Cable 101 Training Series

Cable Math

$2 + 2 = ?$

$mV$

$dBmV$

$2 \text{ to } 1$

$dB = 10 \times \log_{10} \left( \frac{P2}{P1} \right)$

$10^2$

Metric system
Cable Math

Learning Objectives

- Metric System
- Powers of 10
- Logarithms
- dB and dBmV
- Cable Loss
- HFC and Drop Calculations
Metric System

- Metric system is used in most of the world, except the USA.
- Measures volume (liters), weight (kilograms) and distance (meters).
- Smaller or larger units of measure are all based on the power of 10.
- Only one basic unit for distance, the meter.
- 1 Kilometer = 1,000 Meters = 10,000 decimeters = 1,000,000 centimeters.
- 1 Mile = 1,760 Yards = 5,280 Feet = 63,360 Inches.
Powers of 10

- Powers of 10 is used in the decimal system that we use everyday.
- 10 is the basic number in our numbering system, just like the meter is the basic unit of measurement in the metric system.
- Express very large or small numbers in a compact and easy to calculate way.

- \(10^2\) (10 squared) = \(10 \times 10 = 100\)
- \(10^3\) (10 cubed) = \(10 \times 10 \times 10 = 1,000\)
- \(10^6 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1,000,000\)
- \(10^9 = 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 \times 10 = 1,000,000,000\)
Numbers less than zero can be expressed using negative powers of 10

- $10^{-3} = .001$
- $10^{-6} = .000001$
- $10^{-9} = .000000001$
## Powers of 10

<table>
<thead>
<tr>
<th>Power of 10</th>
<th>Number</th>
<th>Decimal</th>
<th>Metric Prefix</th>
<th>Metric Symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>$10^{12}$</td>
<td>$1,000,000,000,000$</td>
<td>Trillion</td>
<td>Tera</td>
<td>T</td>
</tr>
<tr>
<td>$10^9$</td>
<td>$1,000,000,000$</td>
<td>Billion</td>
<td>Giga</td>
<td>G</td>
</tr>
<tr>
<td>$10^6$</td>
<td>$1,000,000$</td>
<td>Million</td>
<td>Mega</td>
<td>M</td>
</tr>
<tr>
<td>$10^3$</td>
<td>$1,000$</td>
<td>Thousand</td>
<td>Kilo</td>
<td>K</td>
</tr>
<tr>
<td>$10^2$</td>
<td>100</td>
<td>Hundred</td>
<td>Hecto</td>
<td>H</td>
</tr>
<tr>
<td>$10^1$</td>
<td>10</td>
<td>Ten</td>
<td>Deca</td>
<td>D</td>
</tr>
<tr>
<td>$10^0$</td>
<td>1</td>
<td>One</td>
<td></td>
<td></td>
</tr>
<tr>
<td>$10^{-1}$</td>
<td>0.1</td>
<td>Tenth</td>
<td>deci</td>
<td>d</td>
</tr>
<tr>
<td>$10^{-2}$</td>
<td>0.01</td>
<td>Hundredth</td>
<td>centi</td>
<td>c</td>
</tr>
<tr>
<td>$10^{-3}$</td>
<td>0.001</td>
<td>Thousandth</td>
<td>milli</td>
<td>m</td>
</tr>
<tr>
<td>$10^{-6}$</td>
<td>0.000,001</td>
<td>Millionth</td>
<td>micro</td>
<td>μ</td>
</tr>
<tr>
<td>$10^{-9}$</td>
<td>0.000,000,001</td>
<td>Billionth</td>
<td>nano</td>
<td>n</td>
</tr>
<tr>
<td>$10^{-12}$</td>
<td>0.000,000,000,001</td>
<td>Trillionth</td>
<td>pico</td>
<td>P</td>
</tr>
</tbody>
</table>
## Metric System

