SKA Project – Guidelines for Mining Activities

Appendix 1 - Propagation Calculations

Units and power density

Radio system parameters are expressed in decibels (dB) to avoid the use of very large or very small numbers and to allow common calculations to be done with addition or subtraction. Decibels represent a ratio with respect to a reference value; for example power in “dBW” stands for “decibels relative to a Watt” while power spectral density in “dBm/Hz” represents “decibels relative to one milliwatt per Hertz”. Standard calculations involving multiplication become addition when the quantities are expressed in decibels; similarly, calculations involving division become subtraction.

For the purposes of this document, two quantities need to be expressed with decibels: propagation loss and power spectral density. All logarithms in the calculations are base 10.

Propagation loss is itself a ratio (power at the end of the path compared to power at the start) and so the units are simply “dB.”

Power density in (dBm/Hz) as used throughout this document is calculated from:

$$\text{Power density (dBm/Hz)} = 10\log\left[\frac{\text{power (mW)}}{\text{bandwidth (Hz)}}\right] \qquad (1)$$

Since 1 Watt is 1000 milliwatts, power density in (dBm/Hz) can be calculated from (dBW/Hz) by adding 30:

$$\text{Power density (dBm/Hz)} = 10\log\left[\frac{\text{power (mW)}}{\text{bandwidth (Hz)}}\right] = 10\log\left[\frac{\text{power (W)}*1000}{\text{bandwidth (Hz)}}\right]$$

$$= 10\log\left[\frac{\text{power (W)}}{\text{bandwidth (Hz)}}\right] + 10\log(1000) = \text{Power density (dBW/Hz)} + 30 \qquad (2)$$

The power density from a number of identical devices can be calculated by adding 10log(number of devices) to the value for an individual device. For example, a single CDMA satellite phone at 1600 MHz has a maximum emission of -34 dBm/Hz. If eight such phones are expected to be used on the site, this increases the maximum emission by 10log (8) or 9 dB, bringing the total emission from these phones to -25 dBm/Hz.

Other sources within the same frequency range should then be added in the same way. Unequal sources are summed as:

Total power density = $10 \log \left\{ 10^{(A/10)} + 10^{(B/10)} + 10^{(C/10)} + \ldots \right\}$ (3)

where the power densities, in dBm/Hz, of the individual devices are *A*, *B, C* etc.

Free space loss

Free space loss represents the weakening of a signal as it spreads out, apart from any other losses due to obstacles in or near the path. It is therefore a conservative estimate of loss since in a real environment, overall path loss will be equal to or greater than the free space loss. With frequency *f* expressed in MHz and distance *d* expressed in kilometres, free space loss is simply:

$$L_{fs} = 32.4 + 20 \log (f) + 20 \log (d) \quad \text{dB} \quad (4)$$

Example: at a frequency of 420 MHz, the free space loss at 100 km is:

$$32.4 + 20 \log (420) + 20 \log (100) = 125 \text{ dB}$$

Note: all calculations involving distance of equipment and activities from the MRO should use the Centre coordinates of the MRO and the coordinates of the nearest part of the proposed tenement or licensed area to the MRO as the determinants of the distance.

Cascaded knife-edge diffraction loss

Additional loss due to diffraction can result when radio energy travels over irregular terrain. ITU-R Recommendation P.526-10 specifies a prediction technique using cascaded knife edges and a digital terrain data base. This section summarises the prediction method.

Refraction through layers in the atmosphere can cause the radio signal to bend towards (or sometimes away from) the earth, so that the “straight line” distance around the earth’s curvature is different than (and typically longer than) the geometric line-of-sight. This is modelled by an “effective earth radius” which is the physical radius (6370 km) multiplied by a *k*-factor. The *k*-factor varies with time but the median value of 4/3 is recommended for initial diffraction calculations.

From a digital database, a terrain profile is extracted; point spacing of 250 metres is typical. At each profile point, a height *h* is calculated, representing the height of the terrain above a line joining the first and last point of the profile and accounting for effective earth radius. Using the same unit for all variables, where h_n is the n^{th} terrain point, d_{ab} is the distance from the first point of the profile to the last point, d_{an} and d_{nb} are the distances from the n^{th} point to the first and last point, respectively, and r_e is the effective earth radius, *h* is calculated as:

$$h = h_n + [d_{an} d_{nb} / 2 r_e] - [(h_a d_{nb} + h_b d_{an}) / d_{ab}] \quad (5)$$

The dimensionless diffraction parameter ν is then calculated for wavelength λ (still in self-consistent units) at each point of the profile:

$$\nu_n = h\sqrt{2d_{ab}/\lambda d_{an}d_{nb}} \quad (6)$$

The point with the highest value of ν is termed the principal edge, p, and the ν value is labelled ν_p. If ν is greater than -0.78, the process is repeated twice, once between the beginning of the path and p, and then between p and the end of the path. If ν_p is less than -0.78, diffraction loss is negligible and the calculation can be abandoned.

The terrain points with the largest value of ν on either side of the principal edge are termed "auxiliary edges" with values ν_t and ν_r. Again, ν values less than -0.78 indicate negligible loss and the contribution of that edge is ignored. Diffraction is then calculated for the path of length *D* (km) by:

$$L = J(\nu_p) + \{1.0 - \exp(-J(\nu_p)/6)\}\,[\,J(\nu_t) + J(\nu_r) + 10.0 + 0.04D\,] \quad (7)$$

where $J(\nu)$ is approximated (for ν greater than -0.78) by:

$$J(\nu) = 6.9 + 20\log\left(\sqrt{(\nu - 0.1)^2 + 1} + \nu - 0.1\right) \quad \text{dB} \quad (8)$$

The total predicted loss on the path is the sum of $J(\nu)$ and free space loss from equation (4).

Calculation of received power

The relationship between received power and emitted power is:

received power density (dBm/Hz) = emitted power density (dBm/Hz) – path loss (dB)