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Modified Design of Microstrip Patch Antenna for UWB Applications

Bashar Bahaa Qas Elias[1], Haider Aljanabi[2]

Abstract: Ultra-wideband (UWB) patch antenna for Ku/K band applications is presented. In this paper, a microstrip line feed has been modified to an elliptical gradient structure, and the conventional radiator patch has been developed through the use of the symmetrically circular slots. These modifications have been used to improve the performance of the antenna significantly. Upper and lower frequency ranges achieve UWB antenna performances start from 11.57 GHz to 21.45 GHz. Proposed antenna exhibits good impedance matching, which makes it convenient to work in various applications. Besides that, the reflection coefficient is reduced attained to –31.81 dB over the operating band. The antenna is developed and analyzed using the commercially available software FEKO simulator based on the method of moments (MoM). Other parameters results such as sidelobe level (SLL) and beamwidth (half power – 3 dB) are added and discussed significantly. The proposed design is fabricated and tested experimentally, and the results show that a satisfying agreement with the simulation results.

Keywords: Modified antenna, Ultra-wideband (UWB), Reflection coefficient, Slots, Feed line, FEKO.

1 Introduction

The development of ultra-wideband antennas with high impedance matching, compact size, stable radiation patterns, and low manufacturing costs has attracted lots of attention in recent years [1]. Microstrip patch antennas have been widespread, depending on their low profile, lightweight, ease of fabrication, and compatibility with integrated circuits [2−4]. As in the rest of the antennas, they are also given some hindrances, ranging from narrow bandwidth to low gain. Therefore, this paper is mainly concentrated on the bandwidth enhancement procedure. Numerous techniques have been clarified in the past to obtain UWB, performance such as the use of a thick substrate, stacked patches, use of active and passive devices, shorting pins, using an impedance matching network, and different feeding arrangement [5]. Recently,

[1,2]Al Nisour University College, Department of Computer Engineering Techniques, Iraq;
E-mails: bashar.bahaa.eng@nuc.edu.iq; haider.th.eng@nuc.edu.iq

various methods reported in improving the functioning of the impedance bandwidth of the microstrip antenna. This work contains the effect by inserting slots on the radiating structure [6 − 10] and feed reconfiguration. Wireless technology is part of the significant areas of research in the world of communication systems today, and a study of communication systems is incomplete without an understanding of the operation of antennas. These requirements force antenna designers to investigate low profile antennas with an appropriate bandwidth for each band [11 − 14]. Microstrip patch antenna comprises of a radiating patch on one side and ground plane on the other side and a substrate layer as a sandwich between them. To achieve the UWB performance of the microstrip antenna, many researchers and scientists have been publishing more articles in this field.

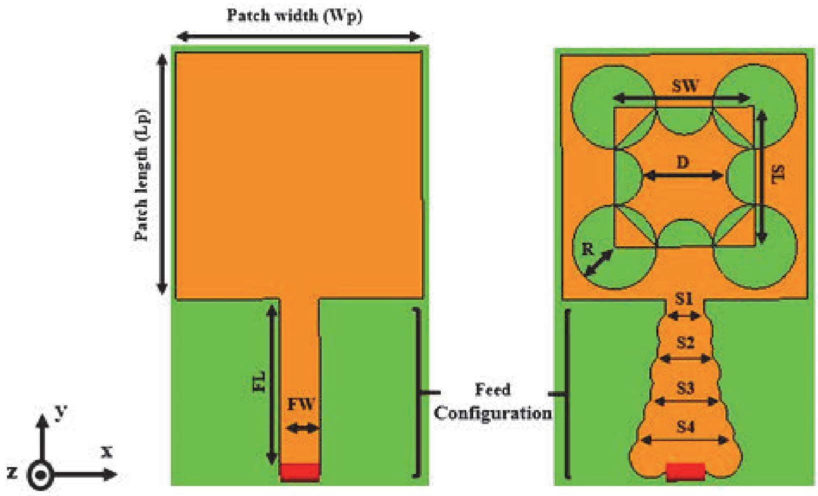
In 2016, Sayed Ali and Deepak Jhanwar designed a compact triple band-notch direct-fed Flower-shaped Hexagonal Microstrip Patch Antenna for embedding in UWB (Ultra-WideBand) systems [15]. Karmugil and Anusudha proposed an efficient design of a circular shaped microstrip patch antenna for Ultra-Wideband (UWB) applications with partial ground structure [16]. Mewara, Kumawat, and Sharma presented an ultra-wideband antenna consisting of an extra radiating patch with bandwidth enhancement and band notch characteristic [17].

