Athens Course: Antenna Design and Measurement Techniques

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Universidad Politécnica de Madrid (UPM)

Objectives

- To familiarize students with antennas, in a quite practical way.
- Students will acquire knowledge about all the main aspects of designing and measuring antennas.
- The course is divided in two different parts: Antenna Design and Antenna measurement
- A visit to the facilities of a Spanish Antenna company is included.
- A visit to the antenna measurement facilities of the University is included.

Lecturers

- Manuel Sierra Castañer (MSC)
- Pablo Padilla de la Torre (PPT)
- José Manuel Fernández González (JMFG)
- Sara Burgos Martínez (SBM)
- Francisco José Cano Fácila (FCF)
- Andrés García Aguilar (AGA)
- Alfonso Muñoz Acevedo (AMA)
- Fernando Martín Jiménez (FMJ)

Programme

Main topics

Monday 16th	Introduction to Antenna Parameters.
Tuesday 17th	Antenna Applications and Measurements
Wednesday 18th	Visit to “INDRA Sistemas” + Laboratory
Friday 204th	Laboratory + Exam

Programme

Monday

10.00-10.30	Introduction	MSC	A206
10.30-10.45	Break		
10.45-12.00	Antenna Parameters	MSC	A206
12.00 – 13.00	High Frequency Circuit Analysis	PPT	A206
13.00-14.00	Lunch		
14.00-15.00	High Frequency Circuit Analysis	PPT	A206
15.00-16.00	Exercises	JMFG/PPT	A206

Programme

Tuesday

9.00-11.00	Antenna Applications	AMA/AGA/ FCF	A206
11.00-11.15	Coffee Break		
11.15-13.00	Antenna Applications	AMA/AGA/ FCF	A206
13.00-14.00	Lunch		
14.00-16.00	Introduction to Measurement Techniques + Visit	SBM/MSC/ FCF	A206 B031

Programme

Wednesday

9.00-13.00	Visit to INDRA SISTEMAS	FMJ	
13.00-14.00	Lunch		
14.00-16.00	Laboratory 1: Measurements	SBM/MSC /FCF	B-031

Programme

Friday

9.00-11.00	Laboratory 2: Simulations	PPT/JMFG/ AMA/AGA	A-037
11.00-11.30	Coffee Break		
11.30-13.00	Exam		B1

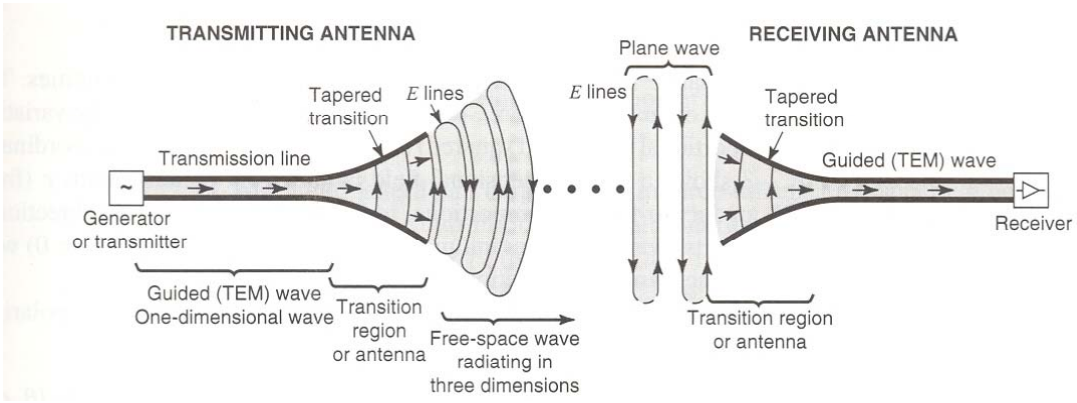
Evaluation

- Exercises, Laboratory, lecture attendance: 40%
- Final exam: 60%

Topics

Introduction to Antenna Parameters

An antenna is generally a “metallic design to radiate and receive radio waves” that match the output of the transmitter or the input of the receiver to the medium.



