Radio dissemination of the national standard of frequency †

By J. H. DELLINGER and E. L. HALL*

THE fundamental standard in radio communications is that of frequency. In order that the maximum number of radio messages or programs may be transmitted simultaneously, it is necessary that the frequencies of the radio waves which carry them be maintained very accurately. If the frequency varies, the message or program will interfere with others carried on adjacent frequencies. Therefore accurately maintaining frequency is a basic requirement of all radio operation.

Means must be provided to insure that all stations operate accurately on the same frequency basis. Fortunately, the standard of frequency has the unique property that it can be made widely available by means of radio transmission. Radio waves of which the frequency is carefully controlled and accurately known furnish a standard of frequency which is simultaneously available everywhere that the waves can be received.

To meet this need, the Bureau of Standards has provided a standard frequency service regularly for the past nine years. It has transmitted special waves from its own station, on announced frequencies which have been carefully maintained in terms of the national primary standard of frequency kept by the Bureau. The transmissions are at scheduled times announced and published in advance. Their accuracy has at all times been more than adequate for the needs of radio service. These needs have become more and more rigorous, and the accuracy of the Bureau's standards and of the transmissions has progressively increased. The technique of the transmissions has also improved; the waves actually transmitted are held constant to the same accuracy as that of the primary standard itself, upon which the transmissions are based. The accuracy is better than a part in 5 million, and is being steadily improved.

It is the goal of the Bureau to make these transmissions with adequate power and on suitable frequencies to provide reliable frequency standards at all times everywhere in the United States. The nature of radio wave transmission is such that when this is achieved, a fair service of the same kind will be rendered throughout a large part of the world; and it may be possible eventually to make the service actually reliable and available throughout the whole world. During the present year the transmissions are made every Tuesday for two hours in the afternoon and two hours in the evening. Arrangements have been made to extend this so as to provide the same service every day instead of only one day a week. It is expected that this extended service will be on the air before the end of the year. The program contemplates eventually making the service continuous all day every day. If this goal is achieved a frequency service will then be available at all times and places.

A New Transmitter

At the present time the transmissions are carried on with a transmitter of one-kilowatt power. In the new transmitter about to be installed this will be increased to 30 kilowatts, which should be adequate. The principal transmissions are on a frequency of 5,000 kilocycles per second. They have been received and utilized satisfactorily, practically everywhere in the United States, including the west coast, Alaska, and Canal Zone. They have also been measured in Italy and England. The frequency mentioned is a satisfactory one for night use. It is expected to use 15,000 as well as 5,000 kilocycles for the daytime transmissions. Other frequencies, such as 10,000, 20,000, and 25,000 may be used if found necessary to cover greater distances reliably. Besides the carrier frequencies mentioned, it is expected to have the transmitted waves carry one or more modulation frequencies. The frequencies tentatively in view are 10,000 cycles per second and 60 cycles per second. The former will have a variety of uses for radio and physical purposes. The use of a 60-cycle modulation is discussed further herein.

The physical equipment for transmitting the standard frequencies and insuring their accuracy is in two major parts, a transmitting station and a monitoring station. The transmitting station is at Beltsville, Md., 12 miles northeast of the main radio laboratory of the Bureau of Standards in Washington, D. C. The monitoring station is in the Bureau's main radio laboratory.

The transmitting set is essentially a harmonic amplifier, successive stages multiplying the frequency up from an input frequency of 200 kilocycles. Symmetrical doublet antennas are used. The input frequency is taken directly from the primary frequency standard of the Bureau; i.e., the national standard of frequency. This is done in either of two ways. The primary frequency standard consists of a group of seven piezo oscillators of special design; five of these piezo oscillators are maintained at the main Bureau laboratory, but two of them are at the transmitting station. All of them are intercompared regularly, and the absolute frequency is measured daily; their means constitutes the primary standard. The transmitter frequency can be controlled by any one of them. When one of the piezo oscillators at the transmitting station is used, its frequency (200 kc.) is applied directly to the transmitter input. When one of those at the main Bureau laboratory is used, its frequency is demultiplied to 10 kc. this frequency is carried over a wire line to the transmitting station, and there multiplied up to 200 kc. and applied to the transmitter input. This method of line control has been made practicable by the development of a quartz plate filter to eliminate line noise.

The transmitter was designed particularly for constancy of frequency. Measurements made continuously at the monitoring station during every transmission show that this has been gratifyingly achieved. With the temporary 1-kilowatt transmitter, in use up to the present, the frequency is held steady throughout the whole of each transmission better than a part in ten million; it is furthermore held accurately on the stated frequency within that amount.

The measurements at the monitoring station (12 miles from the transmitting station) have been showing a characteristic difference between afternoon and evening transmissions. The frequency of the received waves at this distance is quite constant during the evening transmissions, but shows variations of one or two parts in ten million during the afternoon transmissions. At this frequency (5000 kc.) and time of day (2 to 4 p.m.) and distance (12 miles), the received waves evidently consist in considerable part of waves returned from the upper atmosphere which vary slightly in frequency because of Doppler effect

† A paper presented at the I. R. E. Convention, April 8, 1932, Pittsburgh, Penna.
* Bureau of Standards, Washington, D. C.

in the ionized upper atmosphere.

