iJRASET
International Journal For Research in Applied Science and Engineering Technology

INTERNATIONAL JOURNAL FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 10 Issue: VI Month of publication: June 2022

DOI: https://doi.org/10.22214/ijraset.2022.43987

Analysis of Microstrip Patch Antennas for Effective Bandwidth

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Abstract-Local Area networks work in frequency ranges 900 MHz, 3.6 GHz, 4.9GHz, 5 GHz, 5.9 GHz, 6 GHz and 60 GHz. It supports broadband communication and provides end to end communication without any propagation delays. For establishing LAN network, antennas are employed to transmit and receive signals. But the existing antenna designs for wireless LAN cannot accommodate higher bandwidths even though they provide good gain. Microstrip patch antennas are considered as they have high compatibility rates, low volume and are easy to manufacture. This paper proposes the design of a microstrip patch antenna with effective bandwidths at 1 GHz and 2.4 GHz using microstrip feed technique with dielectric materials such as FR 4 Epoxy, Arlon 450 and Taconic35. The results are shown in graphical format and have been tabulated. From the results we can conclude that FR 4 Epoxy with 1.6 mm substrate height has given best results among Taconic 35, Arlon 450 and FR 4 Epoxy. From the results we can conclude that we have achieved better bandwidths when compared to the previous works available.

Keywords— Rectangular Microstrip Antenna (RMSA), Circular Microstrip Antenna (CMSA), Voltage Standing Wave Ratio (VSWR), Return Loss (RL), Co-Axial Feeding, Microstrip Feed

I. INTRODUCTION

In recent times wireless communication is progressing rapidly with advancement in technology and research. Wireless Communications are used in day to day life applications such as bluetooth, broadband services, cellular communication and microwave communication. Wireless Local Area Network (LAN) application is one of the most emerging technology. Wireless LAN (WLAN) is a wireless computer network that links two or more devices using wireless communication to form LAN within a limited area. Wireless LAN is based on IEEE 802.11 standard. The IEEE 802.11 has two basic modes of operation: Infrastructure and Ad-hoc mode. In infrastructure mode, mobile units communicate through Wireless Access Point (WAP) whereas in adhoc mode they communicate directly through peer to peer. To employ wireless systems, microstrip patch antennas are used as they possess good geometrical shapes with rectangular, circular and elliptical configurations. Microstrip Patch Antennas can be further divided on the basis of the shape of antenna, namely Rectangular Microstrip Patch Antenna (RMSA),Circular Microstrip Patch Antenna (CMSA) and Non-Linear Microstrip Antenna (NLMSA) These antennas have low profile, low volume, effective polarizations, and easy to fabricate. These antennas support multiband frequencies ranging from MHz to GHz and supports dual band with high mobility rates and data rates up to 54 Mbps.The existing antenna designs for WLAN supports frequencies at 900 MHz, 1GHz and 2.4 GHz using coaxial feed technique with linear polarisations, but cannot exhibit higher bandwidths. This paper focuses on designing microstrip patch antenna where a greater bandwidth can be achieved. Two antennas named RMSA and CMSA are designed using dielectric materials FR 4 epoxy, Taconic 35 and Arlon 450 with permitivities of 4.4, 3.5 and 4.5. The height of the substrate is 1.6 mm. The antennas are designed using microstrip feed technique at 1 GHz and 2.4 GHz and the results were compared with 2.4 GHz coaxial feed [1].In the previous works, researches focused on developing antennas for wireless systems and multiband frequencies. The designs were confined to achieve Voltage Standing Wave Ratio (VSWR)$\leq$ 2 and S11 (Return Loss (RL)) parameters. Antennas using circular polarisation were designed to accommodate high data transmission rates. The proposed work majorly focuses on effective bandwidths for patch antennas using microstrip feed for Wireless LAN applications.

II. LITERATURE SURVEY

In the year 2005 [14], the antenna was designed for 2 frequencies (2.4 and 5.4GHz) using the microstrip feed technique. In the subsequent year (2006) same microstrip feeding technique was used for 2.2 GHz [3].In the year 2010, two types of feeding, co-axial and aperture feeding techniques for 1.25 GHz using a substance with ϵ_r=2.2 (Arlondiclad 880)[10]. In 2014, microstrip antenna was analysed for the frequencies 5.2 and 9.75 GHz [2]. In the same year, an experiment was conducted to decide the best among RMSA, CMSA and NLMSA

