Basic Electronics Series

Understanding the Decibel Scale – Eliminating the Confusion

- The decibel scale is confusing to most new ham operators
- It is a logarithmic scale
- As such, it is NOT linear
- In the Technician Class training and study guides, are taught two things:
  - Doubling or halving a power level is a change of plus or minus 3dB, depending upon direction
  - A change with a factor of 10X is a change of plus or minus 10 dB, again dependent upon direction of change

- The decibel is used as a means of comparison of two values.
- The most common comparisons are to power levels, as in between two diffent antennas, or with and without an amplifier
- dB are also used in discussing audio levels
- There must be a base value or a basis for comparison, which is effectively used as a comparison standard
- Using the decibel allows comparison of very large and/or very small values without having to manipulate a large string of zeroes

Comparison Example

- Suppose a ham transmits an outbound signal at an RF signal strength of 100 W, and that signal is received at some remote point, with a 10µV signal being induced on the receiving antenna. That 10µV signal, through a 50Ω impedance coaxial cable to the receiver, will develop a power level of 2pW (picowatts), or 0.000000000002 watts. This means that the transmitted signal was 50 trillion (5×10^{13}) times stronger than the received signal.

Comparison Example Continued

- Manipulating those values, with all of those zeroes, is likely to result in arithmetic errors.
- The decibel scale makes such comparisons cleaner and more elegant.
- The decibel scale is based on positive and negative powers of 10
- A 1 to 1 comparison, *i.e.*, no change, is a 0dB change.

Number	Powers of 10	Base_{10} Logarithm	=	Log Value
10,000,000	1×10^{7}	$\log_{10}(10,000,000)$	=	7
1,000,000	1×10^{6}	$\log_{10}(1,000,000)$	=	6
100,000	1×10^{5}	$\log_{10}(100,000)$	=	5
10,000	1×10^{4}	$\log_{10}(10,000)$	=	4
1,000	1×10^{3}	$\log_{10}(1,000)$	=	3
100	1×10^{2}	$\log_{10}(100)$	=	2
10	1×10^{1}	$\log_{10}(10)$	=	1
1	1	$\log_{10}(1)$	=	0
.10	1×10^{-1}	$\log_{10}(0.1)$	=	-1
.01	1×10^{-2}	$\log_{10}(0.01)$	=	-2
.001	1×10^{-3}	$\log_{10}(0.001)$	=	-3
.0001	1×10^{-4}	$\log_{10}(0.0001)$	=	-4
.00001	1×10^{-5}	$\log_{10}(0.00001)$	=	-5
.000001	1×10^{-6}	$\log_{10}(0.000001)$	=	-6
.0000001	1×10^{-7}	$\log_{10}(0.0000001)$	=	-7
.00000001	1×10^{-8}	$\log_{10}(0.00000001)$	=	-8

Logarithm Table on Previous Slide

- Table is truncated for presentation size
- Scale can go on infinitely.
- According to table…
  - $\log_{10}$ of 10,000 is 4
  - $\log_{10}$ of 0.001 is -3
  - $\log_{10}$ of 100 is 2
  - $\log_{10}$ of 1,000 is 3
  - $\log_{10}$ of 0.00001 is -5

Logarithms and Decibels

- The Base_{10} logarithm of a number is also known as a *bel*, after Alexander Graham Bell.
- Ten decibels are equal, in sum, to one bel, as a *deci*bel is equivalent to one-tenth of a bel.
- The chart and table on the next two slides depict the relationships between decibels and Base_{10} logarithms

dB	Power Ratio
100	10,000,000,000
90	1,000,000,000
80	100,000,000
70	10,000,000
60	1,000,000
50	100,000
40	10,000
30	1,000
20	100
10	10
6	3.981
3	1.995 (≈2)
1	1.259
0	1

dB	Power Ratio
0	1
-1	0.794
-3	0.501 (≈1/2)
-6	0.251
-10	0.1
-20	0.01
-30	0.001
-40	0.000 1
-50	0.000 01
-60	0.000 001
-70	0.000 000 1
-80	00.000 000 01
-90	0.000 000 001
-100	0.000 000 000 1

Notes on the Decibel Table

- The power ratios are understood to be ratios to a value of 1:
  - 3dB is equivalent to a power ratio of about 2:1
  - 10dB is equivalent to a power ratio of 10:1
  - 20dB is equivalent to a power ratio of 100:1
  - 30dB is equivalent to a power ratio of 1,000:1
  - -6dB is equivalent to a power ratio of 0.251:1
  - -20dB is equivalent to a power ratio of 0.01:1

Calculations

- Gain is calculated using the formula

  Gain (dB) = 10 x log(P2/P1)

- Suppose we were to be comparing a 4-element Yagi to a dipole, and the published spec on the Yagi says it has about a 6dB signal gain over the dipole. What exactly does that mean?
- The table and/or the chart will reveal that a 6dB power gain is a gain of about four times the power.
- Here is how that is worked out…
  - Gain (dB) = 10 x log (4/1) (4 times the power)
  - Gain (dB) = 10x 0.602 (from a calculator – log 4 = .60206
  - Gain (dB) = 6.02

Back to the Example…

- The $\log_{10}$ of the 100W outbound signal is 2
- The $\log_{10}$ of the 2pW received signal is roughly -12 (it is actually -11.69897, which rounded to the nearest whole number is -12).
- A scientific calculator tells us that the $\log_{10}$ of 50,000,000,000,000 is 13.69897 (note the span from the $\log_{10}$ of the 100W signal and the $\log_{10}$ of the 2pW signal – the total span is 13.69897!
- 13.69897 x 10 = 136.9897, or 137dB
- Isn't that a whole lot easier than dealing with a number like 50 trillion?

What are dBd and dBi?

- dBd and dBi are comparative values with respect to specific standard antenna types
  - dBd is antenna gain compared to a half-wave dipole antenna in its direction of maximum radiation
  - dBi is antenna gain compared to an isotropic radiator
- An *isotropic radiator* is a theoretical point-sized antenna that is assumed to radiate equally and evenly in all directions.
  - Thus, the 3-D radiation pattern of an isotropic antenna is a sphere centered around the antenna point.
  - It is theoretical only and does not exist in reality.

Relationship of dBd and dBi

- There is a fixed relationship between these two comparative values…
  - Gain in dBd = Gain in dBi – 2.15dB
  - Gain in dBi = Gain in dBd + 2.15dB
- Example – if an antenna has 6dB more gain than an isotropic radiator, how much gain does it have compared to a dipole?
  - Gain in dBd = Gain in dBi – 2.15dB
  - Gain in dBd = 6dBi – 2.15 dB = 3.85 dBd

Questions??