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## 22 CALCULATOR FUNCTIONS

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### 22.1 INTRODUCTION

There are several basic calculator functions available in WRAP to assist in many useful calculations of relevance for spectrum management, radio network planning or just in general for various radio-technical applications. The calculators reside in the following windows and tools:

- **Edit Station: Satellite Calculations** (only available for Class of Station *Earth Station* and *Space Station*)
  - Earth station geometry
  - Visibility of the geo-stationary orbit
  - Antenna noise
- **Edit Antenna**
  - Relationship between antenna gain, parabolic diameter, frequency, beam width
  - Gain conversions dBi – dBd - dBv
- **Edit Transmitter**
  - Occupied bandwidth for defined percentage of power
  - Transmitter power within defined frequency limits
  - Conversions between EIRP, ERP and EMRP
  - Automatic spectrum generation from modulation type
- **Edit Receiver**
  - Intercept point
  - Level of intermodulation products
  - Noise figure, noise temperature, bandwidth, noise power
  - Sensitivity in dBm for defined noise figure, bandwidth, signal-to-noise ratio
-  **Radio Calculator**
  - Units*
    - Power
    - Voltage
    - Spectral density
    - Logarithms
    - Field strength and power flux density
    - Frequency and wavelength
    - Frequency bands: MHz and letter designation
  - Propagation*
    - Free space loss, frequency, distance
    - Okumura-Hata/COST-231 Hata model with selectable parameters
    - Field strength, radiated power, distance
    - Received power, field strength, frequency
    - Earth radius factor for percentage of time

*Traffic*

- Erlang B formula
- Erlang C formula

*Cables*

- Loss as a function of cable type, length and frequency (data stored in WRAPdB)
- Incident/reflected power, VSWR, reflection coefficient, mismatch loss, return loss

-  **Separation Distance**

Calculation of minimum frequency separation between a transmitting station and a receiving station for non-interference based on the transmitter spectrum as defined in the *Edit Transmitter – Frequency Characteristics* tab, the receiver selectivity defined in the *Edit Receiver – Frequency Characteristics* tab and the receiver sensitivity. This tool is also available in the *Divide Allotment – Setup* window. For a given distance [km] separation the calculator gives the minimum frequency separation. For a given frequency separation the tool gives the minimum distance [km] between the two stations. The propagation model is selectable. If a propagation model based on detailed terrain information is selected the minimum distance [km] can not be calculated. The two stations can either be selected from the database or from the project.

-  **Geographic Calculator**

- Coordinate conversions
- Azimuth and distance between two points
- Free space transmission loss between the two points
- Calculation of roughness ( $\Delta h$ ), maximum/minimum/median/average heights within a map-defined area or along a map-defined line.

Refer to reference [B08] for details on the calculation methods.

The following figures are examples of the windows with the calculator functions.

The 'Edit Station' dialog box is divided into several sections:

- Earth Station Geometry:**
  - Surface Pos: Long (16°34'09.60" E), Lat (57°01'20.40" N)
  - Satellite Pos: Long (43°55'32.00" E), Lat (0°00'00.00" N)
  - Elevation [deg]: 20.91
  - Azimuth [deg]: 148.34
  - Distance [km]: 39474.63
  - Earth station height above sea [km]: 0.982
  - Satellite height above sea [km]: 35786
  - Calculate with refraction:
- Visibility of the Geostationary Orbit:**
  - Minimum elevation angle [deg]: 5
  - Longitude west limit [deg]: -47.83
  - Longitude east limit [deg]: 80.97
- Antenna Noise:**
  - Common Parameters:**
    - Frequency [GHz]: 6.1
    - Elevation angle [deg]: 20.9
    - Vapour density [gm/m<sup>3</sup>]: 7.5
    - Galactic temperature [deg]: 45
    - Earth station height [km]: 0.982
  - Rain Parameters:**
    - Earth station latitude [deg]: 16
    - Rain rate 0.01% [mm/h]: 40
  - Clear air plus rain:**
    - 0.1%: Noise temperature [K]: 36.58, Noise power [dB(W/Hz)]: -212.97
    - 0.01%: Noise temperature [K]: 75.46, Noise power [dB(W/Hz)]: -209.82
  - Clear air:**
    - Noise temperature [K]: 8.98
    - Noise power [dB(W/Hz)]: -219.07

Figure 22.1: Satellite calculations.

