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Design of Elliptical Microstrip Antenna for Multiband Wireless Signal Processing Applications

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Abstract. A simple multiband elliptical patch antenna for Ultra Wide Band (UWB) applications is introduced in this paper. For bandwidth enhancement, a U – shaped slot carved in the middle of the patch antenna. The obtained bandwidth for the presented microstrip antenna for S11 < -10 dB spans 5 GHz to 12 GHz. The multi resonance frequencies (band-I (5.374 – 5.517) GHz, band II (5.864 – 6.004) GHz, band III (6.126 – 6.289) GHz, band IV (6.522 – 6.404) GHz, band V (7.307 - 8.027) GHz band VI (8.755 - 10.00) GHz band VII (10.00 - 11.033) GHz & band VIII (11.383 - 12.00) GHz). Which are proper for different wireless functions, making this offered antenna appropriate for Ultra Wide Band (UWB) applications. The measurements of the submitted antenna are (50 × 50) mm^2 using a Flame Resistant (FR4) substrate with a relative permittivity of 4.3 and a thickness of 1.5 mm. The presented elliptical multiband antenna has been offered and tested by using strip line feeding technique. The setup mechanism and execution evaluation of configured multiband microstrip antenna was handled by using a (CST) microwave studio.

INTRODUCTION

In 1953, the idea of microstrip antennas appeared when Deschamps proposed it in USA. Mainly, the microstrip antennas were used with applications in both the civil and military sections. Compared with the conventional microwave antennas, there are a number of advantages that making the microstrip antenna more suitable in radiometers, remote sensing radars, personal communication systems, aircrafts as well as in satellites and missiles. Some of these advantages are their low fabrication cost, thin profile and lightweight. Therefore, such an antenna is easily manufactured in large quantities .

Linear and circular polarizations are achievable by easily altering the feeding mechanism or by putting switches in suitable positions. Dual frequency and dual polarizations can simply be accomplished by a reactive loading, like carving slots on the patch.[1]

The simple design of the microstrip antenna contains a radiating patch made from copper or gold on the upper flank of the substrate that has a bottom plane on the different side. For a good radiation performance of the microstrip antenna, a dense dielectric substrate with a low dielectric constant is required. Moreover, this offers adequate radiation, bigger bandwidth, and a more efficiency. However, such a configuration will increase the antenna's size [2].

The microstrip antennas can be classified into four main groups: microstrip patch antennas, microstrip traveling wave antennas, printed slot antennas and microstrip dipoles.

A microstrip patch antenna contains a radiating patch of a non-planar geometry above the dielectric substrate and the ground plane on opposite side. The radiator patch is usually square, elliptical, circular, or any familiar shape. All these shapes work similarly to the dipole antenna, and so, their radiation properties are the same.

The proposed antenna have focused on the microstrip patch antennas category. This is due to the simplicity, effectiveness and the lower cost. This type of microstrip antenna has the largest impedance bandwidth compared with the other types of microstrip geometries that can be achieved to the microstrip antenna, making this microstrip antenna type suitable for multiband applications.

A different type of techniques can feed microstrip patch antennas. These techniques can be categorized into two groups: a direct (contacting) method and indirect (non-contacting) method. In the first category, the Radio

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Frequency (RF) power is fed directly to the patch using a connecting element, the microstrip patch antennas use a coaxial probe feed or a microstrip feed line. These feeding techniques are very similar in process, and present a single degree of freedom in the design of the microstrip antenna component within the position of the feed point to modify the input impedance level. On the other hand, the indirect method includes an aperture coupled microstrip feed, proximity-coupled feed and a coplanar waveguide feed. In this category, the electromagnetic field connection is achieved to transfer power from the microstrip feed line to the radiating patch of the microstrip.[3]

In microstrip feed line technique, a conducting microstrip is connected to the edge of the microstrip radiator patch. The microstrip line feed can be counted as an extension part of the microstrip patch, were both of them can be manufactured at the same time. The conducting microstrip is smaller in width comparing to the microstrip patch .

