Point – to – point Radiocommunication

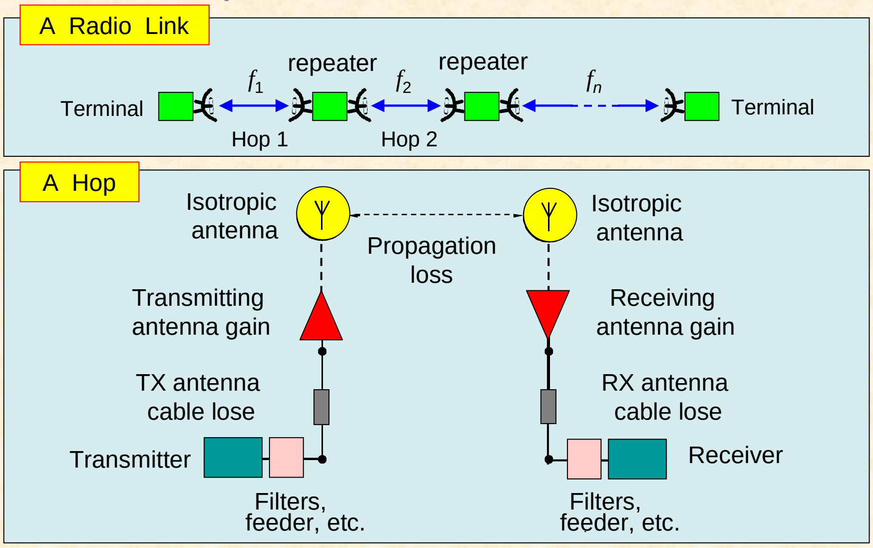
SMS4DC training seminar

27 November – 1 December 2006

Content

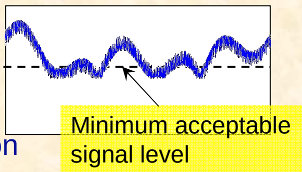
- Technical overview
- SMS4DC Software link calculation
- Exercise

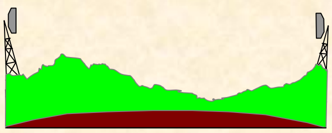
Point-to-point Radiocommunication Link



Definition

- *Point-to-point communication*
  Radiocommunication between specified fixed stations
- *Fading*
  Fluctuation of signal level respect to stable condition for number of reasons
- *Path Profile*
  A vertical cut of terrain along propagation path between transmitter and receiver
- *NFD*
  Discrimination gained because of TX emission and RX reception masks
- *Polarization*
  The locus of electric field vector fluctuation
- *SWR*
  Standing Wave Ratio ([1+|Γ|]/[1-|Γ|])





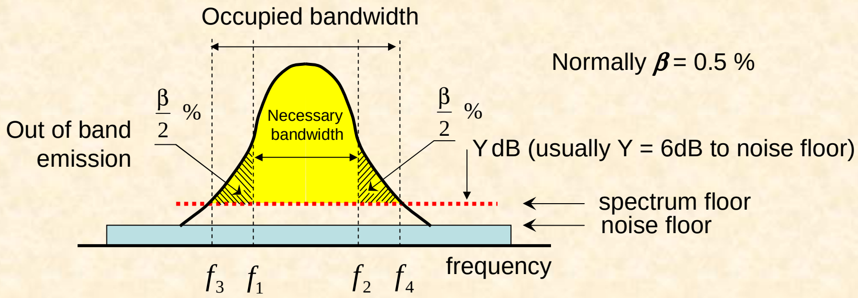
Link Budget

- Total Loss = [Free Space Loss]
  + [Atmospheric Gaseous Loss]
  + [Rain Attenuation]
  + [Clear Air Fading]
  + [Diffraction Loss]
  + [NFD]
- Flat Receive Level = $P_T + G_T$
  – [Free Space Loss]
  – [Atmospheric Gaseous Loss]
  – [Diffraction Loss]
  – G_R
  – [Receiver Insertion Loss]
- Fade Margin = [Flat Receive Level] – [Receiver Threshold]
- Insertion Loss= [Cable Loss]+[Branching Loss]+[Mismatch Loss]

