High Frequency Receiving Antennae in the NWT & Y Radio System

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Photographs by the Author

ONE of the main projects of the Northwest Territories and Yukon Radio System during the summer of 1949 was the redesign of the receiving antenna plant at Edmonton. The modifications to the antenna system involved the redesign and relocating of many of the existing antennae and the replacement of nitrogen-filled coaxial transmission lines by an open-wire transmission line system.

PURPOSE AND SCOPE

It is the purpose of this article to outline briefly a few of the more practical fundamentals in the design of high-frequency antennae and radio-frequency transmission lines. Many people know that the limits of antenna and transmission line theory are boundless. A smaller number, however, realize that a basic knowledge of the principles of radio-wave transmission coupled with common sense, is sufficient to ensure the efficient installation of antenna apparatus.

FIXED PLANT ANTENNA PARK

The primary requirements for a permanent or fixed plant antenna park include negligible interference between transmitters and receivers, and a minimum of man-made static sources in the proximity of the receiving antennae. An ideal arrangement places the transmitting antennae and the receiving antennae in separate locations, carefully chosen to eliminate mutual interference and local static.

The Headquarters of the Northwest Territories and Yukon Radio System employs separate transmitting and receiving sites. The receiving station, in which thirty-two short-wave antennae operate, encompasses an area of about 100,000 square yards (see Figure 1). Careful siting and design of the antennae efficiently utilizes every square yard of space. With the exception of the rhombics, each aerial is designed for a particular frequency. Balanced transmission lines connect each antenna to a control

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Condensed from an essay submitted by the author during the fourth year of the Course in Applied Science at the University of British Columbia. Major Lambert bases this essay on practical experience he gained as Technical Maintenance Officer during the summer of 1949 with the NWT & Y Radio System. He graduated in Electrical Engineering in June, 1950, and is presently serving in the West Coast Signal Regiment (RF) in Vancouver, where he is an engineer with Canadian Pacific Communications. During the Second World War he was adjutant of Sigs 4 Cdn Armd Div in the Northwest Europe campaign.
--Editor.

