oxford University Press, 1950) p. 27–8; Baker, p. 303–4.



The cavity magnetron which made microwave radar possible. Source: The National Research Council.

usually reflected by the ionosphere and thus are less likely to produce echoes which might confuse the readings of the echo off the target aircraft. As well, they are more easily concentrated into a beam and directed. This allows for more effective use of the system's power and more precise coverage of specific surveillance areas. Finally, UHF waves are less prone to earth reflection than longer waves and could be depended upon to detect low flying aircraft with greater accuracy. This device and the radar systems built around it gave the Allies an important edge in radar technology over both the Germans and the Japanese.[162]

NRC researchers also produced radar equipment specially suited to Canadian coastal defence requirements, in addition to designing a variety of shipboard and aircraft sets for the Canadian forces. They also did important development work on a radio proximity fuse for anti-aircraft shells which would allow the shells to be detonated at precisely the correct time to insure the destruction of the target.[163] These and many other smaller projects became part of the massive scientific and technological war effort which produced a great many useful radio-based which were used extensively by those actively engaged in fighting and by those working on the home front.

By the time the war was over, radar technology was highly sophisticated. Moreover, the cooperative scientific and technological projects that made its rapid evolution possible also insured that many countries could put these systems to good use in peacetime roles. Civil aviation benefited, and continues to benefit, greatly from radar-based navigational aids including such systems as Ground Control Approach (GCA) and Radar Approach Control (RAPCON).[164]

Radar also proved useful for marine navigation after the war. In 1945–46, the Department of Transport obtained several Type 268 radar sets designed for use by the British Navy and installed them in a number of ships to assess their value in non-military situations. The responses of those involved in these tests were favourable and within a year some 100 ships were equipped with similar sets to be used until equipment designed especially for merchant marine vessels became available. As well, the Department of Transport in cooperation with the National Research Council sponsored the development of "shore-based radar aid to shipping for use at harbour entrances."

Wartime research and development also produced at least two specialized forms of radar which had important civilian applications. Long range aid to navigation or LORAN as it came to be known was a sophisticated position finding system "based on the difference in the time of arrival of pulse type radio signals transmitted from a pair of stations." The time difference was then measured on a LORAN receiver and interpreted using "specially prepared charts or tables" to establish a craft's position. This system was used for both military and civilian purposes after the war. In 1947, the Canadian and U.S. air forces cooperated in the establishment of a northern chain of LORAN stations to provide early warning of enemy air attack. In 1949 this network was closed down and eventually replaced by a system that could cope more effectively with the unique conditions in the north. The civilian application of LORAN to marine navigation was far more successful. In 1947–8, the Department of Transport took over three LORAN stations from the Canadian navy and began to operate them as navigational aids for merchant shipping on both coasts. Today, LORAN is still used for long range marine navigation although it is now supplemented by other systems such as Omega.[165]

SHORAN was the short range equivalent of LORAN and was also a product of war-related research. After the war, however, it was applied to the problem of surveying and mapping the Canadian north. A series of experiments in 1947 proved that this system of position finding was faster and more accurate than the astronomic methods previously used. As a result, the government set up an extensive SHORAN program aimed at mapping the north. From 1949 to 1957 personnel from the RCAF, the NRC, the Meteorological Service and the Geodetic Survey cooperated in this effort and the end result was the most comprehensive and accurate map of the north yet produced by any means.[166]

162. Eggleston, pp. 35–46; Crowther and Whiddington, pp. 18–20.
163. Eggleston, pp. 46-73.
164. Group Captain E.J. Gauthier, "The Evolution of RCAF Telecommunications, Part III," *Roundel*, (January–February 1965) p. 20.
165. *Annual Report for 1945–46*, p. 187; *Annual Report for 1946–47*, p. 195; *Annual Report for 1947–48*, pp. 200–1; Department of Communications chart, "Spectrum Allocations in Canada."
166. Gauthier, "The Evolution of RCAF Telecommunications, Part III," pp. 18–20.

5 Technical Principles

What is Radio?

"Radio" is a general term referring to the radiation and detection of signals propagated through space as electromagnetic waves to convey information. It encompasses wireless or radio telegraphy, voice radio and some features of telephony such as microwave relay systems, radio and television broadcasting, radar, radio aids to navigation and satellite communication.

An electrical disturbance causes electromagnetic waves in much the same way that a pebble thrown into a pond of water causes a series of ripples in the water's surface. In both cases the waves spread out in all directions transferring the energy from the site of the disturbance to another point some distance away. All electromagnetic waves travel at about the speed of light but their other characteristics are variable. Amplitude is the "magnitude of the disturbance of a wave"; frequency is the number of complete waves propagated past a fixed point in one second (measured in cycles/second or hertz); and wavelength is the distance between one wave and the succeeding or preceding one (measured in metres). The higher the frequency of the wave, the shorter its wavelength will be.

The waves used in radio represent only a small part of the electromagnetic spectrum—the portion ranging from a low frequency of 3 kilohertz to a high frequency of 300 gigahertz. The radio spectrum itself is further divided into a number of frequency bands, each possessing different characteristics which make it useful for certain purposes but not for others. All of these frequencies, low and high, are inaudible to the human ear and therefore must be altered to provide a means for the passage of information.[167]

167. *Encyclopedia Britannica Macropaedia*, 1984 ed., s.v. "Radio"; *The McGraw-Hill Encyclopedia of Science and Technology*, 1982 ed., s.v. "Amplitude Modulation"; Mike Bienstock, *Radio and Television - how they work*, (New York: John F. Rider Publisher, Inc., 1963) p. 7; Signal Corps, U.S. Army, *The Principles Underlying Radio Communication*, 2nd edition, (Washington: Government Printing Office, 1922) pp. 19–20.

How Radio Works

In order to communicate using electromagnetic waves, four basic requirements must be met. At the transmitting end, regular electromagnetic disturbances are produced in a circuit by rapidly reversing the direction of the current. These disturbances are routed via a transmitting circuit into an antenna which radiates them into space as electromagnetic waves. These waves must then produce electric currents in a receiving circuit some distance away from the transmitter. They enter this circuit by way of the receiving antenna. The final requirement is to change the currents in the receiving circuit into a form that can be perceived by the operator.[168]

Wireless or Radio Telegraphy

One of the earliest and simplest systems for conveying and interpreting the information carried by radio waves was wireless or radio telegraphy. As its name suggests, this system used telegraphic code, usually Morse code, to impress a message on the radio waves. A sending key was attached to the transmitting equipment in such a way that it acted as an on-off switch. When a spark gap was used to generate waves, as long as the key was held down in the on position, groups of high frequency waves were sent off from the antenna following one another in regular succession. Each dot or dash of the code was represented by a certain number of groups of waves depending on the particular configuration of the transmitter i.e. how many wave trains per second it produces. These wave groups and the spaces between them are produced by holding and releasing the key. At the receiving end, the detector changed the wave trains into a series of pulses of current (having a frequency equalling that of the wave groups themselves) which could be heard on a loudspeaker or headphones as a combi-

168. *Encyclopaedia Britannica Macropaedia*, 1984 ed., s.v. "Radio"; L.B. Turner, *Wireless Telegraphy and Telephony*, (Cambridge: Cambridge University Press, 1921) pp. 65–6; Signal Corps, U.S. Army, pp. 19–20.

nation of long and short notes and which were then translated back into words by the operator.

When continuous wave transmission was used, another step had to be added to this process. Each dot or dash was represented by one, unbroken wave train and the frequency of the waves was so high that the listening devices could not respond to it. And even had they been able to, the frequency was well beyond the range of human hearing. In order to overcome this problem, two different techniques were developed. The first technique used various methods to break up the continuous waves so that the number of groups of waves per second was within the audible range. The second technique was more complex but ultimately proved to be more important since it eventually made voice radio possible. Known as the heterodyne principle, this reception method involved the blending of two radio frequency signals—the transmitted one and one produced locally at the receiver. When combined in the receiver, these two frequencies produce a series of beats the frequency of which is equal to the difference between the original frequencies. By choosing the correct frequency for the local signal, the resulting beat frequency will be well within the audible range. The detector translates these beats into a clear tone and, as with the spark system, the pattern of the tone reflects the dots and dashes of the coded message.[169]

Radio Telephony or Voice Radio

Radio telegraphy was eventually eclipsed by radio telephony—voice communication by radio. In voice communication, radio waves flow continuously without breaks in what is called a carrier wave. The information is superimposed on the carrier by a process known as modulation in which "one of the carrier-frequency characteristics, such as its amplitude, its frequency, or its duration" is varied. For point-to-point radio, one common form of modulation is amplitude modulation.

In amplitude modulation (AM) radio, the high frequency carrier wave is combined with a second signal called the information signal which is produced by converting the lower audio frequencies characteristic of music or the human voice into electrical oscillations using a microphone. These audio-frequency oscillations modulate or vary the amplitude of the carrier wave. The particular pattern of variation reflects the pattern of the sound waves of the words spoken into the microphone. This basic process is reversed at the receiving station where the two signals are separated and the carrier signal is filtered out leaving the audio information signal which is passes into earphones or a loudspeaker.[170]

How Radio Waves Travel

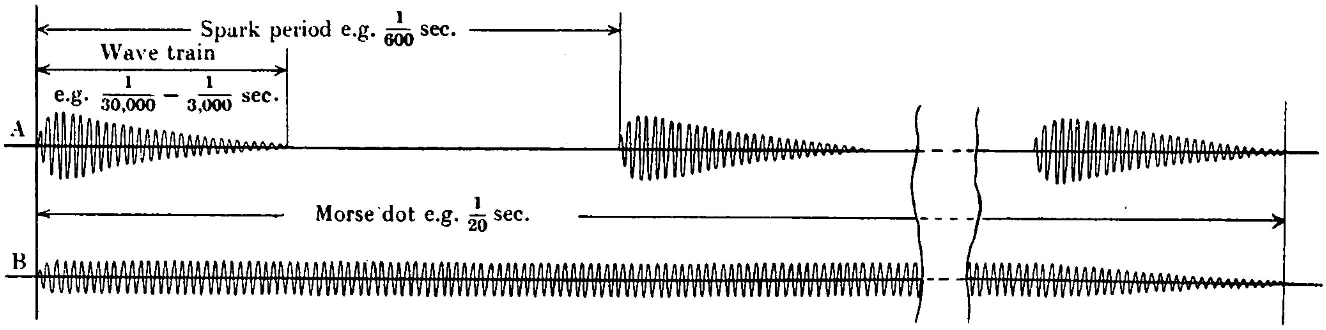
How radio waves travel from a transmitter to a receiver depends upon their frequency. Although radio frequency waves, like light waves, tend to travel in straight lines from the point of generation, certain frequencies are affected by the earth's atmosphere in ways that can be used to expand the uses of radio. Very low frequency radio waves generally follow a path that is close to the earth's surface and which follows its curve. These waves, which are called ground waves, have frequencies below 30 kilohertz and can be received reliably at distances of up to thousands of miles, but are usually limited to telegraph-type signals since their information-carrying capacity is limited.

Long distance voice transmission can be achieved with higher frequency sky waves which can be reflected to extend the range of transmission. Certain layers of the earth's atmosphere known collectively as the ionosphere reflect radio waves. Sky waves are sent up into space from the transmitter and reflected by the ionosphere back down to the receiving station. The character of the ionosphere varies with the time of day, the season, geographical location and the activity of the sun to such a degree that this type of transmission is not always dependable. But until the development of satellites, it was used extensively in Canada and elsewhere for various forms of radio communication including Marconi's beam system.

Higher frequency waves which travel in straight lines are known as direct waves. These are used in "line-of-sight" transmission and reception where the construction of very tall antennas or a series of relay antennas enables the transmitter and receiver to "see" one another. The transmission of direct waves is not dependent on the unpredictable state of the ionosphere. Because their transmission distance is limited, these direct wave systems tend to be used for local transmissions. Thus, the frequency or frequencies used in one geographical

169. C.E. Mendenhall, A.S. Eve, D.A. Keys, and R.M. Sutton, *College Physics*, (Boston: D.C. Heath and Company, 1956) p. 156; Turner, pp. 74–5; Signal Corps, U.S. Army, pp. 422–33.

170. *Encyclopedia Britannica Macropaedia*, 1984 ed., s.v. "Radio"; Mendenhall, et al., p. 457.



Spark and continuous wave signalling. With spark signalling as shown in A, a series of wave trains and spaces equalling about 1/20 of a second, make up the dot, while in continuous wave systems, a single wave train of the same duration is used. Source: L.B. Turner, Wireless Telegraphy and Telephony, *(Cambridge: Cambridge University Press, 1921)* area, a city for example, for mobile or cellular radio can be re-used in many other areas without interference. These systems are also used over long distances such as in the case of the telephone relay networks which consist of a series of repeater or relay towers that maintain line-of-sight contact across the country. The main drawback of these systems is the cost of building and maintaining the relay stations required to cover any great distance.[171]

Ultimately, the choice of radio system depends on three main considerations: the complexity of the information to be conveyed; the distance over which it must travel; and the degree of reliability or predictability required for its reception at a specific time and place.

171. Mendenhall, et al., p. 461.

6 The Process of Scientific and Technological Change

Radio, then, is a complex means of communication which requires not only an extensive knowledge of the equipment needed to create radio waves, but also an understanding of the character and behaviour of the waves themselves and of the environments through which they travel. This level of knowledge and understanding only evolves over a long period of time as a result of ongoing scientific research and technological invention and innovation. That evolutionary process is itself extremely complex in an intellectual sense as well as in an economic, political and social one. By its very nature, scientific and technological progress is a cumulative process in which each generation of scientists and inventors builds on knowledge gained through work done in previous centuries. Consequently, any specific breakthrough or invention must, in a certain sense, always be seen as a collective effort based on the efforts of many individuals over time. As well, the relationship between pure and applied science, between basic research which explores theoretical principles and technological invention and innovation which seek to develop practical applications for those principles, is a subtle and constantly fluctuating one that defies simple explanation. The two types of work often cannot be clearly distinguished from one another and the former does not necessarily come before the latter.

Moreover, in addition to the problems involved in unravelling the intellectual evolution of new discoveries, there are equally difficult issues with which to struggle in the economic, political and social spheres. Developments in science and technology are always subjected to the pressures of market forces and therefore concerns about practical and commercial viability cannot help but have an influence on the directions that research will take. The form and extent of that influence, however, varies greatly. Sometimes the market provides the direct inspiration for the development of an idea, for example when a company striving to maintain its competitive edge instructs its scientists and technicians to create a more sophisticated product or production technique. In other cases, the entrepreneurial drive is stimulated by a breakthrough in fundamental scientific research often made by someone who is pursuing knowledge for its own sake without regard for the exigencies of the marketplace. In most instances, however, it is difficult to identify precisely when and how market factors, in all their many forms, influence the progress of science and technology in our society.

In the political sphere, the attitude and approach of governments toward science and technology can also have a profound effect on the pace and direction of change. In general, governments want to encourage and promote economic growth in their societies. This often leads to the formulation of policies that encourage scientific research and technological development. In addition, governments have many unique responsibilities particularly in fields like defence, public health, the environment, transportation, communications and international trade. Scientific or technological advances that might have applications in these areas are necessarily of interest to government officials.

