

Simulation of Rectangular Monopole Antenna using Matlab

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Abstract:

The use of single wideband antenna which covers wide range frequencies is very desirable for many applications including wireless and high data rate communications, imaging and sensing, position and tracking and radar. Here the realization of the planar monopole antenna which can work at different frequencies with good radiation was presented. The design a broadband monopole planar rectangular antenna that is printed on printed circuit board (PCB) consisted of a rectangular patch and a ground plane. Besides mathematical procedure, the step in designing this antenna needed a simulation to get more accurate hypothesis before realizing the antenna. In this study, researcher applied Matlab that can be used for designing and simulating the antenna in more detail and more accurate result. The result of this software was compared with measurement result in practice. Even though there was some differences in the result of the simulation and measurement of presented antenna, both of them worked at frequency range of 1.5 GHz - 2.7 GHz, hence the can be used for commercial communication technology such as HSDPA, Wimax, Bluetooth and Wifi.

Key Word: Broadband Rectangular Planar Monopole Antenna, Planar Monopole Antenna, Matlab.

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I. Introduction

The use of a single wideband antenna which covers a wide range of frequencies is very desirable for many applications including wireless and high data rate communication, position and tracking, sensing and imaging, and radar. Planar plate monopole antenna is a candidate. They are interesting due to their broad impedance bandwidth, linearly polarized unidirectional radiation pattern and are very cost effective to construct. They are planar structure, where a thin planar metal element can be used instead of the traditional wire element of a monopole antenna. It was first described by (Dubost & Zisler, 1976), who observed the wide impedance characteristics of this antenna. The antenna is capable of covering the 2-18GHz band with good radiating properties.

Wide bandwidth in a wireless communication system of consequence is done by transmitting high frequency data as exemplified in Wimax (2.3 GHz and 5.5GHz mobile Wimax for fixed Wimax), 2.4 GHz WLAN, HSDA (high speed downlink access) 1.9 GHz or 2.1 GHz). Antennas with small size are generally constructed in microstrip concept with a variety of forms. Basically, a microstrip antenna has a narrow bandwidth due to the high quality factor Q reaches the value 100 (Balanis, 1982:722), but research results have shown that the microstrip antenna with very wide field of frequency bands has been generated (Mazinani and Hassani, 2009, Ahmad and Jar'alla, 2008, Azari and Rowhani, 2008, and Promburt, 2009). In their study, rectangular patch and ground of antenna are built on printed circuit board and other material such as alumina. For microstrip structure, the printed circuit board chosen usually was a high quality dielectric materials such as FR4 or Roger 4003.

Researches of antennas relate to frequency of mobile communication have been conducted and reported but a broad band planar antenna that works in the range from 1.5 to 2.7 GHz is still a bit done. The reported researches usually use software to simulate their design and the software are commercial simulator such as Advanced Design System (ADS software), Ansoft HFSS and IE3D so that the researchers can estimate the results of their work. In other hand, a software such as Matlab is rarely used to simulate the designed antenna. The main reasons are it is complicated and the limitation of the Matlab its self. Although the Matlab has disadvantages as stated above but it has advantages over other software such as [1] designer can, step by step, design the structure of the antenna, [2] the facilities that available are adequate to perform basic parameter of antenna such gain, reflection coefficient, input impedance, input resistance, reactance input, and radiated power.[3] Using Matlab does not need a license.

Based on the reasons stated above, the authors want to study, design, and construct of broadband planar rectangular monopole antenna (Alkurbo, Pramono And Santoso 2012)by simulate printed circuit board as material for radiator and ground using Mathlab.

