Journal of Nano- and Electronic Physics
Vol. **18** No 4, 04019(4pp) (2026)

Журнал нано- та електронної фізики
Том **18** № 4, 04019(4cc) (2026)

REGULAR ARTICLE

Analysis of a Compact Cross Shaped BPF for Satellite Communication Applications

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(Received 25 March 2026; revised manuscript received 19 August 2026; published online 21 August 2026)

RF BPFs are frequently used in wireless communication applications due to their versatility, low reflection coefficient, superior selectivity and compact size. In order to improve reflection coefficient, transmission coefficient, and group delay, a compact cross shaped BPF is designed utilizing a ring resonator and a cross-shaped structure. Multi band applications is supported by this cross-shaped resonator. The dimensions of the cross shaped BPF are 12 × 34 mm². A 50 Ω microstrip transmission line is utilized to attach the wide band microwave bandpass filter, which is designed utilizing RT duroid 5880 with ε_r of 2.2, δ of 0.0009. An-soft HFSS v13 which is based on FEM, is used to numerically design and simulate a cross shaped BPF using circular ring resonator. According to the results of the designed filter, the cross shaped BPF resonates at 11.26 GHz, 17.01 GHz, 14.28 GHz and 19.66 GHz with S_{21} of 0.2 dB at all resonating frequencies. Reflection coefficients of – 20.1 dB, – 33.6 dB, – 28.9 dB and – 41.2 dB with fractional bandwidths of 4.1 %, 4.15 %, 10.9 %, and 2.3 %, respectively has been observed. These results make the cross shaped BPF suitable for satellite communication applications.

Keywords: Multi band BPF, Reflection co-efficient, Group delay, Transmission coefficient.

DOI: 10.21272/jnep.18(4).04019 PACS number: 84.40.Ba

1. INTRODUCTION

BPFs are widely utilized in a variety of applications to select frequencies for use. A common feature of satellite and wireless communication systems is the microwave multiband BPF. Recently, research on compact microstrip BPFs has become more popular because to their exceptional performance and small size. Due to its widespread use in wireless communication, RF BPF design is often in demand. Numerous microwave applications have made use of small triple band BPFs created by employing SIRs. In recent years, a number of methods have been released. Dual-band bandpass filters can be made with SIRs. SLRs are also used to generate multi band filters [1-4]. In [5-6], new BPF choices are introduced. In [7], a multi band BPF using RT duroid 5880 substrate. However, because [8] states that the RT 5880 substrate has more bandwidth, we have selected it. Microwave bands are relatively difficult to fabricate, despite their great effectiveness and ease of design. As a result, researchers have been attempting to convert theoretical circuits with mixed microwave band elements into straightforward microstrip circuits and vice versa [9]. The construction of microstrip SBFs and LPFs, which utilize simple microstrip topologies, benefited greatly from these circuit improvements. Equivalent circuits using LC circuits for microstrip BPFs are not commonly provided in the literature because of the intricacy of the used structures [10, 11].

A cross shaped bandpass filter for satellite communication applications is presented in this article. Initially, a 50 Ω impedance circular ring is attached to the microstrip transmission line. The filter's resonant frequency is then tuned according to the intended resonating frequency ranges by subtracting a circle and then joining to a cross-shaped structure. With dimensions of 12 × 34 mm² this cross shaped BPF makes the filter smaller and more compact. Fractional bandwidth of 4.1 %, 4.15 %, 10.9 %, and 2.3 % is attained at 11.26 GHz, 17.01 GHz, 14.28 GHz and 19.66 GHz. This approach has allowed thoroughly analyze the EM characteristics of the cross shaped BPF. Cross shaped BPF covers multi band satellite communication applications.

2. ANALYSIS OF CROSS SHAPED BPF

The choice of substrate is typically influenced by two elements, such as losses and absorption coefficients. Because it is lightweight, and easy to fabricate RT duroid 5880 has been selected as the substrate

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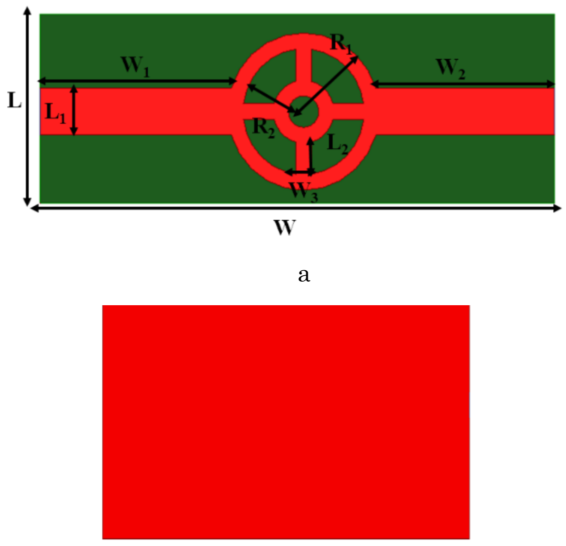
Cite this article as: S. Kalli, et al., *J. Nano- Electron. Phys.* 18 No 4, 04019 (2026) https://doi.org/10.21272/jnep.18(4).04019

