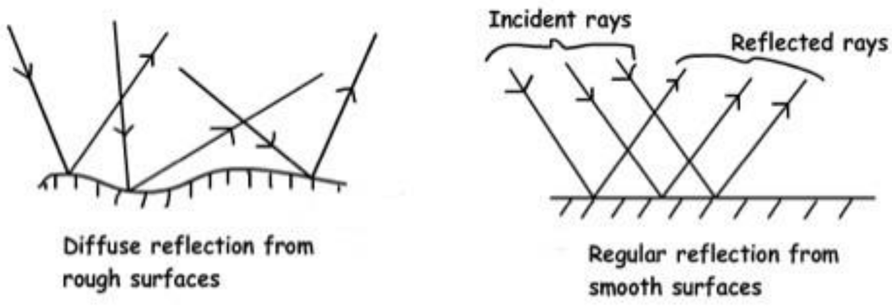
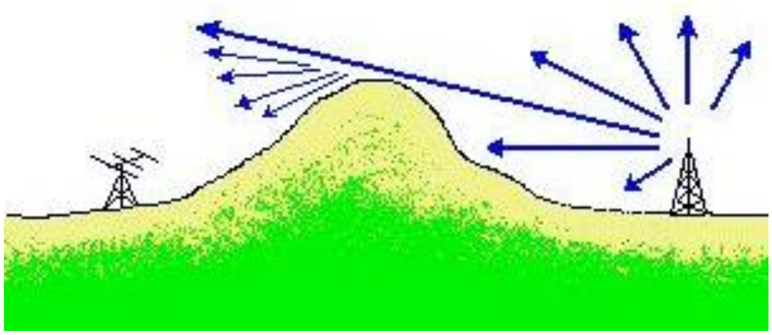
a. The surface is *smooth* if its minimum to maximum protuberance h is less than h_c,

b. The surface is *rough* if protuberance is greater than h_c.



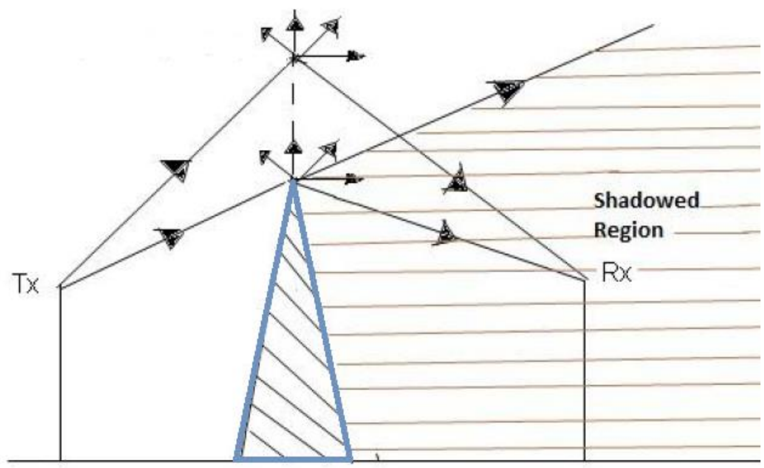
4.3.3 Diffraction

- Diffraction is the phenomena that occur when radio waves encounter obstacles that have sharp irregularities (edges). The secondary waves resulting from the obstructing surface are present throughout the space and even behind the obstacle.



- The radio wave changes in amplitude and phase and penetrates the shadow zone, deviating from a straight line path.

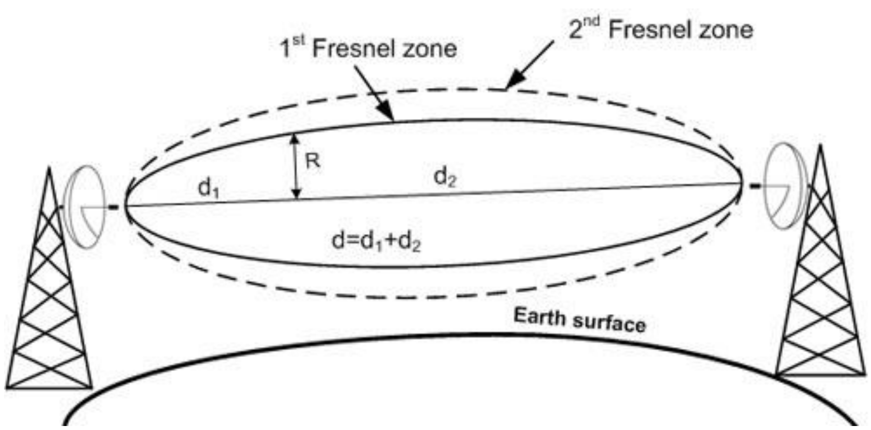
- Diffraction is explained by Huygens-Fresnel principle which states that all points on a wavefront can be considered as the point source for secondary wavelets which form the secondary wavefront in the direction of the prorogation.
- In mobile communication, diffraction, scattering and reflection have a great advantage since the receiver is able to receive the signal even when not in line of sight of the transmitter.
- At high frequencies, diffraction, like reflection, depends on the geometry of the object, as well as the amplitude, phase, and polarization of the incident wave at the point of diffraction.



