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Simple Strip Line Ring Wideband Band Stop Filter with Extended lower Pass band and Multiple Bands for RF Applications

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Abstract: Microwave band stop filters (BSF) are widely used in Wireless communication and RF circuits for their effective suppression of spurious while allowing desired signals to pass. Compact WBSFs with high skirt selectivity are in demand for many communication and radar systems. The proposed wideband band stop filter (WBSF) with extended lower pass band is a transmission line ring with one embedded capacitor. The transmission zeros configuration results wide and controllable stop band by providing interference between two signal paths. A lumped capacitor used that prevents the stop band from repeating at odd multiples of the fundamental stop band center frequency, resulting in a much wider lower pass band. The circuit is simple, very compact and easy to fabricate. A simulated WBSF has a 20 dB rejection bandwidth of 93.75 percent at a center frequency of 3.2 GHz. The proposed filter fabricated on FR4 substrate and is useful in GPS applications.
Keywords: WBSF, lumped capacitor, GPS.

I. INTRODUCTION

Microwave band stop filters (BSF) are used in RF circuits and wireless communication for effective suppression of spurious allowing desired signals to pass. WBSFs with high skirt selectivity are in demand for communication, radar systems. Conventional BSFs which uses shunt open circuit stub and coupled-line is generally large and narrowband. Several BSF configurations in planar technology with rejection and wide stopband are recently been used. Li, et al.and Hsieh and Wang describe that WBSFs combine the quarter-wavelength lines with a coupled-line sections of same electrical length. The WBSFs also achieved for connecting two quarter-wavelength coupled-line sections, one of a short circuit and other with open circuit. The signal interference technique is being used for designing WBSFs for good skirt selectivity.

The WBSF structure is made of two parallel transmission lines with different electrical lengths and characteristics. By successfully replacing the transmission zeros near stop band edges, signal interference techniques enables the sharp rejection with high skirt selectivity. In addition, the performance of this filter is improved with additional lines. For Example, Kanti, et al.uses a parallel-coupled transmission line section for improving BSF performance with five transmission zeros in stopband. Similarly, the use of open-ended coupled-line will significantly enhances the 20 dB rejection bandwidth. Furthermore, ultra-wide bandwidth and sharp rejection can also balance with two-section open stubs.

The bandwidth of the upper pass band filters is generally narrow; worse, the bandwidth of the upper pass band decreases as the bandwidth of the stop band increases. In this project, we describe WBSF that improves the stopband and broadens the upper passband. The structure includes two bilateral transmission lines and one capacitor which reduce signal interference. This generates three adjustable transmission zeros in the controllable stopband for rejection and which expands the upper passband tremendously compared to the similar structures, through the use of the embedded capacitor.

II. CONFIGURATION

The modified model of transmission line is shown in below figure and it can be decomposed into two parallel sections.

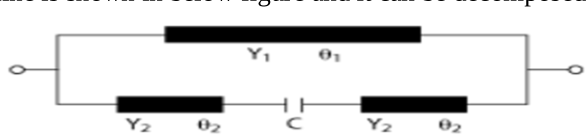

Fig. 1 : modified model of transmission line

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One is the upper transmission line section which having a characteristic admittance Y1 and electrical length of θ1; the other one is the cascaded structure which consisting of two bilateral transmission lines with characteristic admittance of Y2, electrical length θ2 and one capacitor. Considering the entire structure to be lossless, the overall Y matrix is as given below

$$Y_{21}^{U} = jb_{21}^{U} = jY_1 \csc\theta_1$$

$$Y_{21}^{L} = jb_{21}^{L} = \frac{-j2\pi fC}{\cos^2\theta_2 - 4\pi fC\sin\theta\cos\theta_2/Y_2}$$

