TRANSMISSION RATING SYSTEM
GENERAL DESCRIPTIVE INFORMATION

1.0 INTRODUCTION

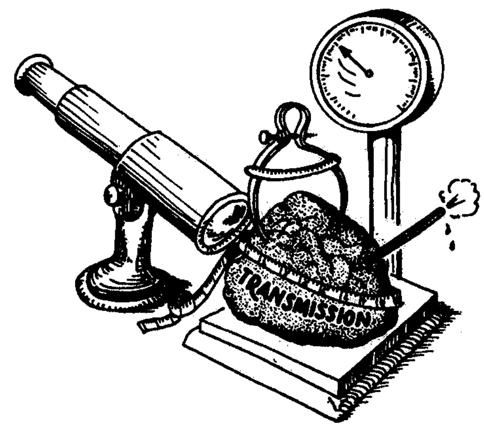
In most of our transmission work we are dealing with electrical measurements or computations. But the trouble is that electrical quantities alone will not tell us how well people can talk over the telephone, because people talk and hear acoustically — not electrically. And, for this reason, before we can tell anything about talking we must have some method of evaluating and measuring the effectiveness with which telephones convert from acoustical quantities to electrical quantities and vice versa.

And this is what any transmission rating system should do.

Because the physical and electrical things which the telephone does are so closely tied in with the reactions of people, and because the units and methods of measurement are usually different in acoustics and electricity, the rating system problem is inherently complex.

Let's look at just a few of these problems:

1. What basis will we use to tell how good a connection is?
2. How will we express the results of whatever method we select—should we use the db scale?
3. How will we take into account such things as sidetone, noise or echo?

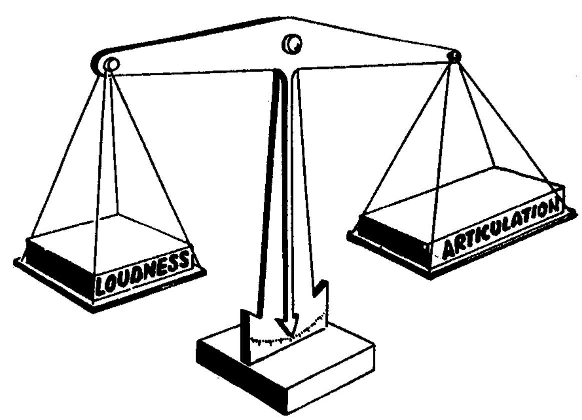


We can easily see that there are many and varied possible ways of setting up a rating system—and all of them have pitfalls. For example:

If we use articulation as the sole criterion, we could pursue it to the point where such things as frequency response and freedom from distortion become so important in our minds that we tend to forget that in order to understand something we must at least hear it.

On the other hand, if we use volume as the sole criterion, we may pursue that path to the point where we may tend to forget that regardless of how loud the sound is, we cannot understand anything unless a sufficiently wide band of frequencies reaches our ear and the sounds are not too badly distorted.

The Bell System has tried several of these, and just for background let's review some of the steps we have gone through.



1. Back in the old days loudness was the criterion. We had so much electrical loss in our circuits that we got all we could out of the transmitters and receivers by taking advantage of the mechanical resonance of the transmitter and receiver diaphragms. Those old instruments were very good at about 1000 cycles but not nearly as good at other frequencies. As a result they did not give a faithful reproduction of the human voice. The surprising thing is that the human ear clamped up against the receiver, plus the human brain, did a pretty good job of supplying the missing frequencies and interpreting the distorted sounds.
2. Then we decided to go to "effective transmission." In this system all of the possible factors—loudness, bandwidth, sidetone, distortion, noise and so forth—were included in one set of db's, and telephones and connections were rated as so many db poorer or better than a so-called reference system.

   But, there were several difficulties with this way of doing things.

   First, this system failed to provide any objective method of measuring the effective loss of a telephone connection; that is, by meters or other physical means.

The telephones used in the reference system soon became obsolete. In time most of the telephones under test outperformed those of the reference system and therefore the effective loss of most sets turned out to be negative. Even the over-all loss of many connections is a negative figure. This is confusing to many people.

Except for a few transmission people most telephone men did not understand the reference system and there was no tie between the figures and their own experience.

3. Now we are back primarily on a loudness basis again, but, we think, on a far sounder basis than before.

One reason why the basis is sounder is that our telephones have more uniformly flat frequency characteristics, and the sidetone and distortion are controlled more uniformly. Therefore, we don't have to worry about differences in these factors so much. And, in those cases where the differences are important, we can take account of impairments that exist due to noise, excessive sidetone, distortion, and so forth, by corrections.

It is this new system that is the subject of this practice.

But let's remember that no rating system can be perfect because no rating system can completely represent human reactions.

The problem, therefore, is to find that rating system which approaches the ideal as closely as practicable, and still remains simple and understandable.

2.0 FACTORS AFFECTING TRANSMISSION

A good rating system should take into account the most important factors that affect how well we can hear and be heard, and understand and be understood.

The factors that control transmission fall into two general categories:

1. Those that we, the people who are responsible for transmission, cannot control.
2. Those that we can control.

Into the first category falls such things as:

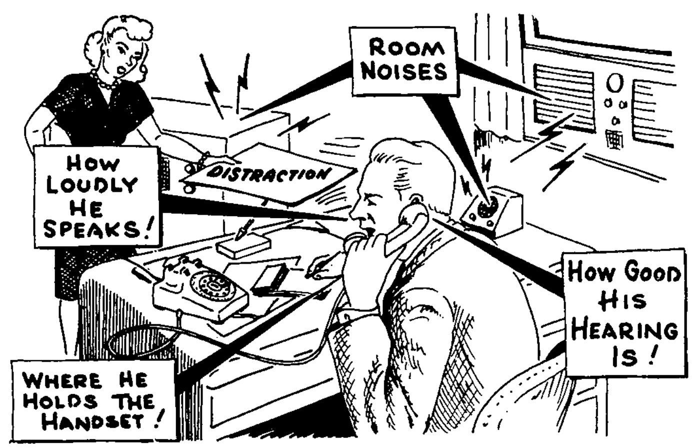
How loudly the talker speaks.

How the talker holds the transmitter with respect to his lips.

The noise conditions at the listener's telephone location.

How good the listener's hearing is and how he reacts to different volumes.

How the listener holds the receiver with respect to his ear.



The fact that we cannot control these things does not mean that we can forget them.

It is up to us to make transmission so good that these factors do not have too much effect on how well our customers can hear and be heard, and understand and be understood.

In this sense these factors that we cannot control are important to us.

Now let's go to the factors that we can control.

Probably the most important factor affecting transmission is volume; our customers cannot understand one another if the output isn't loud enough. For the purpose of our rating system we will say that volume means loudness.

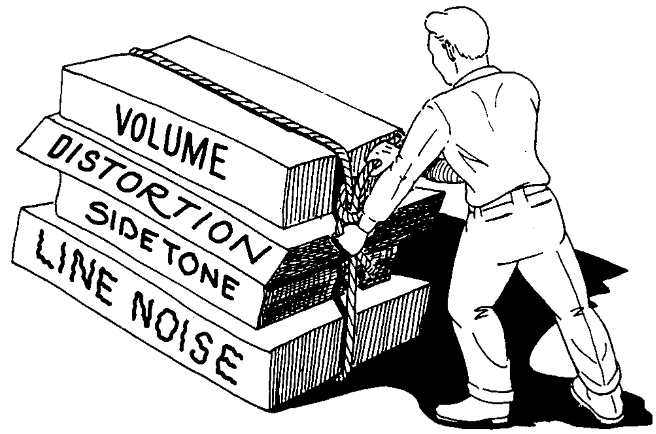
Frequency distortion is another factor.

Average speech is made up of a wide band of frequencies from about 100 cycles per second on up. For purposes of transmission on message circuits we are interested in a band of frequencies from about 200 cps to 3000 or 4000 cps. If we can transmit this band of frequencies as the talker utters them, the output will be a satisfactory reproduction of the speech input for telephone purposes.

However, if some of these frequencies are not transmitted at all or if some are reduced in volume more than others, the output will not sound the same as the input, and we have frequency distortion. Frequency distortion can be so bad that the output is hard to understand.

