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CHAPTER X

ULTRA-HIGH-FREQUENCY COMMUNICATION

In the previous chapter an apparently satisfactory communication system operating at medium-high frequencies was discussed, so the question naturally arises as to the reason for a communication system utilizing ultra-high frequencies. The reason lies in two weaknesses of the medium-high frequencies. These are (1) the scarcity of these frequencies, and (2) their susceptibility to static.

To elaborate on the first characteristic mentioned above, the increase in the number of airplanes in one sector of an airway has greatly increased the number of contacts that must be made on the frequency used in that sector. When this occurs, an attempt is made to secure a second frequency; however, the frequencies that were available have all been allocated, and so it is necessary to turn to the ultra-high-frequency spectrum in order to secure the desired channels. The use of ultra-high frequencies as a substitute for the medium-high frequencies has been questioned because of their widely different propagation characteristics. It is true that the propagation characteristics of the ultra-high frequencies are such as to render them inapplicable in the manner in which the medium-high frequencies have been used, but a plan has been formulated which, if followed, indicates that the ultra-high frequencies will be as useful as those of the lower spectrum.

In the previous chapter communication over long distances was discussed, but from what has been said in Chap. III, it is apparent that the ultra-high frequencies can be used over short distances only; however, an analysis of the communications that are necessary for the proper operation of a commercial transport airplane shows that they are of the following types:

1. To the company dispatcher for giving and requesting information pertinent to method of procedure
2. To another airplane in the vicinity for the purpose of obtaining direct weather and positional information. Positional information is for the prevention of collisions

3. To the Airways Traffic Control group (via the company station) for permission to proceed to the airport from the airway
4. To the airport control tower for barometer readings and airport clearance

Of these four types of information interchange, three occur when the airplane is near the vicinity of the airport. One study made by an airline showed that of the total time that a frequency was utilized 60 per cent was for communication near the airport. If this is true, the ultra-high frequencies will indeed perform a huge task. Although it is very difficult to state that one type of communication is more important than another, the lower fuel supply carried by an airplane when it nears its destination and the dangers of collision prevalent at the larger air terminals make close-in communication of prime importance. Here the fact that ultra-high-frequency waves are but slightly susceptible to static would indicate that they can be expected to perform a good service, since their use should enable this vital information to reach the pilot regardless of the atmospheric conditions. There is another characteristic of these frequencies which also contributes to making them ideally suited for this particular service. Since all the information communicated when an airplane is close in is of interest chiefly to the airplane, the limited range of these frequencies allows their use at any number of terminals separated by a distance of only about 150 miles without interference, so the same frequency may be used simultaneously over many portions of the same airline.

It can be noticed that the preceding discussion has been made on a basis of what is to be rather than on a basis of what has been done. The reason for this is that ultra-high-frequency communication for the airlines is to be inaugurated in 1942. The work done thus far has been of an experimental or development character, and this chapter is more in the nature of a laboratory report than a history of an accomplished fact. The airlines of the country have conducted tests on the system for communications and believe that it will be practical. They have done developmental work on antennas and have set up specifications for equipment that is desired. Purchase orders have been issued for this equipment, but its delivery is now long overdue. The system set up contemplates the use of frequencies in a band of 140 to 144 megacycles. It is intended that this system will provide a common channel to allow the airplanes of the various airlines to communicate with each other. Another purpose is to remove the airport control-tower communications from the medium-high and 278-kc. frequencies and place them on the ultra-high-frequency band. The company communications on ultra-high frequencies that are contemplated vary with the individual airlines. Some that have been hard pressed for additional frequencies intend to equip their ground stations fully with this ultra-high-frequency equipment, whereas others are making only partial installations while awaiting further service proving of the equipment.

Wave Polarization for Communications Use.—The type of polarization that has been chosen for communications use is vertical and is, therefore, in direct contrast with that for range use. One of the principal reasons for this choice is that it permits the use of a very simple antenna on the airplane. A further reason is that vertically polarized waves are somewhat less attenuated during propagation than are horizontally polarized waves. Whether or not this second factor will prove significant in actual practice remains to be seen.