If θ1= π when f = f, then $Y_{21}^{U}=+\infty$ at frequency f1

For lower section, at the frequency, obviously, there is a series resonance when f = f2. For this design, f2 is always set lower to f1 which generate three transmission zeros.
Then the total parallel Y matrix of structure can be expressed as

$$f_2 = \frac{Y_2}{4\pi C\tan\theta_2}, Y_{21}^{L} = +\infty$$

$$\left[Y_{21}^{T}\right] = \left[Y_{21}^{U}\right] + \left[Y_{21}^{L}\right]$$

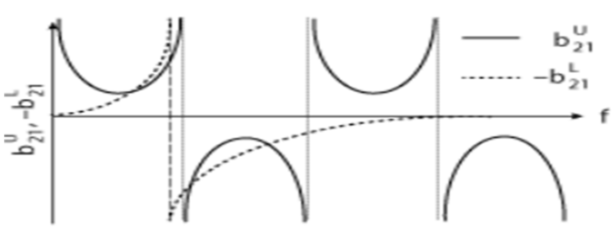
The BSF creates transmission zeros at frequencies where |S21| = 0, and the relationship between the scattering matrices and admittance matrices can be given by

$$S_{21}^{T} = \frac{-2Y_{21}^{T}Y_0}{\left(Y_{11}^{T} + Y_0\right)\left(Y_{22}^{T} + Y_0\right) - Y_{12}^{T}Y_{21}^{T}}$$

The condition for production of transmission zeros which can be simplified by setting $Y_{21}^{T}=0$, which gives the relationship

$$Y_1 \csc\theta_1 = \frac{2\pi fC}{\cos^2\theta_2 - 4\pi fC\sin\theta_2\cos\theta_2/Y_2}$$

The relevant graph of above Equation is shown in below Figure



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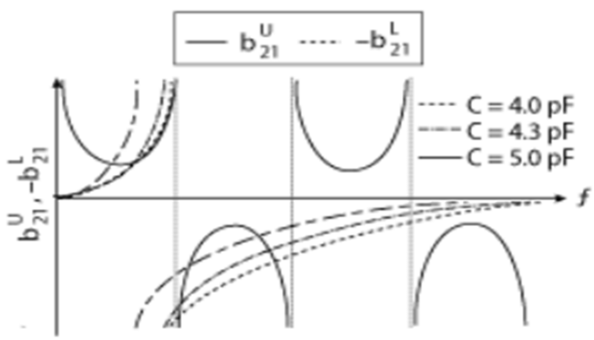
The thick line and dashed line represent b_{21}^{U} and - b_{21}^{L}, respectively, the intersection points in the curves will reveal the approximate locations of stop band transmission zeros. The first transmission zero positioned at fz1 is generated at the lower side of f1 since f2< f1 is satisfied in this design. Another two transmission zeros fz2 and fz3 are also provided between f1and 2f1when

$$b_{21}^{U}\left(\frac{3f_1}{2}\right) > -b_{21}^{L}\left(\frac{3f_1}{2}\right)$$

By choosing appropriate parameters, the structure produce three transmission zeros for a BSF response. Note that transmission zero distribution in this design is not symmetrical about central transmission zero, while the transmission zero distributions of almost all the previous reported WBSFs are equal. In fact, by tuning C or Y1, different transmission zero distributions provide either symmetric or asymmetric responses. The asymmetric band stop filter response can eliminate the restriction of fixed central transmission zero, resulting in better flexibility and adjustability compared with previous reported WBSFs.

From the above analysis, given upper and lower transmission line parameters, the transmission zero distribution can be adjusted by changing C. With increasing C, f2 decreases, moving the first transmission zero lower. Meanwhile, the dashed line (-) becomes sharper, pushing the second transmission zero higher and drawing third transmission zero lower. Accordingly, the transmission zero separation between fz1 and fz2 increases while the transmissions zero separation between fz2 and fz3 decreases increasing C. As shown in Figure , different BSF responses with different transmission zero distributions can be obtained by changing C. It concluded with use of capacitor it is possible to have multiple bands. Another interesting result is by changing the substrate the extended upper band high pass filter becomes low pass filter with extended lower band