Antenna properties

- The properties that have to achieve a good antenna are:
  - Good radiation efficiency

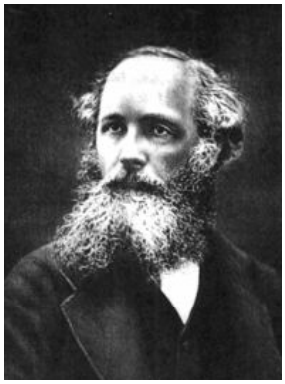
$$\eta_r = \frac{P_{radiated}}{P_{input}} \leq 1$$

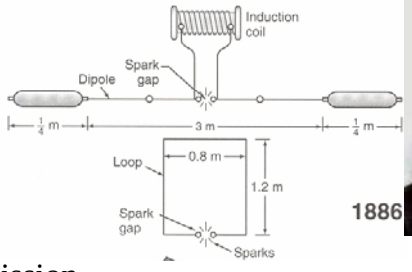
  - Good radiation pattern appropriate to the application
  - Good match to the transmission line

Antenna history

The communications by electric methods does not begin until the introduction

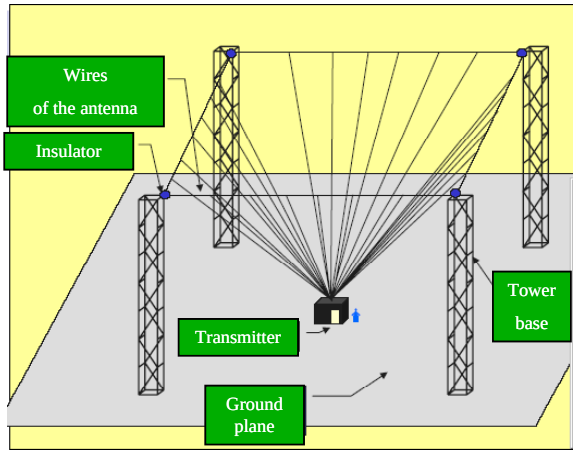
- 1844: Telegraphy Wire
- 1864: Maxwell Equations
  - •Mathematical model
    - •Maxwell equations
      - •Scottish physicist
  - •Predicts theoretically the existence of electromagnetic waves
- 1878: Telephone wire
- 1886: First radio experiment of Hertz
  - •German physicist
  - •Detects experimentally the existence of EM waves
  - •Construct a resonant radiating source at 75 MHz (2 metallic plates connected to an inductive coil) and a receiver system with an open loop and with a gap.
    Sparkles proves that there is energy transmission.

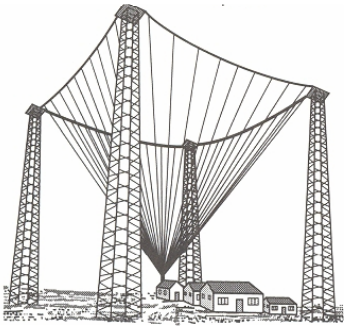




Antenna history

- 1897: Patent of wireless telegraphy (Marconi)
  - • Italian engineer
- 1901: First transatlantique communication system (Marconi)
  - •Using a transmitter of sparkles at 60 KHz
  - •Radio Link Europe-USA
    - •Cornouailles (GB) – Terre-Neuve (Canada)





Monopole antenna with low gain

Antenna history

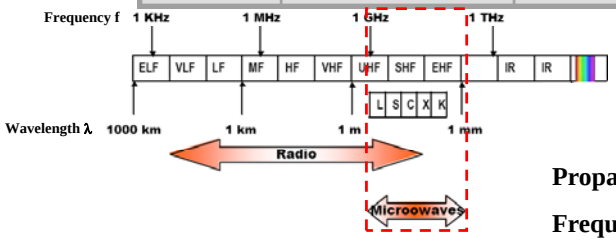
- From Marconi until 1940, the radio technology was focused in the use of different wire antennas reaching the range frequency of UHF (300 – 3000 MHz).
- During the Second World War, new antennas are introduced (as waveguides, horns antennas and reflector antennas) for radar applications at microwave frequencies (from 1 GHz).
- In 1960, antennas for satellite communications.
- From 1970, concept of printed microstrip antennas.

