

## **AN ULTRA-WIDEBAND ANTENNA WITH BAND REJECT CAPABILITY AND ITS CHARACTERIZATION IN TIME DOMAIN**

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**Abstract**—In this paper a square monopole antenna has been proposed which can be used for Ultra Wideband applications. Band-notch performance is introduced by an E-shaped slot on the patch. The dimensions are optimized to give not only the usual 3–10 GHz bandwidth with rejection in the 5–6 GHz band which is commonly used for WLAN, but also short received pulse duration when transmitted and received using a pair of these antennas. The demonstration of short received pulse-width is the primary novelty reported. The performance is verified by time domain measurements, in addition to the usual antenna characterization.

### **1. INTRODUCTION**

The antenna forms one of the most important and crucial part of UWB system design for the 3.1–10.6 GHz band [1]. Many antennas with different feeding techniques have been reported, including antennas which reject a small band in this wide range [2–7]. Their characterization has been primarily in frequency domain (return loss, radiation pattern, etc.) [9–18], but some time domain characterization is also reported [7, 8]. Till now the effect of incorporating a band-notch on the pulse-shape has not been experimentally investigated although this has been simulated [19–21]. These simulated results do

not necessarily give a good indication of experimental results because the pulse generating circuit may perform differently depending on the load characteristics. This was taken care of in [22] by using a resistive attenuator between the antenna and the circuit, which reduces the output power. In this work an attenuator was not used.

In this paper a band-notched square monopole antenna is proposed for UWB applications and optimized for performance in frequency and time domains. There are many reported ways to introduce band stop characteristics like U-slot, double U slot [4], inverted U-slot, Resonant Parasitic patches and slot etc. We have used an E-shaped slot on the patch.

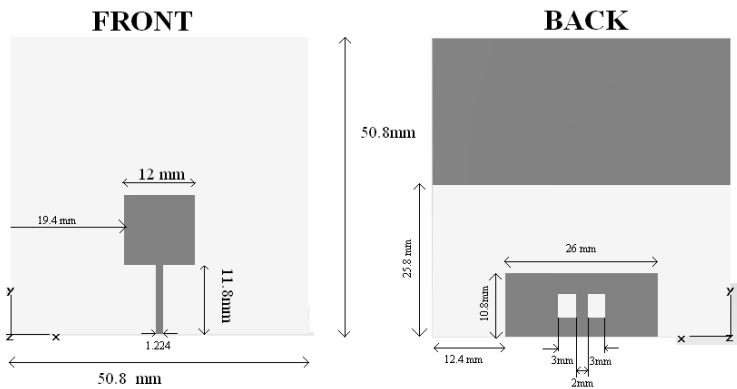


Figure 1. Geometry of proposed UWB antenna.

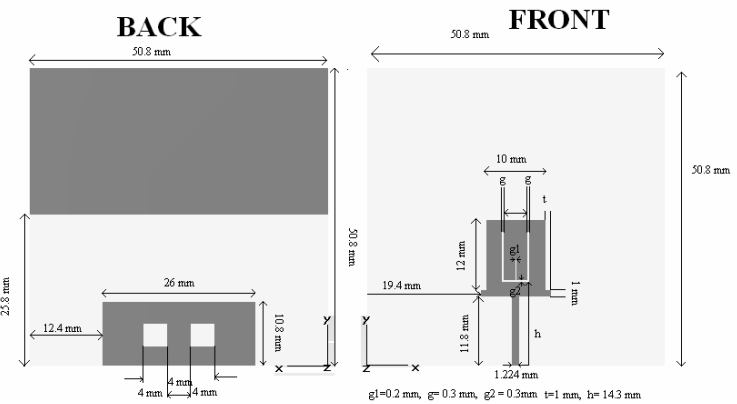
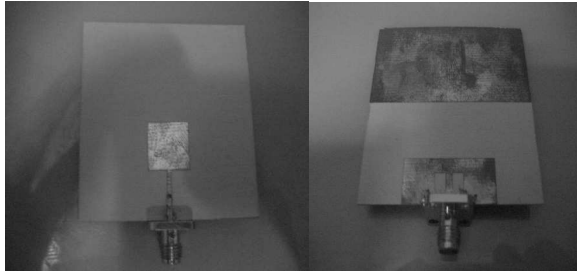


Figure 2. Geometry of proposed band-notched antenna.



