Lecture 01: Introduction to the course (ECE 344)

Prepared By
Dr. Eng. Sherif Hekal
Assistant Professor, ECE department

Course Information

Course Name: Microwave fundamentals

Course Code: ECE 344

Course Materials are on my website:
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Teaching Staff & Contact

Instructors	Location	Teaching Load
Dr. Sherif Hekal	Room no: SB 5-05 New Building	Part 1 - Lectures
Dr. Gehan Sami	Floor no: 2 New Building	Part 2 - Lectures
Teaching Assistant	**Location**	**Teaching Load**
Eng. Shimaa Ezzat	Floor no: 2 (TA room) New Building	Part 1 & 2 - Tutorials

My rules

- No eating
- No drinking
- Silence except for asking questions
- Shutdown your Mobile, Tablet, etc. and put in your pocket.

Course meeting time & Location Part 1 – Dr. Sherif Hekal

ECE 344

		Number / week	Day	Time	Location
Contact hours	lectures	1.5 h	Sunday	10:40-12:10	Room SB4-1
		1.5 h	Tuesday	9:00 – 10:30	Room SB4-1
	tutorial	1.5 h	Monday	10:40-12:10	Room SB4-18
	Labs	1.5 h	Monday	10:40-12:00	Microwaves Lab
Office hours		2 h	Tuesday	10:40 – 12:30	My room

Course Assessment – Part 1
Dr. Sherif Hekal

ECE 344

Assessment Type	Percentage
Attendance	5
Midterms	15
Project	10
Final Exam	45
Total	75

Course Objectives

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The course aimed to:

- Describe principles of microwave engineering and technology.
- Derive and solve the wave equations in many microwave structures such as transmission lines and waveguides to analyze the wave propagation along them.
- Use of Smith chart for determining the wave characteristics on a transmission line and determine the input impedance and calculate perform the impedance matching .
- Investigate different passive microwave components such as: power dividers/combiners, couplers, resonators and cavities.

List of References

ECE 344

Text Book

David M. Pozar "**Microwave Engineering**" 4th Edition Wiley publishing:2011 (ISBN-10: 0470631554)

Recommended Books

T. Koryu Ishii "**Handbook of Microwave Technology**, **Volume 1: Components and Device**s" Academic press 1995

Syllabus

ECE 344

No.	Topics	No of hour
1	Course Objectives and Outline & Review of Electromagnetic Fields	4
2	General Transmission Line Theory & Circuit Model of Transmission lines	4
3	General Transmission Line Equations & Standing Wave Properties	4
4	Transmission Line Parameters & Lossless Transmission Line – Smith chart	4
5	Microstrip Transmission Line Structure &Stripline Transmission Line Structure	4
6	Advanced Design System (ADS) program- Simulation for microwave circuits	4
7	Rectangular Waveguide	4
8	Power transmitted in rectangular waveguide	4
9	Matching techniques - Quarter wavelength transformer - Smith chart - Single stub matching-Double stub matching	4
10	Microwave network analysis-S matrix-Z matrix-Y matrix-ABCD matrix	4
11	Microwave Passive devices- analyze and design Directional coupler	4
12	Microwave Passive devices- analyze and design Power dividers	4

Simulators

- ADS (Advanced Design System)
- CST (Computer Simulation Technology)

Example of Questions

A 75 Ω coaxial transmission line has length of 2.0 cm and is terminated with a load impedance of 37.5 + j75 Ω. If the dielectric constant of the line is 2.56 and the frequency is 3.0 GHz. Find (i) the input impedance to the line, (ii) the reflection coefficient at the load, (iii) the reflection coefficient at the input and (iv) the SWR on the line.

Example of Questions

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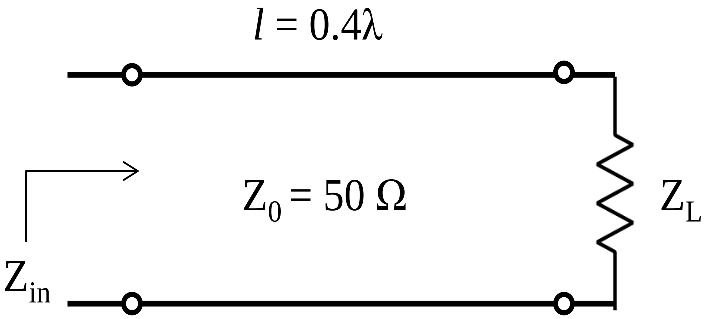
- Use the Smith chart to find the following quantities for the transmission line circuit below where $Z_L = 40 - j30\ \Omega$:
  - The SWR on the line.
  - The reflection coefficient at the load.
  - The load admittance.
  - The input impedance of the line.
  - The distance from the load to the first voltage minimum.
  - The distance from the load to the first voltage maximum.



Example of Questions

An air-filled rectangular waveguide of 5 cm x 2 cm cross section is operating in the TE_{10} mode at a frequency of 4 GHz. Determine

- The group velocity.
- The guided wavelength.
- The attenuation to be expected at a frequency which is 0.95 times the cut-off frequency (assuming the guide walls to be made of perfect conductors).

Example of Questions

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- Design a bandpass filter having a 0.5 dB equal-ripple response, with N = 3. The center frequency is 1 GHz, the bandwidth is 10%, and the impedance is 50 Ω.

Electromagnetic spectrum

- The field of radio frequency (RF) and microwave engineering generally covers the behavior of alternating current signals with frequencies in the range of 100 MHz (1 MHz = 10^6 Hz) to 1000 GHz (1 GHz = 10^9 Hz).
- RF frequencies range from very high frequency (VHF) (30–300 MHz) to ultra high frequency (UHF) (300–3000 MHz),
- while the term *microwave* is typically used for frequencies between 3 and 300 GHz, with a corresponding electrical wavelength between $\lambda = c/f = 10$ cm and $\lambda = 1$ mm, respectively.

Electromagnetic spectrum

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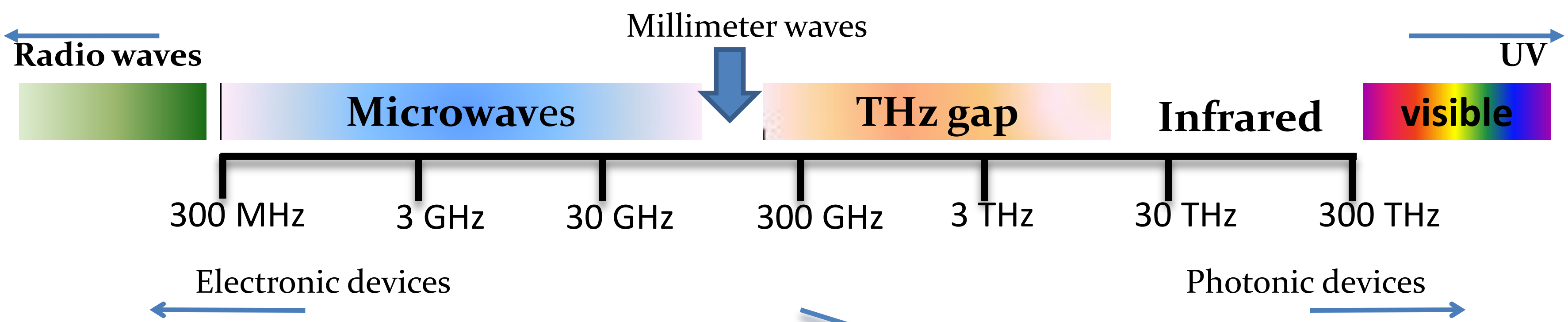

