Rating the Transmission Performance of Telephone Circuits

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This paper discusses the rating of the transmission performance of telephone circuits on the basis of the rate of repetitions in telephone conversations and presents the rating method set up on this basis, which is being adopted in the Bell System for determining and expressing the data for the transmission design of the telephone plant.

A METHOD of rating the transmission performance of telephone circuits is of course an essential in specifying the grades of transmission service to be furnished, in designing, constructing and maintaining telephone systems to provide the desired grades of service economically and in the development of the various elements of the telephone system which affect its transmission. As the art of telephone transmission has developed and greater refinements have become possible and desirable, changes have naturally been made in the methods of specifying and rating transmission performance. Since many such changes have been made in recent years, it seems opportune to discuss the rating of transmission performance and to set forth the rating method which is now being adopted in the Bell System for determining and expressing the data for the transmission design of the plant. In this connection, various methods which have been employed for measuring the transmission performance of telephone circuits will be discussed to indicate their application and also their relation to the new rating method. It is the purpose here to discuss this rating matter primarily from the qualitative standpoint rather than to present in quantitative detail the various relations involved in rating telephone transmission. Obviously, the determination of many of these relations presents sufficient material for separate treatment.

In carrying on a telephone conversation three major functionings are involved, namely, that of the talker in formulating his ideas and uttering words to convey these ideas, that of the telephone circuit in taking the sounds of these words and reproducing them at another point, and, lastly, that of the listener in hearing and recognizing these reproduced sounds and in comprehending the ideas which they are intended to convey. It is evident that all three of these functionings affect the success of the telephone conversation. Since, however, the functionings of the talker and listener are common to both direct and telephone conversations it might seem that the consideration of the transmission

performance of a telephone circuit could be limited to the functioning of the circuit itself. In line with this, there has been some tendency to confine such considerations to relations between the sounds reproduced by the telephone circuit and the sounds impressed upon it. The performances of the talker and listener, however, are materially affected in certain important respects by the telephone circuit, and determinations of the relative merits of the transmission performances of different telephone circuits, must therefore go farther than the performances of the circuits themselves and take account of the combined action of the talker, circuit and listener.

Characteristics of Conversation

In view of this reaction of the telephone circuit on the talker and listener, attention is directed to the pertinent characteristics of their performances in both face-to-face and telephone conversations.

Direct Conversation

In direct or face-to-face conversations both the talker and listener more or less subconsciously adjust their actions in many respects to each other and to their circumstances. The loudness of talking is placed initially at a level which experience has shown to be suitable for the conditions and for the particular listener. If the listener indicates verbally or by his expression that he is understanding easily or with difficulty, some further adjustment may be made in the loudness of talking. Since the talker judges his own talking level largely by the loudness with which he hears his own voice, this level will be a function of the amount of reverberation in the place in which he is talking. Apparently for a wide variation of loudness in the customary talking range, the speaker is not in general conscious of the amount of energy which he is expending. Noise at the place of conversation also plays a part in determining the talking levels since it makes louder talking necessary in order to permit a given degree of understanding on the part of the listener.

Along with an adjustment in talking level, the talker may improve his enunciation if difficulty of understanding is expected or indicated by the listener. There may also be a change in the manner of expressing the ideas in avoiding words which experience has shown are difficult to understand and an idea may be stated in more than one way in order to insure its comprehension. Other adjustments on the part of the talker may be determined by his opinion of the mental acuity of the listener, by the familiarity of the listener with the matter under discussion and by the interest in it. These factors affect the way of ex-

pressing an idea, the kind and number of words used and hence the time taken.

The listener also adjusts himself to the conditions by an amount which is determined somewhat by his interest in the matter under discussion. He may strive to comprehend the transmitted ideas and require few repetitions by the speaker or he may refrain from exerting himself and so tend to evoke greater effort on the part of the talker. At times he may pretend not to understand in order to get confirmation of a statement or to gain time in replying to a question.

In view of these factors and of the normal variations of different talkers and listeners in all these respects, the portion of the questions and statements of conversation which is correctly understood and the time required to interchange certain ideas may vary widely for different conversations even when they are carried on under a fixed set of local conditions. If it were desired to determine a measure of the conversational satisfactoriness of these conditions, in addition to some quantitative method for rating each conversation, there would be required, therefore, observations on a large number of conversations between different people in order to take account of the variables due to the material of conversation, the people, and their abilities and desires to accommodate themselves to the conditions.

