Transatlantic Radio Telephony

By RALPH BOWN

MANY of the technical and scientific features of Transatlantic Radio Telephony have been discussed individually in considerable detail in engineering papers. Furthermore, through the agency of the newspapers much general information has been published regarding the development of commercial telephone service between the old world and the new. Most of this published material either is sketchy in nature or is concentrated upon some detail of the system and it is difficult to gain from it a connected picture of how the final result was built up through several years of continued effort. The following has been written in an attempt to provide such a connected story.

As soon as the successful experiments carried out by the Bell System engineers in 1915 had resulted in the reception of intelligible speech in Paris and Honolulu transmitted from near Washington, D. C., it became a foregone conclusion that sooner or later a serious attempt would be made to bridge the Atlantic Ocean by radio telephone service which would be available to the public at large.

While the 1915 experiments were successful, they also served to emphasize the tremendous difficulties which had to be overcome. The onset of war activities prevented continuing a direct attack on these difficulties but the developments incidental to the wartime use of radio had a profound effect on the instrumentalities necessary to their solution. In particular the development of vacuum tubes for transmitting purposes made considerable progress. Other radio developments carried out immediately subsequent to the war also aided the program.

When transatlantic telephony was taken up again for active consideration, it was obvious that the first requirement was for a transmitting station which would be sufficiently powerful to deliver satisfactory signals on the other side of the ocean. Since the amount of power which would be required to do this was unknown, it was decided to construct a transmitter which was sufficiently large to approach the economic limit of what it seemed it could be worth while to attempt to employ in a commercial undertaking. For this purpose there were available water-cooled vacuum tubes [1] each capable of handling about

[1] "A New Type of High-Power Vacuum Tube," W. Wilson: BELL SYSTEM TECHNICAL JOURNAL, Vol. 1, No. 1, July 1922, pp. 4–17.

10 kw. of power. It was decided that about 20 of these tubes were as many as could be reasonably expected to work satisfactorily in a parallel combination. In order to use these powerful tubes in the most advantageous and economical way, the transmitter was constructed to radiate what is called a single sideband carrier eliminated transmission.

In the ordinary radio telephone transmission such as is used in broadcasting, the radiation sent out consists of a carrier frequency together with two sidebands. The carrier transmits no intelligence but the complete message is transmitted in duplicate since each sideband contains the entire message. By eliminating one of the sidebands and the carrier it is possible to send out the intelligence using only one sideband. If the entire power capacity of the transmitting system is thus concentrated on a single sideband, the power is used several times more effectively.

Since it is more difficult to filter a single sideband away from its carrier and its brother sideband as the frequency becomes higher it was decided to produce the single sideband at a relatively lower frequency as is done in wire carrier telephony and then step it up by a modulation process to the desired position in the frequency range.[2] The voice was therefore modulated upon a 30-kilocycle carrier, and the single sideband produced by passing the modulated result through a band pass filter. This band is then combined in a second modulator with a frequency of 90 kilocycles and the resulting difference frequency, which is a sideband at 60 kilocycles, after passing through another band filter is ready to be amplified to high power for radiation from the antenna. Four preliminary stages of amplification are necessary before the final high power 20-tube amplifier is reached.[3]

When this transmitting apparatus first became available for experimental trial, it was set up at the large radio station at Rocky Point, Long Island, since the experiments were at that time being made in cooperation with the Radio Corporation of America, and the Radio Corporation arranged to lend one of its large and efficient antennas[4] at that station. Subsequently this antenna was leased for use in the final experiments and in giving a commercial service.

[2] "Production of Single Sideband for Transatlantic Radio Telephony," R. A. Heising: *Proceedings of the Institute of Radio Engineers*, Vol. 13, No. 3, June 1925, pp. 291–312.

[3] "Power Amplifiers in Transatlantic Radio Telephony," A. A. Oswald and J. C. Schelleng: *Proceedings of the Institute of Radio Engineers*, Vol. 13, No. 3, June 1925, pp. 313–361.