Frequency bands

Frequency band	Designation	Typical service
3–30 kHz	Very low frequency (VLF)	Navigation, sonar
30–300 kHz	Low frequency (LF)	Radio beacons, navigational aids
300–3000 kHz	Medium frequency (MF)	AM broadcasting, maritime radio, Coast Guard communication, direction finding
3–30 MHz	High frequency (HF)	Telephone, telegraph, and facsimile; shortwave international broadcasting; amateur radio; citizen's band; ship-to-coast and ship-to-aircraft communication
30–300 MHz	Very high frequency (VHF)	Television, FM broadcast, air traffic control, police, taxicab mobile radio, navigational aids
300–3000 MHz	Ultrahigh frequency (UHF)	Television, satellite communication, radiosonde, surveillance radar, navigational aids
3–30 GHz	Superhigh frequency (SHF)	Airborne radar, microwave links, common-carrier land mobile communication, satellite communication
30–300 GHz	Extremely high frequency (EHF)	Radar, experimental

Microwave bands

Band	Min freq	Max. freq	Max. λ	Min. λ
L	1 GHz	2 GHz	30 cm	15 cm
S	2 GHZ	4 GHz	15 cm	7.5 cm
C	4 GHz	8 GHz	7.5 cm	3.75 cm
X	8 GHz	12.4 GHz	3.75 cm	2.42 cm
Ku	12.4 GHz	18 GHz	2.42 cm	1.66 cm
K	18 GHz	26.5 GHz	1.66 cm	1.11 cm
Ka	26.5 GHz	40 GHz	11.1 mm	7,5 mm
mm	40 GHz	300 GHz	7.5 mm	1 mm



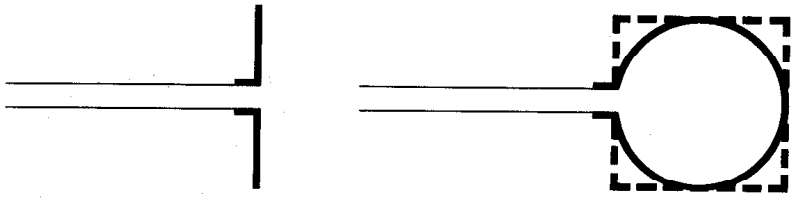
Wavelength in free space in [m]:

$$\lambda = \frac{c}{f}$$

Propagation velocity in free space: c = 300'000'000 m/s

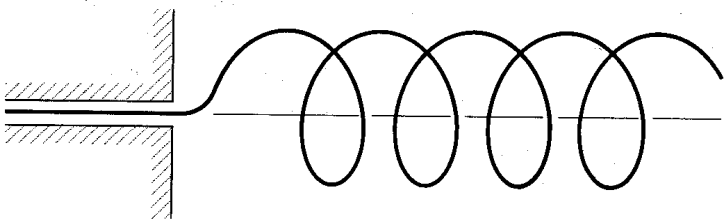
Frequency: f in [Hz]

Linear antennas (current elements and progressive wave antennas)



