San Jose State University

Antenna Project

EE172 Extra Credit Project

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12/20/2009

ABSTRACT

Two antennas will be designed, constructed, and tested to operate at 2.4GHz and have a 10dB output. The two designs that will be used are the Omni-Antenna, and the Biquad antenna. These two antennas will be physically constructed out of available materials. These antennas will be simulated to construct a generalized radiation pattern. Both antennas will be tested in a laboratory to measure their radiation pattern.

INTRODUCTION

Antenna Characteristics

Four main characteristics of an antenna are important in characterizing the behavior of the antenna.

- Antenna radiation patterns
- Power Gain
- Directivity
- Polarization

Antenna Radiation Patterns

An antenna radiation pattern is plot that can be done in both 2-D and 3-D. In 2-D, there are two planes correspond to vertical and horizontal plane of the antenna. The elevation pattern shows the behavior of the antenna in the vertical plane. The behavior on the horizontal plane is described by the azimuth pattern. Combining two graphs together and we can get a 3-D plot of the radiation pattern.

Power Gain

Power gain is the parameter that we usually see on datasheets of antenna. The unit that is used to describe the power gain is dBi. The "i" stands for isotropic antenna. The isotropic antenna is used as reference for all antennas since it has perfect spherical radiation pattern and unity gain.

Directivity

Directivity is a measure of how good an antenna can direct its power in particular direction. One can measure the directivity by taking a ratio of radiation intensity to the radiation angle. Usually, directivity and power gain is proportional to one another. An antenna that has high directivity usually has higher power gain since it can concentrate its radiation in one direction rather than radiate into arbitrary direction.

Polarization

Polarization is a very important concept in antenna use and design. One can have the best antenna and still get poor reception if the polarization of signal and the antenna do not match. Polarization is the orientation of Electric field. It is a convention to refer to only E field when we talk about EM waves in general, since we only need E field to know the direction of H field. Several type of polarization exists. The basics types are Linear, Circular and Elliptical polarizations.

Biquad antenna

THEORY

The BiQuad antenna is a simple antenna design that offers many advantages. First is the simplicity of the design. Biquad antenna can be built with materials found in most hardware stores. It offers good directivity due to the metallic reflector used in the design. The radiating element are two square with the side length equal to 1/4 midband wavelength, 32mm for 2.440GHz in our case. The theoretical beam width is 70 degrees but can vary widely with the reflection plane size and shape. Typically, the gain is about 10-12 dBi. Typical use of the biquad is standalone directional antenna or feeder of a parabolic dish. Polarization of the antenna is 90 degrees from the position of orientation of the biquad, i.e. horizontal biquad has vertical polarization.

DESIGN

The biquad antenna was constructed using the following materials:

- 400 mm long Copper Wire with a thickness of 1.5mm
- 40 mm long Coaxial cable with a impedance of 50 Ohms
- A Reflector in 140 mm in diameter
- Solder with a Soldering Iron
- N-type connector

The Copper wire was bent into a "Bow-tie" shape. The following figure shows the "Bow-tie" shape in more detail:

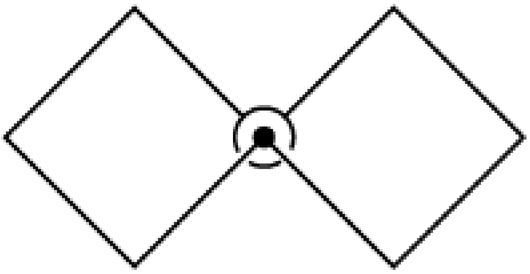

Figure 1. "Bow-tie" design.

Each angle of the bowtie was measured to be at 90 degrees. Each length of the copper wire was measured to be 32 mm. The Coaxial cable was cut open to expose the shielding wire and the core wire. These wires were soldered onto middle portion of the "Bow-tie" copper wire. The top section of the "Bow-tie" was connected to the shielding part of the coaxial cable. The bottom section of the "Bow-tie" was connected to the inner core part of the coaxial cable.