[4] For a description of this type of antenna known as a multiple tuned antenna see "Transatlantic Radio Communication," E. F. W. Alexanderson: *Proceedings of the American Institute of Electrical Engineers*, Vol. XXXVIII, Part II, 1919, p. 1089.

Simultaneously with the development of this transmitting apparatus, the art of measuring the strength of received radio signals and the amount of static, or radio noise, present at a receiving station had been developed.[5] Therefore in order to try out the effectiveness of the transmitting apparatus, engineers provided with suitable measuring equipment were dispatched to England and set up their apparatus near London. Satisfactory signals were received from the Rocky Point transmitter and in January 1923, it was possible to demonstrate one-way talking across the Atlantic Ocean on a much more satisfactory basis than had previously been possible.

Then there ensued a program of weekly tests wherein signals were sent from Rocky Point each hour for the 24 hours of one day each week and measurements of received signals, radio noise, and intelligibility tests of spoken words were made in England. This one-way telephone circuit was in other words used as a sample whereby the variations to which radio telephony is subject could be explored, catalogued and studied over an extended period of time so estimates could be made of the improvements which would be necessary before anything in the way of reliable communication could be established.

The British General Post Office became so interested in the subject as the result of the initial experiments that they decided to cooperate with the American Company to the fullest extent in determining what the possibilities of transatlantic radio telephony were. They therefore constructed an experimental receiving station and made arrangements to have a transmitter similar in general character to that being used at Rocky Point installed in the new high-powered telegraph station then under construction at Rugby.[6]

The study of transmission initiated in 1923 has been continued to the present time and a large volume of statistical information has been collected.[7] There are two main kinds of variation which have to be contended with. First, the strength of signal changes radically

[5] "Radio Transmission Measurements," Ralph Bown, C. R. Englund and H. T. Friis: *Proceedings of the Institute of Radio Engineers*, Vol. 11, No. 2, April 1923, pp. 115–152.

[6] "The Rugby Radio Station of the British Post Office," E. H. Shaughnessy: *Journal of the Institution of Electrical Engineers*, Vol. 64, June 1926, pp. 683–713. Also "Transatlantic Radio Telephony. Radio Station of the British Post Office at Rugby," E. M. Deloraine: *Electrical Communication*, Vol. 5, July 1926, pp. 3–21.

[7] "Transatlantic Radio Telephony," H. D. Arnold and Lloyd Espenschied: Bell System Technical Journal, Vol. II, No. 4, pp. 116–144, or *Journal of the American Institute of Electrical Engineers*, August 1923. Also "Transatlantic Radio Telephone Transmission," Lloyd Espenschied, C. N. Anderson and Austin Bailey: Bell System Technical Journal, Vol. IV, No. 3, pp. 459–507, or *Proceedings of the Institute of Radio Engineers*, Vol. 14, No. 1, February 1926, pp. 7–56.

with the time of day, being stronger at night. Second, the amount of radio noise present is usually less in the morning and increases towards the evening and well into the night. It is not the absolute strength of the signal which is controlling, but the extent to which it dominates the noise, therefore the ratio between the signal and the noise is the thing which indicates the satisfactoriness with which communication can be carried on. While signal transmission does not change widely between summer and winter, the amount of noise present in the summer time is usually very much greater than that in the winter time, so that the difficulties of communication in the summer are greatly increased.

It soon became apparent that the amount of increase in the signal-to-noise ratio which would be necessary to put conversation on anything like a practical basis would be so great that to hope to get it by increasing the power at the transmitting end was quite out of the question. Thus improvement had to be looked for at the receiving end and the problem became one not of increasing the signal strength, but of decreasing the amount of noise which was allowed to get into the receiving set along with the signal. There are three known ways of decreasing the effect of static in a case of this kind.

Since static is distributed over the entire frequency range, the first and most obvious one is to use such high selectivity that only the signal frequencies are permitted to enter the receiving set. This reduces the amount of static to that which is encompassed by the frequency band occupied by the signal.[8] If suitable band filters are employed it is possible to obtain a degree of selectivity such that practically all static noise which can be eliminated by this method is prevented.

