A wideband dipole antenna based on a non-uniformly segmented structure

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Abstract— **The design of a wideband, vertically polarized omnidirectional dipole antenna based on a non-uniformly segmented structure is presented. The proposed non-uniformly segmented configuration mitigates the phase change of the currents flowing in the long dipole arms, so that the reverse currents which deteriorate the radiation pattern can be avoided, and a stable omnidirectional pattern can be maintained over a wide frequency band. Simulation results show that the proposed dipole has a wide pattern bandwidth of 66%, ranging from 1.96 GHz to 3.90 GHz, with S_{11} less than -10 dB. Within the band, the main lobe of the dipole remains in the broadside direction in the E-plane and the antenna achieves the desirable omnidirectional radiation pattern, with a gain flatness of less than 0.3 dB in the H-plane.**

Index Terms—**wideband, vertically polarized, dipole antennas, non-uniformly segmented structure, omnidirectional pattern.**

I. INTRODUCTION

Antennas that can provide vertically polarized omnidirectional radiation are in demand in many applications, such as wireless sensor networks (WSN), cellular networks, and wireless local area networks (WLAN) [1], in which a wide bandwidth and a high gain are usually preferred. The dipole antenna is one of the most frequently used radiators to obtain the aforementioned radiation characteristics and has the advantages of simplicity and low cost [2]. Although a large number of methods have been proposed to improve the gain and bandwidth of dipole antennas [3]-[6], the performance of the dipole has been found to be intrinsically limited by its physical size [7]. In order to simultaneously obtain a higher gain and a wider bandwidth, the size of the dipole needs to be increased. However, in traditional dipole configurations, reverse currents flow in the dipole arms when the physical length of the dipole exceeds a wavelength, and this in turn deteriorates the radiation pattern owing to the splitting of the main lobe.

The composite right/left-handed (CRLH) structure can be used to prevent the reverse currents on a long dipole, because of its capability to achieve a zero propagation constant at the zeroth-order resonant frequency [2]. The segmented line structure, as one of the CRLH structures, has attracted considerable attention, since it is relatively easy to fabricate [8]-[11]. The phase variation along this structure can be controlled by tuning the lengths and widths of the segmented strips. A dipole antenna based on a uniform segmented structure has been presented in [12], and a stable omnidirectional pattern within a wide bandwidth has been achieved.

In this paper, a novel design of the dipole antenna is proposed, based on the use of the non-uniformly segmented line structure, to achieve a wider bandwidth with high gain. The transmission characteristics of the proposed non-uniformly segmented structure are investigated. Simulation results of the impedance bandwidth and radiation characteristics of the above dipole are presented and discussed.

II. ANTENNA CONFIGURATION

Fig. 1 shows the configuration of the proposed wideband dipole antenna. Each arm of the dipole consists of two groups of metalized strips printed on different sides of the substrate. The strips in each group are evenly spaced but have different lengths. Two coupled microstrip lines with length l_i and width w_i are printed on different sides of the substrate to match the antenna. The substrate employed in this work has a dielectric constant of 2.65 and a thickness of 0.8 mm. The dimensions of the antenna are optimized to maintain unidirectional currents flowing in the dipole arms to provide the widest pattern bandwidth. These dimensions are listed in Table I.
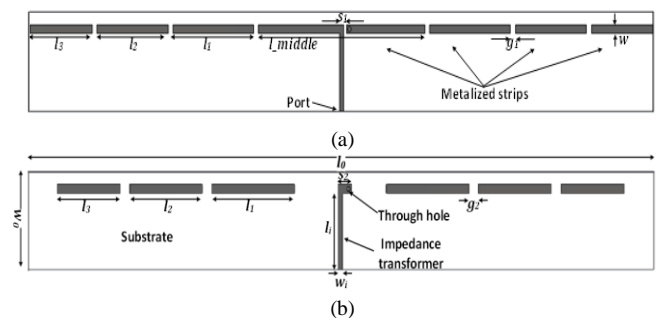

Fig. 1. Antenna configuration. (a) front view. (b) back view.

