Corso di Laurea in Ingegneria Informatica, Biomedica e delle Telecomunicazioni

Corso di Campi Elettromagnetici
a.a. 2017-2018

18 Maggio 2018

Antenna Parameters

Introduction

- To describe the performance of an antenna, definitions of various parameters are necessary.
- Some of the parameters are interrelated and not all of them need be specified for complete description of the antenna performance.

Antenna Parameters

Parameters of the Tx Antenna

Parameters of the Rx Antenna

Tx Antenna parameters

- Effective length
  - Radiation pattern
  - Radiation pattern lobes
  - Beamwidth
- Directivity
- Gain
- Radiation Resistance
- Equivalent circuit of the tx antenna
- Input Impedance and Input Resistance

Parameters of the Tx Antenna

Effective length

$$r >> D$$

$$r > \frac{2D^2}{\lambda}$$

$$r >> \lambda$$

Fraunhofer region

$$\begin{cases} \mathbf{E}(\vec{\mathbf{r}}) = \mathbf{E}(r,\vartheta,\varphi) = \frac{j\zeta I}{2\lambda}\frac{e^{-j\beta r}}{r}\mathbf{l}(\vartheta,\varphi) \\ \zeta\mathbf{H}(\vec{\mathbf{r}}) = \hat{i}_r \times \mathbf{E}(\vec{\mathbf{r}}) \end{cases}$$

$\mathbf{l}(\vartheta,\varphi) = l_\vartheta(\vartheta,\varphi)\hat{i}_\vartheta + l_\varphi(\vartheta,\varphi)\hat{i}_\varphi$ is the **effective length** of the antenna

….. Memo ….

Elementary electrical dipole

$$\mathbf{E}(\vec{\mathbf{r}}) = \frac{j\zeta I}{2\lambda}\frac{e^{-j\beta r}}{r}\Delta z \sin\vartheta \,\hat{i}_\vartheta$$

$$\zeta\mathbf{H}(\vec{\mathbf{r}}) = \hat{i}_r \times \mathbf{E}(\vec{\mathbf{r}})$$

Small loop antenna

$$\mathbf{E}(\vec{\mathbf{r}}) = \frac{\zeta\beta\Delta S I}{2\lambda}\frac{e^{-j\beta r}}{r}\sin\vartheta \,\hat{i}_\varphi$$

$$\zeta\mathbf{H}(\vec{\mathbf{r}}) = \hat{i}_r \times \mathbf{E}(\vec{\mathbf{r}})$$

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$\mathbf{l}(\vartheta,\varphi) = l_{\vartheta}(\vartheta,\varphi)\hat{i}_{\vartheta} + l_{\varphi}(\vartheta,\varphi)\hat{i}_{\varphi}$ is the **effective length** of the antenna

Elementary electrical dipole $\mathbf{l}(\vartheta,\varphi) = \Delta z \sin\vartheta\,\hat{i}_{\vartheta}$

Small loop antenna $\mathbf{l}(\vartheta,\varphi) = -j\beta\Delta S \sin\vartheta\,\hat{i}_{\varphi}$

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Radiation pattern

- An antenna *radiation pattern* or *antenna pattern* is defined as “a mathematical function or a graphical representation of the radiation properties of the antenna as a function of space coordinates”.
- In most cases, the radiation pattern is determined in the *far- field region* and is represented as a function of the directional coordinates.

We can describe the angular behavior of the field radiated by the antenna by representing its effective length.

$$\mathbf{E}(\vec{\mathbf{r}}) = \mathbf{E}(r, \vartheta, \varphi) = \frac{j\zeta I}{2\lambda} \frac{e^{-j\beta r}}{r} \mathbf{l}(\vartheta, \varphi)$$

…memo…

In the Fraunhofer region the Poynting vector simplifies as $\mathbf{S} = \frac{1}{2\zeta} |\mathbf{E}|^2 \, \hat{i}_r$

Radiation pattern

a. *field* pattern (*in linear scale*) typically represents a plot of the magnitude of the electric or magnetic field as a function of the angular space.

b. *power* pattern (*in linear scale*) typically represents a plot of the square of the magnitude of the electric or magnetic field as a function of the angular space.

c. *power* pattern (*in dB*) represents the magnitude of the electric or magnetic field, in decibels, as a function of the angular space.

Radiation pattern

- Often the *field* and *power* patterns are properly normalized, yielding *normalized field* and *power patterns*

Radiation pattern

an example: the electrical elementary dipole

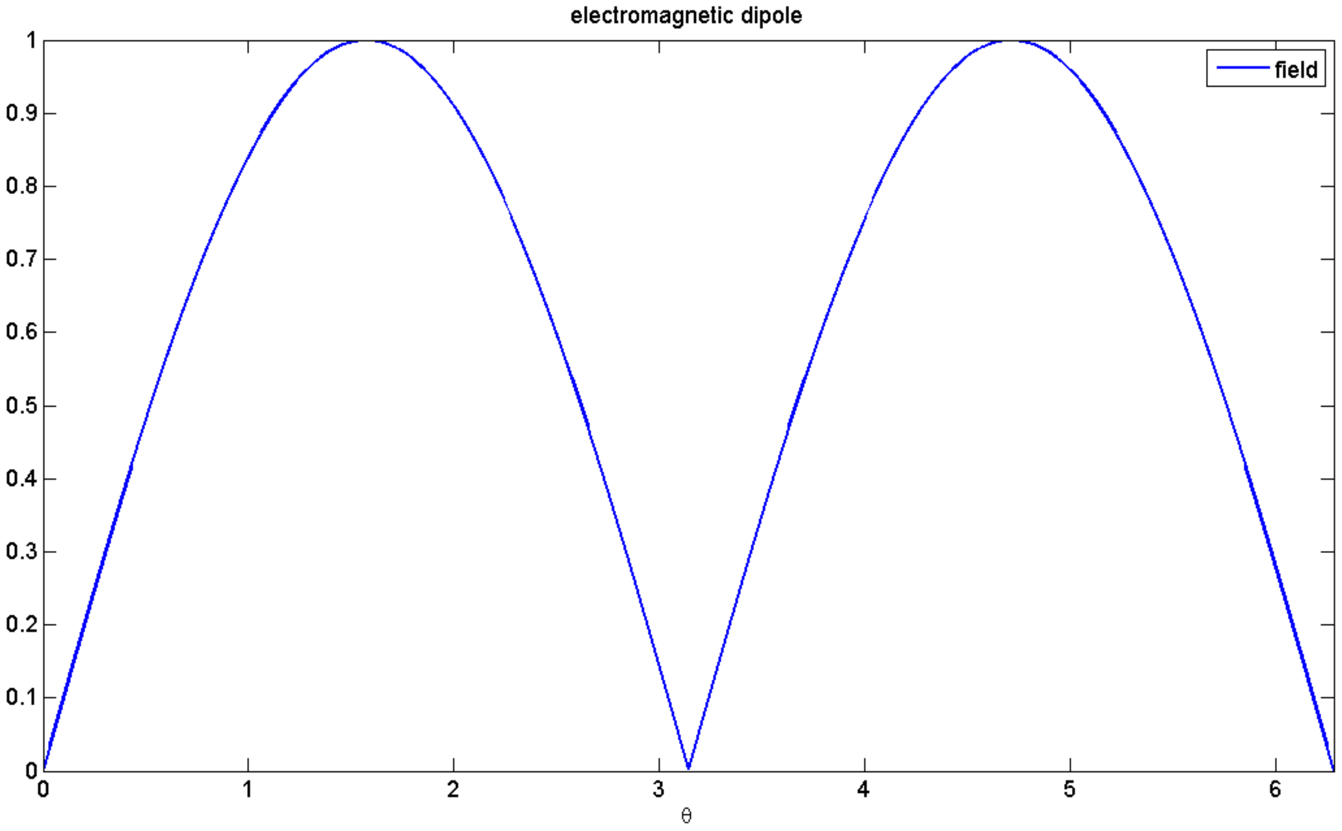
$$\mathbf{l}(\vartheta,\varphi)=\Delta z\sin\vartheta\,\hat{i}_{\vartheta}$$

