Design and Analysis of Circularly Polarized Broadband Patch Antenna Using Quasi-Lumped Impedance Surface

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Abstract- Growing uses of Micro strip Patch in wireless communications, have encouraged the rapid development of the Patch antenna for RF and microwave applications. This paper is a comparative study and documentation of the design of circularly polarized broadband antenna and effect of lumped parameters on the antenna design. The incredible highlights of different review papers are incorporate in this manuscript.

Index Terms- Microstrip Patch Antenna (MPA), Quasi-Lumped Parameter, Figure of Merits, Axial Ratio, Circular polarization.

I. INTRODUCTION

The Microstrip patch antenna are comprehensively used in microwave applications in perspective of the few points of intrigue they have, i.e., manufacturability, repeatability etc.The performance requirements of patch antennais a function of width (W), thickness (t), relative dielectric constant (εr) and the ground (conducting) plane.The fields in the microstrip extend within two media first one is air above and second one is dielectric belowso that the structure is inhomogeneous. Due to this inhomogeneous nature,with the presence of the two guided-wave media, the waves in a microstrip line cannot vanished the longitudinal componentsof magnetic and electric fields.we know that the propagation velocities will depend notonly on the material properties, but also on the physical dimensions of the microstrip.

When the longitudinal components of the fields for the dominant mode of a microstripline remain very much smaller than the transverse components, they may beneglected. In this case, the dominant mode then behaves like a TEM mode, and theTEM transmission line theory is applicable for the microstrip line as well. This is called the quasi-TEM approximation and it is valid over most of the operating frequencyranges of microstrip.

The contents of the paper are organized as follows: Section IIdescribe, different types of resonators based on discontinuities. Section III discuss the basic concepts and design equations for Quasilumpedelements. And finally, a conclusion is reached in section IV.

II. CLASSIFICATION OF RESONATORS AND DISCONTINUITIES

There are different types of resonators, depending upon the shape andperformance characteristic of the resonator, which is classified as Single mode, Dual mode, Triple mode and Quadruple mode.

Microstrip discontinuities commonly encountered in the layout of practical antenna include steps, open-ends, bends, gaps, and junctions. Figure.1, 2, 3 and 4 illustrates all of the above discontinuities structures and their equivalent circuits. The effects of discontinuities can be frequently used in the patch antenna design.

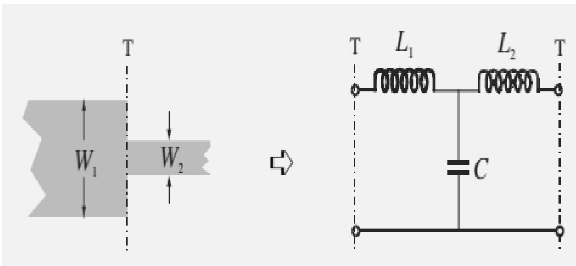

Figure.1 Microstrip step discontinuities.

The capacitance and inductances of the equivalent circuit indicated in Figure 1 for a symmetrical steps can be approximated by the following formulation.

Likewise different discontinuity are used for design of microstrip antenna by calculating required parameters.

$$c = 0.00137h\frac{\sqrt{\varepsilon_{re1}}}{Z_{c1}}\left(1 - \frac{W_2}{W_1}\right)\left(\frac{\varepsilon_{re1}+0.3}{\varepsilon_{re1}-0.258}\right)\left(\frac{\frac{W_1}{h}+0.264}{\frac{W_1}{h}+0.8}\right)(pF) \ldots\ldots\ldots\ldots\ldots (1)$$

$$L_1 = \frac{L_{W1}}{L_{W1}+L_{W2}}L, \qquad L_2 = \frac{L_{W2}}{L_{W1}+L_{W2}}L \ldots\ldots (2)$$

Where,

$$L_{wi} = \frac{Z_{ci}\sqrt{\varepsilon_{rei}}}{c} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

$$L = 0.000987h\left(1 - \frac{Z_{c1}}{Z_{c2}}\sqrt{\frac{\varepsilon_{re1}}{\varepsilon_{re2}}}\right)^2 \ (nH) \ldots\ldots (4)$$

