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TESTS WITH ULTRA-HIGH-FREQUENCY RADIO TRANSMITTING AND RECEIVING EQUIPMENT FOR ITINERANT AIRCRAFT COMMUNICATION

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Tests With Ultra-High-Frequency Radio Transmitting and Receiving Equipment for Itinerant Aircraft Communication

SUMMARY

This report describes an investigation undertaken for the purpose of determining that ultra-high frequencies can be utilized for itinerant aircraft-to-ground communication. Equipment suitable for itinerant aircraft is described together with characteristics of the airplane antenna. The results of aircraft-to-ground transmission are highly satisfactory in spite of the low power used. Based upon the use of an antenna 65 feet high at the ground station and an airplane flying not less than 1,000 feet above level earth, the service area will have a minimum radius of 50 miles. It is concluded that the adoption of the ultra-high frequencies will result in a substantial reduction in radio interference and aerodynamic drag due to the antenna together with improved transmission performance when compared with present practice.

INTRODUCTION

Experience with radio transmission at frequencies in the portion of the spectrum above 60 megacycles has demonstrated the desirability of utilizing such frequencies for communication with aircraft.

Prior to the beginning of these tests, a frequency of 141.780 megacycles had been tentatively assigned to itinerant aircraft. Recently this has been changed to 140.10 megacycles, and it is anticipated that airport control towers will be assigned several channels between 129 and 132 megacycles.

A considerable amount of information has been published concerning transmission characteristics of frequencies of the order mentioned and equipment suitable for use thereon. Consequently, the investigation about to be described was undertaken for the purpose of evolving equipment which would meet the requirements of itinerant aircraft, and of ascertaining that satisfactory aircraft-to-ground transmission could be achieved. The factors considered are (1) Communication performance, (2) economy, and (3) restriction of equipment weight and aerodynamic drag caused by the antenna.

EQUIPMENT

A transmitter and receiver conforming to Civil Aeronautics Authority specifications BA-241 and 242, respectively, were obtained from a commercial source. Both are designed for aircraft operation. The transmitter utilizes a crystal-controlled oscillator, has a carrier output of 10 watts at 141.78 megacycles, and is capable of being fully modulated with speech from a conventional aircraft-type microphone. Weight of the complete transmitter including cables is 21 pounds. The receiver is of the superheterodyne type with a crystal-controlled oscillator and may be pretuned to any frequency between 120 and 142 megacycles. It weighs 23 pounds, including cables. For the tests made in connection with this project, the transmitter was installed in a Waco type "N" airplane and the receiver was situated on the ground at the Silver Hill experimental station near Washington, D. C. Both the transmitter and receiver operated with vertical antennas approximately one-half wave-length long. The antenna on the airplane comprised a telescoping unit of nickeled tubing similar to the "whip" antennas commonly used in mobile service. It was mounted on a ceramic insulator on top of the fuselage about 5 feet behind the propeller. The separation between the antenna and a metal plate integral with the airplane framework was 4 inches Lateral support was provided by two braces formed of bakelite rods A conductor 6 inches long connected the lower end of the antenna to a coupling unit located inside the airplane From the coupling unit, a ¼-inch coaxial transmission line about 7 feet long ran to the transmitter This line is of the type employing a spun glass spiral cord to insulate the center conductor from the sheath Its characteristic impedance is nominally 70 ohms An asymmetrical pi-type section was used to match the transmission line to the antenna, the impedance of which was 380 ohms resistive and 160 ohms capacitive The matching section comprised an inductance inserted between the antenna and the center conductor of the line with variable capacitances connected between both sides of the inductance and ground For the conditions given above, the inductance had a value of 0 15 microhenries, the condenser at the antenna end of the inductance had a maximum capacitance of 10 micromicrofarads, and the maximum value for the other condenser was 15 micromicrofarads The receiving antenna was mounted at the top of a 65-foot wooden pole It was formed of two similar sections of 2-inch brass pipe mounted end to end and separated by a special fitting A 6-inch ceramic insulator was used to support each tubing section The special fitting had a ceramic bushing through which a central conductor could be passed A ⅜-inch coaxial transmission line ran from this fitting to the receiver The transmission line sheath was connected to one of the antenna pipe sections, and the central conductor was connected to the other antenna section Carrier strength of incoming signals was determined by recording values of intermediate frequency amplifier plate current which had been calibrated to indicate carrier amplitude by replacing the antenna with a standard signal generator When working at lower and more conventional frequencies, it is customary to refer to radio-frequency carrier amplitude in terms of volts/meter However, measurements of this term at frequencies considered here are subject to large errors Consequently, carrier strength will be referred to in terms of arbitrary units

