Effective Radiated Power

In the main beam of the antenna power radiated:

\[ E_{\text{IRP}} = P_x G_x \text{ (W)} \]

The effective radiate power (ERP - defined relative to a half-wave dipole antenna). Gain of a half-wave dipole antenna is 2.2 dBi.

\[ \text{ERP (dBi)} = \text{EIRP (dBi)} + 2.2 \text{ dBi}. \]

Impedance Match

Impedance mismatch will reduce the power delivered from source to load by \( (1 - I_{\text{IRP}}) \).

\[ I_{\text{IRP}} \]

In a radio link this can happen:

1. Between transmitter and TX antenna
2. Between RX antenna and receiver.

Impedance mismatch factor

\[ E_{\text{imp}} = (1 - |\mathbf{z}_x|^2)(1 - |\mathbf{z}_r|^2) \]

Polarization Mismatch

For max. transmission both antennas should be polarized in the same direction.
RECEIVE VOLTAGE IS DOT PRODUCT OF ELECTRIC FIELD AND POLARIZATION VECTOR OF THE RECEIVE ANTENNA.

\[ \text{POLARIZATION LOSS} = |\mathbf{e}^\perp \cdot \mathbf{e}^\parallel|^2 \]

WHERE

\( \mathbf{e}^\perp \) represents polarization of electric field of incident plane waves,

\[ \mathbf{E}^\perp = e^\perp E^\parallel e^{-j\omega t} \]

\( \mathbf{e}^\parallel \) represents polarization of electric field of receive antenna when operating as TX antenna,

\[ \mathbf{E}^\parallel = e^\parallel E^\parallel e^{-j\omega t} \]

(SKIP EXAMPLE 4.4)

EQUIVALENT CIRCUITS FOR TX AND RX ANTENNAS

---

**Generator** \( Z_g \) \( \quad \text{TX ANTENNA} \)

**SAME** \( Z_A \)

**RX ANTENNA** \( Z_L \)

**Receiver**
4.3 ANTENNA NOISE TEMPERATURE

BACKGROUND AND BRIGHTNESS TEMP.

A RECEIVE ANTENNA AT TEMP. $T$ HAS AVAILABLE OUTPUT NOISE POWER,

$$N_0 = k T_B$$

ANTENNAS SEE VARIOUS BACKGROUND NOISE TEMPERATURES, $T_B$:

- **SKY (TOWARDS ZENITH)** 3-5 K (COSMIC BACKGROUND RAD.)
- **SKY (TOWARDS HORIZON)** 50-100 K
- **GROUND** 290-300 K

**FIGURE 4.10** Background noise temperature of sky versus frequency, $\theta$ is the elevation angle measured from the horizon. Data are for sea level, with surface temperature of 15°C, and surface water vapor density of 7.5 gm/m$^3$.  

4.3 Antenna Noise Temperature 127
WHEN THE BEAMWIDTH IS LARGE, THE BRIGHTNESS TEMP. IS FOUND BY WEIGHTING THE SPATIAL DISTRIBUTION OF THE BACKGROUND TEMP. BY THE PATTERN FUNCTION OF THE ANTENNA,

\[
\overline{T_b} = \frac{\int_{\theta=0}^{\pi} \int_{\phi=0}^{2\pi} T_b(\theta, \phi) D(\theta, \phi) \sin \theta \, d\theta \, d\phi}{\int_{\theta=0}^{\pi} \int_{\phi=0}^{2\pi} D(\theta, \phi) \sin \theta \, d\theta \, d\phi}
\]

WHERE \( T_b(\theta, \phi) \) = DISTRIBUTION OF BACKGROUND TEMP.

\( D(\theta, \phi) \) = DIRECTIVITY (POWER PATTERN FUNC.)

IF \( T_b(\theta, \phi) = \overline{T_b} \) (CONSTANT)

THEN \( \overline{T_b} = T_b \)

ANTENNA NOISE TEMP.

LET A RECEIVE ANTENNA BE AT PHYSICAL TEMP. \( T_p \).

\[
\begin{align*}
\text{BRIGHTNESS TEMP:} & \quad \overline{T_b} \\
\text{ATTENUATOR:} & \quad T_p \\
\text{LOSS IN ANTENNA:} & \quad L = \frac{1}{e} \geq 1 \\
\text{ANTENNA TEMP:} & \quad T = \frac{N_{\text{added}}}{k_b} = (L-1)T_p \\
\end{align*}
\]

\[
\begin{align*}
\overline{T_A} & = \frac{\overline{T_b}}{L} + \frac{(L-1)T_p}{L} = e_{\text{rad}} \overline{T_b} + (1-e_{\text{rad}})T_p \\
\end{align*}
\]
(SEE EXAMPLE 4.5)

\[ \frac{G}{T} \]

GAIN/TEMP. RATIO OF RECEIVE ANTENNA

\[ G/T \text{ (dB)} = 10 \log_{10} \frac{G}{T_A} \text{ (dB/K)} \]

SIGNAL TO NOISE RATIO \( \propto \frac{G}{T_A} \).