The presented multiband antenna in this research, are fed with the microstrip feed line because it is the simplest and cheapest technique among the others.

For the same field, various advantages of the multiband antenna over the traditional antenna. Multifunction achieved, the cost and the size are reduced rather than the separate task of the conventional antenna. In addition to creating multiband resonance for modern requirements to wireless communication systems for instance, Sajid A. suggested a multiband microstrip antenna operates at three band frequencies (2.6, 6, and 8.5) GHz for (WiMAX, vehicular LAN and weather radars) applications, with overall area 40×30 mm^2.[4]

The Ultra Wide Band (UWB) technique in the last 20 years has been used for many applications, for example, military and sensing applications, radar, etc.

Since 2002, there are a considerable number of researches has been published for this excellent technology [5]. Currently this technique using for wireless communication with a high data rate for numerous applications.

The Federal Communications Commission (FCC) for commercial use assigned the frequency band from 3.1 GHz to 10.6 GHz for UWB technique [5]. To scope such a requirement, there are a large number of a brilliant antenna designs about this subject (elliptical, circular, hexagonal, etc.) microstrip antenna can be used to consumed the whole UWB frequency bands .

In 2019, a compact ultra-wideband (UWB) reconfigurable antenna with dual notch band has been proposed. The dual notch band half–elliptical reconfigurable antenna is located above FR-4 substrates (32 × 32.6) mm^2.

Today, various types of patch antennas are used in many wireless applications. These antennas have different shapes of the antenna elements, feeding techniques, in addition to polarization type, which can be used for a numerous applications in Wireless Local Area Network (WLAN), Ultra Wide Band (UWB) communications, GPS (1.56 GHz), GSM1800 (1.8 GHz), PCS1900 (1.96 GHz), Multi-band GNNS [6 – 11].

For a wide range of applications in scientific, medical, and industrial fields, a multiband microstrip antenna was studied and designed [12 - 14]. Which have a working frequency at 902 – 928 MHz, 2400 – 2480 MHz, 5150 – 5350 MHz. in addition to 3.5 GHz, 5.9 GHz, 9.2 GHz and 13.1 GHz.

It is desired that a single antenna can operate in a large number of applications such as (WLAN) and (WiMAX). Therefore, researchers design the multiband antenna, such as a double-band antenna for a WLAN system [15, 16]. 2.4/5.2/5.8 GHz bands loop antenna is proposed [17].

The multi-band Planar Inverted-F Antenna (PIFA) for the Wireless (WWAN) system used in [18], multi-band microstrip antenna having various polarization states is offered .[19]

In [20], a robot head shaped antenna with compact size and high bandwidth is offered. Simple multiband microstrip.

Reconfiguring technique can be also achieved to the multiband antenna design to increasing the functionality of the microstrip patch antenna by managing the frequency bands, radiation pattern or antenna polarization. With this technique, a single antenna can be utilized for various mixtures of applications like a Wi-Fi, Wi-Max, 3G, etc. within a microwave frequency bands in Electromagnetic Scope [21-23].

In our work, the method of raising the amount of echoing frequencies and bandwidth of the antennas offered by employing a prolonged ellipse patch antenna with a U – shaped niche. The suggested antenna was arranged with a new graph and the dielectric layer was developed to have the highest number of matching frequencies and other properties.

The conditions to expand functionality, such as direction finding, radar, control and command, within a specified volume, place a more significant responsibility in the transmitting and receiving systems. Microstrip antennas, with the capacity to release more than one routine at distinct frequencies are essential in modern telecommunication systems.

Several advantages of the multiband antenna corresponded to the classic antenna in the exact class. It achieved multifunction for an equivalent antenna. Similarly, the dimensions and expense of the antenna can be underrated contrast to the separate task of the conventional antenna.

