ECE 344

MICROWAVE FUNDAMENTALS
PART1-Lecture 1

Dr. Gehan Sami

Many Slides from: ECE 5317_6351 Microwave Engineering *Prof. David R. Jackson*

Course Objectives

For students undertaking this course, they will be able to:

1. Derive and solve the wave equations in many microwave structures such as transmission lines and waveguides and analyze propagation of wave along these structures.
2. Use smith chart to determine input impedance of TL loaded with different passive elements
3. Use of Smith chart for designing matching circuits as L section, single stub, double stub and quarter wave transformer
4. Analyze typical microwave networks using impedance, admittance, and scattering matrix representations
5. Analyze the behavior of different microwave devices such as power divider/combiner, and couplers

First Part Course Contents

- ❑ Course Objectives and Outline
- ❑ Circuit Model for Transmission lines
- ❑ General Transmission Line Equations
- ❑ Standing Wave Properties
- ❑ Advanced Design System (ADS) program- Simulation for microwave circuits
- ❑ Quarter wavelength transformer
- ❑ Smith chart
- ❑ Rectangular Waveguide

Teaching and learning methods:

- Face2face-Online Education - Tutorial/exercise
- Mini project using ADS
- Research and reporting – presenting

Assessment Methods:

- Writing exam
- Online Exam
- Quizzes
- Research and Report Assignment
- Project Assignments
- In class Questions

Course Assessment (150/2)

Part 1 Dr. Gehan Sami

• Attendance/Quiz	5
• Midterms	10
• ADS_Project	5
• Assignment_Report/presenting	5
• Final Exam	50
• Total	75

Note: ADS project on selected type of filters. Assignment on one RF circuit used in RF power harvesting

List of References

Textbook:

D.M. Pozar "*Microwave Engineering*", 4th edition, Wiley publishing

- *Related readings:*

R.E. Collin "*Foundations for microwave engineering*", McGraw-Hill, 2nd ed., 1992

-ECE 5317_6351 Microwave Engineering Prof. David R. Jackson [University of Houston/Texas/United states]

Simulators

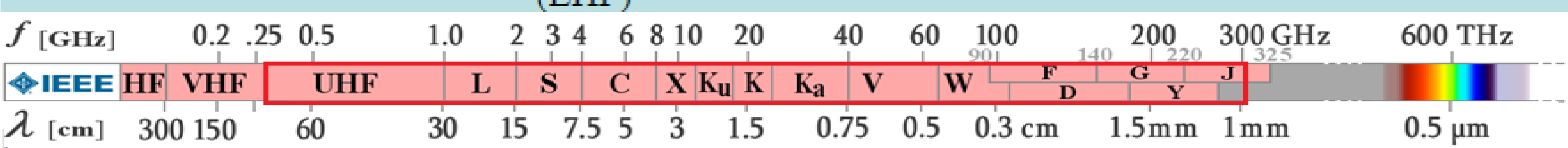
- HFSS High Frequency Structure Simulator.
- ADS Advanced Design System

Introduction

- Microwave refer to alternating signals with frequencies between 300MHz and 300GHz,with wavelength between λ=c/f=1m and 1mm.

Frequency Spectrum Designations

Frequency band	Wavelength	Designation	Services
3 to 30 kHz	100 to 10 km	Very Low Frequency (VLF)	Navigation, sonar, submarine
30 to 300 kHz	10 to 1 km	Low Frequency (LF)	Radio beacons, navigation
300 to 3000 kHz	1000 to 100 m	Medium Frequency (MF)	AM broadcast, maritime/coast-guard radio
3 to 30 MHz	100-10 m	High Frequency (HF)	Telephone, telegraph, fax; amateur radio, ship-to-coast and ship-to-aircraft communication
30 to 300 MHz	10-1 m	Very High Frequency (VHF)	TV, FM broadcast, air traffic control, police, taxicab mobile radio
300 to 3000 MHz	100-10 cm	Ultrahigh Frequency (UHF)	TV, satellite, radiosonde, radar, bluetooth, PCS, wireless LAN
3 to 30 GHz	10-1 cm	Super High Frequency (SHF)	Airborne & automotive radar, microwave relay, satellite, mobile communication, local wireless ntw
30 to 300 GHz	10-1 mm	Extremely High Frequency (EHF)	Radar, experimental, security systems



• Why we use microwaves

microwave signals offer wide bandwidths, and have the added advantage of being able to penetrate fog, dust, foliage, and even buildings and vehicles to some extent

