# Ultra-wideband bandpass filter with notch band based on quadratic Koch Island structure

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**ABSTRACT**

An ultra-wideband bandpass filter with a notch band centered at 7.2 GHz is proposed to remove the interference caused by satellite communication signal coexciting within the ultra wide band. The filter comprises of two seperated quadratic koch island structures connected to the main transmission line to generate the notch band at the desired frequency. The designed ultra wide bandpass filter passes frequencies from 3.09 GHz to 10.61 GHz with a notch band from 7.12 to 7.46 GHz centered at 7.2 GHz and with a rejection level of 21.3 dB.The resonant frequency and bandwidth of the notch can be varied by the variation in the physical parameter of the filter. The proposed filter is fabricated, tested and compared with simulated results.



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## 1. INTRODUCTION

Ultra-wideband (UWB) is a very attractive wireless transmission technology due to its advantages of being short-range, low power, having high data rate and short broadcast time using 3.1 - 10.6 GHz unlicensed frequency spectrum. The disadvantage of UWB technology is the existence and interference caused by other radio based technologies like Wi-Fi, Wimax, Bluetooth, Zigbee, satellite communication etc which lies within the same frequency spectrum of UWB. Bandpass filters passing the UWB frequency band and rejecting the bands alloted for other technology which cohabit within the UWB sprectrum, finds much interest in moderm wireless communication systems. The conventional methods for achieving this consists of bandpass filter design incorporating a high pass and a low pass filter together in a single structure [1, 2]. It is difficult to achive compactness for such designs and also impedance matching networks are needed at the output and input stages. Other UWB bandpass filter designs include the incorporation of stepped-impedance resonators [3-6], defected microstrip structures [7], stub loaded resonators [8-11], defected ground stuctures [12], CRLH Cell [13, 14], multi mode resonators [15-18].A resonator combining interdigital structure and defected ground structure is used for designing UWB filter with a notch in [19].The coupled sections which are tightly aligned needs high accuracy in manufacturing in stepped impedence resonators and multi mode resonators and size of these filters are also not compact. Also tuning of transmission zero is not so easy in all designs. In stepped impedance resonators, the control of resonant frequencies is difficult to attain and are rarely reported. Defect ground structure can effectively reduce the size of the filter, but these structures face leakage of the floor and also attaining broadband characterisicsis difficult. The microstrip filter based on defected microstrip structure can solve the floor leakage problem and UWB filters incorporated with CRLH Cell can reduce the size of the filters.

This paper presents the design and development of microstrip UWB notch filter based on quadratic Koch island structure to remove the interference of satellite signal coexcisting in the UWB band.The proposed design enables the tuning of the resonant frequency of the notch by varying the size of the notch depth of the quadratic Koch Island loaded to the transmission line.

## 2. METHODOLOGY

### 2.1. Quadratic Koch Island Generation

The design of the filter is based on quadratic Koch Island fractal. The initiator of this fractal structure is a square shown in figure 1(b) and generator given in Figure 1(c) is applied to each side of the square. Performing the first iteration we get the Koch Island structure with the same area of the initial square but the circumference seen increased as given in Figure 1(a).With application of each iteration on the fractal, the fractal section length l (n) decreases as given in the equation (1) and the circumference C increases for each iteration and as given in the equation (2) where $x0$ is the side length of the square and n is the number of times the fractal iteration is carried out.As the iterations tends to infinity the over all length terminates at a constant value and C tends to infinity keeping the area constant[20].

$$l(n) = \left(\frac{1}{4}\right)^n x0 \quad (1)$$

$$C = 4(2^n x0) \quad (2)$$

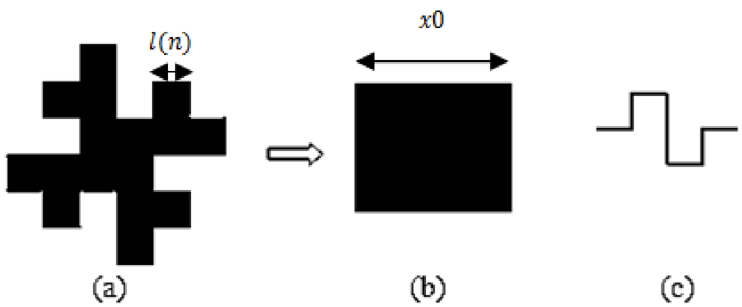



Figure 1. (a) Quadratic Koch Island after first iteration (b) Square Initiator (c) Generator

