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Design of Novel Filtenna for Wireless Applications

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Abstract. *In this paper, a novel design based on a dual-mode ring resonator, the filtering balun, feeding the printed dipole antenna, the filter balun antenna (FBA), is presented. One port on the structure allows the signals to be phase-shifted 180 degrees from one unbalanced port to two balanced signals. The suggested designs use a single dual-mode ring resonator to operate as both a filter and a balun at the same time. Compact designs are achieved by applying feeding to the second layer. Another unique characteristic of the filtering balun is its ability to alter, based on perturbation size, the phase error and magnitude imbalance of the two balanced signals. With the use of the Advanced Design System (ADS) software, numerous structures have been developed, modeled, and evaluated. To achieve the highest performance, every section of the design is assessed and optimized. Because the substrate is a lossy type (FR4), the realized transmission coefficients, which are poorer than expected ideal values, make the suggested design a strong contender for narrow-band wireless applications. For S2,1 and S3,1, the signal is routed through two vias and fed into a dipole antenna in the opposite phase by employing the zero iteration for filtering the balun in the first layer to condense with the second layers. The antenna structure is a printed dipole antenna operating at 2.4 GHz.*

Keywords: *Microstrip filtenna, Balun, filters, antenna.*

1. INTRODUCTION

Almost every application in daily life is now dominated by wireless communication networks, which are now a necessary component of everything, particularly since the emergence of Internet of Things (IoT) technology. Global location systems like GPS, Wi-Fi, and Bluetooth, communication, devised connections, and other services can all be covered by multiple systems on the same device. As a result, a complex design is necessary because every function needs its own RF chain. Merging several elements into a single design, however, is a constant goal of designers for a variety of reasons, including affordability and compact size. In This research paper is studied for the purpose of presenting a design that includes these concepts and is composed of three integrated RF component. Most researchers' efforts are focused on the process of integrating two components with each other and giving the properties of these two components the same design. The most prominent of these studies deals with combining a filter with a balun or combining an antenna with a filter. In this research, we will combine three RF components filter, balun, and antenna, with an innovative design consisting of only two layers to reduce the size and give the best performance.
Many RF and optical applications, including microwave filters [1-3], baluns [4-5] oscillators [6-7], sensors [7-8], unit cells of metamaterial devices [9–10], optical filters [11], and microwave multiplexers [12], depend on the dual-mode ring resonator. Only the filters and baluns will be covered in this introduction. The ring resonator was first employed by the writers of [1-2] as a microwave bandpass filter in their early

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research. Their research centered on using the patch stub to disrupt the two modes in order to stimulate them. The author provided a thorough analysis of the use of ring resonators in filter designs in [3]. To find out how different perturbation layouts affected the overall performance, several configurations were examined. Depending on the amount of the disturbance, the inductive and capacitive couplings were defined. Whereas the inductive connection produces a Chebyshev transfer response, the capacitive coupling produces an elliptical transfer characteristic response. The former has a high selectivity since it adds zeros to the response. The latter is less selective because it contains no zeros. Nevertheless, the passband is not rippled. Numerous academics have been drawn to investigate ring resonators and their applications as a result of these two intriguing achievements. The intrinsic properties of the four sides of the dual-mode ring resonators, which have regions with maximum fields but varied phases, helped in the construction of the balun as shown in [4-5]. When using a ring resonator, the addition of a third port distinguishes the filter from the balun. Additionally, the ring resonator balun provides bandpass filter capabilities, combining two purposes into a single design structure. Subsequently, other research endeavours have surfaced, with miniaturization being among them. Minkowski, Koch, Gasket, and other curves were used by the authors in [13–15] to create compact dual-mode ring resonators-based designs of microwave bandpass filters using fractal geometry.
The Balun design also made use of fractal curves, although it did so with an open-loop resonator [16–17]. The kind of Koch-fractal was applied. The primary distinction between an open loop and a dual-mode ring resonator is that the latter can adjust the bandwidth by varying the amount of the perturbation; for this reason, it is the one used in this study.

2. The suggested filtering balun configuration combined with antenna

According to the dual-mode square ring resonator, the suggested Filtering Balun Antenna FBA is created; Figure 1 provides an overview of the process. The second layer of design included the dipole antenna, which has a resonance frequency of 2.4 GHz. The ground layers in addition to being used as a ground, it is also used for another function, which is to provide a reflector between the first and second layers to ensure no interference between the two layers. The proposed FBA resonant frequency is determined by measuring the closed square ring resonator's whole perimeter. As stated otherwise, the basic resonant frequency arises when the perimeter's total length equals a wavelength plus any harmonics brought about by the scattered transmission lines' inherent properties.

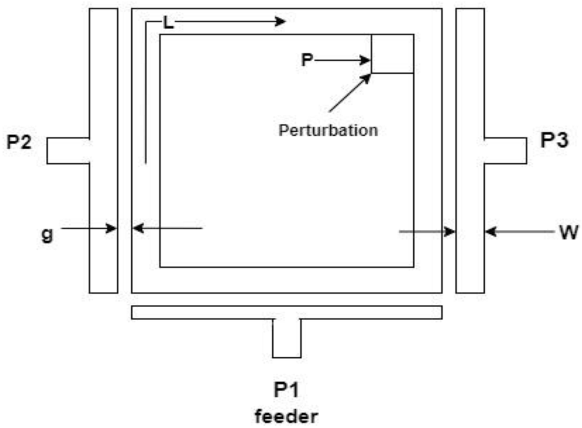

Fig. 1 A- shows a schematic layout of first layer the dual-mode ring resonator used as a filtering-balun component. The gap which is located between the feed and the resonator is shown by g, the microstrip

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transmission-line width by w, the physical length, L, equal to a quarter-wavelength by p, and the feeding number by P1, P2, and P3.