II. Design and simulation

For a planar monopole antenna, the lower frequency corresponding to VSWR = 2 can be approximately calculated by equating its area (in this case, a rectangular disc monopole) to that of an equivalent cylindrical monopole antenna of same height L and equivalent radius r, as described below (Kumar and Ray, 2003:362)

$$2\pi rL = WL \tag{1}$$

Which gives

$$r = \frac{W}{2\pi} \tag{2}$$

The input impedance of a 1/4 monopole antenna is half of that of the 1/2 dipole antenna. Thus, the input impedance of an infinitesimally thin monopole antenna is $36.5 + j 21.25 \Omega$, which is inductive. The real input impedance is obtained when a slightly smaller length of the monopole is used as given by (Kumar and Ray, 2003:362):

$$L = 0.241 \lambda F \tag{3}$$

Where

$$F = \frac{L/r}{1+L/r} = \frac{L}{L+r}$$

So that the wavelength λ is obtained as:

$$\lambda = (L + r)/0.24 \text{ Therefore, the lower frequency } f \text{ L is given by: } f L = c/\lambda = (30 \times 0.24) / (L + r) = 7.2/(L + r) \text{ GHz}$$

Where, L is the length of the monopole, r is the effective radius of an equivalent cylindrical monopole antenna and p is the length of the feed line in cm.

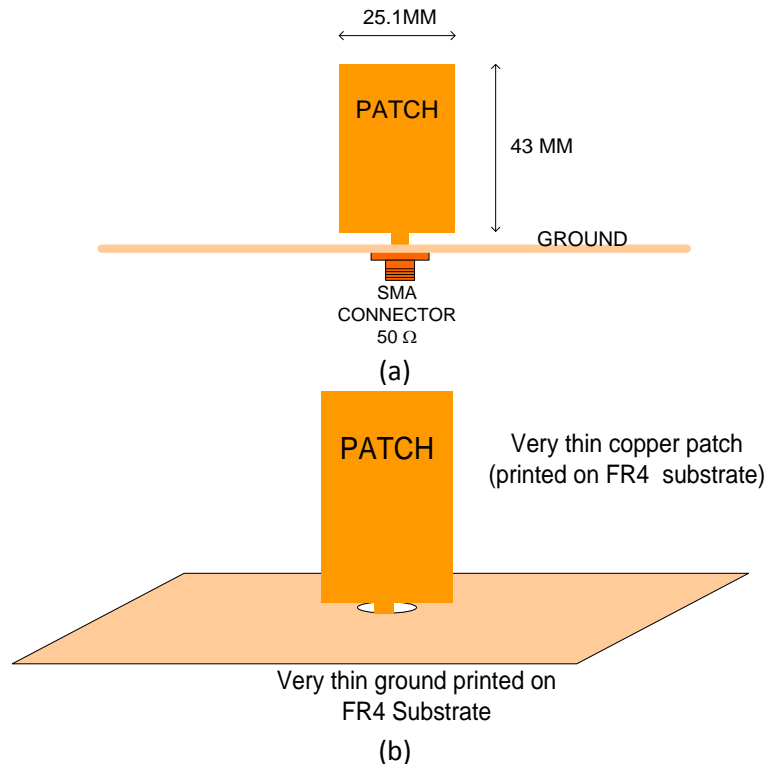


Figure 1 Printed Rectangular Monopole Antenna (a) front view (b) actual shape

However, unlike the planar disc monopole antenna, this configuration has dielectric layer on one side of a printed monopole. This dielectric material increase the effective dimensions of the monopole leading to reduction in the lower frequency. This is also confirmed by simulation studies. Hence, appropriate equation for the lower frequency is given as (KP Ray and Ranagga ,2006):

$$fL = 7.2/(L + r + p) \text{ GHz} \tag{5}$$

For lower frequency side of 1.5 GHz, and p and r are assumed to 0.4 cm and 0.1 cm respectively, so that the length (L) of radiator is 43 mm. The width of radiator can be calculated by $W = 2\pi r$ so that $W = 25.1$ mm. A printed rectangular patch on a printed circuit board can be treated as thin plate so that the presented antenna can be assumed as rectangular planar monopole. The reason is as follows, the skin depth of current on copper that