TESTS

With equipment set up as described above flights were made along radials emanating from the Silver Hill station Position and altitude of the aircraft were recorded together with carrier strength at the receiver In addition, compass heading of the airplane was recorded when it was flown in a circle for the purpose of determining the variation in its antenna response for different headings In conducting this test, care was taken to keep the distance to the receiver great as compared to the diameter of the circle around which the ship was flown The airplane was placed in a horizontal position for each reading while flying around this circle

RESULTS

The field strength data obtained in the tests are plotted in figures 1 and 2 Figure 3 shows the characteristics of the airplane antenna For discussion purposes, there is plotted in figure 4 the relation between altitude of the aircraft and the line-ot-sight distance, assuming the ground station antenna to be erected 65 feet above the surface of the earth

DISCUSSION

Itinerant aircraft now transmit on 3105 kilocycles or the auxiliary frequencies of 3120 and 6210 kilocycles, and receive airport control tower instructions on 278 kilocycles At intermediate points along the airways, such aircraft receive transmissions from Civil Aeronautics Authority stations operating in the intermediate frequency band, 200 to 400 kilocycles The 3105-kilocycle channel is subject to sporadic fading and skip effects This is also true with the two auxiliary frequencies The size of the aircraft antenna required for efficient transmission introduces additional drag which is relatively appreciable for many light airplanes Also, the weight restrictions are such that the power available is barely sufficient for satisfactory reception at the control tower when the background noise level rises above

