A New Miniature Ultra Wide Band Planar Microstrip Antenna Based on the Metamaterial Transmission Line

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Abstract— **In this article, a simple and miniature ultra wide band (UWB) printed planar antenna with excellent radiate characteristics is presented. A method to reduce the size and enlarge the bandwidth of Metamaterial (MTM) antennas utilizing a composite right/left handed transmission line (CRLH-TL) is suggested. We proposed an efficient way to foot print area reduction and extend the bandwidth accompanying improvement the gain and the efficiency of metamaterial antennas, which has been examined by full-wave simulation. Compact size, UWB, low cost, high gain, unidirectional radiation patterns and fitting impedance characteristics are the chief advantages of the suggested antenna, which are obtained by proposed method. The antenna has a compact size of 12.2mm × 9.2mm × 1.6mm or $0.08\lambda_0 \times 0.06\lambda_0 \times 0.01\lambda_0$ (λ_0 : the free space wavelength at 2GHz), and provides the impedance bandwidth about 140% between 1.2 and 6.8GHz for VSWR < 2 and also the peak gain and the maximum efficiency are 7.28dBi and 92.3%, respectively, at 5.2GHz. The suggested method can be utilized to design new miniature and UWB metamaterial antennas and microwave components for mobile handset implementations.**

Keywords- Miniature antenna, ultra wide band (UWB) antenna, composite right/left-handed transmission line (CRLH-TL), metamaterial (MTM).

I. Introduction

Ultra Wide Band (UWB) technology [1] has been identified as the most promising way for short-range wireless communications that can achieve both high data rate and low power consumption. The initial design challenge is attaining a broadband impedance matching from 1.2 GHz to 6.8 GHz. Ideally, the UWB antenna should be compact, planar, low cost, and reliable. Compatibility and ease of integration with electronics for mobile communications too desirable. Furthermore, in order to gratify the different claims for wireless services, small antenna with broad bandwidth and well radiation characteristics are required. The metamaerials are highly attractive for the design of small antennas and microwave components [2], [3]. The CRLH-TL supply a conceptual path for performing compact antennas. However, these CRLH-TL small antennas typically have narrow bandwidths. Numerous assays have been performed to enlarge the bandwidth of metamaterial antennas. In this article, guidelines for miniature UWB MTM antenna design are suggested and a miniature and low cost very broad band metamaterial antenna is presented that offers circuit integration possibilities. We present of the methods to the size reduction and the bandwidth intensification of metamaterial antennas by utilizing two unit cells of the CRLH-TL. In this article, for foot print area reduction we using of the MTM technology and the printed planar technique and for extending of the bandwidth we employing a few value of the loaded series capacitance on the CRLH-TL and as well as with employing of the uniform excitation mechanism, a larger aperture and suitable choosing of the antenna structural parameters attending their values can obtain appropriate radiation performances, Hence, small size and wideband performance accompanying good radiation characteristics can achieve.

The rest of paper is systematized as follows. The proposed antenna design procedure is elaborated in section II. In section III, we introducing various performance including dimension, impedance bandwidth and radiation patterns characteristics of the suggested antenna. Further discussion and conclusion are raised at last.

II. Antenna Design Considerations

As debated in [2], [4], various implementations can be employed to actualize the composite right/left-handed transmission line unit cell including surface mount technology chip components and distributed lines. However, lumped elements are not suitable in antenna design since of their lossy characteristics and discrete values. We using printed planar technique for our antenna design, since printed planar structures are good candidate for antenna design because of their advantages which include foot print area reduction, loss

