STANDARD FREQUENCY DISSEMINATION*

By
M. S. STROCK
(Assistant Physicist, Bureau of Standards)

In the radio laboratory of the Bureau of Standards, the term "standard frequency dissemination" designates that phase of the work devoted to making frequency standards widely available. The Bureau does this in a number of ways including the calibration of piezo oscillators and frequency meters, but this paper deals with the standard frequency disseminations through the medium of radio transmission.

The basis of this scheme depends upon the fact that a standard of radio frequency may, neglecting the effects of interference, be transmitted over great distances and reproduced at the receiving station with an accuracy equal to that attainable at the source of the frequency. Hence, if a radio transmitting station is operating on a constant frequency of accurately known value, that station serves as a disseminator of the frequency over an area determined by the effective range of transmission and reception.

The Bureau of Standards has three avenues for this means of standard frequency dissemination. First, standard frequency transmissions; second, selection by actual frequency measurements of certain transmitting stations which are termed "standard frequency stations;" third, the selection of certain "constant frequency stations" which maintain their frequencies close to the licensed values.

The standard frequency signals are transmitted from the Bureau's station WWV and from other stations which are equipped to make the transmissions with accuracy and regularity and which employ frequency standards in agreement with those used at the Bureau of Standards. Announcements of these transmissions are made from time to time in the Radio Service Bulletin, in the newspapers and in

* (Paper presented at a meeting of the American Section of the International Union of Scientific Radio Telegraphy, April 21, 1927.)
*Published by permission of the Director of the National Bureau of Standards of the U. S. Department of Commerce.
Received by the Editor June 27, 1927.

radio magazines. The transmissions from the Bureau of Standards have been maintained approximately once each month since 1922. Prior to October, 1924, the range of frequencies covered was from 125 to 2,000 kilocycles, but since that date this has been extended to 6,000 kilocycles. Evidence of the importance and general use of these transmissions was given by the fact that an announcement of their possible discontinuance in April, 1926, brought many objections from various laboratories.

In cooperation with the transmissions from WWV, similar transmissions were established from station 6XBM at Stanford University, California, in September, 1924. A standard frequency meter was built at the Bureau of Standards, given an initial calibration, and shipped to the University. A final calibration in terms of the Bureau's frequency standard was obtained by means of harmonics based upon a few fundamental frequency values. The values were determined by simultaneous measurements of transmitting stations by observers at the Bureau and Stanford University and from a small frequency meter having a number of fixed points determined in the Bureau's laboratory. The transmissions from 6XBM were terminated in June, 1926.

During the past year and in cooperation with the Bureau of Standards, standard frequency transmissions have been established from station 1XM, Massachusetts Institute of Technology, and from station 9XL, Gold Medal Flour Co., near Minneapolis, Minn. These transmissions cover the higher frequencies of direct value to amateurs.

Recently the accuracy of the standard frequency transmissions from WWV has been somewhat increased. Heretofore the transmission frequencies were determined by reference to primary standard frequency meters having high precision and constancy in calibration. The transmissions are now based upon a single frequency value of a quartz plate used in a piezo oscillator, checked during transmission by a standard frequency meter. A special advantage of the piezo oscillator as compared with the frequency meter is that it is unaffected by any power fluctuations which may occur in the transmitting set, but a change in the transmitted frequency is manifested in the head phones connected to the piezo oscillator by a deviation from zero beat.

The measurements upon standard frequency stations

have been regularly maintained since November, 1923, and the results of these measurements are published monthly in the Department of Commerce Radio Service Bulletin. Only stations sufficiently close to the Bureau of Standards laboratory to be regularly and reliably received are measured. The number of stations that can be listed is necessarily limited. At the present time there are thirteen standard frequency stations, and these lie within the frequency range from 17 to 1,000 kilocycles.

For the measurements of the frequencies of the standard frequency stations the Bureau of Standards now has two completely equipped laboratories. One of these is located at the Bureau, while the other is situated near Kensington, Maryland, in a location which is almost entirely free from interference from electrical machinery and electrical apparatus.

The apparatus for measuring the frequencies of distant transmitting stations comprises a receiving set, a local generator, and a frequency meter. The generator is tuned to zero beat, and it is then exactly reproducing the frequency of the distant station subject to a slight error due to an audible beat in the band of audio frequencies approximately 32 cycles in width. The frequency of the local generator is then measured by means of the frequency meter. In the case of measurements of transmitting stations having frequencies of approximately 25 kilocycles or less, the width of the audio frequency band in the region of zero beat is sufficiently wide to introduce objectionable error in the measurements. To overcome this, a method is employed which involves adjusting the variable condenser of the local generator so that an audible beat of equal pitch is heard each side of the condenser setting corresponding to exact zero beat. A type of variable condenser is employed such that the changes in dial setting are directly proportional to the change in its capacity. The true zero-beat setting of the condenser is therefore located half-way between the settings giving the beat of equal pitch. Another method is to adjust the local generator until the beat produced matches the beat from an audio tuning fork having a frequency of accurately known value.

Improvements in the accuracy with which station frequencies can be measured have recently been made. One of

these improvements is merely a refinement of the original method and involves the use of a frequency meter so constructed as to give high precision. A method of securing increased accuracy in the measurements which is somewhat new in its application is through the use of a heterodyne frequency meter in conjunction with a piezo oscillator. A heterodyne frequency meter is a generator constructed to give high precision and provided with calibration curves plotted to a large scale. In making a station measurement, the zero-beat adjustment is obtained in the same manner as before. The setting of the condenser of the heterodyne meter is then noted and although this is read to a high degree of precision, the frequency corresponding to it is not highly accurate. This is due to the fact that the calibration of the heterodyne meter does not remain constant. A correction for this frequency is obtained by utilizing harmonics from the piezo oscillator and the heterodyne meter. These points are then located upon the curve sheet and determine a new curve of high accuracy which is exactly similar in shape to the corresponding portion of the original curve. The intersection of this new curve with the station setting of the heterodyne meter is the true frequency of the station. The accuracy of this method may be extended to a very high order, the principal limitations being the accuracy of calibration of the piezo oscillator and the effects of temperature and humidity upon this calibration and the scale chosen for the calibration curves of the heterodyne meter.

Since the number of stations upon which frequency measurements can be made is limited, an additional scheme for compiling a list of stations that may serve as standards was adopted by the Bureau. These are the constant frequency stations listed each month in the Radio Service Bulletin, In April the list included approximately 5 per cent of the broadcasting stations in the United States. The selection of these stations depends upon the nature of the transmitting equipment which must not be subject to sudden changes in frequency, upon care and diligence on the part of the station operators, and the use of a special device for determining the station frequency. The special device may be a frequency indicator or a piezo oscillator.

The standard frequency dissemination work herein described is furthered by the issuance of mimeographed publi-

cations on methods of utilizing station frequencies, and apparatus for station frequency regulation. The Letter Circulars, obtainable by request from the Bureau of Standards, are named below.

Letter Circular 171, "Methods and apparatus for measurement of the frequencies of distant radio transmitting stations."

Letter Circular 180, "Specifications for frequency indicator, Bureau of Standards Type B, for use in radio transmitting stations."

Letter Circular 186, "Specifications for portable piezo oscillator, Bureau of Standards Type N."

Letter Circular 214, "Requirements of constant frequency stations."

Letter Circular 223, "Use of the piezo oscillator in radio broadcasting stations."