Link Budget

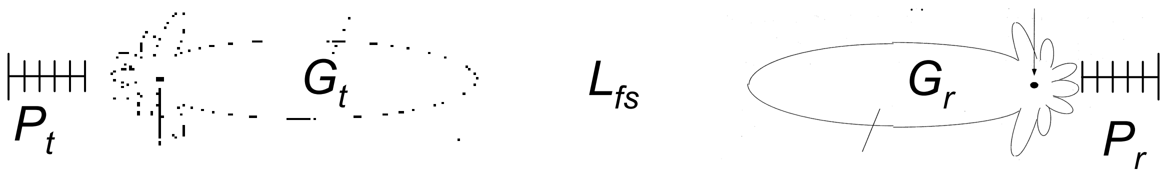
Link budget

The transmitter delivers a power, P_t to the transmitting antenna. This antenna, is assumed to have a antenna gain G_t. The product

$$EIRP=P_tG_t$$

is usually denoted the Effective Isotropic Radiated Power (EIRP) and is exactly the power we have to feed to an isotropic antenna to get the same result as with an antenna with antenna gain.

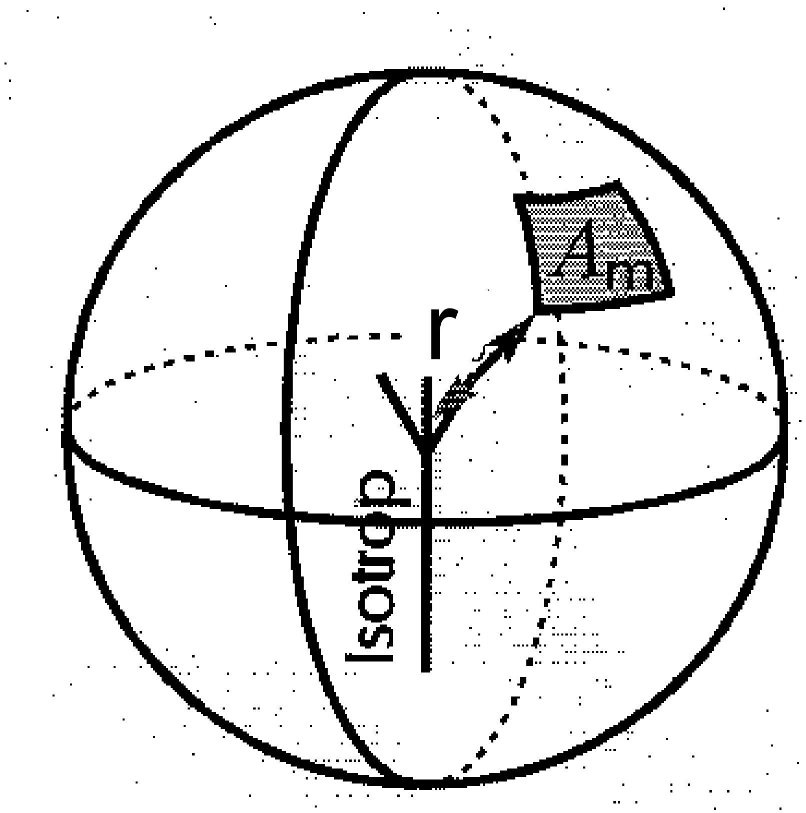
The receiving antenna also have an antenna gain, Gr, which must be included in the link budget.



Furthermore, the radiated EIRP is attenuated on its way between the transmitting antenna and the receiving antenna. The attenuation that the signal suffers is called path loss, L.

The received power is according to: $$P_r = P_t \frac{G_tG_r}{L}$$

Free space Link budget



Sphere area: $A_{tot}=4\pi r^2$

Receiver antenna area: A_m

Received power: $$P_r = P_t \frac{A_m}{A_{tot}}$$

Attenuation: $$L = \frac{P_t}{P_r} = \frac{A_{tot}}{A_m} = \frac{4\pi r^2}{A_m}$$

Free space Link budget

The path loss, L, is dependent on what kind of propagation model that is used, in this case we assume free space propagation, L_{fs}.

Even if the isotropic antenna does not have any antenna gain, G_t, (it is one) the effective area (aperture) is :

$$A_{iso} = \frac{\lambda^2}{4\pi}$$

It is not a trivial issue to derive a point's effective area ????

