Design and Implementation of Microwave Inverted 'L' and 'J' Filter

P.Chandra Sekhar, M.V.Sai Tej, U.N.S.Vijayshri, J.Nitish Kumar

***Abstract-** In this paper, a filter is proposed using micro strip, series of patch. S-parameters, return loss and VSWR are calculated for the filter. A reference filter is designed using a series of patches and is modified into an inverted L and J line filter (proposed filter). The proposed filter can be easily implemented and has excellent filter characteristics which are near to the ideal filter. There are many practical applications of this filter for example in microwave radio relay communication systems, radio astronomy, RADAR. The entire simulation is done using CST Microwave Studio.*

***Index Terms**— Filter, micro strip, return loss, S-parameters, VSWR, transmission coefficient.*

I. INTRODUCTION

A filter is a linear time invariant system used for removing undesirable noise from desired signals. A filter is designed to pass a band of desired frequencies without any distortion called pass band of the filter and to totally block a band of unwanted frequencies called the stop band of the filter. For an ideal filter, in the pass band the frequency response of the filter is equal to one and in the stop band the frequency response of the filter is zero [6].

A microwave filter is a two port network used to control frequency response at a certain point in a microwave system by providing transmission at frequencies within the pass band of the filter and attenuation in the stop band of the filter. The microwave region of the electromagnetic spectrum has certain unique properties. These enable microwave signals to propagate over long distances through the atmosphere under all but the most severe weather conditions. The radiating elements and the feed lines are usually photo etched on the dielectric substrate. [13]

In its most basic form, a Micro strip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. The patch is generally made of conducting material such as copper or gold and takes any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate.

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II. S-PARAMETERS

A two-port network is an electrical circuit or device with two pairs of terminals. Any circuit can be transformed into a two-port network provided that it does not contain an independent source. Linear two-port networks are characterized by a number of equivalent circuit parameters, such as their transfer matrix, impedance matrix and scattering matrix. The scattering matrix relates the outgoing wave's b1 and b2 to the incoming wave's a1, a2 that are incident on the two-port network [4].

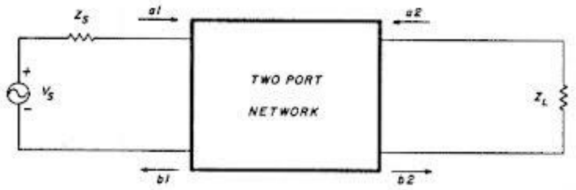

Figure 1: S-parameters

$$\begin{pmatrix} b_1 \\ b_2 \end{pmatrix} = \begin{pmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \end{pmatrix}$$

Scattering matrix

Scattering parameters or S-parameters are used to characterize or model mathematically linear circuits functioning at microwave frequencies. At low frequencies, several types of parameters are available like z-parameters, y-parameters, hybrid-parameters, etc to model the circuits. But all these parameters, for their measurement, require the implementation of short circuit or open circuit at various ports of the circuit which is difficult at microwave frequencies. In addition, these parameters are defined in terms of voltages and current which are not used at microwave frequencies. Because of these difficulties in characterizing high frequencies, another type of parameters known as scattering parameters are devised to use for microwave circuits[3]. In practice, the most commonly quoted parameter in regards to antennas is S_{11} and S_{21}. S_{11} represents how much power is reflected from the antenna and hence is known as the reflection coefficient or return loss. If S_{11}= 0 dB, then all the power is reflected from the antenna and nothing is radiated [12].

III. RETURN LOSS

In telecommunications, return loss of signal power resulting from the reflection caused at a discontinuity in a transmission line or optical fiber. This discontinuity can be a mismatch with the terminating load or with a device inserted in the line. It is usually RL (dB) =10log10 (P_i/P_r) where RL (dB) is the return loss in dB.

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Pi is the incident power and Pf is the reflected power. Return loss is related to both standing wave ratio (SWR) and reflection coefficient. Increasing return loss corresponds to lower SWR. Return loss is a measure of how well devices or lines are matched. A match is good if the return loss is high. A high return loss is desirable and results in a lower insertion loss. Return loss is a used in modern practice in preference to SWR because it has better resolution for small values of reflected wave. [11]
Return loss is defined as the ratio of power available from the source to the power reflected from the filter. Return loss tells us how well impedances match; how close they are to being equal in value (ohms) to each other.

