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UWB Filtennas with Dual Bandnotch for WiMAX and WLAN Bands using Circular and Square Resonators

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Abstract

This paper presents the design and results of an UWB filtenna with dual bandnotch present at WiMAX 3.5 GHz and WLAN 5.8 GHz bands. The filtenna is formed by the implementation of a filtering section - consisting of a circular ring resonator and two square ring resonators - within an UWB antenna. The filtenna was simulated using electromagnetic software and the simulated results of return loss, radiation patters, gain and efficiency have been presented. The return loss of the filtenna show a passband from 2.93–12.32 GHz; with dual bandnotch present at 3.48 GHz and 6 GHz at a return loss of less than 3 dB. Also, the results indicate that the gain and efficiency of the filtenna is significantly reduced at the dual bandnotch frequencies. Obtained radiation results show stable bi-directional patterns in the E-plane and omnidirectional patterns in the H-plane.

1 Introduction

Since the release of unlicensed frequency band 3.1–10.6 GHz for ultra-wideband (UWB) commercial communications [1], the race for commercialising UWB technology is heating up. The UWB covers a wide frequency range and is overlapped with a number of other wireless services; such as WiMAX and WLAN bands of 3.4–3.6 GHz and 5.725–5.825 GHz respectively. Since the power level of these frequency bands is more than that of the UWB, these services interfere with UWB signals, causing signal distortion and loss of sensitivity. Hence, filtering is needed for using the UWB in the best way.

A possible and effective solution is to realise notches at the unwanted frequencies. In order to achieve this, a number of techniques can be employed, such as employing stubs [2], [3] applying slots [4] and capacitive loops [4] or using split-ring resonators [5]. However, in the above-mentioned works, either the filters have been cascaded with the antenna [2]–[3], rather than being integrated within – thus the filtennas are higher in costs, have bigger sizes and are more complex – or the bandnotch are not sharp enough or not at a good rejection value [4]–[5].

This work presents an UWB filtenna, which is developed by incorporating circular and square ring resonators within the top metallisation of an UWB filtenna. This procedure does not affect the size at all and the obtained bandnotch are measured at a good rejection value and are sharp.

2 Layout of the Proposed Filtenna

The proposed filtenna is illustrated in Figure. 1. The filtenna is designed with a mid-band frequency of 6.85 GHz. It is inductively coupled to the source and is excited via port 1 with a 50 Ω feedline. The designed structure utilises defected ground structure with a partial ground plane of length 13.1 mm. The filtenna is symmetrical with respect to in the longitudinal. A spade shape is chosen for the top design. Due to the gradual change in structure of the radiating patch of this shape, a broadband impedance bandwidth is easily achieved. This also provides a smooth shift from one resonant mode to another. Between the top patch and the feedline, lie two rectangular patches of different sizes. These improve impedance matching and also provide good characteristic at the higher frequencies.

The bandnotch at 3.5 GHz is caused by a $\lambda_g/2$ circular ring resonator which lies within the top radiating patch; where λ_g is the guided wavelength at 3.5 GHz. The length of the circular resonator may be determined by subtracting the gap of 0.8 mm from the outer circumference of the resonator. The end-value would be roughly equal to $\lambda_g/2$ at 3.5 GHz. The 5.8 GHz bandnotch is formed by the two coupled square ring resonators. Two resonators have been used in order to enhance the capacitive coupling and obtain better rejection characteristics. Each resonator is $\lambda_g/2$ long; where λ_g is the guided wavelength at 5.8 GHz. Similar to the calculation of the circular resonator, the gaps of 0.5 mm have to be subtracted from the total perimeters of the two square resonators.

Further optimisation and fine-tuning of the lengths of the three resonators may be required with the aim of achieving the exact frequency bands. At each bandnotch frequency, the current within the top metallisation will be concentrated around the edges of the respective resonator; thereby a stopband at that frequency will be obtained.

In order to obtain the reference characteristics of the filtenna without the resonators, all three resonators were removed and the subsequent structure simulated as well.

