Point To Point Microwave Transmission

Contents

What is Transport ?

- Transport is an entity that carries information between Network Nodes

- Information is sent over a carrier between Network Nodes.

- Carrier is sent over a Transmission Media

- Commonly used Transmission Media :
  - Copper Cables
  - Microwave Radio
  - Optical Fiber
  - Infra Red Radio

Microwave Radio Basics

1. Basic Modules
2. Configuration
3. Applications
4. Advantages

Microwave Radio - Modules

- Microwave Radio Terminal has 3 Basic Modules
  - Digital Modem : To interface with customer equipment and to convert customer traffic to a modulated signal
  - RF Unit : To Up and Down Convert signal in RF Range
  - Passive Parabolic Antenna : For Transmitting and Receiving RF Signal
- Two Microwave Terminals Forms a Hop
- Microwave Communication requires LOS

Basic Hardware Configurations

- Non Protected or 1+ 0 Configuration
- Protected or 1+1 Configuration, also known as MHSB
  - In MHSB Modem and RF Unit are duplicated

Microwave Radio – Capacity Configurations

- Commonly Used Capacity Configurations
  - 4 x 2 Mbps or 4 x E1
  - 8 x 2 Mbps or 8 x E1
  - 16 x 2 Mbps or 16 x E1
  - 155 Mbps or STM1

Microwave Radio - Applications

- As Transport Medium in
  - Basic Service Networks
  - Mobile Cellular Network
  - Last Mile Access
  - Private Networks

Microwave Radio Advantages

- Advantages over Optical Fiber / Copper Cable System
  - Rapid Deployment
  - Flexibility
  - Lower Startup and Operational Cost
  - No ROW Issues
  - Low MTTR

Microwave Radio - Manufacturers

- Few well known Radio Manufacturers
  - Nokia
  - Nera
  - NEC
  - Siemens
  - Digital Microwave Corporation
  - Fujitsu
  - Ericsson
  - Alcatel
  - Hariss

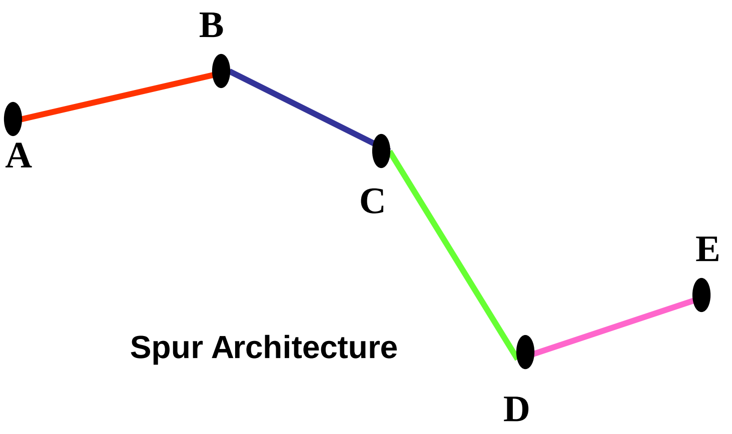
Microwave Network Planning Aspects

1. Network Architecture
2. Route Configuration
3. Choice of Frequency Band

Network Architecture

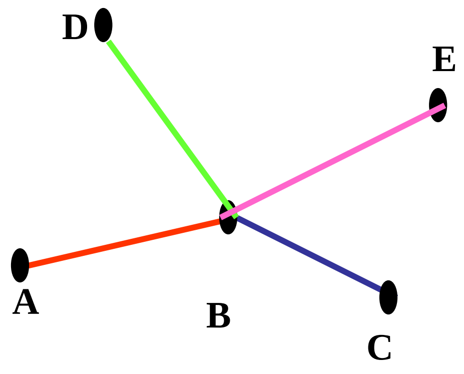
- Common Network Architectures
  - Spur or Chain
  - Star
  - Ring
  - Mesh
  - Combination of Above

Spur Architecture



- For N Stations N-1 Links are required
- Nth station depends on N-1 Links

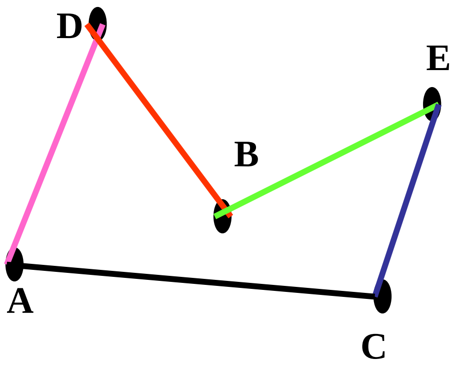
Star Architecture



Star Architecture

- For N Stations N-1 Links are required
- Each Station depends on Only 1 Link

Loop Architecture



Loop Architecture

- For N Stations N Links are required
- Route Diversity is available for all stations

Loop protection is effective against faults, which are caused by e.g.

•power failure

•equipment failure

•unexpected cut of cable

•human mistake

•rain and multipath fading cutting microwave radio connections

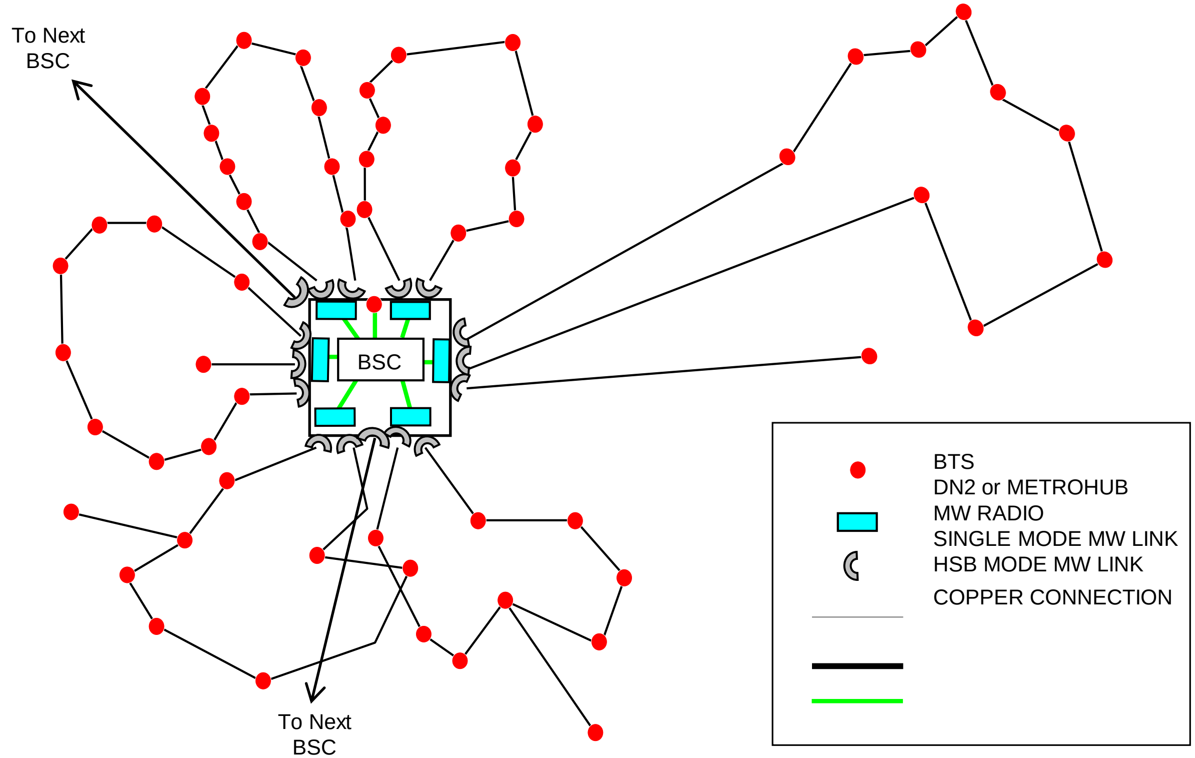


Figure 2. Primary solution where loop masters (DN2) are co-located in the BSC.

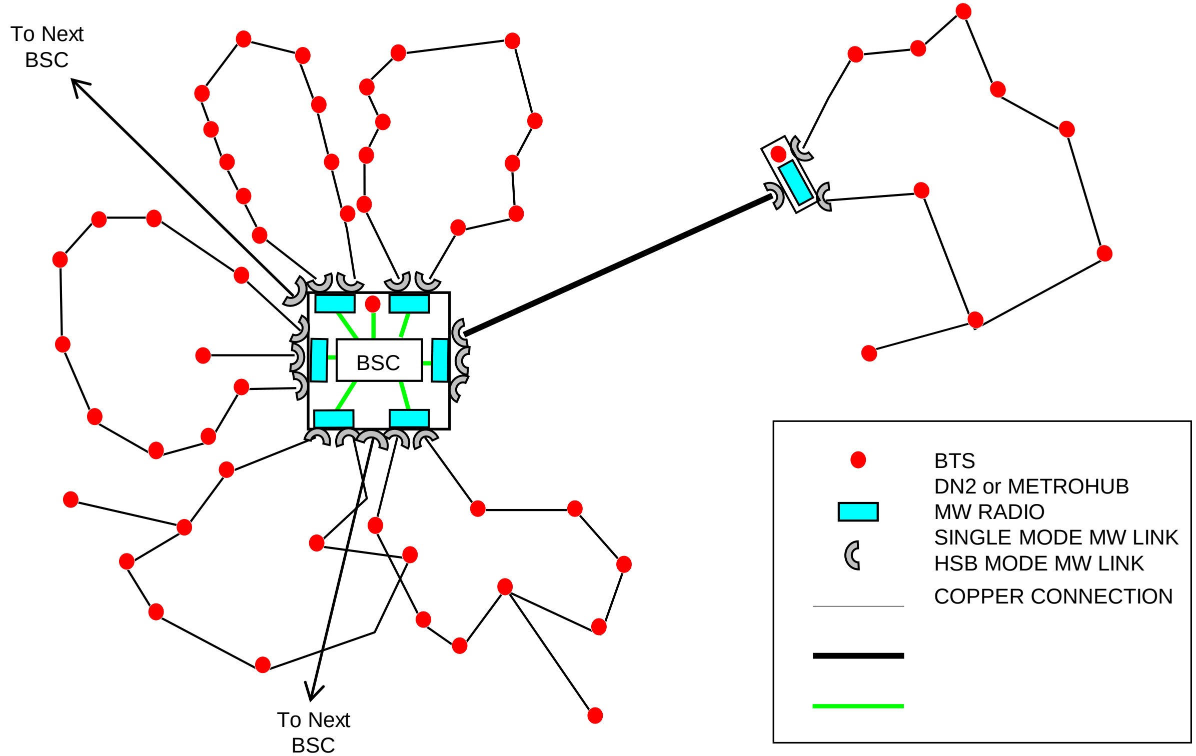
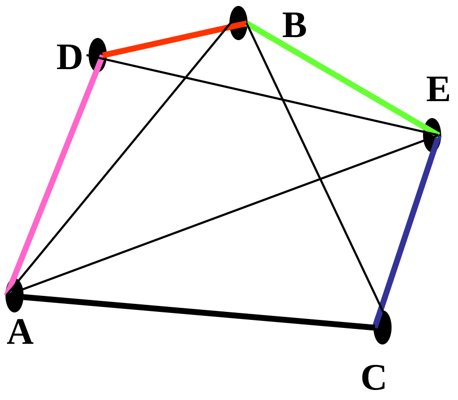