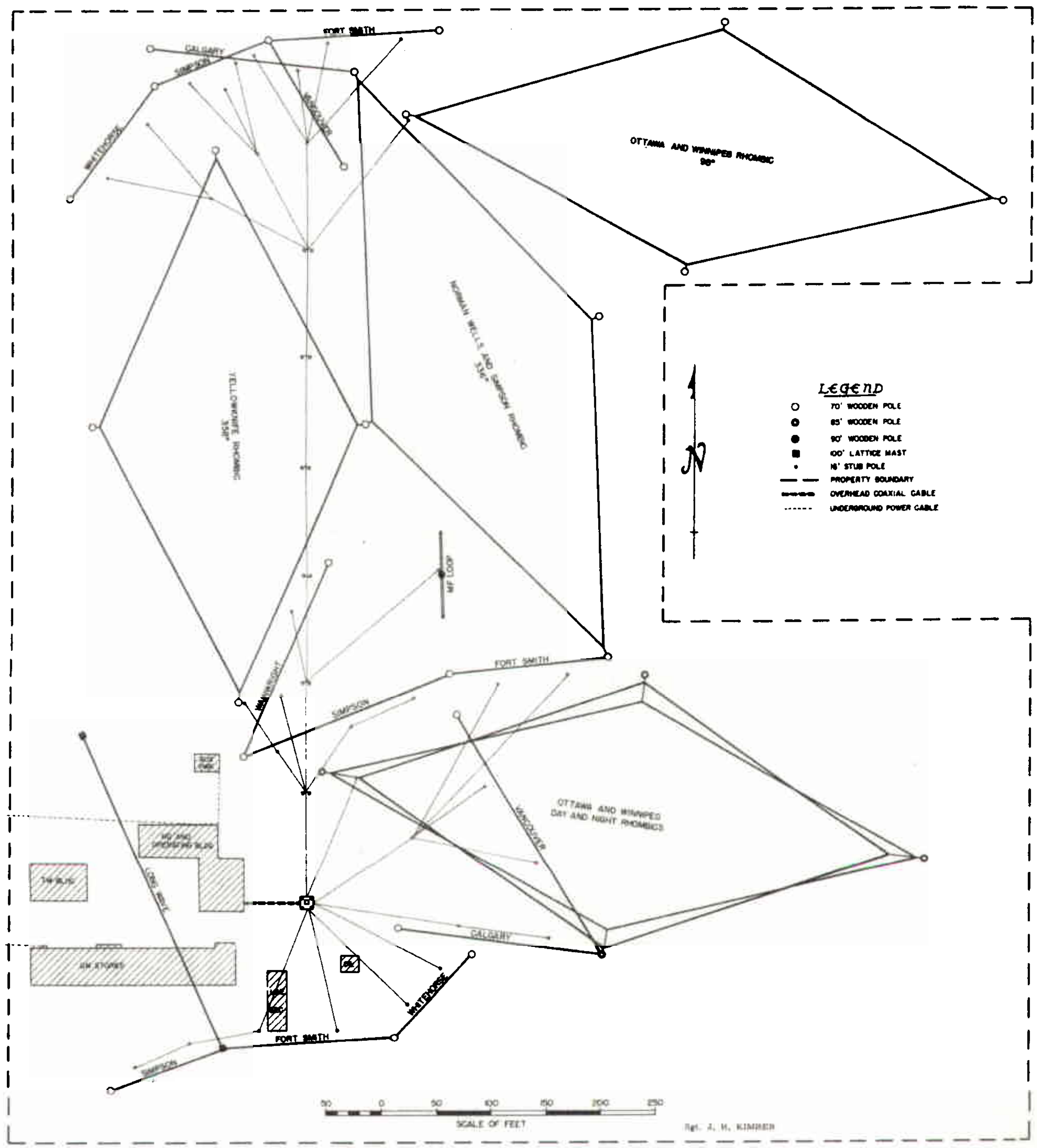


FIGURE 1

THE RECEIVING ANTENNA ARRAY, HQ NWT & Y RADIO SYSTEM, EDMONTON panel, situated in the operating room. Every antenna has the best possible directivity to make the "capture area" a maximum. The Vancouver, Calgary, Fort Smith, Fort Simpson, Whitehorse, Ottawa and Winnipeg circuits have space diversity reception afforded by the spacing, 5 to 10 wavelengths apart, of pairs of the antennae tuned to these circuits. For example, the Vancouver circuit operates on a frequency of 4640 kilocycles, a wavelength of about 100 feet. The separation between the Vancouver circuit antennae is 700 feet, or seven wavelengths.

HALF-WAVE ANTENNAE

One of the simplest wire receiving antennae is the horizontal half-wave dipole. The centre-tapped variety is preferable for use with the type of low-impedance receiver and balanced transmission line employed on the NWT & Y Radio System. When erected at a height approaching one-half wave length, a half-wave antenna responds well to radio waves which strike it at a low angle. The fact that long-distance HF sky waves return to earth at a low angle ensures the success of the half-wave doublet in long-distance communication.

At Edmonton 27 half-wave antennae are used, each designed to operate on a selected frequency between 3.28 and 13.35 megacycles. Constructed from No. 10 hard-drawn copper wire, the antennae radiate from a height of about 65 feet. Although this is not the proper height for long-distance reception at the lower and higher end of the frequency band covered, the signal/noise ratio from this installation is satisfactory. Since it is necessary, at these frequencies, to abstract as much energy as possible from the passing radio waves, the antennae are positioned for maximum directivity, the length of the wire being at 90 degrees to the direction of the incoming signal.

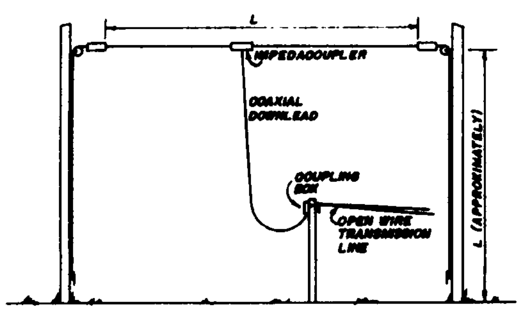


FIGURE 2

HALF-WAVE DIPOLE RECEIVING ANTENNA

HORIZONTAL RHOMBIC ANTENNAE

Horizontal rhombic antennae have excellent directivity and power gain characteristics, both of which are essential to long-distance sky wave communication. The rhombic aerial consists of an array of four non-resonant wires arranged in the form of a four-sided diamond. A balanced RF transmission line joins one end of the diamond; a terminating resistance connects the other end which points in the direction of the transmitting station.