For example, nonloaded cable will introduce frequency distortion because the loss of nonloaded cable increases with frequency. If a band of frequencies from 200 cps to 3000 cps, and all at the same level, is introduced at the input of a circuit and sent over 10 miles of nonloaded cable, the level of the higher frequencies at the receiving end will be much below the level of the lower frequencies.

If the frequency distortion is bad enough, what you hear at the output will be hard to understand.



Another factor which might give us trouble is sidetone. Sidetone, like the other factors we have mentioned, is a major subject itself.

But for what we are talking about, it is sufficient that we know that sidetone is the sound that reaches our own receiver from our own transmitter.

Too much sidetone will give us trouble while we are talking and may give us trouble while listening.

Too much sidetone while talking, will cause us to unconsciously lower our voice, which is just as bad as adding more loss to the connection.

If we have too much sidetone and we happen to be in a noisy location, our transmitter will pick up the room noise and we will hear it in our own receiver at such a level that it will be difficult to hear the distant talker. In other words, the noise will mask the incoming speech.

Sidetone in modern telephone sets has been lowered to the point where it is pretty satisfactory. If it were to be reduced a lot further, and there were no line noise, the telephone would sound so dead that the subscriber might think it was out of order.

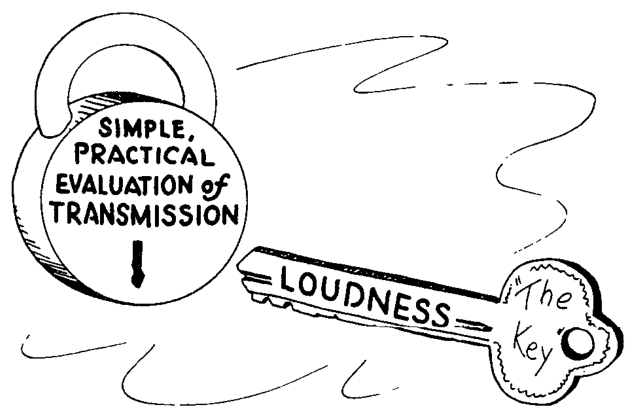
Noise is the final factor we will mention. Noise as it applies to transmission falls into two classes, room noise and line noise. We have already discussed room noise a little but there is one thing we should add. Room noise interferes not only as sidetone, but also as leakage around the receiver cap. Line noise covers such things as power hum, crosstalk, internal noise and contact noise. Both room noise and line noise tend to mask the desired signal, and, therefore, affect transmission.

3.0 LOUDNESS RATING SYSTEM

We have said that loudness or volume is perhaps the most important factor affecting transmission.

So we are going to base our rating system fundamentally on loudness.

The rating which we obtain on this basis will be called the loudness loss.



On the average the other factors that affect transmission have been improved to a point where further improvement will not have significant effect on our ability to hear and be heard and understand and be understood.

For most of our present-day telephone sets sidetone is reasonably satisfactory.

Most of our sets and circuits do a good job of transmitting the band of frequencies we are interested in.

With present equipment and instruments, noise is becoming less of a problem.

This is true on the average. There will, however, be cases when we cannot ignore these factors and they will be of such magnitude that we will have to take a penalty for them. These penalties will be added to the loudness loss to obtain a rating which will be called the subjective loss. The loudness loss will be used as a working measure of field performance and the subjective loss will be used in special cases, such as for design of special service lines.

Loudness is then the major variable that we have to worry about on most calls and is the logical base for the rating system.

Actually we are going to use pressure measurements obtained from simple objective meter readings as an indication of loudness.

To be exact, true loudness is not related in a simple manner to pressure since loudness is actually a subjective rating. In other words, if we use pressure measurements to obtain the ratings of two circuits we will not get a difference between the results that is exactly the same as we would get if we asked a human listener to judge the difference between the two connections.

However — and here we are sacrificing exactness for simplicity — for the purpose of our rating system we can use pressure measurements and they will give us a good approximation of true loudness differences.

The device we use to measure these pressures, modifies the signal through a frequency shaping network so that the indications are related to the loudness that would be heard by a human ear. We will discuss this device in more detail later.

Our rating system, then, is in terms of the ratio of acoustic pressure at the listener's ear to the acoustic pressure at the talker's lips.

When the output pressure from the receiver is less than the pressure at the talker's lips we have a loss. When it is greater we have a negative loss, or in other words, a gain. When they are equal the rating is zero.

However, this does not mean that the loudness of the sound in the receiver is the same as the loudness at the talker's lips, even though both of the pressure measurements are made with the same loudness weighting. This is because the relation between loudness and pressure is different depending on whether the sounds are heard with one ear from a confined source such as a telephone receiver, or with two ears from an open source such as a talker's lips.

It does mean this, however:

If the same talker spoke alternately through two different telephone connections, the difference in pressure measurements (loudness-weighted) at the two receivers is approximately the same as the amount of electrical attenuation which, on the average, human listeners would insert in the louder of the two connections in order to make the two sound equally loud.

The measurements we use are in terms of acoustic pressure. The unit used to express pressure is the bar which is equal to 10^6 dynes per square centimeter. For convenience, since the bar is rather a large unit (about equivalent to atmospheric pressure), acoustic pressure may be expressed in millibars (bar 10^{-3}). We will use millibars in our formulas because it gives us the results we want as far as magnitude is concerned.

The fact that we make our pressure measurements with meters, opens the door to the possibility of obtaining readings in the field as well as in the laboratory. This would permit our new system to be used for maintenance work as well as for design work.

The new rating system will enable us to obtain the ratings of the component parts of a connection as well as the over-all. And we will be able to add up these component ratings to obtain the over-all rating.

We have used acoustic pressure rather than acoustic power for two reasons.

First, acoustic power is very difficult to measure while acoustic pressure is relatively easy to measure.

Second, the human ear seems to be a pressure-sensitive rather than a power-absorbing device. In the same way we may say that a vacuum tube is voltage-operated rather than power-operated.

4.0 OVER-ALL RATING

Now that we have a pretty good idea of what the rating system is, let's see how we use it to obtain the rating of an over-all connection.

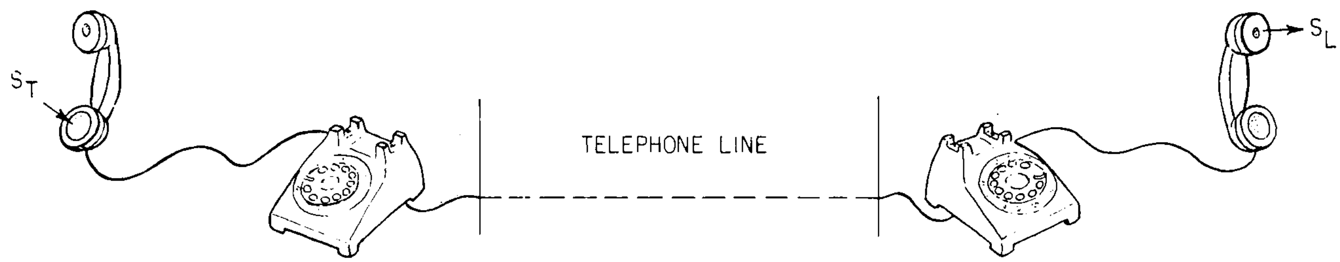


FIG. 1

In Fig. 1 we will call the output pressure in millibars at the ear of the listener S_L, and the input pressure in millibars at the lips of the talker S_T. Keeping in mind that the rating is dependent upon the ratio of the output to the input, we can say that the rating of the over-all connection is a function of the ratio S_L/S_T.

When S_L is equal to S_T we have what we call the "unity pressure ratio" condition, thus:

$$\frac{\text{Output}}{\text{Input}} = 1 = \text{unity pressure ratio}$$

If S_L is less than S_T we have a loss, and if S_L is greater than S_T we have a gain.

Up to now we haven't mentioned the unit that we are going to use in expressing our gains and losses — let's discuss that a little.

We have come to use the db as a measure of transmission, and that is the unit we want to use here. The db is simply an expression of a ratio put into logarithmic form so that we can add and subtract db's rather than multiply and divide ratios.

