Design of Highly Selective X- Band band-pass filter using Micro-strip Coupled Line

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***Abstract*—In this paper we have designed a highly selective X-band band-pass filter using Micro-strip coupled line. This filter filter works at 9 GHz at a pass band width of 1 GHz. The filter is printed on a substrate of dielectric constant of 4.4 and thickness of 1.6 mm. We obtained a return loss of (> 70dB) at resonant frequency. The proposed design has a insertion loss of (< 1dB). The Agilent ADS software is used to design the band-pas filter and calculate s-parameters. The designed band-pass filter can be employed in very highly accurate applications.**

Keywords—Filter, Ads, Bandpass, X-band, coupled

I. Introduction

Filters are important component for every available electrical system. They remove unwanted features from a a electrical signal. The are very widely used in electronics and telecommunication, in radio, television, audio recording, radar, control systems, music synthesis, image processing,and computer graphics. A band pass filter allows though but blocks components with frequencies, called its pass-band. The main function of such a filter in a transmitter is to limit the band width of the output signal to the band allocated for the transmission. This prevents the transmitter from interfering with other stations.The X band is the designation for a band of frequencies in the microwave radio region of the electromagnetic spectrum. In some cases, such as in communication engineering, the frequency range of the X band is rather indefinitely set at approximately 7.0–11.2 GHz.

II. Literature Review

The design and implementation of a new power divider using coupled microstrip lines are presented[1]. The proposed divider can be considered as an integration of a single-stage coupled line bandpass filter and a conventional Wilkinson divider. The area of the divider layout is compact owing to the small width and spacing of the coupled lines. Two-way and three-way equal power dividers are designed for the bandwidth between 3–5 GHz having a measured power division of −3.2 and −5 dB, respectively.[2] presents a dual-band filtering power divider (FPD) by employing square-loop resonator loaded by open stubs. The even-and odd-mode equivalent circuits of the proposed resonator area analysed and design equations are derived. For demonstration,the power divider (PD) is fabricated and measured. A band-selective power divider is demonstrated in [3] for the first time. By replacing lumped element right-handed (RH) and left-handed (LH) transmission lines (TL) in a conventional Wilkinson power divider, it is possible to achieve both power division and filtering simultaneously. By utilizing the positive phase propagation property of an RHTL, which works as a low-pass filter, and the negative phase propagation property of an LHTL, which works as a high-pass filter, the band-selective quarter-wave sections required to construct a Wilkinson power divider are implemented. The fabricated circuit shows an insertion loss in the range 1.7 dB–2.5 dB in the passband, with the circuit dimensions of merely 12 mm by 10 mm.

A novel miniaturized parallel coupled-line bandpass filter with suppression of second, third and fourth harmonic frequencies, is demonstrated in this paper. The simulations and measurements of a 2.0 GHz prototype bandpass filter are presented. In addition, the size of the prototype filter circuitry can be reduced up to 20%. [4]. This new coupled-line element cascade configuration leads to a new N-stage parallel coupled-line bandpass filter. In addition to this structure, [5] introduced modified maximally flat parallel coupled-lines (MF-PCL) resonators by using enhanced coupling techniques. This structure has a size reduction of about 40% in three-order filter.

III. Design Equations

To design and analyze the Band-Pass Filter for X-band Applications with cascaded coupled line sections using micro-strip line implementation.

Layout of an (N + 1)-section coupled line bandpass filter

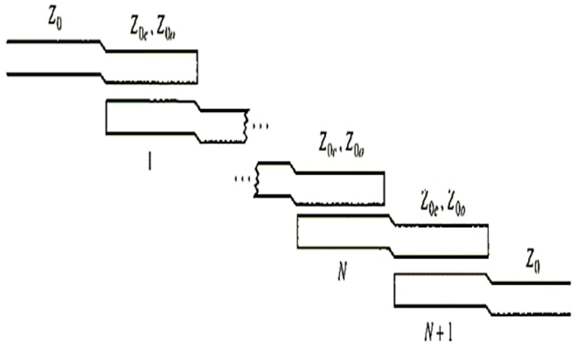


Fig 1 Layout of an (N + 1)-section coupled line band-pass filter

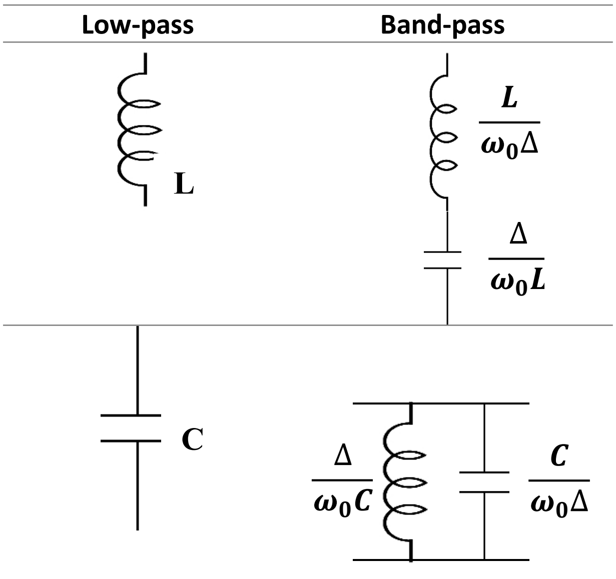
The Steps to be followed are as follows:

1. Determine the order of the system.
2. Prototype values of desired filter (ex: Butter-worth, Bessel) are taken according the order. We have taken maximally flat filter values with zero delay.
3. Admittance inverter values are calculated using prototype low pass values.
4. The Admittance values are converted to Odd and even value impedance.
5. Using Linc-Calc tool Width, length and Spacing ratio is found out from odd and even impedance values for the coupled line sections.

