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A COMPACT BAND-NOTCHED UWB PLANAR MONOPOLE ANTENNA WITH PARASITIC ELEMENTS

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Abstract—In this paper, a planar microstrip UWB monopole antenna with a good band-rejection is presented. By using a pair of arc shaped parasitic elements around the patch, an excellent notched frequency band for rejecting the WLAN band (5–6 GHz) can be obtained. The arc shaped strips are parametrically studied and the effects of them on the radiation patterns and time domain behaviour of the UWB antenna are investigated.

1. INTRODUCTION

Recently, there have been many efforts to avoid interference between the UWB antennas and other narrow band systems that work in the UWB frequency interval (3.1 GHz to 10.6 GHz). Especially in the case of microstrip UWB planar antenna, many and various methods have been presented in the articles to design a UWB antenna with a band-rejection characteristic. They utilize different techniques such as embedding half wave slots in the patch [1–3], inserting slots in the ground plane or into the feed line [4–6], and locating filtering structures in the vicinity of the feed line [7–9]. Another idea introduced in [10] is attaching parasitic patches to the antenna. It provides band-notched feature by loading the antenna at the notch frequency.

This paper describes a new method to design a UWB antenna with band-notched feature by using a pair of arc-shaped parasitic strips. These parasitic elements are employed symmetrically beside the patch which leads to weak radiation at the notch frequency. This property can be used to avoid the possible interference between UWB systems (3.1–10.6 GHz) and WLAN systems (5.15–5.85 GHz) with a Voltage Standing Wave Ratio (VSWR) more than 17 in this frequency band. Simple shape (and therefore simple design procedure) and compact

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structure are the main advantage points of the proposed antenna. Additionally, a deep band notch is produced using a pair of parasitic strips that have no perturbation on the radiation element. To analyze the effect of parasitic strips dimensions on the notch frequency, a parametric study is done. The radiation patterns and the time domain behaviour of the antenna with and without parasitic elements are depicted. The proposed band-notched structure has negligible effects on the performance of the antenna at the remaining passband.

2. ANTENNA DESIGN

Figure 1 illustrates the geometry of the proposed band-notched antenna. It consists of a simple circular monopole antenna and a pair of arc-shaped parasitic strips besides the patch. The circular monopole microstrip antenna is a common type of planar UWB antenna [11]. It comprises a circular disc monopole and a 50 ohm microstrip feed line printed on the same side of the dielectric substrate and a ground plane on the other side of the substrate. The selected substrate here is RT/Duroid 4003 with a relative permittivity of 3.38 and a thickness of 1/32 inch. The antenna is designed to cover the frequency band of between 3.1 to 10.6 GHz. The optimized antenna parameters are as follows: $L = 39\,\text{mm}$, $W = 35\,\text{mm}$, $R = 9\,\text{mm}$, $Lg = 17.8\,\text{mm}$, $Wf = 1.8\,\text{mm}$.

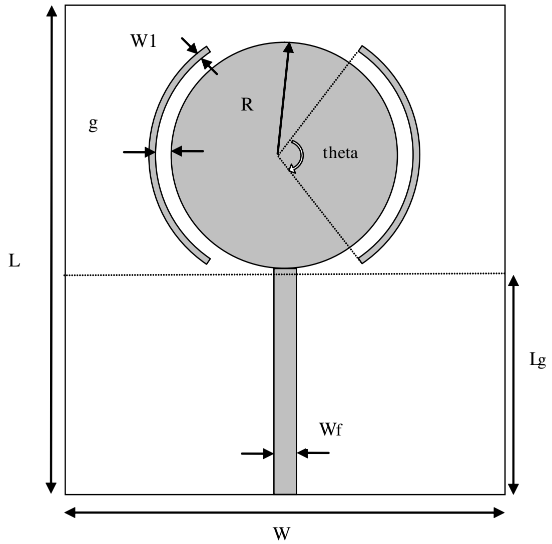

Figure 1. Configuration of the proposed antenna.

Since the current distribution of the antenna is stronger at its edge, suppressing the radiation of the antenna edge leads to form a band-notched region. As the antenna is in the shape of a disc, a pair of arc-shaped strips is attached to the UWB antenna structure in order to achieve band-notch operation.

