Antenna Overview
Introduction

• The antenna is the interface between the transmission line and space
• Antennas are passive devices; the power radiated cannot be greater than the power entering from the transmitter
• Antennas are reciprocal - the same design works for receiving systems as for transmitting system
• The following slides will cover the following topics:
  – Antenna Parameters
  – Antenna Types
  – Antenna Matching
Radiation Resistance

1. Typically, the length of a half-wave dipole is 95% of one-half the wavelength measured in free space. The half-wave dipole looks like a resistance of 70 ohms at its feed-point.

2. The portion of an antenna’s input impedance that is due to power radiated into space is known as **radiation resistance**

3. When the material loss is taken into consideration, antenna efficiency is defined as $P_{\text{rad}}/P_{\text{in}} = R_r/(R_r + R_L)$.

4. Antenna has a resonance frequency.
Return loss/VSWR

- If the frequency is above resonance, the feed-point impedance has an inductive component; if the frequency is below resonance, the component is capacitive. At the resonance frequency, the antenna is pure resistance.
- The Reflection Coefficient is defined as the ratio of reflected power to incident power.
- The VSWR is defined as the

\[
\Gamma = \frac{V_r}{V_i}, \quad \Gamma = \frac{Z_L - Z_O}{Z_L + Z_O}
\]

\[
S_{11} = -20 \log_{10} |\Gamma| \text{ dB}
\]

\[
\text{VSWR} = \frac{|V_{\max}|}{|V_{\min}|} = \frac{1 + |\Gamma|}{1 - |\Gamma|}.
\]
Radiation Patterns

- Antenna coordinates are shown in three-dimensional diagrams
- The angle $\phi$ is measured from the $x$ axis in the direction of the $y$ axis (Azimuth - 'azəməθ) plane, 360 Degree)
- The $z$ axis is vertical, and angle $\theta$ is usually measured from the horizontal plane to the zenith (Elevation Plane, 180 Degree)
Plotting Radiation Patterns

Typical radiation patterns are displayed in a polar plot in most antenna data sheet

Diple 3D Radiation Pattern
Azimuth Plane Pattern
Elevation Plane Pattern
Gain and Directivity

- In antennas, power gain in one direction is at the expense of losses in others.
- Directivity is the gain calculated w.r.t. an isotropic radiation.
- Antenna Gain for standard dipole is 2.15dB.

\[
P_{iso} = \frac{Total \ Power}{Total \ Area} = \frac{E}{4\pi R^2}
\]

And the antenna gain is defined as:

\[
Gain \ (\text{dBi}) = 10 \log \frac{P_{\text{max}}}{P_{iso}}
\]
Beamwidth

- A directional antenna can be said to direct a beam of radiation in one or more directions.
- The width of this beam is defined as the angle between its half-power points.
- A half-wave dipole has a beam-width of about 79° in one plane and 360° in the other.
- Many antennas are far more directional than a dipole.
**Major and Minor Lobes**

1. In the left diagram, the antenna has one *major lobe* and a number of minor ones.
2. Each of these lobes has a gain and a beam width which can be found using the diagram.
3. Front-to-back ratio: The *ratio* of power gain between the *front* and *rear* of a directional antenna. Ratio of signal strength transmitted in a forward direction to that transmitted in a backward direction.
Effective Isotropic Radiated Power and Effective Radiated Power

• In practical situations, we are more interested in the power emitted in a particular direction than in total radiated power.

• Effective Radiated Power (ERP) represents the power input multiplied by the antenna gain measured with respect to a half-wave dipole.

• Effective isotropic radiated power is the total power that would have to be radiated by a hypothetical isotropic antenna to give the same signal strength as the actual source in the direction of the antenna's strongest beam.

• An Ideal dipole has a gain of 2.15 dBi; EIRP is 2.15 dB greater than the ERP for the same antenna combination.

\[
\text{EIRP(dB)} = \text{ERP(dB)} + 2.15
\]
Antenna Effective Area

• The antenna effective area is defined as: the ratio of the available power at the terminals of a receiving antenna to the power flux density of a plane wave incident on the antenna from that direction (If the direction is not specified, the direction of maximum radiation intensity is implied).

