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Harmonic Suppression Dual-band Dipole Antenna with Parasitic Elements and a Stub

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Abstract

A dual-band harmonic suppression dipole antenna suitable for energy harvesting system is presented in this paper. A linear dipole with two parasitic elements is designed and fabricated with a capability to eliminate the harmonic of higher order modes. At first, the antenna resonates at 900 MHz and 2.7 GHz. Therefore, a parasitic element is added into each of the dipole's arm to tune the second frequency band to 2.4 GHz to fit into wireless application. However, the presence of two parasitic elements has generated an unwanted harmonic at 4.0 GHz. Thus, a stub has been integrated into the antenna's terminal (feed line) to suppress the 4.0 GHz frequency. This technique is suitable for developing a multiband antenna with harmonic suppression. The antenna is fabricated on a FR-4 board with the size of 72×152 mm^2 which operates efficiently at 0.8 GHz and 2.4 GHz which is suitable for wireless communication applications. The prototype can suppress the undesired harmful harmonics present within the frequency range of 3 to 5 GHz. The antenna has a good potential to be used in a rectenna system with a dual-band frequency operation but with better performance. Simulation and measurement results obtained are in a good agreement, which have confirmed the proposed design concept.

Keywords: *dual-band dipole antenna, parasitic elements, harmonic suppression antenna, stubs-filter*

1. Introduction

Harmonic suppression antenna find applications in rectifying antenna (RECTENNA) system for energy harvesting and reconfigurable antenna but with better performance [1]-[4]. The antenna has a capability to eliminate the unwanted frequencies within a specified frequency range, operating in a single or dual operating frequencies without degrading the antenna's performance. It used the internal filter to suppress the unwanted frequencies and hence, is able minimize the whole antenna size as well as avoiding interconnection losses between the circuit components. The design includes the integration of the antenna with stubs or defected ground structure (DGS).

Embedding stubs or DGS into the balun makes it possible to reduce the antenna's physical size while at the same time, provide a good performance. A typical dual-band dipole could be designed by introducing parasitic elements on the radiating arms. A multiband dipole antenna which used a parasitic strip operates at 2.45 GHz (Band 1) and 5.8 GHz (Band 2) has been proposed in [5]-[6]. Two parasitic elements have been added into the arms of a dipole antenna to produce a triple-band frequency of operations at 0.92 GHz (Band 1), 2.45 GHz (Band 2) and 5.8 GHz (Band 3), respectively [7]. In [8], a parasitic element has allowed a monopole antenna to operate at 1.91 to 2.74 GHz and 4.58 to 5.93 GHz.

The presence of harmonics in dipole antennas is undesirable in many applications. These uncontrolled frequencies (second frequency and above) are able to be suppressed with the integration of stubs and DGS on the terminal of the antenna. A dual-band harmonic suppression antenna is proposed in [9]-[10]. A dual-band antenna which uses a circuit called a stub-loaded resonator to produce a dual- band frequency at 3.6 GHz and 5.2 GHz and suppressed the frequency band from 6.0 to 12 GHz has been proposed in [9]. In [10], a dual-band antenna operates at 2.45 GHz and 5.8 GHz is proposed and has the capability to

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suppress the frequencies of 4.9 GHz, 7.35 GHz, 9.8 GHz, 11.6 GHz, 12.25 GHz, 14.7 GHz and 17.4 GHz.

This paper presents the design and fabrication of a dual-band dipole antenna with harmonic suppression capability that operates at 0.8 GHz and 2.4 GHz while suppresses the frequency band of 3 GHz to 6 GHz. The undesired harmonics have been removed by using stubs which is similar to that in [11]. Previously, a single band harmonic suppression dipole antenna has been reported in [11]-[13] while [14] discussed on the harmonic suppression UWB dipole antenna.

2. Design of Dualband Harmonic Suppression Dipole Antenna

The proposed antenna geometry is shown in Figure 1. It consists of two parasitic elements integrated into each of the dipole's arm, open circuit stubs and a balun. The parasitic elements are located at the centre of each arm.

