POWER AND DISTANCE

Calculating the transmit and receive antenna gain

We will assume for this paper that the corporations using this system will have directional dishes at least as large and focused as a typical dish antenna one would have on the roof of their house. The gain of this antenna will be modeled using equation 2 from Spectral Efficiency of Mobile VSAT Systems and is shown below:

$$G(\theta) = G_{max}\left(\frac{2^{n+1}(n+1)!\,J_{n+1}(\pi d/\lambda \times \sin\theta)}{(\pi d/\lambda \times \sin\theta)^{n+1}}\right)^2 = G_{max}G_{norm}(\theta)$$

We take θ as our off-axis angle in degrees as 2^o. For an ideal parabolic antenna, n=1 and we note that J_{n+1} is the Bessel function of the first kind with order n+1. The typical Ku Band dish antenna that a subscriber would use has a diameter of d=.46 meters. The frequency under consideration is 14.2 GHz which gives a wavelength of λ=.0211268 meters. The equation can be further simplified by defining:

$$G(\theta) = G_{max}\left(\frac{2^{1+1}(1+1)!\,J_{1+1}(\varphi)}{(\varphi)^{1+1}}\right)^2 = G_{max}G(\theta)$$

$$\varphi = \frac{\pi d \sin\theta}{\lambda} = 2.387224$$

$$J_2(2.387224) = 0.428906$$

$$G(2^o) = 0.602096$$

We take G_{max} to be the boresite gain which will be approximated by $G_{max} = hA\left(\frac{4\pi}{\lambda^2}\right)$ with h being the efficiency taken to be h=.55 and A the surface area defined as $A = \frac{\pi d^2}{4}$. This gives us:

$$G_{max} = hA\left(\frac{4\pi}{\lambda^2}\right) = h\left(\frac{\pi d^2}{4}\right)\left(\frac{4\pi}{\lambda^2}\right) = 2573.42$$

$$G(\theta) = G_{max}G(\theta) = 32\ dB$$

Loss and Noise

We will use the standard free space loss model for our calculations with($\lambda = 0.211268\ m$):

$$L_{free\ space} = \left(\frac{4\pi r}{\lambda}\right)^2$$

Distance (m)	Free Space Loss	Free Space Loss (dB)
1000	3.538×10^{9}	95.49
5000	8.845×10^{10}	109.47
10000	3.538×10^{11}	115.49
50000	8.845×10^{12}	129.47
100000	3.538×10^{13}	135.49
150000	7.960×10^{13}	139.01

The noise at the receiver (N_o) is calculated using:

$$N_o = k\,T_o\,F$$

We take k to be the Boltzmann's constant (k = 1.38×10^{-23} W/Hz), T_o as the room temperature (T_o = 290 K) and F being the noise factor (F = 4).

$$N_o = (1.38 \times 10^{-23})\,(290)\,(4) = \ 1.6 \times 10^{-20} = \ -196dB[W/Hz]$$

In an ideal scenario there should be no interference from other devices operating on this frequency. This is mostly due to the fact that these two antennas will be highly directional and are used for point to point transmission. The side and rear lobes are also small which will help to keep the interference from other users to a minimum. The interference would be much larger for typical satellite downlink and would be dependent on the satellite spacing. Further calculations on interference can be made but will be omitted in this paper since the interference levels should be negligible.

Data Rate

To properly determine the bit speed and maximum distance we can transmit we will use the relation:

$$\frac{E_b}{N_o} = \frac{C}{R_b N_o} = \frac{\ _t}{kR_bL_{free}}\frac{G}{T}$$

With our E_b/N_o (10 dB) and G/T (1.5) fixed, we are able to vary the transmit power and distance between locations. These two terms will invariably affect our bit rate (R_b) and our free space loss (L_{free}). The transmit $EIRP_t$ is our transmit power, P_t and our antenna gain G_t. Fixing our transmit power at 1 mW gives us the following table:

Distance (m)	R_b (G bits per second)
1000	4869
5000	194.8
10000	48.79
50000	1.948
100000	0.4879
150000	0.216

of 200 Mbps. This is the approximate distance from Manila to Urdaneta. Assuming a company residing in Manila wanted to open a branch in Urdaneta they could use this novel system with decent data rates.

Calculating Effective Link Budget

The Link Budget for this paper will be calculated using the Friis equation (in dB):

$$P_r = P_t + G_t + G_r - L_{path} - N_{interference}$$

Using the values from above at a distance of 150 km and ignoring the interference term:

$$P_r = -30 + 32 + 32 - 139$$

$$P_r = -105dB[W]$$

Closing Remarks

This paper gives us a better understanding of how feasible it would be to reuse the Ku Band for terrestrial purposes. We can clearly see that the application seems practical from the corporate user's point of view. The two locations of Manila and Urdaneta City were chosen to emphasize how practical this solution can be and how it can be used to replace in ground fiber. Phased arrays can be used instead of standard directional antennas to help reduce interference in certain areas. With the high data rate and distance for use, this solution is proven to be feasible for companies looking for secure data transfer with minimal infrastructure.