Design Equations:

A low pass filter can be transformed to band-pass filter using the below table:

Table 2 Summary of Prototype Filter Transformations



The low pass filter is given by:

$$L_1^{'} = \frac{\Delta Z_0}{\omega_0 g_1}$$

$$C_1^{'} = \frac{g_1}{\Delta\omega_0 Z_0}$$

$$L_2^{'} = \frac{g_2 Z_0}{\Delta\omega_0}$$

$$C_2^{'} = \frac{\Delta}{\omega_0 g_2 Z_0}$$

Where $\Delta = (\omega_2 - \omega_1)/\omega_0$ is the fractional bandwidth of the filter. Invertor Constants can be solved for (N=2):

$$J_1 Z_0 = \left(\frac{C_1 L_1^{'}}{L_1 C_1^{'}}\right)^{1/4} = \sqrt{\frac{\pi\Delta}{2g_1}},$$

$$J_2 Z_0 = J_1 {Z_0}^2 \left(\frac{C_2 L_2^{'}}{L_2 C_2^{'}}\right)^{1/4} = \frac{\pi\Delta}{2\sqrt{g_1 g_2}},$$

$$J_3 Z_0 = \frac{J_2}{J_1} = \sqrt{\frac{\pi\Delta}{2g_2}}.$$

After the J_ns are found, Z_{0e} and Z_{0o} for each coupled line section can be calculated below equations.

The above results were derived for the special case of N = 2 (three coupled line sections), but more general results can be derived for any number of sections, and for the case where $Z_L \neq Z_0$ (or $g_{N+1} \neq 1$, as in the case of an equal-ripple response with N even). Thus, the design equations for a bandpass filter with N + 1 coupled line sections are

$$J_1 Z_0 = \sqrt{\frac{\pi\Delta}{2g_1}},$$

$$J_n Z_0 = \frac{\pi\Delta}{2\sqrt{g_{n-1} g_n}}, \quad \text{for n=2,3,…,N,}$$

$$J_{N+1} Z_0 = \sqrt{\frac{\pi\Delta}{2g_N g_{N+1}}}.$$

The odd-even impedance can be calculated from below equations.

$$Z_{0e} = Z_0[1 + JZ_0 + (JZ_0)^2]$$
$$Z_{0o} = Z_0[1 - JZ_0 + (JZ_0)^2]$$

IV. Filter Design

The simulation is done using Agilent Advanced Design Software. The substrate

Substrate Design Parameters:

i. Dielectric constant **Er**=4.4

ii. Relative permeability **Mur**=1.0

iii. Substrate thickness **H**=1.6 mm

iv. Ground plane to substrate spacing **Hu**=3.9e+34 mm

v. Metal thickness **T**=0.036 mm

vi. Conductivity **Cond**=4.1e7

vii. Dielectric loss tangent **TanD**=0.001

viii. Dielectric Loss Model=1

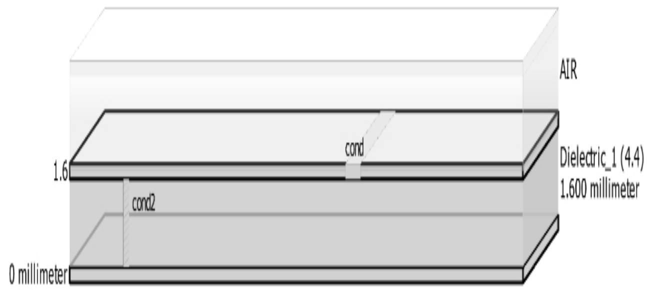


Fig 2 Substrate Design

Table 3. Design Values

n	Gn	Admittance Invertor (Z_0J_n)	Z_0E (Ω)	Z_0O(Ω)
1	0.618	0.5522	92.8562	37.6312
2	1.618	0.1885	61.2016	42.3516
3	2	0.1047	55.7777	45.317
4	1.618	0.1047	55.7777	45.317
5	0.618	0.1885	61.2016	42.3516
6	1	0.5522	92.8562	37.6312

Table 4 Dimensions for Distributed Elements

Component	Zo (Ω)	W (mm)	L (mm)	S (mm)
TL1	50	3.27839	4.3752	-
CLIN 1	50	1.4322	4.588	0.3882
CLIN 2	50	3.0085	4.2849	1.2498
CLIN 3	50	3.6408	3.1728	1.1698
CLIN 4	50	3.6408	3.1728	1.1698
CLIN 5	50	3.0085	4.2849	1.2498
CLIN 6	50	1.4322	4.588	0.3882
TL2	50	3.27839	4.3752	-
TL – Transmission LINE CLIN – Coupled LINE				