THE RECEIVED POWER (FRIIS EQN)

\[ S_i = \frac{G_T G_x P_x \lambda^2}{(4\pi R)^2}, \text{ WHERE } R \text{ IS DISTANCE OF } T_x \text{ TO } R_x. \]

\[ N_i = k T_A B, \]

ERROR IN BOOK (IT HAS A G HERE)

FOR RECEIVER

\[ \frac{S_i}{N_i} = \frac{G_T G_x P_x \lambda^2}{k T_A B (4\pi R)^2} = \left( \frac{G_T}{T_A} \right) \frac{G_x P_x}{k B} \frac{\lambda^2}{(4\pi R)^2} \]

(EXAMPLE 4.6)
Example 4.5

An antenna has

\[ O(\theta) \]

linear

1000

10

\[ 30 \]

\[ 1 \]

\[ -90 \to -30 \to 0 \to 30 \to 90 \to \theta \]

And

\[ T_B(\theta, \phi) = \begin{cases} 10K & \text{for } |\theta| \leq 30^\circ \\ \text{look for } 30^\circ < |\theta| \leq 90^\circ \end{cases} \]

Let

\[ e_{\text{rad}} = 1 \quad (\lambda_0, \rho_0) \]

Find \( T_A \)

\[ T_A = e_{\text{rad}} T_B + (1 - e_{\text{rad}}) T_\rho \]

\[ = T_B \]

Where

\[ T_B = \frac{2\pi}{\int_{\theta=0}^{2\pi} \int_{\phi=0}^{\pi} \frac{T_B(\theta, \phi)}{O(\theta, \phi)} \sin \theta \, d\theta \, d\phi} \]

\[ = \frac{1}{\int_{\theta=0}^{2\pi} \int_{\phi=0}^{\pi} O(\theta, \phi) \sin \theta \, d\theta \, d\phi} \]

\[ = \frac{\int_{\theta=0}^{1} 10 \sin \theta \, d\theta + \int_{\theta=1}^{30} 0.1 \sin \theta \, d\theta + \int_{30}^{90} 1 \sin \theta \, d\theta} {\int_{\theta=0}^{2\pi} \sin \theta \, d\theta} \]

\[ = \frac{-10 \cos \theta \Big|_{0}^{1} - 0.1 \cos \theta \Big|_{1}^{30} \cos \theta \Big|_{30}^{90}} {-\cos \theta \Big|_{0}^{1} - 0.01 \cos \theta \Big|_{1}^{10} \cos \theta \Big|_{10}^{60}} \]

\[ = 0.00152 + 0.034 + 0.866 = 86.4 \, K \]

\[ 0.0102 \]

\[ T_A = 86.4 \, K \]
Example 4.6

\[ f = 12.2 \text{ to } 12.7 \text{ GHz} \]
\[ B = 20 \text{ MHz} \]

\[
\begin{align*}
\rho & = 120 \text{ W} \\
G_x & = 34 \text{ dB} \\
G_x & = 2512 \\
R & = 33.5 \text{ dB} \\
T_b & = 50 \text{ K} \\
F & = 11 \text{ dB} \\
\text{CNR} & = 12.2 \text{ dB}
\end{align*}
\]

(a) Find EIRP (Effective Isotropic Radiated Power)

\[
\text{EIRP} = \rho_x G_x (W) = (120)(2512) = 3.01 \times 10^{-5} W = 54.8 \text{ dBm}
\]

(b) Find \( G/T \)

Find equivalent noise temp. of antenna + LNB

\[
T_e = T_A + T_{LNB} \quad \Rightarrow \quad T_b + (F-1)T_0 = 50 + (1.29 - 1)(290) = 134 K
\]

\[
G/T \ (\text{dB}) = 10 \log \frac{G_T}{T_A} \ (\text{dB/K})
\]

\[
10 \log \frac{22.39}{134} = 12.2 \text{ dB/K}
\]

(c) Find \( P_{t+1} \) (Received Carrier Power)

\[
\text{Friis Eqn.} \quad P_t = \frac{\rho_x G_x \lambda^2}{(4\pi R)^2} = 1.63 \times 10^{-12} W = -117.9 \text{ dBm}
\]

(d) Find CNR (Carrier-to-Noise Ratio)

\[
\text{CNR} = \frac{P_t G_{LNB}}{R_T B G_{LNB}} = 44.1 = 16.4 \text{ dB}
\]