The 'Edit Antenna' dialog box contains the following sections:

- Antenna gain:**
  - Maximum gain [dBi]: 46 (with a 'Toggle' button)
  - Lobe width [°]: 0.841395
  - Diameter [m]: 3.795
  - Frequency [MHz]: 6500
- Gain conversion:**
  - [dBi]: 46
  - [dBd]: 43.9
  - [dBv]: 41.2

Figure 22.2: Antenna calculations.

*Figure 22.3: Transmitter calculations.*

*Figure 22.4: Receiver calculations.*

The screenshot shows the 'Radio Calculator' window with the 'Units' tab selected. The interface is organized into several sections for different types of calculations:

- Power:** Fields for Power [W] (13), Power [mW] (13000), Power [dBW] (11,1394), and Power [dBm] (41,1394).
- Voltage:** Fields for Impedance [Ohm] (49,85), Voltage [μV] (1,33), Voltage [dBμV] (2,47703), and Power [dBm] (-104,5). A 'Toggle' button is present.
- Spectral density:** Fields for Spectral dens. [dBW/Hz] (-67,04), Bandwidth [kHz] (16), and Power [dBW] (-25). A 'Toggle' button is present.
- Logarithms:** Fields for x (28), 10log(x) (14,4716), and 20log(x) (28,9432).
- Field strength and power flux density:** Fields for Field strength [μV/m] (501,2), Field strength [dBμV/m] (54), Power flux density [W/m2] (6,663e-010), and Power flux density [dBW/m2] (-91,7633).
- Frequency and wavelength:** Fields for Frequency [MHz] (935) and Wavelength [m] (0,3206).
- Frequency bands:** A table listing various frequency bands and their corresponding designations.

At the bottom, there are 'OK' and 'Cancel' buttons.

Frequency	Band
< 0.5	P
0.5 - 2.0	L
2.0 - 4.0	S
4.0 - 8.2	C
8.2 - 12.4	X
12.4 - 18.0	Ku
18.0 - 26.5	K
26.5 - 40.0	Ka

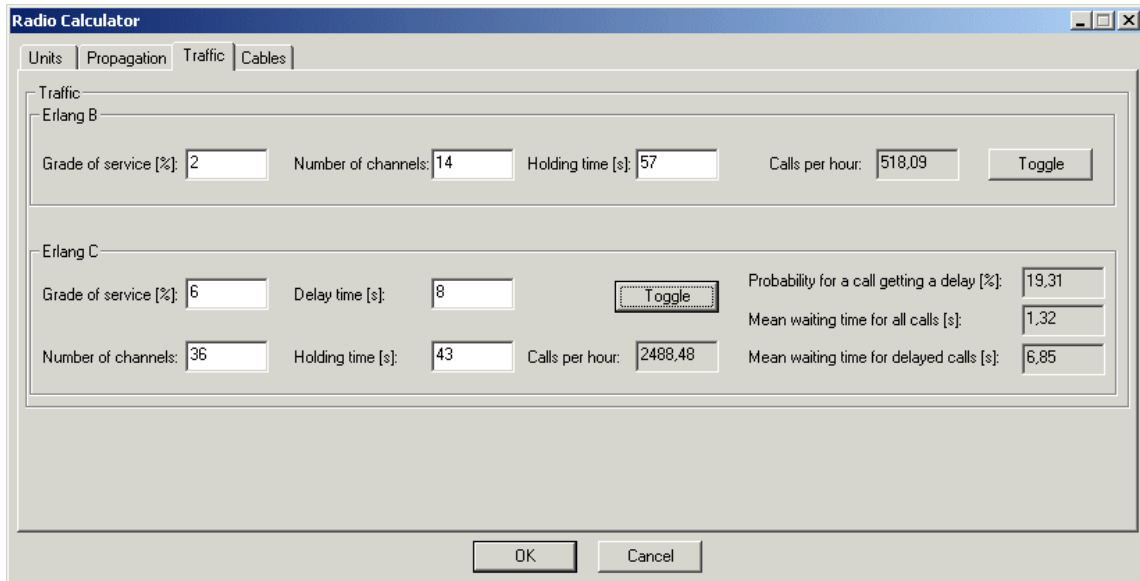
Figure 22.5: Radio Calculator – Unit conversions.