Again, however, the specific form that this interest takes differs from one area to the next and changes over time. In certain sensitive defence research fields, governments often have their own group of scientists and technicians working on projects. Similarly, environmental protection and public health programs depend to a very large extent on scientific work done by experts within the bureaucracy. The government uses less direct measures to encourage research and development in other fields. Such measures include tax incentives, low interest loans, government markets for goods or services, grants of public money and better patent protection. Finally, government interest may be limited to purchasing the latest model of a new technology from the company that offers the lowest price without investing any money in the research and development that went into it. All of these actions on the part of governments can have profound effects on the direction that research takes and the amount of time and money invested in it by entrepreneurs, scientists and inventors alike.

A society's opinions about technology in general and about specific forms of technology will also have an impact on the evolution of an idea or an invention. The overall approach that a society takes will depend upon such things as the type of economy it has, the political outlook of its government, and the relative strength and cohesiveness of the business, labour, professional (including scientists and technicians) and consumer groups within it. Some of these groups tend to believe that all scientific and technological advances are positive because by increasing our knowledge of the environment, we can learn to control it for the benefit of all mankind. Others accept the usefulness of technology and the importance of expanding our understanding of the world but insist that each step forward has costs as well as benefits and that these must be weighed carefully by the members of a society. The interaction of these factors will help to determine not only what kinds of technology are given priority—military, medical, agricultural, consumer, etc., but also how carefully new technologies are managed and regulated by public authorities and who has access to them.

7 Major Advances Before 1900

The Scientists

These general principles of scientific and technological change are clearly evident in the development of radio as a viable means of communication. In its early stages, late in the nineteenth century, the evolutionary process was driven primarily by the work of scientists and inventors. Between 1819 and 1835, important advances were made in scientific knowledge of the forces of electricity and magnetism. The work of men such as Hans Christian Oersted, André Marie Ampère, William Sturgeon, Michael Faraday and Joseph Henry demonstrated that through the interaction of electrical and magnetic forces it was possible to produce high voltage electric current. This "afforded a means of generating and studying the effects of electrical discharges on a scale not possible with the laboratory apparatus previously at hand." By 1853, Henry and William Thomson, later Lord Kelvin, had established the oscillatory nature of electrical discharges, the former by practical experimentation and the latter by mathematical formulas.[172]

The intellectual gap between an awareness of oscillatory electrical discharges and a knowledge of how these produce electromagnetic waves was bridged by another British mathematician, James Clerk Maxwell. Between 1860 and 1865, Maxwell produced a series of equations proving that "all changes in electric and magnetic forces sent waves spreading through space." He further determined that "electro-magnetic action must travel through space at a definite rate in waves" and that the speed of these waves is "exactly equal to that of light [186,000 miles [297,600 kilometres per second]...." This mathematical proof made possible the application of the extensive knowledge existing at the time about the behaviour of light waves to electro-magnetic waves. As well, although some in the field were sceptical about Maxwell's predictions, they inspired others to seek concrete evidence of the existence of these waves and their characteristics.[173]

One of the first scientists to undertake the task of proving Maxwell's theory in the laboratory was Heinrich Hertz, a gifted German physicist. In 1888, using "a simple loop of wire with a small air-gap," he detected electro-magnetic waves produced by a wave-transmitter which consisted of "a battery, induction coil, and spark-gap." He also attempted "to reflect the waves from a large zinc plate" opposite the transmitter in order to measure their length and velocity. Through these and other experiments he demonstrated not only that these waves travel led at the speed of light but also that they "obeyed many of the laws of optics" as Maxwell's equations had predicted.[174]

Further advances were made by Oliver Lodge and Professor A.S. Popov in the 1890s. Lodge, a professor of experimental physics at University College, Liverpool, "designed an effective system of wireless reception" using "a spark gap for collecting the waves, a coherer for detecting them, a relay for magnifying the currents, an inker for registering Morse dots and dashes, and a trembler for tapping back the coherer." The coherer itself was not an original invention having been developed by Professor Edouard Branly in 1892, but Lodge's use of it for detecting electro-magnetic waves was an important innovation. It consisted of a glass tube which contained some loose metal filings and which was part of a circuit. When electrical discharges occurred near the tube, the resistance of the filings decreased "causing them to cohere and permit a flow of current from the local battery," thus signalling the presence of electro-magnetic waves. The trembler was used to shake up or de-cohere the filings so that further waves could be detected. This method of detection "proved more sensitive to feeble signals than Hertz's loop, and made it

172. Donald McNicol, *Radio's Conquest of Space*, (New York: Murray Hill Books, Inc., 1946) pp. 8–21.

173. W. Rupert Maclaurin, pp. 13–4.

174. Charles R. Gibson, *Wireless Telegraphy and Telephony Without Wires*, (London: Seeley, Service & Co. Ltd., 1914) pp. 51–2; Maclaurin, pp. 14–8.

possible to detect wireless waves at greater distances."[175]

In 1895, Lodge's system of wave detection was improved by Professor Popov, a physics teacher at the Torpedo School in Kronstadt. Concerned about "the effects of local sparks at the relay contact," Popov set out to protect the coherer from these. He inserted "choking coils in the wires along which the waves from such sparks could run," and built an antenna using "a long vertical wire, insulated at its upper end and connected to the earth through the coherer at its lower end." Although Popov personally was more interested in detecting "atmospheric disturbances" than in receiving signals, the reception system he designed was, nevertheless, an important advance in radio technology.[176]

These advances, with the exception of Henry's work which was undertaken in the United States, were made in Europe and the United Kingdom, but they did not go unnoticed in Canada. In 1895, a Canadian physics lecturer, C.A. Chant, gave a lecture highlighting a number of these breakthroughs before the audience at the twenty-third meeting of The Astronomical and Physical Society of Toronto. After a general introduction outlining the important achievements of Faraday and Maxwell in the field of electromagnetism, Chant went on to show some of the characteristics of electromagnetic waves by carrying out a series of simple experiments. He used a spark gap transmitting device which received its energy from an induction coil and a coherer connected to a galvanometer as a detector/receiver. For the benefit of the audience, he attached a small mirror to the needle of the galvanometer and shone a beam of light onto it so that when the needle moved in response to the energy received from the waves, everyone would see a light spot move along the wall of the lecture room.

With this apparatus, Chant demonstrated undirected transmission of electromagnetic waves and then, using a reflective copper hat around the spark gap, showed how the effect of the waves on the receiver could be strengthened by channelling the energy in one direction. As well, he offered a simple method for determining the approximate length of the waves produced, suggesting that they would be 3-6 times the diameter of the sphere used in the spark gap. Based on this method he postulated that the waves produced by his 12.7 centimetre sphere were "about 18 inches [45.7 cemtimetres] long, and their frequency...over 600 millions per second." Chant also showed how the waves could be reflected, refracted and polarized, thereby proving to anyone there who still doubted it, that electromagnetic waves, though much lower in frequency, were in many ways the same as light waves.[177]

Chant, the men whose work he discussed and demonstrated in his lecture and all of the early investigators of electromagnetic waves were scientists. Most, if not all, of them were conducting research in universities, "an environment where the goals were largely non-commercial." Far from concerning themselves with the possible practical applications of their apparatuses, they concentrated their attention on proving some scientific principle, on making some unique and lasting contribution to pure science, on pursuing and acquiring new knowledge for its own sake.[178] Some may have made an abstract ideological connection between the progress of science and the progress of society generally but, overall, scientists in this period tended to see the research ideal as sufficient justification in and of itself for whatever work they chose to undertake. Even Lodge, whose name is associated with the tuning patent which was such an integral part of early radio reception equipment, believed that the "ideas and devices" he and other scientists had developed were public rather than private property. He had to be persuaded by Alexander Muirhead and by the rapid commercialization of the new technology by others who were determined to lay legal claim to it, to take out patents on his inventions.[179]

The Early Inventors

Ultimately, it was left to researchers and experimenters outside the sphere of pure science to combine these various elements and principles to produce a radio set capable of transmitting and receiving signals via electromagnetic waves reliably over increasing distances.[180] Men such as Guglielmo Marconi, John Ambrose Fleming, Reginald Aubrey Fessenden, Lee de Forest, John

175. Maclaurin, pp. 18–9; Gibson, pp. 54–7.
176. Maclaurin, p. 20; Gibson, pp. 60–1; Aitken, *Syntony and Spark*, pp. 193–4.
177. Astronomical and Physical Society of Toronto, *Transactions for the year 1895*, (Toronto: Rowsell & Hutchinson, 1896) pp. 128–39.
178. Maclaurin, p. 30.
179. Aitken, *Syntony and Spark*, pp. 123–6.
180. G.E.C. Wedlake, pp. 28–9; Aitken, *Syntony and Spark*, p. 203.

Stone Stone, Ernst Alexanderson, and Valdemar Poulsen, to mention only a few, were clearly inspired by the work of scientists in the field and by their published results outlining the theoretical principles and experimental equipment essential to the creation and detection of electromagnetic waves. Where these inventors and innovators differed from the men of science was in their ability to perceive a practical need for radio signalling and in their "drive to convert abstract possibility into concrete reality."[181]

Marconi, who had no formal scientific or other education, began experimenting with electromagnetic waves in 1894 at the age of twenty. He was undoubtedly inspired by the work of Augusto Righi, who was his informal tutor and mentor and "one of the few scientists in Europe who, in 1894, thoroughly grasped what Hertz had accomplished, understood his experimental techniques, and shared his vision of the direction in which research should go." Marconi, however, was not interested in following Righi's lead into the study of what we now call microwave optics. Instead he became preoccupied with "the possibility of making wireless communication a practical reality," with turning his genuine interest in science to an essentially utilitarian end.[182]

The publication of the work of Hertz also played a crucial though somewhat less direct role in the direction of Reginald Fessenden's career. He, like Marconi, lacked a formal scientific education but by 1894 had held several positions in the field of electrical engineering including inspecting engineer at the Edison Machine Works and Chair of Electrical Engineering at Purdue University. During this time he had read extensively on scientific subjects paying particular attention to the Hertz's papers and to those dealing with alternating current. By the time he reached Purdue, he was already very interested in the electrical theory underlying high frequency oscillations. Here and in his later jobs, however, his interest in theory was rooted in an essentially practical, engineering project—to develop his own system of communicating via electromagnetic waves.[183]

One of the few early inventors in the radio field to have had a formal training in pure science was Lee de Forest. He received his PhD from the Sheffield Scientific School at Yale in 1899. His dissertation entitled, "Reflection of Electric Waves of Very High Frequencies at the Ends of Parallel Wires," set out to answer two important questions raised by the work of Hertz. Yet like Fessenden and Marconi, de Forest was more interested in applied science. Indeed, throughout his time at Yale, he attempted "to prove himself an inventor" while at the same time complaining at length about the abstract, theoretical instruction he was receiving. What he wanted was training that would enable him to gain a concrete monetary return on his financial investment.[184]

These and many other inventors all over Europe, North America and elsewhere, worked incessantly in the closing years of the nineteenth and the early twentieth centuries, competing with one another to demonstrate to a sceptical world that radio could be a useful and viable technology. The first to achieve this goal was Marconi and his success was due to a variety of factors. He did begin in an unusually favourable position having been born into a wealthy family with important connections in Italy and in Britain and having been tutored by Righi. But this in itself does not explain his rapid rise to the top in the field of radio. Equally important was his entrepreneurial skill—his ability to use and extend his connections, his flair for gaining public attention to promote his product, his concentration on creating equipment for which there was an obvious, immediate and exploitable market and his awareness of the importance of establishing the legal priority of his inventions. Thus it has been argued that the most distinctive thing that Marconi took with him to Britain in 1896 was not his equipment, all of which had been seen before in earlier experiments by Lodge, Branly, Popov and others.[185] What distinguished Marconi from those who came before him was his "confidence that he could create a system of signalling by Hertzian waves that would have commercial and military, not merely scientific, value" and his "unshakable determination to do precisely that."[186]

Marconi set out to accomplish this objective by demonstrating his system to a group of British government officials from the Army, the Navy and the Post Office. Although they had been gathered together through the influence of Marconi's family and friends, they were not unimpressed with the display. Indeed within a year of his arrival, it was

181. Aitken, *Syntony and Spark*, p. 124.
182. Gibson, p. 31; Aitken, *Syntony and Spark*, pages 182–5, 198.
183. Aitken, *The Continuous Wave*, pp. 41–51.
184. Aitken, *The Continuous Wave*, pages 162–9, 175–6.
185. Maclaurin p. 43; Aitken, *Syntony and Spark*, pp. 180–7.
186. Aitken, *Syntony and Spark*, p. 202.

suggested that Marconi's system could "be a great and valuable acquisition" for marine communication. In order to exploit this potential market, however, Marconi had to solve two major technical problems. He had to prove that his system could provide reliable communication for maritime traffic over substantial distances and he had to find "some way in which two or more stations could transmit at the same time without interfering with one another."[187]

Marconi's approach to both of these technological challenges was to use existing apparatus in new and innovative ways. In pursuing the goal of greater distance, he used an oscillator much the same as that developed by Righi and a Branly-style coherer which he had made more sensitive by careful experimentation. These revisions alone may well have enabled Marconi to improve on previous accomplishments in the field but the really crucial element in the achievement of greater distance was innovative antenna design and use.[188] After experimenting with a variety of modifications of the standard dipole antenna, Marconi settled on an arrangement very similar one used by Popov before him (though probably developed independently) consisting of a vertical antenna with two metal plates, one connected to a long wire which in turn was attached to the top of a high pole and the other laid on the ground.[189] With the earth acting as one of the dipole's arms, Marconi was able to extend significantly the range of his transmission making possible the successful long distance demonstrations of the subsequent months and years. At the time no one, including the scientists, really understood why this antenna worked so well but for Marconi the fact that it did was sufficient justification for making it an integral component of his radio system. Moreover, his success, in the absence of scientific research to explain and qualify it, transformed this system from an interesting experimental arrangement to a widely accepted operational formula for long distance communication.[190]

The second major technical challenge which Marconi faced in his attempt to make radio communication commercially viable was how to limit interference between stations. Theoretically, this problem had always existed because spark methods of generating electromagnetic waves were not very clean in the sense that they produced in addition to the desired frequency, "many other signals at harmonics of that frequency," complicating the process of reception. General recognition of this problem came in the last years of the century as the number of transmitters and receivers increased and the trend towards use of high power and long antennas producing low frequency waves was firmly entrenched. Transmitters and receivers tended to be very broadly tuned during this era and thus placed significant demands on the limited space available on the radio spectrum. This problem, which at the time was little understood by scientists or inventors, was exacerbated by the move to lower frequencies since these support fewer users (each user requires proportionally more of the space) than the higher frequencies do. The congestion which resulted threatened to undermine the reliability of radio communication and eventually inspired a variety of technological innovations intended to improve methods of tuning.[191]

Several inventors were involved in the search for better tuning and much legal wrangling ensued in later years as a result of the competing claims arising out of this search. Marconi, as usual, was a central figure in these events. His method of tuning (patent 7777, 1900) was, in large measure, based on work done by Lodge. While working to improve the sensitivity of his coherer, Marconi became convinced of the importance of creating a system in which the receiver responded only to those signals emitted by its corresponding transmitter. This was accomplished by constructing four circuits, two in the transmitter and two in the receiver, which could "be made to resonate at the same frequency" or at some harmonic of that frequency.[192] In a series of tests conducted in the fall of 1900, Marconi's system performed well proving not only that simultaneous transmission was possible with much less interference than had previously been the case but also that tuning improved the quality of long distance communications. These tests confirmed what many inventors already suspected when they took out patents on their work in this area, that market demand for radio equipment was