$$FreeSpaceLoss = \left(\frac{4\pi d}{\lambda}\right)^2$$

RF Signal Spectrum

- Power Spectral Density of *x*(*t*) : $|X(f)|^2$

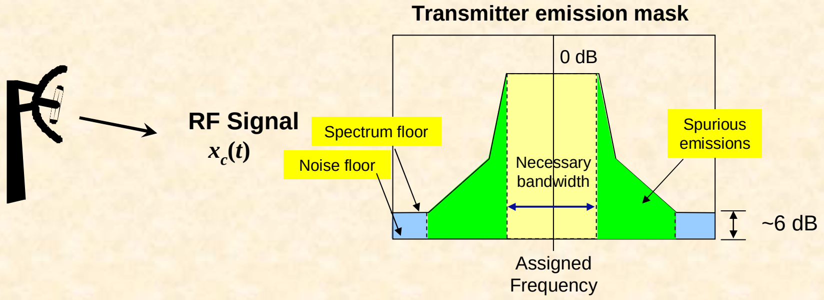


$$P_{x(t)} = \int_{f_3}^{f_4} |X(f)|^2 \, df$$ = Area of yellow color

$$\int_{f_3}^{f_1} |X(f)|^2 \, df = \int_{f_2}^{f_4} |X(f)|^2 \, df = \frac{\beta}{200} P_{x(t)}$$

Transmitting and Receiving Masks

- The power spectral density (PSD)



- Normally each TX has identical corresponding RX receiving masks
- Mismatched TX & RX masks cause additional loss (NFD)

Propagation Effects

- Diffraction fading due to obstruction of the path;
- Attenuation due to atmospheric gases;
- Fading due to atmospheric multipath or beam spreading (commonly referred to as defocusing) associated with abnormal refractive layers;
- Fading due to multipath arising from surface reflection;
- Attenuation due to precipitation or solid particles in the atmosphere;
- Variation of the angle-of-arrival at the receiver terminal and angle-of-launch at the transmitter terminal due to refraction;
- Reduction in cross-polarization discrimination (XPD) in multipath or precipitation conditions;
- Signal distortion due to frequency selective fading and delay during multipath propagation.

Propagation Loss

- Attenuation due to atmospheric gases,
- Diffraction fading due to obstruction or partial obstruction of the path,
- Fading due to multipath, beam spreading and scintillation,
- Attenuation due to variation of the angle-of-arrival/launch,
- Attenuation due to precipitation,
- Attenuation due to sand and dust storms

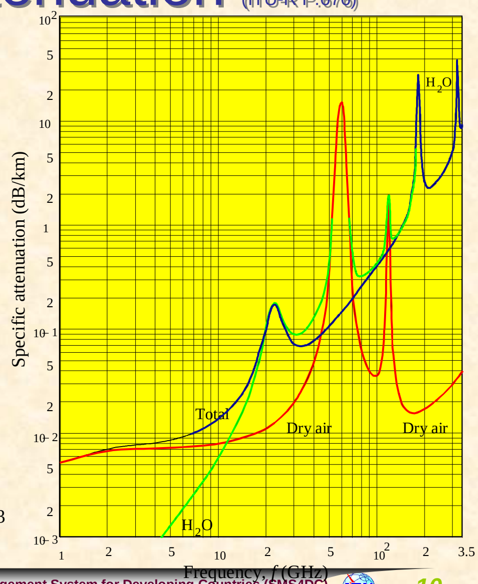
Gaseous Attenuation (ITU-R P.676)

- Considerable loss above 10 GHz

$$A_a = \gamma_a d \quad \text{dB}$$

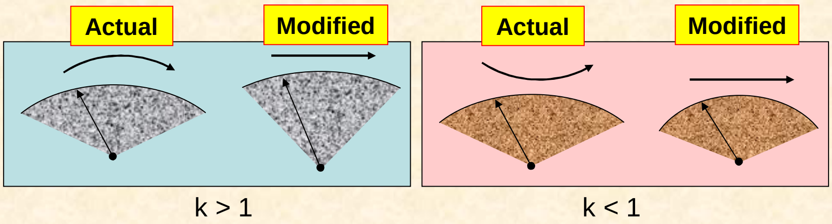
- High attenuation frequencies have special usages

