TECHNISCHE UNIVERSITÄT WIEN

institute of telecommunications

Antennas – an Introduction to Types, Parameters and Measurements

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xtest - Antenna Seminar
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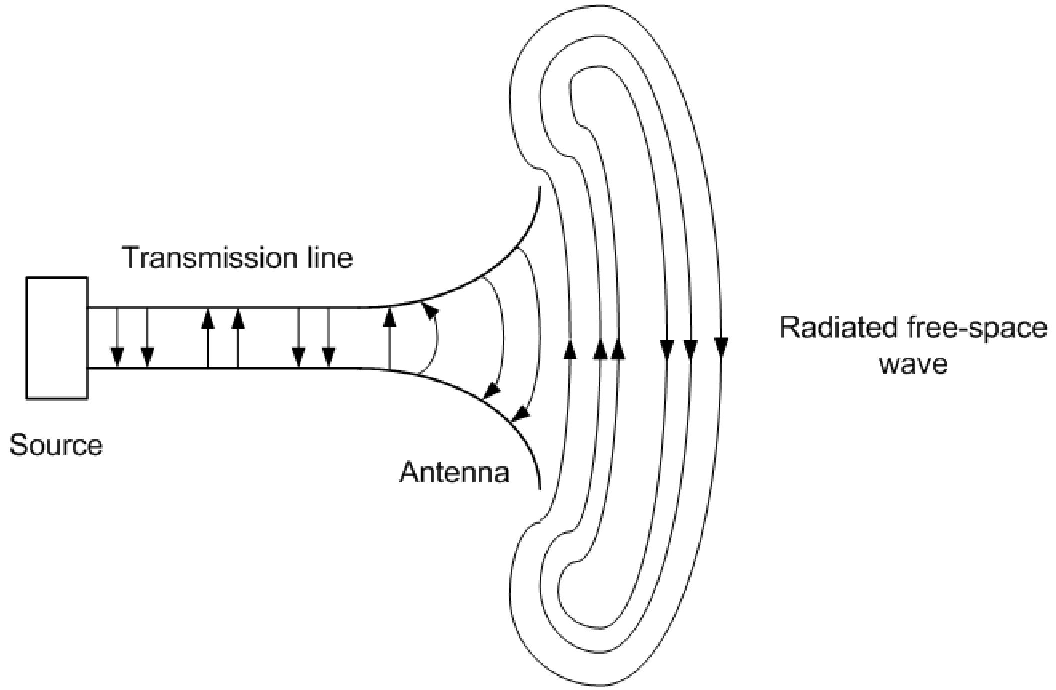
Outline

- Part I – Types and Parameters
  - What's an Antenna?
  - Antenna Types
  - Antenna Regions
  - Typical Antenna Parameters

- Part II – Antenna Measurements
  - Far Field Range
  - Near Field Range
  - Outdoor Range
  - Anechoic Chamber

Antenna Definition

The *IEEE Standard Definitions of Terms for Antennas* defines the antenna as „a means for radiating and receiving radio waves.“ In other words the antenna is the transitional structure between free-space and a guiding device.



Source: C. A. Balanis, Antenna Theory, John Wiley & Sons, Inc., 2005

Antenna Types

Monopol Antenna

Dipol Antenna

UKW Antenna

Yagi-Uda Antenna

Patch Antenna

Slot Antenna

Reflector Antenna

Back Fire Antenna

Loop Antenna

Resonant Antenna

Log Periodic Antenna

Sector Antenna

5G Antenna

Broadband Antenna

Ground Plane Antenna

UWB Antenna

Microstrip Antenna

Massive MIMO Antenna

Multiband Antenna

Directional Antenna

Vertical Antenna

NFC Antenna

Omidirectional Antenna

Planar Antenna

Horn Antenna

Discone Antenna

TX Antenna

MIMO Antenna

Panorma Antenna

Passive Antenna

Dielectric Lens Antenna

RX Antenna

Active Antenna

Spiral Antenna

Integrated Antenna

Array Antenna

Chip Antenna

Inverted-F Antenna

Wearable Antenna

Helical Antenna

On-Chip Antenna

Biconical Antenna

How to Group this Amount of Antennas?

- Some names just say something about realisation aspects:

  Chip Antenna Wearable Antenna Planar Antenna Integrated Antenna

- Some names tell us the intended communication standard:

  UKW Antenna NFC Antenna UWB Antenna 5G Antenna

- Some names share information about some antenna parameters:

  Omidirectional Antenna Directional Antenna Sector Antenna Dual Polarized Antenna

- Some names give us information about the antenna form factor

  Horn Antenna Helical Antenna Spiral Antenna Biconical Antenna

How to Group this Amount of Antennas?

- Some names tell us there is more than just the “Antenna”:

  MIMO Antenna Massive MIMO Antenna Beamforming Antenna Active Antenna

- Use a Design Principle:

  Slot Antenna Reflector Antenna Ground Plane Antenna

- Use Well Known Basic Antennas:

  Dipol Antenna Monopol Antenna Loop Antenna

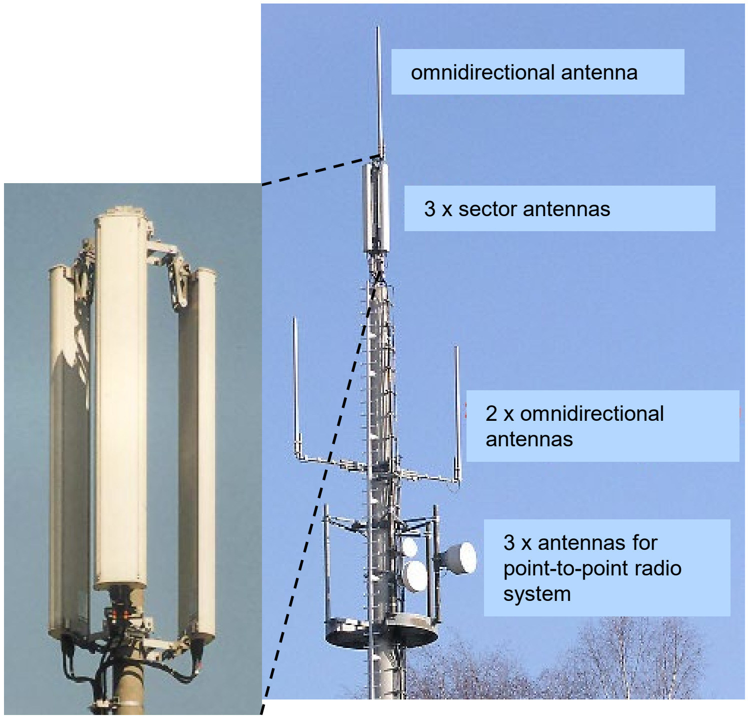
- Finally an Antenna can be operated :

  in resonance or off resonance

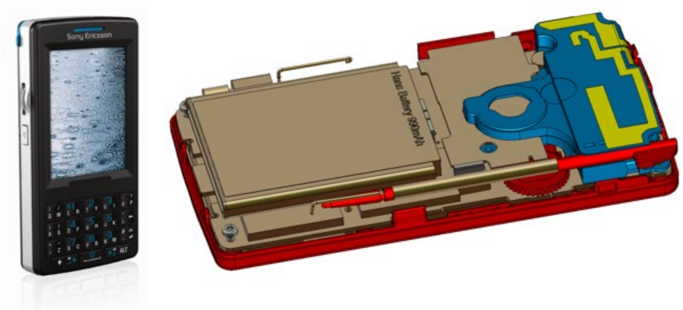
Mobile Communication System

A mobile communication system relies on the wireless communication between a base station and a mobile phone.

Base station (radio mast)



Mobile phone (with integrated antenna)



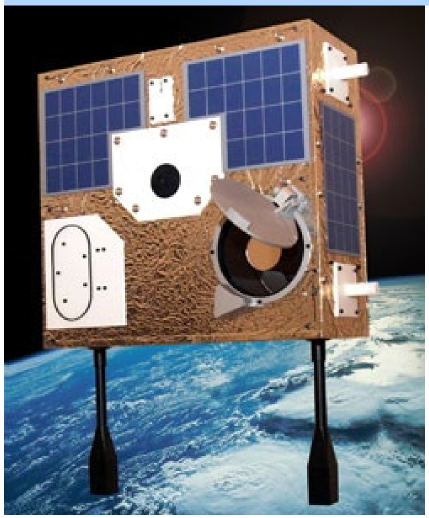
Global system for mobile communications (GSM):
Downlink (base station to mobile phone communication link): 925-960MHz,
Uplink (mobile to base station): 880-915MHz

Source: www.elektrosmoginfo.de, www.cst.com

Satellite Communication System

A satellite communication system relies on the wireless communication between a satellite orbiting the Earth and a ground station on the Earth.

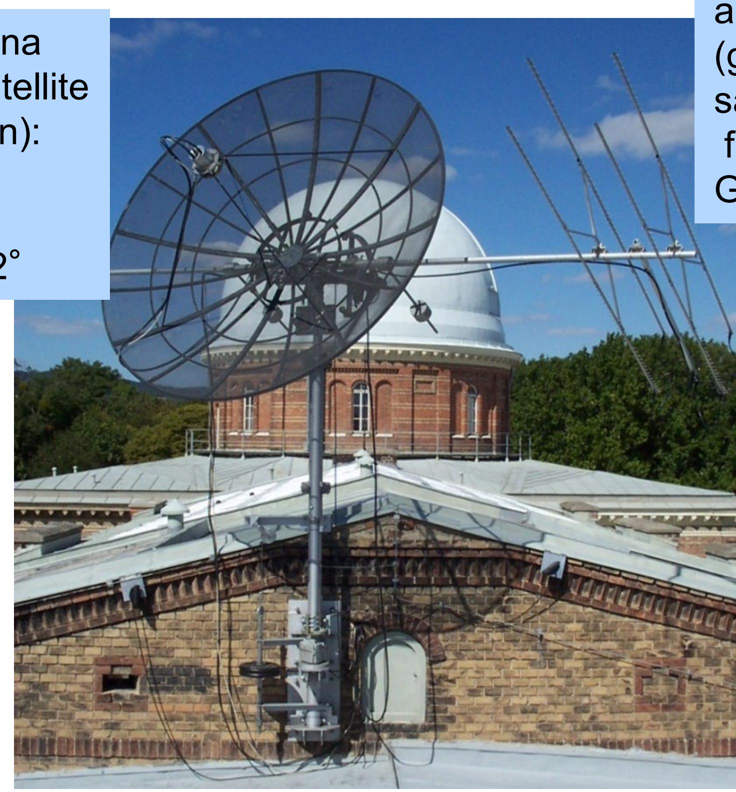
Omnidirectional antennas
Gain 0 dBi



Source:
http://www.mscinc.ca/products/most.html

Parabolic antenna for downlink (satellite to ground station):
f=2.23GHz,
Gain 34.1dBi
Beam width: 3.2°

4 coupled Yagi antennas for uplink (ground station to satellite):
f=2.05GHz,
Gain = 25dBi



Source: W. Keim, „Scientific Satellite Ground Station at 2 GHz in Urban Environment“ (2004)

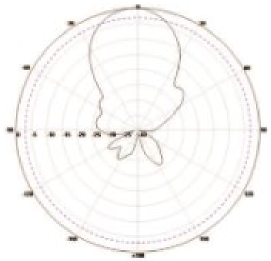
A “Typical” Data Sheet

Highlights

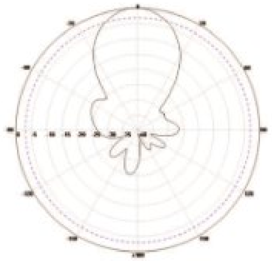
FANT-04ABGN-1414-P-N

This high density 14 dBi patch antenna is well suited for use outdoors, in warehouses, or in manufacturing environments where it must withstand exposure to moisture and dust. The antenna features a 35-degree beamwidth at both the 2.4GHz and 5GHz bands which helps to minimize co-channel interference. This antenna features four dual band N-Type jacks on the back of the antenna.