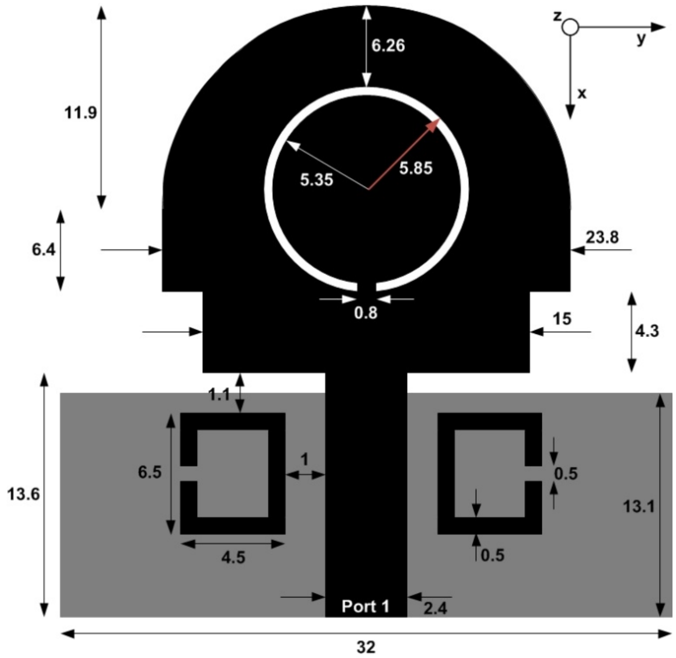

Figure 1: Geometry of proposed filtenna *(black = top metallisation and grey = bottom ground plane)*.

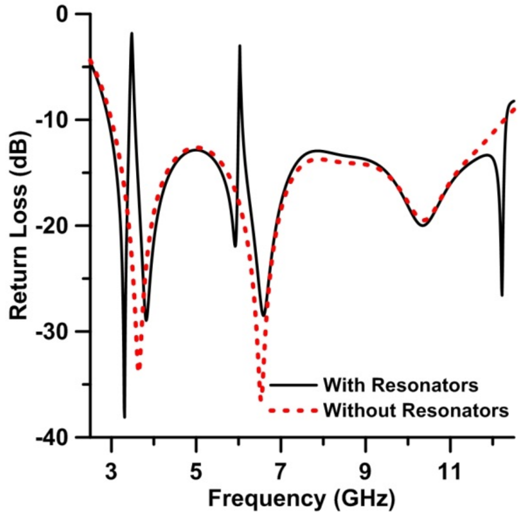

Figure 2: Return loss of filtenna.

3 Results

The structure is designed on a Rogers RT5880 substrate of a thickness of 0.795 mm, having a dielectric permittivity of ε_r = 2.2 and a loss tangent of tanδ = 0.0009. The modelling and simulations are done using the commercially available software *CST Microwave Studio*.

3.1 Return loss

The simulated return loss of the UWB filtenna with and without the three resonators has been shown in Figure. 2. From the result without the three resonators, a full bandpass response can be seen in the 2.93–12.32 GHz frequency range. This means that the filtenna would not suppress the undesired bands of WiMAX 3.5 GHz and WLAN 5.8 GHz.

The result with the introduction of the three ring resonators shows that dual bandnotch are present at 3.48 GHz and 6 GHz at a return loss of 1.82 dB and 3 dB respectively. The dual bandnotch indicate the desired rejection and suppression of the two interfering bands. However, the shifts in the frequencies of the dual bandnotch specify that further optimisation of the lengths of the three resonators is required in order to obtain the exact frequencies.

3.2 Radiation patterns

The radiation patterns of the filtenna in the E-plane and the H-plane simulated with and without the three resonators at the one bandnotch frequency of 3.5 GHz have been shown in Figure. 3 and at one passband frequency of 8.25 GHz in Figure. 4. At both frequencies, stable bidirectional patterns can been seen in the E-plane and omnidirectional patterns in the H-plane.

From the simulation with the resonators at the bandnotch frequency, it can be observed that the patterns have been suppressed in magnitude within both planes. Whereas at the passband frequency, the magnitudes remain largely unchanged with or without the resonators.