Figure 3. Solution of using remote loop master (DN2) co-located in a remote BTS

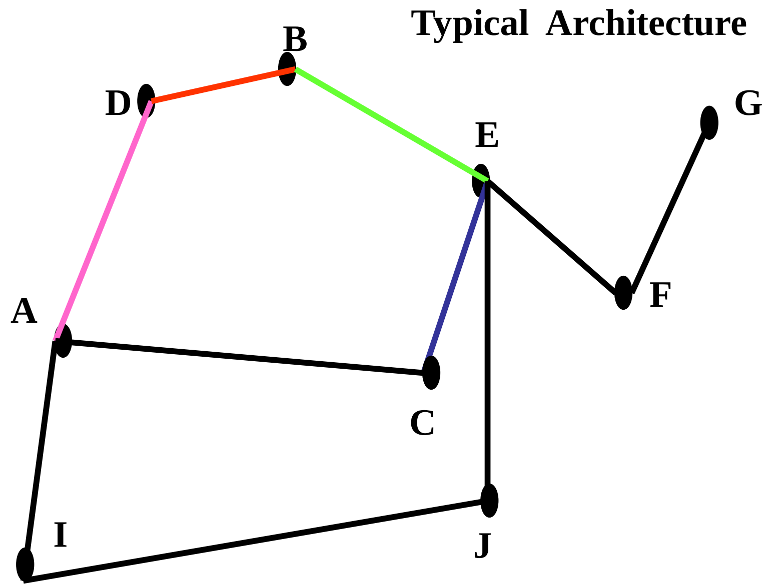
Mesh Architecture



Mesh Architecture

- Each Station is Connected to Every Other
- Full Proof Route Protection
- For N sites (Nx2)-1

Typical Network Architecture



- Typical Network Consist of Rings and Spurs

Network Routes & Route Capacities

- Inter- City routes - Backbone
  - Backbone routes are planned at Lower Frequency Bands
  - 2, 6 and 7 GHz Frequency Bands are used
  - Backbone routes are normally high capacity routes
  - Nominal Hop Distances 25 – 40 Km
- Intra – City routes - Access
  - Access routes are planned at Higher Frequency Bands
  - 15,18 and 23 GHz Frequency Bands are used
  - Nominal Hop Distance 1 – 10 Km

Frequency Bands

- Frequency Band 7, 15, 18 and 23 GHz are allowed to Private Operators for deployment in Transport Network
  - 15,18 and 23 GHz bands are used for Access Network
  - 7 GHz band is used for Backbone Network
  - Different Channeling Plans are available in these bands to accommodate different bandwidth requirements
  - Bandwidth requirement is decided by Radio Capacity offered by the Manufacturer

Microwave Propagation

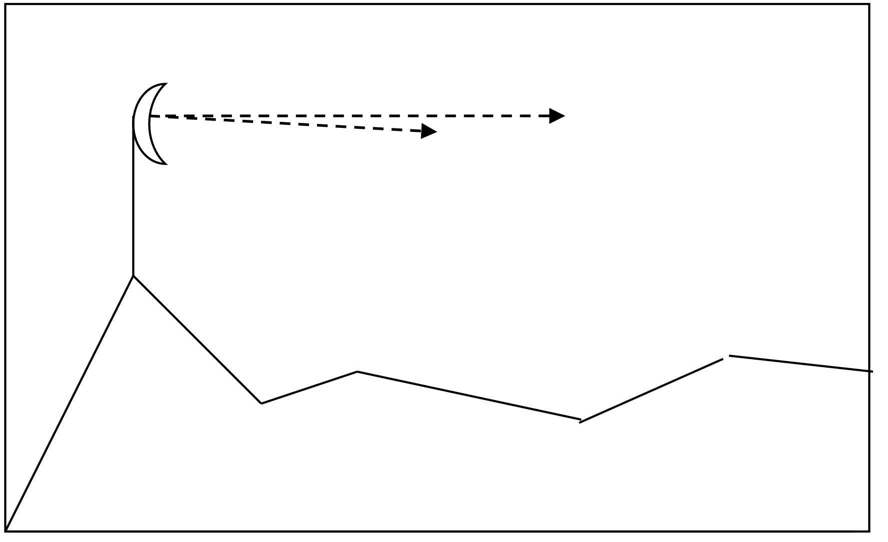
Free Space Propagation

- **Microwave Propagation in Free Space is Governed by Laws of Optics**
- **Like any Optical Wave , Microwave also undergoes**

  - **Refraction**
  - **Reflection**

Free Space Propagation - Refraction

- **Ray bending due to layers of different densities**

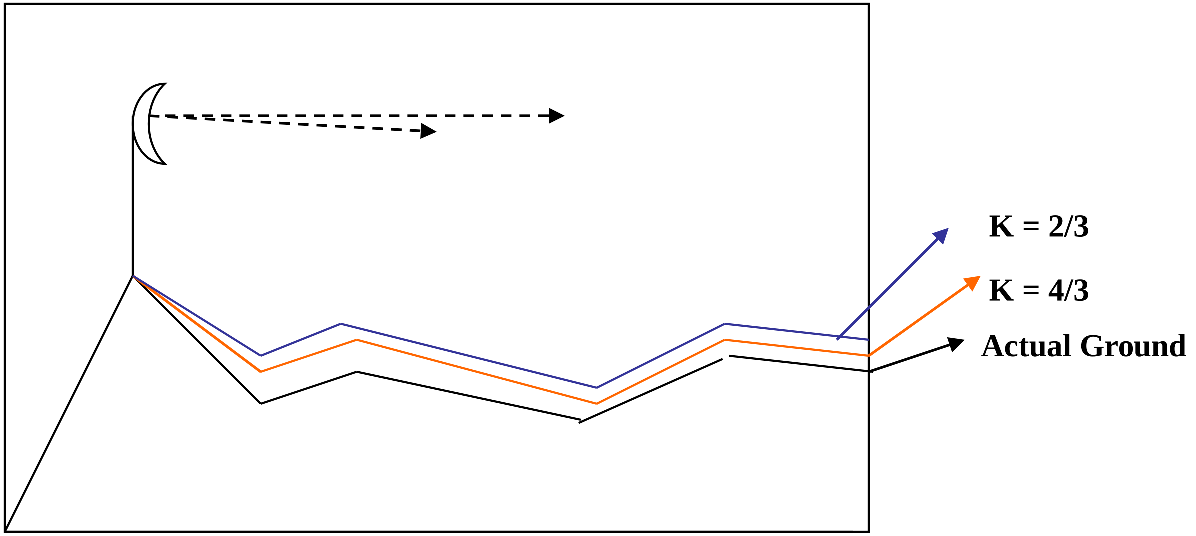


Bent Rays In Atmosphere

Free Space Propagation - Refraction

- **In effect the Earth appears elevated**
- **Earth elevation is denoted by K Factor**
- **K Factor depends on Rate of Change of Refractivity with height**
  - **K= 2/3 Earth appears more elevated**
  - **K= 4/3 Earth appears flatter w.r.t K=2/3**
  - **K=∞   Ray Follows Earth Curvature**