187. Aitken, *Syntony and Spark*, pp. 230–1.
188. Aitken, *Syntony and Spark*, pp. 185–8.
189. Aitken, *Syntony and Spark*, pp. 188–94.
190. Aitken, *Syntony and Spark*, pp. 197–8.
191. Aitken, *Syntony and Spark*, pages 244–5, 268, 277; see also Maclaurin pp. 52–3.
192. Aitken, *Syntony and Spark*, pp. 249–54.

likely to be increased significantly by advances in tuning.[193]

Marconi's unique approach to innovation clearly played a crucial role in establishing radio as a viable and useful form of communication alongside cable telegraphy by 1900. Yet the "highly empirical, trial-and-error manner" in which most of the refinements to the original Hertzian system had evolved left a large gap in theoretical understanding of the interaction between the waves and the equipment. This encouraged uncritical acceptance of Marconi's formula of "the high vertical antenna, the spark gap, the coherer, [and] the faith in long waves for long distance," and led many inventors to concentrate on incremental changes to this tried and true system instead of exploring other less obvious avenues of development and change in radio technology. More over, it made it that much more difficult for those researchers who did depart from the general trend to gain recognition for and acceptance of their work even when it had scientific or practical merit.[194]

Nevertheless, inventors did emerge to challenge the Marconi model of radio communication. One of the first to do so was Reginald Fessenden, a Canadian who did much of his work in the United States. As early as 1899, Fessenden publicly questioned the scientific basis of Marconi's work and began to think in terms of "an entirely new method...characterized by a return to first principles, the abandonment of the previously used methods and by the introduction of methods in almost every respect their exact antithesis." The idea for this new method evolved from two separate but related sources: a general concern (expressed by various researchers including Fessenden) about the inability to tune spark apparatus accurately due to the highly damped character of the waves produced and Fessenden's emerging conception of Hertzian waves as high frequency alternating currents.[195]

The challenge of achieving better tuning led Fessenden to explore new means for both the detection and transmission of electromagnetic waves. By 1897 he was already working to replace the coherer which his studies had shown to be an unreliable detecting device at best. At the same time, his specific complaints about the Marconi system were evolving into a general dissatisfaction with the formula upon which it was based and, by 1900, he was convinced "that damped wave systems were leading wireless technology in a fundamentally wrong direction." Increasingly his attention turned to creating a system based on continuous waves which, he believed, would not only permit better tuning of the signal but ultimately would also make possible the transmission of the human voice rather than just the dots and dashes of Morse code.[196]

The first concrete step in this creative process took place in December 1900 when Fessenden successfully demonstrated speech transmission over a distance of one mile for the U.S. Weather Bureau. Although accomplished using spark technology, this was clearly an important breakthrough because it proved that only by substantially increasing the spark frequency, (from Marconi's eight/second to 10,000/second) and thus approximating as closely as possible continuous wave generation, could the human voice be transmitted. Moreover, it almost certainly reinforced Fessenden's determination to find a method of producing true continuous waves by working out his theoretical conception of Hertzian waves as high frequency alternating currents in practice.[197] From this point forward, his primary preoccupation became formulating and constructing a whole system, based on continuous waves, capable of human voice transmission and reception—radio telephony—that he hoped would prove as valuable as Marconi's system of radio telegraphy.

193. Aitken, *Syntony and Spark*, pp. 258–61; see also Maclaurin pp. 52–3.
194. Aitken, *The Continuous Wave*, pages 35, 40.
195. Aitken, *The Continuous Wave*, pages 32-4, 50-1.

196. Aitken, *The Continuous Wave*, pp. 50–3.
197. Aitken, *The Continuous Wave*, pp. 33–4; Maclaurin p. 59; Ernie Decoste, comparative outline of careers of Marconi and Fessenden, in research files on early radio, p. 2.

8 Radio Technology 1900 –1920

By the turn of the century, it was already becoming apparent that the activities of inventors were moving beyond the boundaries of scientific knowledge of electromagnetic waves established by the work of Hertz. Marconi's various and somewhat weak attempts to explain the success of his grounded antenna in 1896–7 amply demonstrated this.[198] Yet the academic scientists, with the exceptions of Oliver Lodge and Ferdinand Braun, were moving away from research on the lower frequencies then being used for signalling and into the higher frequencies. The inventors, however, continued to push ahead on their own. In doing so they were motivated by the conviction that radio could be developed into a useful technology and that in contributing to that development they could achieve both fame and fortune.

The attempt to achieve these goals required these individuals to be entrepreneurs as well as inventors because they had to finance their research work by selling the idea of radio to investors and eventually to the public. In this context, the fact that some piece of equipment worked consistently was often more important than the explanation of why it did. Though undeniably short-sighted (and criticized as such at the time by many inventors and scientists[199]), this approach gave radio technology a foothold in the world of practical communications at a time when many would readily have dismissed it as purely experimental. This in turn inspired intense commercial competition for the rights to this potentially profitable technology which fed the innovative drive of the inventors.

Determined to demonstrate the originality of their work in order to secure patent rights over it, they constantly sought new answers to common problems in the radio field. As a result, a great variety of transmitters, receivers and antenna systems were devised between 1900 and 1920 which gradually moved the industry away from the rudimentary spark techniques first used by Marconi and towards more sophisticated continuous wave systems.

Prior to 1914, the primary impetus for technological change in radio continued to arise from the two problems that had inspired Marconi's early work—greater distance and less interference. There was no one solution to these problems but rather a wide range of possible methods of refining the component parts to achieve improved performance in the system as a whole. For the purposes of this discussion these developments will be broken down into three basic categories: transmitters and transmission techniques, receivers and reception techniques and antenna systems.

Advances in Transmission 1900 – 1920

Spark Systems

For the first years of the century, advances in transmitting equipment, though significant, generally did not depart much from the spark system established by Hertz and improved by Marconi. In this system oscillations were produced by a spark generated across the gap between two stationary spheres. The first few oscillations were quite strong and provided "the initial forward energy pulse" by which "the energy of the spark was transferred inductively to the aerial circuit." The aerial or antenna then radiated the transferred energy into the atmosphere as electromagnetic waves which came "in short bursts or trains of rapidly diminishing amplitude."[200]

In general this was a simple and fairly reliable system, but its capabilities for long distance transmission were limited. As well, with the increasing number of experimental and other stations that

198. Aitken, *Syntony and Spark*, pp. 194–8.
199. Aitken, *The Continuous Wave*, pp. 29–40.

200. Wedlake, pp. 64, 211–13; W.T. O'Dea, *Radio Communication, Part I. - History and Development*, (London: His Majesty's Stationery Office, 1934) p. 23.

were being established after 1900, its reliability over all distances was significantly reduced by interference. Marconi's transatlantic experiments from 1901 to 1904 demonstrated clearly that a simple increase in the power input of the transmitter was not sufficient to achieve consistently good long distance results. The problem was not how to produce more power and feed it into the spark gap but rather how to get that additional energy to "approach in uniformity that of a sustained frequency" and how to get it into an antenna so that it could be radiated the required distance.[201]

Marconi, his advisor J.A. Fleming and others in the field such as professor C.R. Cross, believed strongly that the highly damped character of the spark train—the whip-crack effect—was absolutely essential to the production of electro-magnetic waves. Yet it was this effect that was at the root of the difficulties. Pulses of energy that began strongly and then quickly faded away produced waves that did the same. These waves had not one but many frequencies and harmonics of frequencies and these were both "prodigally wasteful of spectrum of space and flagrant sources of interference when more than a single station was trying to transmit." In addition, transmission power was reduced "by dissipating it over too wide a band of frequencies."[202] Finally, the trailing off of the spark train allowed some of the energy transferred to the antenna in the "initial forward energy pulse" to flow back into the spark gap thereby diminishing the antenna's radiation power. These problems had been remedied to some extent by the advent of tuned circuits which both reduced interference and improved transmission distances, but even these improvements had limits. Marconi, for example, obtained inconsistent results at best in his transatlantic experiments from 1902 to 1905 despite his use of tuned circuits.[203]

These obvious limitations of spark technology led researchers and inventors to pursue two fundamentally different lines of research. Most chose to improve the established spark system which, at the time, was the only functioning and commercially viable technology in the field. The major advance made in this area after 1900 was the development of transmitters that would cut off the spark train after the initial burst of energy. Two basic methods were used to accomplish this. In the rotary spark gap method, the motion of a wheel created and broke the spark at timed intervals. The quenched spark system depended on the rapid cooling or deionization of the spark path to break off the spark train. Several inventors produced devices utilizing these two systems and among these the most well known were Telefunken's quenched gap and Marconi's rotary synchronous disc discharger both of which quickly became integral parts of their commercial systems. Both of these transmitters, which were developed between the years 1905 and 1909, produced sparks at such a rapid and regular rate that they gave out a musical tone which could be identified even in the presence of interfering signals. Indeed, the Marconi system produced such regular and persistent oscillations that it not only "made precise tuning possible" but also "concentrated all available transmitter power on a single frequency." Some, including Marconi himself, were convinced that with the disc discharger they had achieved true continuous wave transmission.[204]

Marconi's somewhat extravagant claims clearly demonstrate just how far spark transmission techniques had come since 1900. As late as 1904, Marconi and his chief scientific advisor, J.A. Fleming, had dismissed the arguments of those like Fessenden who maintained that Hertzian wave telegraphy could be accomplished without the Hertzian spark. Events and developments after that time, however, demonstrated that better performance (distance and selectivity) increasingly required modification of the essential characteristics of the spark. The end result of this was the disc dischargers at Clifden, Ireland and Glace Bay, Nova Scotia. Opened in 1907, these were "the ultimate" in spark technology and successfully fulfilled their transatlantic communications role for a number of years. Persuaded by this performance, Marconi changed his mind about the importance of the Hertzian spark and declared in front of a parliamentary committee in 1911 that the Clifden station had "a system utilizing continuous waves and employing no spark whatever." Fessenden knew, however, that true continuous waves (as opposed to Marconi's close approximation) could not be produced even by an elaborate spark method such as the discharger and without them

201. McNicol, p. 79; Aitken, *Syntony and Spark*, p. 265.
202. Aitken, *Syntony and Spark*, pp. 74, 247.
203. O'Dea, p. 23; Wedlake, p. 213; Vyvyan, pp. 36–44.

204. Wedlake, p. 213; O.F. Brown, *The Elements of Radio-Communication*, (Oxford: Oxford University Press, 1927) pp. 53–5; McNicol, pp. 101–5; O'Dea, pp. 23–5.

voice transmission, better tuning and more efficient use of the spectrum were not possible.[205]

Continuous Wave Systems

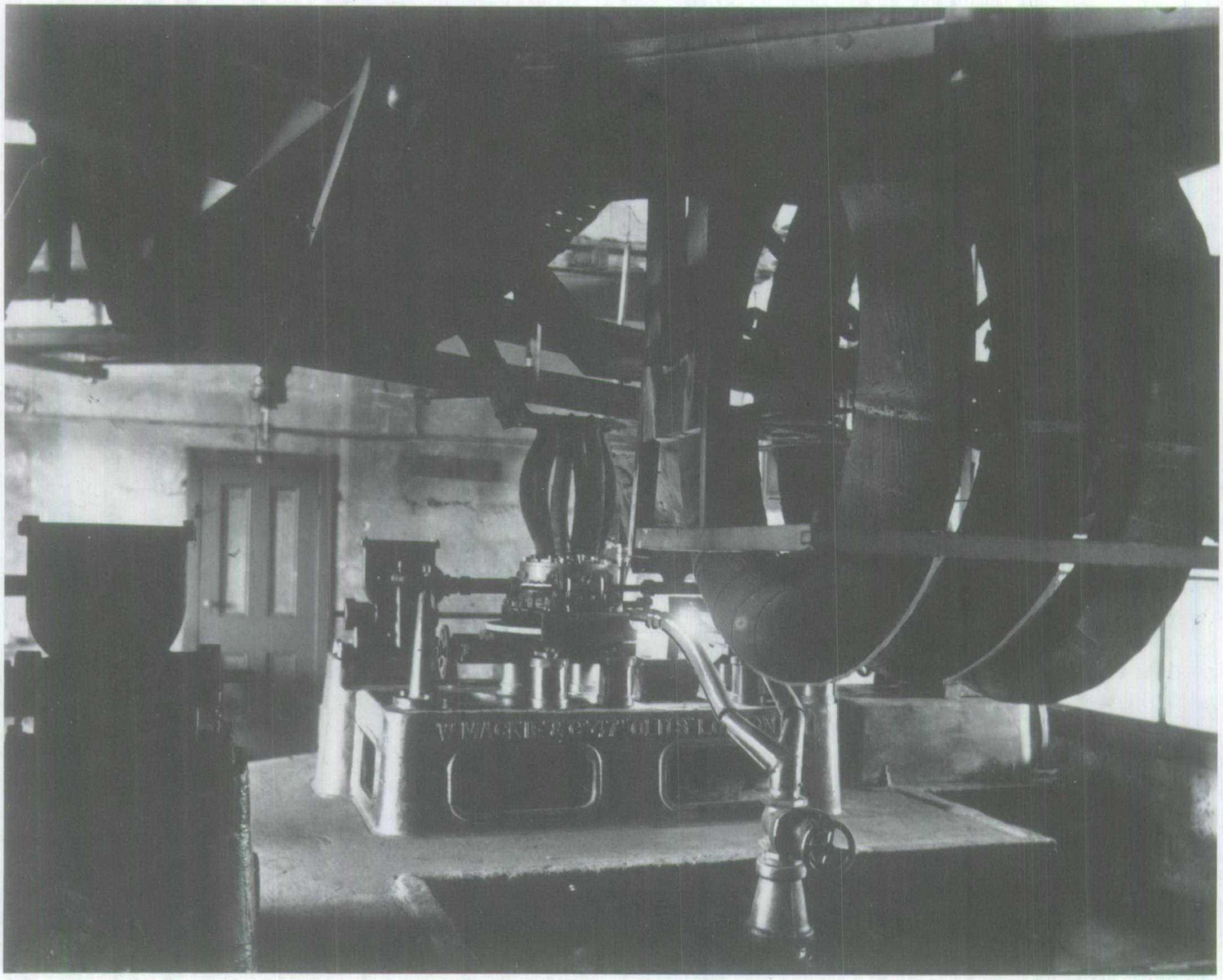
Marconi's conversion (circa 1911) to the idea of continuous wave telegraphy marked the beginning of the end for all forms of spark transmission including that used at Clifden, Glace Bay and later Carnarvon, Wales. Although spark systems continued to dominate for a number of years, their fundamental limitations had been accepted in principle even by the man who established them as the standard in commercial wireless telegraphy. Fessenden, however, had seen the weaknesses of spark methods as early as 1900 and chose to pursue continuous wave transmission which at the time was considered a radically different approach to radio communication. Like all inventors who decide not to follow the main stream of development, these radical thinkers had to fight an uphill battle to gain recognition for their work.