Type of Modulation.—Modulation by varying the frequency(1) rather than the amplitude has recently been highly publicized and has been the subject of much discussion among radio engineers. The outstanding advantage claimed for this type of modulation is that it produces signals that are free from static, and it was necessary for the airlines to decide whether to employ this type of modulation or the more conventional amplitude type. Comparative tests were made with amplitude- and frequency-modulated equipments which were as nearly identical as possible. Although these tests showed some excellent performance for frequency-modulated equipment, they failed to show the advantages that had been claimed by experimenters using frequency-modulated equipment at 40 megacycles. It is believed that the higher carrier frequency employed in these tests, together with the lower ignition noise level on the modern well-shielded airplane, probably accounts for this result. Since it was very urgent that the ultra-high-frequency program be started, and since it was felt that the application of ultra-high frequencies to airline communication would alone introduce many new problems, equipment of a type consistent with the better known art was chosen with the thought that it will be changed at a later time should frequency modulation prove, upon further tests, to have outstanding advantages. Amplitude

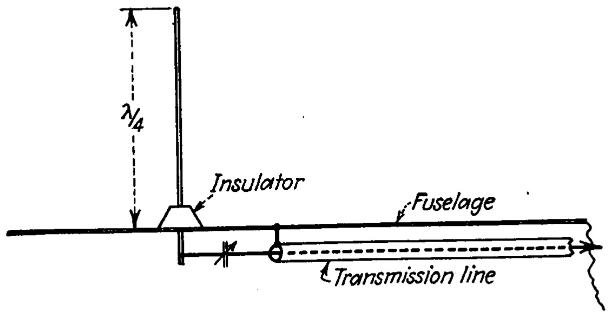

FIG. 181.—Series-fed vertically polarized ultra-high-frequency antenna for aircraft.

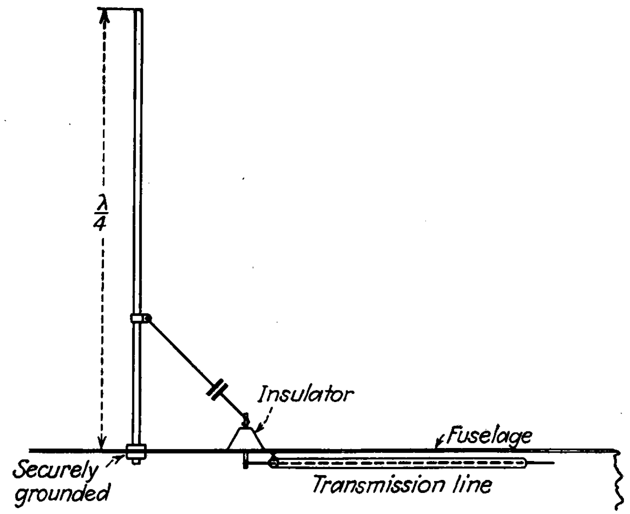

FIG. 182.—Shunt-excited vertically polarized ultra-high-frequency antenna for aircraft.

modulation is to be used, and, in the meantime, the improvements in the design of frequency-modulated equipment will take place.

Ultra-high-frequency Airplane Communications Antenna.—It has previously been mentioned that the employment of vertically

polarized waves permits the use of a simple antenna. The antenna devised is a small vertical rod with a height of about 20 in. This rod is made of stainless steel, has a base diameter of $\frac{1}{4}$ in., and tapers to a $\frac{1}{16}$-in. section. It may be fed either in series or in shunt. If the antenna is fed in series, its base is insulated from the airplane and it is connected to the center

FIG. 183.—Various ultra-high-frequency communications antennas installed on airplane for tests. In the text the antenna immediately in front of the vertical fin is designated as No. 1, that behind the tail as No. 2, that located farthest forward as No. 3, and that mounted on the vertical fin as No. 4. (*Courtesy United Air Lines.*)

conductor of a coaxial transmission line (see Fig. 181). A variable series condenser is used for tuning. The shunt antenna has a length equal to that of the series antenna, but its base is grounded directly to the skin of the airplane. Coupling to it is made by a skew wire transmission line connected at a point about 6 in. from the base of the mast. A condenser having a capacity of about 15 $\mu\mu$f is used to couple the open-wire transmission line to the coaxial line. The coaxial line is brought to the outside of the airplane by means of an insulator, and the necessary small condenser is formed by a sleeve over the end of the insulator lead-in screw (see Fig. 182). The shunt-fed antenna(2) has the advantage in that it separates the electrical problem from the mechanical problem involved in supporting the mast. Masts of this type have at times been broken when their

