

# COMPOSITE RIGHT/LEFT HANDED TRANSMISSION LINE BASED ON OPEN SLOT SPLIT RING RESONATOR

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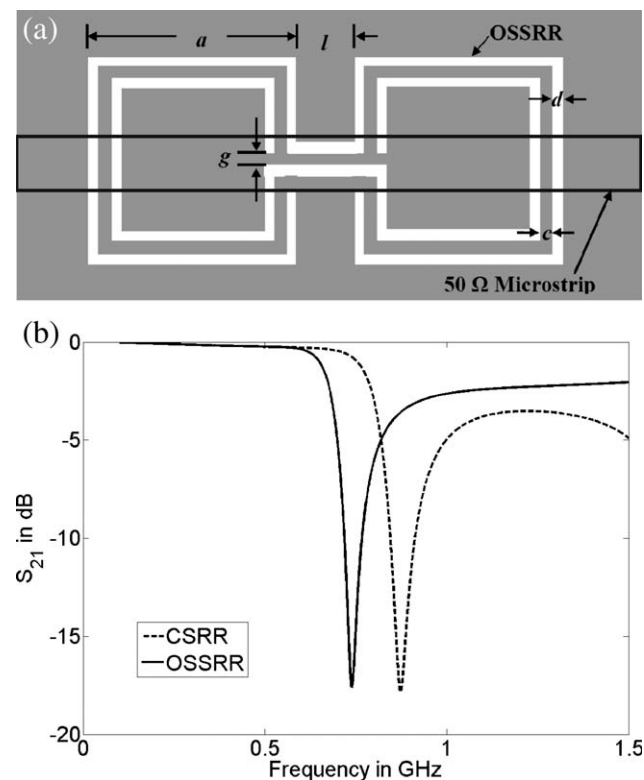
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**ABSTRACT:** In this article, an open slot split ring resonator (OSSRR) is introduced to realize a composite right/left handed (CRLH) transmission line structure in microstrip technology. The CRLH line is synthesized by etching OSSRR in the ground plane and interdigital capacitor in the microstrip line. Simulated and measured scattering parameter of the structure is presented. The dispersion characteristic of proposed structure is also shown. The proposed structure is 15% smaller than the conventional complementary split ring resonator structure. © 2010 Wiley Periodicals, Inc. *Microwave Opt Technol Lett* 52: 1729–1731, 2010; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.25330

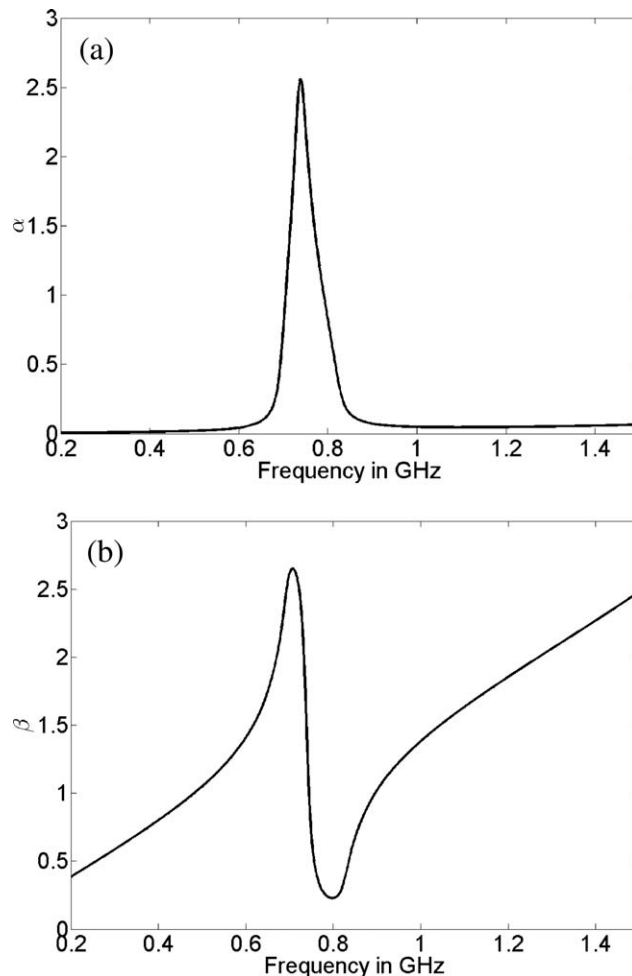
**Key words:** metamaterial; left handed transmission line; split ring resonators

