RESONANT ANTENNA BASED ON CRLH TL

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Abstract --- **In this paper, a study of the compact microstrip antenna based on composite right/left handed (CRLH) metamaterial transmission line is presented. The physical size and operational frequencies of the antenna are determined by the CRLH metamaterial's unit cell. The antenna exhibits monopolar radiation at its fundamental mode of resonant frequency. As it is well known that the composite right/left-handed (CRLH) transmission line (TL) has unique property of an infinite-wavelength wave at specific non-zero frequency because of zero permittivity and permeability [1], [2], [6]. Generally, CRLH includes both LH series C/shunt L and parasitic RH series L/shunt C in its circuit model, resulting in a structure which is LH at lower frequencies and RH at higher frequencies.The operation bandwidth cover the required band widths of the IEEE 802.11 wireless local-area networks (WLAN) standards and worldwide interoperability for microwave access (WiMax) in the 2.97 GHz, 3.345GHz and 3.79 GHz (3.49–3.79 GHz).The zeroth order resonant frequency was found to be at 3.79GHz.**

IndexTerms---**Metamaterials, CRLH TL, backward wave, electrically small antennas.**

I. INTRODUCTION

Metamaterials and, in particular, left-handed (LH) materials [1], [2], have drawn considerable attention in the physics and engineering communities by offering new concepts and potential applications.An interesting approach of LH or negative refractive index (NRI) metamaterials is transmission line theory, from which deep physical insight and efficient design tools have been developed [3], [4], [5], [6], [7]. In this approach, it has been shown that a real physical LH material is in fact composite right/left-handed (CRLH) in nature, exhibiting left-handedness at low frequencies and right-handedness at high frequencies due to parasitic right-handed (RH) effects [8], [9]. This concept has lead to a number of novel microwave applications [10], [11]. One practical distributed implementation of a 2D CRLH structure is the so-called mushroom structure [6], [7]. This structure was initially proposed by Sievenpiper et al. [2] in the context of high-impedance surfaces (Bragg frequencies), where it was used for its stop-band characteristics, for instance for the suppression of spurious surface waves in planar antennas. In [6], [7], the mushroom structure was demonstrated to be appropriate also for positive/negative refractive index effects in its pass bands for appropriate design parameters. To satisfy the demand of compact and versatile wireless communication systems, a compact and dual-band antenna is desirable. Such antennas are required in various wireless systems such as GSM/DCS cellular communication systems and synthetic aperture radar (SAR) systems. Dual-band antennas can be implemented with a composite right/left handed (CRLH) metamaterial transmission line (TL) which has several unique features such as a nonlinear dispersion relation. Unlike other reactively loaded dual-band antenna approaches, the CRLH TL approach offers a more straight-forward design approach based on the dispersion relation of the CRLH TL unit-cell.

The proposed periodic design methodology offers a straight forward design approach based on the characteristics of a single unit-cell. Based on this periodic structure methodology, a CRLH antenna was experimentally verified.

II. COMPOSITE RIGHT/LEFT-HANDED TRANSMISSION LINE THEORY

To realize a resonant-type planar antenna with no dependence on its physical size, a TL structure that supports an infinite wavelength at its fundamental mode is required. A practical realization of a LH TL,which includes unavoidable RH effects, known as a CRLH TL is able to support an infinite wavelength (β=0 when $\omega \neq 0$) and therefore can be used to realize the proposed antenna. The dispersion diagram of the CRLH TL unit-cell is shown in Fig. 1(b). The CRLH TL supports a fundamental LH wave (phase advance) at lower frequencies and a RH wave (phase delay) at higher frequencies.