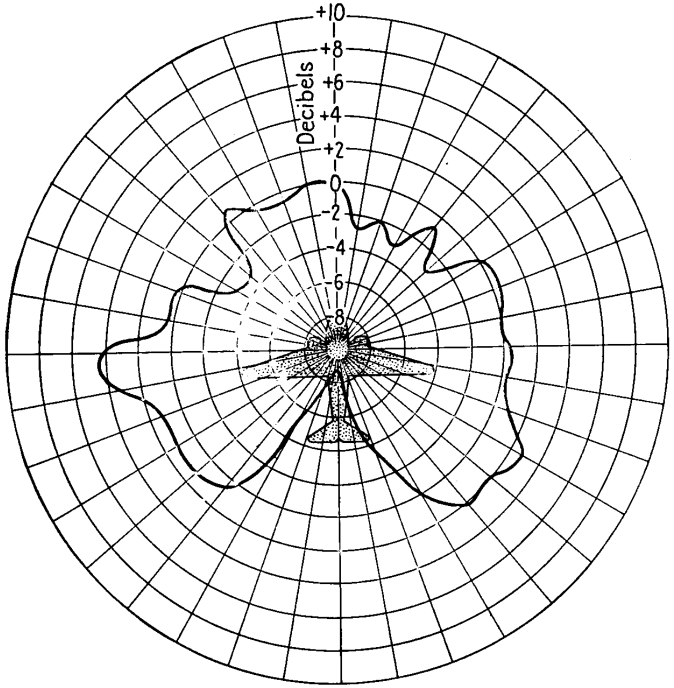

FIG. 184.—Horizontal-plane field pattern of the No. 1 antenna of Fig. 183.

mechanical resonance periods happen to fall near one of the frequencies generated by the propeller.

The length of 20 in. is one-quarter wave length. Longer lengths have been tried without noticeable improvement in field strengths.

The tuning of these antennas must be accomplished with a field-strength indicator. A vacuum-tube voltmeter equipped with a vertical antenna suitably tuned to the carrier frequency is placed near the airplane. The antenna is adjusted until the meter reading is maximum. The stray capacities involved in

directly attached current-indicating devices have made them unsuitable as a means for making adjustments. After the antenna is once adjusted, a resonance indicator at the transmitter is satisfactory for accomplishing further apparatus tuning.

Antenna Space Patterns.—Although the antenna has a simple structure, the determination of its best location on the aircraft

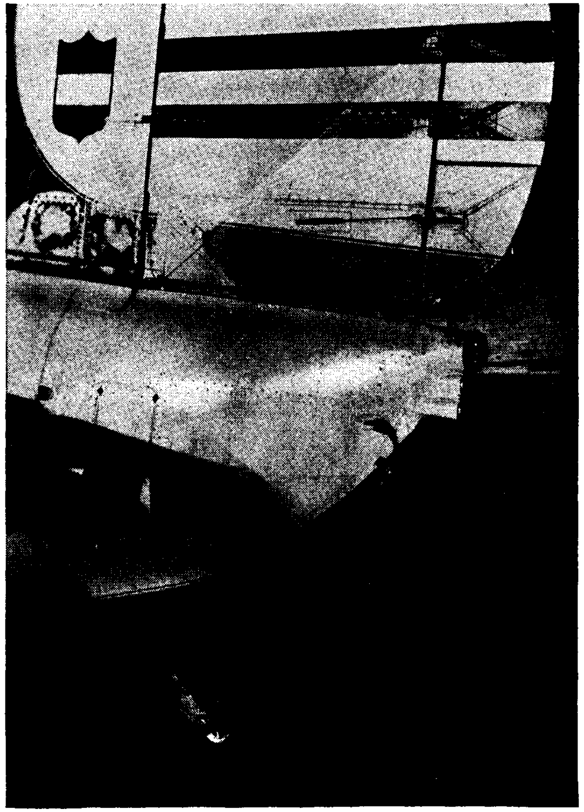

FIG. 185.—Antenna mounted behind tail wheel and below fuselage in order to minimize the effect of the fin shadow. In the text this antenna is referred to as No. 2.

was a problem that required extensive investigation. It was found in the early experiments with ultra-high-frequency waves that the propellers tended to modulate the transmission and reception. This modulation was very complete and took place at a frequency that was the product of the speed of the propellers and the number of blades on them. It was impossible to understand signals so modulated. The discovery of this phenomenon was the source of considerable alarm because of the thought that it might preclude the use of ultra-high frequencies on aircraft. Later investigations, however, showed that this was purely an effect that existed between propeller and antenna, and if the antenna was removed sufficiently from the propeller, this effect was minimized.