A second method of reducing the amount of static is to employ receiving antenna systems which are directional, in other words, systems which are receptive only to signals coming from the direction of the transmitting station and are blind to interfering signals or interfering static coming from other directions. The most practical system which has so far been developed for doing this at long wave-lengths is the so-called wave antenna.[9] This consists of an open wire line three or four miles long which is grounded at both ends in the characteristic impedance of the wire-to-ground circuit. Thus it is substantially an aperiodic system, there being no reflections at the terminals. Radio waves which approach this line from the side produce relatively very

[8] "Selective Circuits and Static Interference," John R. Carson: BELL SYSTEM TECHNICAL JOURNAL, Vol. IV, No. 2, April 1925, pp. 265–279.

[9] "Wave Antennæ," H. H. Beverage, Chester W. Rice and E. W, Kellogg: *Journal of the American Institute of Electrical Engineers*, Vol. 42, March 1923, pp. 258–269; May 1923, pp. 510–519; and July 1923, pp. 728–738.

small currents in the grounding wires at the terminals. Waves which approach longitudinally build up currents in the line wire as they proceed along it and cause relatively large currents in the grounding wire at the distant end. By building such a line so that it points towards the transmitting station and attaching the receiving set at the end most distant from the transmitter it is possible to obtain a considerable degree of directivity. Further development of this simple basic antenna system is obtained by attaching to it various balancing arrangements. Or by combining several antennas together, it is possible still further to improve the directional characteristics.

In order to determine how much advantage could be obtained by the use of wave antenna systems, the British Post Office constructed one at their receiving station in England and the use of one at Riverhead, L. I. was borrowed by the telephone company from the Radio Corporation of America. Measurements taken over a considerable period of time showed that the signal-to-noise ratio on a good system of combined wave antennas was about ten times as great as that on a simple loop antenna. This was very gratifying since it meant that by the use of wave antennas the transmission would be improved just as much as if the transmitting station power had been multiplied 100 times.

At the receiving end quite aside from the special nature of the directive antenna systems, the amplifying and detecting apparatus must be of a character suited to the amplification and detection of single sideband-carrier eliminated signals. In order to detect signals of this kind it is necessary that a carrier be resupplied to the signal before detection. This is done by means of a local oscillator. Thus the signal actually supplied to the detector differs from the ordinary signals such, for instance, as are used in broadcasting, only by the fact that one of the sidebands is missing. This is of no importance since the complete signal may be detected from the carrier and one of the sidebands. The actual apparatus being used at the American receiving station is similar to the modulating apparatus employed at the transmitting end for producing a single sideband in that the process at the receiving end is substantially reversed. By means of a double detection type receiving set having a beating oscillator frequency of about 90 kc., the 60 kc. incoming sideband is reduced to approximately 30 kc. in the first detection. It is then passed through filters, amplified and has added to it the carrier frequency. The second detection brings it back to voice frequency and after further amplification it is ready to go on to the wire line to the terminal.

A third way in which it is possible to avoid the effects of static is to place the receiving station in a more northerly latitude, bringing the signals down to the business centers by wire. In order to determine the extent to which this was useful, measurements were made at Green Harbor, Mass., and at Belfast, Me., over a considerable period of time. These measurements were made on telegraph signals specially transmitted by the British General Post Office from its telegraph stations. It was found that in Maine the signal-to-noise ratio was, at least during the important hours of the day, something like six or eight times that which was obtained on Long Island. In other words, the improvement was as great as would have been obtained by multiplying the power of the English transmitting station some fifty times. It was therefore decided to build a receiving station equipped with wave antennas at Houlton, Me.

These two improvements, the one in the antenna and the other in its location, taken together comprise an astounding advance in the battle against static. To get the same results by increasing the power of the transmitting station while using older receiving methods it would be necessary to employ transmitting apparatus rated at one million kilowatts, a power which is obviously far beyond either the technical or economic possibilities.

