The Lenkurt Demodulator

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dba

and Other Logarithmic Units

Logarithmic units are widely used in the communications industry as the most practical and convenient means of expressing the extremely wide range of power ratios encountered. The ratio of very strong signals and noise may be 100 million billion to one, or more. When expressed in decibels, the most common logarithmic unit, this tremendous range becomes, simply, 180 db. Other, more specialized units, such as dba, dbrn, vu, and dbx are related to the decibel but require more complex definitions.

In this article dba, dbrn and vu are explained in detail. Shorter explanations of other units are also included.

The decibel is commonly used in the communications industry to express a ratio between two quantities of power. Neither quantity needs to be defined to express the ratio in decibels or *db*, and for many purposes, a knowledge of the ratio alone is sufficient. For example, the gain of a linear amplifier or the attenuation of a pad can be expressed in decibels without knowing either the input or output power of the device. Frequently, however, there is a need to know the ratio between signal (or noise) power at some point in a circuit and some fixed, known quantity of power. In this case, it is customary to express the ratio as so many db above or below the reference power.

The most common reference power used in the telephone industry is *one milliwatt*. Because signal power is almost always undergoing attenuation (a division process) or amplification

About this article

This article is revised from the January, 1954 article by A. M. Seymour, then Editor of the DEMODULATOR. *The original article has been reprinted many times and has been adopted without change as a Bell System Practice. Because of extreme continued interest in this subject, the article has been brought up to date by the addition of material on measurement units that have come into general use since the original article was written, and is reprinted here again.*

(a multiplication process) the expression of power directly in watts or milliwatts would often require lengthy and cumbersome calculations. A more convenient method of indicating an amount of power is to express it as being so many db above or below a reference power of one milliwatt, because adding and subtracting decibels provides the same result as multiplying and dividing power. Because of its widespread usage, "decibels above or below one milliwatt" is usually abbreviated ±*dbm*.

In addition to dbm, there are several other logarithmic units in use in the telephone industry which are expressed as db above or below some reference power. The most important of these are *dba, dbrn, dbx,* and *vu*.

Dba and dbrn (formerly written db-RN) are used to indicate the actual interfering effect of noise in a communications channel, by relating it to the interfering effect of a fixed amount of noise power or reference noise. *Dbx* is a unit for expressing crosstalk coupling on transmission lines. *Vu* is used to designate the ratio between the "volume" (or loudness) of spoken or musical sounds and a reference volume.

Dba and dbrn

Dba and dbrn are closely related units; in fact, the abbreviation *dba* means, effectively, *dbrn adjusted*. Both terms originated from research conducted by the Bell Telephone Laboratories and the Edison Electrical Institute to determine the transmission impairment caused by noise interfering with speech. Since noise may consist of random frequencies with widely varying amplitudes, it was necessary to evaluate the interfering effects of single frequencies or relatively narrow bands of frequencies, to obtain usable data.

A large number of listening tests were made with different tones introduced as interference. The degree of interference was determined by comparing the power of each tone with the power of a 1000-cycle tone that created the same degree of interference. For example, if the interfering effect of a particular tone was to be determined, that tone was superimposed on a specially selected conversation at a reference power level. When the interfering tone was removed, a 1000-cycle tone was superimposed on the same conversation and its power level adjusted until the listener judged that it had the same interfering effect. The difference noted between the power levels of the selected tone and the 1000-cycle tone was then considered to be the difference in interfering effect.

When this same test was performed for a number of different tones in the voice frequency spectrum and for a number of different listeners using the same apparatus, it was possible to plot a graph such as Figure 1 showing the relative interfering effects of different frequencies in the voice frequency spectrum compared to 1000 cycles. Such curves are called *weighting* curves. With this information available it was possible to construct equalizing networks such that each component frequency of the voice frequency spectrum was attenuated in the same manner as it appeared to be attenuated by the average ear with the listening test apparatus. By using these equalizers in conjunction with a suitable amplifier, rectifier and d-c meter it was further possible to measure electrically the interfering effect of any frequency or combination of frequencies.

