PRACTICAL MICROWAVE RADIO LINK DESIGN

EEEN 566-ANTENNA & RADIOWAVE PROPAGATION

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INTRODUCTION

1. By now you know that that clear line of sight is required between two microwave, but there is a lot more to it than that.
2. **First,** the earth is not flat. It is circular and has hills, valleys and even mountains.
3. **Second,** radio waves get reflected and refracted.
4. **Third,** radio waves are spread out. They are not pencil thin.
5. **Fourth,** we share the radio spectrum with other users.

FREE SPACE LOSS(1)

1. **Free Space Path Loss (FSPL) defines** the power loss between two isotropic radiators in free space, expressed as a power ratio.

2. The free-space path loss (FSPL) formula derives from the Friis transmission formula that states power gain of an antenna system as:

$$\frac{P_r}{P_t} = G_t G_r \left(\frac{\lambda}{4\pi D}\right)^2$$

1. The FSPL formula expresses a loss value that is the reciprocal of gain and assumes the directivity for the transmit and receive antennas are isotropic, i.e $G_t = G_r = 1$ which yields:

$$FSPL = \left(\frac{4\pi D}{\lambda}\right)^2$$

FREE SPACE PATH LOSS FORMULA (2)

Free Space Path Loss formula given by:

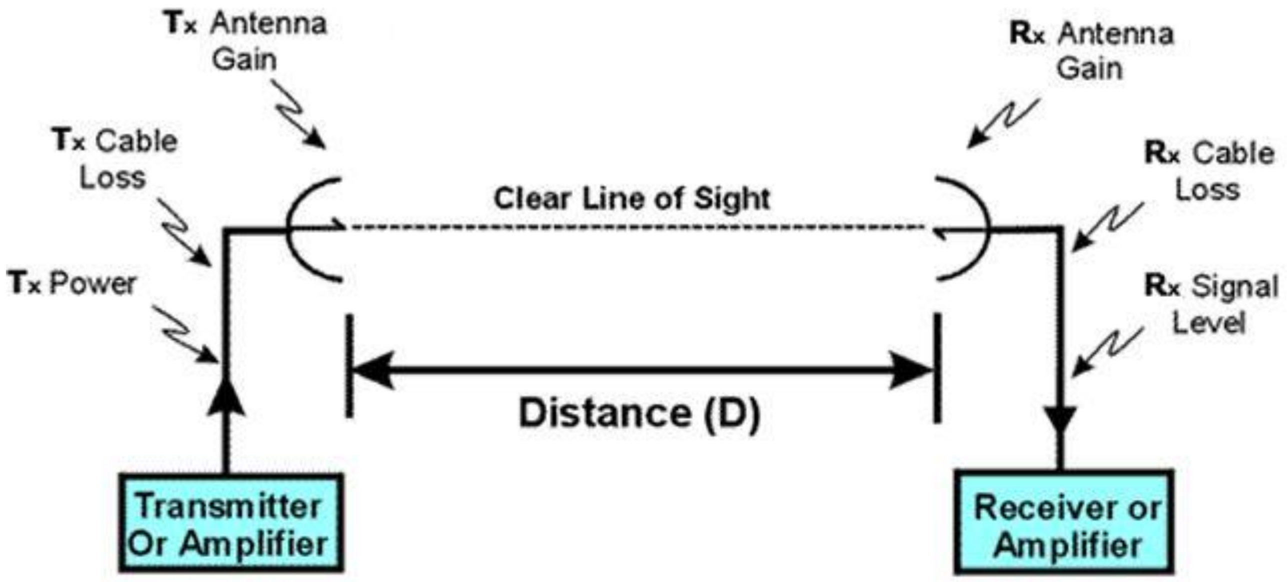
$$FSPL = \left(\frac{4\pi D}{\lambda}\right)^2$$

Can also be rewritten as:

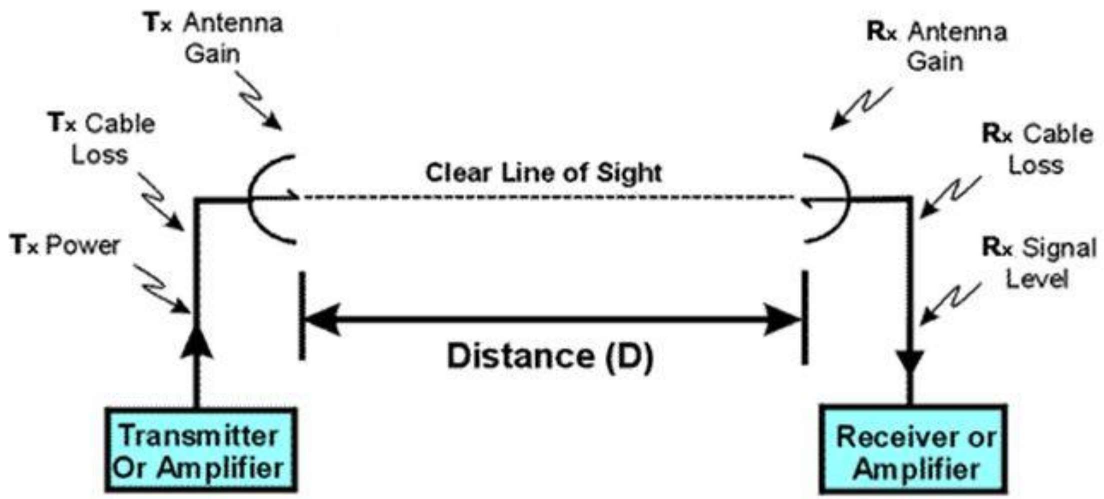
$$FSPL = \left(\frac{4\pi Df}{c}\right)^2$$

