*The Standard-Frequency Set at WWV**

By Hoy J. Walls†

Probably no radio station has ever rendered the American radio world so great a service as that of WWV in transmitting the standard wave signals. Before these signals began both broadcast and amateur waves were uncertain and often wavemeters disagreed violently. Since the signals began those in the East have been able to make precision calibration on their own wavemeters and to pass the information on into the West.

WWV is here described by the man who has been most active in furthering the progress of this service.

DURING the past year the Bureau of Standards has been transmitting standard frequency signals from station WWV over a frequency range from 125 to 2000 kilocycles. These signals have been received with enthusiasm by all classes of radio operators. The frequencies from 125 to 500 kilocycles have proven useful to operators of Government, commercial and ship stations. Frequencies from 500 to 1,300 kilocycles have assisted materially in keeping the broadcasting stations on their assigned frequencies and the frequencies from 1300 to 2000 kilocycles have enabled the amateurs to keep within their bounds. The purpose of this article is to describe the apparatus used at the Bureau of Standards for transmitting these signals.

The transmitting set is a 1-K.W. continuous wave set of the "master-oscillator power-amplifier" type especially designed to operate over a wide range of frequencies and to permit rapid change from one frequency to another. A photograph of the set is given in Fig. 1.

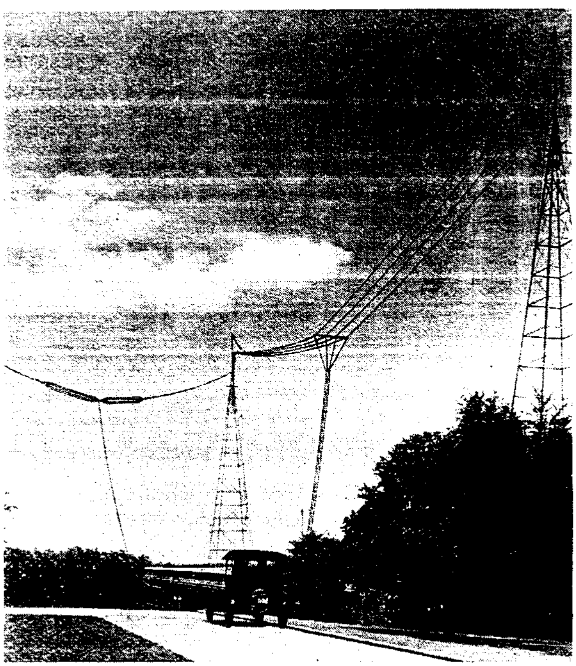

Fig. 2

A Radiating System That Would Make Almost Any Ham Jealous. WWV Uses The Large Antenna for Transmitting The Longer Waves of Their Standard Wave Transmissions and the Small Antenna for the Short Waves.

On the upper shelf is mounted the master-oscillator, modulator and speech amplifier tubes and their associated tuning and other apparatus. On the bottom of this shelf on the left side of the frame is mounted the variable condenser that is used in coupling the master-oscillator to the grids of the amplifier tubes. The next shelf carries the amplifier tubes with their separate plate fuses and grid choke coils. Under these tubes on the next shelf are mounted the antenna tuning condensers and one of the antenna inductors. The bottom shelf holds the filament lighting transformer, amplifier grid battery, the modulator and speech amplifier grid batteries. On the floor directly under the set is a large condenser which is used in the antenna circuit, between the set and the ground, to prevent grounding the direct - current high voltage supply when the ground connection is used. The two large inductors in the rear of the set are used to load the antenna circuit when transmitting on the low frequencies and the small spiral inductor is used as the antenna inductance for the extremely high frequencies. On the panel are mounted all the tuning controls and indicating instruments except the antenna ammeter which is mounted on the rear of the frame.