with 3 substrate materials namely FR4 Epoxy, Arlon 450 and Taconic 35 [1].In this paper the results obtained are compared to the results from [1]. In 2015, work was conducted on 2.4 GHz, but the dimensions of their antenna were29.2 mm x 29.2 mm x 1.6 mm and this antenna was used for WLAN applications [4]. In the same year a microstrip patch antenna was developed on flexible grapheme conducting material[5] In 2017, a major work was observed on the Microstrip patch antenna for wireless communications, 2010 [9], this work was a continuation for the work done in the year [10] In the year 2018,
three experiments were conducted:
Larger bandwidths were observed when a multiband Microstrip Patch Antenna was used in the range of 2.4 GHz and 4.8 GHz [6].
Microstrip patch antennas were used for GPS application for the first time [7].
Microstrip Patch Antennas were used with 2.4 GHz operating frequency and with FR4 Epoxy as substrate [8].
In 2019, there was an upgrade in the work done in the year 2010[10] which produced better results [13]. In the same year, similar type of antenna was used for vehicle applications [12]. This year saw the application of microstrip antenna for wireless application [11].

III. ANALYSIS OF RECTANGULAR MICROSTRIP PATCH ANTENNAS

The rectangular microstrip patch antenna was designed using microstrip feed technique at 1 GHz and 2.4 GHz. The thickness of the substrate is considered to be 1.6mm. The analysis of the antenna was done using dielectric materials like FR4 Epoxy, Arlon 450 and Taconic 35 with permitivities 4.4, 4.5 and 3.5.The basic RMSA patch equations are [1]

$$\text{Width}=\frac{c}{2f_o\sqrt{\frac{\epsilon_r+1}{2}}} \quad (1)$$

$$\epsilon_{reff}=\frac{\epsilon_r+1}{2}+\frac{\epsilon_r-1}{2}\left[\frac{1}{\sqrt{1+12\left(\frac{h}{w}\right)}}\right] \quad (2)$$

$$\text{Length}=\frac{c}{2f_0\sqrt{\epsilon_{reff}}}-0.824 \text{ x h}\frac{(\epsilon_{reff}+0.3)\left(\frac{w}{h}+0.264\right)}{\epsilon_{reff}-0.3)\left(\frac{w}{h}+0.8\right)} \quad (3)$$

Where
C – Speed of light (3 x 10^8) m/s
f_o - Operating Frequency (Hz)
ϵ_r - Di-Electric Constant
ϵ_{reff} - Effective Di-electric Constant
h- Height of the Di-Electric Substance (m)
w- Width of the Patch (m)
l- Length of the Patch (m)

The length and width of the antennas at 1 GHz and 2.4 GHz are tabulated in Table1 and Table 2 respectively.

Table1 Dimensions of the Patch for different material at 1GHz.

Substrate Material	Permittivity (ϵ_r)	Length(in mm)	Width(in mm)
FR4 Epoxy	4.4	71.26	91.22
Taconic 35	3.5	71.26	91.22
Arlon 450	4.5	70.47	90.39

Table 2 Dimensions of the Patch for different material at 2.4GHz.

Substrate Material	Permittivity (ϵ_r)	Length(in mm)	Width(in mm)
FR4 Epoxy	4.4	28	42
Taconic 35	3.5	28	42
Arlon 450	4.5	31.25	47.4

The antennas are simulated using High Frequency Simulation Software (HFSS). The graphical analysis is done in the consideration with VSWR, RL, and Bandwidth (BW) parameters. The RMSA is simulated at 1 GHz and 2.4 GHz using microstrip and resultant VSWR is compared with coaxial feed at 2.4 GHz [1].

Table 3 Comparison of VSWR Values

Substrate Material	1GHz Microstrip feed	2.4GHz Microstrip feed	2.4GHz Co-Axial Feed
FR4 Epoxy	2.9	1.7	1.01
Taconic 35	1.31	1.3	1.16
Arlon 450	3	2	1.56

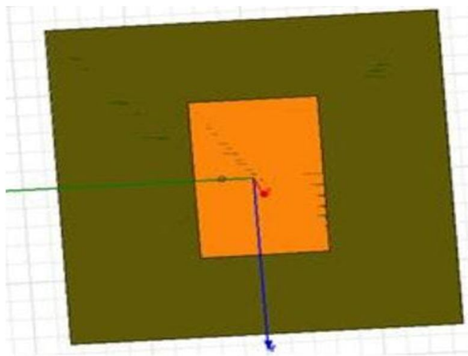

Fig. 1 RMSA Antenna

The variation in the VSWR with frequency is shown in Figure 2.