By this means we can measure each of the parts in an over-all connection in db and add them together to come out with an over-all answer in db.

So, we will express our over-all pressure ratios in db because they are dependent upon the electrical losses in the circuits which are measured in db.

We can say that a given pressure ratio is so many db greater or less than unity ratio.

So getting back to our over-all rating, the over-all loss, R_O, is:

$$R_O = -20 \log_{10} \frac{S_L}{S_T} \text{ db} \tag{1}$$

Although we are going to call the number we get by this formula db, we know that it isn't really a db because it doesn't represent a log of a power ratio. However, a db table, based on current or voltage ratios, will give us the correct numerical values and serves our purpose. For this reason only we call the unit db.

Later in this discusison we will use ratios of acoustic pressure to electrical pressure and we will treat db's in a similarly cavalier manner.

We will say no more about this. We hope that those of you who want to keep the db pure and undefiled are satisfied. The rest of you can forget the whole discussion and go ahead and use a db table based on current or voltage; we can assure you that you won't get into any trouble by doing so.

The talking pressure S_T is measured under free field conditions. The free field condition means that the telephone transmitter is removed from in front of the sound source while the pressure measurement is made. A condenser microphone and a calibrated indicating meter are usually used to measure the acoustic pressure.

After the measurement of S_T has been made, the transmitter is replaced in the modal position* with respect to the sound source. Then the output pressure, S_L, is measured with the receiver coupled to a calibrated condenser microphone by a 6 cubic centimeter coupler which simulates the human ear cavity. The setup for measuring S_L is shown in Fig. 2.

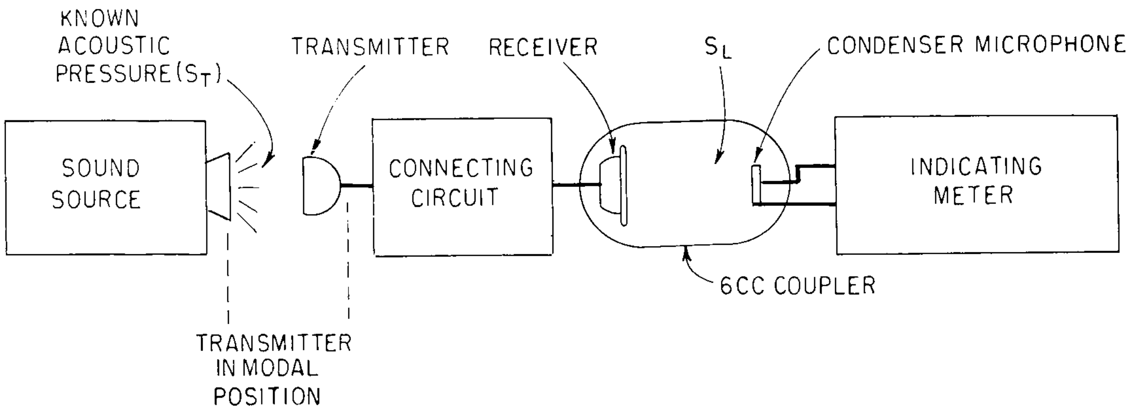
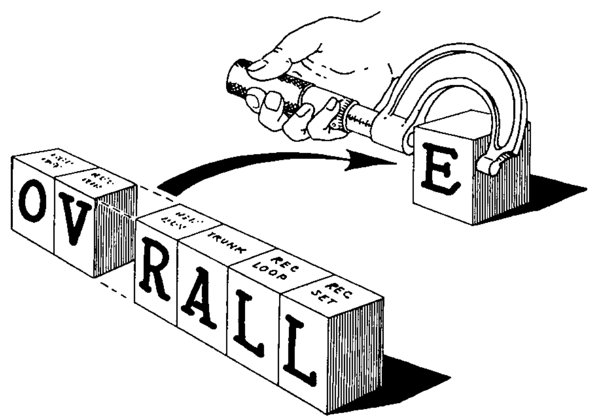


FIG. 2

5.0 COMPONENT RATINGS

We have discussed the over-all connection, but actually a connection consists of numerous things which must, in many cases, be considered individually.



For example:

There is always a loop from each telephone to the central office.

The central offices are interconnected by a trunk.

There is equipment in the central office.

So, in order to have our rating system usable, we must be able to know the loss or gain of each of these things so that we can add them up (in db) to get the over-all loss, and we can break the connection down into three things:

1. The electrical losses or gains of the trunks, the equipment and the loops.
2. The gain or loss of the transmitting telephone set.
3. The gain or loss of the receiving telephone set.

This new rating system does not make any changes in the way we handle electrical losses or gains; i.e., we will continue to handle the losses or gains of trunks and equipment by purely electrical measurements.

But in handling the transmitting and receiving gains or losses of the telephones, we have to work between acoustic and electrical phenomena and we must select methods and quantities which give us answers in terms which can be added to the answers for the strictly electrical parts to give us the right over-all answer, that is:

Transmitting gain or loss

+ electrical gain or loss

+ receiving gain or loss

Must equal over-all gain or loss.

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* The modal position is the same distance and position with respect to the sound source as a transmitter would be when correctly used by a talker whose facial measurements are the average of those of a large number of telephone users.

And in addition, it is desirable (but not essential) that the quantities which express transmitting gain or loss reflect the fact that the transmitter is an amplifying device, i.e., it should indicate a gain.

In reverse fashion, it is desirable (but not essential) that the receiving efficiencies should indicate a loss — at least for current types of receivers, which are not amplifying devices.

We have already selected millibars for acoustic pressures and if we use volts across 900 ohms for electrical pressures, we come out about right on both counts; i.e., the losses or gains of the parts add up right and the quantities accord reasonably well with known facts.

There is one other thing that we should mention before we get into the details of each of the component ratings. In our discussion of the component ratings we will be dealing with voice voltages. We will use V_{TS} to represent the output voltage at the terminals of the set, and V_{TL} the output at the terminals of the loop in the transmitting portion of a connection, and V_W as a measure of the input to the receiving portion. We want to be sure that you understand that these are ac voltages developed by the signal currents and do not refer to the direct currents in the transmitting and receiving sets.

Now we are going on to discuss how we obtain most of the losses and ratings shown in Table 1.

(A) Transmitting Set Rating

We have already expressed the over-all rating, R_O, as:

$$R_O = -20 \log_{10} \frac{S_L}{S_T} \text{ db} \qquad (1)$$

where:

S_L = output pressure at the ear of the listener in millibars.

S_T = input pressure at the lips of the talker in millibars.

We define the transmitting set rating in terms of this same input pressure S_T and the output expressed as the voltage V_{TS} across a 900-ohm pure resistance load at the output of the transmitting set.

The transmitting set rating, R_T, in db is then:

$$R_T = -20 \log_{10} \frac{V_{TS}}{S_T} \text{ db (with dc line current of 100 ma)} \qquad (2)$$

where:

V_{TS} = the voltage across a 900-ohm pure resistance load at the terminals of the set expressed in volts (with dc line current of 100 ma).

S_T = acoustic pressure at the lips of the talker expressed in millibars.

For example:

Suppose we measure S_T and obtain a value of .0158 millibars. This can also be expressed as 15.8 microbars or 15.8 dynes per square centimeter.

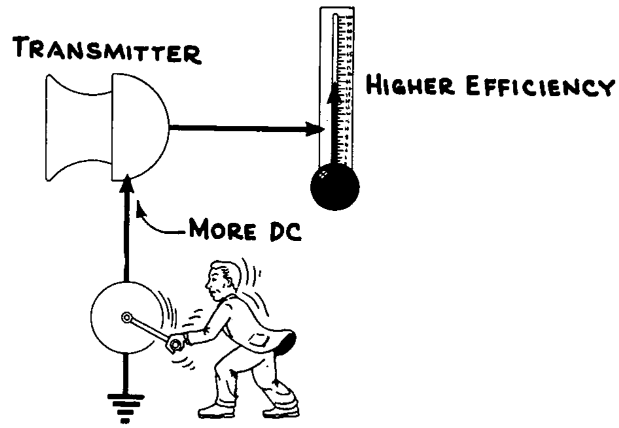
And we measure V_{TS}, with a dc line current of 100 ma, and obtain a value of .448 volts. This can also be expressed as 448 millivolts.