- Knife-edge diffraction model is one of the simplest diffraction model to estimate the diffraction loss. It considers the object like hill or mountain as a knife edge sharp object.

4.4 Fresnel Zones

- As mentioned before, the more is the object in the shadowed region greater is the diffraction loss of the signal.
- The effect of diffraction loss is explained by Fresnel zones as a function of the path difference.
- The successive Fresnel zones have phase difference of π which means they alternatively provide constructive and destructive interference to the received the signal.
- The radius of the each Fresnel zone is maximum at middle of transmitter and receiver (i.e. when $d_1 = d_2$) and decreases as moved to either side.



- It is seen that the loci of a Fresnel zone varied over d_1 and d_2 forms an ellipsoid with the transmitter and receiver at its focii.
  a. If there's no obstruction, then all Fresnel zones result in only the direct LOS prorogation and no diffraction effects are observed.
  b. If an obstruction is present, resulting in diffraction and also the loss of energy.
- The height of the obstruction can be positive zero and negative also.
- The diffraction losses are minimum as long as obstruction doesn't block volume of the 1st Fresnel zone.
- Diffraction effects are negligible beyond 55% of 1st Fresnel zone.

4.5 Link Budget Analysis

- The performance of any communication link depends on the quality of the equipment being used.

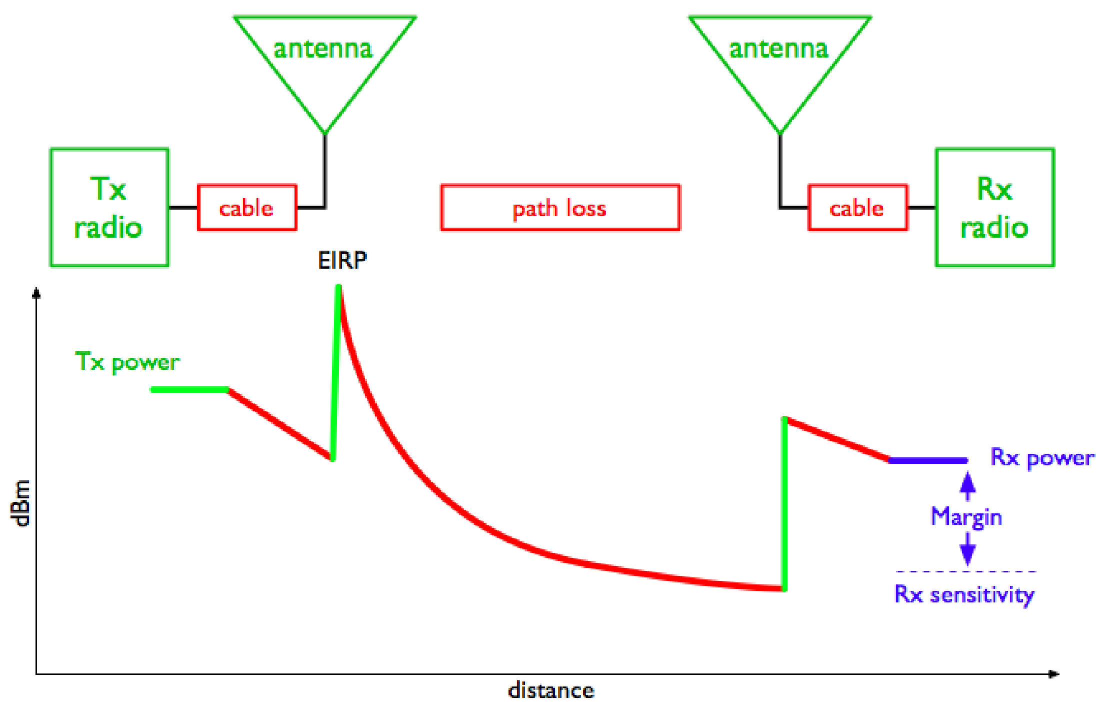
- ***Link budget*** is a way of quantifying the link performance.

- The received power in an 802.11 link is determined by three factors: ***transmit power***, ***transmitting antenna gain***, and ***receiving antenna gain***.

- If that power, minus the ***free space loss*** of the link path, is greater than the ***minimum received signal level*** of the receiving radio, then a link is possible.

- The difference between the minimum received signal level and the actual received power is called the ***link margin***.

- The link margin must be positive, and should be maximized (should be at least 10dB or more for reliable links).



Example link budget calculation

Let's estimate the feasibility of a **5 km** link, with one access point and one client radio. The access point is connected to an antenna with **10 dBi** gain, with a transmitting power of **20 dBm** and a receive sensitivity of **-89 dBm**.