Radiation pattern

an example: the electrical elementary dipole

$$\mathbf{l}(\vartheta,\varphi)=\Delta z\sin\vartheta\,\hat{i}_{\vartheta}$$

Vertical plane (φ=0)

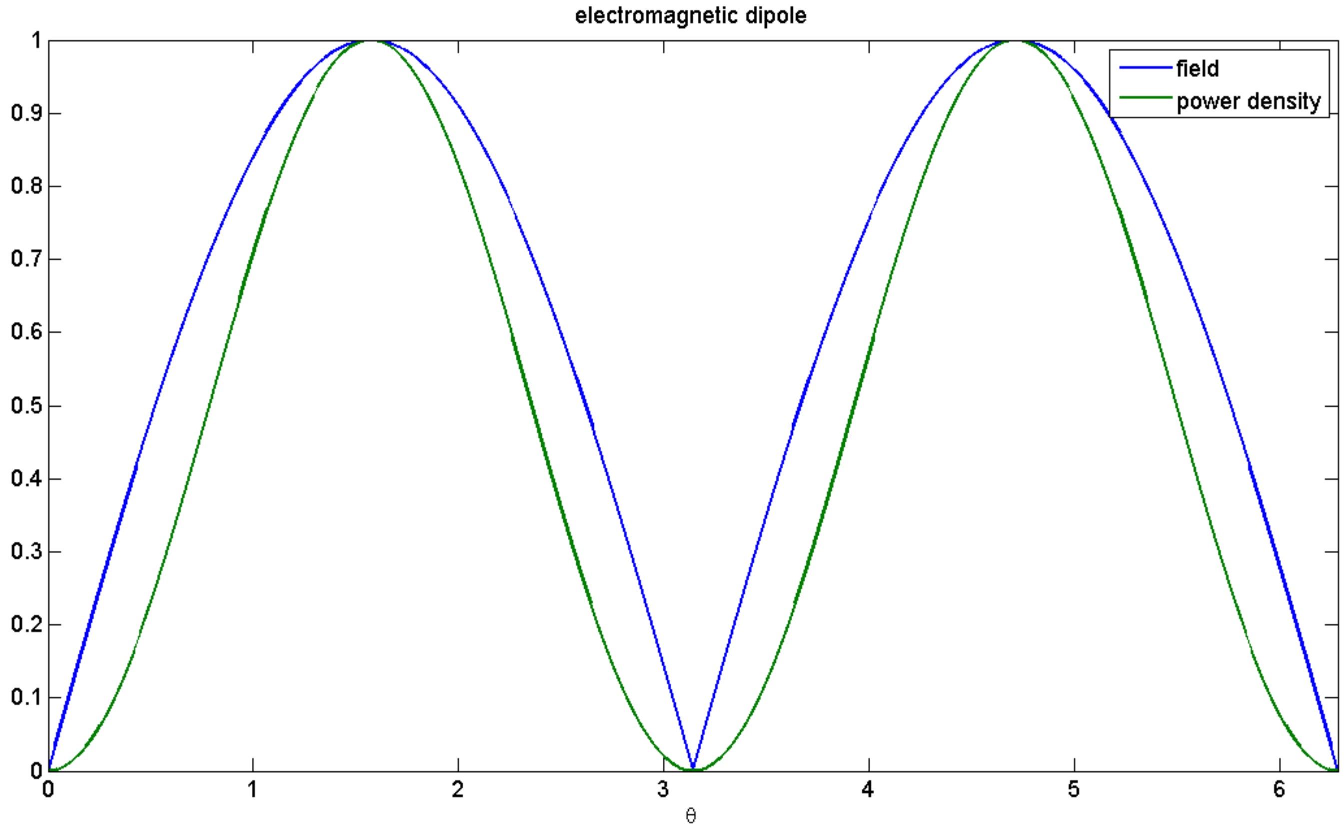


Radiation pattern

an example: the electrical elementary dipole

$$\mathbf{l}(\vartheta,\varphi) = \mathit{\Delta} z \sin\vartheta\, \hat{i}_{\vartheta}$$

Vertical plane (φ=0)