Microwave bands

Band	P	L	S	C	X	Ku	K	Ka
Freq (GHz)	0.23-1	1-2	2-4	4-8	8-12.5	12.5-18	18-26.5	26.5-40

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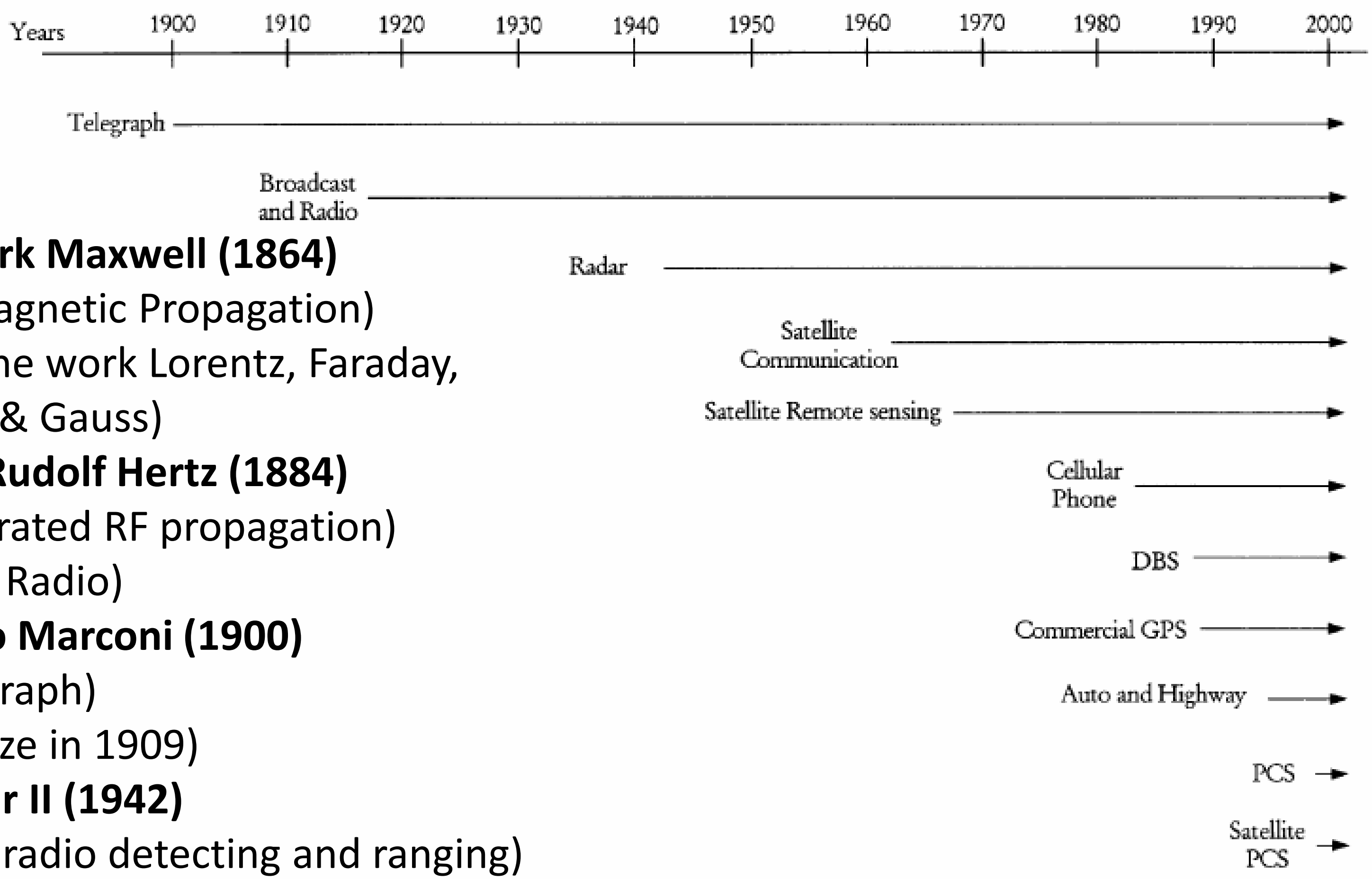
Microwave



James Clark Maxwell (1864)
(Electromagnetic Propagation)
(Unified the work Lorentz, Faraday, Ampere's & Gauss)
Heinrich Rudolf Hertz (1884)
(Demonstrated RF propagation)
(Father of Radio)
Guglielmo Marconi (1900)
(The telegraph)
(Nobel Prize in 1909)
World War II (1942)
(Radar == radio detecting and ranging)

Microwave applications

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- Wireless communications (cell phones, WLAN,…)
- Global positioning system (GPS)
- Computer engineering (bus systems, CPU, …)
- Microwave antennas (radar, communication, remote sensing, …)
- Other applications (microwave heating, power transfer, imaging, biological effect and safety)

Microwave applications

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❑ Communication systems

- UHF TV
- Microwave Relay
- Satellite Communication
- Mobile Radio

❑ Microwave Heating

- Industrial Heating
- Home microwave ovens

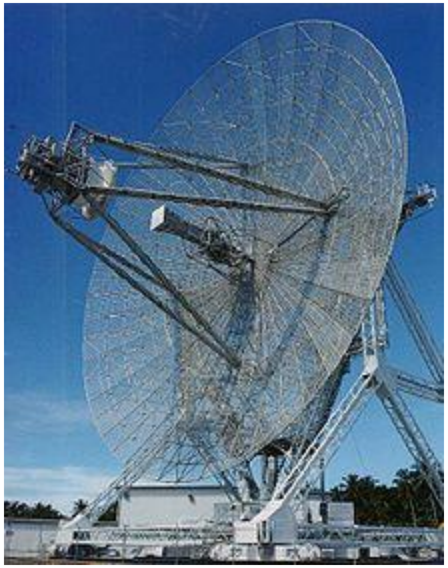
❑ Environmental remote sensing

❑ Medical system

❑ Test equipment

❑ Radar system

- Search & rescue
- Airport Traffic Control
- Navigation
- Tracking
- Fire control
- Velocity Measurement



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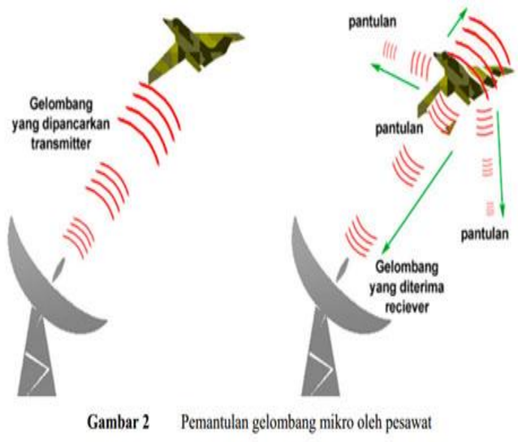
GLOBAL POSITIONING SYSTEM

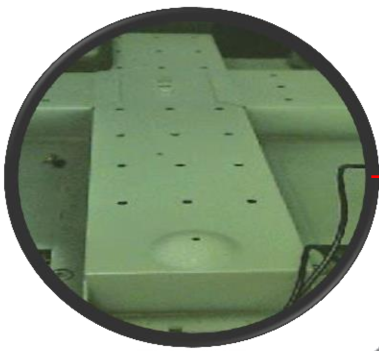


RADAR (RADIO DETECTION AND RANGING)