III.RING STRUCTURE

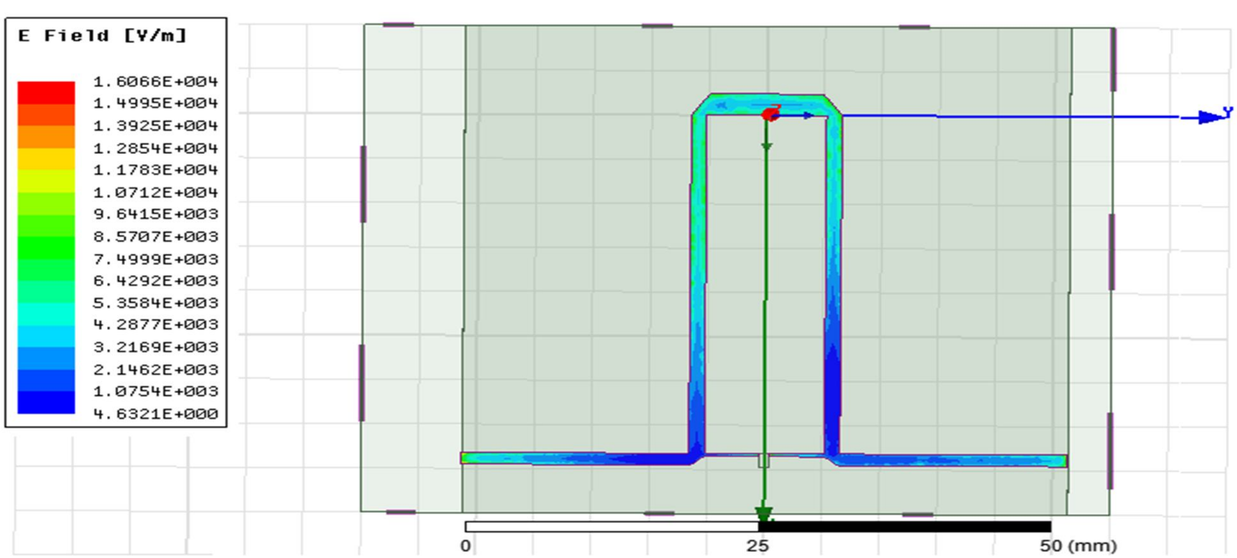


Fig. 2 : Ring structure

The characteristic admittance of upper transmission line is an important factor in adjusting the transmission zero distribution. As indicated in above Figure, when increasing the upper transmission line characteristic admittance Y1, becomes sharper, pushing the first one and the second transmission zeros higher and drawing the third transmission zero lower. The transmission zero separation between fz1 and fz2 changes slightly and the transmission zero separation between fz2 and fz3 becomes smaller with increased Y1. so as shown in Figure , different band stop filtering responses with different transmission zero distributions can also be achieved by altering the Y1.

IV.RESULTS

TABLE I

Insertion losses without capacitor:

S	FR4 substaret	Vacume sub
Freq [GHz]	dB(S(1,2)) []	dB(S(1,2)) []
0.5	-1.223434381	-0.090883534
1	-5.578936936	-1.635662639
1.5	-19.71624641	-8.340658719
2	-31.39223347	-23.53022848
2.5	-1.451167957	-21.65115542
3	-10.6590267	-2.320688333
3.5	-3.450745741	-1.595431008
4	-13.72439199	-3.53317601
4.5	-7.003964415	-4.06405341
5	-5.046785101	-3.487372147