In 2017, Aishvaryaa et al. designed two ultra-wideband frequency reconfigurable microstrip patch antennas for cognitive radio applications, consist of a rectangular patch with microstrip feed - line, and a partial ground plane [18]. Angana et al. proposed a compact microstrip fed band-notched UWB patch antenna with band rejection features to eliminate interference as a result of existing neighboring communication systems within the ultra-wideband (UWB) frequency band [19]. Feng and Jin presented a broadband cavity-backed microstrip phased array antenna. The array antenna uses novel single layer cavity-backed microstrip patch elements supporting broad operating frequency band [20]. Antenna designs are simulated and analyzed by FEKO simulator software based on the method of moments (MOM).

2 Antenna Design

The proposed antenna has been designed using the dry wood sheet as a substrate. It has a dielectric constant of 1.4 and a thickness of 7mm. The modified design is implemented in two successive steps. In the first step, the microstrip line employed to feed the antenna has changed to elliptical gradient structures instead of the traditional rectangular line feed. Feed width is gradually decreased in four levels (S4, S3, S2, and S1 respectively) starting from the port of excitation to the edge of the patch.

Next, four symmetrical circular slots with a radius of (R) have been drilled into the radiator patch plane with a small triangular patch in each slot. Besides, four semi-circular shapes are placed between them and also subtracted from the patch (see Fig. 1). All the dimensions detailed are illustrated (**Table 1**).



(a) (b)

Fig. 1 – *Proposed microstrip antenna in x- y plane:*
(a) *conventional antenna;* (b) *modified antenna.*

Table 1
Antenna design parameters.

Parameter	Value
Patch length (*Lp*)	35 mm
Patch width (*Wp*)	35 mm
Substrate thickness	7 mm
Dielectric constant	1.4
Feed length (*FL*)	25 mm
Feed width (*FW*)	5.61 mm
R	6 mm
D	12 mm
SW	20 mm
SL	20 mm
S1	5.61 mm
S2	7.84 mm
S3	9.84 mm
S4	13.84 mm

3 Simulated Results

The design of the traditional microstrip antenna has been enhanced to reduce the size of the antenna and increase bandwidth. FEKO software based on MoM is used as a simulation tool to analyze the antenna. The results are obtained; the reflection coefficient of the proposed antenna decreased from –11.6 to –31.81 dB at the resonant frequency. Besides that, the relative bandwidth is enhanced to 9880 MHz with the upper and lower frequencies of 21.45 and 11.57 GHz, respectively as compared with its value in the conventional antenna (Fig. 2). The reflection coefficient and bandwidth results are tabulated (**Table 2**).

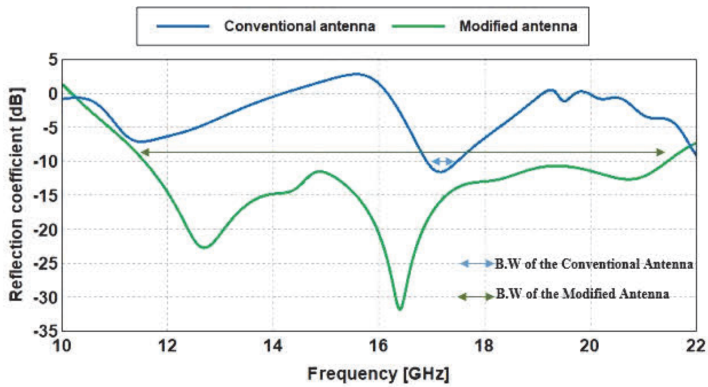


Fig. 2 – *Reflection coefficient results of conventional and modified antennas.*

Table 2

Reflection coefficient and bandwidth results.