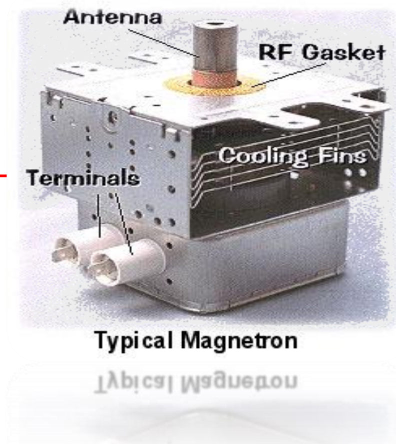
MICROWAVE OVEN

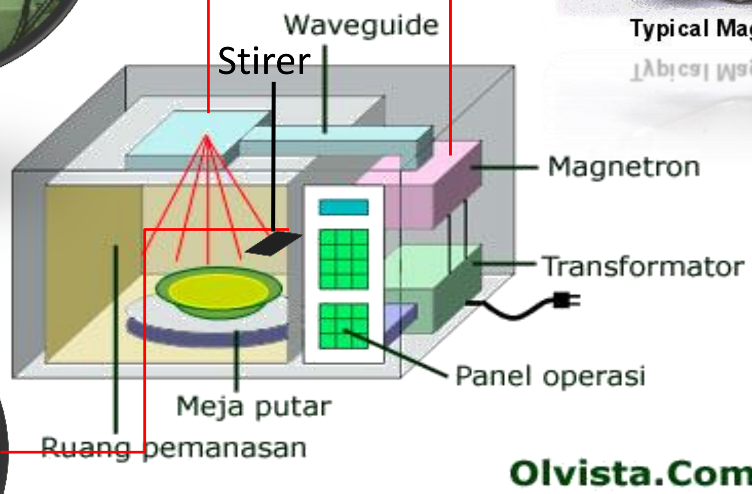
Microwave Oven

A component which designed to arrow the microwave to food chamber



Electric energy is changed to be microwave radiation





A component which its function is to spread microwave in food chamber

Microwave Oven

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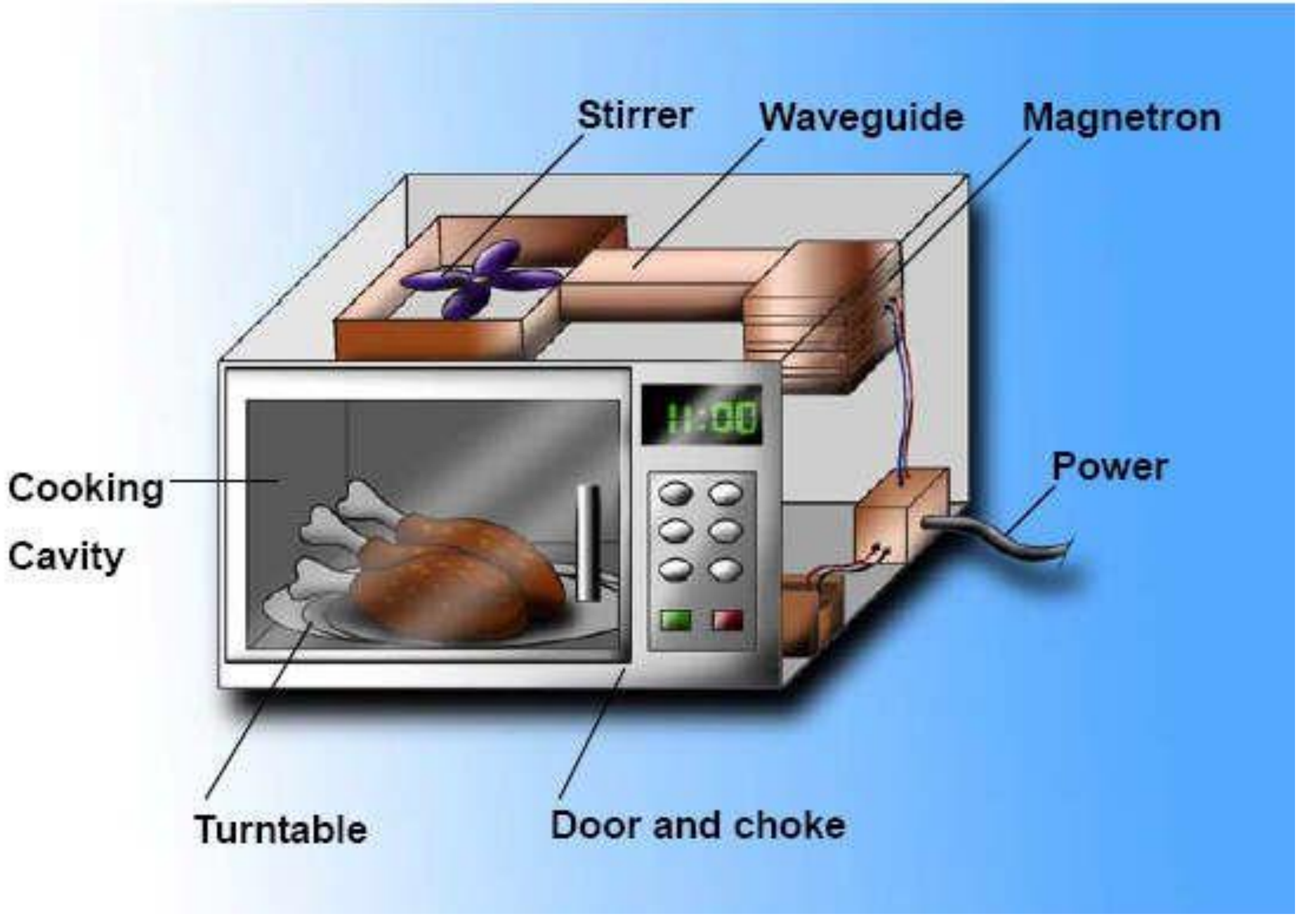

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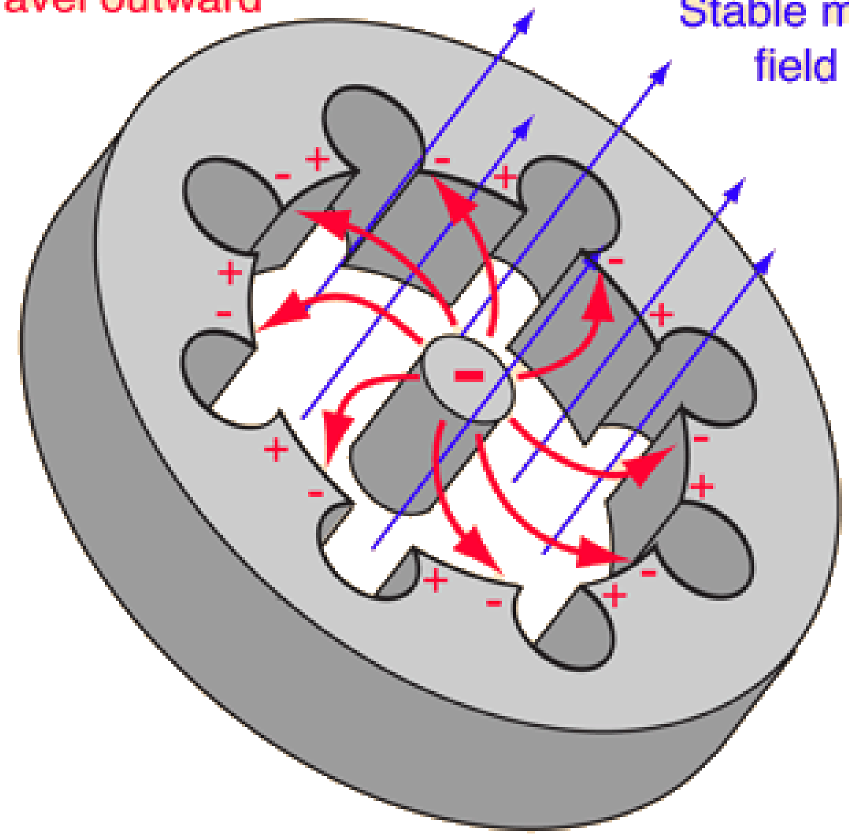
Magnetron



