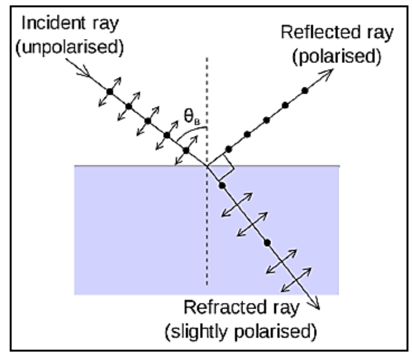
Chapter 4

Q1/ Answer the following branches:

A) Define the Brewster's angle.
B) Calculate the Brewster angle for a wave impinging on ground having a permittivity of $\varepsilon_r = 5$.

Solution:



A) Brewster's angle (also known as the polarization angle) is an angle of incidence at which the wave with a particular polarization is perfectly transmitted through a dielectric surface, with no reflection (reflection coefficient is equal to zero).

B)

$$sin\theta_B = \frac{\sqrt{\varepsilon_r - 1}}{\sqrt{\varepsilon_r^2 - 1}} = \frac{\sqrt{5-1}}{\sqrt{25-1}} = \frac{\sqrt{4}}{\sqrt{24}} = \frac{2}{4.89} = 0.4$$

$$\theta_B = sin^{-1}(0.4) = 23.5^0$$

Q2/A mobile is located 4 *km* away from a base station and uses a vertical λ/4 monopole antenna with a gain of 2.75 dB to receive cellular radio signals. The E-field at 1 *km* from the transmitter is measured to be 2×10^{-3} V/m. The carrier frequency used for this system is 900 MHz.

a) Find the length and the effective aperture A_e of the receiving antenna.
b) Find the received power at the mobile using the 2-ray ground reflection model assuming the height of the transmitting antenna is 60m and the receiving antenna is 2m above ground.

Solution:

d= 4 km

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{900\times10^6} = 0.333m$$

Length of the antenna = $\lambda/4$ = 0.333/4 = 0.0833*m* = 8.33*cm*.

$G = 10^{(2.75/10)} = 1.884$

$$A_e = \frac{G\lambda^2}{4\pi} = \frac{1.884(0.333)^2}{4\pi} = 0.0166\, m^2 = 166\, cm^2$$

$$E_{TOT}(d) \approx \frac{2E_0 d_0}{d} \frac{2\pi h_t h_r}{\lambda d} \qquad V/m$$

$$= \frac{2\times 2\times 10^{-3}\times 1\times 10^3}{4\times 10^3}\left[\frac{2\pi\times 60\times 2}{0.333\times 4\times 10^3}\right] = 5.66\times 10^{-4}\ V/m$$

The received power at a distance *d* can be obtained using

$$P_r(d) = \frac{|E|^2}{120\pi} A_e = \frac{\left(5.66\times 10^{-4}\right)^2}{377}(0.0166)$$

$$= 1.41\times 10^{-11}\ W = -108.5\, dBW\ or\ -78.5\, dBm$$

Q3/ If 65 watts transmitter power is applied to a unity gain antenna with a 900 MHz carrier frequency. Assume unity gain for the receiver antenna.

A) Express the transmitter power in units of *dBm* and *dBW*.
B) Find the received power in *dBm* at a free space distance of 100*m* from the antenna.
C) What is *Pr*(12 km)?
D) Find the effective aperture A_e of the transmitter antenna.