IV. VSWR

When EM waves propagate in two directions inside a transmission line, a "standing-wave" pattern is formed. Voltage standing wave ratio (VSWR) is by definition the ratio of the maximum to the minimum voltages in the line. In telecommunications, standing wave ratio (SWR) is the ratio of the amplitude of a partial standing wave at antinodes to the amplitude at an adjacent node, in an electrical transmission line. [10]
The SWR is usually defined as a voltage ratio called the VSWR. It is also possible to define the SWR in terms of current, resulting in the ISWR, which has the same numerical value. The power standing wave ratio (PSWR) is defined as the square of the VSWR. SWR is used as an efficiency measure for transmission lines, electrical cables that conduct radio frequency signals, used for purposes such as connecting radio transmitters and receivers with antennas. The SWR of a transmission line can be measured with an instrument called an SWR meter, and checking the SWR is a standard part of installing and maintaining transmission lines. [8]

V. TRANSMISSION COEFFICIENT

The transmission coefficient is used in physics and electrical engineering when wave propagation in a medium containing discontinuities is considered. A transmission coefficient describes the amplitude, intensity, or total power of a transmitted wave relative to an incident wave. [5]
In telecommunication, the transmission coefficient is the ratio of the amplitude of the complex transmitted wave to that of the incident wave at a discontinuity in the transmission line.
The probability that a portion of a communications system, such as a line, circuit, channel or trunk, will meet specified performance criteria is also sometimes called the "transmission coefficient" of that portion of the system. The value of the transmission coefficient is inversely proportional to the quality of the line, circuit, channel or trunk. [1]

VI. FILTER DESIGN

A micro strip patch acts as an antenna when it is excited at one end. The micro strip patch when considered to be a two port network acts as a filter if it is excited at both the ends. The micro strip patch antenna consists of a radiating patch on one side of a dielectric substrate which has a ground plane on the other side. The patch is generally made of conducting material such as copper or gold and can take any possible shape. The radiating patch and the feed lines are usually photo etched on the dielectric substrate. In order to simplify analysis and performance prediction, the patch is generally square, rectangular, circular, triangular, and elliptical or some other common shape.[7]

VII. PROPOSED FILTER DESIGN

The proposed filter has a ground plane made of copper with the following dimensions i.e., length is 130mm (twice of the length L), width is 76mm (twice of the width W), and thickness 0.1mm. A substrate is present on the ground plane and the substrate is made from the material FR-4 (lossy), having dielectric constant ($\in_r$) =4.3 and μ=1.the substrate has the same dimensions as that of the ground plane except the thickness or height which is 5mm. The proposed filter is a series of patches which are made of copper (annealed) which is a lossy metal and has μ=1 and ρ= 8930 (kg/m^3) with the dimensions of 20mm length and 40mm width. [9]

Table 1: Details of proposed filter

Filter Components	Symbols and their values for the proposed filter (mm)
Patch	W_c=40, L_c=20
Feed	W_L=4
Ground plane	W=38, L= 65, T= 0.1
Substrate	W=38, L= 65, T= 5

∈r (dielectric constant) = 4.5,
L= 65 mm,
W=38 mm,
h= 5 mm

$W = c/2f_r\sqrt{\frac{2}{(\in r+1)}}$ => f_r = 2.380 GHz

$\in r_{eff}$ = a= $(\in r+1)/2 + (\in r-1)/2\left[1+\frac{12h}{W}\right]^{-\frac{1}{2}}$ = 3.8397

ΔL =0.412*h*[$\frac{(a+0.3)(\frac{W}{h}+0.264)}{(a-0.258)(\frac{W}{h}+0.8)}$] = 2.229 mm

$\boldsymbol{L_{eff}}$ = L+ 2Δ$\boldsymbol{L}$ = 69.458 mm [2].