<table>
<thead>
<tr>
<th>Metric Prefix</th>
<th>Metric Symbol</th>
<th>Common Nomenclature</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tera</td>
<td>T</td>
<td>TB = Terabyte</td>
</tr>
<tr>
<td>Giga</td>
<td>G</td>
<td>GHz = Gigahertz</td>
</tr>
<tr>
<td>Mega</td>
<td>M</td>
<td>MHz = Megahertz</td>
</tr>
<tr>
<td>Kilo</td>
<td>K</td>
<td>KHz = Kilohertz</td>
</tr>
<tr>
<td>Hecto</td>
<td>H</td>
<td></td>
</tr>
<tr>
<td>Deca</td>
<td>D</td>
<td></td>
</tr>
<tr>
<td>deci</td>
<td>d</td>
<td>dB = decibel</td>
</tr>
<tr>
<td>centi</td>
<td>c</td>
<td>cm = centimeter</td>
</tr>
<tr>
<td>milli</td>
<td>m</td>
<td>mV = millivolt</td>
</tr>
<tr>
<td>micro</td>
<td>μ</td>
<td>μV = microvolt</td>
</tr>
<tr>
<td>nano</td>
<td>n</td>
<td>nm = nanometer</td>
</tr>
<tr>
<td>pico</td>
<td>P</td>
<td>pf = picofarad</td>
</tr>
</tbody>
</table>
Metric System

1 Kilometer = 1,000,000 Meters = 0.62 Miles
1 Meter = 3.28 Feet
1 centimeter = .01 meters = 0.39 Inches

Channel 2 = 55.25MHz = 55,250,000 Hertz

0 dBmV = 1millivolt = 0.001 volt

32GB = 32Gigabyte = 32,000,000,000 byte’s
Metric System

32,400 μV (microvolt) \(\text{=}\) 32.4 mV
0.7 V (Volts) \(\text{=}\) 700 mV
860 mV (millivolts) \(\text{=}\) 1,592.4 mV
The logarithm (log) is the number to which the base must be raised in order to produce that number.

Logs express large numbers simply.

Simplifies calculations because the addition and subtraction of logarithms is equivalent to multiplication and division.

Logarithms can be expressed as powers of any number, most cable applications use the power of 10.

Used for decibels, gain, loss, signal levels, carrier-to-noise and noise figures.
Logarithms

1 Kilometer
= 1,000 Meters
= 10 × 10 × 10
= 10³
= log 3
Logarithms

\[
\begin{align*}
10,000 &= \log_{10} 4 \\
100,000 &= \log_{10} 5 \\
1,000,000 &= \log_{10} 6 \\
1,000,000,000 &= \log_{10} 9 \\
1,000,000,000,000 &= \log_{10} 12 \\
\log -3 &= .001 \\
\log -6 &= .000,001 \\
\log -9 &= .000,000,001 
\end{align*}
\]
Logarithms

593,766,821.6382

8.77
Decibels

Decibel is one tenth of a bel and is a ratio that compares any two power or voltage levels such as input level to output level, video carrier to noise floor, etc.
bel

100 W input / 10 W output
10 to 1 ratio
1,000 W input / 100 W output
still 10 to 1 ratio
Decibels

The bel was found to be too large to use for cable communication applications so the decibel, one tenth of a bel, was established.

Written as dB

<table>
<thead>
<tr>
<th>Power Ratio</th>
<th>Value in Belts</th>
<th>Value in decibels</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 to 1</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>2 to 1</td>
<td>0.3</td>
<td>3</td>
</tr>
<tr>
<td>10 to 1</td>
<td>1</td>
<td>10</td>
</tr>
<tr>
<td>100 to 1</td>
<td>2</td>
<td>20</td>
</tr>
<tr>
<td>1,000 to 1</td>
<td>3</td>
<td>30</td>
</tr>
</tbody>
</table>
Decibels

- dB represents the logarithm of a ratio of two signal power or voltage levels
- dB is a relative measurement
- $\text{dB} = 10 \times \log_{10}(P_2/P_1)$, Power
  - $P_1 = \text{Input}$
  - $P_2 = \text{Output}$
- $\text{dB} = 20 \times \log_{10}(V_2/V_1)$, Voltage
  - $V_1 = \text{Input}$
  - $V_2 = \text{Output}$
Decibels

\[ dB = 10 \times \log_{10} \left( \frac{P_2}{P_1} \right) \]

\[ dB = 10 \times \log_{10} \left( \frac{100}{50} \right) \]

\[ dB = 10 \times \log_{10} (2) \]

\[ dB = 10 \times 0.301 \]

\[ dB = 3.01 \text{ Louder (Gain)} \]
Decibels

10 Watts  ---------------  5 Watts

\[ dB = 10 \times \log_{10} \left( \frac{P_2}{P_1} \right) \]
\[ dB = 10 \times \log_{10} \left( \frac{5}{10} \right) \]
\[ dB = 10 \times \log_{10} (0.5) \]
\[ dB = 10 \times -0.301 \]
\[ dB = -3.01 \text{ Loss} \]
Measured in millivolts (mV)

