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PRACTICAL IMPLEMENTATION AND TESTING OF A 3.6 MHZ BANDPASS FILTER

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ABSTRACT

In this paper, a practical implementation and testing of a 3.6MHz Bandpass Filter (BPF) is presented. This circuit was design using butterwort filter design method and simulated using microwave office before the practical implementation and testing using real-world components and equipment. BPF is one of the arrays of components shaping the efficiency of communications systems that play a critical role in refining signal, mitigating interference, and enhancing the overall communication performance. Radio Frequency (RF) BPF has always been an indispensable part of RADAR and other wireless communication systems. The BPF have major functions of frequency band and channel selection, filtering harmonics, and suppress spurious. Therefore, RF BPF has always been a research hotspot in the field of wireless communication systems. The results indicated better performance of the at 3.6 MHz with -14.3 dBm and -13.3 dBm at 3.4MHz with excellent attenuation at cut-off frequencies or reject bands.

1.0 Introduction

In the dynamic landscape of modern communications systems, the relentless pursuit of technological advancements remains pivotal to meet the ever-growing demands of a connected world. Among the array of components shaping the efficiency of these systems, electronic bandpass filter (BPF) plays a critical role in refining signal, mitigating interference, and bolstering overall communication performance [1,2]. For instance, the main impact observed on band-pass filter specifications used in Fifth generation (5G) of mobile wireless network is the complexity due to the wide passband of 5G (3.3-4.2 GHz). This is also due to the high number of close bands to reject (WiFi 2.402-2.482 GHz and n79 band 4.4-5 GHz), keeping good level of insertion loss, and high level of attenuations [2]. As communication systems continue to expand and diversify, the need for precise and selective frequency management becomes increasingly crucial. This article presents the practical implementation and testing of a 3.6 MHz bandpass filter for potential application in FMCW RADAR system, as well as offering insights into its transformative potential for signal processing across diverse communication platforms.

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This filter emerges as a key player in the RADAR system, promising enhanced control over signal transmission by allowing only the desired frequency band to pass through while attenuating unwanted frequencies. This capability becomes particularly pertinent in environments saturated with competing signals, where effective filtering is paramount for maintaining the integrity and reliability of communication links. The importance of the bandpass filter extends across various communication systems, including but not limited to wireless networks, satellite communications, and broadband systems [1,3,4]. Its strategic application lies in its ability to address the challenges posed by interference, noise, and spectrum congestion. By tailoring the passband to the specific needs of the communication protocol, this filter ensures that signals reach their intended destinations with minimal distortion and maximum efficiency. Empirical data and insights from experimental trials will be presented to illustrate the filter's efficacy in this communication scenario. An overview of the design considerations and performance optimization was presented with the aims of bridging the gap between theoretical concepts and real-world applicability. The practical implementation and testing of filters is vital in the evolution of communications systems. Beyond the immediate benefits for signal processing, this contributes to the broader discourse on adaptive and resilient communication technologies. As the modern world navigate the intricacies of an interconnected systems, the integration of innovative filtering solutions becomes imperative for sustaining reliable and efficient communication systems across a spectrum of applications [5]. RF band-pass filter has always been an indispensable part of wireless communication system. It has the function of frequency band and channel selection and can filter out harmonics and suppress spurious. Therefore, RF band-pass filter has always been a research hotspot in the field of wireless communication systems [5,6,7,8].

2. Implementation and Testing

After the design and prototype (simulations) of the filter was completed as detailed in [9], the next step was building the BPF (design implementation). The circuit diagram of implemented is shown in figure 1.0. This circuit was implemented on a microstrip board using the adjusted components that were available as shown in figure 2.0. This consisted of properly shielded two ports as an input and output ports with the first series resonators on series arm, showing first the inductor L and capacitor C. These elements observed on both ends of figure 2.0 have equal values, hence the filter is symmetric, and signals can be applied from either of the ports and taken out from any of ports. The two factors considered during the implementation are that the filter should be constructed properly and ensure it function as designed. These factors can be simplified as the proper **layout** and **shielding** [3]. Proper layout was achieved with the input and output ports kept physically apart to avoid coupling of signals. Also, all inductors in the filter are shielded, and arranged at right angles to each other to ensure proper shielding. These considerations can be observed by looking at figure 2.0, which reduced coupling between inductors and shielding to keep the magnetic field of the coil within the metallic shield. Shielding of the entire filter was necessary to prevent outside signal from getting into the filter and make sure only signal from the amplifier had passed through the filter. the signal input and jacks are coaxial connectors as shown in figure 2.0 [3]. Excessive heating was avoided during soldering that might affect or change the values of the components, which in turn affect the output.