The notch structure, parasitic strips, can be described with three parameters: the flare angle of each strip (theta), the width of the strips (W_1), and the gap distance between the strips and the patch.

Each strip acts as a half-wave resonator at the notch frequency. Therefore the notch frequency at which maximum VSWR is obtained can be calculated as [12]:

$$f_{notch} = \frac{c}{2 * l_{average} * \sqrt{\left(\frac{\varepsilon_r+1}{2}\right)}} \tag{1}$$

where c and ε_r are the velocity of the light and the dielectric constant, respectively.

We define the average length of each strips as:

$$l_{average} = (R + W_1 + g) * theta \tag{2}$$

In the next section by means of an electromagnetic software package, CST Studio, the antenna performance has been simulated and analyzed.

3. RESULTS AND DISCUSSION

3.1. Parametric Study

Figure 2 shows the variation of simulated VSWR with changing different parameters.

The effect of the flare angle on the notch band is depicted in Fig. 2(a). As shown, if the flare angle of strips increases, the notch frequency will decrease. With increasing the width of the parasitic strips or the gap distance between them and the patch, the notch frequency could be decreases, as well (Fig. 2(b) and Fig. 2(c)).

These results also can be deduced from the Equations (1)–(2). Increasing each of three parameters will result in increasing the average length of the strip and it leads to decreasing the notch frequency. On the other hand, as shown, by increasing these parameters the notch will be stronger. It may be due to this fact that by increasing the average length of the parasitic strips the radiation edge of the patch will be more affected by the parasitic strips and the radiation will be more suppressed.

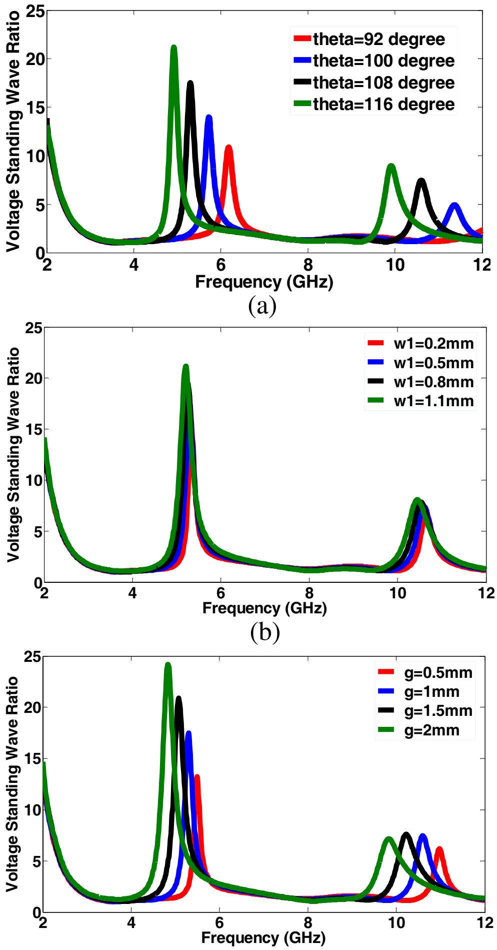

Figure 2. The effect of various parameters on notch frequency, (a) the flare angle of the parasitic strips, (b) the width of the parasitic strips, (c) the gap distance between the parasitic strips and the patch.

3.2. Current Distribution

The final antenna is designed with the following parameters: $W_1 = 0.5\,\text{mm}$, theta $= 108^\circ$, and $g = 1\,\text{mm}$.

Figure 3 shows the measured and simulated VSWR of the proposed antenna.

The proposed antenna has the bandwidth of 3.1 to 10.6 GHz which

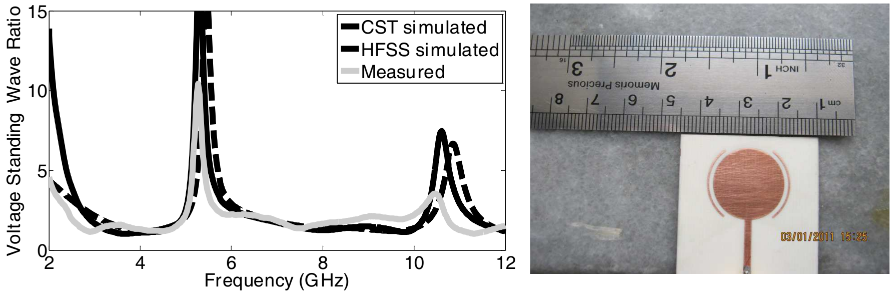

Figure 3. The measured and simulated VSWR of the proposed antenna.

