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Analysis of Circular Microstrip Antenna using Different Substrates for Bluetooth Applications

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Abstract - *In this article, four Circular Microstrip Antennas are designed for different substrates. Four CMSAs are designed using FR-4, Polyester, Quartz Glass and RT/ duroid dielectric material, and having dielectric constants 2.2, 4.4, 3.7, 3.2 respectively at Bluetooth frequency 2.4 GHz. These CMSAs are compared in terms of return loss, Voltage Standing Wave Ratio (VSWR), impedance, peak gain, directivity, radiation pattern, bandwidth, and radiation efficiency. The circular patch is used as the main radiator for all antennas. The maximum bandwidth of 70 MHz has been achieved for FR-4. The ANSYS Electronics Desktop HFSS is used for the simulation.*

Key Words*: *CMSA, Bluetooth-Band, substrate analysis, Dielectric constant.

1. INTRODUCTION

Microstrip antenna is mostly used in a wireless communication application. These antennas are mostly used because it is light weighted, low cost, easy to fabricate, etc. The first antenna was designed by Deschamps in 1953. In telecommunication, the microstrip antenna for fabrication uses microstrip technique on PCB. The microstrip antenna is used for many pragmatic applications like Bluetooth, WLAN, WiMAX so on. There are so many advantages like small volume, light weighted, low profile configuration, easy to fabricate and so on [1]. In this paper, the author represents the design of using different substrate on a rectangular microstrip antenna for S-band. Here we can use a polyester substrate. This patch was purposed to operate at 3 GHz frequency for different substrate material [2]. In [3-4], the author designed E-shaped MSAs for IEEE 802.11 a high-speed WLAN standard.

In [5], microstrip antenna for WALN application using aperture feed and probe feed. Here they can use the square patch with 'dual loop' shape slot cut into patch area slotted antenna of bandwidth is 840MHz is used. The slot loaded MSA for Bluetooth and WiMAX applications is reported, and antenna uses FR-4 dielectric material [6]. In [7], Jiun-Wen Yang et al. represents circularly polarized MSA at 2.4 GHz WLAN application, the square ring patch antenna, a winding structure loaded with 100-ohm resistor chip is used as feeding mechanism of this antenna. In this paper, they can use the RT5880 dielectric substrate. There is a single band slotted MSA is used, and it is used for 5G wireless application. [8]. There are uses of the dual feeding techniques, this is the circularly polarized antenna for a single band and it operates at 2.45 GHz frequency for RFID applications [9]. In [10], authors represent the U-shaped microstrip patch antenna for quad bands S-Band, C-Band and X-Band and antenna uses Teflon based dielectric material. In [11], Rajan Fotedar et al. have been presented various shaped MSAs for 2.4 GHz application with FR-4 dielectric material. A compact and wideband swastika shaped MSA for X-band applications designed with dielectric material FR-4 and excited by coaxial probe [12]. In [13], the author investigated the dual-band slot loaded MSA with FR-4 dielectric substrate. In this paper, they can use H- shape patch antenna. It operates 2.4GHz frequency for WLAN application [14].

In this article, CMSA is studying with four various dielectric constants, it references is given in the below table. These antennas are excited with a coaxial probe feed technique at a frequency of 2.4 GHz for Bluetooth application. in this paper, the thickness of FR4, polyester, and quartz glass 1.6mm is used and for RT/duroid 1.588mm is used for all simulations.

2. DESIGN OF CIRCULAR MICROSTRIP ANTENNA

Fig. 1 shows the schematic of the CMSA. The CMSA is fed by 50 ohm SMA coaxial probe feed technique. The CMSA mainly lie of a metalizing circular patch over a thin microstrip substrate. The ground plane is on the bottom side surface. The probe feed consists of inner and outer conductors, the inner conductor is connected to the radiating element and the outer conductor is attached to the ground plane.