Although the basic components of the two earliest continuous wave systems were developed before the turn of the century, the idea of using these two devices—the alternator and the arc—to produce radio frequency waves was first suggested in 1900 by Fessenden. Disappointed by the qualified success of his first voice experiments in 1900, he set out to increase the spark frequency of his system and to lessen the degree of damping of the discharges. To accomplish this he tried a variety of methods. First he developed a system based on the same concept as the quenched spark later used by Telefunken. This he found to be a great improvement over his earlier spark arrangement but "foreign noise in the telephone" was still a significant problem. Next he moved on to conduct "a series of experiments with Elihu Thomson's oscillating arc, working to raise and stabilize its frequency of operation." He succeeded in producing radiofrequency continuous waves with the arc but again was not happy with the level of noise and distortion.[206]

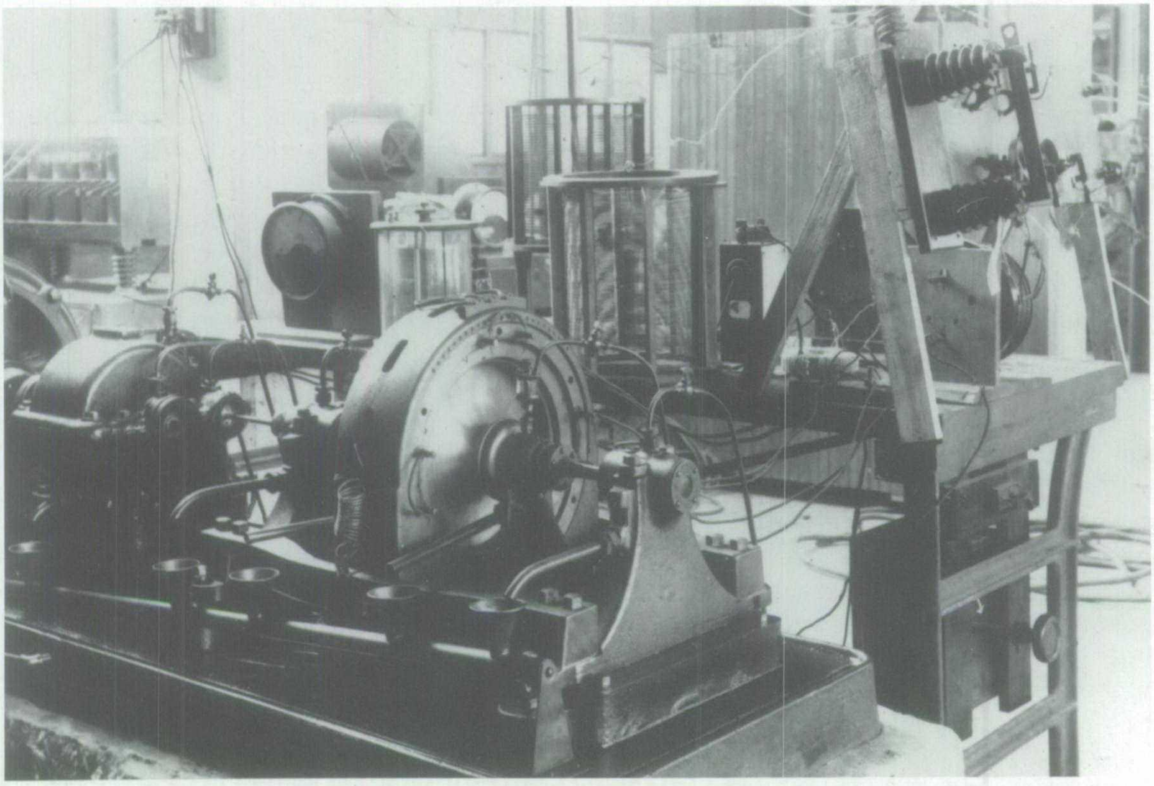
These experiments convinced Fessenden that "for quiet, distortion-free telephony to be possible," not only was it essential to have continuous undamped waves, but that these "had to be perfect sine waves," something that only a very high frequency alternator would be able to produce. Thus in June of 1900, Fessenden forwarded his general specifications for such an alternator to General Electric. Though it sounds simple enough in theory, the practical truth was that with this request, "Fessenden was pressing against the limits of the manufacturing capabilities of his day." Basic alternators were relatively easy to design and to build. In these, currents were "generated by rotating a coil of wire in a magnetic field, or in larger machines by the reverse process of causing a rotating magnetic field to cut across fixed conductors." The speed of rotation required to generate currents of radio frequency, however, posed significant problems. These difficulties were not satisfactorily overcome by the first alternator, built by Charles Steinmetz and delivered to Fessenden at his Brant Rock, Massachusetts station in 1903. The second machine designed by Fessenden and Ernst Alexanderson was greatly improved as a result of the initial experience and in 1906 it was used in a series of successful tests and demonstrations of radiotelephone communication. These included the famous Christmas/New Year's broadcasts of voice and music to ships at sea and the unintentional and unwitnessed reception of adjustment instructions sent to the operator in Plymouth, Massachusetts from Brant Rock at the station in Machrihanish, Scotland over a distance exceeding three thousand miles.[207]

These achievements were, indeed, impressive. They proved not only that Fleming and other adherents of spark methods were wrong to dismiss high frequency alternating currents and continuous waves as a means of transmitting radio signals but also that radio could potentially do much more than transmit telegraphic signals—it could transmit "commercial-quality" speech.[208] Yet these important experimental successes did little to establish the place of the high frequency alternator and its originator in the commercial arena. There were two main reasons for this. The system was still experimental and thus not easy to market. As well, by 1906, Marconi had already established a dominant position in the radio communication field making it difficult for other inventors to compete against him and his widely used spark system for investment dollars and buyers. These reasons alone, however, do not fully explain Fessenden failure to make a commercial success of his continuous wave system. After all, Marconi's system

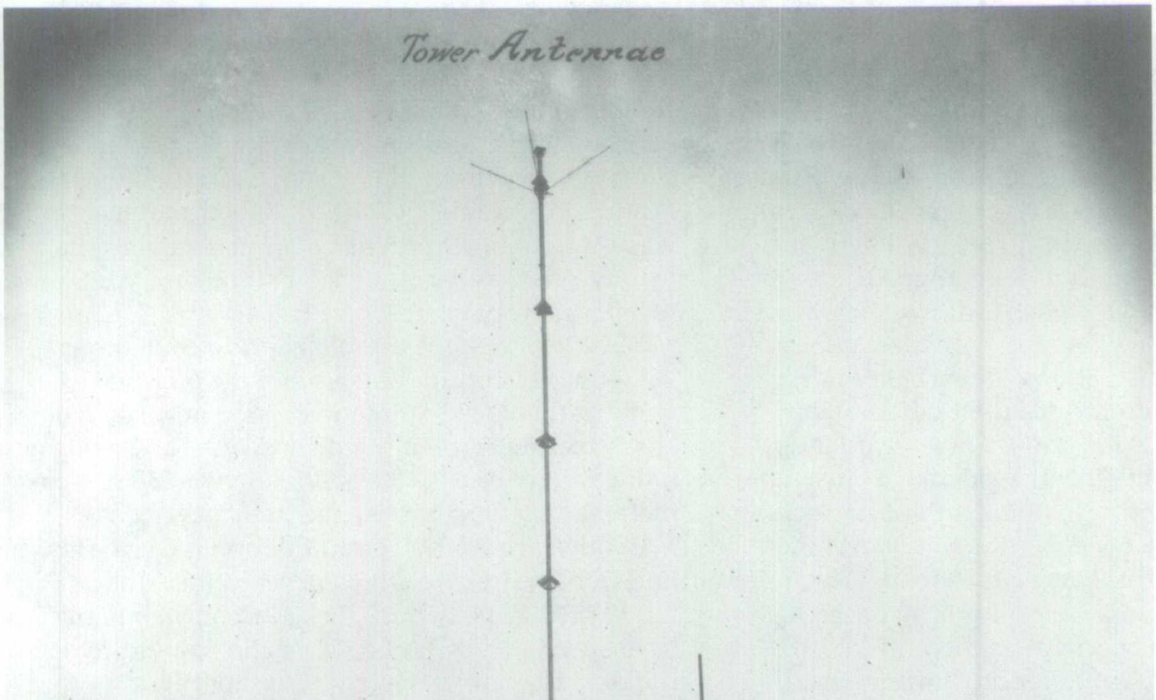
205. Aitken, *Syntony and Spark*, pp. 278–82; McNicol, pp. 78–9.
206. Aitken, *The Continuous Wave*, pp. 61–2.
207. Aitken, *The Continuous Wave*, pp. 61, 63–70, 72–5.
208. Aitken, *The Continuous Wave*, pp. 67–9.



Disc discharger and primary coil of spark transmitter at Glace Bay station, about 1913.
Source: NMST



High frequency alternator at National Electric Signalling Company station at Brant Rock, Massachusetts, used from 1908 to 1910. Source: NMST



Tower antenna, Brant Rock, taken 30 January 1906. Source: Department of Archives and History, Raleigh, North Carolina, neg. no. N.77.10.37.

had also been experimental when he entered the market and, although the fact that he was the first in the field gave him an advantage, his position was not unassailable as the American developers of the arc were to prove after 1909.

In the end it must be conceded "that Fessenden's failure to show how the new technology could be integrated successfully into the marketplace" was due mostly to his lack of skill as a businessman. Unlike Edison and Marconi who were entrepreneurs as well as inventors, Fessenden was not sufficiently concerned with inventing for the market. He seemed to believe that if an invention had scientific and technical merit, it was certain to sell whether there was an immediately identifiable need for it or not. As a consequence of this attitude and of the undefined relationship between Fessenden and his financial backers, the company formed around his inventions was not a success and after 1911 neither Fessenden nor the company were in a position to continue research and development of the alternator. This, combined with the fact that the alternators were "expensive and complicated machines to build," meant that continuous wave radio using the Fessenden-Alexanderson alternator did not become a commercial reality until the beginning of World War I.[209]

Ironically it was the arc system that Fessenden had rejected in 1900 that facilitated the eventual the entrance of continuous wave transmission into the radio market. As early as 1900, William Duddell had demonstrated that, if arranged a certain way, the arc became "a device that would convert direct into alternating current, with oscillations of constant amplitude." Yet he did not believe that the arc could be used to produce the high frequency oscillations essential for radio. Three years later, however, a Danish engineer, Valdemar Poulsen, proved him wrong by developing an arc arrangement that "could be used to transmit continuous oscillations of a useful frequency." He achieved the necessary increase in power output by operating the arc in a hydrocarbon atmosphere.[210]

Like Marconi and his antenna, Poulsen could not explain why this system worked but he was immediately aware, as Marconi had been, that because it did work and was simple to build, it had real commercial potential. Based on the originality of the hydrocarbon atmosphere, Poulsen was able to patent his system and a syndicate was formed to market and develop it. By 1906 three stations had been opened, two in Denmark and one in England and by 1908 speech and music were being successfully transmitted between a fourth station near Berlin and one of the original Danish stations on a regular basis. Distances of up to 848 kilometres were achieved.[211]

While Poulsen continued to work on his system in Europe, he sold the U.S. rights to Cyril Elwell who made great strides with the system after 1909. Out of his small laboratory and manufacturing plant in California came a series of five and twelve kilowatt arcs which he used to demonstrate the substantial distances that the system could cover and its superior tuning capabilities. The commercial success of Elwell's arc, however, was limited until 1912 when the Poulsen Wireless Corporation under the direction of financier Beach Thompson took control of Elwell's much smaller and financially troubled Poulsen Wireless Telephone and Telegraph Company. Though no longer in control of the company, Elwell persuaded Thompson that the greatest potential for profit lay in exploiting the Pacific marine communication market which was not yet dominated by Marconi. In a mere forty-seven days, Elwell succeeded in constructing and equipping an arc station in Honolulu to communicate with the company's San Francisco station. The quality of communication was good by night and although it was not reliable by day, the company quickly established a clientele by offering very competitive rates.[212]

This achievement established the commercial legitimacy of continuous wave radio techniques and clearly placed Marconi and the advocates of spark technology "on the defensive." The Pacific arc link covered over 2,100 nautical miles (3889 kilometres), equalling and slightly surpassing the Marconi transatlantic circuit between Glace Bay and Clifden, Ireland which covered just under 2,000 (3704 kilometres). The Marconi Company "reassured its stockholders" of the superiority of the disc discharger system claiming that it and its inventor were "mainly responsible for the progress...made in long distance wireless telegraphy" since 1907. In the U.S. and elsewhere, though, continuous wave arc transmission was making significant inroads into the radio commu-

209. Aitken, *The Continuous Wave*, pp. 45–6, 70–2, 85, 158–9.
210. Aitken, *The Continuous Wave*, p. 115; Wedlake, pp. 214–5.
211. Aitken, *The Continuous Wave*, p. 121.
212. Aitken, *The Continuous Wave*, pp. 122–37.

nication market. In Britain, the Universal Wireless Syndicate (with the help of Elwell who had left the Poulsen Wireless Company) acquired the necessary licenses to operate a transatlantic circuit using the arc system between Newcastle, New Brunswick and Ballybunnion, Ireland in 1913 in direct competition with the Marconi Company. As well, between 1912 and 1917, the U.S. Navy established a network of stations using arc technology that covered distances of up to 12,480 kilometres into the Panama Canal zone and throughout the Pacific. Despite their claims to the contrary, Marconi officials clearly recognized the importance of this technology and acquired the British rights to the Poulsen arc patents in 1914. By this time they already owned the rights to the Goldschmidt high frequency alternator which they had purchased only a few months after reaffirming their faith in the disc discharger in December 1912.[213]

Because of its simplicity and durability, the arc accomplished what the alternator, at least in its earliest forms, could not—it made continuous wave radio transmission a commercial reality. Nevertheless, it had certain important weaknesses. In general, "high-powered sets were commonly attended by the serious radiation of harmonic frequencies." As well, arc transmitters were "relatively slow to start up after a period of inactivity and considerable care was necessary to avoid obtaining a bad note due to variations in the frequencies of the oscillations generated." Both the carbon cathode and the arc chamber also placed significant maintenance demands on station personnel. Finally, for all its "advantages of robustness, durability, and the easy clearance of faults," the arc system "was not ideal as a generator of continuous waves." The high frequency alternator not only produced a purer wave "free from harmonics" but also performed more efficiently—at levels of 60 per cent or more (76, 79 and 84 per cent according to some reports) compared to around 30–50 per cent for the arc.[214]

By around 1920, there were some 6,623 registered radiotelegraph stations throughout the world including 5,821 ship stations and 802 land stations. Even ship stations which tended to use smaller sets, were moving away from simple spark methods and towards quenched spark or arc. Similarly, land stations, especially the larger ones, increasingly employed continuous wave transmission. Among the land stations, there were at least twelve "capable of transmitting telegraph messages on a regular inter-Continental basis." Marconi's station at Carnarvon and the Norwegian station at Stavanger both used the timed spark system, though Marconi apparently recognized the inherent limitations of this system when he purchased the British rights to the Poulsen arc patents in 1914. High power arcs were used in several locations including the American west coast, the Pacific, the Canal Zone, in Bordeaux, France and Nauen, Germany. The latter station also had and used high frequency alternator sets as did the other German long distance station at Eilvese, the American station at New Brunswick, New Jersey and the Paris Radio Central station in France.[215]

Although the work of Fessenden, Poulsen and others clearly demonstrated by 1914 that the future of radio lay in continuous wave transmission, their systems of generating and transmitting radio waves did not dominate the field for very long. As early as 1915, a new transmitting technology, the oscillating vacuum tube, was on the horizon and, in the years following World War I, it would eclipse the alternator and the arc.[216]

Advances in Reception 1900–1920

In the early years of radio, reception techniques tended to be tailored to suit particular type of transmitter being used. Certain methods and devices worked well with spark systems, while others were required to detect and record signals sent via arc or alternator transmitters. Whatever system was being used, the "most vital" component of the receiver was the detector. (It was so important that the receiver as a whole came to be known as the detector.) Prior to 1900, the primary device used for detecting radio waves was the coherer. But there was increasing dissatisfaction with the coherer because it was not continuously active and because most researchers believed that its sensitivity and stability could be improved upon. Out the many attempts that were made to replace the coherer, four major types of detectors emerged: electrolytic detectors, magnetic detectors, crystal detectors and vacuum tube or valve detectors.

