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***Research paper***



# CRLH-Transmission Line for Design and Analysis of Compact Microstrip Patch Antenna

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**Abstract**

The composite right/left-hand transmission line is displayed as an ordinary Transmission Line having two type of properties, first one left-hand properties and second one right-hand properties. By demonstrating a metamaterial based CRLH as a comparing TL, TL hypothesis can be utilized for analysis and plan one-, two-, or even three-dimensional CRLH metamaterials. The structure of CRLH-TL has the arrangement of metamaterial transmission line (TL) made out clearly by composite right-/left-hand (CRLH) unit cells. The Composite Right Left Handed (CRLH) transmission lines are on recent displayed as a kind of artificial transmission lines with various microwave applications. This examination take a gander at various types of execution of these transmission lines and the impact over the execution. The examination is passed on utilizing both lumped parts and microstrip utilization of the unit cells. As a summed up, show for CRLH TL provides for an incredible level of excellent stage reaction, for instance, double band task, nonlinear frequency, bandwidth capacity upgrade, and furthermore the presence of basic frequency with zero phase velocity. In this paper, we discuss about a Microstrip Patch antenna which is based on composite right/left-hand transmission line.

***Keywords***: *CRLH-Transmission Line, Metamaterial, Microstrip Patch Antenna.*

## 1. Introduction

Transmission lines are basic parts in current circumstance of mobile network, as are utilized to associate reception apparatuses to transmitters and receiving, or as full components in oscillators and filters, for impedance coordinating in mixer and amplifiers [1]. Exactly if the electrical wavelengths is very small or equal to the physical estimations of a network, the length ends up closure into basic and transmission line speculation is utilized instead of standard circuit examination. Henceforth, high-frequency transmission lines can be consider as transmission lines that are proposed to pass on electromagnetic waves. The fundamental electromagnetic properties of right-hand, left-hand or composite right/left hand transmission lines and the physical properties of left-hand materials are re-seen in this fragment in light of a general transmission line approach.

The Russian physicist Veselago in 1968 [2] firstly examined the wave characteristics in a material with a negative electric permittivity and a negative permeability resulting such type of material is known as a left-handed (LH) material because the electric field, attractive field, and the wave vector of an electromagnetic wave support or follow the left-hand rule. [3. 4]. A couple of application have been investigated with the help of introduction of composite right/left-handed (CRLH) transmission line [5, 6].

The composite right/left-handed (CRLH) transmission line (TL) [7] is a TL made out of the intermittent reiteration of a unit cell containing a series wise arrangement of inductance and a shunt capacitance and also an arrangement capacitance and a shunt inductance. At lower frequencies, the arrangement capacitance and shunt inductance give left-handedness which are identified with the parallel phase and group velocities) [7, 8]. The parallel stage and group velocities are basically used to identified the series inductance and shunt capacitance at higher frequency.

The CRLH TL is typically non-resonating and hence shows the upsides of lower misfortune and expansive data transmission than full sort left-hand (LH) materials [9]. Moreover, the CRLH TL appropriately addresses real dispersed LH structures [7], which have unavoidable conveyed parasitic series inductance and shunt capacitance, in appear differently in relation to the glorified LH TL which speaks to only an arrangement capacitance and a shunt inductance in the unit cell.

Considering the CRLH cells open another class of gadgets and applications, for instance, in reverse wave directional couplers [10], tunable radiation edge and beamwidth reception apparatuses [11], zeroth-mastermind resonator radio wires [12]. Over the latest couple of years, CPW (Co-Planar Waveguide) CRLH based contraptions were examined and made on semiconductor substrate, for instance, band pass channels [13], resonating antennas [14] and directional couplers [15]. An unadulterated type of LH transmission line [16] can't be physically recognized as a result of RH parasitic effects. Hence, a LH transmission line is a more extensive model of a composite right/left-hand (CRLH) transmission line, which similarly fuses RH attributes. The general model of a CRLH TL is showed up in Fig. 1 and involves a series RH inductance LR (Inductor R) (a series LH capacitance CL(capacitor L), a shunt RH capacitance CR (capacitor R), and a shunt inductance LL (Inductor L).