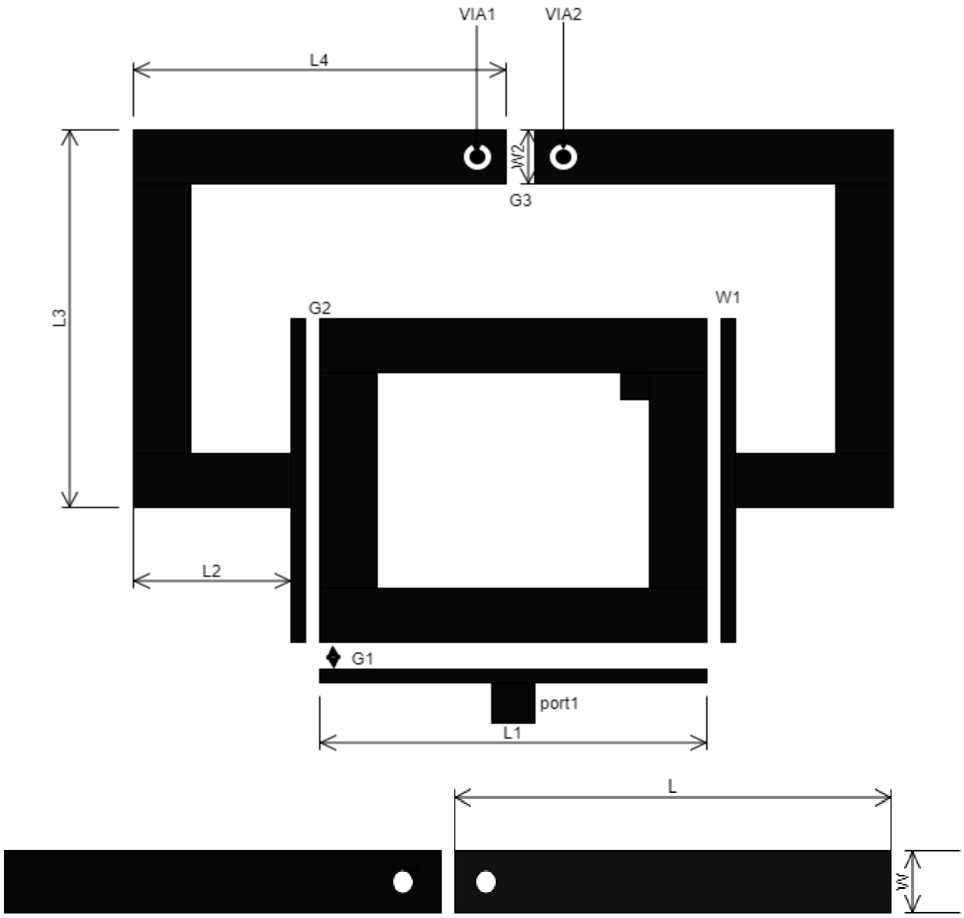

Fig.1 B- first and second layer printed dipole filtenna

variable	unit	variable	unit
L	**29 mm**	**W**	**3 mm**
L 1	**21 mm**	**W1**	**0.5 mm**
L 2	**9.2 mm**	**W2**	**3 mm**
L 3	**22 mm**	**G1**	**0.6 mm**
L 4	**23.4 mm**	**G2**	**0.5 mm**
VIA	**0.5 mm**	**G3**	**0.8 mm**

The Filtering-Balun-Antenna Design

Figures 1A and B show the structure of FBA. It is made out of a square-ring resonator that has a single wavelength throughout. As will be seen later, there is a perturbed stub linked to one of the internal corners that functions to excite the even-odd modes. Three ports are present: two output ports and one input port, or the other way around. The two output ports are out of phase with one another, or balanced. Unless stated

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otherwise, the electrical lengths of the two output ports differ by 180°. Since printed dipole antennas require a 180° phase difference between the two arms in order to ensure that the antennas radiate, the baluns that will be discussed in this work are suitable nominees to be used with printed dipole antennas. front (also known as boresight). The primary grating lobe will split into two halves and tilt to move away from boresight if this requirement is not met, resulting in the radiation being null on the front side [18]. Further details regarding the dual-mode reign resonator analysis are available for interested readers in [3]. For the sake of simplicity, we shall only cover the fundamentals here. The resonator's transmission-line model shown in Figure 1 (A, B). is shown in Figure 2, which also mentions the input and output ports. Two equal sections will be extracted from the input signal. There is no output response if there is no perturbation (p = 0), as each output port gathers signals from two routes that cancel each other out with a 180° phase difference. Figure 4 displays the current distribution in order to illustrate the cancellation procedure. Near the output ports, when the current is at its lowest, the coupling becomes extremely weak. Nevertheless, the analogous shunt capacitance Cp functions as a J-inverter, reversing the phases of the signals that flow through it when there is a disturbance (i.e., p > 0). This facilitates the in-phase alignment of the two signals at each output port, resulting in an output response. Additionally, Figure 3 shows the present distribution in this instance. The present distribution's peaks and minimum are 90° rotated. Stated differently, the highest current distribution occurs in the coupling area between the resonator and the output ports.