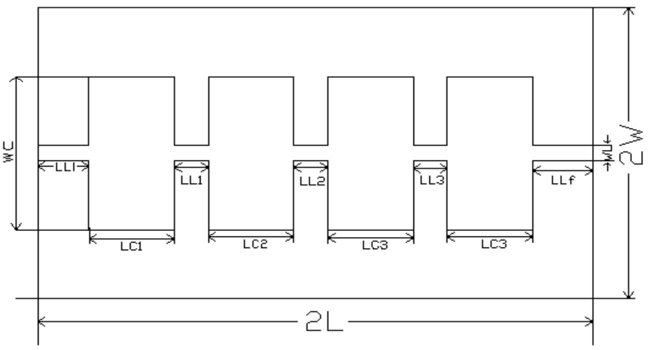

Figure 2: Reference filter

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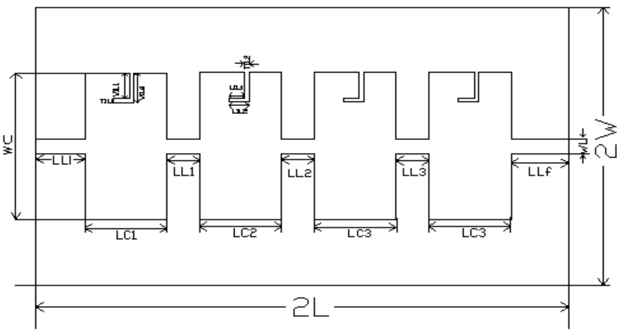

Figure 3: Filter 1

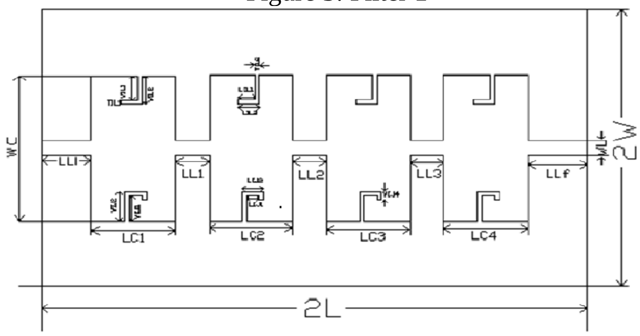

Figure 4: Proposed filter

L=65mm, W=38mm, $LL_i = \frac{L}{5.42}$,

$WL_i = WL_1 = WL_2 = WL_3 = WL_f = \frac{W}{9.5}$,

$LC_1 = LC_2 = LC_3 = LC_4 = \frac{L}{3.25}$,

$WC_1 = WC_2 = WC_3 = WC_4 = \frac{W}{0.56}$,

$LL_1 = LL_2 = LL_3 = \frac{L}{8.125}$,

$LL_f = \frac{L}{4.643}$, $LIL_1 = \frac{L}{16.25}$,

$WIL_1 = WIJ_1 = \frac{W}{5.43}$, $TIL_1 = TIJ_1 = TIJ_3 = \frac{L}{65}$,

$LIL_2 = LIJ_2 = \frac{L}{13}$, $WIL_2 = WIJ_2 = \frac{W}{4.75}$,

$TIL_2 = TIJ_2 = \frac{W}{38}$, $LIJ_1 = \frac{L}{21.667}$, $WIJ_3 = \frac{W}{38}$, $WIJ_4 = \frac{W}{19}$