Microstrip Patch Antenna Design

In general, by examining the effect of different parameters on the UWB antenna performance, it has been eyed that dominant factor in the suggested antenna interpretations is the patch length (Lp) in terms to the guided wavelength λg:

$$\lambda g = \frac{\lambda_o}{\sqrt{\varepsilon_e}} \tag{1}$$

Where ε_e is the effective relative dielectric constant, and the magnitude of the ε_e trusts on ε_r, and the ratio of the feed line width to substrate altitude W_f / h ≥ 1, employing equation 2:

$$\varepsilon_e = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2} \left(\frac{1}{\sqrt{1 + \frac{12h}{W_f}}}\right) \tag{2}$$

Then, the resonant frequency (fr), relative to the radiating element length (Lp) is determined by:

$$f_r \cong \frac{c_o}{2(L_p)\sqrt{\varepsilon_e}} \tag{3}$$

Where c_o is the speed of light in free space.

Table (1), details the optimum extents of the suggested antenna. The body of the antenna is defined and established in existing works of the publications. Figure 1, displays the layout of the presented antenna. The substrate altitude, h is utilized to be 1.5 mm, and the thickness of the patch and the ground plane t is 0.07 mm. The offered antenna is created where the resonance frequency f_o is utilized to be (5.3 – 12) GHz, and the dielectric fabric picked is the FR4 with a dielectric coefficient of ε_r=4.3.