At the open end of a microstrip line with a width of W, the fields do not stop abruptly but extend slightly further due to the effect of the fringing field. This effect can be modeled either with an equivalent shunt capacitance Cp or with an equivalent length of transmission line Δl, as shown in Figure2. The relation between the two equivalent parameters may be found by

$$\Delta l = \frac{cZ_cZ_p}{\sqrt{\varepsilon_{re}}} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where c is the light velocity in free space. A closed-form expression for Δl/h is given by

$$\frac{\Delta l}{h} = \frac{\xi_1\xi_3\xi_5}{\xi_4} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where

$$\xi_1 = 0.434907\frac{\varepsilon_{re}^{0.81} + 0.26\left(W/_h\right)^{0.8544} + 0.236}{\varepsilon_{re}^{0.81} - 0.189\left(W/_h\right)^{0.8544} + 0.87}$$

$$\xi_2 = 1 + \frac{\left(W/_h\right)^{0.371}}{2.35\varepsilon_r + 1}$$

$$\xi_3 = 1 + \frac{1 + 0.5274\tan^{-1}[0.084\left(W/_h\right)^{1.9413/\xi_2}}{\varepsilon_{re}^{0.9236}}$$

$$\xi_4 = 1 + 0.037\tan^{-1}[0.067\left(W/_h\right)^{1.456}][6 - 5\,exp[0.036(1 - \varepsilon_r)\ \ ]$$

$$\xi_5 = 1 - 0.218\,exp[-7.5\frac{W}{h}$$

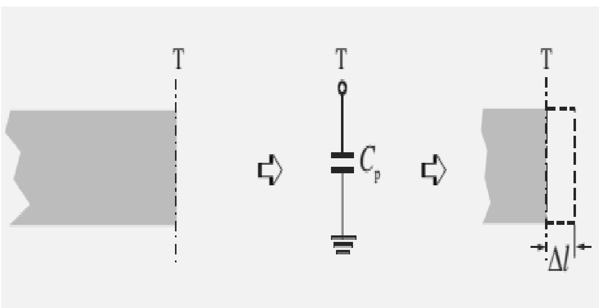

Figure.2 Microstrip open-end discontinuities

A microstrip gap can be represented by an equivalent circuit, as shown in Figure 3. The shunt and series capacitances Cp and Cg may be determined by

Cp = 0.5Ce

Cg = 0.5Co – 0.25Ce

Where

$$\frac{C_0}{w}\left(\frac{pF}{m}\right) = \left(\frac{\varepsilon_r}{9.6}\right)^{0.8}\left(\frac{s}{W}\right)^{m_0} \exp(k_0)$$

$$\frac{C_e}{w}\left(\frac{pF}{m}\right) = 12\left(\frac{\varepsilon_r}{9.6}\right)^{0.9}\left(\frac{s}{W}\right)^{m_e} \exp(k_0)$$

With

$$m_0 = \frac{W}{h}\left[0.619\,log\left(W/_h\right) - 0.3853\right]$$

$$for\ 0.1 \le \frac{s}{W} \le 1.0$$

$$k_0 = 4.26 - 1.453log\left(W/_h\right)$$

$$m_0 = 0.8675$$

$$for\ 0.1 \le \frac{s}{W} \le 0.3$$

$$k_e = 2.043\left(\frac{W}{h}\right)^{0.12}$$

$$m_0 = \frac{1.565}{\left(\frac{W}{h}\right)^{0.16}} - 1$$

$$for\ 0.3 \le \frac{s}{W} \le 1.0$$

$$k_e = 1.97 - \left(\frac{0.03}{\frac{W}{h}}\right)$$

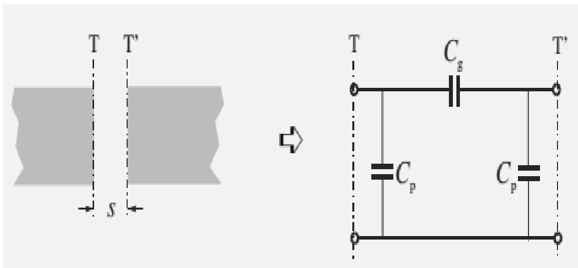

Figure.3 Microstrip gap discontinuities.

Right-angle bends of microstrips may be modeled by an equivalent T-network, asshown in Figure 4. The closed-form expressions forevaluation of capacitance and inductance is given by :

$$\frac{C_0}{w}\left(\frac{pF}{m}\right) = \left\{\frac{(14\varepsilon_r + 12.5)W/h - (1.83\varepsilon_r - 2.25}{\sqrt{W/h}} + \frac{0.02\varepsilon_r}{W/h}\right\} for\frac{W}{h} < 1$$

$$\frac{C_0}{w}\left(\frac{pF}{m}\right) = \left\{\frac{(9.5\varepsilon_r + 12.5)W}{h} + 5.2\varepsilon_r + 7\right\} for\frac{W}{h} \ge 1$$

$$\frac{L}{h}\left(\frac{nH}{m}\right) = 100\left\{4\sqrt{\frac{W}{h}} - 4.21\right\}$$

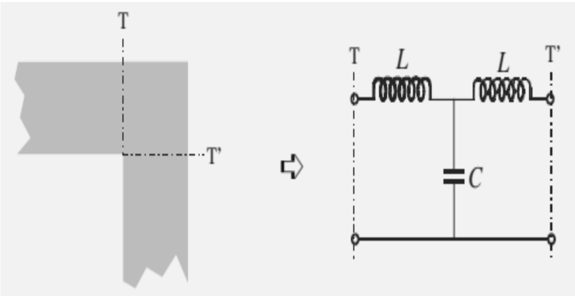

Figure.4 Microstrip bend discontinuities.

