

A Rectangular Patch Antenna based on Flexible and Non-Flexible Substrates for Wireless Applications



Kailash Chandra, Pramod Kumar, S K Sriwas, Mahendra Kumar, Shounak De, Tanweer Ali

Abstract: Microstrip antenna is one of the most popular types of printed antenna. It plays an excellent role in today's world of wireless communication systems. Microstrip antenna offers the advantages of thin profile, light weight, low cost, ease of fabrication and compatibility with the integrated circuitry. In this paper, the design of a rectangular patch antenna based on flexible and non-flexible substrate is presented. First a simple rectangular shape patch antenna using microstrip feeding based on FR4 substrate is designed. The designed antenna operates at a center frequency 2.3 GHz with bandwidth ranging from 2.25 to 2.35 GHz (100 MHz). The same rectangular patch is subjected to two different flexible substrate i.e. Kapton polyimide film with thickness of 0.82 mm and Kapton polyimide film with thickness of 0.85 mm. With Kapton polyimide as substrate having thickness of 0.82 mm resulted in a center frequency of 2.4 GHz with bandwidth ranging from 2.36 to 2.45 GHz (90 MHz). With Kapton polyimide as substrate having thickness of 0.85 mm, the antenna provides a center frequency at 2.3 GHz, with bandwidth ranging from 2.25 to 2.35 GHz (100 MHz). The other radiational parameters (such as impedance matching, radiation pattern, radiation efficiency and gain) from all the three substrate are studied. The antenna based on FR4 substrate is finally fabricated and its results are compared with the simulated ones.

Keywords : Kapton polyimide film, Antenna, FR4, Microstrip.

I. INTRODUCTION

Nowadays in wireless communication systems, antennas that are designed to operate over several bands have received

immense attention. Microstrip patch antennas are preferred to satisfy needs of GPS/GNSS, WiMax/WLAN and satellite communication. In comparison to conventional antennas, microstrip patch antennas have numerous advantages such as low weight, lesser in cost, low volume, simpler to fabricate and conformity. In addition to this, they can also provide wider bandwidth, frequency rapidity and flexible feed line. Basically a microstrip patch antenna is made up of a radiating patch, a dielectric substrate and a ground plane. The dielectric substrate lies between the ground plane and the patch. A microstrip patch antenna is most appropriate for aviation and mobile applications. In consideration of their low-power consuming capacity, this Antenna can be utilized even in low-power transmitting and receiving applications.

A basic microstrip patch antenna is first designed. The objective was to create a single band antenna for the Wi-Fi network applications. The antenna size is $60 \times 60 \text{ mm}^2$ and the substrate used is FR4 (Flame Retardant) epoxy. The microstrip antenna consist of a radiating patch, a feed line, ground plane and a lumped port which is used to concatenate the feed line and the ground plane. The radiating patch unite with the feed line for the proper conductivity. The whole antenna elements say radiating patch, feed line and the ground plane are designed with copper. Next a microstrip patch antenna system is designed on a flexible material with an objective to create a single band antenna for the application of Wi-Fi range. The antenna size is $70 \times 70 \text{ mm}^2$ and the substrate used is Kapton polyimide film with two substrate thickness say 0.082 mm and 0.85 mm. In this case antenna design geometry is same as that of FR4 antenna (Non-flexible antenna) but the only difference is the usage of substrate and its thickness. In detail the design geometry of the microstrip patch antenna over a non-flexible material (FR4 substrate) operates on 2.45 GHz. It is observed that the acceptable gain is achieved at this frequency with a appreciable bandwidth say (minimum above 100 MHz). While detailing on the other case, it is been observed that the microstrip antenna designed on flexible substrate operates at same frequency of FR4 antenna say 2.45 GHz. Since it's flexible in nature the gain and the bandwidth of this antenna varies proportionately to the thickness. The gain pattern is Directional. The simulation for both the designs is carried out using High Frequency Structural Simulator (HFSS).

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* Correspondence Author

Kailash Chandra, Department of E&C, Dr. AKTU Lucknow

Pramod Kumar, Department of E&C, Manipal Institute of Technology, Manipal Academy of Higher Educaion, Manipal, India Email: 79.pramod@gmail.com

S K Sriwas, Electronics & Communication Engineering Department, Bundelkhand Institute of Engineering and Technology (BIET), Jhansi (UP), India

Mahendra Kumar, Electronics & Communication Engineering Department, Bundelkhand Institute of Engineering and Technology (BIET), Jhansi (UP), India

Shounak De, Department of E&C, Manipal Institute of Technology, Manipal Academy of Higher Educaion, Manipal, India Email: shounak.de@manipal.edu

Tanweer Ali (Corresponding Author), Department of E&C, Manipal Institute of Technology, Manipal Academy of Higher Educaion, Manipal, India, Email: tanweer.ali@manipal.edu

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The performance and the execution of an Antenna can be characterized by different parameters, such as , Radiation Pattern, Frequency vs Reflection Coefficient ,Voltage Standing Wave Ratio (VSWR) , Antenna Radiation Efficiency and the Gain.

In general a microstrip patch antenna which consist of a radiating patch, microstrip feed, ground plane and the substrate which is shown in the Fig. 1.