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less and non-discrete values. A new compact and UWB antenna with improvement gain based on CRLH-TL is presented in here, which consists of two unit cells, while each unit cell design by two rectangular radiation patches with printed H-shaped gaps into radiation patches, and the spiral inductor accompanying vertical via connected to the ground plane. The proposed planar antenna was designed on a Rogers_RT_Duroid5880 substrate with dielectric constant of 2.2 and 1.6mm thickness. The design of proposed metamaterial antenna is based on the CRLH-TL unit cell displayed in Fig.1. The antenna is based on two unit cells. The unit cells are constructed of the transmission lines with four printed H-shaped gaps into rectangular radiation patches and two spiral inductors connected to ground plane through two metallic via. In this structure, port 1 is excited with input signal and port 2 is matched with 50Ω load impedance, as illustrated in Fig.2. The printed H-shaped gaps into radiation patches established series capacitances (C_L) and the spiral inductors accompanying two metallic via connected to ground plane acts like shunt inductances (L_L). The host TLs possesses the right-handed parasitic effects that can be seen as shunt capacitances (C_R) and series inductances (L_R).The shunt capacitance C_R is mostly come from the gap capacitance between the patch and the ground plane, and the unavoidable current that flow on the patch establish series inductance L_R, which indicates that these capacitance and inductance cannot be ignored. The formation of the miniature UWB MTM antenna is exhibit in Fig.2. Equivalent circuit model of this antenna structure is based on a composite right/left-handed transmission line model utilized as a periodic structure which shown in Fig.3.

In this article, metamaterial antenna which act in the left-handed area ($\beta < 0$) is designed. Since the lowest mode of operation is a left-handed mode, the propagation constant (β) near to negative infinity ($-\infty$) at the cutoff frequency, and reduce its magnitude as frequency is increased. Making employ of this phenomenon, a physically compact and electrically large antenna can be developed [4] and too by using printed planar technique which consist of employing printed H-shaped gap which results to series capacitance (C_L), we can achieve foot print area reduction. The physical length, width, height of the antenna is 12.2mm, 9.2mm, 1.6mm, respectively, or, $0.08\lambda_0\times 0.06\lambda_0\times 0.01\lambda_0$ (λ_0 : the free space wavelength at f = 2GHz). Furthermore, we present an effective approach to enlarge the bandwidth of the metamaterial antennas with a fixed antenna size. By employing a few value of the loaded series capacitance on the composite right/left-handed transmission line, broadband performance can achieve. A few value of the loaded series capacitance will be realized by implementation of the printed H-shaped gaps with closely space edges into rectangular patches of the radiation patches. We using of this approach to enlarge the bandwidth of the antenna; therefore, we achieving a UWB antenna with wide impedance bandwidth from 1.2GHz to 6.8GHz which corresponding to 140% bandwidth. Thus, our antenna has 5.6GHz bandwidth and overall size of this antenna is 12.2mm× 9.2mm× 1.6mm, which shown its size is very compact in comparison with UWB antenna size and its bandwidth is very large.

Beside the small size and broad bandwidth, non uniform excitation mechanism may reduce the aperture efficiency, therefore decreasing the antenna radiation efficiency and gain. In this article, an efficient way for have high gain and efficiency is employed to good satisfy the severe needs of modern commercial applications. With employing of the uniform excitation mechanism by utilizing port 1 and port 2, whereas port 1 is excited with input signal and port 2 is matched to 50• load impedance to furnish maximum excitation of the antenna region supplying higher antenna radiation gain and efficiency, good impedance matching and existence of just one main beam. Also, in this antenna design, in order to have high gain, a greater aperture is utilized. Meanwhile, with appropriate selecting number of the unit cells (N) constructing antenna structure and suitable choosing the structural parameters of the antenna including spiral inductors attending their values such as number of turns (N), inner radius measured to the center of the conductor (Ri), conductor width (W) and conductor spacing (S), we will be achieved excellent radiation performances. The radiation gain and efficiency of the suggested antenna are changed from 0.02dBi to 7.28dBi and from 8.8% to 92.3%, respectively, into frequency band 1.2-6.8GHz, that shown very good radiation characteristics.