Pressure: 1 013 hPa
Temperature: 15° C
Water vapour: 7.5 g/m^3



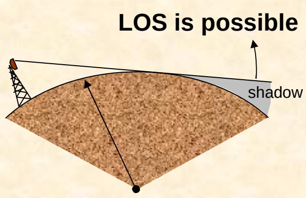
k-factor

- Electromagnetic wave bends while passing through non-homogenous medium,
- Vertical profile of atmosphere is non-homogeneous,
- Median effective Earth radius factor : $k_{50} = 157/[157 - \Delta N]$
- Effective radius of Earth in km: $a_e = 6371 \times k_e$
- See ITU-R P.453 for Δ*N* (vertical refractivity gradient),

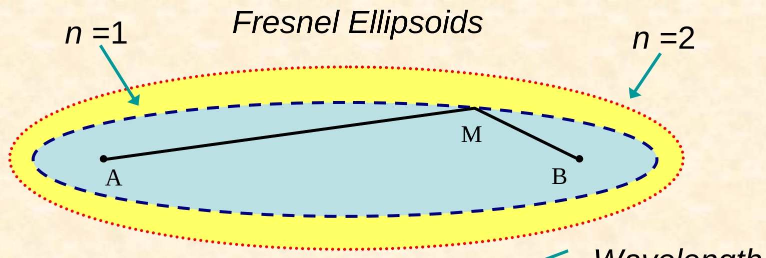


Propagation by Diffraction (ITU-R P.526)

- Diffraction over a spherical earth for trans-horizon paths
- Diffraction by obstacles inside Fresnel zone
- Consideration of diffraction from round, wedge and sharp obstacles, single and multiple (in P.452 propagation model)



Fresnel ellipsoids

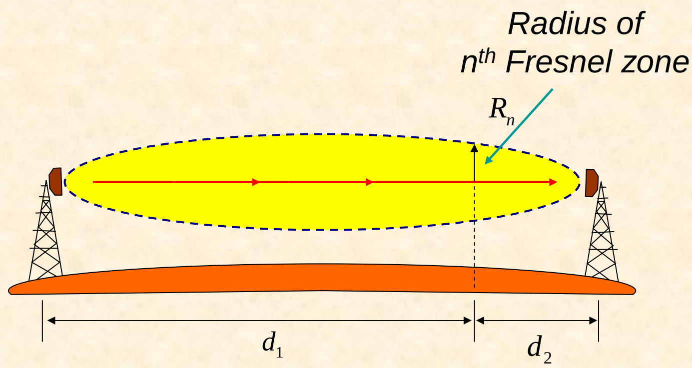


Wavelength

$$\mathrm{AM} + \mathrm{MB} = \mathrm{AB} + n\frac{\lambda}{2}$$

- More than 90% of power, propagates inside first ellipsoid
- For Line – of – Sight (LOS) communication first Fresnel ellipsoid should be enough clear

Fresnel zone

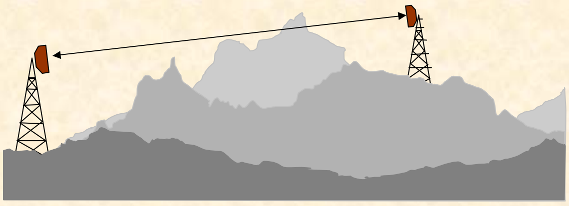


$$R_n = 550\left[\frac{n\, d_1\, d_2}{(d_1 + d_2)\, f}\right]^{1/2}$$

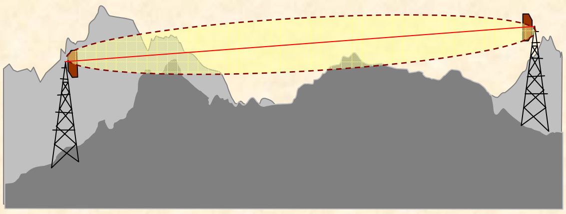
f is frequency in MHz and all distances are in km