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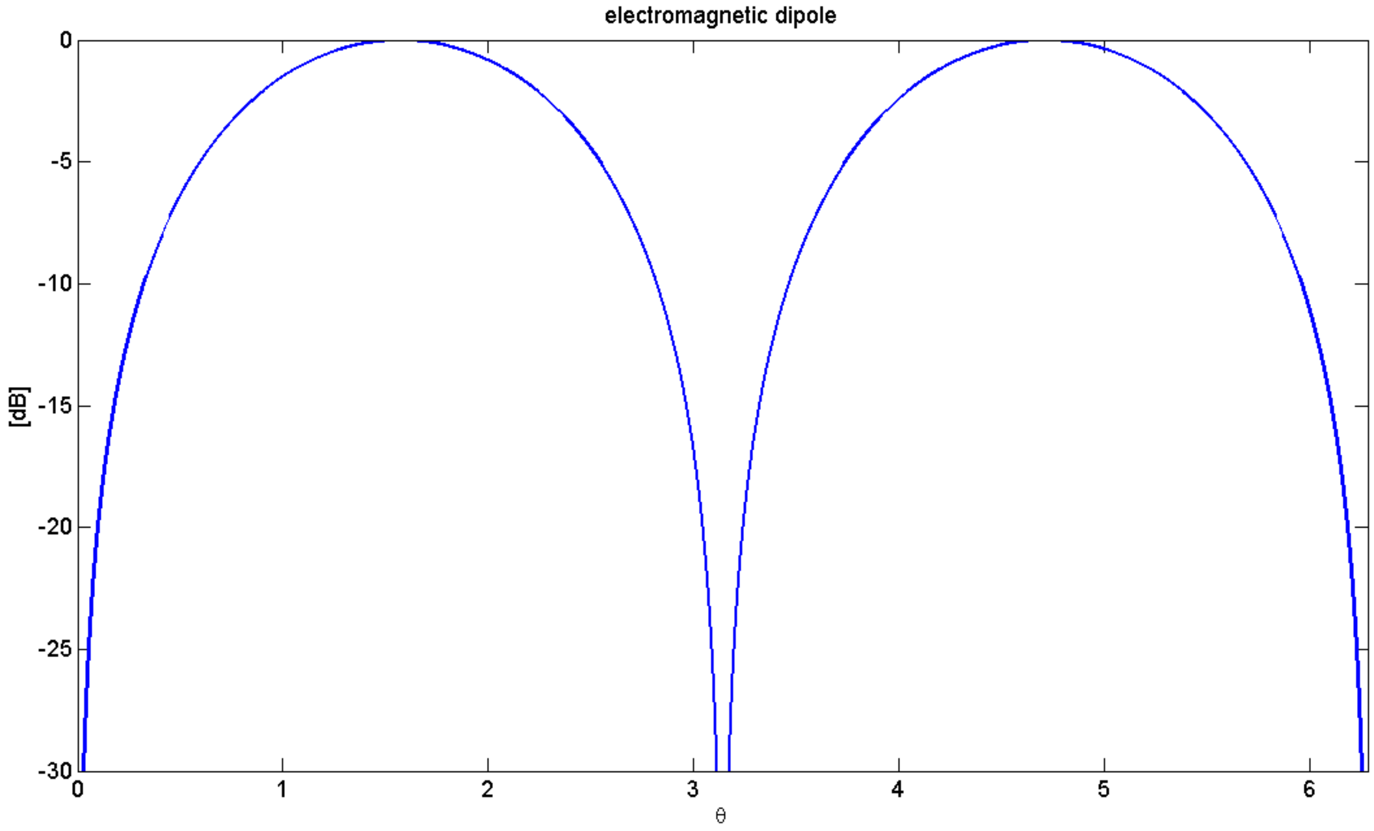

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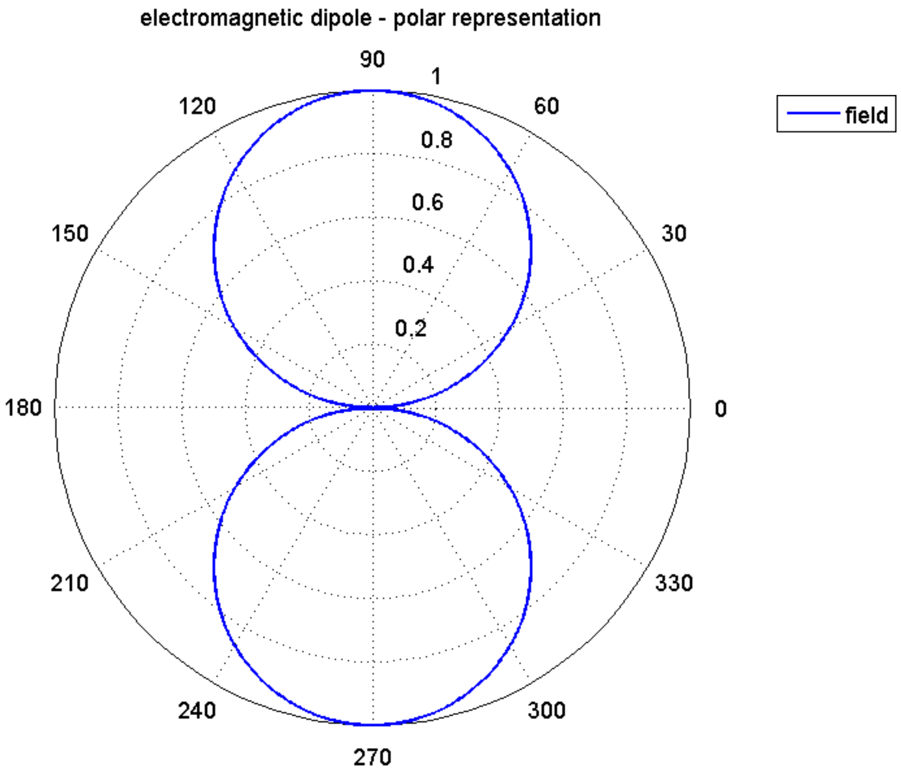

Radiation pattern

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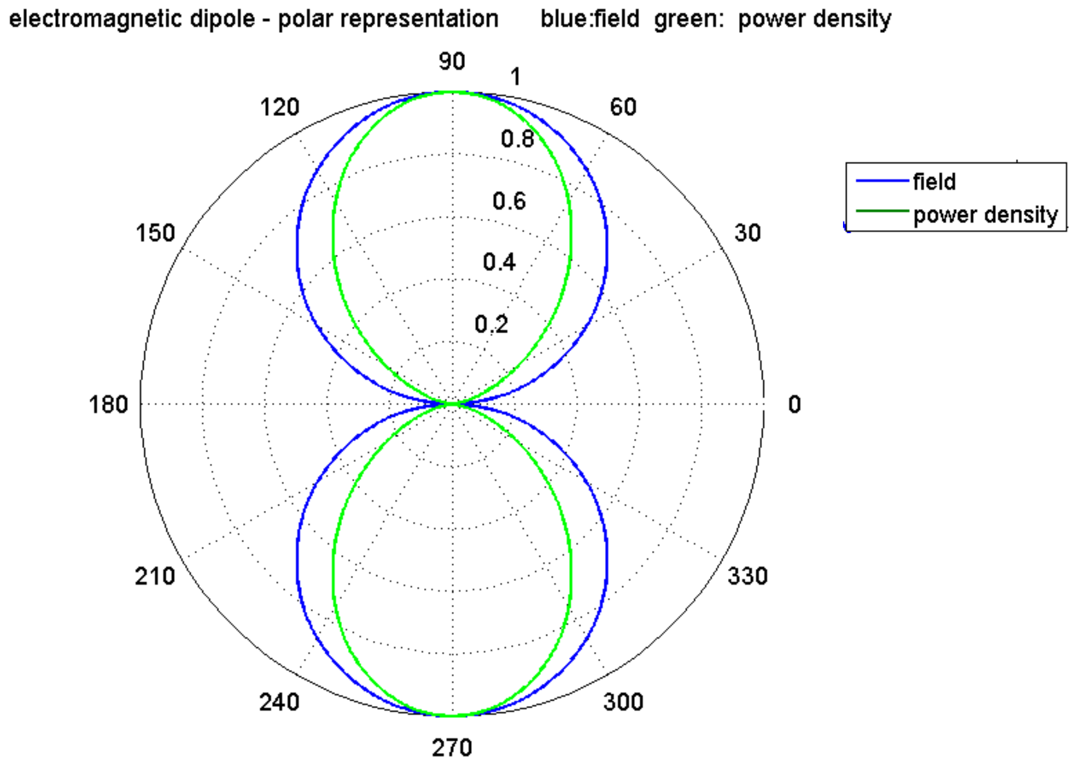