has resistivity $1.724 \cdot 10^{-8}$ ohm per meter can be calculated by skin depth (Hund,1989) , $(m) = \sqrt{\frac{r}{\pi f \mu}}$ where r is resistivity in ohm per meter, f is frequency in Hz, and μ is permeability in Henry per meter. At frequency of 1.5 GHz, the value of skin depth is $1.7 \mu\text{m}$, so that the thickness printed copper on PCB of $25 \mu\text{m}$ is much greater than requirement. From the calculation result it can be concluded that the printed radiator can be treated as a thin plate. The length of ground should be greater than $2 \times \frac{1}{4} \lambda$ (Balanis, 2005:511), so that the size of ground plane of 6 cm x 10.5 cm is adequate to fulfill the ground criteria.

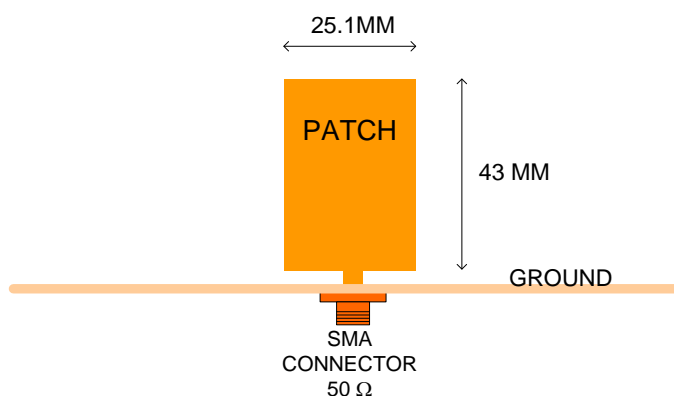


Figure (2) Dimension of presented Antenna

III. Simulation

The aim of simulation is to get predicted characteristic of presented antenna using matlab. By applying that software researcher can design and simulate the antenna easily. The following chart explains several steps to design and simulate the presented antenna.

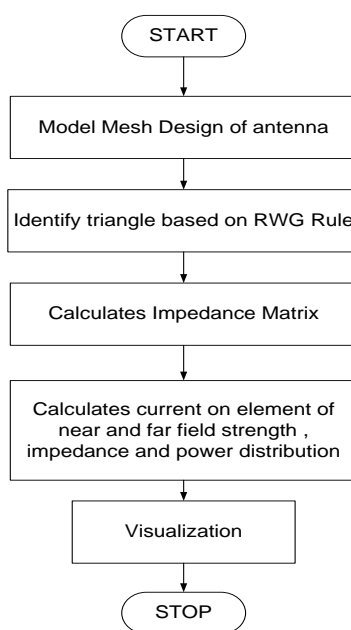


Figure 3 Flow chart of RWG-MoM Method.

Mesh Design of Antenna

Rectangular monopole antenna has 3 basic parts named radiator, monopole and plate grounding

1 Radiator

The radiator of antenna is a tin metal rectangular in shape and it has area of width (W) times length. The construction of rectangular mesh can be done by applying Delaunay sub routine as shown below

```
L=0.2;           %Plate length (along the x-axis)
W=0.2;           %Plate width (along the z-axis)
Nx=2;           %Discretization parameter (length)
Nz=2;           %Discretization parameter (width)
L_mono = 0.02;
%Set vertexes of the radiator
epsilon=1e-6;
M=1;
for i=1:Nx+1
    for j=1:Nz+1
        %Mesh on Monopole area
        if ((i-1)/Nx == 1/2)
            X(M) = -L/2+(i-1)/Nx*L;
            X(M) = X(M)-0.002;
            X(M+1) = X(M)+0.004;
            Z(M) = -W/2+(j-1)/Nz*W-epsilon*X(M);
            Z(M+1) = -W/2+(j-1)/Nz*W-epsilon*X(M+1);
            M=M+2;
            % Mesh normal on other monopole area
        else
            X(M) = -L/2+(i-1)/Nx*L;
            Z(M) = -W/2+(j-1)/Nz*W-epsilon*X(M);
            M=M+1;
        end
    end
end
end
%Use Delaunay triangulation
TRI = delaunay(X,Z);
t=TRI'; t(4,:) = 0; %radiator has the index zero!!!
p=[X; zeros(1,length(X)); Z];
```