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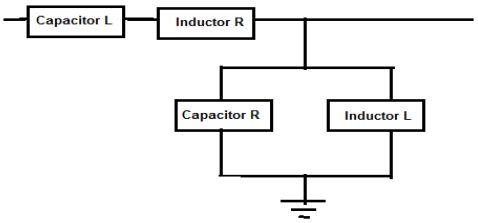



**Fig 1:** General Model of CRLH Transmission Line

## 2. Principles to realize the composite right/left handed transmission line

The conclude standards of the composite right/left hand transmission line are clarified as underneath:

• The reverse handedness at the high frequencies and low frequencies are indicated or represented by the Dual band composite right/left hand transmission line, or the structure of standard CRLH TL. Meanwhile, applying reasonable methodology, D-CRLH TL reliably shows a sharp stopband. The D-CRLH TL may be consider as a base to construct notch filter and a double band balun.

• The Transmission line (LT-TL) based on cross section define a good with the standard right-hand (RH) TL and over a wide range of frequency, a consistent stage contrast in the phase response.

• The Inter digital capacitors are analyse and define that the Inter digital capacitors alone can be consider as a left-hand transmission line. The proper calculation of both component (inductors and capacitors) in the respective circuit shows that it is controlled by the estimations of FSIDC [16].

## 3. CRLH Unit Cell

A CRLH unit cell [17] is a blend of round and hollow formed metal (large immaculate electric conveyor) and microstrip holes whose conduct is relative to the mix of series capacitors and shunt inductors independently. Basically the Metamaterial based unit cell may be consider as transmission line approach of unit cell. The transmission line approach is define the combination of shunt inductance and series capacitance. The basic circuits of a CRLH-unit cell is shown in Fig.2 (a) and (b).

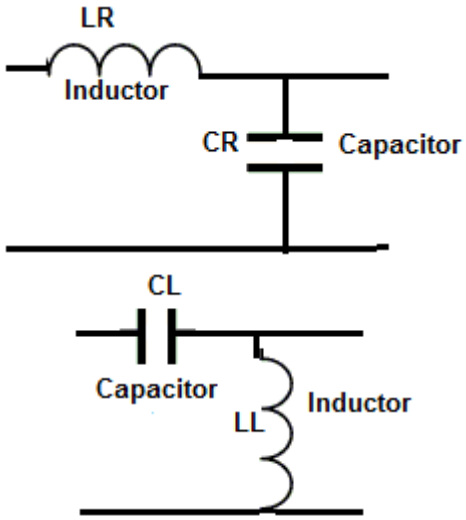



**Fig. 2**. Equivalent circuits model of a unit cell of (a) RH-TL (b) and LH-TL.

In the following circuits, $L_R$, $C_R$ and $L_L$, $C_L$ are define the values of inductance and capacitance for RH-TL and LH-TL respectively. To analysis the CRLH- Unit cell, the value of propagation constant and the characteristic impedance will be [29]

$$\beta_{RH\text{-}TL} = \omega \sqrt{(L_R C_R} \quad (1)$$

$$Z_{CRH\text{-}TL} = \sqrt{(L_R / C_R} \quad (2)$$

$$\beta_{LH\text{-}TL} = (-)\ 1/\ \omega \sqrt{(L_L C_L} \quad (3)$$

$$Z_{CLH\text{-}TL} = \sqrt{(L_L / C_L} \quad (4)$$

Total propagation constant is

$$\beta = \beta_{RH\text{-}TL} + \beta_{LH\text{-}T} \quad (5)$$

$$= \omega \sqrt{(L_R C_R)} - 1/ (\omega \sqrt{(L_L C_L)} \quad (6)$$

The equations (1), (2), (3) and (4) are consider as the dispersion equations which are direct belong to Right Hand Transmission Line and Left Hand Transmission Line respectively.