material. The most accessible material is RT duroid 5880 which has the following physical characteristics: a thickness of 0.254 mm, a tan δ of 0.0009 and a ε_r of 2.2. BPF design is designed simple by excluding via holes. Two $\lambda/2$ transmission lines is attached to the circular resonator which is the main component. Fig. 1 represents the top surface and bottom surface of the cross shaped BPF. An-soft HFSSv13 which is based on FEM has been utilized to design the cross shaped BPF. The dimensions that were utilized to design the cross shaped BPF are shown in Table 1. The mathematical formula that was utilized to design the cross shaped BPF are mentioned (1-3).



a

b

Fig. 1 – Cross shaped BPF

$$a = \frac{F}{\sqrt{1+\frac{2h}{\Pi\varepsilon_r}}[\ln\left(\frac{\Pi f_r}{2h}\right)+1.7726]} \quad (1)$$

$$F = \frac{8.791*10^9}{f_r\sqrt{\varepsilon_r}} \quad (2)$$

where h is the substrate thickness and 'a' is the ring resonator's radius, which may be found using Eqs. (1), (2) is used to derive F. The substrate's resonance frequency is denoted by f_r. According to the theory, f_r may be changed by changing the substrate's radius; as the radius increases, f_r decreases. The outcomes of the simulation results derived from theoretical formulas (1)-(2). Multiple bands are obtained by etching a circle ring resonator from the circular patch, which is part of the cross shaped BPF. Two microstrip half-wavelength transmission lines with an impedance of 50 Ω are connected to the circular ring that feeds this cross shaped BPF. Table 1 listed the dimensions used in the design of this cross shaped BPF. Fig. 2 represents the equivalent circuit of the cross shaped BPF which consists of a series (or) shunt combination of L and C and these values are tuned to resonate at the desired operating frequency.

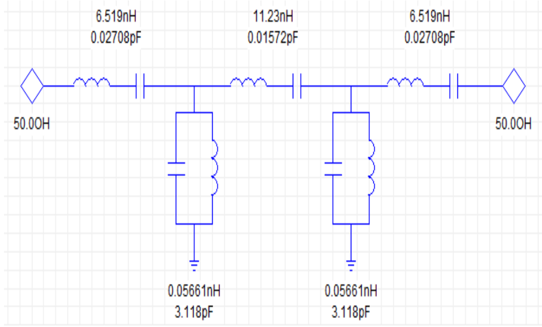


Fig. 2 – Equivalent circuit of cross shaped BPF

Table 1 – Geometric parameters of the cross shaped BPF

S. No	Variable	Values (mm)
1	L	12
2	W	34
3	L_1	3
4	L_2	2
5	W_1	12.4
6	W_2	12.4
7	W_3	1
8	R_1	5
9	R_2	4

3. RESULTS AND DISCUSSIONS

Fig. 1 depicts the cross shaped BPF, which was simulated using HFSSv13. Full ground plane has been utilized for better results in terms of S_{11}, S_{21} and group delay. The performance of the cross shaped BPF was achieved using 10.0 GHz-20.0 GHz frequency range.

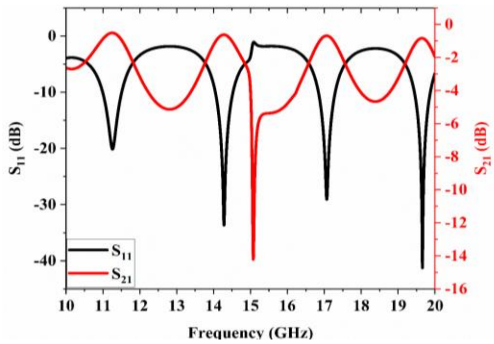


Fig. 3 – S-parameters of the cross shaped BPF

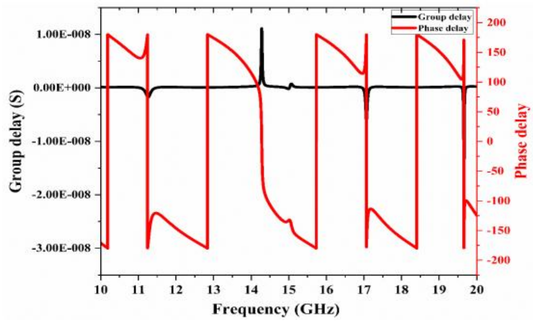


Fig. 4 – Phase delay and group delay of the cross shaped BPF

Fig. 3 shows the cross shaped BPF's S-parameters, while Fig. 4 show the cross shaped BPF's phase delay and group delay. The cross shaped BPF's simulated S_{11} and

