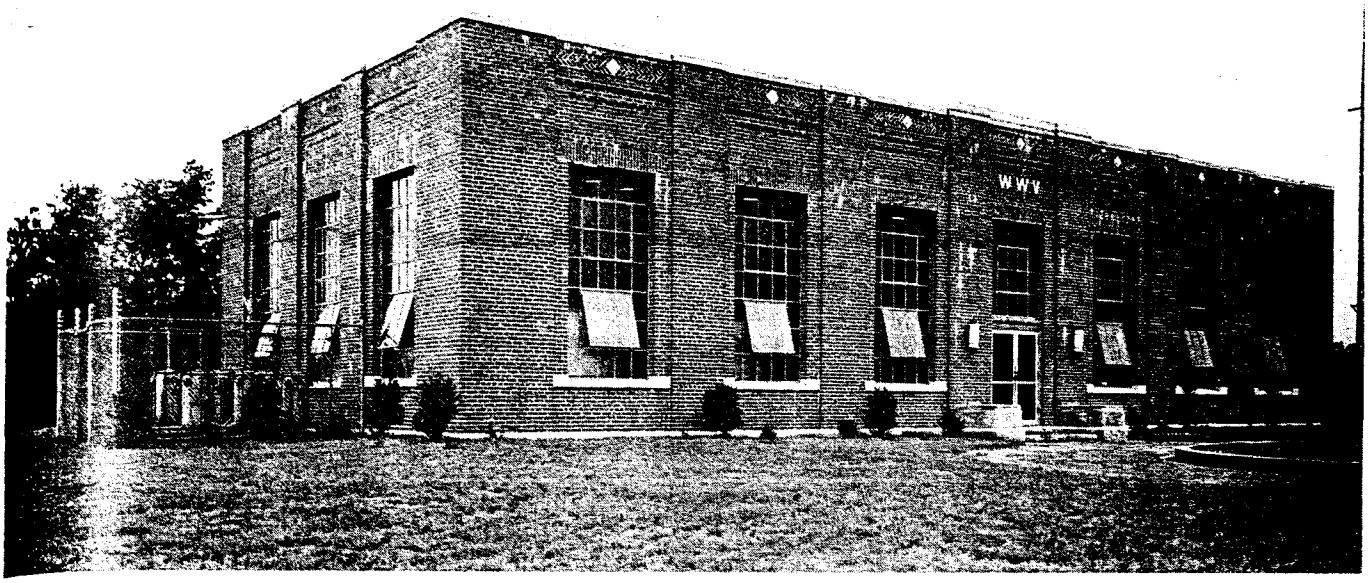

STATION WWV, LOCATED NEAR WASHINGTON, D. C., AND OPERATED BY THE BUREAU OF STANDARDS ON A 24-HOUR SCHEDULE

WWV STANDARD FREQUENCY BROADCASTS

How the Central Radio Propagation Laboratory of the National Bureau of Standards Makes Primary Frequency Standards Available to the Radio Industry

BY W. W. GEORGE*

THE progress of the radio industry in the use of high frequencies, and the crowding of more and more services into the various bands has increased the need for and the use of extremely accurate frequency-measuring equipment. And as tolerances have been steadily decreased, calibrating means of an extremely high order of accuracy have become an essential facility in factories, laboratories, and field installations.

Radio station WWV, operated by the Central Radio Propagation Laboratory of the National Bureau of Standards, at Washington, D. C., provides primary frequency standards for calibration and measurement purposes by the transmission of eight radio frequencies. These are: 2.5, 5, 10, 15, 20, 25, 30, and 35 mc. Seven or more transmitters are on the air at all times, day and night. This insures reliable coverage of the United States, and extensive coverage of other parts of the world.

The accompanying photographs show some of the details of the installation at WWV. The basic component of all the services, with the exception of the radio propagation disturbance warnings, is a quartz crystal unit with a series-resonance frequency of approximately 100,000 cycles per second. Using vacuum-tube circuits, the crystal oscillates continuously, and the resulting frequency is multiplied and divided to give the appropriate frequencies for the five services. Three separate crystal units and associated apparatus are maintained at the station. As the entire service depends upon the maintenance of constant frequency, the crystal units are sealed in painstakingly insulated boxes and kept in a vault approximately 25 ft. below the surface of the earth, under conditions of constant temperature and humidity.

