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Design of Coax-Fed E-Shaped Microstrip Patch Antenna with Triple Bands

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Abstract- Due to its small size, light weight, ease of integration, microstrip patch antenna is been widely applied to the fields of mobile radio, wireless communications, radar systems and so on. This paper presents a method of designing the millimeter-wave microstrip antenna which could be use in government and commercial applications, such as mobile radio and wireless communications that have similar specifications. The designed antenna can achieve triple band performance to simultaneously cover the 1.18GHz, 2.42GHz and 4.05GHz frequency with return loss of -12.50dB, -12.60dB and -15.50dB respectively. The simulation results of the designed triple band E-shaped Microstrip Patch Antenna were also presented. The antenna is of low profile, conformable to planar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology. It was proved that the designed antenna is feasible and realizable. Because such antennas have a very low profile, are mechanically rugged and can be shaped to conform to the curving skin of a vehicle, they are often mounted on the exterior of aircraft and spacecraft, or are incorporated into mobile radio communications devices [1]-[5].

Index Terms- Coaxial Probe Feed, E-shaped Microstrip Patch antenna, HFSS-Software, Triple Frequency Bands.

I. Introduction

Recently, many communication systems are required to be small in size, which arouses the interest to fusing the step impedance resonator in microwave monolithic integrated circuits. Compared with conventional microwave antennas, microstrip patch antennas are with small size, light weight, simple to manufacture, low cost, and ease of integration such as in mobile radio and wireless communication applications [1]. In high-performance aircraft, spacecraft, satellite, and missile applications, where size, weight, cost, performance, ease of installation, and aerodynamic profile are constraints, low-profile antennas may be required. Presently there are many other government and commercial applications, such as mobile radio and wireless communications with similar specifications. To meet these requirements, microstrip antennas [3] can be used. These antennas are low profile, conformable to planar and nonplanar surfaces, simple and inexpensive to manufacture using modern printed-circuit technology, mechanically robust when mounted on rigid surfaces, compatible with MMIC designs, and when the particular patch shape and mode are selected, they are very versa-tile in terms of resonant frequency, polarization, pattern, and impedance. In addition, by adding loads between the patch and the ground plane, such as pins and varactor diodes, adaptive elements with variable resonant frequency, impedance, polarization, and pattern can be designed [3].

This paper describes a method of design of the rectangular Coax-Fed E-shaped microstrip antenna with its distinguish resonant frequencies. The simulation is done using ANSOFT HFSS software; High Frequency Structure Simulator (HFSS) is a high- frequency simulation software which is based on a finite element method and its accuracy and powerful features makes it a common tool for antenna designers, the proposed E-shaped in this paper was no exception. The proposed printed E-shaped antenna is very suitable for integration with wireless local area network (WLAN) applications, widely used in the areas of mobile radio and wireless communication applications, also found very useful in the field of global navigation satellite systems(GNSS), global positioning system (GPS). Other important areas of applications include biomedical, missiles and much more. Currently, the wireless area network (WLAN) in the 2.4-GHz (2.4-2.485 GHz) and 5-GHz (5.l5-5.875 GHz) bands is the most renowned networks for accessing the internet and also the antenna for an AP not only requires dual band operation but also needs to have an appropriate radiation profile in both bands, namely equal gain, wide beam width, and high front-to-back ratio. The future generation wireless networks require systems with broad band capabilities in various environments to satisfy numerous applications as smart grid, personal communications, home, car, and office networking. its conformability makes it very much desirable for the use in mobile phone, hand held devices and vehicles such as aircrafts, spacecrafts, marine craft, trains and cars. [1]-[4]

II. ANTENNA DESIGN

The most commonly employed microstrip antenna is the rectangular patch. The rectangular patch antenna is approximately a one-half wavelength long section of rectangular microstrip transmission line. As the antenna is loaded with a dielectric as its substrate, the length of the antenna decreases as the relative dielectric constant of the substrate increases [3]. In this approach, the E-shaped metal film was printed on a dielectric substrate, which is sitting on and perpendicular to a perfectly conducting ground plane. The E-shaped Microstrip antenna is designed to operate at a triple frequency band, the patch was designed as rectangular shaped resonating on FR4_epoxy substrate with relative permittivity dielectric constant of 4.4 and height (H) of 1.6mm. The length (L) of the patch is 27.99mm and width (W) is 37.2 mm. The area of the ground plane sets 74.4 × 55.98 mm^2. To obtain the desired optimum performance in terms of VSWR and radiation pattern, two rectangular slots with dimension of 19.1mm x 8mm were cut out from both the upper and lower side of the rectangular patch thus; forming the E-shaped patch shape which in turn yields a significant improvement in terms of the VSWR that became less than two (VSWR<2) for all the three frequency bands. The two slots were separated by a distance of 8mm, this gives the E structure presented by figure 1. However, it is also important to point out that figure 1 and figure 2 were drawn not into the scale of the proposed antenna, thus it has been enlarged for clarification purpose.