Just remember that if you use millibars for S_T, you must use volts for V_{TL}, and if you use microbars for S_T, you must use millivolts for V_{TL}.

Then, the transmission set rating, R_T, will be:

$$\begin{aligned} R_T &= -20 \log_{10} \frac{V_{TS}}{S_T} \\ &= -20 \log_{10} \frac{.448}{.01582} \\ &= -20 \log_{10} 28.2 \\ &= -20 \times 1.45 \\ R_T &= -29.0 \text{ db} \end{aligned}$$

The transmitting efficiencies of commercial telephone sets vary with the amount of direct current which flows through the transmitter. Because of this, some value of line current must be selected as a standard at which the transmitting set rating is ordinarily specified. Variations in transmitting set ratings with variations of transmitter current from this standard are known as current-supply losses or gains. (We will talk more about current-supply losses and gains later.) A current of 100 ma has been chosen arbitrarily as the standard appropriate for 300- and 500-type sets now in use.



It may be necessary to select other standards appropriate to future types of sets.

The condition for measuring the transmitting set rating in the laboratories is shown in Fig. 3.

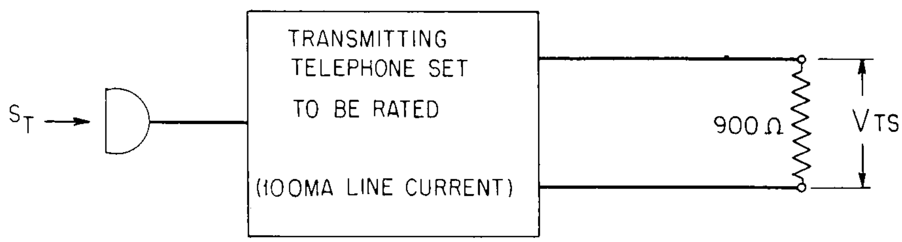


FIG. 3

Again, the measurement of S_T is made under free field conditions. V_{TS} is measured with the transmitter in the modal position with respect to the sound source.

For the moment we won't worry about why we selected the 900-ohm termination — we will discuss it in more detail later.

Because the transmitter unit actually introduces energy in transforming the acoustic signal into an electric signal, we have selected units of measurement which will give a negative numerical value to the transmitting set rating. Thus, we have a negative loss, or, in other words, a gain.

(B) Transmitting Loop Loss

The transmitting loop loss is obtained in a manner similar to that used in obtaining the transmitting set rating.

That is, we measure the input pressure, S_T, the same way we did in rating the set and measure the output across a 900-ohm resistance at the output terminals of the loop rather than at the output terminals of the set.

The transmitting loop loss is the loss of the entire transmitting loop from the acoustic input of the transmitting telephone set to the central office.

This is shown in Fig. 4.

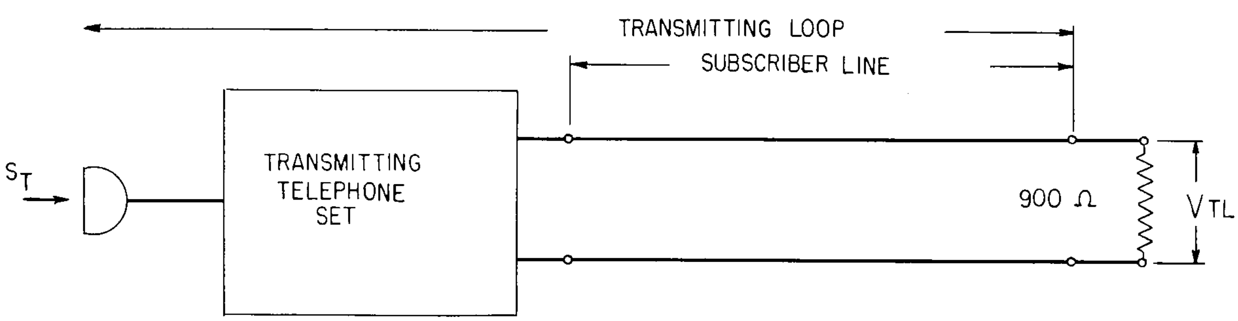


FIG. 4

We can express the transmitting loop loss, L_T, in terms of db as:

$$L_T = -20 \log_{10} \frac{V_{TL}}{S_T} \text{db} \quad (3)$$

where:

V_{TL} = the voltage across a 900-ohm pure resistance load at the central office end of the loop expressed in volts.

S_T = the acoustic pressure at the lips of the talker expressed in millibars.

Any ratio $\frac{V_{TL}}{S_T}$ will be so many db with respect to unity ratio where V_{TL} is numerically equal to S_T.

The measurement of S_T is made under free field conditions. V_{TL} is measured with the transmitter in the modal position with respect to the sound source.

(C) Transmitting Conversion Loss

The transmitting conversion loss is actually the same as the transmitting set rating except that the conversion loss is measured at any value of line current other than 100 ma.

The transmitting conversion loss, C_T, in db is then:

$$C_T = -20 \log_{10} \frac{V_{TS}}{S_T} \text{ db (at operating line current)} \quad (4)$$

where:

V_{TS} = the voltage across a 900-ohm pure resistance load at the terminal of the set in volts (at operating line current).

S_T = acoustic pressure at the lips of the talker in millibars.

(D) Transmitting Current Supply Loss

The difference between the transmitting conversion loss and the transmitting set rating is actually the effect of varying the line current from 100 ma to some other amount. This is called the transmitting current supply loss.

Current Supply Loss = Conversion Loss — Set Rating

If the operating line current happens to be 100 ma the transmitting conversion loss will be equal to the transmitting set rating and there will be no transmitting current supply loss.

For line currents less than 100 ma the transmitter in most sets does not do as good a job and the sign of the transmitting current supply loss is positive, indicating a loss. For line currents greater than 100 ma the transmitter in most sets does a better job and the sign of the current supply loss is negative, indicating a gain.

(E) Transmitting Subscriber Line Loss

The only loss or rating involved in the transmitting portion of an over-all connection that we have not discussed, is the subscriber line loss. The subscriber line loss is the insertion loss of the subscriber line between 900 ohms and the impedance of the transmitting set and is the difference between the transmitting loop loss and the transmitting conversion loss.

Subscriber Line Loss = Loop Loss — Conversion Loss

We have covered the losses in the transmitting portion, now let's see how we obtain the losses in the receiving portion of the connection.

(F) Receiving Set Rating

The receiving set rating is fixed by the ratio between the acoustic pressure in millibars delivered by the receiver to the ear of the listener, and the source voltage, $\frac{V_W}{2}$, which energizes the set as a load. V_W is the open circuit voltage of the 900-ohm source.

We can express the receiving set rating, R_L, in db as:

$$R_L = -20 \log_{10} \frac{S_{LS}}{\frac{V_W}{2}} \text{ db (at 100 ma line current)} \qquad (5)$$

where:

S_{LS} = output pressure in millibars at the ear of the listener.

V_W = open circuit voltage across a 900-ohm source which energizes the set as a load (with dc line current of 100 ma).

For example:

If we measure S_{LS}, with a dc line current of 100 ma, and obtain a value of .00141 millibars, and measure $V_W/2$ and obtain a value of .0282 volts, then the receiving set rating, R_L, will be:

$$R_L = -20 \log_{10} \frac{S_{LS}}{V_{W/2}} = -20 \log_{10} \frac{.00141}{0282}$$

$$= -20 \log_{10} \frac{1}{20}$$

When we invert the quantity $\frac{1}{20}$ to 20, we change the sign to plus and we have:

$$R_L = +20 \log_{10} 20 = 20 \times 1.3$$

$$= 26.0 \text{ db}$$

The principle of measuring the receiving set rating is shown in Fig. 5. The actual apparatus used in the laboratory for this purpose will be discussed later.

