

# Pathloss Version 5.1

The program is intended for experienced telecommunications network designers and a knowledge of radio wave propagation is a prerequisite to using this program.

## PROGRAM OPTIONS

The Pathloss program is offered in several options structured as follows

**PL50B (Basic)** This is the basic point to point link design program and is the foundation for all other options

**PL50C (Coverage)** This option adds multi sectored base stations for the design of point to multipoint networks and local coverage displays

**PL50I (Interference)** This option calculates the intra-system interference between any two groups of sites in the network display or between the external database (ODBC) and a group of sites in the network display.

**PL50T (Total)** This option includes both the coverage and interference options. In addition, this option allows the following operations:

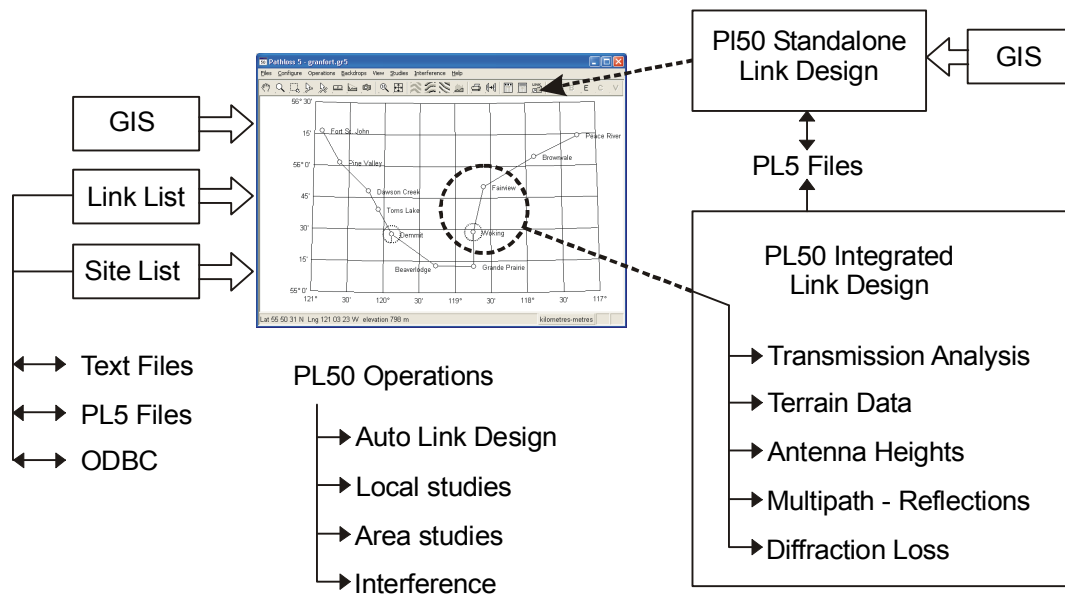
- interference between point to point links, point to multipoint links and base stations.
- area coverage calculations using multiple base stations working into a user specified area

In the following sections the designators (C), (I) and (T) are used to denote that this specific program option is required. Where the option (C) or (I) option is specified, the option (T) will also include this capability. If a specific option is not specified, the basic program (B) includes this option.

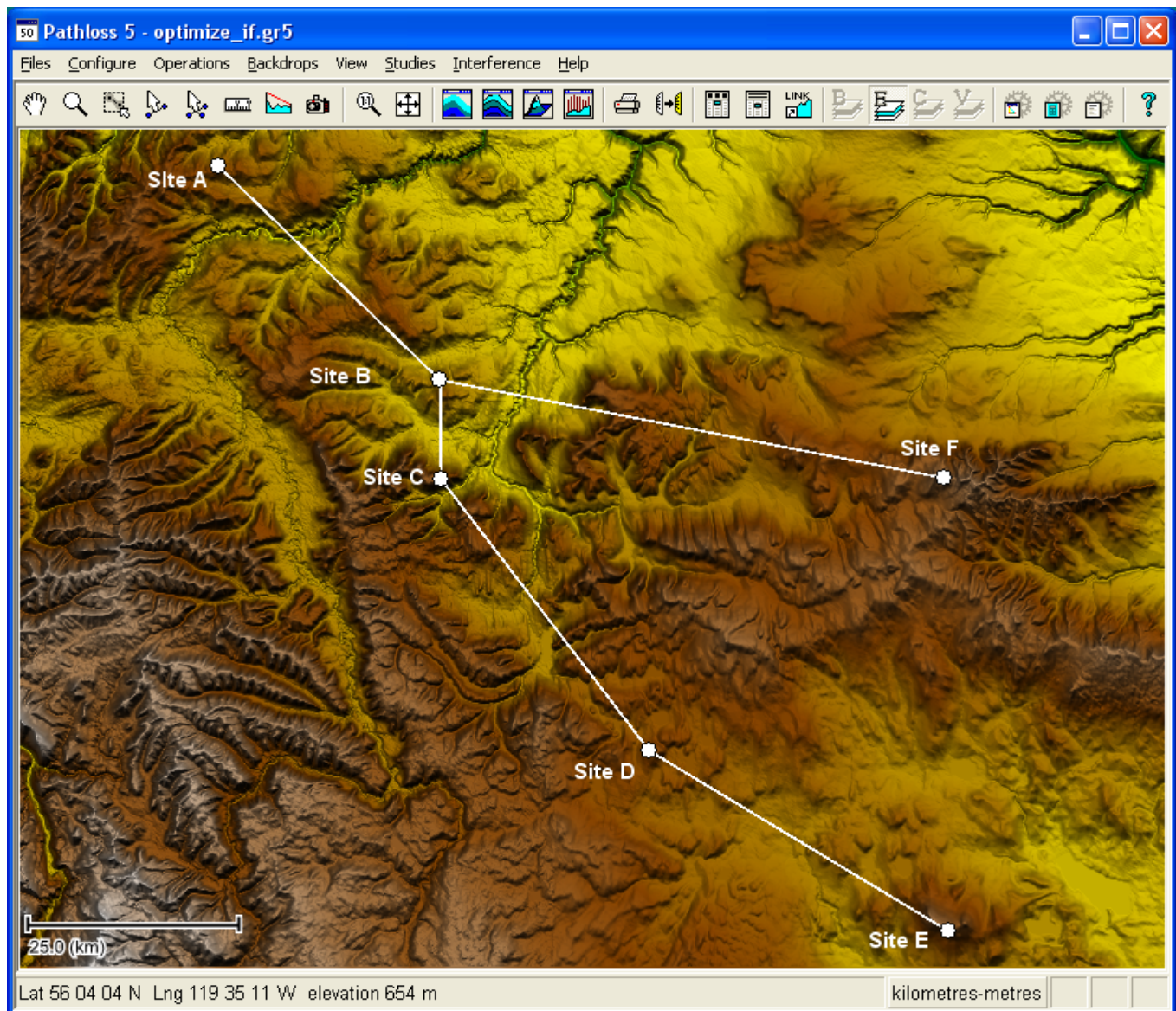
## PROGRAM ORGANIZATION

The diagram below shows the basic organization of the Pathloss program. The network display is the main window of the PL50 program and provides a graphical representation of the users sites and links. The link design sections are accessed by clicking on a specific link. A stand alone link design program is also provided to access individual link design files which are not part of the network display.

### PL50 Network Display



## PL50 Network display



A typical network display is shown above.

### Basic network display features.

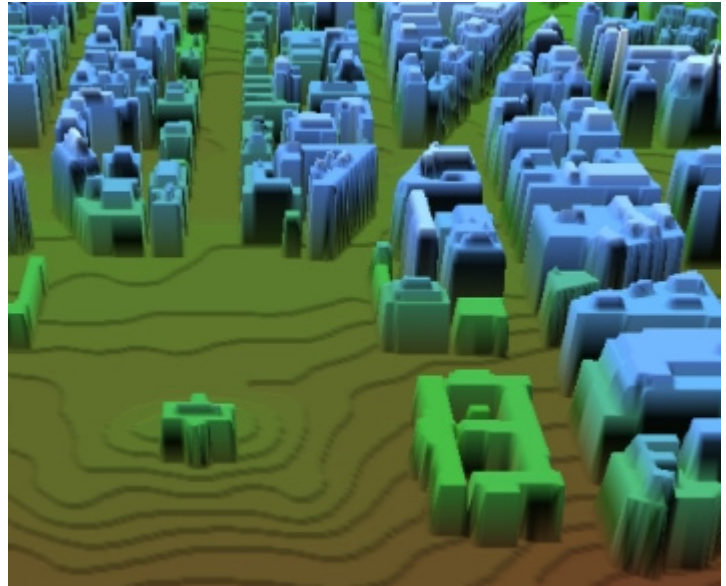
- Create a flat or shaded elevation backdrop over the current displayed area. The colors and ranges are user defined.
- Create a clutter backdrop showing the land usage.
- Display a geo-referenced image file as the backdrop. This can be in any image format (tiff, jpeg, png bmp).
- Display a vector file in the network display.
- Add pictures to the network display from photographs or other images.

- Create and manipulate a 3D image of the network display.
- Measure the distance between any two points.
- Dynamically generate a path profile by dragging the mouse between any two points on the network display.

## Network display design operations

The following design operations are carried out in the network display: Additional details are provided in the following sections: *Automated link design*, *Local and Area studies* and *Interference calculations*.

- Generate point to point link designs between any two groups of sites in the network display including all sites to all sites
- Generate point to multipoint links from a base station to any combination of remote sites or remote sites within a specified radius from the base station (C).
- Design point to point links for a user specified connectivity.
- Design point to multipoint links for a user specified connectivity (C).
- Modify existing links for different equipment, design criteria and specific calculation algorithms.
- Find the best route between any two sites using a specified design criteria.
- Generate local studies. These are signal strength and line of sight displays centred on a base station. Any number of local studies can be created (C).
- Generate an area study. This consists of a single user defined area (circle, square or polygon). The signals strength from multiple base stations are calculated into this common area. In addition to signal strength, the display can show, the most likely server, carrier to interference and simulcast delay spread (T).
- Interference calculations can be carried out between two groups of links or between all links in the network display (I)
- Analyze all interference case at a specific site. Change any of the parameters affecting the interfering levels and immediately see the results or the changes (I).



## Site and Link lists

The site and link lists represent the user's data. As a minimum, a site is defined by its name and geographic coordinates and a link is defined by the end site identities. The user interface is the site list from which data can be imported by any of the following means:

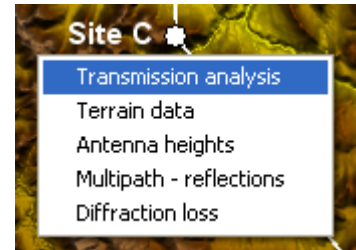
- Text files containing a list of sites.
- Text files containing a list of links (two sites per line).
- Existing Pathloss data files (pl5, pl4, pl3).
- An ODBC interface to an existing data base.

## Link design sections

Link design consists of the following sections:

- Transmission analysis - link performance considering multipath, obstruction and rain fading
- Terrain data - generate path profiles and add buildings, trees or ranges to the profile
- Antenna heights - determine the antenna heights to meet a specified clearance criteria or value of diffraction loss
- Multipath - reflections - analyse specular reflections and simulate ducting conditions
- Diffraction loss

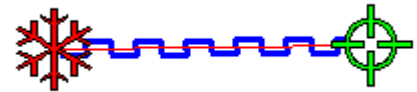
Each link is saved in its own file using the extension pl5. In the network display, the link design sections are accessed by clicking on a specific link. A stand alone version of the link design sections is also provided to allow access to pl5 files which are not included in the network display. The stand alone program name is Pathloss Link (PL50L) and is associated with the .pl5 files. This can be directly accessed from the Windows desktop icon, from the tool bar in the Pathloss 5 program or by double clicking on a pl5 file.



A detailed description of each design section is provided later in this document.