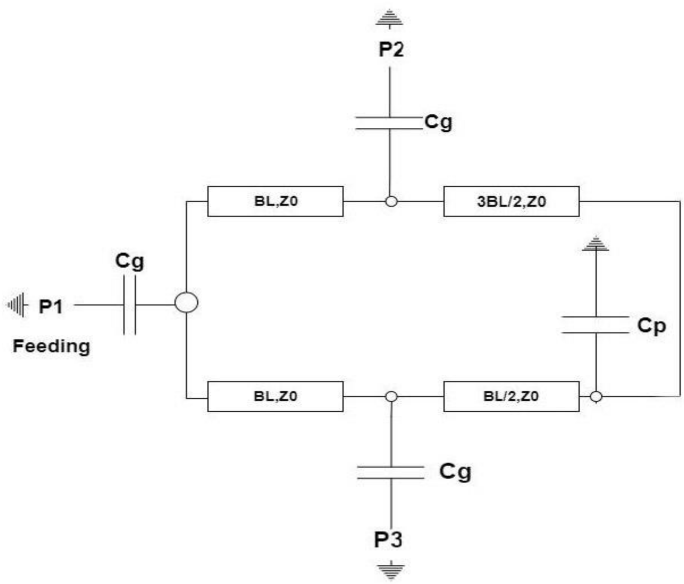

Figure 2 shows the transmission line model for the dual-mode square ring filtering-balun component. Cp stands for the equivalent capacitance of the perturbation stub, and Cg is the equivalent capacitance caused by the gap between the ring resonator and the feed.

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3. RESULTS AND DISCUSSION

An extensive description of the research's findings is given in this section. The Advanced Design System ADS software is used for full-wave simulation in the design, simulation, and analysis of FBA. The proposed FBAs' layout schematic is displayed in Figure 1, and the S-parameters that match it are displayed in Figure 4. As may be observed, the result is consistent with the succinct analysis that was previously provided. To illustrate how well the perturbation size works. As shown in Figure 5, p in the dual mode square ring resonator is adjusted in steps of 2 mm, from 0 to 6 mm. The S21 and S31 are canceled because the two modes have the same frequency, but they are out of phase when p = 0 mm. The applications like S21 and S31 are excited for the state p = 2 mm because the two modes have the same phase shift and nearly identical frequencies, despite small variations. We can state that the frequency difference between the two modes rises as p increases. Due to the growing phase difference between the two modes, the center frequency will respond weakly. Figure 6's responses are all narrow bands due to the dual-mode ring resonator's intrinsic properties. This indicates that these designs will make excellent choices for low-noise applications. A higher bandwidth is known to increase the amount of noise that enters the system.

While -3 dB is the optimal level, the S21 and S31 are about -4 to -5 dB. The additional loss is a result of the FR4-type substrate being utilized in this instance, which is lossy. Because the substrate utilized in this study is just 1.6 mm thick, some electromagnetic waves would radiate into space, which may cause radiation loss. The availability of substrate in the local marketplaces is the cause of this restriction. Because the signals will be more bonded to the structures and less likely to leak, substrates with modest thicknesses are therefore favored for guided radio frequency components like filters, resonators, transmission lines, etc. The answers have decreased as a result of these two causes. However, substrates with low losses should be employed, specifically for commercial reasons, to have superior reactions. Figure 7 shows the phase disparities between the two output ports for each of the suggested FBAs. These phase variances are nearly equivalent to 180°.

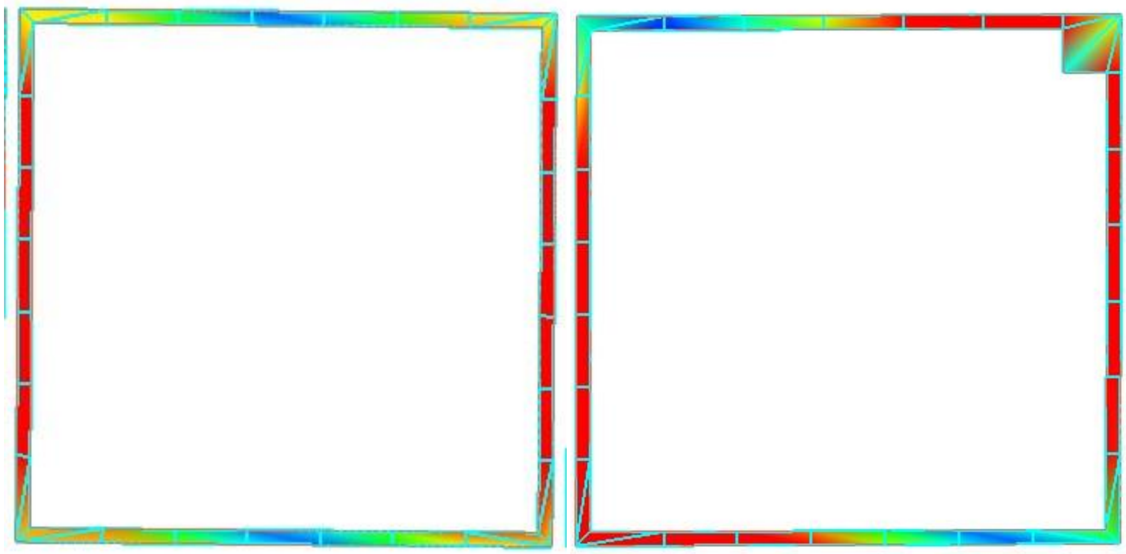

Fig. 3 the simulated current density at resonance both with and without perturbation in sequential order.