The British Post Office, having in mind that all Great Britain was already more northerly in latitude than Maine, decided to build a temporary receiving station near Wroughton, England, leaving the question of a more northern location for later experiments.

On both sides of the Atlantic, suitable wire circuits had been arranged to tie the transmitting and receiving stations, to terminal points in New York and London. There were then available early in 1926 the means whereby a complete channel could be set up from New York to London and one from London to New York. These two channels were operated on different radio frequencies, the American transmitter sending on 57 kc. while the British transmitter sent at about 52 kc.

At this point, with the major radio problems if not solved, at least well in hand, the undertaking became more a telephone toll circuit problem for the time being. The simplest way to connect up a system of this kind is to follow the practice which is employed for long 4-wire telephone circuits. Where the circuit needs to become a 2-wire circuit for termination in an office where it may be switched to subscribers, the outgoing and incoming wires are brought together through a hybrid coil or 3-winding transformer. This well-known device, by means of a balancing arrangement, has the property of directing currents incoming on the receiving leg of the 4-wire circuit into the

2-wire line without permitting them to go into the outgoing leg of the 4-wire circuit. The currents coming from the 2-wire line go into both sides of the 4-wire circuit but travel on the receiving leg only until they meet with a repeater which, being directed against them, prevents further travel. The amount of amplification which can be maintained in such a circuit is dependent upon the effectiveness of the balance maintained between the real 2-wire line and the artificial line or network at the hybrid coil. The transatlantic circuit was set up for initial two-way experiments in accordance with this procedure. Since the east-bound and west-bound channels were on different frequencies, the selectivity of the receiving sets prevented any cross-fire from the local transmitter into the local receiving circuit.

Since it is necessary to deliver signals to the distant receiving station of the maximum possible amplitude in order to maintain a favorable signal-to-noise ratio, it was essential that the transmitters be kept loaded up to full output even though the voice currents coming from the speakers might vary widely due to differences in voices and differences in attenuation of connected 2-wire circuits. This was done by changing the gain in the repeaters, the operation being carried out by a control operator in a manner similar to that employed in broadcasting stations. In order to maintain the overall gain around the circuit constant to avoid singing difficulties, it was necessary to change the amplification at the receiving end in such a manner as to compensate for changes at the transmitting end.

Experimental operation of the system on this basis was hindered by the fact that the two frequency bands being employed for the two oppositely directed channels were also being used by a number of radio telegraph stations, some of these being so powerful as to produce interfering signals which very seriously hampered telephone conversation. It was evident that some arrangement must be made to enable the telephone communications to be carried on in frequency bands which were used by them exclusively. The fact that radio telephony inherently requires a wider band for its accomplishment than does radio telegraphy made it desirable to use every device available to narrow the band occupied in order to reduce to a minimum the necessary displacement of existing telegraph services. The employment of single sideband carrier eliminated transmission had already cut in half the frequency space required over that which would be needed if the ordinary form of modulated transmission were used. In order to cut down still further the width of frequency band occupied it was decided to attempt to operate both the east-bound and the west-bound channels on exactly the same frequency band. If this could be done the entire system would utilize only about 3000 cycles.

In this sort of arrangement, it is evident at once that selectivity at the receiving station is of no further avail in preventing interference from the local transmitter and that unless means are provided greatly to reduce this crossfire or to set up the circuit in some fashion so that it is harmless, the local circuit from transmitter to receiver with return by wire will be in a singing condition, since it is not practicable to obtain at the hybrid coil anything like a sufficient balance to prevent this.