If the above listing is executed, the result of radiator will be as follows

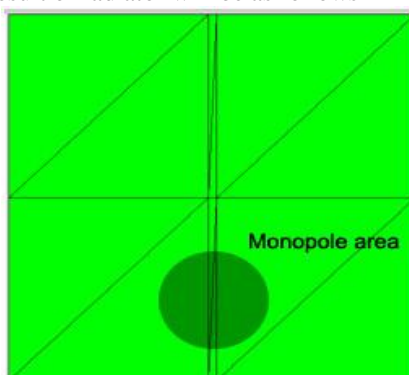


Figure 4 radiator

Figure 4 shows that the radiator has been meshed in triangle (as condition for RWG method) by adding a special mesh for monopole feed.

2 Monopole

Monopole is used for modeling feed point connected to the radiator. The model of monopole can be constructed as follows

```
%Create monopole
t_monol = [feed2(1); feed1(1); feed1(1)+1; 0];
```

```
t = [t t_mono1];
t_mono2 = [feed2(1); feed2(2); feed1(1)+1; 0];
t = [t t_mono2];
```

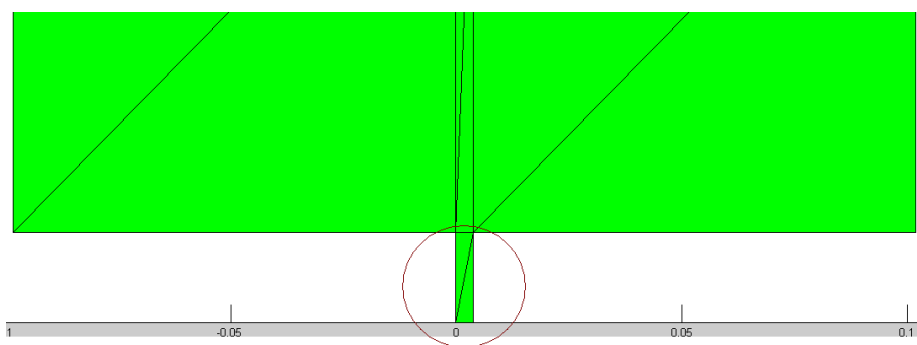


Figure 5 creating feeding point of monopole.

3 Plate Grounding

A plate grounding with triangle mesh can be designed by using program listing as follows

```
%create matrix position
Ny      = Nz;
L_plate = 0.4;           %Dimension of Plate
W_plate = 0.4;

M = Total_node_rad;
Y(1:length(Z))= 0;
feed2 = [];
for i=1:Nx+1
    if ((i-1)/Nx == 1/2)
        for k=1:2
            for j=1:Ny+1
                x = -L_plate/2+(i-1)/Nx*L_plate;
                x1 = x + (0.004*k-0.006); %to create 0.002 path at plate
                X = [X x1];
                y = -W_plate/2+(j-1)/Ny*W_plate-epsilon*x1;
                y1 = -W_plate/2+(j-1)/Ny*W_plate;
                Y = [Y y];
                Z = [Z (-L/2)-L_mono];
                M = M + 1;
                if (y1==0)
                    feed2 = [feed2 M]; %find feed point at plate
                end
            end
        end
    end
else
    for j=1:Ny+1
        x = -L_plate/2+(i-1)/Nx*L_plate;
        X = [X x];
        y = -W_plate/2+(j-1)/Ny*W_plate-epsilon*X(M);
        Y = [Y y];
        Z = [Z (-L/2)-L_mono];
        M = M+1;
    end
end
end
p = [X;Y;Z];
```

```

%Create Mesh on Plate
Node_plate = Total_node_rad + 1;
for i=1:Nx+1
    for j=1:Ny
        t_plat1 = [Node_plate; Node_plate+1; Node_plate+Ny+2;1];
        t = [t t_plat1];
        t_plat2 = [Node_plate; Node_plate+Ny+1; Node_plate+Ny+2;1];
        t = [t t_plat2];
        Node_plate = Node_plate + 1;
    end
    Node_plate = Node_plate + 1;
end
end