Radiation pattern

an example: the electrical elementary dipole

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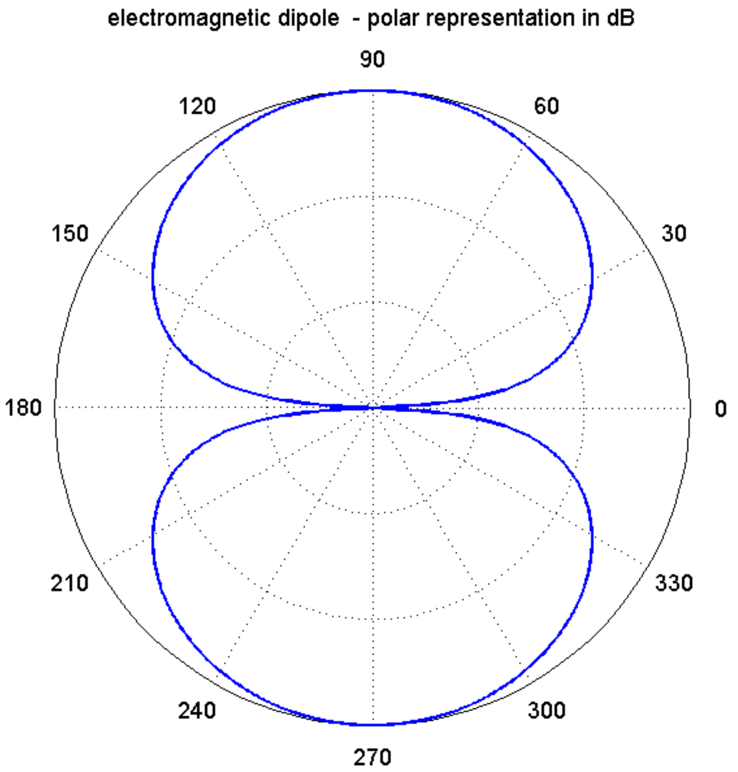
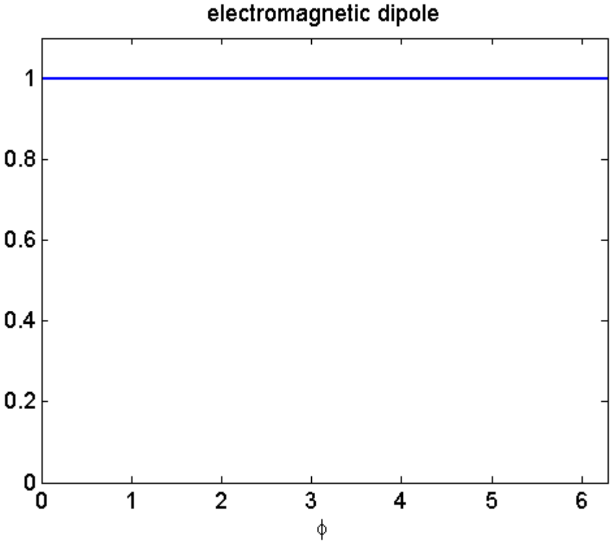


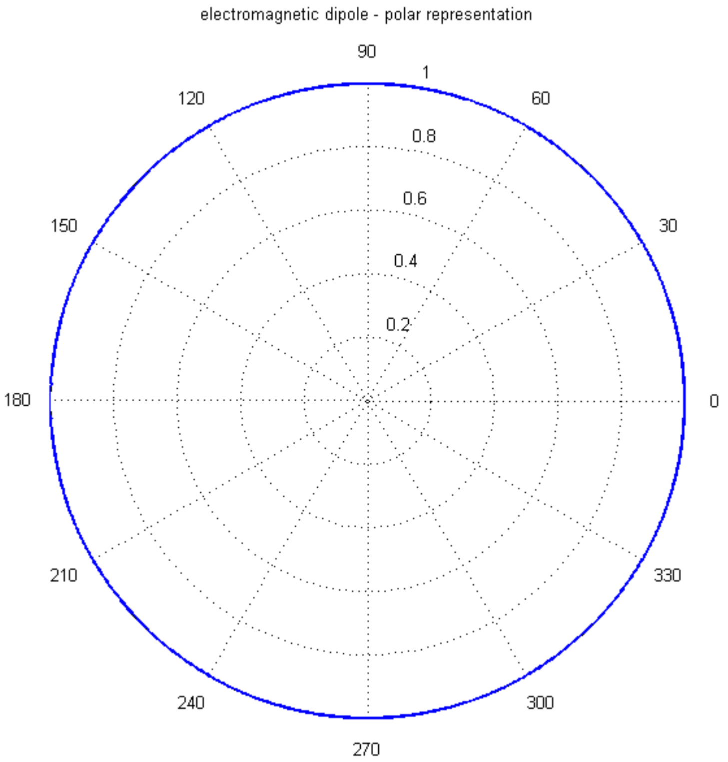
Radiation pattern

an example: the electrical elementary dipole

$$\mathbf{l}(\vartheta,\varphi)=\Delta z\sin\vartheta\,\hat{i}_{\vartheta}$$

Horizontal plane (θ=π/2)



