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Design and Construct of Broadband Printed Rectangular Monopole Antenna

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Abstract: *In this paper, we have investigated an rectangular monopole antenna that was printed on a printed circuit board (PCB). The antenna consists of a rectangular patch and a ground plane so that the antenna acts as a planar monopole antenna which is broadband. Broadband planar monopole antennas have all the advantages of the monopole in terms of their cost, and ease of fabrication besides, yielding very large bandwidths. For many applications large bandwidth is required. We have fabricated and tested printed rectangular monopole antennas for wireless application. The presented antenna was design for lower side frequency of 1.5 GHz so that it can be applied to a commercial frequency such as HSPDA, Wimax, Bluetooth, and Wi-Fi. Basically, the parameters of the presented antenna were the same with a monopole antenna but broadband.*
Keywords: *printed rectangular monopole antennas, broadband, S11, radiation pattern*

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.

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[5], but research results have shown that the microstrip antenna with very wide field of frequency bands has been generated [1][2][8][9]. In their study, rectangular patch and ground of antenna are built on printed circuit board. One of the most popular antennas employed in mobile communication systems is the monopole antenna and its family. The monopole antennas are convenient to match to 50 ohms, and are unbalanced. This eliminates the need for a balun, which may have a limited bandwidth (BW)[5]. The simplest member of the family is the quarter wave monopole above a prefect ground plane. The impedance BW achievable for the quarter wave monopole antenna is dependent on the radius of the cylindrical stub, and increases with increased radius. This is true up to a point where the stepped radius from the feed probe to the cylindrical element becomes abrupt.

II. DESIGN OF ANTENNA

In this research, study of a printed rectangular monopole antenna with wide ground plane will be proposed, the printed antenna is made from a thin copper material printed on Rogers substrate and the ground plane is positioned under the patch and it is made from a thin copper material as well so that the plane can be assumed to be perfect ground plane. The dimensions of antenna were estimated using formulation given for planar disc monopole antenna the lower frequency for VSWR = 2 is given as [7]:

$$2\pi rL=WL \qquad (1)$$

which gives

$$r=W/2\pi \qquad (2)$$

The input impedance of a l /4 monopole antenna is half of that of the l /2 dipole antenna. Thus, the input impedance of an infinitesimally thin monopole antenna is 36.5 + j 21.25 □ , which is inductive. The real input impedance is obtained when a slightly smaller length of the monopole is used as given by[7]:

$$L = 0.24l\ \square\ F \qquad (3)$$

where

$F= (L/r)/(1+L/r)=L/(L+r)$, so that the wavelength □ is obtained as: □ $= (L + r)/0.24$, Therefore, the lower frequency f L is given by:

$$f_L = c/\square = (30 \times 0.24) / (L + r) = 7.2/(L + r)\ \text{GHz} \qquad (4)$$

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.

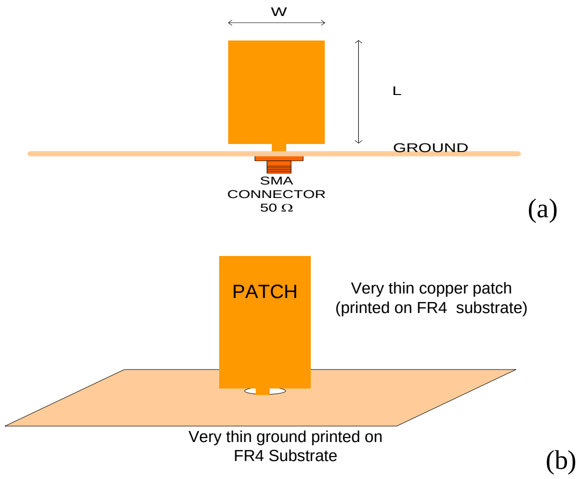

Fig 1. Printed Rectangular Monopole Antenna (a) front view (b) actual shape

However, unlike the planar disc monopole antennas, this configuration has dielectric layer on one side of a printed monopole. This dielectric material increases the effective dimensions of the monopole leading to reduction in the lower frequency. This is also confirmed by simulation studies. Hence, more appropriate equation for the lower frequency is given as[7]:

$$f = c / \lambda = 7.2 /(l + r + p)\times k \text{ GHz} \qquad (5)$$

where k can be thought of as $\sqrt{\varepsilon_{eff}}$ 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 $1.724.10^{-8}$ ohm per meter can be calculated by skin depth , $= \sqrt{\frac{r}{\pi f \mu}}$ (m) 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 1.7µm, so that the thickness printed copper on PCB of 25 µm is much greater than requirement. From the calculation result can be concluded the printed radiator can be treated as a thin plate.