VIII. RESULTS

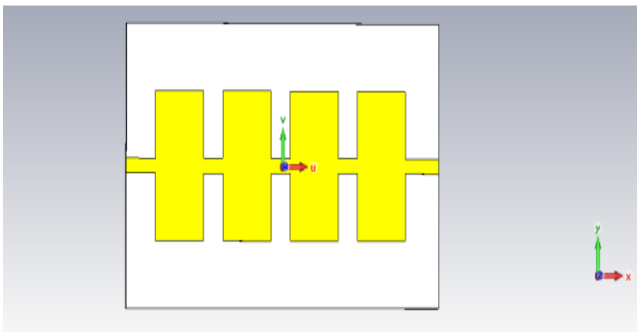

Figure 5: Reference filter

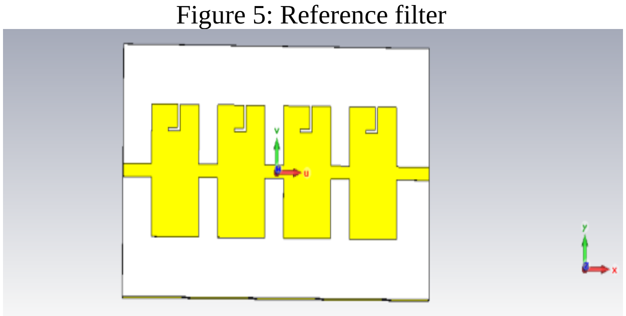

Figure 6: FIlter-1

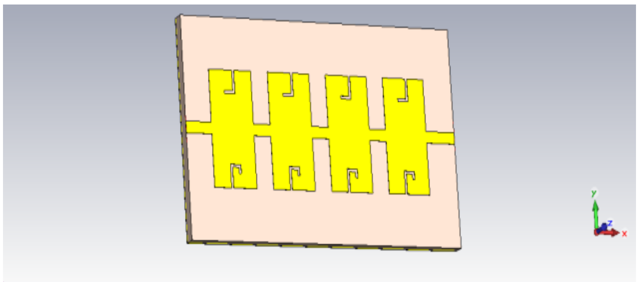

Figure 7: Proposed filter

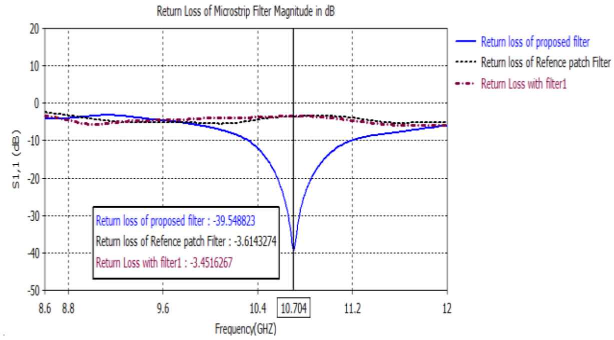

Figure 8: Return loss of all the three filters

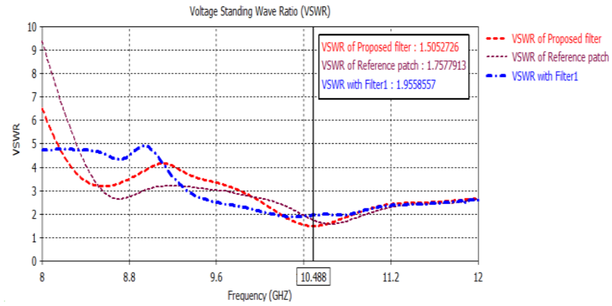

Figure 9: VSWR of all the three filters

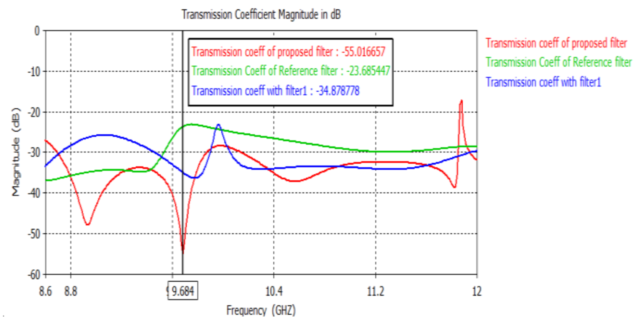

Figure 10: Transmission coefficient of all the three filters

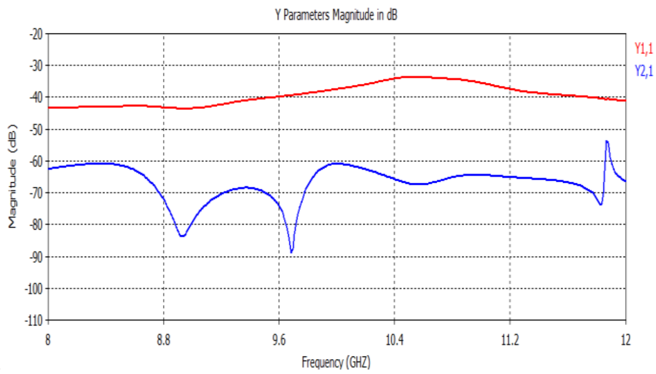

Figure 11: Y-parameters of proposed filter

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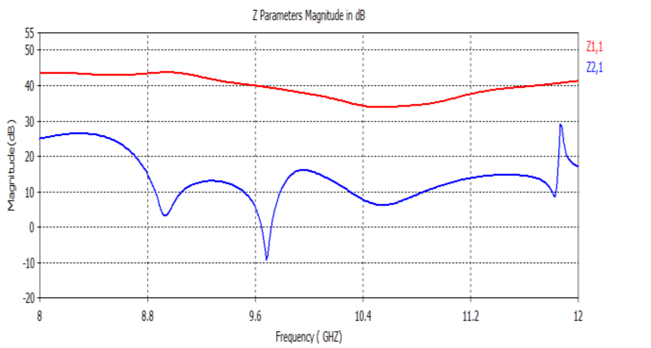