213. A.H. Morse, *Radio Beam and Broadcast*, (London: Ernest Benn Ltd., 1925) pp. 76–7; Aitken, *The Continuous Wave*, pp. 130–1, 137–9, 142, 159.
214. O'Dea, pp. 27–9, 31.
215. Aitken, *The Continuous Wave*, p. 159; O'Dea, pp. 31–2.
216. O'Dea, p. 30.

Electrolytic Detectors

In this group of detectors a local circuit was connected through an electrolyte or conducting liquid to a telephone receiver. A fine wire, usually platinum, was immersed in a solution such as nitric acid and when a small flow of current from a local battery was passed through it, bubbles formed around the end of the wire preventing the passage of current into the telephone.[217] When electromagnetic waves were received, their energy was sufficient to break the bubbles and complete the circuit allowing current to pass into the telephone. Many variations of this detector were developed. The first recorded patent was awarded to M.J. Pupin, the second to R.A. Fessenden and the third to Lee de Forest, all in the United States. But similar inventions were registered in other countries during the same period, including for example, W. Schloemilch's work in Germany and Ferrie's work in France.[218]

All of these electrolytic detectors, like the coherer before them, were used to receive spark generated signals. But unlike the coherer, they were continuously active as well as being much more sensitive. One historian has even argued that one of Fessenden's electrolytic detectors, the liquid barretter (1902), provided "radio technology with its most sensitive detecting device until the invention of the triode vacuum tube." In some situations such as rough seas, the sensitivity was lost because of their inherent delicacy. A far more serious drawback for Fessenden and other proponents of continuous wave radio was the inability of electrolytic detectors to produce a clear and distinct sound in the telephone upon receiving incoming continuous wave signals. Something more than the characteristic "buzz" would be required for "practical telegraphy" in Fessenden's view.[219]

Magnetic Detectors

As with the electrolytic type of detector, there were many versions of the magnetic detector. All of these used the effects caused by the magnetic fields formed around current-carrying wires or coils to detect the presence of radio signals. Marconi and Fessenden, among others, patented several models of this type of detector in 1902 and after to use with spark apparatus. Fessenden seemed to prefer the barretter for radio work though, and his magnetic devices remained largely experimental though some later became important in other fields such as tape recording of sound.[220] Marconi, on the other hand, badly needed a practical replacement for the coherer in his growing network of marine stations and used one of his magnetic designs to fill this role.

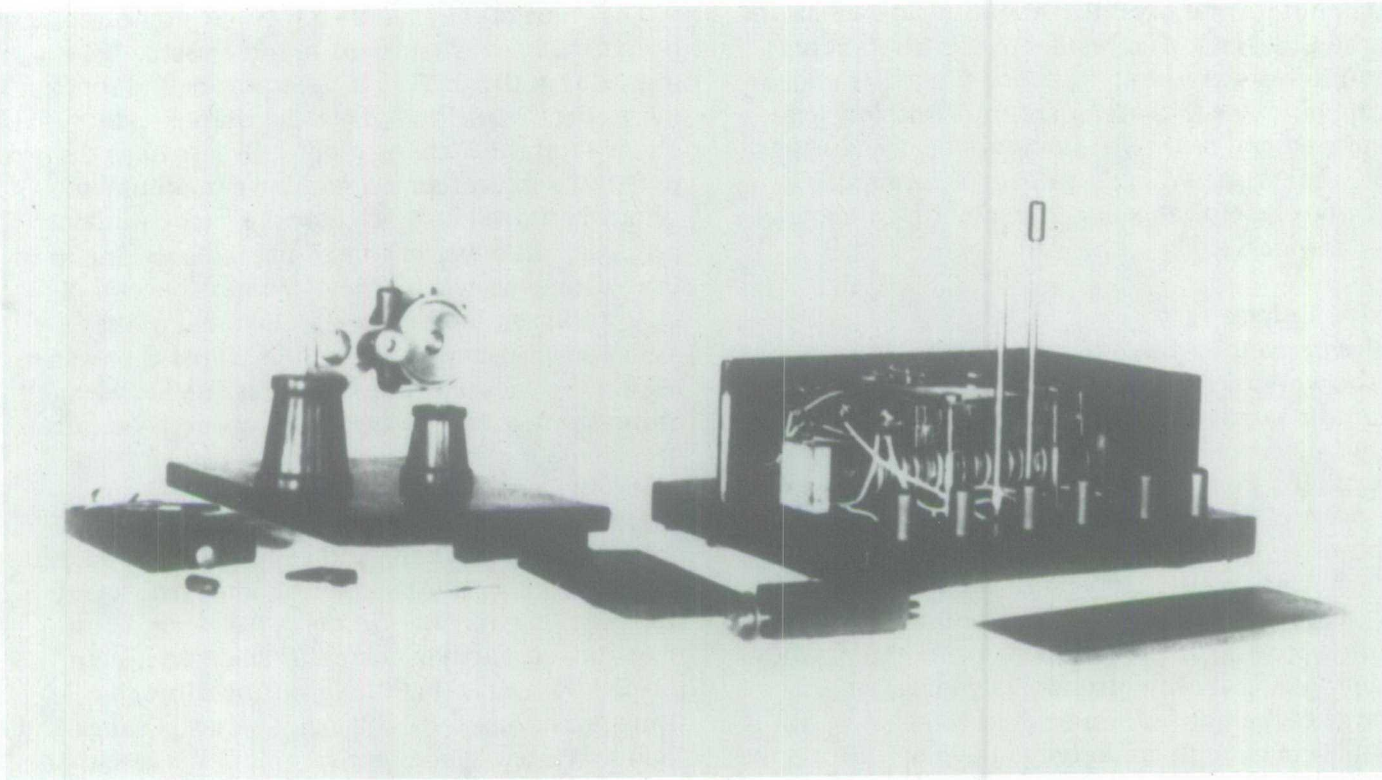
In the Marconi system, when radio signals enter the receiver as electrical impulses, they cause a sudden change in the magnetism of an iron wire which is being pulled through the magnetic field of two permanent magnets. The sudden changes in magnetism are registered in a telephone receiver connected to the detector as a series of clicks. The constantly rotating wire made this detector continuously active and, although the clockwork drive required to accomplish this was something of a disadvantage, the maggie as it was fondly called, was very stable. But what was gained in stability was lost in sensitivity such that some marine operators claimed "that with a magnetic detector signals could be copied from another ship only when it was passing within sight."[221]

Crystal Detectors

This type of detector, of which there were numerous varieties, was based on the unique conducting properties of certain mineral crystals. As early as 1874, Ferdinand Braun noted that such crystals would conduct current effectively in one direction but not in the other. It was discovered that the alternating or reversing character of radio waves could be changed into a series of direct current impulses that would activate a telephone receiver by passing them through such a crystal. This principle was first incorporated into radio reception by the Telefunken Company in 1901 using Braun's psilomelan detector. By 1906 there were several different versions available employing a variety of crystals and forms of contact.[222]

Though used initially in spark systems, the crystal detector could also be used in continuous wave receivers. As early as 1907, Lee de Forest sold thirty-seven radio telephone sets based on arc

217. MacLaurin, pp. 60–1; Charles R. Gibson, *Wireless of Today*, (London: Seeley, Service & Co. Ltd., 1925) pp. 118–9.
218. Vivian J. Phillips, *Early Radio Wave Detectors*, (London: Peter Peregrinus Ltd., 1980) p. 74.
219. Aitken, *The Continuous Wave*, pp. 57–8; MacLaurin, p. 61; A.P. Morgan, *Wireless Telegraphy and Telephony*, (New York: The Norman Henley Publishing Co., 1920) p. 59.
220. Phillips, p. 95.
221. Aitken, *The Continuous Wave*, p. 57 in footnote #53; John W. Stokes, *Seventy Years of Radio Tubes and Valves*, (New York: The Vestal Press Ltd., 1982) p. 3.
222. O'Dea, pp. 13–4; Phillips, pp. 206–10.



Fessenden's liquid barretter. Source: NMST transmitters and crystal or vacuum tube receivers to the U.S. Navy. The results of this attempt at continuous wave radio were not altogether encouraging but once this system of transmission was improved and refined in the years before, during and after World War I, crystal detectors quickly became one of the most common forms of receiver on the market.[223]

Valve Detectors

Valve or vacuum tube detectors originally grew out of the work of Thomas Edison who discovered that a certain current created within his two element light bulbs would flow in one direction but not in the other. Around the same time that the rectifying property of crystals was being applied to radio reception, Ambrose Fleming determined that the Edison Effect could be used in a similar fashion. His diode valve consisted of a vacuum tube containing a cathode and an anode connected to the antenna circuit. The incoming signal varied the charge of the anode from positive to negative but the flow of current could only take place during the positive swings because during the negative phases the electrons given off by the locally heated cathode were repelled due to their similar charge. When the current flowed through the tube it operated a telephone receiver to which it was connected. This two element tube was "no more reliable, stable, or sensitive" than the crystal and was not nearly as widely used even though the Marconi Company held the rights to it.[224]

It was not until the advent of the audion or triode around 1907 and its refinement after 1913, that valve or vacuum tube detectors enjoyed widespread use. Looking "for a detector that would not infringe the Marconi or Fessenden patents," Lee de Forest developed a series of tube detectors between 1906 and 1908 and, without fully understanding the principles behind it, came up with the three-element audion tube. The third electrode was a grid which was attached to the antenna in order that its voltage could be altered with alternating swings in current caused by the incoming radio waves. The cathode was heated to incandescence as before but instead of using "the degree of heat applied to the cathode" to control the emission of electrons, de Forest used the changing charge of the grid to do this.[225]

223. Morgan, p. 10.
224. Stokes, p. 4; McNicol, pp. 162–3; MacLaurin, pp. 46–8; Aitken, *The Continuous Wave*, p. 215.
225. MacLaurin, pp. 74–6.

The value of the de Forest tube as a detector has been debated by historians of radio. Some have argued that the de Forest tube provided "a much more effective method of control than could be obtained in the Fleming diode." Others have disputed this interpretation and have maintained "that when used as a detector the triode Audion performed little better than a plain diode" due to "its extremely low efficiency." What is beyond dispute, however, is that the development of the Audion "set in motion a chain of events that was to lead to the vacuum tube becoming the key element around which, for the next half century, the future development of both receivers and transmitters would hinge."[226]

The first recorded step in this chain of events occurred between 1911 and 1913 when the Lieben-Reisz gas relay, an Austrian version of the vacuum tube, was used by the German, Meissner, to amplify audio frequency currents. This was accomplished by connecting the first tube through a transformer to a second tube or series of tubes and then to the telephone receiver. Meissner also made what turned out to be a much more significant discovery, one which was also being made at the same time in by Edwin Armstrong and de Forest in independent experiments in the United States. It was found that by arranging the tube circuit so that some of the energy derived from the incoming oscillations could be fed back into the tube a second time, much stronger signals could be fed into the telephone. Meissner also demonstrated that continuous oscillations set up in the tube by this feedback system were not, as de Forest believed, a nuisance to be eliminated,[227] but rather a source of continuous waves. In 1913, he demonstrated "the transmission of speech by radiotelephony" using the gas relay as a generator of radio waves. Eventually de Forest too saw the value of the radio frequency oscillations and filed patents on his version of the oscillator and the feedback circuit in 1914 and 1915 respectively. He first put the oscillator to use for reception of continuous wave signals in a system that he sold to both Federal Telegraph and the U.S. Navy.[228]

226. MacLaurin, pp. 74–6; Stokes, p. 8.
227. Gerald F.J. Tyne, *The Saga of the Vacuum Tube*, (Indianapolis: Howard W. Sams & Co. Inc., 1977) p. 114; Aitken, *The Continuous Wave*, p. 238.
228. O'Dea, p. 15; Aitken, *The Continuous Wave*, p. 239; MacLaurin, pp. 77–9.

Within a few years, the oscillating vacuum tube had become, along with "the crystal or rectifying detector" the dominant form of detector in employed for wireless telegraphy.[229]

Heterodyne Reception

When de Forest incorporated the vacuum tube oscillator in his receiver, he was employing the heterodyne system of reception. This method of reception depends on the mixing of two radio frequency currents, one from the incoming signal and one produced locally at the receiver (de Forest used the vacuum tube oscillator in this role).[230] These two currents differ slightly in frequency and, when they are mixed in the receiver, produce a separate or beat frequency which equals the difference between the two original frequencies. Thus the correct combination of frequencies will result in a final frequency that is within the audible range of the human ear.

This principle which was to become one of the most important in the history of radio technology, was first developed in 1901 by Fessenden who was searching for a reliable and sensitive continuous wave reception technique. His first methods for applying the process were not very sophisticated but ultimately he devised a system using an arc as the local source of oscillations which was successfully tested for the U.S. Navy in 1910. Yet despite the superior "sensitivity and static control" demonstrated by the heterodyne system, it did not enjoy widespread use for many years at least in part because the equipment was "cumbersome," and the arcs were noisy and the waves they produced were not "undistorted sine waves." Consequently little came of Fessenden's "brilliant conceptual breakthrough" until the invention and refinement of the vacuum tube oscillator after 1912. It then became an absolutely essential principle and "has remained fundamental to radio technology ever since."[231]

Advances in Antenna Design 1900 -1920

The efficiency of radio transmission and reception depends to a large extent on antenna design and placement as well as on the design of transmitters and receivers. In the first two decades of the century great improvements were made in the efficiency these important components. The model established by Marconi in the late nineteenth century was for an elevated vertical antenna with an earth connection or ground. This formula continued to be a valuable one into the twentieth century but after 1905 new designs were developed which had different capabilities and uses.