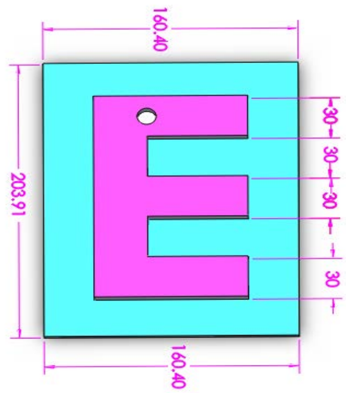


Figure 1: E-shaped printed antenna

A 50 Ω coax probe feed is directly attached via the circular cut out (Lumped port) on the upper arm of the E-structure with a radius of 1.5mm circular port. The cylindrical coax pin is made up of the pec (Perfect electric conductor) material with a radius of 0.6mm and the height of 1.6mm. The coaxial-line feed defines; where the inner conductor of the coax is attached to the radiation patch while the outer conductor is connected to the ground plane [3] as can be seen in figure1. For the radio frequency system, application of these antennas must be matched to the traditional 50Ω impedance of the front end circuitry. Therefore, the impedance network has to be plugged between the source and antenna.

III. ANALYSIS AND CONFIGURATION

In this paper, the transmission-line model was employed to configure the designed E-shaped patch antenna because it is easier to illustrate and it gives good physical insight. Although in some applications, such as in government security systems, narrow bandwidths are desirable. However, there are methods, such as increasing the height of the substrate, which can be used to extend the efficiency and bandwidth [3]. In microstrip patch antenna there are some well-known methods to increase the bandwidth of patch antennas, such as, cutting a resonant slot in the patch, reduced ground plane, the use of thick substrate, the use of a low dielectric substrate, the use of various impedance matching feeding techniques, the use of slot antenna geometry and multi-resonator stack configurations. However, the bandwidth and the size of an antenna are generally reciprocal conflicting properties such that improvement of one of the characteristics normally results in degradation of the other one. Various shapes of cutting slots and slits have been designed on patch antennas to reduce their size. These shapes of slots that are embedded on the antenna are used to increase the surface current path, so in this design was the reason for the E-shaped patch. The figure 2 below gives the Isometric view of the designed E-shaped patch antenna with triple frequency bands.

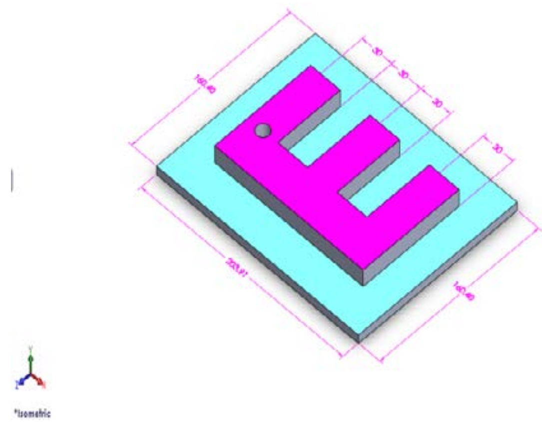


Figure 2; Isometric View of the E-shaped Patch Antenna

To decrease the resonant frequency of an antenna for a given surface area, the current path must be maximized within the area. For efficient radiation, the size of Microstrip antenna should be λ/2. If the size reduces less than λ/2, the radiation efficiency of antenna decreases along with other antenna parameters. The miniaturization of antenna and improvement in bandwidth can be achieved by etching the slot in ground and patch of Microstrip antenna of proper length and width value [4].

The simulated results were obtained by using the Ansoft HFSS; high frequency structure simulator (HFSS) software. The measured simulated characteristics of the antenna were presented as regards to the return loss (in figure 4), voltage standing-wave ratio (in figure 5). Finally the design is covered with a vacuum air box and then validation and thus simulation and analysis as shown in figure 3 below.