Since any noise or tone superimposed on a conversation has an interfering effect, it was desirable to express all quantities of interfering effect in positive numbers. To accomplish this, a power of 10^{-12} watt or -90 dbm at 1000 cycles was selected as the reference power because a 1000 cycle tone having

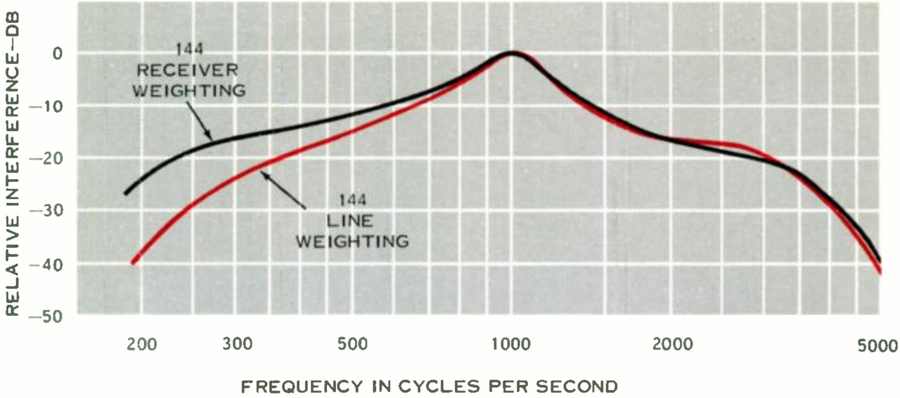

Figure 1. Relative interfering effects of different frequencies when using 144-type telephone sets. Red curve includes attenuating effect of complete loop, including exchange circuit. Black curve shows only attenuation effects of 144 set itself.

a power level of -90 dbm appeared to have negligible interfering effect. Therefore, all other noise powers likely to be encountered would have a positive interfering effect that could be expressed in *db above reference noise* of -90 dbm at 1000 cycles or, in abbreviated form, as dbrn.

These early experiments and tests to evaluate the interfering effect of noise were made with Western Electric Type 144 handsets and resulted in the weighting curves in Figure 1. The line weighting curve (red) of Figure 1 includes the attenuating effect of a typical exchange circuit, subscriber loop, and telephone set. The receiver weighting curve (black) of Figure 1 includes only the attenuation effects of a telephone set itself.

Later, an improved type of handset (Western Electric Type F1A) came into general use with a type F1 transmitter and HA1 receiver. This equipment was less sensitive at the 1000-cycle reference frequency, but had a more uniform frequency response. When tests similar to those used for 144 telephone sets were conducted with this handset, the weighting curve shown in Figure 2 was obtained and designated F1A weighting. The tests indicated that the new handset gave approximately a 5-db improvement over the electrical and acoustical performance of the 144 handset when using line weighting. Because of the differences in sensitivity and frequency response, noise measurements with the F1A weighting provided indications about 5 db higher than with the 144 weighting. Rather than change existing standards, a new reference noise power of -85 dbm ($10^{-11.5}$ watt) was introduced which produced identical noise measuring set readings for equal transmission impairments. The change in reference noise power necessitated a change in the units used to express interfering effect and resulted in the adoption of a new unit called *dba*— which means "decibels adjusted."

Recently, a newer line weighting was introduced in the Bell System, reflecting the performance of more recent equipment. As in the change from 144 weighting to F1A weighting, the new

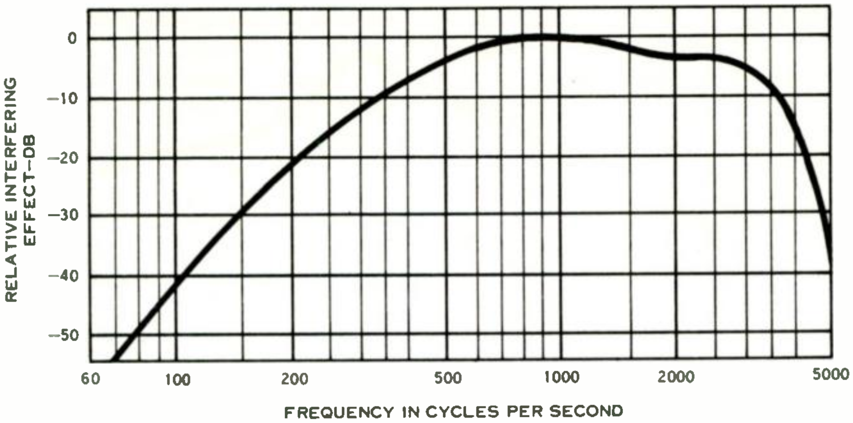

Figure 2. F1A line weighting characteristic. This curve closely approximates line weighting characteristics of most of the world's telephones, and has been adopted by CCITT.

characteristic — which is called C-message weighting — has required a change in the noise power to which it is referred. Since the new equipment improves on the older equipment, an even higher reference power than the -85 dbm F1A reference would be required to express equal interfering effects with equal numbers. Since this might have resulted in some measurements having to be made in terms of "negative" values of noise, the original -90 dbm (10^{-12} watt) reference power was reinstated. Interference measured with this weighting is expressed in "dbrn C-message" units to distinguish it from the earlier "dbrn 144-line."