Diffraction Fading
Obstruction of the Path

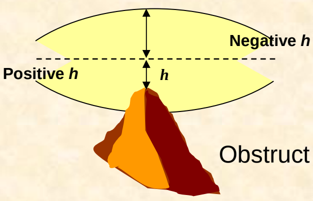
- No LOS path



- Obstruction inside Fresnel zone

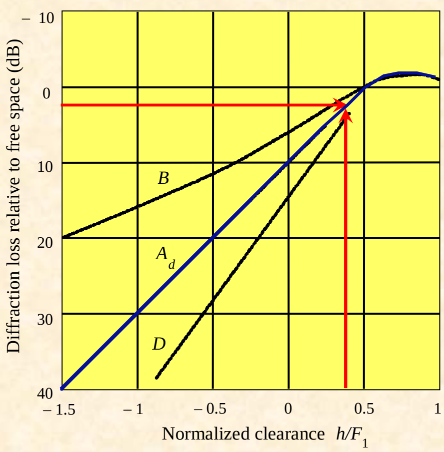


Diffraction loss and clearance



- 0.6 F_1 clearance is necessary for tropical climate

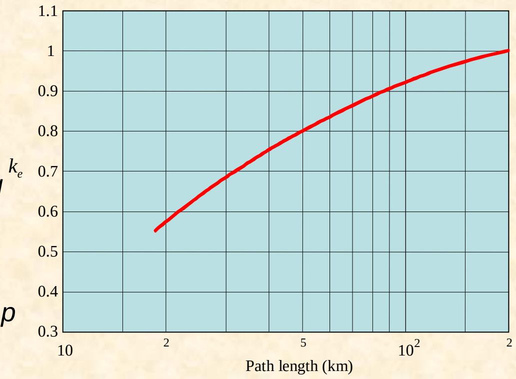
B: theoretical knife-edge loss curve
D: theoretical smooth spherical Earth loss curve, at 6.5 GHz and *k* = 4/3
A: empirical diffraction loss for intermediate terrain
F: radius of the first Fresnel zone
h: amount by which the radio path clears the Earth's surface



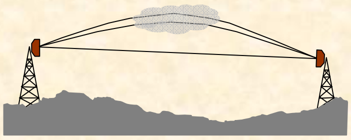
Antenna Height Determination
(Single Antenna in tropical climate)

- ***Step 1***: Determine antenna heights for $1.0F_1$ clearance in median *k*- factor ($k_{50} = (157/(157\text{-}\Delta N))$ or $k = 4/3$)
- ***Step 2***: Determine antenna heights for $0.6F_1$ using effective *k*-factor from the following figure
- ***Step 3***: Select the larger antenna heights

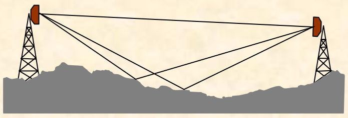
- *In <u>temperate climate</u> step 2 will be down using $0.0F_1$ for single isolated obstruction or $0.3F_1$ for obstruction is extended along a portion of the map*



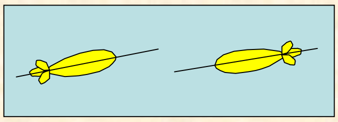
Multipath Fading



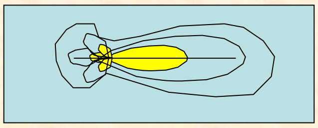
atmospheric Multipath



surface Multipath



Antenna Decoupling
(governs the minimum beamwidth)



Beam Spreading
(defocusing)

Multipath Fading Elements

- Multipath fading depends on:
  - Refractivity gradient in the lowest 65m of atmosphere
  - Area terrain roughness
  - Path inclination
  - Exceedance time percentage
  - Frequency
  - Altitude of antennas
- Calculation method explained in ITU-R P.530

Hydrometer Attenuation

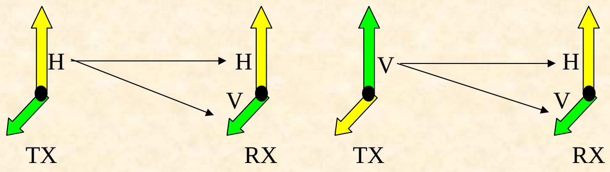
- Can be ignored in frequencies below 5 GHz
- ITU gathered rain statistics during 15 year (ITU-R P.837),

$$\gamma_R = kR^{\alpha} \quad \text{dB}$$

- Specific attenuation γ_R depends on polarization and frequency,
- Rain attenuation exceedance can be estimated within 0.001% to 1% of the time