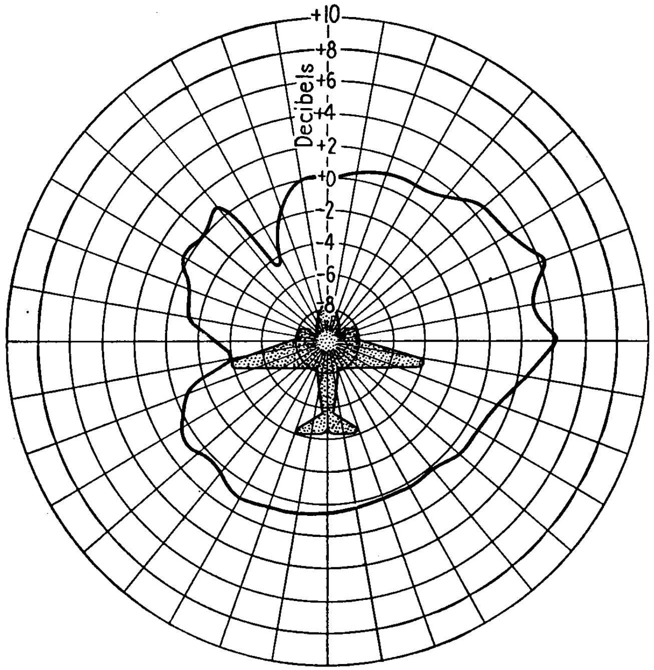

FIG. 186.—Horizontal-plane field pattern of the antenna shown on Fig. 185.

One of the possible locations is shown at number (1) in Fig. 183. This antenna is located on top of the fuselage and at an arbitrary distance from the vertical fin. By flying in a circle with an airplane equipped with this antenna, the field-strength pattern shown in Fig. 184 was obtained by using recording devices. It can be seen from this figure that signal is not transmitted in the direction toward the rear of the airplane's vertical fin. Clearly, this is a "shadow" effect caused by this vertical member.

Another similar antenna was located below the fuselage and to the rear of the tail wheel, as shown in Fig. 185. The

thought was that this location would eliminate the vertical-fin shadow. As shown in Fig. 186, this shadow is eliminated; however, when the airplane is banked, the effects of the wings can be noticed.

Since the fuselage might give a shadow above the airplane, the antenna behind the tail wheel was connected in parallel with the antenna over the fuselage, without attempting to secure

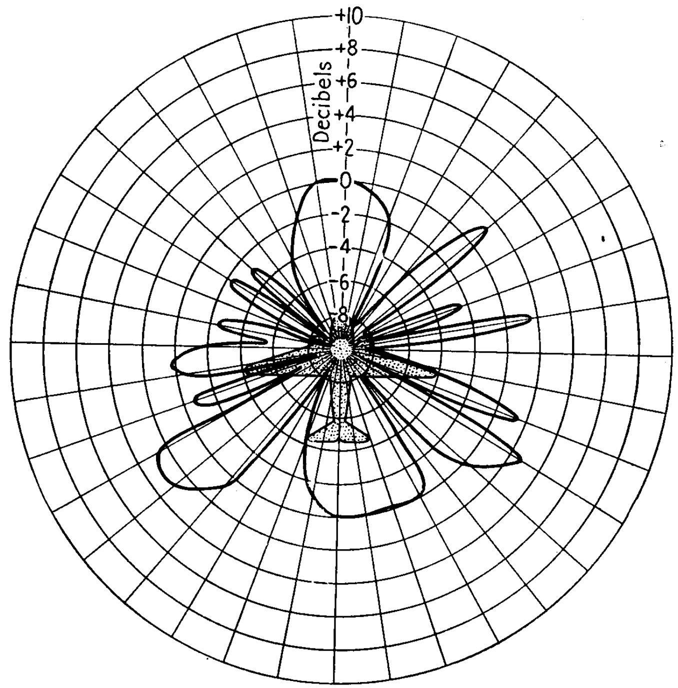

FIG. 187.—Horizontal-plane field pattern resulting from the combination of the No. 1 and No. 2 antennas.

optimum phasing. The results are shown in Fig. 187. This pattern is not satisfactory because it produced a large number of areas in which no signals were present, or rather where the signal strength was very low.

Another antenna location is shown by number (4) in Fig. 183. This antenna is located on the highest point on the airplane, that is, on top of the vertical fin. This location has the disadvantage that it requires a longer transmission line than do other antennas, it is difficult to service, and it may interfere with certain hangar structures. As shown in Fig. 188, however, its field pattern is quite good. The slight lobes shown are probably caused by the banked attitude of the airplane.

