EE 172 Final Project Report

915 MHz Cantenna and Patch Antennas Design

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Abstract:

A 915 MHz antennas will be designed, constructed, measured and tested. The patch antenna will be a half and the cantenna at quarter wavelength of the design frequency.

The patch antenna will consist in a ground-plate and the patch itself separated at some distance. The cantenna will consist basically in a metal threaded rod, some washers separated at a quarter wavelength.

Both antennas will follow the theoretical design and then will be fine tuned using a Network Analyzer until reaching the desired frequency range. The idea behind our practical design is that the dimensions of the antennas can be modified easily to obtain the best performance between the desired frequency range.

Patch Antenna

The patch antenna radiates its maximum power on the direction normal to the plane of its surface.

The patch antenna was designed as a half wavelength, the dimensions were determined using the following formulas:

Where fr is the frequency of operation of the antenna (or resonant frequency), μo and εo are fundamental physical constants, and, εr is a property of the substrate.

A half-wave patch antenna has an open circuit at the end opposite to the feedline (an infinite impedance) while the center represents a short circuit (no or low impedance).

So, this represents a little problem when attempting to match the antenna with a 50-ohm feedline. The problem can easily be solved by reducing the area of the feedline (matching). The optimal matching of the antenna can visually be determined by having the antenna connected to the network analyzer (match mode) until reaching the best value (closer to the center of the Smith Chart).

Cantenna

Basically the cantenna consist in an assembly of spacers, washers and a metal rod, the whole assembly is called collector. In the design hex nuts where used to achieve required separation between the washers (the most important variable in the equation of the design).

The reflector is a closed can. Attached to the center pin of the N connector is a metal rod, soldered into place that points straight into the center of the can, just shy of, but not touching the threaded rod with the washers. The position of the rod was fixed using cardboard washers that controlled the Z direction (in and out of the can)

This type of design is very practical because just by modifying the distance between the washers the antenna range will change, making very easy to work in different frequencies.

The fine tuning of the antenna is achieved by changing the Z position of the rod.

Calculations of the design:

Frequency: 915 MHz = 915 x 10^6 Hz
C (speed of light)*Time=Wavelength
Period (length of time for 1 cycle)*Frequency= 1
T*F=1
Equation 1: W (meters)= 3.0x10^8 (m/s)*T
Equation 2: T(s/cycle)*915x10^6=1