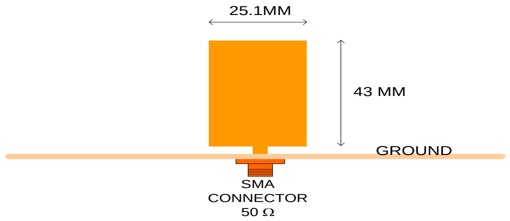

Fig 2. Dimension of Presented Antenna

III. RESULTS AND DISCUSSION

The presented antenna was a planar monopole antenna that printed on a printed circuit board (PCB). The copper thickness was measured with a micrometer to make sure that the copper thickness is greater than the skin depth for frequency of 1.5 GHz It gave result that the thickness of substrate plus copper was 836 µm, and the thickness of substrate was 825 µm, so that the thickness of copper plate was 11 µm. The thickness of the copper plate is much greater than skin depth at frequency 1.5 GHz (1.7 µm).

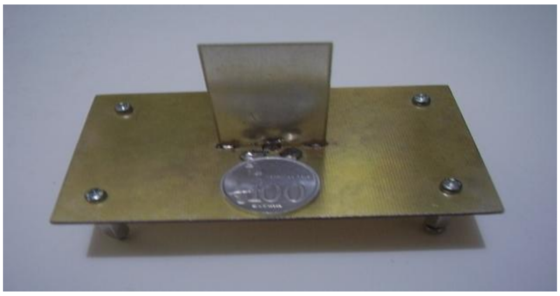

Fig 3. Scaled prototype of presented antenna

1. S_{11} Measurement

S_{11} parameter shows how much energy reflected by the antenna, therefore it can be said that S_{11} represents the levels of matching between the antenna and the line impedances. If there is no reflected power, it means that they are matched each other and the antenna's impedance equals characteristic impedance of line. S_{11} parameter can be measured by using a RF spectrum analyser or a network analyser. The value of S_{11} allowed usually is – 10 dB that means the reflected power to be 10%. Measurement result showed S_{11} of -10 dB occurred at frequency of 1.5 GHz as expected.

The value of S_{11} will continually decreased up to frequency of 2.7 GHz as shown in Figure 3. The lowest S_{11} that can be detected by the instrument was -15 dB that occurred at frequency of 2.7 GHz. At this frequency, the antenna has standing wave ratio (SWR) of 1.27.

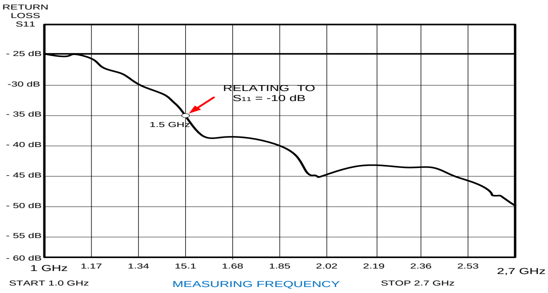

Fig 4. S_{11} of presented antenna

The input impedance of the antenna consists of radiation resistance and reactance components. These values depend on frequency so that the input impedance of antenna does not absolutely figures the quality of the antenna. Ideally, antenna has input impedance that contains radiation resistance only (should be equal to impedance characteristic of transmission line) and it does not depend on frequency.

2. Gain Measurement

The aim of gain measurement is to know the gain of the antenna under test (AUT) in dBd or dBi . Reference antenna used in this measurement is a dipole antenna that theoretically has gain of 2.15 dBi. Antenna gain can be defined as the ratio of the power received by the antenna from a far-field source on the antenna's beam axis to the power received by referent antenna (isotropic antenna). Usually this ratio is expressed in decibels, and these units are referred to as "decibels-isotropic" (dBi). An alternate definition compares the antenna to the power received by a lossless half-wave dipole antenna, in which case the units are written as dBd. Since a lossless dipole antenna has a gain of 2.15 dBi, the relation between these units is gain in dBd = gain in dBi - 2.15 dB. For a given frequency the antenna's effective area is proportional to the power gain. An antenna's effective length is proportional to the square root of the antenna's gain for a particular frequency and radiation resistance. Due to reciprocity, the gain of any antenna when receiving is equal to its gain when transmitting.

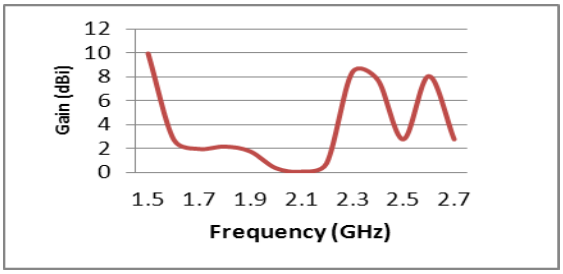

Fig 5. Gain of presented antenna

Measurement result shows that the presented antenna has gain variously from 10 dBi to 0 dBi as shown in Figure 4 that shows the presented antenna has gain of 1.75 dBi at 1.9 Ghz, 8.35 dBi at 2.3 GHz, and the gain of 7.75 dBi at frequency 2.4 GHz. These mean that the presented antenna can be applied at wifi network and Wimax spectrum of 2.35 GHz.

