Practical Application of the Recently Adopted Transmission Unit

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THE purpose of this paper is to outline the practical considerations involved in the use of the transmission unit (abbreviated *TU*), which was recently adopted by the Bell System to replace the mile of standard cable in transmission engineering work. A description of the *TU*, together with a discussion of the considerations which led to its adoption has been given by Mr. Martin in another article in this issue.

Effect of Adopting the *TU* as Regards Transmission Standards

The transmission standards in general use vary from 18 miles of standard cable to about 30 miles of standard cable, depending upon the locality and the class of service such as local and toll. It has become customary among telephone people interested in standards of service to associate certain figures for transmission standards with the corresponding standards of service which they represent. It is a distinct advantage, therefore, to retain the same figures for the same standards of service when changing to the new unit. The zero of reference was so selected, therefore, that 24 *TU* is equivalent to 24 miles of standard cable in volume reproduction. This means that if one talks with the same loudness over a circuit of 24 *TU* as over a circuit of 24 miles of standard cable, the volume received from each will be the same. As the attenuation corresponding to the *TU* is only about 6 per cent. less than the attenuation corresponding to the mile of standard cable and 24 miles represents the mean between the highest and lowest standards in common use, transmission standards on the new basis are very little different numerically from the same standards on the old basis. The former 18-mile standard is equivalent in transmission to 17.6 *TU* and the 30-mile standard is equivalent to 30.4 *TU*. The same numerical values can, therefore, generally be used for transmission standards in the new system, as in the old, since the greatest differences encountered will be 0.4 *TU*.

It is also true that a given transmission loss specified in miles will correspond very closely in numerical value to the same loss expressed in *TU*. People not directly engaged in transmission work, therefore, may generally disregard the slight difference which exists in considering transmission losses expressed in *TU* as compared with standard cable.

Use of the *TU* in Transmission Studies

In making transmission studies it has previously been the practice to express the transmission efficiency of limiting subscribers' loops in terms of the resistance of a 22-gauge loop which would have the same total transmitting and receiving loss, thus a 400-ohm loop meant a loop which had the same total transmitting and receiving loss as a loop of 22-gauge ASA cable having a resistance of 400 ohms. At the time of changing from miles to *TU*, it was decided to abandon this method of expressing limiting loop losses in the Bell System and to express them directly in *TU*; thus a 5 *TU* loop means a loop whose total transmitting and receiving loss, taking into account the efficiency of the subscribers' set, is 5 *TU*. The following table gives a number of limiting loops expressed in *TU* and their equivalents in ohms of 22-gauge cable as defined above, assuming the use of the most efficient type of subscriber's set now available.

Limiting Loops Expressed in *TU*	Limiting Loops Expressed in Ohms
3	312
4	350
5	387
6	424
7	461
8	499
9	537
10	573
11	610

Conversion from Miles to *TU* and Computation of Transmission Equivalents

During the transition period in the adoption of the *TU* it will frequently be necessary to convert transmission data which are expressed in miles, to *TU*. This is easily accomplished by multiplying by a conversion factor and in the case of the transmission efficiencies of subscribers' sets by also correcting for the difference in the reference zero which was brought about for reasons referred to above. Two units both known as miles have been in common use as a measure of transmission; they are the standard cable mile and the 800-cycle mile. A different conversion factor is required for each.

The attenuation constant of standard cable for the complex currents used in the transmission of speech varies appreciably with the length of cable considered, since for long lengths the higher frequencies are attenuated to such low values as to have very little effect on the received volume. The best average figure is 0.122, although this value has yet to be determined more precisely by careful laboratory tests. The attenuation corresponding to one *TU* for currents of any

frequency is 0.115. The ratio of the effect on volume of the mile of standard cable to the TU is, therefore, $\frac{0.122}{0.115}$ or 1.06, and equivalents obtained by comparison with standard cable by means of talking tests can therefore be converted to TU by multiplying by this factor, as previously indicated.

The 800-cycle mile which has been commonly used in expressing computed transmission losses, has an attenuation of 0.109 to currents of any frequency, and therefore data expressed in 800-cycle miles are converted to TU by multiplying by $\frac{0.109}{0.115}$ or 0.95.

For making talking tests the field has been supplied with artificial cables which were slightly different from standard cable, having a capacity of .06μf. per mile instead of .054 μf. Miles of this artificial cable may be converted to TU by multiplying by 1.12.