Vertical Antennas

A great many variations of the vertical antenna were devised in this period, including some very elaborate ones. The popularity of these antennas was largely due to their good radiating capability. Grid, fan and inverted pyramid types were common; Marconi used inverted pyramid antennas with qualified success in his early transatlantic work. The umbrella antenna was another vertical arrangement first used by the Lodge-Muirhead group and later adopted by the Germans and the Japanese. The major drawbacks of both the inverted pyramid and umbrella antennas, especially in long distance work was the amount of space required to erect them and the lack of directional capability since the energy was radiated in every direction.[232]

Horizontal, Flat-top and Directional Antennas

In an attempt to improve the efficiency and reliability of his transatlantic stations, Marconi experimented with a series of different antenna designs. His tests convinced him that an inverted L type antenna would produce better results than the existing inverted pyramids. The L, which was essentially horizontal, had directional radiation properties that the vertical designs did not and after 1905 was employed by many stations in the Marconi network. Many other horizontal designs were developed around the same time, some of which took the shape of T's, V's, or inverted U's. They were widely used in places where the space and height requirements for vertical antennas posed a problem most notably on board ships.[233]

Two other forms of directional antenna were developed during this period and are worth noting. In 1907, Italians Ettore Bellini and Alessandro Tosi patented their directional antenna. Consisting of two open ended triangles connected via a series of coils a spark gap, the direction of radiation could

229. Phillips, p. 212, quoting the 1919 edition of *Manual of wireless telegraphy for the use of naval electricians.*
230. MacLaurin, pp. 77–8.
231. MacLaurin, pp. 61–2; Aitken, *The Continuous Wave*, pp. 58–60; see also McNicol, pp. 133–4 and Brown, pp. 86–8.

232. O'Dea, pp. 32–3; Morgan, pp. 18–20.
233. O'Dea, p. 32; Morgan, pp. 19–22.

be changed simply by rotating the primary coil of the spark gap (see diagram). This system later became important in the development of direction finding apparatus employing radio waves. The double loop antenna patented by Pickard in 1907 was one of several versions produced in this period in an attempt to eliminate static. Pickard's was "in principle similar to the Bellini-Tosi arrangement."[234]

Interference and Tuning

The problem of interference was one of the primary concerns of radio inventors throughout the period from 1900 to 1920. Although Marconi's tuned circuits had improved selectivity significantly over what it had been prior to 1900, the continued dominance of spark methods of transmission in combination with the rapidly increasing number of radio users meant that the radiofrequency spectrum was becoming crowded with signals. All of these signals had to compete with one another to be heard and that competition was becoming so intense that the International Radiotelegraph Conferences in 1906 and 1913 made reduction of interference a priority in their discussions.

Strict international regulation was, at best, a temporary solution especially since there were national interests at stake in some of the radio companies. The real solution was a technological one and it was rooted in the shift from highly damped spark generated waves to single frequency continuous waves. With the advent of the quenched spark, disc discharger, the arc and the alternator, steady progress was made towards cleaner transmission and more efficient use of the spectrum. After World War I, this evolution would be completed by the spread of the vacuum tube oscillator which made continuous wave radio much more convenient and inexpensive than it had been with the earlier systems. This trend would also be reinforced by the movement away from long wave and towards short wave transmission after 1920.

234. McNicol, pp. 93–6; L.H. Walter, *Directive Wireless Telegraphy*, (London: Sir Issac Pitman & Sons, Ltd., 1922) pp. 10–2, 35–43.

9 Radio Technology 1920 –1950

Between 1900 and 1920, the main thrust of technological change in radio was the move from spark forms of transmission and reception to continuous wave systems. Driven by the desire to achieve greater distances and to reduce interference, inventors devised various means to produce, transmit and receive continuous or near-continuous radio waves. Out of this creative process arose the vacuum tube which, by 1920, was known to be capable of generating, amplifying and detecting radio waves and which was quickly becoming the central feature of all new radio systems, replacing other forms of transmission such as the arc and the high frequency alternator.

In the years after 1920, technological progress revolved around the ongoing development and refinement of the vacuum tube. The direction of that development was, however, profoundly influenced by the re-discovery of short waves and the realization that these higher frequency waves could provide the basis for a reliable system of radio communication. For the next fifty years, most radio research and development tended to concentrate on "the exploration of ever-higher frequencies" and on adapting the existing and emerging vacuum tube technology to meet the requirements of short wave propagation, transmission and reception.[235] These requirements included not only modifications in tube design but also in circuit and antenna design. As well, there was an obvious need for more extensive knowledge of the ionosphere and how and why it reflected certain radio waves and not others.

The Move to Short Waves

In the period prior to 1920, short waves were thought to be virtually useless for commercial radio communication over any significant distance. Hertz's original experiments had been carried out using short waves, as had some of Marconi's early work. Yet the commercial formula established by Marconi and followed by others in the field was the longer the wave, the greater the distance over which communication could be successfully established. Even inventors like Fessenden who challenged some of the principles of Marconi's system, accepted this fundamental premise. In part, this was a consequence of the lack of knowledge of the various characteristics of radio waves and the atmosphere through which they travelled. It was also due to the inventors' need to produce a marketable system as quickly as possible in order to support further research and development. Since long waves had produced the most consistent commercial quality results, it was this end of the spectrum (above 200 metres in wave length) that preoccupied inventors.

There was, as a consequence of this preoccupation, intense competition among large commercial interests for space at the low frequencies and governments placed strict limits the number and type of users permitted access to this area of the spectrum, especially after the Titanic disaster and the International Radiotelegraph Conference of 1912. Amateur operators, who were often blamed for the interference which plagued even the high-powered systems of the period, were relegated to wavelengths shorter than 200 metres. Forced to make the best of a bad situation, these enterprising individuals were the first to show that communication could be carried on using these shorter waves.

Amateurs in both the United States and Canada stayed as close as possible to the 200 metre maximum set by law and, using fairly simple, low-power spark transmission equipment and crystal detectors, were able to communicate with one another. The limited range of their installations was overcome to a certain extent by the formation of the American Radio Relay League which made possible the passage of messages from one amateur to another across much of the continent. As well, many amateurs took full advantage of technologi-

235. Aitken, *The Continuous Wave*, p. 513.

cal progress in the field (especially the move to continuous wave systems) and were able to extend the range of their equipment still further. In a series of tests arranged by the American Radio Relay League (A.R.R.L.) in 1921 no fewer than thirty American stations—including at least one Canadian—were heard in Britain despite the fact that they were transmitting on the 200-metre wavelength and that none had a maximum power exceeding one kilowatt. The following year, the signals of 316 stations were heard across the Atlantic in Britain and in continental Europe.

From the point of view of most amateurs, these tests proved only that long distance radio communication could be successfully carried out using 200 metre waves. To a handful of innovative individuals, however, they were evidence that established opinion concerning the limitations of short waves might be open to question. From about 1921 on, these pioneers explored the potential of waves between 180 and 35 metres in length and determined not only that the existing technology could be made to work at these high frequencies (i.e. early transmitting tubes) but also that communication could be established using this type of system.

The repeated attempts of these innovators to convince fellow amateurs to follow their lead met with little success until late in 1923 when a two-way contact was made between an American and a French station working on the 100 metre band. This achievement (and mounting evidence from other sources including the U.S. government Bureau of Standards) finally convinced many amateurs that waves under 200 metres in length could provide the basis for reliable long distance communication. As a result, for several months after the 100-metre contact was made, distance records were set and broken with great regularity by amateurs experimenting with shorter and shorter waves. Four continents were linked and "a reliable Europe-America traffic route" was created before September 1924 when the government of the United States officially allocated parts of the short wave spectrum (150 to 200, 85.6 to 75, 42.8 to 37.5, 21.2 to 18.7, and 5.3 to 4.7 metres) to amateur operators.

In the years after 1924, amateurs continued to make an important contribution to the field of short wave radio. They worked on the various wave lengths assigned them and developed a body of practical knowledge on their capabilities and limitations in different circumstances. Moreover, they shared their ideas about and experiences with short wave communication at conferences and in various publications relating to amateur radio. This provided a valuable and accessible source of short wave data especially since the information came from amateurs located all over the world who were using many different types of equipment.[236]

Increasingly, however, the contribution of amateurs was overshadowed by the work of larger interests such as private companies and governments which, by 1923, had begun to recognize that short waves could have valuable applications in commercial long distance communication work. In this year, both the British Marconi Company and the Radio Corporation of America (RCA) conducted tests on wave lengths under 100 metres, the former working on 97 and 92 metres over long distances (up to 2300 nautical miles) (4260 kilometres) while the latter used 120, 90, 60 and 40 metres over a dis-tance of around 480 kilometres (Belfast, Maine to New York city). Both companies were encouraged by their results which demonstrated that short wave signals could in fact be effectively transmitted over considerable distances.

These and other test results prompted the competing companies to make a more concrete commitment to this new method of radio communication. By the fall of 1924, RCA set up "a 10-kw., 103-meter transmitter at Tuckerton, N.J., was successfully handling traffic to South America under conditions which were impossible on the long waves because of static."[237] Meanwhile, the Marconi people were convinced that they "had a new system which would probably replace the existing long wave system for long range communication," and on this basis contracted with the British Post Office in July, 1924 to build and operate a network of short wave radio stations throughout the British empire.

236. DeSoto, pp. 72–4, 82–7, 95–8; see also Radio Club of America, *The Story of the First Trans-Atlantic Short Wave Message*, Commemorative Issue of *Proceedings of the Radio Club of America*, October, 1950 and *From Spark to Space The Story of Amateur Radio in Canada*.

237. Most of the direct quotations in this section on the short wave competition between Marconi and RCA come from three long letters to the editor of *FM and Television News* published in July, August and September 1948 and available in the NMST Library. Pages are as follows: July pp. 24–5, 60, 62; August pp. 18, 42, 44; September pp. 52, 65–6. Other reference sources for quotations and general information include: Vyvyan, pp. 83–5; Baker, pp. 224–5; A.W. Ladner and C.R. Stoner, *Short Wave Wireless Communication*, (London: Chapman & Hall Ltd., 1943) pp. 14–5.

Much of the Marconi system was, according to R.N. Vyvyan who had been "entrusted with the carrying out of the Imperial Contract," still in the experimental stages of development. For example, "[n]o grid aerial on Franklin's proposal had as yet been erected. Very little was known as to the behaviour of short waves other than 90 or 100 metres except over very short distances, and no plans or designs had been prepared for any commercial short wave station." Yet the contract stipulated quite stringent requirements for reliable two-way communication (at a rate of 100 words per minute for 7 to 18 hours of the day depending on location), and in order to meet these requirements, research activity was immediately intensified within the company.

This accelerated research and development drive seems to have given the Marconi Company the crucial edge in the race to turn a promising experiment into the world's first commercial long distance short wave radio network. In the two months following the signing of the British Post Office contract, Marconi and his colleagues made a remarkable discovery. In an attempt to increase daylight working hours, they tested a series of wavelengths between Poldhu (which had been equipped with a short wave transmitter as early as April 1923) and Marconi's yacht *Elettra* as it sailed from Britain to Spain, Italy, Syria and back again. They found, much to their own surprise and that of virtually everyone else in the radio field, that "the daylight range of practical communication over long distances increased very rapidly as the wave length was reduced." They also determined that by using a reflector at the transmitter to focus the radio waves into a beam (as Hertz had done in his experiments over very short distances), the signal strength at the receiver could be significantly increased even over very long distances.

These surprising results were confirmed by yet another series of tests using the Poldhu transmitter working on the 32 metre wavelength and special receivers set up at or near Montreal, New York, Rio, Buenos Aires and Sydney, Australia. It was determined, among other things, that communication with Sydney could be carried on for 23 hours out of 24, an unexpected and unheard of length of time. This information helped to establish the best wavelengths to use for various distances which in turn influenced the design of the transmitter and determined "the size and form of aerials to be erected on the mast already in process of construction at the Imperial beam stations."

Yet, in spite of these significant advances, the emerging Marconi system still had very real competition in the short wave radio field, particularly from RCA. Officials from RCA had been asked to observe the Poldhu tests and make measurements from their stations in the northeastern United States. As a consequence they were acutely aware of the breakthrough that had been made and, although they admitted that the success of Marconi's tests "quite overshadowed" the promising tests they were conducting with the short wave transmitter at Belfast, the RCA researchers maintained that their tests were also "headed in the right direction to lead to the discovery that the short waves were effective during the daylight hours." Moreover they now had the benefit of the information derived from the Poldhu tests to add to their increasing store of knowledge on the subject.

By late 1924 both companies, therefore, had sufficient knowledge of short wave propagation to embark on a program of design and construction of short wave radio stations. According to RCA sources, they put "the world's first high power 15-meter transmitter" into "regular commercial" operation in January 1926. Located at Rocky Point, Long Island, this station, according to Dr. H.H. Beverage (a noted RCA researcher), "was used with great success in handling traffic to Buenos Aires during the daylight hours." Beverage also claimed that, by "the early autumn of 1926," when Marconi opened the first link in the Imperial chain between Britain and Canada, RCA was already "operating a considerable number of shortwave circuits to various parts of the world with reasonable success."

There is some evidence to suggest, however, that these claims are somewhat inflated. The RCA short wave stations were still only supplementary to the main long wave network and they suffered from a poor signal-noise ratio, echo signals and excessive fading which greatly reduced signalling speeds. Similar problems plagued the newly opened Telefunken circuit between Germany and South America and it seems that in both instances the difficulty was rooted in the failure to accept the importance of directional antenna arrangements.

The Marconi Company, though slower to open its first short wave stations officially, had, by all accounts, a far superior system. Even the RCA officials who had been invited to Drummondville to "look over the operation" were forced to acknowledge that "the Marconi beam system out-performed to a considerable degree anything that RCA or, for that matter, any other organization had in operation." Another radio expert, Major E.H. Armstrong, (who was not particularly sympathetic to RCA) offered an even more positive interpretation of these events based on the description given him by an RCA observer who was present at the tests, W.A. Winterbottom. Armstrong maintained that the results of the beam demonstration were "so wonderful" that the RCA observers, including Dr. Beverage, "could hardly believe it," until they themselves connected a receiver to the system and listened first to some short wave signals from France and then to the powerful signals coming in from the beam station in England. There was simply no comparison and, as Armstrong pointed out, it is "a matter of historical record," not personal opinion that after having witnessed this demonstration, Winterbottom who was responsible for "maintaining the place of RCA in the field of world communications, acted immediately and insisted, in the face of opposition, upon buying one of the beam systems from British Marconi." The system "was duly installed and operated at Riverhead and Rocky Point, Long Island, the receiving and transmitting centers of RCA Communications."

And the Marconi beam system continued to surprise not only outsiders but Marconi people as well. As a series of circuits opened around the world, performance records revealed better traffic-handling capabilities than expected. In Australia, for example, the beam installation was found to be able to handle three times as much traffic per day on average as had been specified (20,000 words per day) in the contract with the Australian government. By September, 1927, circuits were operating in Britain, Canada, Australia, South Africa and India, and according to Marconi sources all were doing a very brisk business by December of that year.

With this successful debut, the short wave beam system became the new standard for long distance radio communication technology, changing completely the established formula of long wave, high-power stations which all the major radio interests, including Marconi, had invested so much money and research effort in perfecting. At Marconi, the emphasis had already (at least since the BPO contract of 1924) shifted to the development of this new technology so that the major preoccupation there became refining the existing system as practical experience and ongoing research suggested more efficient ways to proceed. Marconi's competitors in America, Germany and France faced a greater challenge since even those companies that were already working with short waves had to find some way of equalling the performance level of the beam system without infringing the Marconi-Franklin patents. RCA was not alone in deciding that the best way to accomplish this was to buy one of the Marconi systems (transmitter, antennas and receiver) and let their research teams attempt to produce their own version based on the operating principles that could be derived from the design of the equipment.

