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A Triple-Band Dipole Antenna with Harmonic Suppression Capability

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Abstract: This paper presents a triple-band microstrip dipole antenna with undesirable harmonic suppression capability that has a prospective to be applied in the LTE/WLAN and energy harvesting systems. The proposed antenna has three parasitic elements and a stub to suppress the harmonic of higher order modes. Initially, the antenna resonates at 0.9 GHz, 2.7 GHz and 5.4 GHz. Hence, the parasitic elements are added into each of the dipole's arm to tune the second and third frequency band to 2.4 GHz and 5.8 GHz. However, the presence of these three parasitic elements has generated an unwanted harmonic at 4 GHz. Therefore, a stub has been connected to the terminal of the antenna to eliminate that frequency. The final design is now consists of a triple frequency bands (0.8 GHz, 2.4 GHz and 5.8 GHz) which are free from the undesirable harmonics. The corresponding measured reflection coefficients on those frequencies are -32.42 dB, -18.28 dB and -27.10 dB. The antenna is fabricated on a FR-4 printed circuit board with a relative permittivity, εr of 4.3, loss tangent, tan δ of 0.0190 and thickness, h of 1.6 mm. The overall size of the substrate of the antenna is 72 × 152 mm2. The simulated and the measured results are in a good agreement, which validates the suggested antenna design.

Keywords: Triple band; dipole antenna; harmonic suppression, parasitic element; stub-filter.

1. Introduction

Triple-band antennas have the potential to be applied in the LTE/WLAN and energy harvesting systems such as in handheld unit terminal with multimode features [1-2]. The antennas have the capability to operate at three resonant frequencies, simultaneously. The design includes integrating the antenna's arm by using parasitic elements, branch arm and loading a metamaterial on the radiating elements [1-12]. The integration of balun into the dipole antenna has made it possible to operate in a triple-band frequency. The dipole antenna uses three stubs as the parasitic elements to enable it to operate at 2.45 GHz, 3.5 GHz and 5.5 GHz. The size of the antenna pro-posed in [1] is compact but the structure is too complex. Two parasitic elements have been used in the dipole antenna in order for the antenna to operate at 2 GHz, 5.5 GHz and 9.6 GHz [3]. The dipole antenna with a size reduction has two parasitic elements that operate at 1.79 GHz, 2.03 GHz and 2.41 GHz. It has a simpler structure as reported in [4].

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References in [5-7] produce among the latest approach to implement triple-band antennas which is by using metamaterial structure. In [5], 1.1/1.8/2.4 GHz dipole is designed by using a compo-site right/left-handed (CRLH) loading on the dipole arm. The antenna performs well on the gain and efficiency too. A bow-tie antenna which uses two pairs of complementary capacitive loaded loop (CCLL) slots has allowed the antenna to work at 2.5 GHz, 3.5 GHz and 5.5 GHz [6]. The antenna size is small with a simple structure and has a good radiation pattern. In [7], two metamaterials are loaded on the monopole antenna and it operates at 2.45 GHz, 3.65 GHz and 5.4 GHz. The configuration shows an innovative structure. The folded high gain 3-D dipole antenna with branch arms operates at 0.8 GHz, 1.7 GHz and 2.3 GHz has been reported in [8]. A similar structure is reported in [9], which employed three branch arms so that it can operate at 2.4 GHz 3.5 GHz and 5.8 GHz. The antenna dimension is compact. In [10], the small and practical dipole with branch arms operates at 0.7 GHz, 2.3 GHz and 2.5 GHz. Other studies on triple-band antennas have also been reported in [11-12]. Other new designs of triple-band antenna are reported in [13-18].

This paper presents the design of a triple-band dipole antenna with harmonic suppression capability that operates at 0.8 GHz, 2.4 GHz and 5.8 GHz. The second and third bands are controlled by the parasitic elements while the undesired harmonic is removed by using a stub that is similar to the work reported in [19]. Previously, a harmonic suppression dual-band dipole antenna has been reported in [20] while the work on a single-band dipole antenna can be read in [21]. The proposed design and the discussion on the results obtained are presented in Section II to III. Finally, section IV concludes the work.