The Maxwell equation are basically used to define the relation between electric field, magnetic field, propagation constant, and Poynting vector for a transverse electromagnetic (TEM) plane wave, as shown in fig (see Fig. 3).

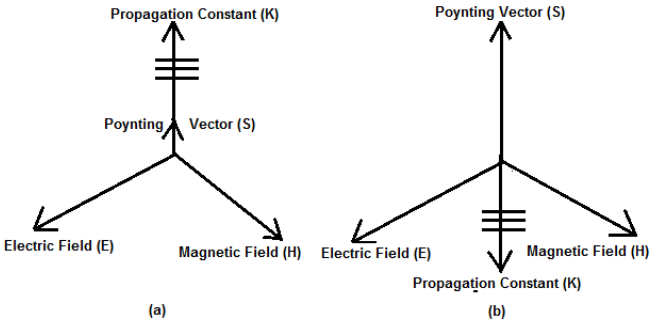



**Fig. 3**: relation between Electric field (E), magnetic field (H), propagation constant (k), and Poynting vector (S) for (a) Right-handed medium. (b) Left-handed medium

By using the above relation, the phase velocity which is parallel to the direction of phase propagation & Group Velocity, which is parallel to the direction of power flow or Poynting vector will be

$$vp = \omega / \beta \quad (7)$$

$$vg = d\omega / d\beta \quad (8)$$

So that, because of spreading of the waves demonstrating anti parallel stage and group velocities despite the Left Hand media, called forwarded [18]. Similarly, it takes starting now and into the foreseeable future, since vitality transfer is persistently outward from the source, the heading of spread of the wave fronts in a Left Hand medium is really inside to the source. Notwithstanding the manner in which that Veselago might be viewed as the father of left-hand media [17], over 3 decades go until the point that the standard Left Hand material was considered and introduce by Smith et al. in 2000 [19]. This metamaterials describe the composite structure of conducting wires and split ring resonators (SRRs) [20].

## 4. Dispersion Diagram of CRLH-TL

The CRLH transmission line model define that it is a combination of band-pass channel, low-pass and high pass channels, separately [20]. The CRLH-TL dispersion diagram (fig 4), indicates the change in propagation constant wrt frequency. The series and shunt resonances will be-

$$\omega se \text{ (Series resonances)} = \omega s = 1/ \sqrt{L_R C_L} \quad (9)$$

$$\omega sh \text{ (Shunt resonances)} = \omega p = 1/ \sqrt{L_L C_R}, \text{ respectively} \quad (10)$$

This shows that Series resonances less than shunt resonances but some time it is possible that shunt resonances may be greater than Series resonances. A pure Right Hand line (where $L_L = C_L$ may be $\infty$) and pure Left Hand line (where $L_R = C_R$ may be $\infty$) is describe by [23]. The propagation may be consider as backward when group velocity and phase velocity both have opposite sign (if $\omega < \min(\omega s, \omega p)$) but it may be forwarded nature when group velocity and phase velocity both have same sign ($\omega > \max(\omega s, \omega p)$).At low and high frequencies, the transmission characteristics of a CRLH Transmission line will in general proceed as absolutely Left Hand and Right Hand transmission lines, independently this is an immediate consequence of periodicity, since a RH transmission line exhibits an all-pass reaction at all frequencies. A transmission line is said to be unbalanced when the series resonance, $\omega s$, does not agree with the shunt resonance, $\omega p$, resulting a stop band appears between these frequencies and a transmission line is said to be balanced when these frequencies are comparable, $\omega s = \omega p = \omega_0$. [21].Figure 4 demonstrates a typically scattering outline of consistent LH to RH transition [22].

