The dB in Communications

by

Jeff Beasley, Ph.D.
jbeasley@nmsu.edu
Department of Engineering Technology
New Mexico State University

Abstract: *The db (decibel) is a relative unit of measurement commonly used in communications for providing a reference for input and output levels. This tutorial provides an overview of the use of the dB in communication systems. The tutorial also includes a table of standard dB terms.*

I. dB Tutorial

The term **dB** or **decibel** is a relative unit of measurement used frequently in electronic communications to describe power gain or loss. Decibels are used to specify measured and calculated values in audio systems, microwave system gain calculations, satellite system link-budget analysis, antenna power gain, light-budget calculations and in many other communication system measurements. In each case the dB value is calculated with respect to a standard or specified reference.

The dB value is calculated by taking the log of the ratio of the measured or calculated power (P2) with respect to a reference power (P1). This result is then multiplied by 10 to obtain the value in dB. The formula for calculating the dB value of two ratios is shown in equation 1. Equation 1 is commonly referred to as the power ratio form for dB.

$$dB = 10 \, log_{10} \frac{P_2}{P_1}$$

(Eq. 1)

Equation 1 can be modified to provide a dB value based on the ratio of two voltages. By using the power relationship $P = V^2/R$, the relationship shown in equation 2 is obtained.

$$db = 10 \log_{10} \frac{V_2^2 / R_2}{V_1^2 / R_1} ; \quad (let \ R_1 = R_2)$$

$$\therefore \quad dB = 10 \log_{10} \frac{V_2^2}{V_1^2}$$

(Eq. 2)

By simplifying the equation, a dB relationship based on voltage ratios instead of power is obtained. The voltage gain calculation is shown below in equation 3.

$$dB = 20 \ log_{10} \ \frac{V_2}{V_1}$$

<div align="right">(Eq. 3)</div>

The dB unit is often used in specifying input and output signal level requirements for different communication systems. An example of specified audio levels can be found in microwave transmitters. It is common for a +8dBm input level to be specified. Notice that a lower case **m** has been attached to the dB value. This indicates that the specified dB level is relative to a 1 milliwatt reference. In standard audio systems 0dBm is defined as .001 watt measured with respect to a load termination of 600 ohms. A 600 ohm balanced audio line is the standard for professional audio and telecommunications.

<div align="center">

0 dBm is defined as 1 mW measured with respect to a 600 ohm termination

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The voltage measured across a 600 ohm load for an 0dBm level is .775 volts. This value is derived below using equation 1.

$$dB = 10 \ log_{10} \ \frac{P_2}{P_1}$$

$$where \ P_2 = \frac{V_2^2}{600} \ and \ P_1 = .001 \ watts$$

Since 1mW is the specified reference for 0dBm, the voltage reference can be derived as shown in equation 4.

$$0dBm = 10 \ log \ \frac{V_2^2/600}{.001}$$

$$0dBm = log \ \frac{V_2^2/600}{.001}$$

$$log^{-1} 0 \ dBm = \frac{V_2^2/600}{.001}$$

$$\frac{V_2^2/600}{.001}$$

$$.6 = V_2^2$$

$$\therefore \ .77459 = V_2$$

$$dB = 20 \ log_{10} \ \frac{V_2}{V_1}$$

<div align="right">(Eq. 4)</div>

This is the voltage reference for 0dB with respect to a 600 ohm load. To determine the voltage required at the input of the microwave transmitter to provide a +8dBm level, use the voltage gain equation 3 letting V1 equal the .775 reference in the equation

$$dBm = 20\,log_{10}\frac{V_2}{.775}$$

To solve for V2 for a +8dBm level;

$$+8dBm = 20\,log_{10}\frac{V_2}{.775}$$

$$.4 = log\,\frac{V_2}{.775}$$

$$log^{-1}(.4) = \frac{V_2}{.775}$$

$$\therefore\;\; 1.946712 = V_2$$

Thus for a +8 dBm level to be present at the input of the microwave transmitter, approximately 1.95 volts must be present across the 600 ohm input.