XPD Degradation
(*XPD*: Cross-polarization discrimination)

- *XPD* defined in ITU-R P.310
- A measure of polarization diversification

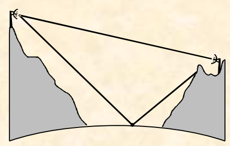


$$XPD = \frac{P_{R,CoPol}}{P_{R,XPol}}$$

- Multipath occurrence and precipitation degrade *XPD*

Techniques to Reduce Multipath Fading

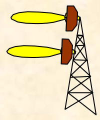
- Using inclined path to reduce flat fading due to atmospheric mechanisms (beam spreading, antenna decoupling, and atmospheric multipath);
- Reducing the occurrence of significant surface reflections;
  - Using terrain shielding,
  - Moving reflection point to poorer location



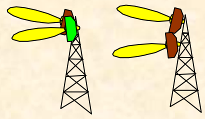
- Using vertical polarization over water
- Prevention of larger value of clearance
- Using diversities

Diversity Technique

- Space diversity
  - To combat specular surface reflection
  - To combat surface multipath fading



- Angle diversity (two antennas in different orientation, in same or different heights)

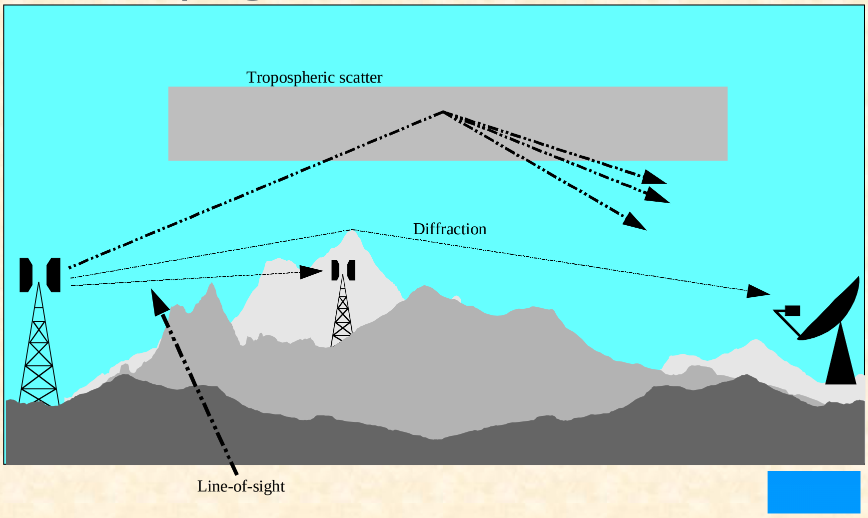


- Frequency diversity, more than one frequency used for transmission

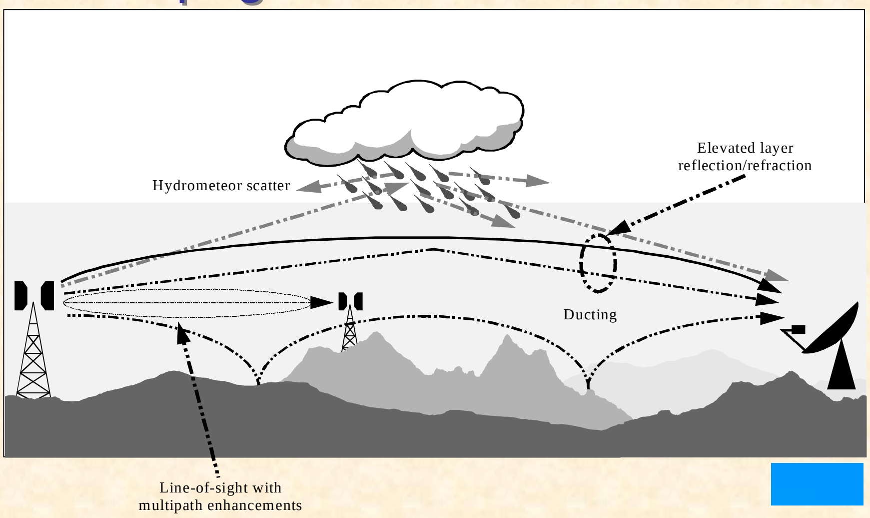
Interference Mechanisms

- Long-term mechanisms
- Short-term mechanisms

Long-term Interference Propagation Mechanisms (P.452)