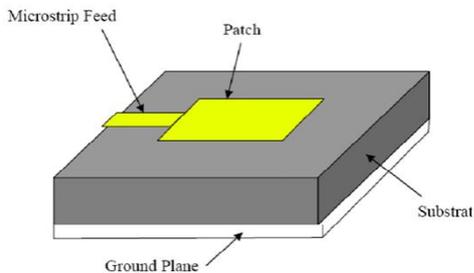


Fig. 1: Microstrip antenna [1]

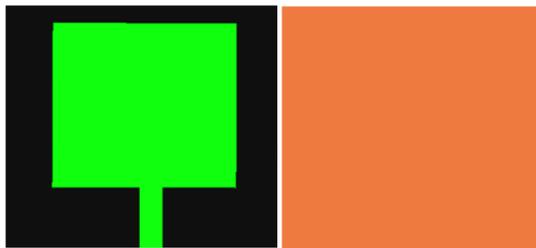


Fig. 2: (a) The top view of microstrip patch antenna design (b) bottom view of microstrip patch antenna design.

In the recent years there has been witnessed a lot of revolutionary changes in the Wireless communication technology especially in terms of transmissions and receptions of data's. For the purpose of this higher data communication there must be a requirement of a specialized antennas which can cover up all the specifications and strategies which is necessary for the high speed data transmission. Desperately Conventional antennas are not capable for the above mentioned requirements, and also conventional antennas are found to be quite non-flexible in its structure. Conventional antennas are very difficult to execute in the locations with low availability of network coverage. These antennas consume large amount of power and it can be very difficult to execute in the fast growing world, where the size of the devices tends to decrease every year. Higher data rates is always something that is desirable in today's world. It can be useful in multiple areas like gaming, HD videos and so on. In detail the microstrip technology played a major role in taking the step from 3G to 4G wireless technology. The microstrip antennas have proved to be an excellent candidate which can cover up all the above specifications and the requirements, this is due to the capability to generate highly reliable signals in addition to low cost and high data rate features. Thus a microstrip antenna offers low volume, low cost, highly reliable and compact sized antenna.

Mandana Mehrparvar and Farrokh Hodjat Kashani presented a paper based on a Microstrip antenna that shortened to 50% utilizing one kind of metamaterial. In this paper the both the author's focused more on the microstrip

antenna and elaboration of its advantageous possibilities and demerits. They clearly introduce the concept of the metamaterial by covering all the lucrative nature of the metamaterial in case of microstrip antenna. It's been clearly observed that the above mentioned antenna is properly analyzed, designed and simulated on RT/ Duroid 5880 material substrate by utilizing CST studio. The paper details that with the implementation of metamaterial concept the above mentioned antenna is well capable to produce a radiation efficiency which makes the respective antenna to transmit and receive data's without any loss of signals. Which provides of 92%. The observed directivity and bandwidth of the mentioned antenna is 2.7 dB and 0.5% at 2.03 GHz respectively. It also been observed that the designed geometry of the mentioned antenna is capable much enough to radiate good VSWR and a better Reflection coefficient [1-2].

Falguni Raval et.al presented a paper detailing a Microstrip antenna with and without metamaterial. Overall knowledge of this paper elaborates about the lucrative nature and the main advantages by making variation in the size of the above mentioned patch antenna. The paper also detailed about the introduction of the metamaterial concept. Metamaterial introduction helps to produce miniaturized antennas. The paper brings the attention to the point that the antenna with the metamaterial is well compact as it compared with normal conventional antennas. Finally the paper concludes with the results that, the rectangular antenna without the metamaterial produce a gain of 7.9 dB whereas the antenna with metamaterial produce a gain 6.09 dB that resonate at a frequency of 9.91 GHz [3].

Galaba Sai Rajesh et. al presented a Microstrip antenna based on Metamaterial for multiband application. The paper focus more on the shape and size of the substrate used say Square, Hexagonal, and Star are the three geometrical shapes for the patches that have been mainly analysed, designed and simulated over a CSR-RIS material by using CST software tool.. It is identified from the paper that the thickness of the substrate material plays a crucial role in defining the antenna performance parameters such as directivity, total gain, and return loss and so on. The proposed patch antenna array with 5 elements provide high gain of 10.6 dB and is caliber to use in the field of "Airborne Synthetic Aperture Radar System (SAR)" [4-6].

Hazel Thomas presented a paper that propose a antenna design consist of 3 parallel rectangular open slots (PROSS), etched on the ground plane of the microstrip antenna which can be used for multiband applications [7]."

Shivam Mokha et. al presented this paper based on Design of Flexible Patch Antenna .The proposed design achieves an evolution from simple Rectangular "Microstrip Patch antenna towards a flexible Microstrip patch antenna. The proposed designs includes the study of Microstrip patch antenna with substantially negligible thickness, on a Kapton Polyimide film substrate with the conductive ground plane as well as the patch made of Copper. Thus, the proposed antennas designs represent a Flexible Patch antenna which is operable at robust, thin and has a low profile.

These properties make it very useful in applications where space available is less and also where efficiency cannot be compromised [8-10].

Sheerma Manna presented a microstrip patch antenna specifically for the field of biomedical applications. In detail the paper provide an information that the designed antenna is well sophisticated and capable to radiate signals which is very much precise and noise.