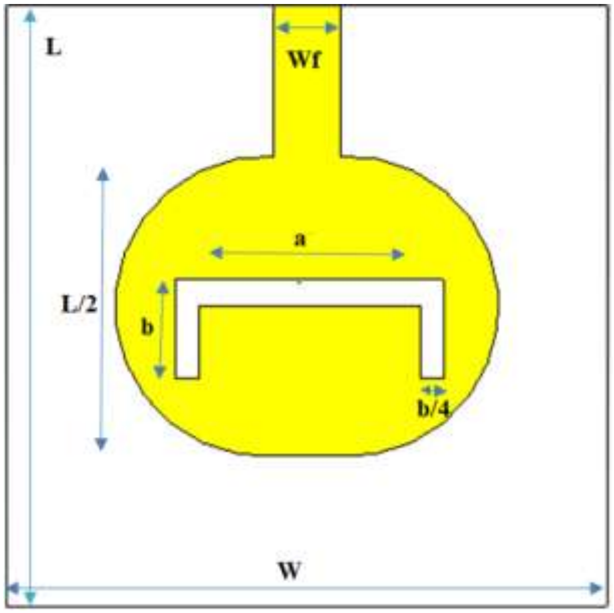

FIGURE 1. Antenna Diagram

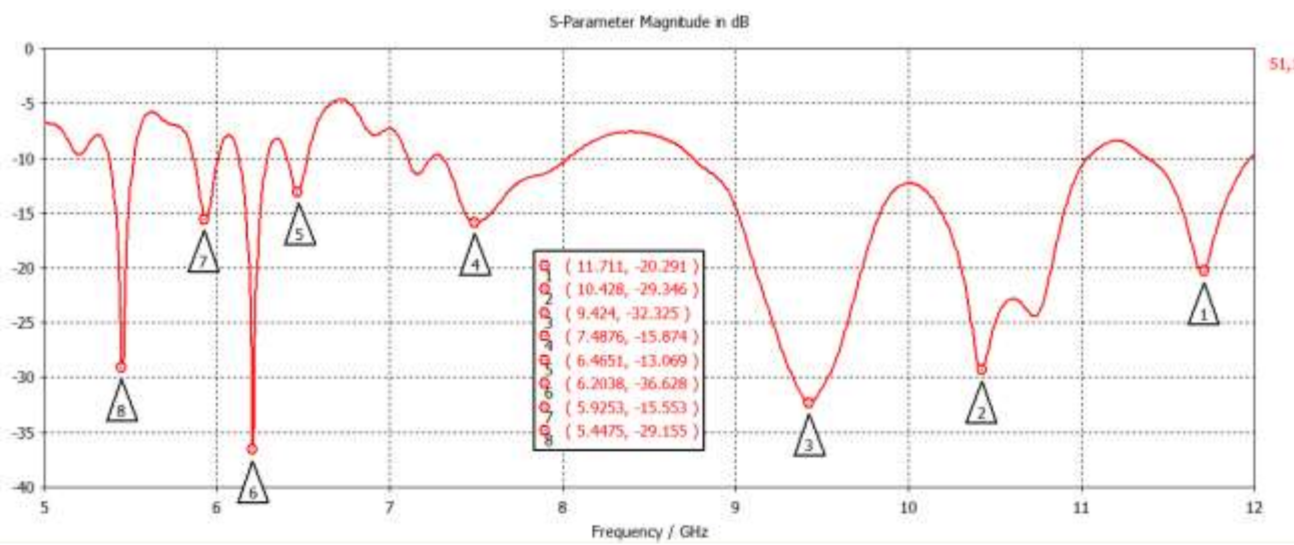

FIGURE 2. Bands of the Antenna

TABLE 1. Created Antenna Proportions

Term	L	W	Wf	a	b
Weight (mm)	50	50	11	18	8

System Outcomes

With the designing of different configurations. Multiband was achieved over eight bands that is band-I (5.374 – 5.517) GHz, band II (5.864 – 6.004) GHz, band III (6.126 – 6.289) GHz, band IV (6.522 – 6.404) GHz, band V (7.307 - 8.027) GHz band VI (8.755 - 10.00) GHz band VII (10.00 - 11.033) GHz & band VIII (11.383 - 12.00) GHz with corresponding return losses between (-13.07 to -36.6) dB. The table below shows the operative frequency and other parameters of the designed antenna as shown in Figures (3-9).

TABLE 2. The parameters of the offered antenna.

Frequency Bands (GHz)	Bandwidth (MHz)	Return Loss (dB)
12.00 – 11.383	617	-20.29
11.033 – 10.00	1033	-29.35
10.00 – 8.755	1245	-32.36
8.027 – 7.307	720	-15.87
6.522 – 6.404	118	-13.07
6.126 – 6.289	163	-36.63
5.864 – 6.004	140	-15.73
5.374 – 5.517	143	-29.17

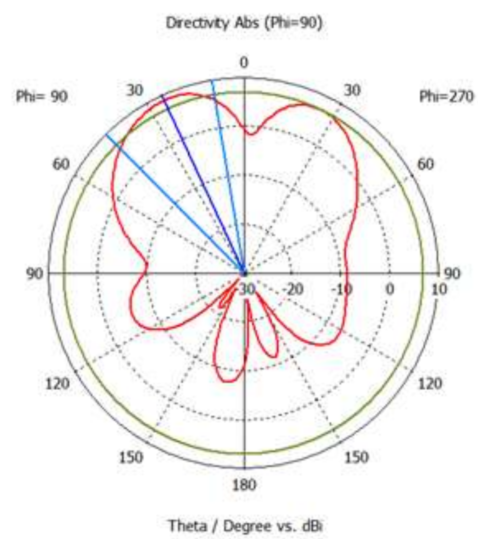

FIGURE 3. Lobe value is 8.8 dBi and the angular distance at 3 dB is 35.3° while lobe tendency equal to 25° with side lobe rank of -1.9 dB of radiation routine at a frequency of 5.45 GHz.