### ***Thematic Mapping***

The site symbol and link lines can be customized to make network elements quickly identifiable. The site symbol uses a true type font character such as Webdings or Wingdings to denote the type of the site. The color denotes the status.



The link line can be coded as a variety of line style to denote the type and the link status is denoted by the line color.

A line of sight status can also be coded into the link line. In the example show, the square wave blue line represents the line of sight status and the solid red line represents the link type and status.

### **Groups and Selections**

All operations in the network display are based on groups or selections of sites and links. Groups are named and are saved in the gr5 file. A selection serves as a temporary group. A group can contain sites, links or sites and links. A site or link can belong to multiple groups.

Groups are also used to control the network visibility.

### **External Database**

An ODBC connection to the Pathloss program is available to create a pre-defined set of relational tables using the user's database. Site and links in the Network display can be exported to and reimported from this database. In addition, site frequency data can be imported into this database from text files (CSV) making it possible to analyse interference between the network display and the database.

### **Export features**

The network display including site, links, local and area studies can be exported in the following formats:

- Google Earth kml
- MapInfo Tab file
- ERSI shapefile

In the case of ERSI shapefiles and tab files, the local and area studies are exported in vector contour format which simplifies further analysis in these programs



## Reports

All reports are written to a 3rd party RTF (Rich text file) editor which allows a direct interface with standard word processors like Microsoft Word. The text editor supports all of the graphic displays used in the program.

Composite reports can be generated for a selection or group of links

In addition to the formatted text and graphic RTF reports, comma separated values (CSV) reports can be generated.

## AUTOMATED LINK DESIGN

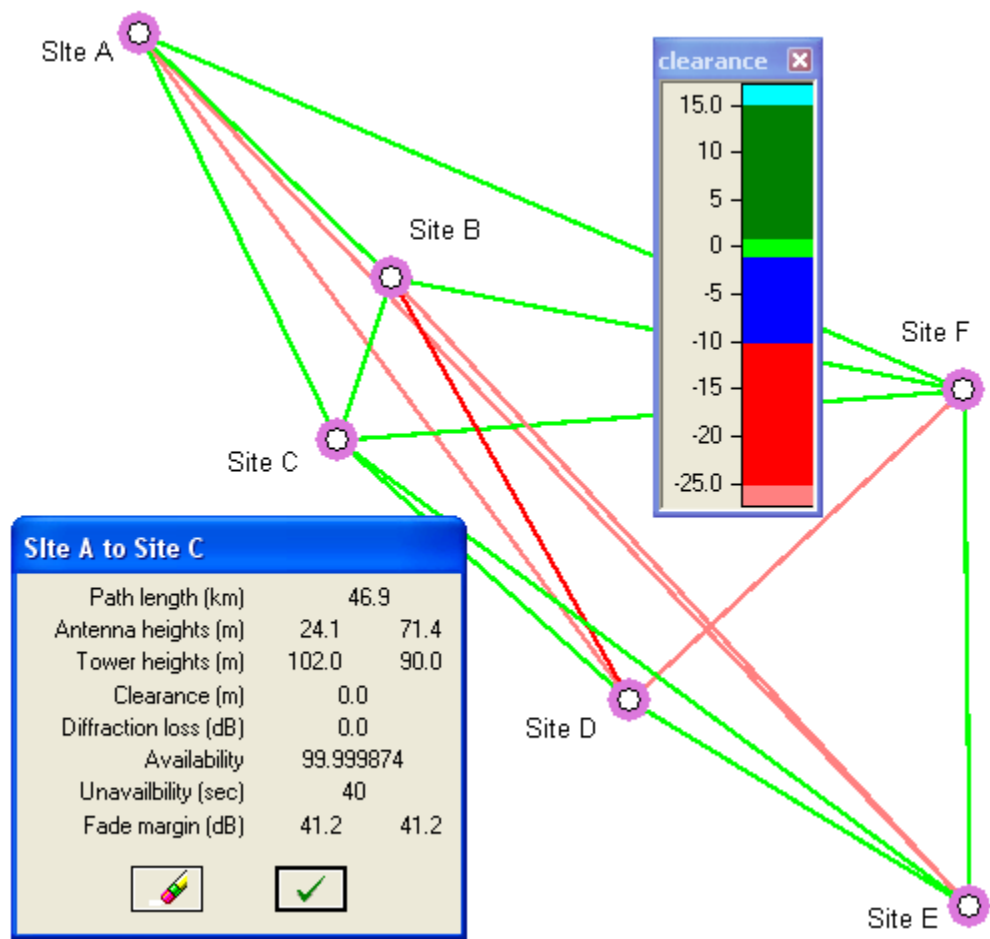
An automated link design carries out the basic design operations of a link in a single step. This designer allows for powerful batch processing of many links. The designer operations include:

- Path profile generation
- Antenna height calculations or assignments
- Adding radio, antenna, transmission line and antenna coupling unit equipment specifications
- Determine the multipath fading parameters and rain statistics based on the site coordinates
- Calculate the link availability
- Optimize the design to meet a specific performance objective, by changing antenna gains, transmit power and adding frequency or space diversity to the design

The Automated link design feature is used in the following operations.

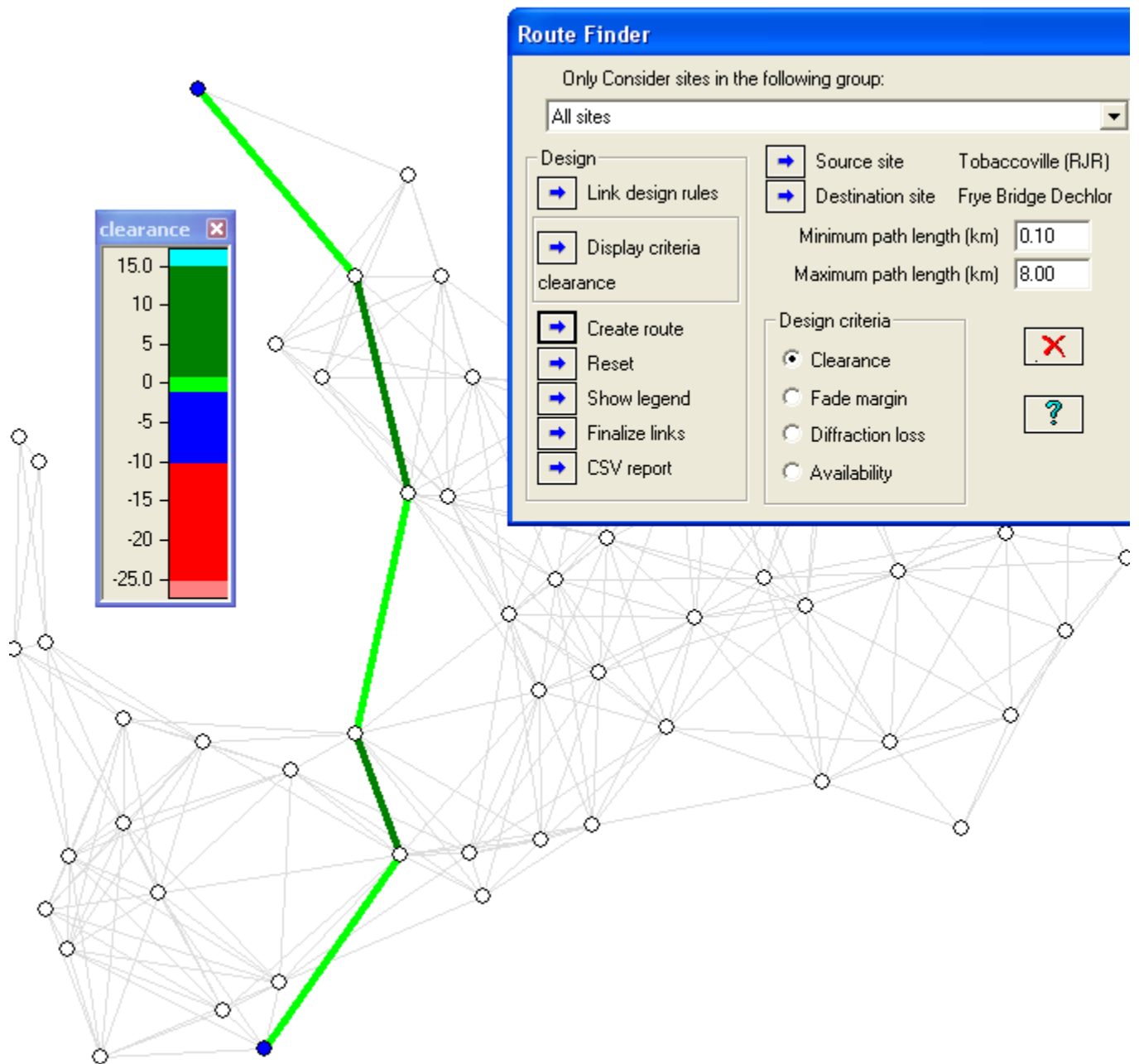
- Design a single link
- Create all possible links between any two groups of sites or all sites to all sites.
- Create links from a base station to a group of remote stations or to remote stations within a specified radius. (PL5C)
- Design links based on a user specified connectivity.
- Edit or modify existing link designs.
- Given a group of sites, determine the best route between two sites

The results are color coded based on a user specified design criteria such as fade margin, availability or clearance.



An example of automatic link design for 6 sites is shown above. Links between every combination of sites have been created and designed in one step. The links have been color coded based on the relative clearance of the antenna heights to the design criteria is used. Rejection criteria are used to selectively remove links to arrive at the final configuration.

An example of the *Route finder* display is shown below. In this operation, the user imported a list of sites, specified



the start and end point and the design criteria and clicked the create route button. Every possible link is analysed within the constraints of the maximum and minimum path lengths. The best route is displayed color coded according to the design criteria, - An extremely powerful feature included in the basic program (PL5B)

## Link Design Rules

All automated link design operations are based on a set of user defined *Link Design Rules* consisting of the following:

### Calculation options

These are the specific algorithms used in the calculations and include the multipath fade, diffraction loss and rain methods

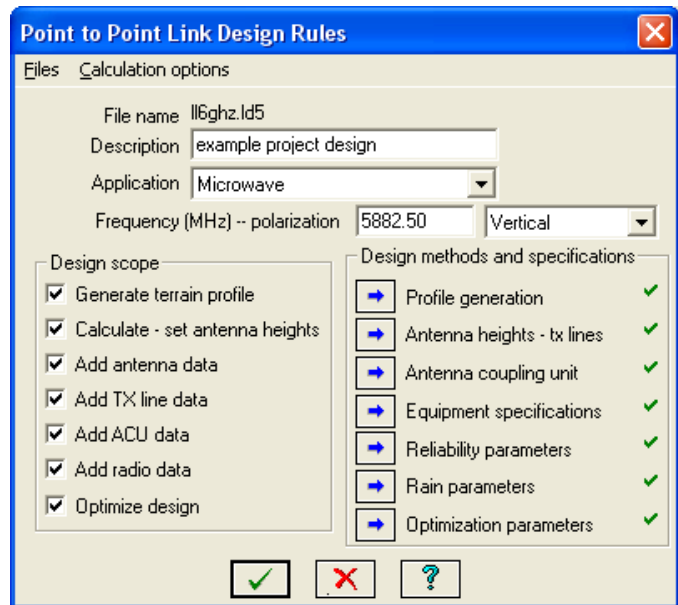
### Design Scope

The scope of the design is organized as shown in the dialog on the right. In the case of a link feasibility study based on antenna heights, the scope could be limited to *Generate terrain profile* and *Calculate - set antenna heights*

### Design methods and specifications

This section includes the antenna, radio and transmission line specifications and the methods to be used in the calculations. As an example, the antenna height calculation options are shown in the dialog on the right.