### 2.2. Filter Structure

The proposed filter structure has a feeding microstrip transmission line with width W and height h. For w/h ≥ 2 and characteristics impedance $Z_{line} = 50\ \Omega$ for the matching conditions on input and output ports, the expression for w of the feeding microstrip line is given by equation (3) where $\varepsilon_r$ is the relative dielectric constant of the substrate [21].

$$w = \frac{2h}{\pi}\left\{\left(\frac{60\pi^2}{Z_{line}\sqrt{\varepsilon_r}} - 1\right) - \ln\left(2\frac{60\pi^2}{Z_{line}\sqrt{\varepsilon_r}} - 1\right) + \frac{\varepsilon_r - 1}{2\varepsilon_r}\left[\ln\left(\frac{60\pi^2}{Z_{line}\sqrt{\varepsilon_r}} - 1\right) + 0.39 - \frac{0.61}{\varepsilon_r}\right]\right\} \quad (3)$$

Two symmetric and offset quadratic Koch island structure with equal side lengths $W_a$ and $W_b$are loaded to the transmission line with a distance $W_c$ apart to get an ultra wideband with notch characteristics. The desired passband is attained by dual stub matching technique used for filter designs [22]. The first iterated quadratic Koch fractal structure has an optimized side length of 15mm positioned 17.59 mm length apart in the filter structure as shown in the Figure 2.The design and simulations are performed in CST Microwave Studio to get optimized parameters.The prototype of the filter is fabricated using RT Duroid 5880 substrate with $\epsilon_r = 2.2$ and height h = 0.787 mm.The measurements are taken using vector network analyzers.The simulated and measured results are in good agreement with each other. The optimized design parameters in mm for the realized filter are given in Table 1.

Table 1. Optimized design parameters (dimensions in mm) of the filter.

| $W_a$ | $W_b$ | $W_c$ | W | $l(n)$ | $x0$ |
|---|---|---|---|---|---|
| 15 | 15 | 17.59 | 2.91 | 2.5 | 10 |

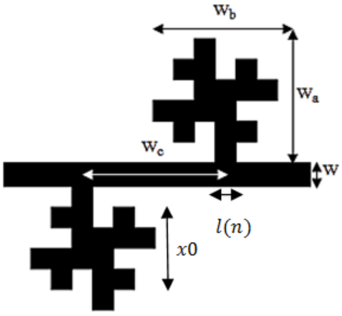



Figure 2. Layout of the proposed UWB notch filter.

## 3. RESULTS AND DISCUSSION

The simulated and measured S parameter characteristics of the Ultra Wide Band notch filter based on Koch fractal is shown in Figure 3. The filter characteristics is having a notch band from 7.12 GHz to 7.22 GHz separating two wide pass bands from 3.38 to 7.11 GHz and 7.23 GHz to 9.66 GHz. The pass band of the filter is from 3.38 GHz to 9.7 GHz with the notch central frequency at 7.2 GHz.The notch rejection level is at 21.2 dB. The pass band insertion loss for the filter is 0.39 dB. The slight variation in the measured and simulated plots is due to the impedence mismatch between the connectors of the cable to the device or the substrate loss.