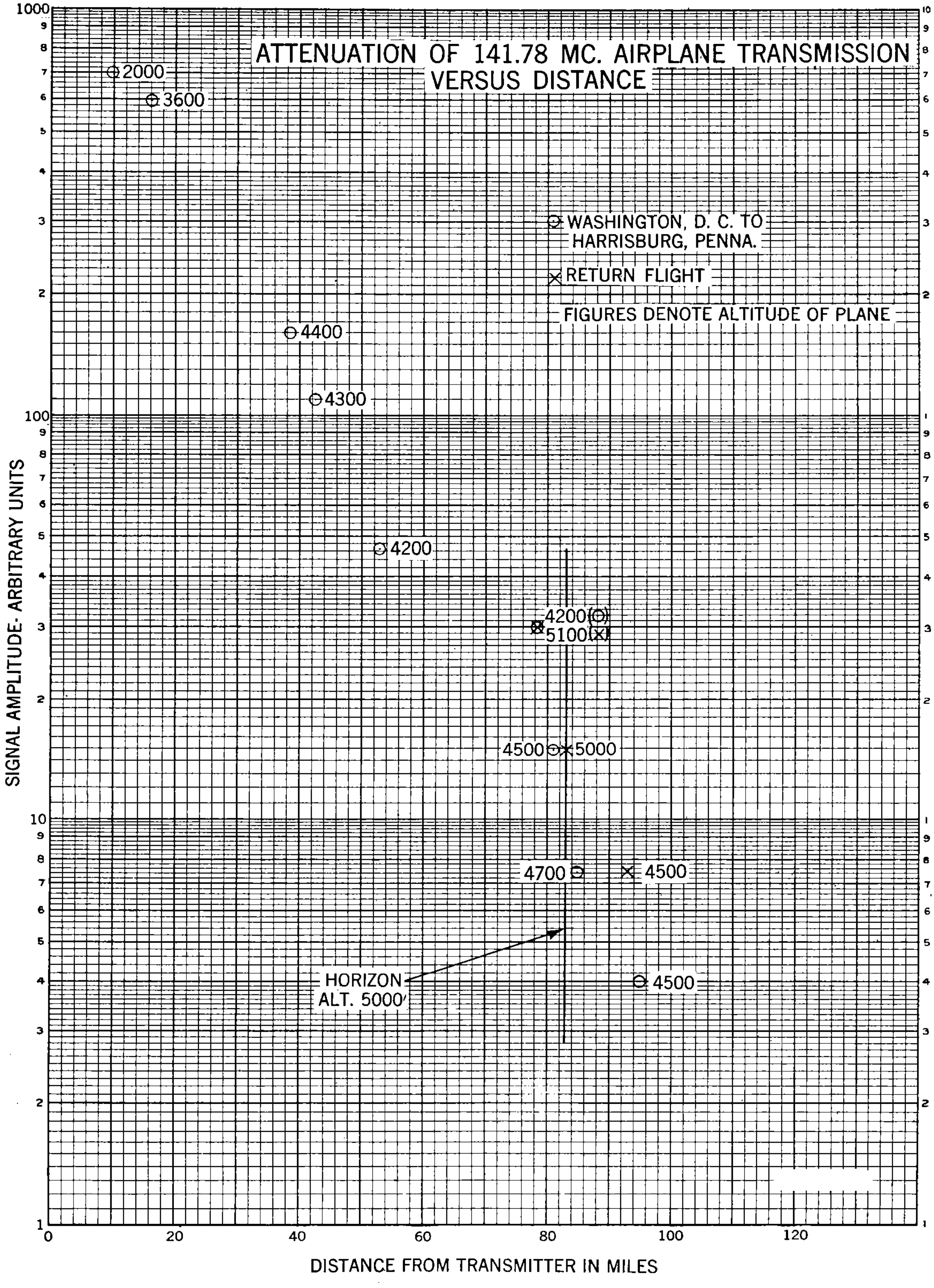

Figure 1.—Attentuation of 141.78 mc. airplane transmission.

