Design and Improvement Measure of a New Dual Band Multipolarization Antenna Using a Single Layer Substrate for C Band Applications

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***Abstract*—A novel dual-band multipolarization slotted patch antenna with a single-layer substrate and one feeding port for C-band applications is presented. The measured results show that impedance bandwidth in which return loss is less than −10dB is from 5.7 GHz to 6.1 GHz and from 7.5 GHz to 7.8 GHz. The Axial Ratio (AR) of the antenna is < 3dB and allows the both right-handed (RH) and left-handed (LH) circular polarized (CP) from 7.6 GHz to 7.8 GHz and from 7.5 GHz to 7.6 GHz for linear-polarization. The radiation pattern is quasi-directional on the greater part of the working band. The software CST Microwave studio is used for simulation which results are in great agreement with the measured parameters. The proposed antenna can be used in occasions where the antennas need to have dual band and multi-polarization for its advantages of compact structure and low cost.**

***Index Terms*—Dual band antenna, multi-polarization antenna, axial ratio, circular polarization, slotted patch.**

I. Introduction

The fast and consecutive technological advancement of recent communication keeps demanding simple profile and more low cost, simple structure, and portable wireless devices. So, antennas in present day purposes need to be multifunctional and multi-polarized to adapt to gadget necessities. Multi-polarization antennas have been utilized to meet modern wireless system requirements as a cost-effective solution [1]. The multi-polarization capabilities help a wireless communication networks to fight against channel interference, increase the system capacity, or fulfill different tasks with a single-antenna deployment [2]. Patch antenna, as a planar and low cost candidate, has been very popular for designing the multi-polarization antenna [3]. In order to avoid a multi-polarization antenna, many technical and several methods have been reported founded on the patch antenna.

Some researchers have done experiments on the design of multi-polarization antenna up to some extent. Liu *et al.* designed and implemented a multi-polarization antenna with two independent ports working with linear and circular polarizations which are realized by a circular patch and a monopole antenna loaded with a disc, adding three copper poles between the patch and the disc to adjust the matching of the monopole antenna [4]. Shen Liu *et al.* proposed a multi-polarization patch antenna with a single-layer substrate [5]. Mousavi reported a multiband multi-polarization integrated monopole slots antenna [6]. The antenna proposed in [7] consists of two layers, one for the patch and another layer for the reflectors. References [1], [8] and [9] illustrated a compact reconfigurable microstrip antenna switching pin diodes inserted with antenna. Effect of the metamaterial structure on the antenna for a multi-polarization performance was presented in [10]. Moreover, in some research publications, multi-polarization performances have been explored in order to design antenna by adding a metallic reflector to generate a broadside radiation in [11] and [12]. However, in those cited publications the objective was to design a multi-polarization antenna but the majority of the reported antennas are generally designed with complicated structure, large sizes, multilayer, and feeding with a complicated network. For example, some other techniques are employed, such as using a complicated feeding network in [13] or a large size antenna array in [14].

The main point in this article is to design a new multi-polarization slotted antenna model for C-band technologies that have a simple new structure with low geometric complexity, single layer, one feeding port, and low cost.

Details of the conception are illustrated and discussed in this paper. Simulation is achieved using the Finite Integration Technique (FIT) based computer simulation technology microwave studio (CST MWS) [2]; and further experimental validations with the measure of the antenna are proposed [6]. For the latter, in this paper, we will show a performance comparison between the proposed and referenced antennas which gives us good results.