Free Space Propagation - Refraction



Effect of Refractivity Change

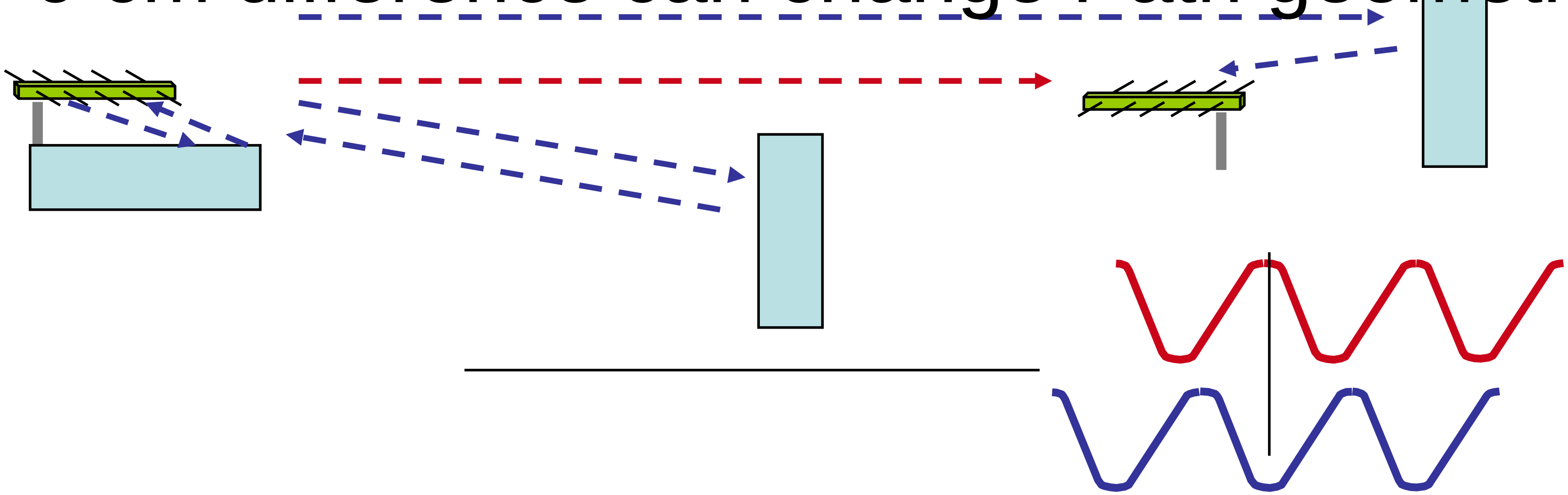
Free Space Propagation – Reflections

- Microwaves are reflected over
  - Smooth Surfaces
  - Water Bodies

- Reflected Signals are 180° out of phase
- Reflection can be a major cause of outages
- Link needs to be planned carefully to avoid reflections

RF Propagation
Reflections

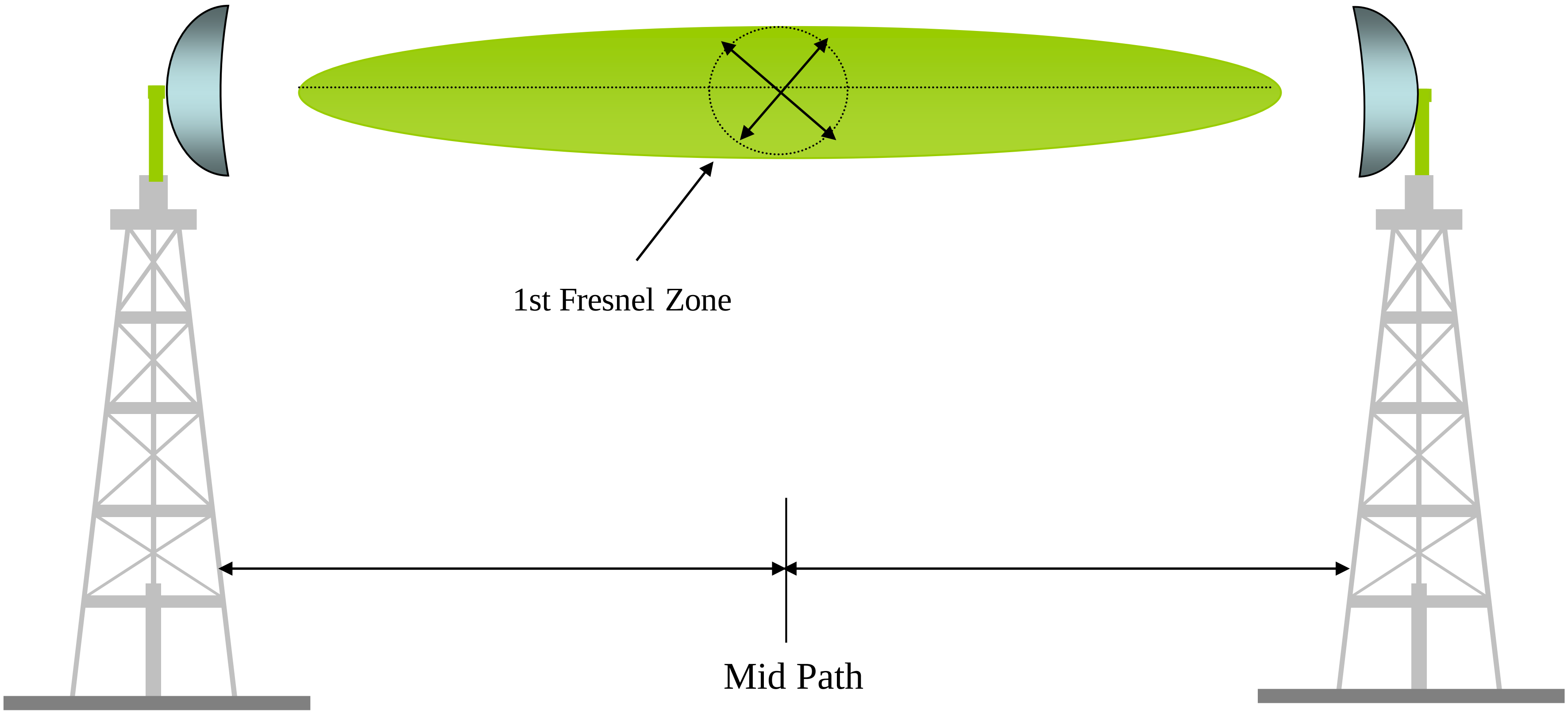
- Reflections can come from ANYWHERE - behind, under, in-front
- 6 cm difference can change Path geometry



Fresnel Zone

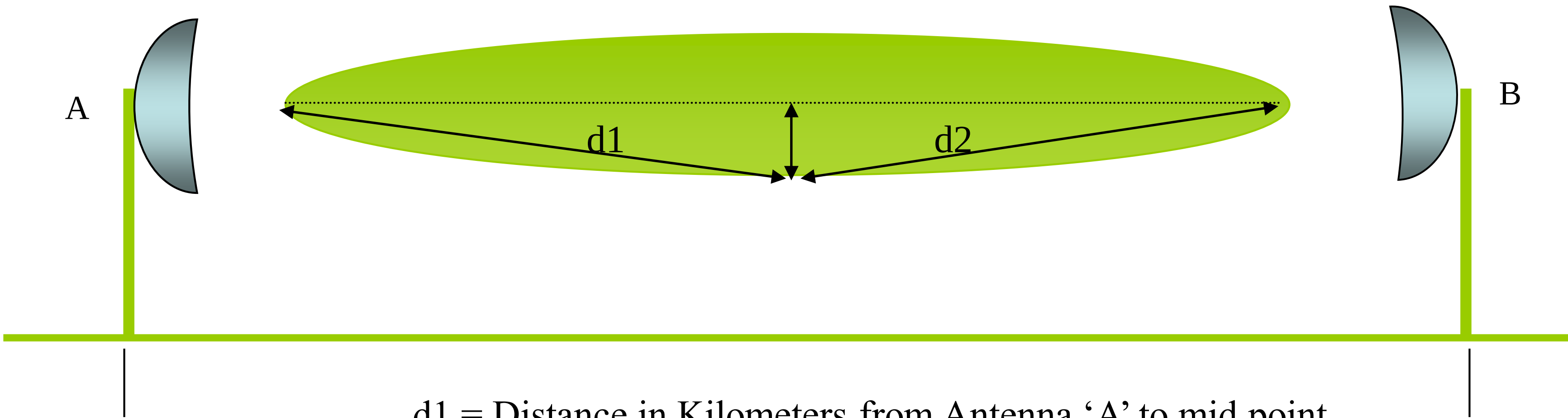
- The Fresnel zone is the area of space between the two antennas in which the radio signal travels.
- For Clear Line of Sight Fresnel Zone Should be clear of obstacles
- It is depands on Distance and Frequency