This antenna is potent to generate signals in the range of Wi-Fi network of frequency 2.45 GHz. The proposed microstrip patch antenna has a rectangular patch structure with a microstrip feed. In this project Roger is utilized as the substrate material which is required for the respective Antenna geometry design. The substrate Roger has a dielectric constant of 10.2. The design geometry is simulated using IE3D software. From the simulation results, it shows that it covers the frequency band 2.38 GHz to 2.52 GHz. In general a "Microstrip patch antenna" is preferred, due to its flexible nature in shape, conformal and miniaturization can be achieved to a greater extent [11]."

A basic microstrip patch antenna is first designed. The objective was to create a single band antenna for the Wi-Fi network applications. The antenna size is $60 \times 60 \text{ mm}^2$ and the substrate used is FR4 (Flame Retardant) epoxy. The microstrip antenna consist of a radiating patch, a feed line, ground plane and a lumped port which is used to concatenate the feed line and the ground plane. The radiating patch unite with the feed line for the proper conductivity. The whole antenna elements say radiating patch, feed line and the ground plane are designed with copper. Next a microstrip patch antenna system is designed on a flexible material with an objective to create a single band antenna for the application of Wi-Fi range. The antenna size is $70 \times 70 \text{ mm}^2$ and the substrate used is Kapton polyimide film with two substrate thickness say 0.082 mm and 0.85 mm. In this case antenna design geometry is same as that of FR4 antenna (Non-flexible antenna) but the only difference is the usage of substrate and its thickness. In detail the design geometry of the microstrip patch antenna over a non-flexible material (FR4 substrate) operates on 2.45 GHz. It is observed that the acceptable gain is achieved at this frequency with an appreciable bandwidth say (minimum above 100 MHz). While detailing on the other case, it is been observed that the microstrip antenna designed on flexible substrate operates at same frequency of FR4 antenna say 2.45 GHz. Since its flexible in nature the gain and the bandwidth of this antenna varies proportionately to the thickness. The gain pattern is Directional. The simulation for both the designs is carried out using High Frequency Structural Simulator (HFSS). The performance and the execution of an Antenna can be characterized by different parameters, such as , Radiation Pattern, Frequency vs Reflection Coefficient ,Voltage Standing Wave Ratio (VSWR) , Antenna Radiation Efficiency and the Gain.

1.2 Design methodology

In general for the correct design of any antenna", its parameter of design such as length, width, type of substrate etc. is very important. So, to achieve proper antenna design with better radiation performance a rectangular patch antenna is designed by utilizing microstrip equations. The

specifications were that it needed to be desired frequency say 2.45 GHz to satisfy the needs of various applications which comes under the Wi-Fi range of network.

The proposed antenna is designed, analysed and simulated by utilising the High-Frequency Structure Simulator (HFSS). The suggested antenna is a microstrip patch antenna, therefore its design in HFSS needs some geometrical and simulation parameters. The geometrical parameters of the proposed antenna are calculated utilising microstrip equations which has shown in below. In fact, the major simulation parameter of an antenna is the frequency that can be defined according to the application of the proposed antenna. 2.45 GHz is the frequency range which is selected for this project as which generally provides Wi-Fi range of applications. After the computation of geometrical parameters, the design of the suggested antenna can be modelled in the HFSS. Here two kinds of antennas were analysed, designed, and fabricated as per the results obtained from the simulated design. For the simulation and fabrication purpose two types of substrates were utilised such as FR4 (Flame Retardant) substrate and Kapton polyimide film substrate. In detail the FR4 substrate comes under non-flexible material and the Kapton polyimide film comes under the type of flexible material. Soon after the simulation, several simulated parameters such as frequency vs reflection coefficient, VSWR, total gain in dB, bandwidth were analysed and correct the results in such a way, which is close to the referenced one by optimising the proposed design geometries of Antennas. Antenna Radiation Efficiency is checked on beforehand of the fabrication. The radiation efficiency is considered as one of the important parameter to examine the proper working antenna. The antenna radiation efficiency is denoted in terms of percentage and at least 50% of efficiency is recommended for the proper operation of the fabricated antenna. The following algorithm shows the overall proposed methodology of the microstrip antenna.

1.3 Design Equations

The first stage of the antenna is a basic microstrip patch antenna. The equations used to design the antenna is as follows [8]:

The Width of the microstrip patch antenna can be calculated by using equation (1)

$$W = \frac{c}{2f_0 \sqrt{\frac{\epsilon_r + 1}{2}}} \quad (1)$$

The Length of the microstrip patch antenna can be computed by using equation (2)

$$L = L_{\text{eff}} - 2\Delta L \quad (2)$$

The Effective length of the Microstrip Patch antenna is given by equation (3)

$$L_{\text{eff}} = c / (2f_0 \sqrt{\epsilon_{\text{eff}}}) \quad (3)$$

The Fringe factor of the Microstrip Antenna is given by equation (4)

$$\Delta L = 0.412h \frac{(\epsilon_{eff}+0.3)(\frac{w}{h}+0.264)}{(\epsilon_{eff}-0.258)(\frac{w}{h}+0.8)} \quad (4)$$

The Effective dielectric constant of the patch antenna is given by equation (5)

$$\epsilon_{eff} = \frac{\epsilon_r+1}{2} + \frac{\epsilon_r-1}{2} [1 + 12 \frac{h}{w}]^{-1/2} \quad (5)$$

The Width of the feed line of patch antenna can be calculated by using the below formula

$$\frac{w}{h} = \frac{8 \exp(A)}{(\exp(2A)-2)} \quad (6)$$

where,

$$A = \frac{Z_c}{60} \left[\frac{\epsilon_r + 1}{2} \right]^{0.5} + \frac{\epsilon_r - 1}{\epsilon_r + 1} \left\{ 0.23 + \frac{0.11}{\epsilon_r} \right\}$$