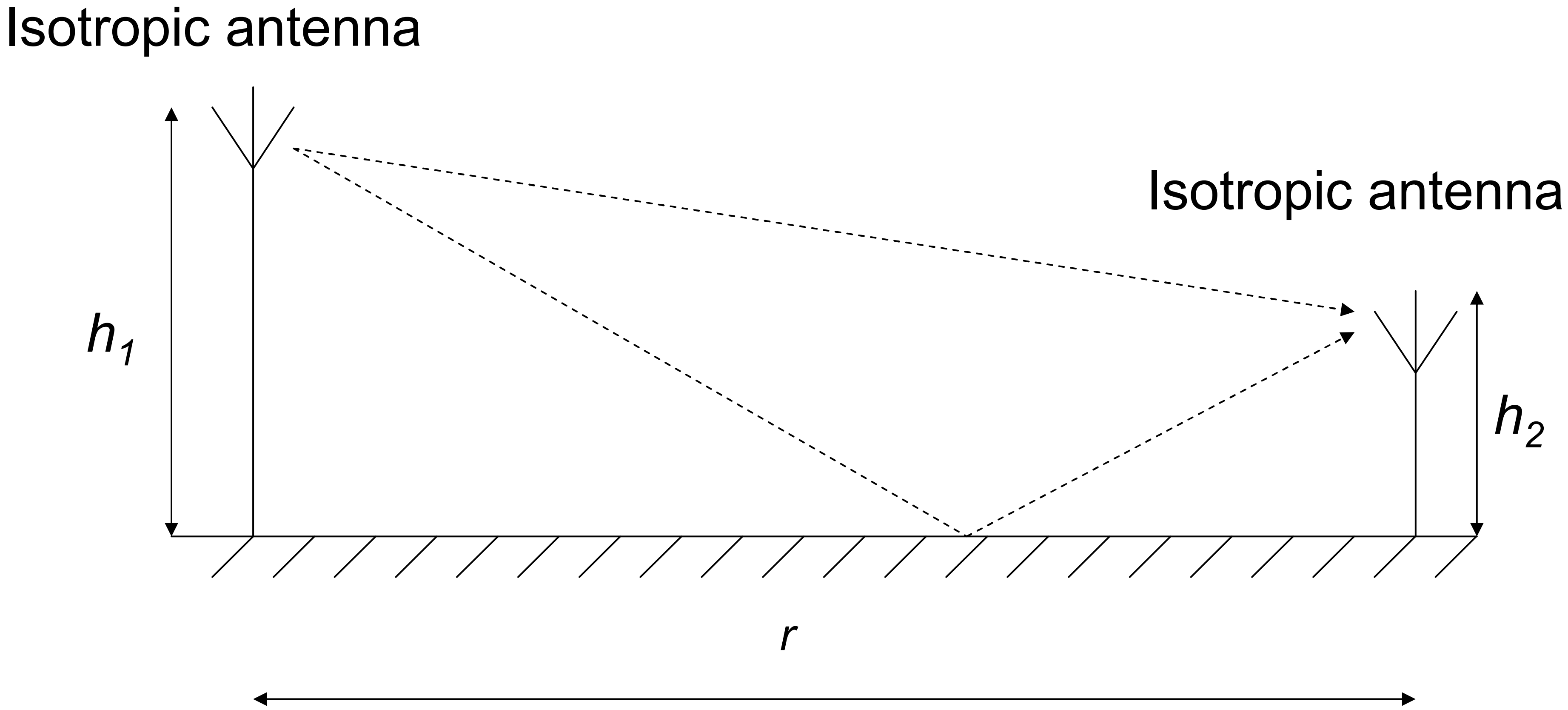
The free space path loss, L_{fs}, is then according to:

$$L_{fs} = \frac{4\pi r^2}{A_{iso}} = \frac{4\pi r^2}{\lambda^2 / 4\pi} = \left(\frac{4\pi r}{\lambda}\right)^2$$

Free space Link budget

- It is worth noting that the free space path loss increases with frequency.
- This often gives rise to the misunderstanding that RF waves with higher frequency would have higher path loss than RF waves with lower frequency in free space propagation, **this is wrong**.
- The frequency dependence is due to the fact that the expression includes the **aperture** of the isotropic antenna .
- The **aperture will decrease at higher frequencies** because the hypothetical isotropic antenna, whose dimensions are adapted to the wave length, will be smaller.