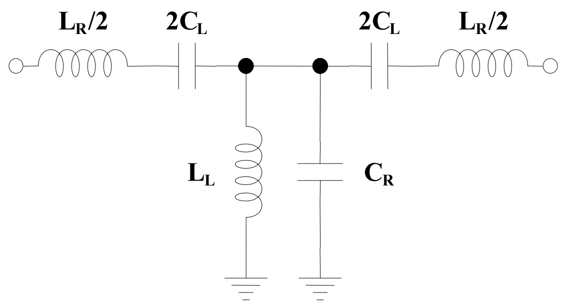
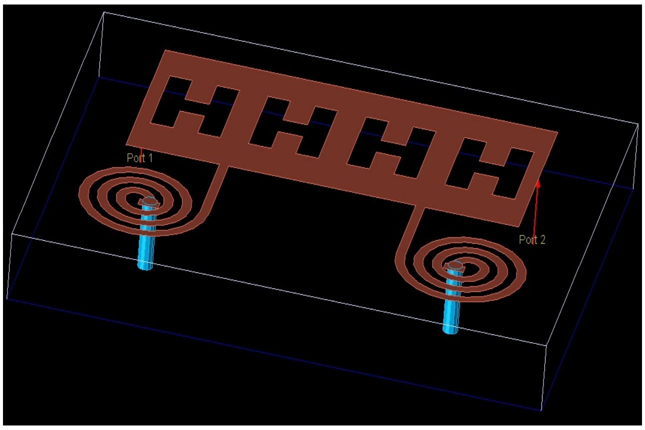


Figure 1. Proposed Antenna: equivalent circuit model for composite right/left-handed transmission line of the one unit cell.



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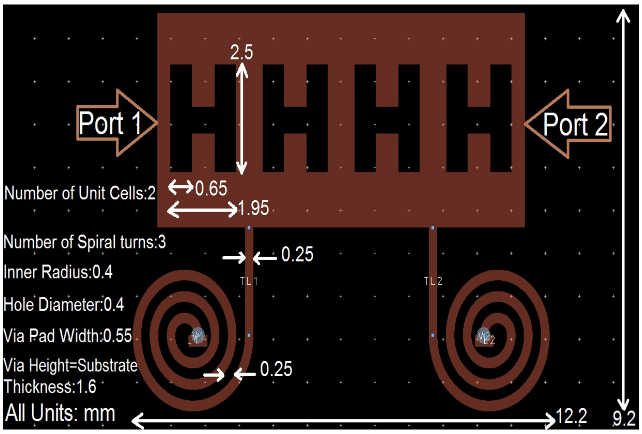


(b)

Figure 2. Configuration of the proposed miniature UWB MTM antenna, a) Isometric view, b) Top view attending the antenna structural parameters.

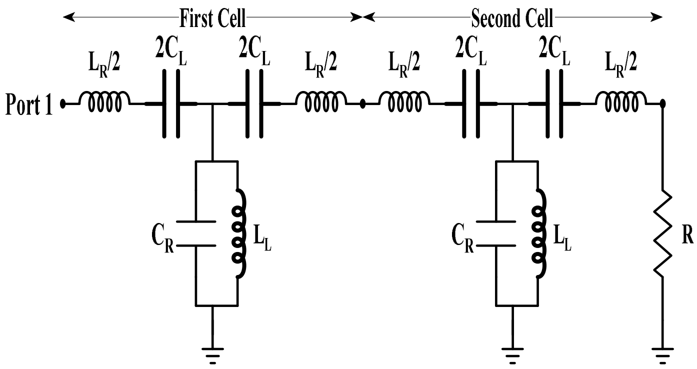


Figure 3. Suggested antenna: equivalent circuit model contributed of the symmetrical two unit cells.

For the demonstration of the MTM antenna with decreased size and enlarged bandwidth accompanying increased gain, a MTM antenna based on two unit cells is designed. The performances of the presented methods and metamaterial antenna structure are verified by full-wave simulations. One advantage of the presented methods, they are very easy to implement miniature UWB metamaterial antennas with increase gain by correctly presenting the CRLH-TL unit cells. The proposed antenna has much smaller size than UWB antennas and wider bandwidth accompanying superior radiation characteristics than compact antennas. Our antenna is an excellent candidate for wireless communication systems.