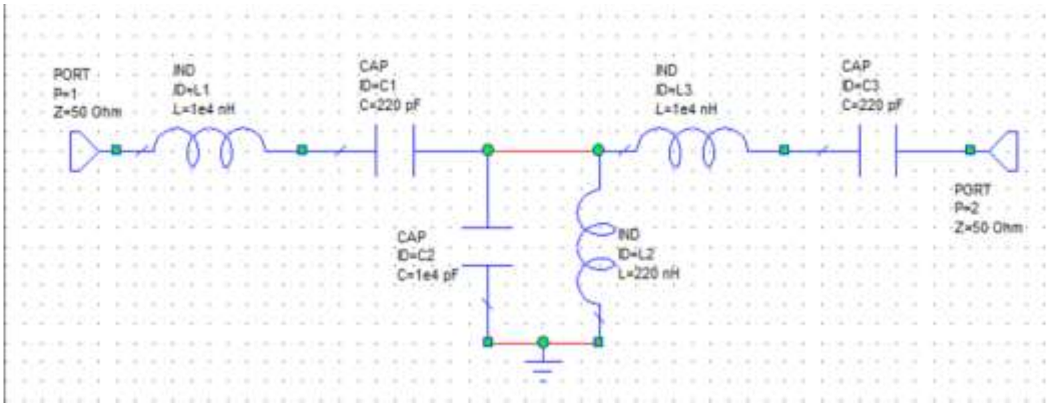

Figure 1.0: Practical Schematic Diagram of the BPF with Adjusted *LC* Values

The implemented design of the BPF was tested using practical equipment setup including the implemented microstrip board BPF, IFR 2025 RF signal generator 9kHz-2.5GHz, IFR 2399C 1kHz-3GHz spectrum analyser, and *50 Ω* impedance cables as shown in figure 3.0. The BPF was found to be working according to the design with an excellent output at *3.4 MHz* and *3.6 Hz* as shown in the results section.

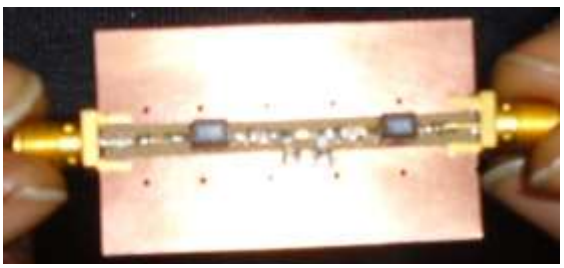

Figure 2.0: Microstrip Board BPF Implementation

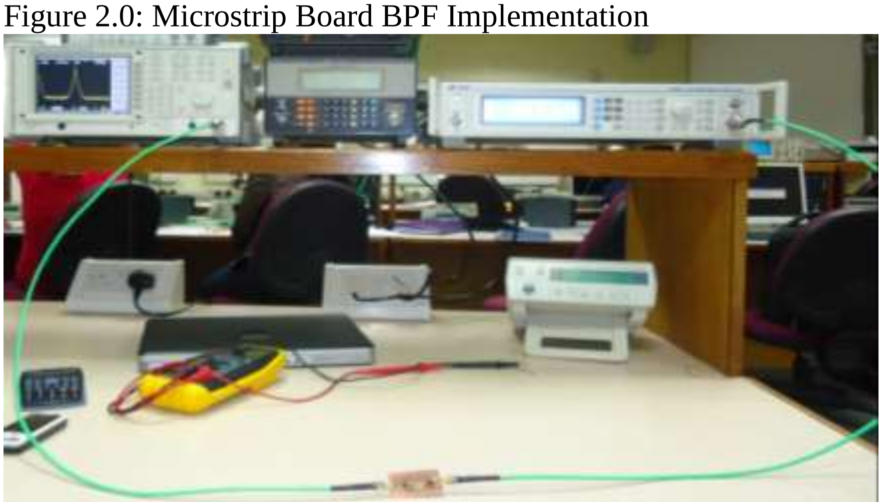

Figure 3.0: Testing Setup of the 3.4 MHz Microstrip Bandpass Filter Design Implementation