The Length of the patch antenna can be calculated by using the below formula

$$L = \frac{\lambda_g}{4} \quad (7)$$

Where, $\lambda_g = \frac{c}{fr \sqrt{\epsilon_{eff}}}$

Where, W_p is the patch width of the antenna, L_p is the patch length of the microstrip antenna, h_s is the substrate height=1.6mm for the FR4 substrate, height = 0.85mm for the Kapton polyimide film material and height =0.082 mm for the Kapton polyimide film material, c is the speed of light in vacuum, ϵ_{efc} is the materials’s effective dielectric constant, ϵ_r is the material’s dielectric constant, A is a constant, W_f is the feed line width and L_f is the feed line length of each antennas.

II. SIMULATION PARAMETERS

The simulation parameter such as dielectric constant, thickness and the loss tangent of each respective substrates is shown in Table 1.

Table 1: Simulation parameters and the values for the respective substrates

No.	Parameters	F R 4	Kapton polyimide film	Kapton polyimide film
1	Dielectric Constant	4.4	1.6	1.6
2	Thickness (mm)	1.6	0.82	0.85
3	Loss Tangent	0.018	0.002	0.002

2.1 Designed Values For FR 4 Substrate

The below obtained parameter values plays an important role in producing the required frequency of 2.45 GHz which mainly operates in Wi-Fi network range. The whole values are calculated manually by utilizing the above mentioned microstrip equations, where C indicates the speed of the light in vacuum, ϵ_r is the relative permittivity of the FR 4 substrate which has a predefined value of 4.4 and f_0 indicates the operating frequency which is designed for 2.45 GHz. The antenna performance parameters of the FR4 antenna and the respective calculated values are shown in the Table 2.

Table 2 : Designed parameter values for FR 4 substrate.

No.	Parameter	Value s
1.	Width of the Patch (mm)	37.26
2.	Effective Dielectric constant.	4.073
3.	Effective Length (mm)	30.34
4.	Fringe Factor (mm)	1.53
5.	Length of the Patch (mm)	28.80
6.	Width of the Feed.	3.2
7.	Length of the Feed.	15.2

2.2 Designed Values for Kapton polyimide film Substrate

The below obtained parameter values plays an important role in producing the required frequency of 2.45 GHz which mainly operates in Wi-Fi network range. The whole values are calculated manually by utilizing the above mentioned microstrip equations, where C indicates the speed of the light in vacuum, ϵ_r is the relative permittivity of the Kapton polyimide film substrate which has a predefined value of 1.6 and f_0 indicates the operating frequency which is designed for 2.45 GHz. The fringe factor of the Kapton polyimide film is very small as we compare with FR 4 substrate. Since the Kapton polyimide film is flexible in nature the total gain of the simulated design is observed as negative. The thickness of the substrate plays a crucial role in deciding Antenna radiation efficiency. In this case the thickness of Kapton substrate is very small say 0.082 mm, as a result of that the production of Antenna radiation efficiency is pretty much low say 9%, which makes the Antenna lossy. The Table 3 shows the manually calculated values for Kapton polyimide substrate with a thickness of 0.85 mm.

Table 3: Designed parameter values for Kapton polyimide film substrate with a thickness of 0.85mm

No.	Parameters	Values
1	Width of the Patch (mm)	41.3
2	Effective Dielectric constant	3.39
3	Effective Length (mm)	33.27
4	Fringe factor (mm)	0.0127
5	Length of the Patch (mm)	33.192
6	Width of the Feed (mm)	1.9
7	Length of the Feed (mm)	15.2

2.3 Designed Values for Kapton polyimide film Substrate

The below obtained parameter values plays an important role in producing the required frequency of 2.45 GHz which mainly operates in Wi-Fi network range.



The whole values are calculated manually by utilizing the above mentioned microstrip equations, where C indicates the speed of the light in vacuum, ϵ_r is the relative permittivity of the Kapton polyimide film substrate which has a predefined value of 1.6 and f_0 indicates the operating frequency which is designed for 2.45 GHz.

The fringe factor of the Kapton polyimide film is very small as we compare with FR 4 substrate. The thickness of the substrate plays a crucial role in deciding Antenna radiation efficiency. In this case the thickness of Kapton substrate is 0.85mm, as a result of that the production of Antenna radiation efficiency is pretty much good say 84%, which makes the Antenna good to radiate. Table 4 shows the designed parameter values for Kapton polyimide film substrate with a thickness of 0.082mm.

Table 4: Designed parameter values for Kapton polyimide film substrate with a thickness of 0.082mm.

Sl. No.	Parameters	Value
1	Width of the Patch (mm)	41.29
2	Effective Dielectric constant (mm)	3.39
3	Effective Length (mm)	33.27
4	Fringe factor (mm)	0.022
5	Length of the Patch (mm)	33
6	Width of the Feed	0.9
7	Length of the Feed	18.7

III. SIMULATED RESULTS

This session details about the simulated results of three antennas which is designed on two different substrates such as FR4 and Kapton polyimide film substrates. In case of Kapton substrate, there are two different thickness used for the better examination of the radiation efficiency.