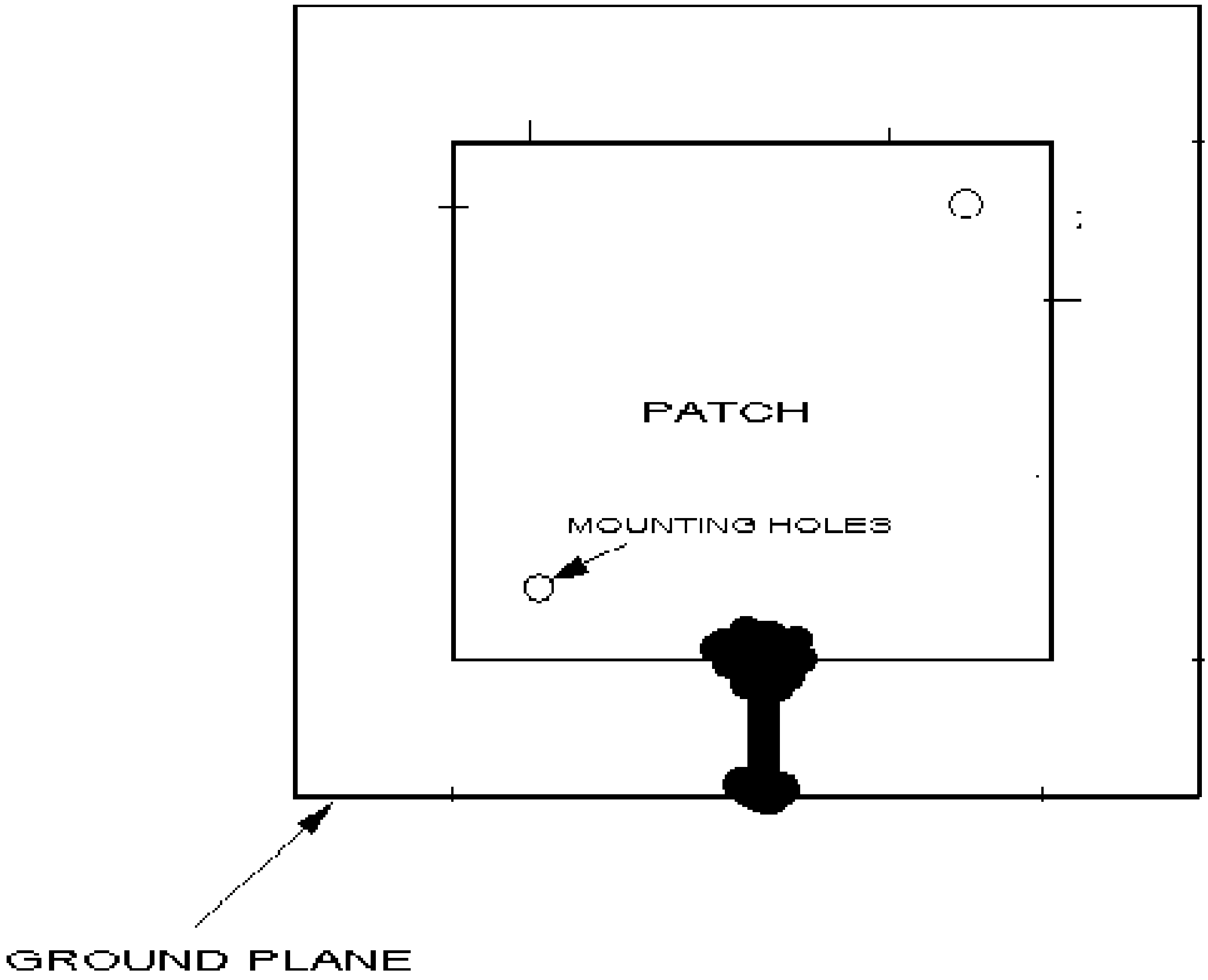
W(m)=3.0x10^8*(1/915x10^6)
W(m)=0.327 m

For quarter wave: 0.327/4= 0.0819m = 8.19cm (minimum).

Therefore, the separation between the washers should be at least 8 cm.

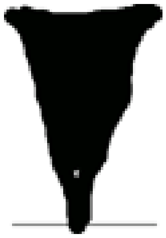
Building and matching the patch antenna

A patch antenna was built with the design goals of providing 6dB or better gain at 915MHz when matched to a 50-Ohm load. A patch antenna is simply a large ground plane with a raised smaller sheet (patch) above it. A sheet of copper or wire is used to connect the signal (raised patch) to the connector and ground plane. The top sheet is suspended by not conductive nylon nuts and bolts. A diagram of the patch antenna is found bellow:

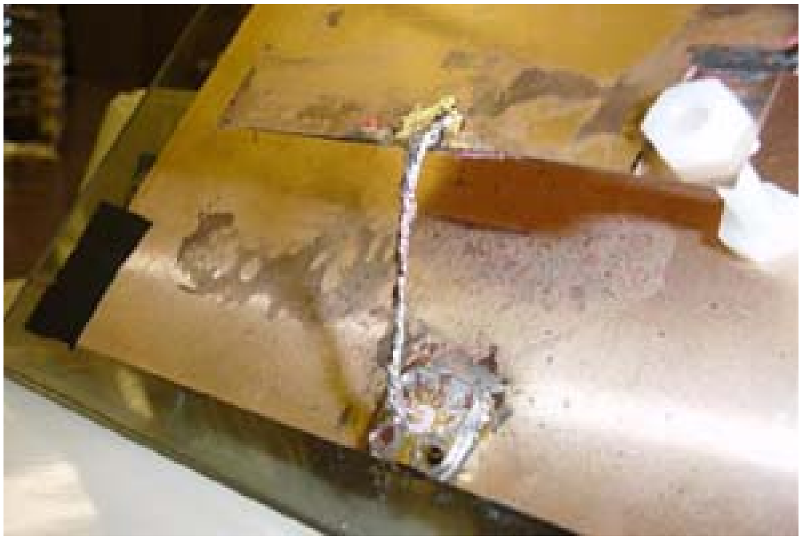


Matching

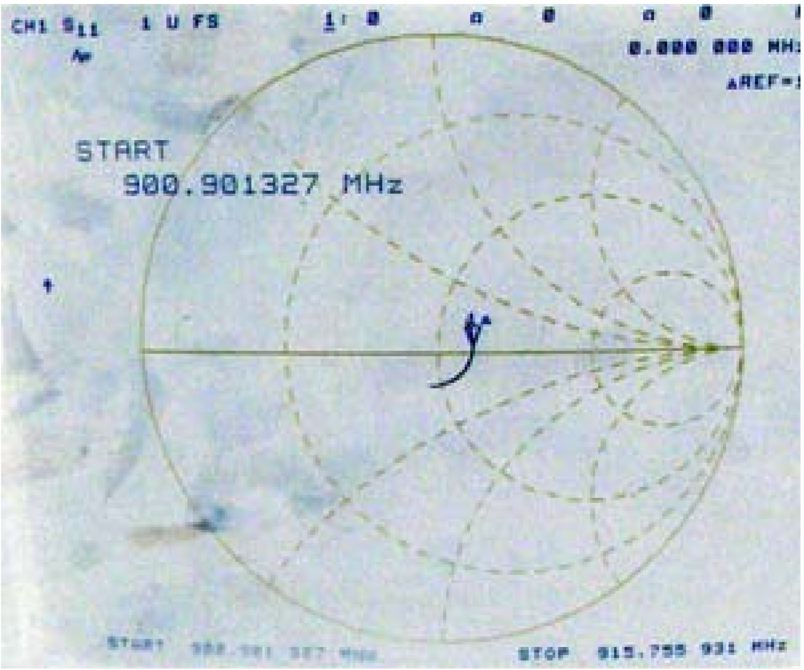
Matching was done by taking a strip of copper below and cutting it between the top and bottom plates while the antenna was hooked up to the network analyzer. The strip of copper tape was cut into the following shape:



This resulted in an extremely poor match. The more the strip of copper was cut thin, the better matching was obtained. Finally the strip looked like a piece of wire it was so thin! At this point, for added rigidity and durability, the copper tape was replaced with 14 gauge stranded copper wire. Needle nose pliers were used to spread the wire flat and thin to help better match the antenna. Once an ideal match to 50 Ohms was obtained, a light coat of solder was spread out over the antenna to preserve its shape and match. This can be viewed in the photograph below:

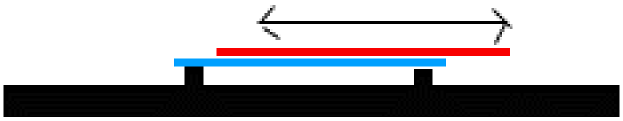


The end result is an excellent match as seen in the smith chart display from the network analyzer below:



Theory vs. Reality

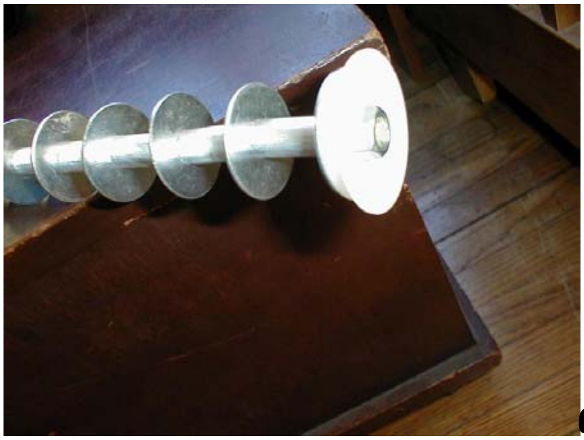
There was a big issue when it came to comparing theory versus reality in this antenna design. According to dimensions and calculations of the patches, the antenna should have naturally resonated at 915MHz. When connected to the network analyzer, the frequency ended up being approximately 1.3 GHz! Extra copper sheeting was added to the ground plane. From there another sheet was added on top of the existing top patch. In the diagram below, the **black** represents the ground plane in the patch antenna. The **blue** represents the existing patch and the **red** represents the patch that was added on top of the existing **blue** patch. This allowed us to slide the **red** patch onto of the blue patch while measuring the reflection on the network analyzer allowing us to tune down the antenna from 1.3 GHz to the desired 915 MHz. A diagram of this clever construction can be viewed below.



Building and matching of the "Cantenna"

The circular yagi or "cantenna" was a challenge to find parts for. It is an unusual size for an antenna, and there are not conventional parts made to build one at 900Mhz. The parts that we ended up using were an air duct coil, the backing of a light fixture, a long bolt shaft, and some electrical tape.

The air duct is perhaps the most interesting innovation. This part was used as the shielding and ground for the antenna. The shield need to wrap completely around the center element, and is specked to a little more than two times the size of the elements. The elements themselves are three inches in diameter. This can make for an interesting design problem.



This picture above shows the shape of the elements used in this antenna. The basic construction of the antenna is as follows.

1) The elements are constructed to resemble the picture above using the correct parameters for a given frequency.

2) The elements above are placed in position inside a metallic can with one lid open and one closed. The pattern will radiate out the open side.

3) A connector is placed inside the can, with an extended positive lead protruding into the can, and hovering just behind the end of the element array, without touching it.

This type of design will cause the signal to be bounced off the walls of the can inside the antenna, and amplified by the array.

There are a few design parameters that have to be compensated when testing. The first is the size of the elements. The second is the spacing of those elements, and finally there is the distance from the active lead to the element array. All three affect the array in a different manner.

Starting to tune the antenna is a challenge. To get the resonant frequency, the spacing between the elements needed to be changed. The original frequency of the cantenna was much too high. In order to lower it, the spacing between the elements was increased from around 80 mm to 100mm. This number was found after a long period of moving the element closer and further apart until the network analyzer displayed a resonant frequency of 915 MHz for the antenna.

The SWR is matched in a different manner. Once the resonant frequency is obtained, the match is pretty close at it. The way to improve the SWR from here is to change how far or close the active pin is to the element array. Using the smith chart function of the analyzer, a matched position was found for the antenna in question.

One reason for the need to change the design parameters of the antenna in the testing phase might be the inherent inaccuracy of the material used. For instance, we used a standard size heating duct as an antenna shield, and light fixture backing as elements. These do not have perfect measurements for the antenna we are building by any means, so other changes had to be made to make the materials work for our purpose.

Conclusion

This project showed the importance of testing and materials used. Although the design that was used for both antenna types was sound and proven to work many times, reality dictates that the first time out of the gate will not be perfect. As we made more and more changes to either antenna to match frequency and impedance to what was specified, the shape and appearance of the antennas changes gradually to look more interesting. The field of RF is challenging and interesting for just this reason, one never knows just what is going to transpire to make the component behave.