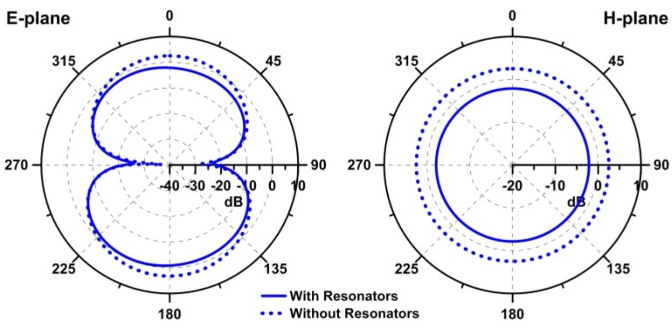

Figure 3: Radiation patterns of filtenna at 3.5 GHz.

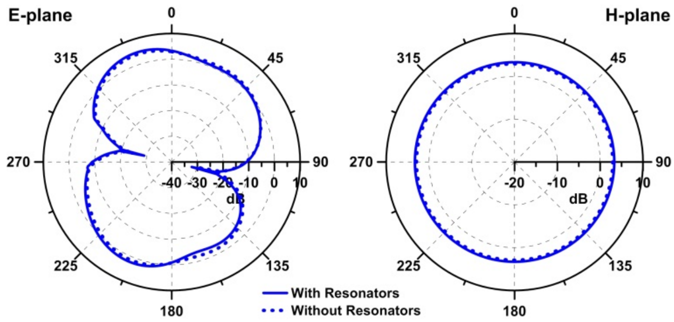

Figure 4: Radiation patterns of filtenna at 8.25 GHz.

3.3 Gain and efficiency

The simulated gain and efficiency of the filtenna have been presented in Figure. 5 and Figure 6 respectively. The average gain within the passband of the structure is 4.28 dBi. The gains at the dual bandnotch frequencies of 3.48 GHz and 6 GHz are reduced at 0.21 dBi and -2.48 dBi. The gain response is echoed in the efficiency result as well: while the average efficiency within the passband is 93.9 %, this value drops to about 15.8 % and 19.3 % at the two bandnotch respectively.

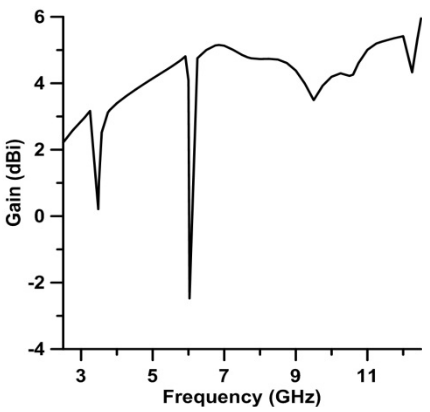

Figure 5: Gain of filtenna.

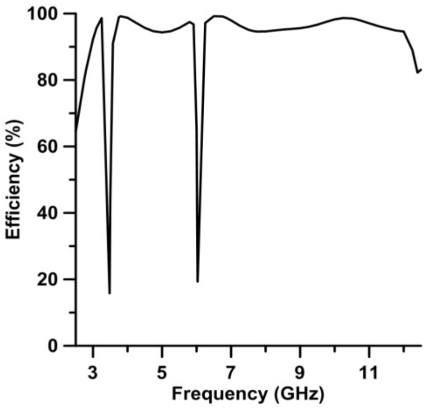

Figure 6: Efficiency of filtenna.

4 Conclusion

In this work, an UWB filtenna has been has been proposed and presented. The filtenna has been formed by incorporating a circular ring resonator and two square ring resonators within the top metallisation of the proposed structure. The simulation results of the filtenna have been provided. A full UWB, with dual bandnotch present at 3.48 GHz and 6 GHz, has been attained for the filtenna. Even though the dual bandnotch frequencies have been slightly shifted from the intended goal, these can be easily adjusted in the final design. The gain and efficiency of the filtenna also show a significant dip in their values at the dual bandnotch. This filtenna configuration could be quite useful for indoor UWB applications with no interferences from WiMAX and WLAN signals.

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