Development of Airplane Radiotelephone Set

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SHORT range radiotelephone sets were used extensively by both the Army and Navy during the last few months of the war.* These were made in a variety of different forms, including airplane and seaplane sets, ground sets, and sets for submarine chasers and destroyers. This article will describe one of these radiotelephone equipments, which is coded by the Signal Corps as the SCR-68 set. It was designed for airplane use, and its development involved many peculiar difficulties involving noise, vibration, shocks on landing, etc.

ARRANGEMENT OF EQUIPMENT

A view of the various parts of the equipment is shown in Fig. 1. A wind-driven generator, located on one of the struts of the landing gear, furnishes the

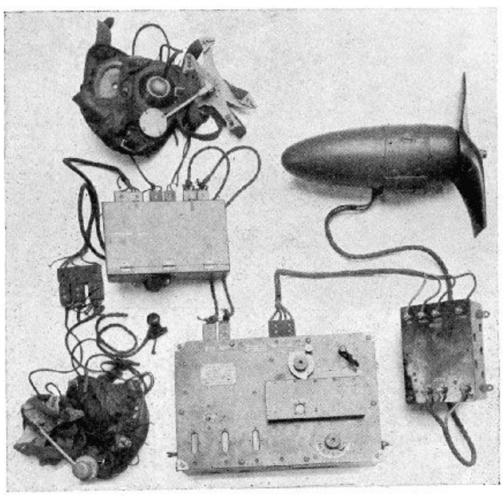

FIG. 1—AIRPLANE RADIOTELEPHONE EQUIPMENT

power supply, which is led through a filter box containing an inductance and condensers for smoothing out the commutator ripples. The power is then led to the radio set proper in which the transmitting and receiving circuit equipment is assembled. The two plugs shown at the lower right hand side of the set lead to an interphone box, by means of which the radio operator may also talk with the pilot, using an ordinary telephone circuit. Usually the antenna consists of two small braided copper wires trailed from the wing tips. When flying alone so that there is no danger of entanglement, there is some advantage in using a single wire about 300 feet long with a two pound lead weight shaped like a fish attached to the end. Recent developments have made it possible to employ much shorter antennæ, which however require the use of shorter wave lengths. Fig. 2 shows a pilot and observer seated in an airplane which is fitted with this equipment. The helmet which contains the receivers is designed to fit the operator's head snugly in order to exclude wind

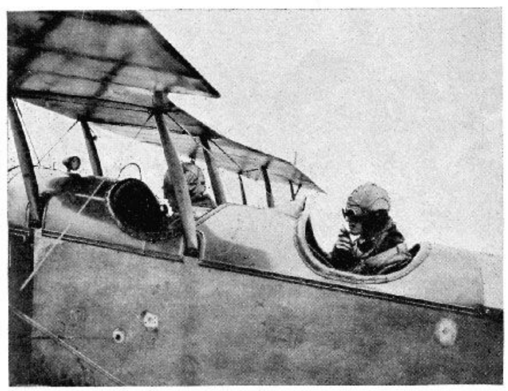

FIG. 2—PILOT AND OBSERVER WITH RADIO EQUIPMENT

noises. It was found necessary to have the helmet cover completely the bony parts of the head so as to prevent transmission of noise to the ear drums.

RADIO SET

The outside and inside appearance of the radio set proper, which contains the transmitting and receiving tubes with their auxiliary circuit equipment, is shown in Figs. 3 and 4. A schematic diagram of the transmitting circuit, is shown in Fig. 5, which consists of two three-element vacuum tubes connected to an input transformer operated by a microphone telephone transmitter. The oscillator tube feeds an oscillation circuit in which the inductance is supplied by the antenna coil and part of the capacity by the antenna.

When the transmitter is actuated there is a certain normal value of voltage impressed upon the grid of the modulator tube, this value being adjusted until the plate current of the modulator is about the same as that of the oscillator. The characteristic curve of the

*The success of the airplane radiotelephone was announced in General Squier's report on "Aeronautics in the United States" presented at the January meeting of the A.I.E.E. The development and quantity production of this radioequipment within the limited time available has been classed as one of the achievements of the war. The work was undertaken at the direction of the Radio Development Section of the Signal Corps. The manufacture of the radio sets was assigned to the Western Electric Co., while the associated power equipment was made by the Westinghouse Electric & Mfg. Co. and the Crocker-Wheeler Co. The paper on "Radio Telephony" by Messrs. Craft and Colpitts, presented to the A.I.E.E. in February 1919, gives a summary of the research and development work of the American Telephone & Telegraph Co. and the Western Electric Co. It describes the demonstrations in transatlantic telephony made in 1915 and 1916, the subsequent use of radiotelephony between ships, and finally the quantity production of short range radiotelephone sets used by the Army and Navy in the war.