Short-term Interference Propagation Mechanisms (P.452)



Exercising SMS4DC

Types of RF Channel Arrangements

- Homogeneous channel arrangement

$$f_n = f_0 + f_{offset} + n \cdot XS \quad \text{MHz}, \quad n = 0,1,2,....$$
$$f'_n = f_0 + f'_{offset} + n \cdot XS \quad \text{MHz}, \quad n = 0,1,2,....$$

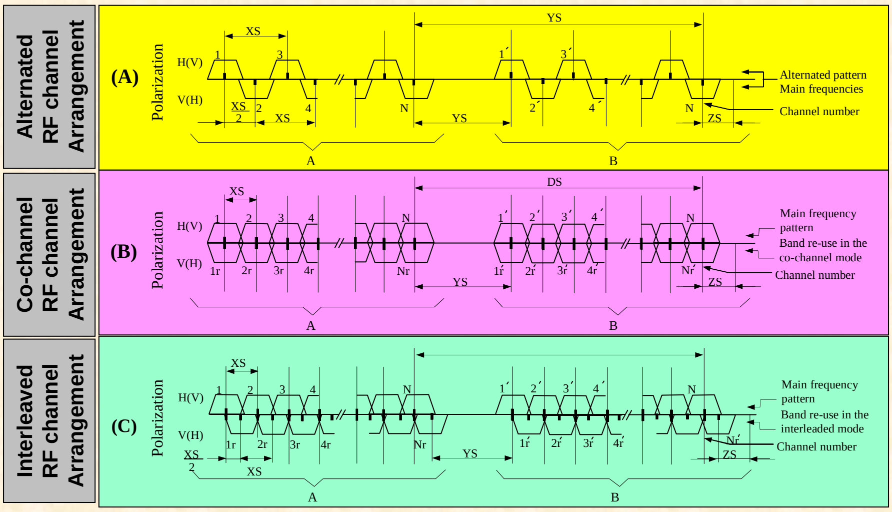
- Uniform channel arrangement

$$f_n = f_0 + n \cdot XS \quad \text{MHz}, \quad n = 0,1,2,....$$

- Non-uniform channel arrangement
- References:
  - ITU-R Recommendations, F series,
  - CEPT Recommendations,

Homogeneous RF Channel Arrangements

(F.746)



A: “go” channels B: “return” channels

Uniform Channel Arrangement

- Suitable for Simplex operation mode
- More common in the bands shared between Fixed and Mobile
- The only choice for TDD transmission
  – Transmitting and receiving will be down in different time slots

Exercising SMS4DC software (1)

- Link Calculation provided for following models in the menu of Propagation Model:
  – ITU-R P.370
  – ITU-R P.1546
  – ITU-R P.526
  – ITU-R P.452, and
  – ITU-R P.530

- **Step 1:** Lunch the SMS4DC software
- **Step 2:** Lunch the DEM view using toolbar push button

Exercising SMS4DC software (2)

- **Step 3:** Establish Fixed station **A** using set the frequency to 890 MHz
- **Step 4:** Choose antenna “ant_ALE8603_806.ant” and check the antenna pattern
- **Step 5:** Establish an other Fixed station **B** using set the frequency to 880 MHz
- **Step 6:** Choose antenna “ant_ALE8603_806.ant” and check the antenna pattern
- **Step 7:** Open the administrative part from “Database->Licensing”
- **Step 8:** Select “Anonymous Station” and find station **B**,

Exercising SMS4DC software (3)