Where

D is the distance in meters



FREE SPACE PATH LOSS FORMULA (3)



If the antennas are NOT isotropic, we can write:

$$FSPL = \frac{1}{G_t G_r}\left(\frac{4\pi D f}{c}\right)^2 = \frac{1}{G_t G_r}\left(\frac{4\pi D f}{3\times 10^8}\right)^2$$

$$FSPL = \frac{1}{G_t G_r}\left(\frac{4\pi D f}{3\times 10^5}\right)^2$$ when D is in Kms

Where the loss in expressed in dBs, we can write:

$$FSB(dB) = 20\, log_{10}(D) + 20 log_{10}(f) + 20 log_{10}\left(\frac{4\pi}{3\times 10^5}\right) - G_{TX} - G_{RX}$$

$$= 20\, log_{10}(D) + 20 log_{10}(f) + 20 log_{10}(32.44) - G_{TX} - G_{RX}$$

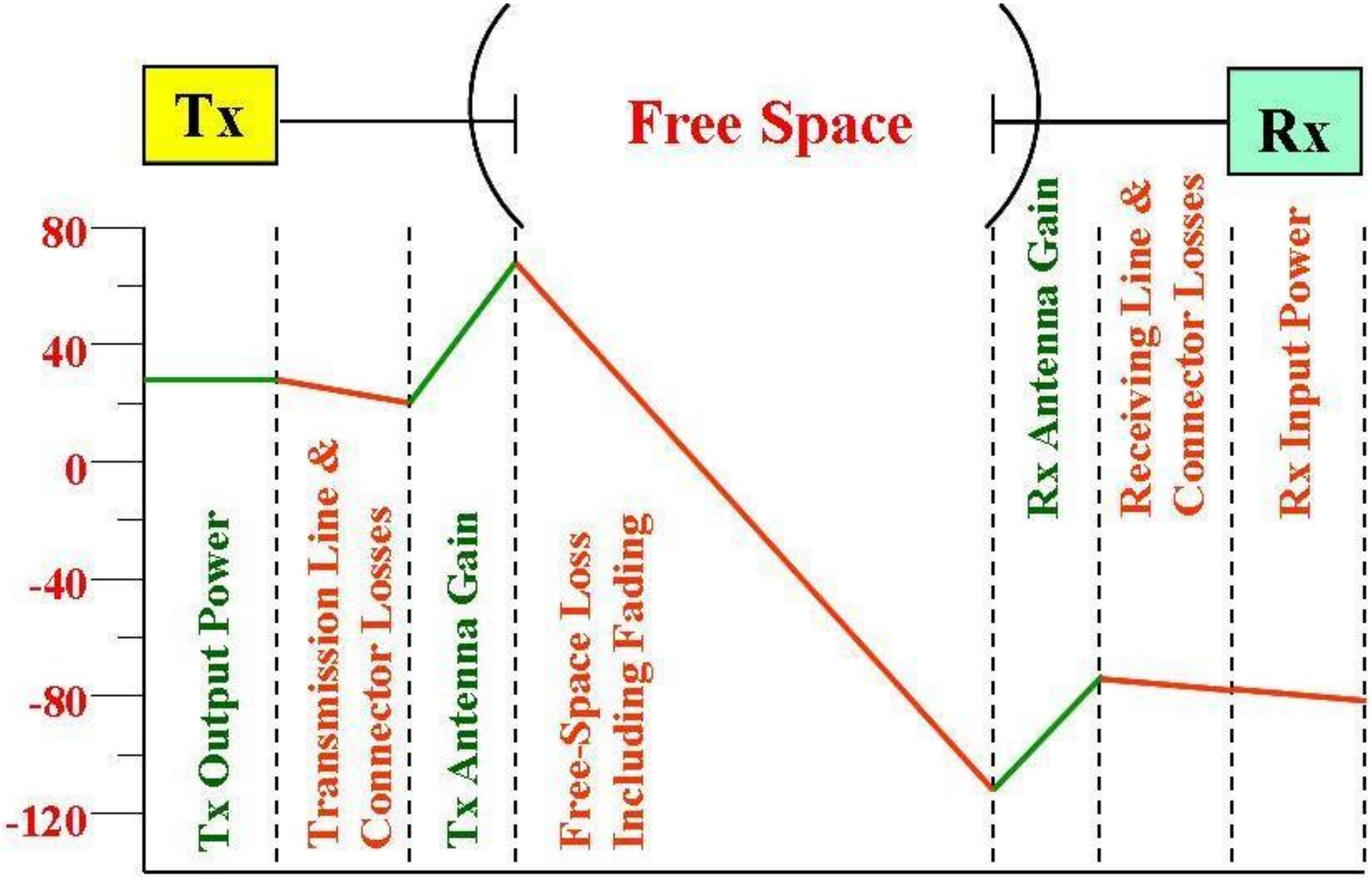
where

D is the distance in kms

G_{TX} and G_{RX} are expressed in DBs and include cables losses

RECEIVER SENTITIVITY

Receiver sensitivity is the weakest RF signal level (usually measured in dBm) that a radio needs receive in order to demodulate and decode a packet of data without errors.