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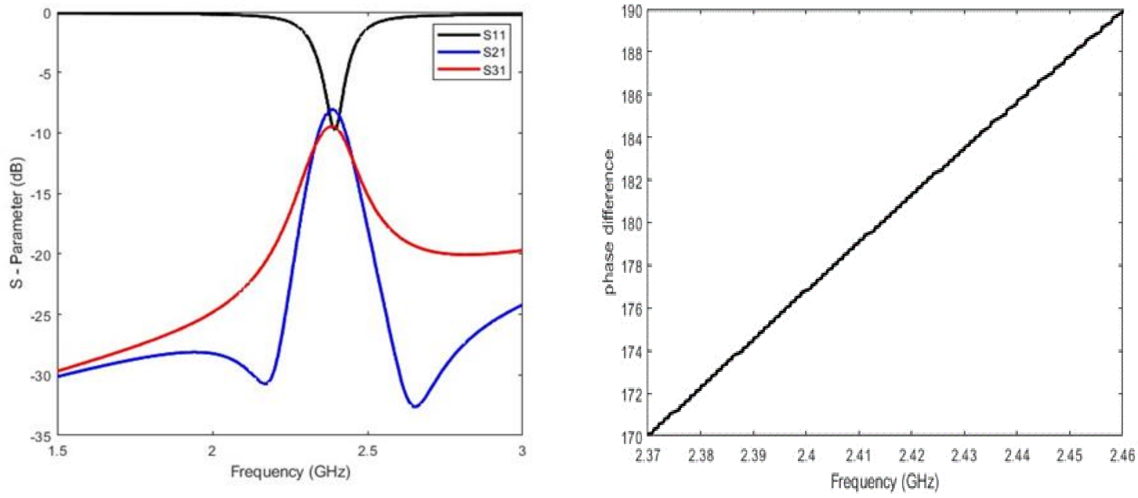

Fig. 4: The S-Parameters responses of the first layer before combination the two layers and phase difference between S2,1 and S3,1.

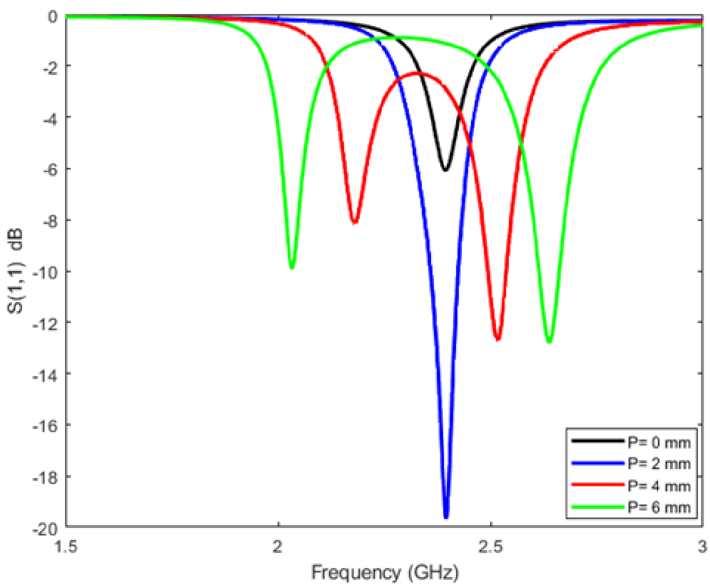

Fig. 5: The S-parameters responses S11 of the first layer BPF with balun, when p is changed from 0mm to 6mm with a step of 2mm, the best results using the 2 mm at 2.4 GHz Frequency.

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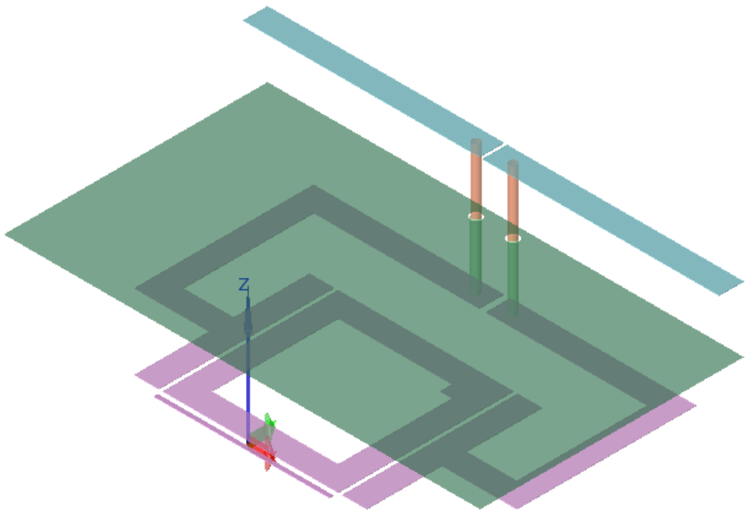
ISSN -2708-3985

The Combination Design for FBA in Two Layers

The dual-mode microstrip band pass filter ring resonator compact with baluns in the first layer is used in the suggested design for FBA by using copper conductors with FR4 in the two layers. The antenna is contained in the second layer. In the design, a printed dipole antenna was used. Without coming into contact with the ground layer that sits between the two layers, there are two vias that connect the first layer to the second layer. The substrate that is being used is FR4, measuring 32 mm in width and 59 mm in length, with a thickness of roughly 1.6 mm for each layer.