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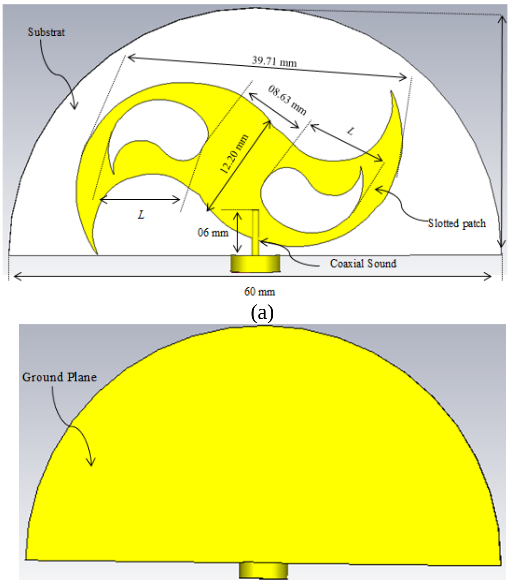
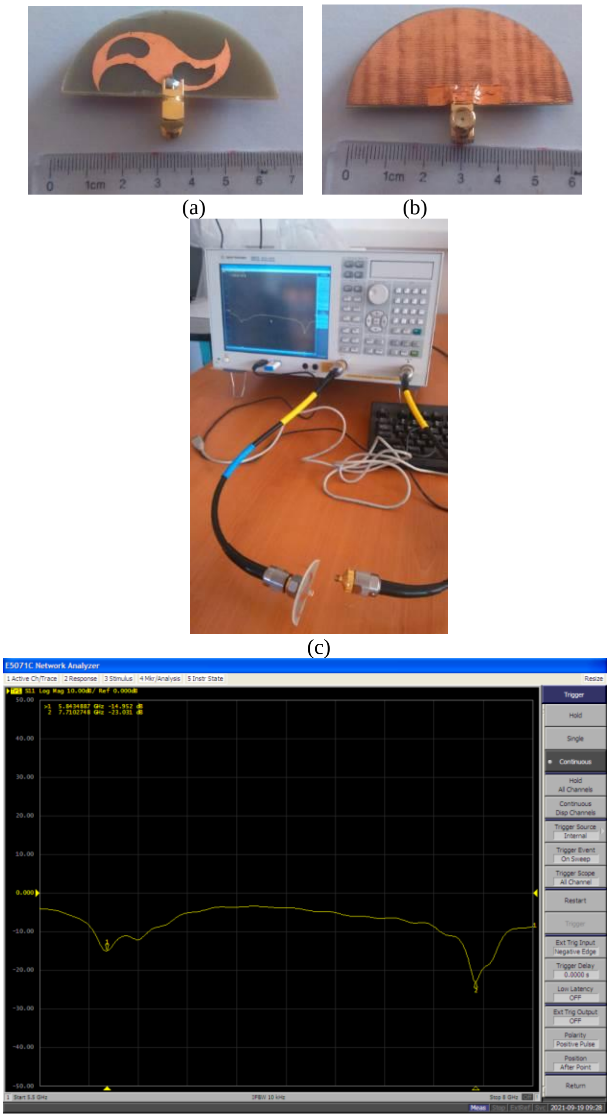


(a) (b)

Fig. 1. The schematic diagram of the proposed antenna: (a) front, (b) bottom.



(a) (b) (c) (d)

Fig. 2. Proposed antenna: (a) and (b) photograph; (c) and (d) under measure.

II. ANTENNA CONFIGURATION

Fig. 1 (a) and (b) show the geometry of the proposed slotted antenna [15]. The antenna consists of a new radiating patch mounted with two slots placed on a substrate plane, the substrate size is 60mm×30 mm, and the slotted patch is adjusted in the middle of the substrate as appeared in Fig. 1. A 50 Ω coaxial cable excites the antenna.

III. EXPERIMENTAL RESULTS AND DISCUSSIONS

To validate, the prototype antenna is fabricated and measured [16]. Photographs of the antenna are shown in Fig. 2 (a) front view and Fig. 2 (b) bottom view [17], Fig. 2 (c) and Fig. 2 (d) the proposed slotted antenna under measure. The manufactured patch antenna is assembled in FR substrate that ε_r=4.4. Agilent E5071C vector network analyzer range that from 300 kHz to 20 GHz used to measure the reflection coefficient.

The proposed slotted antenna was simulated using a software package CST Microwave and validated with practical production on FR4 substrate. The simulated and measured S11 characteristics of the antenna are depicted in Fig. 3. The S11 result of the fabricated antenna operates from 5.7 GHz to 6.1 GHz and from 7.5 GHz to 7.8 GHz that appeared in C band technology. The major advantage of this latter structure antenna is resumed in its small size, lost cost, single layer and one 50Ω feeding cable excites the antenna.

