Zeroth Order Resonator Antenna (ZORA) using CRLH Transmission Lines

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Abstract—A compact Zeroth Order Resonator Antenna (ZORA) is implemented as a part of course work for Radio Frequency Integrated Circuits and Systems (E8-242). This work is based on [1]. Due to the unique properties of Compact Right/Left Handed (CRLH) transmission lines, the size of the antenna is independent of the frequency of operation. This compact structure is made of two unit cells each comprising Metal Insulator Metal (MIM) capacitors, and short circuited shunt stubs. The size of the antenna was restricted to $2.6 \times 2 \text{ cm}$ for a design frequency of 2.4 GHz. The design has been verified using Advanced Design System (2009) Momentum simulator.

I. INTRODUCTION

CRLH Transmission lines and other applications based on it are derived from the idea of Metamaterials. They exhibit properties such as negative permittivity ($\epsilon$) and permeability ($\mu$). More commonly, they are referred as Left Handed Materials (LHM). Electric field, magnetic field and direction of propagation form a Left Handed (LH) triad.[2] Due to this the em-waves can have anti-parallel phase and group velocities. Transmission line approach to the development of LH materials resulted in CRLH lines. The basic structure of a CRLH line consists of many unit cells cascaded together. The structure of a unit cell is shown in the figure 1.

One of the interesting properties of CRLH line is that it is capable of supporting zeroth order resonator mode. The key implication is that CRLH line can support waves of infinite wavelength ($\lambda$). Due to this propagation constant $\beta$ is identically zero inside the CRLH line and there is no phase difference across the line. The zeroth order resonant frequency is independent of the size of the structure. It depends only on the reactive loadings of the line. Therefore, this results in compact antenna structures. As the voltage across any pair of nodes across the transmission line is zero at any instant of time, the resistive losses in the line are decreased. The author of [1] has proposed a compact ZORA. It consists of two unit cells. In order to reduce the antenna size and to improve its efficiency, two asymmetrical straight metal-strip lines are used for the shunt inductors instead of commonly used meander lines as in [4].

II. ANTENNA DESIGN

The subscripts L and R in the component variables denote “left” and “right” respectively. The series capacitor ($C_L$) is obtained by Metal Insulator metal (MIM) capacitors, shunt inductor ($L_L$) by a short circuit stub connected to CPW like ground plane. The parasitic inductor ($L_R$) and capacitance ($C_R$) is provided by the plates of MIM capacitor, and shunt stub respectively. A perspective view is shown in the figure 2. A CRLH ZORA can be terminated in an open or short circuit. A short circuit termination gives a zeroth order resonant frequency ($f_{sc}$) determined by series inductor and capacitor. Whereas, an open circuit termination results in the resonant frequency ($f_{oc}$) determined by the shunt LC circuit.

$$f_{sc} = \frac{1}{2\pi\sqrt{L_L C_R}}$$

$$f_{oc} = \frac{1}{2\pi\sqrt{L_R C_L}}$$

The series MIM capacitor cannot radiate energy effectively with few cells. Therefore, mostly interdigital capacitors are used. But this may result in reduced impedance bandwidth, coupling between lines etc. Also, fabrication is difficult with
meander lines and inter digital capacitors. An open ended ZORA is preferred in [1]. The resulting structure mainly radiates from the shunt stub lines. Also, the orientation of the stubs can alter the radiation pattern. For a design frequency of 2.4 GHz, the unit cell parameters are $L_L = 11 \, nH$, $C_L = 1.5 \, pF$, $L_R = 1.1 \, nH$ and $C_R = 0.4 \, pF$. The shunt stubs are have a length of $\lambda/8$. Here, only shunt stub determines the frequency. The wavelength of propagation in a microstrip line, the value of width (W) and length (L) for the microstrip line are obtained from the Line calc function in ADS 2009. The input is coupled to CRLH line through a gap which is matched to a 50 $\Omega$ input line. Here, it was found to be 0.75 mm in length. The critical parameter in the design and implementation of this structure is the length and width of the shunt stub. Since, both $L_R$ and $C_L$ are realized by the same stub, these parameters are dependent on each other. Therefore, there is only one degree of freedom in choosing the required frequency. Also, for frequencies of the order of $1-2$ GHz, high value of $L_L$ is required. This may result in shunt stubs with widths that are too small to fabricate.

### III. Layout, Figures

The layout simulated in ADS2009 and the actual circuit is shown in the figure 3. $S_{11}$, measured at the input port is shown in the figure 4. The radiation pattern is shown in the figure 5.

### IV. Results

Experimentally, it has been found that current distribution is maximum along the shunt stub lines [1]. Since, the stub lines are located on both sides of the printed circuit board, radiation pattern has a significant backlobe. If a reflection coefficient of $-4 \, dB$ is considered to be tolerable, antenna has a bandwidth of 100 $MHz$. The cross filed radiation (perpendicular to the stubs) is small compared to the co-field radiation. Gain of $2.4 \, dB$ was measured at the design frequency. Half power beam width (with respect to E-field) is measured to be about 60°.

In [1], size of the antenna is given importance. Only two unit cells are used. Antenna with better performance can be obtained if other factors are also included in the design such as the spatial orientation of the stubs, increasing the number of unit cells etc. for better directivity.

### References


Figure 4. Reflection coefficient ($S_{11}$)

Figure 5. Radiation Pattern