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The general arrangement of the antennas used is shown in Fig. 2. The large flat top T antenna which is supported between the two towers is approximately 120 feet high and 200 feet long, and is insulaed with molded composition insulators. Its natural frequency is approximately 750 kilocycles. The smaller T cage antenna which is supported between one of the towers and a mast on an adjacent building is 90 feet high and 80 feet long and is insulated at each end with five 4-inch porcelain insulators in series. The horizontal portion is a 6-wire cage, 24 inches in diameter, and the down-lead is a 4-wire cage 4 inches in diameter. Its natural frequency

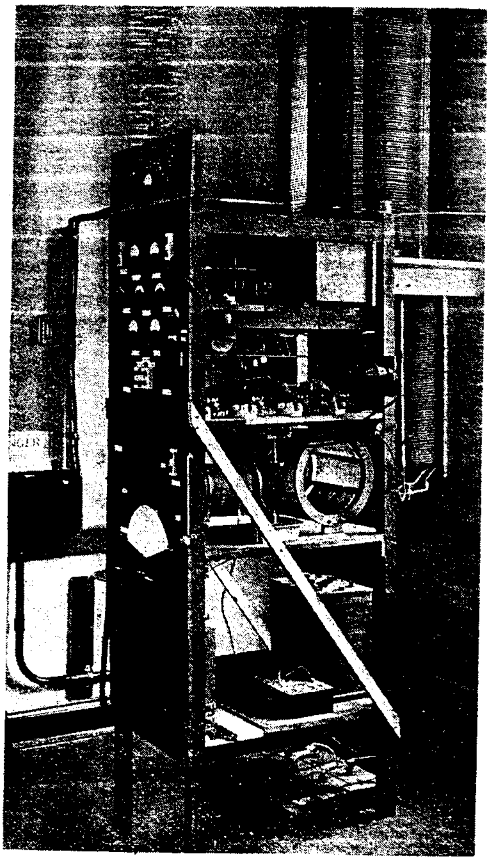

Fig. 1

The 1-KW. Master-Oscillator Power-Amplifier Set At WVV by Which Many Amateur Wavemeters Have Been Calibrated.

when used with the counterpoise is approximately 1325 kilocycles. The counterpoise is about 10 feet above the ground and directly under the small cage antenna. It is made of six wires 120 feet long and spaced six feet apart. It is supported at six points and is insulated with porcelain insulators. The two antenna leads and the counterpoise lead are brought into the operating room through holes in a plate glass window. A ground connection consisting of approximately 1000 feet of No. 4 copper wire buried six inches in the ground directly under the small antenna in a rectangle approximately 150 feet long and 50 feet wide is also available.

When transmitting on frequencies from 150 to 300 kilocycles the large antenna is used together with the counterpoise and ground connected in parallel. No attempt is made to tune the counterpoise when used with the ground connection. For frequencies from 400 to 2000 kilocycles the small cage antenna is used with the counterpoise, in which case the latter becomes a part of the tuned antenna circuit.

The circuit diagram of the transmitting set is given in Fig. 3. The master-oscillator which is shown in the center of the diagram employs a 50-watt tube in a Hartley circuit made up of the inductance L_4 and the capacity C_4. The indicator L_4 consists of 30 turns of ¼ inch edgewise wound copper ribbon on a form 9 inches long and 12 inches in diameter. The condenser C_4 has a capacity of 0.0003 mf and is used for frequencies from 250 to 2000 kilocycles. To obtain lower frequencies it is necessary to parallel C_4 with two fixed condensers whose capacities are 0.002 and 0.004 mf.

Series feed is employed in a manner somewhat unusual in a Hartley circuit but quite common in other circuits. By introducing the plate voltage across a condenser in the filament tap the radio-frequency voltage across the choke coil L_7 is reduced to a negligible value. This method as well as any series feed method has the disadvantage that all parts are "alive" with both the radio frequency and the direct currents, and care must be taken while making adjustments with the plate voltage on. To prevent possible damage to the amplifier tubes should condenser C_5 flash over, a large well insulated condenser (about 2.3 μf) is put in series with condenser C_5 to prevent the direct current from the master-oscillator from reaching the grids of the amplifier tubes. The filaments of the "master-oscillator," modulator, and speech amplifier tubes are lighted by direct current from a 21-volt, 12-ampere storage battery.