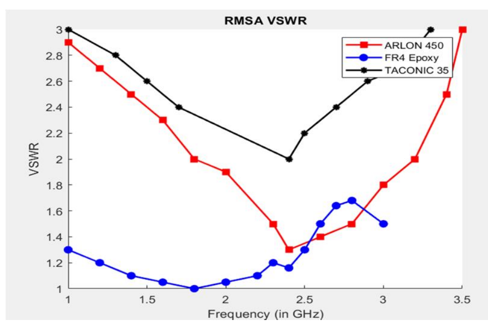

Fig. 2 The VSWR values of RMSA Antenna

The microstrip feed technique and coaxial feed technique at 1 GHz and 2.4 GHz for FR4 Epoxy material measures VSWR in the range of 1.16 to1.3. For an antenna with VSWR ≤2 is considered to be a perfect value. This concludes that FR 4 Epoxy gives good value in terms of VSWR, whereas

Arlon 450 and Taconic 35 exhibit high VSWR values, because of which they can't be considered. The table 4 compares the values of microstrip feeding technique and coaxial feeding technique at 2.4 GHz and 1 GHz obtained for Return Loss.

For S11 parameters (RL) the RMSA is simulated at 1 GHz and 2.4 GHz using microstrip and resultant RL is compared with coaxial feed at 2.4 GHz[1]the RL parameters are recorded as Table 4 or Figure 3. Figure 3, shows the variations in VSWR values with frequency.

Table 4 Comparison of Return Loss Values

Substrate Material	1GHz Microstrip feed	2.4GHz Microstrip feed	2.4GHz Co-Axial Feed
FR4 Epoxy	-6.04	-10	-11.39
Taconic 35	-16	-25	-32.67
Arlon 450	-5.9	-10	-17.76

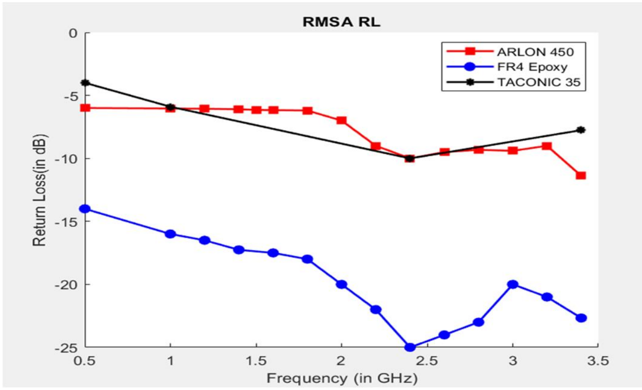

Fig. 3 The RL values of RMSA Antenna

The microstrip feeding technique and coaxial feeding technique at 1 GHz and 2.4 GHz for FR 4 Epoxy material measures RL in the range from -32.67 to -16. This gives a conclusion that FR 4 Epoxy gives good value in terms of Return Loss, whereas Arlon 450 and Taconic 35 exhibit high RL values, because of which they cannot be considered. Table 5 compares the bandwidths obtained for microstrip feeding technique and coaxial feeding technique at 2.4GHz and 1 GHz.

Table 5 Comparison of Bandwidth Values (in MHz)

Substrate Material	1GHz Microstrip feed	2.4GHz Microstrip feed	2.4GHz Co-Axial Feed
FR4 Epoxy	22	125	25
Taconic 35	22.2	121	60
Arlon 450	15	61	40

Arlon 450 obtained a bandwidth of 125 MHz at 2.4 GHz microstrip feed, but when it is compared with FR 4Epoxy, the bandwidth is 121 MHz From the above results, it is noted that FR 4 epoxy using microstrip feed at 2.4GHz is the best antenna which satisfies VSWR and RL values with effective bandwidth.

IV. ANALYSIS OF CIRCULAR MICROSTRIP PATCH ANTENNAS

The circular microstrip patch antenna is designed using FR4 epoxy, Taconic35, Arlon 450 with a height of 1.6 mm. The basic CMSA patch equations are [1]

$$a=\frac{f}{\sqrt{1+\frac{2h}{f\pi\epsilon_r}[\ln(\frac{\pi f}{2h}+1.7726)]}}$$

The radius for FR4 epoxy, Taconic 35, Arlon 450 at 1GHz is 40.72mm, 47.45mm, and 41.177mm respectively. At 2.4 GHz the radius for FR4 epoxy, Taconic 35, Arlon 450 at 1GHz is 17mm, 18mm, and 17mm respectively.
The Figure 4 shows the CMSA antenna designed in HFSS.

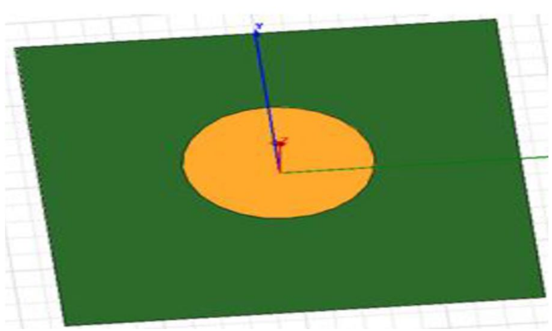

Fig. 4 CMSA Antenna

Table 6 shows the comparison in values of microstrip feed technique and Co-Axial feed technique at 2.4 GHz and 1 GHz for VSWR.