Electrons from a hot filament would travel radially to the outside ring if it were not for the magnetic field. The magnetic force deflects them in the sense shown and they tend to sweep around the circle. In so doing, they "pump" the natural resonant frequency of the cavities. The currents around the resonant cavities cause them to radiate electromagnetic energy at that resonant frequency.

Magnetron

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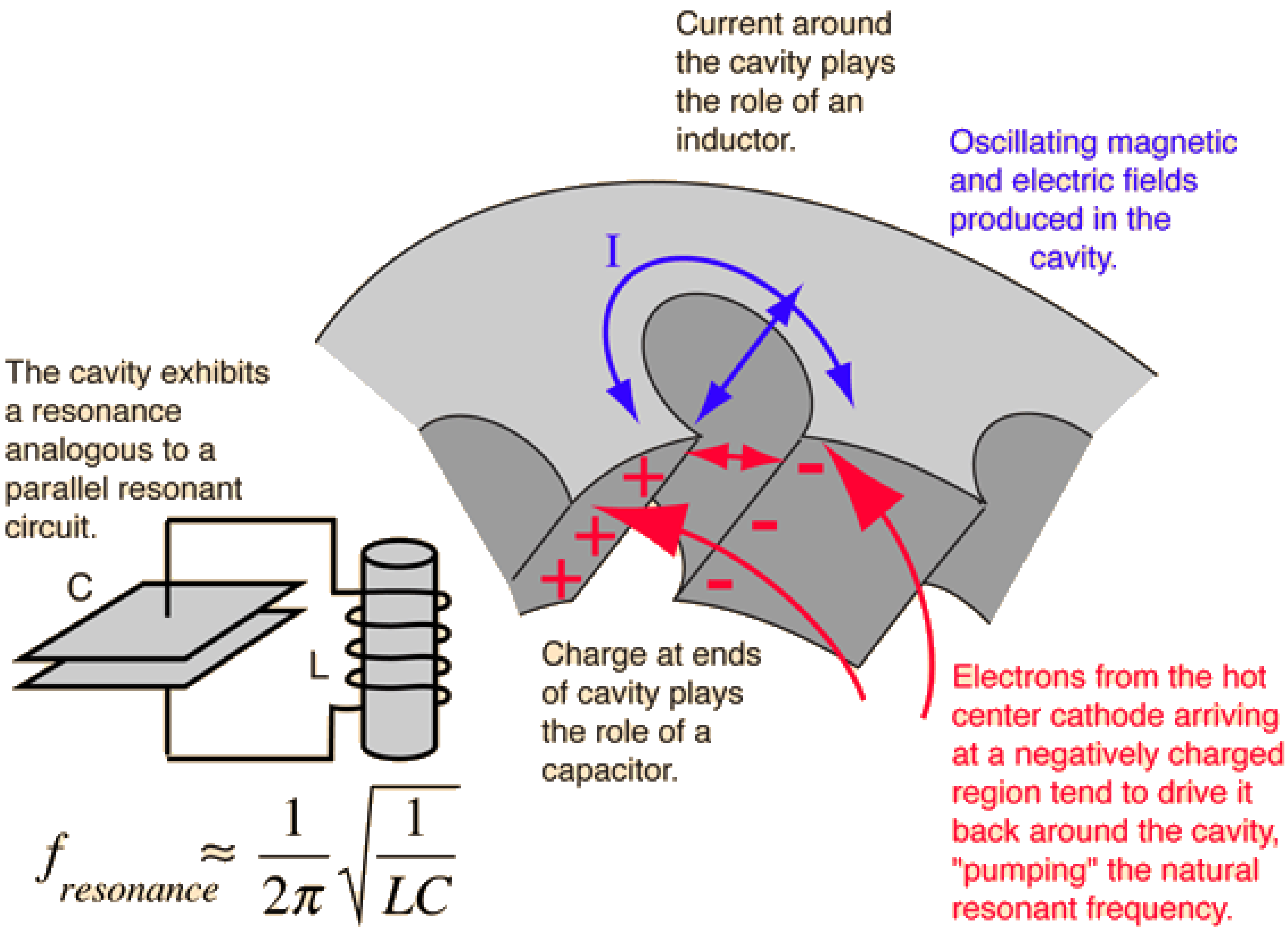

Magnetron

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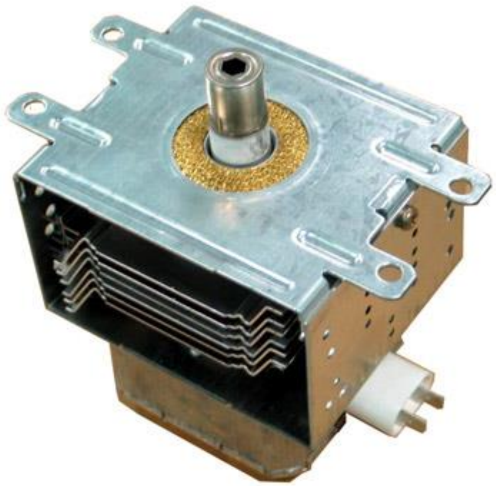