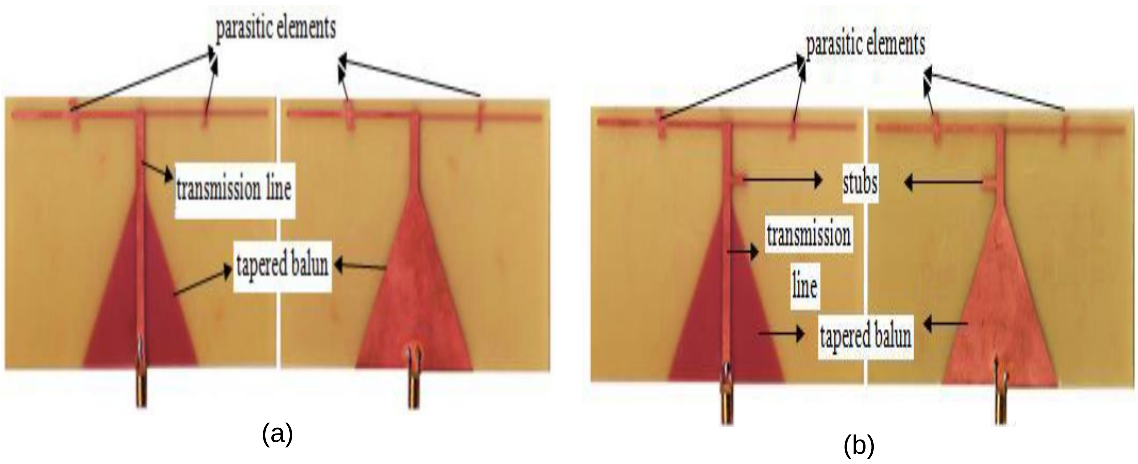

Figure 1. The proposed dipole antenna: (a) Without stub (b) With stub

The size of the antenna is 72×152 mm^2. The balun has a ratio of 50:72 electromagnetic transition between the unbalanced 50 Ω SMA connector to 72 Ω balanced antenna. The dimensions of the radiating arms, parasitic elements, stub, terminal and balun are tabulated in Table 1. Simulations are performed in CST MWS commercial software. The antenna is designed and fabricated on a FR-4 board.

Table 1. Dimensions of the Proposed Dualband Harmonic Suppression Dipole Antenna

Elements	Proposed Design	
	Item	Unit (mm)
Total size	Length	72
	Width	152
Transmission Line	Length	68
	Width	4
Tapered balun	Height	26
	Width	26
Arms	Length	69.5
	Width	1.5
Stub	Length	9
	Width	2
Parasitic elements	Total length	8
	Width	1
Terminal	Length	17
	Width	4

3. Results and Analysis

The prototype of the antenna is constructed by using a technique called a wet-etching. The measurements are performed by using a AVB14 Vector Network Analyser (VNA) and the far-field measurements have been conducted in an anechoic chamber. The measured reflection coefficient and voltage standing wave ratio (VSWR) can be viewed in Figure 2 and 3. It is observed that the antenna operates at 0.8 GHz and 2.4 GHz, with one harmonic frequency at 4.0 GHz having the return loss of -20.98 dB, -27.93 dB and -22.64 dB, respectively. The parasitic elements have successfully tuned the second resonant frequency to 2.4 GHz and at the same time, produced a harmonic frequency. A stub is used to eliminate harmonic at 4.0 GHz. Therefore, the antenna only operates at 0.8 GHz and 2.4 GHz with reflection coefficients of -16.64 dB and -25.96 dB. The corresponding VSWR are displayed in Figure 3. The complete results are tabulated in Table 2.

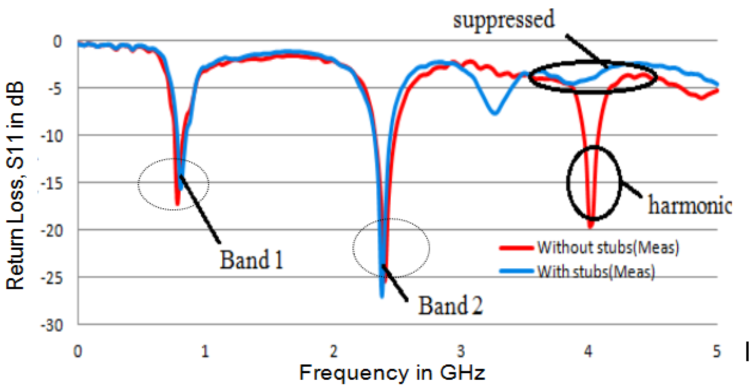

Figure 2. Measured reflection coefficient of the dual-band dipole antenna with and without stub

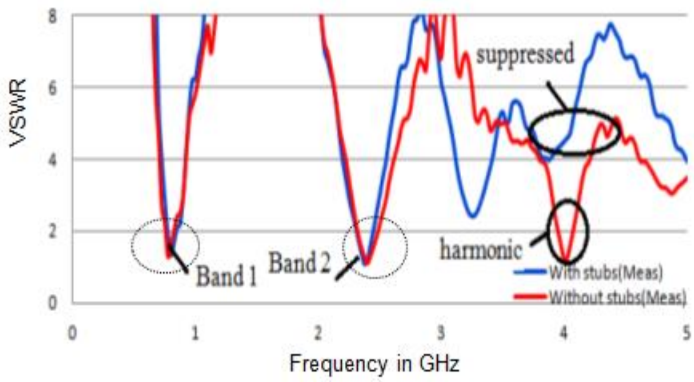

Figure 3. Measured VSWR of the dual-band dipole antenna with and without stub

Table 2. The Simulation and Measurement Results of Reflection Coefficient and VSWR