**Figure 3.** Front and back views of the UWB antenna.



**Figure 4.** Front and back views of the UWB antenna with band-notch.

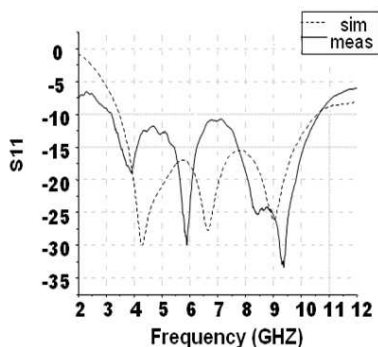
## 2. ANTENNA DESIGN

The geometry of proposed antenna without band-notch is shown in Figure 1 and the version with band-notch is shown in Figure 2.

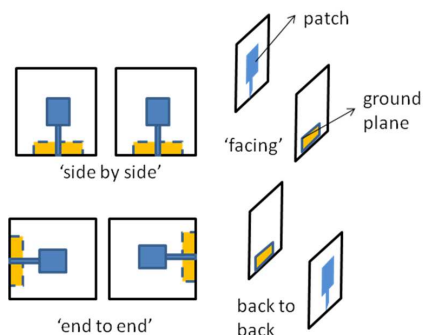
The photographs of actual fabricated antennas are shown in Figure 3 and Figure 4. One of the features of this design is that the separated ground-plane patch at the feed end affects the higher cut off frequency (10.6 GHz) while length of the reduced ground plane at the other end affects the lower cut off (3.1 GHz). This makes it easy to optimize the two features separately.

## 3. FREQUENCY DOMAIN RESULTS

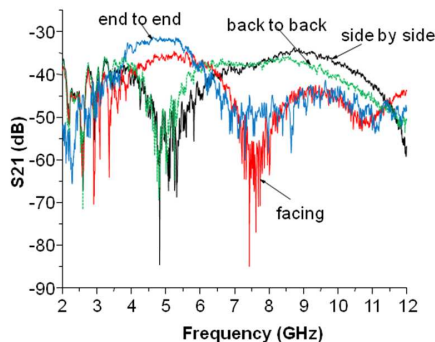
The reflection coefficient of the UWB antenna without notch is shown in Figure 5. All simulations in this work were done with CST Microwave studio [23]. The results are fairly typical of UWB antennas. We next show the transmission measurement through a pair of these antennas spaced by 30 cm. There are 4 orientations, as shown in Figure 6. The measured  $|S_{21}|$  is shown in Figure 7.



**Figure 5.** Reflection coefficient of the UWB antenna.



**Figure 6.** The 4 orientations for  $S_{21}$  measurement.



**Figure 7.** Transmission through the UWB antennas.

It can be seen from Figure 7 that the ‘end to end’ configuration is best for UWB communication, while the back-to-back and side-by-side configurations giving rise to a ‘stop-band’ around 5 GHz. Purely from this point of view, the antenna is not a very good one — better antennas have been reported in [8]. We next discuss the band-notched antenna.

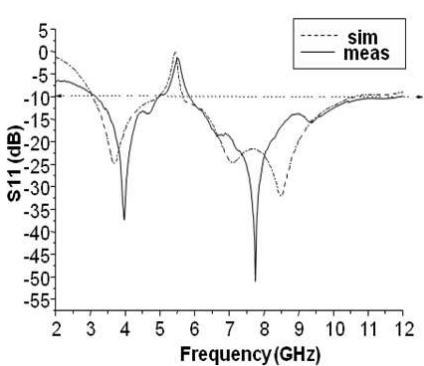
The reflection coefficient is shown in Figure 8.

The transmission through two antennas is plotted in Figure 9 for the ‘facing’ and ‘side by side’ orientations. It can be seen that the side-by-side orientation gives a narrow notch, with the response being otherwise quite flat till 7 GHz. The other case gives a good response up to 10 GHz, but the ‘notch’ is much wider.

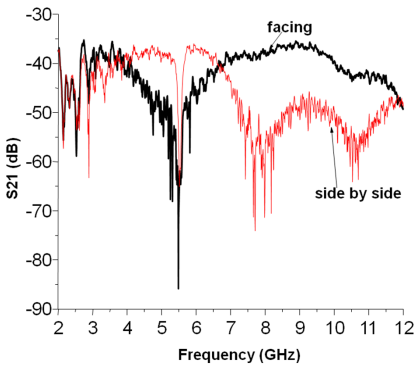
We have carried out radiation pattern measurements of these antennas throughout the band, which show the expected trend —

distorted figure of 8 in the  $E$ -plane and close to uniform in the  $H$ -plane (linear polarization). A sample is shown in Figure 10, including measured gain.