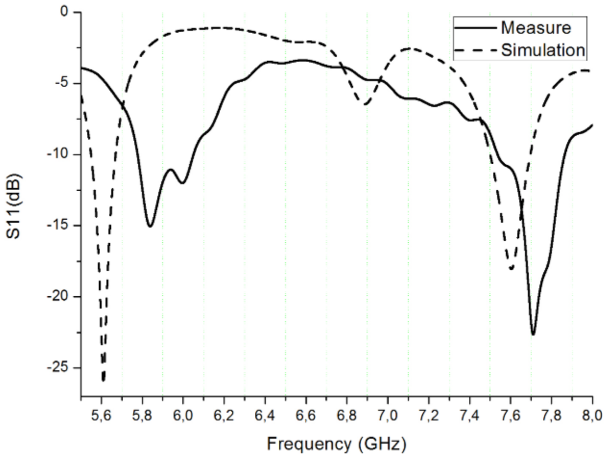


Fig. 3. Simulated and measured reflection coefficient of the proposed slotted antenna.

Fig. 4 (a) shows the simulated characteristics S11 of the slotted antenna with different permittivity of the substrate. The results S11 obtained reveal a good result at 5.8 GHz and 7.7 GHz with a permittivity equal to 4.2 and 4.3 respectively. On the other hand, Fig. 4 (b) shows the variation effect of the length (L) of the slots of the antenna on the reflection coefficient results. The simulated S11 result obtained with L=11.4mm in Fig. 4 (b) indicates good conformity with the measurement result. Thus, the mismatch in Fig. 3 between the simulation and measurement curves related to the imprecision of the permittivity of the substrate used, and more especially due to an error during the manufacturing and processing of the slots of the antenna.

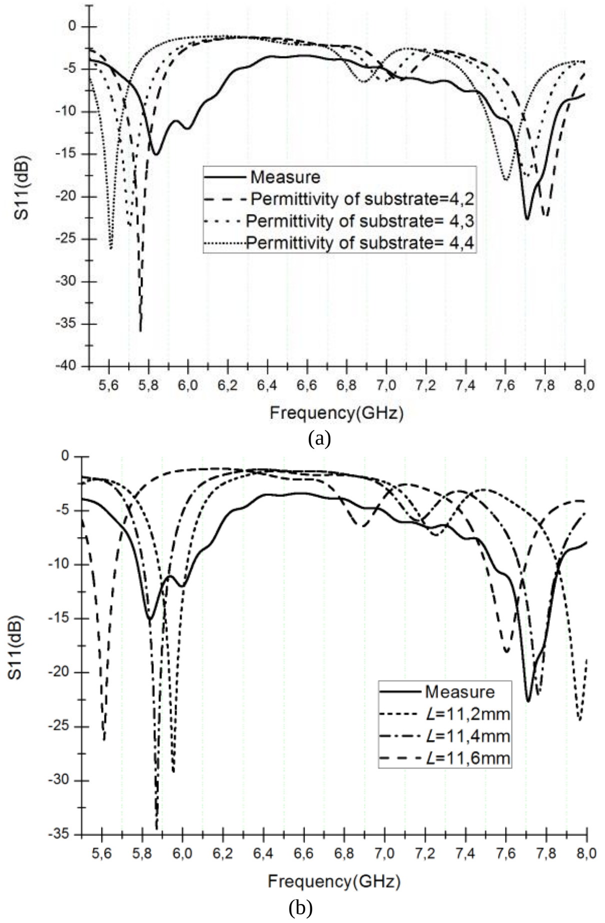


Fig. 4. Simulated and measured S11 results of the proposed antenna; (a) the variation of the permittivity of the substrate and (b) the variation of the length (L) of the slots of the antenna vs. Frequency.

Fig. 5 shows the simulated results of the proposed slotted antenna. Fig. 5 (a) shows the variation gain in dBi vs frequency from 5.5 GHz to 8GHz, the maximum gain is 6.2 dBi at 5.7 GHz and 5.8 dBi at 7.6 GHz [10]. In Fig. 5 (b) the axial ratio is less than 3dB in C-band ranging from 7.6 GHz and Fig. 5 (c) depicts the variation of axial ratio (dB) and gain (dBi) against frequency. The proposed antenna, suggesting good Circular Polarization (CP) characteristics (less than 3dB in AR) from 7.6GHz [12], [13], where the gain total is 5.8 dBi was achieved at 7.6 GHz.