2. Harmonic Suppression Triple Band Dipole Antenna

2.1 Design Methodology

Description of overall methodology is shown in Figure 1.

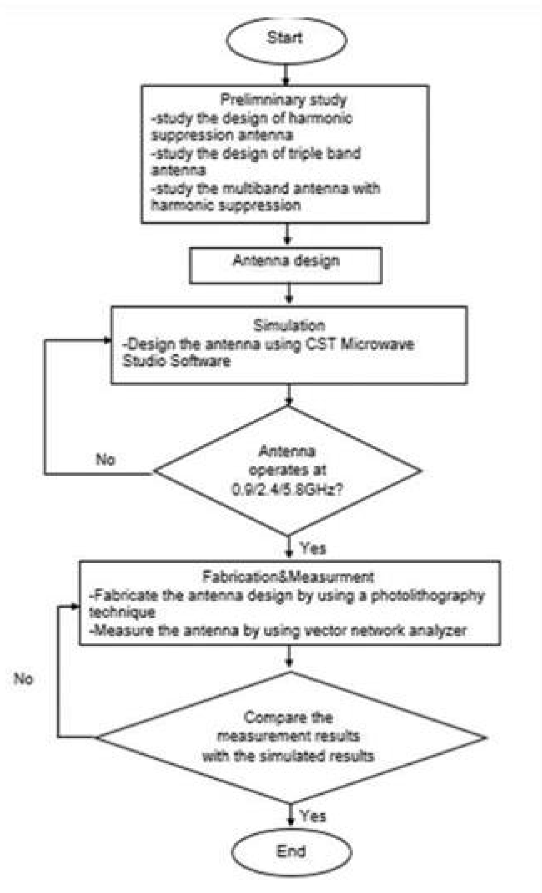


Fig. 1 - Flow chart of the works

3. Simulation and measurement set up

First and foremost, formulation of the proposed antenna which is typical double-sided dipole antenna integrated tapered balun is done. The dimensions obtained from the calculations can be used proper guideline in order to design dipole antenna with parasitic elements and a stub at the target resonance frequency. By doing this, the physical dimensions adjustment of the antenna can be correlated. All the designs and simulations for the antenna design in this study are done using Computer Simulation Technology (CST) Microwave Studio Software. In CST, there are two basic solvers that can be used to simulate the design, which are the frequency domain solver and the transient solver. The transient Solver of CST Microwave Studio software is a general-purpose 3D electromagnetic simulator. Real time domain simulation is useful for studying the field propagating through a component or along traces of a PCB and can be used in a huge range of EM applications. Therefore, the transient solver is chosen to simulate the design of the proposed antenna since it is suitable to calculate the return loss by observing the scattering coefficients. Furthermore, the radiation pattern and current density can also be obtained.

Moreover, the parametric sweep function that is available in CST software is used in order to investigate the effects of varying the size of parasitic elements and a stub on the bandwidth and cut off frequency of the antenna. All the dimensions and the simulated results are presented in section 3. Measurement is performed in order to validate the simulated result experimentally. It is divided into two parts which are S-parameters and radiation pattern, respectively. The measurement techniques refer to the testing of the antennas to ensure that the antenna meets specifications or simply characterize it. Antenna parameters that are measured in this work are S-parameter and radiation pattern. The procedures and equipment used in antenna measurements are vector network analyser and anechoic chamber. Before starting measure the S-parameters, calibrations are needed in order to eliminate the graph ripples or noise. Next, the antenna with SMA connector is connected to the VNA through co-axial cable. The S-parameter has been obtained and analysed. For radiation pattern, the measurement set up is done in a full anechoic chamber. In this method two antennas are used which is transmitting antenna as a primary antenna and antenna under test as a secondary antenna. Both antennas are put face to face at certain distance. The primary antenna is not moving while the secondary antenna is moved along a circular path at a constant radius. The field strength reading and direction of the secondary antenna with respect to the primary antenna are recorded along the circle at different points. The plot of radiation pattern is made either polar form or in a rectangular form. Other studies on simulation setup using CST software as well measurement setup have also been reported in [22-23].