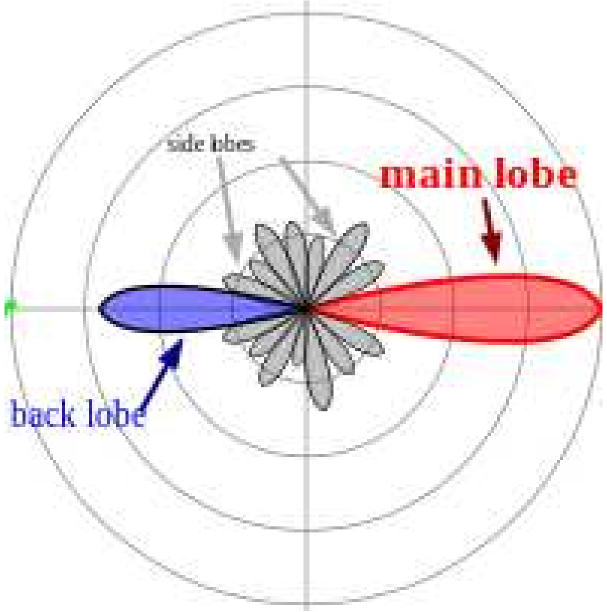


Tx Antenna parameters

- Effective length
  - Radiation pattern
  - Radiation pattern lobes
  - Beamwidth
- Directivity
- Gain
- Radiation Resistance
- Equivalent circuit of the tx antenna
- Input Impedance and Input Resistance

Radiation pattern

- It is clear in figure that in some very specific directions there are zeros, or *nulls*, in the pattern indicating no radiation.
- The protuberances between the nulls are referred to as *lobes*, and the main, or major, lobe is in the direction of maximum radiation.
- There are also *side lobes* and *back lobes*.
- A *back lobe* is "a radiation lobe whose axis makes an angle of approximately 180◦ with respect to the beam of an antenna." Usually it refers to a minor lobe that occupies the hemisphere in a direction opposite to that of the major (main) lobe.
- *Side lobes* and *back lobes* divert power away from the main beam and are desired as small as possible.