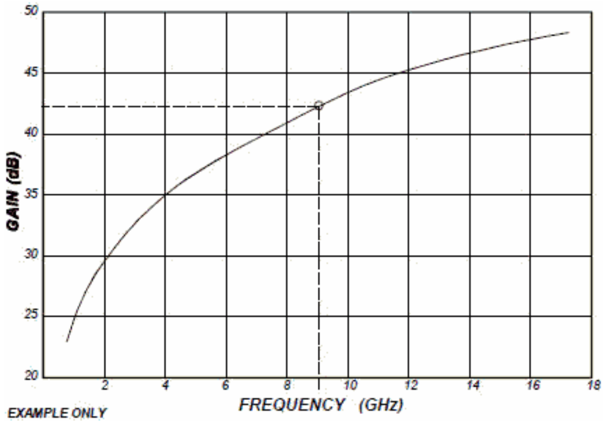
Microwaves are widely used for point-to-point communications because their small wavelength allows conveniently-sized antennas to direct them in narrow beams, which can be pointed directly at the receiving antenna

high frequency of microwaves gives the microwave band a very large information-carrying capacity.

Antenna gain is proportional to the electric size of the antenna. for Dish antenna physical size almost equal to Electrical size

$$D_{\max} = \frac{4\pi A}{\lambda^2}$$

f ↑, gain ↑



Gain of a Typical 6 Foot Dish Antenna (with Losses)

Voyager spacecraft

The Voyager spacecrafts were built to fly past the outer planets (Jupiter, Saturn, Neptune and Uranus) and study them closely

Voyager 1 is currently about 11 billion kilometers away from Earth and is still transmitting -- it takes about 10 hours for the signal to travel from the spacecraft to Earth (speed $3X10^8$ m/s)

The Voyager spacecraft use 23-watt radios. This is higher than the 3 watts a typical cell phone uses

The Voyager spacecraft has an antenna that is 3.7 meters in diameter, and it transmits to a 34 meter antenna on Earth.

The Voyager satellites are also transmitting in the 8 GHz range, and there is not a lot of interference at this frequency.

-the earth antenna transmits back to the spacecraft, it uses extremely high power (tens of thousands of watts) to make sure the spacecraft gets the message

<u>The key to receive signals</u>

- Very large antennas
- Directional antennas that point right at each other
- Radio frequencies without a lot of man-made interference on them

https://voyager.jpl.nasa.gov/

Microwave Applications

<u>Three main applications of microwaves in everyday life:</u>

1- Heating

-Microwave ovens

2- Remote sensing

- Radars (radio direction and ranging),detect object position or velocity (or both).
- RFID
- Radio astronomy

3- Communications

- satellite, radio, television, wireless phone and data transmission applications

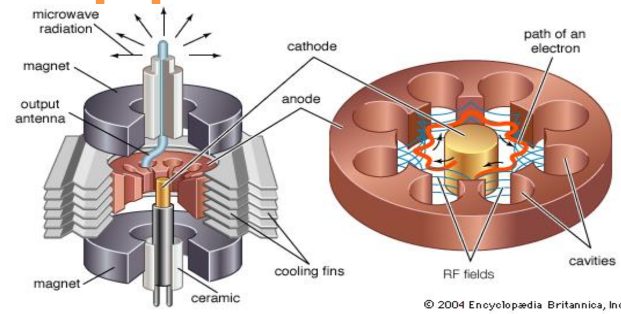
- Other applications as:

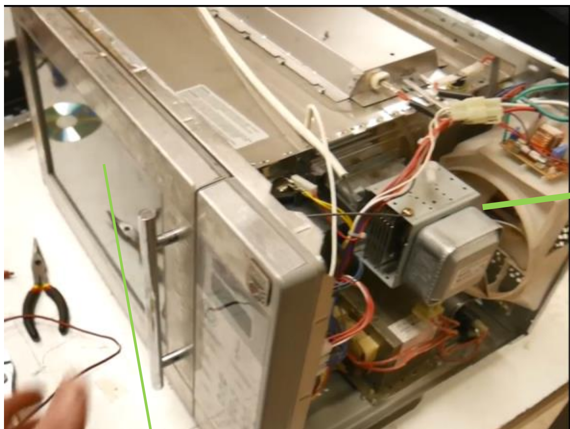
- Medical applications
- Directed energy weapons