S_{12}, with respect to frequency is shown in Figure 3, a transmission zero has been observed. According to the simulation results, the cross shaped BPF is appropriate for satellite communication applications because it resonates at 11.26 GHz, 17.01 GHz, 14.28 GHz and 19.66 GHz with S_{12} of 0.20 dB and reflection coefficients of – 20.1 dB, – 33.6 dB, – 28.9 dB and – 41.2 dB with fractional bandwidths of 4.1 %, 4.15 %, 10.9 %, and 2.3 %, respectively. The group delay of the cross shaped BPF is shown in Fig. 4. It has been found that the filter's group delay is not constant, with a group delay of 0.2 nS has been recorded. The cross shaped BPFs phase delay is shown in Fig. 4, which shows that there is no phase inconsistency within the pass band and that the signal's phase fluctuation is linear.

Figs. 5, 6 displays the cross shaped BPF's *E* and *H* field distribution. The filter's current distribution is shown in Fig. 7, with a peak value of 100 A/m. Arrows in H-field distribution indicates which way the current is flowing. The filter's simulated results show that it selects signals effectively.

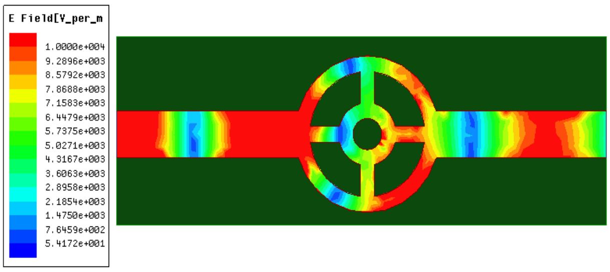


Fig. 5 – Cross shaped BPFs *E*-field distribution

Fig. 6 – Cross shaped BPFs *H*-field distribution

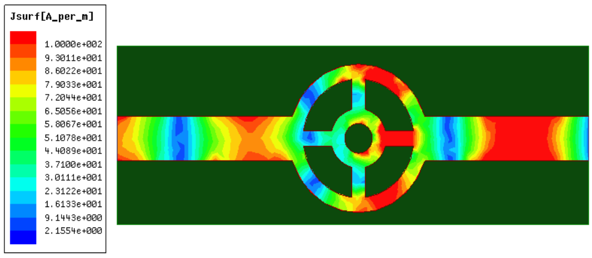


Fig. 7 – Cross shaped BPFs Surface Current distribution

4. CONCLUSION

A compact, low loss microstrip BPF was designed using a cross-shaped resonator for multi band satellite communication applications. This filter is perfect for satellite communication applications because it resonates at four resonant frequencies: 11.26 GHz, 17.01 GHz, 14.28 GHz and 19.66 GHz with S_{12} of 0.2 dB at all resonating frequencies. Reflection coefficients of – 20.1 dB, – 33.6 dB, – 28.9 dB and – 41.2 dB with fractional bandwidths of 4.1 %, 4.15 %, 10.9 %, and 2.3 %, respectively has been observed. This filter can be used for a various microwave application because it is very small and gives more fractional bandwidth.

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Аналіз компактного хрестоподібного BPF для застосувань супутникового зв'язку

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Радіочастотні ППФ часто використовуються в бездротовому зв'язку завдяки своїй універсальності, низькому коефіцієнту відбиття, чудовій селективності та компактному розміру. Для покращення коефіцієнта відбиття, коефіцієнта передачі та групової затримки розроблено компактний хрестоподібний ППФ з використанням кільцевого резонатора та хрестоподібної структури. Цей хрестоподібний резонатор підтримує багатодіапазонні застосування. Розміри хрестоподібного ППФ становлять 12 × 34 мм². Для підключення широкосмугового мікрохвильового смугового фільтра використовується мікросмужкова лінія передачі 50 Ом, яка розроблена з використанням RT duroid 5880 з ε_r = 2,2, δ = 0,0009. An-soft HFSS v13, заснований на методі скінченних елементів, використовується для чисельного проєктування та моделювання хрестоподібного ППФ з використанням круглого кільцевого резонатора. Згідно з результатами розробленого фільтра, хрестоподібний ППФ резонує на частотах 11,26 ГГц, 17,01 ГГц, 14,28 ГГц та 19,66 ГГц з S21 0,2 дБ на всіх резонансних частотах. Спостерігалися коефіцієнти відбиття – 20,1 дБ, – 33,6 дБ, – 28,9 дБ та – 41,2 дБ з частковими ширинами смуги пропускання 4,1 %, 4,15 %, 10,9 % та 2,3 % відповідно. Ці результати роблять хрестоподібний ППФ придатним для застосування в супутниковому зв'язку.

Ключові слова: Багатодіапазонний коефіцієнт BPF, Коефіцієнт відбиття, Групова затримка, Коефіцієнт передачі.