Very small and cumbersome numbers
3.1623 mV
Experiments were made in the early days of television to determine the minimum signal strength needed to produce a noise free picture.
1 millivolt was established as the minimum signal level needed to produce a good noise-free video picture.

1 milli-volt measured across 75 ohms equals 0 dBmV, this is the standard we use today.
dBmV

dBmV is a reference related to voltage and is an absolute measurement.

<table>
<thead>
<tr>
<th>dBmV</th>
<th>mV</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>20</td>
<td>10</td>
</tr>
<tr>
<td>18</td>
<td>7.9</td>
</tr>
<tr>
<td>12</td>
<td>4</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>1.8</td>
</tr>
<tr>
<td>4</td>
<td>1.6</td>
</tr>
<tr>
<td>3</td>
<td>1.4</td>
</tr>
<tr>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>1</td>
<td>1.1</td>
</tr>
<tr>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td>-6</td>
<td>0.5</td>
</tr>
<tr>
<td>-12</td>
<td>0.25</td>
</tr>
</tbody>
</table>

Each 6dB increase doubles the voltage; each 6dB decrease halves the voltage.

20 dB changes produce a 10-fold change in voltage.
dBmV

dBmV is a reference related to voltage and is an absolute measurement
dB & dBmV

\[ \text{dB} = 20 \times \log\left(\frac{2.1135}{3.1623}\right) \]
\[ \text{dB} = 20 \times \log(0.67) \]
\[ \text{dB} = 20 \times (-0.17) \]
\[ \text{dB} = -3.4 \]

3.1623 mV in
2.1135 mV out
1.0488 mV loss

2.1135 mV out
2.1135 mV out
dB & dBmV

10 dBmV in

6.5 dBmV out

3.5dB loss

6.5 dBmV out

6.5 dBmV out
dB & dBmV

If you can measure it, it’s “dBmV”
Absolute signal measurement
0 dBmV = 1mV across 75 ohms

If you have to calculate it, it’s “dB”
Ratio between two power or voltage levels
Represents Gain or Loss
Cable Attenuation

One of the essential steps in the troubleshooting process is how to calculate the amount of attenuation that a length of coaxial cable has.

To determine the loss you need to know 3 things:

1. Type of cable
2. Frequency used
3. Cable length
Cable manufactures provide cable loss tables that indicate the loss of cables in dB per 100 feet at different frequencies.

<table>
<thead>
<tr>
<th>MHz</th>
<th>RG-59</th>
<th>RG-6</th>
<th>RG-11</th>
<th>0.625</th>
<th>0.875</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>0.77</td>
<td>0.58</td>
<td>0.38</td>
<td>0.13</td>
<td>0.09</td>
</tr>
<tr>
<td>45</td>
<td>1.75</td>
<td>1.39</td>
<td>0.89</td>
<td>0.4</td>
<td>0.29</td>
</tr>
<tr>
<td>55</td>
<td>1.88</td>
<td>1.54</td>
<td>0.96</td>
<td>0.45</td>
<td>0.32</td>
</tr>
<tr>
<td>330</td>
<td>4.5</td>
<td>3.74</td>
<td>2.35</td>
<td>1.14</td>
<td>0.82</td>
</tr>
<tr>
<td>450</td>
<td>5.3</td>
<td>4.4</td>
<td>2.75</td>
<td>1.35</td>
<td>0.97</td>
</tr>
<tr>
<td>550</td>
<td>5.9</td>
<td>4.9</td>
<td>3.04</td>
<td>1.51</td>
<td>1.09</td>
</tr>
<tr>
<td>750</td>
<td>6.96</td>
<td>5.54</td>
<td>3.65</td>
<td>1.79</td>
<td>1.29</td>
</tr>
<tr>
<td>870</td>
<td>7.54</td>
<td>6.11</td>
<td>4.06</td>
<td>1.95</td>
<td>1.41</td>
</tr>
<tr>
<td>1000</td>
<td>8.09</td>
<td>6.55</td>
<td>4.35</td>
<td>2.11</td>
<td>1.53</td>
</tr>
</tbody>
</table>
Cable Attenuation