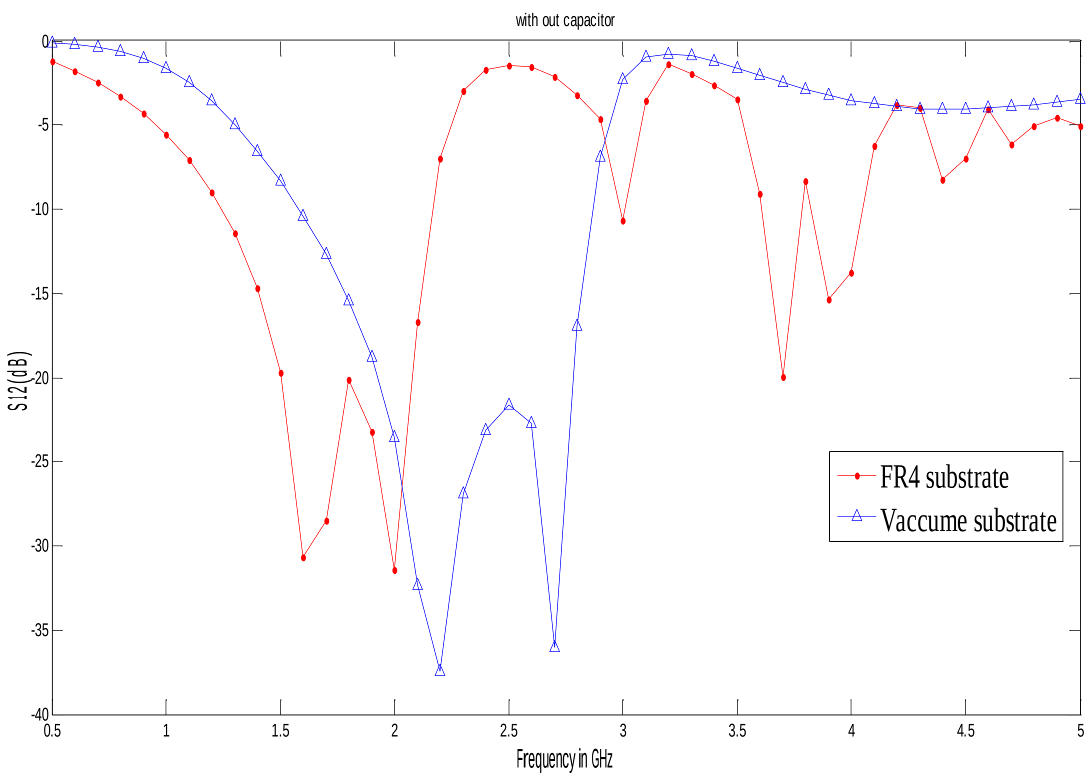


Fig. 3 : S12 curves of Ring structure strip filter on vaccum substrate and FR4 substrate

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A. Insertion Losses With Capacitor

TABLE III
Using vacuum as substrate

Freq [GHz]	dB(S(1,2)) [vac4]	dB(S(1,2)) [vac4.3]	dB(S(1,2)) [vac53]
0.5	-1.418523776	-1.482958151	-2.434095956
1	-11.74129241	-9.967947865	-6.229133545
1.5	-20.04988963	-18.63620727	-14.9112187
2	-16.99005113	-17.51285051	-20.7163467
2.5	-9.497382909	-9.623241105	-10.91227043
3	-19.19918295	-15.76810693	-9.619322577
3.5	-1.691167069	-1.719410042	-1.695171901
4	-3.7218964	-3.708181899	-3.696600496
4.5	-4.404615618	-4.44344915	-4.359107068
5	-4.006940106	-4.184992294	-3.970201135