3.1 Simulated Results of FR 4 Antenna

This session contains the simulated geometry results of microstrip antenna which is designed on the FR 4 substrates which has a fixed thickness and a dielectric constant of 1.66 mm and 4.4 respectively. The antenna performance parameters of FR4 antenna such as reflection coefficient, VSWR, total gain, radiation pattern and the antenna radiation efficiency are measured and shown in the Fig.14, Fig.15, Fig.16, Fig.17 and Fig.18. The final view of the measured values of each performance parameter of the antenna is clearly mentioned on the Table 5.

It is been observed from Fig.14 that the reflection coefficient is -16.02 dB for the frequency of 2.3 GHz.

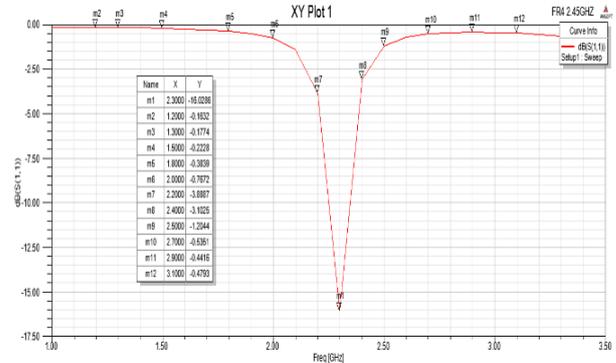


Fig. 14: Frequency vs reflection coefficient

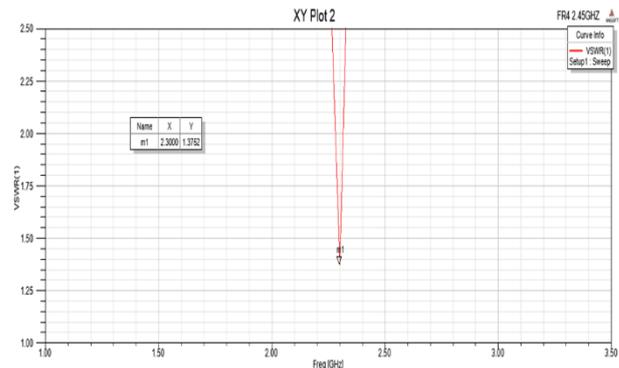


Fig. 15: VSWR of the FR4 antenna

The VSWR is about 1.37 for the designed frequency of 2.3 GHz as shown in the Fig.15.

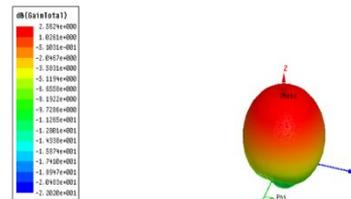


Fig. 16 : Total gain in dB

The total gain is obtained as 2.564 dB which is positive in nature as shown in the Fig.16. Since the gain is positive, the designed antenna is good enough to make transmission and reception of the signals.

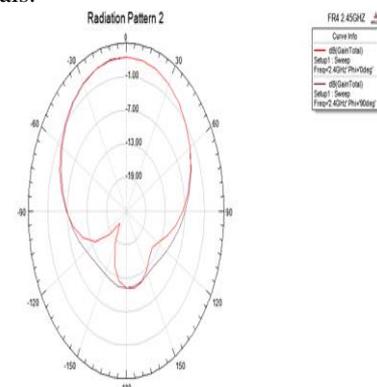


Fig. 17 : Directional Radiation Pattern

3.1.1 Overall Results Obtained from the Simulation

The below Table shows the brief idea on the simulated results of FR4 antenna. The Table contain all the noted values for the specified performance parameters.

Table 5 shows the Overall simulated results of FR4 antenna

Sl.No.	Parameters	Values
1	Reflection coefficient	-16.02 dB
2	VSWR	1.37
3	Total gain in dB	2.564
4	Radiation pattern	Directional
5	Radiation Efficiency	50%

3.2 Simulated Results of Kapton Antenna with the thickness of 0.082 mm

This session contains the simulated geometry results of microstrip antenna which is designed on the Kapton polyimide film substrates which has a fixed thickness and a dielectric constant of 0.082 mm and 3.5 respectively. The antenna performance parameters of Kapton antenna such as reflection coefficient, VSWR , total gain, radiation pattern and the antenna radiation efficiency are measured and shown in the Fig.18, Fig.19, Fig.20, Fig.21 and Fig.22. The final view of the measured values of each performance parameter of the antenna is clearly mentioned on the Table 6. It is been observed from below plots, that the reflection coefficient is -11.075 dB, VSWR of about 1.702, total gain of -3.454 dB, a Directional radiation pattern and the antenna radiation efficiency of 9.4%.

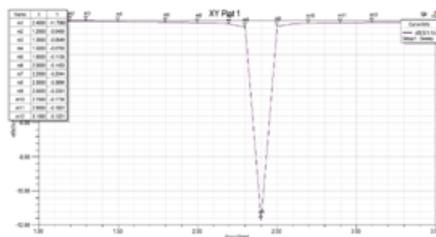


Fig. 18 : Frequency vs Reflection coefficient (S11)

The reflection coefficient is -11.075 dB for the frequency of 2.3 GHz as shown in the Fig.18.