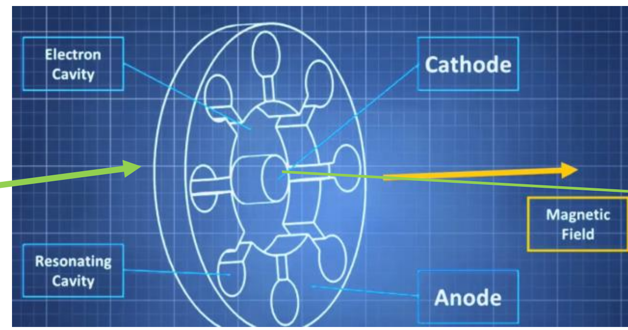
https://www.microwaves101.com/

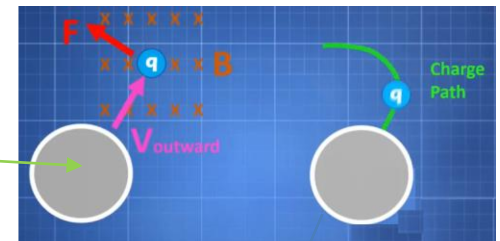
Microwave Applications

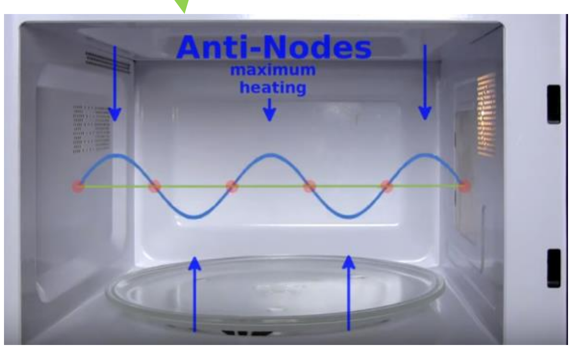
Microwave ovens



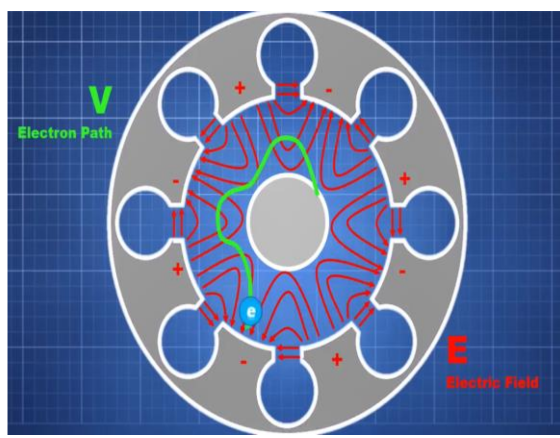


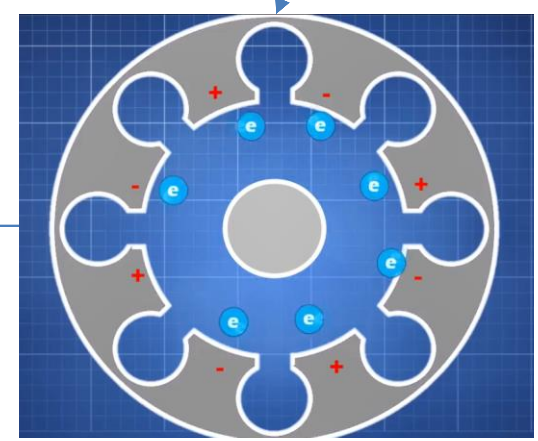






f=2.45GHz

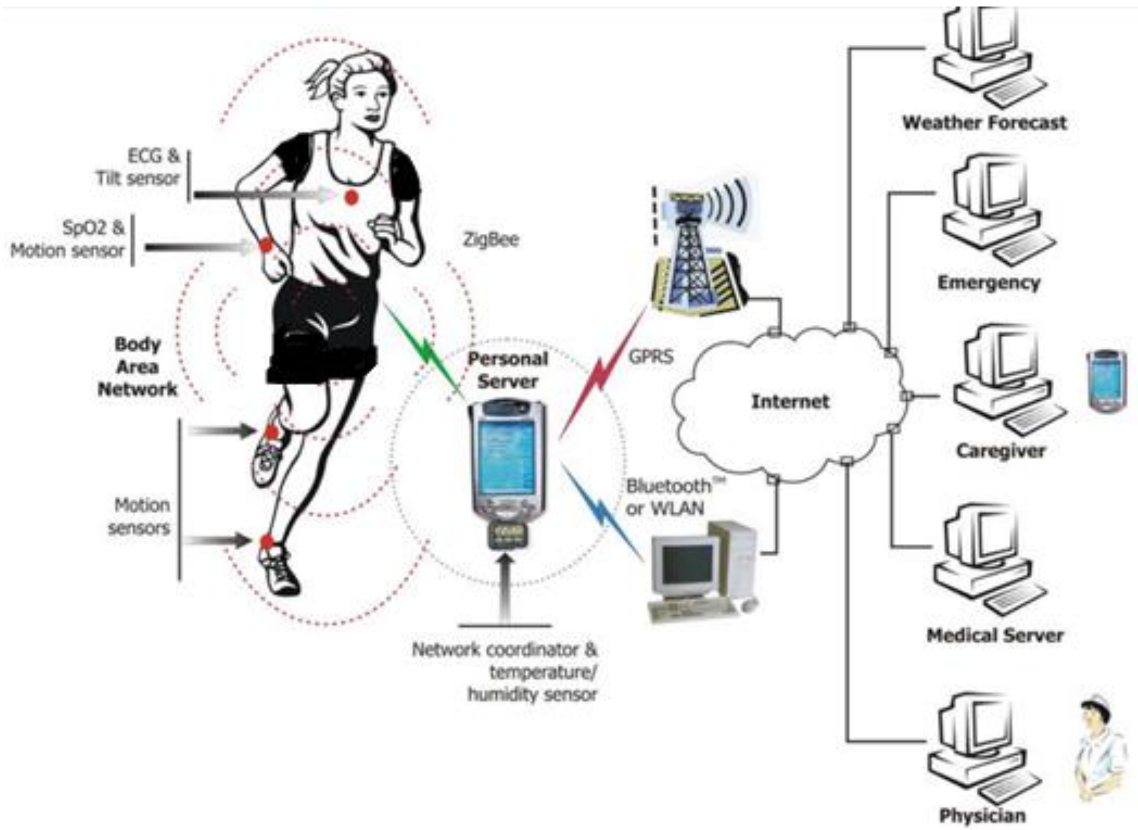