Not surprisingly, RCA was first to incorporate the advances made by Marconi and Franklin into their emerging technology. According to Dr. Beverage, the engineers assigned to the project concentrated on producing a system that provided diversity reception (ie ability to receive different wavelengths) and directional radiation as the Marconi system did but which cost less to build. In just over a year after the 1926 Poldhu-Montreal tests, RCA had produced and installed its own short wave equipment "on all of its major circuits. Shortly thereafter, the Marconi beam system at Riverhead and Rocky Point was dismantled, since the RCA developments outperformed it."

The international competition to develop the most efficient and cost-effective long distance short wave communication system gave renewed impetus to the process of technological change in the radio field as a whole. By confronting and grappling with the practical problems of communicating with radio waves under 100 metres in length, researchers and engineers opened the way to use of higher and higher frequencies. Each new area of the spectrum that became available for use represented "a massive increment to the resource base" and these new frequencies eventually made possible television, FM broadcasting, radar, microwave networks, and satellite relays.[238]

The conquest of this new electromagnetic frontier grew out of the solutions that were found to four fundamental technological problems posed by the move to short wave transmission in the late 1920s. This shift up the spectrum required the development of durable, dependable vacuum tubes that could generate, receive and amplify high frequency radio waves, efficient directional antennas and feeder systems, and comprehensive knowledge of the ionosphere and its various effects on the transmission of higher frequency waves.

238. Aitken, *The Continuous Wave*, p. 513.

Vacuum Tube Development

The use of vacuum tubes in radio communication equipment had begun in earnest in the years before World War I. By 1913 it was known that these tubes could be made to function as simple detectors, as rectifiers of alternating current, as amplifiers of rectified radio frequency signals, and as generators of radio frequency oscillations for heterodyne reception and for transmission. The practical applications of these tubes were limited, however, by a variety of weaknesses which became obvious when the they were used in certain configurations and for certain purposes. In the years after 1914 (when AT&T purchased the rights to the de Forest triode) correcting these weaknesses became a main focus of electronics research in North America and Europe.

One of the first problems to be confronted in the application of vacuum tubes to radio was that of tube evacuation. The earliest tubes, known as soft tubes, were not highly evacuated. It was believed that the presence of residual gases was necessary to achieve the level of ionization required for operation—a level which the filament or cathode could not, it was thought, produce on its own when heated.

By 1914, however, some researchers in the field of electron emission were not convinced that these gases were essential at all and began to experiment with ways of developing hard or highly evacuated tubes to obtain pure electron emission. Following the lead of scientists like O.W. Richardson, C.D. Child and J.E. Lilienfeld, Irving Langmuir began working on means of evacuating a tube "to a degree where residual gases play no appreciable part in its functioning" around 1914. In the research laboratories of the General Electric Company in the United States, he and his associates designed pumps to remove gases from tubes themselves as well as special techniques for removing occluded gases from the materials that made up the tube and which could be released after the vacuum tube was in operation.[239]

Langmuir used these processes to produce the Pliotron tube in 1915. It was soon recognized that this and other hard tubes had much more stable operating characteristics than their soft counterparts. This stability was of crucial importance for military uses of radio and, as a result, highly evacuated tubes quickly became the focus of most research and development in the field during the war. This trend was continued into the 1920s with the development new evacuation and vacuum maintenance techniques including electron bombardment and heating of the anodes prior to tube sealing to release gases in the metallic parts of the tube, covering the grids with gas-free varnish (1921), and, finally, the introduction of the magnesium "getter" (1924) which formed a metallic coating on the inside of the tube that absorbed any traces of occluded gas that might be released during operation. Both heat treatment of metallic parts and getters, generally magnesium or barium, became and remained a standard feature in the construction of most vacuum tubes from this point forward.

The desire to achieve better and more consistent electron emission led to a second important breakthrough in vacuum tube design. The source of electrons in hard vacuum tubes was the cathode or filament and it became clear to researchers early on that different types of filaments had different characteristics. In most instances, what scientists wanted was a filament that provided good emission but which required as little heating as possible to reach that level of emission. This meant that the tube consumed less energy and that there was less extra heating of the other electrodes in the tube including anode and grid. It was also important that the cathode not be so brittle or fragile that it would break easily during transport or other routine activities.

These general operational objectives were achieved by a variety of means which reflected the different specialized roles which tubes had increasingly assumed in radio. Many early tubes had been designed with pure tungsten filaments which was a satisfactory emitting material but only at high temperatures. By 1914, researchers such as Irving Langmuir were working with a new type of tungsten filament treated with thorium, refractory oxides and heat. Though it took several years to refine this thoriated tungsten filament to a point where it could be manufactured for sale (1921), it eventually proved to be less brittle than its pure tungsten precursor and, more importantly, required "very much less current to heat it."

As tube development advanced in the twenties and thirties, the thoriated tungsten filament was followed by the development of the oxide-coated filament. This filament, which was made by coating a base wire with a barium compound in one of

239. O'Dea, pp. 38–40; see also MacLaurin, p. 97 and Tyne, pp. 134–45 for a more detailed description of Langmuir's work.

several ways, needed only about one fifth the heating power of the original pure tungsten filament to reach a good emission level. Except for certain specialized uses (such as in high-powered transmitters where the specific characteristics of the thoriated tungsten filament tube were very valuable), oxide-coated filaments became the rule in most other types of tubes.[240]

Improved electron emission from the cathode led to changes in the design of the other electrodes in vacuum tubes. Both the anode, which attracts the electrons emitted from the cathode, and the grid (or grids in later tubes), through which the electrons flow on their way to the anode, tend to heat up in the course of the operation of the tube. The level of heat build-up had to be controlled in order for the tube to function properly throughout its normal operating life. Various methods were developed to accomplish this. Constructing the electrodes out of metals that dissipate heat readily or coating them with such materials—nickel or molybdenum for anodes and platinum or zirconium for grids—was one type of practical solution. Others included blackening the surface of the anode or adding blackened fins to anodes and grids (which improved the efficiency of heat dissipation by radiation at a lower temperatures) or using copper supports as a means of rapidly carrying the heat generated during operation away from the grid.

For the vacuum tubes used in transmitters, especially high-powered ones, the problem of heat build-up was even more acute and therefore required a more elaborate system of dissipation. This system involved making the anode part of the tube's exterior envelope so that it could be cooled by a constant flow of water or oil over it. The design and construction of such tubes was made difficult by the fact that a vacuum-tight seal between the glass ends that held the other electrodes and the metal anode was essential. Since glass and metal react very differently at certain temperatures, there was a tendency for cracking to occur in the tube where the two substances met. Attempts to build exterior anode tubes began around 1923 but it was not until 1924, when the Philips Company introduced the copper-glass seal (which due to the mechanical weakness of the copper did not crack), that the widespread production of this type of tube became a reality. Within a decade, exterior anode tubes were being built with ratings of up to 500 kw compared with the 20 kw ratings of some of the early experimental tubes.[241]

The copper-glass seal played a crucial role in the design of the Marconi beam system transmitter between 1924 and 1926. High frequency transmitting tubes had all of the common problems of high-power transmitting tubes and more, since higher frequency operation was even harder on the seals. The introduction of larger seals gave only inconsistently better results due to the interaction between high frequency currents in the tube and its glass envelope. A lasting solution was found with the development of the CAT or Cooled Anode Transmitting tube, an external anode design that had a copper anode/envelope cooled by oil circulation. Two such tubes were used in the beam transmitter system that performed so impressively in the autumn of 1926.[242]

The exterior anode vacuum tube was just one of many different types to emerge in response to the increasingly specialized demands of post-war radio communication. As the properties and potential capabilities of these electronic devices were more fully understood by scientists and researchers, other important changes were made in basic vacuum tube design in order to get the tubes to perform additional functions. One of the most significant general changes to take place over the years between 1920 and 1950, was the development of multi-electrode tubes. To the original diode and triode (which contained cathode and anode and cathode, anode and grid respectively) were added tetrodes, pentodes, hexodes, heptodes, octodes and, eventually, multiple tubes which had two or more electrode systems in one envelope. The additional electrodes in these tubes were, for the most part, grids and they provided greater control of electron emission so that tube performance could be more accurately tailored to suit the specific needs of particular types of circuits. Through various arrangements of these control, screen and suppressor grids, the roles of many tubes became narrower but they performed their functions more effectively.[243]

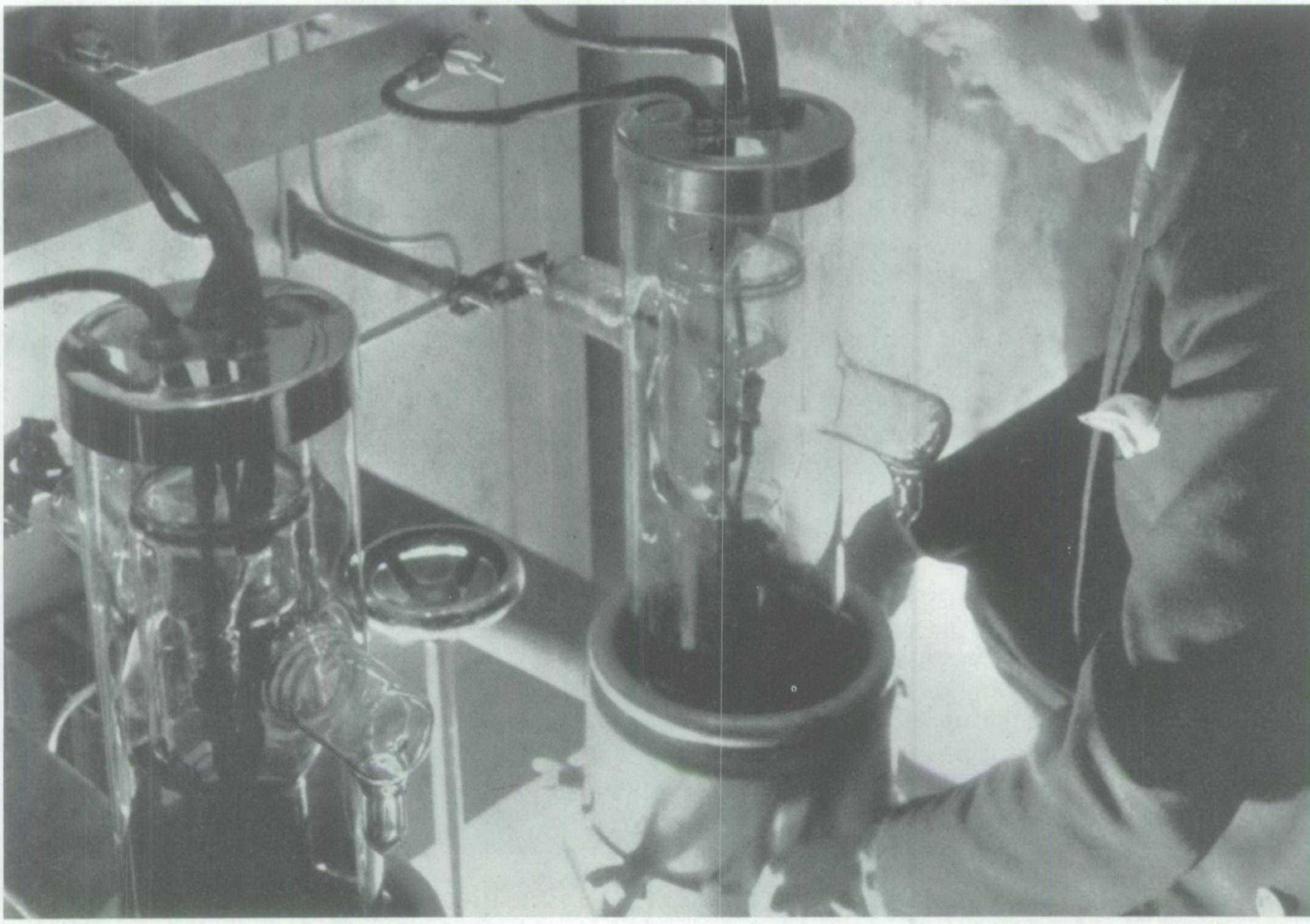
One final vacuum tube development deserves mention here even though its greatest impact was in the field of radio broadcasting as opposed to

240. O'Dea, pp. 42–3; J. Deketh, *Fundamentals of Radio-Valve Technique*, (Eindhoven: N.V. Philips' Gloeilampenfabrieken, 1949) pp. 41–3; J.P. Heyboer and P. Zijlstra, *Transmitting Valves*, (Eindhoven: N.V. Philips' Gloeilampenfabrieken, 1951) p. 4.

241. Heyboer and Zijlstra, pp. 10–18,; Deketh, pp. 46–8; O'Dea, pp. 48–9.

242. Vyvyan, pp. 85–6; Baker, pp. 221–2.

243. Heyboer and Zijlstra, pp. 23–4; Deketh, pp. 117–22.



This photograph shows the remarkable size of some vacuum tubes. The ones pictured here are 100,000 watt transmitting tubes with external anodes that are cooled by the circulation of oil or water through the metal casing at the bottom of the tube. Source: Orrin E. Dunlap, Jr., The Story of Radio, *(New York: The Dial Press, 1935)* radio communication. Alternating current tubes grew out of the desire to free radio receivers from dependence on battery-generated power which was expensive and at times frustrating to use. In order to make use of the alternating current available from the mains supply, however, a way had to be found to keep the cathode hot and emitting constantly despite the fluctuating character of alternating current. The method adopted was the indirectly heated cathode in which the emitting surface was separated from the heating element so that temperature and emission levels of the cathode could be made largely independent of small fluctuations in the heater temperature. The cathode material used in such tubes must have "considerable heat capacity." In North America, credit for the development of this type of tube belongs to several people. Hubert Freeman and Wallace Wade, both of Westinghouse, did the development work and a third Westinghouse employee, Fred McCollough, "evolved manufacturing methods." Ted Rogers, a Canadian, "solved the problems preventing it [the AC tube] from becoming a commercial reality."[244]

Directional Antenna Arrays

Although many pre-1920 radio antennas possessed certain directional capabilities, it was not until the re-discovery of short waves in the mid twenties that highly directional antennas were developed for commercial long distance transmission and reception. It had long been known that radio waves could be reflected—Hertz used a reflector in his experiments—and concentrated into a directional beam. But the preoccupation of inventors with long waves, made use of reflectors unworkable since the antenna systems would have had to have been extremely large, larger even than the mammoth long wave antennas already in use.

Marconi re-introduced reflectors when he began experimenting with short wave transmission and soon determined that signal strength was greatly improved by their use. C.S. Franklin was given the job of developing an antenna/reflector system for use in the imperial chain based on these experimental results. It was a very difficult assignment both because of the scale and because of the lack of an established body of experience and knowledge from which he could draw.