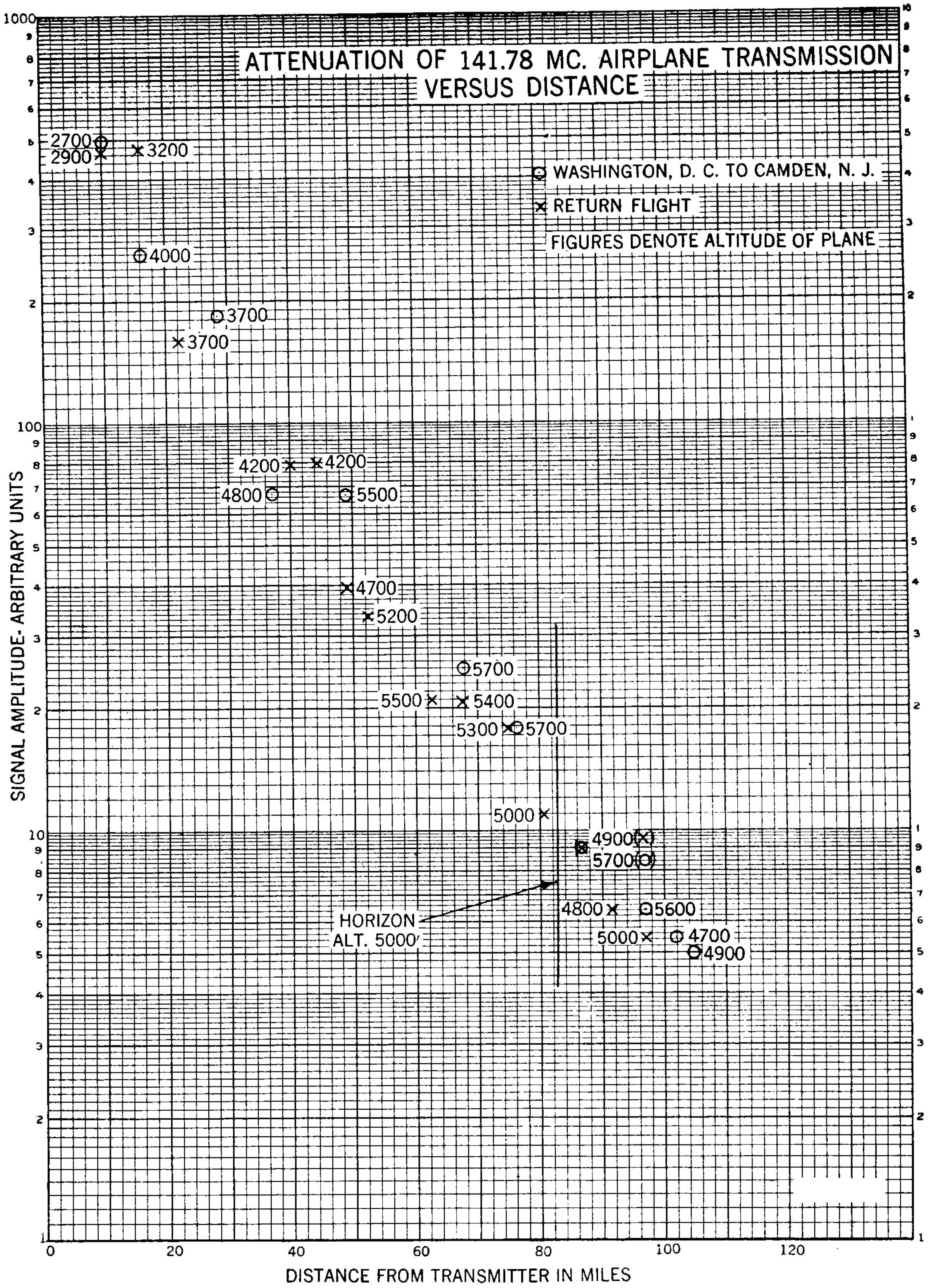

Figure 2.—Attenuation of 141.78 mc. airplane transmission.