The received waves are regularly observed by personnel of the army, the navy, the Department of Commerce radio division, and airways division, as well as operators of non-government transmitting stations and radio laboratories. One of the results of the mass of data thus accumulated is its contribution to our knowledge of radio transmission phenomena. We now have data on the reception of 5000 kilocycles at all distances up to 3000 miles, afternoon and night, for more than a year. This will aid greatly in the planning of future transmission schedules. The 5000 kilocycles now used covers the whole United States reasonably well in the evening transmissions, but gives service over only about 600 miles in the afternoon. The latter situation will doubtless be improved when the power is increased to 30 kilowatts, but as already stated the use of a higher frequency, probably 15,000 kc., is expected to provide wholly satisfactory day service. The regular availability of the transmissions for reception measurements, with a view to increasing the knowledge of wave transmission phenomena, is one of the valuable features of the service.

One of the uses of the transmissions is the maintenance of the frequency standards of the radio supervisors of the radio division, Department of Commerce, all on the same frequency basis. All of the offices of that service regularly observe the standard frequency transmissions, and set their standards to agree with them. Thus the radio enforcement service of the country is placed directly on the national frequency basis.

Wide Use

The standard frequency transmissions are used for the calibration of frequency standards by radio laboratories, manufacturers, and transmitting stations. Their use by transmitting stations will doubtless increase, thus getting the radio stations of the country more and more on a single frequency basis and minimizing radio station interference. At present this is done by periodic checking of the station frequency standard. In time, when the standard frequency service becomes continuous, direct control of the frequency of many stations will be possible. Even under present conditions. the available service is a substantial aid in the approximate synchronization of broadcast stations, elimination of heterodyne interference, and extension of service area.

The accuracy of the standard frequency transmissions is so good that they serve adequately every purpose of time-difference or time-rate standards as well as frequency standards. They are specially convenient for this purpose because they give a standard which is available from instant to instant instead of available only by integrating processes over long intervals (as in the case of time-signals). If it is found useful, a special signal can be put on the standard frequency transmission at prearranged times to indicate a specific summation of a number of cycles, thus facilitating the use of the transmissions as time-duration signals. Jewelers and persons engaged in physical measurements, geodetic, seismological, and similar work, can by the use of simple receiving equipment, receive the signals and utilize them, by means of chronographs, etc., for whatever time-rate or time-duration purposes they desire. The accuracy is far superior to that obtainable with chronographs checked by time signals.

Another purpose served by the transmissions is the furnishing of a convenient means of intercomparison of the principal frequency standards and clocks of the world.

Mention has been made of the plan to have the transmitted waves carry certain modulation frequencies. Tentatively, 10,000 and 60 cycles per second are in view. If some other frequency would be useful, as for example for a television synchronizing frequency, it may be added. The 10,000-cycle modulation frequency may be useful as a basis for radio broadcast station standards.

The 60-cycle modulation frequency has two possible applications to electric power company operations. Electric clocks are now operated from power supply systems in which special means are provided at the power station to correct the frequency from time to time so that the departures (of the order of one-half per cent) of frequency from minute to minute shall integrate to zero and keep the time correct over long periods. The means of introducing the correction from time to time would be facilitated by the availability of the highly accurate 60-cycle frequency provided by our transmissions. The other possible application may be the utilization of the frequency as a master control which would determine the rate of a steadily operating control device in turn amplified and serving as a speed regulator of primary power plants. It is not yet known whether this application can be worked out in practice, but it would be very valuable in the interconnecting of power plants in a network. There would be much greater smoothness of operation when sudden shifts of load take place between power plants if all were of identically the same frequency.

In conclusion, the standard frequency transmissions of the Bureau of Standards have a growing value in the perfecting of radio technique, they furnish a reliable and accurate basis of determining time rates and intervals, and may be of service in power station operation. The accuracy required is already assured. The reliability and availability of the service is being constantly improved. Good progress is being made toward the ultimate goal of making the service available at all times and places.

Acknowledgment

The authors desire to acknowledge the assistance rendered in the development of this project by the many organizations that have cooperated in making measurements, and to the Chesapeake and Potomac Telephone Company, which furnished an experimental line for distant control experiments. Their colleagues in the Bureau of Standards who have been responsible for the success of this work are: L. Mickey and A. D. Martin, development of the transmitting station; V. E. Heaton and E. G. Lapham, development of standard piezo oscillators and monitoring methods; C. G. McIlwraith, A. H. Hodge, and W. D. George, primary standard and line control.

▲

SOURCES OF LIGHT FOR TELEVISION

(*Concluded from page* 16)

Its expected life at 25 ma. d-c. operating current is in excess of 300 hours and at 15 ma. is in excess of 500 hours.

Any coupling arrangement may be used provided that the recommended current ratings are not exceeded.

The characteristics of the Speed crater lamp are as follows:

Cathode spot sizes.....015, .020, .030, .040
Ignition voltage (av.)...170-200 volts d-c.
Operating voltage (av.).....130 volts d-c.
Extinguishing current (approx.).....3 ma.
Maximum operating current.....30 ma.
Recommended operating current..20-25 ma.
D-c. resistance at 25 ma. (approx.) .....5,000 ohms
A-c. current necessary for complete modulation approximately 5 ma. less than d-c. operating current.

▲

CKWO, WINDSOR, CANADA

The twin towers for radio station CKWO, the Windsor station which will be operated by Essex Broadcasters Ltd., were completed in May. These towers are the highest in Canada, rising 200 feet, and are spaced 500 feet apart.

The first part of the construction work on the station, which in addition to broadcasting the finest Canadian programs will carry features of international interest through a hookup with the Columbia Broadcasting System, is completed on schedule and work is progressing with the building, which will be 53 feet across the front and 40 feet deep.