Design and analysis of probe fed ETMSA

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***Abstract*: Microstrip patch antenna has been hogging major antenna researches since 20 years and still there are new breakthroughs every year. A researcher who wants to design a printed antenna must be familiar with the design basics. Although, there can be a lot of shapes in printed antenna, but for most of those the design concept and formula spring from the basic microstrip antennas. Most basic microstrip antennas are rectangular, circular and triangular. This paper walks through the design of 3 GHz equilateral triangle microstrip antenna. The design and simulation has been done using HFSS 11.**

***Keywords:* ETMSA (Equilateral Triangular Microstrip antenna), triangular patch antenna, Cross and co-polarization, VSWR bandwidth, Return loss**

I. INTRODUCTION

Wireless systems are playing an ever increasingly important role in society. Whether they are used to assist in the distribution/collection of large amounts of information or to make home entertainment systems more convenient, wireless systems are becoming more and more integrated into daily activities. The utilization of wireless technology is not currently confined to either the commercial or the military sectors. In fact, it seems that both sectors are striving for wireless solutions to enhance their resources, or simply to make their product more readily accessible and useful to the consumer.

One of the important enabling technologies for wireless communications is the transducer, which converts guided energy to radiated energy (and vice versa): the antenna. Although advances in antenna engineering cannot be credited for the globalization of wireless technologies, it still plays an important role, whether it provides an aesthetically pleasing solution or helps improve the overall radio frequency (RF) link budget, or allows multiple users to utilize the single interface and thereby increase the capacity. It is undeniable that good radiator engineering allows for better wireless systems.

Nowadays antenna are to be mostly installed in mobile devices, unmanned high speed vehicles and aircrafts. Mobility and many other applications, demands an antenna small in size, easily to integrate, flexibly polarized and highly efficient. Microstrip antenna was invented with some of its demerits, but it soon became popular because of the advantages it had. Standard literature [2] say that a printed microstrip antenna can be of any shape until it works as expected. Some of the most common shapes are rectangle, square, circle and triangle.

In the sections to follow we are going to discuss about triangular antenna, its design and simulation.

II. TRIANGULAR PATCH ANTENNA

A. *Introduction to triangular patch antenna*

The performance of triangular antenna is similar to the performance of Rectangular microstrip patch antenna with an added advantage of physically being small. Probe feed is widely used to feed microstrip antenna. Probe feed also does not pose radiation losses. Therefore, in this work equilateral triangular antenna is designed with coaxial feed

B. *Equilateral Triangular Microstrip antenna (ETMSA)*

The ETMSA is designed using the design formula available in [1]. Patch is designed over a Polyflon NorCLAD substrate with ε_r = 2.55, and loss tangent δ=0.0011. In contrast to the method of excitation in [3], the proposed ETMSA is excited with a coaxial port. The main problem with microstrip feeding used in [3] is that it results in losses even before the supplied current reached the antenna. Also, for impedance matching, an inset is made. For this, a significant portion of the patch is cut-out which disturbs the shape of antenna.

Only problem with coaxial probe may occur if the substrate thickness is high, it causes large cross polarization. Therefore the substrate chosen has thickness of just 0.159 cm.

It is better to feed the triangular antenna near the vertex than near the edge, because when current originates from the vertex, it gets gradually increasing patch width. This will result in wider bandwidth. Fig 1 shows the first glimpse of the proposed antenna.

FIG. 1 PROBE FED ETMSA

III. Design Methodology

A. Design formula

To design any antenna, it is required to know the resonant frequency. The operating frequency of the proposed antenna is 3 GHz. This frequency has very useful frequency range around it.

$$f_0 = \frac{2c}{3S_e\sqrt{\epsilon_e}} \quad (1)$$

$$S_e \cong S + \frac{4h}{\sqrt{\varepsilon_r}} \quad (2)$$

According to eqn (1) and (2), other than resonant frequency we also need to know about the substrate over which the antenna is to be printed. In eqn (1) and (2) S is length of the side of equilateral triangle, S_e is the equivalent side length, h is the thickness of the substrate. ε_r is the relative permittivity, and ϵ_e is the effective permittivity.

B. Choice of the substrate

The substrate should be chosen in such a way that it has very less loss tangent. Since relative permittivity has direct effect on the effective height and gain of the antenna, choosing it intelligently is also important. If the effective permittivity is too high, it will strengthen the field and required thickness will also be less, but it will reduce the gain of the antenna. On the other hand, if the effective permittivity is less, it will increase the gain but the substrate will have to be thicker.