Antenna	Resonant frequency (GHz)	Reflection coefficient (dB)	Upper frequency (GHz)	Lower frequency (GHz)	BW (MHz)
Conventional	17.16	–11.6	17.47	16.92	550
Modified	16.4	–31.81	21.45	11.57	9880

The proposed antenna is used for Ka and K band applications such as satellite communication and radar applications. Total gain characteristics in 3D plots are represented (Fig. 3). It observed that the gain is reduced to half (10 dB) in the proposed antenna (Fig. 3b). On the other hand, this value increases to 15 dB in the upper and lower frequencies of the modified antenna (Figs. 3e and 3f). Besides, the gain is prescribed in polar plots (Fig. 4). It's noted that no back radiation in the proposed antenna, that's will be increasing the radiation efficiency of the antenna. In spite of reduced the gain in a proposed antenna, its value is still acceptable and suitable for use in various applications operates under the given band in this paper.

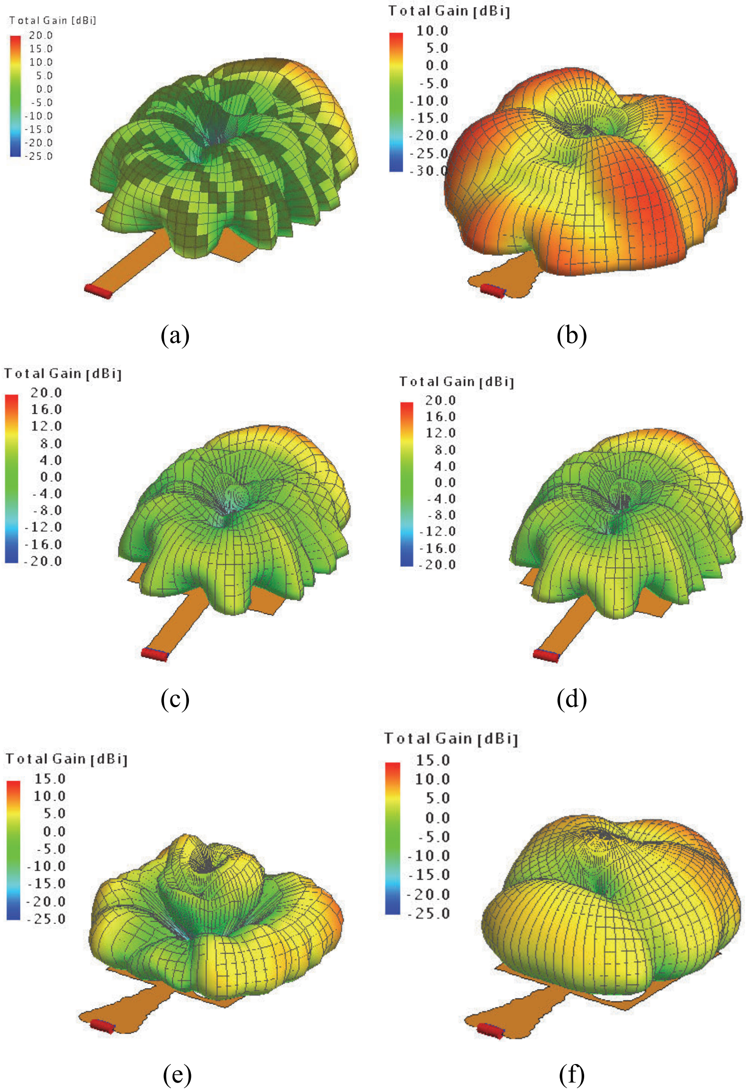
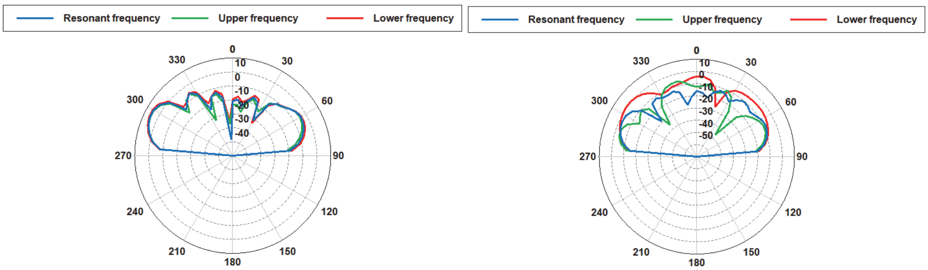