FRESNEL ZONES



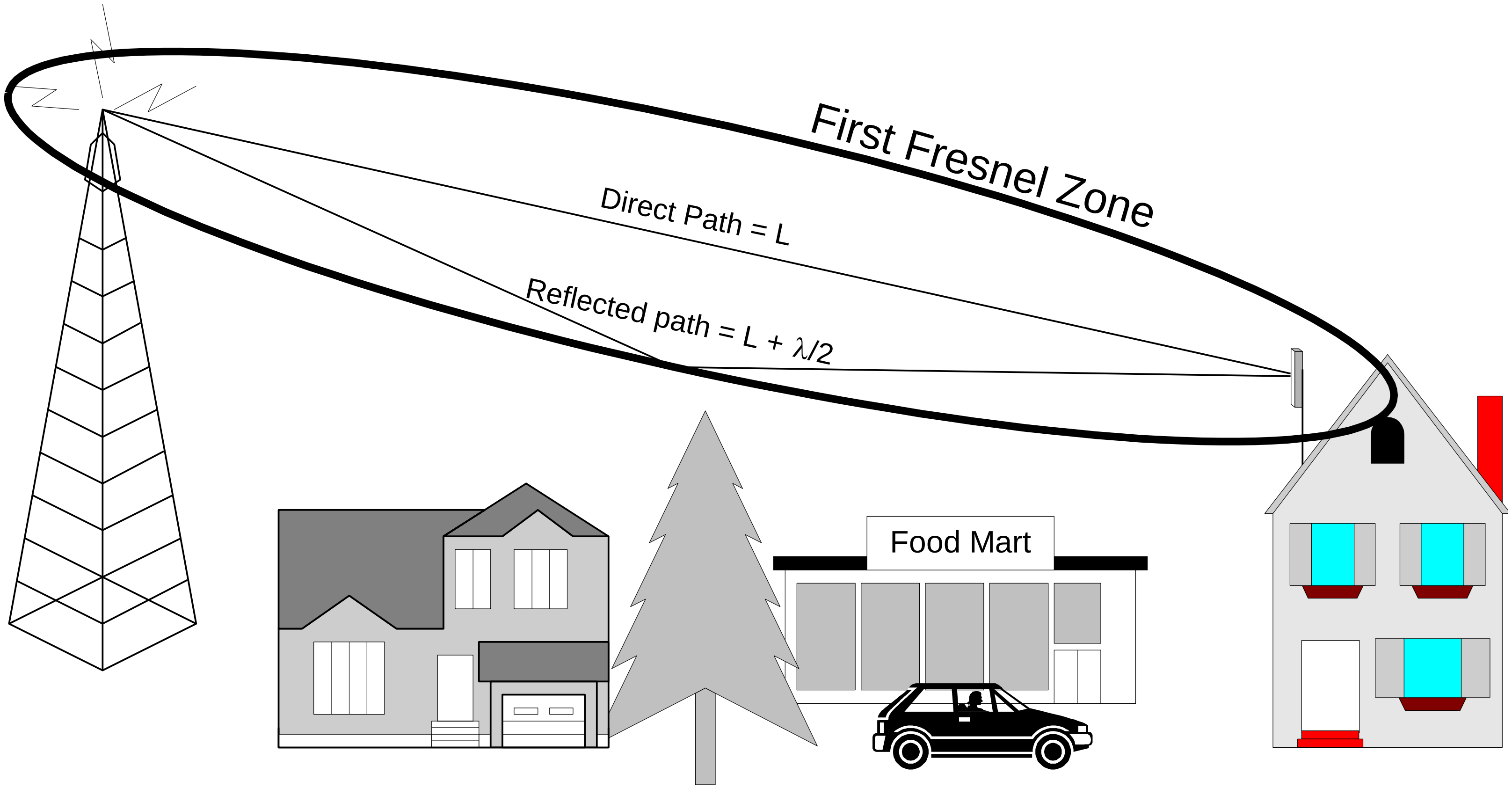
FRESNEL ZONE CLEARANCES

$$1^{ST} \text{ Fresnal Zone} = 17.3\sqrt{(d1*d2)/f(d1+d2)}$$



d1 = Distance in Kilometers from Antenna ‘A’ to mid point
d2 = Distance in Kilometers from Antenna ‘B’ to mid point
f = Frequency in GHz

RF propagation
First Fresnel Zone

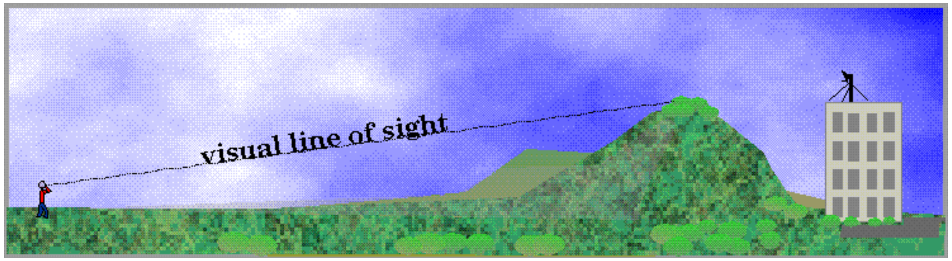


RF propagation

Free space versus non free space

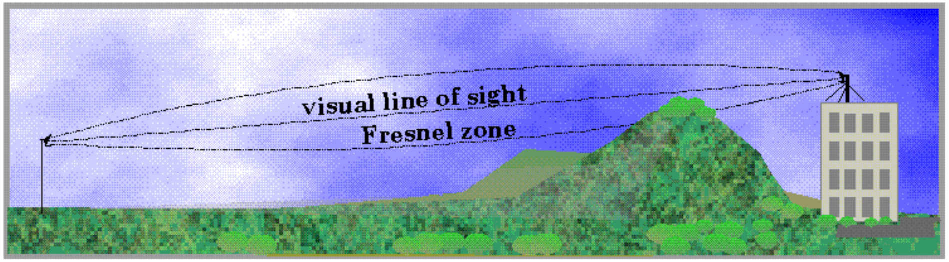
Non-free space

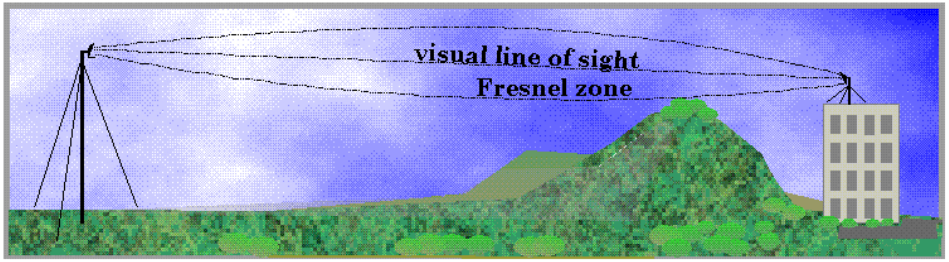
- Line of sight required
- Objects protrude in the fresnel zone, but do not block the path



Free Space

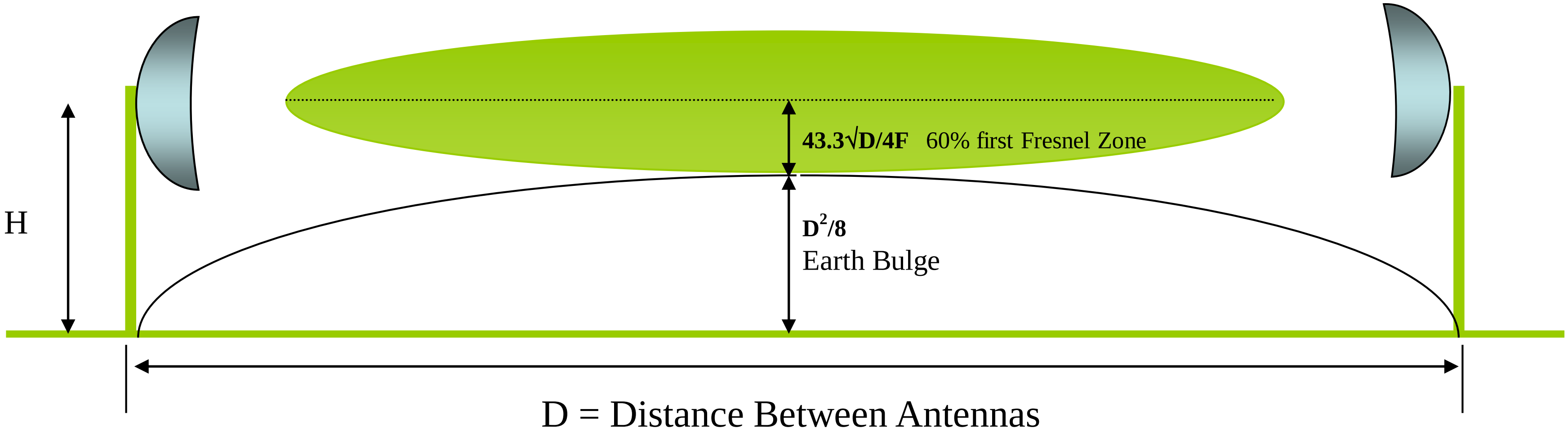
- Line of sight
- No objects in the fresnel zone
- Antenna height is significant
- Distance relative short (due to effects of curvature of the earth)





FRESNEL ZONE & EARTH BULGE

Height = $D^2/8 + 43.3\sqrt{D/4F}$



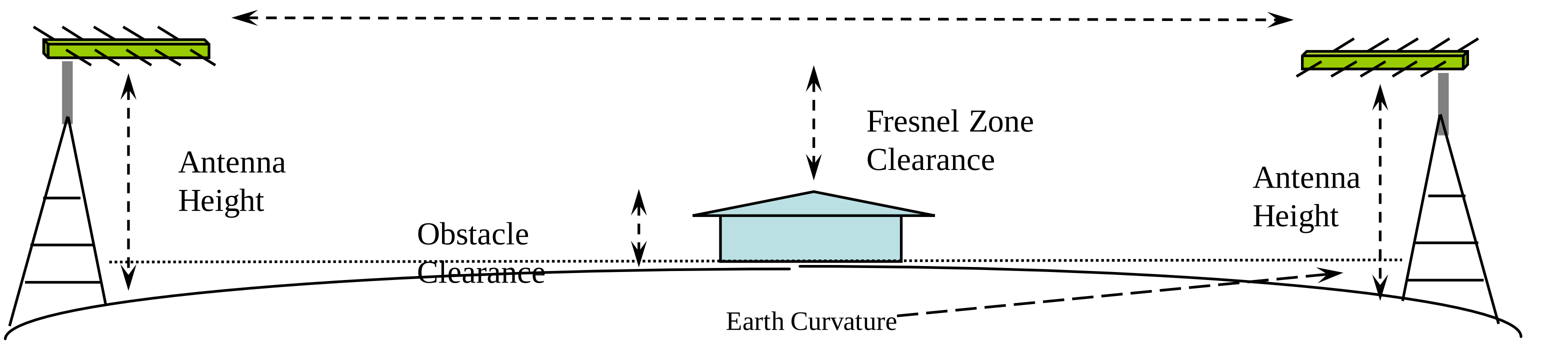
RF Propagation
Antenna Height requirements

Fresnel Zone Clearance = 0.6 first Fresnel distance (Clear Path for Signal at mid point)	Clearance for Earth's Curvature
• 30 feet for 10 Km path	•13 feet for 10 Km path
•57 feet for 40 Km path	•200 feet for 40 Km path

Midpoint clearance = 0.6F + Earth curvature + 10' when K=1

First Fresnel Distance (meters) **F1= 17.3 [(d1*d2)/(f*D)]**$^{1/2}$ where D=path length Km, f=frequency (GHz) , d1= distance from Antenna1(Km) , d2 = distance from Antenna 2 (Km)

Earth Curvature **h = (d1*d2) /2** where h = change in vertical distance from Horizontal line (meters), d1&d2 distance from antennas 1&2 respectively