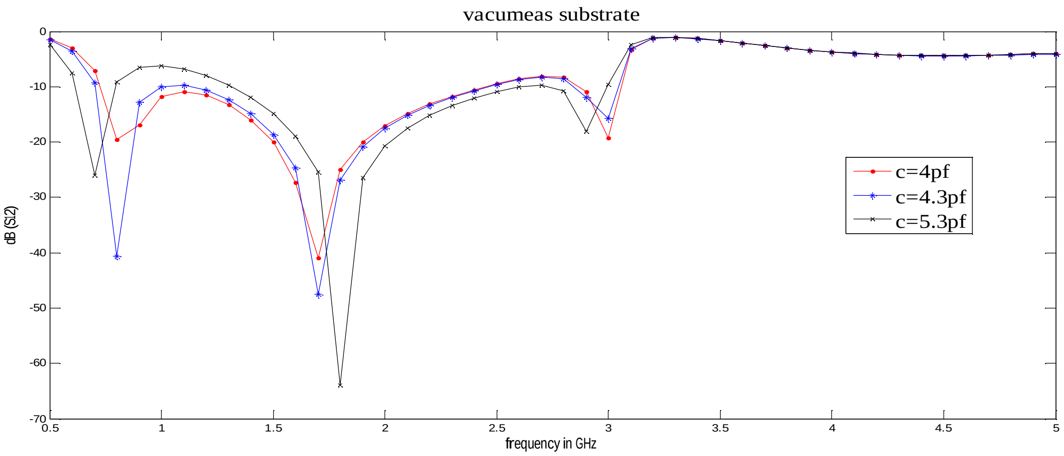

Fig. 4 : S12 curve of Ring structure strip filter with embedded capacitor on vaccum substrate

B. Using FR4 Substrate

TABLE IIIII

FR4 Substate			
Freq [GHz]	dB(S(2,1)) [4.3fr]	dB(S(2,1)) [4fr4]	dB(S(2,1)) [5fr4]
0.5	-0.735461386	-0.583962509	-1.220924805
1	-4.878641231	-4.447213488	-5.812982863
1.5	-0.509930458	-0.459056024	-0.709874513
2	-1.242222072	-1.274999811	-1.205806466
2.5	-4.93186473	-4.93142279	-4.904412697
3	-22.40371508	-23.28232073	-20.99690546
3.5	-10.53431737	-11.09392879	-9.939098535
4	-4.796917214	-4.771882949	-4.815370496
4.5	-3.807955565	-3.811914057	-3.848389322
5	-30.19492331	-28.32145291	-39.81814695