4. Proposed design

The geometry of the proposed antenna is shown in Figure 2. It consists of a /2 dipole arm, parasitic elements, open circuit stub and balun. The stub, balun and parallel-strip feed line are designed in a similar manner to the work in [20-21] The antenna has a double- sided dipole arms and the parasitic elements act as the radiating elements. The antenna without the parasitic element is first constructed from a standard dipole. The feed line with a tapered balun is used for the 50- impedance matching. The balun resonates at /4 and the resonant frequency is 900 MHz. A stub is added to suppress the undesired harmonic while the parasitic elements are used to control the second and the third frequency bands. They are located on the feed line and dipole arms, respectively. The size of the antenna is 150 × 76 mm2. The antenna is simulated on a FR-4 substrate having a relative permittivity, ε_r of 4.3, loss tangent, tan δ of 0.0019 and thickness, h of 1.6 mm. The complete dimensions of the elements are summarized in Table 1.

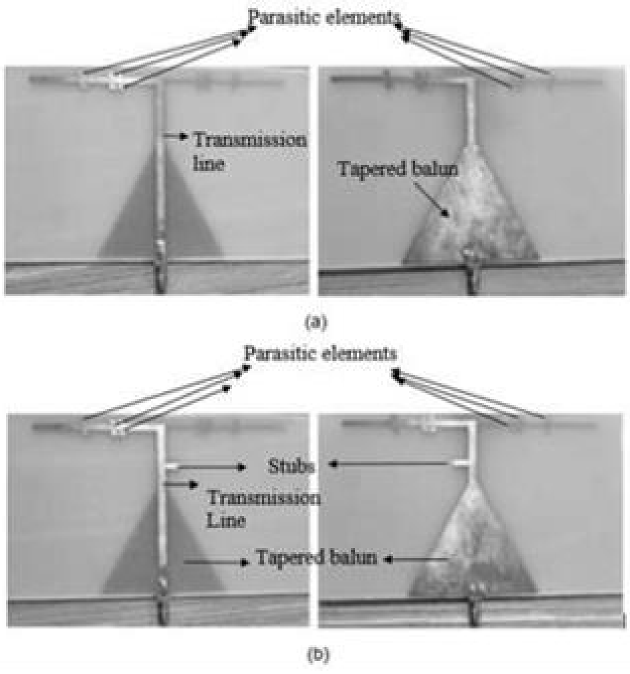


Fig. 2 - Dipole antenna; (a) without stub and (b) with stub

Table 1 - Dimensions of the proposed triple-band harmonic suppression dipole antenna

Elements	Proposed design	
	Parameter	Value (mm)
Total size	Length	71.5
	Width	150
Transmission line	Length	67
	Width	3.2
Tapered balun	Height	26
	Width	26
Arms	Length	76
	Width	1.5
Stub	Length	9
	Width	2
Parasitic element#1	Total length	6
	Width	1
Parasitic element#2	Total length	6
	Width	2
Parasitic element#3	Total length	6
	Width	1.5
Terminal	Length	16
	Width	3.2

3. Results and discussion

The simulated and measured reflection coefficients of the dipole without stub are presented in Figure 3. Table 2 compares the reflection coefficients of the antenna – with and without a stub. As can be seen from the figure, it can be seen that the antenna operates at four frequencies of 0.82 GHz, 2.4 GHz, 4 GHz, and 5.82GHz. From these four operating frequencies, the unwanted harmonic is the one at 4 GHz. In order to eliminate the harmonic, a stub is used. The reflection coefficient of the antenna with a stub can be viewed in Figure 4. It can be seen that the harmonic has been suppressed and the antenna now operates at 0.82 GHz, 2.4 GHz, and 5.82 GHz. The proposed antenna exhibits a dough-nut-shaped radiation pattern in the E-plane and almost omni-directional H-plane pattern as can be seen in Figure 5 and 6. Furthermore, Table 3 summarizes the comparison of operating frequency for a single band dipole antenna [21], dual-band dipole antenna [20] and the proposed antenna in this work.