How to calculate cable loss:

1. Use the cable loss table to find the loss thru 100 feet of cable
   - loss through RG-6 cable at 550MHz = 4.9dB

2. Divide the length of the cable by 100
   - 140’ (cable length) ÷ 100 = 1.4 (the multiplier)

3. Multiply the result from step 2, by the cable loss in step 1
   - 1.4 X 4.9 = 6.86 dB
Example 1, calculate the loss through 118 feet of RG-6 cable at 870 MHz

1. Using the cable loss table find the loss thru 100 feet of RG-6 cable at 870 MHz
   \[6.11 \text{ dB}\]

2. Divide the length of the cable by 100
   \[
   \frac{118}{100} = 1.18
   \]

3. Multiply 1.18 by the cable loss per 100 feet (6.11)
   \[
   1.18 \times 6.11 = 7.21 \text{ dB cable attenuation}
   \]
Example 2, calculate the loss through 56 feet of RG-6 cable at 45 MHz

1. Using the cable loss table find the loss thru 100 feet of RG-6 cable at 45 MHz
   - 1.39 dB

2. Divide the length of the cable by 100
   - \( \frac{56}{100} = 0.56 \)

3. Multiply 0.56 by the cable loss per 100 feet (1.39)
   - \( 0.56 \times 1.39 = 0.78 \text{ dB cable attenuation} \)
HFC Plant
Taps

4 Port Tap

In

DC

2 Way

Out

2 Way

2 Way

2 Way
Taps

- 23 Tap

45 dBmV

-1 dB
-16 dB

-3.5 dB

44 dBmV

22 dBmV

@ Tap Ports
Taps

14 Tap

35 dBmV

-7 dB

-2.6 dB

-3.5 dB

-3.5 dB

-3.5 dB

21 dBmV

@ Tap Ports

32.4 dBmV
Taps

23, 20, 17, 14, 11, 8 Values
HFC Plant Return

- Fiber Node
- Line Extender
- Tapped

Target
18dBmV

0.5
0.8
1.1
1.6
3.3

18dBmV

41dBmV
39dBmV
37.3dBmV
35.9dBmV
35.0dBmV
35.8dBmV
Levels in the Home
Forward and Return
Use the following as average guidelines to calculate proper operating levels. Each system/operator will have different standards to follow but the math is the same.
How is forward signal loss determined?

- Output levels at tap
- Length of drop and attenuation
- Passive devices in home
- House cable attenuation
- Active devices in home
<table>
<thead>
<tr>
<th>Component</th>
<th>Analog</th>
<th>Digital</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Distribution Plant</strong></td>
<td>10dBmV</td>
<td>15dBmV</td>
</tr>
<tr>
<td><strong>Drop = 200’of RG6</strong></td>
<td></td>
<td>-3dB</td>
</tr>
<tr>
<td></td>
<td></td>
<td>-11dB</td>
</tr>
<tr>
<td></td>
<td>7dBmV</td>
<td>4dBmV</td>
</tr>
<tr>
<td><strong>Data Splitter</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Amplifier/Gain</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Splitter = 2 Way</strong></td>
<td>-3.5dB</td>
<td>-3.5dB</td>
</tr>
<tr>
<td></td>
<td>3.5dBmV</td>
<td>0.5dBmV</td>
</tr>
<tr>
<td><strong>Outlet Cable = 100’of RG6</strong></td>
<td>@ 55MHz -1.5dB/100’</td>
<td>@ 750MHz -5.5dB/100’</td>
</tr>
<tr>
<td></td>
<td>-1.5dB</td>
<td>-5.5dB</td>
</tr>
<tr>
<td><strong>CPE</strong></td>
<td>2.0dBmV</td>
<td>5.0dBmV</td>
</tr>
</tbody>
</table>
# Forward Exercise

