



Fundamentals of Mobile Radio Communications

Exercise 4: Antennas and Propagation in Free Space

M.Sc. Maik Weber

June 2, 2025

1 Antennas - Basic Terms

1.1 What do dBi and dBd mean?

In general, an antenna does not radiate a signal equally in all spatial directions, but concentrates the transmitted power in the desired main direction of radiation (characterised by the antenna pattern; called *main lobe*). By focusing the power, a **gain is obtained in the area illuminated by the antenna compared to a so-called isotropic radiator**, which radiates the power equally in all directions. This gain is given in dBi and indicates that it is a gain compared to an isotropic radiator.

The gain of a $\lambda/2$ dipole, defined by its main lobe, is given in dBd. This gain is approximately 2.15 dBi.

1.2 What do the abbreviations EIRP and ERP mean?

Equivalent isotropic radiated power (EIRP) is the transmission power that would have to be applied to an isotropic (omnidirectional) radiator to produce the same field strength at a distance as a directional antenna in its main transmission direction. The Equivalent Radiated Power (ERP) refers to a dipole radiator and is therefore lower than the EIRP by a factor of 1.64 \Rightarrow 2.15 dB.

$$EIRP_{\text{dBm}} = P_{\text{TX, dBm}} + G_{\text{dBi}}$$

$$ERP_{\text{dBm}} = P_{\text{TX, dBm}} + G_{\text{dBd}} = P_{\text{TX, dBm}} + G_{\text{dBi}} - 2.15 \text{ dB} = EIRP_{\text{dBm}} - 2.15 \text{ dB}$$

1.3 Sketch the possible antenna configurations in the context of multi-antenna systems (SISO, SIMO, MISO, MIMO).

2 Antennas - Analysis of radiation patterns

To investigate the radiation properties of an antenna, the radiation pattern in vertical and horizontal direction can be considered. In fig. 1, the radiation pattern of a Kathrein 742212 Multi-band antenna at 2.1 GHz with an antenna gain of 18 dBi is shown.

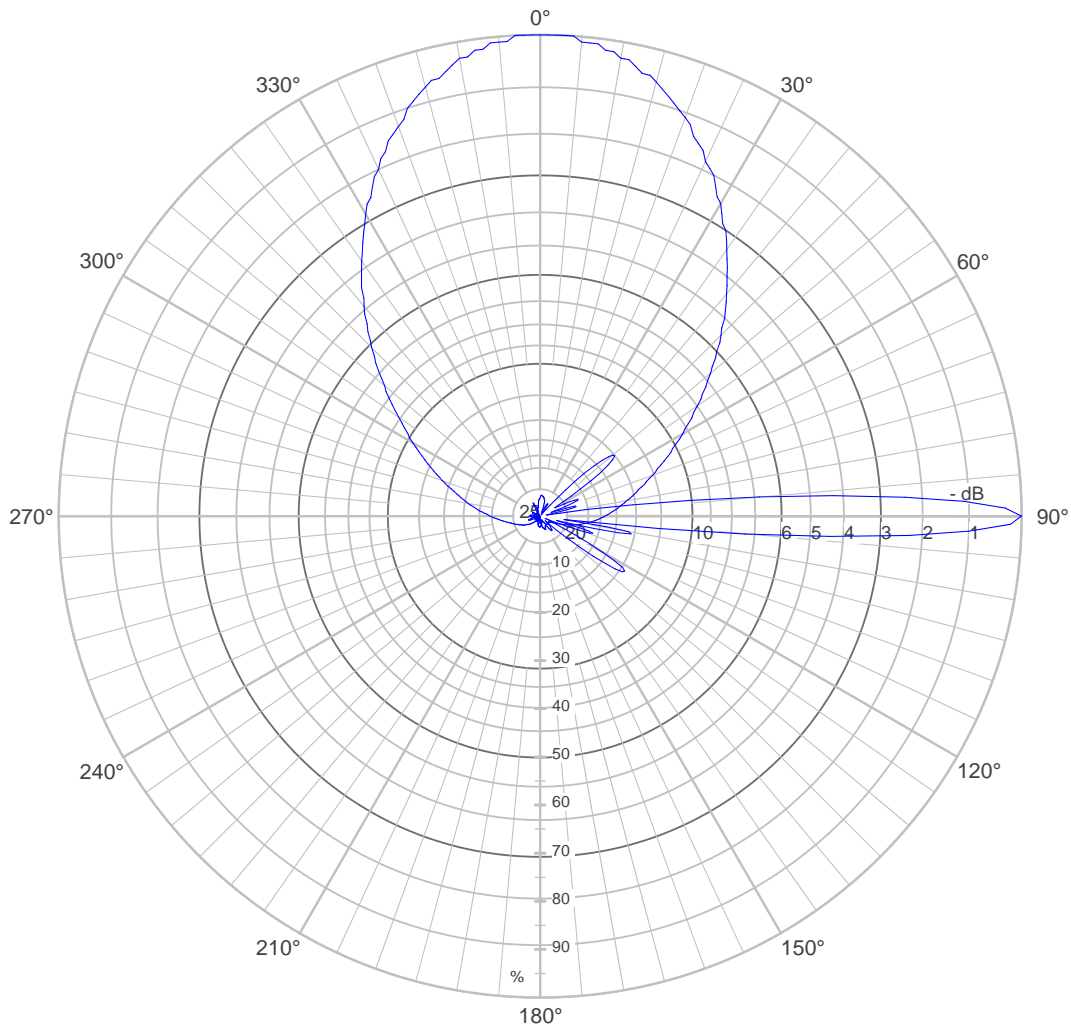


Figure 1: Radiation pattern of Kathrein 742 212 Multi-band antenna at 2.1 GHz

2.1 What is the antenna gain for the main lobe?

2.2 What is the antenna gain for a 50° horizontal deviation from the main lobe?

2.3 Consider a base station amplifier with maximal output power of 20 W, cable losses of 3 dB and the antenna gain of the Kathrein antenna. How much is the EIRP and the ERP?

3 Propagation in Free Space

3.1 What is the Friis transmission formula in linear and logarithmic scale?

Transmit and receive power are related as follows:

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

From that relation one can find the free-space path loss (FSPL) defined as:

$$FSPL = \left(\frac{4\pi d}{\lambda} \right)^2 = \left(\frac{4\pi d f}{c_0} \right)^2$$

In decibels, the following equation holds:

$$\begin{aligned} FSPL_{dB} &= 10 \log_{10} \left(\frac{4\pi d}{\lambda} \right)^2 \\ &= 20 \log_{10} \left(\frac{4\pi d f}{c_0} \right) \\ &= 20 \log_{10} \left(\frac{d}{1 \cdot 10^{-3} \text{ km}} \right) + 20 \log_{10} \left(\frac{f}{1 \cdot 10^{-6} \text{ MHz}} \right) + 20 \log_{10} \left(\frac{4\pi}{\frac{c_0}{\text{m/s}}} \right) \\ &\approx 32.4 + 20 \log_{10} \left(\frac{d}{\text{km}} \right) + 20 \log_{10} \left(\frac{f}{\text{MHz}} \right) \end{aligned}$$

3.2 Compute the FSPL for distances of 100 m, 1 km and 10 km at 1800 MHz.

3.3 What is the difference in FSPL if you reduce the frequency to 900 MHz?

3.4 What is the difference in FSPL if you increase the frequency by factor 10?