SPECIFICATIONS		
Frequency Range	2400-2500 MHz	5150-5850 MHz
Bandwidth	100 MHz	700 MHz
Gain	14 dBi	14 dBi
Vertical Beamwidth	35°	35°
Horizontal Beamwidth	35°	35°
VSWR	≤2	
Nominal Impedance	50 ohms	
Polarization	Vertical / Linear	
Isolation	≤28dB	
Max Power	50 Watts	
Connectors	N-Type Male	
Pigtail Length	Need to order separately	
Mounting Method	Mast Mounting	
Dimensions	14.96 in. x 14.96 in. x 1.3 in. (38 cm x 38 cm x 3.3 cm)	
Weight	7.5 lbs. (3.4 kg)	
Pole Diameter	1.97 in. - 4.7 in. (5 cm to 11.94 cm)	
Environment	Indoor / Outdoor	
Operating Temperature	-22°F to +158°F (-30°C to +70°C)	



H Plane

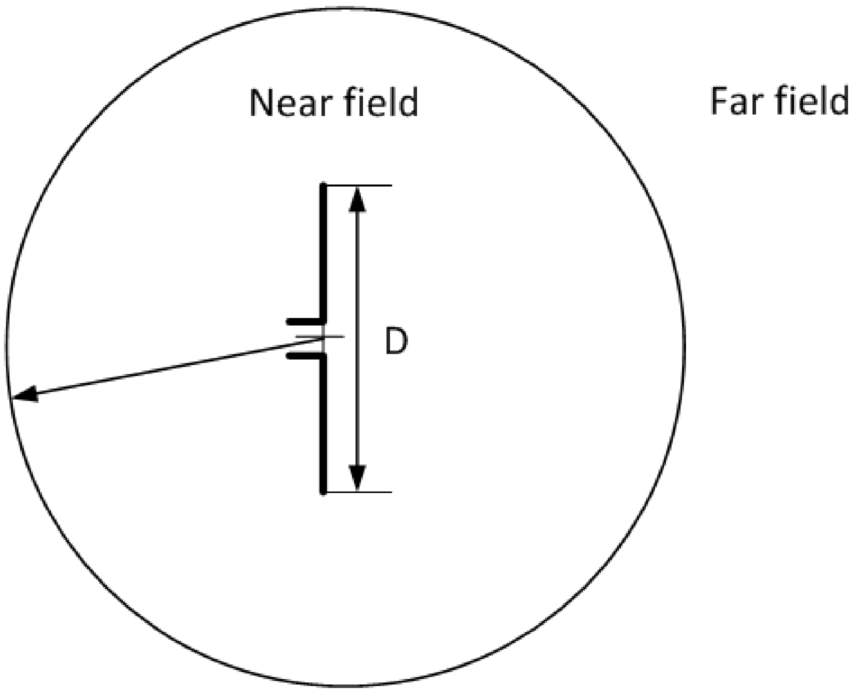


E Plane

Near Field / Far Field

The Rayleigh distance distinguishes between the antenna's near field and far field. The angular distribution of the energy does not change with distance in the far field of the antenna.

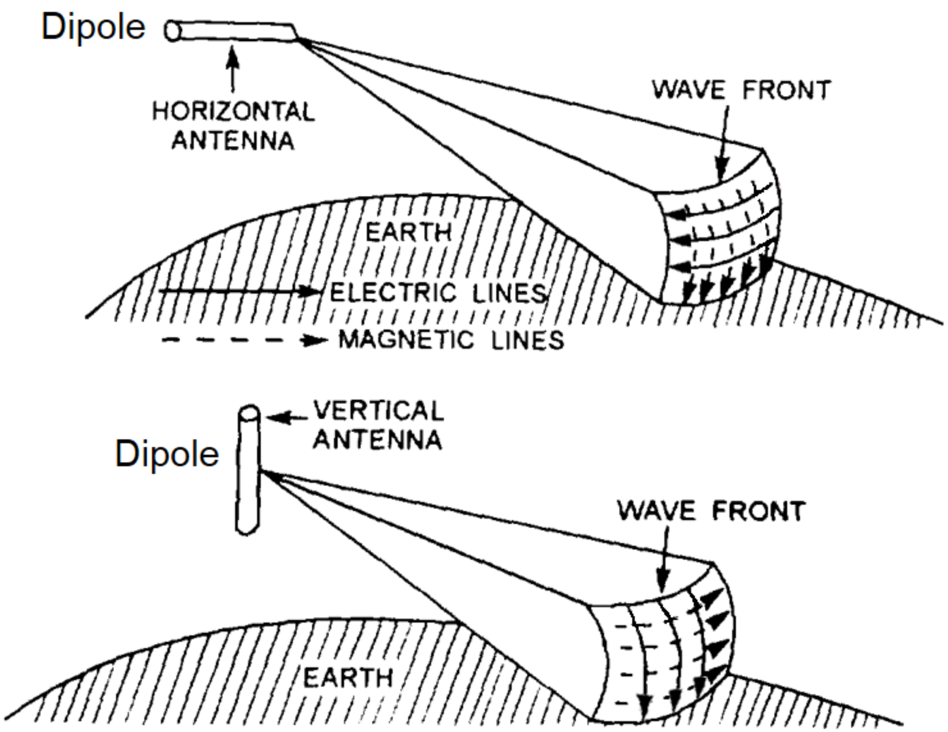
$$d_{Rayleigh} = \frac{2D^2}{\lambda} + \lambda$$



For very small antennas (D<< λ) this leads to too small values

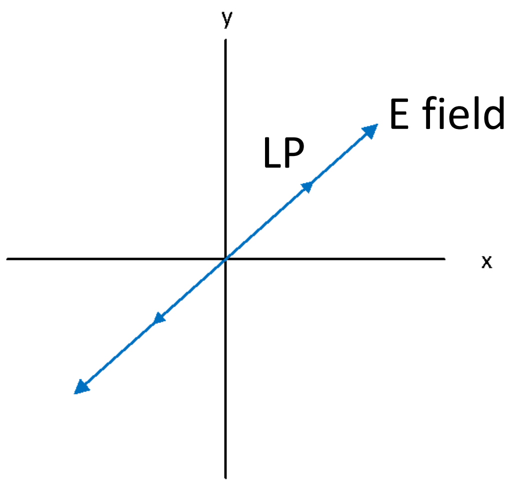
Polarization

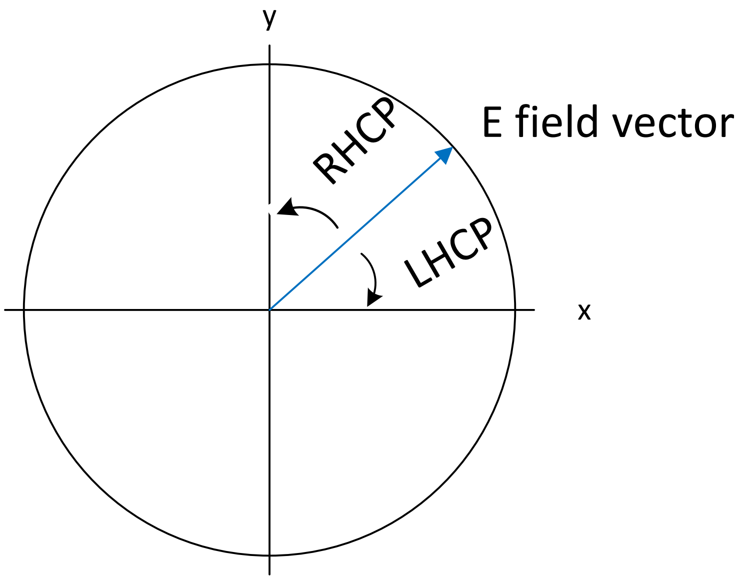
The polarization describes the orientation of the electric field vector in the far field. In Earth-bound applications polarization frequently is given with respect to the Earth's surface. Polarization is determined by the physical structure of the antenna and by its orientation.



Source: US Navy, Electronics Technician, Volume 7-Antennas and Wave Propagation, 1995

Linear and Circular Polarization





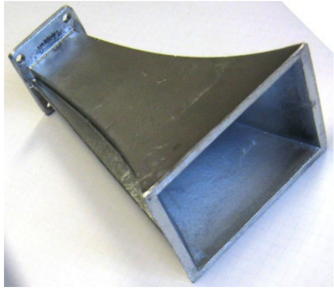
LP….linearly polarized

RHCP….right-hand circularly polarized

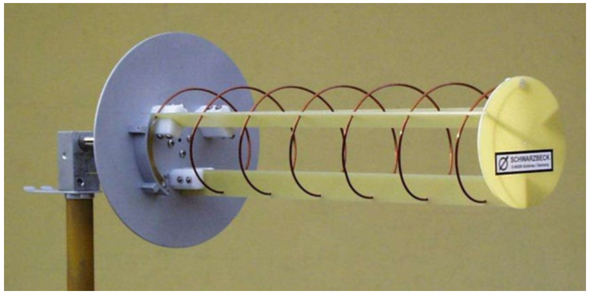
LHCP….left-hand circularly polarized

Antenna Examples

- linear polarized antennas:
  - Monopol antennas
  - Dipol antennas
  - Horn antennas



- Circular polarized antennas:
  - Helix antennas
  - Spiral antennas
  - Horn antennas



Source:
http://schwarzbeck.de/Datenblatt/khlx0810L.pdf

Cross Polarization Ratio

- Two orthogonal polarizations are called cross polarized
  e.g. horizontally and vertically, right-hand and left-hand

- Antennas can only interact with EM Fields equally (co)-polarized as the antenna it self.