(a) Dipole

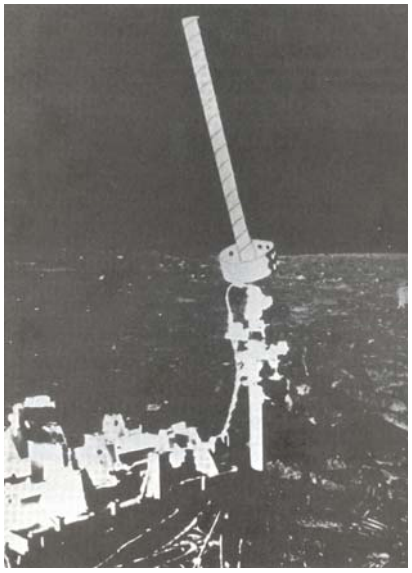
(b) Circular (square) loop



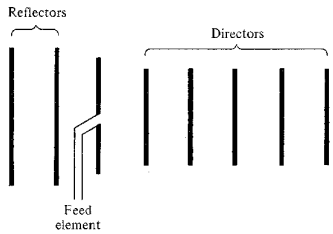
(c) Helix

Figure 1.2 Wire antenna configurations.

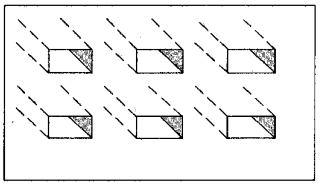
Linear Antennas



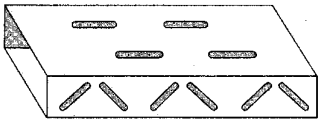
Arrays



(a) Yagi–Uda array



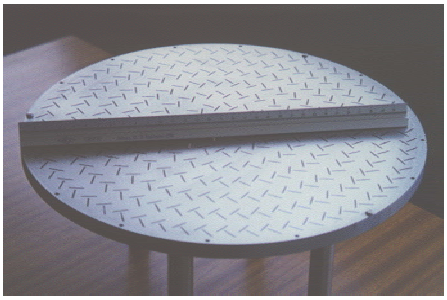
(b) Aperture array



(c) Slotted-waveguide array

Figure 1.4 Typical wire and aperture array configurations.

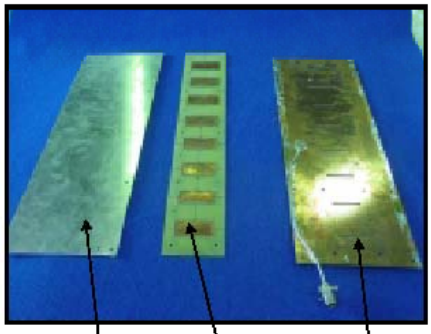
Base station antennas for mobile systems application: DECT (3.5 GHz): Vertical 65°, 90° antennas

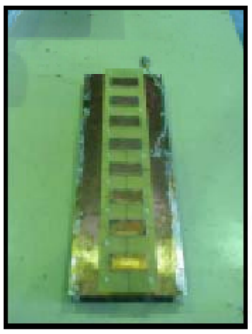


TV reception via satellite for DBS (12 GHz) systems application

Arrays

Base station antenna DCS1800 for mobile communication

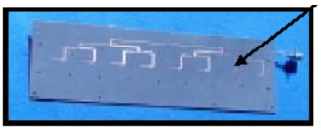


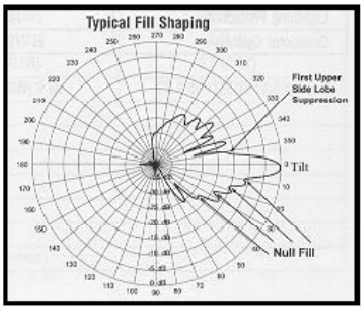


Patches

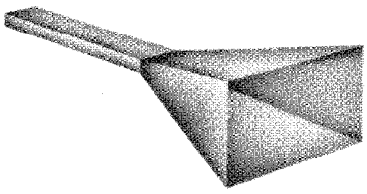
Ground plane

Slots (opposite side substrate with feeding network)

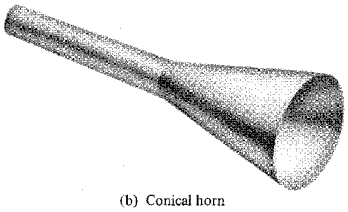




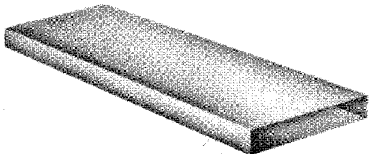
Aperture (Horns)



