Equivalent Circuit Modelling of Microstrip Patch Antenna (MPA) Using Parallel LCR Circuits

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***Abstract*—*In this paper, the equivalent circuit model of designed circular slotted microstrip patch antenna has been proposed using parallel resonance phenomenon. The proposed model is composed of eight series connected parallel LCR circuits. It has been observed that the response of microstrip patch antenna can be analyzed using resistor, inductor and capacitor. The response (return loss S_{11}) of microstrip patch antenna can be equivalently modelled by using parallel resonant circuit. The circuit modelling has been done using RF toolbox of MATLAB. The comparative study and effect of adding shunt LCR circuits has been studied and analyzed.*

Keywords—Microstrip patch antenna, resonance, return loss, RF Toolbox, LCR network.

I.INTRODUCTION

Microstrip Patch antennas have been popular due to their low cost, small size and ease of manufacturing. Basically, a Microstrip patch antenna consists of two metal surfaces (Copper or Gold) separated by a dielectric having specific permittivity relative to air [1]. To manufacture microstrip patch antenna, lithography process has been used. The fabrication of MPA is similar to Printed Circuit Board fabrication as it is basically a two-dimensional physical geometry [2]. Due to its small size its resonant frequencies fall in the range of UHF or higher frequencies. So these are used in UHF or higher frequency range [6].

A series LCR circuit is basically a bandpass filter, which passes a certain range of frequencies and attenuates all others frequencies. The S_{11} response of the microstrip patch antenna is approximately modelled by making use of series LCR circuits connected in parallel. This method of modelling is one of the easiest method to equivalently model S_{11} response of microstrip patch antenna [4]. Parallel resonance can also be used to equivalently model the S_{11} response of microstrip patch antenna. It is as efficient and easy as series resonance phenomenon.

II.Geometry of Microstrip Antenna

The fig. 1 and fig. 2 shows the top and bottom view of the designed microstrip patch antenna respectively. The designed microstrip patch antenna has rectangular substrate, a rectangular patch and a defected ground surface. The rectangular substrate is of FR4 material having dielectric constant 4.4 with rectangular patch and defected ground of PEC material (for example copper) [5].

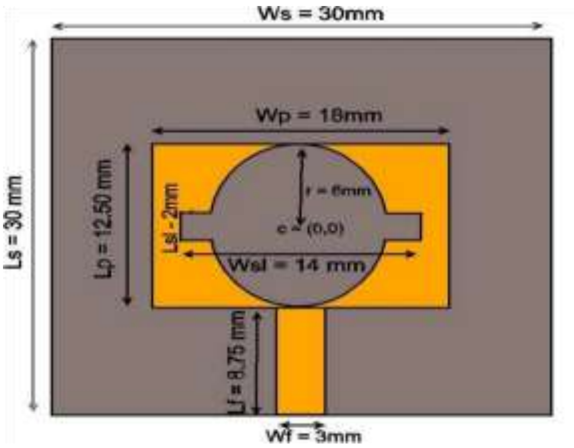

Fig. 1 Top view of Microstrip patch antenna [5]

The patch has a notched circular slot and ground has been reduced in size whose dimensions has been shown in fig. 1 and fig. 2, respectively. The complete dimensions of the microstrip patch antenna have been given in the table 1.

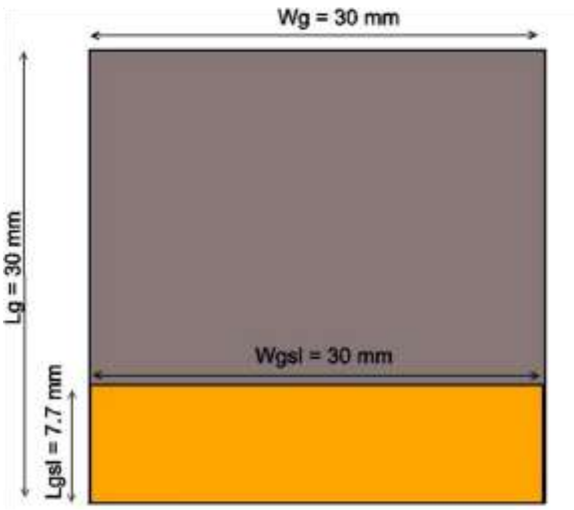

Fig. 2 Bottom view of Microstrip Patch Antenna [5]

Table 1 Dimensions of Microstrip patch antenna [5]

Antenna Parameter	Specification
Length of substrate (L_s)	30mm
Width of substrate (W_s)	30mm
Length of Patch (L_P)	12.50mm
Width of Patch (W_p)	18mm
Length of feed (L_f)	8.75mm
Width of feed (W_f)	3mm
Radius of circular slot (r)	6mm
Coordinates of Centre of circle (c)	(0,0)
Length of rectangular notch in circle (Lsl)	2 mm
Width of rectangular notch in circle (Wsl)	14mm
Length of slot (Lsl)	8mm
Width of slot (Wsl)	10mm

III.Results of Designed Microstrip Antenna

The theoretical and practical results of designed microstrip patch antenna has been shown in the fig. 3 and fig. 4.