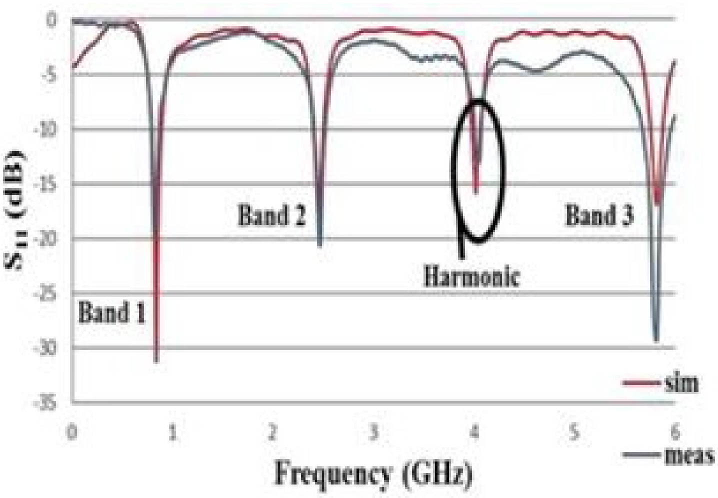


Fig. 3 - Reflection coefficients of the triple-band dipole antenna without a stub

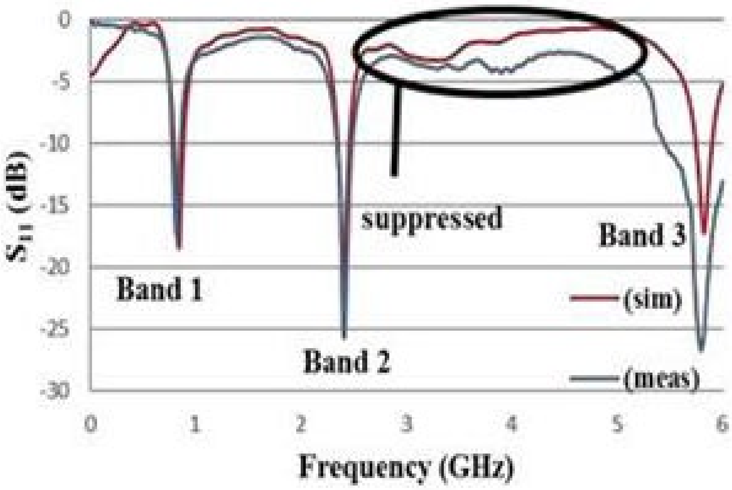
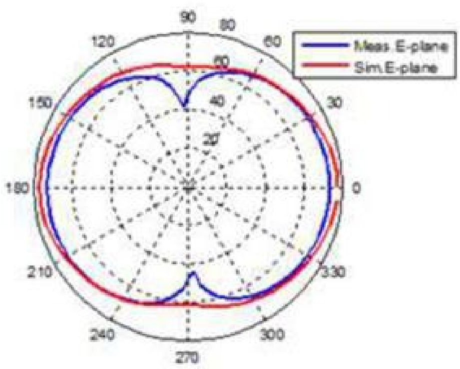


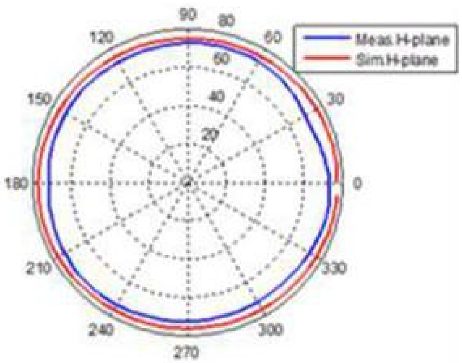
Fig. 4 - Reflection coefficients of the triple-band dipole antenna with a stub

Table 2 - Reflection coefficients of the proposed antenna with and without a stub