Nevertheless, Franklin produced a remarkably successful, if complex, antenna system in the space of less than two years. His beam array consisted of two parallel lines of wires placed at right angles to the chosen transmission path and spaced between 1/4 to 3/4 of a wave length apart. The front line of wires, the antennas, were fed directly from the transmitter through an elaborate feeder system designed by Franklin to insure that each wire was energized uniformly. The back radiation from these wires was reflected forward by the second line of wires, the reflectors, thereby concentrating the radiation in one direction. Ultimately, it was this antenna array that separated Marconi's short wave system from the competition in 1926 and for good reason since later research found that, with this type of antenna system, signal strength could be increased by as much as sixty times over that of a single non-directional antenna. In the attempt to equal and surpass the performance of the Marconi stations, a variety of improvements were made in the Franklin system by its competitors. Most of these involved some simplification of Franklin's complex design and, in general, later arrays were less costly and smaller. Overall, however, the level of antenna efficiency established by Franklin had not been surpassed as late as 1943.[245]

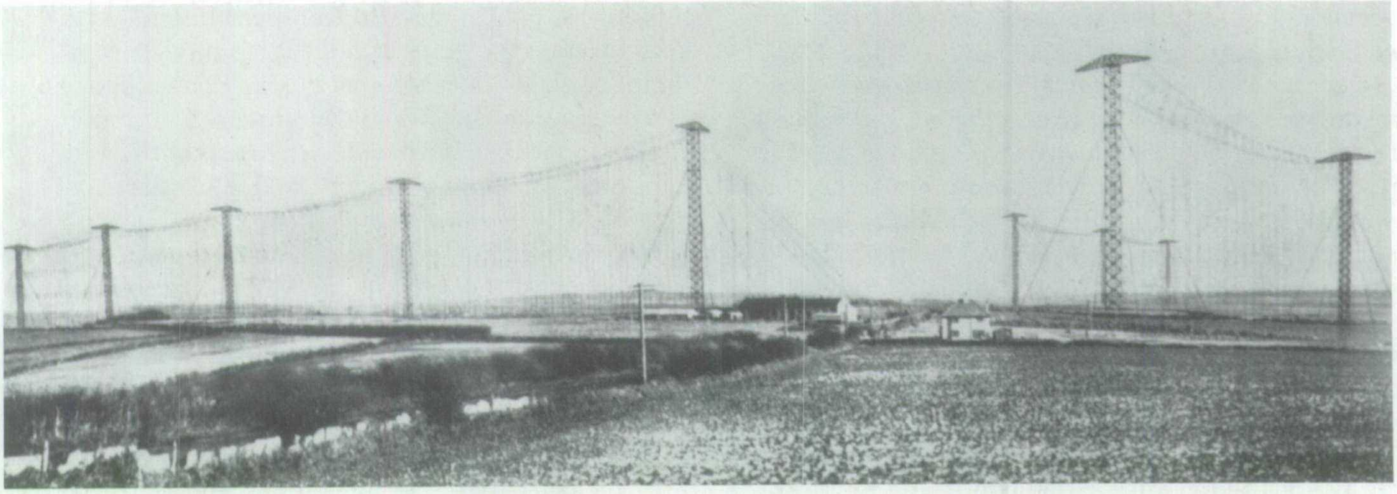
Ionospheric Research

As early as 1893, Nikola Tesla was convinced that the atmospheric layers which we now know as the ionosphere were conductive. Eight years later, two researchers working independently of one another—Oliver Heaviside and Arthur Kennelly—came to a similar conclusion and went on to suggest that these conducting layers would reflect or refract (bend) radio waves of certain frequencies sent upwards back to the earth. This, they argued would make radio transmissions beyond the line of sight possible.

This explanation was confirmed in 1923 when pulses of radio energy sent upward were received back on the earth after an interval of time. By measuring the amount of time required for this reflection to take place, researchers were able to estimate the height and number of layers. It soon became clear, however, that these layers were not constant but changed over the course of each day

244. Maurice Chaplin, "Rogers Batteryless Radio Receiving Sets: A Brief History," unpublished paper (1984), pp. 10–12, 41; Deketh, p. 46.

245. Vyvyan, pp. 78–94; O'Dea, pp. 55–6; Ladner and Stoner, p. 5.



These antennas at the Dorchester beam station are the same as those at the Drummondville station near Montreal. Source: R.N. Vyvyan, Wireless Over Thirty Years, *(London: George Routledge & Sons, 1933)* as well as from season to season and that they behaved differently in different parts of the world.

Over the course of the next four decades more extensive experiments were conducted to establish precisely how, when and why these changes in the ionosphere took place. It was eventually determined that there were three layers making up the ionosphere—D, E and F—and that the reflective properties of each were different depending on the time of day. It was also found that sun spots had a profound effect on the level of ionization and thus on the reflective potential of these layers. More importantly from the point of view of radio in Canada, auroral activity was proven to be a significant factor in ionospheric behaviour and its influence become more pronounced the farther north (or south in southern hemisphere) one went.

Much of northern Canada was dependent on radio for its communications needs and those operating the systems (including the Canadian government) in the north were well aware of their inconsistent performance at certain times of the day and in certain seasons. As a consequence a great deal of government-sponsored research was carried out in an attempt to overcome the problems associated with radio transmission in this area. Canadian scientists were, as a consequence, at the forefront of this type of research and eventually determined that although the behaviour of the ionosphere in the arctic regions could be predicted to some extent, consistently reliable radio communication could only be guaranteed with the use of satellites. Since then satellites have been used in more and more roles in the north and elsewhere and have greatly increased the predictability of radio communications.[246]

Conserving the Radio Frequency Spectrum

The radio frequency spectrum is part of the natural spectrum of electromagnetic radiation. The frequency bands which make up the radio portion of the electromagnetic spectrum range from 10 kilohertz (10^4 hertz) to 300 gigahertz ($3x10^{11}$ hertz). Wavelength is inversely related to frequency so that the corresponding wavelengths for these low and high frequencies are 30,000 metres and .1 centimetre respectively. Each of these frequency bands can only support a certain number of users and, from the earliest years of radio, this has led to competition for useable space. As a consequence of this competition, national governments and international agencies have, since the turn of the century, been forced to regulate the use of spectrum carefully.

When the existence of the radio frequency spectrum was first theoretically proved by the work of James Clerk Maxwell in the 1860s and demonstrated experimentally by Heinrich Hertz in the late 1880s, scientists did not fully understand its nature or its dimensions. Practical experience acquired by the first radio inventors suggested that only the lower frequencies were commercially useful and that these frequencies could support a comparatively small number of users since each required a sizeable bandwidth to function effectively. In order to support the fledgling radio communications technology, governments quickly stepped in to limit the number and type of users at these frequencies.

This increasingly strict regulation combined with continuing competition for space, inspired scientists, inventors and radio enthusiasts to develop ways of using the lower frequencies more efficiently so that a greater number of users could be accommodated. Early attempts at tuning and the eventual shift from spark systems of wave generation to continuous wave systems both contributed to more frugal use of spectrum space though this was not necessarily the goal of those who pioneered these improvements. Regulation also led to the exploration of higher frequencies, particularly by those who were prohibited from using the lower ones. Amateurs were among those excluded and, in the years after World War I, they demonstrated the capabilities of waves above 1500 kilohertz. Their main goal had been to make the best of the marginal space that had been granted them, not to explore the unknown area of still higher frequency waves. But in attempting to make these frequencies work for them, they began a process that increased useable spectrum space significantly.

In the years since these early advances, researchers have continued to look for ways to reduce the amount of spectrum space required to meet the communications needs of the various users and to increase the overall space available to accommodate new users and new needs. The former objective has been pursued in a variety of ways most of which involved finding methods of attaining more exact control of frequency, narrower

246 *Encyclopaedia Britannica Macropaedia*, 1984 ed., s.v. "Radio"; Maclaurin, pp. 35–6; Doris Jelly, *Canada 25 Years in Space*, (Montreal: Polyscience Publications Inc., 1988) pp. 92–4.

bandwidths, and greater selectivity. One of the most important advances in this direction came in the 1920s with the development of single-side-band transmission and reception which significantly reduced the bandwidth required for communication of voice signals. This process has been greatly refined since then and is now a standard feature of many forms of radio communication.

The search for more spectrum space has continued as well. At the time of the international radiotelegraphy conference in London in 1912, only a small fraction of the radio frequency spectrum was being systematically exploited—the area below 1000 kilohertz which consisted of wavelengths greater than 300 metres. Fifteen years later, the shift to short waves for radio communication had begun and this led to greatly expanded use of the high frequency band and to the first limited commercial use of the lower end of what later became known as the very high frequency band. Occupation and exploitation of the VHF band progressed through the 1930s so that by 1938, frequencies up to 200 megahertz were being allocated by international and national regulatory bodies. The early thirties also witnessed the first attempt to use ultrahigh frequency (UHF) waves for commercial purposes when Standard Telephones and Cables established a commercial relay link at 1700 megahertz across the Straits of Dover in 1931.

This trend continued after World War II, fuelled by the systematic and concentrated research that was carried out during the war on microwave radar. In the late 1940s, the superhigh frequency (SHF) band was developed and used extensively (as it still is) for such things as aeronautical radio-navigation and the microwave relay systems set up by Bell and other telephone companies. By 1959, the lower end of the extremely high frequency (EHF) band was allocated for certain specialized purposes most of which involved satellites. As the evolution of satellite technology continued through the sixties, seventies and eighties, more and more space on this and other bands was allocated to this type of use.

Yet even with the steady expansion of the useable radio frequency spectrum up into the higher bands and the development of techniques that allow for denser population at the lower frequencies, spectrum space is still scarce. The number of users and potential users (whether commercial interests, individuals, local or national governments) has grown at least as quickly as the amount of available space and, as a consequence, competition has remained intense since 1920. To cope with this competition, the rudimentary regulatory framework that emerged out the international conferences of 1906 and 1912, was gradually expanded and made more comprehensive in the decades after World War I. The main international body responsible for allocation of spectrum space today is the International Telecommunications Union, an agency of the United Nations. This agency sponsors regular meetings called World Administrative Radio Conferences at which spectrum allocations are requested, discussed and granted. Canada has been a participant in these conferences (and their predecessors) since the earliest years of radio and continues to take an active role. Our government through the Department of Communications is also involved in similar North American organizations which, like their international counterparts, attempt to work out the problems posed by the ongoing competition for space and the resulting congestion of the radio frequency spectrum.[247]

247 Harvey J. Levin, *The Invisible Resource Use and Regulation of the Radio Spectrum*, (Baltimore: The Johns Hopkins Press, 1971) pp. 19–24, 201–36; Tomlinson, pp. 129–77; Aitken, *Syntony and Spark*, pp. 32–4, 37–9; *Encyclopeadia Britannica Macropaedia*, 1984 ed., s.v. "Radio" and "Electromagnetic Radiation"; *The McGraw-Hill Encyclopedia of Science and Technology*, 1982 ed., s.v. "Radio Spectrum Allocations" and "Single Sideband."

10 Conclusion

Radio communication has had a significant, if not immediately apparent, impact upon the western world since its beginnings in the early 20th century. As one of three different but complementary forms of rapid electronic communication—along with the telegraph and the telephone—radio technology was a crucial component in the international communications network that began to take shape in the mid 19th century. The primary builders and users of this network until well after World War I were big businesses and governments, whose objectives tended to revolve around improving the efficiency of international trade and commerce and gaining economic, political and strategic advantage over their competitors.

As is generally the case with new and relatively untried technologies, radio's role in this emerging communications infrastructure was initially quite limited. It was used almost exclusively to fill gaps in the existing telegraph and telephone systems. The most glaring gap in what was otherwise an extensive and well-established system was the lack of any viable means of communicating with ships at sea. This inability to remain in close contact with a pivotal component of both the transportation and naval defence systems had profound commercial and military implications, particularly in the period of intense commercial and military rivalry that preceded World War I. Merchant vessels did not have access to the latest information on market prices for the goods they carried or on the location of potential buyers for those goods. Also, once at sea, crews had to depend on their instincts, experience and eyesight to judge the onset of inclement weather and in the case of difficulties—mechanical or other—they had to hope that another ship would pass within sight of their visual distress signals. As well, navigation was still far from precise and the lighthouses and lightships commonly used in approaches to ports provided inadequate aid to mariners in bad weather.

Given Britain's status as the dominant maritime and naval power in the late 19th century, it is not surprising that this was where radio technology first gained a firm commercial foothold. The British Post Office, which was responsible for overseeing developments in electric communication on land as well as for use in British territorial waters, set up Marconi's radio demonstrations in 1896 and 1897. Once it was clear that he had a viable system, his first major customers for radio equipment, predictably, were the British Admiralty (1900) and Lloyd's, the marine insurance and intelligence company (1901). A variety of national governments, including the Canadian, followed the lead of these important maritime interests and began setting up radio installations of various kinds along their coasts.

The idea of using radio to supplement long distance communication, particularly along the busy transatlantic routes, was also taken up by various governments and business interests. But the importance of these installations was limited by the fact that most of the market was adequately served by the existing submarine cables which offered greater reliability and security. The technical limitations of long wave radio also prevented the widespread adoption of land-based radio stations as a means of linking remote areas separated from the line networks by difficult terrain or great distances in the first two decades of the 20th century.

Radio's expansion beyond the world of marine communication was not just restricted by technical problems. Governments in general were anxious to see that the important work of the marine stations was not interfered with by the development of too many competing installations. As well, the political and strategic realities of the day reinforced what was already a long established policy of government involvement in any matters relating to international trade, communications and transportation. As a result, the use of radio was strictly regulated, if not directly controlled, by governments around the world. They, along with a handful of radio manufacturing companies formed around the crucial inventions, became and for some time remained, the main players in the radio communication field.

World War I served to solidify these close relationships between governments and radio interests. But the intense research and development activity that took place during the war improved the technical capabilities of radio to such an extent that it began to fill a number of new roles. In Canada, with its large areas of resource-rich but isolated wilderness, radio was used to connect fur trading posts and mining, lumbering and hydroelectric developments to the centres of commerce. As well, in Canada and around the world, radio soon became an essential component of the emerging network of aviation related installations. Technical advances also made intercontinental voice communication by radiotelephone a reality in late 1920s and early 1930s.

By the time World War II broke out, radio technology was firmly established in the communications infrastructure of Canada and of the world; its crucial role in the war served to extend and entrench its place there. Despite continuing concerns about the inherent insecurity of radio, all sectors of the military relied heavily on it during the conflict. This dependence once again produced significant advances such as microwave radar and increasingly efficient mobile radio systems.

Ongoing general research and development conducted before, during and immediately following the war also made tuning more precise, reduced interference and increased the capabilities of low-powered systems. As a result, radio communication equipment was not only more effective and easier to operate, but a greater number users could function without adversely affecting one another. With improved technology, more and more people in Canada saw the potential for employing radio. At the same time strict government limitations on the number of installations became less important and access to radio communication systems was gradually increased.

Before too long, radio communication technology had come to be seen as indispensable in a variety of contexts. Fleets of commercial, public utility and emergency vehicles have depended on it since the 1940s. It was the basis of all overseas voice communication until 1957 and most voice communication to Canada's north until the 1970s. Even today, cellular phones are linked into the main telephone system by radio, which carries the signals over the wireless gap between the mobile sets and line network. And long distance calls in Canada and elsewhere often do not travel on wire but are sent as microwave transmissions between towers that stretch across the country. Similarly, the satellites that are now the mainstays of northern and overseas telecommunications, receive and send information carried on radio waves. Radio communication has thus been integrated into our complex modern communications infrastructure to such an extent that large sections of our commercial, governmental and social frameworks would be hard pressed to function effectively without it.

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