EDGES MEMO #004
RFI MEMO #019

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To: RFI Group
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Subject: RFI avoidance by lowering the antenna

It is well known that the height of an antenna from the ground has a significant effect on the path loss. The path loss relation by Bullington (Radio Prop. Fundamental, Bell System Tech. J., vol **36**, May 1957, pp. 573-626.)

$$Pathloss = G_T G_R\, h_T^2 h_r^2 \big/ d^4$$

where $G_{T,R}$ are antenna gains

$h_{T,R}$ are antenna heights

d = distance

is extreme as it predicts infinite path loss with antennas on the ground from a 2 ray model. In practice the Bullington formula needs to be modified. Bruns (SPJE, vol **5417,** 2004) sines an effective height

$$H_{eff,v} = \frac{|E_0|\lambda}{2\pi\sqrt{|E_0|-1}}$$

where $E_0 - E - j60\lambda\sigma$

at 100 MHz $H_{eff,v} \sim 0.3m$ for $\left(E = 113\, and\ \sigma = 0.005\right)$

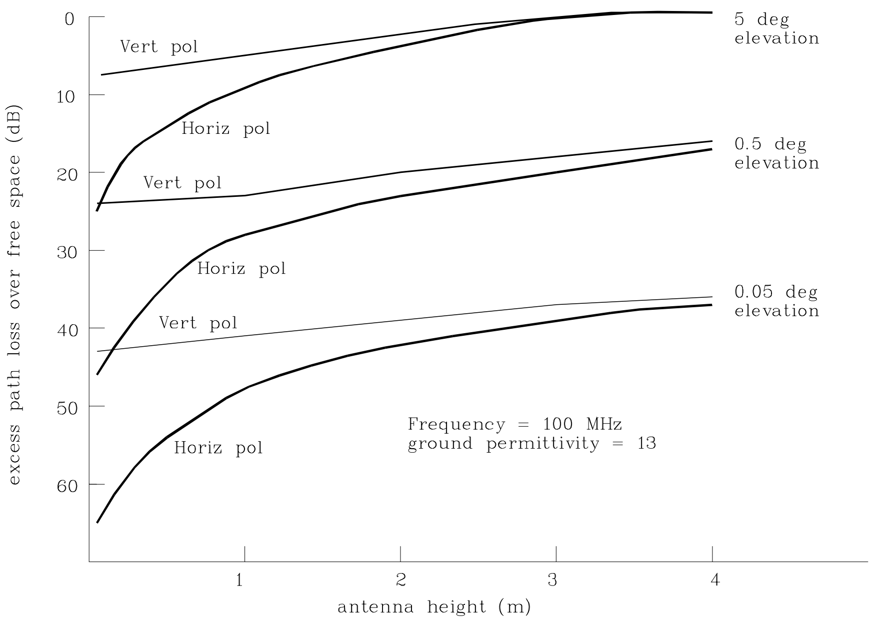
Bruns gives no derivation or reference but shows that the resulting path loss is within 10 dB of measurements of unattended ground sensors (UGS) for d~20-200 m. In the cellular bands average path loss predicted by the Bullington model is pessimistic. Typical distance exponent dependence ranges from 3 to 4. I have done some EZNEC simulations at 100 MHz and get the following results:

				EZNEC	Xia
Polarization	Receive antenna	Distance (km)	LOS angle (deg)	Excess loss over free space (dB)	Ex. Loss (dB)
V	Monopole	1	0.6	20	23
V	Monopole	10	0.06	40	42
V	Droopy dipole	1	0.6	20	23
V	Droopy dipole	10	0.06	50	43
H	Dipole	1	0.6	40	38
H	Dipole	10	0.06	60	58
H	Dipole	1	6	20	18
H	Dipole	10	6	20	18
H	Dipole and ground plane raised 1 m	1	0.6	30	26

Transmit antenna is a Vertical or horizontal dipole well off the ground whose height is set to give the line of site (LOS) angle. The receiver antenna is a monopole, droopy dipole or dipole 1/10 wavelength over a half wave diameter ground plane placed on the ground. The ground is assumed to be $\sigma = 0.005, E = 13$ but these values are extremely non critical. The frequency is 100 MHz. Also shown are values calculated from the 2 ray model of Xia (IEEE Trans. Ant. Prop. Vol. **41**, No10, pp. 1439-1447, 1993). I also plot in Figure 1 the analytic expressions of Xia as a function of antenna height and source elevation.

Conclusions

Placing an antenna on the ground results in a substantial improvement in the rejection of signals from the horizon. Low angle horizontal polarization is more strongly rejected than vertical. Once the source elevation is above about 5 degrees the added rejection is only dependent on the angle and is not dependent on the distance to the source. Any antenna must have a metal ground plane of at least a half-wavelength to prevent signal loss at high elevations. The deuterium array's rejection of RFI could probably have been further improved by lowering the ground screens but this is not practical in this location due to snow accumulation.


0
10
20
30
40
50
60
excess path loss over free space (dB)
1
2
3
4
antenna height (m)
Vert pol
Horiz pol
5 deg
elevation
Vert pol
Horiz pol
0.5 deg
elevation
Vert pol
Horiz pol
0.05 deg
elevation
Frequency = 100 MHz
ground permittivity = 13