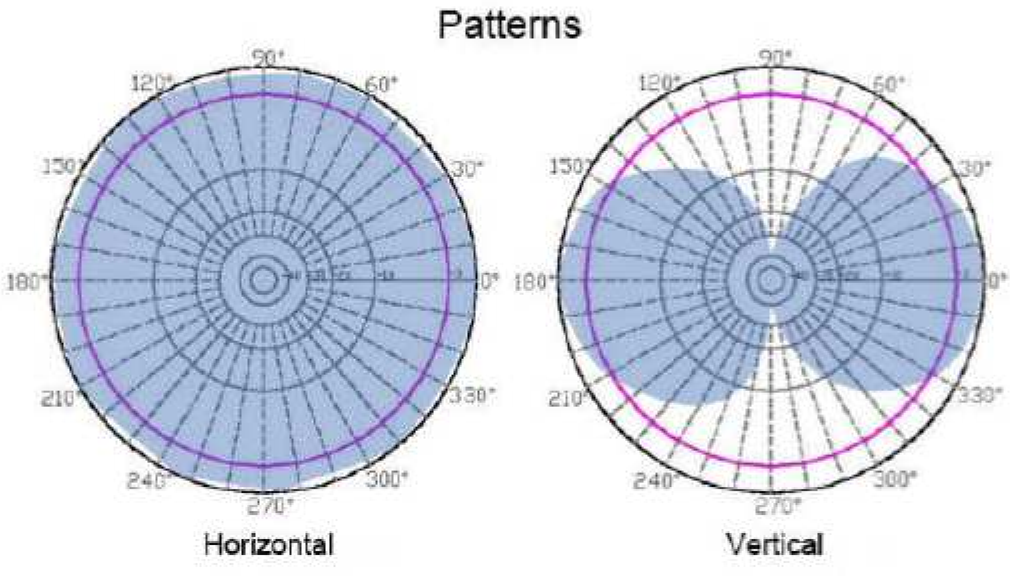


Radiation pattern

three examples from the real life

Radiation pattern

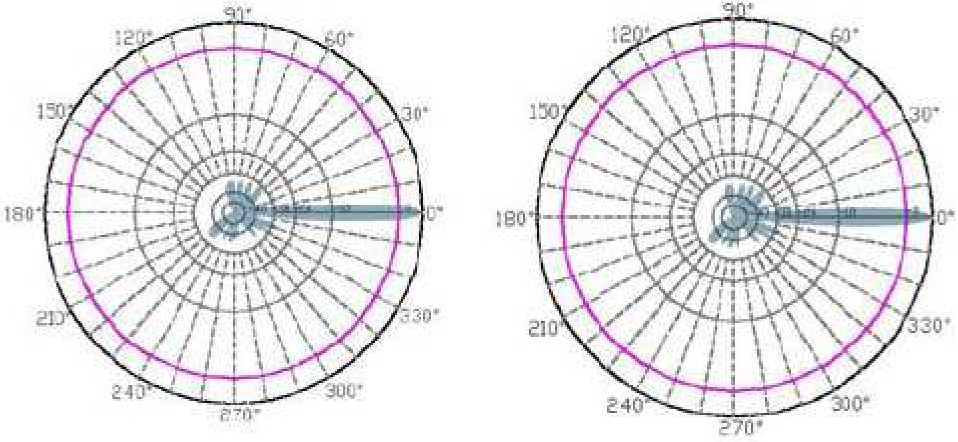
three examples from the real life



ZDAEW1900-3 **Patterns**

Radiation pattern

three examples from the real life



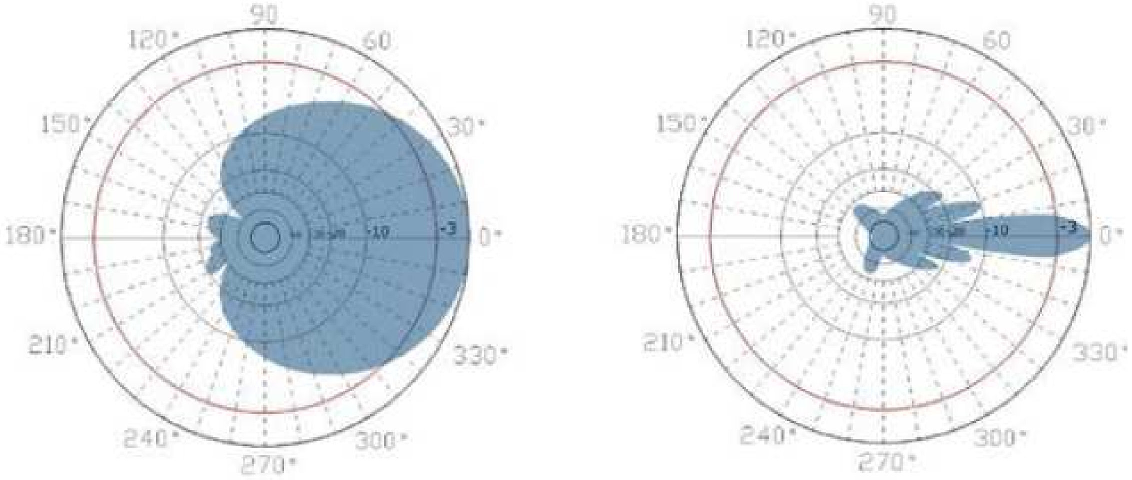
Horizontal

Vertical

ZDASP5400-29-6 **Patterns**

Radiation pattern

three examples from the real life



Horizontal

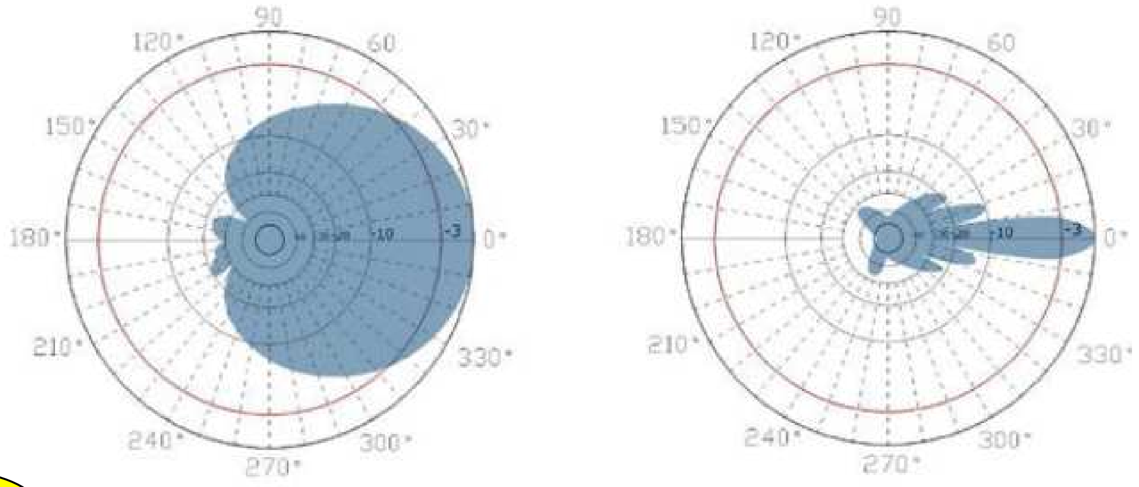
Vertical

ZDADJ800-13-90 Patterns

Radiation pattern

three examples from the real life

….they should be isotropic in the horizontal plane!!



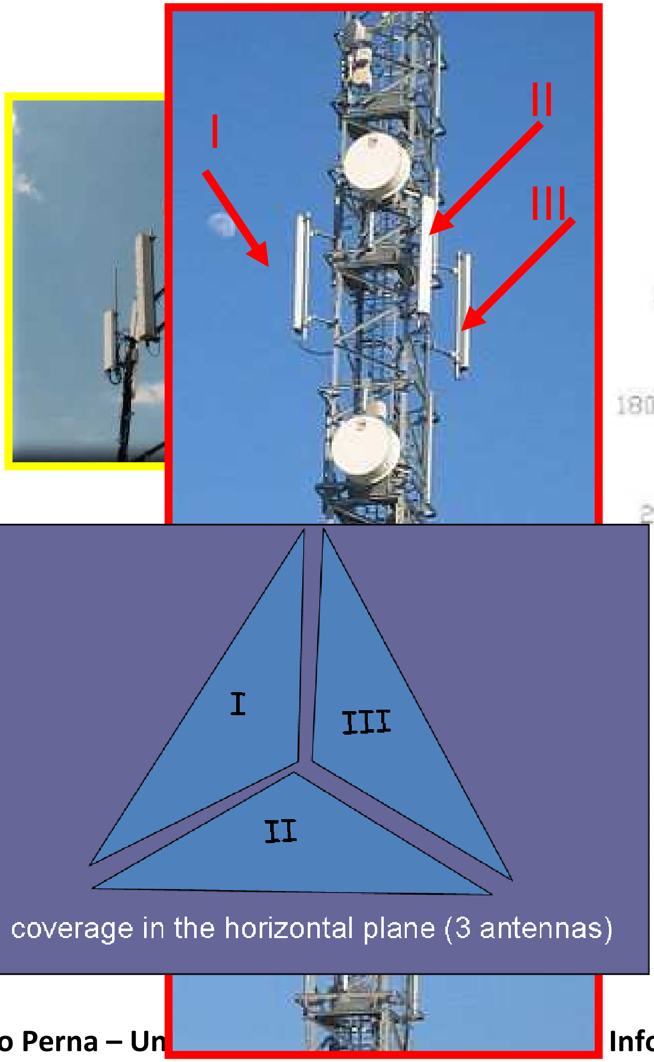
Horizontal

Vertical

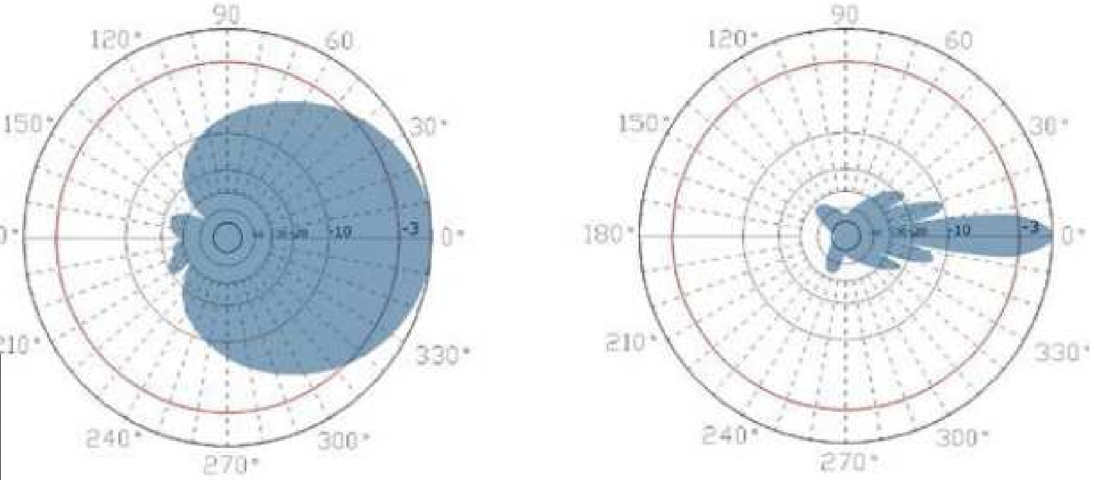
ZDADJ800-13-90 Patterns

Radiation pattern

three examples from the real life



Cell coverage in the horizontal plane (3 antennas)