Telephone Conversations

In telephone conversations, there are adjustments between talker and listener as is the case in direct conversations, but there are certain definite differences in this regard because of the interposition of the telephone circuit between the participants. Here also, the speaker tends to adjust his talking level to the loudness with which he hears his own voice. In this case, however, he hears his own voice not only through the air path, but also through the "sidetone" of the telephone set, that is, through the electrical path from his own transmitter to his own receiver. When this electrical path is more efficient than the acoustic path, the sidetone will tend to control the talking level. It has been found that varying the sidetone of the set has on the average a definite effect on the talking volume of the speaker, the talking volume being lowered as the efficiency of the sidetone path becomes greater.

In a telephone conversation, there is also a tendency for a person in talking to adjust his volume on the basis of the loudness with which he hears the person at the other end of the circuit. If the voice of the other person comes through weakly, he judges that the connection requires loud talking and acts accordingly. If the listener indicates that

he is not understanding, the talker may talk more loudly or closer to his transmitter, and also make such adjustments in enunciation and in setting forth his ideas as in the case of direct conversation. Also, the loudness of talking may be affected by the room noise at the location of the speaker, which noise incidentally may not reach the listener and so play no part in his reception. Aside from cases where the room noise at the far end is severe enough to be heard over the telephone circuit, the speaker does not have definite knowledge of the room noise at the listener's end and therefore is not in a position to adjust his manner of talking to this condition except in so far as the listener may indicate difficulty in understanding.

In listening, the result is of course dependent upon the position of the receiver with respect to the ear. The local room noise reaches the ear to which the receiver is held both by the path between the ear cap of the receiver and the ear, and also through the sidetone path of his telephone set. Some telephone users have learned that this effect may be reduced by holding the receiver tightly to the ear and by covering the mouthpiece of the transmitter when they are listening.

It is evident that the success of telephone conversations depends not only upon the performance of the telephone but also upon the performances of its users, the material of their conversations, the way in which they talk into the transmitters and hold the receivers to their ears and the room noise conditions. In addition, it is seen that the performance of the telephone affects the performances of the users in such important respects as the loudness of talking, the manner of presenting the ideas and the amount of effort exerted to understand. Also, the effect of the room noise is a function of the circuit characteristics. Furthermore, the reactions of the circuit performance on those of the users are not constant but may vary from person to person and from conversation to conversation. In view of the random nature of these factors, which are beyond the control of those who design and operate the telephone system, the service performance rating of a telephone circuit should be on a basis which takes adequate account of their ranges and combinations in practice. This points to a rating based on a statistical analysis of results obtained under service conditions.

To determine and specify these factors so that it may be known how to duplicate the range of service conditions in laboratory investigations would be a prodigious task. Moreover, the duplication of these conditions under control is bound to introduce a large element of artificiality which would vitiate the results or at least raise serious questions as to their dependability.

The practical solution is to get sufficient data regarding the results obtained over telephone circuits of different performance characteristics

by their normal users in carrying on regular conversations. This requires a suitable quantitative method of rating conversations and observations on a sufficient number of conversations over each circuit condition to be investigated to constitute a reliable sample. This does not mean necessarily that all the practicable circuit conditions have to be observed in this manner but rather that sufficient data be so obtained for the establishment of correlations with performance measurements which are susceptible to laboratory determination. The fundamental point is that service performance ratings need to be based on service results in order to take proper account of all the factors involved.

Transmission Performance of Circuits

The distinction has been made between two kinds of transmission performance of a telephone circuit, namely, that indicated by relations between output and input sounds and that indicated by the results obtained by the users of the telephone in carrying on their conversations under service conditions. Performance indications of the first kind will be referred to as "transmission characteristics" of the circuit. The second kind of performance may be termed "transmission service performance." The distinction between these two kinds of performance is an important one and should be kept clearly in mind.

The output sounds dealt with in transmission characteristics are not only the reproduced sounds which correspond to the input sounds but also the accompanying extraneous sounds which are delivered by the circuit. Also, the output sounds to be investigated cover not only those delivered by the receiver at the far end of the circuit but also those reproduced by the receiver in the station set containing the transmitter energized by the input sounds. The sounds from the near receiver include both those transmitted through the sidetone path of the set and those returned to the sending end by reflection at impedance irregularities in the circuit. Due to the time required for propagation over the circuit these latter sounds may be delayed with respect to the sidetone and hence appear as echoes. Likewise, echo sounds may be delivered at the far receiver.