Plane Earth path loss model



$$L_{pe} = \left(\frac{4\pi r}{\lambda} \right)^2 \left(\frac{\lambda r}{4\pi h_1 h_2} \right)^2 = \frac{r^4}{h_1^2 h_2^2}$$

Okumura’s path loss model

- Okumura’s empirical model (based on measurements) is one of the most used path loss models for signal prediction in urban areas. This model is applicable for frequencies in the range 150 MHz to 2000 MHz (approx.).
- To determine the path loss according to Okumura’s model the free space path loss first must be calculated.
- The Okumura’s diagram gives correction values to the simple free space model for urban environments.

Example Okumura's model

Frequency, *f*: 900 MHZ

Base station height, h_1: 200m

Mobile unit height, h_2: 3m

Distance, *r*: 30 km

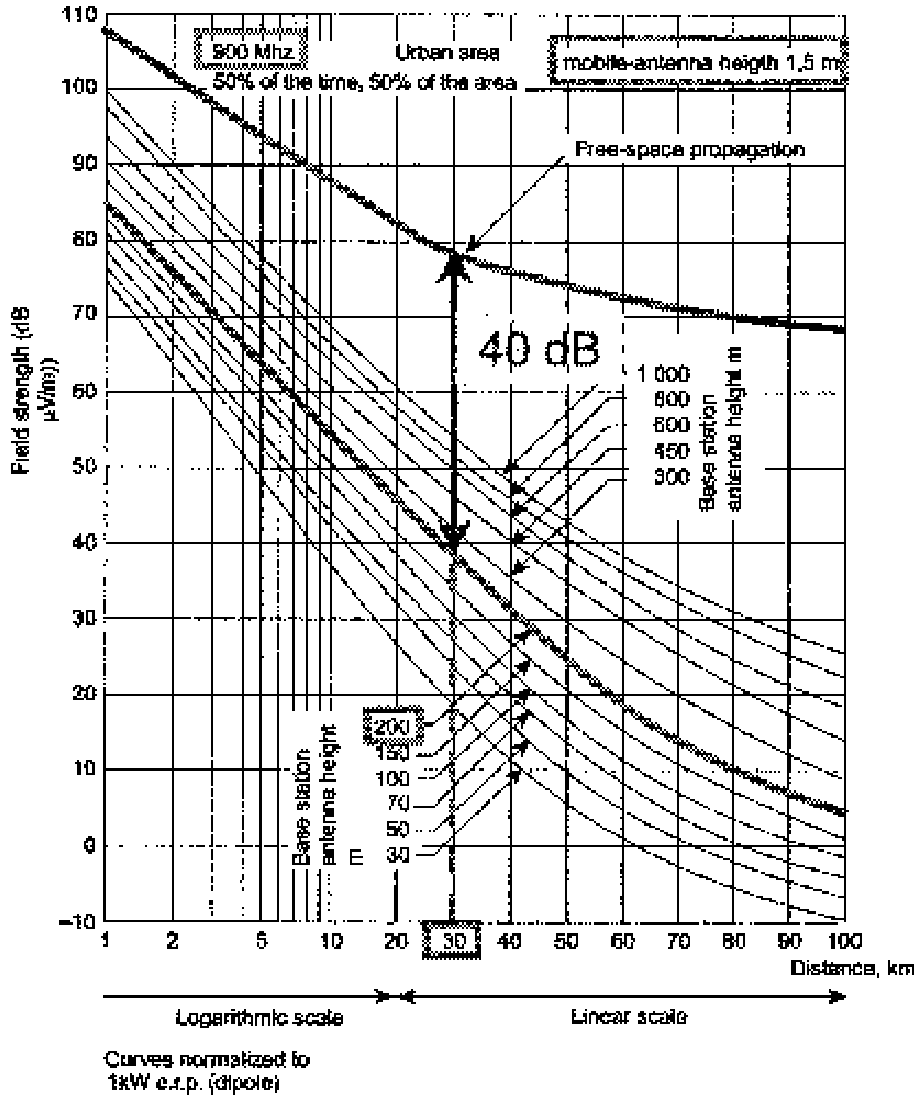
The wave length, ●, is:

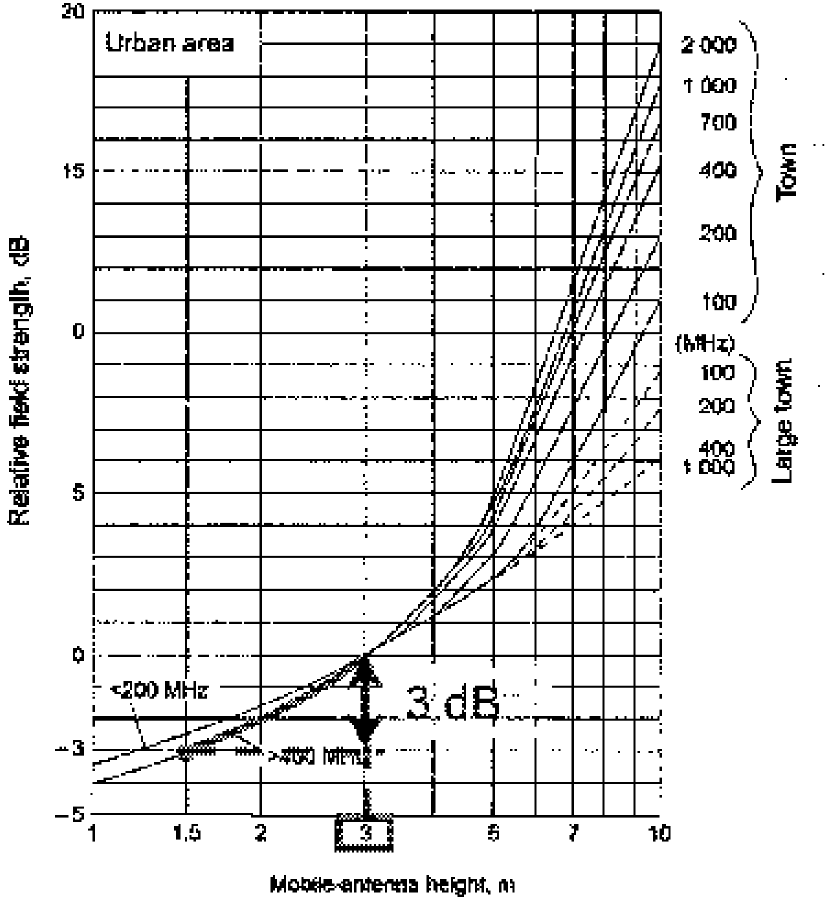
$$\lambda = \frac{c}{f} = \frac{300000000}{900000000} = 0.33$$

The free space propagation, L_{fs} is:

$$L_{fs} = 10\log_{10}\left(\frac{4\pi r}{\lambda}\right)^2 = 10\log_{10}\left(\frac{4\pi 30000}{0.33}\right)^2 = 121dB$$

Example - Okumura's model cont.





$L_{ok} = 121 + 40 - 3 = 158$ dB

Link budget - Signal to Noise Ratio

The receiver is characterized by its system noise factor $F = T_{sys}/T_0$. Assuming the system uses a bandwidth *B* we can express the *SNR* (the link budget) as:

$$\frac{S}{N} = \frac{P_r}{N} = \frac{P_t G_t G_r}{LFkT_0 B}$$

For a digital modulated system the corresponding link budget would be:

$$\frac{E_b}{N_0} = \frac{P_t \tau_b G_t G_r}{LFkT_0} = \frac{P_t G_t G_r}{LFkT_0 R} = \frac{P_{EIRP} G_r}{LFkT_0 R}$$

Link budget - Signal to Noise Ratio

We can express the link budget on logarithmic form also:

$$\left(\frac{S}{N}\right)_{dB} = (P_t G_t)_{dB} - (L)_{dB} + (G_r)_{dB} - (F)_{dB} - (kT_0)_{dB} - (B)_{dB}$$

$$\left(\frac{E_b}{N_0}\right)_{dB} = (P_{EIRP})_{dB} - (L)_{dB} + (G_r)_{dB} - (F)_{dB} - (kT_0)_{dB} - (R)_{dB}$$

Link budget - decibel