Fig. 6 (a) and Fig. 6 (b) show the simulated far-field 3D and both polar radiation patterns E-plane (RHCP, LHCP) and H-plane (RHCP, LHCP) of the new slotted antenna at 7.7 GHz. The main beam in E-Plan (LHCP) deviates from the z-axis by 45° for 3.29 dBi of gain with a 3-dB beamwidth of 56.5°. And the main beam in E-Plan (RHCP) deviates from the z-axis by 300° for 1.27 dBi of gain with a 3-dB beamwidth of 47.6°. For H-Plan, the main beam in (LHCP) deviates from the z-axis by 230° for 1.74 dBi of gain with a 3-dB beamwidth of 32.6°. And, the main beam in H-Plan (RHCP) deviates from the z-axis by 120° for 2.77 dBi of gain with a 3-dB beamwidth of 36°. In the present patterns, the LHCP in E-plan dominates. Full wave simulation was carried out using CST software. These results in Fig. 6 (a), and Fig. 6 (b) are simulated at 7.7 GHz giving a maximum gain of 5.68 dBi.

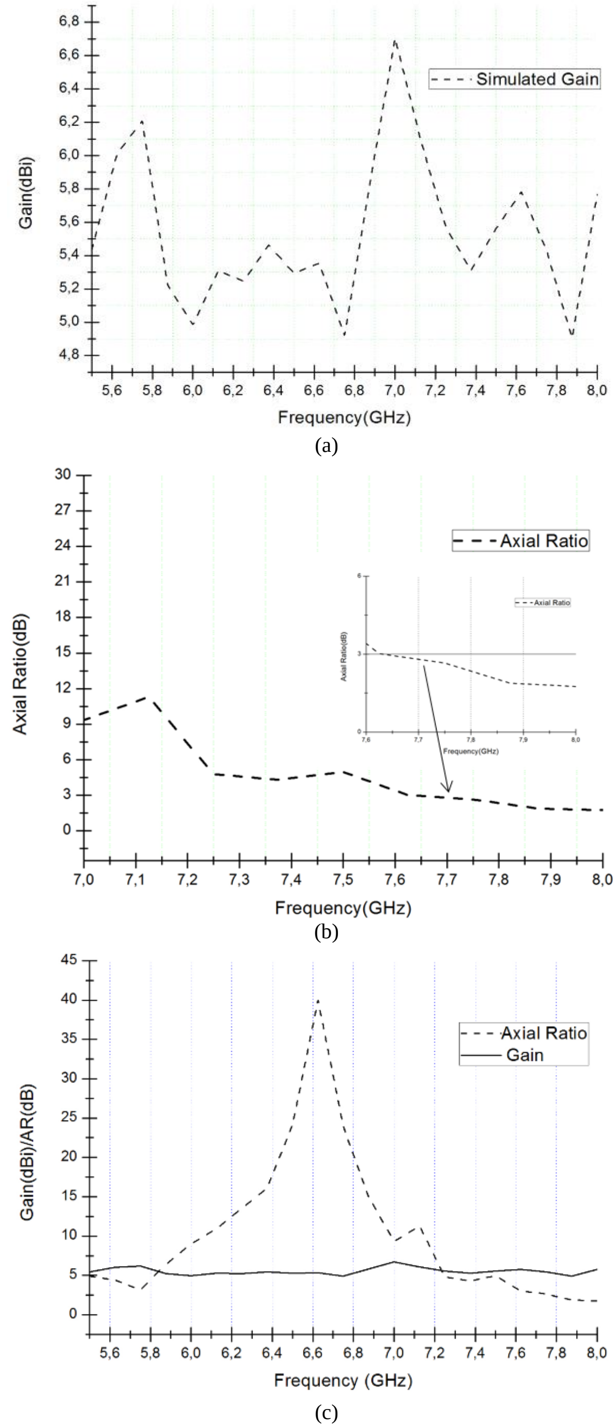


Fig. 5. Simulated results of the proposed antenna; (a) gain; (b) axial ratio (AR); (c) comparison between gain and AR vs. Frequency.