Table 6 Comparison of VSWR Values

Substrate Material	1GHz Microstrip feed	2.4GHz Microstrip feed	2.4GHz Co-Axial Feed
FR4 Epoxy	2.26	1.7	1.5
Taconic 35	1.7	1.5	1.22
Arlon 450	2	1.9	1.26

The Figure 5 shows the variation in the value of VSWR with frequency.

The microstrip feed technique and coaxial feed technique at 1 GHz and 2.4GHz for FR4 Epoxy material measure VSWR are in the range of 1.22 to 2.26. For an antenna with VSWR≤ 2 is considered to be a perfect value. This concludes that FR 4 Epoxy gives good value in terms of VSWR, whereas Arlon 450 and Taconic 35 exhibit high VSWR values, because of which they can't be considered.

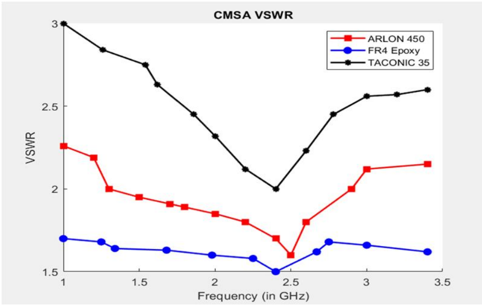

Fig. 5 The VSWR values of CMSA Antenna

Table 7 compares the values of microstrip feeding technique and coaxial feeding technique at 2.4 GHz and 1 GHz for Return Loss.

Table 7 Comparison of Return Loss Values

Substrate Material	1GHz Microstrip feed	2.4GHz Microstrip feed	2.4GHz Co-Axial Feed
FR4 Epoxy	-8.3	-9.8	-13.88
Taconic 35	-11	-20.1	-19.99
Arlon 450	-9	-10	-18.53

The Figure 6 shows the variation in RL values with frequency.

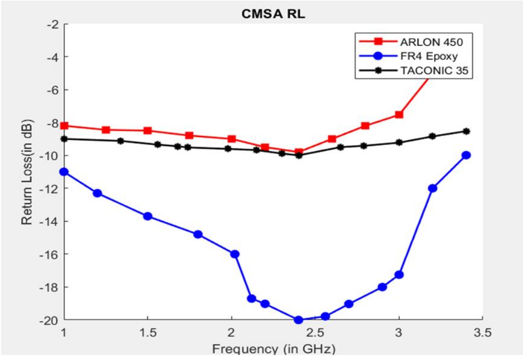

Fig. 6 The RL values of CMSA Antenna

The microstrip feeding technique and coaxial feeding technique at 1 GHz and 2.4 GHz for FR 4 Epoxy material measures RL ranging from -19.99 to -8.3.This gives a conclusion that FR 4 Epoxy gives good value in terms of Return Loss. The bandwidth can be resulted by calculating the difference between maximum and minimum frequencies.

Table 8 compares the values of the microstrip feeding technique and coaxial feed technique at 2.4GHz and 1 GHz obtained for bandwidth.

Table 8 Comparison of Bandwidth Values (in MHz)

Substrate Material	1GHz Microstrip feed	2.4GHz Microstrip feed	2.4GHz Co-Axial Feed
FR4 Epoxy	5	89	52
Taconic 35	20.6	80	25
Arlon 450	20	70	28.9

When observed from the above table, Arlon 450 has obtained a bandwidth of 89 MHz at 2.4 GHz microstrip feed, but when it is compared with FR4 Epoxy, the bandwidth is 80 MHz From the above results, it can be noted that FR 4 Epoxy using microstrip feed at 2.4 GHz is the best antenna which satisfies VSWR and RL values with effective bandwidth.

V. CONCLUSION

From the above results, RMSA is the best suited antenna for Wireless LAN Applications in terms of VSWR, RL, and Bandwidth in comparison with the values obtained in CMSA. The VSWR values obtained for the dielectric material FR4 Epoxy have achieved the best results for higher bandwidth at 2.4GHz microstrip feeding technique in terms of bandwidth measuring 122 MHz, VSWR with value 1.3 and S11 Parameters(Return Loss) -25db and gain of 4.2dBi.From the results obtained it can be concluded that RMSA with FR4 Epoxy as the substrate will give the best results, in comparison of the paper from [1] it can be understood that in that paper NLMSA was a better option among RMSA and CMSA, but the design of NLMSA is very difficult when compared to RMSA and CMSA. So it can be concluded that the design of RMSA is cost efficient and time efficient as compared to NLMSA.

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