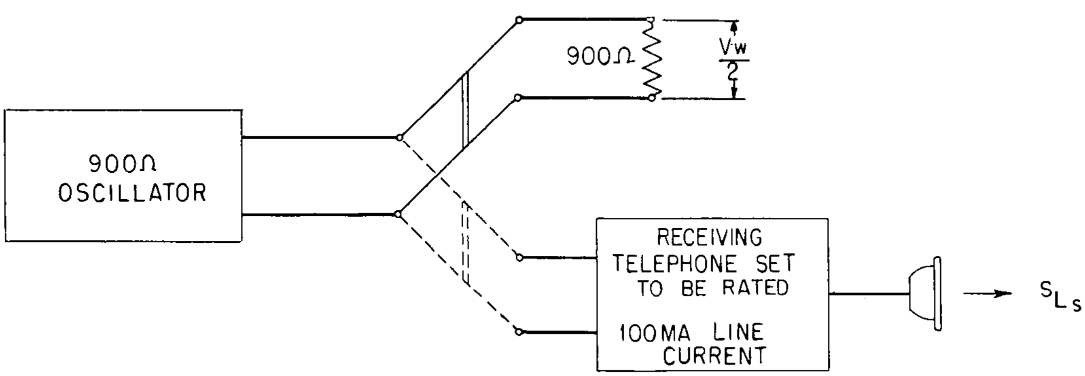


FIG. 5

With the switch in the upper position we can measure one-half the open circuit voltage and with the switch in the lower position we can measure S_L.

Again we have specified the 100 ma value of dc line current because if we are to compare sets we must compare them under similar conditions.

The numerical value of the receiving set rating should be positive to reflect the loss of energy in the receiver unit. The units of measurement — the volt and the millibar — that we have selected do give us positive values for the receiving set rating. This will be true in all cases unless amplification is introduced in the circuit. But the important thing is that the method of rating will not change — we will obtain our rating in terms of a ratio of output to input.

You are probably wondering how we arrived at one-half the open circuit voltage of the source by measuring across a 900-ohm load, let's discuss it a little. The condition for measuring the open circuit voltage in Fig. 5 is equivalent to the circuit shown in Fig. 6A.

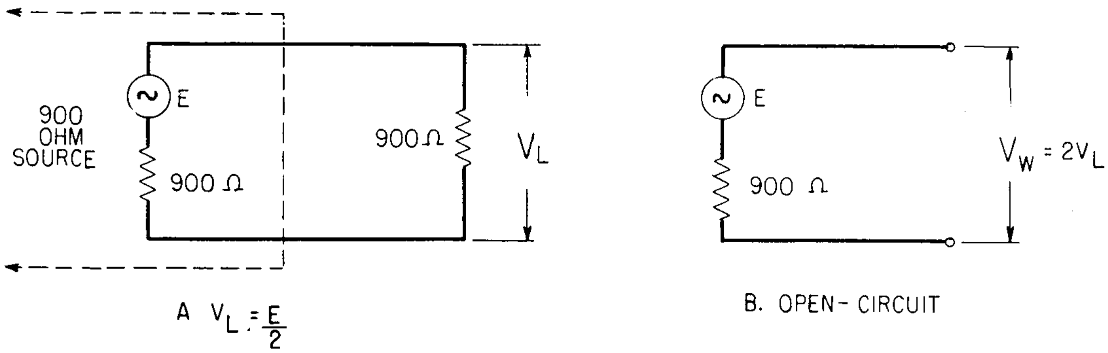


FIG. 6

If we terminate this source in a 900-ohm load, the voltage across the load, V_L, will be equal to one-half the voltage E. In Fig. 6B no current flows and there is no voltage drop across the 900-ohm resistor. The open circuit voltage, V_W, is then equal to E and is twice the voltage measured across the 900-ohm load in Fig. 6A.

The value that we measure across the 900-ohm load $V_W/2$, is then the voltage impressed on the load under ideal conditions; that is, when the impedance of the source and the impedance of the load are matched in phase as well as in magnitude. Actually, the impedance of the receiving set and the receiving loop (we will discuss the receiving loop next) is often not 900 ohms. Therefore, we must make an allowance for the mismatch between the source and the load. By using the voltage which would be impressed under ideal conditions, and measuring S_L under actual conditions, we have made an allowance for this mismatch.

(G) Receiving Loop Loss

The receiving loop loss includes the loss of the entire receiving loop from the central office out to, and including, the acoustic output of the receiving telephone set.

The receiving loop loss is obtained by nearly the same method used to get the receiving set rating.

We use the same source voltage, $\frac{V_W}{2}$, but we connect it to the entire receiving loop. A new value of output pressure, S_{LL} is then measured.

We can express the receiving loop loss, L_L, in db as:

$$L_L = -20 \log_{10} \frac{S_{LL}}{\frac{V_W}{2}} \text{ db} \tag{6}$$

where:

V_W = open circuit voltage of a 900-ohm source at the central office end of the receiving loop, in volts.

S_{LL} = output pressure expressed in millibars.

Fig. 7 shows, in principle, the measurement of $\frac{V_W}{2}$ and S_{LL}.

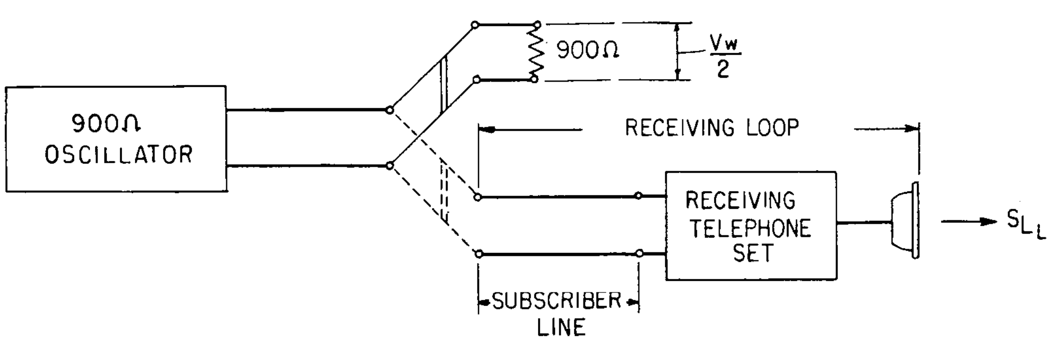


FIG. 7

In Fig. 7 with the switch in the upper position we can measure $\frac{V_W}{2}$, and with the switch in the lower position we can measure S_{LL}.

(H) Receiving Conversion Loss

The receiving conversion loss is the same as the receiving set rating except that the line measurements of input and output are made with operating line currents instead of with a preselected value of line current.

The receiving conversion loss, C_L, in db is then:

$$C_L = -20 \log_{10} \frac{S_{LS}}{\frac{V_W}{2}} \text{ db (at operating line current)} \qquad (7)$$

where:

S_{LS} = acoustic pressure at the ear of the listener in millibars.

V_W = open circuit voltage across a 900-ohm source which energizes the set as a load (at operating line current).

We want the numerical values of the receiving conversion loss to be positive to reflect the loss of the receiver unit. This is achieved by our choice of units, as mentioned before.

(I) Receiving Current Supply Loss

The difference between the receiving set rating and the receiving conversion loss is the receiving current supply loss.

Current Supply Loss = Conversion Loss — Set Rating.

On sets with current controlled equalizers, for line currents less than 100 ma the sign of the loss is usually negative indicating a gain because the receiving set is more efficient on long loops. For currents greater than 100 ma the sign of the loss is usually positive indicating a loss.

For telephone sets without equalizers there is no receiving current supply loss and the receiving conversion loss is the same as the receiving set rating.

(J) Receiving Subscriber Line Loss

The receiving subscriber line loss is the difference between the receiving loop loss and the receiving conversion loss.

Subscriber Line Loss = Loop Loss — Conversion Loss

(K) Line Loss and Connecting Circuit Loss

We are not going into any detail on these two losses since we will continue to use purely electrical measurements which do not involve acoustic quantities to obtain these values. However, from Table 1 we can see that, if need be, we can obtain these losses from the losses and ratings that we have defined above.