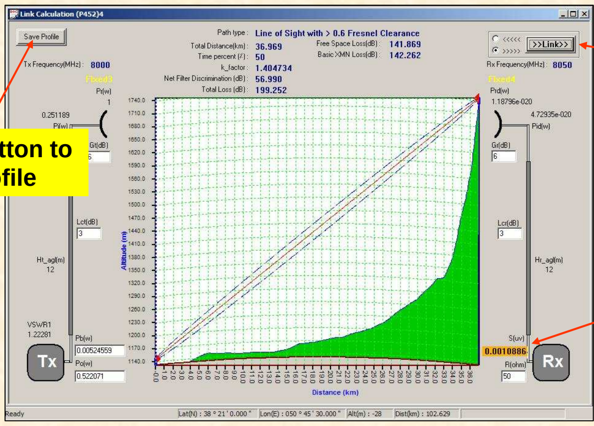
- **Step 9:** Open Antenna Information Table of station **B**
- **Step 10:** Push the “Modify” button,
- **Step 11:** Change the field “Class of Antenna” from “T” to “**R**”
- **Step 12:** Push the “Save” button,
- **Step 13:** Find the station **A** and go to the level of “Frequency”
- **Step 14:** Push the “Add Receiver” button top of the “Frequency Information” table of station A. The “Add Receiver” dialog box will appear.
- **Step 15:** Select the “Point” Radio button. All the selectable receivers will be displayed in relevant spreadsheet

Exercising SMS4DC software (4)

- **Step 16:** Choose the station **B** from table under POINT section and push ok
- **Step 17:** Close Administrative dialog box
- **Step 18:** Open the “Database” menu and select “Display Link”.
- **Step 19:** Select the record of new established hop
- **Step 20:** Push OK button to display stations of selected hop on map

Exercising SMS4DC software (5)

- **Step 21:** Open the menu “Propagation Model” and select Link item under the ITU-R P.370 propagation model



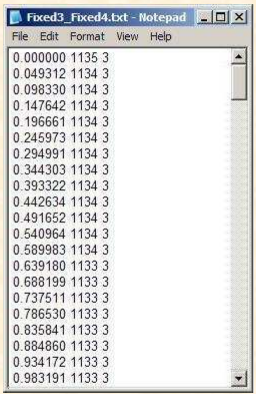
Changing direction of calculation

Push button to save profile

Values with colored background can be tried respect to the editable values

Exercising SMS4DC software (6)

- **Step 21:** Repeat step 21 for P.452 and P.526 propagation model. See the different calculated results
- **Step 22:** Repeat step 21 for P.530 propagation model. See the different calculated results
- **Step 23:** Use mouse drag to change antenna height and manage reflection points
- **Step 24:** Push “Reflection Points” button to see spreadsheet of reflection points



Profile data

Exercising SMS4DC software (6)

Reflection Points

No	Coordinates	Distance(km) : d1	Distance(km) : d2	Height_ASL(m)	Delta_R(km)	Grazing Angle(Deg.)
1	050E0811 35N5841	1.087	35.882	1133.407	0.000	0.621
2	050E0831 35N5845	1.592	35.377	1132.541	0.000	0.534
3	050E0844 35N5849	1.928	35.041	1133.077	0.000	0.481
4	050E0928 35N5900	3.083	33.886	1133.160	0.000	0.428
5	050E0929 35N5900	3.122	33.847	1133.355	0.000	0.419
6	050E0959 35N5908	3.906	33.063	1133.964	0.000	0.414
7	050E1059 35N5923	5.473	31.496	1147.656	0.000	0.315
8	050E2904 36N0400	33.925	3.044	1371.429	0.016	3.105
9	050E2951 36N0412	35.160	1.809	1487.258	0.014	3.588
10	050E3000 36N0415	35.391	1.578	1503.716	0.014	3.921
11	050E3022 36N0420	35.970	0.999	1565.516	0.013	4.603
12	050E3029 36N0422	36.152	0.817	1583.252	0.012	5.426
13	050E3057 36N0429	36.892	0.077	1720.341	0.004	8.758

Exit Number of Ground R

P530 - Availability

Rain	Availability (%)	Outage (in Sec.)	Outage (in Min.)
WORST MONTH	99.090638	23570.659968	392.844333
ANNUAL	99.730995	84949.712177	1415.828536

Multipath	Availability (%)	Outage (in Sec.)	Outage (in Min.)
WORST MONTH	99.961351	1001.769856	16.696164
ANNUAL	99.991510	2680.961044	44.682684

Exit

- **Step 25:** Push “Availability” button to see the availability calculation result

End