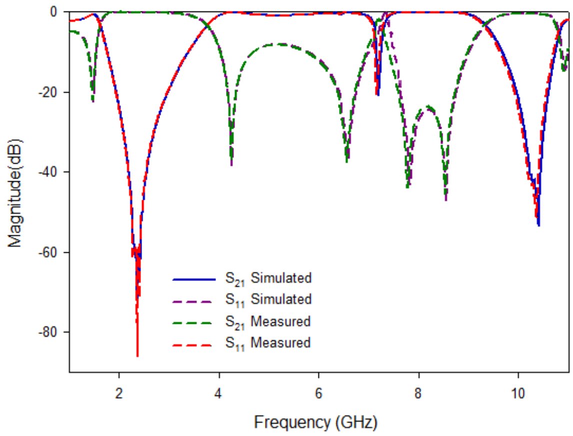



Figure 3. S Parameter Characteristics of the Ultra Wide Bandpass filter with Notch Band

### 3.1. Tuning of the Notch Band Frequency and Notch Bandwidth

Figure 4 (a) and (b) depicts the layout of the filter with notch depth t = 0.5mm, 1.0 mm respectively from the notch margin of the standard Koch Island filter shown in Figure 2. The simulated $S_{21}$ and $S_{11}$ characteristics of the UWB Koch island filter with varying values of notch depth t from the notch margin of the standard Koch Island filter is shown in Figure 5(a) and (b).The frequency of the notch band, bandwidth of the notch and the upper frequency skirt varies as the t value varies.As the value of t increases towards the inner part of the Koch Island from the margin the center notch frequency shifts towards the lower frequency side.The bandwidth of the notch decreases and the upper frequency limit of the UWB frequency liitdeceases.The lower frequency limit is have no significant change. The various performance characteristics of the filters shown in figure 4 are tabulated in the Table 2.

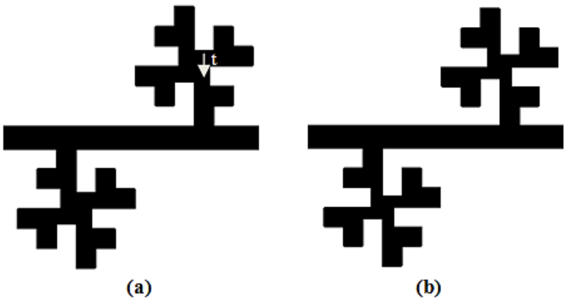
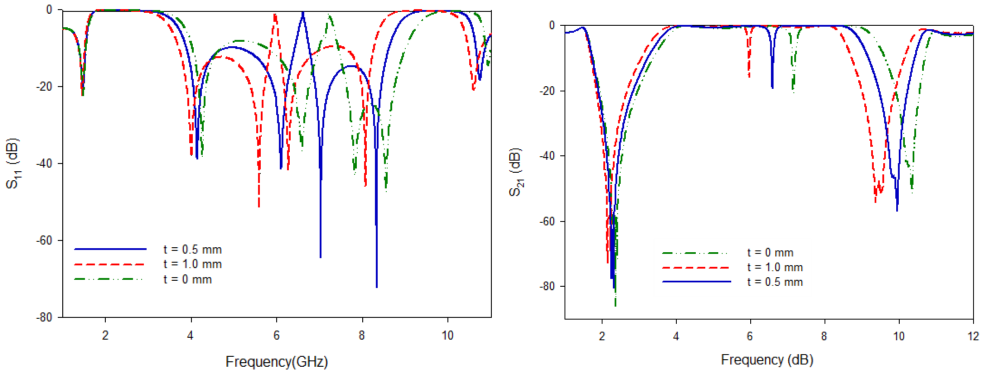



Figure 4. Layout of the Koch Island UWB Filters with varying t values at(a) .5 mm (b) 1.0 mm




**(a)** **(b)**

Figure 5. S Parameter Characteristics of the UWB Koch Island filter for varying t values (a) $S_{11}$ Plot (b) $S_{21}$ Plot