## 1. INTRODUCTION

Over the past few years, a new type of artificial materials called as metamaterials has attracted the attention of many researchers. The presence of such material with negative permittivity ( $\epsilon$ ) and negative permeability ( $\mu$ ) was theoretically investigated by a Russian scientist Veselago in 1968 [1]. After few decades, Pendry [2, 3] experimentally demonstrated the existence of negative  $\epsilon$  and negative  $\mu$  materials. In such metamaterials the wave prop-



**Figure 1** (a) Schematic of OSSRR (b) Simulated scattering parameter of OSSRR

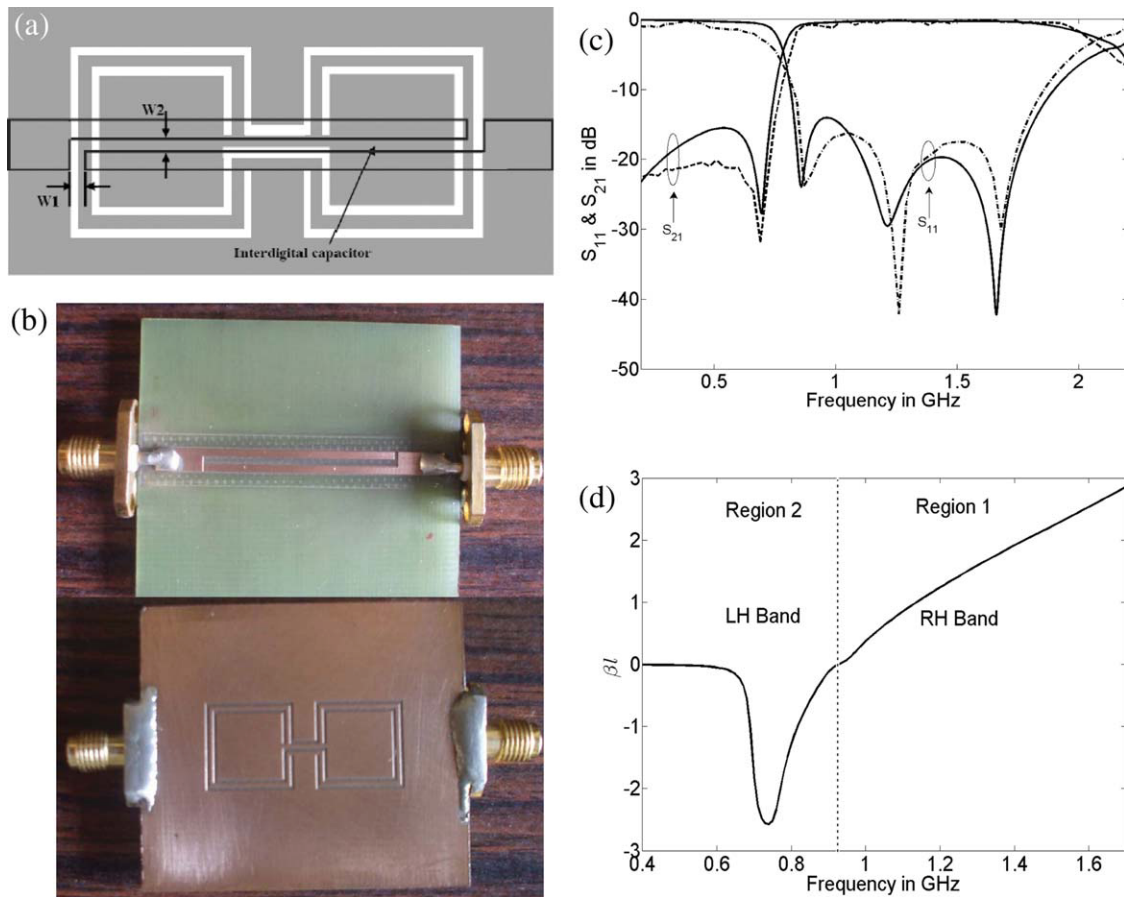


**Figure 2** Propagation characteristics of OSSRR (a) attenuation constant and (b) phase constant

agation is governed by the left handed rule instead of right handed rule. So these artificial materials are also called as left handed (LH) materials or backward wave materials. In LH material, the electromagnetic wave propagation is opposite to that of energy flow. As a result, the electromagnetic waves propagating through metamaterials have phase and group velocities in opposite direction to each other. Left handed materials can be realized by either using transmission line approach (TL) or resonant type approach. In resonant type approach, the host line is loaded with various types of resonant structures and series gaps to exhibit left handed property. In [4], complementary split ring resonator (CSRR) is used to realize the composite Right/Left handed (CRLH) transmission line. Planar transmission line medium with negative refractive index based on complementary omega like structure is proposed in [5]. Recently, negative index metamaterials composed of triangular open-loop resonator and wire structures are demonstrated in [6]. In [7], CRLH transmission line is implemented by combining open split ring resonators (OSRRs) and open complementary split ring resonators (OCSRRs) using CPW technology. Very recently, compact CRLH transmission line is synthesized using complementary spiral resonator (CSR) [8]. In this communication, we propose a new, compact planar CRLH transmission line for microstrip technology.

## 2. REALIZATION OF CRLH TRANSMISSION LINE

CRLH planar transmission line can be synthesized by OSSRR and interdigital capacitor. OSSRR is modified and negative