Figure 4.0: Input and Output *50 Ω* Impedance Cable Connection of the BPF

3. Results and Discussion

The practical characteristics for the implemented BPF are obtained by connecting the input port of the microstrip BPF to an RF signal generator with reference power level of 10 dBm and carrier frequency set to *3.4 MHz* (practical) and *3.6 MHz* (simulated) using *50 Ω* as shown in figure 3.0 and 4.0. The output response was obtained by connecting the output port of the microstrip BPF to a spectrum analyser with frequency range of 1 kHz-3 GHz as I shown in figure 3.0. The outputs displayed the graph of the transmission coefficient using scattering (S) parameter, S_{21} in figures 5.0 to 8.0 by the spectrum analyser represents the practical (real) response of the implemented fourth (4^{th}) order High Frequency (HF) BPF design using practical components on a microstrip line board. After carefully setting up all the parameters needed on both the signal generator and spectrum analyser the responses were observed as shown in figures 5.0 to 8.0. The S-parameter indicating the transmission coefficient, S_{21} (dBm) (figure 5.0 and 6.0) and the calculated bandwidth (figure 7.0 and 8.0) were shown with their corresponding values at different carrier frequencies of the implemented design.

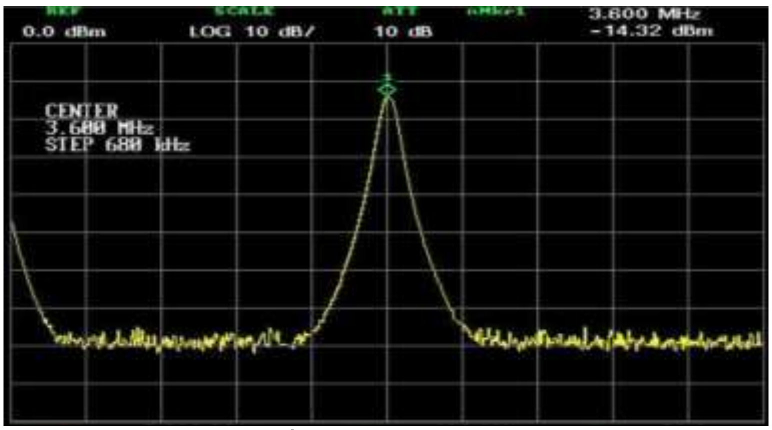

Figure 5.0: Microstrip 4^{th} order BPF at 3.6 MHz Frequency

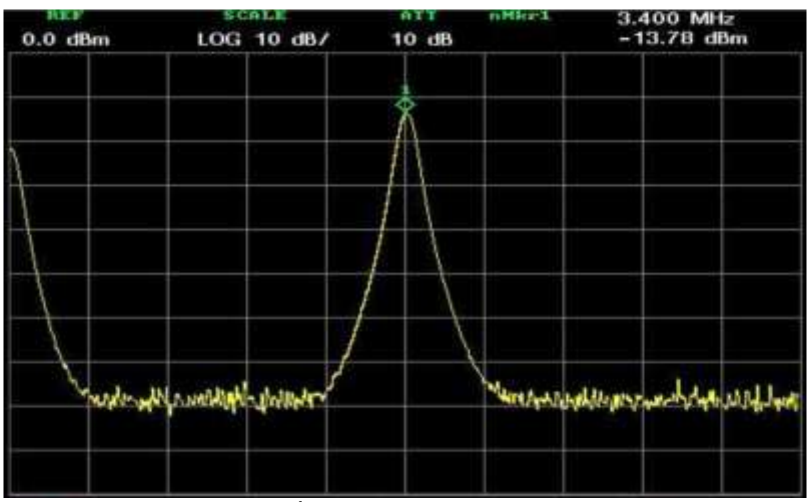

Figure 6.0: Microstrip 4^{th} order BPF at 3.4 MHz Frequency

It was observed from figures 5.0 and 6.0 that comparing the designed and experimental characteristics of the filter, at different centre frequencies of *3.6 MHz* and *3.4 MHz* the measured values of the transmission coefficient S_{21}(dBm) are -14.32 dBm and -13.78 dBm respectively. Hence both are matched well which shows the effective design procedure for microstrip filter. The proposed BPF design and fabricated on a microstrip board was connected to the IFR-2025 Spectrum analyser through 50 Ω ports. These experimental results provided an excellent insight of the design and implementation since it is in accordance with the execrated results.

