

(August 30, 1939).

STANDARD FREQUENCIES AND OTHER SERVICES BROADCAST BY  
NATIONAL BUREAU OF STANDARDS.

The National Bureau of Standards broadcasts standard frequencies and other services from its radio station WWV, at Beltsville, Md., near Washington, D.C. The services include: (1) standard radio frequencies, (2) standard time intervals in the form of pulses accurately spaced one second apart, (3) standard audio frequency, (4) standard musical pitch, 440 cycles per second, (5) bulletins of information on the ionosphere and radio transmission conditions. The frequency of 440 cycles per second, and its carrier, a standard 5 megacycles (= 5000 kilocycles = 5 000 000 cycles) per second, are now broadcast continuously day and night.

The standard frequency broadcast service makes generally available the national standard of frequency, which is of value in scientific and other measurements requiring an accurate frequency. Any desired frequency may be measured in terms of any one of the standard frequencies, either audio or radio. This may be done by the aid of harmonics and beats with one or more auxiliary oscillators.

1. Standard Radio Frequencies.

These frequencies are useful to radio transmitting stations for adjusting their transmitters to exact frequency, and to the public generally for calibrating frequency standards.

The standard radio frequencies are broadcast in three different ways. One of these is the 5-megacycle carrier frequency of the 440-cycle standard of musical pitch described in Sec. 4 below. This frequency of 5 megacycles per second is broadcast continuously at all times day and night, with a radiated power of 1 kilowatt. In the middle and western part of the United States this broadcast is receivable at night only. In using this 5-megacycle frequency (or the radio carrier frequencies of the next paragraph), caution is necessary to avoid confusion with the side-frequencies; one way of checking is observation during an announcement interval.

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Another form of broadcast of standard radio frequencies is the broadcast of 5, 10, and 20 megacycles per second as the radio carrier frequencies of the standard audio frequency each Wednesday (except nationally legal holidays) described in Sec. 3 below. These frequencies are broadcast at the same times of day as listed in the next paragraph, with a radiated power of 20 kilowatts.

The third and most convenient form of broadcast of standard radio frequencies is the broadcast of 5, 10, and 20 megacycles per second each Tuesday and Friday (except nationally legal holidays) which are continuous waves (CW), unkeyed and unmodulated, except for a short pulse each second as described in Sec. 2 below. The radiated power is 20 kilowatts. The broadcast is given successively on the three radio carrier frequencies, as follows:

10:00 to 11:30 A.M., EST, 5 megacycles per second.  
Noon to 1:30 P.M., EST, 10 megacycles per second.  
2:00 to 3:30 P.M., EST, 20 megacycles per second.

Of these emissions, those on 5 Mc/s are particularly useful at distances within a few hundred miles from Washington, those on 10 Mc/s are useful for most of the rest of the United States, and those on 20 Mc/s are useful in the western part of the United States and in other parts of the world. (On account of the general lowering of optimum frequencies for long-distance transmission, incident to ionosphere changes in the 11-year sunspot cycle, the 20-megacycle broadcast may be changed to 15 megacycles some time in 1940.)

During the first three and the last three minutes of the 90-minute emission on each radio frequency, announcements are given; they are made both by telegraphic keying and by voice, and include the station call letters (WWV) and a statement of the frequency and the accuracy. The accuracy of the frequencies is at all times better than a part in 10 000 000.

## 2. Standard Time Intervals.

The CW broadcast each Tuesday and Friday, described in Sec. 1 above, carries a short pulse once each second (except during announcements). The pulse lasts 0.005 second and consists of five cycles of 1000-cycle modulation (50%) on the carrier frequency; this type of pulse is more readily receivable by ordinary radio receivers than a unidirectional pulse would be. The length of the intervals thus marked between each second and the next is accurate within 0.000 01 second, as sent out from the transmitter. Measurements of the one-second intervals as received have not been made to this accuracy, but measurements made at one receiving location showed no error within the limits of precision of the measurement, which was about 0.000 03 second. Vagaries

occurring in the transmission medium may cause fluctuations materially greater than this at particular places or times where there is excessive fading (see discussion in Sec. 3 below).

These standard seconds signals constitute in effect a standard frequency of one cycle per second, and are derived from the Bureau's primary standard of frequency which is in turn based upon the standard time service maintained by the U. S. Naval Observatory. They are of special value in physical measurements, in geodetic, seismological, and similar work, in rapid checking of pendulums and chronometer rates, and wherever short time intervals of great accuracy are needed. They are not capable of giving absolute time, as needed in navigation for example, for which astronomical observations or the Navy's time signals are required. The seconds are, however, in consistent sequence from one broadcast to another.