The national standard of frequency, of which the National Bureau of Standards is the custodian, is fundamental to much of the work in radio, electronics, and acoustics, and in other fields where measurements require accurate frequencies. Any desired frequency, including those throughout the microwave region, can be precisely measured, by reference to the standards broadcast by the station, with the aid of one or more auxiliary oscillators, harmonic generators, and radio receivers. The accuracy of each of the transmitted radio and audio frequencies is better than 1 part in 50 million. All the transmitters operate with vertical, nondirectional antennas.

The services provided by WWV transmissions are: 1) standard radio frequencies, 2) time announcements, 3) standard time intervals, 4) standard audio frequencies, 5) standard musical pitch, 440 cycles per second, corresponding to A above middle C, 6) radio propagation disturbance warning notices. All of the frequencies are useful for field-intensity recording by persons interested in studies of radio propagation. The four highest frequencies are broadcast particularly for this purpose. The radio frequencies and other data are:

Mc.	*EST*	*Output Kw.*	*AF*
2.5	7:00 P.M. to 9:00 A.M.	1.	440 cycles
5	7:00 P.M. to 7:00 A.M.	10.	440
5	7:00 A.M. to 7:00 P.M.	10.	440 and 4000
10	continuously	10.	440 and 4000
15	continuously	10.	440 and 4000
20	continuously	0.1	440 and 4000
25	continuously	0.1	440 and 4000
30	continuously	0.1	440
35	continuously	0.1	440

The station call letters and other announcements in voice are given each hour and half hour.

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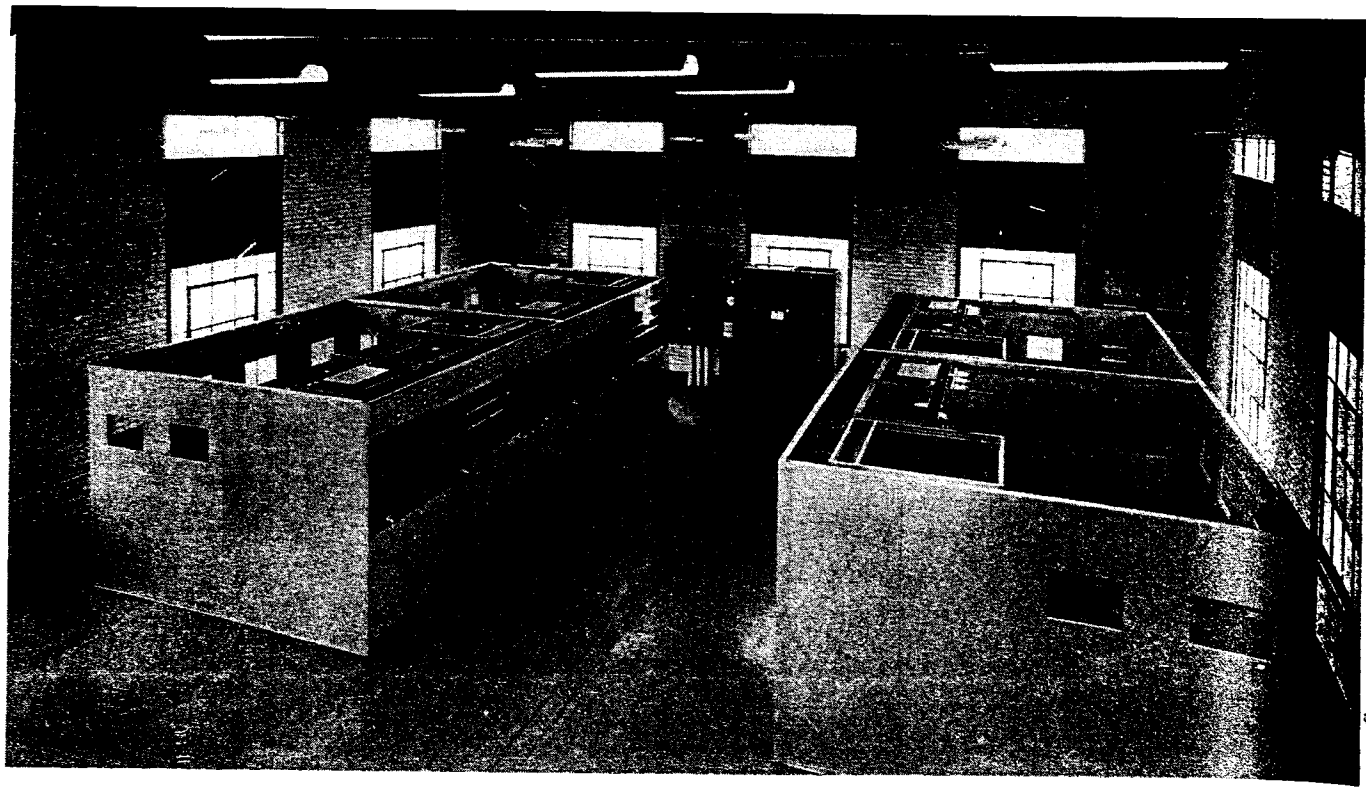