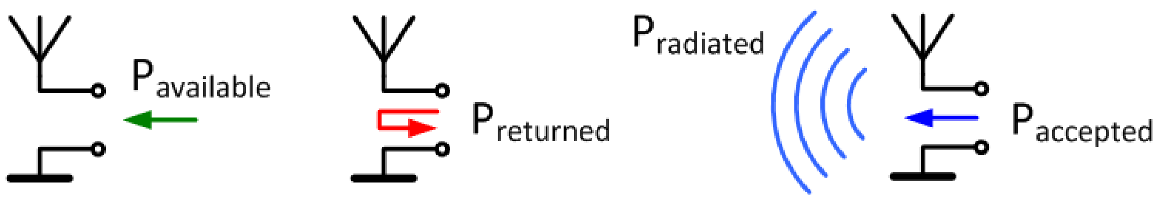
- A minimum (in theory zero) reception is possible of an orthogonal polarized antenna.
  e.g. a horizontally polarized antenna can not receive from an vertically polarized antenna

- This discrimination of the orthogonal polarization is specified with the ratio of the cross polarized to co-polarized reception – Cross Polarization Ratio

Radiation Efficiency

The radiation efficiency of an antenna takes into account losses. It is defined as the radiated power divided by the accepted power:

$$\eta = \frac{P_{radiated}}{P_{accepted}}$$

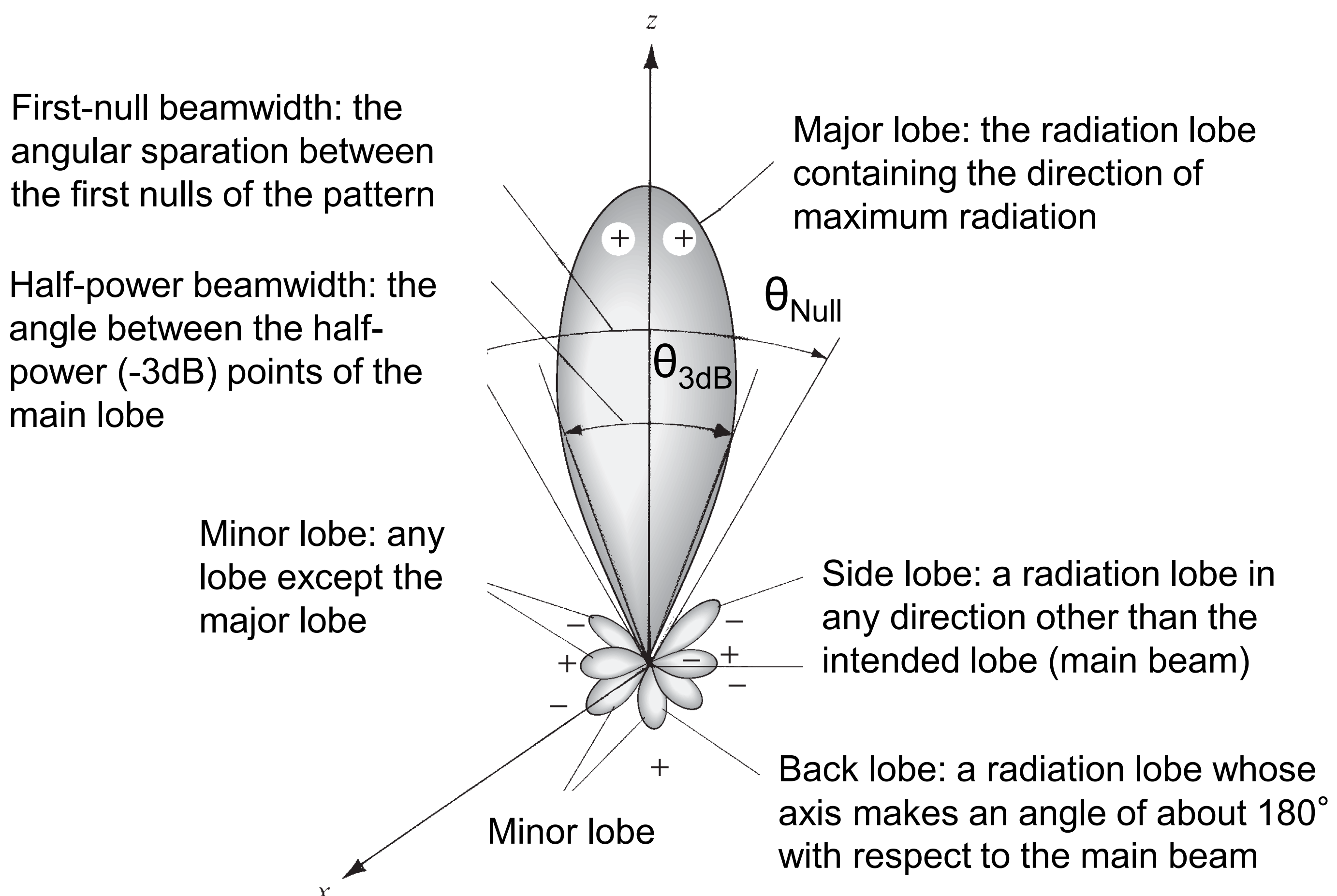


Caution: often different "definitions" are used e.g.

$$\eta = \frac{P_{radiated}}{P_{available}}$$

Radiation Pattern

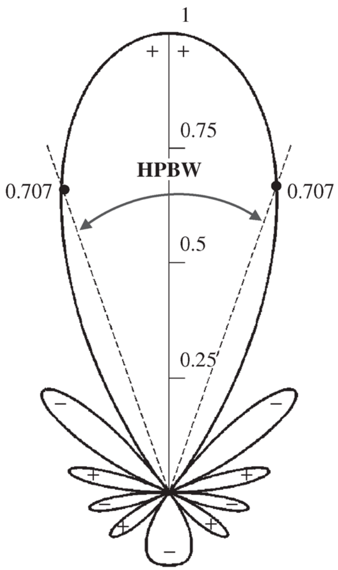
The radiation pattern of an antenna is a graphical representation of the radiation properties of the antenna. In the far field, the shape of the radiation pattern is independent of distance.



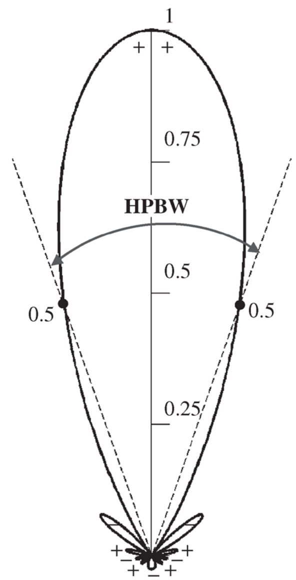
Source: C. A. Balanis, Antenna Theory, John Wiley & Sons, Inc., 2005

Radiation Pattern

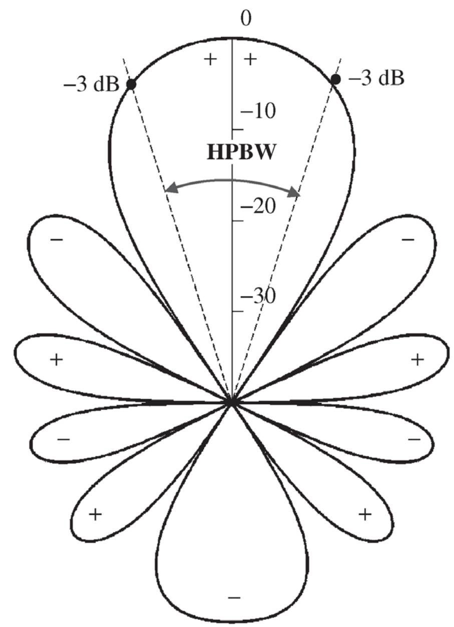
Examples for graphical representation of a radiation pattern of a 10-element linear antenna array.



Field pattern (linear)



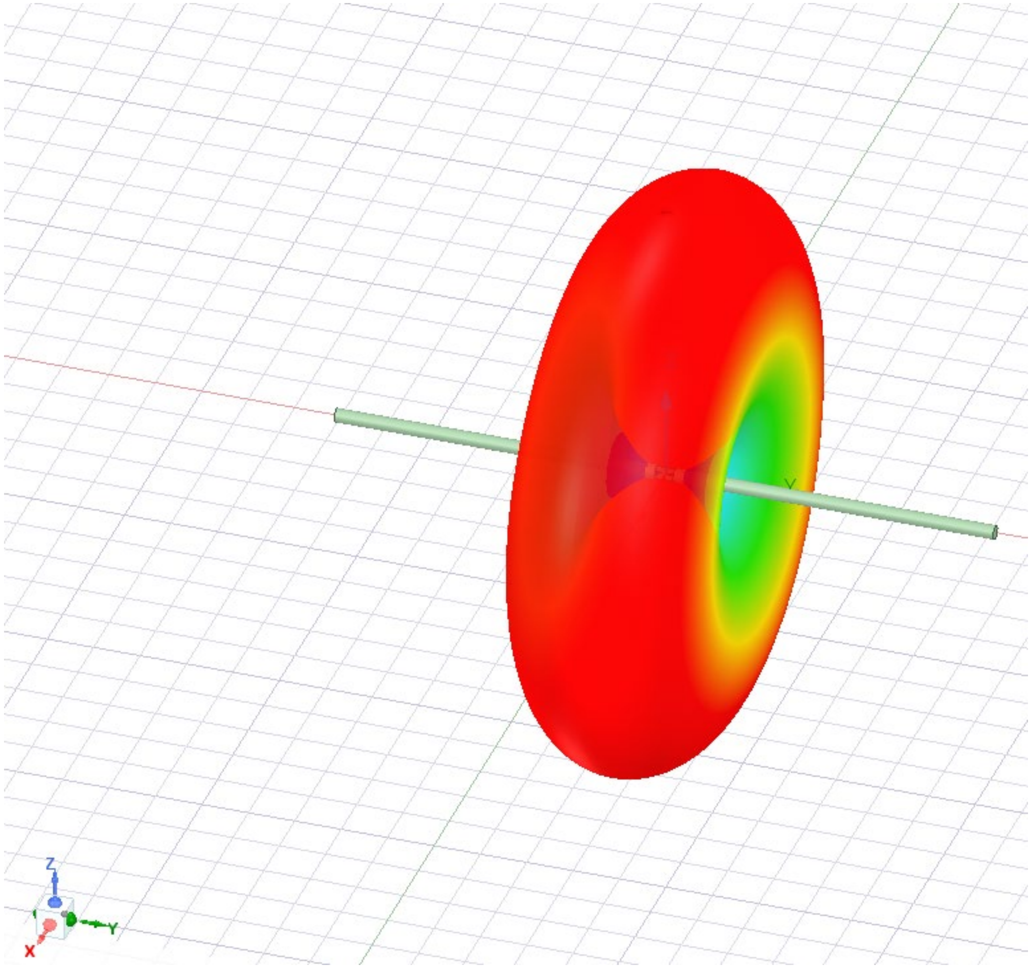
Power pattern (linear)