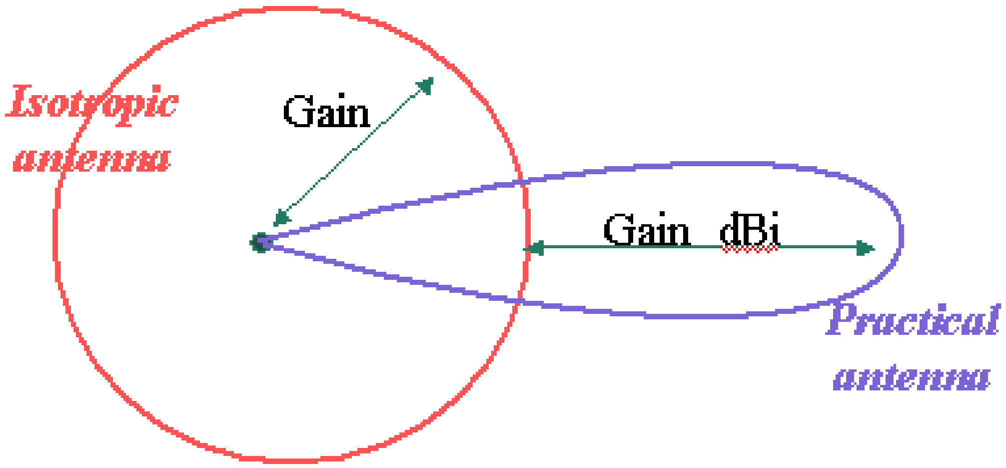
EFFECTIVE ISOTROPIC RADIATED POWER (EIRP)-1

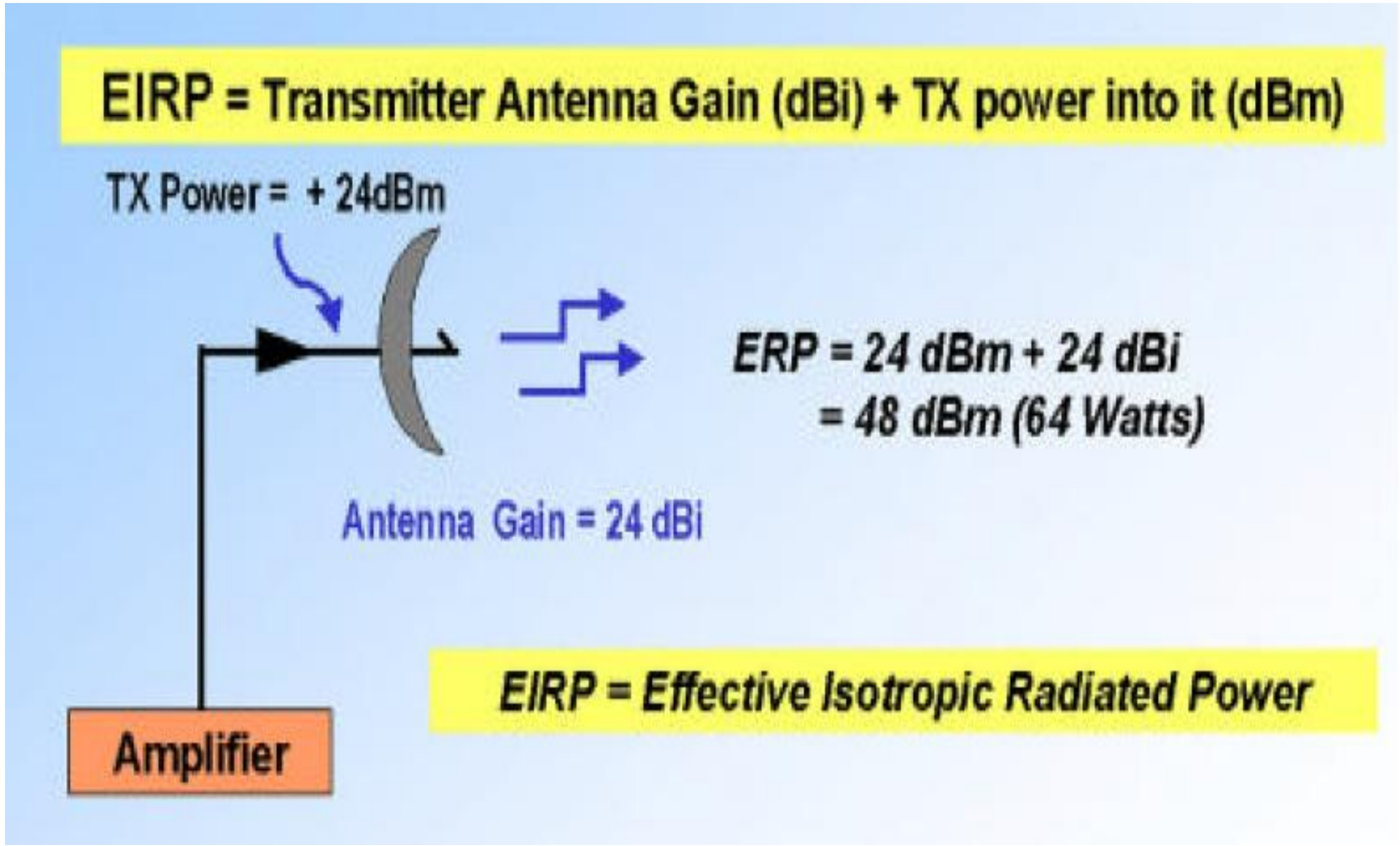
1. **Effective isotropic radiated power (EIRP)** is the actual RF power as measured in the main lobe (or focal point) of an antenna.