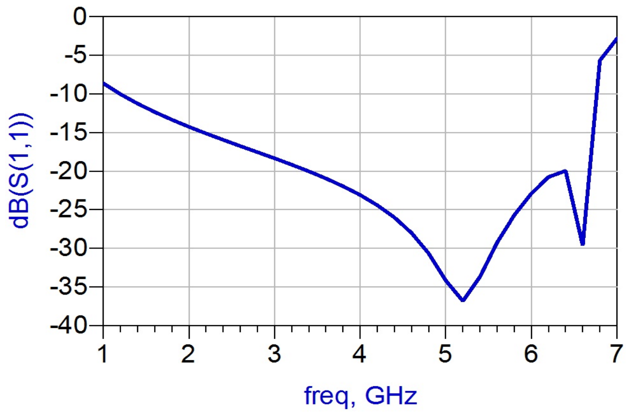
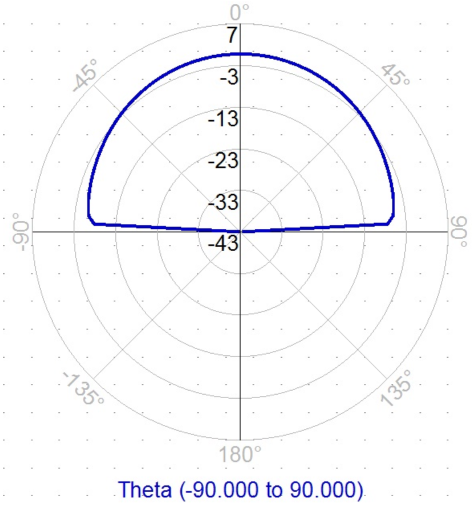


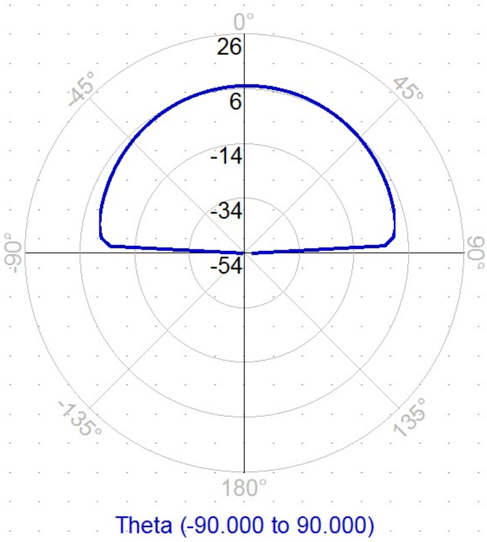
Figure 4. Simulated S_{11} parameter.

III. Antenna Simulation Results and Discussion

The antenna was designed on a Rogers_RT_Duroid5880 substrate with dielectric constant 2.2 and thickness h= 1.6mm. The physically size of the antenna is 12.2×9.2×1.6mm^3 (0.08 λ_0×0.06 λ_0×0.01 λ_0). Fig.4. exhibit the simulated S_{11} parameter of the design suggested antenna. The simulated results were achieved utilizing Agilent ADS full-wave simulator. The simulated return loss bandwidth (-10dB) is 5.6GHz (1.2-6.8 GHz). This corresponds to 140% bandwidth, which is very more than compact antennas bandwidth. The simulated gain patterns of the designed antenna at 2, 4.4, 6.6 and 6.8GHz are plotted in Fig.5. The radiation patterns are unidirectional characteristics. The simulated gains at 2, 4.4, 6.6 and 6.8GHz are 0.1, 7.15, 7.1 and 2.06dBi, respectively. The simulated radiation efficiency is 18.94% at 2GHz, 78.4% at 4.4GHz, 90.57% at 6.6 and 28.3% at 6.8GHz. The antenna gain changes from 0.02dBi to 7.28dBi, and the efficiency is fluctuated from 8.8% to 92.3%, the maximum gain and efficiency of the suggested antenna occurs at f = 5.2GHz, which are equal to 7.28dBi and 92.3%, respectively. To validate the design procedure, the suggested antenna was compared with several compact and UWB antennas and their radiation characteristics and their dimensions were summarized in Table I and Table II, respectively.