Microwave Network Planning Process

1. Design Basis
2. Line of Sight Survey
3. Link Engineering
4. Interference Analysis

Planning Process

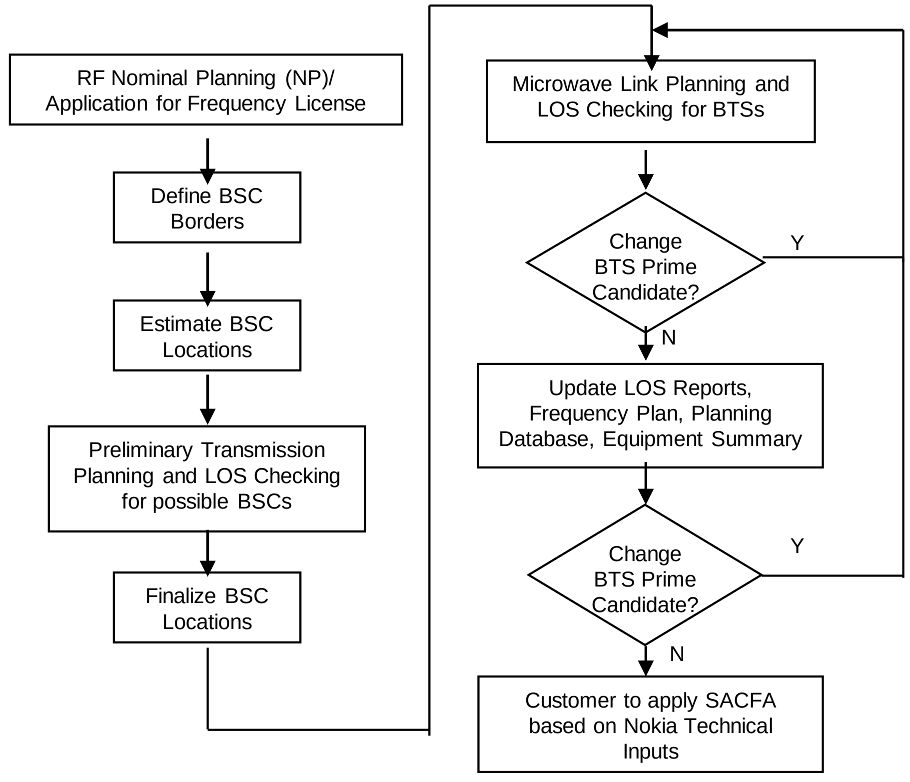


Figure 1. Microwave Link Planning Process

Design Basis

- Choice of Radio Equipment
- Fresnel Zone Clearance Objectives
- Availability / Reliability Objectives
- Interference Degradation Objectives
- Tower Height & Loading Restrictions

Microwave Network Planning Process

- Map Study for feasibility of Line of Sight and Estimating Tower Heights
- Actual Field Survey for refining map data and finalizing Antenna Heights
- Link Power Budgeting & Engineering
- Frequency and Polarization Assignments
- Interference Analysis (Network Level)
- Final Link Engineering (Network Level)

Map Study

- SOI Maps are available in different Scales and Contour Intervals
- 1:50000 Scale Maps with 20 M Contour Interval are normally used for Map Study
- Sites are Plotted on Map
- Contour values are noted at intersections
- Intersection with Water Bodies is also noted
- AMSL of Sight is determined by Interpolation

Map Study

- Vegetation height (15-20m) is added to Map Data
- Path Profile is drawn on Graph for Earth Bulge Factor (K) =4/3 and 2/3
- Fresnel Zone Depths are Calculated & Plotted for Design Frequency Band
- Antennae Heights are Estimated for Design Clearance Criteria

Field Survey

- Equipment Required
  - GPS Receiver
  - Camera
  - Magnetic Compass
  - Altimeter
  - Binocular / Telescope
  - Flashing Mirror
  - Flags
  - Inclinometer
  - Balloon Set
  - Measuring Tapes

Data Required

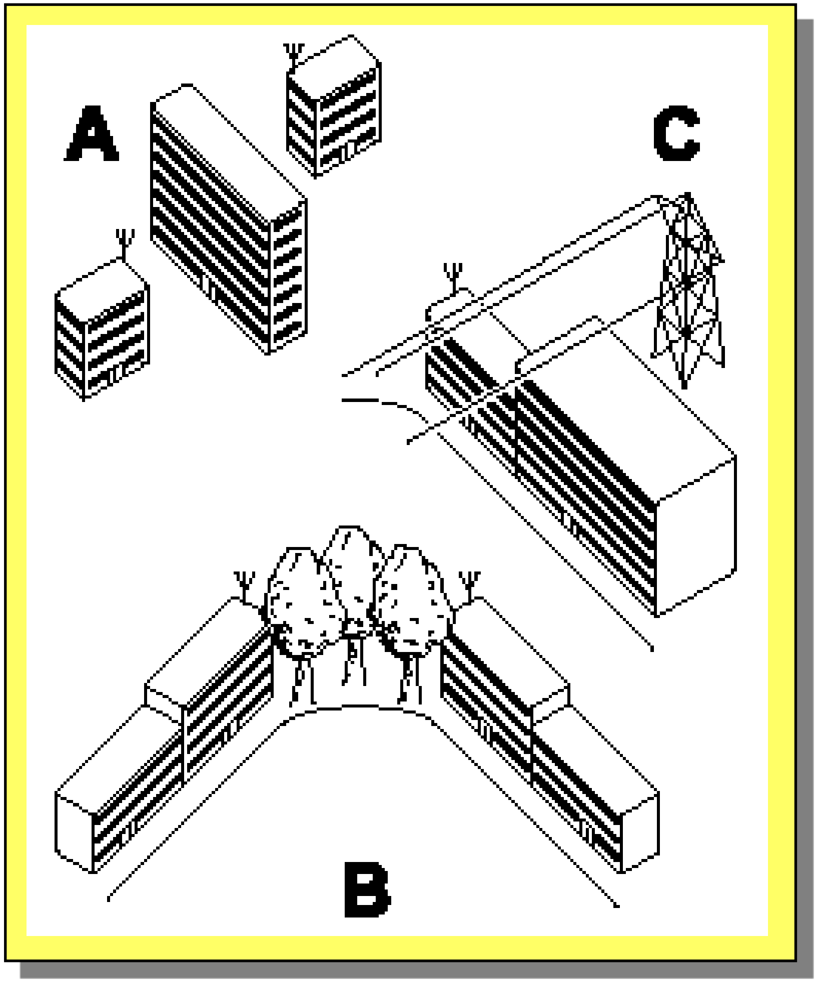
- Map Study Data

Field Survey

- Field Survey
  - Map Data Validation
  - Gathering Field inputs (Terrain Type, Average Tree/Obstacle Height, Critical Obstruction etc.)
  - Line of Sight Check, if feasible ,using flags, mirror
  - Data related to other stations in the vicinity , their coordinates, frequency of operation, antenna size, heights, power etc.
  - Proximity to Airport / Airstrip with their co-ordinates
- Field inputs are used to refine existing path profile data , reflection point determination, reflection analysis

RF propagation

Environmental conditions



- Line of Sight
  - No objects in path between antenna
  - a. Neighboring Buildings
  - b. Trees or other obstructions
- Interference
  - c. Power lines

Fading

- **Phenomenon of Attenuation of Signal Due to Atmospheric and Propagation Conditions is called Fading**

- **Fading can occur due to**
  - **Refractions**
  - **Reflections**
  - **Atmospheric Anomalies**

Fading

- **Types of Fading**
  - **Multipath Fading**
  - **Frequency Selective Fading**
  - **Rain Fading**

Multipath Fading

- **Multipath fading is caused due to reflected / refracted signals arriving at receiver**
  - **Reflected Signals arrive with**
    - **Delay**
    - **Phase Shift**
- **Result in degradation of intended Signal**

- **Space Diversity Radio Configuration is used to Counter Multipath Fading**

Frequency Selective Fading

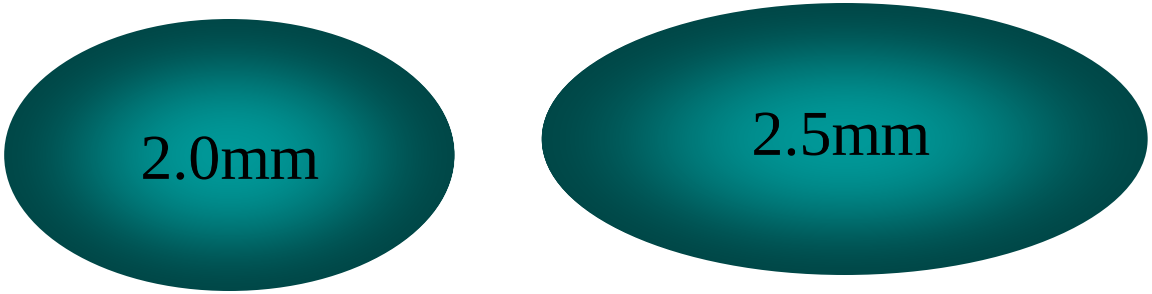
- **Frequency Selective Fading**
  - **Due to Atmospheric anomalies different frequencies undergo different attenuation levels**
  - **Frequency Diversity Radio Configuration is used to Counter Frequency Selective Fading**

Rain Fading

- **Frequency Band > 10 GHz are affected due to Rain as Droplet size is comparable to Wavelengths**
- **Rain Fading Occur over and above Multipath and Frequency Selective Fading**
- **Horizontal Polarization is more prone to Rain Fades**
- **Path Diversity / Route Diversity is the only counter measure for Rain Fade**

Drop Shape and Polarization

As raindrops increase in size, they get more extended in the Horizontal direction, and therefore will attenuate horizontal polarization more than vertical polarization