2. It is equal to the sum of the transmit power into the antenna (in dBm) added to the dBi gain of the antenna.

3. Since it is a power level, the result is measured in dBm.

EFFECTIVE ISOTROPIC RADIATED POWER (EIRP)-2



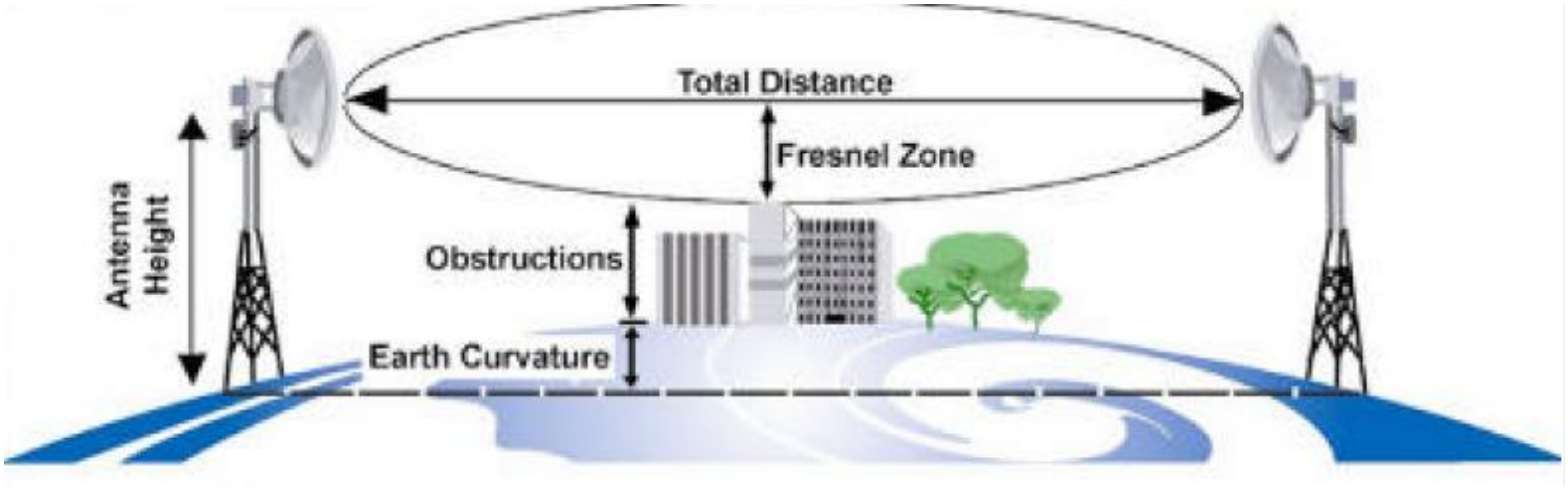


FRESNEL ZONE (1)