Power pattern (dB): accentuate in more detail those parts of the pattern that have very low values

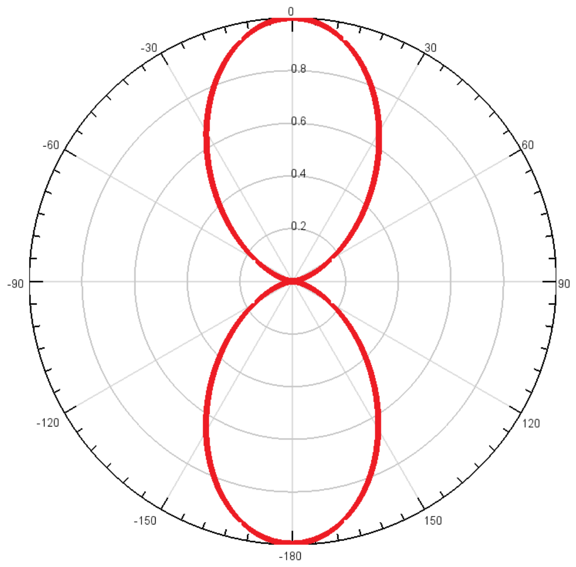
Source: C. A. Balanis, Antenna Theory, John Wiley & Sons, Inc., 2005

3D Radiation Pattern – Example Dipol

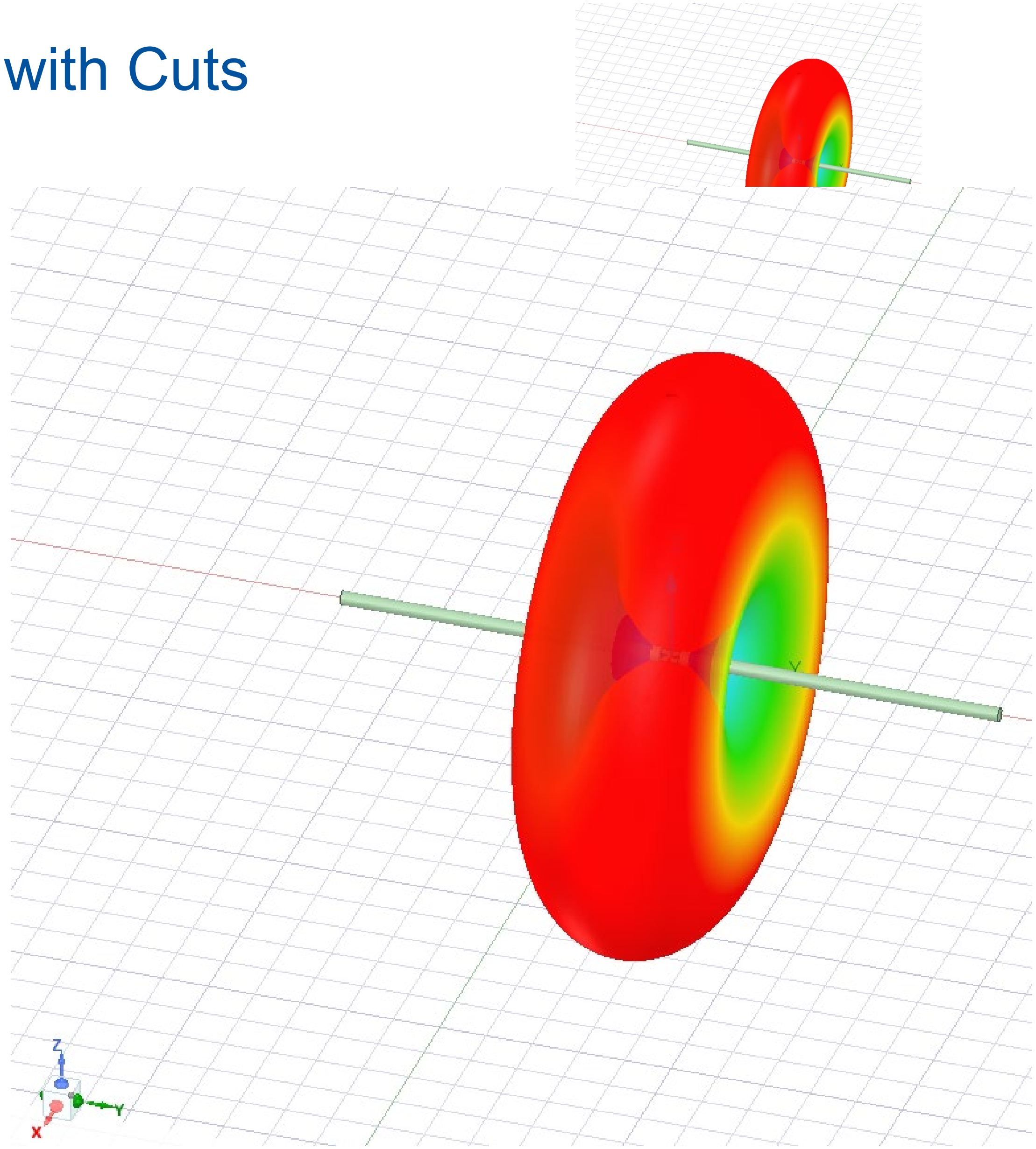


Pattern Representation with Cuts

Horizontal Cut
Azimut Plane



E-Plane



Antenna Gain

Gain is defined relative to a reference antenna, and usually given in Decibels versus the reference.

Frequently, the reference antenna is a lossless isotropic radiator. The respective reference antenna is normally indicated by a superscript.

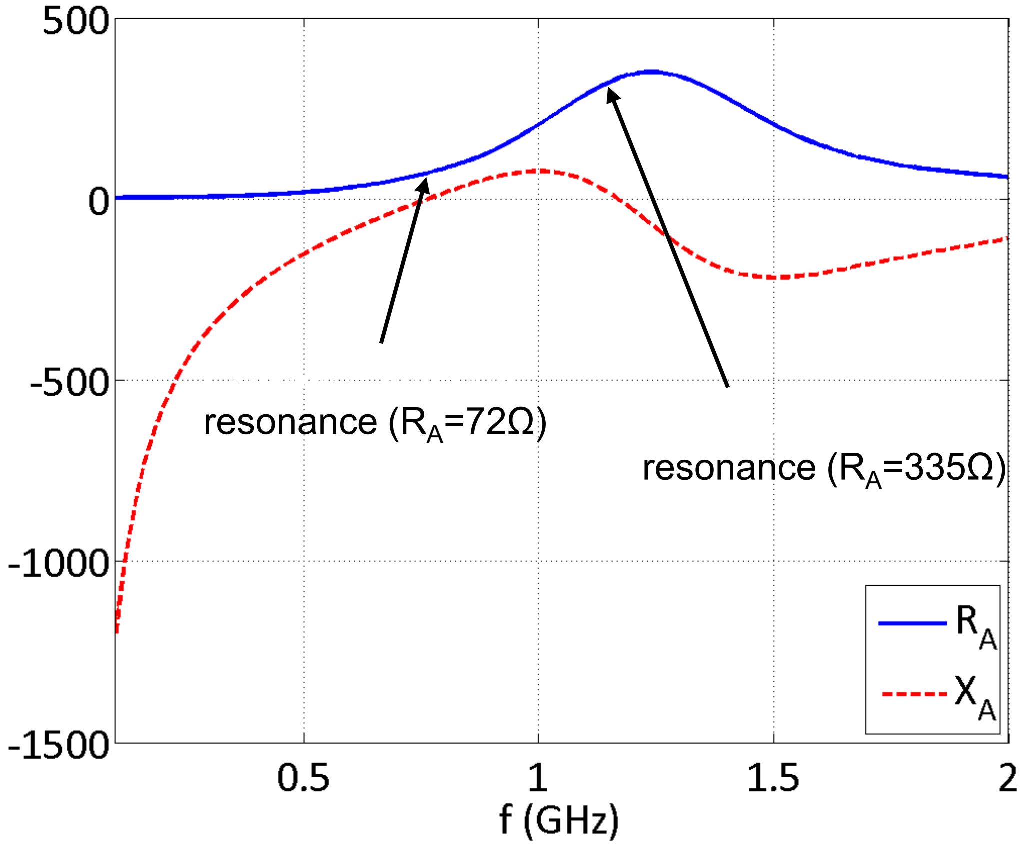
$$G(\theta,\varphi) = \frac{radiation \quad intensity(\theta,\varphi)}{\frac{input \quad power}{4\pi}}$$

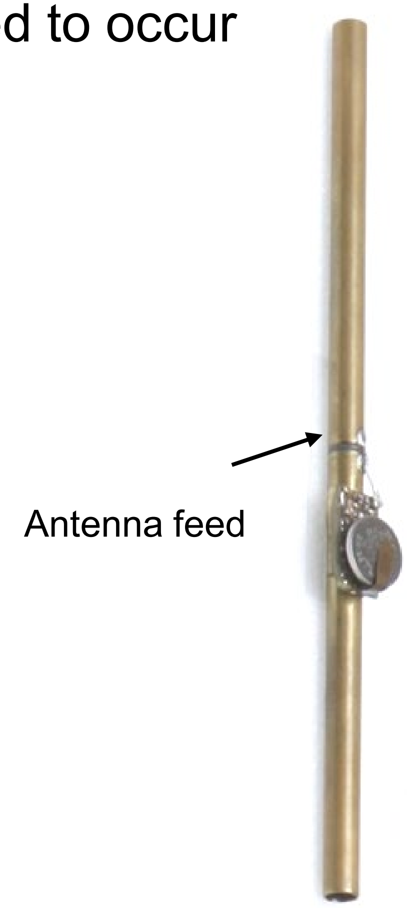
$$G(dB) = 10\log_{10}(G)$$

Example: gain of a half-wave dipole versus an isotropic radiator is G_i(dB) = 2.15 dBi.