It was found that with the American receiver in Maine some 500 miles from the transmitting station, the local signals were so reduced by distance that the further reduction which could be obtained by virtue of the antenna directional characteristics was sufficient to permit operation. At the English end, however, due to the proximity of the receiving station to the transmitting station, this so-called "radio balance" method of operating could not be employed. This difficulty had been foreseen and there had been developed a switching device based upon certain similar switching devices called echo suppressors which are employed in long toll circuits.[10] The function of this apparatus was in part to supplement the hybrid coil in its office of preventing received signals from getting into the transmitting line. The arrangement is one in which switching means are employed alternately to disable the transmitting or receiving side of the radio circuit automatically in response to the voice currents produced by the speakers at the two ends. Each end of the system was provided with a device of this character operating on substantially the same principles. Briefly, the functioning of the device is as follows:

When no one is speaking on the circuit the transmitting voice paths are blocked at both the New York and London ends of the system but the receiving paths are open so that incoming radio signals pass freely through to the ears of the subscribers. When a speaker, for instance, in America, speaks, his voice currents actuate the device to block off his receiving path and to open his transmitting path so that his voice goes out. Since the other end of the circuit is in a receiving condition, the voice currents travel through the entire system to the listener's ear. When the American speaker has finished, his apparatus is automatically restored to the receiving condition and the British speaker is, by the functioning of the apparatus in London, able to

[10] "Echo Suppressors for Long Telephone Circuits". A. B. Clark and R. C. Mathes: *Journal of the American Institute of Electrical Engineers*, Vol. XLIV, June 1925, pp. 618–626. Also "Telephone Repeaters," C. Robinson and R. M. Chamney: *The Electrician*, December 12, 1924, pp. 665–667.

speak through the circuit. Certain interlocking arrangements are provided so that the voice of only one speaker can go through the entire system at one moment. In this way, the two speakers are prevented from talking simultaneously without either one hearing the other. In addition to facilitating two-way operation of the radio channels on the same frequency band the voice operated devices have other valuable features.

The difficulties of reducing the transmission to the narrowest possible band having been overcome, it was necessary to find a free band of this width. Negotiations by the British Post Office people with European stations and by the American Telephone and Telegraph Company with United States stations finally resulted in the moving of a sufficient number of stations to open up a free band having its central frequency at 60 kc. and this frequency is being employed in service.

The above description covers substantially the system which is being used at the present time for giving the commercial transatlantic radio telephone service. This service is not as yet free from difficulties due to unsatisfactory performance of the radio portions of the system. Further development work is being pursued in an attempt to improve these matters. On the English side the British Post Office, after having made comparative measurements of signals and noise in various parts of Scotland, has undertaken and now has under construction a new receiving station at Cupar near Dundee, Scotland. This will provide the greater freedom from radio noise which can be obtained by increasing the latitude of the receiving station. At both the receiving ends of the system, improvements are being made in the directive characteristics of the receiving antennas.

So far very little has been said about the operation of the system. At the New York and London terminals where the transmitting and receiving circuits join, there is a considerable amount of apparatus which includes the automatic switching devices, the repeaters with their gain controls, and a variety of measuring apparatus for determining and maintaining the characteristics of the entire system. This apparatus is under the charge of men called technical operators. Two of them, one in New York and the other in London, have the duty of maintaining the best possible transmission conditions on the system by making the most favorable adjustments. The local transmitting and receiving stations are under their charge in so far as apparatus adjustments which affect the circuit performance are concerned. Communication between the stations and the terminal is provided by means of order wires.

As the circuit passes out of the realm of the technical operator going towards the wire system of the country, it consists of an ordinary two-wire trunk which goes to an operating position in the long distance office. At each end of the circuit two telephone operators are employed. One of these operators makes contact with the telephone network in her country to make ready connections for attachment to the transatlantic link. The other operator directs her attention to the transatlantic link and to dealings with her correspondent at the other end in the way of passing call information, making the final connections, pulling down the connections when subscribers have finished, and so on. From the subscribers' standpoint a call is made in the same way as any other long distance call. He asks for "long distance," gives the information regarding the person he wishes to reach in England and then awaits the return call from the long distance operator. When the person called has been located and the transatlantic link is available, the subscriber receives a ring and is connected with his correspondent. They talk back and forth in exactly the same manner as they would over any wire toll circuit and except for the possibility of occasional noises on the circuit which are obviously of radio origin it is difficult for them to realize that their voices are crossing the Atlantic by radio.