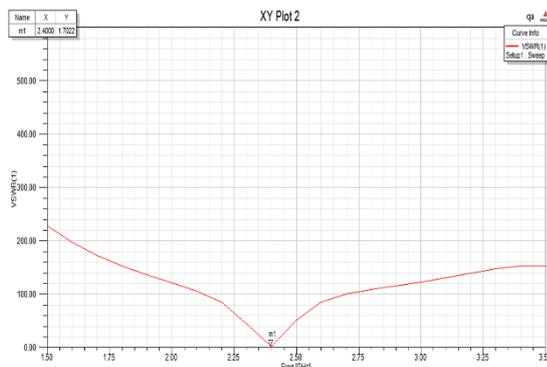


Fig. 19: Frequency vs VSWR

The VSWR is about 1.702 for the designed frequency of 2.3

GHZ as shown in the Fig.19.

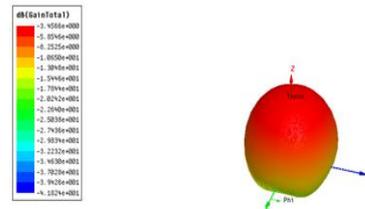


Fig. 20 : Total gain in dB

The total gain is obtained as -3.45 dB which is negative in nature due the flexible nature of Kapton substrate as shown in Fig.20.

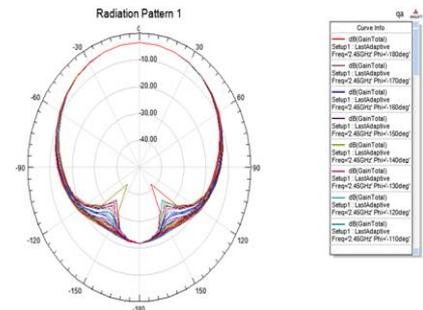


Fig. 21: Radiation pattern

3.2.1 Overall simulated results

The brief idea on the simulated results of microstrip antenna designed on Kapton substrate is clearly mentioned on the Table 6. The Table contain all the noted values for the specified performance parameters. The gain is negative and the radiation efficiency is 9% which is too small to make a radiation due to the flexible nature of the Kapton substrate.

Table 6: Overall simulated results of Kapton antenna with thickness of 0.082 mm.

Sl. No.	Parameters	Values
1	Reflection coefficient	-11.075 dB
2	VSWR	1.702
3	Total gain in dB	-3.45
4	Radiation pattern	Directional
5	Radiation Efficiency	9.8%

3.3 Simulated Results of Kapton Antenna with the Thickness of 0.85 mm.

This session contains the simulated geometry results of microstrip antenna which is designed on the Kapton polyimide film substrates which has a fixed thickness and a dielectric constant of 0.85 mm and 3.5 respectively. The antenna performance parameters of Kapton antenna such as reflection coefficient, VSWR, total gain, radiation pattern and the antenna radiation efficiency are measured and shown in the Fig.23, Fig.24, Fig.25, Fig.26 and Fig.27.

The final view of the measured values of each performance parameter of the antenna is clearly mentioned on the Table 7. It is been observed from the Fig.s say Fig.23 to Fig.27, that the reflection coefficient is -12.66 dB, VSWR of about 1.608, total gain of 3.249 dB, a Directional radiation pattern and the antenna radiation efficiency of 47%.

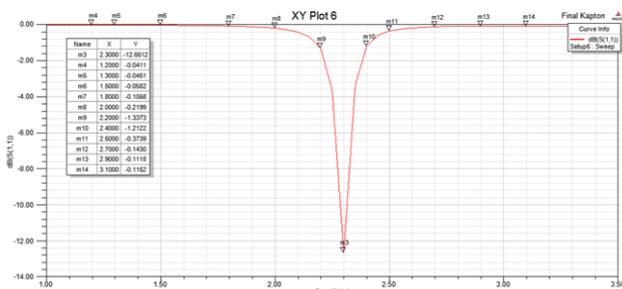


Fig. 23: Frequency vs S11

It is been observed from the Fig.23, that the reflection coefficient is -12.66 dB for the frequency of 2.3 GHz.

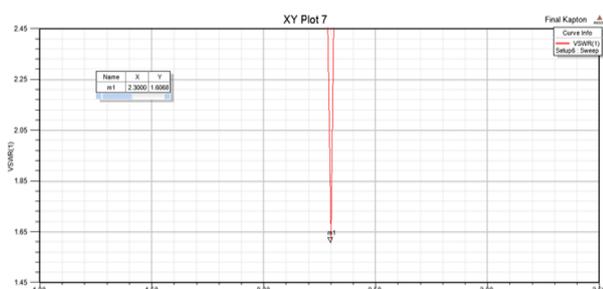


Fig. 24: Frequency vs VSWR

The VSWR is about 1.608 for the designed frequency of 2.3 GHz as shown in the Fig.24.

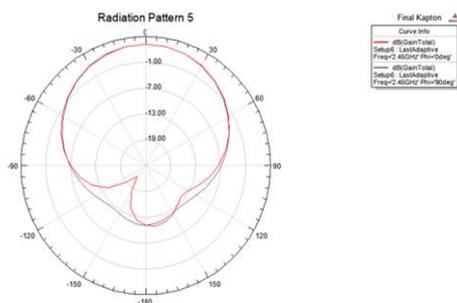


Fig. 25 : Directional Radiation Pattern

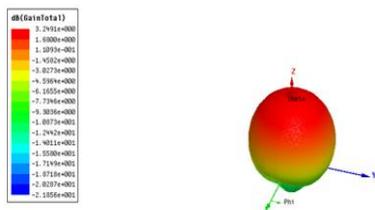


Fig. 27 : Total Gain in dB

It is been observed that the total gain is obtained as 3.25 dB which is positive in nature which resulted due to the change in the thickness of the Kapton substrate material from 0.082

mm to 0.85 mm as shown in Fig.27.