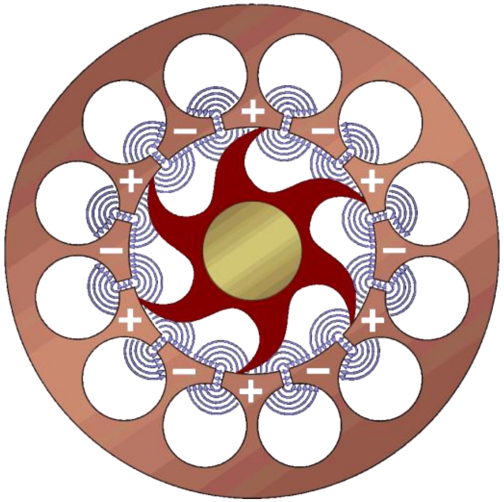

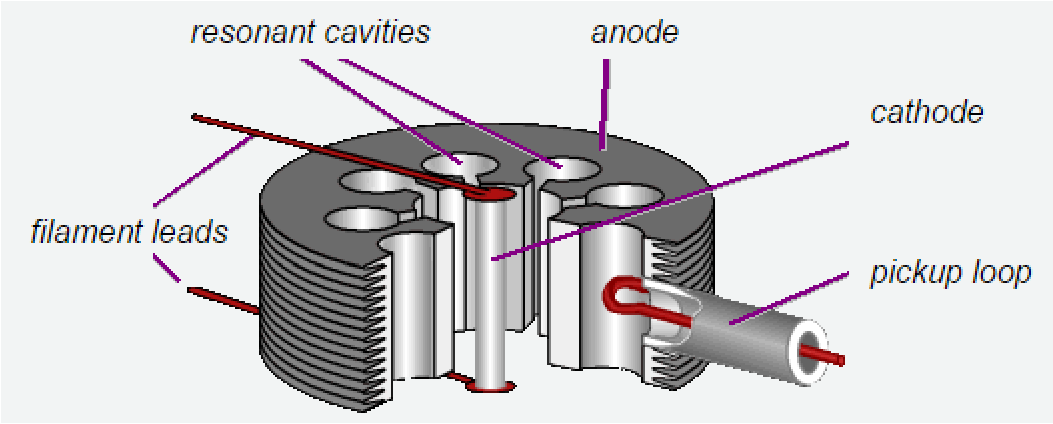

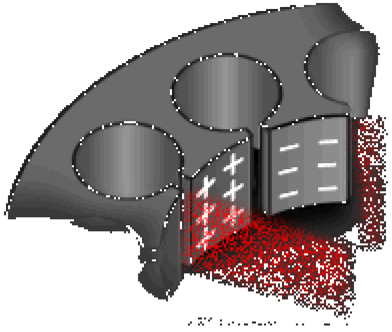

Transmission lines

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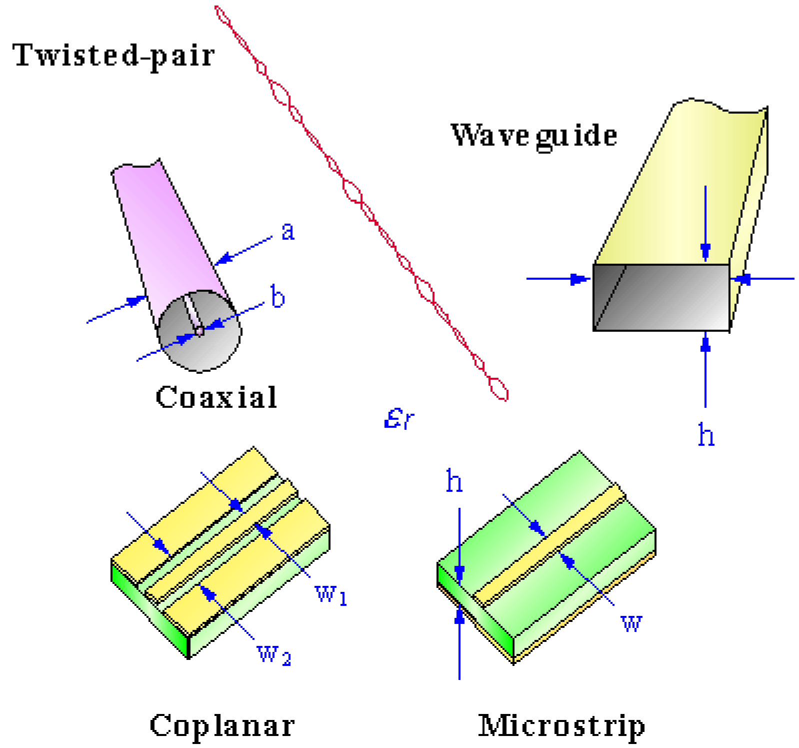
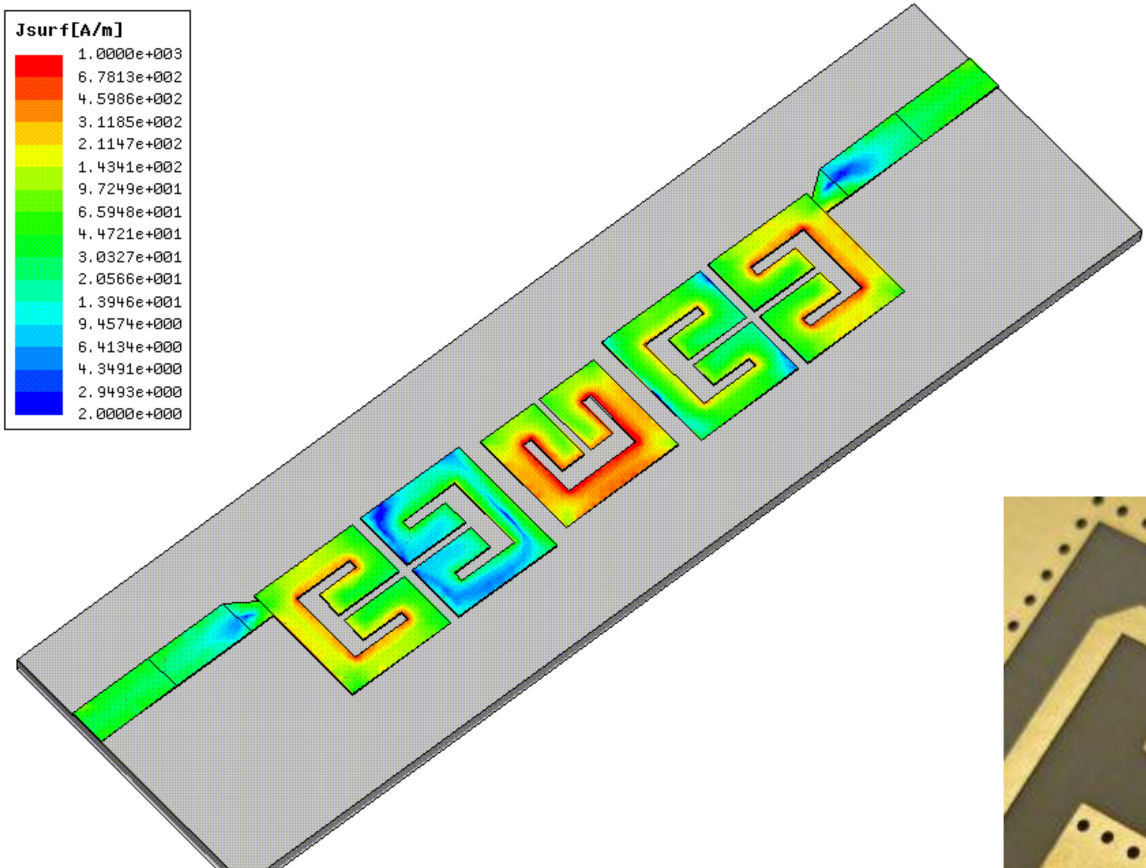
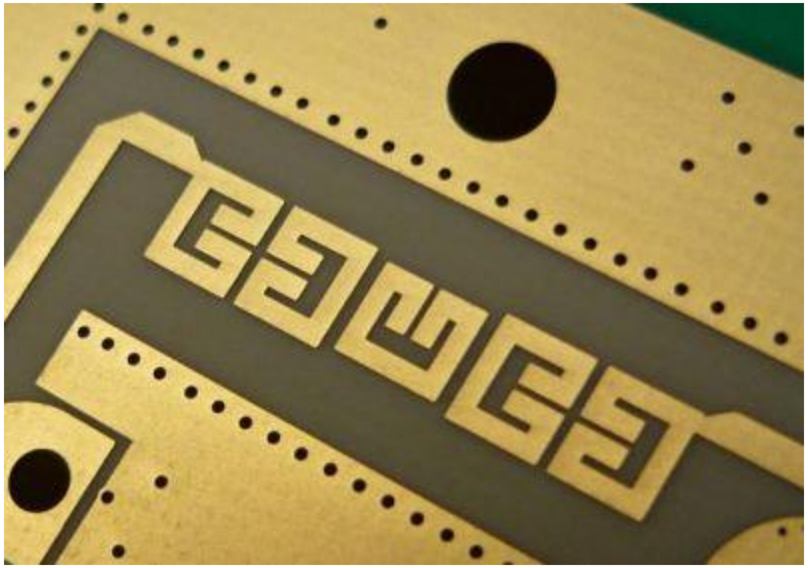
Transmission lines

- A device that transfers energy from one point to another with a minimum loss.
- Forms:
  - Twisted pair
  - Coaxial cable
  - Stripline
  - Microstrip
  - Waveguide



Microwave Filters





Compact Hairpin Band Pass Filter
Based on the traditional hairpin design, this 7GHz filter was made compact for a microwave backhaul company.