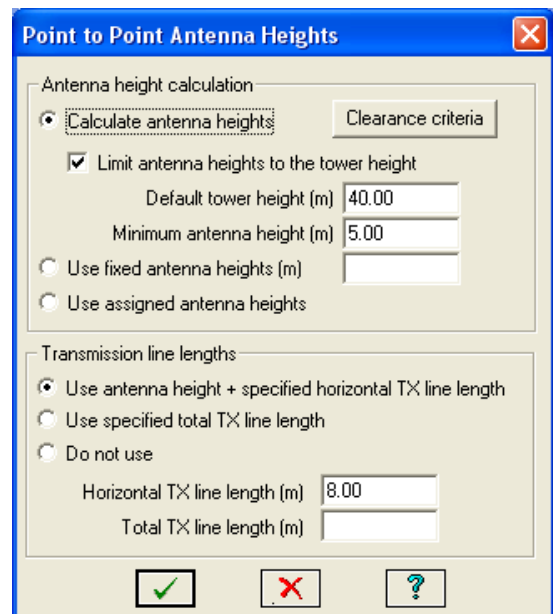
The link design rules are saved in separate files.



The 'Point to Point Link Design Rules' dialog box is shown. It has a 'Files' tab and a 'Calculation options' tab. The 'Calculation options' tab is active. It contains the following fields and options:

- File name: 116ghz.Id5
- Description: example project design
- Application: Microwave (dropdown)
- Frequency (MHz) -- polarization: 5882.50 Vertical (dropdown)
- Design scope (checkboxes):
  - ☒ Generate terrain profile
  - ☒ Calculate - set antenna heights
  - ☒ Add antenna data
  - ☒ Add TX line data
  - ☒ Add ACU data
  - ☒ Add radio data
  - ☒ Optimize design
- Design methods and specifications (checkboxes with arrows):
  - ☒ Profile generation
  - ☒ Antenna heights - tx lines
  - ☒ Antenna coupling unit
  - ☒ Equipment specifications
  - ☒ Reliability parameters
  - ☒ Rain parameters
  - ☒ Optimization parameters

At the bottom are three buttons: a green checkmark, a red X, and a question mark.



The 'Point to Point Antenna Heights' dialog box is shown. It has a 'Clearance criteria' button. The 'Antenna height calculation' section contains the following options and fields:

- ☒ Calculate antenna heights
- ☒ Limit antenna heights to the tower height
  - Default tower height (m): 40.00
  - Minimum antenna height (m): 5.00
- ☐ Use fixed antenna heights (m)
- ☐ Use assigned antenna heights

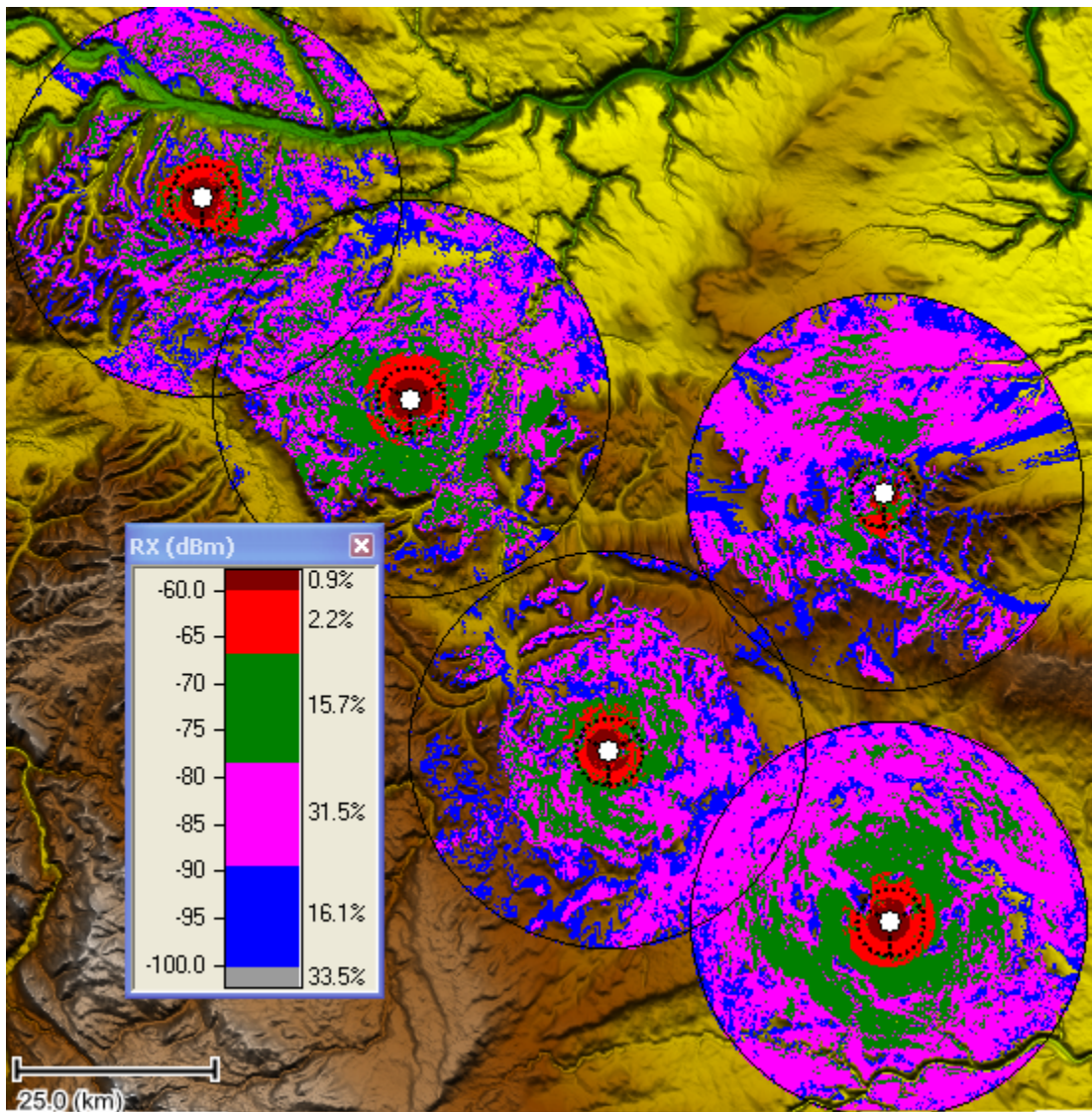
The 'Transmission line lengths' section contains the following options and fields:

- ☒ Use antenna height + specified horizontal TX line length
- ☐ Use specified total TX line length
- ☐ Do not use
  - Horizontal TX line length (m): 8.00
  - Total TX line length (m):

At the bottom are three buttons: a green checkmark, a red X, and a question mark.



## LOCAL STUDIES (PL5C)

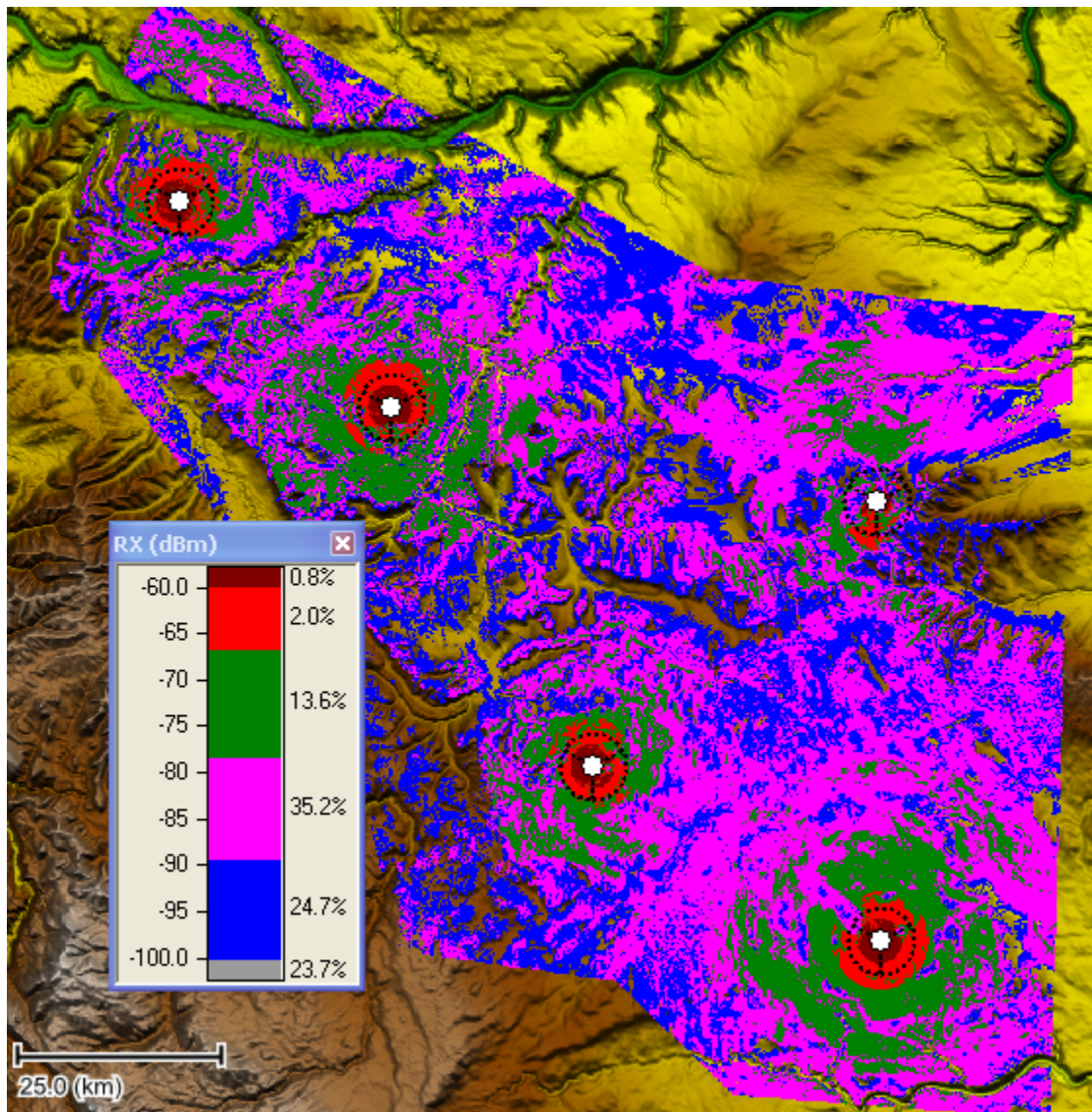


The network display above illustrates the concept of local studies. A number of sites have been designated as base stations. This step specifies the base antenna sector arrangement and the radio and antenna specifications for both the base and mobile sites. A coverage radius and cell size is specified for each base station and the signal strength is calculated from each base station into its area. The results are displayed using a user defined color legend. In the coverage overlap areas, the highest signal level is shown. This legend also shows the overall percentage of coverage for each signal level.

The display criteria can show receive signal expressed in dBm, dBW, dBμV, dBμV/m, fade margin or simply line of sight. Changes can be made to the display criteria of equipment specifications without regenerating the basic loss calculations.

The local study display can be exported to Google Earth in raster format or to an ESRI shape file or MapInfo tab file in a vector format.

## AREA STUDIES (PL5T)



In an area study a common area is specified for all base stations. This coverage area can be a rectangle, ellipse or polygon as shown in the above network display example. The coverage area is divided up into uniform cells. The signal strength from each base station is calculated into each cell in the coverage area.

In addition to the receive signal formats available for local studies, the area study display criteria includes the most likely server, data throughput for adaptive modulation radios, carrier to interference, and simulcast delay spread

The area study display can be exported to Google Earth in raster format or to an ESRI shape file or MapInfo tab file in a vector format.