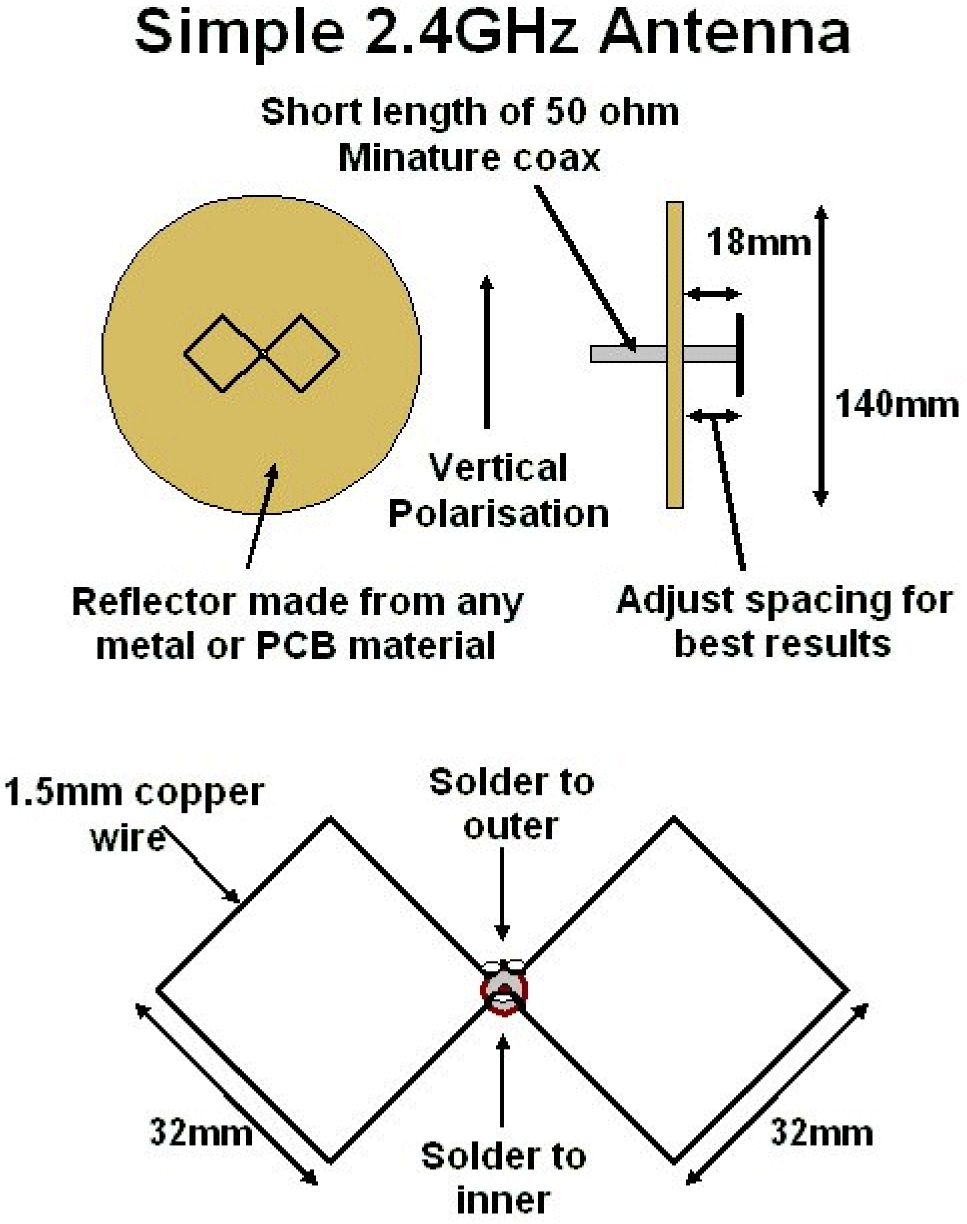

Figure 2. BiQuad Design Schematic.

The reflector was created out of aluminum foil and a hefty stack of paper. The aluminum foil covered the whole outer surface while the stack of paper filled the middle of the reflector. This reflector was placed onto the coaxial cable. The back side of the coaxial cable was connected to the N-type connector. The coaxial cable was stripped to reveal the wiring. The inner cable was soldered to the probe portion of the N-type connector. The shielding was soldered to the outer ground part of the N-type connector. The figure below shows the completed design of the BiQuad antenna.