<u>Solution:</u>

<u>A)</u>

$P_t = 65\ W = 65\times 10^3\ mW$

$$P_t(dBm) = 10\log[P_t(mW)] = 10\log[65\times 10^3] = 48\, dBm$$

$$P_t(dBm) = 10\log[P_t(W)] = 10\log[65] = 18\, dBW$$

B)

$$\lambda = \frac{c}{f} = \frac{3\times 10^8}{900\times 10^6} = 0.33m$$

$$P_r = \frac{P_t G_t G_r}{L}\left(\frac{\lambda}{4\pi d}\right)^2$$

$$P_r = \frac{65\times1\times1}{1}\left(\frac{0.33}{4\pi\times100}\right)^2 = 4.48\times 10^{-6}\ W = 4.48\times 10^{-3}\ mW$$

$$P_{r(dBm)} = 10\log\left(P_r(mW)\right) = 10\log(4.48\times10^{-3}) = -23.4\ dBm$$

c)

$$P_r\ (12\ km) = P_{r(dBm)}(100) + 20\log\left(\frac{100}{12000}\right) = -23.4 - 41.58 = -65\ dBm$$

$$A_e = \frac{G\lambda^2}{4\pi} = \frac{1(0.33)^2}{4\pi} = 0.00867\ m^2 = 86.7\ cm^2$$

c) ---

Q4/ If 60 wattsis applied to a 1.5 gain antenna with a 0.9 *GHz* carrier frequency, find the received power in *dBm* at a free space distance of 150*m* from the antenna. What is *Pr (9 km)*? Assume gain=2 for the receiver antenna.

Solution:

$$\lambda = \frac{C}{f} = \frac{3\ x\ 10^8}{0.9\ x\ 10^9} = 0.333\ m$$

$$P_r(d) = \frac{P_t G_t G_r}{L}\left(\frac{\lambda}{4\pi\ d}\right)^2$$

$$P_r(150) = \frac{60\ x\ 1.5\ x\ 2}{1}\left(\frac{0.333}{4\pi\ 150}\right)^2 = 5.61\ x\ 10^{-3}\ mW$$

$$= 10\log(5.61\ x\ 10^{-3}) = -22.5\ dBm$$

$$P_r(9km) = P_{r(dBm)}(150) + 20\log\left(\frac{150}{9000}\right) = -22.5\ dBm - 35.56\ dB = -58.06\ dBm$$

Q5/ Find the far-field distance for an antenna with maximum dimension of 3*m* and operating frequency of 950 *MHz*.

Solution:

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{950} = 0.315m$$

$$d_f = \frac{2\times D^2}{\lambda} = \frac{2\times3^2}{0.315} = 57.14m$$

Q6/ Calculate the link budget from one side only, when the 39920 *km* GEO satellite communication link with a transmitter power of 2*kW* that is applied to the transmitter antenna gain of 40*dBi*. The satellite receiver is connected to an antenna with 35*dBi* gain and a receive sensitivity of -100*dBm*. The cables in both systems are short, with a loss of 1 *dB* at each side at the 12 *GHz* frequency of operation.

Solution:

$$Tx\ Power = 10\log(2000 \times 10^3 mW) = 63\ dBm$$

$$Total\ gain = Tx\ Power + Tx\ Antenna\ Gain\ - Cable\ loss(Tx)$$

$$+ Rx\ Antenna\ gain - Cable\ loss(Rx)$$

$$= 63\ dB + 40\ dBi - 1\ dB + 35\ dBi - 1\ dB = 136\ dB$$

$$\lambda = \frac{c}{f} = \frac{3\times10^8}{12\times10^9} = 0.025m$$

$$Path\,Loss(PL) = -20\log\left(\frac{\lambda}{4\pi d}\right) = -20\log\left(\frac{0.025}{4\pi\times39920\times10^3}\right) = 206dB$$