• For linear wire antenna, simply increasing the size of antenna does not guarantee an increase in effective area; however, with other factors being equal, antennas with higher effective areas are generally larger.

\[ A_{\text{eff}} = \frac{\lambda^2}{4\pi} G \]

• Friis Transmission equation:

\[ P_r = \frac{P_t G_t}{4\pi R^2} A_{\text{eff}} \quad A_{\text{eff}} = \frac{P_t G_t}{4\pi R^2} \cdot \frac{\lambda^2}{4\pi} G_r \quad G_r = \frac{\lambda^2}{(4\pi)^2} G_t G_r P_t \]
Ground Effect to an Isotropic Radiator

- When an antenna is installed within a wavelength of the ground, the earth acts as a reflector and has a considerable influence on the radiation pattern of the antenna.
- Ground effects are important up through the HF range. At VHF and above, the antenna is usually far enough above the earth that reflections are not significant.
- Ground effects are complex because the characteristics of the ground are variable.
Antenna types

• Other types of simple antennas are:
  – The folded dipole
  – The monopole antenna
  – Loop antennas
  – The five-eighths wavelength antenna
  – The Discone antenna
  – The helical antenna
  – Horn antenna
  – Reflector antenna
  – Embedded PCB antenna
The Folded Dipole

- The folded dipole is the same length as a standard dipole, but is made with two parallel conductors, joined at both ends and separated by a distance that is negligible compared with the wavelength.
- The current in the folded dipole is in phase with the original dipole. So, for the same current, the radiation power is 4 times of the standard dipole. That gives that the folded dipole has approximately 4 times the input impedance of a standard dipole (~300 Ω).
- The folded dipole has wider bandwidth.

\[ P = (2I)^2 R = I^2 \cdot (4R) \]
The Monopole Antenna

- For low- and medium-frequency transmissions, it is necessary to use vertical polarization to take advantage of ground-wave propagation.
- A quarter-wavelength monopole antenna with a perfect ground reference is identical as a standard dipole (Ground has mirroring effect).
- Fed at one end with an unbalanced feedline, with the ground conductor of the feedline taken to earth ground.
Loop Antennas

- Sometimes, smaller antennas are required for certain applications, like AM radio receivers.
- These antennas are not very efficient but perform adequately.
- One wave-length circumference loop antenna is considered as fundamental as half wavelength dipole (radiation resistance ~ 200 Ω).
- Two types of loop antennas are:
  - Air-wound loops
  - Ferrite-core loopsticks
The Five-Eighths Wavelength Antenna

- The five-eighths wavelength antenna is used vertically either as a mobile or base antenna in VHF and UHF systems.
- It has omni-directional response in the horizontal plane.
- Radiation is concentrated at a lower angle, resulting in gain in the horizontal direction.
- It also has a higher impedance than a quarter-wave monopole and does not require a good ground.
The biconical and Discone Antenna

- Biconical antennas are broadband dipole antennas, typically exhibiting a bandwidth of three octaves or more. A common subtype is the bowtie antenna, essentially a two-dimensional version of the biconial design which is often used for short-range UHF television reception.
- A discone antenna is a version of a biconical antenna in which one of the cones is replaced by a disc.
- It also has an omnidirectional pattern in the horizontal plane and a gain comparable to that of a dipole.
- The feedpoint resistance is typically 50 ohms.
- Typically, the length of the surface of the cone is about one-quarter wavelength at the lowest operating frequency.
The Helical Antenna

- Several types of antennas are classified as helical.
- Normal-mode helical antenna: rubber ducky antenna used with many handheld transceivers. The loading provided by the helix allows the antenna to be physically shorter than its electrical length of a quarter-wavelength.
- Axial-mode helical antenna: when the helix circumference is one wavelength of operation. The radiation from each helix is in phase. This is a non-resonant traveling wave mode and circular polarization.
Antenna Arrays