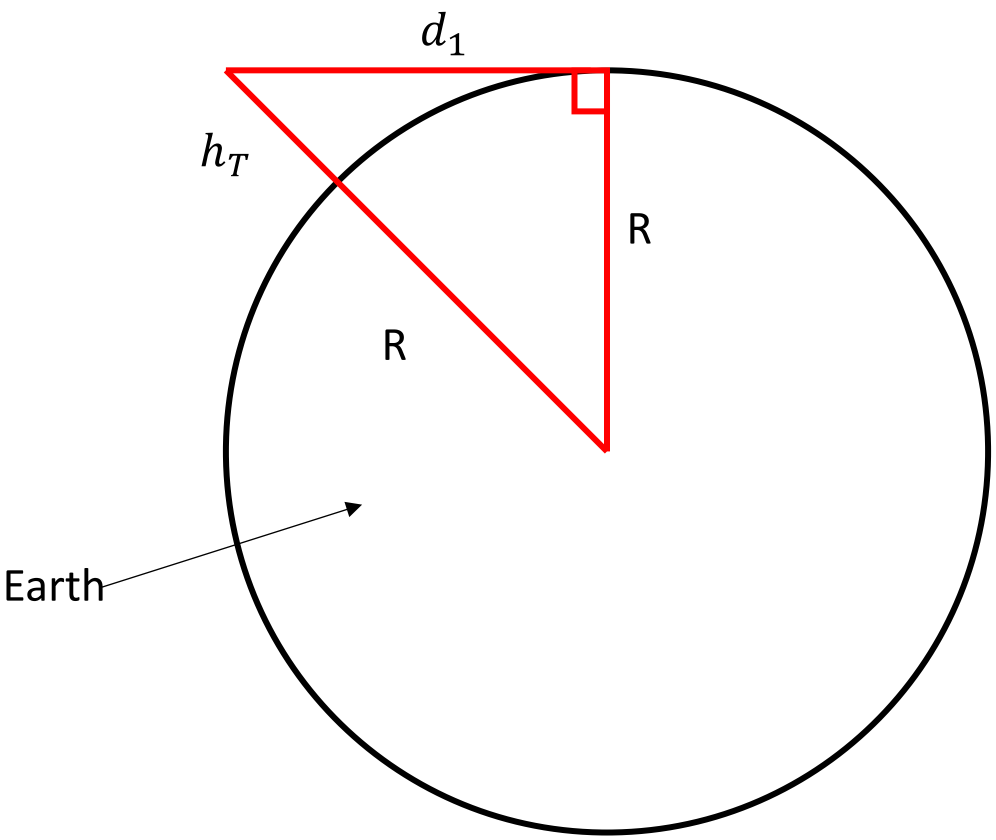
1. Radio waves travel in a straight line, unless something refracts or reflects them. But the energy of radio waves is not “pencil thin.”
2. They spread out the further they get from the radiating source — like ripples from a rock thrown into a pond.
3. The area that the signal spreads out into is called the **Fresnel zone**.
4. If there is an obstacle in the Fresnel zone, part of the radio signal will be arbsobed and also diffracted or bent away from the straight-line path.
5. The effect is that on a point-to-point radio link, this refraction will reduce the amount of RF energy reaching the receive antenna.

FRESNEL ZONE(2)

As the distance increases, the Fresnel zone gets fatter and higher antennas are required.



ANTENNA HEIGHT & THE HORIZON (1)



$$(h_T + R)^2 = (d_1)^2 + (R)^2$$

$$h_T^2 + 2h_T R + R^2 = (d_1)^2 + (R)^2$$

$$d_1^2 = h_T^2 + 2h_T R$$

But

radius of earth, R = 6371 kms

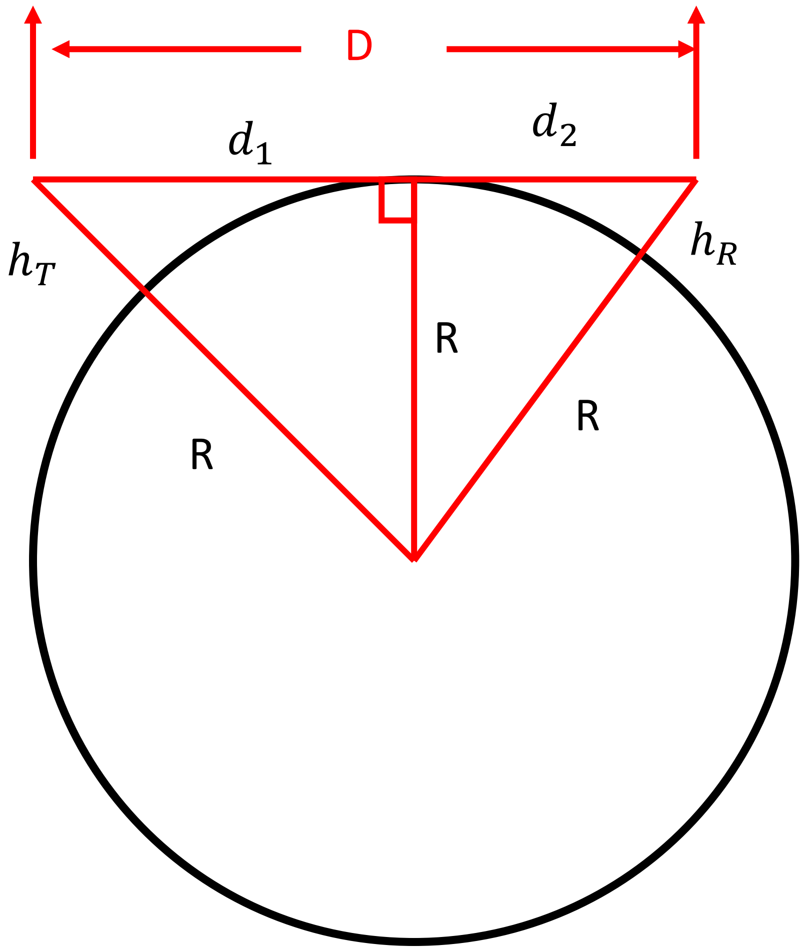
and

h_T << 1 km

Hence

$$d_1 = \sqrt{2h_T R}$$

ANTENNA HEIGHT & THE HORIZON (2)



$(h_T + R)^2 = (d_1)^2 + (R)^2$

$(h_R + R)^2 = (d_2)^2 + (R)^2$

If we ignore h_T^2 and h_R^2

R = 6371 kms

Then

$$D = d_1 + d_2 = \sqrt{2h_T R} + \sqrt{2h_R R}$$

$$= 3.569\left(\sqrt{h_T} + \sqrt{h_R}\right) \text{ Kms}$$

RULE OF THUMB ON DISTANCES BETWEEN MICROWAVE REPEATERS

1. Why is the distance between two microwave repeaters limited to 40 Kms?
2. Why as a rule of thumb, would you say that there are 10 repeater stations between Nairobi and Mombasa?