Table 2. Performance Characteristics of the UWB Koch Island Filters

| Performance Parameter / Filter Type | Notch Central Frequency (GHz) | Notch Bandwidth (MHz) | Lower Frequency Limit (GHz) | Pass band Insertion loss and Notch Signal Rejection (dB) | Upper Frequency Limit (dB) |
|---|---|---|---|---|---|
| t = 0.0 mm (Fig 2) | 7.20 | 145 | 2.41 | 0.49, 20.5 | 10.31 |
| t = 0.5 mm (Fig 4 a) | 6.59 | 132 | 2.31 | 0.23, 19.24 | 9.98 |
| t = 1.0 mm (Fig 4 b) | 5.97 | 108 | 2.29 | 0.21, 15.84 | 9.59 |

The current distribution on the surface of the filter at pass band frequency 5.5 GHz and at the notch band 7.20 GHz is shown in figures 6 (a) and (b) respectively.The current density inside the quadratic Koch Island structure increased at the notch band prohibiting 7.2 GHz center resonant frequency.Figure 7 shows the photograph of the quadratic Koch Island UWB filter.The comparison of the proposed work with some of the reported UWB filters with notch band is shown in Table 2. Compared to the filters mentioned, the proposed work is not having any coupled structures or gaps between the transmission lines.This helps to reduce the losses caused and also makethe filter, simple in structure. The tuning of notch band central frequency and bandwidth of the notch band can be simultaneously done by controlling a single parameter t, the notch depth.In the reported papers given in Table 3, various performance characteristics are controlled by varying more than one physical dinemsions.The insertion loss is very low as 0.39 dB.

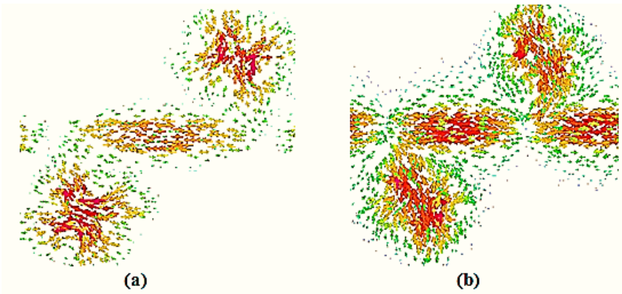



Figure 6. Surface Current Distribution at (a) 5.5 GHz (b) 7.20 GHz

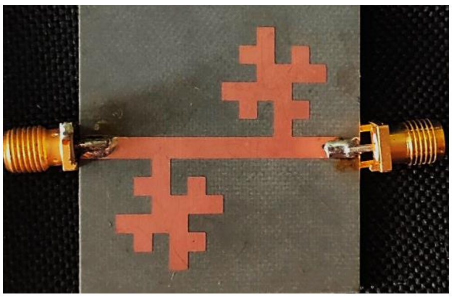


Figure 7. Prototype of the UWB Quadratic Koch Island Filter.

Table 3. Comparison with some reported UWB filters with notch band

| Ref | UWB Pass Band (GHz) | Center Notch Frequency (GHz) | Overall Size (mm x mm) | Notch Band Rejecion (dB) | No: of Notches |
|---|---|---|---|---|---|
| [9] | 2.8–11.8 | 3.6/5.9/8.0 | 31 X 20 | >10 | Three |
| [11] | 3.6 -10.1 | 6.0 | 20 × 15 | > 20 | Single |
| [13] | 3.1-10.6 | 6.18/5.9/ 5.7/5.5/ | 16.4 x 5 | >10 | Four |
| This Work | 3.09-10.6 | 7.2 | 30 x 32 | >20 | Single |

## 4. CONCLUSION

Design and development of a microstrip ultra-wide band passband filter based on quadratic Koch Island fractal is presented. The quadratic Koch Island structure itself is acting as the stub loaded to the transmission line reducing the complexity of the filter structure.An ultra-wideband bandpass filter have a good rejection levels at the notch band and have a very low pass band insertion loss. Additionally, the resonant peaks of the notch band and notch bandwidth can be tuned by adjusting the notch depth t.The quality factor of the filter is inversely propostional to the bandwidth of the filter.The proposed structure finds application in removing interference signal of satellite communication which cohabits within UWB band. The filter designs are verified from the measurement and the results are in good agreement with the simulation results**.**

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