The field-strength pattern shown in Fig. 189 is for an antenna located over the fuselage. It is in front of the vertical fin of the airplane as was the number (1) antenna; however, Fig. 189 does not show any sharp nulls to be

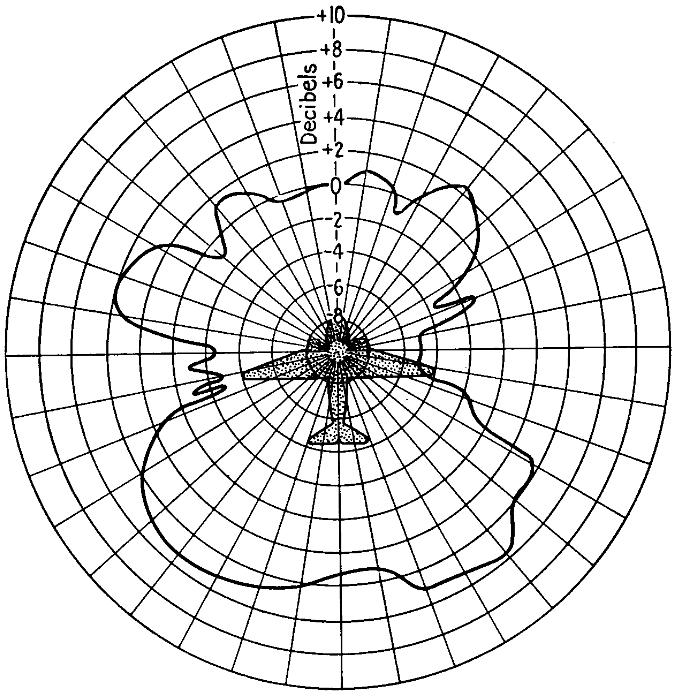

FIG. 188.—Horizontal-plane field pattern of the antenna mounted on the vertical fin.

present. The location for this antenna was determined experimentally. A vacuum-tube voltmeter was placed directly in back of the airplane's vertical fin, and the antenna was moved along until a point was found where the signal to the rear was maximum. This location was found to be quite critical. Moving the antenna as little as 3 in. greatly changed the results. The exact mechanism that is operating to cause this transmission has not yet been analyzed; however, it must be that the various

surfaces on the airplane are acting to cause reflection to its rear. On a larger airplane two such spots were located. Both of these were to the rear of the airplane where propeller modulation was not a factor.

Other Transmission Anomalies.—The field strength produced at a ground receiving station by an airplane carrying the vertical antenna located at the optimum distance in front of the vertical

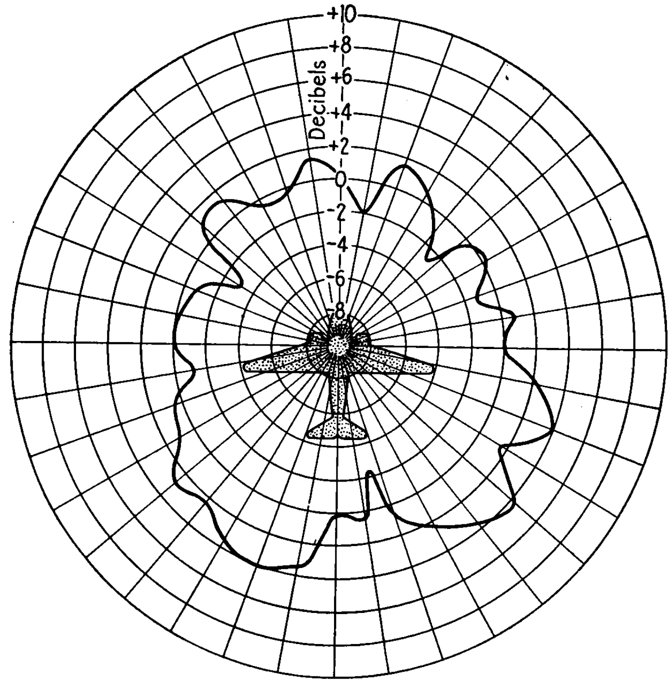

FIG. 189.—Horizontal-plane field pattern of the antenna mounted on top of the fuselage and at a distance in front of the vertical fin which makes the radiation to the rear of the airplane maximum.

fin, as the airplane flew toward, over, and away from the station, is shown in Figs. 190 and 191. The data on the curve of Fig. 190 are taken with the airplane at an altitude of 1,000 ft.; the data of Fig. 191 were taken with the airplane at an altitude of 4,500 ft. Referring to Fig. 191, a number of dips in the field-strength curve may be seen. Although the relation between the data of Figs. 190 and 191 is not absolute, it can be seen that the ratio between the maximum and minimum field strength is not so