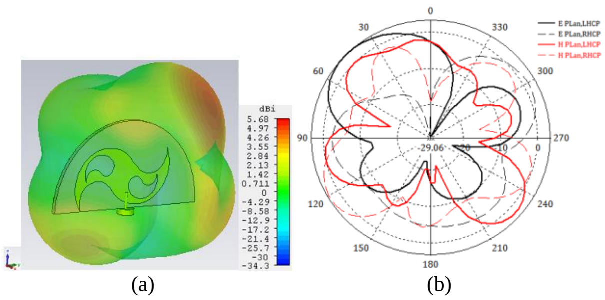


Fig. 6. Simulated radiation patterns at 7.7 GHz of the proposed antenna, (a) 3D, (b) E-plane (LHCP and RHCP) and H-plane (LHCP and RHCP).

TABLE I: PERFORMANCE COMPARISONS BETWEEN THE PROPOSED AND SOME PREVIOUSLY REPORTED MULTIPOLARIZED ANTENNAS

Ref.	Resonance frequency (GHz)	Antenna size (mm^2)	Max Gain	Complexity	Polarization
[1]	from 3.1 to 3.45	43×43	5 dBi	Consists of four pin diodes	Multi
[2]	From 2.1 to 2.9	120×120	9 dBi	Consists of four pin diodes	Multi
[4]	from 1.21 to 1.85 and from 1.45 to 1.8	80×80	Port1=6dB Port2 = 1.75 dB	Consists of three layers/ feeding network	Multi
[5]	From 350 MHz to 525 MHz (P band), and from 1.9 GHz to 2.4 GHz (S band)	300×280	P band =4.5dBi S band =7.5 dBi	Thickness of one layer =66mm /two feeding ports	Multi
[6]	At 1.575 and 1.62 (GPS/Iridium bands) at 1.8 (band GSM)	70×70	2.5 dBi	Two feeding ports	Multi
[8]	At 2.4	The circumference of the circular patch= 207 mm	From 2.64 to 3.52 dBi	Consists of 12 pin diodes/ two layers/feeding network	Multi
[9]	From 2.325 to 2.775	Antenna radius=40mm	6.1 dBi	Consists of 04 pin diodes/feeding network/tree layers	Multi
[16]	From 5.46 to 6.76 GHz From 8.18 to 10.48	Antenna=26×26 Reflector=60×60	8.7 dBi	Consists of pin diodes, capacitor and inductor/ two layers/	Dual
[18]	From 13.09 to 14.05	36×36	8.49 dBi	Based on reflective metasurface/ two layers	Dual circular polar
This work	From 5.8 GHz to 6.1 GHz and from 7.4 GHz to 7.8 GHz	60×30	6.2 dBi at 5.7 GHz and 5.8 dBi at 7.6 GHz	One feeding port/single layer/low cost	Multi

In order to evaluate the usefulness and advantages of this work, the performance of the measured prototype is outlined in Table I to compare with the reported antennas. These common approaches based on multipolarization antennas. The comparison focuses on the resonance frequency, antenna size, maximum of gain, and manufactured complexity. In [1], [2], [9], and [16], the antennas mentioned have only one layer but consists of more than four pin diodes (12 pin diodes for [9]) and large size such as [2]. It can be seen in [5]-[6] that although the antennas have two bands, there are still two feedings ports. References [4] and [8] the selected antennas are feeding with a complex network.

On the other hand, [18] shows a good gain in the Ku band but the manufacturing process of the antenna with two layers relies on a metasurface reflector composed of 32 unit cells. The size of each unit cell is (6mm x 6mm x 2mm) with a metal floor on each cell which complicates any integration of this antenna model in small circuits. However, compared with this work, the scheme of the proposed slotted antenna is with less complexity, cited, for example, one feeding port, single substrate layer, and small size. The comparisons show too, that the proposed new antenna model has achieved improved performance in dual bands and good gain value.

IV. CONCLUSION

A layout using novel conception, the design and measurement results for a new structure, low cost, single layer multipolarization slotted antenna for C-band applications were discussed in this paper. The antenna is based on a one-feed concept that provides to control the dual band frequency from 5.7 GHz to 6.1 GHz and from 7.5 GHz to 7.8 GHz, and supports multiple polarizations and patterns. The antenna is proved to cover highly LHCP in E-plan at 7.7GHz. The proposed slotted antenna is feasible to operate in the desired C-band applications.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Both authors conducted the research and antenna design. Abdellatif Berkat is responsible for the simulation and measure of the antenna. Abdellatif Berkat and Mohamed Latrach wrote the paper. All authors had approved the final version.

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