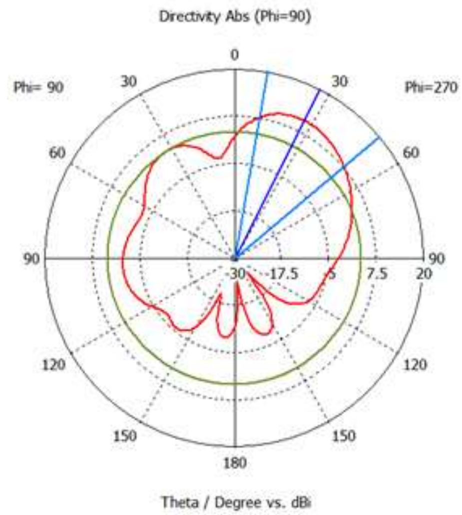

FIGURE 4. Lobe value is 10.7 dBi and the angular distance at 3 dB is 39.9° while lobe tendency equal to 27° with side lobe rank of -7.2 dB of radiation routine at a frequency of 5.93 GHz.

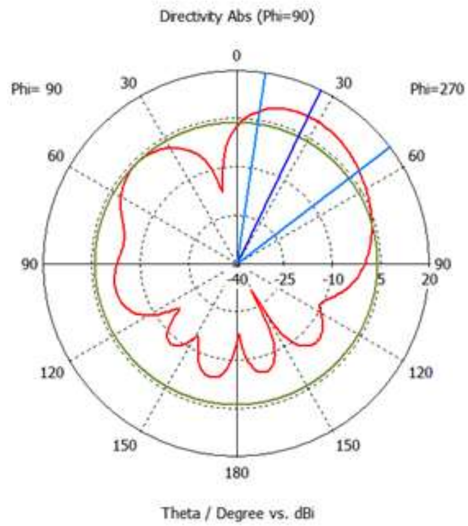

FIGURE 5. Lobe value is 10.8 dBi and the angular distance at 3 dB is 44.3° while lobe tendency equal to 26° with side lobe rank of -6.8 dB of radiation routine at a frequency of 6.2 GHz.

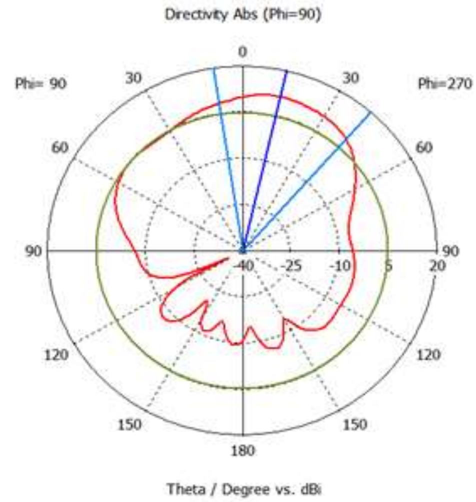

FIGURE 6. Lobe value is 11.2 dBi and the angular distance at 3 dB is 49.8° while lobe tendency equal to 13° with side lobe rank of -6.2 dB of radiation routine at a frequency of 7.5 GHz.

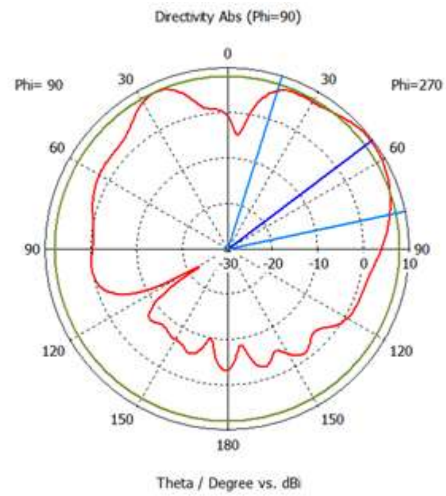

FIGURE 7. Lobe value is 9.5 dBi and the angular distance at 3 dB is 60.6° while lobe tendency equal to 53° with side lobe rank of -1.5 dB of radiation routine at a frequency of 9.42 GHz.