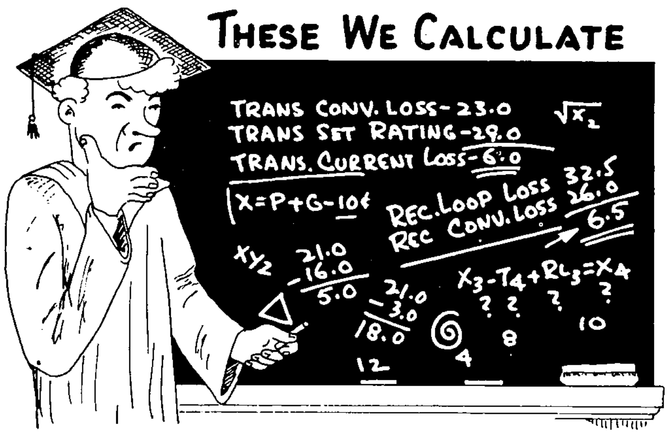
The line loss is the over-all rating minus the sum of the transmitting and receiving conversion losses.

The connecting circuit loss is the over-all loss minus the sum of the transmitting and receiving loop losses.

(L) Summary of Component Losses

We can measure the following losses by means of electro-acoustic methods, the principles of which we have discussed.

1. Telephone set ratings,
2. Conversion losses,
3. Loop losses,
4. Over-all loss.



From these we can obtain the following:

1. Current supply losses,
2. Subscriber line losses,
3. Connecting circuit loss,
4. Line loss.

6.0 900-OHM VALUE

Before we go into an example showing the numerical values that we will probably encounter, let us very briefly discuss the 900-ohm value that we have used in defining the transmitting set and receiving set ratings.

The majority of all actual telephone connections involves two loops connected to each other by some form or combination of trunks. The inclusion of trunks in the connection increases the two loop losses by the attenuation, reflection and interaction losses associated with the trunks. While there is considerable variation in the impedances of facilities making up loops and trunks, the resulting reflection and interaction losses can be minimized, and in many cases may be neglected altogether, by a choice of a compromise impedance for the rating definitions, which is reasonably representative of the entire distribution of loop and trunk impedances. These are the considerations that dictated the choice of the 900-ohm value.

7.0 TYPICAL EXAMPLE

Now let us take a typical telephone connection as shown in Fig. 8 and see what numerical values we get.

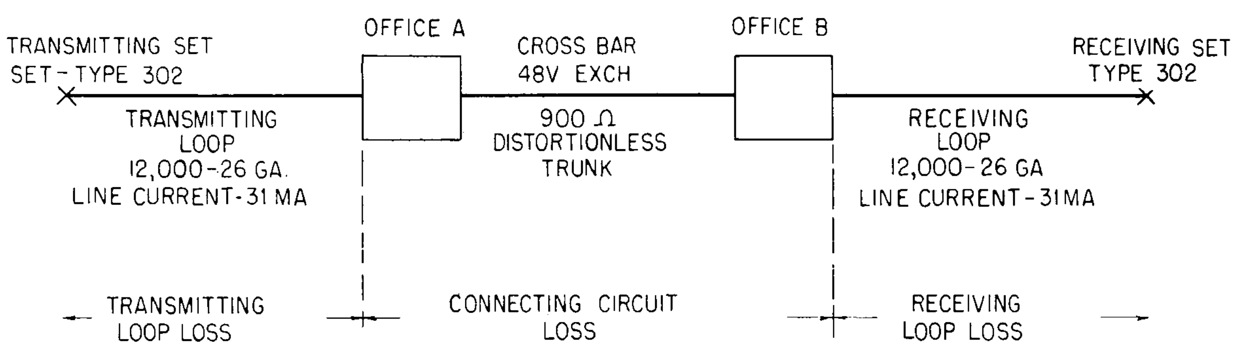


FIG. 8

The numerical values that we use in this example are from preliminary measurements and should be considered as only approximate values. They are shown here only to give you some idea of the magnitude of the losses or ratings.

First of all let us look at the values that we can obtain directly from voltage and acoustic pressure measurements.

(A) Transmitting Set Rating (100 ma)	—29.0 db
(B) Transmitting Conversion Loss (31 ma)	—23.0
(C) Transmitting Loop Loss	—16.5
(D) Receiving Set Rating (100 ma)	+26.0
(E) Receiving Conversion Loss (31 ma)	+26.0
(F) Receiving Loop Loss	+32.5
(G) Over-all Loss	+21.0

Now let's see how we derive the other losses from these ratings and losses that we have obtained directly.

(H) Current Supply Losses

The current supply losses are obtained from the conversion losses and the set ratings:

(a) Transmitting

Transmitting conversion loss	—23.0 db
— Transmitting set rating	—29.0
Transmitting current supply loss	6.0 db

(b) Receiving

Receiving conversion loss	26.0 db
— Receiving set rating	26.0
Receiving current supply loss	0.0 db

Since the 302-type sets in our example do not have equalizers, the receiving conversion loss is the same as the receiving set rating.

(I) Subscriber Line Losses

From the loop losses and the conversion losses we can obtain the subscriber line losses:

(a) Transmitting

Transmitting loop loss	—16.5 db
— Transmitting conversion loss	—23.0
Transmitting subscriber line loss	6.5 db

(b) Receiving

Receiving loop loss	32.5 db
— Receiving conversion loss	26.0
Receiving subscriber line loss	6.5 db

Since, in our example, the transmitting and receiving loops are identical, the subscriber line losses are equal.

(J) Connecting Circuit Loss

From the over-all loss and the loop losses we can obtain the connecting circuit loss:

Over-all loss		21.0 db
— Sum of loop losses	32.5 + (—16.5)	16.0
Connecting circuit loss		5.0 db

(K) Line Loss

From the over-all loss and the conversion losses we can obtain the line loss:

Over-all loss		21.0 db
— Sum of conversion losses	26.0 + (—23.0)	3.0
Line Loss		18.0 db

Now just what does this 21.0 db over-all loss that we obtain in our example mean?

It means simply that the level of pressure at the ear of the listener is 21 db below the level at the lips of the talker.

Another way of saying the same thing would be to say that the output is 21 db below our zero db point of unity ratio where the output would be equal to the input.

It might help some of you if we write it this way:

—29.0	+6.0	+6.5	+5.0	+6.5	+26.0	=	21.0
Trans. Set Rating	Trans. Current Supply Loss	Trans. Line Loss	Conn. Circuit Loss	Rec. Line Loss	Rec. Set Rating		Over-all Loss

8.0 THE MEASURING EQUIPMENT

For those who are interested in the laboratory equipment used to obtain the ratings we use, we will include a brief description of this equipment. We want to be sure that it is clearly understood that the equipment that we describe here is the equipment that has been used in the laboratory for obtaining preliminary values of ratings and losses.

The laboratory apparatus is not final and changes will undoubtedly be made. Also the equipment described here is not the same as the equipment to be developed for field use. The latter will probably look entirely different, but is expected to perform in approximately the same fashion.

The important thing to remember is that the principle of the rating system, which we have described, will not change although the apparatus we use may change.

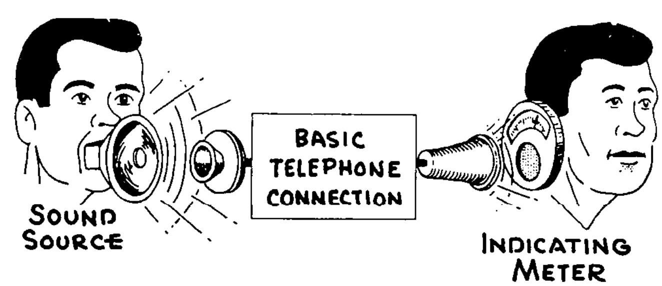
The laboratory equipment we are discussing is called the Electro-acoustic Transmission Measuring System, or EATMS.

It is important that we realize that the EATMS is not used as a reference standard such as the Working Reference System, which many of you may remember was used in the past.

It is simply a device which will permit us to introduce acoustic energy to an over-all circuit and measure pressures at the input or output, or voltages at intermediate points of the circuit, in such a way that differences between measurements at like points in two circuits are indicative of the loudness difference between them.

A diagram of the EATMS is shown in Fig. 9. It is made up of three basic parts:

1. The sound source which takes the place of a talker in a telephone connection.
2. The meter for indicating acoustic pressure or electric voltage which takes the place of a listener in a telephone connection.
3. The basic telephone connection which is an intermediate link between the sound source and the indicating meter.