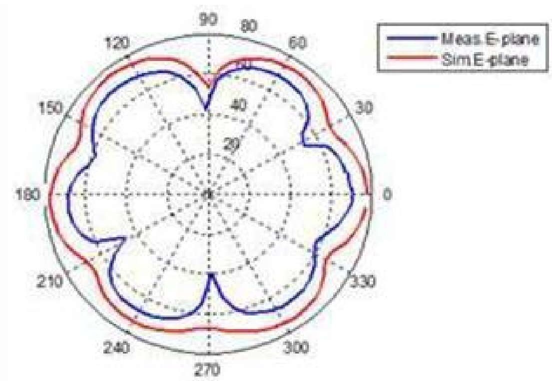
Freq. (GHz)	Antenna with no stub		Antenna with a stu	
	Sim.	Meas.	Sim.	Meas.
0.8	-32.42 dB	-18.49 dB	-18.40 dB	-17.62 dB
2.4	-18.28 dB	-19.32 dB	-24.39 dB	-23.38 dB
4.0	-15.75 dB	-13.49 dB	-1.20 dB	-3.08 dB
5.8	-17.50 dB	-29.62 dB	-17.16 dB	-22.75 dB



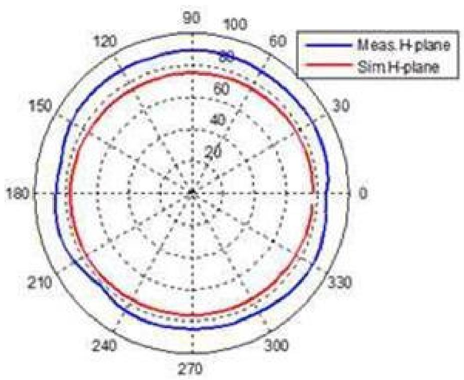
(a)



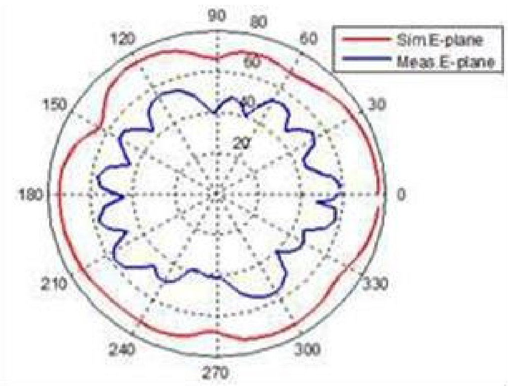
(b)



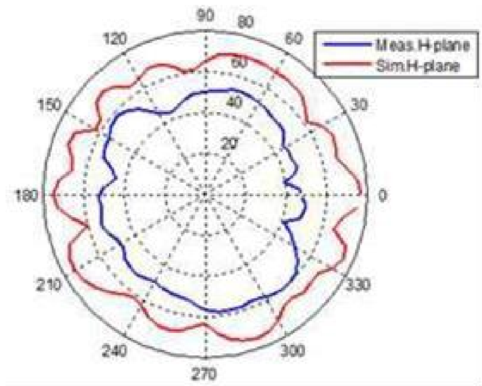
(c)



(d)



(e)



(f)

Fig. 5 - Radiation patterns of the triple-band dipole antenna in the *E*-plane at: (a) 0.8 GHz; (b) 2.4 GHz; (c) 5.8 GHz and Radiation patterns of the triple-band dipole antenna in the H-plane at: (d) 0.8 GHz; (e) 2.4 GHz; (f) 5.8 GHz

5. Conclusion

A triple-band microstrip dipole antenna with harmonic suppression capability from the presence of an integrated open circuit stub is presented in this paper. Three parasitic elements are added on the dipole's arm to allow a triple-band frequency operation at 0.8 GHz, 2.4 GHz and 5.8 GHz. The stub which is located at the feed line of the antenna suppresses the unwanted harmonic at 4.0 GHz. The corresponding measured reflection coefficients are -17.62 dB, -23.38 dB and -22.75 dB at the respective frequencies. The simulation and measurement results are in a good agreement.

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