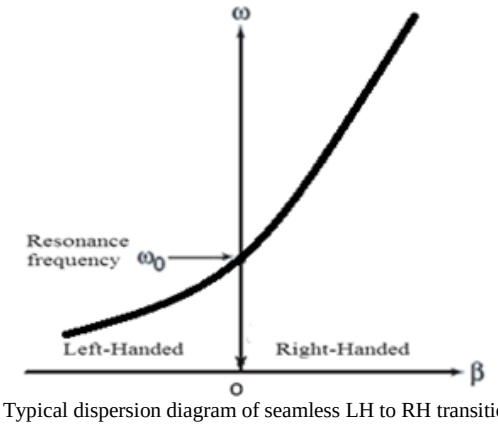



**Fig. 4:** Typical dispersion diagram of seamless LH to RH transition [23].

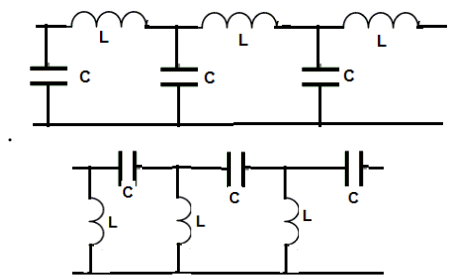
## 5. Theoretical Analysis of Composite Right/Left-Handed (CRLH)

A concept about the composite right/left hand (CRLH) transmission line, which included the combination of both right-hand and Left Hand properties and expanded the transmission line approach for metamaterial design, was proposed and inspected in [24]. An unadulterated LH transmission line can't be physically recognized as a result of RH parasitic effects. Presently around, a LH transmission line should be portrayed using a more extensive model of a composite right/left-hand (CRLH) transmission line, which furthermore consolidates RH attributes.

A CRLH transmission lines have been proposed in [25] with astounding phase response of the CRLH transmission line, including dual band task, bandwidth enhancement, nonlinear reliance of the recurrence, and the presence of fundamental frequency with zero phase velocity.

The guided-wave applications and transmitted wave uses of CRLH TL including recurrence examination and electronically filtered leaky-wave antennas, zeroth order resonating antenna and so forth;, were in like manner displayed [26].

A right-hand transmission line and a Left Hand Transmission line is shown in figure 5(a) & 5 (b), which contains series inductors and shunt capacitors & shunt inductors and series capacitors. Sometime inductors in the right-hand transmission line may be replaced by capacitors in the left-hand transmission line model, and capacitors may be replaced by inductors. It is an ideal model, which does not exist in nature




(a) Pure RH transmission line (b) Pure LH transmission line

**Fig. 5:**. Equivalent circuit model of RH and LH transmission line

A transmission line circuit which consists of series resonators $L_R$ and $C_L$ and shunt resonators $C_R$ and $L_L$, where the word "L" and "R" represent the left-hand and right hand, differentially, known as Composite Right-Left Hand Transmission Line (CRLH-TL) in other words CRLH-TL is a combination of left-hand and right-hand transmission line. At lower frequency, $C_L$ and $L_L$ are dominant, the transmission line indicates left-hand characteristics but at high frequency, $L_R$ and $C_R$ are dominant, the transmission line demonstrates right-hand characteristics [21].

The combined circuit model of Left Hand Transmission & Right Hand Transmission Line (CRLH-TL) is shown in Fig. 6, which contains for per unit length impedance Z (a for each unit-length inductance $L_R$ with a times-unit-length capacitance $C_L$) and for per unit-length consent Y (a for each unit-length capacitance $C_R$ in parallel with a times-unit-length inductance $L_L$). When Z and Y have zeros at a comparative frequency, the CRLH transmission are classified "balanced" [27].