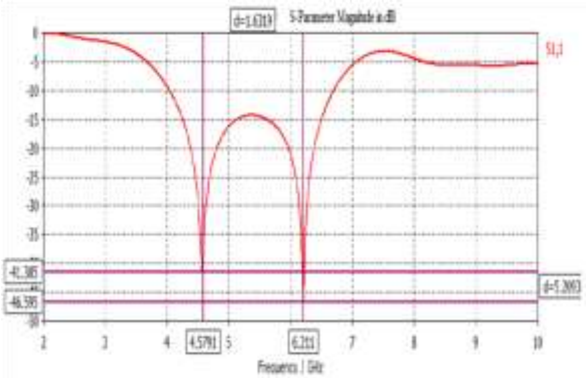

Fig. 3S_{11} response of Microstrip patch antenna using CST MWS 2010 [5]

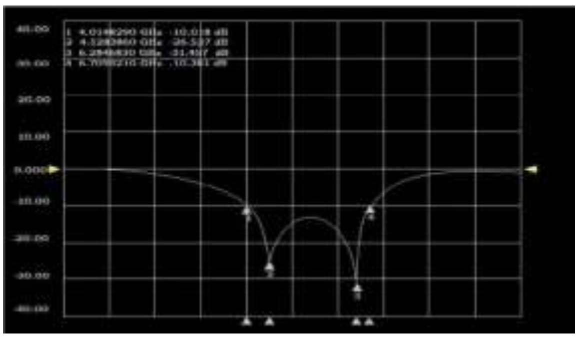

Fig. 4S_{11} response of Microstrip patch antenna using a Network Analyzer (E5071C ENA series) [5]

It can be observed in fig. 3 that there are two dips at 4.7191 GHz and 6.211 GHz having return loss 41.385 dB and 46.595 dB respectively in theoretical results. The practical results in fig. 4 has been observed using Network Analyzer (E5071C ENA series). It can be observed that in practical results, there are two dips at 4.528 GHz and 6.285 GHz having return loss 26.527 dB and 31.457 dB respectively.

IV.Equivalent Circuit Modelling

The equivalent circuit modelling has been done using parallel LCR circuit which acts as a band pass filter i.e. pass a certain range of frequencies and attenuates all others frequencies. A parallel LCR circuit is shown in fig. 5.

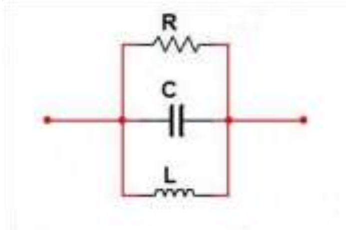

Fig. 5 A parallel LCR circuit

The various equations which have been used in design to accomplish the results has been shown here [3].

$$Q = \frac{R}{2\pi f L} = 2\pi f C R = R\sqrt{\frac{C}{L}} \quad (1)$$

$$f_r = \frac{1}{2\pi\sqrt{LC}} \quad (2)$$

$$BW = \frac{f_r}{Q} \quad (3)$$

Where
Q for Quality factor
R for the Resistance
f for the Frequency
C for the Capacitance
BW for the Bandwidth
f_r for the resonant frequency

The results have been approximately modelled by making use of four parallel LCR circuits connected in series as shown in fig. 6. The results have been shown in fig. 7. The table. 2 shows the values of the resistors, capacitors and inductors used in the circuit.