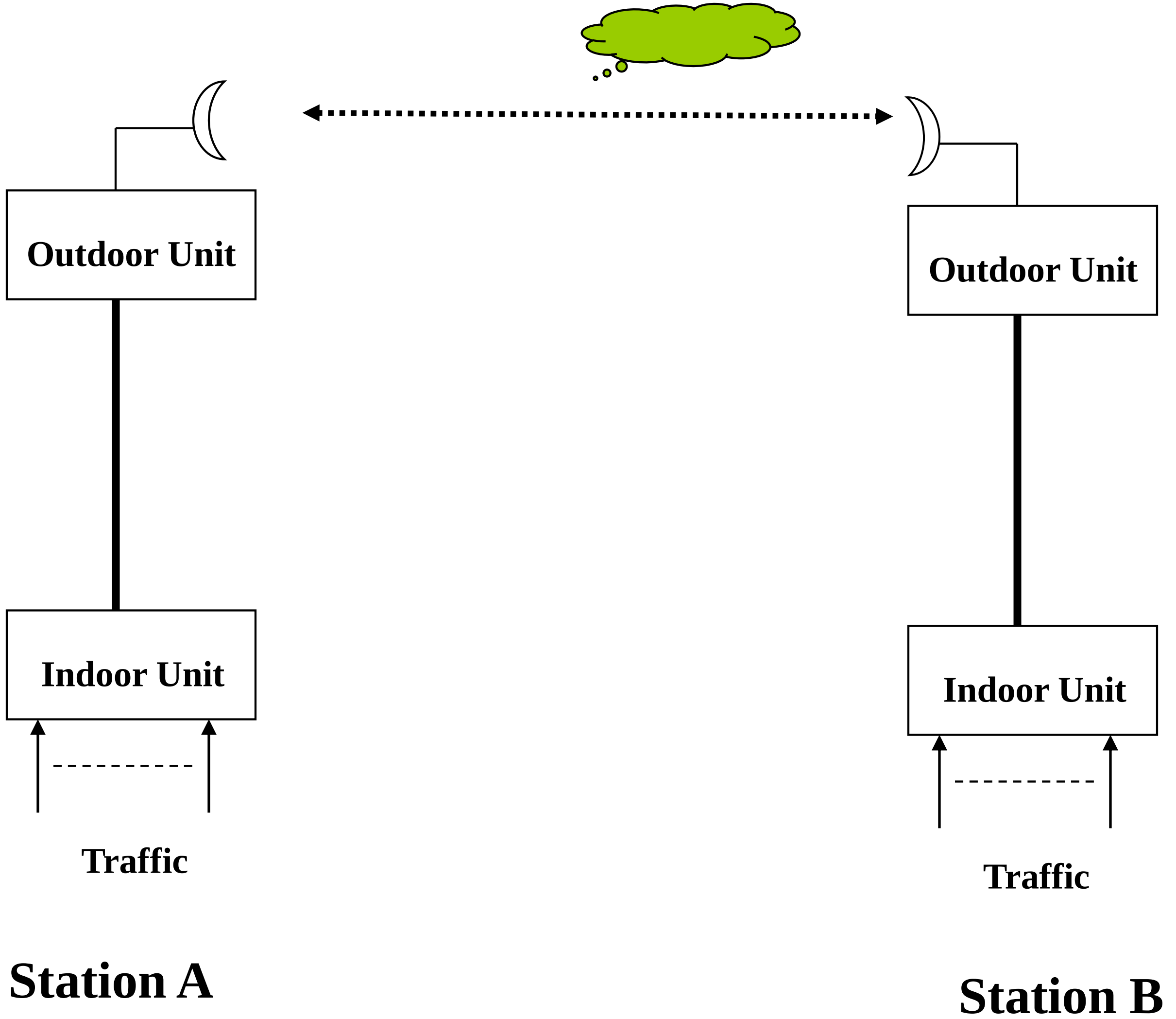
Fade Margin

- **Margin required to account for Fading – Fade Margin**
- **Higher Fade Margin provide better Link Reliability**
- **Fade Margin of 35 – 40 dB is normally provided**

Link Engineering & Reliability

1. Link Budgeting
2. Reliability Predictions
3. Interference Analysis

Hop Model



Outdoor Unit
Indoor Unit
Traffic
Station A
Outdoor Unit
Indoor Unit
Traffic
Station B

Link Power Budget

Received Signal Level = R_{xl}

$$R_{xlB} = T_{xA} - L_A + G_A - F_l + G_B - L_B$$

Where

T_{XA} = Trans Power Station A
L_A = Losses at Station A (Misc.)
G_A = Antenna Gain at Station A
F_l = Free Space Losses
G_B = Antenna Gain at Station B
L_B = Losses at Station B
R_{xlB} = Rx. Level at Station B

R_{XL} must be > Receiver Sensitivity always

Link Power Budget – Receiver Sensitivity

Lowest Possible Signal which can be detected by Receiver is called Receiver Sensitivity or Threshold

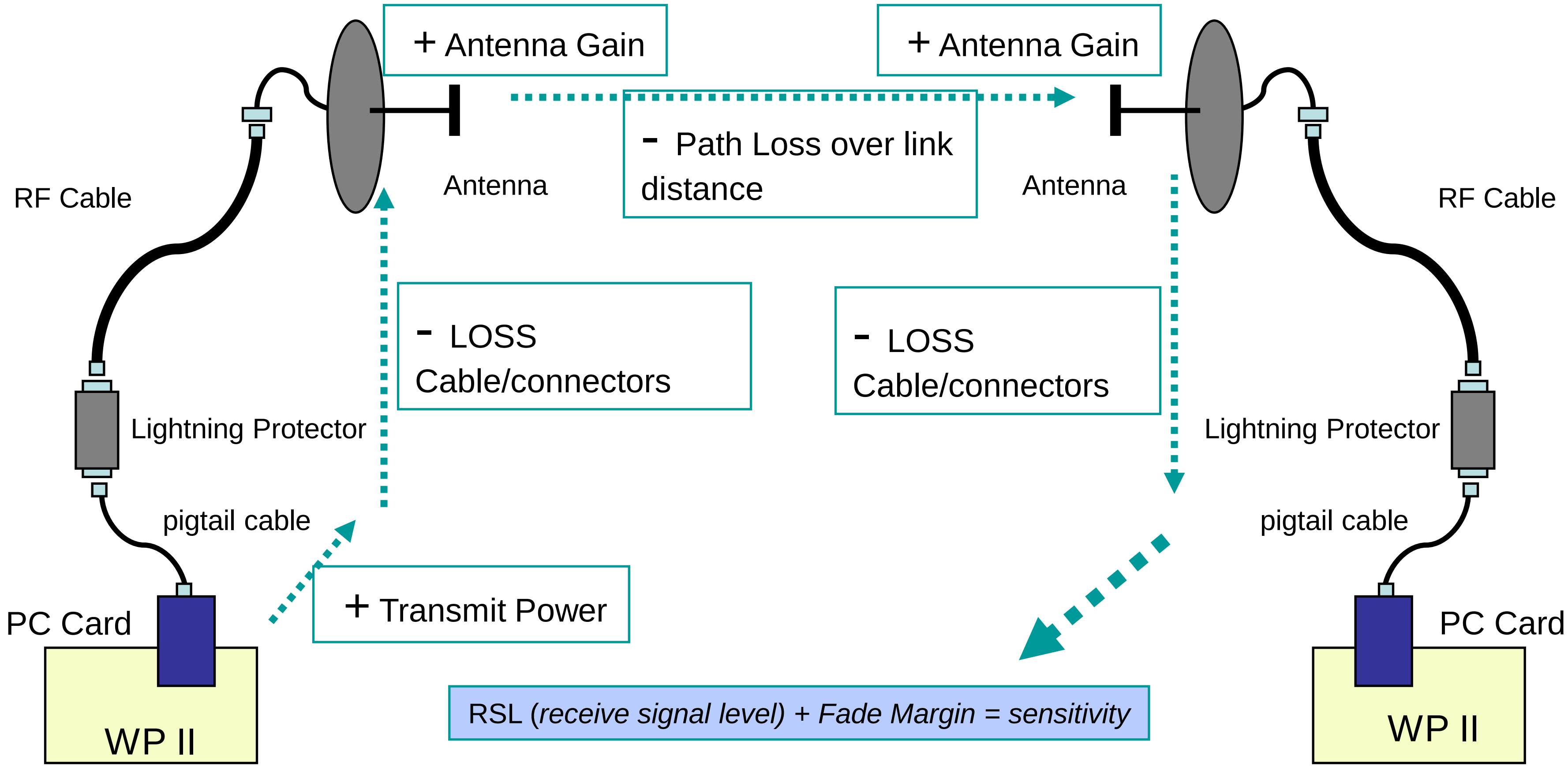
- Threshold Value is Manufacturer Specific
- Depends on Radio Design

- Higher (-ve) Value Indicates better Radio Design

Link Engineering

- Software Tools are used
  - Inputs to the tool
    - Sight Co-ordinates
    - Path Profile Data
    - Terrain Data & Rain Data
    - Equipment Data
    - Antenna Data
    - Frequency and Polarization Data
  - Tool Output
    - Availability Prediction

RF propagation
Simple Path Analysis Concept (alternative)



Calculate signal in one direction if Antennas and active components are equal

Link Engineering – Interference

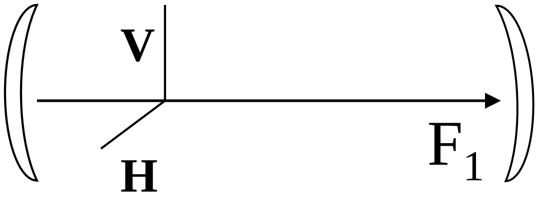
- Interference is caused due to undesirable RF Signal Coupling