transmitting tube, Fig. 7, shows that as the grid becomes more negative, the plate current decreases at constant plate voltage, and with positive grid voltage it increases. This may be described by saying that the resistance of the plate circuit may be varied by varying the grid voltage. An inspection of the curve shows that this variation may be from a very high value to a small value for positive grid voltages. The transmitter voltage acts upon the grid of the modulator and causes the resistance of the plate circuit to vary through a wide range in accordance with the speech voltage. Since this circuit shunts the plate circuit of the oscillator tube (at audio but not at radio frequencies) the oscillator will be robbed of current or have additional plate current forced through it in accordance with the speech voltage. It is seen that this system is essentially a constant current system, since it is supplied through a low frequency choke coil, the function of which is to maintain practically constant

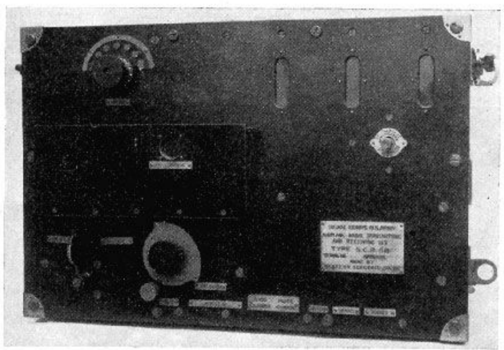

FIG. 3—SIGNAL CORPS SCR-68 RADIO TELEPHONE SET

current to the two tubes no matter how the plate currents may vary individually.

A complete schematic circuit of the set is given in Fig. 6. A multibladed switch, the handle of which is shown in Fig. 3, is used to make the necessary circuit changes between transmitting and receiving. As all adjustments may be made on the ground, this switching is the only manipulation required by the operator. The handle is designed for use with a heavily gloved hand. The receiving circuit consists of a detecting tube and two stages of amplification, being similar in principle to the receiving circuits in common use in telegraph sets. The characteristics of the receiving tube are shown in Fig. 8. The battery which furnishes plate current for the receiving tubes is mounted in the radio set and is made up in two 22.5 volt units each weighing a little over a pound. These units are composed of 15 small dry cells. The complete transmitting and receiving set is approximately 17 by 10 by 7 inches and weighs 21 pounds.

GENERATOR

The wind-driven generator furnishes plate voltage at from 275 to 300 volts and filament voltage at from 25 to 30 volts. The development of the generator proved to be a considerable problem in itself, as it was necessary to secure constant voltage over a range of speed from 4000 to 12 000 r.p.m., which corresponds to an airplane speed range up to 160 miles per hour. In addition to all of the ordinary requirements for power equipment there was the additional requirement of furnishing current free from commutator ripples and brush noise. The regulation was accomplished by means of a vacuum tube regulator while the noise was suppressed by means of special generator design and the use of a filter. Fig. 9 shows its appearance with the "stream line" tail removed.

GENERATOR PROPELLER

The generator propeller is built of birch mounted on an aluminum hub, and has a weight of about 14 ounces. It is essentially an air screw similar to the engine propeller, except that it runs with a small slip below synchronous speed* while the engine propeller

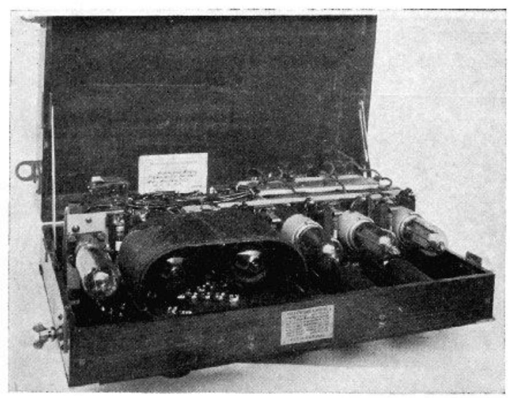

FIG. 4—INSIDE VIEW OF SET

runs somewhat above synchronous speed. Fig. 10 shows the characteristic curves of a propeller, having a pitch of 0.80. These were taken in a wind tunnel at the Washington Navy Yard. The no load speed is exactly proportional to the first power of the wind velocity as seen by comparing the curves for 50 and 60 miles per hour. The point of maximum power is roughly proportional to the cube of the wind velocity. This might be expected from the fundamental consideration that the kinetic energy of a cubic foot of air is proportional to the square of the velocity while the number of cubic feet striking the propeller per second is proportional to the first power of the velocity.

As the wind tunnel was not equipped to give higher wind velocities, no information was obtained as to the velocity range over which the above stated laws would hold. It was not convenient to take such measurements on an airplane, but our experience gives us reason to believe that the laws hold over the entire range up to the maximum velocity of which the airplane was capable.

*The synchronous speed may be defined as the speed at which no power would be taken from or delivered to the air current.