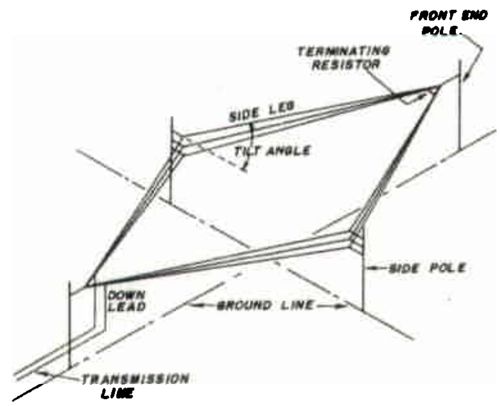


FIGURE 3

HORIZONTAL RECEIVING RHOMBIC ANTENNA

The directivity of a properly designed rhombic greatly reduces the response in all directions relatively separated from the desired direction.

Since a transmitting rhombic reacts equally well as a receiving antenna, it is fair to describe the design of a receiving rhombic in terms of radiation. The shape of the rhombic antenna depends upon the length of the side legs, and the size of the tilt angle. The magnitude of the tilt angle in relation to the length of the side legs must achieve two results:

§ that the main lobe of radiation of the individual antenna leg, considered as an isolated non-resonant wire, has an angle equal to 90 degrees minus the tilt angle with respect to the wire; and

§ that the distance between the mid-points of adjacent legs, via the wire, is a half wavelength greater than the distance between the mid-points.

When both requirements are fulfilled, the direction of maximum response is in the direction of the antenna axis.

A change in frequency has the effect of

changing the leg length of the antenna. For side legs over three wavelengths long, the optimum tilt angle does not vary appreciably with changes in leg length. Under these conditions the rhombic antenna has broadband properties, enabling one antenna to be used over a wide range of frequencies. In practice the rhombic responds favourably over a frequency range of 2.5 to 1.

Although a single wire is generally used for the sides of receiving rhombics, a three-wire "curtain" is frequently employed. The conductors come together at the front and rear apexes and separate by several feet at the side poles. The introduction of the "curtain" lowers the input impedance of the antenna (about 800 ohms), reduces the value of the terminating resistor, and ensures a more uniform impedance over the frequency band. Since the power dissipated in a receiving rhombic is small, non-reactive resistors of a few watts rating are suitable as terminating resistors.

The NWT & Y Radio System has five broad-band rhombic receiving antennae at Edmonton. An example is the rhombic in use on the radio circuit to Norman Wells and Fort Simpson. The direction of the antenna axis follows a true north bearing of 336 degrees which passes through both outstations. The length of the antenna legs is 300 feet. This distance varies from two to five wavelengths for the frequencies 6.675, 8.340, 10.910 and 13.350 megacycles, which are used on this circuit. The tilt angle, 68 degrees, does not vary appreciably with the different frequencies. The other dimensions of the rhomboid are: length 575 feet, width 225 feet and height above ground 65 feet. The radio signals transmitted from Norman Wells return to earth at Edmonton (about 1000 miles due south) with a low angle of incidence.

TRANSFER OF ENERGY TO RECEIVER

Despite the efficiency of an antenna, the energy captured from a radio wave may diminish to a negligible value if the path from antenna to receiver is not properly designed. The ideal arrangement for minimum losses places the receiver as close to the antenna as possible, the signal then having little opportunity to attenuate. The best conditions for the reception of radio signals, however, demand that the antenna be placed in a noise-free location remote from the operating site. The distance between sites may vary from a few hundred yards to several miles. In order to avoid any major signal losses between antenna and receiver, it is customary to utilize a carefully designed RF transmission line system. There are several methods of constructing transmission line systems. However, each plan includes the following basic components:

- an antenna down-lead
- a RF impedance-matching network
- a RF transmission line
- a transmission line terminating structure
- an antenna control panel.

ANTENNA DOWN-LEAD

The down-lead for the half-wave dipole is RG-11/U solid-dielectric coaxial cable whose characteristic impedance is about 72 ohms. With the characteristic impedance at the centre of a dipole being also about 70 ohms, it is possible to join the down-lead directly to the antenna without a subsequent loss in signal energy. A patented "Impedacoupler" provides a neat, secure and weatherproof connection from the antenna to the coaxial cable. The length of the down-lead which leads to the top of a 16-foot stub pole is about 70 feet. The attenuation in RG-11/U is fairly high, 0.8 decibels per 100 feet, but with such a short down lead the attenuation of the signal is negligible.