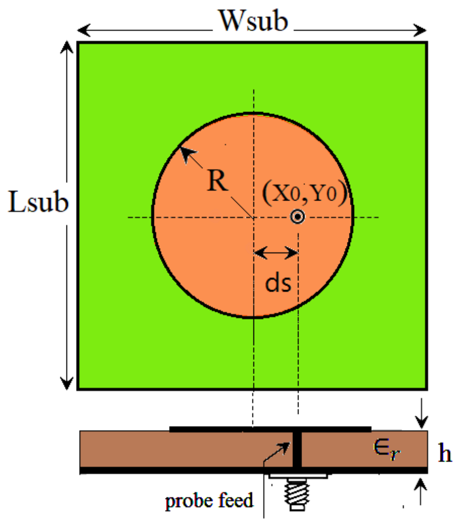

Fig -1: Schematic of circular microstrip antenna

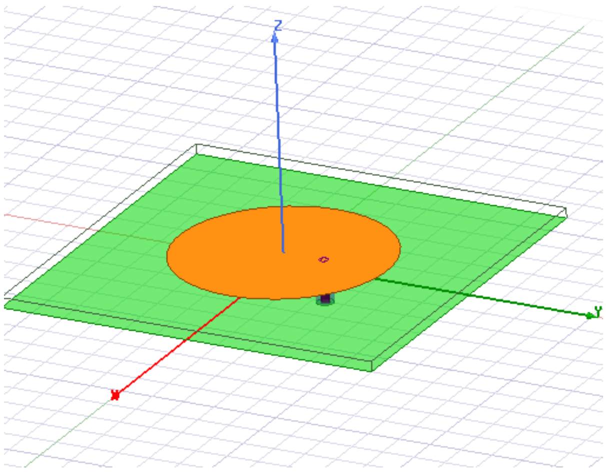

Fig -2: HFSS generated Circular microstrip antenna

Fig.2 shows a photograph of the HFSS generated Circular microstrip antenna. The probe feed is located where impedance matching takes place. The radius of the CMSA is calculated from followings equations [1]. Where, ϵ_r is dielectric constant of substrate and h is the height of substrate, c is speed of light. All CMSAs have been designed for 2.4 GHz frequency.

The Radius of CSMA is given as

$$\frac{F}{\left\{1+\frac{2h}{\pi \epsilon_r F}\left[\ln\left(\frac{\pi F}{2h}\right)+1.7726\right]\right\}^{1/2}}$$

where,

$$F = \frac{8.791\times10^9}{f_r\sqrt{\epsilon_r}}$$

The substrate dimension is given as

L_s=L+6h

W_s=W+6h

Table -1: Substrate Materials

Substrate Type	ϵ_r	*tan δ*	f_r *(GHz)*	*h(mm)*
FR-4	4.4	0.02	2.4	1.6
Polyester	3.2	0.003	2.4	1.6
Quartz Glass	3.78	0	2.4	1.6
RT/duroid 5880	2.2	0.0009	2.4	1.588

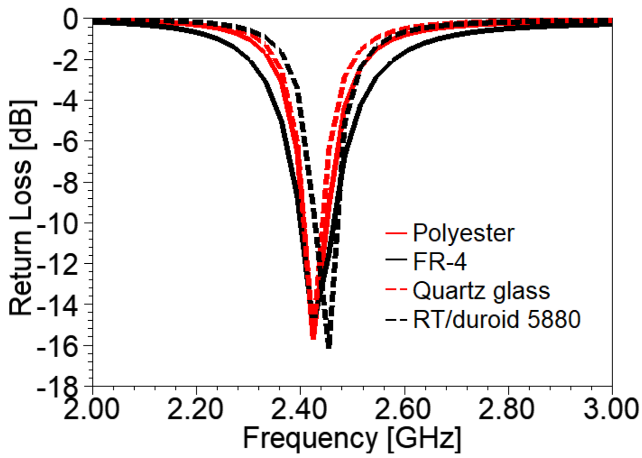

Fig -3: Return loss versus frequency of proposed CMSAs.