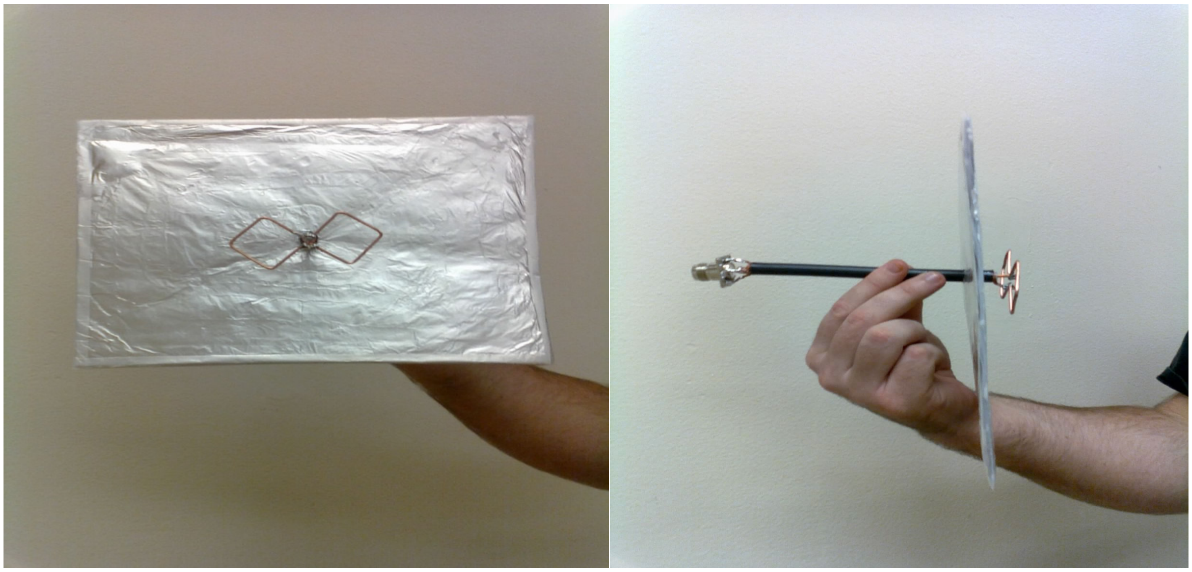

Figure 3. Fabricated BiQuad Antenna.

Pictured above is our completed BiQuad Antenna.

ANALYSIS AND MEASUREMENTS

The radiation pattern of the BiQuad Antenna was first simulated on the program 4NEC2X. Below is the simulated radiation pattern:

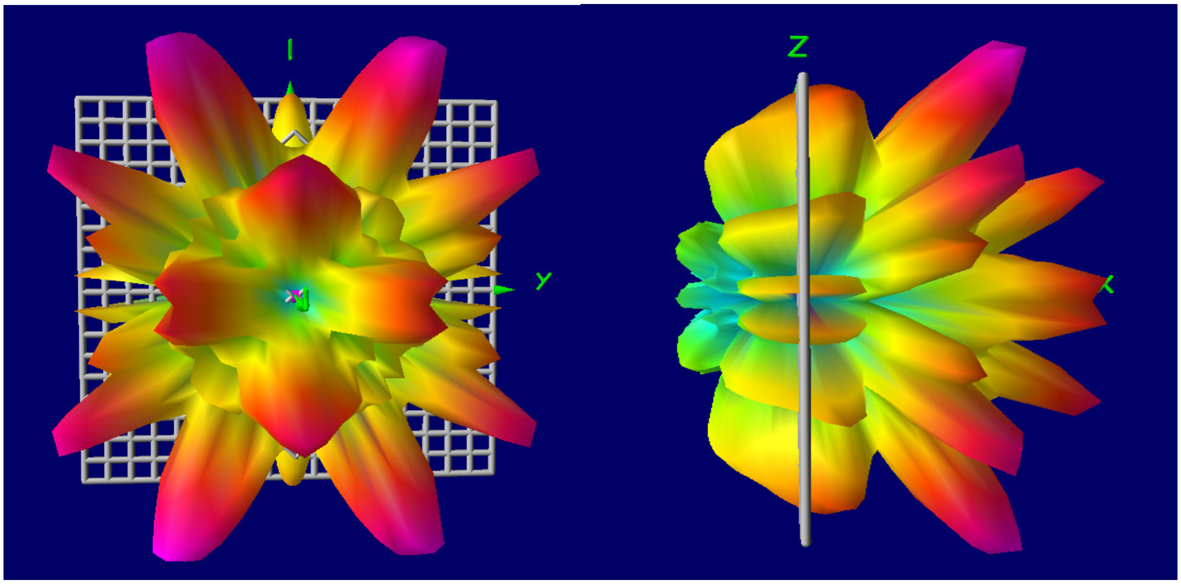

Figure 4. (PROGRAM NAME) Simulation of BiQuad Radiation Pattern.

From this simulation we can see that the waves expand out directionally. The waves that hit the reflector get reflected back onto the "Bow-tie" antenna.

A quarter-wavelength dipole antenna was built to act as a reference while the radiation pattern was measured for the BiQuad antenna.

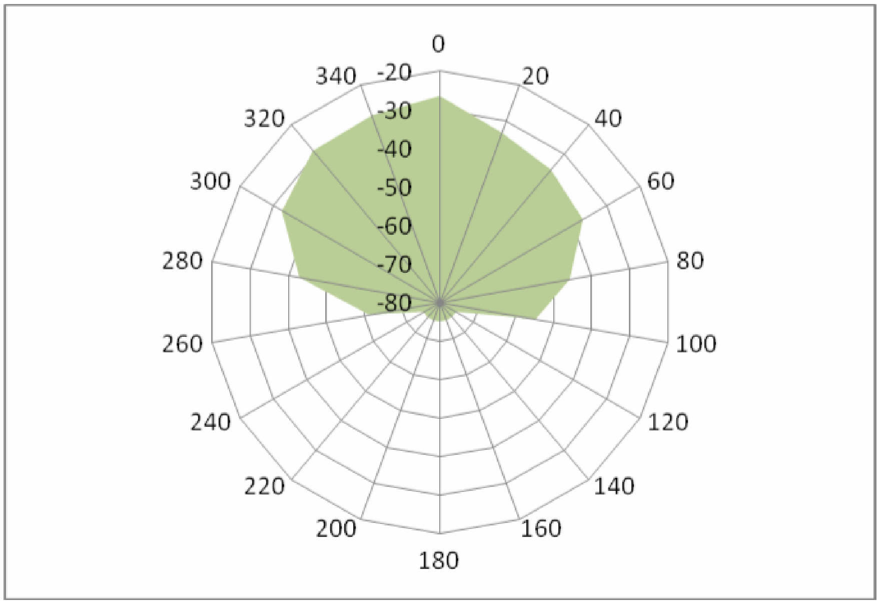

Figure 5. Measured Radiation Pattern

Figure 5 is the measured azimuth radiation pattern of the biquad antenna showing the basic directionality of it.

Omni collinear antenna

THEORY

Omni-directional antenna is an antenna that has 360 degrees of coverage. The antenna that we built for this project is called collinear antenna. Collinear antenna is one of the most popular designs due to its high gain at reasonable cost. Collinear antenna falls under the classification of a multiple element dipole antenna. This type of antenna behaves like dipole. The radiation pattern becomes more directional as more elements are stacked up on each other. The azimuth pattern is still roughly circular. The elevation pattern, however, becomes more directional. Therefore, the user should adjust the direction of this antenna accordingly to his or her location. Even with only 3 add sections of dipoles the beam width becomes -3dB at ±45°.