Fig. 3 – *3D total gain plots of microstrip antenna in x-y plane for* (a) *conventional antenna at resonant frequency* (b) *modified antenna at resonant frequency* (c) *conventional antenna at upper frequency* (d) *conventional antenna at lower frequency* (e) *modified antenna at upper frequency* (f) *modified antenna at lower frequency.*

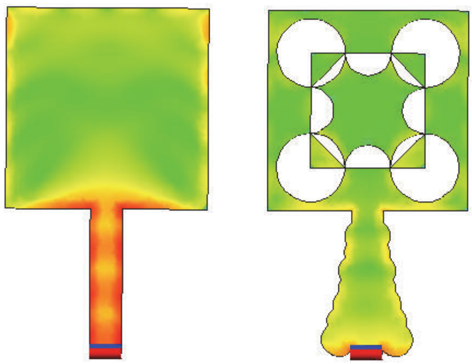
The current distribution result at the resonant frequencies for the conventional and modified antennas is presented (Fig. 5). For the conventional antenna, it observed that the current distribution has a high magnitude along the feed line (Fig. 5a). Applied the proposed modifications cause a change in patch geometry and influence the current distribution in a radiator patch (Fig. 5b).

Changing the current flow in the patch has been an influence on the value of the resonant frequency. On the other hand, Impedance matching plays an essential role in the antenna performance. The simulated results show that the impedance matching characteristics of the modified antenna (Fig. 6). It achieved good impedance performance close to 50 Ω as comparing with the conventional antenna (**Table 3**).



(a) (b)

Fig. 4 – *Polar gain results of microstrip planar antenna at:* (a) *conventional antenna;* (b) *modified antenna.*



(a) (b)

Fig. 5 – *Current distribution results produced:* (a) *conventional antenna at* 17.16 GHz; (b) *modified antenna at* 16.4 GHz.

Table 3
Impedance matching results.

Antenna	Resonant frequency (GHz)	Impedance matching (Ω)
Conventional	17.16	38.8
Modified	16.4	51.8

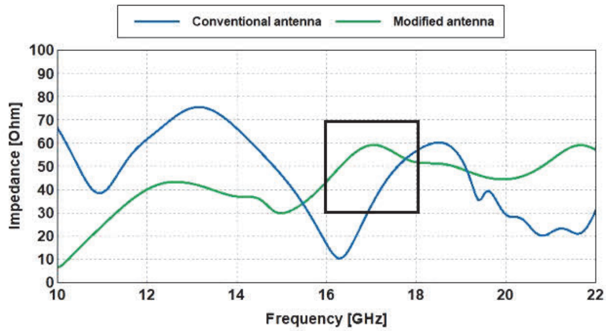


Fig. 6 – *Impedance matching results for the conventional and modified antennas.*

The sidelobe level is another parameter that is studied in this paper, which is usually represented as the unwanted radiation in undesired directions. It observed that SLL had been reduced to 5.72 dB at the resonant frequency of the modified antenna. Besides, the radiation patterns of the proposed antennas are also characterized by their beamwidths. Beamwidth is slightly decreased to 20.15 deg as compared with its result of the conventional antenna. Results of SLL and beamwidth for both antennas are presented in polar form (Fig. 7).