III. QUASILUMPED ELEMENTS

Microstrip line short sections and stubs, whose physical lengths are smaller than aquarter of guided wavelength λgat which they operate, are the most common componentsfor approximate microwave realization of lumped elements in microstripstructures, and are termed quasilumped elements. They may also be regardedas lumped elements if their dimensions are even smaller, say smaller than λg/8.Some important microstrip quasilumped elements are discussed in this section.

A. High and Low Impedance Short Line Sections

Figure 5, represents a short length of high-impedance (Zc) lossless line terminated at both ends by relatively low impedance (Z0) is represented by a π equivalent circuit.

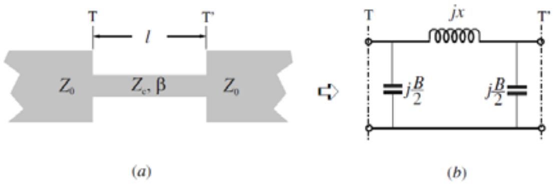

Figure 5 High-impedance short-line element.

$$x = Z_c \sin\left(\frac{2\pi}{\lambda_g} l\right) \quad \text{and} \quad \frac{B}{2} = \frac{1}{Z_c} \tan\left(\frac{\pi}{\lambda_g} l\right) \qquad \text{.............(7)}$$

Figure 6, represents a short lengthof low-impedance (Zc) lossless line terminated at both ends by relatively high impedance(Z0) is represented by a T equivalent circuit.

$$B = \frac{1}{Z_c} \sin\left(\frac{2\pi}{\lambda_g} l\right) \quad \text{and} \quad \frac{x}{2} = Z_c \tan\left(\frac{\pi}{\lambda_g} l\right) \qquad \text{.......(8)}$$

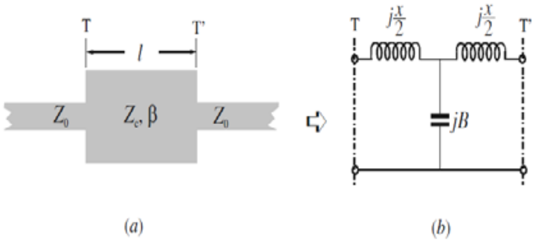

Figure 6 Low-impedance short-line element.

B. Open- and Short-Circuited Stubs

According to the transmission line theory, the input admittance of an open-circuited transmission line having a characteristic admittance Yc = 1/Zc and propagation constant β= 2π/λgis give by

$$Y_{in} = jY_c \tan\left(\frac{2\pi}{\lambda_g} l\right) \qquad \text{…………………….. (9)}$$

where l is the length of the stub. If l <λg/4 this input admittance is capacitive. If the stub is even shorter, say l <λg/8, the input admittance may be approximated by

$$Y_{in} \approx jY_c\left(\frac{2\pi}{\lambda_g} l\right) = j\omega\left(\frac{Y_c l}{v_p}\right) \qquad \text{…………… (10)}$$

where vpis the phase velocity of propagation in the stub. It is now clearer that such a short open-circuited stub is equivalent to a shunt capacitance C = Ycl/vp.

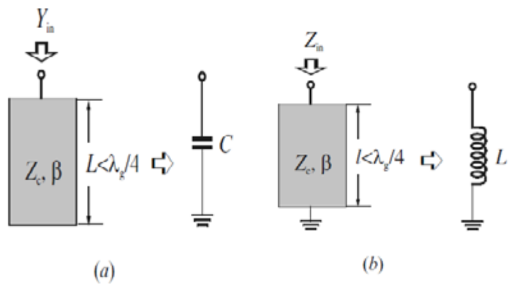

Figure 7 Short stub elements: (a) open-circuited stub; (b) short-circuited stub.

IV. CONCLUSION

In this paper, an extensive study is performed on the basic concept of design equation for microstrip antenna along with different type of microstrip resonator and discontinuities in detail, we are able to establish the relationship between the microstrip lines and radiation of patch. We had also discuss two groups of quasilumped parameters with the help of patch dimension, this theory can be apply on the patch antenna designing. from the above discussion we can see that the how a microstrip line can act as inductor and in which scenario it will act as capacitor. Thus the above survey give us the basic idea of implementation of quasilumped parameter in patch antenna design for different frequency.

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