

(Replaces Letter Circular No. 565)

Revised to May 1, 1940.

STANDARDS OF FREQUENCY AND MUSICAL PITCH 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. The frequency of 440 cycles per second, and its carrier, a standard 5 megacycles (= 5000 kilocycles = 5 000 000 cycles) per second, are 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.

The services scheduled herein differ from those prior to this date as follows: (a) the frequency of 20 megacycles per second is replaced by 15 megacycles per second; (b) announcements are given by voice only, not by telegraphic keying; (c) the announcements during the musical pitch broadcasting are given every five instead of every ten minutes; (d) the ionosphere bulletins are discontinued.

1. Standard Radio Frequencies.

These frequencies are useful to radio transmitting stations for adjusting their frequency control equipment 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. It is receivable at night throughout the United States, and is receivable in daytime within a few hundred miles of Washington. In using this 5-megacycle frequency, caution is necessary to avoid confusion with the side-frequencies; one way of checking is observation during the announcement interval which occurs every five minutes with the 440 cycles off for one minute.

Another form of broadcast of standard radio frequencies is the broadcast of 5, 10, and 15 megacycles per second as the radio carrier frequencies of the standard audio frequency (1000 cycles per second) 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. In measurements with these carrier frequencies, caution is necessary to avoid confusion with the side-frequencies.

The third, and for some purposes most useful, form of broadcast of standard radio frequencies is the broadcast of 5, 10, and 15 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, 15 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 15 Mc/s are useful in the western part of the United States and in other parts of the world.

During the first two and the last two minutes of the 90-minute emission on each radio frequency, announcements are made by voice; they give 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 always, however, in consistent sequence from one broadcast to another.

### 3. Standard Audio Frequency

The standard musical pitch, 440 cycles per second, serves as a standard audio frequency. However, for some purposes another frequency is more convenient. Therefore, 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, 15 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 two and the last two minutes of

the 90-minute emission on each radio carrier frequency, announcements are made by voice; they give 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 phase or frequency as received at a particular place. The average frequency received is as accurate as that transmitted. As far as the radio carrier frequencies are concerned, the 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 to reduce the effects of fluctuations in amplitude or phase of the received audio frequency, and to use audio-frequency filters to reduce disturbance.

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 and 3 hereof. This broadcast is receivable at night throughout the United States, and is receivable in daytime within a few hundred miles of Washington.

Announcements are made by voice every five minutes, on the hour and each five minutes thereafter; they give the station call letters (WWV) and a statement of the pitch and the radio carrier frequency. 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

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

very far beyond any musical requirements.

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", 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.

Department of Commerce,  
Washington, D.C.