Heretofore, all noise measurements made with either 144 weighting or F1A weighting have been expressed in dba, since, when using 144 weighting, dba and dbrn are numerically equal, represent the same amount of noise power, and have the same interfering effect. This is not true of dbrn C-message, however. Although the same reference noise power is used as in 144 weighting, the broader frequency response of C-message weighting results in much less noise power being attenuated by the weighting characteristic. Thus, a 3-kc band of uniform noise is attenuated 8 db by the 144 weighting characteristic, 3 db by the F1A weighting, but only 1.5 db by the C-message weighting.

Where the noise is known to be evenly distributed across a 3000-cycle voice frequency band, measurement can be made with a suitable transmission measuring set or ac voltmeter. Because the weighting networks attenuate various frequencies differently, one milliwatt of evenly distributed noise (flat noise) produces only 82 dba of interfering effect with 144 and F1A weighting. Therefore, measurements of *flat noise* in dbm can readily be converted to dba by adding 82 to the reading (-50 dbm +82 = +32 dba). In the case of C-message weighting, however, noise power is calculated by adding 90 -1.5, or 88.5 to the flat noise power. If noise power is again -50 dbm,

Noise=

$-50 + (90 - 1.5) = 38.5$ dbrn $_{\text{C-message}}$.

In case of measurements made at 1000 cps, however, it is only necessary to make a comparison with the reference power, since there is no weighting effect on a 1000 cps tone. Thus, a 1000 cps signal having a power of 0 dbm would yield 90 dbrn (144 line), 85 dba, and 90 dbrn (C-message).

Although these conversions are quite straightforward for 1000-cycle tones and flat noise, conversion of other types of noise power to meaningful noise terms may become quite complicated. Noise, as found in transmission lines and electronic apparatus, varies widely as to its component frequencies and their relative amplitudes. It seldom consists of a single frequency. The chief source of noise in open-wire voice frequency circuits is induction from power lines and apparatus.

In open-wire carrier and radio systems, noise comes from a variety of sources including power lines, atmospheric disturbance and interference from radio transmitters. While cable circuits are not subject to any great degree of noise from atmospherics or power lines, the low power levels used make them subject to noise caused by the thermal agitation in circuit components. Noise at carrier frequencies is often distributed evenly across a channel bandwidth. In open-wire voice frequency circuits, however, noise is more often concentrated at certain frequencies, usually odd harmonics of the local power frequency.

Single interfering frequencies other than 1000 cycles can also be measured in dbm and converted to dba by use of the weighting curves. For example, if a 300-cycle interfering tone is measured to be -40 dbm, the F1A line weighting curve shows that it is 15 db less interfering than a -40 dbm, 1000 cycle tone;

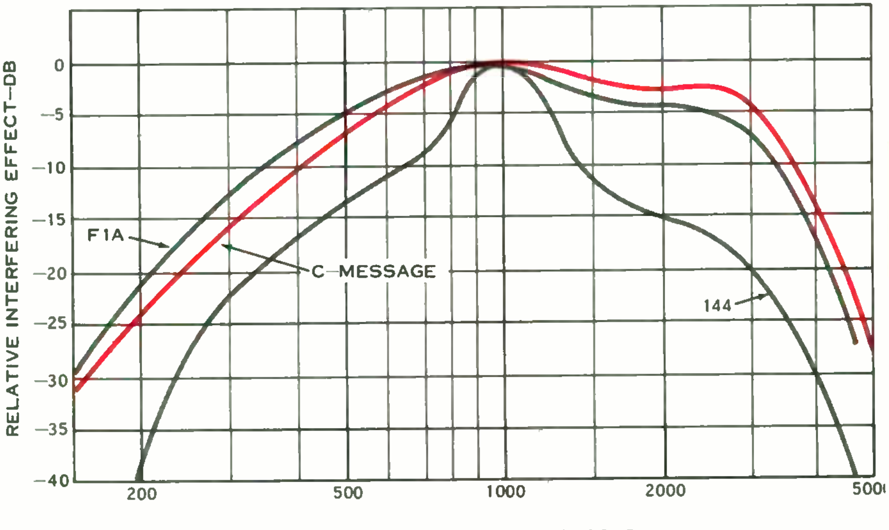

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Figure 3. New C-message weighting characteristic, compared with 144-line weighting and F1A-line weighting. In all three curves, interfering effect of various frequencies is referred to 1000-cycle interference.