The bandwidth was obtained by setting both the signal generator and spectrum analyser to the desired carrier frequency and power levels. The spectrum analyser settings to display bandwidth (BW) as shown in figures 7.0 and 8.0 was obtained by setting the *measure button option***.** Carrier frequencies were varied from the signal generator until the required bandwidth is obtained for each of them. Because of practical factors such as cable loses and other effects on the component due to soldering**,** the responses are not perfect as the theoretical (ideal) output response.

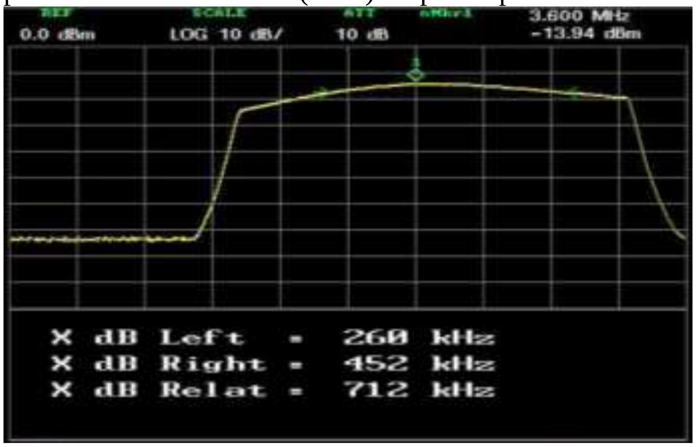

Figure 7.0: Microstrip 4th order BPF Bandwidth at 3.6 MHz

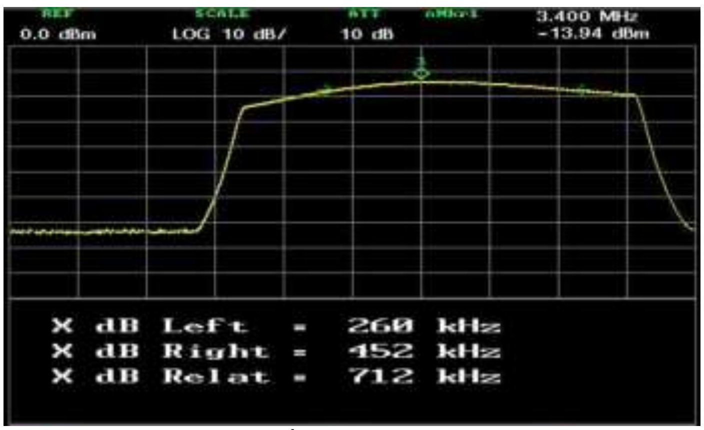

Figure 8.0: Microstrip 4th order BPF Bandwidth at 3.4 MHz

The above filter was design to achieve a *3 dB* bandwidth of *800 kHz* ($2f_m$) with f_m of *400 kHz* that allowed an *IF* of *3.6 MHz* (calculated) or *3.4 MHz* (practical) from several frequency components, the other frequencies above and below the *IF* were attenuated. The modulating (intelligence) frequency signal, f_m was given as *400 kHz* in during the design [9]. Although an ideal or theoretical design of the filter cannot be achieved 100% in practice due to external and internal constraints, but an acceptable result of *712 kHz* was obtained which is about 90% of the ideal *800 kHz*. The response of this filter was quite excellent in both the simulated [9] and the implemented filter. However, the anticipated *3 dB* bandwidth was *800 kHz* but *712 kHz*, because the ideal one might not be realised due to some limitations in the real circuit such as soldering, components value changes due to excess heating, losses in the cables, loose connection, external interference, etc. Smaller values of harmonics compared to the *IF* are filtered out or rejected by the BPF. High values of harmonics will be rejected by the upper side cut-off while low frequency harmonics will be attenuated by the lower side cut-off point. These results are summarised in table I below for both the original design and the practically implemented.