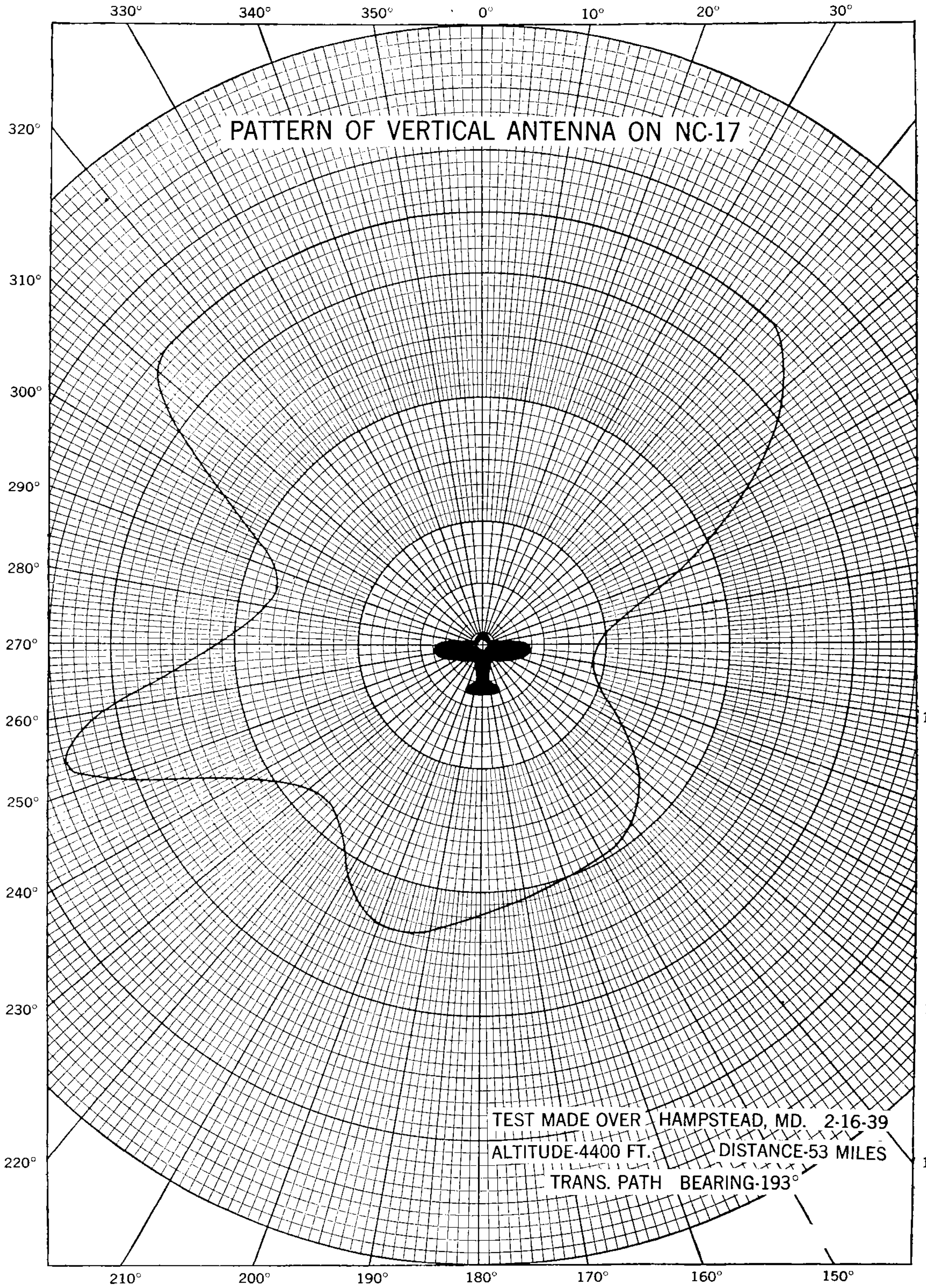

Figure 3.—Pattern of vertical antenna on NC–17.

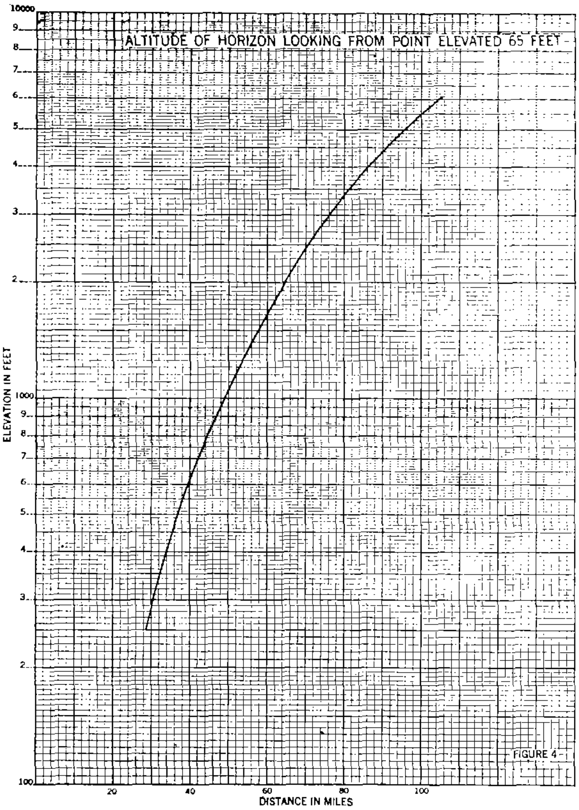

Figure 4.—Altitude of horizon looking from point elevated 65 feet.