Input Impedance

The input impedance $Z_A=R_A+jX_A$ at the antenna's feeding point is a function of frequency f. Frequently resonances are defined to occur where $X_A=0\Omega$.





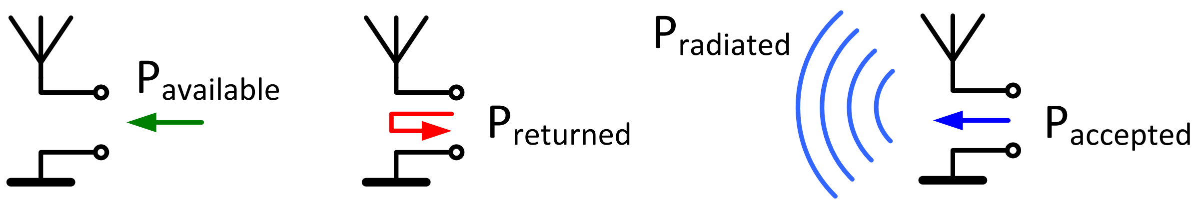
R_A ... antenna restistance
X_A ... antenna reactance

Reflection Coefficient

The reflection coefficient, Γ, is the ratio of the amplitude of the reflected wave to the amplitude of the incident wave (maximum power transfer for Γ=0).

$$|\Gamma|^2 = \frac{P_{returned}}{P_{available}}$$

$$|\Gamma|(dB) = 10\log_{10}\left(\frac{P_{returned}}{P_{available}}\right)$$



$$\Gamma = \frac{(Z_A - Z_0)}{(Z_A + Z_0)}$$

P ... power

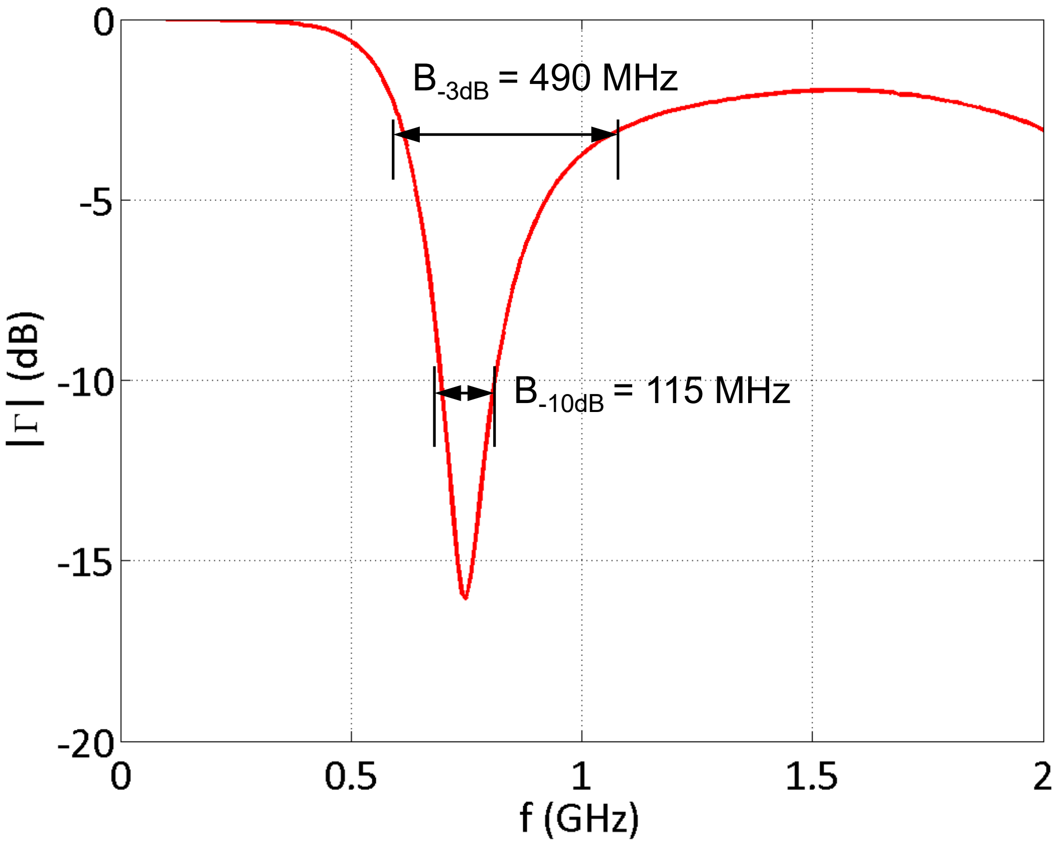
VSWR – Voltage Standing Wave Ratio

The Voltage Standing Wave Ratio is the ratio of voltage maximum and voltage minimum of a standing wave .

$$VSWR = \frac{|U_{max}|}{|U_{min}|} = \frac{1+|\Gamma|}{1-|\Gamma|}$$

Bandwidth

The bandwidth of an antenna is defined as the range of frequencies within which the performance of the antenna (radiation pattern, gain, input impedance, matching) comply with the requirements.



Effective Area and Antenna Factor

- The effective area of an antenna describes the ability of an antenna to convert an incident plane wave into power at its terminals based on the power flux density S.

- For each antenna an effective area A_e can be defined

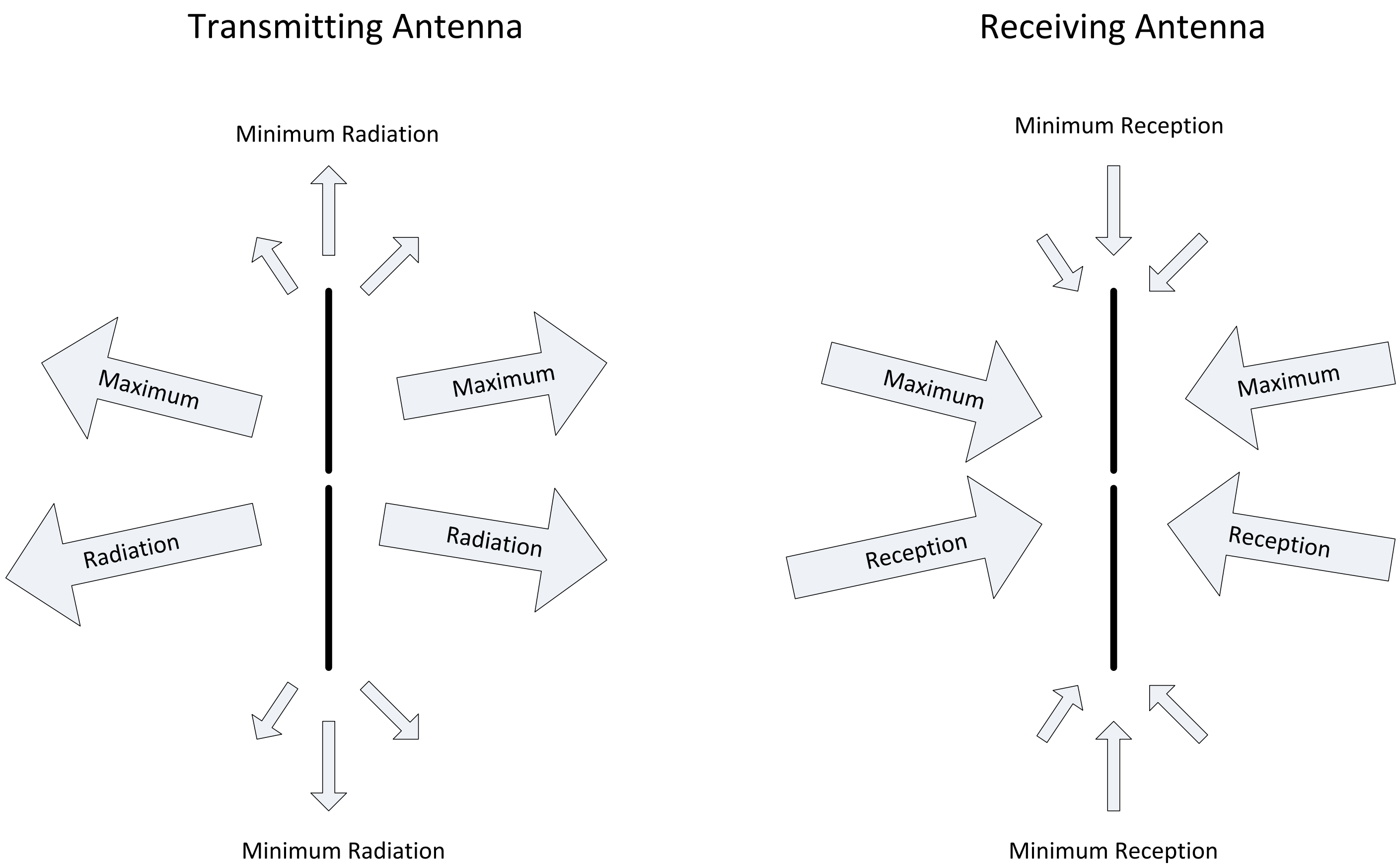
$$A_e = \frac{P_r}{S} = \frac{\lambda^2}{4\Pi} G$$

- The antenna factor AF of an antenna describes the same ability and is defined as the ratio of the E field and the produced voltage:

$$AF = \frac{E}{U}$$

Reciprocity Theorem

The electrical characteristics of an antenna apply equally, regardless of whether the antenna is used for transmitting or receiving.