The centrifugal stresses in the propeller blades were considerable. A testing machine was constructed which showed that propellers made with properly selected wood could be safely operated at 12 000 r.p.m. It was later found possible to employ propellers of somewhat greater pitch thus reducing the normal speed.

PERFORMANCE

The complete radio equipment is designed for short range communication over distances of a few miles only, although it has been used up to distances of 18

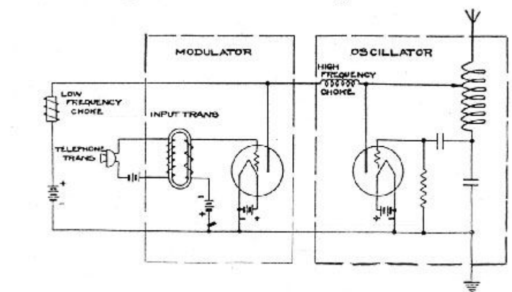

FIG. 5—SCHEMATIC DIAGRAM OF MODULATION SYSTEM

miles under very favorable conditions. Adjustments are provided which permit the use of wave lengths from 200 to 500 meters. The power output to the antenna at a wave length of 400 meters with a single wire antenna 300 feet long is about 0.75 watt. It is interesting to note that out of this 0.75 watt radiated, the power received by another set three miles away would be of the order of 10^{-8} watts.

Ordinarily there is no trouble from atmospheric static owing to the use of such short wave lengths. However, the ignition system of the airplane engine sets up electrostatic disturbances which produce a very sharp crackling in the receiver unless the ignition wir-

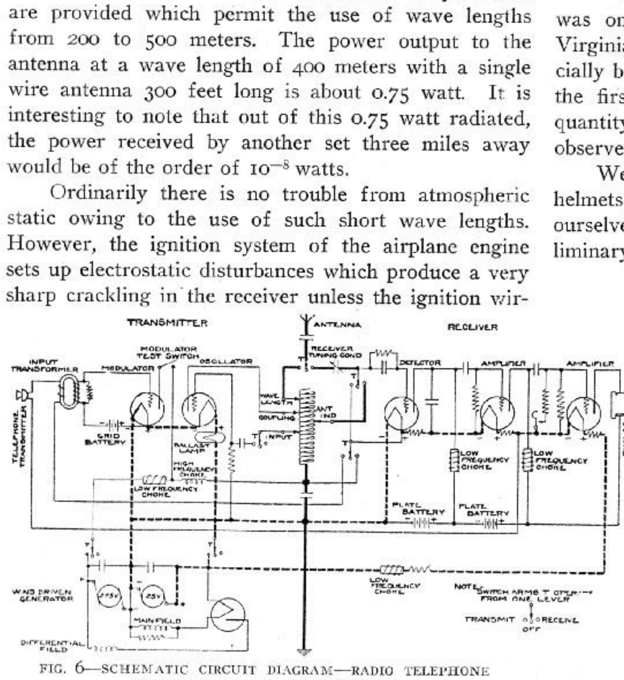

FIG. 6—SCHEMATIC CIRCUIT DIAGRAM—RADIO TELEPHONE TRANSMTTING AND RECEIVING SET

ing is properly shielded by a grounded metal sleeving. There is also a certain amount of noise due to the generator commutation ripples. When transmitting, the ratio of the amplitude of these disturbances to the amplitude of the transmitted signal is sufficiently low, but as the received signal is extremely minute, a very small commutator ripple will be comparable to the strength of the voice current. For this reason a choke coil is employed in the receiver filament circuit which suppresses these disturbances. In addition, the two condensers in Fig. 6 are connected across the generator armature leads and assist by partially absorbing the commutator ripples. These condensers together with the choke coil are mounted separately in the filter box.

TRIAL FLIGHT

The writer has a very distinct recollection of the first flight in which he talked by radiotelephone. It

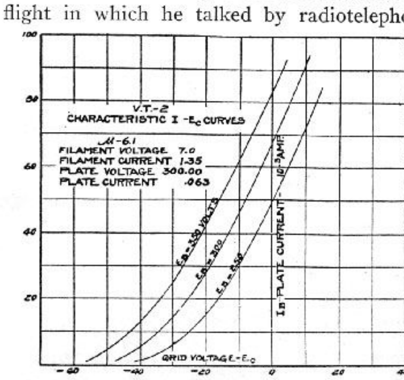

FIG. 7—CHARACTERISTICS OF TRANSMITTING TUBE

was on April 12, 1918, at Langley Aviation Field, Virginia. Previous flights had been made with specially built models of the radio set but this was one of the first trials of a tool-made set representative of quantity production. The purpose of the flight was to observe the operation of the set and note any defects.