SYSTEM OPERATING MARGIN (SOM)

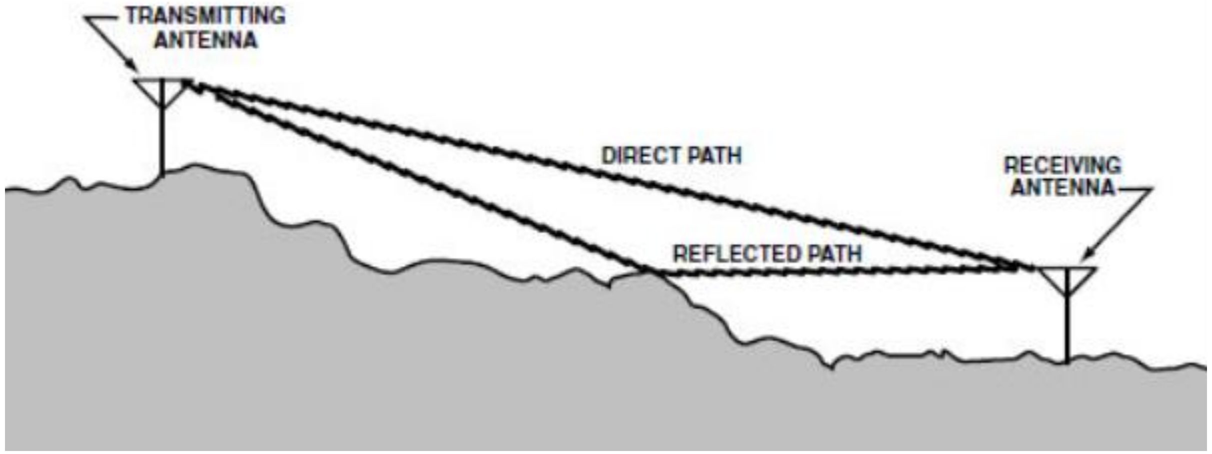
System operating margin (SOM) (also referred to as fade margin) is the difference (measured in dB) between the nominal signal level received at one end of a radio link and the signal level required by that radio to assure that a packet of data is decoded without error.

$$SOM = RX_{signal} - RX_{sensitivity}$$

MULTIPATH INTERFERENCE

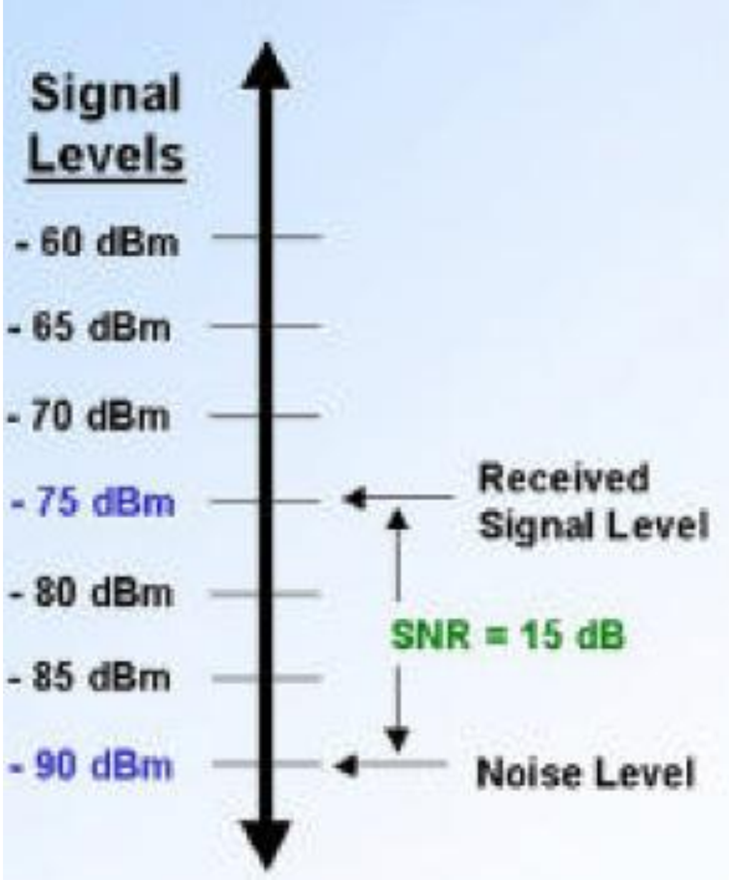
Multipath interference occurs when signals arrive at a remote antenna after being reflected off the ground or refracted back to earth from the sky.