TABLE I. DIMENSION OF THE PROPOSED ANTENNA

Parameter	Value (mm)	Parameter	Value (mm)
l_middle	35	g_1	1
l_1	17	g_2	2
l_2	15	s_1	0.6
l_3	13	s_2	2.7
w	1.4	l_0	131
w_i	0.9	w_0	16
l_i	12.5		

To demonstrate the ability of the proposed structure to mitigate the phase change of the currents flowing in it, the current phase variations along one of the dipole arms are monitored at certain frequency points (2, 3, and 4 GHz). The results are compared in Fig. 2 with those for a continuous strip used in conventional dipoles, as well as with those for the uniformly segmented structure proposed in [12]. The figure shows that the phase of the currents on the proposed non-uniform structure changes significantly slower than those on the uniform structure and the continuous strip, especially at 3.0 GHz. This, in turn, helps to circumvent the unwanted phase reversion problem on a long dipole, which is approximately 1.3 λ_0 long at 3.0 GHz, and the antenna maintains a single main lobe in the broadside direction across a very wide band.
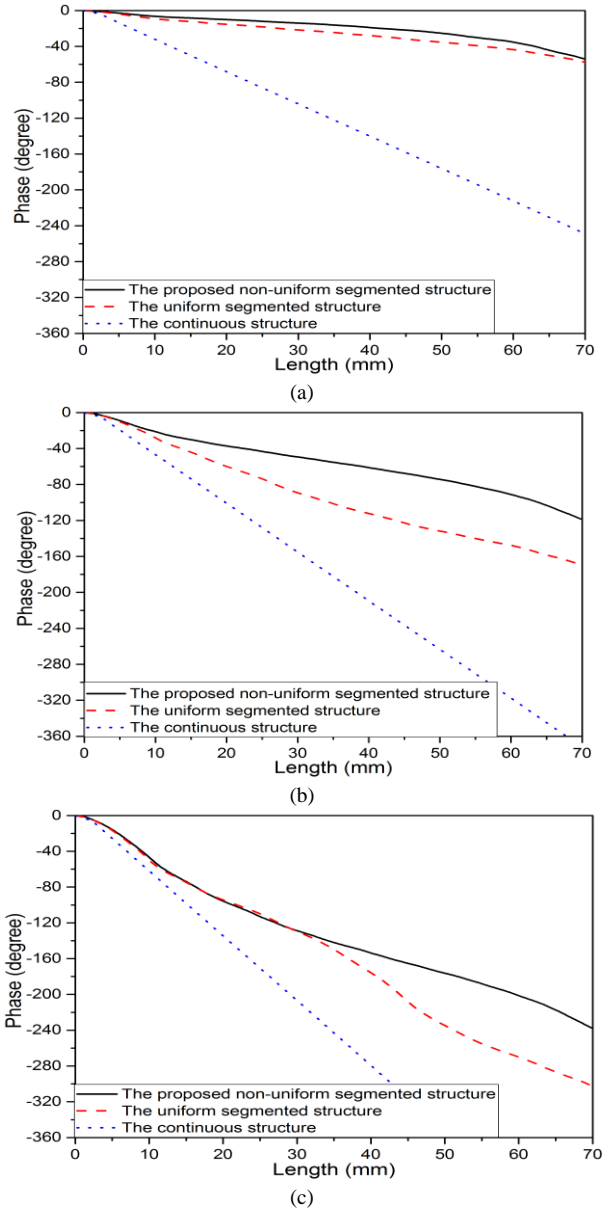

(a)

(b)

(c)

Fig. 2. Phase of current flowing in three different structures. (a) 2.0GHz. (b) 3.0GHz. (c) 4.0GHz.