Microwave imaging

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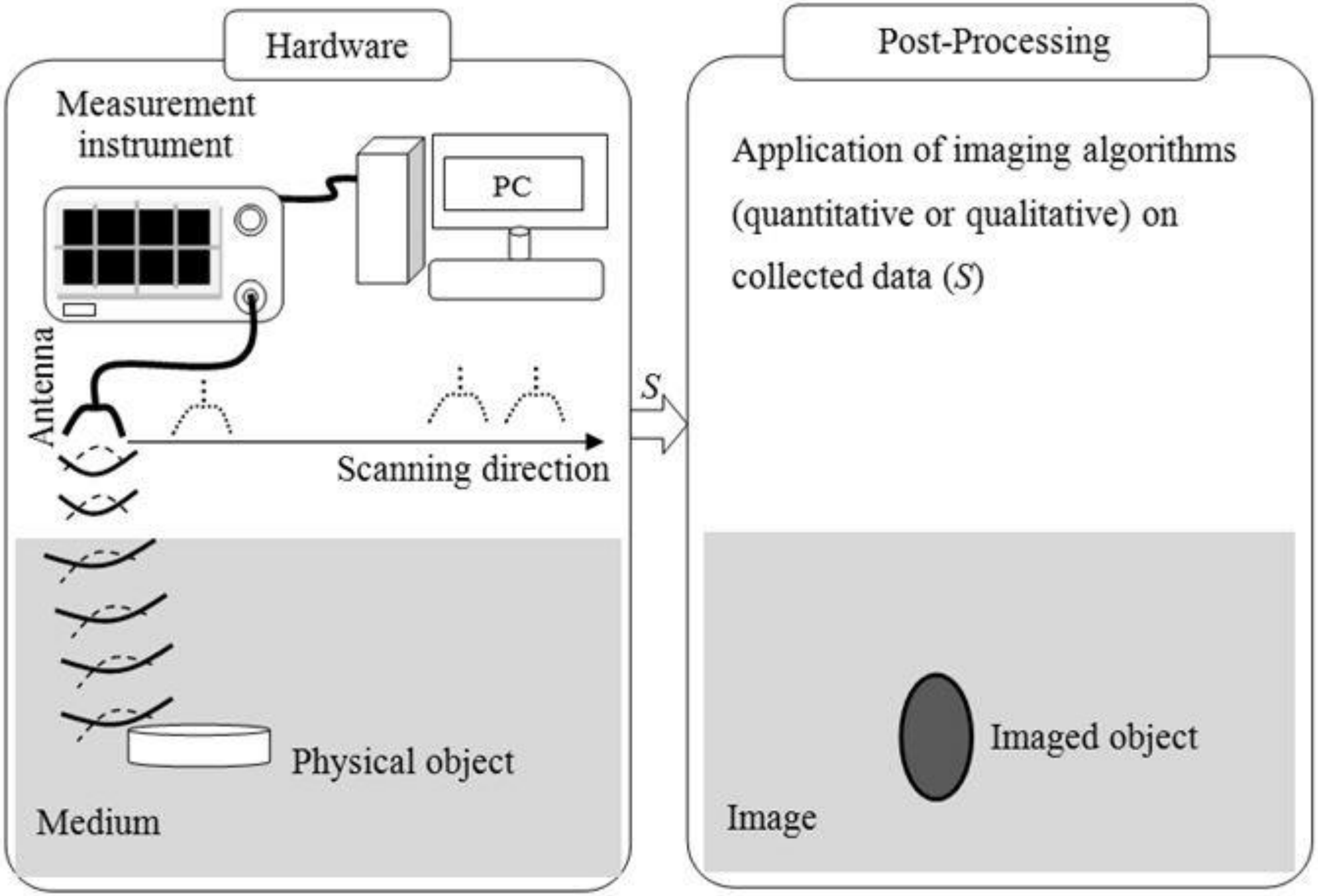
Microwave imaging is a science which has been evolved from older detecting/locating techniques (e.g., radar) in order to evaluate hidden or embedded objects in a structure (or media)using electromagnetic (EM) waves in microwave regime (i.e., ~300 MHz-300 GHz).



Microwave imaging

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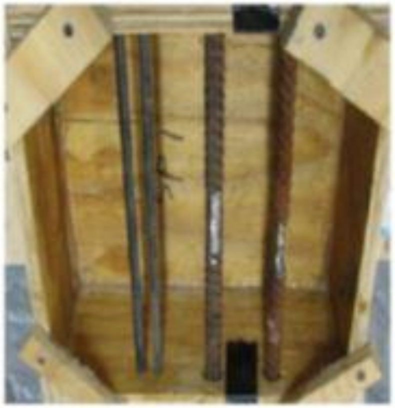

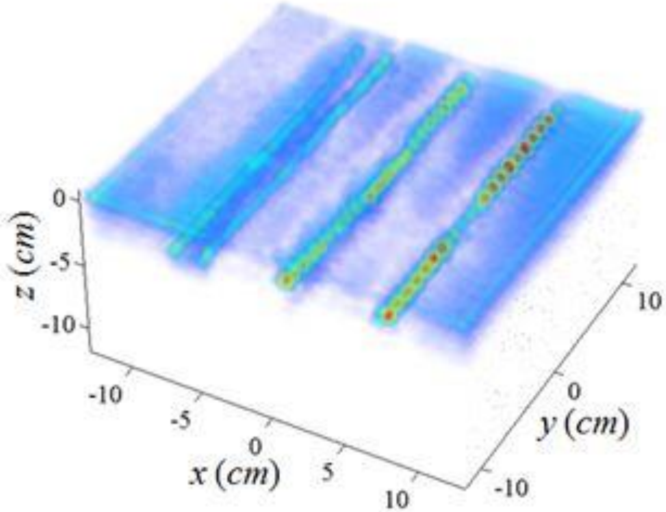

Microwaves

- in general, the lumped circuit element approximations of circuit theory may not be valid at high RF and microwave frequencies.
- Microwave components often act as distributed elements, where the phase of the voltage or current changes significantly over the physical extent of the device because the device dimensions are on the order of the electrical wavelength.
- At much lower frequencies the wavelength is large enough that there is insignificant phase variation across the dimensions of a component.

Why Microwaves?

- Antenna gain is proportional to the electrical size of the antenna. At higher frequencies, more antenna gain can be obtained for a given physical antenna size.
- More bandwidth (directly related to data rate) can be realized at higher frequencies.
- Microwave signals travel by line of sight and are not bent by the ionosphere as are lower frequency signals. Satellite and terrestrial communication links with very high capacities are therefore possible, with frequency reuse at minimally distant locations.
- The effective reflection area (radar cross section) of a radar target is usually proportional to the target's electrical size. This fact, coupled with the frequency characteristics of antenna gain, generally makes microwave frequencies preferred for radar systems.
- Various molecular, atomic, and nuclear resonances occur at microwave frequencies, creating a variety of unique applications in the areas of basic science, remote sensing, medical diagnostics and treatment, and heating methods.