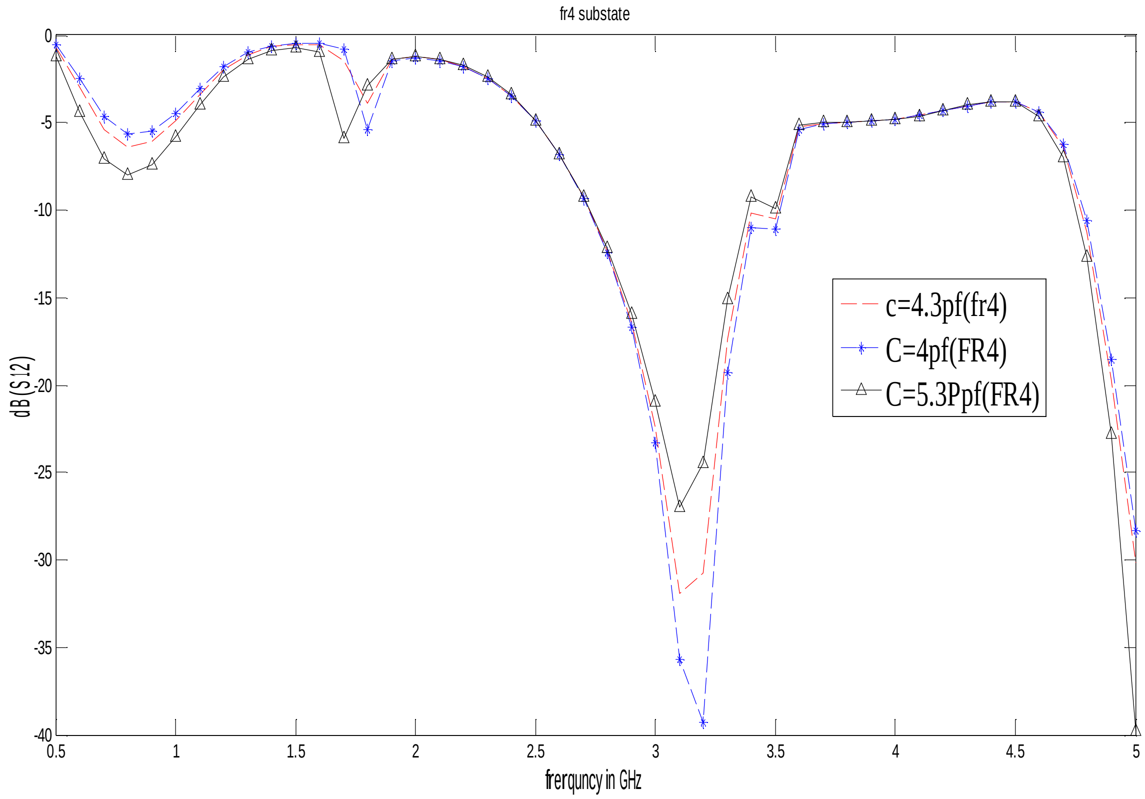

Fig. 5 : S12 curve of Ring structure strip filter with embedded capacitor on FR4 substrate

C. Compression Between Vacuum Substrate And Fr4 Substrate

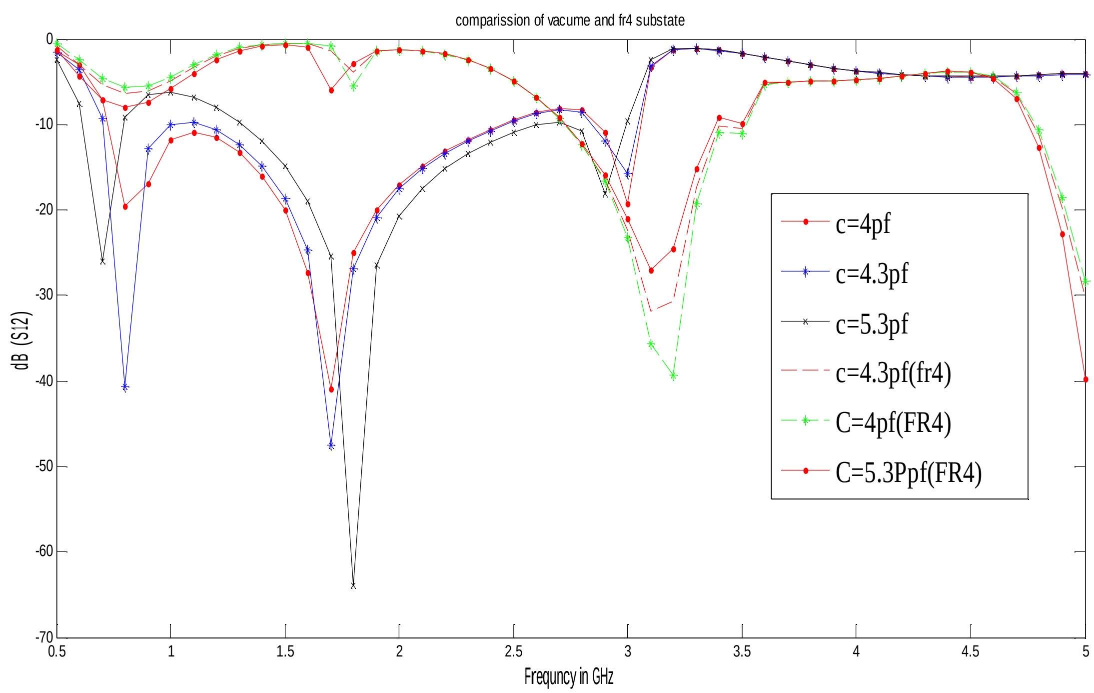

Fig.6 : Compression between Vacuum substrate and FR4 substrate

V. CONCLUSION

The WBSF with extended lower pass band is realized by using two transmission line and one lumped capacitor. The results are compared with our capacitor. The distributions of the three transmission zeros can be easily and flexibility adjusted by changing the value of the embedded capacitor and the circuit characteristic admittance to obtain the desired performance. Moreover, the WBSF exhibits sharp rejection in the stop band. The circuit size is only 0.022 λg that is 50mm so it suitable for applications where small size is important. Design equations, curves and theoretical analyses are provided. The results are compared with and without capacitor. And the results also show the insertions losses with vacuum as substrate and FR4 as substrate. It concluded with use of capacitor it is possible to have multiple bands. Another interesting result is by changing the substrate the extended upper band high pass filter becomes low pass filter with extended lower band