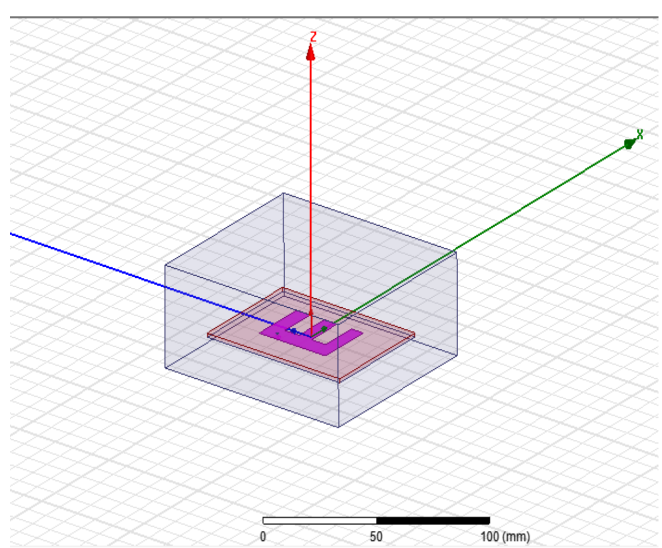


Figure 3: Simulation of the patch antenna.

IV. RESULTS AND DISCUSSION

In this section the rectangular patch antenna was designed and experimental results regarding the radiation characteristics are presented and summarized as can seen in the table 1 below. The simulated results were obtained by using the Ansoft simulation software; high frequency structure simulator HFSS. The measured simulated characteristics of the antenna are shown from the return loss, voltage standing-wave ratio (VSWR), radiation pattern as well as the current distribution in the patch. Good return loss and radiation pattern characteristics were all obtained in the frequency band of interest.

Table 1

S/N	Frequency (GHz)	Return loss (dB)	VSWR	Bandwidth (MHz)
1	1.18	-12.50	1.50	300
2	2.42	-12.60	1.45	280
3	4.05	-15.50	1.50	300

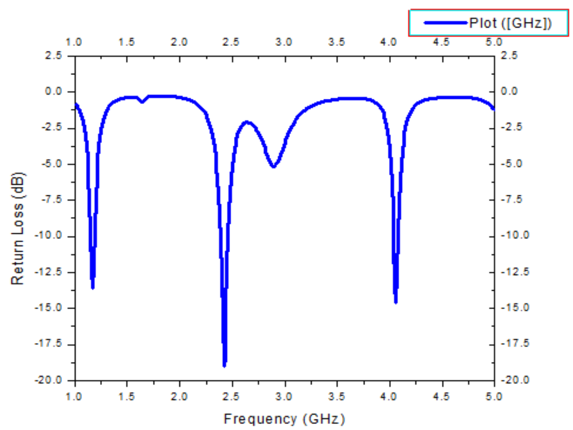


Figure 4: Return Loss

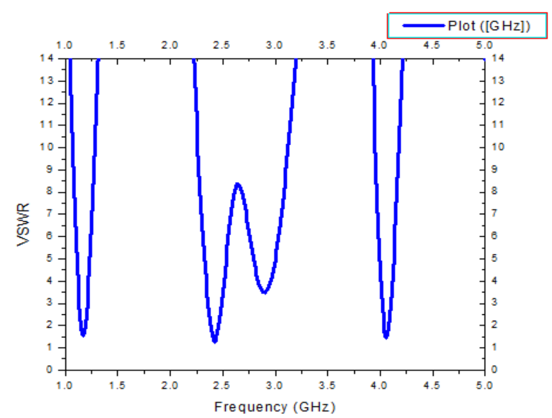
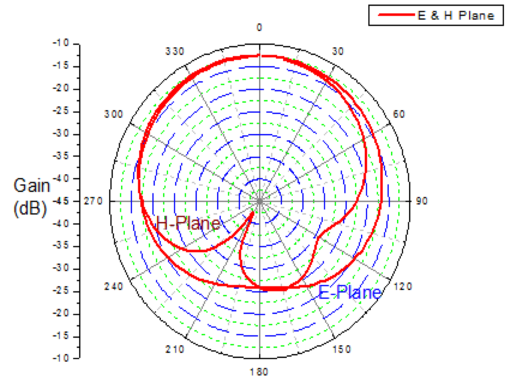
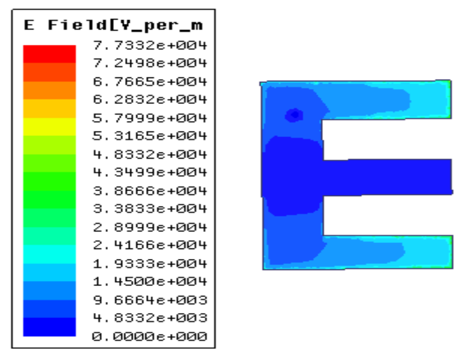


