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"TU" Becomes "Decibel"

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SOME years ago the mile of standard cable was displaced as the unit of transmission in the Bell System by a younger brother. This newcomer in the family of transmission units, being without a given name, adopted that of the family and became known as the "transmission unit" or "TU". It has now been given the more distinctive title of "decibel", commonly abbreviated "db". The prefix "deci" indicates one-tenth, while "bel" is derived from the name of Alexander Graham Bell.

The members of the transmission unit family resemble each other in that they all measure the logarithm of the ratio of two powers, currents or other quantities which express the magnitudes of the waves being compared. This is a desirable property from two standpoints. First, it insures that two sounds of the same general nature and quality which differ by a given number of transmission units have the same difference in loudness regardless of their absolute loudness. The difference in loudness of two sounds may be measured by the number of intermediate steps that can be distinguished in passing from one loudness to the other. Within the limits of accuracy of Weber's law, in order to produce a recognizable increase in loudness, the intensity must be multiplied by a factor which is independent of the actual intensity. Hence, the number of recognizable steps is equal to the number of times which the smaller intensity must be multiplied by this factor to give the larger. This is the exponent to which the factor must be raised to equal the ratio of the two intensities, and by definition is the logarithm of the ratio of the intensities to a base equal to the minimum recognizable intensity ratio. It follows, therefore, that the logarithm of the intensity ratio to any base will always be proportional to the difference in loudness and so a logarithmic unit becomes a suitable measure by which to express the effect of a transmission system on the loudness of the received sound.

In the second place, the use of a logarithmic unit facilitates the deduction of the overall transmission properties of a system from those of its parts. Suppose, for example, that

some telephone system is being compared with a reference system. We may picture the test system as being derived from the reference system by successively replacing each part. Each change causes the received power to change in a particular ratio. By multiplying together all these ratios we get the ratio in which the power is changed in going from the reference to the test system. If, however, we measure the effect of each replacement by the logarithm of the corresponding ratio, we have only to add the effects of the individual steps to get the overall effect.

The members of the family, while alike in being logarithmic, differ in the base to which the logarithm is taken. However we may go from one base to another by introducing the proper multiplying factor. Hence the difference between the various units is effectively one of size only. Among the units in use when the TU was chosen, the 800 cycle mile of standard cable is of such size that the number of miles is given by 10.56 $\log_{10} P_1/P_2$, where P_1 and P_2 are the two powers involved. For the so-called βl unit then in use in parts of Europe the number is $\frac{1}{2} \log_e P_1/P_2$, or what is equivalent, $\log_e J_1/J_2$, where J_1 and J_2 are the currents involved. (When currents are used it is assumed that they flow in equal impedances.) If we transform the βl unit to common logarithms the number is given by $1.151 \log_{10} P_1/P_2$. In order that the TU might be roughly equal to the "mile of standard cable," the size selected for the TU was so chosen that the number of TU is $10 \log_{10} P_1/P_2$.

In view of the desirability of the universal use of one unit for telephone transmission work, the Bell System took up this matter with various foreign telephone administrations and suggested that they consider the TU for this purpose. This led to considerable discussion as to the relative merits of a transmission unit based on common logarithms such as the

> *The International Advisory Committee unanimously recommends the following definitions*:
>
> The unit of transmission expresses the ratios of apparent or real power, of potentials or of currents in transmission systems. In practice, the number of units of transmission in a given case is expressed in terms of a logarithm.
>
> If it is a case of two powers P_1 and P_2, the number of units is,
>
> in the naperian system, $\frac{1}{2} \log_e |P_1/P_2|$;
>
> in the decimal system, $\log_{10} |P_1/P_2|$.
>
> If it is a case of two voltages V_1 and V_2 or of two currents J_1 and J_2, the number of units is,
>
> in the naperian system, $\log_e |V_1/V_2|$ or $\log_e |J_1/J_2|$;
>
> in the decimal system, $2 \log_{10} |V_1/V_2|$ or $2 \log_{10} |J_1/J_2|$.
>
> The naperian unit is called "neper". The decimal unit is called "bel". A decimal sub-multiple of these units may be used, as "decineper" and "decibel".

TU, and one based on natural logarithms such as the βl unit. Action was finally taken in the form of a recommendation by the International Advisory Committee on Long Distance Telephony of Europe to the effect that the use of both units be recognized as standard in Europe.

It was also recommended that distinguishing names be assigned to the two transmission units. For the βl unit, which is so defined that the number of units is given directly by the natural logarithm of a *current* ratio, the term "neper" was chosen in honor of John Neper,* who first conceived the idea of logarithms. In the case of the TU, however, the common logarithm of a *power* ratio is multiplied by ten to get the number of units. This suggests that the TU is in the nature of a derived unit and that the primary unit should bear the same relation to the common logarithm that the neper does to the natural logarithm. The name "bel" was accordingly assigned to this primary unit. Since the number of TU corresponding to a given ratio is ten times the number of bels, the TU itself is equal to one-tenth of a bel, and so it became the "decibel".

In view of this recommendation, the Bell System has decided to use the term "decibel" as a name for the transmission unit. The transition from the old to the new will naturally be a gradual one. There will be no occasion to make changes in existing apparatus or written material, but rather the db will replace the TU in new work.

** While this spelling may appear unfamiliar, the form "Napier" is comparatively modern. The name appears to have been going through a transition during the mathematician's lifetime and while his signatures show a variety of spellings, he generally used the oldest form "Neper."*