• Simple antenna elements can be combined to form arrays resulting in reinforcement in some directions and cancellations in others to give better gain and directional characteristics

• Arrays can be classified as broadside or end-fire (uni-directional)
  – Examples of arrays are:
    – The Yagi Array
    – The Log-Periodic Dipole Array
    – The Turnstile Array
    – The Monopole Phased Array
    – Other Phased Arrays
Reflectors

• An antenna reflector is a device that reflects electromagnetic waves. Antenna reflectors can exist as a standalone device for redirecting radio frequency (RF) energy, or can be integrated as part of an antenna assembly.

• The surface may consist of one or more planes or may be parabolic

• Typical reflectors are:
  – Plane and corner Reflectors
  – The Parabolic Reflector
**Microwave Horn**

- Horns are widely used as antennas at microwave band. A horn antenna is used to transmit radio waves from a waveguide, flaring into an open-ended conical or pyramidal shaped horn on the other end.
- It provides a gradual transition structure to match the **impedance** of a waveguide to the impedance of free space, enabling the waves from the tube to radiate efficiently into space.
- An advantage of horn antennas is that since they have no resonant elements, they can operate over a wide range of frequencies, a wide bandwidth.
- The usable bandwidth of horn antennas is typically of the order of 10:1, (for example allowing it to operate from 1 GHz to 10 GHz).
- The gain of horn antennas ranges up to 25 **dBi**, with 10 - 20 dBi being typical.
Mobile and Portable Antenna

- Miniture PCB or flex PCB type
- Lower antenna efficiency
- Considering the environmental variable
- Extensive simulation during the design
- Example:
  - PCB antenna
  - Surface mount antenna
Embedded Surface Mount antenna
Antenna Matching

- Antenna matching is to maximize the power delivery - minimize the reflection.

- Matching Method:
  1. Capacitive/Inductive matching
  2. Transformer/Balun Matching
  3. LC matching.
  5. Gamma Matching (HF, VHF, UHF)
Capacitive/Inductive matching

- If the desired working frequency is lower than the resonate frequency, the antenna is capacitive, use a parallel/serial inductor to move the resonate frequency into the working band.
- If the desired working frequency is higher than the resonate frequency, the antenna is inductive, use a parallel/serial capacitor to move the resonate frequency into the working band.
- If the final real input resistance is off the transmission line impedance, a transformer is required for impedance matching.
Transformer Matching

• Transformer matches between two real impedance.
• Transformer can serve as a balun
• 1:2 turn ratio creates an 1:4 impedance match (ie. 50 Ω to 200 Ω match)
• Transformer match works from HF to UHF band
• At higher frequency, the ferrite core become lossy.
LC matching

- LC matching is found in high frequency circuit.
- Smith Chart:
  - Open/short
  - Target Impedance
  - Example: 50+75j
  - Capacitive area
  - Inductive area
If you have a multi-band antenna (LTE antenna, 2.4G/5G), you need to carefully select a matching topology so that the matching at one band won’t cause mismatch on the rest of the band.
Matching with Stud

In high power transmission, the LC matching is not possible due to the power loss.

Stud matching is a cheaper and effective solution.
Delta and Gamma Matching

- Both Delta and Gamma matching is widely used for Yagi antenna matching
- The delta match involves fanning out the ends of the balanced feeder to join the continuous radiating antenna driven element at a point to provide the required match.
- Gamma matching is an alternative with narrowing bandwidth.

![Diagram of Delta and Gamma Matching]
Test Equipment:

- Vector Network Analyzer – Return loss and input impedance
- Anechoic Chamber – Antenna radiation pattern, efficiency, etc.
JWC Technologies - Antenna Vendor

www.jwctech.com

- Best in-class (Performance/cost)
- Free tuning services
- Flextronics preferred vendor.
- Product line
  - GPS/GLONAS:
  - WIFI/Bluetooth,
  - LoRaWan/Sigfox/ERT Radio
  - GSM/LTE
  - VHF/UHF
  - Automotive Antennas