Transmission characteristics do not in themselves show the service performance as realized by the users of the telephone but are essentially indications of the functioning of the circuit in reproducing sounds. They provide, therefore, a means for investigating and specifying the performance of a telephone circuit without involving many, and in some kinds of transmission characteristics any, of the actions of the talker and the listener in conversation. With the establishment of proper

correlations between transmission service performance and transmission characteristics, these latter can of course be used to indicate service performance.

In addition to specifying any kind or grade of circuit performance on the basis of performance results there is the method, which has had important practical application, of indicating performance in terms of types of instruments and circuits and of the conditions of their use. For example, a statement of the types of transmitters, receivers, station sets and cord circuits and of the length and types of loops and trunk, together with specific conditions of use, provides an indirect specification of a performance. This method, which is extensively used in many fields, may be termed the "instrumentality designation method." An outstanding application of this method in telephone transmission work is the Standard Cable Reference System [1] which was so widely employed to provide a scale of performance. This method has many present applications where physically determined characteristics are unavailable or are difficult of definite determination and specification. Also, the designation of instrumentalities is convenient in many cases because it provides a ready means of specifying a practical combination of various kinds of transmission characteristics. While this method is often expedient practically, taken by itself, it is inherently cumbersome for the development of improved instrumentalities because of the lack of physical indication of the features to be investigated.

Transmission Characteristics

The usefulness to the listener of the speech sounds reproduced over a telephone circuit is a function of their loudness, of their distortion or degree of departure from facsimile reproduction, and the magnitude and character of the extraneous sounds or noise which accompany them. Transmission characteristics are therefore directed primarily to indications of the effects of the circuit and its parts on the reproduction of sounds in these three respects. As already indicated, transmission characteristics are determined not only for the path from transmitter at one end to receiver at the other, but also for the sidetone and echo paths.

Speech sound transmission characteristics, that is, expressions of the relations between impressed and reproduced speech sounds, while they have been extensively used, present some difficulty in quantitative determination and specification because of their complex nature. Also, the human element is involved in the persons used as generators

[1] "Master Reference System for Telephone Transmission," Martin and Gray, *Bell System Technical Journal*, July 1929.

of the speech sounds to be investigated and as observers to give indications of loudness and distortion and of their effects on the recognition of the reproduced sounds. Two outstanding kinds of relations of this type are those given by volume tests and articulation tests, which will be discussed later. It has therefore been of great convenience to take a further step and to study and specify the performance of telephone circuits and their parts in terms of their functioning for single-frequency sounds and currents. In this procedure, this functioning is investigated for a number of different single-frequency sounds and currents, so taken as to cover the range of frequencies transmitted by the circuit. In the single-frequency transmission characteristics, the personal element is eliminated and the measurements are made entirely on a physical basis.

A great deal of attention has been given to the correlation of speech sound and single-frequency transmission characteristics so as to enable the former to be derived from the latter and so extend the application of the type which is more readily susceptible to quantitative determination. Also, use has been made of easily specifiable multi-frequency sounds and currents to permit the physical measurement to approach more nearly speech sound conditions, of phonographic reproduction to reduce the personal factor in the generation of speech sounds for measurement purposes and of meter arrangements to simulate the ear ratings of sounds, particularly from the standpoint of relative loudness.

As a result of the correlation of speech and single frequency characteristics, extensive use has been made of determinations at selected typical single frequencies to check the design, installation and maintenance of lines and other associated circuit elements.

The widely used volume test is essentially a means of specifying the action of a telephone circuit or its parts, on the relation between the reproduced and impressed sounds from the standpoint of their relative loudness. In this test use has been made for many years of the Standard Cable Reference System and recently of the Master Reference System for Telephone Transmission [2] as references for comparison. These reference circuits with their adjustable trunks provide a means of obtaining different loudness ratios between input and output sounds. By talking alternately over the reference circuit and the one being investigated and adjusting the trunk of the reference system until the output sounds of the two circuits are judged to be equally loud, a specification of the loudness reproduction ratio is obtained of the circuit under investigation in terms of the length of the trunk in the reference system. The effect of a change in the

[2] See Reference (1).

telephone circuit, such as the replacement of one receiver by another, is measured in terms of the change required in the reference trunk to give a loudness balance for the second condition. In this way, measurements are also obtained of the effect on the loudness reproduction ratio of the various parts of telephone circuits. When the circuits used commercially consisted of apparatus and lines similar to those in the Standard Cable Reference System and the major controllable factor was the loudness reproduction ratio, such measurements constituted reasonably adequate means for indicating the comparative functioning of circuits and apparatus.