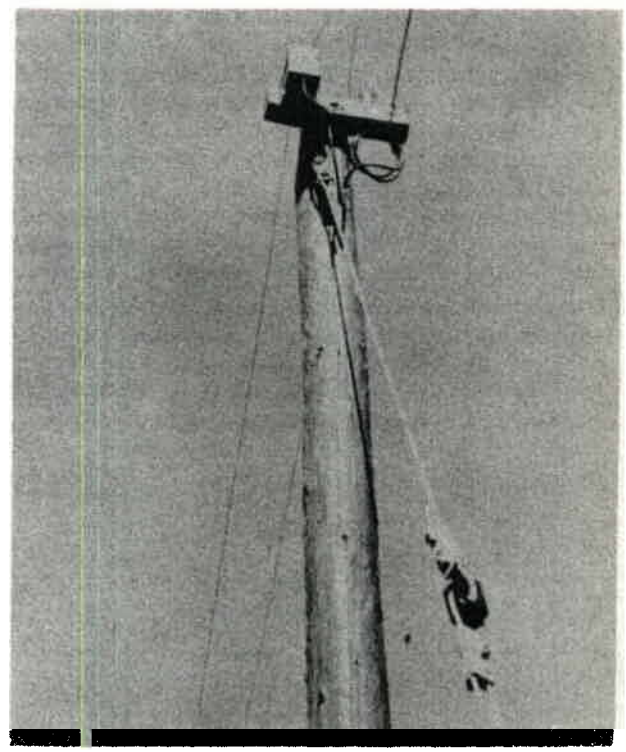


FIGURE 4

COUPLING BOX ON STUB POLE, SHOWING CONNECTION TO THE DOWN-LEAD AND TRANSMISSION LINE

The rhombic antenna down-lead is quite different in design, being essentially a 600-ohm open wire transmission line. The main transmission line continues from a nearby stub pole directly to the receiving end of the antenna. There is a small mismatch between the 600-ohm down-lead and the 800-ohm antenna but it is negligible compared to the antenna gain over a wide band of frequencies.

IMPEDANCE-MATCHING NETWORK

An impedance-matching network solves the problem of connecting together two circuits of unequal impedance. In this system a pi-section low-pass network connects 72-ohm coaxial cable to 600-ohm open wire transmission line.

The design of the networks also ensures maximum response to the frequency for which the antenna is designed. The coaxial cable enters the coupling box through a threaded collar, ensuring a watertight joint. 54 coupling boxes of this type are in use on this transmission line system.

RF TRANSMISSION LINE

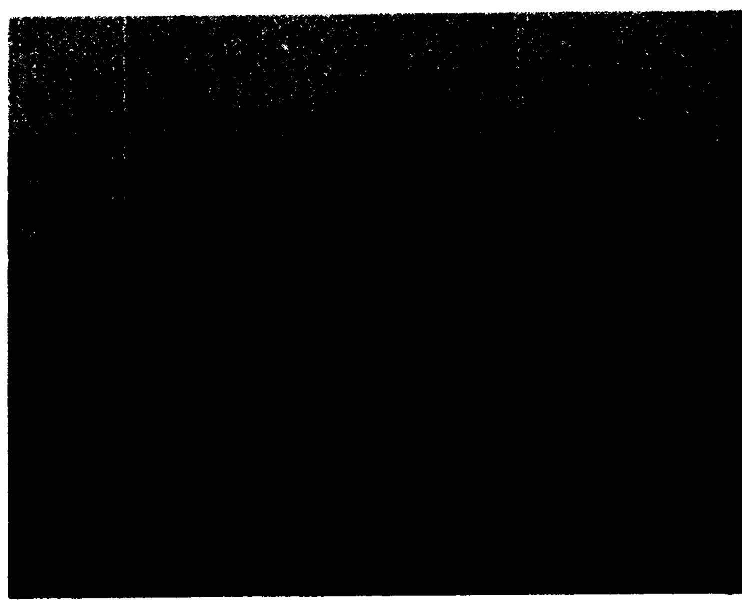
After passing through the down-lead and the coupling box, the energy from the antenna faces a long transmission path. The losses up to this point are almost negligible. Fortunately, an open wire transmission line has a low transmission loss. On this system, No. 10 copperweld wire is used from the antenna down-lead coupling box to an identical box at the terminating structure. This two-wire transmission line has a characteristic impedance of approximately 600 ohms. For all practical purposes the loss in an open wire line under 100 feet in length is neglected at high frequencies. The transmission line is soldered firmly to insulated lugs on the outside of the coupling box. Spaced insulators on the cross-arms of 16-foot stub poles support the line between the down-lead and the terminating structure.