Microwave Applications

Medical applications

Patient monitoring

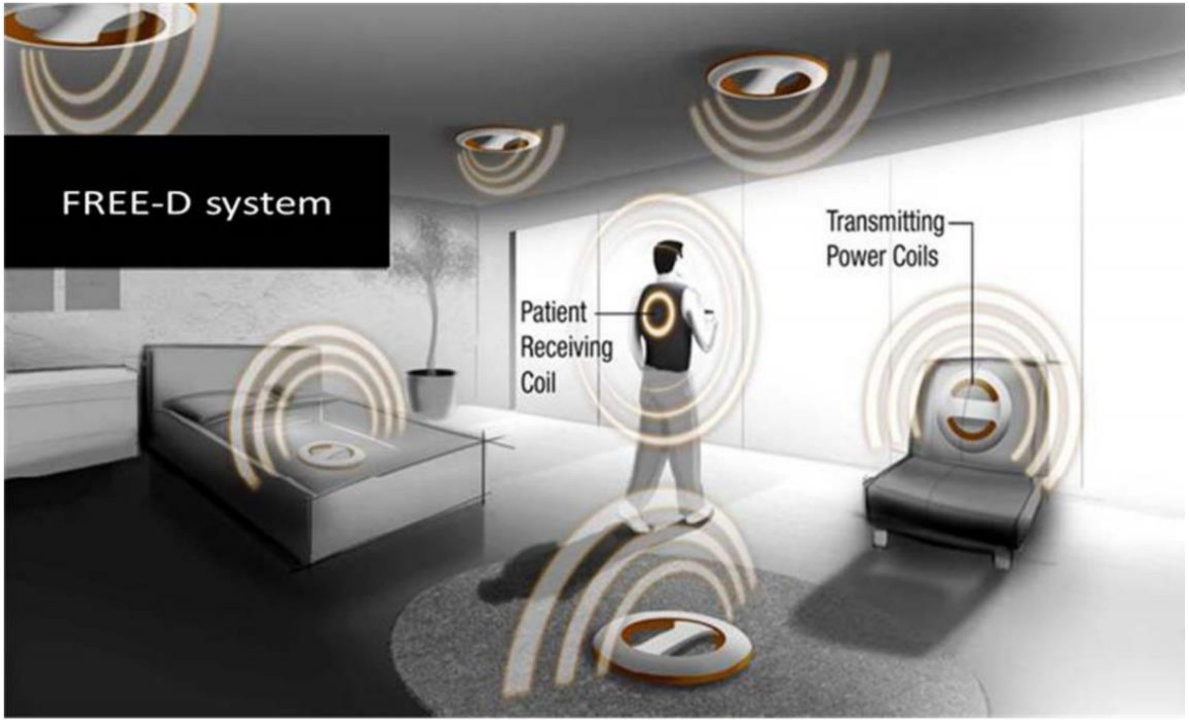


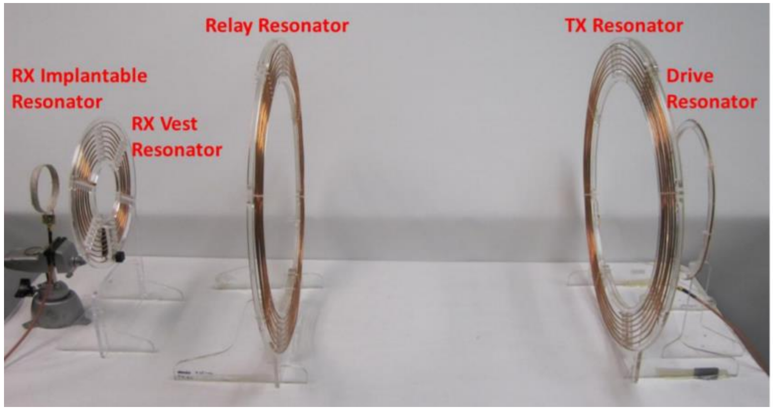
Figure

Wireless Body Area Network of Intelligent Sensors for Patient Monitoring

Microwave Applications

Medical applications





Free-range Resonant Electrical Energy Delivery System (FREE-D) for a Ventricular Assist Device

University of Washington

Transmission Line

II. Rectifier Circuit Design

A rectifier circuit RF-DC can be implemented with one or more Schottky diodes, a low-pass filter at the input of the circuit, a DC load (RF-block capacitor + resistor) and a matching network, as shown in Fig.1.