The power amplifier consists of four 250-watt tubes connected in parallel. Radio-frequency voltage from the master-oscillator circuit L_4C_4 is fed through the condenser C_5 directly to the grids of these tubes. Small choke coils L_6 are used in series with the grids to prevent parasitic oscillations. A negative voltage of about 200 volts is used on the grids of the amplifier tubes. This voltage is obtained partly from dry batteries and partly from the voltage drop across the resistance R_6 in the plate circuit. The use of such high negative voltage on the grids of amplifier tubes causes considerable distortion in the amplifier plate current which results in higher total efficiency but increases the intensity of the harmonics in somewhat greater proportion than it does the output on the fundamental frequency. The amplifiers feed directly into the antenna circuit consisting of the inductors L_8 and L_9 and the condensers C_9 and C_{10}. For frequencies from 1000 to 2000 kc the small spiral inductors mounted on the rear of the transmitting set and the variable condenser C_{10} are used above the natural frequency of the antenna. For frequencies from 400 to 1000 kc the inductor mounted in the transmitting set frame is used and fine adjustment is secured by means of the variable inductor L_9 which is mounted back of the antenna ammeter. A single-pole double-throw switch is provided for placing either the variable inductor L_9 or the variable condenser C_{10} in the antenna circuit. For still lower frequencies the inductors mounted on the wall in the rear of the set are connected in the antenna circuit as loading coils. Series plate feed is employed in the amplifier for much the same reasons as were given in the master-oscillator circuit. The set is keyed by opening the amplifier grid circuit and allowing the amplifier tubes to block. Since the master oscillator circuit is not keyed some current from this circuit passes through capacity between the grids and plates of the amplifier tubes into the antenna. This current causes a weak "back wave" which can be heard for several miles.

For frequencies from 75 to 500 kc, four 250-watt tubes are used in the power amplifier. For frequencies from 500 to 1500, three tubes are used, and from 1500 to 2000 kc, only two tubes are used. On the lower frequencies it is possible to operate four tubes in parallel in the amplifier and obtain outputs corresponding to their ratings, but on the higher frequencies with the circuit arrangement used satisfactory performance is not obtained with more than two amplifier tubes in parallel. In fact the output from two amplifier tubes on frequencies between 1500 and 2000 kilocycles is greater than when three or even four tubes are used.

The high voltage supply to the transmitting set as well as the filament supply are all in grounded iron conduit and hence the capacity between the wires carrying the plate and filament supply to the set and the ground is appreciable. This results in some grounding of the counterpoise through this capacity and introduces considerably more resistance into the antenna circuit. Because of this condition greater output can be obtained on some frequencies by disconnecting the bypass condenser C_9. However if the antenna circuit could be insulated from the set by employing inductive coupling rather than conductive coupling higher efficiency would probably be obtained but it would result in tuning apparatus which for this work would be somewhat cumbersome.

In tuning the transmitting set to any desired frequency the master-oscillator circuit, which has been calibrated and adjusted so that the tube is operating satisfactorily, is set at approximately the desired frequency. The capacity of the coupling condenser C_5 is reduced, the antenna inductance set on the approximate value and low voltage is supplied to the plates of the amplifier tubes. The antenna circuit is then tuned to resonance with the "master-oscillator" circuit by varying either the capacity C_{10} or the inductance L_9 depending on whether the desired frequency is above or below the natural frequency of the antenna. When resonance is reached, it is indicated by a maximum reading of the antenna ammeter A_1, and a minimum reading of the plate ammeter A_2. The capacity of the coupling condenser is increased and full voltage applied to the amplifier tubes. The set is then adjusted for maximum output by varying the amplifier plate inductance and the coupling condenser. Fine adjustments are then made in the tuning by means of a small variable condenser in the master-oscillator circuit and by a small variable inductor in the antenna circuit. When large changes are made in frequency