The screenshot shows the 'Radio Calculator' window with the 'Propagation' tab selected. The interface is organized into several sections for propagation calculations:

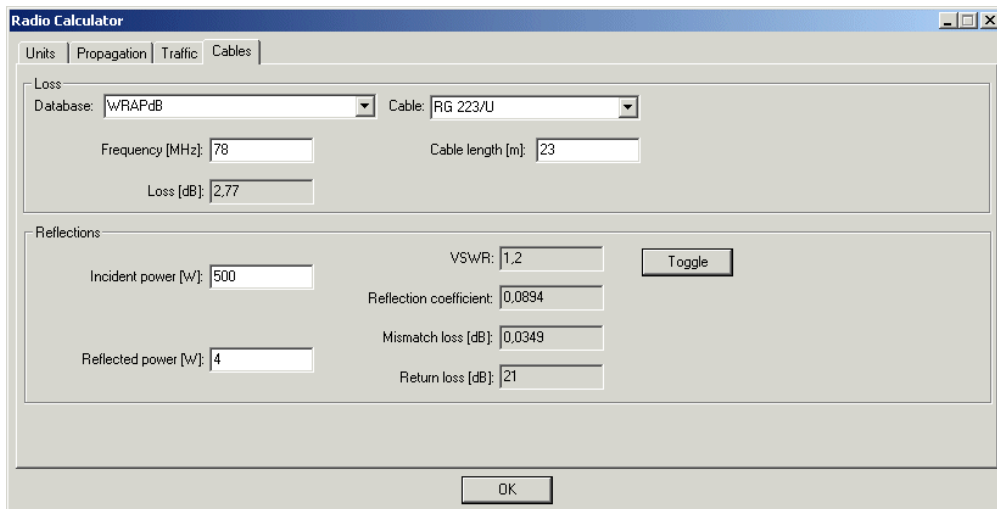
- Free space:** Fields for Frequency [MHz] (100), Distance [km] (1), and Transmission loss [dB] (72,45). A 'Toggle' button is present.
- Okumura-Hata:** Fields for Station Height [m] (100), Antenna Height [m] (1), Environment (Dense Urban), Frequency [MHz] (1000), Distance [km] (10), and Loss [dB] (153,50). A 'Toggle' button is present. There is also a checkbox for 'Correction factor relative Urban loss' with a value of 0 dB.
- Field strength:** Fields for Distance [km] (1), Radiated power [dBW] (0), and Field strength [dBμV/m] (74,80). A 'Toggle' button is present.
- Received power:** Fields for Frequency [MHz] (100), Field strength [dBμV/m] (0), and Power [dBm] (-117,20). A 'Toggle' button is present.
- Earth radius factor:** Fields for Time percentage [%] (50) and Effective earth radius factor (1,3).

At the bottom, there is an 'OK' button.