$$Expected\ P_r = Total\ gain - Free\ space\ loss$$

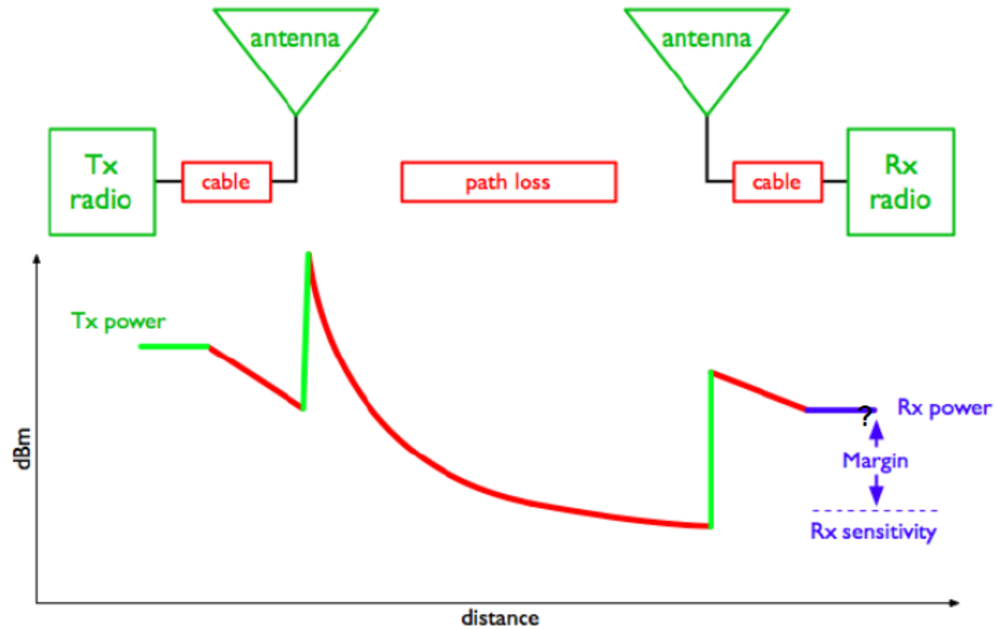
$$= 136\ dB - 206\ dB = -70dBm$$

$$Link\ Margin = Expected\ P_r - Sensitivity\ of\ Client$$

$$= -70 - (-100) = 30\ dB$$

Q7/ A- Calculate the link budget (only from Tx to Rx) for the 10*km* transmitting distance of 20*w* power that is applied to the transmitter with antenna gain of 20*dBi*. The receiver is connected to an antenna with 25*dBi* gain and a receive sensitivity of -80 *dBm*. The cables in both systems are short, with a loss of 1 *dB* at each side at the 13 *GHz* frequency of operation.

B- Label on the following figure the calculated and given parameter on the bellow figure.



Solution:

A)

$$Tx\ Power = 10\log(20 \times 10^3 mW) = 43\ dBm$$

$$Total\ gain = Tx\ Power + Tx\ Antenna\ Gain\ - Cable\ loss(Tx)$$
$$+ Rx\ Antenna\ gain - Cable\ loss(Rx)$$
$$= 43\ dB + 20\ dBi - 1\ dB + 25\ dBi - 1\ dB = 86\ dB$$

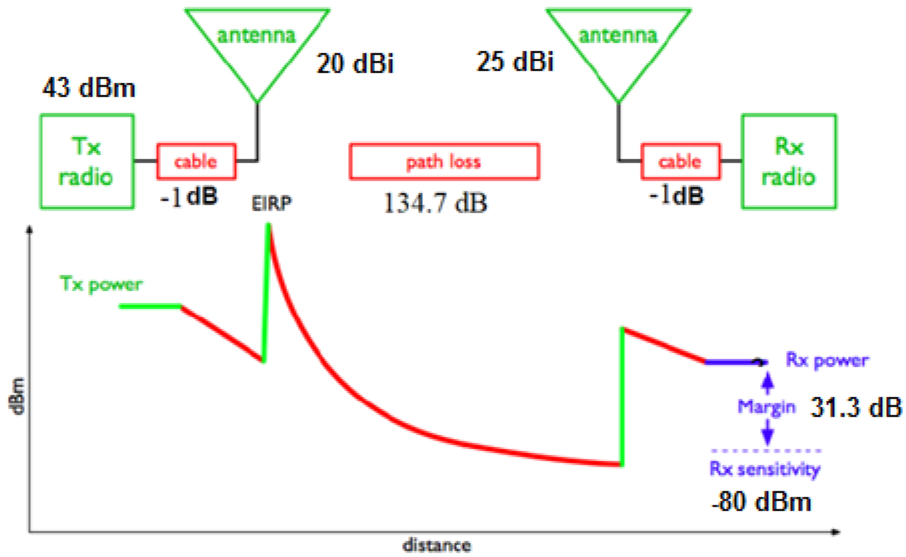
$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{13 \times 10^9} = 0.023m$$

