Using Decibels - 2

Rules:

- Squares:

  (Multiply by 2)

$$10\log_{10}(A^2)$$
$$= 2 \text{ x } 10\log_{10}(A)$$
$$= 20\log_{10}(A)$$
$$= 2 \text{ x } (A \text{ in dB})$$

- Square roots:

  (Divide by 2)

$$10\log_{10}(\sqrt{A})$$
$$= \frac{10}{2}\log_{10}(A)$$
$$= \frac{1}{2} \text{ x } (A \text{ in dB})$$

Thinking in dB

- Its useful to be able to think in dB

Linear Ratio	dB	Linear Ratio	dB
0.001	-30.0	2.000	3.0
0.010	-20.0	3.000	4.8
0.100	-10.0	4.000	6.0
0.200	-7.0	5.000	7.0
0.300	-5.2	6.000	7.8
0.400	-4.0	7.000	8.5
0.500	-3.0	8.000	9.0
0.600	-2.2	9.000	9.5
0.700	-1.5	10.000	10.0
0.800	-1.0	100.000	20.0
0.900	-0.5	1000.000	30.0
1.000	0.0	18.000	12.6

Note that 18 is 2*3*3.
Since: 2 = 3 dB
and: 3 = 4.8 dB
you can find 18 in dB in your head by adding 3 + 4.8 + 4.8 = 12.6
You don't even need a calculator!
This is <u>really</u> handy for checking link budgets quickly.

References in dB

- dB values can be referenced to a standard
- The standard is simply appended to dB
- Typical examples are:

Units	Reference
dBi	isotropic gain antenna
dBW	1 watt
dBm	1 milliwatt
dBHz	1 Hertz
dBK	1 Kelvin
dBi/K	isotropic gain antenna/1 Kelvin
dBW/m^2	1 watt/m^2
dB$	1 dollar

Link Budget

Translating to dBs

- The transmission formula can be written in dB as:

$$P_r = EIRP - L_{ta} - L_p - L_a - L_{pol} - L_{ra} - L_{other} + G_r - L_r$$

- This form of the equation is easily handled as a spreadsheet (additions and subtractions!!)
- The calculation of received signal based on transmitted power and all losses and gains involved until the receiver is called "Link Power Budget", or "Link Budget".
- The received power Pr is commonly referred to as "**Carrier Power**", ***C***.

Link Power Budget

Tx

EIRP

Transmission:
+ HPA Power
- Transmission Losses
  (cables & connectors)
+ Antenna Gain

Now all factors are accounted for as additions and subtractions

- Antenna Pointing Loss
- Free Space Loss
- Atmospheric Loss
(gaseous, clouds, rain)
- Rx Antenna Pointing Loss

Reception:
+ Antenna gain
- Reception Losses
  (cables & connectors)
+ Noise Temperature
Contribution

Rx

P_r

4 Easy Steps to a Good Link Power Budget

- First, draw a sketch of the link path
  - Doesn't have to be artistic quality
  - Helps you find the stuff you might forget
- Next, think carefully about the system of interest
  - Include all significant effects in the link power budget
  - Note and justify which common effects are insignificant here
- Roll-up large sections of the link power budget
  - Ie.: TXd power, TX ant. gain, Path loss, RX ant. gain, RX losses
  - Show all components for these calculations in the detailed budget
  - Use the rolled-up results in build a link overview
- Comment the link budget
  - Always, always, ***always*** use units on parameters (dBi, W, Hz ...)

Simple Link Power Budget

Parameter	Value	Totals	Units
Frequency	11.75		GHz
Transmitter			
Transmitter Power	40.00		dBm
Modulation Loss	3.00		dB
Transmission Line Loss	0.75		dB
Transmitted Power		**36.25**	**dBm**
Transmit Antenna			
Diameter	0.5		m
Aperture Efficiency	0.55		none
Transmit Antenna Gain		**33.18**	**dBi**
Slant Path			
Satellite Altitude	35,786		km
Elevation Angle	14.5		degrees
Slant Range	41,602		km
Free-space Path Loss	206.22		dB
Gaseous Loss	0.65		dB
Rain Loss (allocated)	3.50		dB
Path Loss		**210.37**	**dB**

Parameter	Value	Totals	Units
Receive Antenna			
Radome Loss	0.50		dB
Diameter	1.5		m
Aperture Efficiency	0.6		none
Gain	43.10		dBi
Polarization Loss	0.20		dB
Effective RX Ant. Gain		**42.40**	**dB**
Received Power		**-98.54**	**dBm**
Summary			
Transmitted Power	36.25		dBm
Transmit Anntenna Gain	33.18		dBi
EIRP		69.43	dBmi
Path Loss		210.37	dB
Effective RX Antenna Gain		42.4	dBi
Received Power		-98.54	dBm

Why calculate Link Budgets?

- System performance tied to operation thresholds.
- Operation thresholds C_{min} tell the minimum power that should be received at the demodulator in order for communications to work properly.
- Operation thresholds depend on:
  - Modulation scheme being used.
  - Desired communication qual
  - Coding gain.
  - Additional overheads.
  - Channel Bandwidth.
  - Thermal Noise power.

We will see more on these items in the next classes.

Closing the Link

- We need to calculate the Link Budget in order to verify if we are "closing the link".

  $P_r >= C_{min}$ ➔ Link Closed

  $P_r < C_{min}$ ➔ Link not closed

- Usually, we obtain the "Link Margin", which tells how tight we are in closing the link:

  $Margin = P_r - C_{min}$

- Equivalently:

  $Margin > 0$ ➔ Link Closed

  $Margin < 0$ ➔ Link not closed

Carrier to Noise Ratios

- C/N: carrier/noise power in RX BW (dB)
  - Allows simple calculation of margin if:
  - Receiver bandwidth is known
  - Required C/N is known for desired signal type
- C/N_o: carrier/noise p.s.d. (dbHz)
  - Allows simple calculation of allowable RX bandwidth if required C/N is known for desired signal type
  - Critical for calculations involving carrier recovery loop performance calculations

System Figure of Merit

- G/T_s: RX antenna gain/system temperature
  - Also called the System Figure of Merit, G/T_s
  - Easily describes the sensitivity of a receive system
  - Must be used with caution:
    - Some (most) vendors measure G/T_s under ideal conditions only
    - G/T_s degrades for most systems when rain loss increases
      - This is caused by the increase in the sky noise component
      - This is in addition to the loss of received power flux density

System Noise Power

System Noise Power - 1

- Performance of system is determined by C/N ratio.
- Most systems require C/N > 10 dB.
  (Remember, in dBs: C - N > 10 dB)
- Hence usually: C > N + 10 dB
- We need to know the noise temperature of our receiver so that we can calculate N, the noise power ($N = P_n$).
- T_n (noise temperature) is in Kelvins (symbol K):

$$T[K] = T[^0C] + 273$$

$$T[K] = \left(T[^0F] - 32\right)\frac{5}{9} + 273$$

System Noise Power - 2

- System noise is caused by thermal noise sources
  - External to RX system
    - Transmitted noise on link
    - Scene noise observed by antenna
  - Internal to RX system
- The power available from thermal noise is:

$$N = kT_sB \ \text{(dBW)}$$

where k = Boltzmann's constant
= 1.38×10^{-23} J/K(-228.6 dBW/HzK),
T_s is the effective system noise temperature, and
B i

We will see more on calculating Ts next class.