```

If the whole program listing is executed, it will give a result as shown in Figure 6

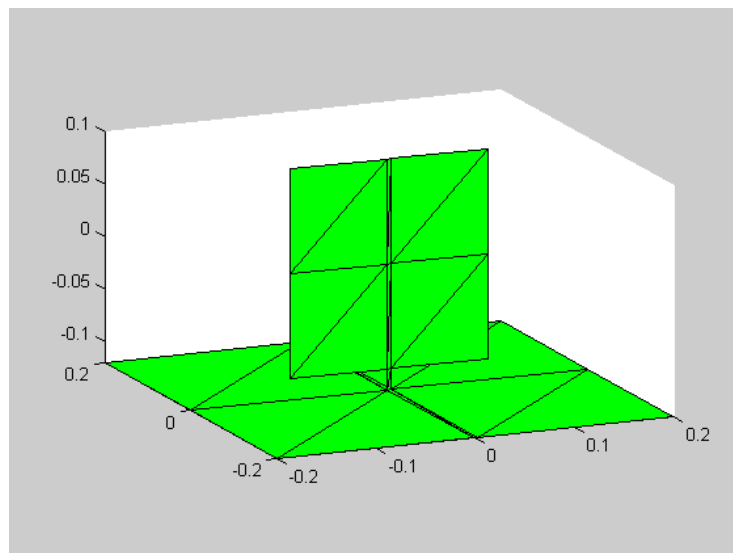


Figure 6 plate monopole antenna.

IV. Simulation Result.

Simulation using Matlab results radiation pattern, reflection coefficient, input resistance, and input reactance displays. The input resistance and input reactance figure an input impedance of an antenna. This input impedance is an importance parameter of antenna because it represents voltage and current at an antenna feeder. This parameter is a function of frequency that means the value of the input impedance is depends on frequency. The display of the input resistance and the input reactance are shown in Figure 7 and Figure 8 respectively

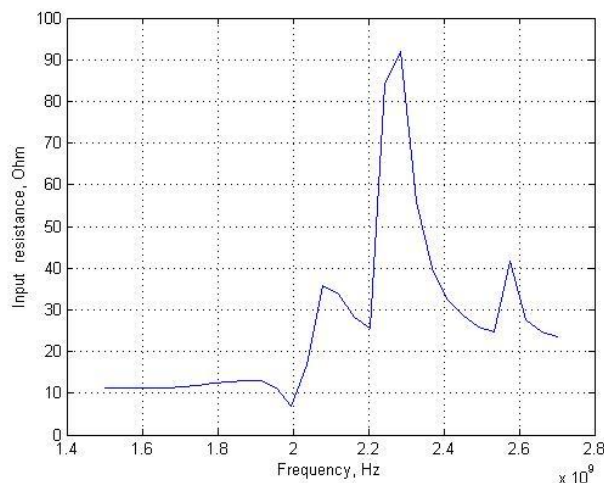


Figure 7 input resistance versus frequency.

Simulation result of the input resistance shows that the value of input resistance is difference from one frequency to another frequency. The value of frequency increases from nearly 10 ohm at 1.4 GHz, and 80 ohms at 2.3 GHz. The data show the value of input resistance of the antenna was less than of 90 ohms. These resistances are not radiation resistance and there is no directly relationship between the input resistance and radiation resistance. Furthermore, the input resistance tends to close with conductor losses, higher resistance higher loss. This loss will affect power received and radiated by the antenna. Theoretically, the input resistance consist of radiation resistance of antenna and loss resistance of antenna. The radiation resistance related to radiated and received power of the antenna.