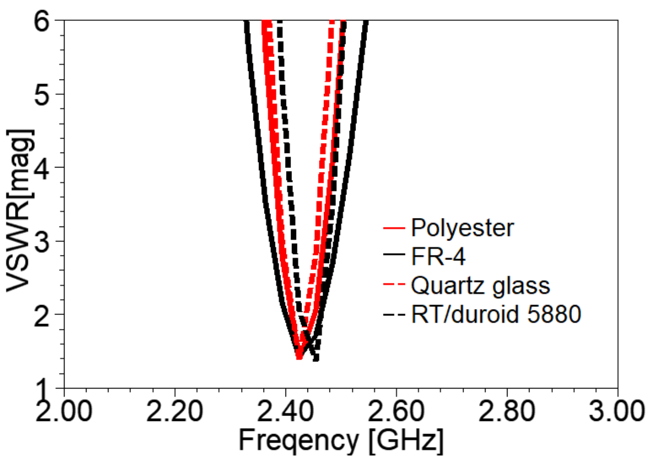

Fig -4: VSWR versus frequency of proposed CMSAs.

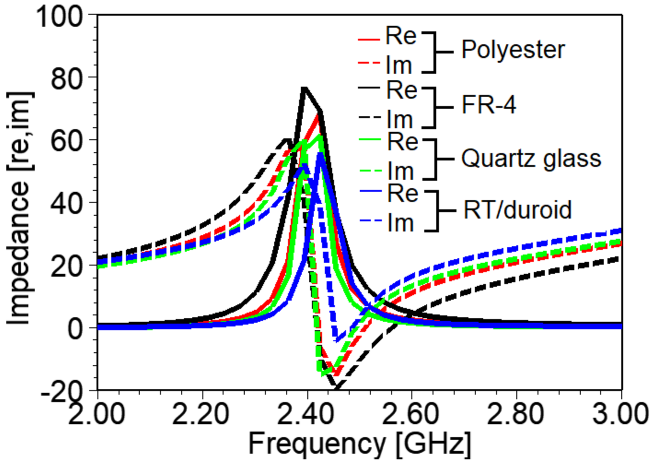

Fig -5: Impedance versus frequency of proposed CMSAs.

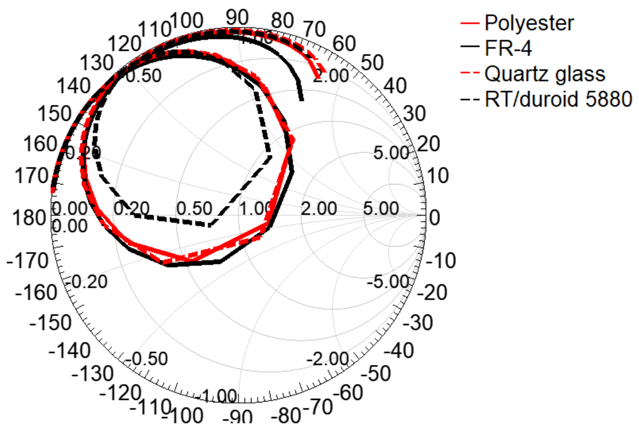

Fig -6: S_{11} curves proposed antennas.

Table -2: Substrate Materials

Parameters /Substrates	RT/duroid	FR-4	Polyester	Quartz glass
Return Loss	-16.13	-14.92	-15.61	-15.56
VSWR	1.36	1.42	1.39	1.40
Impedance (real)	42.02	66.38	31.03	29.23
Peak gain	3.93	1.32	2.58	2.87
Directivity	4.07	2.79	2.92	2.87
Radiation efficiency (%)	96	47	88	100
Bandwidth (MHz)	50	70	40	40