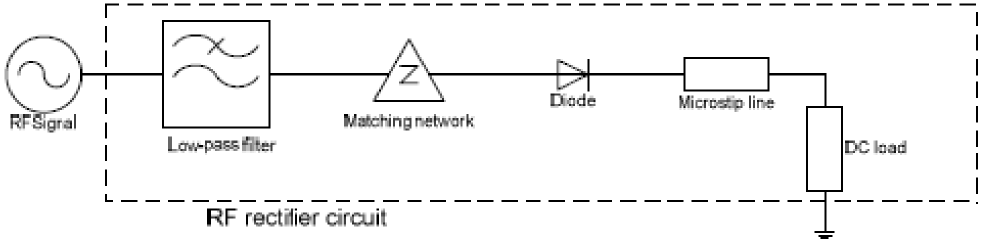
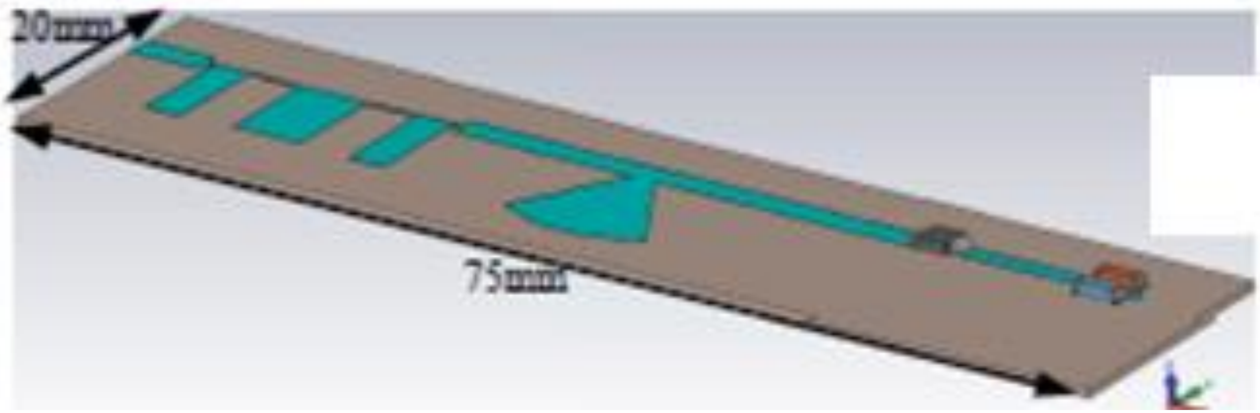
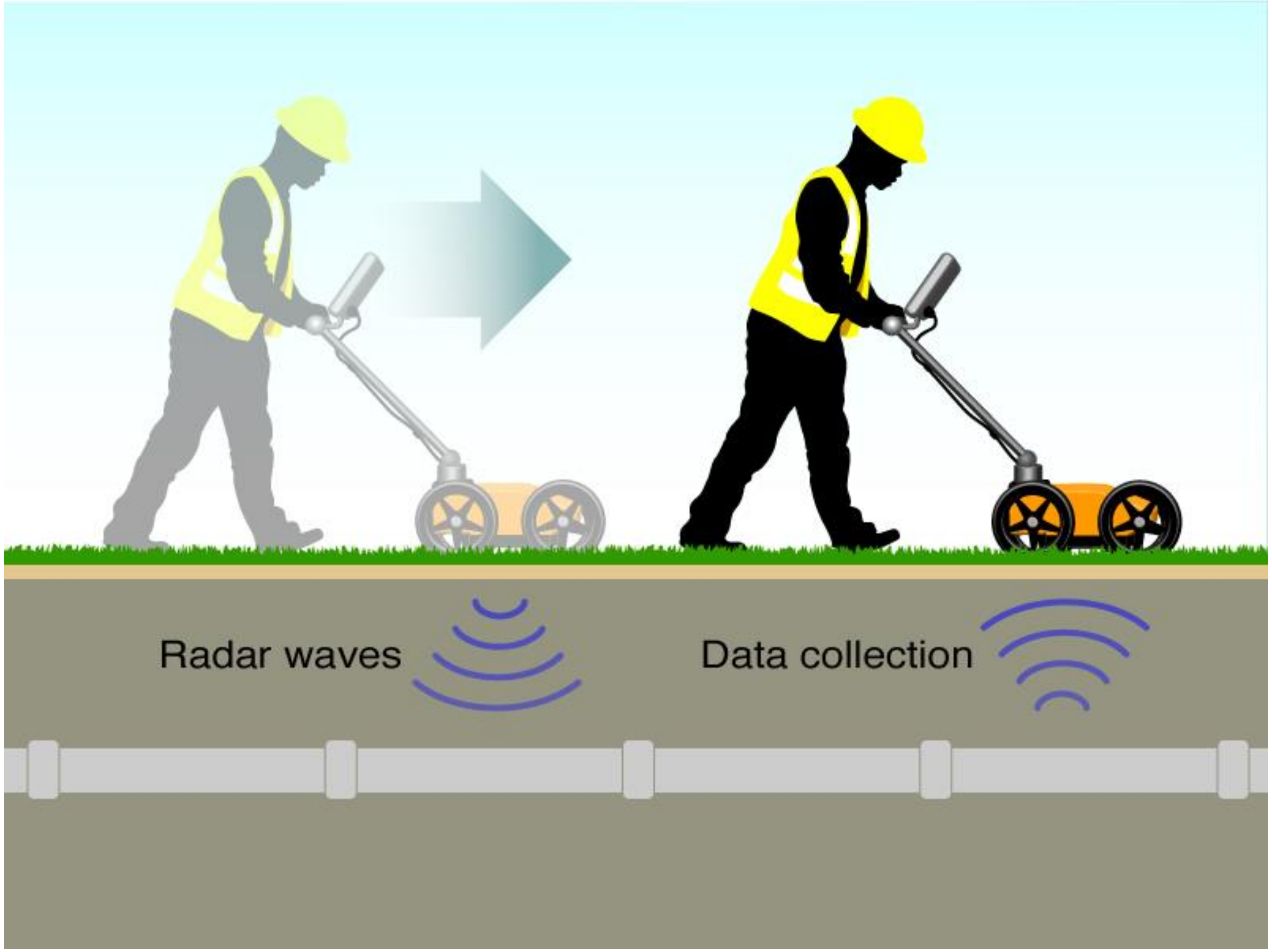


Fig.1: RF energy rectifier circuit.