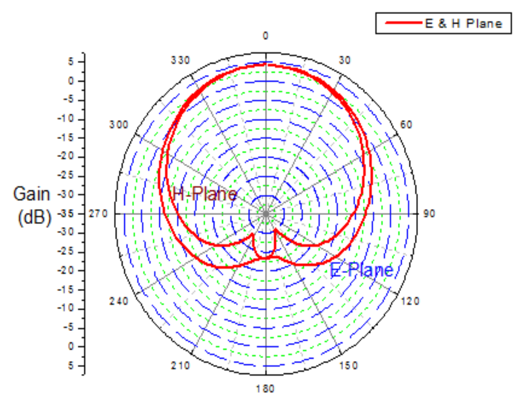
Figure 5: Voltage Standing Wave Ratio (VSWR)



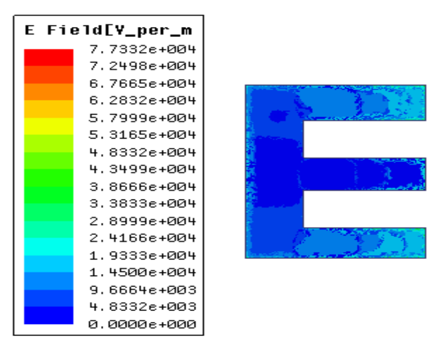
(a) Radition Pattern at 1.18GHz



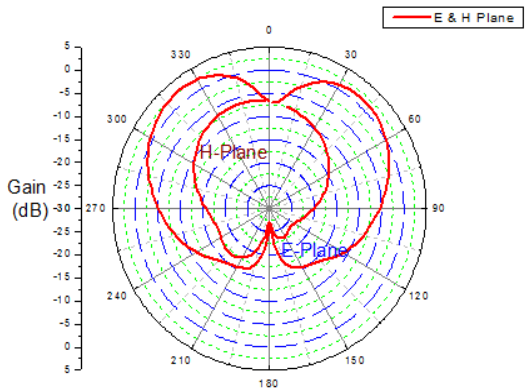
(a) Current Distribution at 1.18GHz



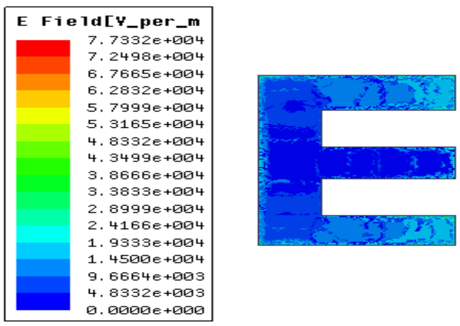
(b) Radiation Pattern at 2.42GHz



(b) Current Distribution at 2.42GHz



(c) Radiation Pattern at 4.05GHz



(c) Current Distribution at 4.05GHz

The radiation patterns for the three frequencies for 1.18GHz, 2.42GHz and 4.05GHz bands with their corresponding current distribution were presented in the figures (a), figure (b) and figure (c) respectively in terms of the E and H planes as shown above. To examine the radiation characteristic of the triple band antenna structure, the current distribution of the triple bands for the 1.18GHz, 2.42GHz and 4.05GHz E-shaped antenna were also presented.

V. CONCLUSION

The designed antenna can achieve triple band performance to simultaneously cover the 1.18GHz, 2.42GHz and 4.05GHz frequency with return loss of -12.50dB, -12.60dB and -15.50dB respectively. The simulation results of the designed triple band E-shaped Microstrip Patch Antenna were also presented. The designed antenna application systems include the wireless area network (WLAN) in the 2.4-GHz (2.4-2.485 GHz), global system for mobile communication (GSM), global positioning system (GPS), Worldwide Interoperability for Microwave Access (Wi-Max), global navigation satellite systems (GNSS) as well as Wireless communications enjoying exponential growth in Industrial, Scientific, and Medical (ISM) band. Other important areas of applications include biomedical, missiles and much more. Therefore, the designed triple band for 1.18GHz, 2.42GHz and 4.05GHz E-shaped patch antenna in this paper are in great demand, and becomes more important. It is suitable for wireless communication systems operating at very lower frequency of 1.18GHz, 2.42GHz and 4.05GHz bands.

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