## INTERFERENCE ANALYSIS (PL5I)

Intra system interference is calculated in the network display. The calculation is organized in groups. Only visible layers will be used in the calculation. The calculations use antenna and radio data files. The minimum conditions to calculate intra system interference are listed below:

- A Pathloss data file (pl5) must be associated with each link to be used in the calculation.
- An antenna data file must be specified for each antenna in the Pathloss data file.
- The transmission analysis must be complete to the level of a receive signal calculation.
- Transmit and receive frequency assignments must be specified for the Pathloss data files used in the calculation.

**Intra System Interference**

Coordination distance (km) 200.00

Maximum frequency difference (MHz) 150.00

Default minimum interference level (dBm) -115.00

Calculation margin (dB) 10.00

Digital interference objective

Threshold degradation (dB) 1.00

☒ Calculate OHLOSS automatically

☐ Ignore diversity antennas

☐ Ignore adjacent channels

☐ Use default antenna patterns in MDB

☐ Use default radio curves in MDB

Study Scope

Analyze All links

against All links

Buttons: Calculate, Cancel, Help, Correlation options, OHLOSS options

A radio data file is optional; however, only the interfering level can be calculated without this file. This file is required to calculate filter improvement and threshold degradation.

The calculation supports fade correlation for both multipath and rain fades. The threshold degradations can be transferred to the Pathloss data files to determine the overall effect of the interference on the availability.

### ***Analysing interference cases at a site:***

All cases at a selected site can be displayed and the parameters affecting the interference can be edited. The results are immediately recalculated and displayed. This is a completely interactive process. On completion, the changes can be made to the Pathloss data files

Interference - Site B

Receiver

1 of 3

Transmitter

1 of 3

Composite threshold degradation

7.74

Correlated threshold degradation

Mp 7.28 Rn 7.06

Availability w/o interference

99.9999% 20 sec

Availability with interference

99.9997% 105 sec

Change PI5 files

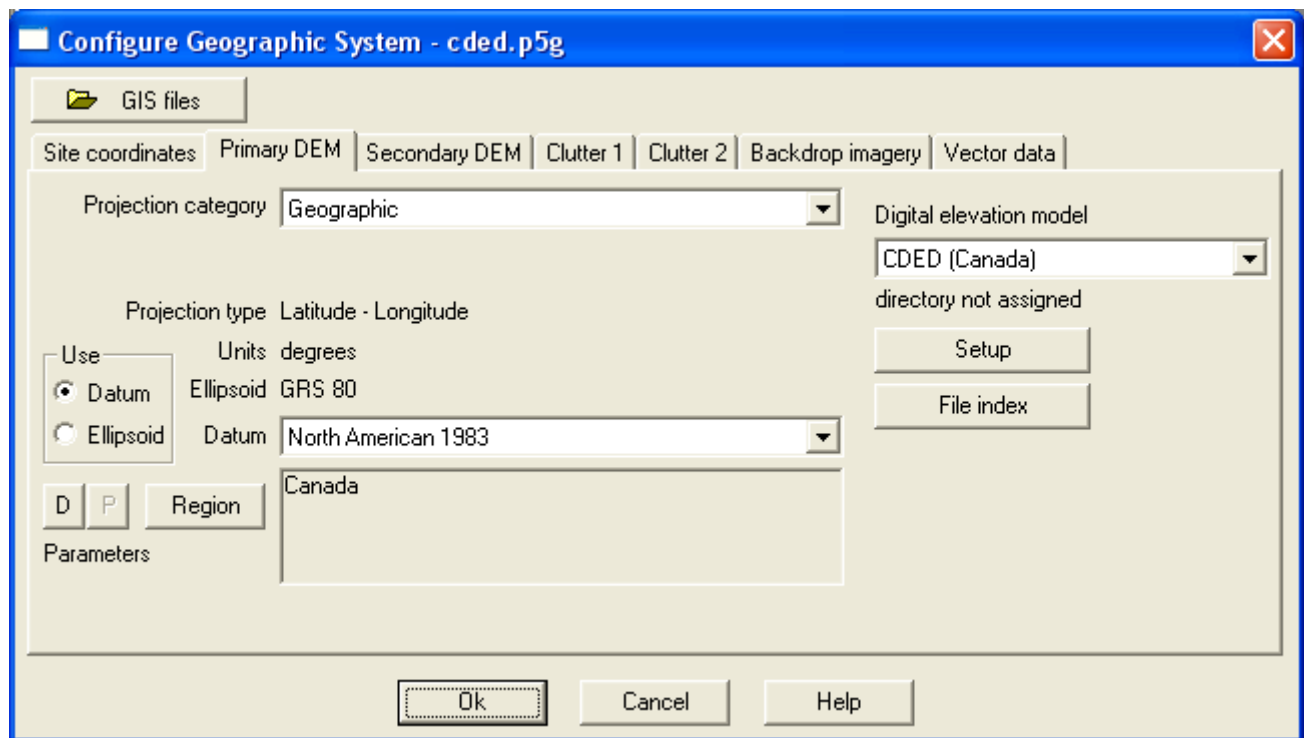
Reset

Help

	Victim RX	Interfering TX
	Site B	Site F
Coordinating station	Site A	Site B
Frequency (MHz)	5878.875H	5878.875V
Antenna model	HPX8-58W	HPX8-58W
Radio model	MDR-6706-8	MDR-6706-8
TX power (dBm)		29.00
ATPC range (dB)		
V-I distance (km)		36.26
True azimuth (°)	313.78	330.47
Discrimination angle (°)	0.00	-197.04
Total discrimination (dB)		69.00
Interfering level (dBm)	-107.75	
Receive signal (dBm)	-40.03	
Frequency separation (MHz)		0.00
Filter improvement (dB)	0.00	
OHLOSS (dB)		
Adjusted interfering level (dBm)	-107.75	
C to I (dB)	67.71	
Threshold degradation (dB)	2.71	
Correlation type	Partially correlated, itx 49.2, atx 73.2 m	
Correlation value	Multipath - 5.0 dB Rain - ignored	



## GIS CONFIGURATION



The pathloss program incorporates a complete GIS capability. No other GIS software is required. The GIS configuration defines the following components

- Site coordinates datum and projection
- Digital terrain elevation models
- Digital clutter models
- Backdrop imagery
- Vector data

Note that the Pathloss program does not use a proprietary data format. The program supports most available industry formats. Furthermore, it is not necessary to have all data in the same datum and projection. For example a typical GIS configuration could be:

- 1/3 second resolution digital elevation data in a geographic latitude - longitude format
- 30 meter resolution clutter data in an Albers equal area conic projection
- Backdrop imagery in a GeoTiff file format with an UTM projection

### Terrain digital elevation models

The following digital elevation model (DEM) raster data formats are supported:

Generic BIL geographic and projected formats - Most commercial elevation data sources and legacy Planet elevation data use this format

MapInfo grd and grc formats

USGS NED (National Elevation Data) with 1, 1/3 and 1/9 arc second resolutions in BIL integer and floating point formats

Canadian CDED data in 3 arc second and 0.75 arc second resolution

SRTM (Shuttle Radar Topography Mission) available from 60° north latitude to 60° south latitude in 3 arc second resolution and 1 arc second in the contiguous United States. The data is available in 1° by 1° blocks in .hgt files.

ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) available from 83° north latitude to 83° south latitude in 1 arc second resolution. This data is supplied in 1° by 1° blocks in a TIFF file format,

DTED (US Defence mapping agency) level 1 and 2 formats

South Africa Gauss Conform data in the NES - Cape datum and the ORT - Hartebeesthoek94 datum

GTOPO30 (Global 30 Arc-Second Elevation Data). Although the resolution of this data is not adequate for detailed design, it is often useful in setting up an unknown data format by comparing results

ESRI ARCINFO This is a proprietary data format and therefore not supported. The public data format is GRIDASCII which is supported by conversion to a BIL format

USGS Digital Elevation models. These are the legacy USGS ASCII data formats which have now been superseded with NED seamless data

- 7.5-Minute DEM 30- x 30-meter data spacing
- 1-Degree DEM 3- x 3-arc-second data spacing

## **Raster clutter data**

The program supports the following clutter data configurations:

- the data consists of a description of the clutter (Categorical) - the user specifies the elevations
- the data consists of clutter elevations, - no description is available
- clutter heights are determined as the difference between a ground elevation DEM and a composite ground and clutter DEM.

The following clutter data formats are supported:

- Generic BIL geographic and projected formats
- USGS National Land Cover Data in 1 arc second resolution
- MapInfo grc format
- GLCC (Global Land Cover Characterization) in 30 arc second resolution

## **Backdrop Imagery**

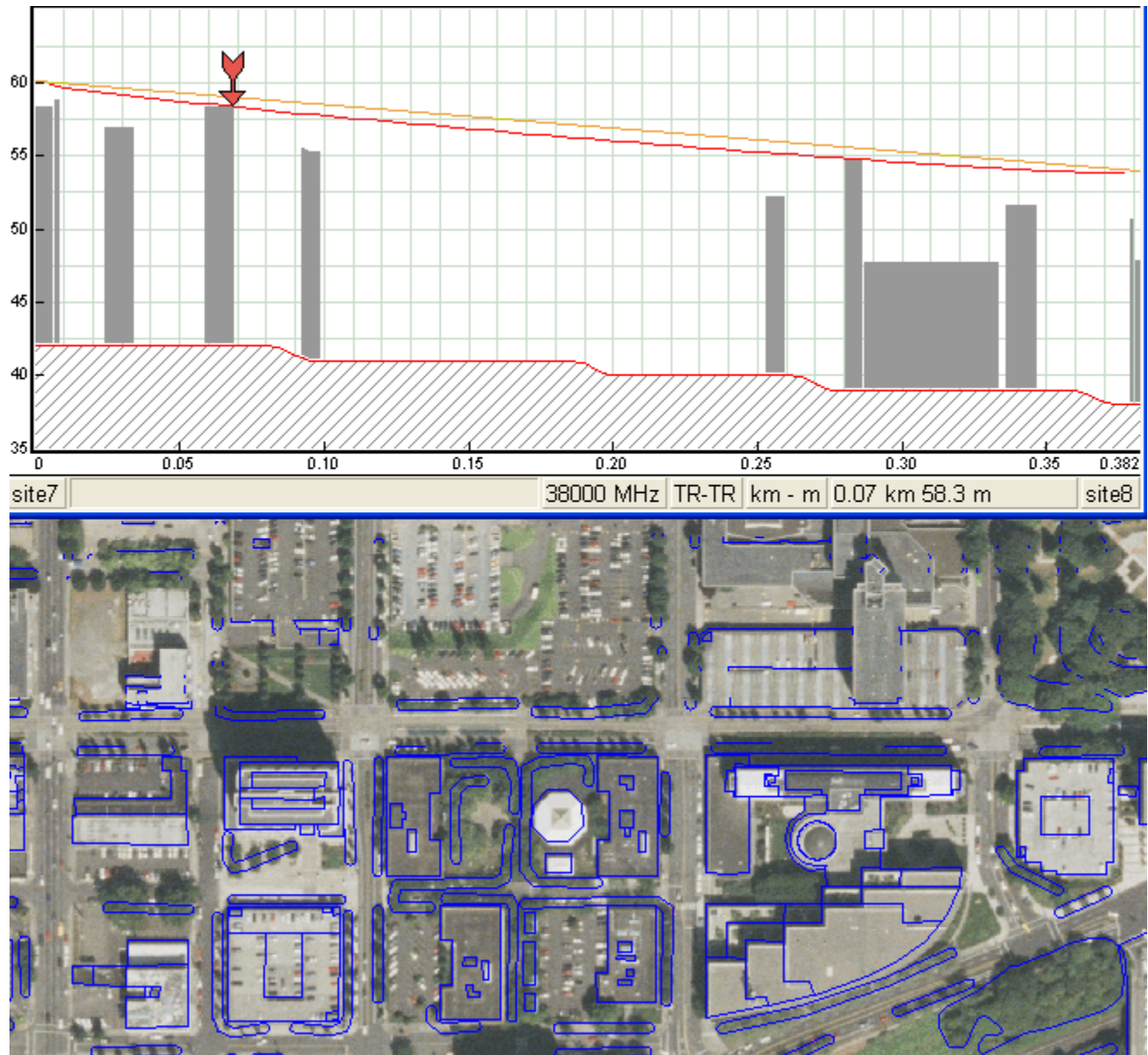
The program supports most raster data formats (tiff, jpeg, bmp, png). The preferred format is geo tiff which includes the required geo referencing information. In other cases, you can manually geo reference the file using the built in geo-referencing utility

## **Vector Data**

- The following vector data file formats are supported:
- Legacy Planet - Odyssey data formats
- MapInfo mapfile
- ESRI shapefile



Mapfiles or shapefiles which contain building outlines and building heights, can be configured to be used as clutter data. The path profiles will include the building data. The network display shown below has a backdrop geo refer-



enced tiff image and a shapefile of building vectors which contains building elevations. The dynamic on screen profile generation feature shows the buildings on the path profile - a valuable feature to determine the feasibility of links in a urban area.