The serial impedance (Z) and shunt admittance (Y) are

$$Z = j(\omega_{LR} - 1/\omega_{CL}) \quad (11)$$

$$Y = j(\omega_{CR} - 1/\omega_{LL}) \quad (12)$$

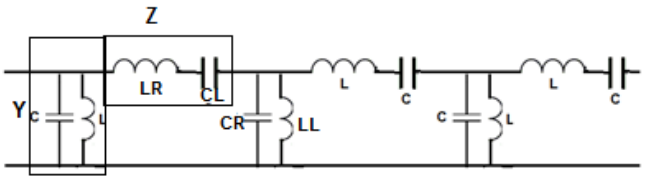



**Fig. 6**:. Equivalent circuit model of composite right/left-handed transmission line

Because of the absence condition of band-gap between left-handed and right-handed regions, the balanced condition will be satisfied, which is

$$L_L C_R = L_R C_L \quad (13)$$

A CRLH-TL contributes LH property at lower frequencies and RH at higher frequencies with a transition frequency. It has been developed that under balanced condition when the series and shunt resonances are equal.

The characteristic impedance of the composite right/left-handed transmission line is

$$Z_E = Z_L = Z_R \quad (14)$$

Where $Z_L = \sqrt{(L_L / C_L)}$ and $Z_R = \sqrt{(L_R / C_R)}$ are represent the pure left-handed and right-handed characteristic impedances which are frequency independent with the homogenous transmission line approach.

The cut-off frequencies of the composite right/left-handed transmission line is

$$\omega_{CL} = \omega_R \sqrt{(1 + (\omega_L / \omega_R) - 1} \quad \textbf{(15)}$$

$$\omega_{CR} = \omega_R \sqrt{(1 + (\omega_L / \omega_R) + 1} \quad \textbf{(16)}$$

$\omega_L = \sqrt{(1/ LL. CL)}$ &$\omega_R = \sqrt{(1/ LR. CR)}$ are the resonant frequencies of the left-handed and right-handed LC circuit, respectively.
The transition frequency can be written as

$$\omega_0^2 = \omega_{CL} . \omega_{CR} = \omega_L . \omega_R = \sqrt{(1/ L_L L_R C_L C_R)} \quad (17)$$

Considering the degree of freedom in the composite right/left-handed transmission linedesign with periodic elements, there are four parameters, namely $L_L$, $C_L$, $L_R$, and $C_R$. Whenthe balanced condition is applied, there are only three independent parameters left [28].

## 6. CRLH-TL and Resonant Type Approach

Since CRLH-TL are not exist openly in nature, these structures are constructed using some passive components like as inductors, capacitors, etc. Preliminary CRLH lines were represented first time by Caloz et al. in microstrip advancement [29]. The open segments in charge of in backward propagation in the two setups were coordinated by semi-lumped portions, for instance, series capacitive holes and shunt metallic inductive strips. This prompt execution is implied as LC organize usage or CL-stacked methodology [30]. Then again, transmission-line metamaterials including a CRLH lead can moreover be created, and it is so-called resonant-type approach [30]. This affirmation involves a host transmission line stacked with two type of resonator, sub wavelength resonators and responsive segments (inductors or capacitors), the full particles being Split ring resonators (SRRs).
The most important structure is provided by Martín et al. [31], and was mindfully in light of and indistinguishable to the first Smith's LH structure. Specifically, a waveguide may be a coplanar was irregularly stacked with sets of SRRs and flag to-ground inductive strips. The SRRs were scratched on the back of the substrate, and underneath the spaces of the CPW remembering the true objective to enhance line-to-resonator magnetic coupling [32].
Another likelihood to realize a CRLH response in perspective of the full sort approach is by strategies for series capacitive gaps, and the proportional type of the SRR, that is, the indicated correlative split-ring resonator (CSRR) [56]. A lumped-component equivalent circuit models, helpful to support a unit cell which is individual and a resonant type approach where a sub-wavelength resonator is used. This resonance type approach also support to resonance response of CRLH-Transmission Line. In 2003 & in 2005 two authors, named Martín et al. [31] and Baena et al. [32], proposed a CRLH-Transmission Line based on SRR-and CSRR models. But in 2008, two authors, named Aznar et al. [33] and Bonache et al. [34], update and correct the previous concept which is proposed in 2003 & in 2005.