INTERIOR VIEW OF STATION WWV, SHOWING FOUR OF THE TRANSMITTERS FOR BROADCASTING PRIMARY-STANDARD FREQUENCIES

Time Announcements ★ The audio frequencies are interrupted precisely on the hour and each 5 minutes thereafter. Following an interval of precisely 1 minute, they are resumed.

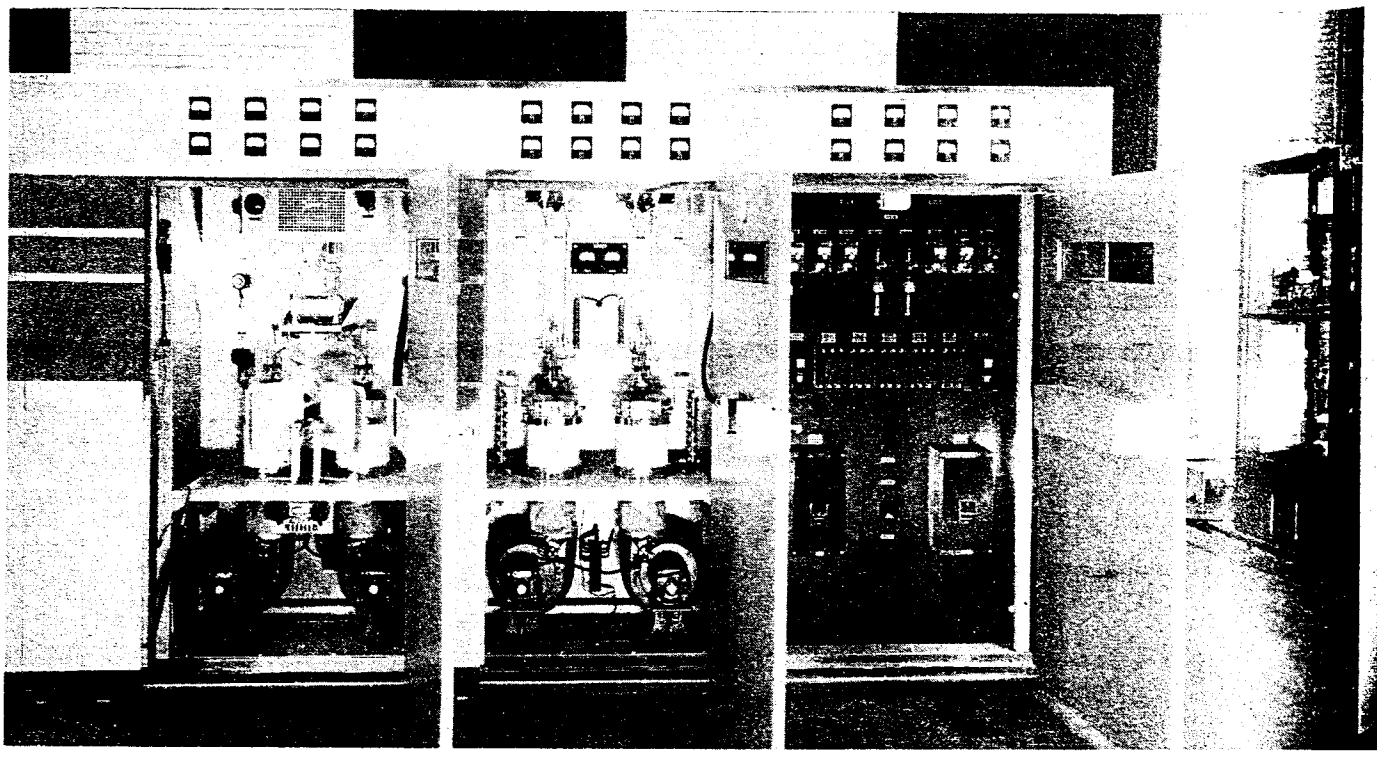
The beginnings of the periods, when the audio frequencies are interrupted, are in agreement with the basic time service of the U. S. Naval Observatory, so that they mark accurately the hour and the successive 5-minute periods.