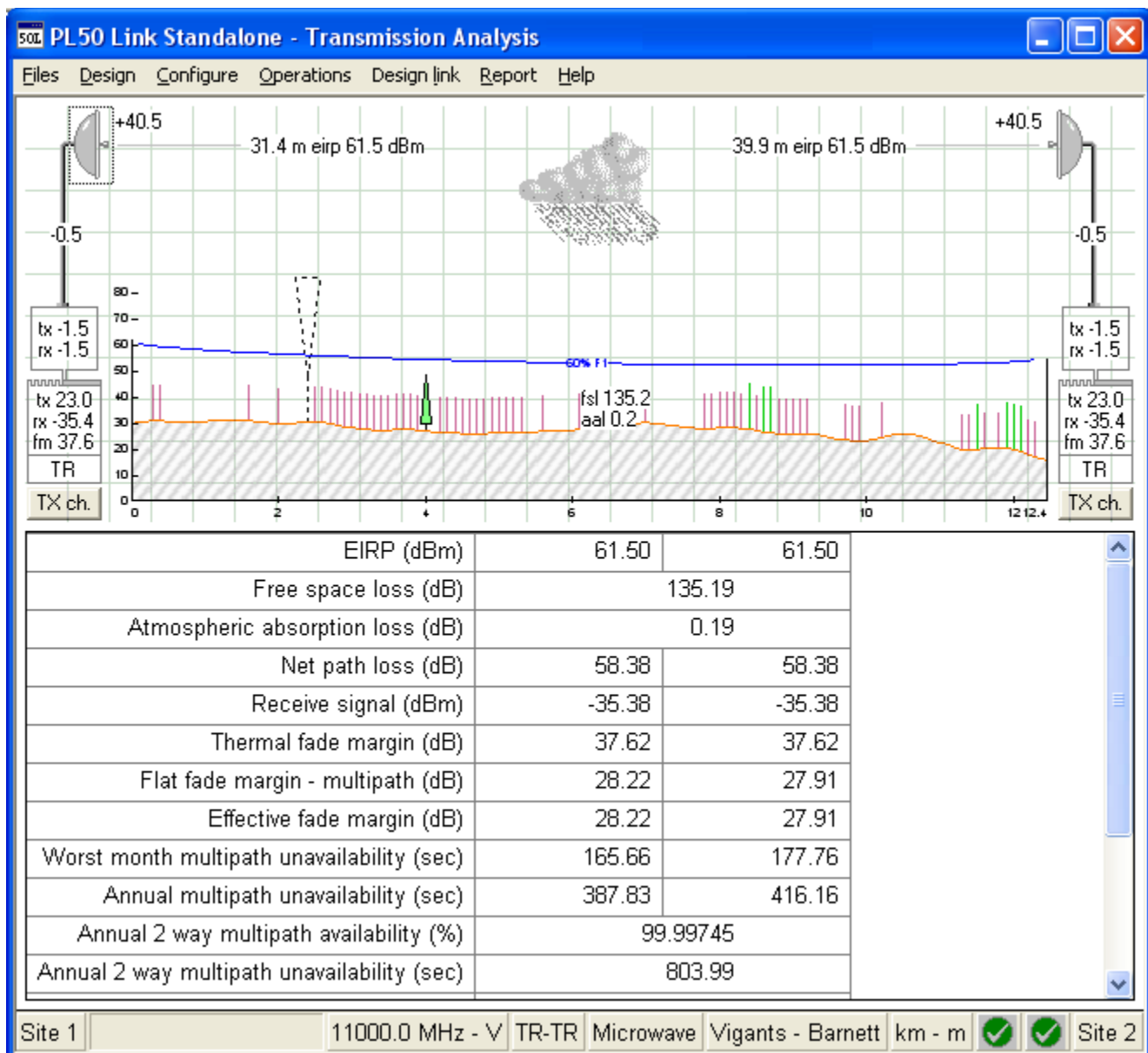
## TRANSMISSION ANALYSIS

The probability of an outage due the following propagation mechanisms are carried out in the *Transmission analysis* design section:

- multipath fading probability
- obstruction fading probability fading due to low values of the earth radius factor

- probability of an outage due to high intensity rain fall

Note that outages due to ducting are available in the *Multipath - Reflections* design section. There is no capability to calculate the outage due to a specular ground reflection.



The *Transmission analysis* design section is the data entry point for all radio, antenna, transmission line, antenna coupling unit and frequency assignment data. Each icon on the display brings up the respective data entry form. Data entry can be carried out using lookup tables, data file indexes or by importing data from an existing file. All calculations are automatically updated as the data is entered or changed.

## Multipath fade algorithms

Vigants - Barnett (C factor or climatic factor and terrain roughness)

Rec ITU-R P.530-6 (path inclination, grazing angle, probability  $dN/dh < -100$  N units /km, path classification)

Rec ITU-R P.530-7/8 (path inclination, probability  $dN/dh < -100$  N units /km, inland path classification, over water modifications)

Rec ITU-R P.530-9/12 (path inclination, area roughness over a 110 x 110 km area, value of  $dN/dh$  not exceeded for 1% of the time)

Rec ITU-R P.530-17 (path inclination, area roughness over a 110 x 110 km area, value of  $dN/dh$  not exceeded for 1% of the time)

## **Rain fade algorithms**

Both the Crane and the ITU-R P.530 algorithms are available.

The ITU-R P.530 uses the rain rate which is exceeded for 0.01% of the time. The sources for this parameter are listed below:

- ITU-R P.837-3 world wide data base
- ITU-R P.837-5 world wide data base
- Rain statistics files - ITU rain regions A to Q
- User specified value

The data for the first three options is included in the program. The 0.01% rain rate is automatically determined using the path center coordinates of the link for these options.

The Crane algorithm uses a rain statistics file. (rain rate and the percent of time that this rate is exceeded)

The Crane rain files for regions a, b, b1, b2, c, d1, d2, d3, e, f and g are provided. In addition for Canada and the United States, an additional 280 rain statistics files are supplied. The correct file to use will be automatically determined by the path center coordinates.

## Obstruction fade algorithms

Obstruction fading at low values of K has been traditionally handled by using two sets of clearance criteria in the *Antenna heights* design section. The first set of criteria provides clearance at the median value of K and the second criteria ensures that an outage will not occur at some low value of K in the order of 0.6. This approach generally results in excessive antenna heights

The obstruction fade algorithm offers an alternate approach to the use of the second clearance criteria.

The algorithm first iterates the value of K until the resulting diffraction loss on the path is equal to the link fade margin. This is referred to as the critical value of K.

The next step is to determine the probability of occurrence for this value of K. Two data sources supplied with the program are available.

The *Public obstruction fading data* is used for Canada and the United States and provides median and standard deviations for K for four seasons as shown in the example above. In other areas, the ITU-R P.453-7 refractivity database is used.

Obstruction (K) fading - Public obstruction fading data	
Obstruction fading method	Iterative diffraction loss calculations
Diffraction algorithm	Pathloss
Path center latitude	37 30 30.00 N
Path center longitude	075 48 12.50 W
Critical value of dN/dh (K)	149.49 (K = 0.51)
February - Median value of dN/dh (K)	-40.30 (K = 1.35)
February - Standard deviation (N units/km)	45.00
February - Fade probability (%)	1.24E-003
May - Median value of dN/dh (K)	-48.60 (K = 1.45)
May - Standard deviation (N units/km)	45.00
May - Fade probability (%)	5.37E-004
August - Median value of dN/dh (K)	-51.50 (K = 1.49)
August - Standard deviation (N units/km)	66.30
August - Fade probability (%)	0.12
November - Median value of dN/dh (K)	-49.10 (K = 1.46)
November - Standard deviation (N units/km)	70.00
November - Fade probability (%)	0.23
Annual obstruction fade probability (%)	0.08778
Annual obstruction fade outage (sec)	27682.06

## Cochannel operation (XPIC)

Cochannel operation, (transmitting and receiving on both polarizations) effectively doubles the capacity of a link. The viability of this arrangement depends on the threshold degradation due to the mutual interference between the two signals.

This in turn depends on the boresight XPD of antennas and the improvement produced by the XPIC device.

The effects of cochannel operation are included in the overall link availability calculation.

The algorithm are based on ITU-R P.530

Cochannel XPD Interference		
	Site 1	Site 2
Enable cochannel operation	On	
Antenna XPD (dB)	30.00	30.00
TX antenna spacing		
XPIF (dB)	15.00	15.00
XPIC device XPD (dB)		
XPD fade margin - multipath (dB)	29.13	28.66
XPD threshold degradation - multipath (dB)	9.06	9.48
XPD fade margin - rain (dB)	39.10	38.98
XPD threshold degradation - rain (dB)	2.33	2.38

## ANTENNA HEIGHTS



The *Antenna heights* design section provides an interactive screen display of the path profile and the user's clearance criteria. In the *Auto* mode, either antenna height can be varied and the other antenna height will be automatically recalculated to meet the clearance criteria. On space diversity applications, the user can switch between the main and diversity antennas,

## Clearance Criteria

Two sets of clearance criteria can be specified for the main and diversity antennas in terms of:

- earth radius factor (K)
- percent of the first Fresnel zone radius
- a fixed height

In addition a minimum clearance can be specified to account for an obstruction very close to the antenna.

	Main	Diversity
1st criteria - K	1.33	1.33
1st criteria - %F1	100.00	60.00
1st criteria - Fixed height (m)		
2nd criteria - K		
2nd criteria - %F1		
2nd criteria - Fixed height (m)		
Minimum clearance (m)		
Frequency (MHz)	5882.50	

## Diffraction Loss

The diffraction loss at two values of the earth radius factor (K) can be displayed as the antenna heights are varied.

The first K is the value exceeded for 99.99% or the time in the worst month in a continental temperate climate. This value is a function of the path length. The second K is user specified.

The first K is used in microwave applications to ensure that the diffraction loss at this low value does not exceed the thermal margin and is an alternative to using a second clearance criteria to account for low values of K

In land mobile applications, a value of 1.33 can be used to set the antenna heights to some acceptable value of diffraction loss

Diffraction Loss	
path length (km)	60.63
Value of K exceeded for 99.99% of the worst month in a continental temperate climate	0.838
diffraction loss at K = 0.838	4.49 dB
diffraction loss at K = 1.330	0.00 dB



## Excess Clearance Display

Clearance details can be displayed at any point on the profile. The coordinates of the point in geographic and projected coordinates are given. Complete details of all parameters are available as shown in the example on the right.