Overview

- In this set of notes we first overview different types of waveguiding systems, including transmission lines.

- We then develop transmission line theory in detail.

Waveguiding Structures

A waveguiding structure is one that carries a signal (or power) from one point to another.

There are three common types:

- Transmission lines
- Fiber-optic guides
- Waveguides

Transmission Line

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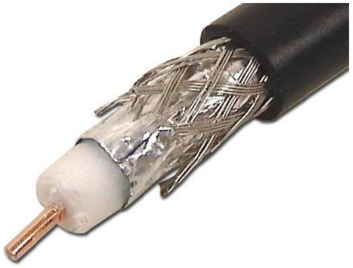
Properties

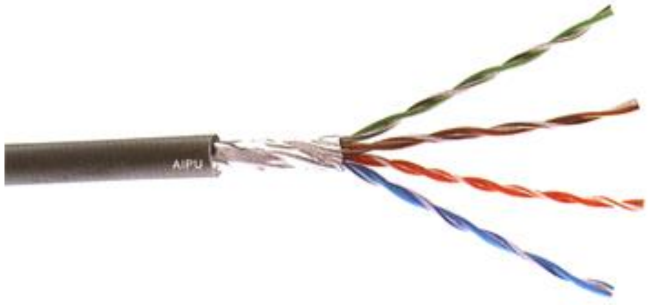
- Has two conductors running parallel (one can be inside the other)
- Can propagate a signal at any frequency (in theory)
- Becomes lossy at high frequency
- Can handle low or moderate amounts of power
- Does not have signal distortion, unless there is loss (but there always is)
- May or may not be immune to interference (shielding property)
- Does not have E_z or H_z components of the fields (TEM$_z$)



Coaxial cable (coax)

Twin lead
(shown connected to a 4:1 impedance-transforming balun)

Transmission Line (cont.)



CAT 5 cable
(twisted pair)

The two wires of the transmission line are twisted to reduce interference and radiation from discontinuities.

Transmission Line (cont.)

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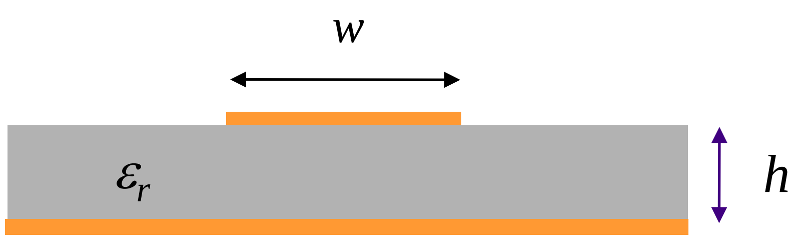
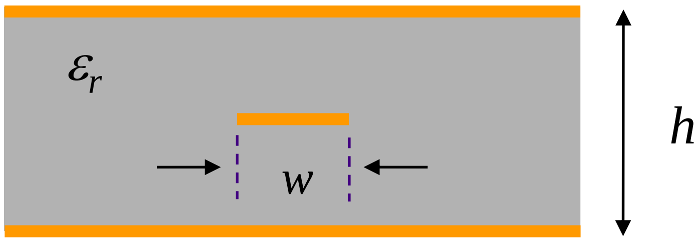
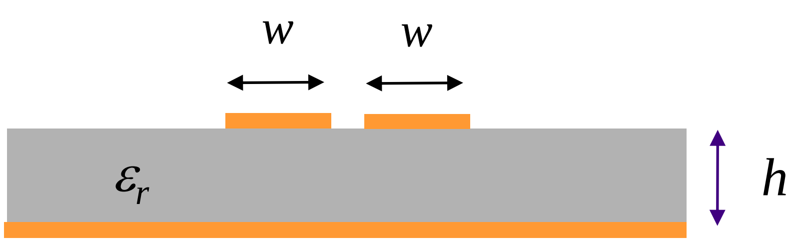
Transmission lines commonly met on printed-circuit boards



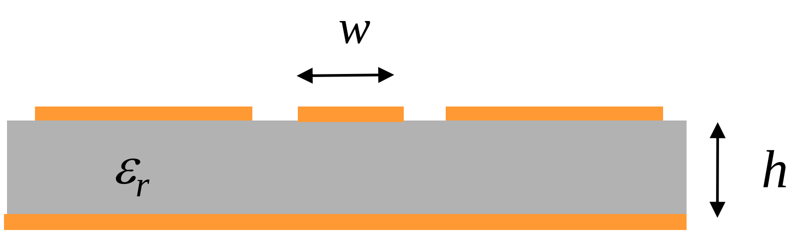
Microstrip



Stripline



Coplanar strips



Coplanar waveguide (CPW)

Transmission Line (cont.)

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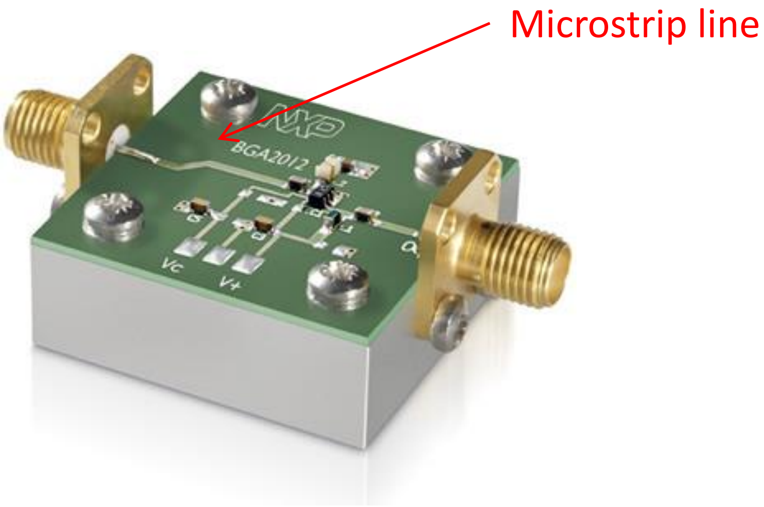
Transmission lines are commonly met on printed-circuit boards.



A microwave integrated circuit.