	Simulations			
Frequency	Return loss		VSWR	
	Ant_without stub	Ant_with stub	Ant_without stub	Ant_with stub
0.8 GHz	-29.506 dB	-20.98 dB	1.07	1.19
2.4 GHz	-20.383 dB	-27.93 dB	1.19	1.08
4.0 GHz	-22.64 dB	-2.9 dB	1.24	5.8
	Measurements			
Frequency	Return Loss		VSWR	
	Ant_without stub	Ant_with stub	Ant_without stub	Ant_with stub
0.8 GHz	-17.10 dB	-16.64 dB	1.61	1.35
2.4 GHz	-20.38 dB	-25.96 dB	1.13	1.11
4.0 GHz	-22.64 dB	-3.10 dB	1.25	5.2

Figure 4 shows the measured E-plane radiation pattern while Figure 5 shows the measured H-plane radiation pattern, which correspond to the co-polarisation or the desired wave radiated by the antenna. By comparing the radiation patterns of the antenna with a stub, there is not much difference in the size and shape of the measured and simulated radiation patterns. This behaviour shows that the radiation patterns are not affected by the presence of stubs.

The results of the simulated gain show that the gain of the antenna with a stub at the respective frequency of operations are close to the antenna without a stub. In addition, the stub has successfully eliminate the operating frequency of 4.0 GHz based on the drastic reduction of the gain to -2.4 dBi. The complete results are tabulated in Table 3.

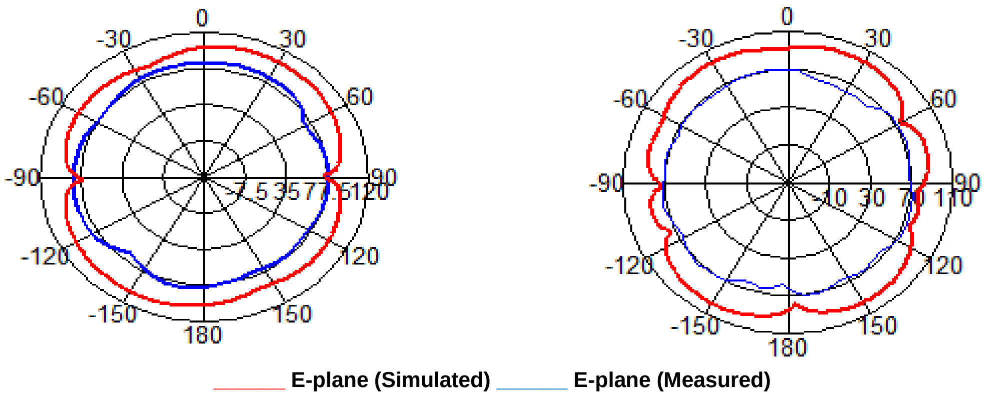

Figure 4. Simulated and measured results of the dipole antenna for E-plane at:
(a) 0.8 GHz and (b) 2.4 GHz

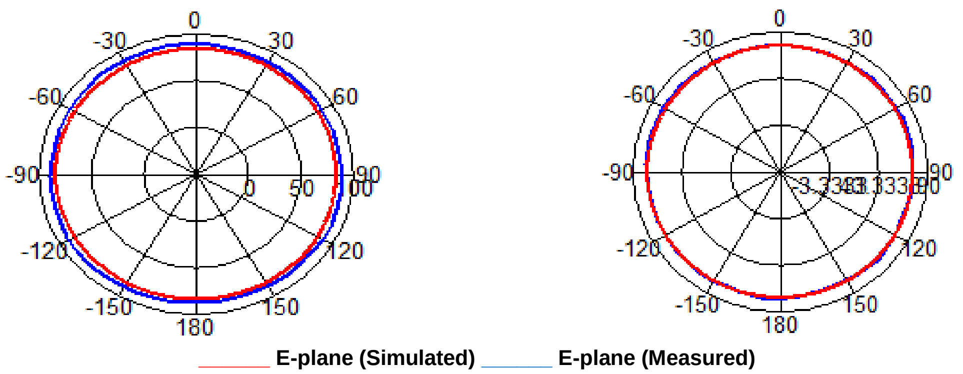

Figure 5. Simulated and measured results of the dipole antenna for H-plane at:
(a) 0.8 GHz and (b) 2.4 GHz

Table 3. Gain of the Antennas

Frequency	Simulations Gain	
	Ant_without stub	Ant_with stub
0.8 GHz	1.71 dBi	1.66 dBi
2.4 GHz	2.25 dBi	2.59 dBi
4.0 GHz	2.62 dBi	-2.40 dBi

4. Conclusion

A microstrip dual-band dipole antenna with harmonic suppression capability with an integrated open circuit stub is presented. Two parasitic elements are added at the centre of each dipole's arm to allow a dual-band frequency operation. The presence of stub at the feed line of the antenna has suppressed the unwanted harmonic. Therefore, the dual-band harmonic suppression antenna is formed from the employment of two parasitic elements and a stub. The simulation and measurement results show that the stubs has successfully suppressed the harmonic frequency allowing the antenna working at dual band frequency.

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