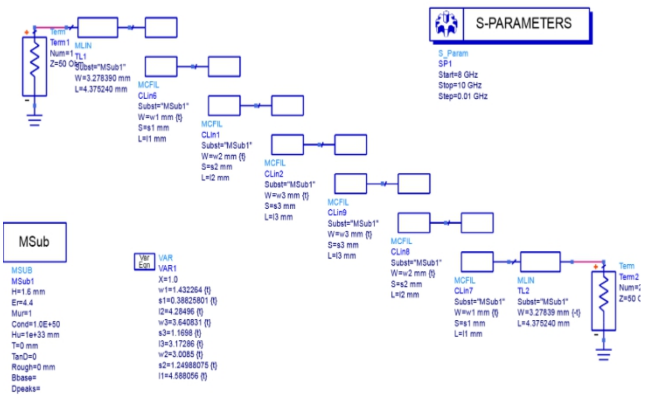


Fig 3 Ads Schematic

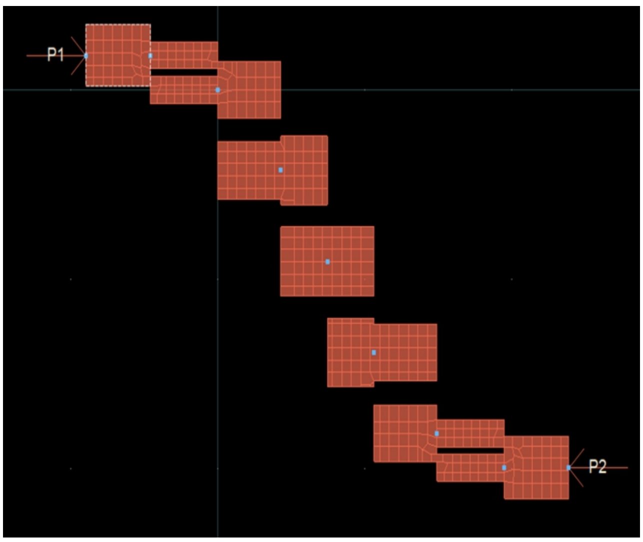


Fig 4 Filter Layout

V. Simulation Results

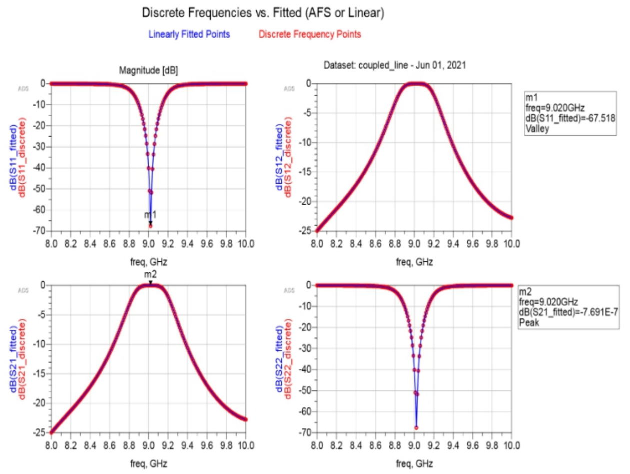


Fig 5 Simulation results of Schematic Design

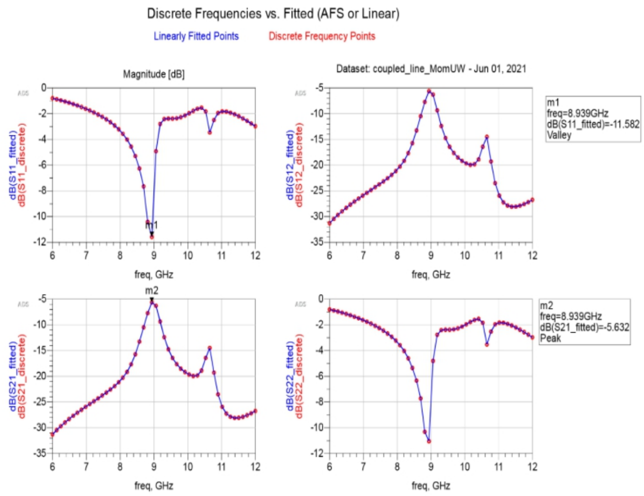


Fig 6 Simulation Results of Filter layout

VI. Analysis and Conclusion

In the schematic Output we can see that band-pass filter has a return loss of 70dB and insertion loss of 0dB without any ripples. When converted to layout with the specified substrate values we can see changes in the pass-band. This is due to non-ideal conditions and coupling effect. But still we can return loss of 12dB and insertion loss of 0dB at 9GHz. This concludes that a highly selective band-pass filter can designed with coupled line for X-band applications, which is at 9GHz.

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