## 7. Transmission Lines and Applications

According to basic concept of a typical transmission lines, a transmission line follow the rule of Right Hand which is define the relation between electric field, magnetic field and wave vectors. A transmission line is the material medium or structure that structures all of part of a route beginning with one place then onto the following one for planning the transmission of energy, for instance, electromagnetic waves or acoustic waves, and furthermore electric power transmission [35]. Reasonable sorts of electrical transmission line fuse coaxial connection, microstrip line, strip lines, and balanced lines et cetera which are depicted in the accompanying[36].
In numerous electric circuits, the signal voltage on the wire at a specific time turned to be equivalent at all focuses at lower frequencies. Therefore the length of the wires associating the components can be overlooked generally. In spite of the fact that, when the signal incorporates high frequency components segments whose wavelengths can be contrasted with or not as much as the length of the wire, the voltage changes in a period interim practically identical to time taken by the signal flow in wire. Therefore for this situation the length winds up to be the primary one and the wire should not be treated as a transmission line [37]. For the analysis point of view, an equivalent circuit model of an electrical transmission line is shown in fig 7, where it is equivalent as a two port network:

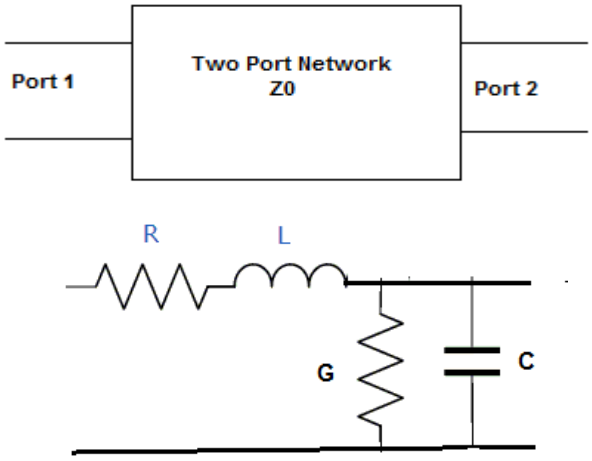



**Figure 7:** (a) Transmission line model: a two-port network, (b) Infinitesimal circuit model of a transmission line

First of all Oliver Heaviside [62], introduce the transmission line model [38], which is based on Maxwell's Equations. The model support a combination of active and passive elements (either in series or in shunt) as shown in Figure 7 (b), and the values of components is defined in terms of per unit length. The basic function of R, L, C, and G with respect to frequency is defined as [38]:
• A series resistor (in ohms per unit length) is used to define the concept of distributed resistance R of the conductors.
• A series inductor (in Henries per unit length) is used to define the concept of distributed inductance L (with respect to magnetic field around the wires, self-inductance, etc.).
• A shunt capacitor C (in Farads per unit length), is used to define the concept of a capacitance C between the two conductors.
• A conductance G which is connected between the signal wire and the return wire (in Siemens per unit length) is used to define the conductance G of the dielectric material
These above parameters or components are known as the fundamental line constants, from which the auxiliary line constants, these being the propagation constant, attenuation constant and phase constant, are determined Transmission lines left hand metamaterials properties. Firstly LH materials have been used and considered to construct SRRs structures. In any case, since full structures are lossy and slender united, a TL approach of LHMs has been created. Utilizing the transmission line speculation to depict and plan LH material was first exhibited in 2002 by Caloz gather [39] etc.

## 8. Conclusions

A general methodology about hypothesis idea and structure applications are presented in this paper. The Composite Right Left Handed Metamaterial is another built material that has unique properties of negative permittivity and negative penetrability. The principal logical diagram conditions on Composite Right Left Handed (CRLH) trans-mission lines and furthermore the circuit model of the metamaterial transmission line have been shown. From the past reference contemplates, the CRLH transmission line has been used as a piece of various microwave applications to develop an insignificant exertion and a lessened size gadgets.

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