3.3.1 Overall simulated results.

The brief idea on the simulated results of microstrip antenna designed on Kapton substrate as shown in the Table 7. The Table contain all the noted values for the specified performance parameters. The gain is negative and the radiation efficiency is 47% which is too good for the antenna to operate on the specified frequency. This resulted due to the change in the thickness of material from 0.082 mm to 0.85 mm.

Table 7: Overall simulated results of Kapton antenna with thickness of 0.85 mm.

Sl. No.	Parameters	Values
1	S ₁₁	12.66 dB
2	VSWR	1.608
3	Total Gain (dB)	3.249
4	Radiation Pattern	Directional
5	Efficiency	47%

3.4 Comparison of the Simulated Results

The following two sub-sessions details about the overall comparisons of the simulated results of three antennas designed on two different substrates say FR4 and Kapton substrates as shown in the Table 8. In that two antennas are designed with Kapton polyimide film with two different thickness.

A single banded microstrip patch antenna is designed for the frequency of 2.45 GHz. It is further simulated using HFSS. The antenna size is 60×60 mm and the substrate used is FR4 epoxy. Since the substrate is non-flexible in nature, the designed antenna is well capable to produce good radiation efficiency. In this project the FR 4 antenna produce a radiation efficiency of 50%. The antenna is applicable for all applications which comes under the Wi-Fi network range. A single banded microstrip patch antenna is designed for the frequency of 2.45 GHz. It is further simulated using HFSS. The antenna size is 70×70 mm and the substrate used is Kapton polyimide film. Since the substrate is flexible in nature, the designed antenna is capable to produce moderate radiation efficiency. In this project two Kapton antenna of different thickness say 0.082 mm and 0.85 mm are designed. Kapton antenna of thickness 0.082 mm produce a radiation efficiency of 9% and antenna with thickness of 0.85 mm produce an efficiency of 46%. The Kapton antenna is applicable for all wearable and short range applications especially in the field of Medical Science.

Table 8: Comparison of Antenna performance parameters of both FR 4 and Kapton Antenna.

Sl. No.	Parameters	FR4 Antenna	Kapton Antenna (0.082mm)	Kapton Antenna (0.85 mm)
1	S ₁₁ (dB)	-16.02	-11.075	12.66
2	VSWR	1.37	1.702	1.608
3	Total Gain (dB)	2.564	-3.45	3.249

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4	Radiation Pattern	Directional	Directional	Directional
5	Antenna Radiation Efficiency	50%	9.8%	47%

3.5 Fabrication Results

This session details briefly about the fabricated FR4 antenna and its corresponding obtained results. The fabricated antenna on FR 4 substrate material is clearly mentioned in the Fig.28.

The overall size of the antenna is 60×60 mm where the united radiating patch and the feed lie is shown as silver coated. A port is used to connect the antenna to either the input source or the output source like CRO. The remaining session indicates the visualization of the measured results purely based on the antenna performance parameters such as reflection coefficient VSWR, and the radiation pattern which is clearly shown in the Fig.29, Fig.30 and Fig.31 respectively.