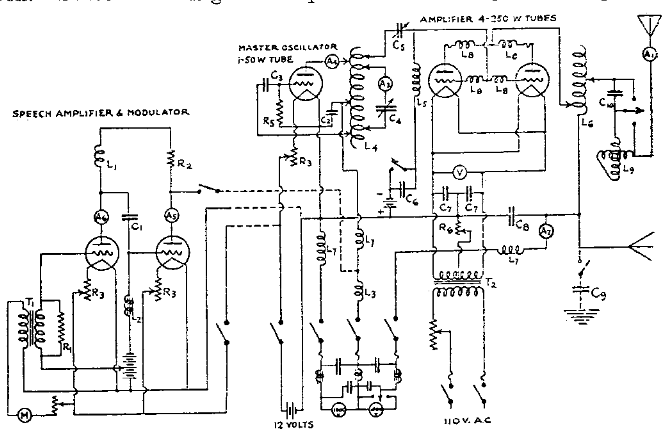

FIG. 3

it is necessary to change the capacity of the coupling condenser C_5. On frequencies from 125 to 500 kc a capacity of approximately 0.001 mf is used; for frequencies from 500 to 1000 kc 0.0006 mf is used, and for frequencies from 1000 to 2000 kc the capacity is reduced as the frequency increases from approximately 0.0006 mf to approximately 0.0003 mf. If this capacity is too large an overload is placed on the master-oscillator which may stop that circuit from oscillating and damage the tube if the plate voltage supply is not quickly disconnected. When making adjustments on low power it has been found desirable to reduce the capacity of the coupling condenser C_5 to about half the normal value since much more power is drawn from the master-oscillator circuit when low voltage is used on the amplifier plates than when high voltage is used.

When telephony is desired the modulator and speech amplifier shown on the left of Fig. 3 are connected in the circuit by means of two switches, one in the plate circuit and the other in the filament circuit. The modulator is a 50-watt tube similar to the "master oscillator" tube. The speech amplifier is a 5-watt tube. In order to secure good upward modulation the set is first adjusted for maximum output and then the output reduced to one-half. If, for example, it was possible to obtain a maximum output of 20 amperes of "carrier" it would be necessary to decrease the amplifier and master-oscillator plate inductance until this output was reduced to 10 amperes to secure good modulation.

The antenna current produced by the set varies from about 8 amperes on 125 kilocycles to a maximum of about 15 amperes on 700 kilocycles . It then decreases to 7 amperes at 1500 kilocycles and to 1.5 amperes at 2000 kc.

A complete frequency calibration of the transmitting set has been made so that the settings may be quickly changed from one frequency to another. Previous to all standard frequency transmissions the set is tried out on all frequencies included in the schedule and the settings checked by means of a standard wavemeter. The primary standard wavemeter is then used during the transmissions as a final check on the settings. It is quite possible by means of fine adjustment controls to set the transmitting set on the desired frequency and measurements with the wavemeter show that the master oscillator keeps the frequency practically constant during the transmission. The small variations in frequency that are noticed can be traced partly to variations in the filament supply voltage which are at times as much as from 5 to 10 percent. and partly to the swinging of the antenna. While the frequency variations caused by the swinging of the antenna have been considerably reduced by the use of the master oscillator, they are not eliminated entirely because of the slight coupling that exists between the antenna and master oscillator through the amplifier tube capacities.

The distance range of the set has been satisfactory. During the year in which it has been in operation the Bureau has received reports of its reception from all U. S. radio districts, Canada, Cuba, England and Italy. Most of the reports show that the received signal intensity is greater the higher the frequency.

Department of Commerce,
Washington, D. C.

Canadian Amateurs Get Short Waves Too

JUST one month after our Department of Commerce announced the bands of short waves for amateur use, our Canadian General Manager Russell advises that the Canadian amateurs have been assigned the same bands, until further notice. The Canadians are required to use pure C.W. but loose-coupled transmitters are not required nor do they have to make application to use these waves.

There is no question but that some of the hoggish commercial interests will protest these assignments in both our Countries, yet we must insist that we hams have as much right to experiment down there as they have, which is all they are doing at present. The short waves are valuable, no question about that, but we don't think they should become the exclusive property of some selfish commercial interest, at least not until after they know what they want. The frequency bands are such that there must be some room for amateur work without interference with any commercial work. Last month we mentioned some of the daylight DX on short waves and we have seen a big jump in amateur activity since the quiet hours were abolished on short waves.

—*F.H.S.*

Short Wave Daylight Transcons

Attention, Gang! Get set for some Sunday daylight Transcons on short waves. The dates probably will be November 9th and 16th. You have plenty of time to get ready by then, but get lined up for your best daylight DX and be ready on the 75 and 80 meter band. Details next month.

—*F.H.S.*