Radio Maths Made Simple

Basic Maths for RAE Students by Bill Sparks G8FBX

Many years ago when Alexander Graham Bell was first experimenting with the telephone, he wanted a unit of sound measurement to indicate that one sound was just discernably louder than another. He called this a bel. It was later found that the ear behaved in a logarithmic way as a receiver of sound. In order to cover the wide range of sounds the ear, at low levels, is very sensitive and the louder the sound, the lower the sensitivity of the ear. This variation in sensitivity was exactly as shown in our original table of 10^0 to 10^6 and upwards, so from 10^0 to 10^1 was taken as 1 bel, 10^1 to 10^2 was a further bel so obviously the ratio of one sound strength to another could be found by subtracting the indices or adding as required.

For radio use the bel was too coarse a relationship so $^1/_{10}$ th bels were used and these were called decibels (dB). Looking at the logarithmic table we find that by multiplying our decimal values of indices by 10 we now have decibels. (10 decibels = 1 bel).

ie 10xlog 1 = 0000
10xlog 2 = 3.01
10xlog 3 = 4.77
10xlog 4 = 6.02
10xlog 5 = 6.98
10xlog 6 = 7.78
10xlog 7 = 8.45
10xlog 8 = 9.03
10xlog 9 = 9.45
10xlog 10 = 10

For instance, if a power level at 1 is increased to 10, it represents 10 dB of gain. If we had a power level of 1 and increased it to 2, we would have 3 dB of gain; by increasing to 4 we would have 6 dB, by increasing to 8 we would have 9 dB and by increasing to 16 we would have 12 dB or

Part 2. Logarithms and dB

$10^{1.2}$. Note that the value is greater than 1 and less than 2 so the value must be between 10 (10^1) and 100 (10^2). It is actually 16.

NOTE: $10^2 = 100$ so 20 dB = (2 × 10) = a power gain of 100. Using this technique we can indicate the ratio of any power level to another in decibels. Bear in mind that we say *ratio* since decibels are not absolute values but only ratios. They become absolute values when they are referred to any starting point. For the purpose of the RAE Part 1 paper re: power output indication, the reference is 1 watt of power so 26 dBW is 26 dB reference to 1 watt. Since 26 = 2.6 in logarithms and 2 is 10^2 or .100, and 0.6 is 4 on our logarithmic scale then 26 dBW = 100 × 4 ($10^{2.6} = 10^2 \times 10^{0.6}$) = 100 × 4 (approx) in power gain and this is the same as saying 400 watts output. Referring to 1 watt as the start we write this as 26 dBW.

Recapping it has been established that the index figure shows the number of '0's in the actual number itself. Also that, in a decimal notation, the decimal point acted as a count of 1 when counting the number of '0's in the fraction. We can show fractions of 10 by showing the number of '0's in the denominator of the fraction with an index in exactly the same way as for numbers greater than 1. But now, in order to show that we are dealing with a decimal fraction less than 1, we place a negative sign in front of the indices.

For example:

0.1 = $= 10^{-1} \times 1$ Note one '0' in fraction

0.01 = $= 10^{-2} \times 1$ Note two '0's in fraction

0.001 = $= 10^{-3} \times 1$ Note three '0's in fraction

and so on.

There are figures down to 10^{-18} in some calculations so the usefulness of this shorthand way of writing is self evident.

eg $\frac{1}{1,000,000,000,000,000,000}$

can be written as $10^{-18} \times 1$

Note that multiplication follows in exactly the same way:

$$\frac{1}{10} \times \frac{1}{100} = \frac{1}{1000}$$

so $0.1 \times 0.01 = .001$

and $10^{-1} \times 10^{-2} = 10^{-1+-2} = 10^{-3}$

We simply add the negatives together.

Roots

The only other arithmetical point of concern is the square root. If a number is multiplied by itself we say the number is 'squared'.

Example: $4 \times 4 = 16$ so $4^2 = 16$

Now, 16 consists of two equal numbers multiplied together. 16 is like a tree with two equal roots, 4 × 4. Thus 4 is called the square root of 16. As you can see from **Fig. 2**, multiplying 3 × 3 gives 9 and if you look at each of the small squares we have 9 equal size squares made up from 3 × 1 one way and 3 × 1 the other way so 3 is called the square root of 9.

Other numbers with their square roots ($\sqrt{}$ means square root of):