<table>
<thead>
<tr>
<th>Component</th>
<th>Analog</th>
<th>Digital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution Plant</td>
<td>10dBmV 55MHz</td>
<td>15dBmV 750MHz</td>
</tr>
<tr>
<td>Drop = 200’of RG6</td>
<td>@ 55MHz -1.5dB/100’</td>
<td>-3dB 750MHz -11dB</td>
</tr>
<tr>
<td>Data Splitter = 2 Way</td>
<td>-3.5dB</td>
<td>-3.5dB</td>
</tr>
<tr>
<td>Amplifier/Gain</td>
<td>0.5dBmV</td>
<td>3.5dBmV</td>
</tr>
<tr>
<td>Splitter = 3 Way Balanced</td>
<td>-5.5dB</td>
<td>-5.5dB</td>
</tr>
<tr>
<td>Outlet Cable = 100’of RG6</td>
<td>-1.5dB 55MHz -5.5dB/100’</td>
<td>-1.5dB 750MHz -5.5dB</td>
</tr>
<tr>
<td>CPE</td>
<td>-2.25dBmV</td>
<td>-3.5dBmV -10.5dBmV</td>
</tr>
</tbody>
</table>

Analog and Digital power levels are given in dBmV. The table includes loss calculations for RG6 cable at 55 MHz and 750 MHz frequencies.
<table>
<thead>
<tr>
<th>Component</th>
<th>55 MHz</th>
<th>750 MHz</th>
<th>Analog</th>
<th>Digital</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution Plant</td>
<td></td>
<td></td>
<td>10dBmV</td>
<td>15dBmV</td>
</tr>
<tr>
<td>Drop = 200’ of RG6</td>
<td>@ 55MHz -1.5dB/100’</td>
<td>@ 750MHz -5.5dB/100’</td>
<td>-3dB</td>
<td>-11dB</td>
</tr>
<tr>
<td>Data Splitter = 2 Way</td>
<td>-3.5dB</td>
<td></td>
<td>7dBmV</td>
<td>4dBmV</td>
</tr>
<tr>
<td>Amplifier/Gain</td>
<td></td>
<td></td>
<td>15dB</td>
<td>15dB</td>
</tr>
<tr>
<td>Splitter = 3 Way Balanced</td>
<td>@ 55MHz -1.5dB/100’</td>
<td>@ 750MHz -5.5dB/100’</td>
<td>-5.5dB</td>
<td>-5.5dB</td>
</tr>
<tr>
<td>Outlet Cable = 100’ of RG6</td>
<td>@ 55MHz -1.5dB/100’</td>
<td>@ 750MHz -5.5dB/100’</td>
<td>-1.5dB</td>
<td>-5.5dB</td>
</tr>
<tr>
<td>CPE</td>
<td>-2.25dBmV</td>
<td></td>
<td>1.85dBmV</td>
<td>4.5dBmV</td>
</tr>
</tbody>
</table>
How is return signal loss determined?

- Output level of device
- Cable attenuation
- Passive loss
- Active gain
- Tap value
- Tap thru put loss
- Feeder cable attenuation
- Input requirement at first active
## Return Exercise

<table>
<thead>
<tr>
<th>Component</th>
<th>Return</th>
<th>Return @ 30 MHz</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution Plant</td>
<td>13.5 dBmV</td>
<td>38.5 dBmV</td>
</tr>
<tr>
<td>Drop = 200’ of RG6</td>
<td>-0.5 dB</td>
<td>-2.4 dB</td>
</tr>
<tr>
<td>Data Splitter</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Amplifier/Gain</td>
<td></td>
<td>40.9 dBmV</td>
</tr>
<tr>
<td>Splitter = 2 Way</td>
<td></td>
<td>-3.5 dB</td>
</tr>
<tr>
<td>Outlet Cable = 50’ of RG6</td>
<td></td>
<td>44.4 dBmV</td>
</tr>
<tr>
<td>CPE</td>
<td></td>
<td>45 dBmV</td>
</tr>
</tbody>
</table>

4.5 dB low - CMTS request modem to turn up 4.5 dB to 49.5 dBmV
Metric prefix’s are used for system measurements

Powers of 10 tells us how many times we have to multiply 10 by itself

Logarithms express large numbers simply

dB represents the logarithm of a ratio of two signal power or voltage levels

dBmV is an absolute signal measurement where 0 dBmV = 1mV across 75 ohms