The term dBm also applies to communication systems which have a standard termination impedance other than 600 ohms. For example, video and some RF systems are terminated with 75 ohms. The 0dBm value is still defined as 1mW but measured with respect to a 75 ohm termination instead of 600 ohms. Therefore the voltage reference for an 0dBm system with respect to 75 ohms is;

$$v = \sqrt{P*R} = \sqrt{(.001)*(75)} = .27386\,volts$$

To calculate the voltage gain or loss with respect to a 75 ohm load use equation 5 if a voltage is specified and the dB value is needed.

$$dBm(75) = 20 \log_{10} \frac{V}{.27386}$$

More commonly encountered in communications are 50 ohm systems. The dBm voltage reference for a 50 ohm system is:

$$V = \sqrt{P \bullet R} = \sqrt{.001 \bullet 50} = .2236 \, volts$$

To calculate the voltage gain or loss, expressed in dB for a 50 ohm system, use equation 3 with the value for V2=.2236. This relationship is shown in equation 5.

$$dBm(50) = 20 \log_{10} \frac{V}{.2236}$$

(Eq. 5)

It is common for power to be expressed in watts instead of milliwatts. In this case the dB unit is obtained with respect to 1 watt and the dB values are expressed as dBW.

0 dBW is defined as 1 watt measured with respect to 50 ohms.

Remember, dB is a relative measurement. As shown by equations 1 and 3, both power and voltage gains can be expressed,in dB, relative to a reference value. In the case of dBW the reference is 1 watt, therefore equation 1 is written with 1 watt replacing the reference P1. This gives equation 6.

$$dBW = 10 \log_{10} \frac{P_2}{1W}$$

(Eq. 6)

It is common in communication receivers to express voltage measurements in terms of dBuV, dB-microvolts. For voltage gain calculations involving dBuV use equation 3 and specify 1uV as the reference (V1) in the calculations as shown in equation 7.

$$dB\mu V = 20 \log \frac{V_2}{1\mu V}$$

(Eq. 7)

There are a multitude of applications involving the use of dB for calculations involving relative values. The important thing to remember is that a relative reference is typically specified or understood when calculating or measuring a dB value.

II. dB Reference Table

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dBm 1 milliwatt (.001W), Typical measurement for audio input/output specifications. Also used in low power optical transmitter specifications.

dBm(600) The standard audio reference power level defined by 1 milliwatt measured with respect to a 600 ohm load. This measurement is commonly used in broadcasting, professional audio applications and is a common telephone communications standard.

dBm(50) This standard is defined by 1 milliwatt measured with respect to a 50 ohm load. This measurement is commonly used in RF transmissions/receiving systems.

dBm(75) This standard is defined by 1 milliwatt measured with respect to a 75 ohm load. This standard is common in some RF systems particularly cable TV systems.

dBmW This is the generic form for a 1 milliwatt reference, also written as **dBm**. This term usually has an inferred load reference, depending on the application.

dBW This is a common form for power amplification relative to a 1 watt reference (usually 50 ohms). Typical applications are found in RF Power Amplifiers and High Power Audio Amplifiers specifications.

dBuV This is a common form for specifying input RF levels to a communications receiver. This is called dB microvolt where 1 microvolt = 1*10E-6V.

dbV While this dB term is defined, it is rarely used in defining communication systems. The dB value is obtained with respect to 1 Volt.

dB/bit This is a common term used for specifying the dynamic range or resolution for a Pulse Coded Modulation (PCM) system such as a CD player. This reference is defined by 20 Log(2)/bit = 6.02dB/bit.

dBi This is dB isotropic . It is used as the reference when defining Antenna Gain.

dB/Hz This is relative noise power in 1-Hz bandwidth. This term is used often in digital communications and in defining a laser's Relative Intensity Noise (RIN). For a laser system, this is an electrical not an optical measurement. A typical[1] RIN for a semiconductor laser is -150 dB/Hz.

dBW/K-Hz This is a common term used when analyzing carrier-to-noise (C/N) in a communications link such as a satellite link budget. This value is based on the Boltzmann's constant expressed in dB as 10 Log(1.38*10E-23) = -228.6 dBW/K-Hz.

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[1]L. Stokes, "What is a dB?," **IEEE Circuits and Devices** ,Vol. 12, No.3, May 1996, page 48.

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