The conversion of subscribers' loop losses to TU is somewhat more complicated as the zero of reference for subscriber's set efficiencies is slightly different on the new basis. In the Bell System, therefore, complete data on subscribers' loop losses in terms of the new unit were made available for engineering work at the time the TU was adopted.

The transmission equivalent of a line per unit of length in TU may be obtained by multiplying the attenuation constant of the line computed in the usual manner by a conversion factor. Calling the computed attenuation constant of the line per unit of length α, the number of TU will be given by the expression: $TU = \frac{\alpha}{0.115} = 8.69\alpha$.

In finding the total loss which a short line or a piece of equipment, such as, for example, a repeating coil will cause when inserted in a given circuit, the current in the receiving apparatus is usually computed for a convenient voltage applied at the sending end of the circuit, first with the repeating coil in the circuit and then with it out, the applied voltage remaining constant. Calling these currents I_1 and I_2 respectively, the current ratio $\frac{I_1}{I_2}$ may be converted into TU by the expression

$$\text{Loss in } TU = 20 \log_{10} \frac{I_1}{I_2}.$$

Transmission Maintenance

The transmission measuring sets used for checking up the maintenance [1] of the plant from a transmission standpoint, have previously

[1] See an article in this issue "Electrical Tests and Their Applications in the Maintenance of Telephone Transmission"—W. H. Harden.

been calibrated in 800-cycle miles, and as the *TU* is of the same nature as this unit, no difficulties are encountered in arranging the sets to read directly in *TU*.

New sets will be manufactured on this basis, but it will, of course, be desirable in order to avoid frequent conversion of data from one unit to the other, to arrange many of the sets which are already in use in the plant to read in *TU*. It is not planned to convert the sets which depend upon ear comparisons, such as the [2] 1-A and 1-B transmission measuring sets and the receiver shunts used in some cases for checking up repeater gains, as the difference when measuring small values is not great and these sets are generally used for a class of work where the required precision is not sufficient to warrant their conversion to the new basis. Visual reading sets, however, such as 2-A, 3-A and 4-A transmission measuring sets and the 2-A repeater gain set, give results which are accurate to about 0.1 *TU* and are usually used for work where a fairly high degree of precision is required. These sets can be changed to read directly in *TU* at a comparatively small expense as it is only necessary to change the calibration of the measuring dials and slide wire potentiometers and the values of certain of the resistances associated with them. The cost of making these changes will be reduced by the fact that it is planned to make certain other desirable changes which will effect improvements in the operation of the sets at the same time. Complete loss data in terms of *TU* which are necessary for checking measured equivalents, have been prepared and will replace the data formerly used.

In toll line maintenance work, record cards are kept which show the layout of toll circuits and the transmission losses of the component parts of each circuit together with the total loss which should be obtained by test if the circuit is not in trouble. In changing over from miles to *TU* these record cards will be revised to show losses in the new unit.

Crosstalk Computations

In handling certain types of crosstalk problems, it has been found convenient to express crosstalk in terms of transmission units rather than crosstalk units. Miles of standard cable have previously been used in such problems. *TU* can be used for this purpose as well as miles and it is somewhat simpler to make the conversion from

[2] See a paper by F. H. Best, "Measuring Methods for Maintaining the Transmission Efficiency of Telephone Circuits." *Journ. A.I.E.E.*, Vol. XLIII, 1924.

crosstalk units to TU than from crosstalk units to miles. Crosstalk may be converted from crosstalk units to TU as follows:

$$\text{Crosstalk in } TU = 20 \log_{10} \left(\frac{\text{No. of Crosstalk Units}}{10^6} \right).$$

The number of TU corresponding to certain numbers of crosstalk units are whole numbers and are therefore, easy to remember as shown in the following table.

Crosstalk in Terms of TU Loss	Crosstalk Units
80	100
60	1,000
54 (Approx.)	2,000
40	10,000
20	100,000

Conclusion

From this discussion the conclusion may be drawn that the adoption of the TU in place of the mile as the unit of telephone transmission can be readily accomplished in its practical application in the plant. During the transition period, before complete lists of the new data have been compiled, and before the measuring apparatus in use has all been changed to the new basis, frequent conversions between miles and TU will be necessary. These conversions can easily be made by multiplying by the proper conversion factor.