(a) Pyramidal horn



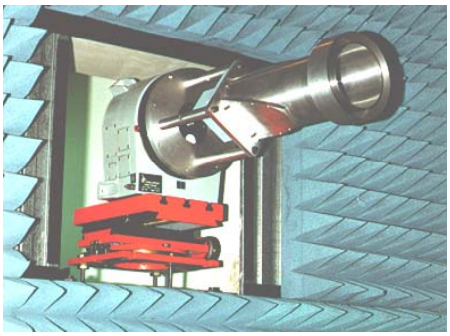
(b) Conical horn



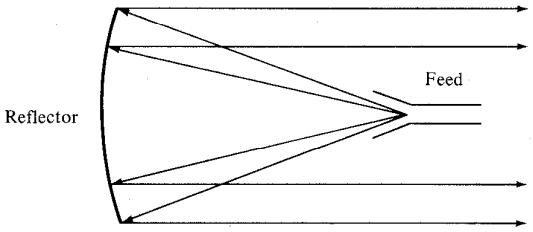
(c) Rectangular waveguide

Figure 1.3 Aperture antenna configurations.

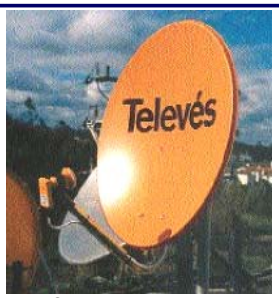
- **Used in the microwave frequency range**
- **High gain**
- **Wide bandwidth**
- **Easy to fabricate**



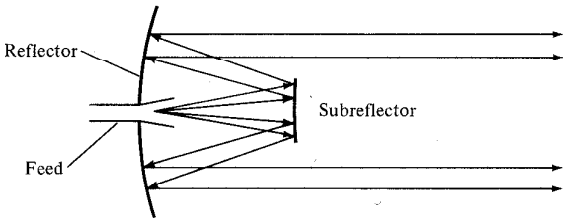
Apertures (Reflectors)



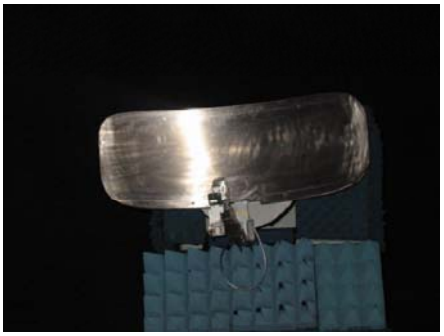
(a) Parabolic reflector with front feed



Antenna for TV reception via satellite

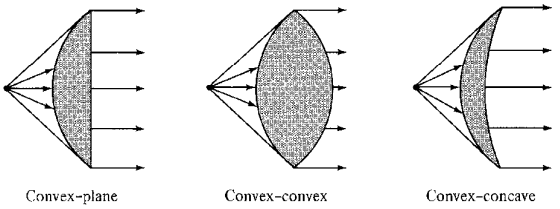


(b) Parabolic reflector with Cassegrain feed

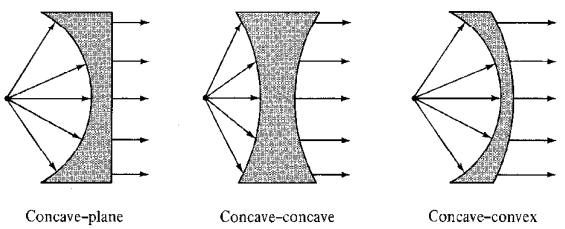


Antenna for satellite communication from a high speed train

Apertures (Lenses)