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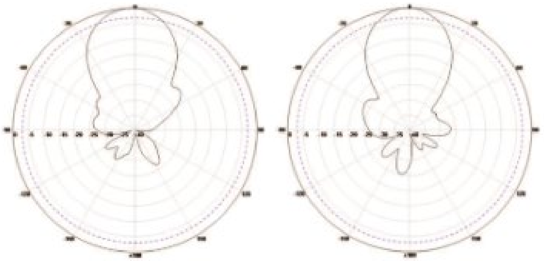

H Plane E Plane

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Part II – Antenna Measurements

- Ideal setting for antenna measurements
  - “free space” environment
  - measurement in “far field conditions”

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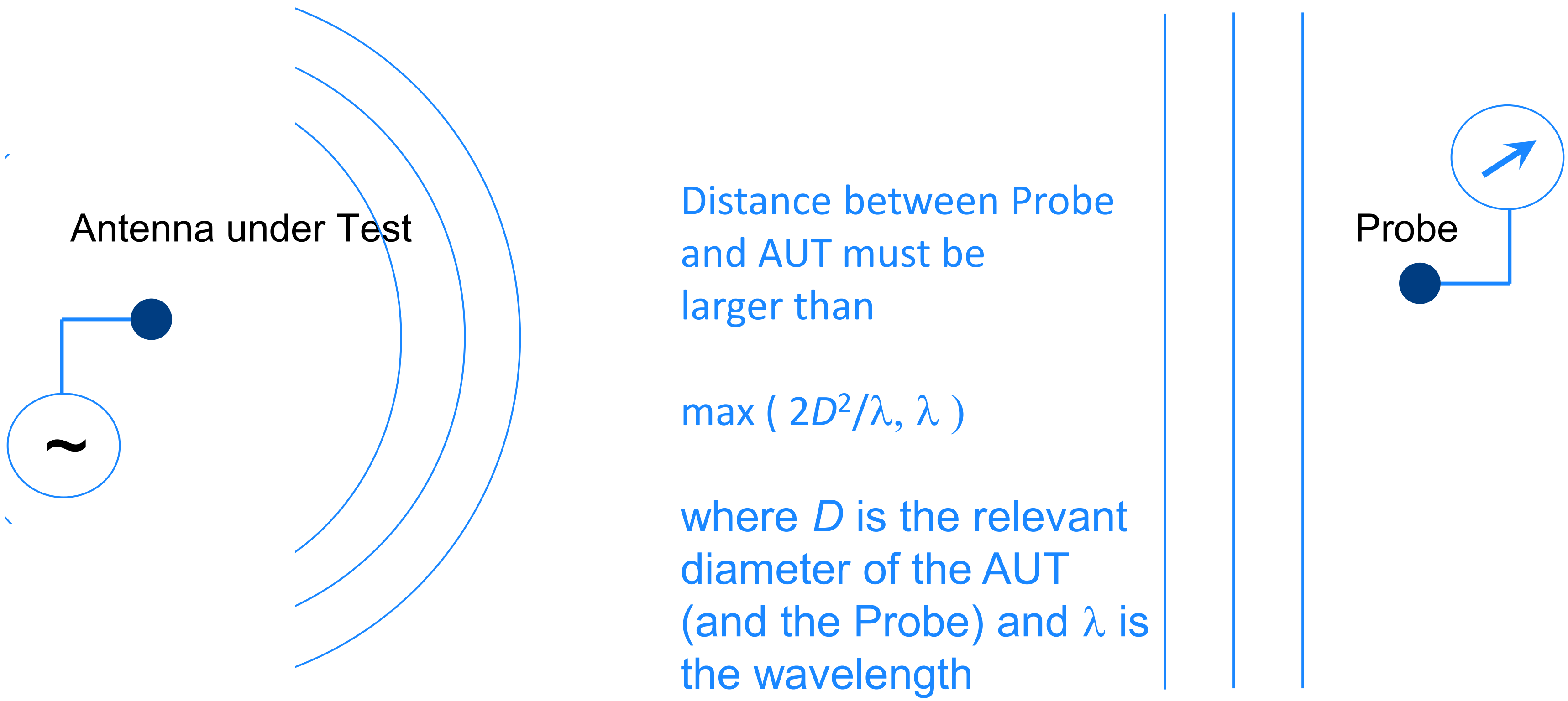

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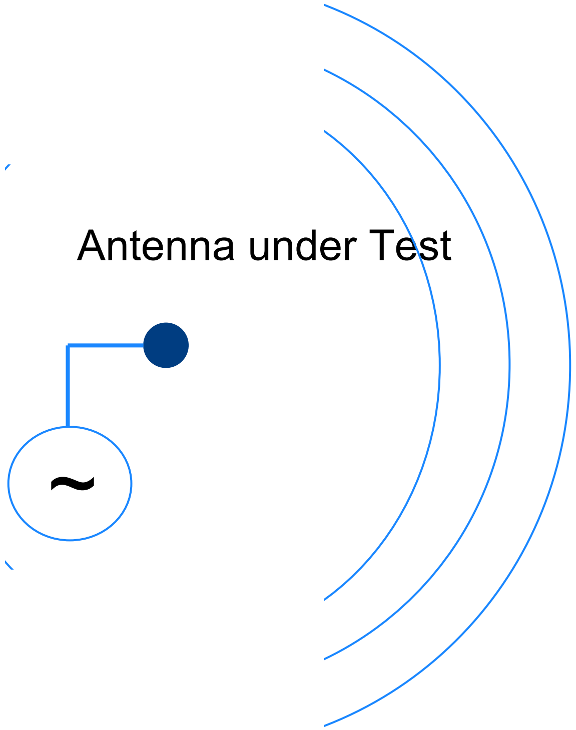
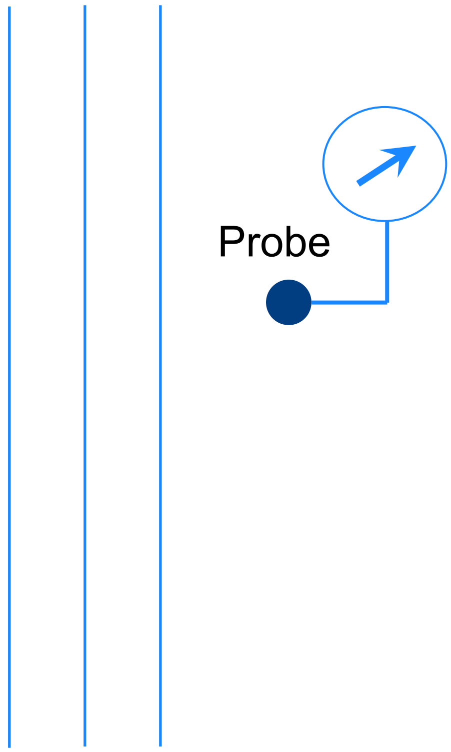


Issues:

Space requirements

How “free” does the environment need to be?



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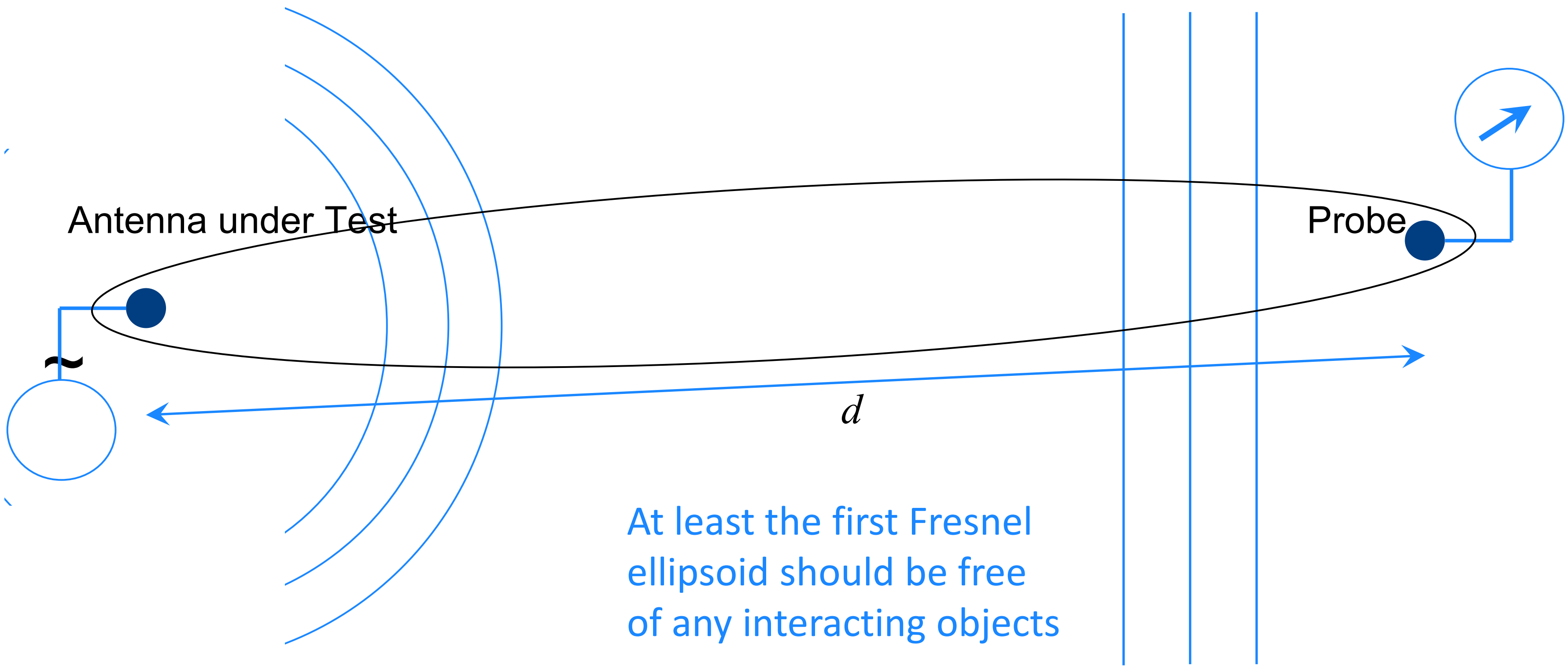