Figure 12: Z-parameters of proposed filter

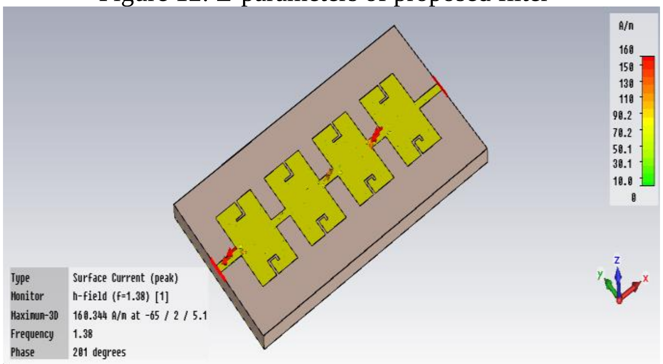

Figure 13: Surface current of proposed filter at 1.38GHz

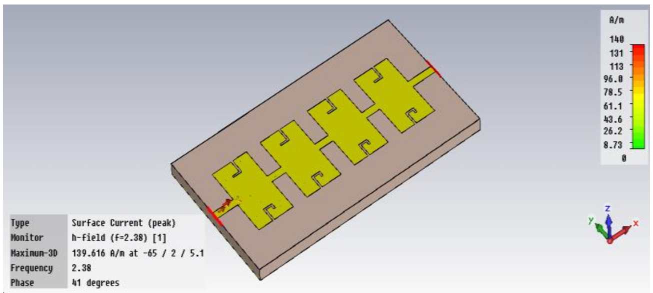

Figure 14: Surface current of proposed filter at port-1 at 2.38GHz

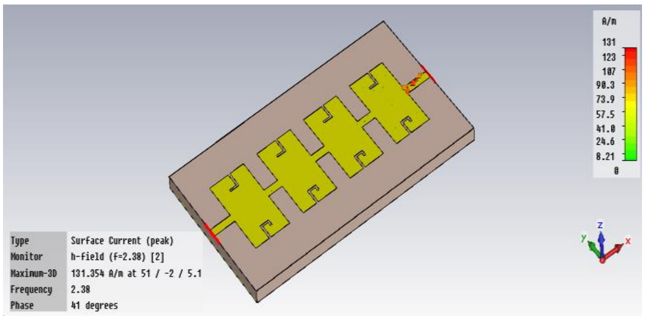

Figure 15: Surface current of proposed filter at port-2 at 2.38GHz

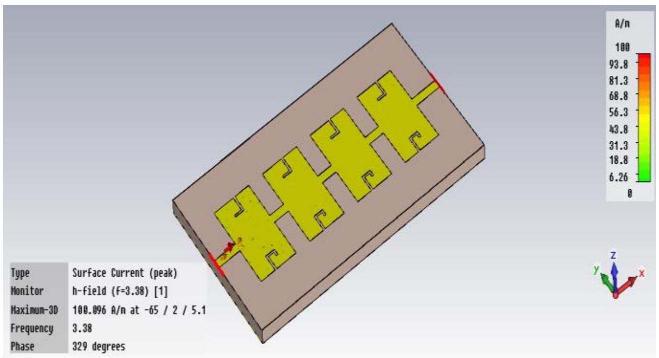

Figure 16: Surface current of proposed filter at port-1 at 3.38GHz

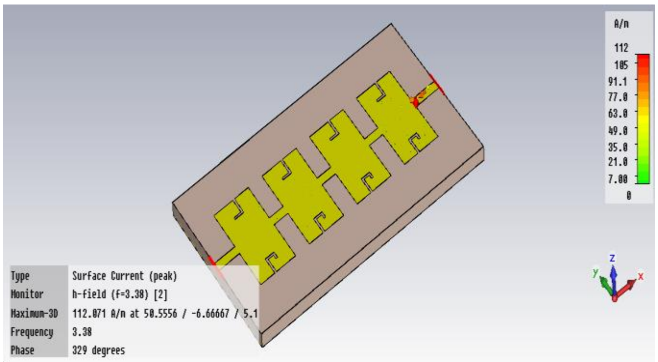

Figure 17: Surface current of proposed filter at port-2 at 3.38GHz

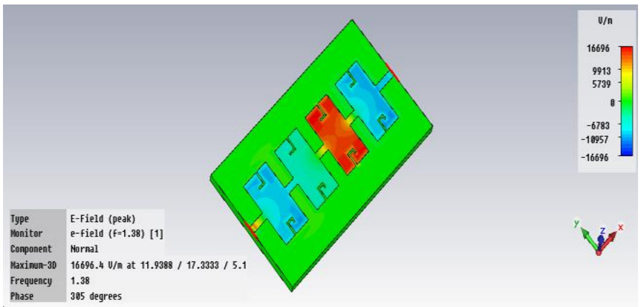

Figure 18: Electric field of proposed filter

