SIGNAL STRENGTH BUDGET FOR EARTH TO SATELLITE TRANSMISSION

Assumptions

All these are reasonable.

1. Receiver system noise temperature: 50 K. This is well within the state of the art.
2. Satellite height: 400 Km
3. Earth is a black body at 300K.
4. Earth completely occults the receiving antenna reception pattern.
5. Receiver bandwidth: 10 KHz. Note that this is the main factor limiting the data rate. It also precludes pulses shorter than 0.1 millisecond.
6. Earth antenna is isotropic; gain = 0 dB.
7. Satellite receiving antenna gain: 15 dB. This is a numerical power ratio of 31.6.
8. Required signal to noise power ratio: 10 dB.

Noise

Total system noise is the sum of the internal receiver noise and the black body noise from Earth: 50 K + 300K = 350 Kelvin.
System noise power = kTB = $1.38 \times 10^{23} \times 350 \times 10^{4} = 4.8 \times 10^{-17}$ W. Here k is Boltzmann's constant, T is the system temperature and B is the bandwidth.
To achieve a 10 dB signal to noise ratio the earth transmitter must produce in the receiver's input stage a signal power of 4.8×10^{-16} watt.
The antenna must capture this power from the incident field and, assuming there are no ohmic losses in the antenna, must deliver it to the receiver.

Antenna effective area

The effective area of the antenna is computed from the gain by the formula $A_{eff} = G\lambda^2/(4\pi)$ where G is the numerical power gain and λ is the wavelength.
For a gain of 15 dB, $A_{eff} = 2.5\,\lambda^2$

Transmitter power

Now it's necessary to specify the wavelength. For 150 Mhz $\lambda = 2.0$ meters, so the effective area is 10 square meters. Then the required intensity at the antenna is 4.8×10^{-15} watt/M^2. As the transmitting antenna is assumed to be isotropic, the required transmitter power can be determined by multiplying the intensity by the area of a sphere of 400 Km radius. The transmitter power thus becomes 0.01 watt.

Discussion

The results is encouraging but are based on assumptions which may turn out to be unrealistic.

1. No allowance is made for man-made interference, such as unintentional out-of-band radiation from other transmitters, and interference from on-board electronics in the satellite.
2. The ground transmitter, possibly mounted on a small animal (bird), probably is an extremely inefficient radiator. No allowance has been made for this. It would be reasonable to add another 10 dB of power for this.
3. How much space will be available for the antenna on the satellite? To what degree and with what precision can it be oriented toward the target? If more space is available than assumed above, a higher gain antenna would decrease the power requirement for the ground transmitter.
4. What is the optimum frequency? If the allocated antenna space on the satellite is fixed, a higher frequency can result in more antenna gain. What effect would this have on the efficiency of the transmitting antenna? For the same length (or diameter for a collar) antenna a higher frequency could result in higher efficiency. Lower frequencies presumably penetrate a forest canopy with less attenuation, but this is still under investigation.
5. What is the required bandwidth? This depends on the rate of data transmission, the coding adopted, the flexibility of the receiver's frequency programming, and whether or not Doppler position location is adopted, among other things. A narrower bandwidth improves the power requirement; for example, reducing the bandwidth by a factor of one-tenth improves the SNR by 10 dB.

There are, of course, many other uncertainties.

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