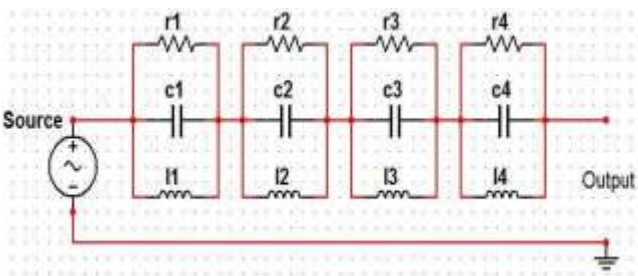

Fig. 6 Four parallel LCR circuits connected in series

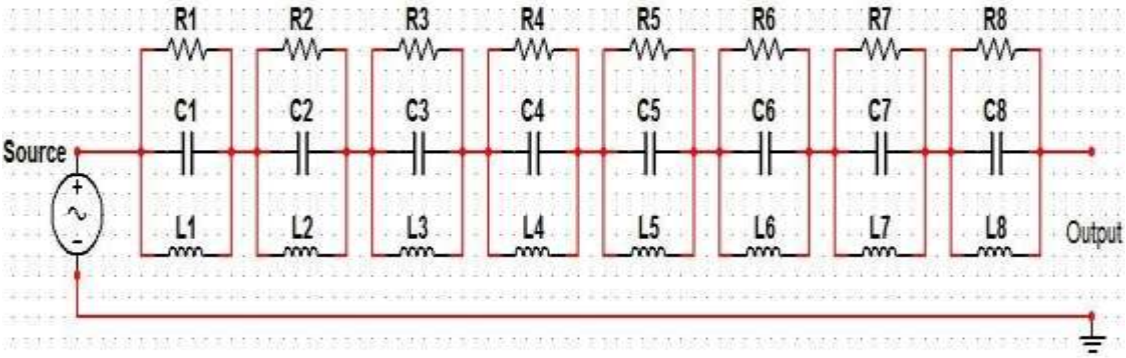

Fig .8 Eight parallel LCR circuits connected in series

Table. 2 Values of Resistors, Capacitors and Inductors

Resistance	Inductance	Capacitance
r_1 = 850 Ω	l_1 = 85.32 pH	c_1 = 7.7085 pF
r_2 = 492.07 Ω	l_2 = 460.99 pH	c_2 = 2.6 pF
r_3 = 50 Ω	l_3 = 202 pH	c_3 = 3.6 pF
r_4 = 45 Ω	l_4 = 230 pH	c_4 = 4.1182 pF

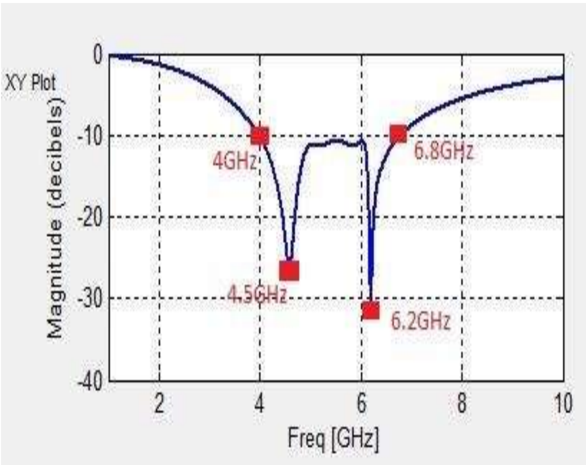

Fig .7 S_{11} response in RF Toolbox

The results have been further improved by using eight parallel LCR circuits as shown in fig. 8. The value of components has been shown in table. 3. The improved response has been shown in fig. 9.

Table. 3 Values of Resistors, Capacitors and Inductors

Resistance	Inductance	Capacitance
R_1 = 67 Ω	L_1 = 166.67 pH	C_1 = 6.84 pF
R_2 = 60 Ω	L_2 = 57.868 pH	C_2 = 11.232 pF
R_3 = 30 Ω	L_3 = 138.89 pH	C_3 = 7.128 pF
R_4 = 35 Ω	L_4 = 166.67 pH	C_4 = 6.12 pF
R_5 = 52 Ω	L_5 = 131.67 pH	C_5 = 5.4 pF
R_6 = 32 Ω	L_6 = 86.833 pH	C_6 = 9.504 pF
R_7 = 482.07 Ω	L_7 = 225 pH	C_7 = 5.4815 pF
R_8 = 830 Ω	L_8 = 41.4 pH	C_8 = 15.494pF

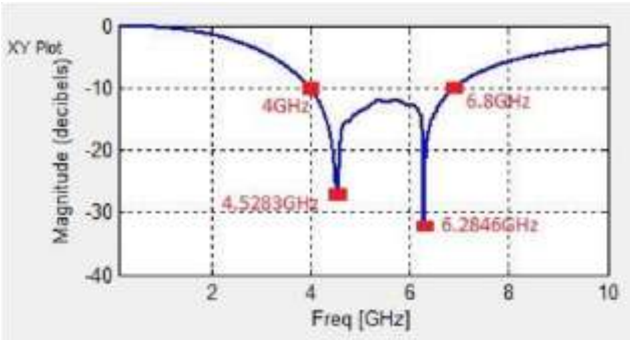

Fig. 9 Improved S_{11} response in RF Toolbox

V.Conclusion

The S_{11} response of the circular slotted microstrip patch antenna has been approximately modelled using parallel LCR circuits connected in series. From the results, it can be concluded that more the number of circuits, more closely the results can be approximated with practical results. Thus, it can be concluded that that the S_{11} response of a Microstrip patch can be equivalently modelled using parallel LCR circuits.

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