The noise on a telephone circuit may be measured in various ways. The method which has been most generally used is that of comparing it with the controllable output of a fixed source of a complex wave shape and adjusting this output until it and the line noise are judged to have equal interfering effects.

With the availability of circuits and apparatus having widely different distortion effects, the volume ratings became insufficient for indicating the relative performances of commercial circuits. The earliest method used in rating distortion effects was one in which observers listening to transmission over the circuits, gave judgments as to their relative merits. By so comparing various kinds and amounts of distortion, two at a time, relative ratings can be established for placing them in order of merit. This procedure was particularly useful in the early days in working out the designs of transmitters and receivers, especially from the standpoint of the location in the frequency range of their points of maximum response. While such a judgment method has the shortcoming of not providing quantitative ratings it has been found that experienced observers can in general obtain results which are relatively consistent with the results of more definite measuring methods. Such judgment comparisons of distortion effects are frequently used, particularly in exploratory work, and are still more or less necessarily relied upon in setting limitations on circuit properties which primarily affect the naturalness of reproduction.

To provide for the need of a method for measuring the relation between the reproduced and impressed sounds from the standpoint of effects of different kinds of distortion, use has been made of the articulation testing method.[3] In this method, which has been widely used in recent years, lists of syllables, usually meaningless monosyllables, are called over the circuits to be rated and the percentage of syllables correctly understood is taken as a measure of the circuit performance.

[3] "Articulation Testing Methods," Fletcher and Steinberg, *Bell Sys. Tech. Jour.*, Oct., 1929.

This testing method thus offers a means of indicating the distortion effects of circuits in terms of the recognizability of the reproduced sounds of speech. Probably one of its first applications [4] was in determining the cutoff frequency to be used in the design of coil loaded circuits.

The articulation testing method provides, of course, quantitative measures in terms of the recognizability of the reproduced sounds of speech not only of distortion effects, but also of the effects of the loudness of these sounds and of the noise which may accompany them. This method has provided a very powerful tool for investigating the effects of changes in the reproduction characteristics of telephone circuits on the recognition of the reproduced sounds and has been particularly useful in indicating the lines to be followed in reducing causes of distortion in circuits and apparatus and in evaluating the impairment caused by noise on telephone circuits. It has been recognized, however, that while such measurements indicate the capabilities of the circuits in reproducing recognizable speech sounds, they do not in themselves give direct measures of the degree of success which the users of the telephone obtain in conversations where their actions are free from the control which is necessary in articulation testing and where the contextural relation of the words plays such a large part in their recognition. To make the results of this type of testing approach more nearly the conversational results, words and sentences have been used in place of the meaningless syllables but it is evident that even with sentences, the control on the actions of the testers and on the ideas to be communicated presents a condition which is quite different from those of regular conversations.

All these ways of investigating and measuring the performance of telephone circuits in reproducing sounds have useful applications in present day transmission work. Frequently it is convenient to use different methods for the various parts of a circuit in specifying the complete functioning of the circuit in reproducing sounds.

Transmission Service Performance

From the standpoint of the users of the telephone circuit, the transmission performance is measured by the success which they have in carrying on conversations over the circuit. Different degrees of success in this process may be taken as being indicated by the number of failures to understand the ideas transmitted over the telephone and by the amount of effort required on the part of the users to impart and receive these ideas. Service performance is of course affected also by

[4] "Telephonic Intelligibility," Campbell, *Phil. Mag.*, Jan., 1910.

accidental irregularities in circuit conditions such as interruptions and cutoffs, but from the standpoint of transmission design, attention can be concentrated on the results obtained when the circuit is in normal operating condition. Since failures to understand and exertion of effort are experienced also in direct conversations, their occurrence in telephone conversations obviously cannot be entirely ascribed to the functioning of the circuit. Variations in these factors for different types of circuits can, however, be used as a measure of the effect of the differences in the transmission characteristics of these circuits.