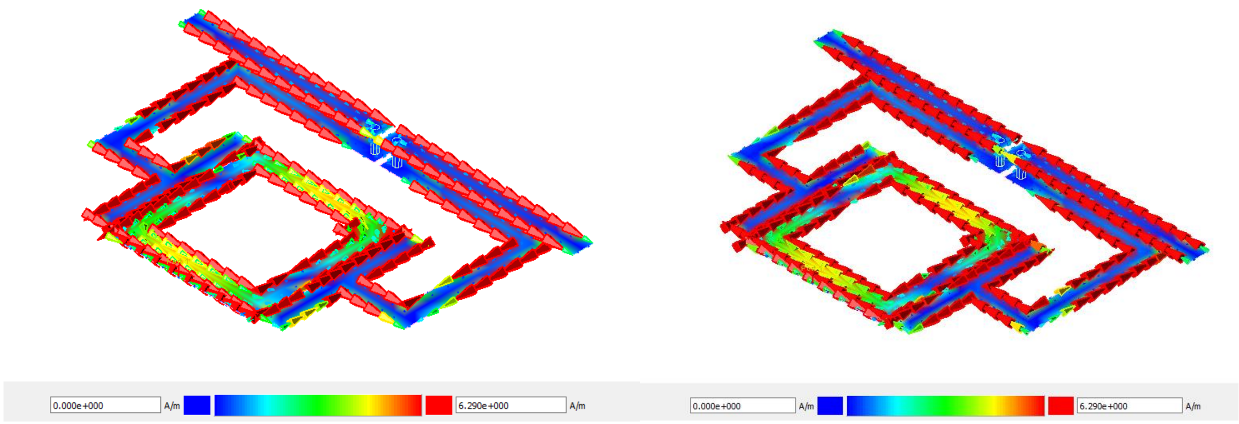


Fig. 6 b: current distribution in proposed design for the two layers in difference phase show the dipole driven phase mutually.

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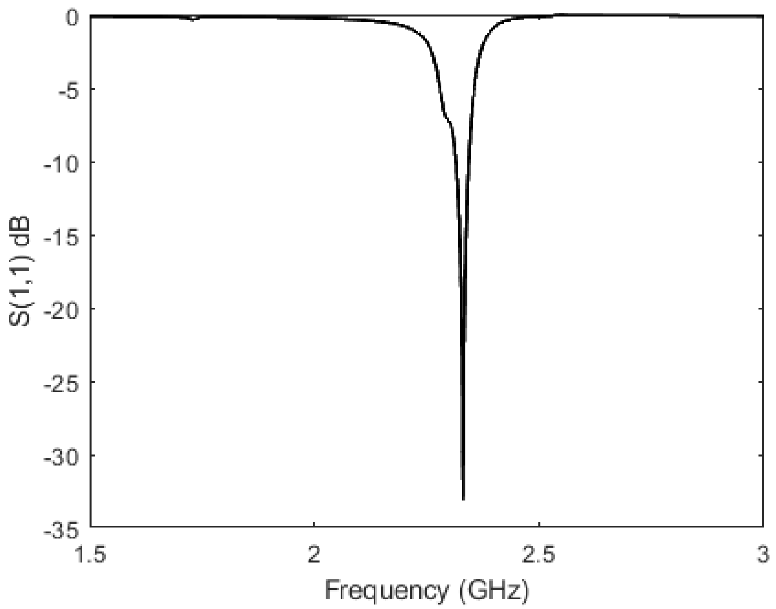

Fig. 7: The S-parameters responses S11 of the BFA design.

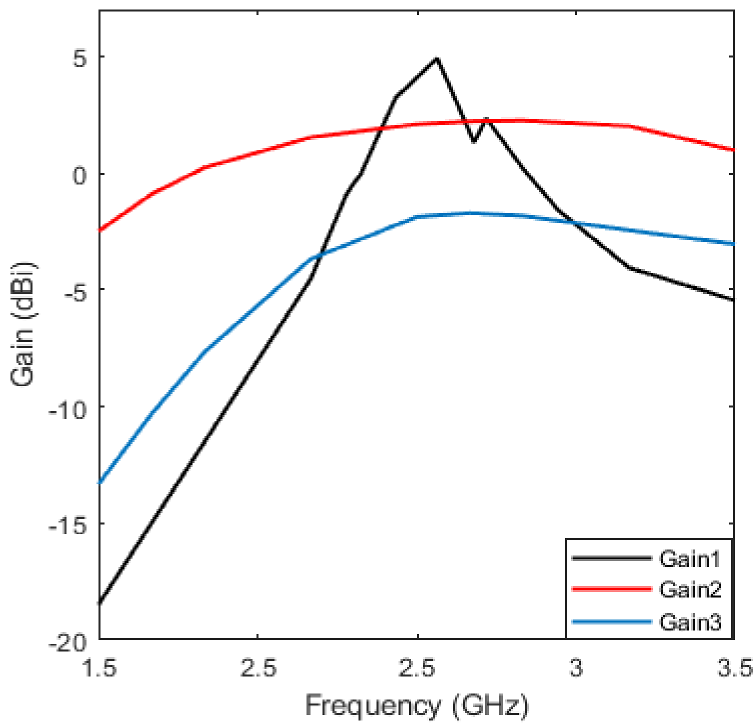

Fig. 8: The Gain1 for FBA, Gain2 for printed dipole with differential feed, Gain3 for printed dipole without differential feeding.

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Figure (8) illustrates this. If the current intensity is in the same phase, it will be opposite to the dipole. As a result, the first current's intensity will cancel out the second current's intensity, and their combined transmission will be null at the feeding point, represented by the first curve. In contrast, if one current has a 180-degree phase difference, the second current will support the first, and the transmission will be as great as possible at the feeding point, which is indicated by the second curve, in the center of the dipole.