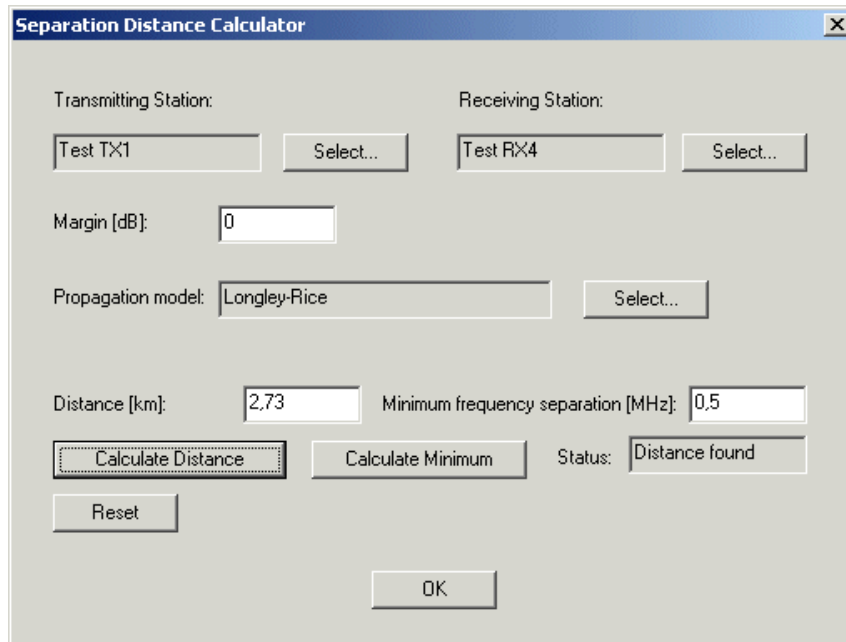
Figure 22.6: Radio Calculator – Propagation.



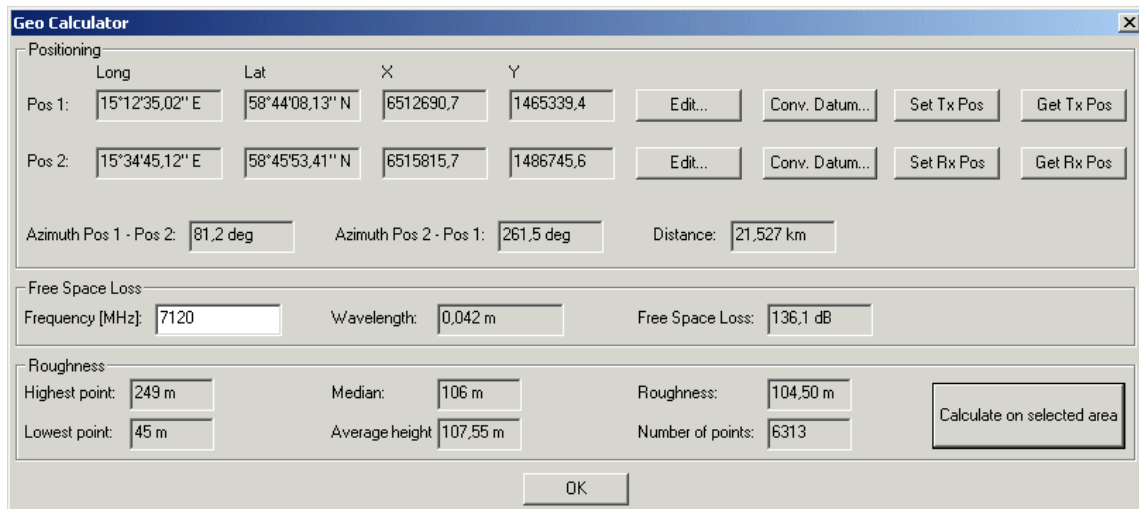
*Figure 22.7: Radio Calculator – Traffic (Erlang B, Erlang C).*



*Figure 22.8: Radio Calculator – Cables.*



*Figure 22.9: Separation Distance calculator – minimum frequency/distance separation fro non-interference.*



*Figure 22.10: Geographic Calculator.*