We climbed into the plane, put on the receiver helmets, adjusted the breast transmitters and strapped ourselves in. While the engine was being given a preliminary spin on the ground to warm it up, we talked

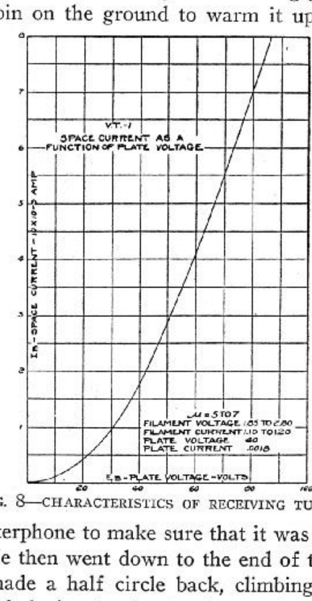

FIG. 8—CHARACTERISTICS OF RECEIVING TUBE

over the interphone to make sure that it was in working order. We then went down to the end of the aviation field and made a half circle back, climbing gradually. The high pitched note due to the revolutions of the wind-driven generator could be heard above the low pitch of the engine propeller, and by looking through the transparent windows at the filaments of the tubes in the set, it was evident that the power supply was working satisfactorily. The pilot then interphoned to let out the antenna. After making the required number of turns to let out 300 feet, the switch of the radio set was placed in the transmit position.

One of the difficult things is to know what to say on occasions of this sort. The only requirement is to talk, so that all sorts of subjects were discussed. I described the river, which was stretched out about 3000 feet below and the white oyster shell roads which are the bane of automobilists along the Virginian coast. Mr. A. A. Oswald, also of the engineering department, of the Western Electric Co., had in the meantime gone up in another plane, and was listening. After talking

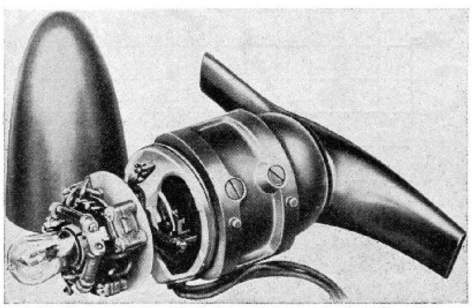

FIG. 9—WIND DRIVEN GENERATOR

for a few minutes I said, "Good-by, Oswald, come in now", and threw over to the receiver position. I could hear the "spit", "spit" of the magneto, for we had not as yet found out how to shield the wiring, and I could also hear the commutator noise of the generator. A moment later I heard, "Hello, Stoller" coming into the receiver, and I must say that in spite of the fact that I had used these sets on the ground and was expecting it, the sudden sound of a human voice which I clearly recognized gave me quite a start. It happened that we were not over two miles apart at the moment and with the antennæ in a favorable position, so that the words were heard quite loudly. Mr. Oswald said that he had heard me distinctly, and then told me to have my pilot turn the plane down toward Old Point Comfort and he would go up the James River. We would then report to each other where we were from time to time and thus determine the range* of the set between airplanes.

We thus talked back and forth for about three-quarters of an hour. The maximum range attained at that time was eighteen miles for a one-way conversation, for it was found on switching back again that the speech had become too faint to be distinguished. We then turned around to go back to the aviation field. We were now flying at a height of about 4000 feet, at a speed of about 80 miles an hour. Suddenly the pilot shut off the engine tipping the plane down at an angle of about 45 degrees, and I could then hear very distinctly the singing note of the generator propeller. The

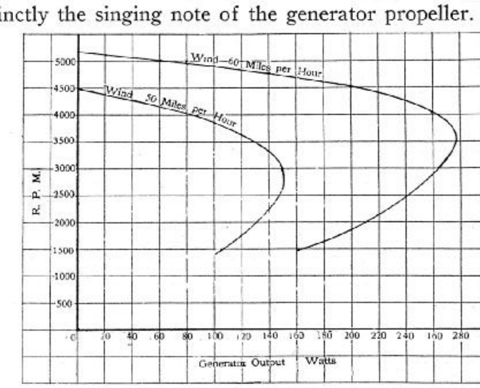

FIG. 10—CHARACTERISTIC CURVES OF 15 INCH PROPELLER
Tested with 300 watt generator.

pilot then turned on the engine, keeping the nose of the plane tilted downward, when the pitch of the wind-driven generator could be heard rising, indicating that we were moving at a very high speed for this type airplane, probably well over a hundred miles an hour. The filaments in the set could be seen at their normal brilliancy, which showed that the generator was regulating properly at this high speed. We were now approaching the aviation field, and the antenna was reeled in. We proceeded until we were directly over the hangars and then the pilot made a spiral for the last 2000 feet, and glided down very smoothly in front of the hangars. We found out that our conversation had been picked up during the first half hour of our trip by the ground set located in one of the hangars.

*The range is about 50 percent greater between planes than between a plane and ground for a two-way conversation.