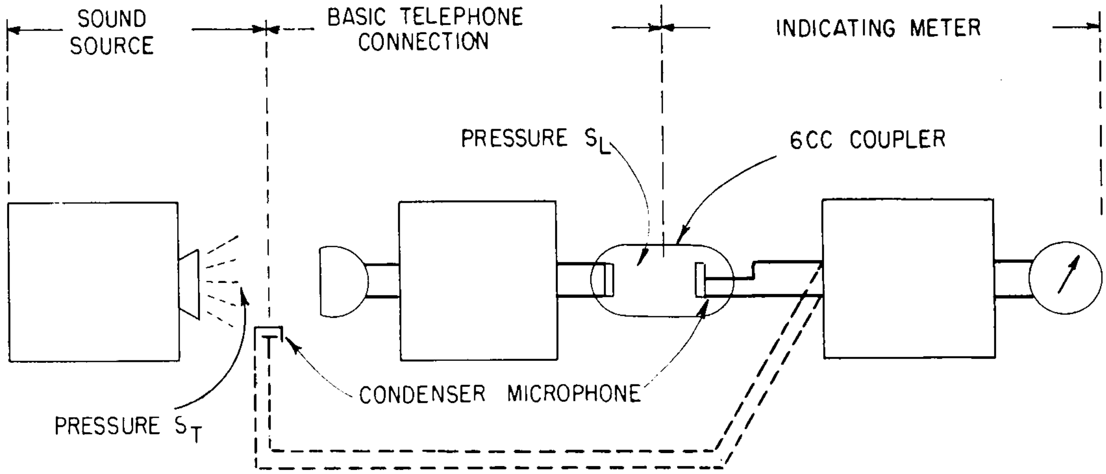


FIG. 9—ELECTRO-ACOUSTIC TRANSMISSION MEASURING SYSTEM

We do not intend to go into the circuit theory of the apparatus but we will look at each of these parts in a little more detail.

(A) Sound Source

We have said that the sound source takes the place of the talker in the telephone connection. This means that its output should be similar to human speech.

The sound source consists essentially of a generator which produces voice frequencies and an artificial mouth to convert the electrical signal into an acoustic signal.

A simplified diagram of the sound source which is now being used is shown in Fig. 10.

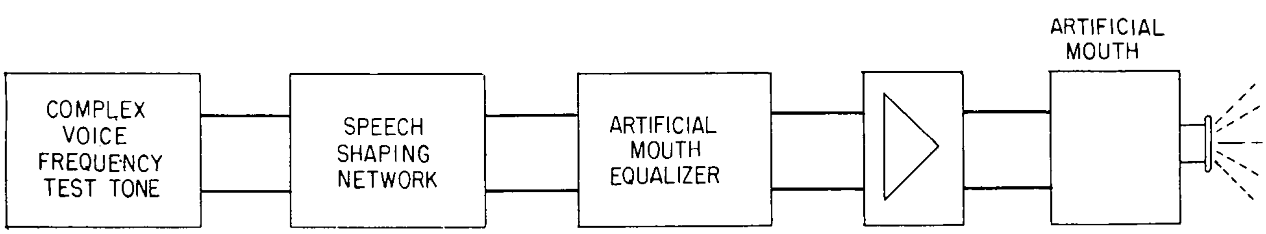


FIG. 10—SOUND SOURCE

The complex tone generator presently used is a "warbler" or variable oscillator in which the frequency of oscillation is varied linearly with time from 300 cps to 3300 cps and back to 300 cps six times each second. The output of the tone generator is then a band of frequencies in the voice frequency range. This output is modified by the speech shaping network so that the amplitudes of the various frequencies are the same as those of the same frequencies in human speech. The average intensities of human speech at various frequencies are shown in Fig. 11. Zero db represents average intensity of speech as a whole.

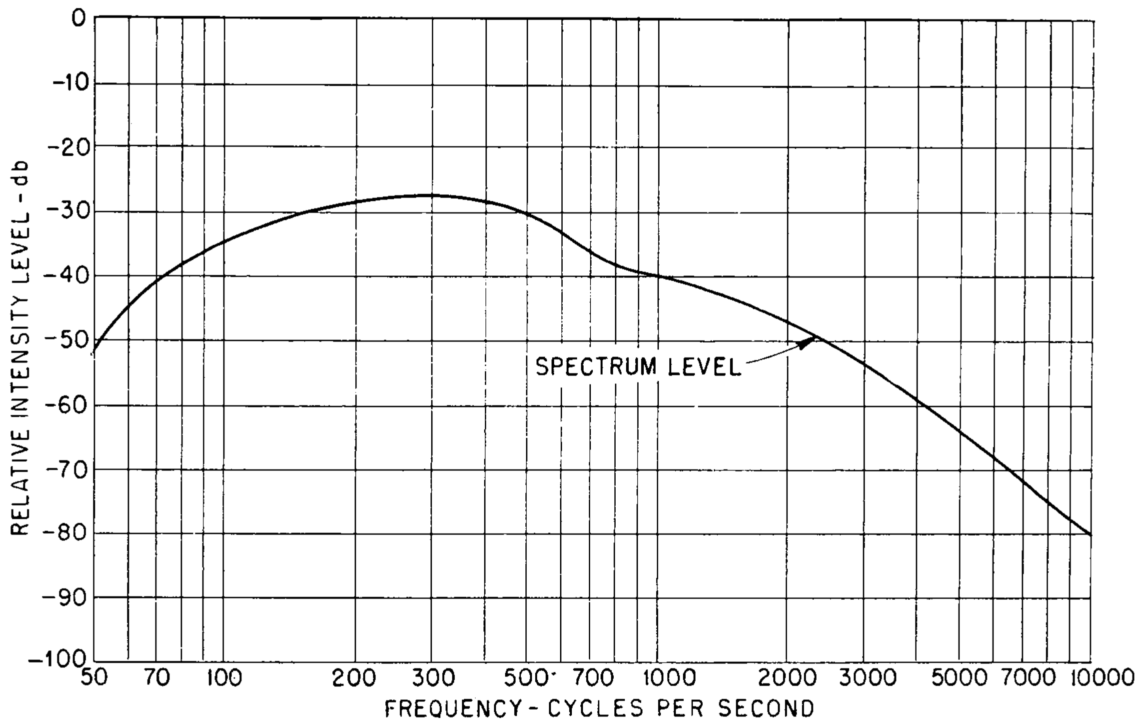


FIG. 11—FREQUENCY-POWER DISTRIBUTION OF SPEECH

The equalizer corrects the output of the artificial mouth so that it will be flat for a flat electrical input. The variable amplifier permits us to adjust the acoustic output level of the artificial mouth to values comparable to the levels of human speech. The artificial mouth itself is simply a device like a loudspeaker, to convert the electrical energy into acoustic energy.

We have then, available to us, a source of acoustic energy whose composition is similar in frequency characteristics to human speech and which can be varied as far as level is concerned.

(B) The Indicating Meter

The indicating meter is our means of measuring acoustic pressure or voltage so that we can get indications that are related to the loudness differences which would be heard by a human ear.

A block diagram of the indicating meter is shown in Fig. 12.