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The equivalent circuit model of the CRLH TL unit-cell is shown in Fig. 1(a). By applying periodic boundary conditions (PBCs) related to the Bloch-Floquet theorem, the CRLH TL unit-cell's dispersion relation is determined to be

$$\beta(\omega)=\frac{1}{p}\cos^{-1}\left(1-\frac{1}{2}\left(\frac{\omega_L^2}{\omega^2}+\frac{\omega^2}{\omega_R^2}-\frac{\omega_L^2}{\omega_{se}^2}-\frac{\omega_L^2}{\omega_{sh}^2}\right)\right) \tag{1}$$

where,

$$\left.\begin{aligned}\omega_L&=\frac{1}{\sqrt{C_L L_L}},\ \omega_R=\frac{1}{\sqrt{C_R L_R}}\\ \omega_{se}&=\frac{1}{\sqrt{C_L L_R}},\ \omega_{sh}=\frac{1}{\sqrt{C_R L_L}}\end{aligned}\right\} \tag{2}$$

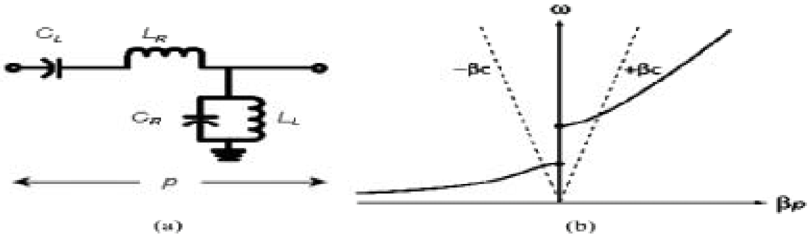


Fig1. RLH TL (a) LC unit-cell of length p.
(b) Dispersion diagram of CRLH TL

In general, the series resonance and the shunt resonance are not equal and two non-zero frequency points with are present. These two points are referred to as infinite wavelength points and are determined by the series resonance and shunt resonance of the unit-cell as given in (2). By cascading a CRLH TL unit-cell of length, times, a CRLH TL of length can be realized. The CRLH TL can be used as a resonator under the resonance condition

$$\beta_n=\frac{n\pi}{L}$$

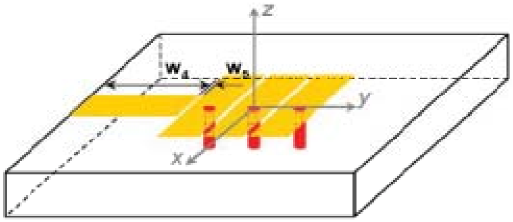
Where, n is the resonance mode number and can be a positive or negative integer and even zero [6]. In the case where, an infinite wavelength is supported and the resonance condition is independent of the CRLH TL's length (i.e., number of unit-cells, can be arbitrary).

III. CRLH TL Unit-Cell Realization

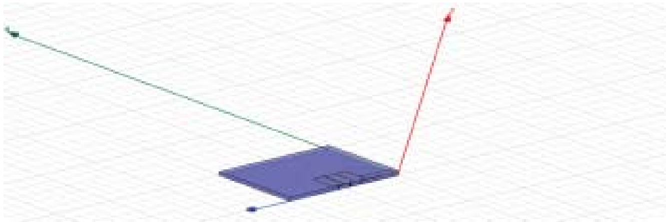
The entire structure was implemented on Arlon AD 250(tm) (ε_R=2.5, h=1.57 mm). A single feed line is used to excite the antenna. A return loss of -11.846 dB, -11.209 dB and -8.427 are experimentally obtained at f_0= 3.79 GHz, f_{-1}=3.345 GHz and at f_{-2}=2.97 GHz, respectively. The antenna size is $\lambda_o/5$ x $\lambda_o/5$ x $\lambda_o/50$. At f_0, an infinite wavelength is supported by the CRLH TL and the electric field along the perimeter of the patch formed by the three CRLH unit-cells is a constant. Therefore, the equivalent magnetic current densities along the edges of the patch form a magnetic loop. Therefore, a monopolar radiation pattern is expected and is confirmed by the experimental radiation patterns of Fig. 5. A maximum gain of 1.98 dBi was achieved at f_0. CRLH antenna input impedance from Fig.6 was found out to be 89.61+j52.45 Ω at 3.33 GHz and was computed by using Ansoft HFSS.