**Figure 3** (a) Schematic of CRLH TL ( $W_1 = 0.6$  mm,  $W_2 = 1$  mm) (b) Photograph of proposed structure (c) Simulated (solid line) and measured (dashed line) scattering parameters, and (d) dispersion relation of CRLH TL. [Color figure can be viewed in the online issue, which is available at [www.interscience.wiley.com](http://www.interscience.wiley.com)]

image of the open split ring resonator. The shape of OSRR is slightly modified and its negative image is etched out from the ground plane to obtain OSSRR. Similar structure in coplanar wave guide technology is proposed for design of wide bandpass filter [9]. But here, for the first time in microstrip technology, OSSRR is utilized to synthesize CRLH transmission line. OSSRR is formed by two concentric square slots having openings at the same side and are connected to another set of concentric square slots [refer to Fig. 1(a)]. This structure is placed under the  $50\ \Omega$  microstrip line. The OSSRR with the dimensions  $a = 12$  mm,  $c = 0.5$  mm,  $d = 0.5$  mm,  $g = 0.5$  mm, and  $l = 3$  mm is placed under a  $50\ \Omega$  microstrip line and simulated using

full wave simulator IE3D [10]. FR4 substrate with dielectric constant  $\epsilon_r = 4.4$  and height  $h = 1.6$  mm is used for all simulations. At resonant frequency  $f_r = 0.74$  GHz, a sharp stopband is observed. To compare the OSSRR with CSRR, the CSRR with same dimensions as OSSRR is simulated and its resonant frequency is observed as  $f_r = 0.88$  GHz. As the circumference of the OSSRR is larger than the CSRR, it results in increased inductance which decreases the resonance frequency of OSSRR. Figure 1 shows the structure of OSSRR and its simulated scattering parameters. To understand the propagation characteristics of OSSRR, attenuation constant and phase constant are plotted in Figure 2 using the following equations [11].

$$\gamma = \frac{1}{l} \cos^{-1} \left[ \frac{\{(1 + S_{11})(1 - S_{22}) + S_{12}S_{21}\} + \frac{Z_{01}}{Z_{02}} \{(1 - S_{11})(1 + S_{22}) + S_{12}S_{21}\}}{4S_{21}} \right] \quad (1)$$

where  $Z_{01}$  and  $Z_{02}$  are the port impedances and  $l$  is the length of the cell. The real part of  $\gamma$  is attenuation constant and imaginary part is phase constant. From the figures, it can be observed that within the stopband, attenuation constant is dominant.