### Antenna Height reports

The following reports are available in the *Antenna heights* design section:

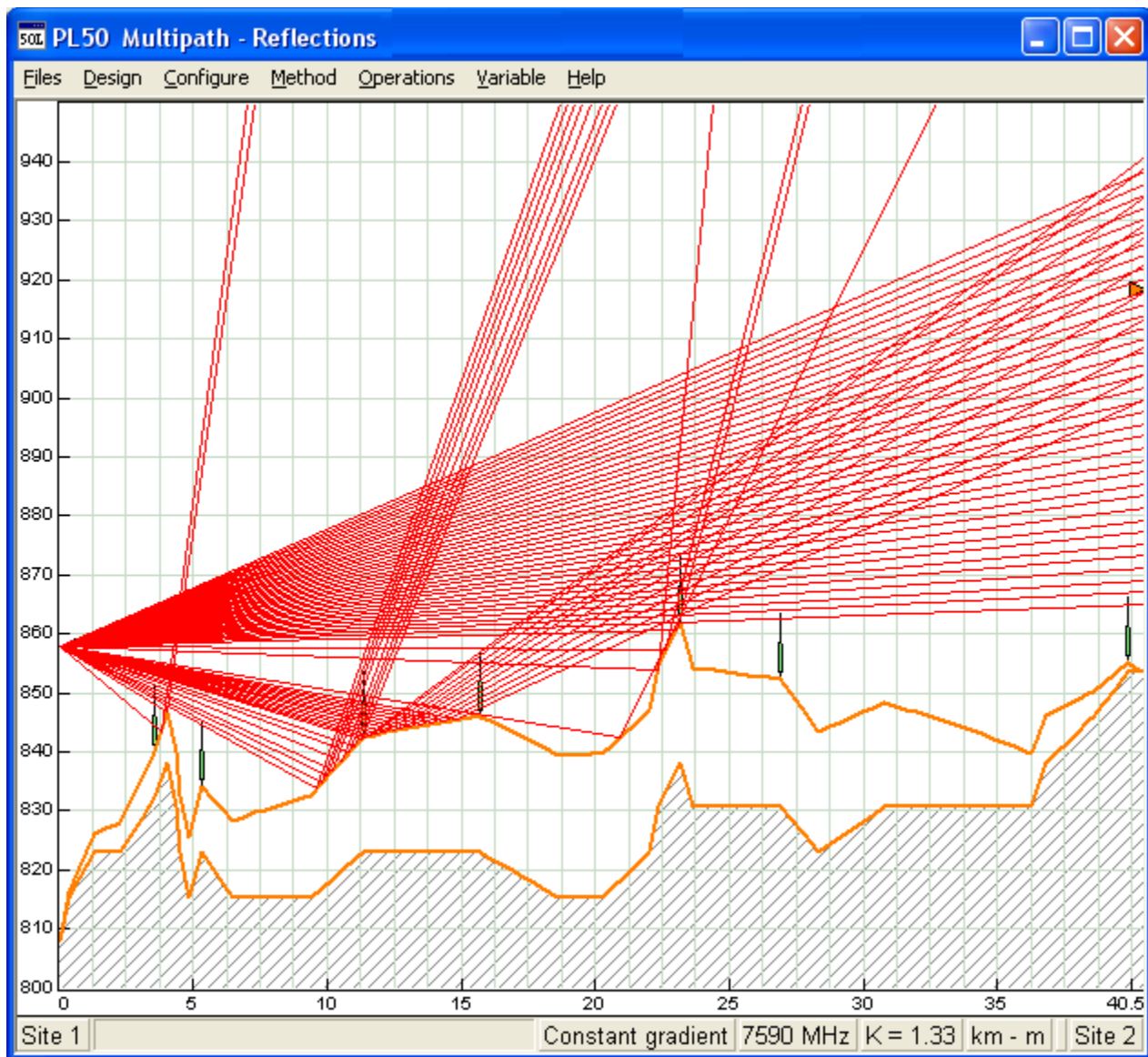
- Clearance report - shows the clearance at each point on the profile which is less than a specified value along with the values of K and %F1
- Antenna height trade-off - The height of one antenna height is varied over an specified range and the corresponding height of the other antenna is show
- Orientation - shows the change of the vertical angle at extreme values of K

## MULTIPATH - REFLECTIONS

The *Multipath - Reflections* design section uses ray tracing techniques on line of sight paths to provide the following functionality

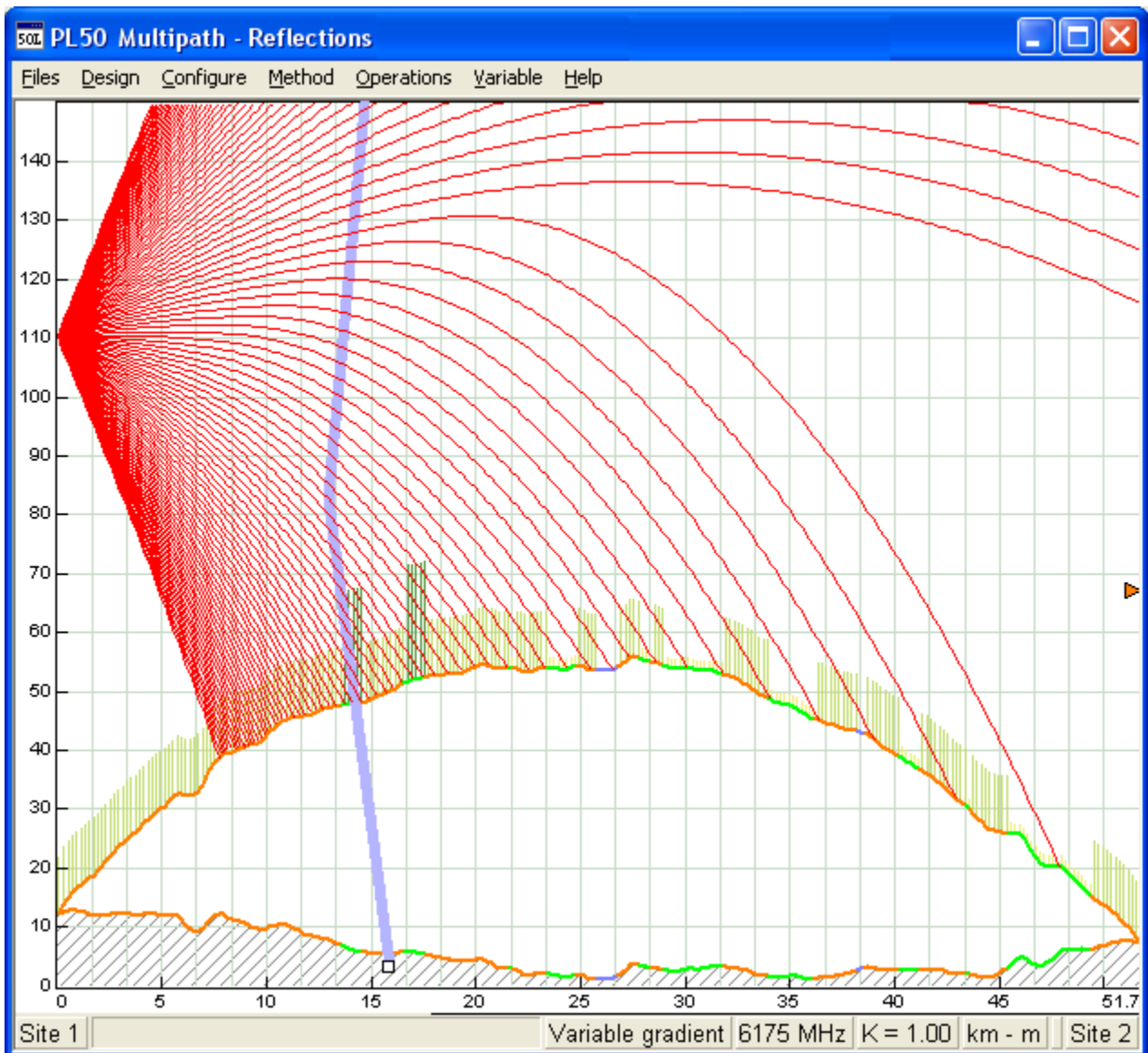
Excess clearance	
Latitude	55 45 57.07 N
Longitude	119 53 04.26 W
Easting ( m)	319041.0
Northing ( m)	6183787.5
UTM zone	11N
Distance (km)	21.20
Elevation (m)	843.49
Structure height (m)	15.00
Controlling criteria	Main - 1
Frequency (MHz)	5882.50
K = 1.33 (m)	49.30
%F1 = 100.0 (m)	26.49
Fixed height (m)	
Minimum clearance (m)	
Criteria total (m)	75.79
Ray elevation (m)	934.28
Excess clearance (m)	0.00
 	

## Constant Gradient Ray Trace:



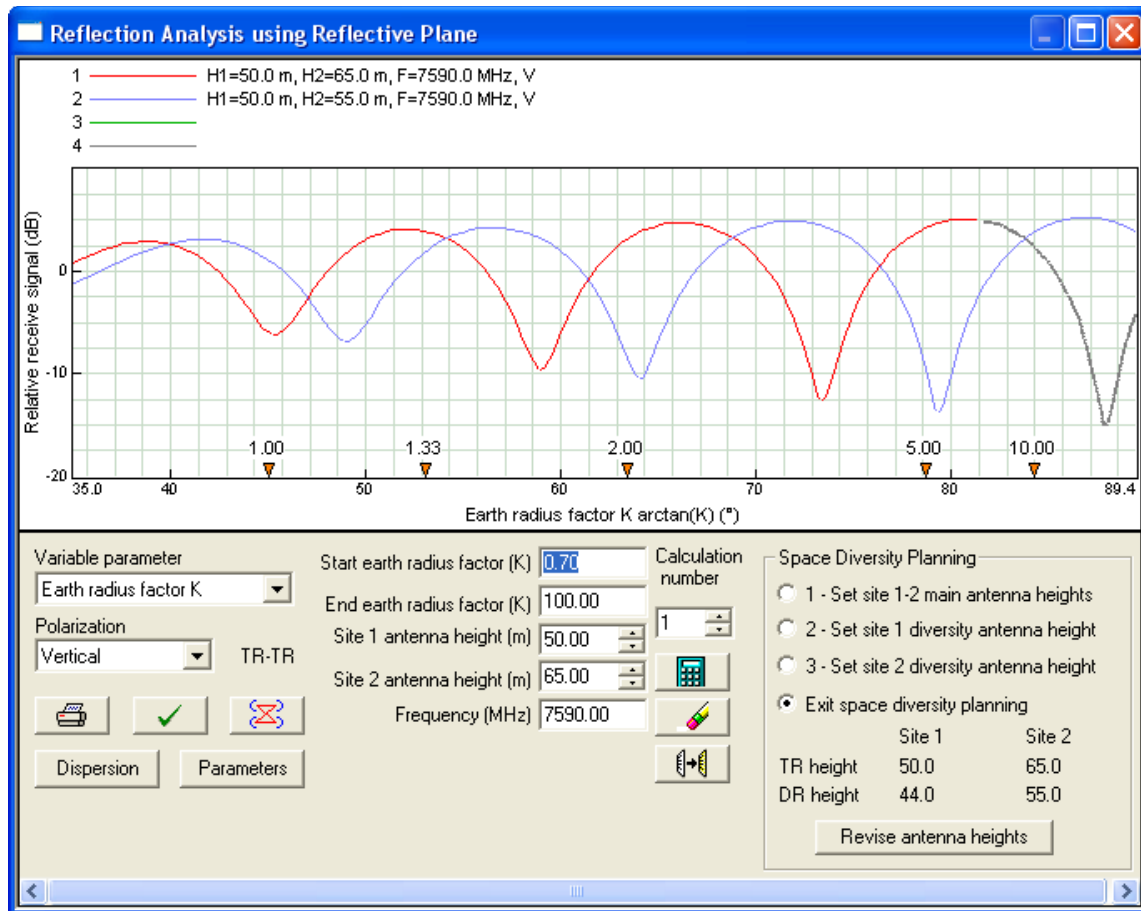
A constant gradient ray trace is used to determine if the path profile geometry can support a specular reflection. This condition is produced when the reflected rays over some portion of the profile arrive above and below the receive antenna. A specular reflection is possible in the example above and would require further analysis. This can be carried out by using a reflective plane or successive ray tracing techniques to quantify the effects of the ground reflections.