Eastern standard time is announced in telegraphic code each 5 minutes. This provides a quick reference to correct time where a timepiece may be in error by a few minutes. The 0- to 24-hour system is used, starting with 0000 at midnight. The first two figures give the hour and the last two figures give the number of minutes past the hour. For example, at 4:55 P.M., or 1655 EST, four figures (1, 6, 5, and 5) are broadcast in code. The time announcement refers to the start of an announcement interval, i.e., when the audio frequencies are interrupted. It occurs immediately after the beginning of each 5-minute interval. At the hour and half-hour it is followed by the station announcement in voice.

Standard Time Intervals ★ There is on each carrier frequency a pulse of 0.005 second duration which occurs at intervals of precisely 1 second. The pulse consists of 5 cycles, each of 0.001 second duration, and is heard as a faint tick when listening to the broadcast; it provides a useful standard time interval, for purposes of physical measurements, and for quick and accurate measurement or calibration of timing devices and very low frequency oscillators. It can be used as an accurate time signal. On the 59th second of every minute, the pulse is omitted. The 1-minute, 4-minute, and 5-minute intervals, synchronized with the seconds pulses, are marked by the beginning or ending of the periods when the audio frequencies are off.

A time interval of 1 second marked by the pulse is accurate, as transmitted, to 1 microsecond (0.000001 second). An interval of 2 minutes or more is accurate to 1 part in 50,000,000.

CLOSE-UP OF ONE OF WWV'S TRANSMITTERS THE RF STAGE IS AT THE LEFT, WITH THE AF AMPLIFIER IN THE CENTER SECTION



The 1-minute interval is provided in order to give time and station announcements, and to afford an interval for the checking of radio-frequency measurements free from the presence of the audio frequencies.

Standard Audio Frequencies ★ Two standard audio frequencies, 440 cycles per second and 4,000 cycles per second, are broadcast. They are given on radio carrier frequencies, as shown in the table.

The two standard audio frequencies are useful for accurate measurement or calibration of instruments operating in the audio or supersonic regions of the frequency spectrum. They may also be used for accurate measurement of short time intervals.

The accuracy of the audio frequencies, as transmitted, is better than a part in 50,000,000. Transmission effects in the medium (Doppler effect, etc.) may result at times in slight fluctuations in the audio frequencies as received. The average frequency received is, however, as accurate as that transmitted.

Standard Musical Pitch ★ The frequency of 440 cycles per second is the standard musical pitch, A above middle C. It is broadcast for 4 minutes and interrupted for 1 minute. This sequence is repeated continuously on each of the radio carrier frequencies. This service is useful to musicians and those concerned with the manufacture or maintenance of musical instruments. Since 1925, the standard in the music industry of the U. S. has been 440 cycles.

Radio Propagation Disturbance Warning Notice ★ A warning of radio propagation conditions is broadcast in code on each of the standard radio carrier frequencies at twenty and fifty minutes past the hour. If a warning is in effect, a series of W's, in the telegraphic code, follow the time announcement; if no warning is in effect, a series of N's follows the time announcement.

A warning means that radio propagation disturbance is anticipated within 12 hours, or is in progress, with its most severe effects on radio transmission paths crossing the North Atlantic; i.e., those paths for which the control points of transmission lie in or near the northern auroral zone. Radio propagation disturbance is characterized by low intensities, accompanied by flutter or rapid fading on the normal frequencies used at the different times of the day, or by complete blackout of signals. By shifting to lower-than-normal frequencies for that time of day, it may be possible to get signals through, although with lower-than-normal intensity. Owing to increased auroral-zone absorption during the disturbance, however, it may be impossible to have reliable transmission on any high frequency. Also, during a period of radio propagation disturbance, direction-finder observations may be unreliable.