IV. Conclusion

The study of infinite wavelength resonant antennas based on periodic structures is demonstrated. The frequency of the antenna does not depend on its physical length, but only on the reactance provided by its unit-cell. In particular, the infinite wavelengths supported by a CRLH unit-cell were used to realize several monopolar antennas. The infinite wavelength frequency is determined by the shunt resonance of the unit-cell. Since the monopolar antenna's physical length is independent of the resonance phenomenon at the infinite wavelength frequency, a monopolar antenna can be arbitrary sized.



2 (a)



2(b)

Fig. 2(a) Model of CRLH dual-mode antenna with permittivity of 2.5, h=1.57 mm, width of the patch, w_1=4.8 mm, gap between successive patch, w_2 =0.2 mm, length of the patch,w_3=15mm, feed line length, w_4=15.0mm, w_5=0.1mm,feed line width,w_6=4.8mm. Fig. 2(b) Simulated Model.

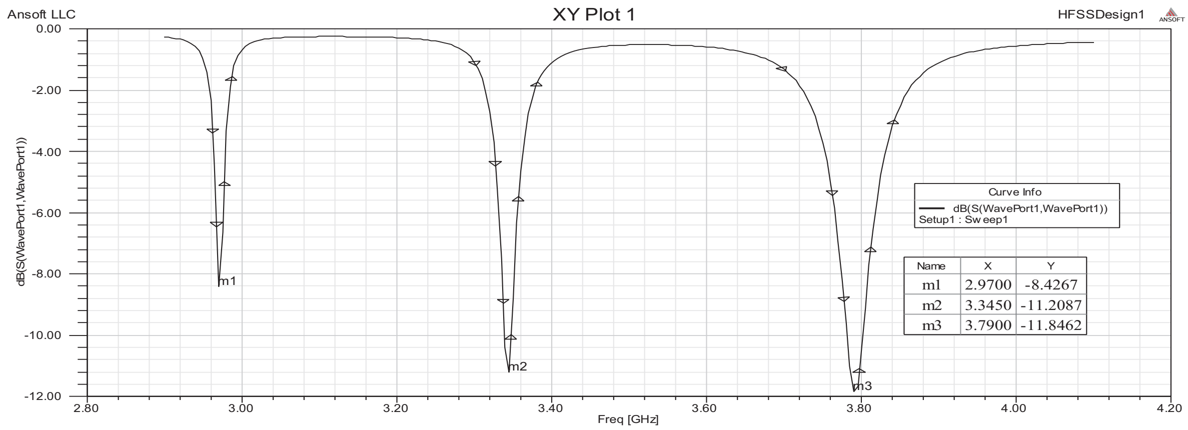


Fig.3 Return Loss of the resonant CRLH TL antenna.

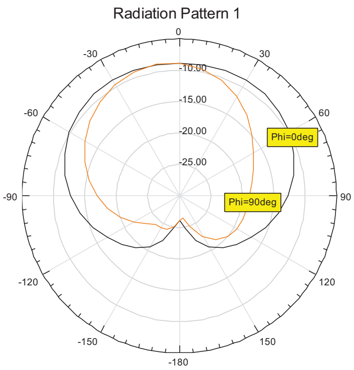


Fig.5 Radiation pattern for n=0 mode (phi=0^0 and phi=90^0)

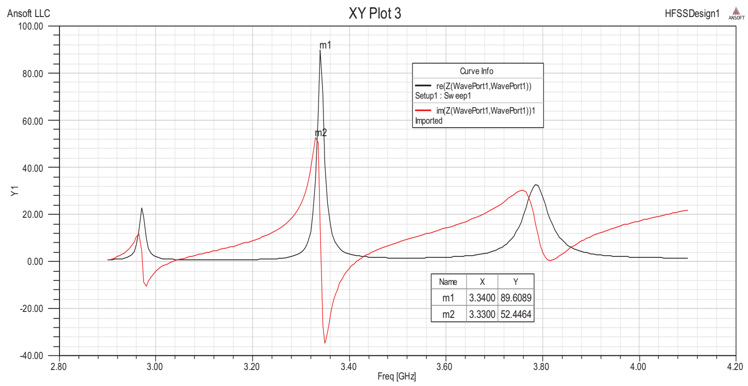


Fig.6 CRLH antenna input impedance

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