The repetitions required in a conversation can be noted but a determination of the effort factor presents difficulties. There is undoubtedly the tendency in carrying on conversations, as in other activities, to exert no more effort than is necessary to obtain what the participants consider to be satisfactory results. This effort, however, will in general be increased as the difficulty of conversing becomes greater and so bears a relation to the increase in repetitions. Also, it is probable that two dissimilar circuits which cause the same rate of repetitions when used for the same service, will, on the average, call for the same amount of effort by their users.

In line with this, the rate of occurrence of repetitions requested by the users of a particular telephone circuit in carrying on their regular telephone conversations can be used as a direct measure of the service performance of the circuit. By determining the repetition rate for a large enough number of different people at the two ends to take account of the variability of their personal characteristics in talking and listening to the telephone and of the conversational material and conditions, a rating can be placed on the service afforded. By making such observations on connections having different transmission characteristics, relative ratings can be established for these various transmission characteristics.

It should be recognized, however, that while the rate of repetitions required can be used for relative ratings of the transmission service performance of different circuits, such ratings in themselves do not give a complete picture of the service from the users' standpoint because they do not show directly the amount of effort required. Some idea of the effort exerted can be formed by the observers who are noting the repetitions but this cannot be quantitative. In addition to the repetition rate and effort there is undoubtedly another factor which affects the users' opinion of the service. In conversing over a circuit having a poor transmission performance, annoyance or irritation may be felt by the users because the amount of effort required may be considered by them to be unreasonable. These factors, by their smallness or large-

ness, may lead the users in the course of their conversations to make favorable or adverse comments regarding the circuit performance. These comments can be noted by the repetition observers and used, together with any notations on effort and annoyance, to supplement the repetition rating in arriving at a better picture of the service.

Effective Transmission Ratings for Plant Design

To provide for the transmission design of the telephone plant along the lines of the previous discussion, ratings, termed "effective transmission" ratings, are being determined which are based on the repetition rate in normal conversations. Circuits of different transmission characteristics are considered to have the same effective transmission if their repetition rates are equal when they are used for the same kind of service. Furthermore, two changes in the transmission characteristics of a circuit are taken as equivalent on the same basis. The effects of such changes, however, are a function of the initial transmission characteristics and it is therefore desirable to take as a basis for rating such changes, a circuit which has characteristics typical in the various respects of the ranges encountered in practice.

As a standard reference circuit for determining an expressing effective transmission ratings, it is proposed to use a modification of the Master Reference System, inserting in this certain amounts of distortion, sidetone and noise to give it transmission characteristics comparable to those of present commercial circuits. Pending the development of this standard reference circuit, however, use will be made of a circuit consisting of station sets and instruments of kinds in general use, loops of typical length and construction connected by typical cord circuits to a trunk of specified transmission characteristics. For this latter it is convenient to assume a trunk having a cutoff typical of the loading systems in use and having a frequency characteristic which is flat below the cutoff point. It is also convenient to assume that the attenuation of this trunk can be varied uniformly for all frequencies below the cutoff point. This circuit may also be assumed to deliver at the two ends a typical amount of line noise and to have typical room noise at the terminals. Such a circuit then specifies a complete combination of transmission characteristics which are typical of the telephone plant in commercial use and may be considered as a working reference circuit. The transmission service performance of such a circuit in commercial use can be changed by varying the attenuation of the trunk and this attenuation, expressed in decibels with respect to some reference value, can thus be taken as constituting a scale for expressing different grades of service performance.

Starting with such a circuit, changes can be made in its transmission characteristics such as varying the attenuation of the trunk and its cut-off, varying the length and type of the subscribers' loops, using different types of transmitters and receivers in order to get different efficiencies and kinds of distortion and changing the type of station circuit to get different amounts of sidetone. By using circuits of these various characteristics in commercial service and determining the repetition rates obtained, a relation can be established between grade of service and transmission characteristics both for different overall circuit combinations and also for the various changes which can be made in such a circuit. An outstanding advantage of selecting the type of circuit which has been indicated, as a working reference circuit, is that it readily permits direct comparisons of the service performance of the working reference circuit, or of circuits having closely similar characteristics, with the service performances of various types of commercial circuits.