## Variable Gradient Ray Trace



A variable gradient ray trace is carried out to determine the susceptibility of ducting on the path. In the above example the a surface duct M profile results in a space wave fadeout on the path. The program includes the ITU-R P.453-8 ducting data base for surface and elevated ducts along with the probability of occurrence. The M profile is determined using the path center coordinates.

## Reflection Analysis using a Reflective Plane definition



The user first defines a reflective plane based on the constant gradient ray trace display. The relative receive signal can be plotted as a function of the following parameters:

- Site 1 antenna height
- Site 2 antenna height
- Earth radius factor (K)
- Frequency (MHz)
- Tidal variations

Complete details of the reflection analysis are presented in the *Dispersion Analysis* data entry form as shown in the example on the right

The following additional parameters are used in the analysis:

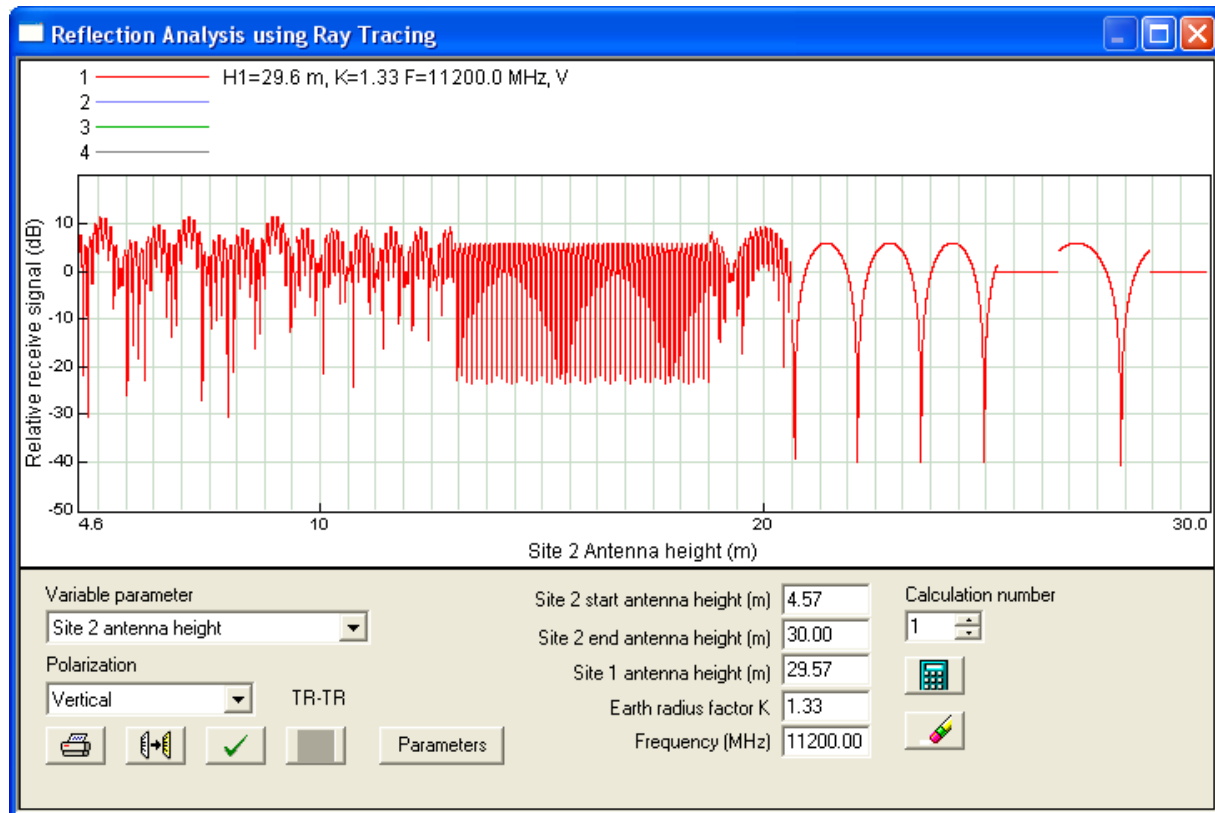
- antenna 3 dB beam widths
- Antenna mechanical up or down tilt
- terrain roughness
- ground cover - clearance loss
- divergence

On space diversity applications, a *Space diversity planning* section is provided to provide the correct spacing between the main and diversity antennas.

This ensures that the main and diversity receive signals will experience signal enhancement at the normal value of K and that simultaneous signal cancellation will not occur on the main and diversity antennas at any value of K

Dispersion Analysis		
	Site 1	Site 2
Antenna height (m)	50.00	65.00
Antenna combination	TR-TR	
Antenna 3 dB beamwidth (°)	1.10	1.10
Vertical angle	-0.05	-0.22
Antenna downtilt (±°)		
Orientation loss (dB)	0.00	0.00
Discrimination angle (°)	0.15	0.07
Discrimination (dB)	0.19	0.04
Earth radius factor K	1.33	
Frequency (MHz)	7590.00	
Polarization	Vertical	
Use divergence	Yes	
Reflection point location (km)	13.13	
Reflection loss (dB)	4.28	
Reflection delay (ns)	0.27	

## Reflection Analysis using Ray Tracing



Ground reflections can be analysed by a series of successive ray tracings. The reflecting surface of the entire profile will be covered and represents a more realistic presentation of the reflection characteristics of the path. The relative receive signal can be plotted as a function of the following parameters:

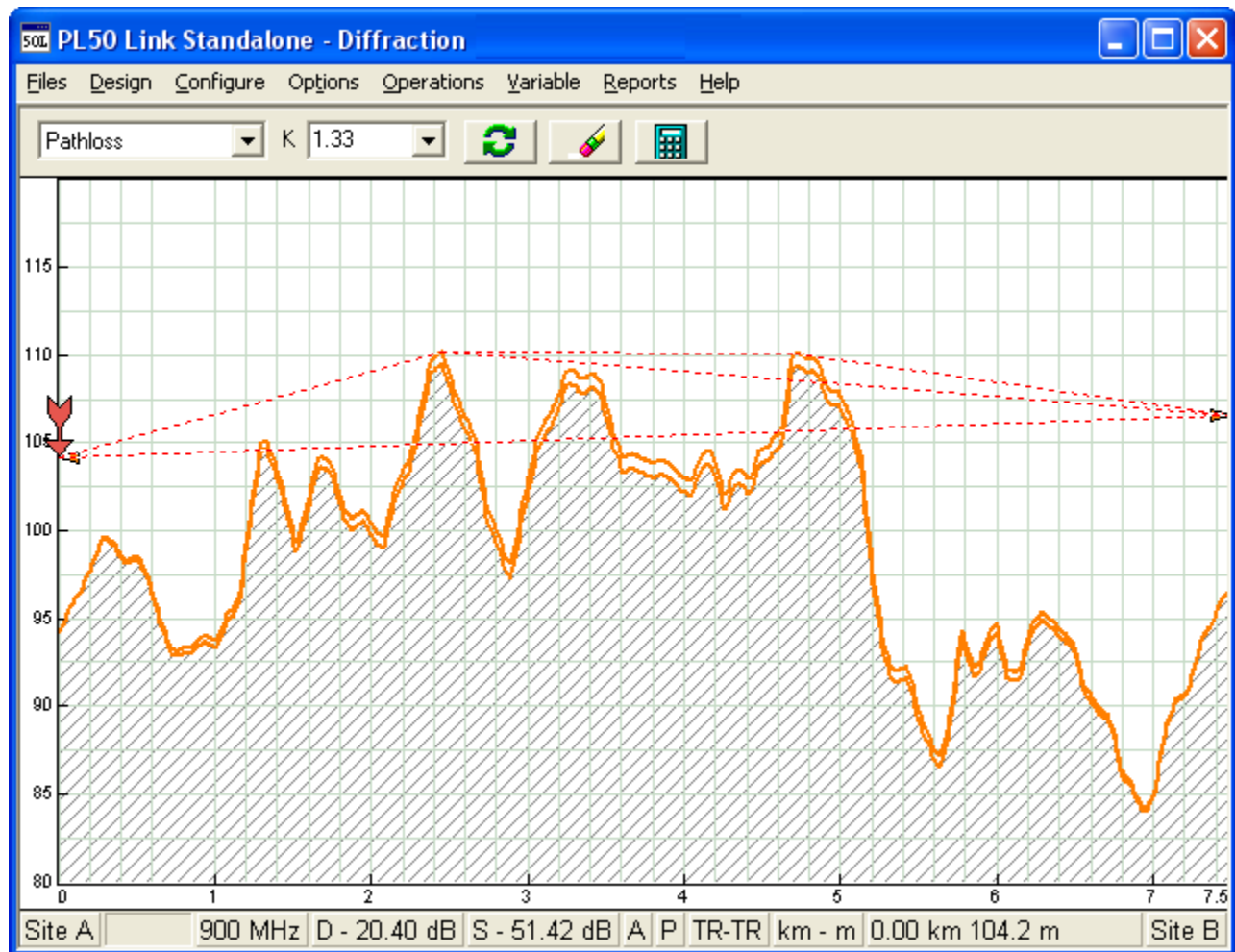
- Site 1 antenna height
- Site 2 antenna height
- Earth radius factor (K)

The following additional parameters are used in the analysis:

- antenna 3 dB beam widths
- antenna mechanical up or down tilt
- single or double reflections
- divergence



## DIFFRACTION LOSS DESIGN SECTION



Diffraction loss calculations are carried out automatically in the automatic design operations. In all other cases, the *Diffraction loss* design section is used to calculate the following:

diffraction loss at the median value of K

diffraction loss at the minimum expected value of K

on interference paths, the term OHLOSS (over the horizon loss) denotes the loss is used to

### Diffraction algorithms

The following algorithms have been implemented

- single and multiple knife edge using the Epstein and Peterson or the Deygout algorithm
- single and multiple isolated obstacle (knife edge with a radius)
- ATT average diffraction loss ( $-10 + 20 (\text{clearance} / F1)$ )
- two ray optics - line of sight paths only
- Longley and Rice irregular terrain
- height - gain used in conjunction with the knife edge - isolated obstacle algorithms, when the clearance from an antenna to its horizon is less than 60% of the first Fresnel zone

In addition, three automatic diffraction algorithms are provided. The terrain profile geometry is analysed to see which combinations of the above algorithms are the best fit to the terrain. These algorithms are

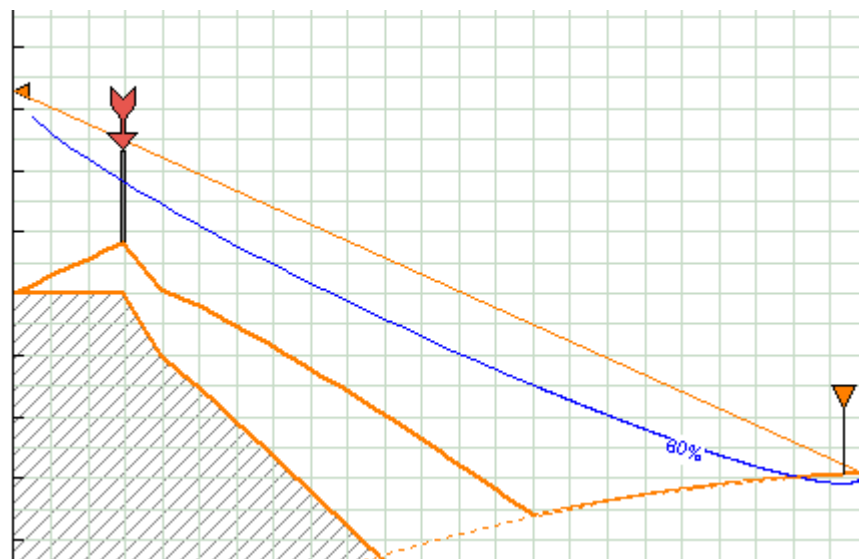
- TIREM
- NSMA
- Pathloss

As an example, the basic logic used in the default Pathloss algorithm is described below.