(a)



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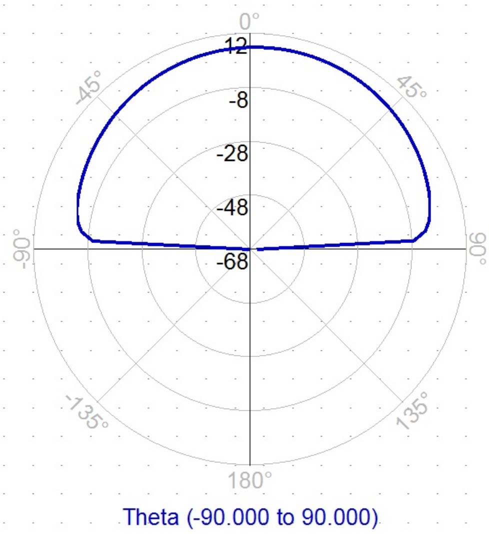

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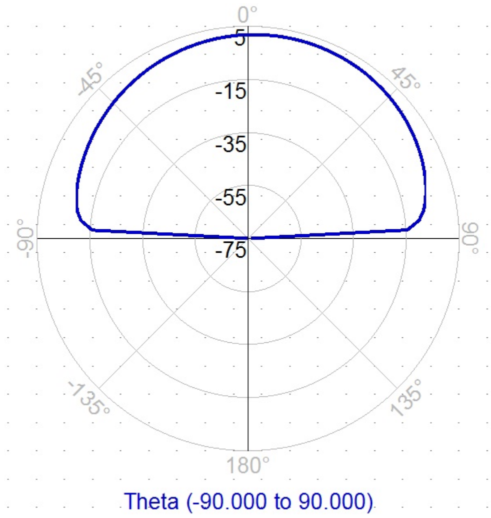

(d)

Figure 5. Radiation patterns (gains) in elevation ($\Phi = 0$ degree), a) f = 2 GHz, b) f = 4.4 GHz, c) f = 6.6 GHz, d) f = 6.8 GHz.

IV. CONCLUSION

In this paper, by employing of the MTM technology, printed planar technique, a few value of the loaded series capacitance on the CRLH-TL and also choosing appropriate distance between H-shaped gaps edges and utilizing of the uniform excitation mechanism, a larger aperture and appropriate selecting of the antenna structural parameters attending their values, we present a method to decrease the antenna size and a efficient way to enlarge the bandwidth and gain of the metamaterial antennas utilizing CRLH-TL. The small size, wideband and good radiation properties of the metamaterial antennas were designed employing the full-wave simulation. With using of the printed planar into radiation patches and a few value of the loaded series capacitance on the CRLH-TL and also with employing of the uniform excitation mechanism, a larger aperture and appropriate structural parameters, the antenna size can be reduced and the antenna bandwidth and gain can be extended. A metamaterial antenna with two unit cells was designed, and a footprint area reduction and a wideband performance with good radiation characteristics were obtained. The presented methods can be employed to design new miniature UWB and high gain metamaterial antennas and devices for mobile handset and wireless communication applications.

TABLE I. RADIATION CHARACTERISTICS OF THE OTHER TWO COMPACT ANTENNAS IN COMPARISON TO THE PROPOSED ANTENNA.

Parameters	[10]	[11]	This Paper
Gain	0.6 dBi	0.45 dBi	7.28 dBi
Bandwidth	1-2 GHz	0.8-2.5 GHz	1.2-6.8 GHz
Efficiency	26%	53.6%	92.3%

TABLE II. DIMENSION OF SEVERAL OF THE UWB ANTENNAS IN COMPARISON TO THE SUGGESTED ANTENNA.

Some UWB monopole antennas	Size of antenna
Slotted planar binomial monopole antenna **[5]**	$30 \times 27.4 \times 1$ mm^3
Slotted circular monopole antenna **[6]**	$26 \times 27 \times 1$ mm^3
Slotted rectangular monopole antenna **[7]**	$18 \times 20 \times 1$ mm^3
Fork shaped antenna **[8]**	$35 \times 30 \times 0.769$ mm^3
Slotted arc_shaped edge rectangular antenna **[9]**	$24 \times 35 \times 0.8$ mm^3
This Paper	$12.2 \times 9.2 \times 1.6$ mm^3

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