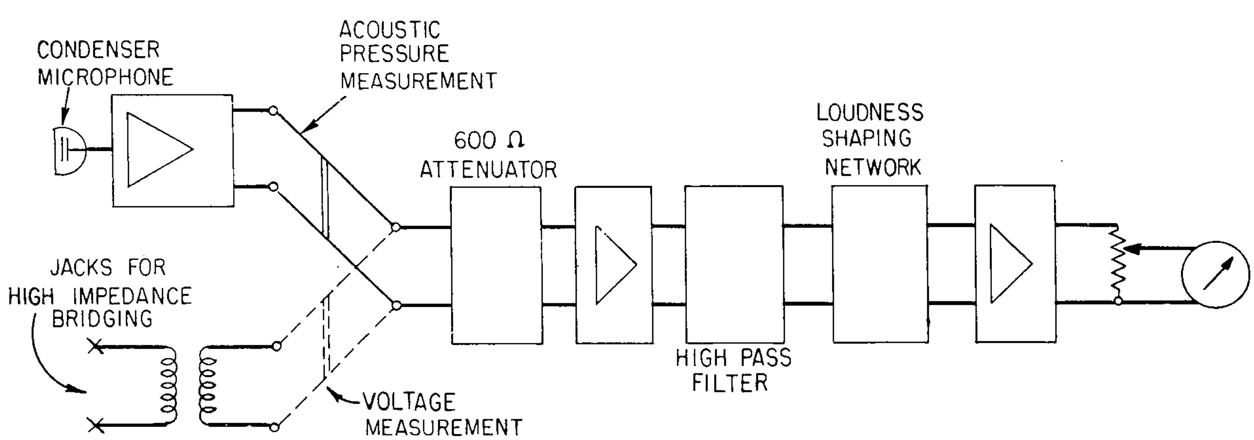


FIG. 12—INDICATING METER

For acoustic pressure measurements the condenser microphone is used. In telephone connections the two points at which we make acoustic measurements are at the input of the transmitter and at the output of the receiver. When we measure the acoustic output of the receiver a six cubic centimeter coupler, which simulates the space between the receiver cap and average ear drum, is used between the receiver cap and the condenser microphone.

We make voltage measurements by means of a high impedance bridging connection. These voltage measurements are used to obtain indications at intermediate points in a telephone connection.

The high-pass filter is used to eliminate or reduce the 60-cycle hum which may be present from the power source. The loudness shaping network weights the different frequencies composing the signals so that they are suitable for making loudness comparisons.

So we have a means of measuring pressures at the input or output, or voltages at intermediate points of the circuit, in such a way that differences between measurements at like points in two circuits are indicative of the loudness difference between them.

(C) The Basic Telephone Connection

The basic telephone connection, as we mentioned previously, is a link between the sound source and indicating meter, useful for laboratory measurements.

It is merely an over-all connection in which we can substitute commercial telephone apparatus so that we can rate the component parts of a commercial telephone connection.

For example, if we want to find the receiving rating of a commercial telephone set, we can connect it in place of the receiving set of the BTC (basic telephone connection) and make the necessary measurements.

If we only wanted to rate over-all commercial connections from the lips of the talker to the ear of the listener we would not need the basic telephone connection.

Fig. 13 is a block diagram of the basic telephone connection. It is essentially a 2-way, 4-wire connection.

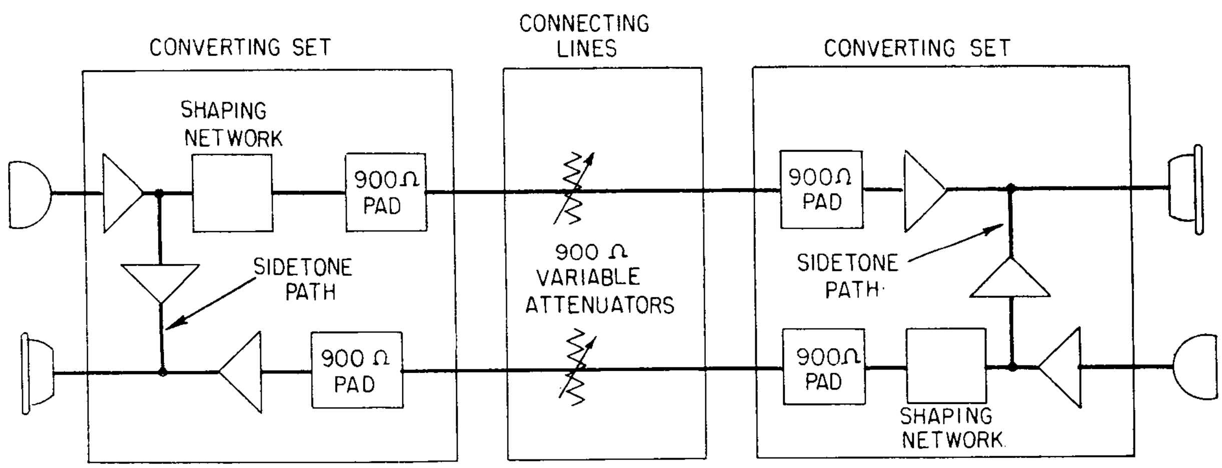


FIG. 13—LABORATORY BASIC TELEPHONE CONNECTION

The unit used as a transmitter is an electro-magnetic device, rather than the customary carbon type, to avoid the instabilities inherent in the latter. It is often important to avoid these instabilities in laboratory work but they have little effect in commercial usage.

The shaping networks used in the transmitting portions of the converting sets give a frequency characteristic that is roughly a compromise between the characteristics of the F1 and T1 carbon transmitter units. Pads are used in both the transmitting and receiving portions of the converting sets so that the impedance of the set is 900 ohms pure resistance and will match the 900-ohm input and output resistance of the connecting lines without reflection.

Amplifiers are used in the transmitting and receiving portions of the converting sets so that the transmitting and receiving levels can be adjusted to convenient values. An amplifier is also provided in the sidetone path of each set to permit adjustment of the sidetone level.

If we want to observe the performance of some item of commercial telephone equipment when it is in an over-all connection, we can do so by substituting it for the corresponding portion of the BTC.

9.0 SUMMARY

Now let's review a little bit and see what we know about the loudness rating system.

We base our rating system on loudness which is the most important factor affecting transmission.

Other factors such as sidetone, noise, and frequency distortion are still important, but in day-to-day engineering of telephone plant their effect in most cases, can be neglected. If these factors are of such magnitude that they will affect transmission, their effect will be allowed for by corrections obtained subjectively which will be added to the loudness losses as penalties.

The actual indications that we will use to obtain our loudness ratings and losses will be in terms of voltage or acoustic pressure.

From these meter indications we will obtain results that are good approximations of the loudness ratings which human listeners would give us on the average. By using simple objective meter readings rather than subjective methods of obtaining our ratings and losses, we have established a method which can be used in the field as well as in the laboratory.

The numerical base for our rating system will be the unity ratio where the output is equal to the input, whether expressed in millibars or in volts.

Our ratings and losses will be expressed as so many db with respect to this unity ratio condition.

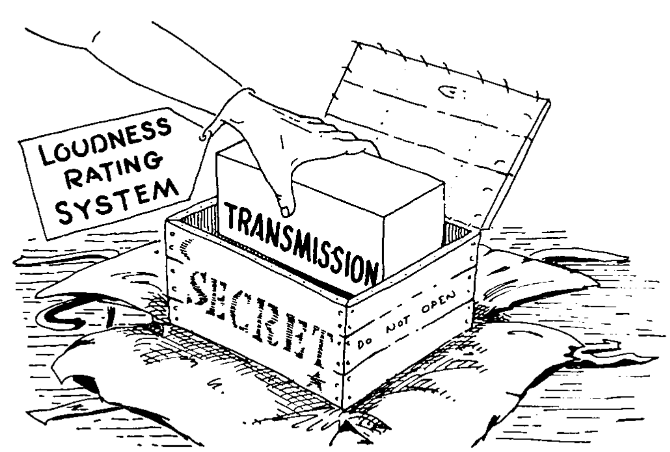
Now what can we do with our new rating system that we haven't been able to do in the past?

One of the important things is that we have a rating method which involves meter measurements, and which therefore permits measurement in the field. This opens the possibility of using field measurements to compare with rating data, and thus to make rating data useful for maintenance as well as for layout purposes.

Another important thing is that we have a rating system which for the first time takes objective measurements and ties them in with the ability of telephone sets to convert acoustic energy to electric energy and vice versa.

Finally, and by no means least important, the new rating system should be a big step toward a new era of understanding transmission. For years transmission has been sadly misunderstood by most telephone people. We have used values that were merely a set of numbers with no physical significance, even to many of the people who were dealing with it every day.

With a new simple base for our rating system we will be able to discuss transmission in easily understandable language and make people realize that transmission isn't such a big secret after all.



Now, we have not attempted to go into any great detail on any phase of the rating system. We have simply given an over-all picture of what the loudness rating system is, why it is, and how it works.

If we know these things we should be able to use the rating system and use it intelligently.

TABLE 1

Components for Rating an Over-all Interoffice Telephone Connection