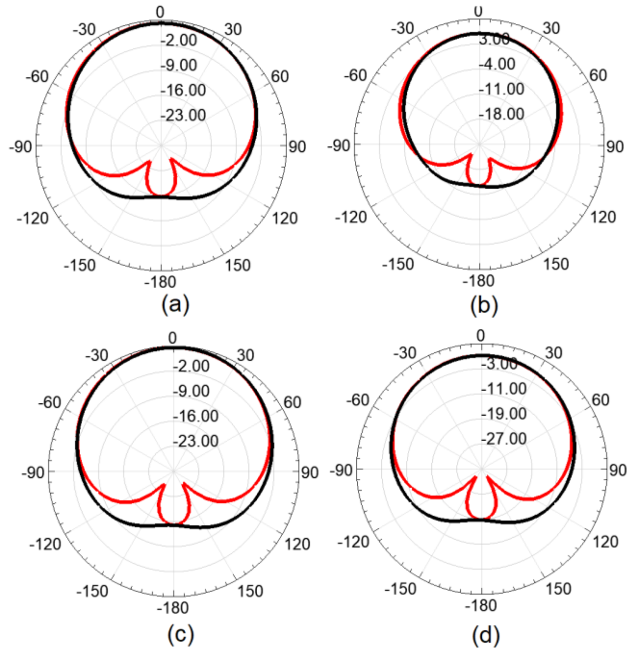

Fig -6: Radiation pattern for (a) FR4, (b) polyester, (c) quartz glass, and (d) RT/duroid

3. RESULTS AND DISSCUSSION

Various substrate materials are considered and simulated them by placing on the proposed model at 2.4 GHz. The parametric analysis is done for the different substrate with respect to parameters such as reflection coefficient (S_11≤-10dB), VSWR (2:1), impedance, peak gain (positive real value) and efficiency. The determination is made on the basis of which substrate showing good result regarding said parameters. Fig.3 shows that return loss versus frequency of proposed four probe fed CMSAs for different substrates, at 2.4 GHz (Bluetooth Band). From the result, return losses are noted as -16.13, -14.92, -15.61 and -15.56 dB respectively and it is observed that maximum return loss is found for RT/duroid. The bandwidths for all substrates are noted as 50MHz, 70MHz, 40MHz, and 40MHz respectively and the maximum bandwidth of 70 MHz is obtained for FR-4.

Fig.4 depicts the VSWR graph versus frequency proposed antenna for coaxial probe feed, at frequency 2.4GHz for CSMA for various substrate such as FR4, polyester, quartz glass and RT/duroid respectively, and VSWR are noted as 1.36, 1.42, 1.39, 1.40 respectively, and it is also noted that good impedance matching for RT/duroid substrate and VSWR for that nearly to the 1.36. It means that the good impedance is matching with ideal value and VSWR is near to the 1. Fig.5 render that impedance versus frequency proposed antenna, in RT/ duroid gives real impedance is 42.02 and imaginary is -17.93, FR4 gives the real value is 66.38 and imaginary value is -10.13, then polyester gives real value is 31.03 and imaginary value is -14.37, and quartz give the real value is 29.23 and imaginary value is -12.96. So, the overall performance from outcomes, it is also observed that good impedance coordinate with the coaxial probe feed technique, so fr4 gives the good performance to us. Fig.6 In all substrate the coaxial probe feeding technique is passed through VSWR line 1 and 2, so VSWR lies between 2:1 for each substrate. Fig.6 depicts S11 curves on the Smith chart of proposed CMSAs. It is observed that all the curves are passes through VSWR 2:1 circle and also noted that good impedance matching has been observed for Polyester. Radiation characteristics for all CMSAs are shown in Fig. 7 and form this it is observed that RT/duroid shows maximum peak gain of 3.9 dBi.

4. CONCLUSION

Generalized observation of the outcomes found by the simulation of CMSAs can help us to draw some conclusions about the tradeoff and design parameters. The purpose of this article is to design coaxial fed CMSAs with different substrates that can operate at Bluetooth frequency of 2.4 GHz and study the performance parameter of CMSAs for each substrate. Form the simulation results, it is encountered that the preferable return loss from RT/duroid is -16.3dB, VSWR of 1.369, peak gain is 3.9, the impedance of 42.02, directivity is 4.07. The substrate FR-4 gives better performance in terms of bandwidth which is 70 MHz and maximum efficiency has been obtained for Quartz glass and it is 100%.

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