Table I: Summarised Results of Implementation and Testing

Design	*IF (MHz)*	BW_{3dB}(kHz)	f_h (kHz)	f_l (kHz)	S_{21}(dBm)
Design	3.6	712	*452*	260	-14.32
Practical	3.4	712	452	260	-13.78

4. Conclusion

Based on the successful implementation and testing of the microstrip board High Frequency Band Pass Filter (BPF), employing practical equipment such as the IFR 2025 RF signal generator, IFR 2399C spectrum analyser, and *50 Ω* impedance cables, this study has yielded promising results. The measured S_{21}(dBm) values of -14.32 dBm and -13.78 dBm for frequencies of 3.6 MHz and 3.4 MHz respectively demonstrate an excellent response. Furthermore, achieving a bandwidth of 712 kHz, which corresponds to approximately 90% of the ideal 800 kHz, underscores the effectiveness of our design. It is noteworthy that the obtained results closely align with the simulated (theoretical) values, albeit with minor deviations. Such deviations are inherent to practical implementation due to constraints not accounted for in simulation environments. Nevertheless, the overall performance of the implemented BPF design is commendable, indicating its potential for real-world applications such as microwave communications and RADAR systems. The outcomes of our study validate the efficacy of the microstrip board HF BPF design and highlight its suitability for practical use in high-frequency applications. Future endeavours may focus on refining the design to further optimize performance while addressing practical constraints encountered during implementation.

Reference

[1] C. Laporte, L. Schwartz, E. Saugier, S. Charley, and H. Ezzeddine, “Compact 5G N77 bandpass filter design mixing IPD and MIS technologies”, in Proc. Of European Microve Conference, pp. 203-206, 2022.

[2] Y. Wu, E. Fourn and P. Besnier, “A Planar Quad-band Band-Pass Filter Employing Dual-Mode Band-Stop Resonators”, in Proc. IEEE MTT-S International Microwave Filter Workshop (IMFW), pp. 79-81, 2021.

[3] V. S. Kushwa and G. S. Tomar, “Design of First Order Parallel Coupled Microstrip Band Pass Filter in Mobile Band”, in Proc. Of IEEE International Conference on Computational Intelligence and Communication Networks, pp. 31-39, 2018.

[4] R. Gómez-García, L. Yang, and D. Psychogiou, “A Frequency Transformation for Co-Designed Multi-Passband/Multi-Embedded-Notch RF Filters”, IEEE Transactions on Circuits And Systems—II: Express Briefs, Vol. 68, (7), pp. 2429-2433, 2021.

[5] F. Wang and B. Luo, “A Novel Design of Wi-Fi Band-pass Filter with Symmetrical Zeros” in Proc. Of IEEE International Conference on Communications, Information System and Computer Engineering (CISCE), pp. 231-234, 2022.

[6] LIN J Y, WONG S W, WU Y M, et al: “Three-way multiple-mode cavity filtering crossover for narrowband and broadband applications”, IEEE Trans. Microwave Theory Technology, 67(3) :896-905, 2019.

[7] L. Zirui, C. Zhongrong, “Design of 400 MHz Ultra-narrowband Microwave Filter”, Modern Electronics Technique, Vol. 44 (11), pp. 19–22, 2021.

[8] R. R. Mansour, “Filter technologies for Wireless Base Station Filters,” IEEE Microwave Mag., Vol. 5 (1), pp. 68–74, 2004.

[9] A. A. Bisu, “Design and Simulation of a 4th Order High Frequency Bandpass Filter for RADAR Communication Systems”, Journal of the Nigerian Association of Mathematical Physics (JNAMP), 2024