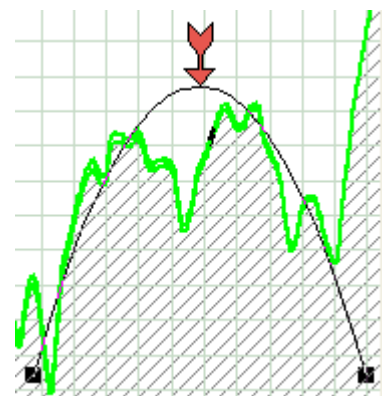
- If the path is line of sight with at least 60% first Fresnel zone clearance (F1), then there is no diffraction loss
- If the path is line of sight but has less than 60% F1, then the Longley and Rice irregular terrain is used.
- If the path is non line of sight and can be characterized as a single edge, the diffraction loss is calculated as a single knife edge with radius (isolated obstacle). The clearance between the antennas and their horizons is then tested for 60% F1 and the height - gain is added if necessary.
- If the path is non line of sight and can be characterized as a multiple edge then the loss is calculated using the the default multiple knife edge algorithm and the height gain term is applied if applicable.
- The Longley and Rice algorithm is used as the default in all other non line of sight cases

Any of the basic algorithms can be used interactively over any section of the profile. Several examples of this type of operation are shown below.

On a reflected path, calculate the loss from the reflection point to either end of the path. In the display on the right, the profile between an end and the reflection point has been selected. The loss of the building is being calculated as a knife edge. This value will be used in the *Multipath - reflections* design section to quantify the effect of the reflection



The isolated obstacle algorithm can be used to consider several closely spaced obstructions as one effective obstacle. In the example shown on the right. The loss will be calculated at the arrow location using the radius which encompasses two obstacles. This type of analysis is useful to resolve ambiguities which may arise in the results.



## Clutter Loss

On profiles which include user entered trees, buildings or ranges an profiles which have been created with a description only clutter data base, the additional loss due the clutter is calculated as follows:

## Buildings

The knife edge loss at the top and base of the building is calculated. The difference between the two values is taken to be the loss of the building. A frequency dependant term is used to calculate multipath propagation around the building. The building loss is the smaller of the two values.

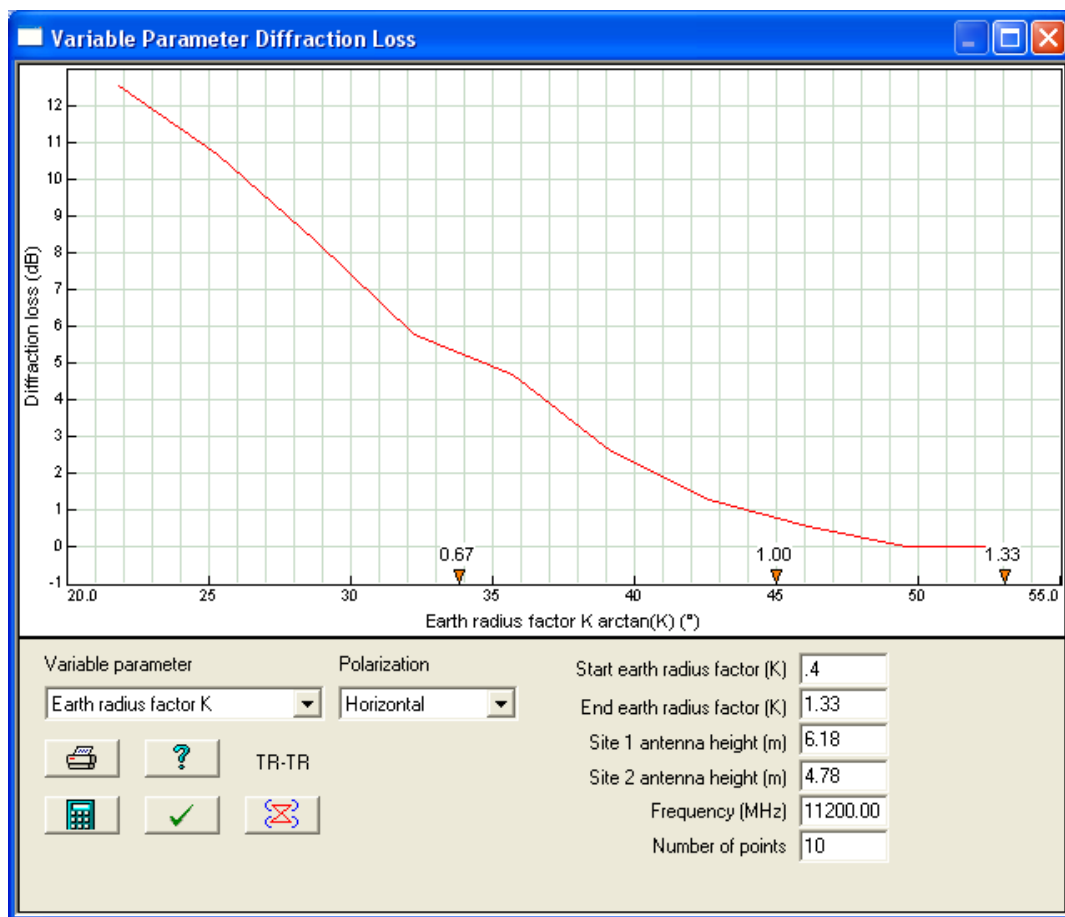
## Trees and vegetation

The knife edge loss is calculated as above. The loss of a lateral wave travelling along the tree tops is then considered. This term depends on the frequency, tree type and whether the foliage is wet or dry. The vegetation loss is the smaller of the two values.

## Tropospheric scatter loss

On non line of sight paths

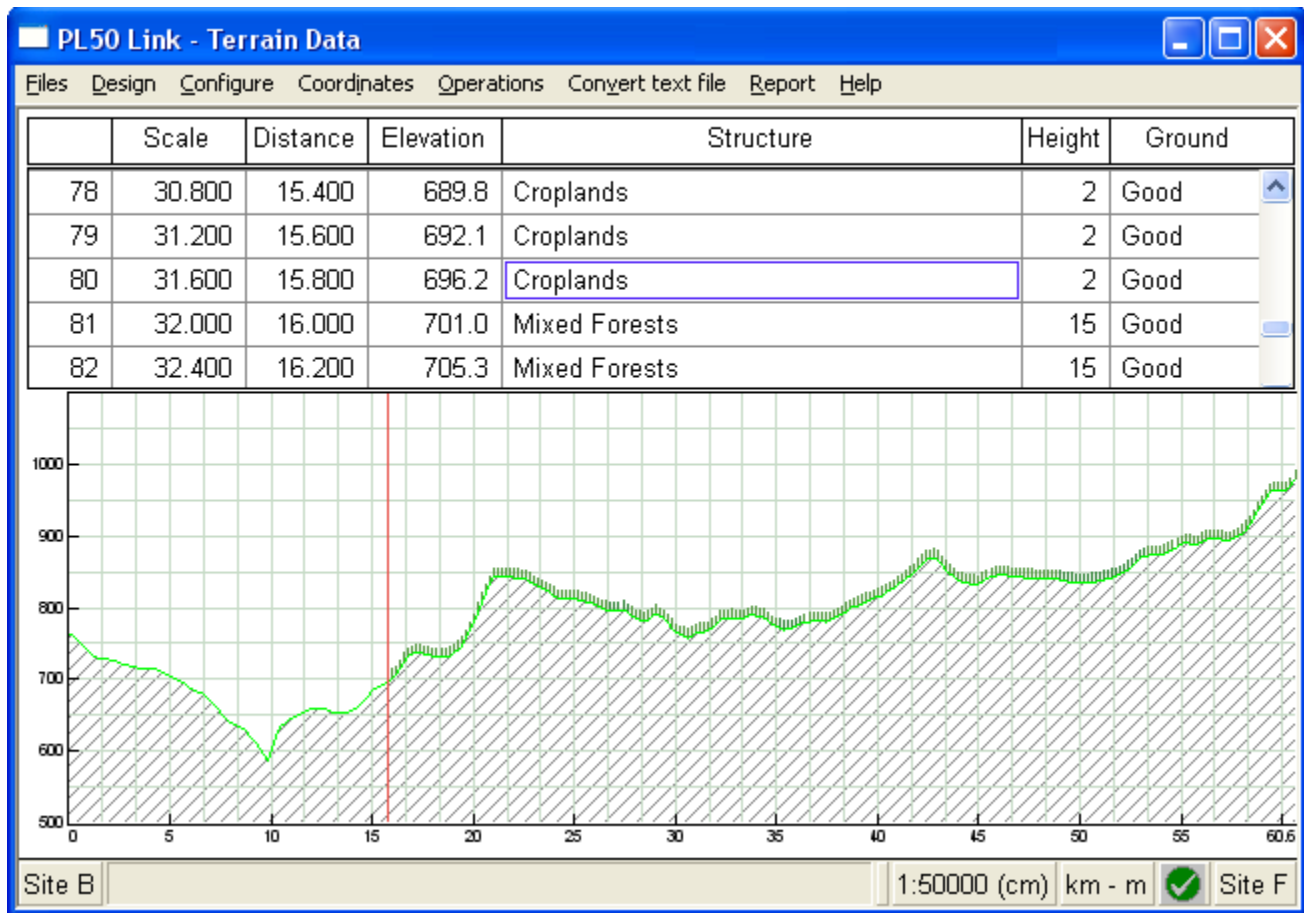
## Variable parameters



Diffraction can be calculated as a function of the following parameters:

- earth radius factor  $K$
- site 1 and site 2 antenna heights
- frequency
- distance along the profile

## TERRAIN DATA DESIGN SECTION



The *Terrain data* design section is used to create and edit a terrain profile. In most cases, the terrain profile will be created using a digital elevation - clutter or vector model as defined in the GIS configuration; however, the profile can be read from a text / csv file or by manual data entry.

If a clutter database is not used, single structures or ranges of structures can be added to the profile.

If a description only clutter data base has been used to generate the profile, a copy of the definition table will be saved

**Clutter** [minimize] [maximize] [close]

Update profile clutter

	ID	description	height (m)	ground type	color
1	1	Evergreen Needleleaf Forest	15.0	good	
2	2	Evergreen Broadleaf Forest	15.0	good	
3	3	Deciduous Needleleaf Forest	15.0	good	
4	4	Deciduous Broadleaf Forest	15.0	good	
5	5	Mixed Forests	15.0	good	
6	6	Closed Shrublands	2.0	average	
7	7	Open Shrublands	2.0	average	
8	8	Woody Savannas	10.0	average	
9	9	Savannas	5.0	average	
10	10	Grasslands	1.0	average	
11	11	Permanent Wetlands	2.0	average	
12	12	Croplands	2.0	good	
13	13	Urban And Built-Up	20.0	poor	
14	14	Cropland/Natural Vegetation Mosaic	10.0	average	
15	15	Snow And Ice	2.0	poor	
16	16	Barren Or Sparsely Vegetated	1.0	poor	
17	17	Water Bodies	0.0	water	

in the pl5 file. This clutter heights in this table can be edited and the changes can be transferred to the terrain profile without affecting the clutter definitions in the GIS configuration.