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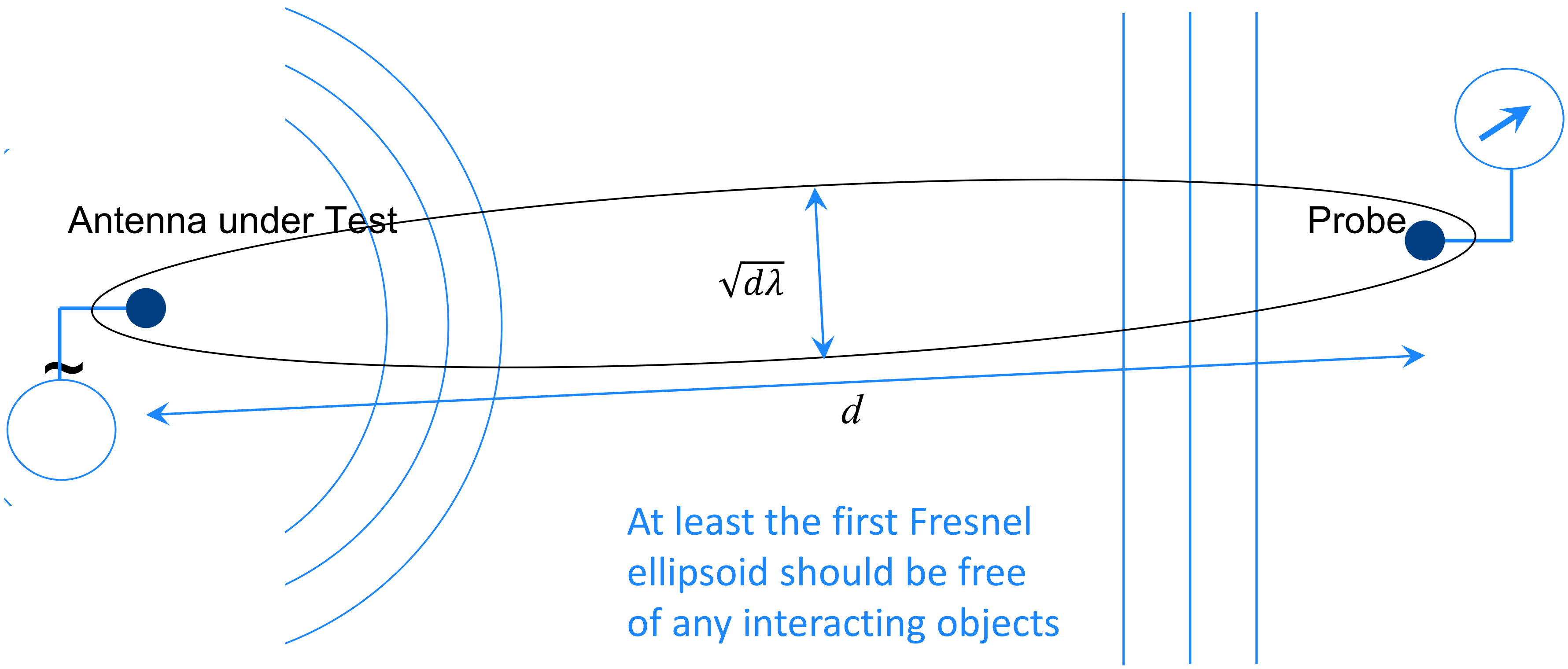
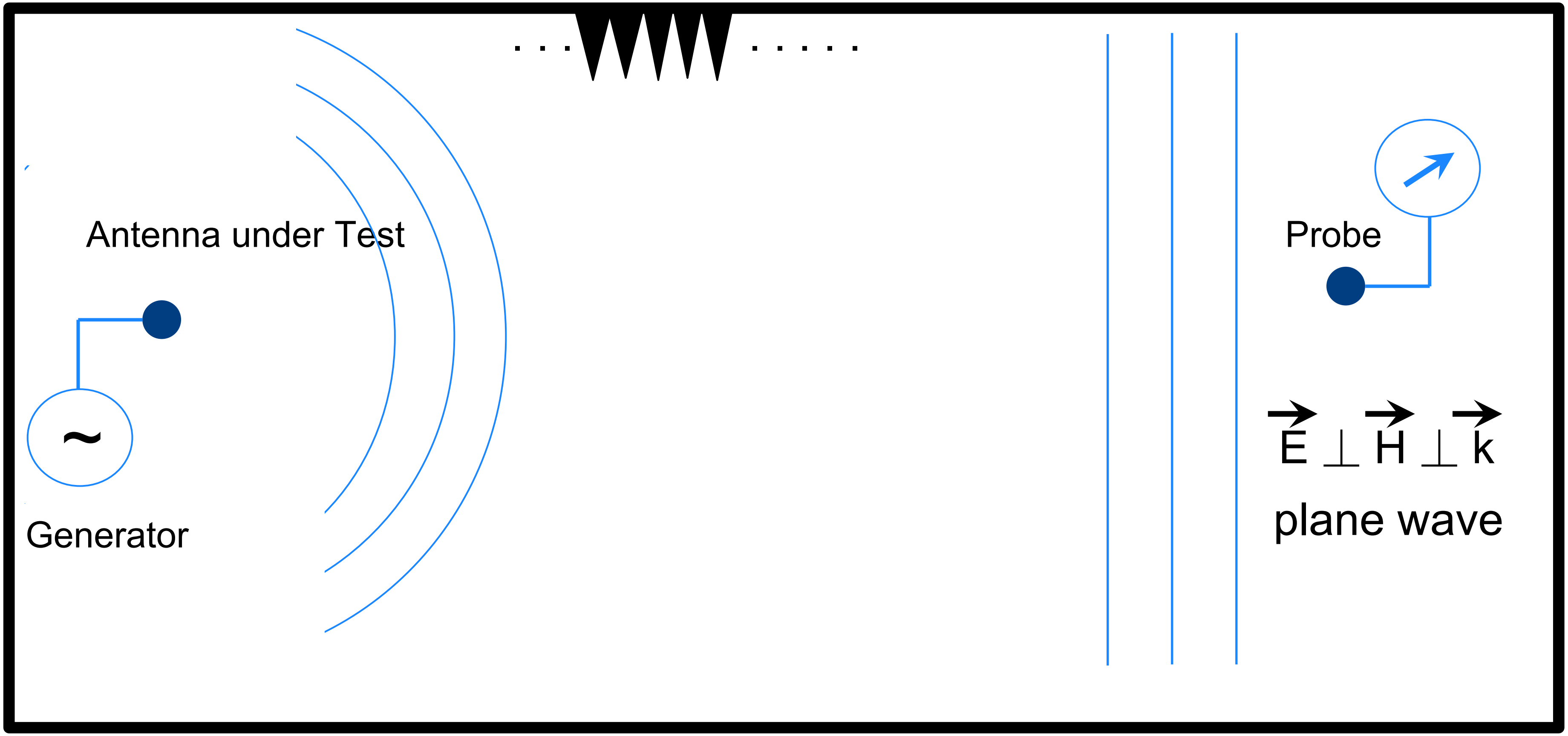


Part II – Antenna Measurements

- Shielded anechoic chamber for antenna measurements
  - Absorbers emulate a "zero multipath" environment
  - measurement in "far field conditions" (chamber may become large)



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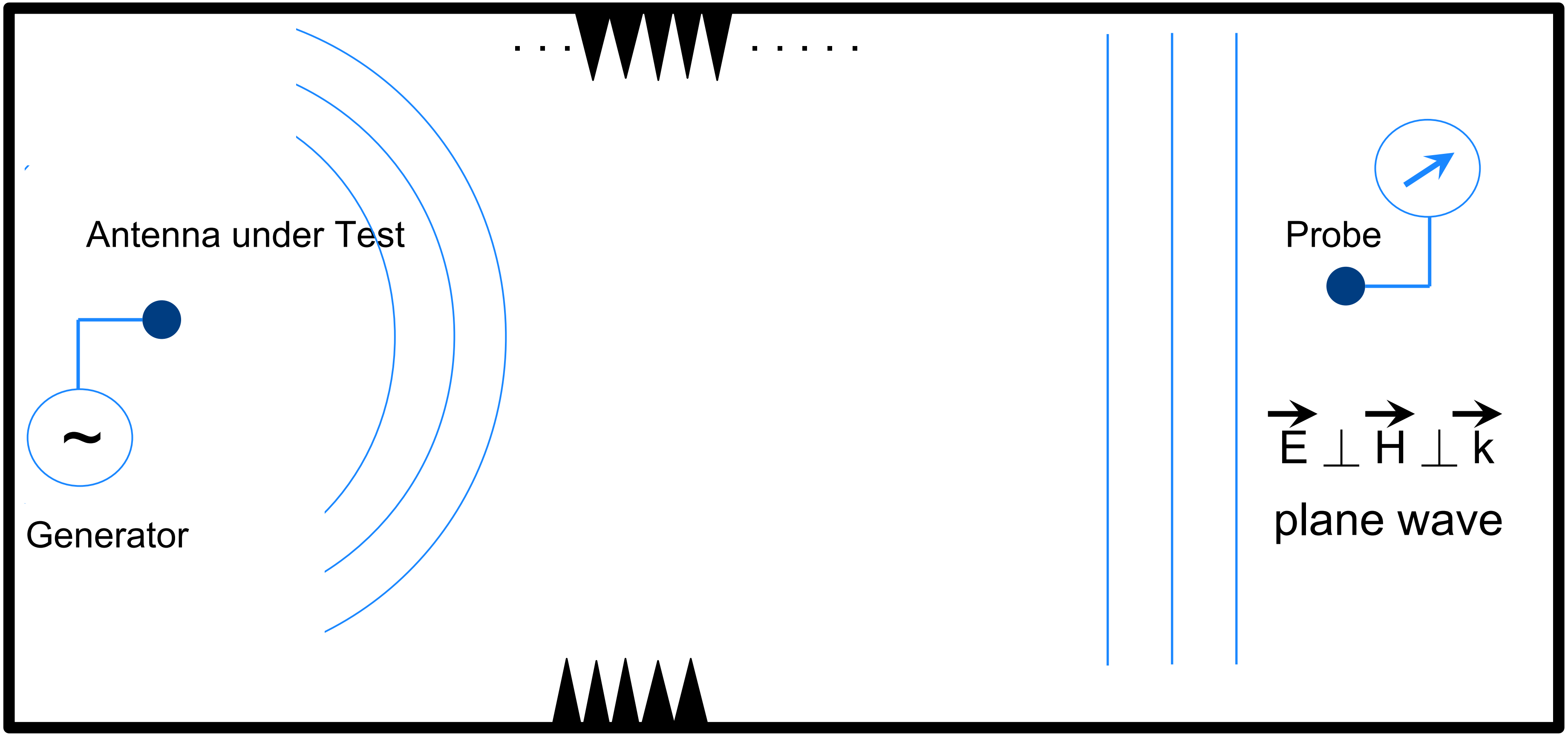
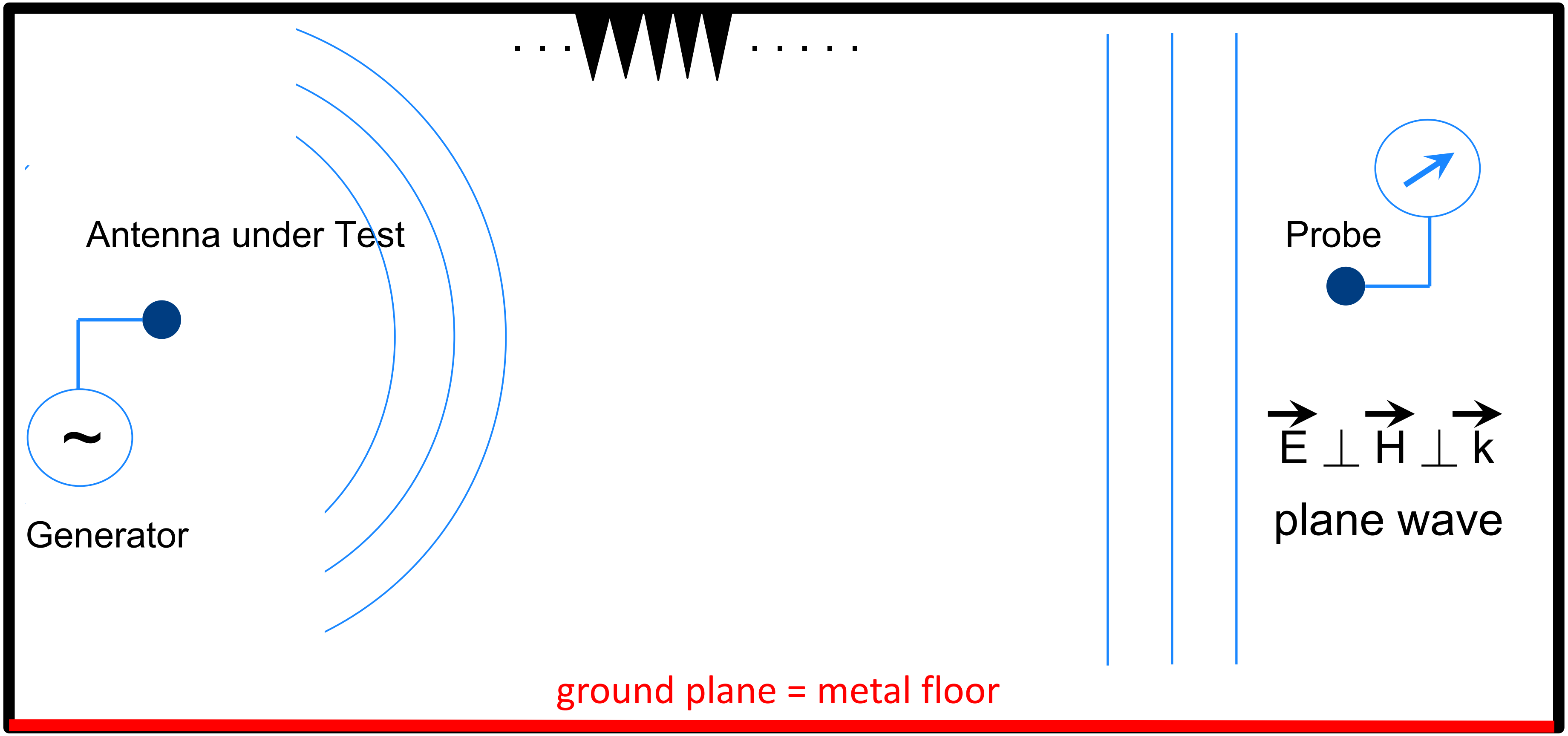