If no warning is in effect, satisfactory transmission should be possible on the normal frequencies.

The usual daily time for changing the announced warning is 2100 GMT (4 P.M., EST). The warning is, however, issued at any hour when disturbance becomes noticeable or anticipated. The announcement is returned to normal whenever conditions seem quiet. Thus any time a radio operator questions reception on North Atlantic paths, it would be advisable to check with the WWV announcement to see whether conditions are considered by the Bureau sufficiently disturbed to make a warning desirable.

Some one of the frequencies of WWV should be receivable at every location in the United States. Only during very severe storms would reception of WWV within the continental United States be difficult. For some Canadian or other users for whom the transmission path from WWV enters into or near the northern auroral zone, it may be impossible to receive any of the WWV frequencies at usable intensities during even moderate storms. It is probable, if no WWV frequency can be heard at hours when normally audible, that a warning is in effect.

The use of WWV for issuing the Bureau's North Atlantic radio disturbance warning makes the service available to all users of high-frequency receivers. The service should be of use in explaining or anticipating radio propagation conditions existing over North Atlantic States during severe radio propagation disturbances.

The radio disturbance warning does not apply to sudden ionospheric disturbances, which are unpredictable. These occur only at times when at least part of the transmission path is in sunlight. This type of disturbance is characterized by the received intensity dropping to zero, very rapidly, usually within a minute or so, and remaining out from a few minutes to two hours. The effect is greater on the lower high frequencies, and on paths close to the equator or whose control points are close to noon. Usually the only transmission possible during a sudden ionosphere disturbance is by VLF or by ground waves over short paths. The use of the highest frequency available, as long as it is below the maximum usable frequency for the path in question, may shorten the duration of the fadeout. During the next few years, while approaching sunspot maximum, these sudden ionosphere disturbances will increase in intensity and frequency of occurrence. They are caused by eruptions on the sun, more of which are observed during the years around sunspot maximum.

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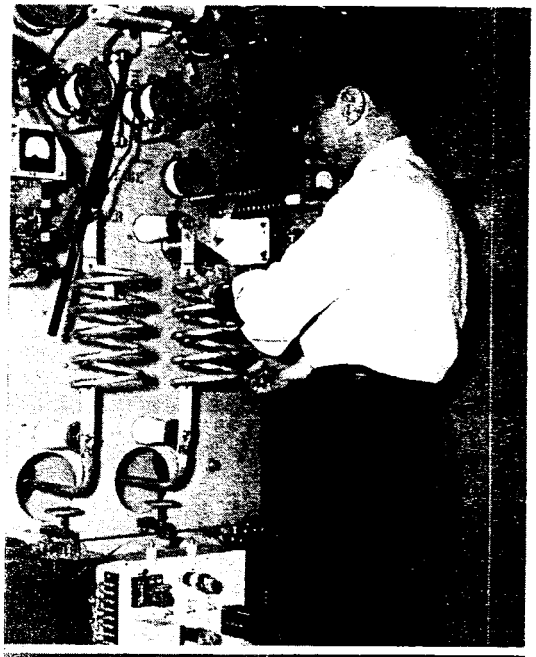
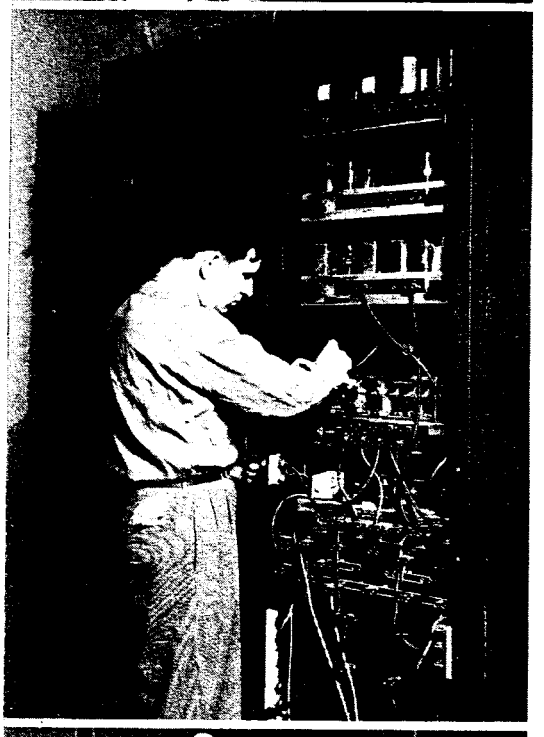
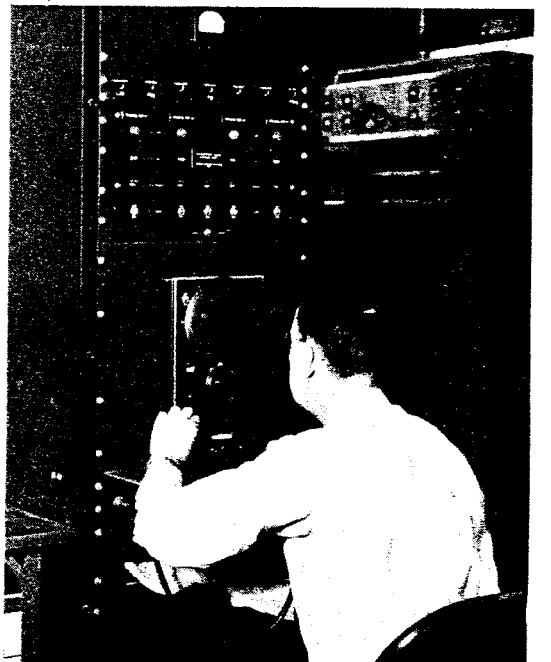