normal. Figures 1 and 2 show graphically the strength of airplane signals as received at the ground station while the ship was flying along a radial from the receiving station. Voice-modulated signals having a carrier strength of not less than 10 on the arbitrary scale provided good intelligibility. It will be seen that signal strength did not drop to this value until a distance of about 80 miles was reached when the airplane was flying at 5,000 feet. These results were achieved with an antenna power of 5 watts, and in the absence of any abnormal background noise. In other experiments, which include continuous recording on a 40-mile point-to-point circuit at 61 megacycles and extensive aircraft tests at 63 and 125 megacycles, there has been no evidence of other than momentary periods when the atmospheric noise became excessive. It will be noted that upon flying beyond the point where the transmission path falls below the horizon the signal strength decreases much more rapidly. Although the signal will not disappear immediately upon dropping below the horizon, reliable communication could not be guaranteed when the distance below the horizon becomes appreciable. If a height of 65 feet is assumed for the ground station antenna, the horizon will be 9½ miles distant for level earth. By assuming that the altitude of the airplane is not less than 1,000 feet, this distance increases, thus providing a service area with a minimum radius of 50 miles.

The airplane antenna pattern shown in figure 3 indicates a maximum response ratio of 3½ to 1. Since this pattern was made by flying the ship in a circle, the point of reflection for that portion of the energy which arrives at the receiver after reflection from the earth's surface must move about. It is possible some of the irregularities in this pattern were introduced in this manner. Furthermore, there were two other antennas on the airplane which affected the pattern; one of these was a vertical "whip type" mounted on top of the fuselage toward the tail and the other was a "V type" extending from the wings to a point on the fuselage near the tail. Lack of time prevented further investigation of the effects of these antennas. The results obtained from flights toward and away from the receiver in various directions failed to indicate any serious variation in signal strength.

The weights of the transmitter and receiver used in these tests are comparable with the weights of the present equipments used in airplanes operated by the Civil Aeronautics Authority. These airplanes are similar to those used by many itinerant fliers. There are no restrictions apparent which would prevent the size and weight of ultra-high-frequency equipment from being reduced to the minimum achieved in existing lower frequency units. Inasmuch as this equipment is in a developmental stage, a direct cost comparison with present lower frequency equipment cannot be drawn. However, ultra-high-frequency equipment suitable for the service considered here need not be subject to complications tending to increase its cost over that of present equipment. Finally, the drag of an efficient ultra-high-frequency antenna is less than one-fourth that of the trailing wire antenna widely used at the lower frequencies.

CONCLUSIONS

In formulating conclusions concerning the proposed use of ultra-high frequencies for itinerant aircraft communication, certain limitations must be recognized as inherent in the existing system. First, more power is required to transmit a satisfactory signal on 3105 kilocycles than at the ultra-high frequencies because of the lower signal-to-noise ratio encountered at 3105 kilocycles for a given antenna power radiated. Second, a much larger antenna is required with the lower frequencies than the ultra-high frequencies for a given antenna efficiency. Third, the interference resulting from aircraft operations on 3105 kilocycles within an area of high traffic density is greater than on ultra-high frequencies. Fourth, 'skip distance' characteristics frequently make it necessary to change between 3105 and 6210 kilocycles, which makes the equipment and operations more complicated.

It is believed that the investigation described above has been conclusive in simulating actual operating conditions. Although the service area is shown to be dependent upon the altitude of the airplane in addition to the height of the ground station antenna, it is concluded that the minimum service radius would be about 50 miles when flying at altitudes as low as 1,000 feet, and would be approximately 90 miles when flying at altitudes of 4,000 feet. Transmission at the ultra-high frequencies has been found to be free from objectionable fading within the service area. It also has been characterized by a low background noise level which permitted good reception in spite of the low power employed. Consequently, it is concluded that adoption of the frequency 140.10 megacycles for itinerant aircraft will result in greatly improved transmission in addition to equipment advantages.