- Threshold is degraded due to interference

- Degraded Threshold results in reduced reliability

Link Engineering – Interference

- Examples of Undesirable RF Couplings

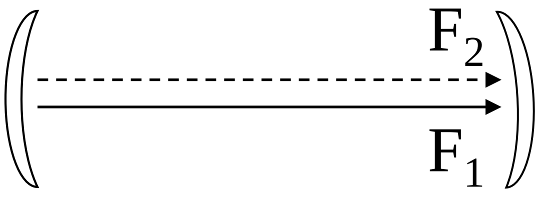


Cross Poler Coupling

- Finite Value of XPD in Antenna is the Prime Cause
- Solution : Use of High Performance Antenna

Link Engineering – Interference

- Examples of Undesirable RF Coupling

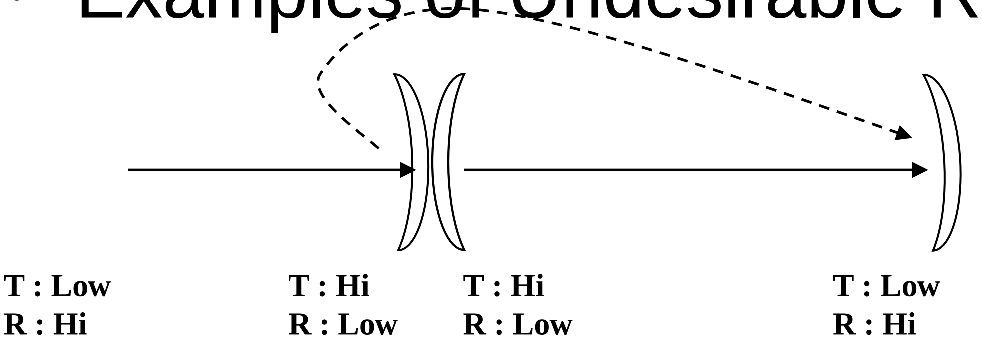


Adjacent Channel

- Receiver Filter Cut-off is tappered
- Solution : Use Radio with better Specifications

Link Engineering – Interference

- Examples of Undesirable RF Coupling

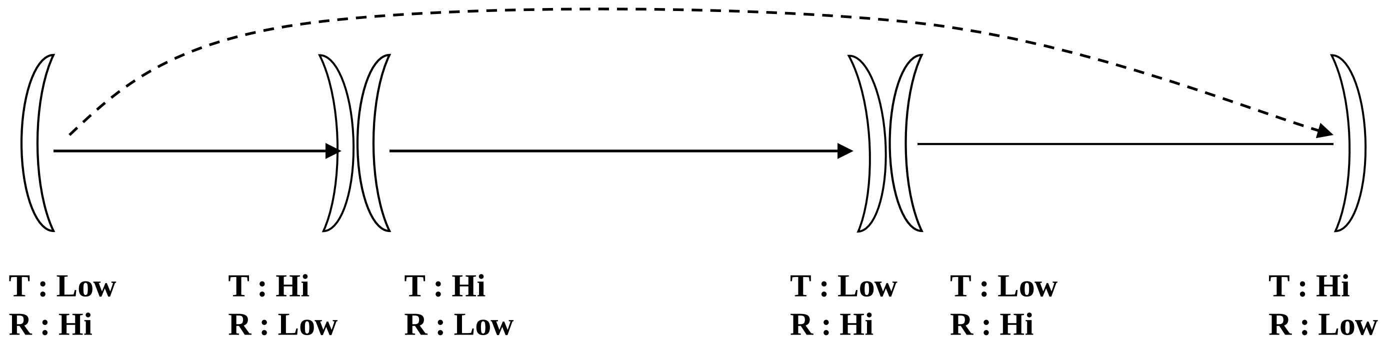


Front to Back

- Finite value of FTB Ratio of Antenna is Prime Cause
- Solution : Antenna with High FTB Ratio

Link Engineering – Interference

- Examples of Undesirable RF Coupling



Over Reach

- Solution : Choose Antenna Heights such a way there is no LOS for over reach

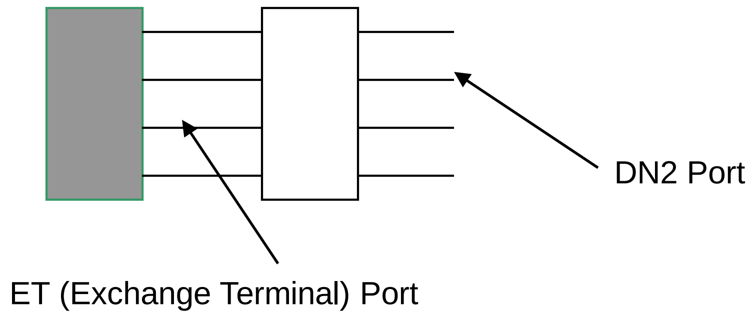
Link Engineering – Interference

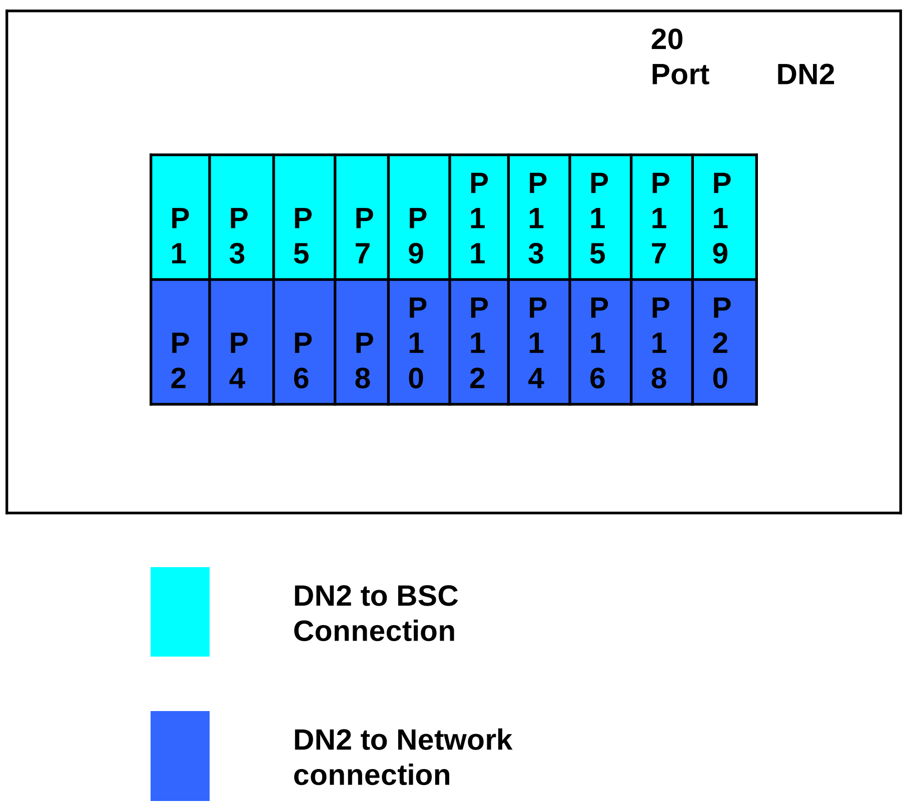
- Interference is calculated at Network Level
  - Interference due to links
    - Within Network
    - Outside Network (Links of other Operators)
  - Interfering Signal degrades Fade Margin
  - Engineering Calculation re-done with degraded Fade Margin

Link Engineering – Interference

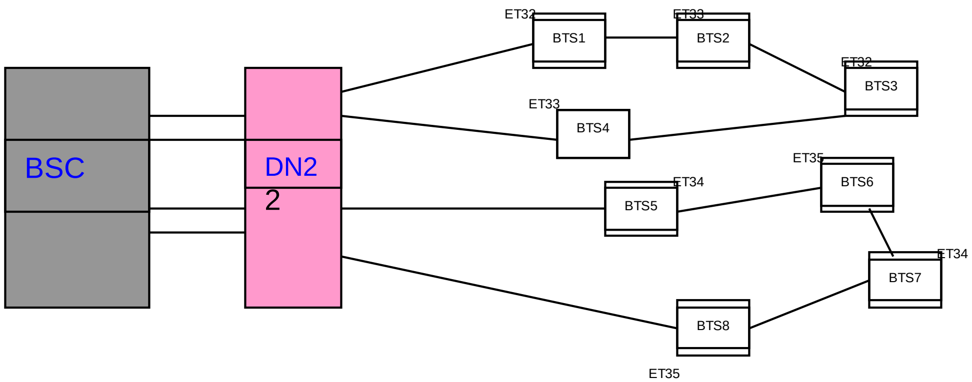
- Counter Measures
  - Avoid Hi-Lo violation in loop
  - Frequency Discrimination
  - Polarization Discrimination
  - Angular Discrimination
  - High Performance Antennae
  - Lower Transmit Power , if possible

•DN2 PORT ALLOCATION:

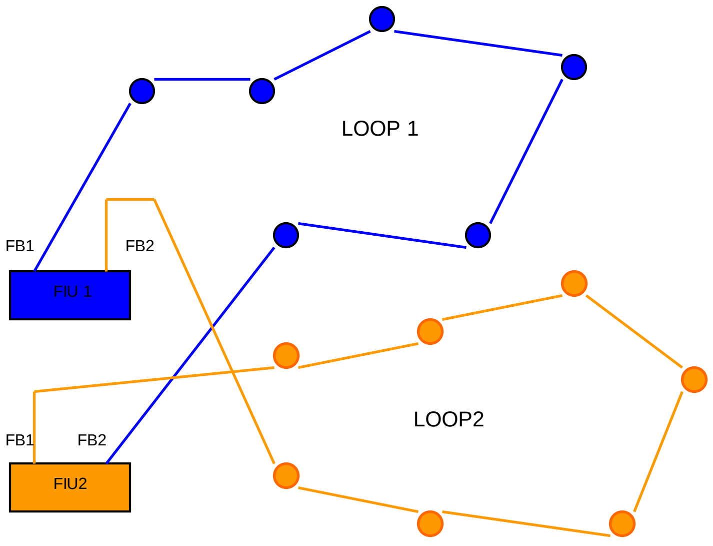




• **STANDARD MICROWAVE RADIO FIU 19 TRIBUTARY ALLOCATION FOR LOOP PROTECTION**



- Loop Protection with Hardware Protection

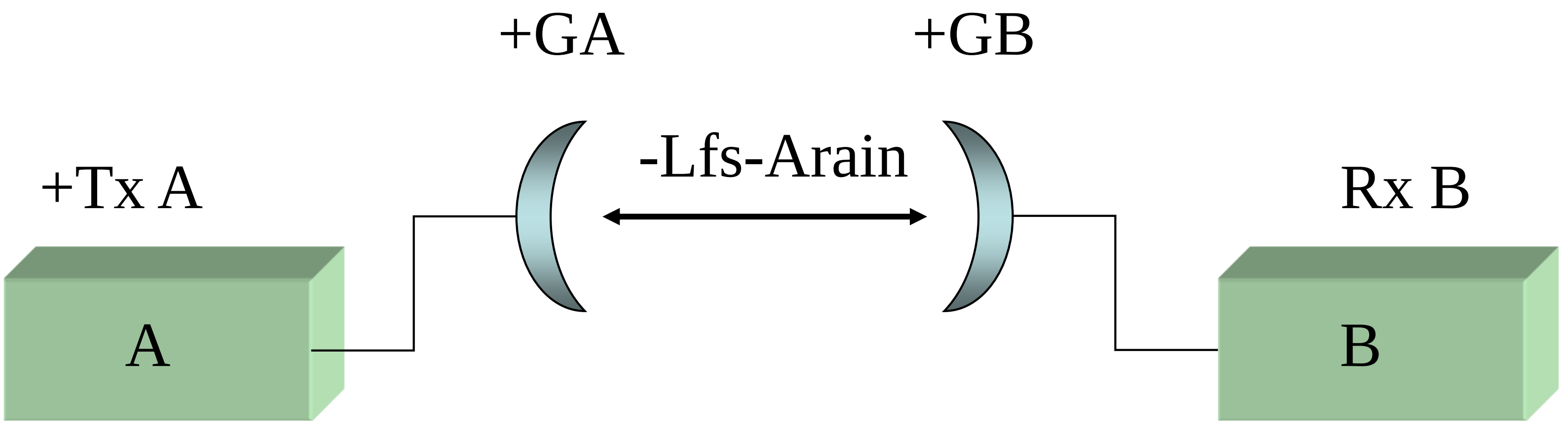


PtP Microwave Transmission - Issues

- Link Performance is Seriously Affected due to
  - Atmospheric Anomalies like Ducting
  - Ground Reflections
  - Selective Fading
  - Excessive Rains
  - Interferences
  - Thunderstorms / High Winds causing Antenna Misalignment
  - Earthing
  - Equipment Failure

Some Useful Formulae

Link Budget



$$Rx_B = Tx_A + G_A - L_{fs} - A_{Rain} + G_B$$

Free Space Loss

$$L_{fs} = 92.45 + 20 \cdot \log(d \cdot f)$$

d = distance in kilometers f = frequency in GHz

Examples

39 GHz

↓

d=1km ---> L = 124 dBm
d=2km ---> L = 130 dBm

26 GHz

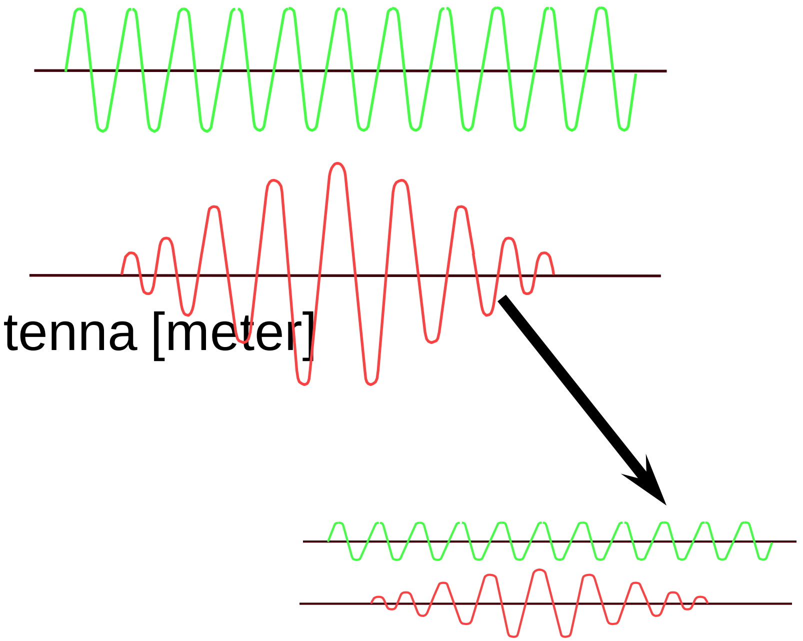
↓

d=1km ---> L = 121 dBm
d=2km ---> L = 127 dBm

RF Propagation
Basic loss formula

Propagation Loss

$$P_R = P_T * G * \left(\frac{\lambda}{4\pi d}\right)^2$$



d = distance between Tx and Rx antenna [meter]

P_T = transmit power [mW]

P_R = receive power [mW]

G = antennae gain

$Pr \sim 1/f^2 * D^2$ which means 2X Frequency = 1/4 Power

2 X Distance = 1/4 Power

Useful Formulae – Earth Bulge

Earth Bulge at a distance d1 Km

= d1 * d2 / (12.75 * K) Meter

Where d2 = (d – d1) Km (d Km Hop Distance)

K = K Factor

Useful Formulae – Fresnel Zone

N^{th} Fresnel Zone Depth at a distance d1 Km

$= N * 17.3 * ((d1*d2) / (f * d))^{-1/2}$ Meter

Where d2 = (d – d1) Km

d = Hop Distance in Km

f = Frequency in GHz

N = No. of Fresnel zone (eg. 1^{st} or 2^{nd})

Tower Height Calculation :

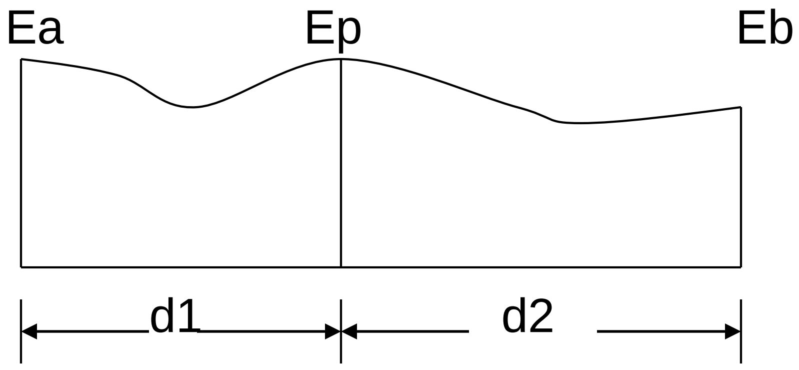
Th = Ep + C + OH + Slope – Ea

C = B1 + F

Slope = ((Ea – Eb) d1)/ D

F = 17.3 ((d1xd2)/f X D) -1/2

B = (d1 x d2) / (12.75 x K)



Where,
Th = Tower Height
Ep = Peak / Critical Obstruction
C = Other losses
B1 = Earth Buldge
F = Fresnel Zone
OH = Overhead Obstruction
Ea= Height of Site A
Eb= Height of Site B
d1= Dist. From site A to Obstruction
d2= Dist. From site B to Obstruction
D = Path Distance
f= Frequency
K= 4/3

Useful Formulae – Antenna Gain

Antenna Gain

$$= 17.6 + 20 * \log_{10} (f * d) \text{ dBi}$$ See Note

Where d= Antennae Diameter in Meter

f= Frequency in GHz

Note # Assuming 60% Efficiency

Useful Formulae
– Free Space Loss

Free Space Loss

$F_l = 92.4 + 20 * \log_{10} (f * d)$ dB

Where

d = Hop Distance in Km

f = Frequency in GHz

Useful Formulae – Geo Climatic Factor

Geo Climatic Factor

$$G = 10^{-T} * (P_l)^{1.5}$$

Where T= Terrain Factor

= 6.5 for Overland Path Not in Mountain

= 7.1 for Overland Path in Mountain

= 6.0 for Over Large Bodies of Water

P_l = P_l factor

Useful Formulae – System Gain

System Gain = (Transmit Power + ABS(Threshold)) dB

Fade Margin = FM = (Nominal Received Signal – Threshold) dB

Path Inclination ϕ = ABS $((h_1 + A_1) - (h_2 + A_2))$ / d

Where h1 = Ant. Ht. At Stn A AGL Meter

h2 = Ant. Ht. At Stn B AGL Meter

A1 = AMSL of Stn A Meter

A2 = AMSL of Stn B Meter

d = Hop Distance in KM

Useful Formulae – Fade Occurrence Factor

Fade Occurrence Factor = σ

$$\sigma = G * d^{3.6} * f^{0.89} * (1+ \phi)^{-1.4}$$

Where

G = Geo Climatic Factor

d = Hop Distance in Km

f = Frequency in GHz

ϕ = Path Inclination in mRad

Useful Formulae – Outage Probability

Worst Month Outage Probability (One Way) % = O_{WM}

$$O_{WM}\ \% = \sigma * 10^{-(FM/10)}$$

Annual Unavailability (One Way) % = $O_{WM} * 0.3$

Assuming 4 Worst Months in a Year

Annual Availability (Two Way) % = $100-(O_{WM}*0.3*2)$