### 3. Standard Audio Frequency.

On each Wednesday (except nationally legal holidays), a frequency of 1000 cycles per second is broadcast as a modulation frequency on the same radio carrier frequencies and at the same times of day as the CW broadcasts, viz:

10:00 to 11:30 A.M., EST, 5 megacycles per second.  
Noon to 1:30 P.M., EST, 10 megacycles per second.  
2:00 to 3:30 P.M., EST, 20 megacycles per second.

The radiated power is approximately 20 kilowatts, with 50% modulation.

The standard frequency of 1000 cycles per second is especially useful in the accurate measurement of audio frequencies and time intervals, calibration of tuning-forks, etc. Except during announcements, the emissions consist of the uninterrupted 1000-cycle frequency superposed on the radio carrier frequency. During the first three and the last three minutes of the 90-minute emission on each radio carrier frequency, announcements are given; they are made both by telegraphic keying and by voice, and include the station call letters (WWV) and a statement of the radio carrier frequency and the audio modulation frequency and the accuracy.

The accuracy of the frequencies (both carrier and modulation) as sent out from the transmitting station is at all times better than a part in 10 000 000. Transmission effects in the medium (Doppler effect, etc.) may result in slight fluctuations in the frequency as received at a particular place. As far as the radio carrier frequencies are concerned, such fluctuations practically never exceed a part in 10 000 000; furthermore, the



presence of the audio modulation frequency does not reduce the accuracy of the radio carrier frequency. Under occasional extreme conditions, momentary fluctuations as great as 1 cycle per second may occur in the audio modulation frequency as received. It is generally possible, however, to use the audio frequency with an accuracy better than a part in a million by employing that one of the three carrier frequencies which has the least fading. It is helpful to use automatic volume control and audio-frequency filters to reduce the effects of fluctuations in amplitude or phase of the received audio frequency.

Measurement of any desired frequency in terms of the received frequency of 1000 cycles per second is facilitated by using an auxiliary oscillator and setting to zero beat between the two fundamentals or two harmonics.

#### 4. Standard Musical Pitch.

The standard pitch in music, 440 cycles per second for A\* above middle C, is broadcast as a modulation frequency on a radio carrier frequency of 5 megacycles per second, continuously day and night at all times except during the short periods of the other 5000-kc broadcasts scheduled in Secs. 1, 3, and 5 hereof.

The station call letters (WWV) are given every ten minutes on the even ten minutes both by voice and by telegraphic keying, so that persons using the service may be sure they are listening to the right station. The radiated power is one kilowatt, with 100% modulation. The accuracy of the 440-cycle standard pitch (and also of the 5,000-kc carrier frequency) as transmitted, is better than a part in 10 000 000 (see Sec. 3 above), which is very far beyond any musical requirements.

#### 5. Ionosphere Bulletin.

Data on the ionosphere and a summary of radio transmission conditions are broadcast each Wednesday afternoon (except nationally legal holidays), the same day on which the 1000-cycle broadcasts are given. The bulletin is given by voice on each of three radio carrier frequencies, as follows:

- 1:30 to 1:35 P.M., EST, 10 megacycles per second.
- 1:40 to 1:45 P.M., EST, 5 megacycles per second.
- 1:50 to 1:55 P.M., EST, 20 megacycles per second.

The broadcast includes statements of the vertical-incidence critical frequencies and virtual heights of the ionosphere layers, maximum usable frequencies for radio transmission, and information on ionosphere disturbances. Values are given for the day

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\*This tone is called A<sub>3</sub> or la<sub>3</sub>.

of the broadcast and the night before. The information is an aid in choosing optimum frequencies for radio communication.

Further information is given in the Bureau's Letter Circular, "Data on Radio Transmission Conditions and the Ionosphere from the National Bureau of Standards."

#### General

Information on how to receive and utilize these various services is given in the Bureau's Letter Circular, "Methods of Using Standard Frequencies Broadcast by Radio", and in the Letter Circular on the ionosphere broadcasts mentioned just above. Either is obtainable on request. The Bureau welcomes reports of methods of use or special applications of these services. Correspondence should be addressed National Bureau of Standards, Washington, D.C.