The substrate selected in this work is Polyflon NorCLAD substrate with ε_r = 2.55, and loss tangent δ=0.0011. Dimension of the substrate will be same as the direction of ground. Ideally the ground must be infinite, but since it is practically impossible following constraints must be met.

$$L_g = L+6h+6h;\ W_g = W+6h+6h \quad (3)$$

L_g and W_g are length and width of the ground plane/substrate. The ground plane in the proposed work is at least 6h away from all the corners of the triangular patch

C. Dimension of the ETMSA

Using eqn (1) and (2), the side of the triangle is calculated to be S = 4cm. Lg and Wg are respectively 7 cm and 8 cm. Equation (2) helps to find the actual side length from effective side length. Effective side length (Se) is the result of the fringing fields from the edges of the patch. These bent fields always tend to increase the effective lengths of the printed microstrip antenna and hence the actual antenna is designed a little smaller.

D. Excitation

The antenna is excited with a coaxial probe. Mostly the antennas that resonates at less than 10 GHz, SMA connector is used at the feed point of the antenna. An SMA connector has outer radius 0.16 cm and inner pin has radius 0.07 cm. The port is designed keeping these facts in mind.

Patch antenna is fed with a coaxial cable hence its terminal impedance must be near 50 ohms. The impedance at the edges of a microstrip antenna is high (of the order of 300 ohms) and approached zero near the center.

For impedance matching, the feed can be from 1/2 to 1/3 of the height of the triangle from the nearest vertex. It can be moved a little to and fro to optimize the impedance, since exactly 50 ohms does not always give best performance.

TABLE I. Dimensions of ETMSA

Dimension	***Denotation***	***Value (cm)***
Side length	S	4
Substrate/ground Width	Wg	8
Substrate/ground Length	Lg	7
Substrate Thichness	H	0.159
Port position	(Fx,Fy)	(1.52,1)

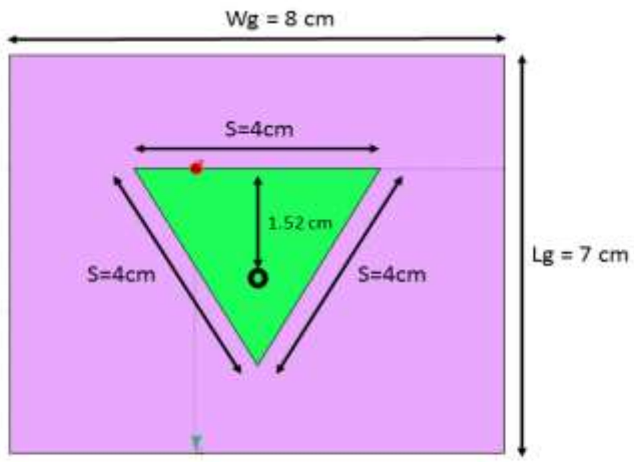

Fig. 2. Dimensions of patch antenna

IV. SIMULATION RESULT

A. *Resonant frequency (Return loss & VSWR)*

Return loss is also known as reflection coefficient. VSWR is voltage standing wave ratio, both of these quantities are the very first things to be observed about an antenna. These figures (Fig 3 and 4) show that antenna is operating at 3 GHz. The standard value of reflection coefficient must be less than -10 dB and VSWR must be less than 2 at operating frequency. The portion of the curve below 2 VSWR and below -10 dB return loss, is considered as the bandwidth of the antenna. The bandwidth is 40 MHz.

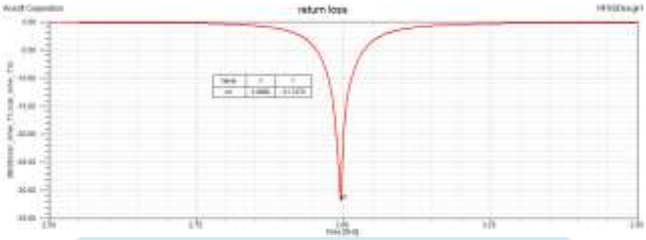

FIG. 3. REFLECTION COEFFICIENT

Minimum value of return loss is -27.33 dB (Fig 3), minimum value of VSWR is 1.1 approx (Fig 4).

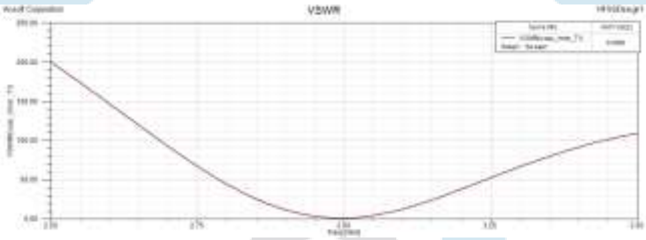

FIG. 4. VSWR

B. *Impedance*

Input Impedance of the antenna is the impedance at its terminals or the ratio of the voltage to current at a pair of or the ratio of appropriate components of the electric to magnetic fields at a point. The input impedance of an antenna should be such that it is easily fed with a coax and is real rather than complex. Input impedance of the proposed antenna lingers around 40-50 ohms over all the operating frequencies (Fig 5). This is good since it matches with the characteristic impedance of the coaxial transmission line. In Fig 5 blue curve is real impedance and red curve is imaginary impedance.