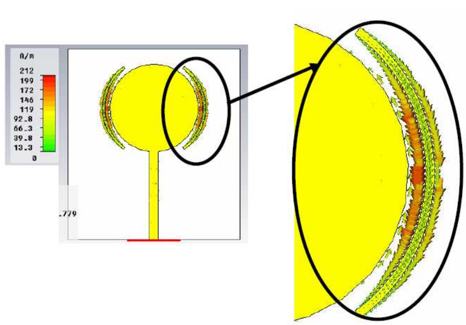

Figure 4. The current distribution at the notch frequency (5.5 GHz).

the frequency band of 5–6 GHz is notched with a maximum VSWR more than 10. As can be seen, the second resonance of the parasitic strips is located at the end of the usable band.

Figure 4 shows the current distribution at the notch frequency. As can be seen, there are dominant current flows on the strips that their direction is opposite with respect to the patch current flows. It causes that the antenna to be nonresponsive at the notch frequency.

Figure 5 shows the simulated gains of the antenna without and with the band-notch function. The proposed antenna has the average gain of 3 dBi. Across the rejection bands (5–6 GHz), the gain can be as low as −6 dBi, when the parasitic elements are used. The simulated efficiency of this antenna ranges from 77% to 96%, except for the notched band.

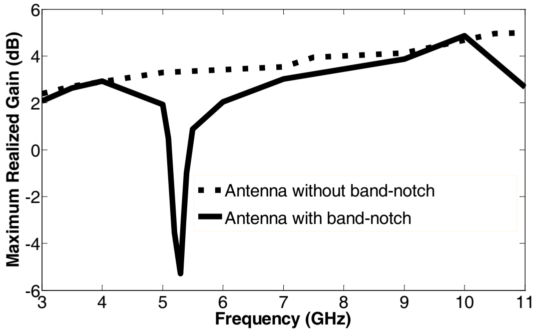

Figure 5. The simulated gain of the antenna.

3.3. Radiation Patterns

Figure 6 presents the radiation patterns of the antenna with and without parasitic strips at three frequencies. The antenna has nearly good Omni-directional patterns in the H-plane and a Bi-directional one in the E-plane. The parasitic strips have negligible effects on the radiation patterns of the antenna. The changes in the radiation patterns at the frequency of 10 GHz are more than two other frequencies which may be due to the effect of the second resonance of the parasitic strips.

3.4. Time Domain Analysis

One of the most important characteristics of UWB antennas is the time domain behaviour of the antenna in which that is required to have minimum distortion in transmitting and receiving modes. To investigate the time domain characteristics of the antenna, two identical antennas are located with a distance of 30 cm in face-to-face and side-by-side configurations. To study the behaviour of the band-notched antenna in various directions, two main configurations are selected. These configurations of time-domain test setup are shown in Fig. 7. If there is no difference between the results of them, it means that the antenna behaviour is independent from the antenna orientation in the whole of frequency band. The distance "D" (center to center distance) is selected so that the antennas are in far-field region of each other. Therefore minor change in the distance between antennas has negligible effect on the response of them. One of the antennas is excited with a UWB signal according to the FCC spectral