Multipath signals will subtract (or add) to the main signal and cause the received signal to be weaker when subtracted (or stronger when added).



SIGNAL TO NOISE RATIO

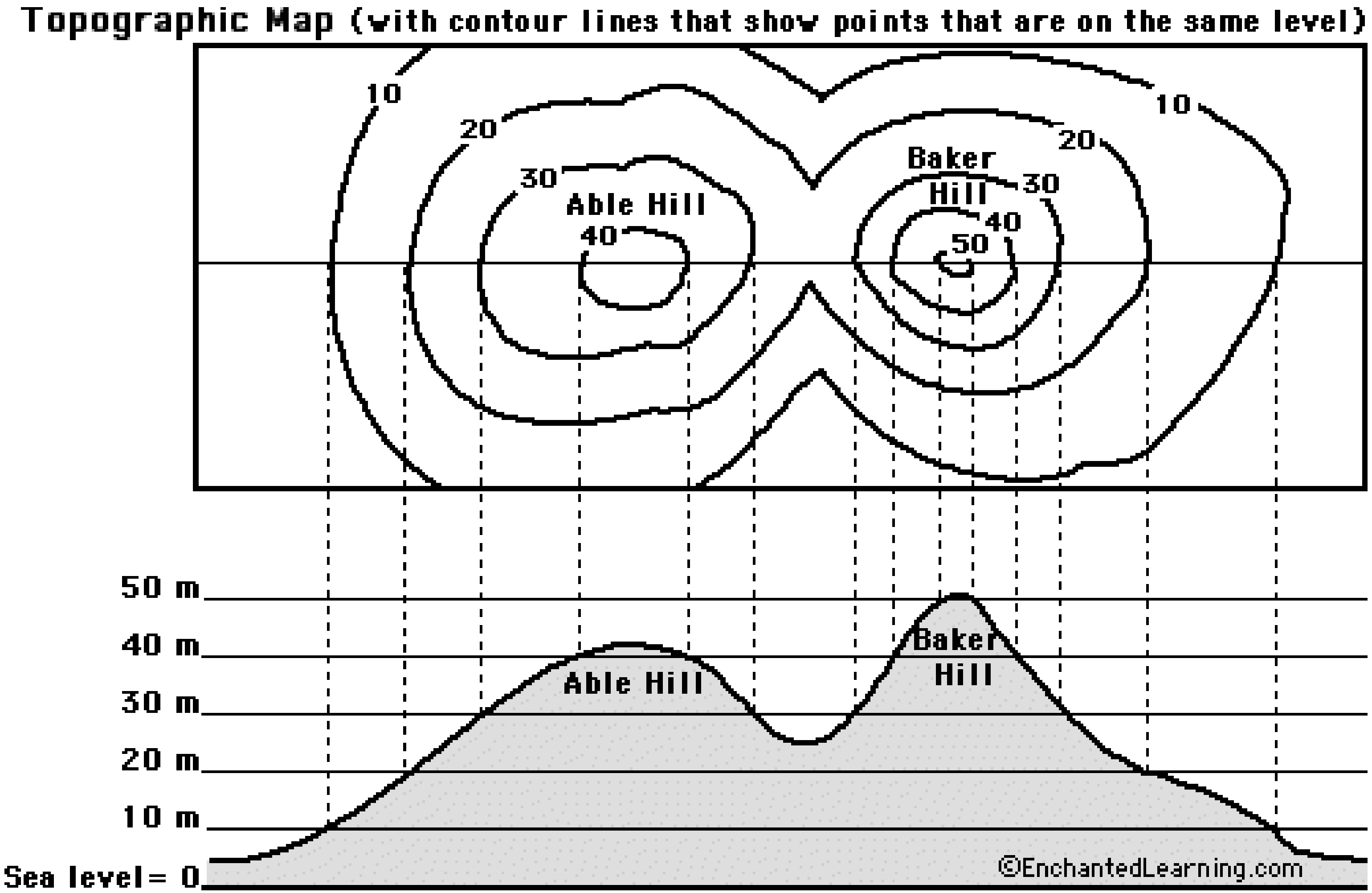
Signal to Noise ratio is the ratio in dBs between the received signal and the noise level experienced by the receiver.



STEP 1 – MICROWAVE LINK DESIGN

1. Verify that it will have not only clear line of sight, but at least 60 percent of the first Fresnel zone is clear of obstructions as well.
2. The longer the distance, the more important this is.

USE CONTOUR MAP TO GET THE ELEVATION



The two hills seen from the side, with elevations marked and dotted lines pointing to the corresponding contour lines.

