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DBMB VOLTAGE OR POWER? (PART 1)

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The concept of decibels often is confusing, especially when it comes to the decibel millivolt (dBmV) the cable industry has used for years as a metric to characterize signal levels. The "mV" in dBmV suggests we're measuring voltage, yet the decibel itself is by definition used to express a ratio of two power levels. Indeed, when dBmV is used to describe signal levels, it technically is an expression of power in terms of voltage.

Why does the decibel even come into play when dealing with signal levels? Quite simply, it's a convenient way to work with very large or very small numbers. To put this in perspective, let's say all of our test equipment only could measure and express signal level in watts. The FCC's minimum allowable analog-TV channel visual carrier level at the input to a subscriber terminal would show up on our test equipment as 0.000000013 watt. Typical per-channel levels at the tap spigot would be 0.000000422 watt, a line extender's per-channel input 0.000001333 watt, and the same line extender's per-channel output 0.000841276 watt. Are we having fun yet?

When measuring signal level at the output of an amplifier or at the input to a cable modem, TV set or set top, just what is it that we're measuring? We're measuring the amplitude of a signal or signals, but what does that mean? To understand, let's go back to some of the basics.

Current can be thought of as the flow of charged particles per unit of time. An analogy is the volume of water flowing through a garden hose. Ampere is a measure of electrical current, and 1 ampere equals 1 coulomb of charge flowing past a given point in 1 second. An analogy might be 1 gallon of water per second flowing through that garden hose. Coulomb is a unit of measure of electrically charged particles, where 1 coulomb equals 6.242 x 1018 electrons.

Electromotive force (EMF) is the force of electrical attraction between two points of different charge potential. EMF is more commonly known as voltage, and the volt is a measure of electromotive force — analogous to water pressure in a garden hose. One volt is the potential difference between two points on a wire carrying 1 ampere of current when the power dissipated between the points is 1 watt (more on "watt" in a moment). An analogy here might be 1 pound per square inch of water pressure in our hypothetical garden hose.

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Resistance is an opposition to the flow of current. Ohm is a unit of resistance, where 1 ohm is defined as the resistance that allows 1 ampere of current to flow between two points that have a potential difference of 1 volt. This latter definition forms the basis for Ohm's Law, which is R = E/I. Here, R is resistance in ohms, E is electromotive force in volts, and I is current in amperes. The equation R = E/I can be shuffled around a bit to give us some of the other variations of Ohm's Law: E = IR and I = E/R.

Where does power fit in all of this? Power is the rate at which work is done or energy per unit of time. One watt of power is equal to 1 volt, causing a current of 1 ampere. One watt is the power required to do work at a rate of 1 joule per second. That is, a joule of work per second is 1 watt. One joule is the work done by a force of 1 Newton acting over a distance of 1 meter. The joule is a measure of a quantity of energy, and it equals 1 watt-second.

If you think about it for a moment, 1 watt simply is the use or generation of 1 joule of energy per second. Other electrical units are, in fact, derived from the watt. As you've no doubt surmised by now, all of this stuff is related. For instance, 1 volt is 1 watt per ampere. Another definition of 1 watt is 1 volt of potential (EMF) "pushing" 1 ampere of current through a resistance, or P = EI, where P is power in watts, and E and I are voltage in volts and current in amperes, respectively. As was the case with Ohm's Law, a bit of equation shuffling will give us E = P/I and I = P/E. Using some basic algebra, substitute the Ohm's Law equivalents for E and I in the formula P = EI, and you'll get a couple other common expressions of power: P = E2/R and P = I2R.

Power calculations and measurements in direct current (DC) circuits and applications are relatively straightforward. For example, if you have a 75-ohm resistor with an applied voltage of 10 millivolts, the current is 0.133 milliampere (I = E/R, or 0.133 milliampere = 0.010 volt/75 ohms) and the power dissipated by the resistor is 1.33 microwatt (P = E2/R = 0.0102/75 = 0.00000133 watt or 1.33 µW).

Because the previous example is a DC circuit, the voltage always will be 10 millivolts and the current 0.133 milliampere. As long as the resistor's value remains constant, it's easy to calculate dissipated power. Alternating current (AC) circuits and applications are more complicated because the instantaneous voltage and current are not constant. In order to equate the varying AC waveform to a DC equivalent component, one must work in the world of root mean square (RMS) voltage and current. A RMS value is found by squaring the individual values of all the instantaneous values of voltage or current in a single AC cycle. Calculate the average of those squares and find the square root of the average.

Useful Values

How can we define useful values for the varying quantities of voltage and current in an AC circuit? RMS gives us effective quantities equivalent to DC values. For instance, 10 mV RMS AC voltage causes the same average power dissipation in a given resistor, as does a 10 mV DC voltage. Likewise, 0.133 mA RMS alternating current has the same heating effect as 0.133 mA direct current. RMS values simplify calculations by making the product of RMS voltage and RMS current equal to average power: PAVG = ERMS x IRMS cos Ø. The theta symbol (Ø) refers to the phase angle difference between voltage and current. If they are in phase, average power is simply the product of RMS voltage and current.

Consider an unmodulated RF carrier that, for this discussion, we'll assume to be a sinusoidal AC waveform. Power measurement of this waveform can be a bit tricky because the product of voltage and current varies during the AC cycle by twice the frequency of the sine wave. In other words, the output of such a signal source as a RF signal generator is a sinusoidal current at the desired frequency, but the product of the carrier's voltage and current has what amounts to an equivalent average DC component along with a component at twice the original frequency. In most cases of RF power measurement, "power" refers to the equivalent average DC component of the voltage and current product.

If you connect a thermocouple power meter to the output of the aforementioned RF signal generator, the power meter's power sensor will respond to the RF carrier's DC component by averaging. This averaging usually is done over a bunch of cycles, which, at RF, still can be a relatively short period of time. Otherwise, if the power meter simply measured an instantaneous point of the sine wave and then measured that sine wave at another instantaneous point, the result would vary according to the instantaneous product of the voltage and current at each measurement point. This is the primary reason why most RF power measurements are expressed in average power.

Next time, I'll get back to the decibel and show how all of this fits together.

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