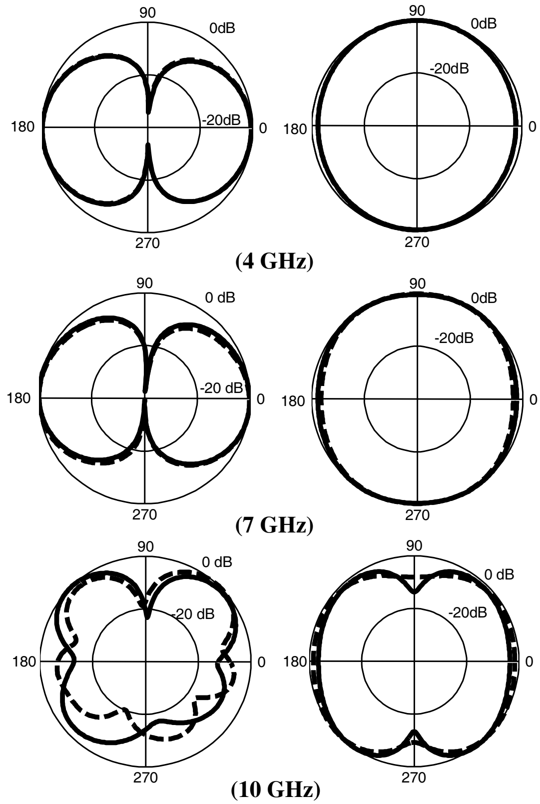

Figure 6. The radiation patterns of the antenna without the parasitic elements (dashed lines) and with parasitic elements (solid lines) in E-plane (right) and H-plane (left) at three frequencies.

mask which is 6th derivative of Gaussian given by Equation (3) [13]

$$s(t) = A\left(\frac{-120}{\sigma^6} + \frac{720t^2}{\sigma^8} + \frac{-480t^4}{\sigma^{10}} + \frac{64t^6}{\sigma^{12}}\right)\exp\left(-\frac{t^2}{\sigma^2}\right) \quad (3)$$

The source and received signals in time and frequency domain are depicted in Fig. 8(a) and Fig. 8(b), respectively. The band-notch operation can be interpreted from the spectrums of the received signals. It can be seen that the band-rejection in the WLAN frequency band is stronger in the Face-to-Face mode with respect to the Side-by-Side one.

To assess the quality of a received pulse, the fidelity of the antenna

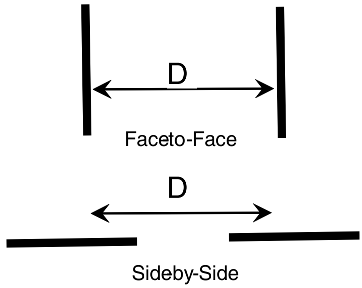

Figure 7. The test setup in the time domain analysis (the distance "D" is from the center to another center).

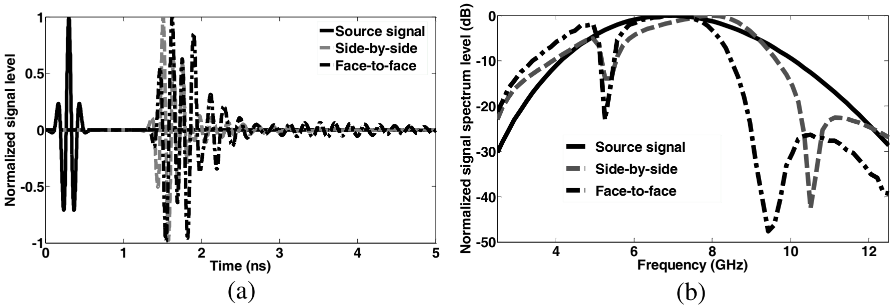

Figure 8. (a) The source and received signals, (b) the spectrums of the source and received signals.

is calculated which is defined in [13] as:

$$F = \max_{\tau} \int_{-\infty}^{+\infty} p_{source}(t) * p_{output}(t-\tau)\, dt \tag{4}$$

where, the source pulse $p_{source}(t)$ and output pulse $p_{output}(t)$ are normalized by their energy, respectively.

The Fidelity factor in both states for the antenna with and without parasitic elements are calculated and depicted in Table 1.

From Table 1, it can be seen that the antenna has better time-domain response in side-by-side mode with respect to the Face-to-Face mode that can be recognized by referring to Fig. 8(b). In this figure the antenna in Face-to-Face mode has stronger notch function than Side-by-Side one. Therefore there is a trade-off between the quality of notch rejection and the time domain behavior. The antenna with stronger notch function will result in more destroyed signal and in turn the fidelity will be degraded.

Table 1. Fidelity factor of the proposed antenna.

	Side-by-Side	Face-to-Face
Antenna without notch	0.9304	0.8122
Antenna with notch	0.8666	0.6858

4. CONCLUSION

A new approach to create stop band in UWB antennas is proposed. Using a pair of arc-shaped parasitic strips besides the patch a band-notched UWB antenna is designed. Stop band properties can be adjusted by the various parameters of the proposed structure This method has negligible effects on the radiation pattern and time-domain of the antenna.

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