III. SIMULATION RESULTS

The impedance bandwidth, radiation patterns, and the gain of the proposed dipole antenna have been simulated using CST microwave studio 2016. Fig. 3 plots the reflection coefficient S_{11} of the dipole antenna, and shows that the achieved impedance bandwidth ($S_{11} \leq$ -10 dB) is 72.5% from 1.96 GHz to 4.19 GHz. Normalized radiation patterns of the dipole antenna in the E- and H-planes are displayed in Fig. 4. The realized pattern bandwidth is 66% from 1.96 GHz to 3.90 GHz, within which the pattern maintains one main lobe fixed in the broadside direction in the E-plane, and a good omnidirectional property with a gain variation less than 0.3dB in the H-plane. The cross-polarization levels across the entire bandwidth are below -28 dB. As shown in Fig. 5, the gain varies from 2.0 dBi to 4.2 dBi within the operating bandwidth.
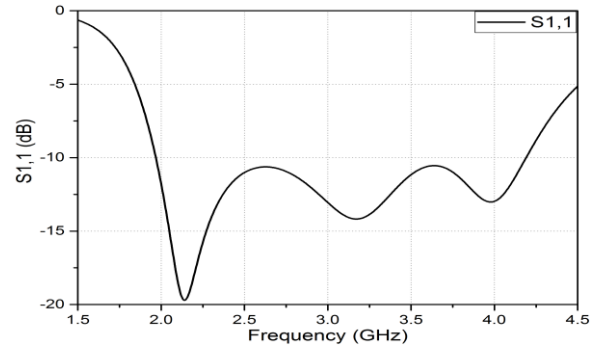

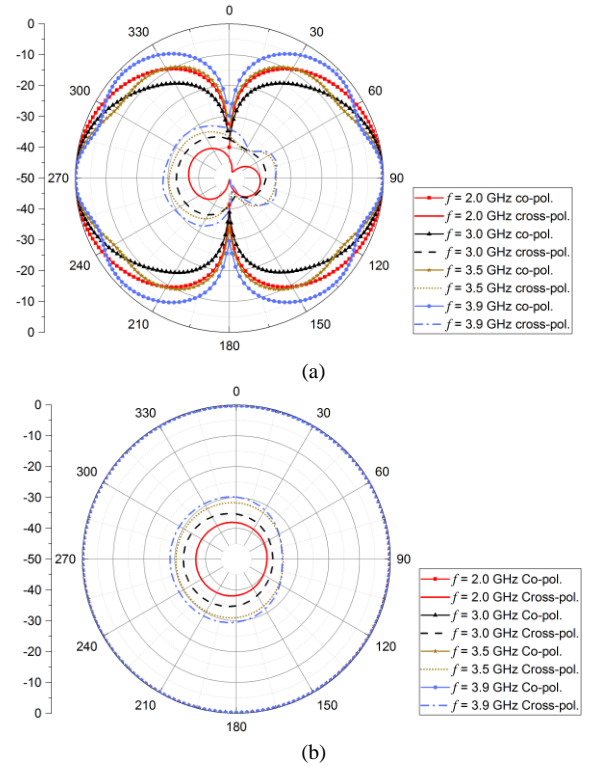Fig. 3. Reflection coefficient values of the proposed antenna.

(a)

(b)

Fig. 4. Normalized radiation patterns of the proposed antenna. (a) E-plane. (b) H-plane.
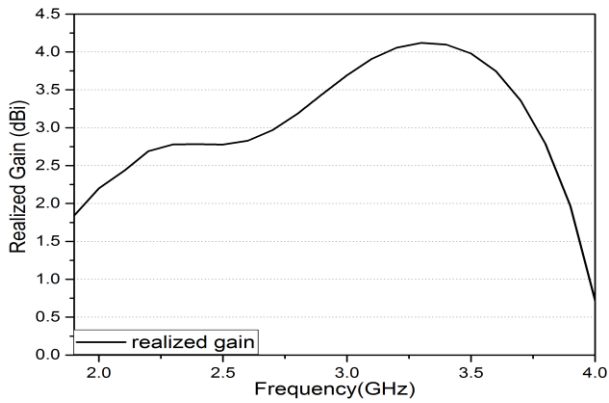
Fig. 5. Realized gain.

IV. CONCLUSION

The design of a wideband omnidirectional dipole antenna, with its arms comprising of a non-uniformly segmented line structure, has been presented in this paper. The proposed structure mitigates the problem of excessive phase variation of currents flowing in it, which in turn helps the proposed antenna to maintain a stable omnidirectional pattern over a very wide band (1.96-3.90 GHz), accompanied by the enhanced gain performance.

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