In order to enhance this idea, we observe the third curve, which has a higher gain and beam selectivity than the second curve. This is because a band-pass filter with a balun integrated into the design produces a filtered feed signal with a 180-degree phase difference. An antenna's effectiveness and performance are enhanced when it is paired with a signal filter, leading to improved performance metrics for the antennas. By adding a feed, you can create your own custom dipole antenna design. The dipole antenna needs to be in the opposite phase in order to function, which was achieved by utilizing the balloon's characteristics found in the filter's unique design. The gain was also adjusted to meet the required specifications, bringing it down to the lowest possible value for the 2.4–2.5 GHz band, which is 4.9–2.4 dpi. In comparison with other designs in size, cost, and efficiency for gain, the objective of the proposed FBA

Table of design properties in comparison with same freq. Band for other designers

Ref. NO.	Substrate type	Dimension L ,W in mm	Resonance Freq. In GHz	Gain in dBi
[20]	FR-4	35 X 30	2.4	0.74
[21]	FRBM-2 Two layers	87.75 X 66.8	2.3	5.5
[22]	Rogers	80 x 80	2.34	4.49 – 5.38
[23]	F4B – Four layers	140.9 x 123	2.5	8
FBA	FR4 – Two layers	58.89 x 32.74	2.4	4.9

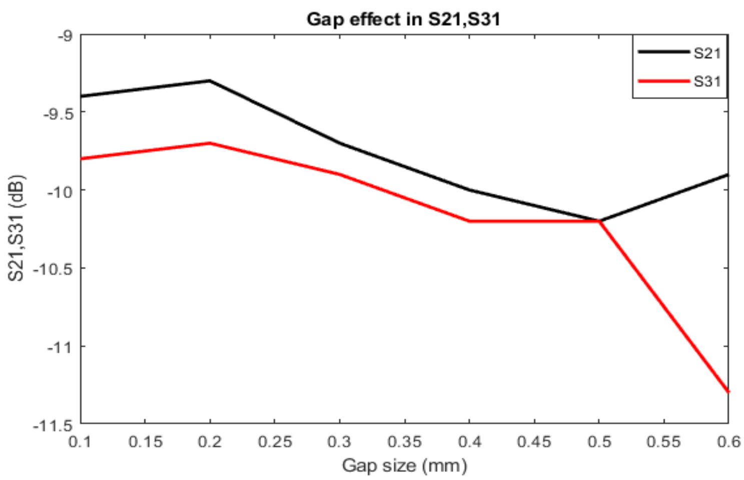

Fig. 9. The effect of the size of the gap between the feed of the square resonator and the first and second outputs.

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In Fig. 9 the effect of the size of the gap between the feed of the square resonator and the first and second outputs, as the results showed that s21 and s31 were the highest possible when the gap was 0.1 mm. However, what we need in the design, in addition to providing two outputs from the resonator, must be different. The phase between them is 180 degrees, which is what worked best when the gap was measured at 0.5 mm.

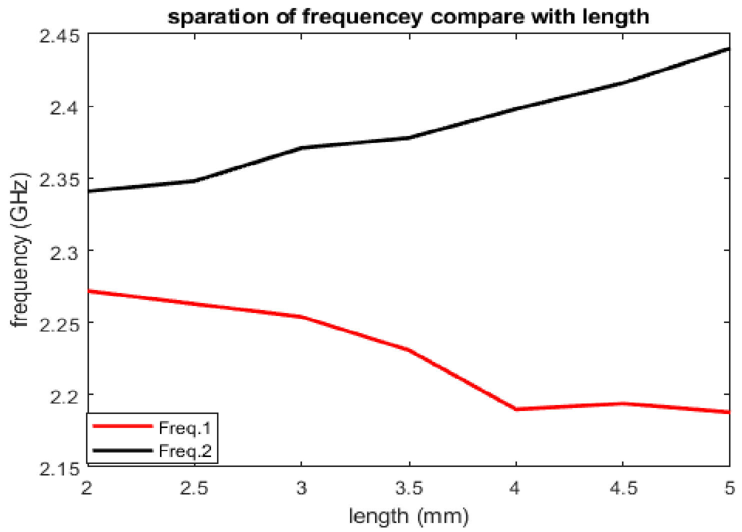

Fig. 10

While we are using the dual mode square resonator, we notice in Figure 10 the process of increasing the separation of the two frequencies combined together, as the larger the size of the inner box inside the square resonator, the greater its value in influencing the first frequency and pulling it away from the fundamental frequency of the resonator.

However, it must be noted that there is a good matching between the supply and the output when the size of the internal square in the resonator is increased.

Simulation and Experimental Results for Dipole Filtenna

We observe from the production data that there are a few observations about the design's ultimate response. Both the manufacturing procedures and the measurement tools in use are to blame for this. With the resources at hand, it was measured and produced. We possess. It produced outcomes. Tangible, which used the ADS program to create an extremely close replica of the design.