3. Radiation Pattern Measurement

The aims of radiation pattern measurement were (1) to understand directional characteristic and half power beam width antenna, (2) to draw polar diagram of radiation pattern of AUT. Frequencies of 1,5 GHz, 2.3 GHz, and 2.4 GHz were chosen at radiation pattern measurement because at those frequencies, the antenna has high gain. Measurement result shows that the presented antenna has

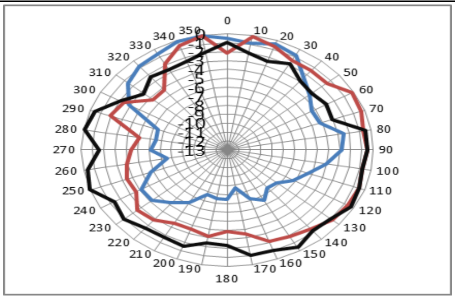

Fig 6. Radiation pattern at difference frequencies 1.5 GHz (blue line), 2.3 GHz (red line), and 2.4 GHz (black line)

Figure 6 shows three radiation pattern of the antenna at different frequencies. Those pictures show how much energy received by the antenna at different angle. For each picture, closer to the centre means lower energy received by the antenna. The maximum energy received the antenna for the three frequencies occurred at angles near zero degree. It means that the antenna able to convert the electromagnetic energy around the antenna to energy at the antenna maximally. In general, the radiation pattern of the antenna can be assumed to be omnidirectional that means the antenna can radiate electromagnetic energy to the space equally at any direction. Figure 5 also shows that the performance of the antenna at frequency 2,4 GHz is better than the antenna performance at 2,3 GHz and at 1.5 GHz. The reason is energy received at frequency 2,4 GHz is greater than energy received at 2,3 GHz and 1.5 GHz. More energy received means the input impedance of the antenna is closer to 50 ohm.

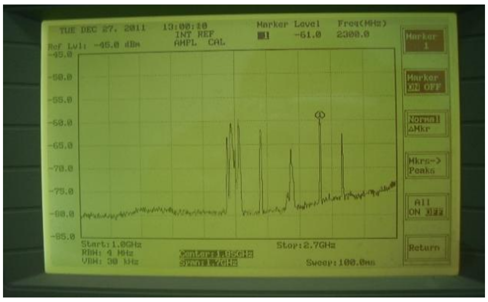

Fig 7. Power received by spectrum analyser at 2.3 GHz

4. Polarization Measurement

The purpose of this measurement is to obtain the polarization of the antenna. Polarization of the antenna refers to the direction of electric field toward ground when it is propagating. An antenna is a transducer that converts radio frequency electric current to electromagnetic waves that are then radiated into space. The polarization of an electromagnetic wave is defined as the orientation of the electric field vector. Recall that the electric field vector is perpendicular to both the direction of travel and the magnetic field vector. The polarization is described by the geometric figure traced by the electric field vector upon a stationary plane perpendicular to the direction of propagation, as the wave travels through that plane. In general, most antennas radiate either linear or circular polarization.

The type of polarization of presented antenna can be known by calculating the ratio of intensity of electric field in major and minor axes. The travelling wave in z axes can be expressed as $E = \hat{x}\, A\cos(\omega t - \beta z) + \hat{y}\, B\sin(\omega t - \beta z)$[6]. For linear polarization, A or B is equals zero and for circular polarization A equal to B, and for elliptical polarization, A is not equal to B and they are not equals zero. The antenna is said elliptically polarized if the ratio of the major and minor axes or known as axial ratio is more than one[4].

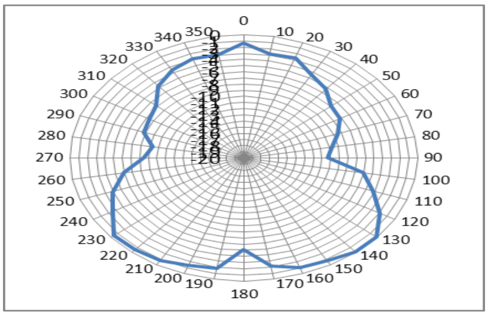

Fig 8. Power received by the presented antenna

Experiment result stated that the maximum power received is -57.4 dBm (1.82 10^{-6} mW) and minimum power received is – 67.7 dBm (2.14 10^{-7} mW) so that the axial ratio is

$$Axial\ ratio = \frac{Major}{Minor} = \frac{\sqrt{1.82\ 10^{-6}\ x\ 337}}{\sqrt{2.14\ 10^{-7}\ x\ 337}} =$$

$$\frac{6.8614\ x\ 10^{-4}}{7.2118\ x\ 10^{-5}} = 9.44$$

or 9.75 dB

The calculated result shows that the antenna is polarized elliptically that is a linear polarization. The expected result of antenna polarization is vertical, this different may be occurred by the area of measurement that there are a lot of matter produces reflection such as metallic object, wall, and concrete floor.

IV. CONCLUSION

From the whole results of parameters measurement of the presented antenna, they are can be concluded as follows (1) .the presented antenna work as expected. Because of the limitation of the instrument, higher frequency side of the bandwidth could not be detected, but the bandwidth of the antenna was more than 1.2 GHz so that the antenna was broadband. The presented antenna has radiation pattern nearly omnidirectional and the polarization of the antenna was ellipse.

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