Microwave Applications

GROUND PENETRATING RADAR AND MICROWAVE TOMOGRAPHY



Transmission Line

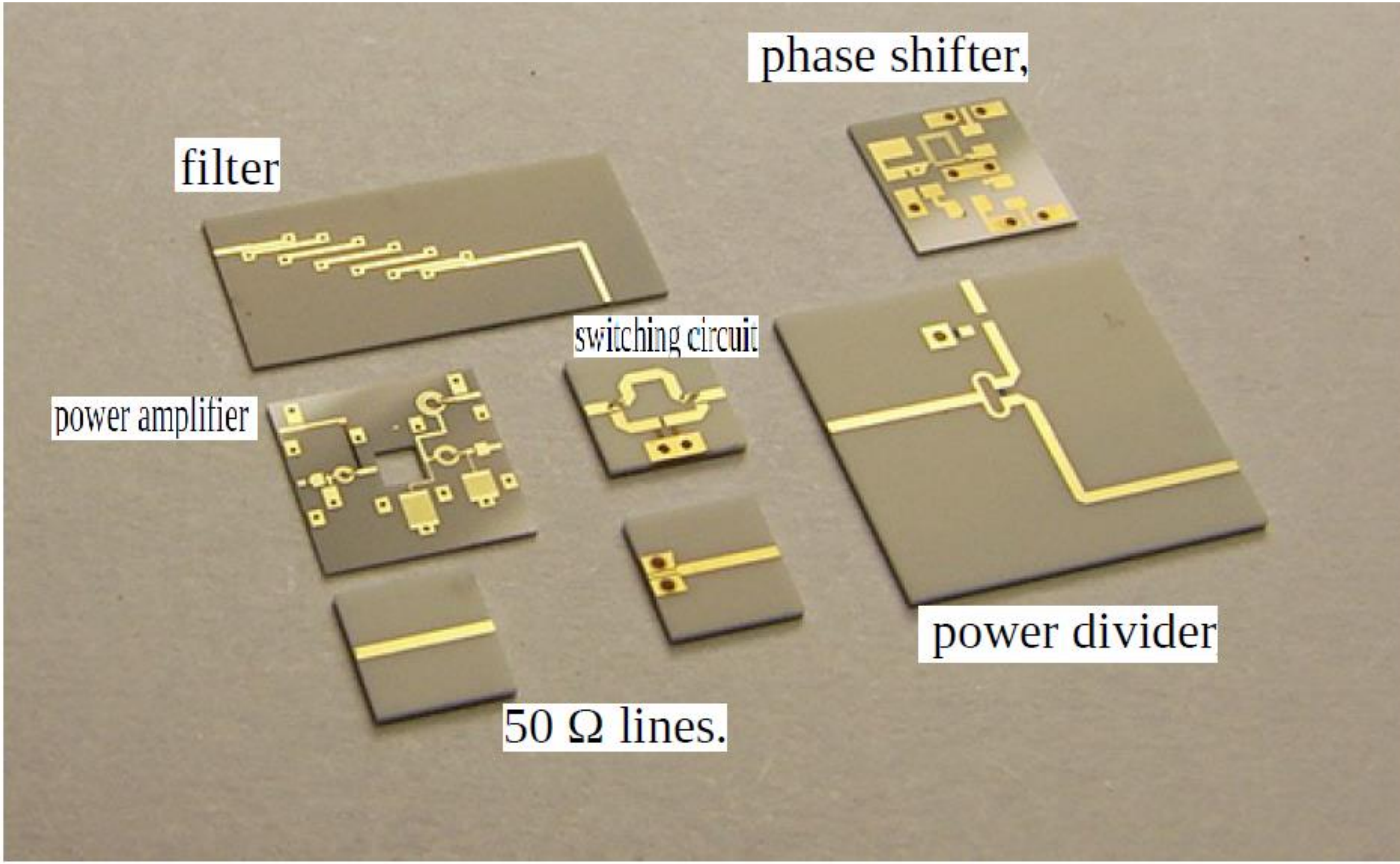
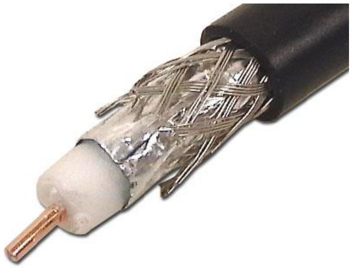


Figure A photograph of substrates produced by the thin-film process.