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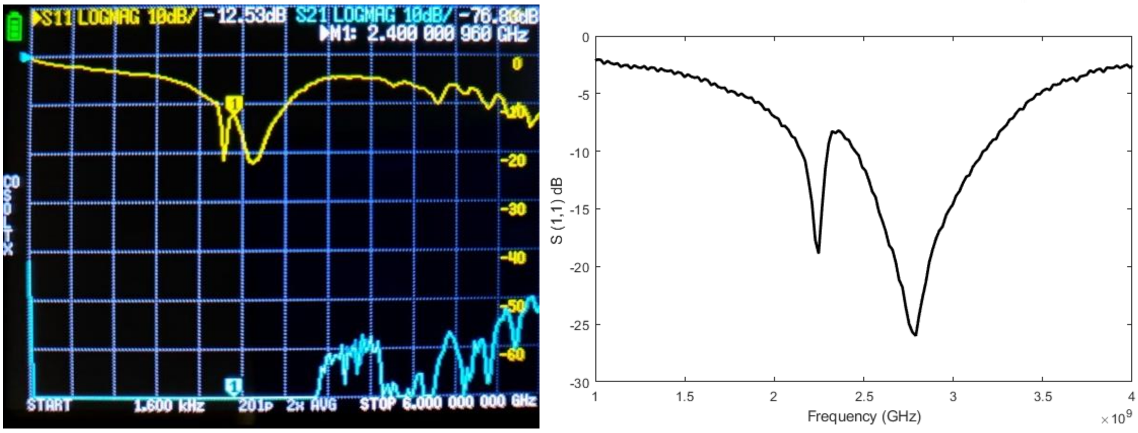

Fig.11 Manufacturing result freq. response S (1,1) for dipole filtenna

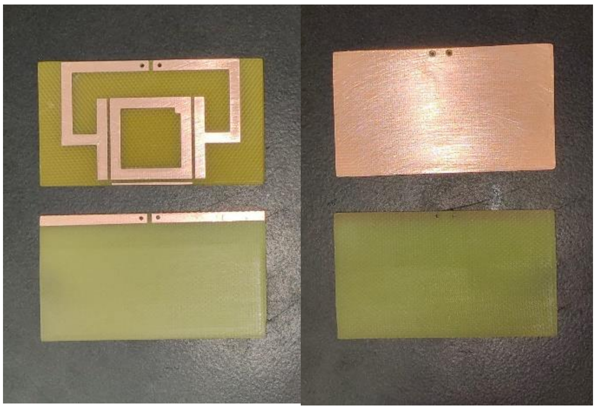

Fig.12 Manufacturing of two layers for dipole filtenna FBA

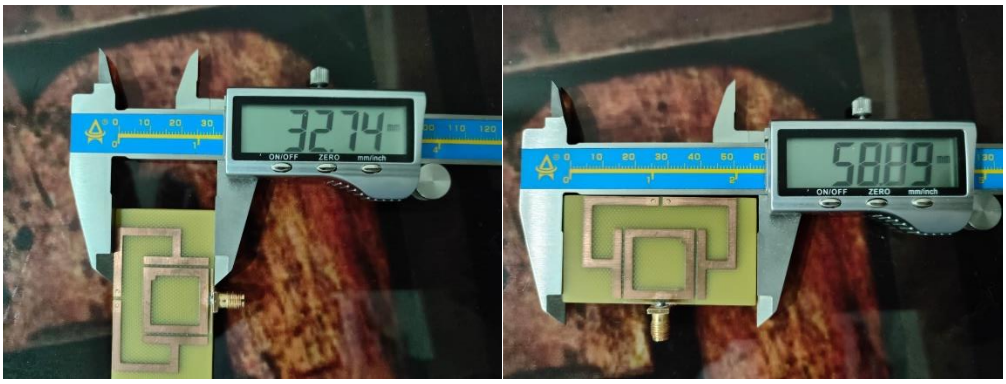

Fig.13 Manufacturing dimension for dipole filtenna with thickness about 3.2 mm

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4. CONCLUSIONS

To the best of the authors' knowledge, the dual-mode ring resonator based on balun-filtering-antenna was showed for the first time in this study. The input signals, especially the dipole antenna, were a suitable fit for applications that operated with two balanced input ports since they were split into two outputs that were out of phase. For each layer in the study, a FR4 substrate with a thickness of 1.6 mm was employed. Its effect was clearly seen on the S21 and S31, with their gain of 4.9 dpi being in the range of -4 to -5 dB in relation to the dual mode square ring resonator. To provide the readers with a nearly comprehensive understanding of the design, a theoretical summary of the study together with a corresponding circuit was also supplied.

REFERENCES

[1] J. S. Hong and M. J. Lancaster, “Bandpass characteristics of new dual-mode microstrip square loop resonators,” Electron. Lett., vol. 31, no. 11, pp. 891–892, May 1995.
[2]] J. S. Hong and M. J. Lancaster, “Microstrip bandpass filter using degenerate modes of a novel meander loop resonator,” IEEE Microwave Guided Wave Lett., vol. 5, pp. 371–372, Nov. 1995.
[3] A. Gorur, "Description of coupling between degenerate modes of a dual-mode microstrip loop resonator using a novel perturbation arrangement and its dual-mode bandpass filter applications," in *IEEE Transactions on Microwave Theory and Techniques*, vol. 52, no. 2, pp. 671-677, Feb. 2004, doi: 10.1109/TMTT.2003.822033
[4] E. -Y. Jung and H. -Y. Hwang, "A Balun-BPF Using a Dual Mode Ring Resonator," in *IEEE Microwave and Wireless Components Letters*, vol. 17, no. 9, pp. 652-654, Sept. 2007,
[5] P. Cheong, T. -S. Lv, W. -W. Choi and K. -W. Tam, "A Compact Microstrip Square-Loop Dual-Mode Balun-Bandpass Filter With Simultaneous Spurious Response Suppression and Differential Performance Improvement," in *IEEE Microwave and Wireless Components Letters*, vol. 21, no. 2, pp. 77-79, Feb. 2011,
[6] M. M. Bajestan, V. D. Rezaei and K. Entesari, "A 2.75–6.25GHz low-phase-noise quadrature VCO based on a dual-mode ring resonator in 65nm CMOS," *2014 IEEE Radio Frequency Integrated Circuits Symposium*, Tampa, FL, USA, 2014, pp. 265-268, doi: 10.1109/RFIC.2014.6851715.
[7] Passaro, V.M.N.; Tullio, C.D.; Troia, B.; Notte, M.L.; Giannoccaro, G.; Leonardis, F.D. Recent Advances in Integrated Photonic Sensors. *Sensors* **2012**, *12*, 15558-15598. https://doi.org/10.3390/s121115558
[8] Passaro, V.M.N.; Troia, B.; La Notte, M.; De Leonardis, F. Chemical Sensors Based on Photonic Structures. In *Advances in Chemical Sensors*; Wang, W., Ed.; InTech: Rijeka, Croatia, 2012. [**Google Scholar**]