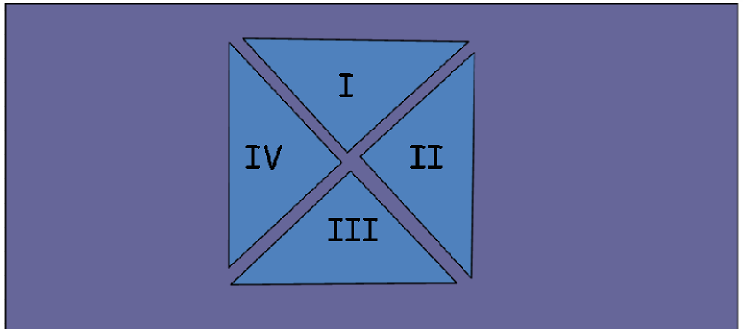
Horizontal

Vertical

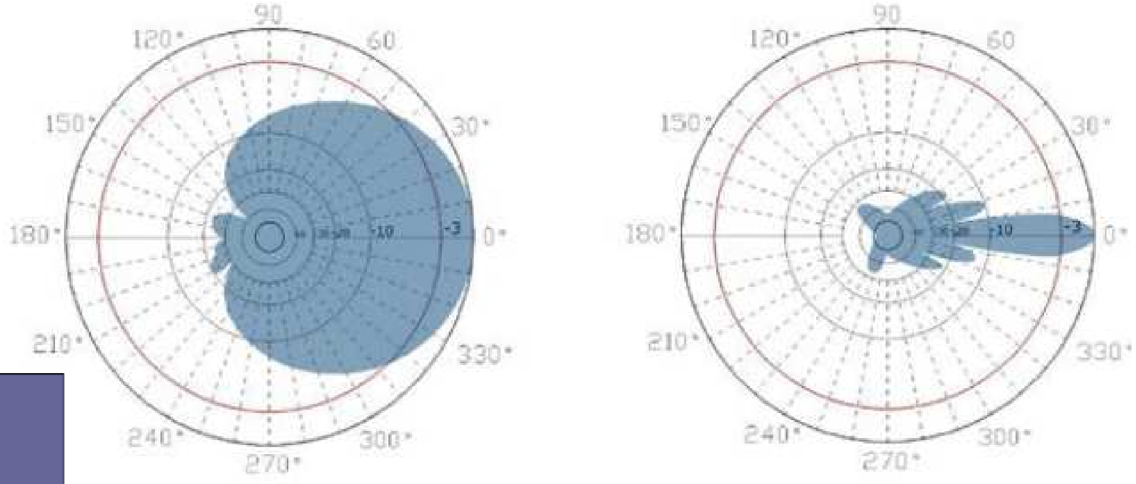
ZDADJ800-13-90 Patterns

Radiation pattern

three examples from the real life



Cell coverage in the horizontal plane (4 antennas)



Horizontal

Vertical

ZDADJ800-13-90 Patterns

Tx Antenna parameters

- Effective length
    - \- Radiation pattern
    - \- Radiation pattern lobes
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Radiation pattern

Beamwidth

- Associated with the pattern of an antenna is a parameter designated as *beamwidth*.
- The *beamwidth* of a pattern is defined as the angular separation between two identical points on opposite side of the pattern maximum.

Radiation pattern

Beamwidth

There are a number of different definitions for the beamwidth

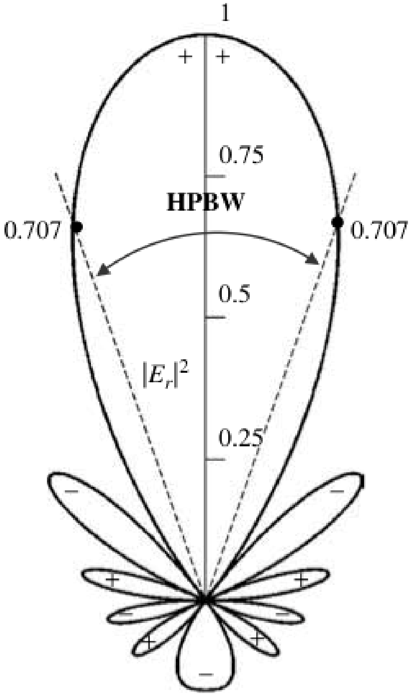
- One of the most widely used is the *Half-Power Beamwidth* (*HPBW*), or 3-dB beamwidth.
- Another one is the angular separation between the two nulls, and it is referred to as the *First-Null Beamwidth* (*FNBW*).

Radiation pattern

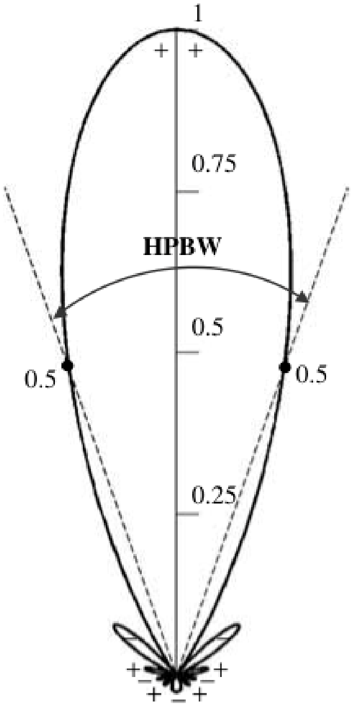
Beamwidth

Two-dimensional normalized *field* pattern (*linear scale*)

Two-dimensional normalized *power* pattern (*linear scale*)