TOP: TRANSMITTER OUTPUT STAGE. CENTER: AF AND TIME-INTERVAL GENERATOR. BOTTOM: CHECKING MODULATION ADJUSTMENT ON OSCILLOSCOPE

WWV BROADCASTS

(CONTINUED FROM PAGE 27)

Distance Range of Reception ★ Of the radio frequencies on the air at a given time, the lowest provides service to short distances, and the highest to great distances. Reliable reception is in general possible at all times throughout the United States and the North Atlantic Ocean, and fair reception throughout the world:

A. By tuning to the different frequencies and selecting the one most suitable at that time. For nighttime conditions over the propagation path, lower frequencies than those used during the day are usually necessary because of skip, but received intensities on those frequencies are much greater than for daytime conditions.

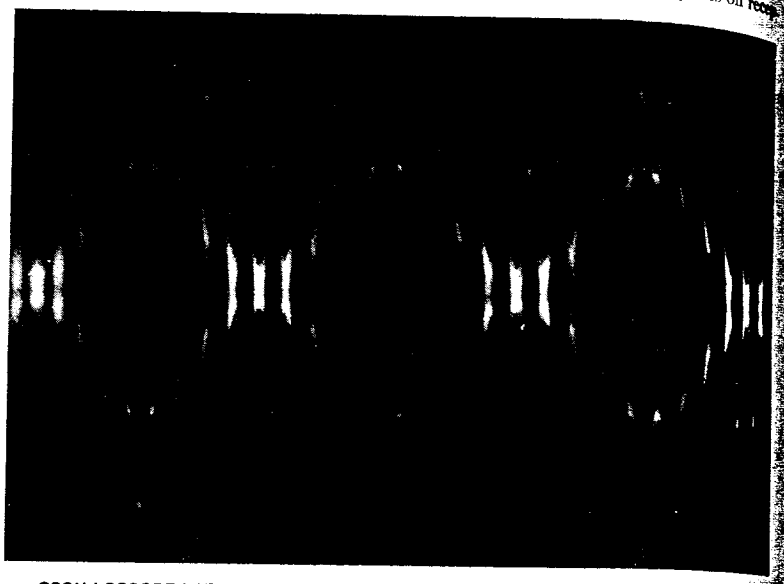
B. By making use of techniques of prediction of usable frequencies.

In spite of the great number of variables affecting radio wave propagation and distance range, techniques exist for the prediction of usable frequencies over any specific path during any future month. By means of such techniques and the Central Radio Propagation Laboratory's forecast service, it is possible for a user to prepare for his locality a graph or table showing the best frequency for any period of the day in any month, three months in advance. Monthly publications giving these techniques and forecasts [1] can be obtained by writing to Central Radio Propagation Laboratory, National Bureau of Standards, Washington 25, D. C.