TERMINATING STRUCTURE

At the terminating structure (figure 7) each dipole transmission line feeds into a coupling box which is a duplicate of the antenna coupling box (figures 7 and 8). The rhombic transmission lines, however, terminate at a wide-band coupling unit (figure 8). Lead-in coaxial cables, RG-11/U, suspended under messenger wire, connect the coupling boxes at the terminating structure to the antenna control panel inside the operating room (figure 9).

FIGURE 7
TRANSMISSION LINES LEADING TO THE TERMINATING STRUCTURE AT EDMONTON

FIGURE 8
RHOMBIC TRANSMISSION LINE COUPLING BOXES



ANTENNA CONTROL PANEL

The antenna terminals of every radio receiver in the operating room are wired to the antenna control panel. Thus it is possible, by means of a jumper, to connect any receiver to any one of 33 antennae. The control panel includes nine multiple antenna couplers, each designed to permit the use of one antenna by three receivers. Vacuum tube circuits in the multicouplers isolate the receivers from one another so that no mutual interference occurs. The wide band characteristic of the rhombic antenna necessitates the use of equipment of this type since, without it, the flexibility of the rhombic is lost. When diversity reception is necessary, the space diversity antennae are connected on the panel to individual receivers whose final outputs are combined. The receiver getting the loudest signal from its antenna cuts out the others through the agency of a combining unit. One of the antennae is always delivering a strong signal despite any fading in the other two. Consequently, a strong signal is available nearly 100 percent. of the time.

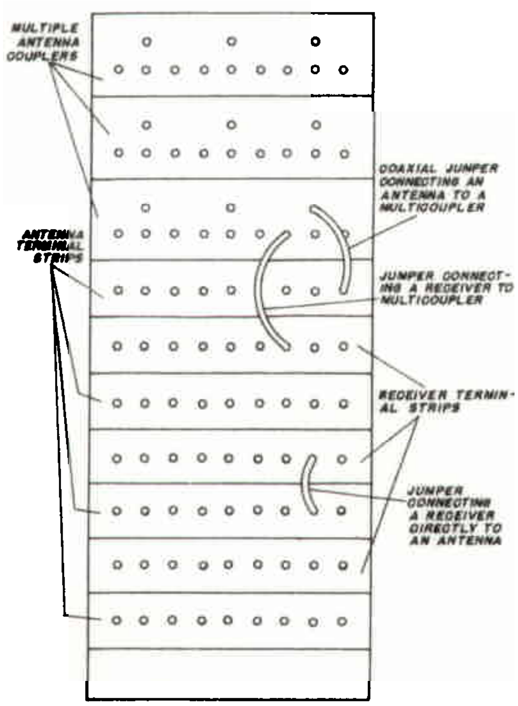


FIGURE 9
ANTENNA CONTROL PANEL

CONCLUSION

The task of an antenna system is complete when the energy abstracted from a passing radio wave enters the superheterodyne circuits of a receiver. Every stage of the long journey of the wave from its source is fraught with obstacles which tend to decrease the amount of energy delivered to the receiver. If the attenuation effects of distance and the ionosphere fail to stop a radio wave, the energy which the wave induces in an aerial may still diminish to zero in the maze of an inefficient antenna system. A properly designed system, including selective antennae, low-loss transmission lines and a noise-free receiving area will usually ensure reliable year-round reception with strong, non fading signals.

New Field Cable Battle-Tested In Korea

A new type of field cable has been used successfully in Korea. Particularly suited to airborne operations, the wire can be laid at speeds up to 120 mph from aircraft. The new cable consists of two conductors, each individually insulated and jacketed and twisted together to form a light, flexible, flat-lying twisted pair. A thin nylon covering provides a tight waterproof container for the strands. Weight is about 46 pounds per mile and talking range is approximately 12 miles.

A companion item is an improved cable dispenser constructed of canvas and tape, which will hold one-half mile of field cable. The wire can be released from the dispenser by packboard from a soldier's back without use of hands, from any land or amphibious vehicle, or any plane. A soldier with a rifle, grenade, PIAT or bazooka can lay the cable by shooting it over rivers or gullies. Two or more dispensers may be connected in tandem and the cable strung without splicing.