Transmission Line

Coaxial cable (coax)

Properties



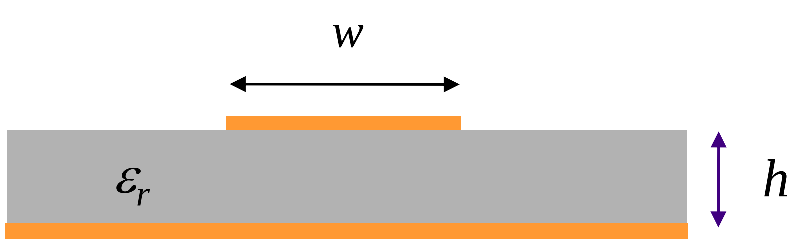
- Can propagate a signal at any frequency (in theory)
- Becomes lossy at high frequency
- Can handle low or moderate amounts of power
- Does not have E_z or H_z components of the fields (TEM_z)

Planar Transmission Lines

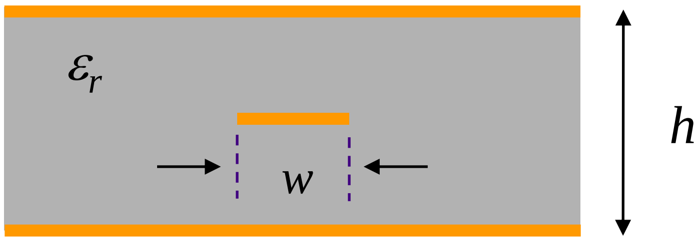
- Microstrip.
- Slot Line.
- Coplanar waveguide.
- Coplanar lines.

Transmission Line (cont.)

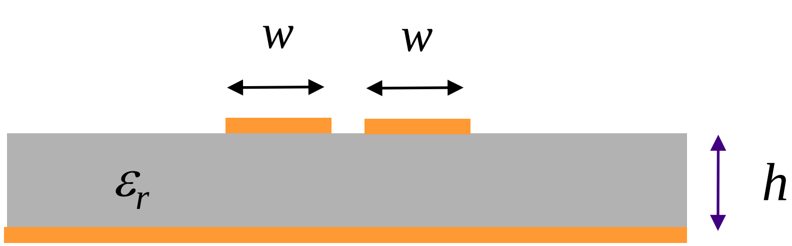
Transmission lines commonly met on printed-circuit boards



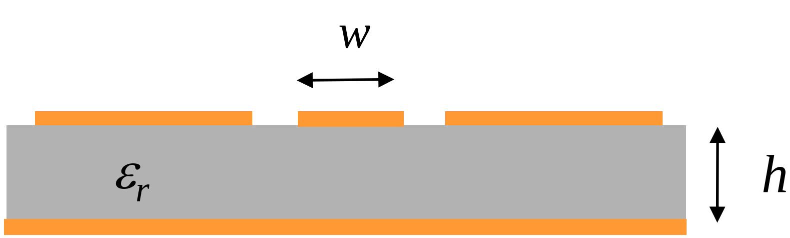
Microstrip



Stripline



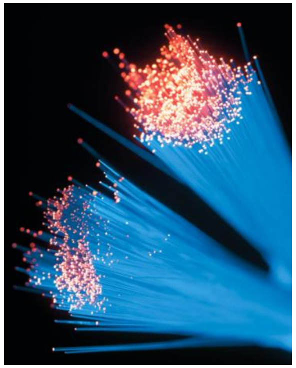
Coplanar strips



Coplanar waveguide (CPW)

Fiber-Optic Guide

Properties



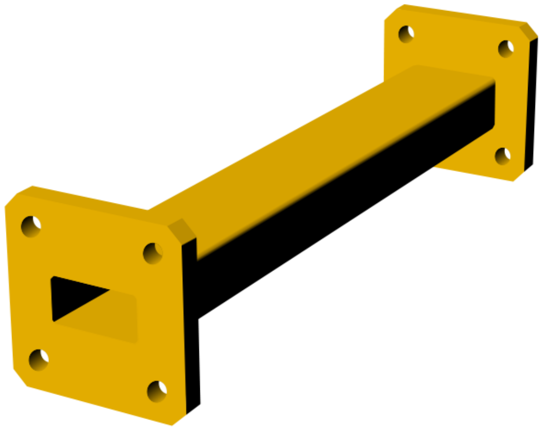
- Has minimal signal distortion
- Very immune to interference
- Not suitable for high power
- Has both E_z and H_z components of the fields

Wave guides

Waveguides

Properties

- Has a single hollow metal pipe
- Can propagate a signal only at high frequency: $\omega > \omega_c$
- 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)