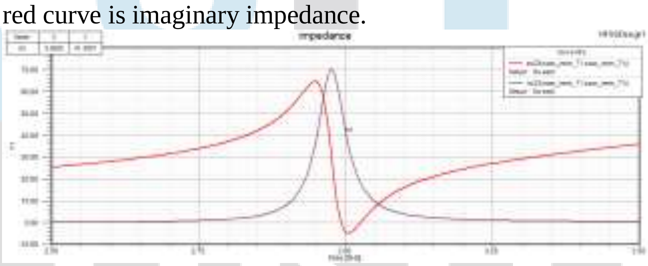

FIG. 5 ANTENNA IMPEDANCE

C. *Gain & Radiation pattern*

Fig 6 shows the gain vs frequency graph of the proposed antenna. Antenna being a passive component, gain does not exact mean the same what it means in an amplifier. It is just the value of top most tip of a pointy radiation pattern. Since the proposed antenna does not have directive application, its maximum gain is about 6.3 dBi at 3.1 GHz which is decent and it is the custom gain of a microstrip antenna.

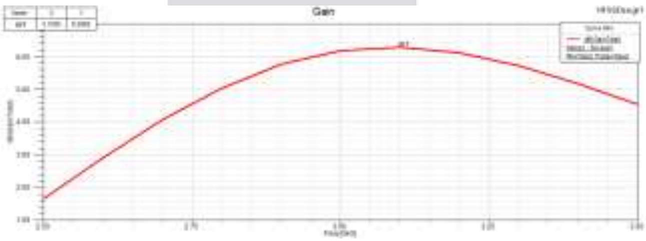

FIG. 6 GAIN

Fig 7 shows the 2D radiation pattern of the proposed antenna at two different vertical angles. These viewing angles show that the radiation pattern is almost symmetrical under the half power beamwidth. Fig 8 shows the 3D radiation pattern. It does not give much information, but it lets us imagine the actual radiation pattern which is in reality invisible.

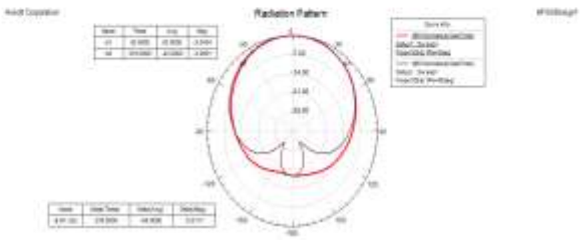

FIG. 7 2D RADIATION PATTERN

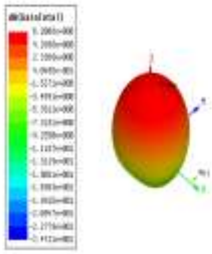

FIG. 8. 3D RADIATION PATTERN

D. Polarization

Polarization is the orientation of the electric field vector in the radiated electromagnetic wave. If the E-field is linear, the antenna emitting it is also called as linearly polarized. Printed antennas are traditionally linear polarized. It is undesirable to get cross polarization unless the antenna is deliberately designed to do so. Fig 9 shows the polarization of the designed antenna. Red colored curve is cross-polarization (undesirable) and blue colored is co-polarization (desirable). It is recommended that undesired polarization must be 20 dB below the desired radiation pattern. Fig 9 shows that cross polarization is 23 dB below.

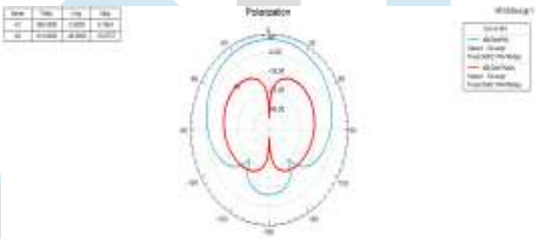

FIG. 9 CO AND CROSS POLARIZATION

V. CONCLUSION

The antenna presented in this paper is an attempt to explore the features of a rather less popular printed antenna behavior. This paper can act as reference for a reader who want to design an equilateral triangle shaped patch antenna from scratch. This antenna complies with the standard theory and the results are in good agreement with expectations.

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