For continuous 24-hour reception without a break, the use of more than one receiver and antenna is necessary. With skilled operators to anticipate times for frequency shifting, and with schedules prepared as under (B) above as a guide, it may be possible in some cases to operate continuously with two receivers. For maximum certainty of reception, it is necessary to employ as many receivers as there are receivable WWV frequencies at the location, leaving them all in operation continuously and combining their outputs.

The Bureau welcomes reports on reception, methods of use, or special applications of the service, particularly with reference to the higher frequencies which have been added recently. Correspondence should be addressed to: Central Radio Propagation Laboratory, National Bureau of Standards, Washington 25, D. C.

[1] "Basic Radio Propagations Three Months in Advance" available from the Superintendent of Documents, U. S. Government Printing Office, Washington, D. C. 15¢ per copy, or $1.50 per year.



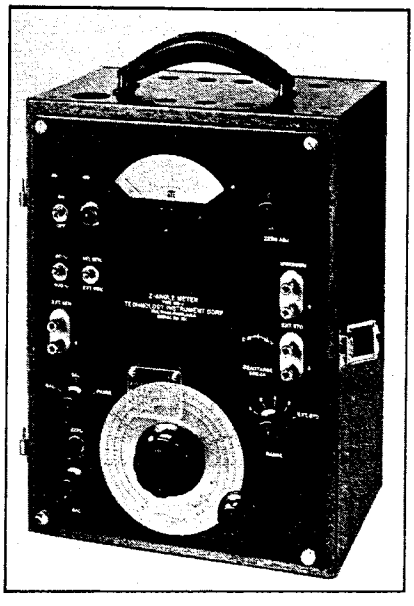
OSCILLOSCOPE VIEW OF 400 AND 4,400 CYCLES AS TRANSMITTED FROM WWV

Z-ANGLE METER

Some surprising discrepancies between calculated and actual characteristics of elements in radio circuits are being disclosed by measurements made with the new z-angle meter. A development of Technology Instrument Corporation, 1058-F Main Street, Waltham, Mass., this instrument is designed to measure the impedance and phase angle, over a range of 30 to 20,000 cycles, of such components as loudspeakers, microphones, transformers, transmission lines, phonograph pickups, and input and output circuits of amplifiers.

Balanced adjustment is accomplished by a single knob carrying a scale calibrated directly in impedance. Phase angle is shown by a direct-reading meter. Supplementary scales are provided on the dial to indicate the dissipation factor D of condensers and the storage coefficient Q of inductors. Also, to indicate whether the phase angle is leading or lagging, a button is provided to cut in an additional condenser. The sign of the phase angle, therefore, is determined by noting the direction of the resultant change in phase angle reading.

The instrument covers .5 to 100,000 ohms impedance in 4 ranges, accurate to ± 1% over the main decade on each scale. As a general-purpose laboratory instrument, the readings cover .5 to 100,000 ohms, 5 microhenries to 500 henries, .001 to 10,000 mfd., as well as Q of .1 to 10 and D of 10 to .1 by direct reading.



Z-ANGLE METER READS IMPEDANCE AND PHASE ANGLE AT 30-20,000 CYCLES

For impedance measurements, a balanced amplifier and VT voltmeter are used to provide a null balance. Only the impedance balance is required to read the value in ohms from the dial. When this balance is obtained, the voltages across the resistance standard and unknown impedance, and across the outputs of the balanced amplifier are equal in magnitude but not in phase. However, when the outputs of the balanced amplifier are switched to parallel connection, the resulting voltage is a direct measure of the phase angle of the unknown impedance. Thus the VT voltmeter can be calibrated in degrees of the phase angle. This also shows Q = Tangent θ, and D = cotangent θ.

EMPLOYEE EDUCATION

During 1947, General Electric will spend $1,000,000 on employee education. One-fourth of this will be used for the Student Engineer or Test Course, in which 3,000 employees are participating. Over 400 others will take the Business Training Course in accounting and business administration. Altogether, 60 courses are conducted throughout the Company's six operating departments.