DESIGN

The Omni-Antenna was designed using the following materials:

- 1 m of RG-213U Coaxial Cable
- N-type Connectors
- 20 mm PVC Conduit (20 mm inside diameter, 22 mm outside diameter)

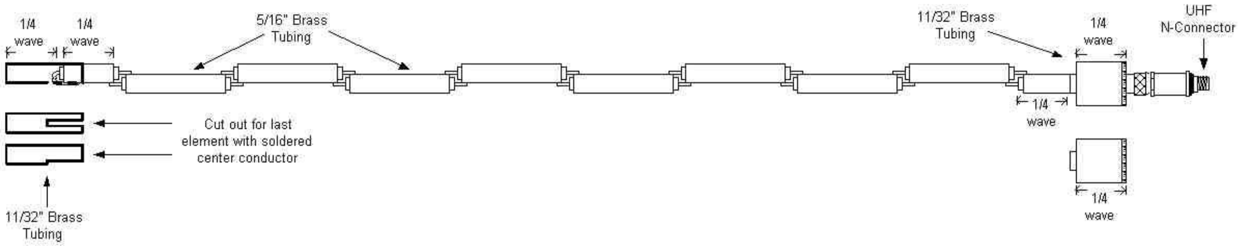

Figure 6. Omni-Antenna Schematic.

The coaxial cable was cut up into 8 sectors. A sector consists of two pieces of coaxial cable connected to each other. Each piece measured a quarter wavelength. The first piece's inner wire was soldered and connected to the second piece's shielding wire. Conversely, the second piece's inner wire was soldered and connected to the first piece's shielding wire. Each sector was measured to half wavelength. Each sector was connected to other sectors. These sectors were connected by having the inner wire connected to the other sector's shielding wire. The shielding wire of the first sector connected to the other sector's inner wire.

ANALYSIS AND MEASUREMENT

$$c = \lambda \times f$$

$$f = 2.4GHz$$

$$c = 3.0 \times 10^8\ m/_s$$

with this we can determine that the wavelength of a 2.4GHz wave is

$\lambda = 12.5cm$

Half-Wavelength Measurements

We want each sector to be half a wavelength long. The velocity factor will be taken into account when doing the calculations of the sector lengths of the coaxial cable. Velocity Factor is important because it affects the wavelength speed. Velocity Factor considers the wavelength change while the wave is going through the dielectric medium to reach the center wire. The equation for velocity factor, Vp, is shown below.

$$L = V_p \times \frac{\lambda}{2}$$

$$V_p = \frac{1}{\sqrt{\epsilon}}$$

Our coaxial cable is made from Polyethylene. Polyethylene's dielectric constant, ϵ, is 2.3.

Polyethylene's velocity factor.

$$V_p = 0.659$$

$$L = 0.659 \times \frac{125mm}{2}$$

$$\boldsymbol{L = 41.2mm}$$

The end of the coaxial cable setup exposed its inner core wire to act as the antenna. This exposed wire was measured to be a quarter wavelength long.

Quarter-Wavelength Measurements

We want our antenna portion of our Omni-Antenna to be a quarter-wavelength long. Since this wire is not shielded by any dielectric, the Velocity Factor does not have to be considered.

$$L = \frac{\lambda}{4}$$

$$L = \frac{125mm}{4} = \boldsymbol{31.25mm}$$

The N-type connector is soldered onto the end of the coaxial cable. The inner cable connects to the probe. The shielding cable connects to the grounding cover of the connector. Then the whole Omni-Antenna was placed into the PVC pipe for stability.

In reality we should have checked S_{11} of the antenna to make sure it was matched to 50Ω and if it wasn't than add a matching network to the bottom of the antenna. Without knowing the impedance though all that will happen is a lower gain than expected.

Figure 7. Fabricated Omni-Antenna.

Pictured above is our completed Omni-Antenna.

The radiation pattern of the Omni-Antenna was first simulated on the 4NEC2X. Below is the simulated radiation pattern:

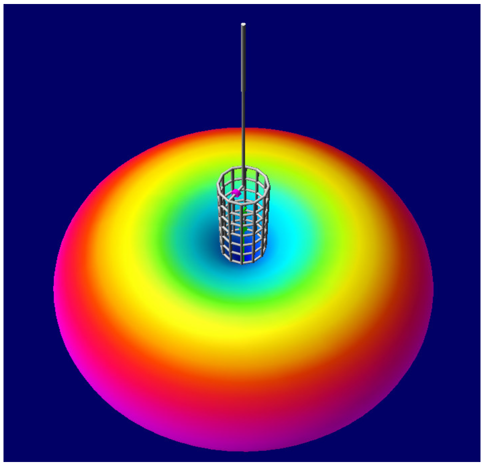

Figure 8. (PROGRAM NAME) Simulation of Omni-Antenna Radiation Pattern.