(a) Lens antennas with index of refraction $n > 1$

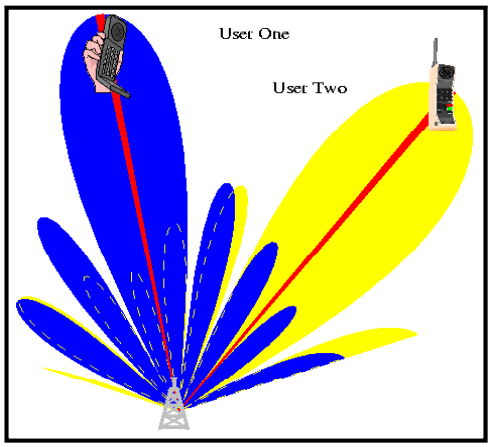


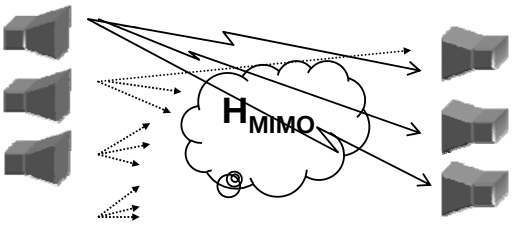
(b) Lens antennas with index of refraction $n < 1$

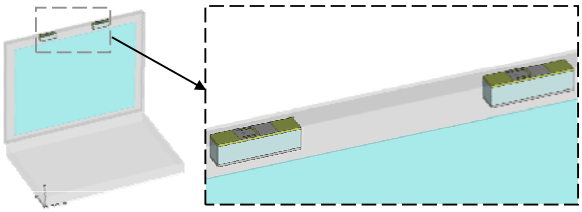
Figure 1.6 Typical lens antenna configurations. (SOURCE: L. V. Blake, *Antennas*, Wiley, New York, 1966).

Adaptive Antennas

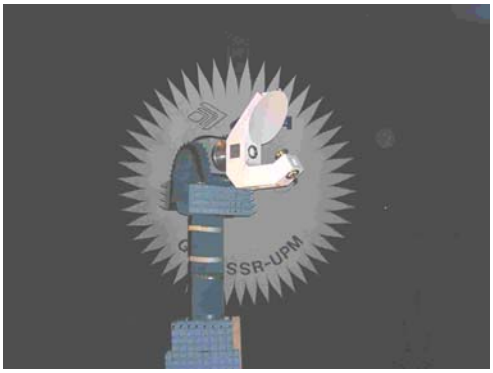
Smart Antennas and MIMO techniques

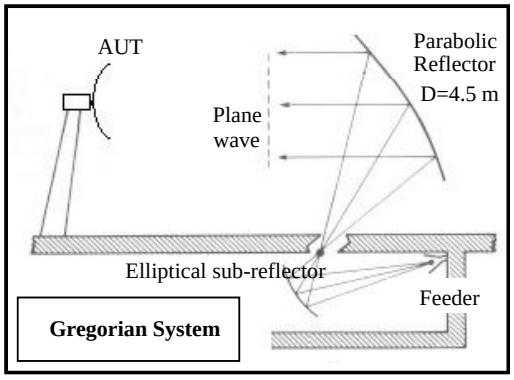


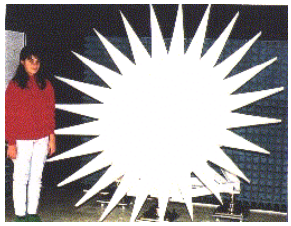


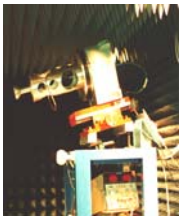


Antenna Measurements



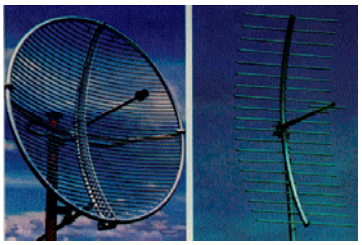






Other antennas

Radioastronomy Interferometer



Grid Reflector

Offset Reflector

(Very Large Aperture, New Mexico)

Topics