The client is connected to an antenna with **14 dBi** gain, with a transmitting power of **15 dBm** and a receive sensitivity of **-82 dBm**. The cables in both systems are short, with a loss of **2dB** at each side at the 2.4 GHz frequency of operation

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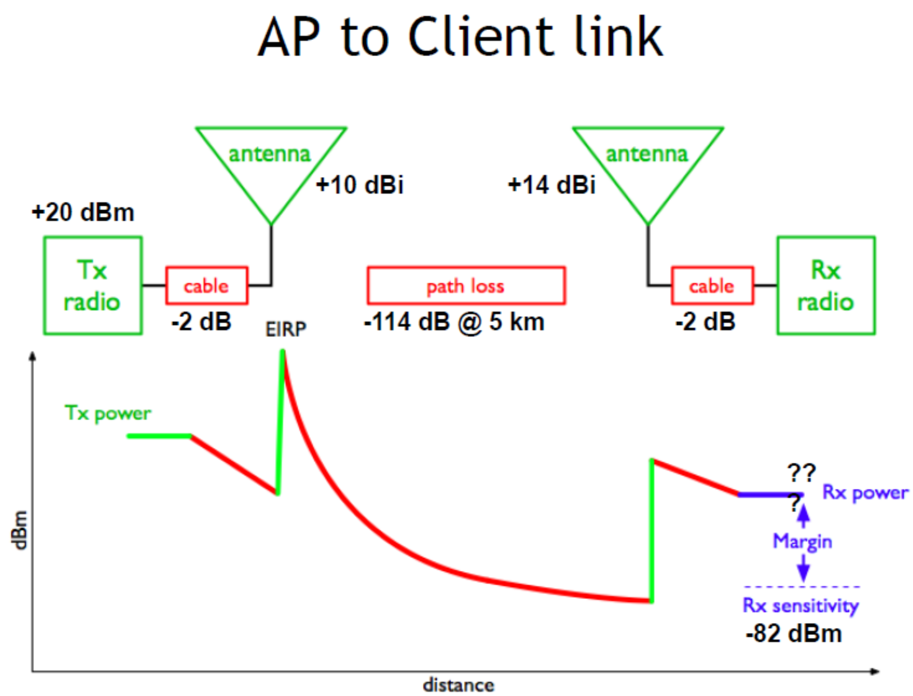
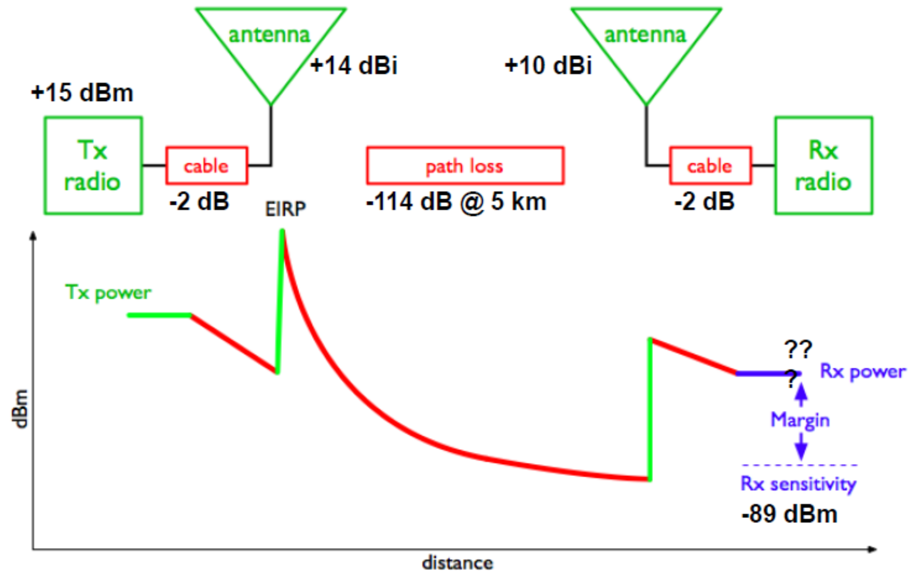
A) AP to Client link



- Total Gain = 20 dBm (TX Power AP) + 10 dB (Antenna Gain AP) – 2 dB (Cable Losses AP) + 14 dB (Antenna Gain Client) – 2 dB (Cable Losses Client) = 40 dB Total Gain
- expected received signal level = 40 dB Total Gain -114 dB (free space loss @5 km) = -74
- *link margin = -74 dBm (expected received signal level) --82 dBm (sensitivity of Client) = 8 dB (link margin)*

B) : Client to AP link



- Total Gain = 15 dB (TX Power client) + 14 dB (Antenna Gain) - 2 dB (Cable Losses Client) + 10 dB (Antenna Gain AP) - 2 dB (Cable Losses AP) = 35 dB Total Gain

- received signal = 35 dB Total Gain -114 dB (free space loss @5 km) = - 79

- link margin = -79 dB (expected received signal level) - - 89 dBm (sensitivity of AP) = 10 dB (link margin)