FIS3001: Instrumentación Científica - Quiz 1

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1 The Decibel (dB) and Its Use

There are instances in which the use of the common prefixes is inconvenient at the very least. In particular, when a physical quantity spans a very large range of numbers, it is difficult to properly grasp the magnitude of the quantity. Often, too, a quantity only has meaning with respect to a reference value. Take, for example, a voltage amplifier. It may be a unity amplifier or may amplify by a factor of 10^6 or more with a reference at 1. Another example is the human eye. It can see in luminance from about $10^{-6} cd/m^2$ to 106 $10^6 cd/m^2$. This is a vast range and the natural reference value is the lowest luminance the eye can detect.

The use of normal scientific notation for such vast scales is inconvenient and is not particularly telling for a number of reasons. Using again the example of our eyes response to light, it is not linear, but rather logarithmic. That is, for an object to appear twice as bright, the illumination needs to be about 10 times higher. The same applies to sound and to many other quantities. In such instances, the quantities in question are described as ratios on a logarithmic scale using the notation of decibel (dB). The basic ideas in the use of the decibel are as follows:

1. Given a quantity, divide it by the reference value for that quantity. That may be a "natural" value, such as the threshold of vision, or it may be a constant, agreed upon value such as 1 or 10^{-6}.
2. Take the base 10 logarithm of the ratio.
3. If the quantities involved are power related (power, power density, energy, etc.), multiply by 10:

$$p = 10 log_{10} \frac{P}{P_0} \qquad [dB]$$

4. If the quantities involved are field quantities (voltage, current, force, pressure, etc.), multiply by 20:

$$\nu = 20 log_{10} \frac{V}{V_0} \qquad [dB]$$

In the amplifier described above, a voltage amplification of 10^6 corresponds to $20log_{10}(10^6/1) = 120dB$. In the case of vision, the reference value is $10^{-6}cd/m^2$. A luminance of $10^{-6}cd/m^2$ is therefore $0dB$. A luminance of $10^3cd/m^2$ $10log_{10}(10^3/1) = 90dB$. One can say that the human eye has a span of $120dB$.

When dealing with quantities of a specific range, the reference value can be selected to accommodate that range. For example, if one wishes to describe quantities that are typically in milliwatts $[mW]$, the reference value is taken as $1mW$ and power values are indicated in decibel milliwatts (dBm). Similarly, if one needs to deal with voltages in the microvolt $[\mu V]$ range, the reference value is taken as $1\mu V$ and the result is given in decibel microvolts $[dB\mu V]$. The use of a specific reference value simply places the $0dB$ point at that value. As an example on the dBm scale, 0 dBm means 1 mW. On the normal scale, $0dB$ means $1W$. It is therefore extremely important to indicate the scale used or confusion may occur. There are many different scales, each clearly denoted to make sure the reference value is known.

As a final note it should be remembered that unit analysis can facilitate understanding of the material and prevent errors in computation.

2 Exercises

1. An antenna only radiates 45% of the power input to it. The rest is lost as heat. What input power (in dBm) is required to radiate 30 dBm ?

2. The output stage of an RF front end consists of an amplifier followed by a filter and then an antenna. The amplifier has a gain of 27 dB , the filter has a loss of 1.9 dB , and of the power input to the antenna, 35% is lost as heat due to resistive losses. If the power input to the amplifier is 30 dBm , calculate the following:

   (a) What is the power input to the amplifier in watts?

   (b) Express the loss of the antenna in dB .

   (c) What is the total gain of the RF front end (amplifier + filter)?

   (d) What is the total power radiated by the antenna in dBm ?

   (e) What is the total power radiated by the antenna in mW ?