From this simulation we can see that the waves propagate outwards like a donut. The radiation pattern of a long dipole which is similar to our collinear antenna is simulated below in figure 9.

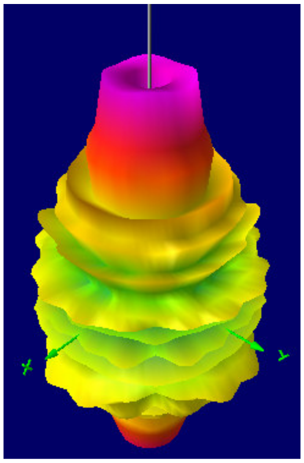

Figure 9. Radiation pattern of a long dipole antenna.

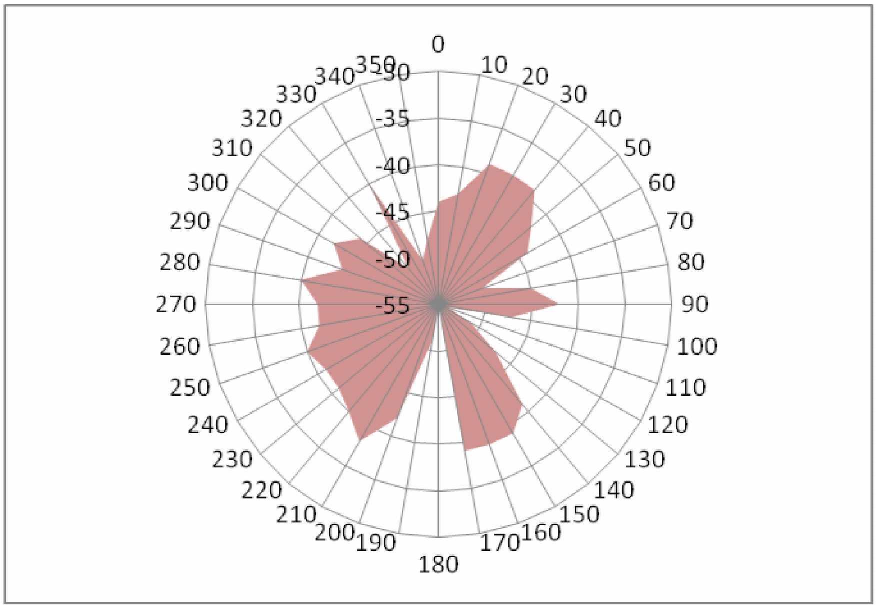

Figure 10. Azimuth radiation pattern of omni-directional

The dead zones in the radiation pattern in Figure 10 are mostly likely due to where we were taking measurements. There were many metal objects in the room that could have both boosted reflection on to the antenna and reflected away much transmitted radiation. Also, as said in the earlier, as half wavelength sections are added the beam width will decrease. We could have been in dead zones above or below the lobe accidentally in our measurements. One last thing is the construction of the antenna. The antenna is far from professionally built and might have a few inherent dead zones from the sub par construction.

CONCLUSION

We have successfully built two working antennas that operate at 2.4GHz and have a 10db or higher gain.

REFERENCES

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[2] F. T. Ulaby, “Radiation and Antennas,” in *Electromagnetics for Engineers,* 1st ed. Prentice Hall, 2004, ch. 10, pp 346.
[3] Miikka Raninen (OH3GPJ), WLAN 802.11b/g Bi-quad antenna: building and testing: Report on reproducing Trevor Marshall's BiQuad Antenna. Obtained from http://koti.mbnet.fi/zakifani/biquad/ on 11/20/2009.
[4] Build A 9 dB, 70cm, Collinear Antenna From Coax By N1HFX. Obtained from http://www.rason.org/Projects/collant/collant.htm on 11/20/2009