[9] Air Mohammad Siddiky, Mohammad Rashed Iqbal Faruque, Mohammad Tariqul Islam, Sabirin Abdullah, A multi-split based square split ring resonator for multiband satellite applications with high effective medium ratio, Results in Physics, Volume 22, 2021, 103865, ISSN 2211-3797, https://doi.org/10.1016/j.rinp.2021.103865.

[10] Wang, Ben-Xin, et al. "A broadband terahertz metamaterial absorber enabled by the simple design of a rectangular-shaped resonator with an elongated slot." *Nanoscale Advances* 1.9 (2019): 3621-3625.

ATU-FJIECE, Volume: 3, Issue: 2, May 24, DD, YYYY, © 2020 FJIECE, All Rights Reserved

[11] D. G. Rabus, M. Hamacher, U. Troppenz and H. Heidrich, "Optical filters based on ring resonators with integrated semiconductor optical amplifiers in GaInAsP-InP," in *IEEE Journal of Selected Topics in Quantum Electronics*, vol. 8, no. 6, pp. 1405-1411, Nov.-Dec. 2002, doi: 10.1109/JSTQE.2002.806692.

[12] Wang, Chunlei, and Kai Chang. "Microstrip multiplexer with four channels for broadband system applications." *International Journal of RF and Microwave Computer-Aided Engineering: Co-sponsored by the Center for Advanced Manufacturing and Packaging of Microwave, Optical, and Digital Electronics (CAMPmode) at the University of Colorado at Boulder* 11.1 (2001): 48-54.

[13] Ali, Jawad K., and Nasr N. Hussain. "An extra reduced size dual-mode bandpass filter for wireless communication systems." *Proc. Progress in Electromagnetics Research Symp., PIERS*. 2011.

[14] Ali, Jawad K., and N. N. Husain. "A new fractal microstrip bandpass filter design based on dual-mode square ring resonator for wireless communication systems." *Iraqi Journal of Applied Physics* 5.1 (2009).

[15] Ahmed, Hayder S., et al. "A compact triple band BSF design based on Minkowski fractal Geometry." *2016 18th Mediterranean Electrotechnical Conference (MELECON)*. IEEE, 2016.

[16] Xu, He-Xiu, Wang, Guang-Ming, Lu, Ke and Chen, Xin. "Fractal-Shaped Balun Using Composite Right/Left-Handed Transmission Line for Bandwidth Enhancement" *Frequenz*, vol. 65, no. 5-6, 2011, pp. 121-126. https://doi.org/10.1515/freq.2011.019

[17] H. -X. Xu, G. -M. Wang, X. Chen and T. -P. Li, "Broadband Balun Using Fully Artificial Fractal-Shaped Composite Right/Left Handed Transmission Line," in *IEEE Microwave and Wireless Components Letters*, vol. 22, no. 1, pp. 16-18, Jan. 2012, doi: 10.1109/LMWC.2011.2173929.

[18] Yongxi Qian, W. R. Deal, N. Kaneda and T. Itoh, "A uniplanar quasi-Yagi antenna with wide bandwidth and low mutual coupling characteristics," *IEEE Antennas and Propagation Society International Symposium. 1999 Digest. Held in conjunction with: USNC/URSI National Radio Science Meeting (Cat. No.99CH37010)*, Orlando, FL, USA, 1999, pp. 924-927 vol.2, doi: 10.1109/APS.1999.789463.

[19] Pozar, David M. *Microwave engineering*. John wiley & sons, 2011.

[20] Pal, P., Sinha, R., & Mahto, S. K. (2021). Synthesis approach to design a compact printed monopole filtenna for 2.4 GHz Wi-Fi application. International Journal of RF and Microwave Computer-Aided Engineering, 31(5). https://doi.org/10.1002/mmce.22619

[21] Song, L., Wu, B., Xu, M., Su, T., & Lin, L. (2019). Wideband balun filtering quasi-Yagi antenna with high selectivity. Microwave and Optical Technology Letters, 61(10), 2336–2341. https://doi.org/10.1002/mop.31903

[22] Zhang, G., Qian, Z., Chen, Y., & Zhao, Y. (2018). A Wide Stopband Balun Bandpass Filter with Its Application to Balanced Quasi-Yagi Antenna. Wireless Communications and Mobile Computing, 2018. https://doi.org/10.1155/2018/4725072

[23] Zheng, L., Zhai, H., Wei, Z., Ma, S., & Shi, J. (2019). A new wide stopband and high gain quasi-Yagi filtering antenna. Microwave and Optical Technology Letters, 61(1), 131–135. https://doi.org/10.1002/mop.31529