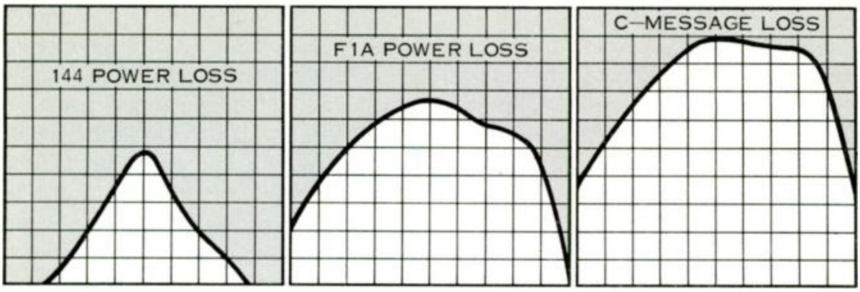

Figure 4. Comparison of loss characteristics of the three weighting curves. Attenuation of wide-band noise or signal is proportional to area outside the curves.

in other words, its interfering effect is the same as that of a 1000-cycle tone of -55 dbm. A -55 dbm, 1000-cycle tone is equivalent to 30 dba. Therefore, the -40 dbm, 300-cycle tone has an interfering effect of 30 dba.

Volume Units

Where programs and certain other types of speech or music are being transmitted, monitoring of the program volume level is necessary to maintain a constant average volume. Failure to maintain the program volume level constant may cause overmodulation of line amplifiers or radio transmitters and cause blasting and distortion from listeners' loudspeakers or handsets. If a simple db meter or voltmeter is bridged across the circuit to monitor the program volume level, the indicating needle will try to follow every fluctuation of program power and will be difficult to read and will have no real meaning. Also, different meters will probably read differently because of differences in their damping and ballistic characteristics.

To provide a standardized system of indicating volume, a special instrument and set of units were created. These instruments are called VU meters or volume indicators and the units of measurement are *volume units* or *vu*. Ordinarily, volume can be measured in vu only on these special instruments because the volume unit is based on the readings of these instruments under a specified set of conditions. One exception to this rule is the Western Electric 2B noise measuring set which can be calibrated to read in vu.

The indicating instrument used in vu meters is a d-c milliammeter having a slow response time and damping slightly less than critical. If a steady sine wave is suddenly applied to the meter, the pointer will move to within 99 percent of its steady state value in 0.3 seconds and overswing the steady state value by 1.0 to 1.5 percent.

A standard volume indicator (meter and associated attenuator) is calibrated to read 0 vu when connected across a 600-ohm circuit carrying 1 milliwatt of sine-wave power having a frequency between 35 and 10,000 cycles per second. For complex waves such as speech, a vu meter will read some value between the average and the peak values of the complex wave. There is no simple relation between the volume measured in vu and the power of such a complex wave. The actual reading will depend on the particular wave shape. For steady sine waves within the frequency range of the instrument, the reading in vu will be equal to the reading of a db meter in dbm connected across the same circuit.

Dba0 and Dbm0

These terms are coming into widespread use in microwave and carrier systems to express noise and signal power in terms of the levels that should exist at a so-called zero transmission level point (0 TLP). As recently defined by the United States Electronics Industries Association:

> The term dba0 is a measure of noise power with reference to zero dbm at the Reference (zero) Transmission Level Point. Noise powers measured at any Transmission Level Point can be expressed in dba0 by correcting the noise power measured for the difference in level between the point of measurement and the Reference Transmission Level Point. The relative noise power in dba is obtained from a power measurement of noise using F1A weighting.
>
> Example: A noise measurement of +20 dba measured at a -4 db point is equivalent to +24 dba0.
>
> The term dbm0 is a measure of power with reference to zero dbm at the reference transmission level point (RTLP). Powers measured at any transmission level point can be expressed in dbm0 by correcting the power measured for the difference in level between the point of measurement and the Reference Transmission Level Point.
>
> Examples: (1) A tone of +36 dbm measured at a +19 db transmission level point is equivalent to +17 dbm0.
>
> (2) A tone of +17 dbm0 is equivalent to +7 dbm measured at a -10 db transmission level point.

Other Units

Various other units are also used in the telephone industry and other sections of the communications field. They include *dbx. dbw, dbRAP, dbv,* and others. Of course, dbx is the most common in the telephone industry.

Dbx is used to indicate crosstalk coupling in telephone circuits (See DEMODULATOR, *November*, 1960). Like dba and dbrn, it may be measured with a noise measuring set. Dbx means decibels above reference coupling. Reference coupling is defined as the coupling necessary to cause a reading of 0 dba on the disturbed circuit when a test tone of 90 dba is impressed on the disturbing circuit. Both values of dba are for the same weighting.

The other units mentioned above are quite simple. Dbw are decibels referred to one watt. Dbk are decibels referred to one kilowatt. Both dbw and dbk are often used to indicate radiated power from radio transmitters. DbRAP means decibels above reference acoustical power which is defined as 10^{-16} watts. Dbv designates decibels referred to one volt. Other logarithmic units in use are similar to these mentioned. ●

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