$$Path\ Loss\ (PL) = \ -20\log\left(\frac{\lambda}{4\pi d}\right) = -20\log\left(\frac{0.023}{4\ \pi \times 10000}\right) = 134.7dB$$

$$Expected\ P_r\ = Total\ gain - Free\ space\ loss$$
$$=\ 86\ dB - 134.7\ dB =\ -48.7\ dBm$$

$$Link\ Margin = Expected\ P_r - Sensitivity\ of\ Client$$
$$=\ -48.7 - (-80) = 31.3\ dB$$

B-



Q8/ Calculate the link budget for the 10*km* transmitting distance of 20*w* power that is applied to the transmitter with antenna gain of 20*dBi and transmitter* sensitivity of -85 *dBm*. The receiver (Rx = 18w) is connected to an antenna with 25*dBi* gain and a receive sensitivity of -80 *dBm*. The cables in both systems are short, with a loss of 1 *dB* at each side at the 13 *GHz* frequency of operation.

A) from Tx to Rx

$$Tx\ Power = 10\log(20 \times 10^3 mW) = 43\ dBm$$

$$Total\ gain = Tx\ Power + Tx\ Antenna\ Gain\ - Cable\ loss(Tx)$$
$$+ Rx\ Antenna\ gain - Cable\ loss(Rx)$$
$$= 43\ dB + 20\ dBi - 1\ dB + 25\ dBi - 1\ dB = 86\ dB$$

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{13 \times 10^9} = 0.023m$$

$$Path\ Loss\ (PL) = -20\log\left(\frac{\lambda}{4\pi d}\right) = -20\log\left(\frac{0.023}{4\ \pi \times 10000}\right) = 134.7dB$$

$$Expected\ P_r = Total\ gain - Free\ space\ loss$$

$$= 86\ dB - 134.7\ dB = -48.7\ dBm$$

$$Link\ Margin = Expected\ P_r - Sensitivity\ of\ Client$$

$$= -48.7 - (-80) = 31.3\ dB$$

b) from Rx TO Tx

$$Total\ gain = Rx\ Power + Rx\ Antenna\ Gain\ - Cable\ loss(Rx)$$

$$+ Tx\ Antenna\ gain - Cable\ loss(Tx)$$

$$= 42.55\ dB + 25\ dBi - 1\ dB + 20\ dBi - 1\ dB = 85.55\ dB$$

$$Expected\ P_r = Total\ gain - Free\ space\ loss$$

$$= 85.55\ dB - 134.7\ dB = -49.14\ dBm$$

$$Link\ Margin = Expected\ P_r - Sensitivity\ of\ Client$$

$$= -49.14 - (-85) = 35.85\ dB$$

Q9 Find the far-field distance for an antenna with maximum dimension of 3m and operating frequency of 950 *MHz*.

Solution:

D =3m, f = 950 *MHz,*

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{950} = 0.315m$$

$$d_f = \frac{2 \times D^2}{\lambda} = \frac{2 \times 3^2}{0.315} = 57.14m$$

Q10 Determine the isotropic free space loss at 5*GHz* for 5 *km* path distance between the transmitter and the receiver.

Solution:

$$\lambda = \frac{c}{f} = \frac{3 \times 10^8}{5 \times 10^9} = 0.06m$$

$$PL(dB) = -20 \log\left(\frac{0.06}{4\pi \times 5 \times 10^9}\right) = 60.3dB$$