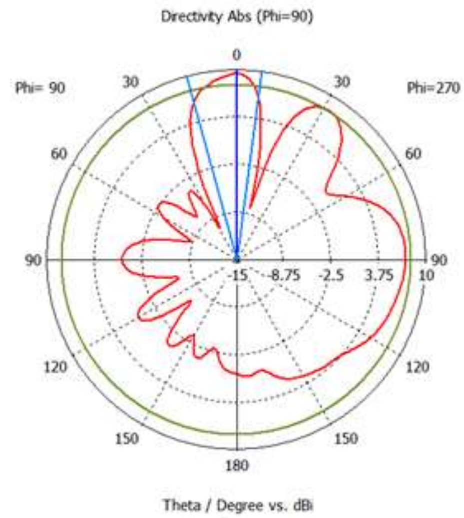

FIGURE 8. Lobe value is 9.4 dBi and the angular distance at 3 dB is 22.9° while lobe tendency equal to 0° with side lobe rank of -1.4 dB of radiation routine at a frequency of 10.42 GHz.

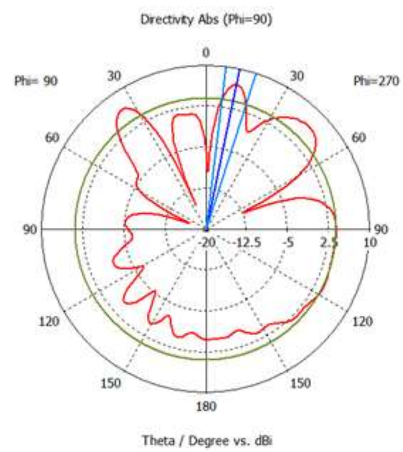

FIGURE 9. Lobe value is 6.9 dBi and the angular distance at 3 dB is 10.9° while lobe tendency equal to 12° with side lobe rank of -2.9 dB of radiation routine at a frequency of 11.7 GHz.

A comparison has been made between the proposed antenna and other proposed in different works were work at the same band as shown in Table (3). This comparison is made for number of bands and compact size of the proposed antenna.

TABLE 3. Comparison

Number of bands	Compact size (mm^3)	Reference
3	$(30 \times 30 \times 1.27) = 1143$	[8]
3	$(32 \times 72 \times 0.8) = 1843$	[12]
3	$(46 \times 50 \times 1.6) = 3680$	[15]
5	$(28 \times 28 \times 1.6) = 1254$	[7]
8	$(103.4 \times 96.56 \times 1.5) = 14976$	[9]
3	$(50 \times 60 \times 1.6) = 4000$	[24]
4	$(85 \times 70 \times 1.6) = 9520$	[25]
8	$(50 \times 50 \times 1.5) = 3750$	Proposed

As shown in the Table above, the proposed antenna gives the highest number of bands with medium compact size compared with other works.

CONCLUSION

The proposed antenna covers the range from 5.3 GHz up to 12 GHz which suitable for UWB communication applications avoiding the most of the standard frequency bands of IEEE 802.11 WLAN systems. A packed-size microstrip patch antenna was created and enforced to work with various frequency bands that can be utilized for different wireless applications. It is a competition to develop a customary microstrip antenna to wrap a single frequency band concurrently by employing a single antenna having adequate properties. It is possible to unravel this issue by using multiband antennas that extend to further frequency bands. Such an antenna provides more limited bandwidth. Trying another feeding technique may positively affects the offered microstrip patch antenna like a proximity or coplanar wave-guide (CPW) feeding techniques. The two frequencies bands in the range of 6 GHz can be used in different application such as Passive sensors (satellite), and Radio-determination applications. The band of 7.307 - 8.027 GHz can cover some applications, such as Weather satellites, MSS Earth stations and Earth exploration-satellite. Furthermore, the frequency band around 9 GHz can utilize for Aeronautical Navigation Civil and military, Radiolocation (civil), Radiolocation (military) and Weather radar.

The presented work can be predominantly accustomed in small wireless sensor networks. It is preferable to underrate the dimensions of the created antenna and hold an extensive number of working frequency bands, on the other hand, the proposed multiband antenna design can be more efficient by applying the reconfiguring technique on the patch structure to managing the frequency bands, radiation pattern or even the polarization of the antenna.

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