Waveguides

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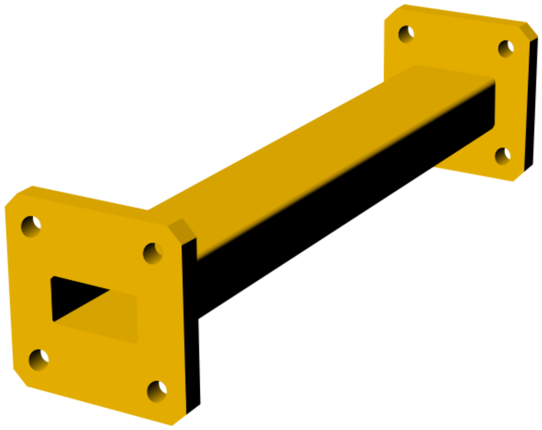
Properties

- Consists of a single hollow metal pipe
- Can propagate a signal only at high frequency: $f > f_c$
- The width must be at least one-half of a wavelength
- Has signal distortion, even in the lossless case
- Immune to interference
- Can handle large amounts of power
- Has low loss (compared with a transmission line)
- Has either E_z or H_z component of the fields (TM_z or TE_z)

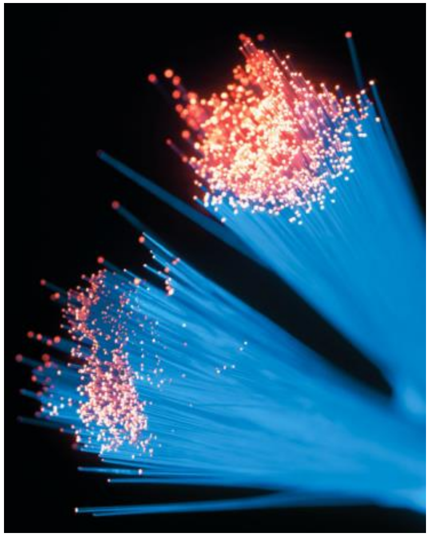


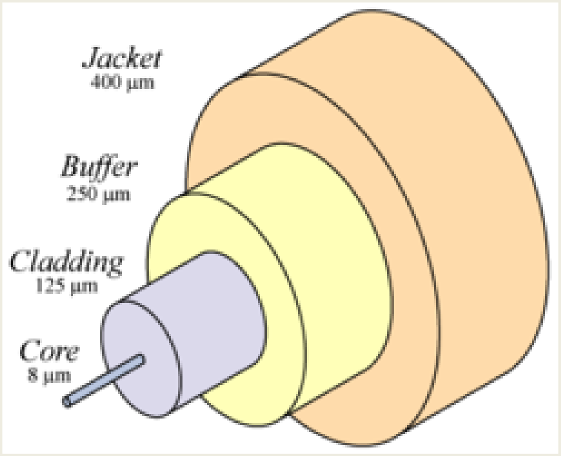
http://en.wikipedia.org/wiki/Waveguide_(electromagnetism)

Fiber-Optic Guide

Properties

- Uses a dielectric rod
- Can propagate a signal at any frequency (in theory)
- Can be made to have very low loss
- Has minimal signal distortion
- Has a very high bandwidth
- Very immune to interference
- Not suitable for high power
- Has both E_z and H_z components of the fields ("hybrid mode")





Fiber-Optic Guide (cont.)

Two types of fiber-optic guides:

1) Single-mode fiber

Carries a single mode, as with the mode on a transmission line or waveguide. Requires the fiber diameter to be small relative to a wavelength.

2) Multi-mode fiber

Has a fiber diameter that is large relative to a wavelength. It operates on the principle of total internal reflection (critical angle effect).

Note: The carrier is at optical frequency, but the modulating (baseband) signal is often at microwave frequencies (e.g., TV, internet signal).

Fiber-Optic Guide (cont.)

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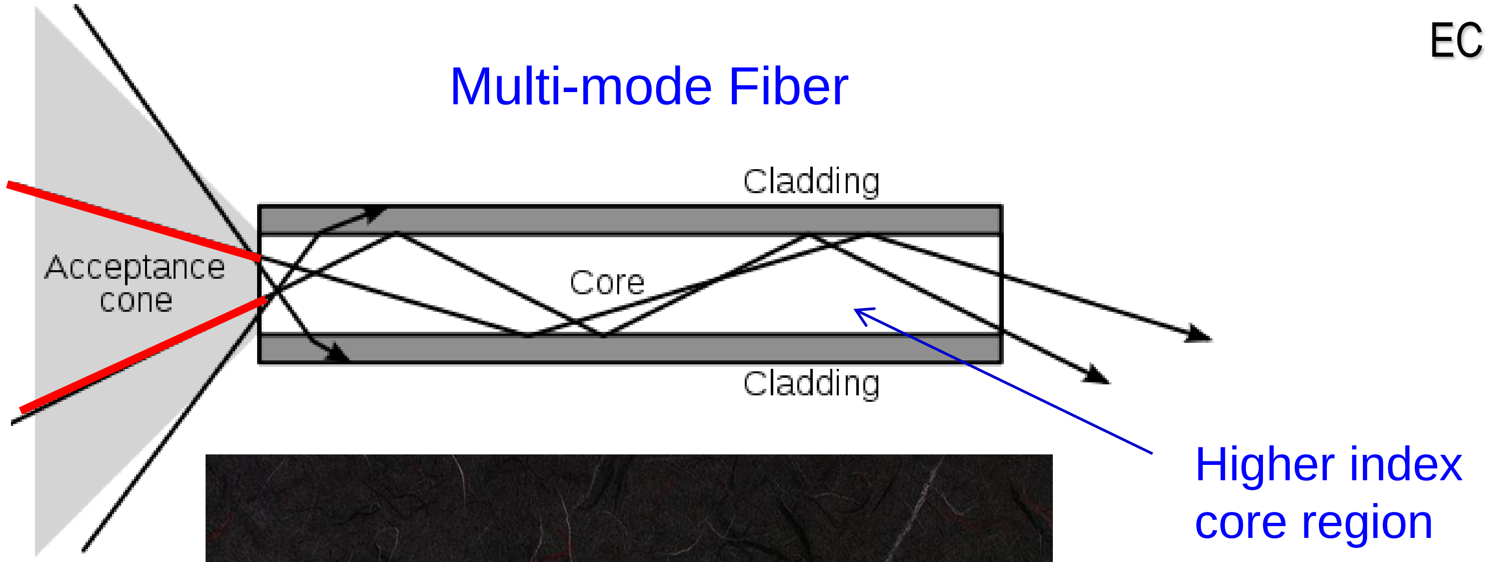
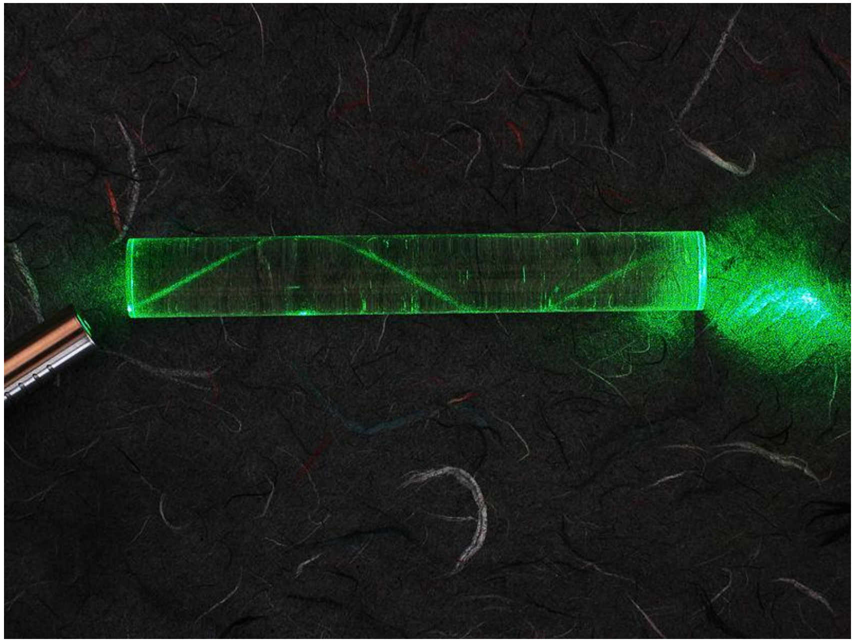
Multi-mode Fiber





http://en.wikipedia.org/wiki/Optical_fiber