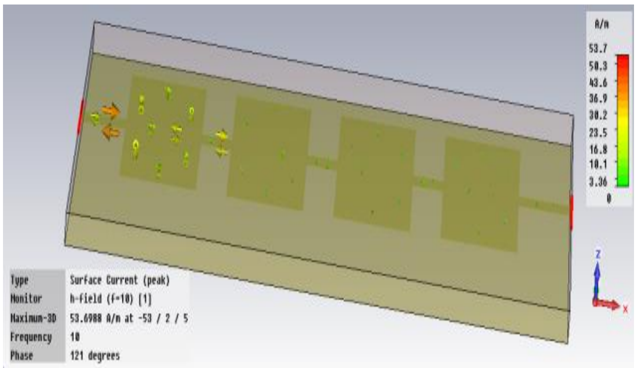

Figure 19: Magnetic field of proposed filter at port-1

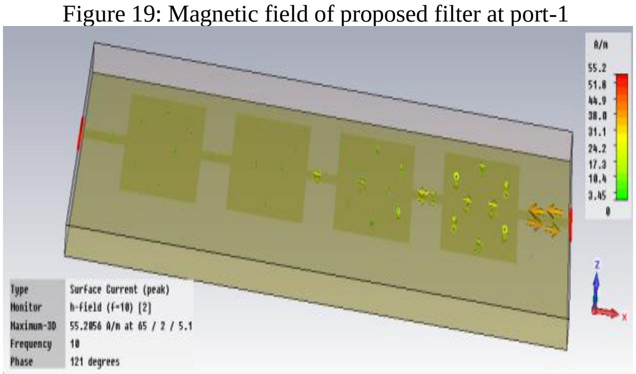

Figure 20: Magnetic field of proposed filter at port-2

IX. CONCLUSION

Microwave inverted 'L' and 'J' line filter at 'X' band frequency is proposed and discussed. Filter characteristics such as Return loss, VSWR and Transmission coefficient of the proposed filter are simulated. These characteristics are better when compared to those of the reference filter. The proposed filter can be used in receivers especially in Radar applications and it can be easily implemented.

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