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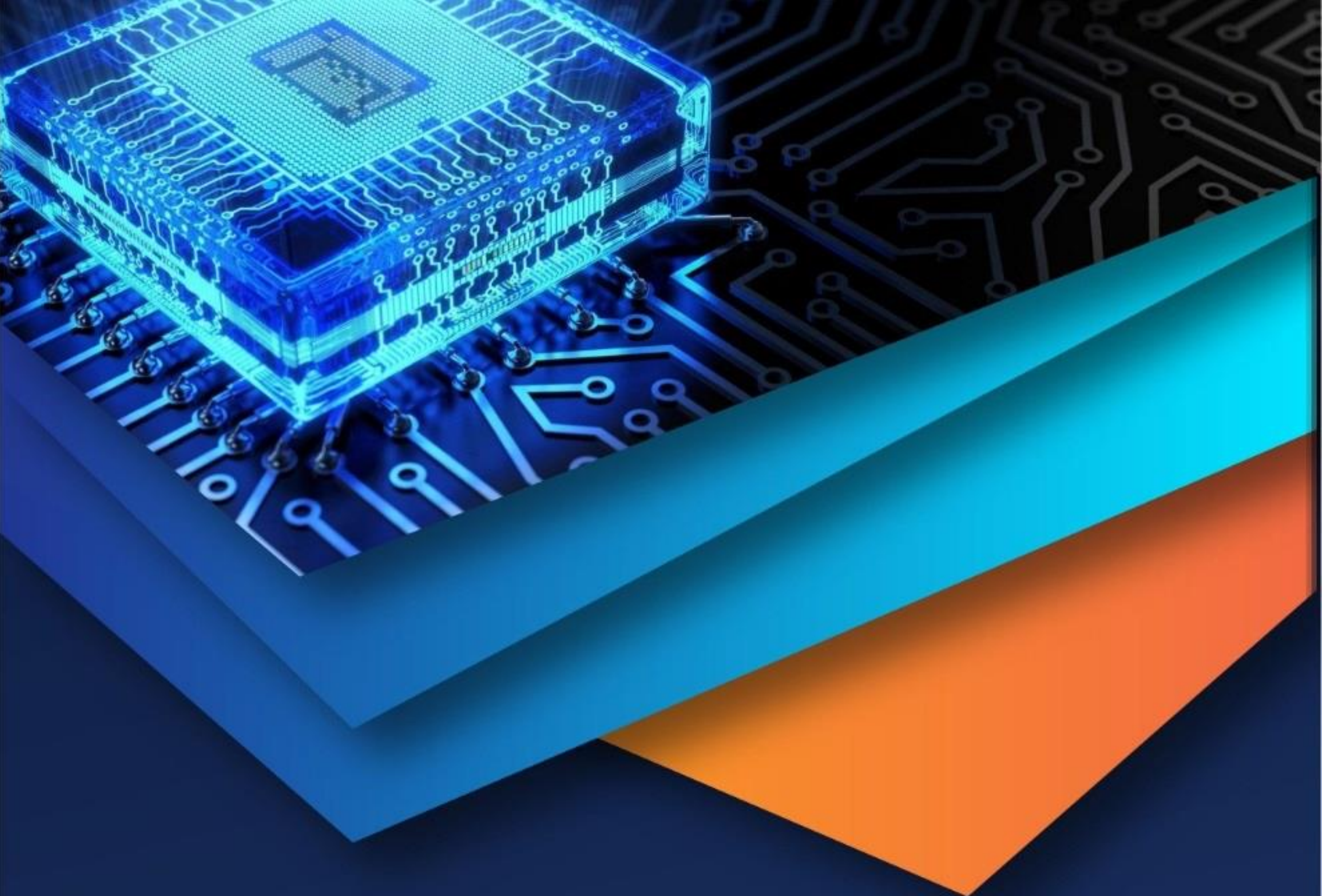

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