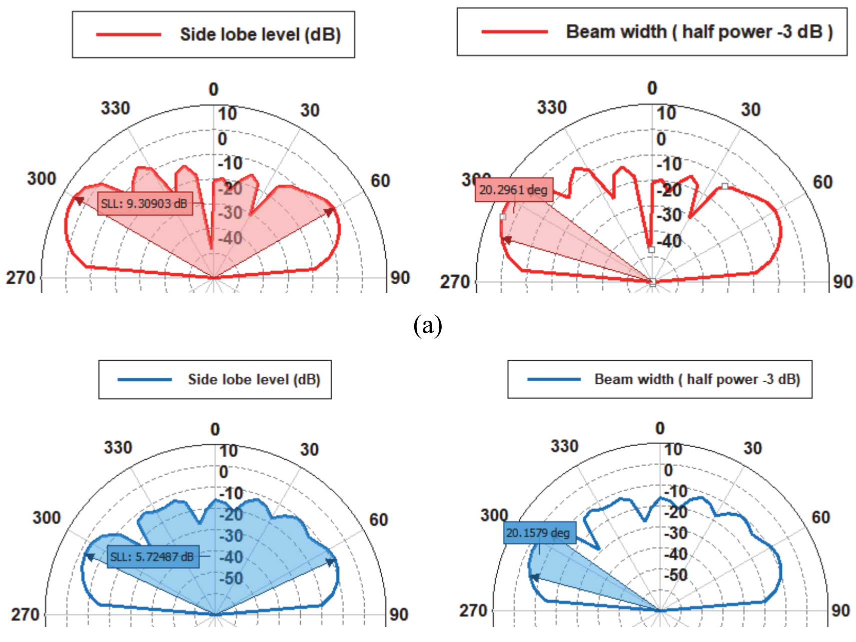


Fig. 7 – *SLL and beamwidth at a resonant frequency of:*
(a) *conventional antenna* (b) *modified antenna.*

4 Experimental Results

The performance behaviour of the proposed antenna after modified has been verified through fabricated it and tested experimentally. The fabricated antenna has an impedance bandwidth of 10.02 GHz with an operating frequency range from 11.58 GHz to 21.6 GHz. The tested antenna is resonating at 16.56 GHz with a minimum reflection coefficient of –52.4 dB (Fig. 7). Results show that a satisfactory agreement with the simulation results.

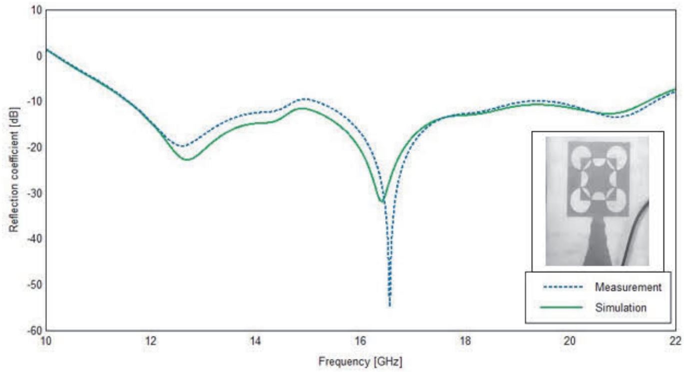


Fig. 7 – *Top view of the fabricated antenna with a comparison of return losses between the measurement and simulation results.*

6 Conclusion

A modified microstrip antenna for Ku/K band applications is presented and discussed theoretically and experimentally. Modifications have included the structure of the feed line and radiator patch. The bandwidth of the modified antenna has been improved to 9880 MHz, and the reflection coefficient has been minimized attained to –31.81 dB at the resonant frequency of a modified antenna. Other parameters have been studied, such as gain, impedance matching, sidelobe level, and beamwidth. The proposed antennas have been simulated and analyzed using commercial software (FEKO) based on the method of moment solver (MoM).

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