Figure 3(a) shows the structure of CRLH line realized using OSSRR and Interdigital capacitor. Two finger interdigital capac-

itor is embedded in the microstrip line to introduce series capacitance. Simulated and measured scattering parameter of the structure is shown in Figure 3(c). To understand the wave propagation in the CRLH TL structure, the dispersion characteristic is obtained using (region 1) and plotted in Figure 3(d). In region 1, the phase and group velocities are in the same direction and

in region 2 both are in opposite direction. This indicates region 1 is Right handed (RH) band and region 2 is left handed (LH) band. The transition frequency between LH band and RH band is observed at 0.92 GHz. At the transition frequency phase constant is zero. By inspecting the dispersion relation, we can observe that the proposed structure exhibit both right handed and left handed characteristics. Compared to the work reported in [8], the proposed structure does not involve any via holes. So complexity is reduced from fabrication point of view.

### 3. CONCLUSION

For the first time in microstrip technology, a new CRLH TL using OSSRR is synthesized and demonstrated using EM simulations. The fabricated results are in close agreement with the simulated results. Propagation characteristics of OSSRR and CRLH transmission line are also investigated. Since the OSSRR resonant frequency is 15% lesser than the CSRR, size of the proposed structure is small when compared to the previous work. Hence circuit miniaturization of microwave devices is possible.

### ACKNOWLEDGMENTS

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## RESONANT FREQUENCY TUNABLE DUAL-BAND MONOPOLE ANTENNA WITH THE GROUND SHORTED INSET SLEEVE

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**ABSTRACT:** The simple printed monopole antenna for dual-band operation with tunability is proposed. It uses the ground shorted inset sleeve of which the length is controlled. This type of antenna can easily produce dual-band characteristics without any additional metal strips or radiating elements. The omni-directional radiation patterns at both design frequencies are similar to those of a conventional monopole. Details of the proposed monopole design and experimental results are demonstrated in this letter. © 2010 Wiley Periodicals, Inc. *Microwave Opt Technol Lett* 52: 1731–1733, 2010; Published online in Wiley InterScience (www.interscience.wiley.com). DOI 10.1002/mop.25308

**Key words:** microstrip monopole antenna; inset sleeve; resonant frequency tunable antenna

### 1. INTRODUCTION

Monopole antennas have been used for the various modern communication systems. Their development has been steady due to their simple design, low cost, and light weight. Printed monopole antennas have been also investigated due to their attractive features such as easy fabrication and omni-radiation pattern. In recent years, many kinds of printed monopole antennas with dual-band operations have been reported [1–5]. A printed C-shaped monopole antenna using a shorted parasitic element for dual-band was reported in Ref. [1], in which dual-band operation can be achieved by the ground shorted parasitic element, which generates a wide operating band for the upper band. In Ref. [2], a meandered strip and conducting triangular section have been utilized for dual-band characteristics. Due to the meandered wire, which generates an additional mode in the vicinity of the upper mode, and the conducting triangular section, which provides good impedance matching for the two bands, dual-band characteristics have been achieved. The monopole antennas reported in Refs. [3, 4] have employed branched metal strips for dual frequency resonant modes. In Ref. [5], a tapered bent folded monopole with dual frequency operation was proposed for wireless local area network systems. In this letter, the ground shorted inset sleeve is utilized as a novel technique for dual-band operation that is applied to a printed monopole of coplanar waveguide (CPW) type. And, the length of the inset sleeve is controlled by the PIN diode for resonant frequency control. This inset sleeve technique differs from the conventional sleeve technique for broad impedance bandwidth. In the proposed antenna, the omni-directional radiation patterns at both operating frequencies can be also obtained. The simulation and optimization were performed using commercial software Ansoft HFSS based on the finite element method.

### 2. ANTENNA DESIGN

Figure 1(a) shows the geometry of the CPW-fed planar inset sleeve monopole antenna (PISMA) for dual-band operation. The