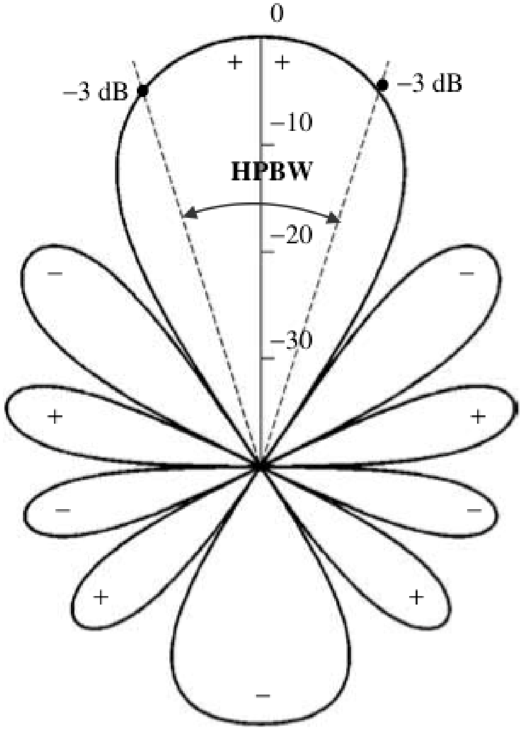
(a) Field pattern (in linear scale)



(b) Power pattern (in linear scale)

Radiation pattern

Beamwidth



(c) Power pattern (in dB)

Two-dimensional normalized *power* pattern (*in dB*)

Radiation pattern

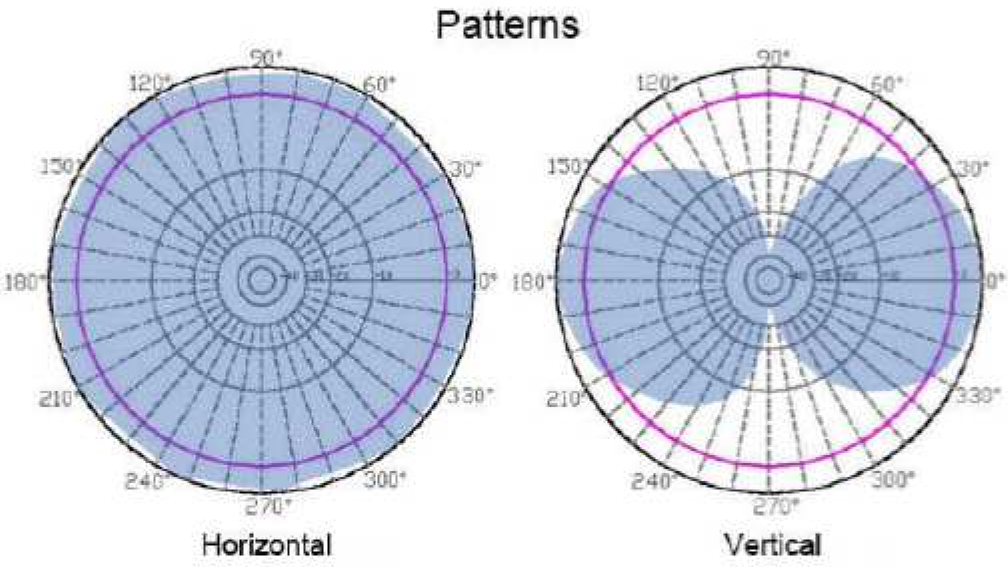
three examples from the real life

Radiation pattern

three examples from the real life

HPBW (vertical) =60°

HPBW (horizontal) =360°



Patterns

Horizontal

Vertical

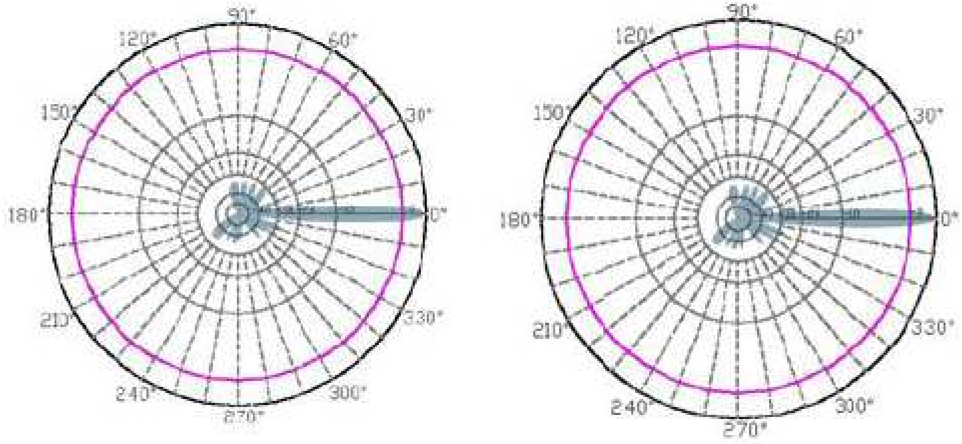
ZDAEW1900-3 **Patterns**

Radiation pattern

three examples from the real life

HPBW (vertical) = 6°

HPBW (horizontal) = 6°



Horizontal

Vertical

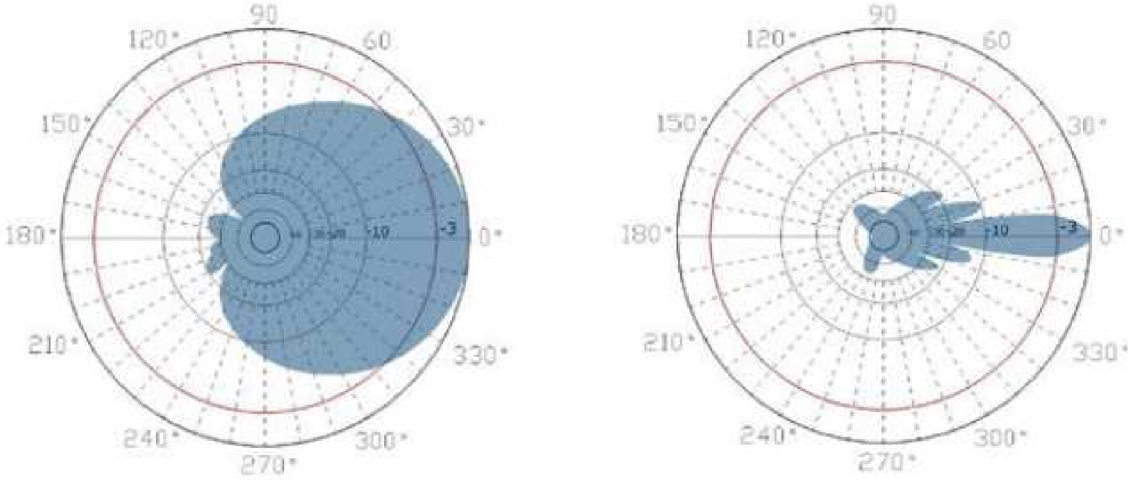
ZDASP5400-29-6 **Patterns**

Radiation pattern

three examples from the real life

HPBW (vertical) = 14°

HPBW (horizontal) =90°



Horizontal

Vertical

ZDADJ800-13-90 Patterns