It is desirable to go one step further and to express the effects of changes in various transmission characteristics all in terms of changes in some one characteristic of the circuit. For this latter has been chosen the attenuation of the trunk. In accordance with this, then, the effect of such things as differences or changes in cutoff of the trunk, line noise, room noise, transmitter and receiver volume efficiencies and distortions, sidetone, and, in fact, of any transmission characteristics of any part of the circuit can each be expressed in terms of an equivalent change in the attenuation of the trunk on the basis of equality of effect on service performance. Thus the ratings of all such effects can be placed on a basis which makes them readily comparable. For the practical range of variations in these factors it has been found that in general the effects so expressed can be added together with a good degree of approximation. Where this is not the case, interrelated sets of effective transmission ratings can be supplied to cover the various typical combinations which are likely to be found in practice. This places the application of the ratings given by this method on a comparable basis with the application of the old volume ratings, that is, the assignment of a number to each part of the circuit, which numbers can be combined by algebraic summation in arriving at an overall rating for any particular circuit.

In line with this, the effective transmission of a trunk, for example, is rated in terms of an attenuation loss of so many db plus a rating in db which expresses the effect of the range of frequencies transmitted with respect to some range selected as standard, plus another rating expressed also in db to take account of the noise on this trunk. Simi-

larly, loop loss curves can be drawn up for the combination of instruments, set, loop and cord circuit such as has been used in the past on a volume basis. On the new basis, these curves will include not only the ratings of volume losses but also the ratings for the distortions in the loop and instruments and the effect of the sidetone on transmitting and receiving. In this manner, the transmission design of the plant can be carried out in about the same manner as it has been on the volume rating basis but the effects of distortion, noise and sidetone can all be included in these effective transmission ratings which are based directly on service performance.

This in outline is the method of determining effective transmission ratings which is now being worked to, its method of formulation and its application. The complete discussion and description of these matters involves innumerable details which, as already stated, it is not the purpose to set forth here. From this outline it is seen that this method provides the following outstanding things:

1. A scale for indicating different grades of effective transmission, which scale is expressed in decibels and is directly correlated with service performance by means of a typical circuit selected as a reference. This permits the specification of grades of service.
2. The use of this same scale as a means of assigning to each element of practical telephone circuits an index, expressed in decibels, which measures its contribution to the effective transmission of the circuit, these indices being of such a nature that those corresponding to the elements in a circuit can be combined in a simple way to give an overall performance index for that circuit. Such a system of indices is necessary for plant design.
3. A means of correlating effective transmission service and circuit transmission characteristics. This correlation is advantageous in setting up the indices of (2) and in development and design work in determining the desirability of possible changes in the performance of the various elements.

The selection for the present of the typical practical circuit described above, as a working reference circuit, has two important advantages, which will be restated. First, by using a reference circuit having typical transmission characteristics, the indices established for changes in the various characteristics within the range of practical interest, are directly applicable to the present plant and can be combined in a simple manner to provide an overall circuit index. Second, and by no means of minor importance in the earlier stages of the application of the

rating method here described, by using as a reference a practical circuit, it is possible and practicable to make direct comparisons of the service performance of the reference circuit, or circuits having closely similar characteristics, with the performances of various commercial circuits.

The maintenance of the first advantage will require, however, changes in the working reference circuit as material improvements are made in the transmission characteristics of the commercial circuits. To obtain the second advantage means the use at present of carbon transmitters in the working reference circuit. These are open to the same objection here as they were in the Standard Cable Reference System, namely, the difficulty of exactly specifying their performance raises questions as to the reproducibility of their performance from time to time. This was one of the major reasons for the replacement of the Standard Cable Reference System as the basis for volume ratings by the Master Reference System for Telephone Transmission with its specifiable performance. To preserve the first advantage mentioned and at the same time to obtain a reference system whose reproducibility can be assured, it is the purpose, as more complete correlations are obtained between transmission characteristics and service performance, to associate with the Master Reference System, the means to make its transmission characteristics meet the requirements necessary to retain the first advantage. Meanwhile the Master Reference System will continue its function as a reference for volume ratings.