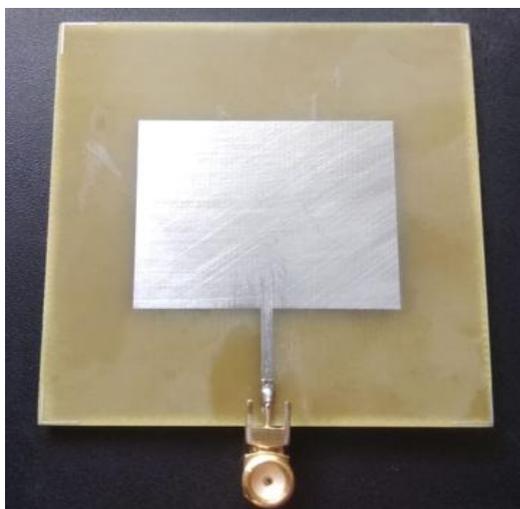


Fig. 28: Fabricated FR4 antenna

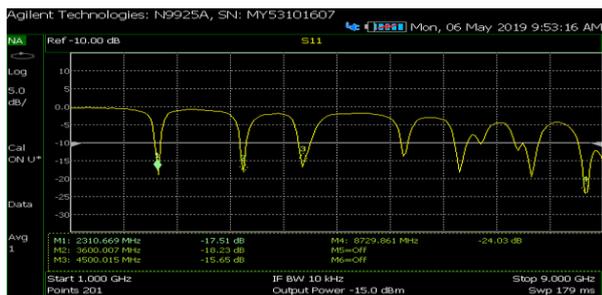


Fig. 29: Frequency vs Reflection coefficient

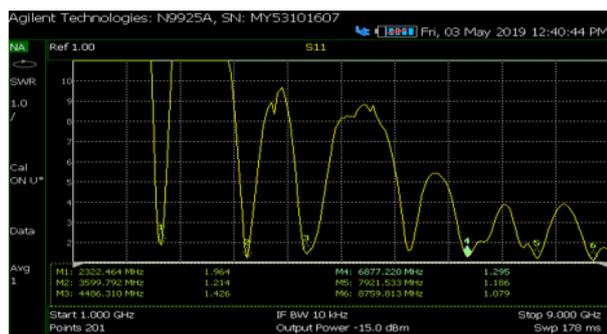


Fig. 30: Frequency vs VSWR

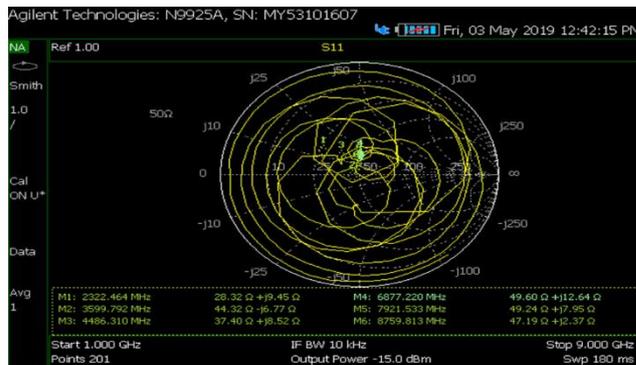


Fig. 31: Radiation Pattern

3.5.1 Comparison of Results

This session shows the comparative study and the total analysis of both simulated and fabricated FR4 antennas. The comparative study and analysis of the antenna is carried out as per the available performance parameters which clearly shown in the Table 9. From the total examination of the above analysis it is been observed that the simulated antenna is better than the fabricated FR4 antenna in terms of reflection coefficient and the VSWR parameters.

Table 9: Comparison of both fabricated and simulated results of FR4 antenna

Sl. No	Parameters	Fabricated Values	Simulated Values
1	Reflection Coefficient	-10.11 dB	-16.02 dB
2	VSWR	1.964	1.37
3	Radiation Pattern	Directional	Directional

IV. CONCLUSION

The objective of the paper is to design a microstrip antenna system on two different substrates which can be used for all applications which fall under the Wi-Fi range of network which has a working frequency of 2.45 GHz. The work starts off by fixing size, substrate and frequency of operation of the microstrip antenna on two substrates say FR4 and Kapton polyimide film substrates with two different thickness. Next, the design is analyzed and the performance is observed. Parametric analysis is then performed to finalize the dimensions to achieve the desired operating characteristics.

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Mahendra Kumar is presently working as Associate Professor in Electronics & Communication Engineering department, Bundelkhand Institute of Engineering and Technology (BIET), Jhansi (UP), India. His interests are in Multiple Access Schemes for area of research interest design of Microstrip Antennas for various applications. He has published many

research papers in different international journals and conference.



Shounak De is currently working as Associate Professor in the Department of Electronics & Communication Engineering at Manipal Institute of Technology, Manipal, India. His research interests are flexible devices, VLSI etc.



Tanweer Ali is an Assistant Professor in the Dept. of Electronics & Communication Engineering at Manipal Institute of Technology, Manipal Academy of Higher Education, Manipal. He is an active researcher in the field of microstrip antennas, wireless communication and microwave Imaging. He has published more than 60 papers in reputed peer reviewed international journal and conferences. He is a senior member IEEE (SMIEEE), and Associate Member of IETE India. He is on the board of reviewers of journals like the IEEE Transactions on Antennas and Propagation, IEEE Antennas and Wireless Propagation Letters, IET Microwaves, Antennas & Propagation, IET Electronics letter, Wireless Personal Communication (WPC), Springer, AEU-International Journal of Electronics and Communications, Microwave and optical Technology letters (MOTL), Wiley, International Journal of Antennas and Propagation, Hindawi., Advanced Electromagnetics, Progress in Electro Magnetics Research (PIER), KSII Transaction of Engineering Science, Korea, International Journal of Microwave and Wireless Technologies, Frequenz, Radioengineering etc.

AUTHORS PROFILE



Kailash Chandra received his Bachelor of Engineering in Electronics and communication engineering from GLA Mathura, India in 2002. He has obtained M.Tech. in VLSI Design from UPTU Lucknow, 2011 and he is pursuing his PhD from Dr. AKTU Lucknow, U.P.



Pramod Kumar received his B.E degree in Electronics and Communication Engineering from Visvesvaraya Technological University in 2002 and received his M.Tech degree in Microwave Engineering from Madhav Institute of Technology & Science; Gwalior, India in 2007. He obtained his PhD degree in Department of Electrical & Electronics Engineering at National Institute of Technology Karnataka, Mangalore, India. Currently, he is working as Associate Professor in the Department of Electronics & Communication Engineering at Manipal Institute of Technology, Manipal, India. He has published more than 40 papers in reputed peer reviewed international journal and conferences.



S K Sriwas received his Bachelor of Engineering in Electronics and communication engineering from Hindustan College of Science and Technology, Mathura, India in 2001. He received his M.Tech in Microwave Engineering (Electronics and Communication Engineering) from Madhav Institute of Technology and Science, Gwalior, M.P., India in 2007. He completed his PhD in the Dept. of ECE in AKTU, Lucknow, India. He is presently working as Assistant Professor in Electronics & Communication Engineering department, Bundelkhand Institute of Engineering and Technology (BIET), Jhansi (UP), India. His interests are in Multiple Access Schemes for Optical Channel, Coding Theory, Electronics Engineering, Electronic Circuits and microwave engineering. He has published 17 research papers in different international journals and conference.