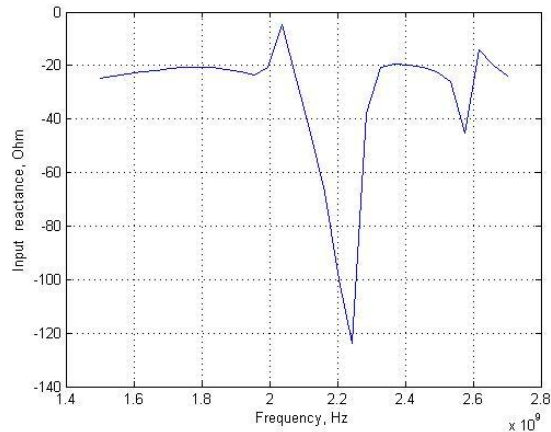


Figure 8 input reactance versus frequency

Figure 8 shows the value of input reactance at difference frequencies. Positive value means the input reactance is inductive and negative value means capacitive. When the value of input reactance equals zero, the input impedance of the antenna is resistive. The antenna has capacitive reactance for the whole range frequency. It means that the input impedance of the antenna is always capacitive. If the antenna is connected to transmission line, the input impedance of the antenna will figure mismatching between the antenna and the line. If the impedance input of the antenna equals to impedance characteristic of the line, they are said to be match otherwise they are mismatch. In practical case, the antenna and the line should be as match as possible so that the antenna will transmit or receive energy maximally.

Radiation pattern of simulated antenna is shown in Figure 9. The figure shows that energy radiated at azimuth plane is nearly the same at all direction.

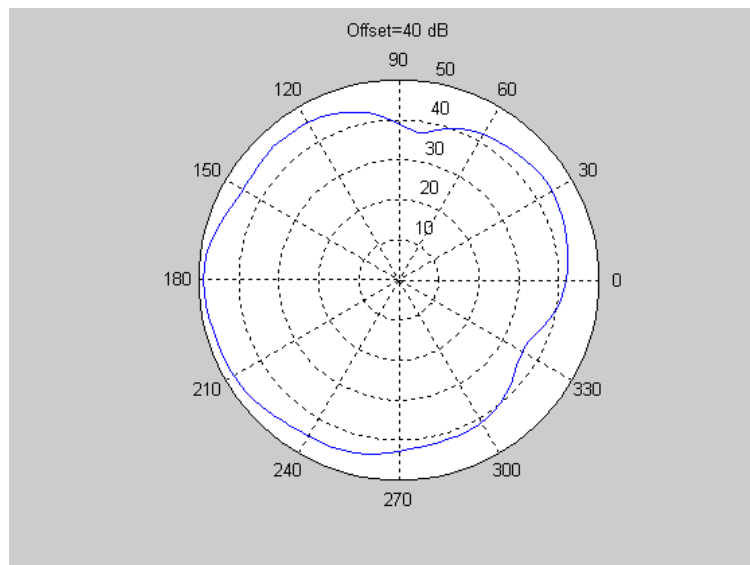


Figure 9 radiation patterns on azimuth plane.

The antenna radiates energy maximally at degree of 180 and the lowest energy radiated the antenna occurs at 330 degree. The hole radiated energy shows that the antenna is omni directional and this is match with the geometry of the antenna (monopole antenna).

Another parameter that displayed by the simulator is reflection coefficient as shown in Figure 11. Reflection coefficient refer to the amount of reflected signal or energy of the antenna on the transmission system, the reflected energy should be as low as possible. Reflection coefficient has no unit, but can be transformed to return loss term which has unit in dB as shown in Figure 11. Reflection coefficient of -10 dB means that the percentage of reflected signal is about 30% from incident signal.