Determination of Ratings

To provide the basis for such a system of effective transmission ratings as has been outlined, several series of tests have been made, the most comprehensive of which has been under way for more than a year between several hundred stations in the American Telephone and Telegraph Company headquarters building and a similar number of stations of the Bell Telephone Laboratories, between which there is a large amount of intercommunication. The connections between these stations are handled over special trunks in which the attenuation, cutoff frequency and line noise can be varied. At the stations, different types of instruments and station circuits have been employed. Observers are connected to each of these trunks who monitor the conversations over them and note the number of repetitions requested in each conversation and also the duration of the conversation. In this way is determined the repetition rate for a number of conversations between a number of different people for the various combinations of circuit characteristics so provided. Thus ratings are established directly of such effects as those of trunk cutoff, noise on the trunk, different types

of transmitters and receivers and of variation of sidetone in the station set. In addition to the observations of repetitions, measurements are made of the talking levels on the trunks by means of volume indicators to determine the reaction of the circuit performance on talking levels.

An illustration of the results of such observation is given in Fig. 1. The curve shows the variation of the repetition rate with change in trunk attenuation for connections having the same kinds of terminal sets and loops at both ends. This then provides a means of expressing different grades of service performance in terms of trunk attenuation in this circuit.

On this figure is shown also the repetition rate obtained for trunks of two different effective upper cutoff frequencies. The change in trunk

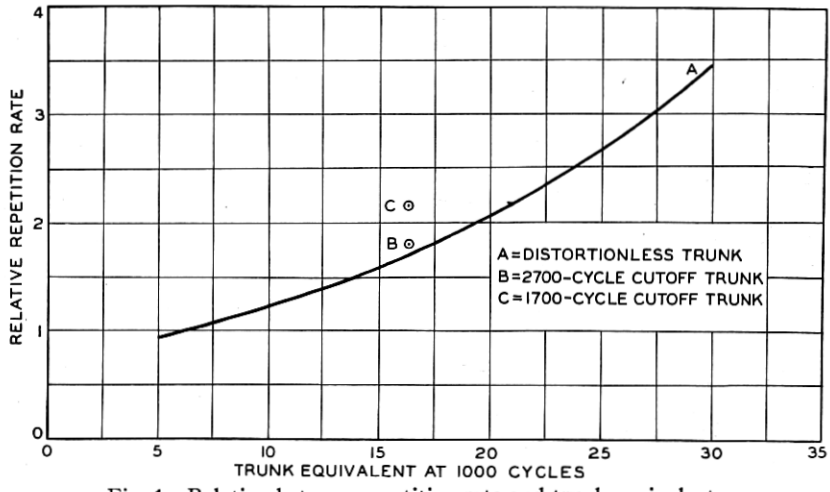

Fig. 1—Relation between repetition rate and trunk equivalent.

attenuation required to produce the same increase in repetition rate as that obtained in going to point C, for example, from the corresponding 1,000-cycle attenuation point on Curve A, is taken as the rating in db of the lower cutoff frequency represented by point C. This rating is about 5 db. The rating of point B with respect to A is obtained in a like manner to be about 1 db and correspondingly the rating of the cut-off frequency of C with respect to B is about 4 db. This illustrates the manner of obtaining effective transmission ratings for any change from the characteristics of the circuit of Curve A.

It is obviously laborious to cover the ranges of all the transmission characteristics of circuits of this kind. The idea is to establish points which will cover the practical range and to use the results of articulation

tests and other similar measurements for interpolating between the points established by the repetition method. In this way it is planned to put the rating of transmission on a basis which indicates the effect on service of changes in the various parts of the circuit.

Conclusion

In concluding, it may be restated that the primary purpose here has been to discuss the rating of the transmission performance of telephone circuits and the method which is being adopted in the Bell System for determining and expressing effective transmission ratings for the design of the plant. The salient features of this method which should be emphasized are the following:

1. In establishing the rating of the transmission performance of a telephone circuit, its performance is taken as that obtained when the circuit forms part of the combination of talker, circuit and listener, where the talker and listener represent the users of the telephone system in commercial service.
2. The ratings of the effective transmission of circuits are based on the rate of repetitions required.
3. The ratings of effective transmission will eventually be referred to a modification of the Master Reference System arranged with typical distortion, sidetone and noise. For a working reference circuit, use is made of a circuit which has transmission characteristics typical of those encountered in service. The trunk of this circuit is taken as adjustable in attenuation for the purpose of providing a scale for specifying different grades of overall transmission performance and also for expressing ratings of the effect on transmission performance of the various transmission characteristics of circuits and their parts.