STEP 2: PERFORM THE SOM CALCULATION

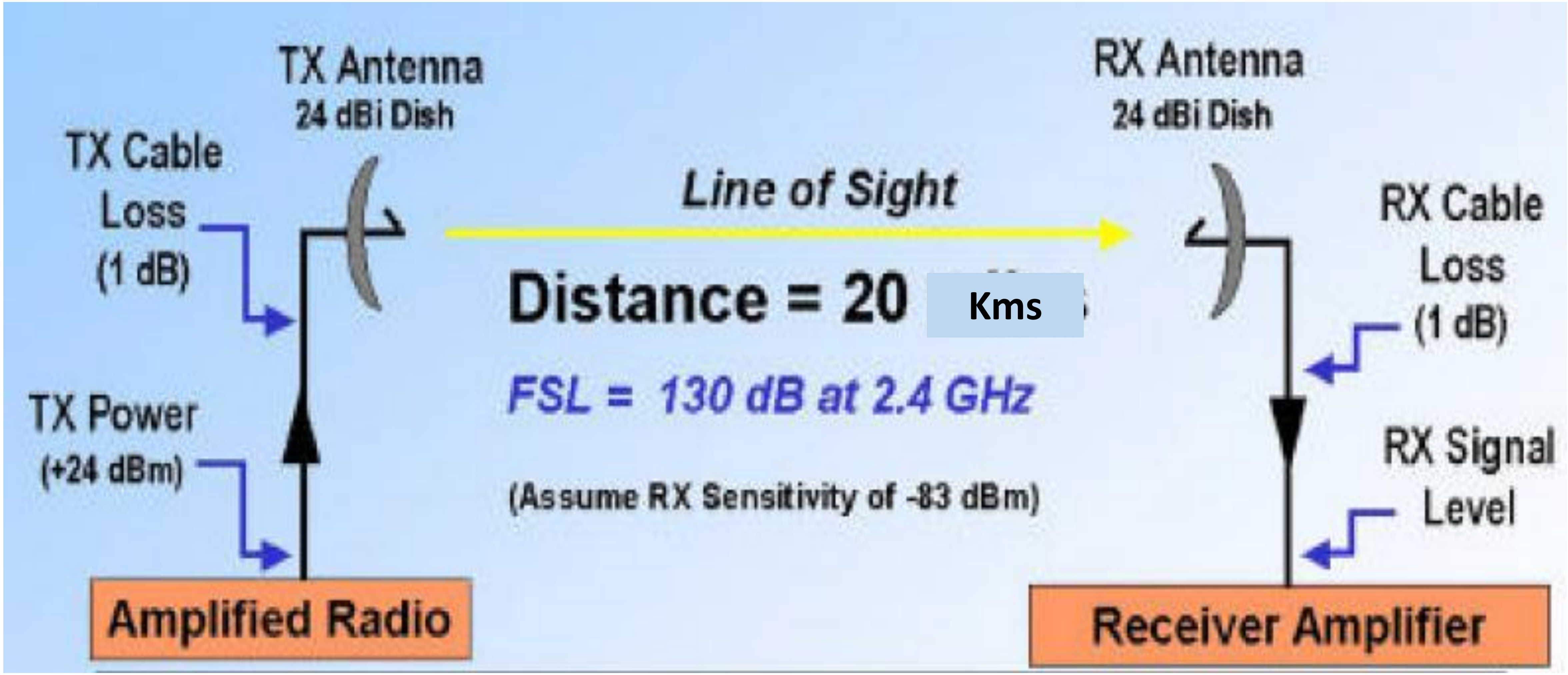
- **Conduct the System operating margin (SOM)** calculation, to test various system designs and scenarios (Tx power, antenna gains, cable types, etc) to see how much fade margin (or “safety cushion”) your link will have.

MINIMUM SOM CALCULATION EXAMPLE (1)

Assume that you are required to design a microwave link at 2.4GHz over a distance of 20 Kms. Conduct a SOM calculation with the following parameters.

- The transmit power is 24dBm
- TX antenna gain is 24dBi
- TX cable loss is 1 dB
- RX antenna gain is 24 dBi
- RX cable loss is 1 dB
- RX sensitivity is -83dBm

MINIMUM SOM CALCULATION EXAMPLE (2)



MINIMUM SYSTEM OPERATING MARGIN (SOM) CALCULATION EXAMPLE

1. To calculate SOM in the example, start with the transmit power (+24 dBm), subtract the coax cable loss (1 dB), and add the transmit antenna gain (24 dBi). This gives you the effective isotropic radiated power:

   EIRP = TX Power - Coax Cable Loss + TX Antenna Gain.

2. Then subtract the Free Space Loss (130 dB), add the receiver antenna gain (24 dBi), subtract the coax cable loss (1dB) and you get the signal reaching the receiver:

   RX Signal = EIRP - FSL + RX Antenna Gain – Coax Cable Loss

3. Compute the difference between the received signal and the radio's receiver sensitivity to determine the SOM.

   In this example, the received signal is –60 dBm and the receiver's sensitivity is –83 dBm giving a theoretical System Operating Margin (SOM) of 23 dB.

INTERFERENCE & NOISE

1. In practice, the SOM is not the only determining factor. Noise and interference at the receiver also determines the reliability of a link.
2. The presence of noise or interference on a radio link will reduce the SNR.
3. Interference can be as a result of co-locating at a site with other radios operating in the same band.
4. The designer must establish what frequency spectrum any co-located radios are occupying.
5. If the co-located radio links have energy or sideband noise on your receive channel and the antennas are close to yours, you will likely get interference from them, perhaps to the point where your link will not work.