Part II – Antenna Measurements

- Shielded anechoic chamber for EMC measurements
  - Absorbers emulate a “zero multipath” environment
  - measurement in “far field conditions” (chamber may become large)



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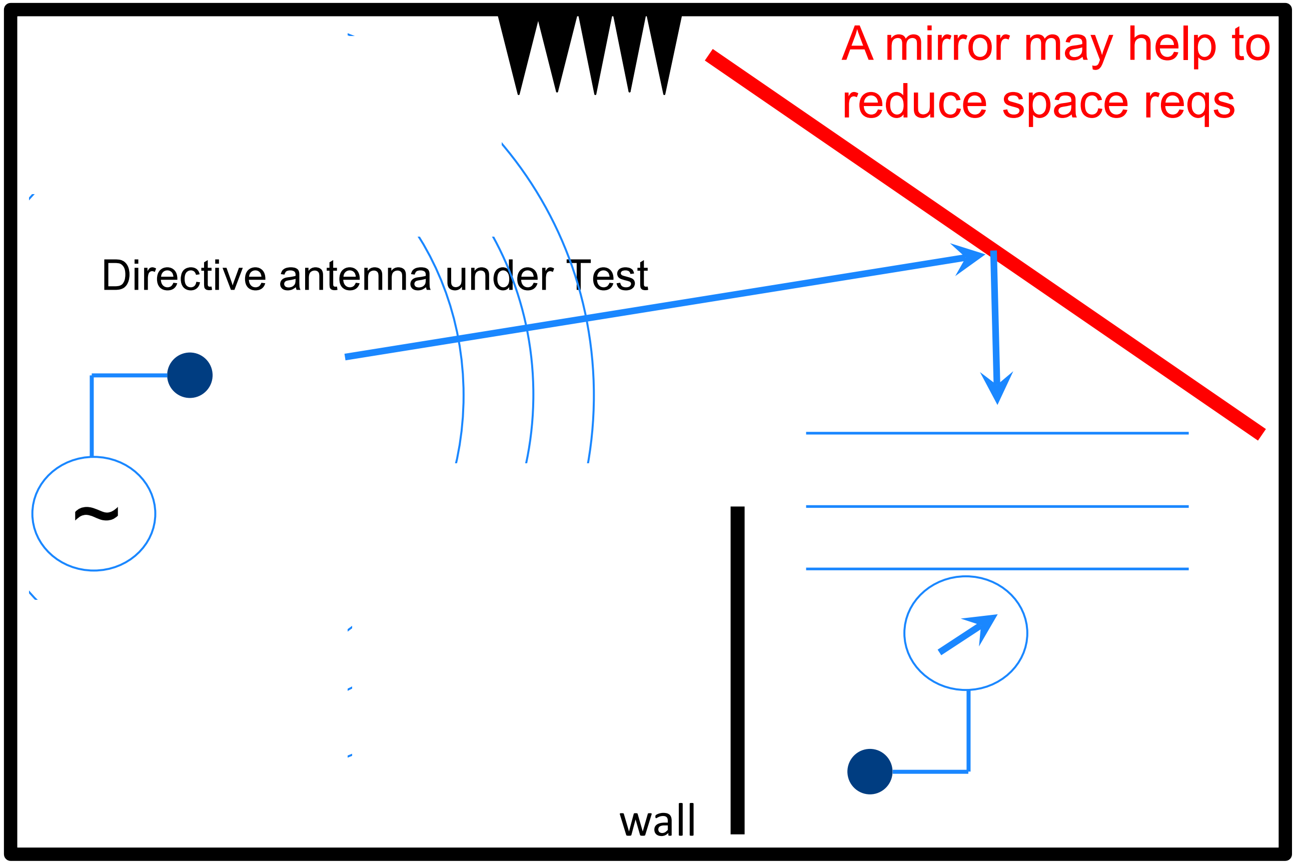
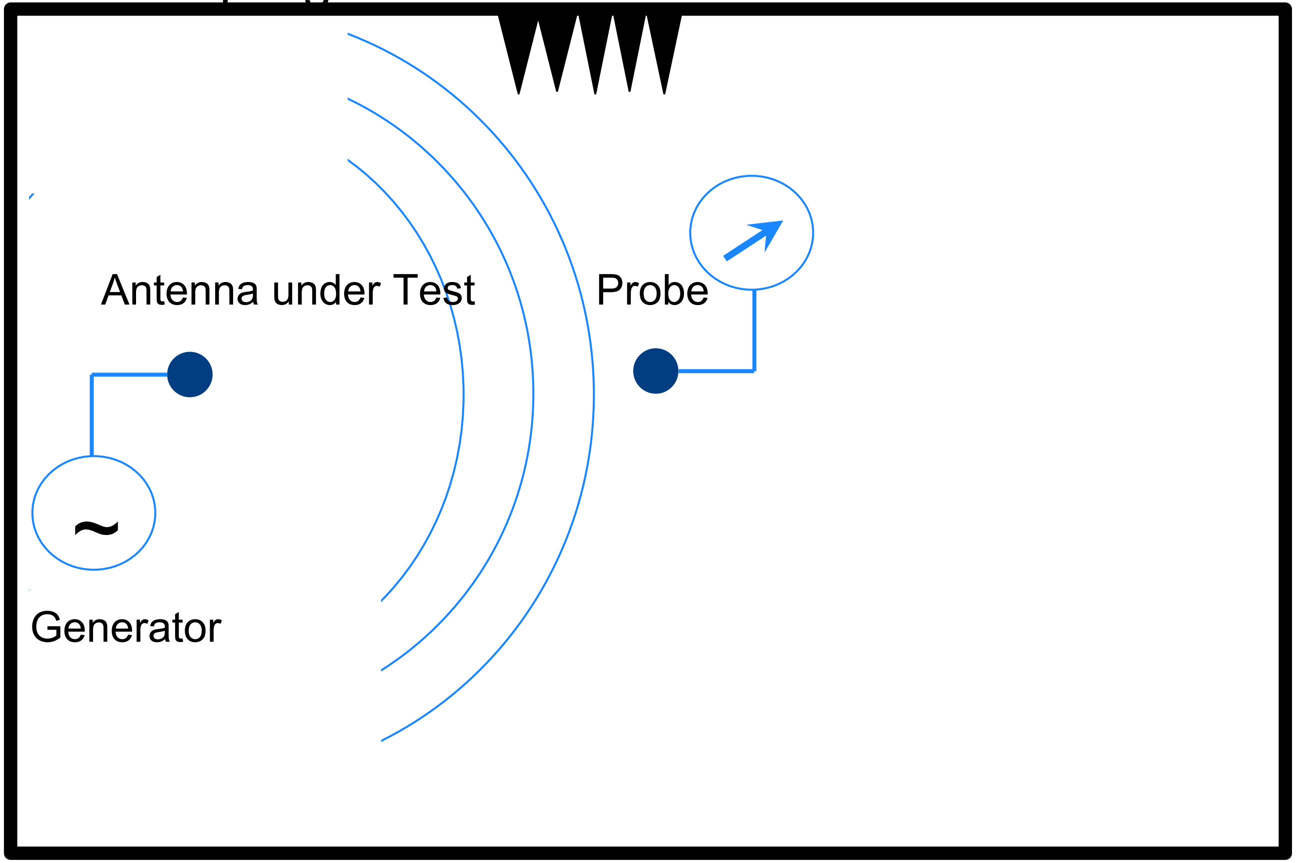


Part II – Antenna Measurements

- Measuring in the near field is also possible
- Near field data can be extrapolated to far field data
- Sampling theorem asks for a “dense” measurement grid on a sphere



Part II – Antenna Measurements

- Recent new development: Sparse measurements in the near field
- Sparse near field data can also be extrapolated to far field data
- Sparse reconstruction requires a “less dense” measurement grid