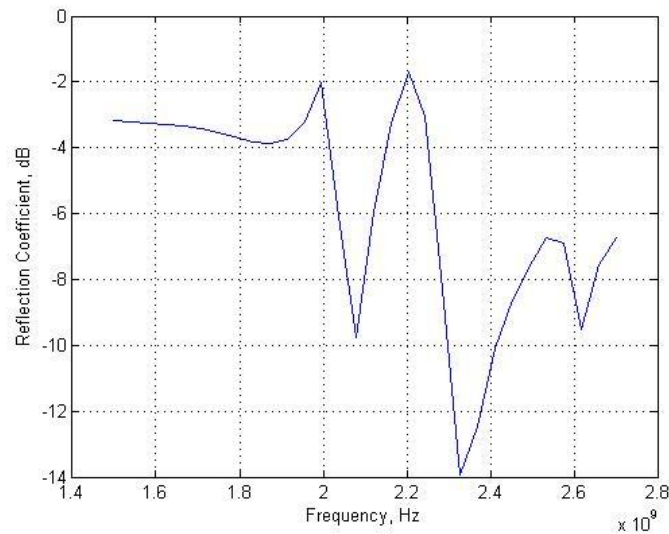


Figure 11 Reflection of coefficient versus frequency

The value of reflection coefficient figures reflected power of the antenna at feeder point. The maximum value of reflection coefficient is one and the minimum value is zero. When there is no reflected power, the value of reflection coefficient is zero and one indicates all power is reflected back by the antenna. The figure shows the that the lowest value of reflection coefficient occurs at frequency of 2.33 GHz, this means that at thus frequency the reflected power is the lowest.

The parameter of reflection coefficient is relative close to the input impedance of the antenna and when the input impedance is equal to the impedance characteristic of transmission line, the reflection coefficient is zero or ∞ dB.

Another parameter that displayed by the simulator is the gain of the antenna. Parameter gain refers to the energy radiated by the antenna at certain direction when compared to a reference antenna at the same distance and the same input energy. The reference antenna chosen is usually dipole antenna or isotropic antenna. In practical case, the reference antenna is usually a dipole.

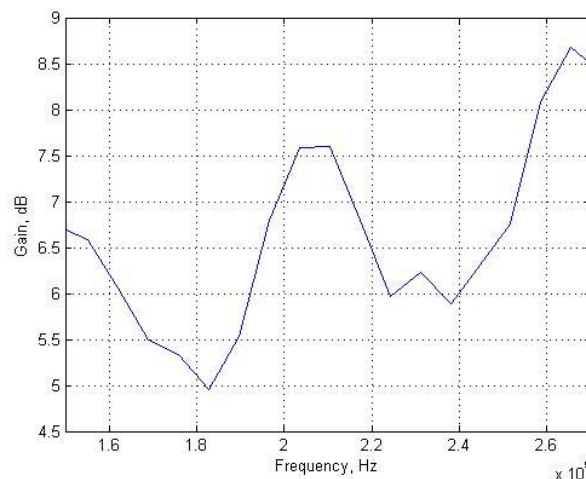


Figure 12 Gain versus frequency.

Figure 12 shows that the gain of the antenna is depend on frequency. The minimum gain of 5 dB occurs at frequency of 1.8 GHz and maximum gain (8.5 dB) occurs at frequency of 2.7 GHz. the value of the gain is related to isotropic antenna (dBi).

V. Conclusion

There were differences of parameters between simulation and measurement, the maximum gain related to simulation was 6.2 dBi where as the maximum related to measurement was 9.95 dBi. Reflection coefficient of the presented antenna at 1.5 GHz related to measurement was 0.33 (SWR=2) where as simulation gave result of -0.6. Maximum radiated power at azimuth angle occurred at -30° but measurement was at -10° .

VI. Suggestion

Although the bandwidth of antenna very wide but the gain of antenna was not constant for the whole bandwidth frequency so that the existence of a reflector can be considered however, the existence of it can change the radiation pattern of the antenna.

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