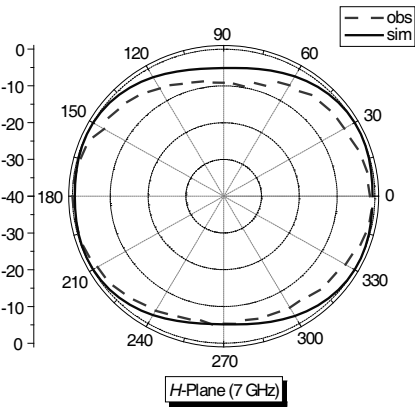
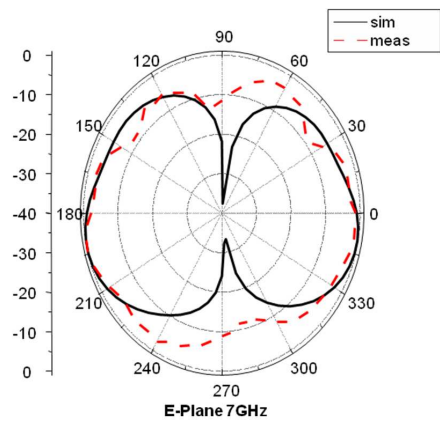
Group delay of the transmission between the antennas is shown in Figures 11 and 12. It can be seen that the group delay is flat for both cases, other than in the notch-band, where it is naturally meaningless. These plots are for the antennas facing each other (Figure 6).



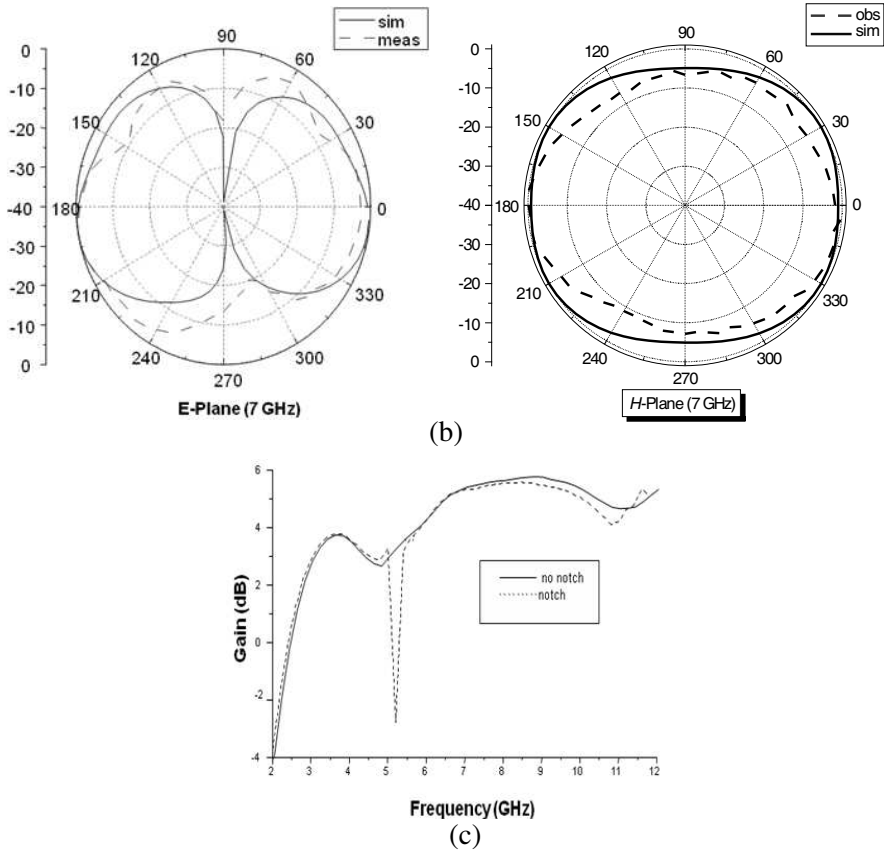
**Figure 8.** Reflection coefficient of the proposed band-notched antenna.



**Figure 9.** Transmission through band-notch antennas.



(a)

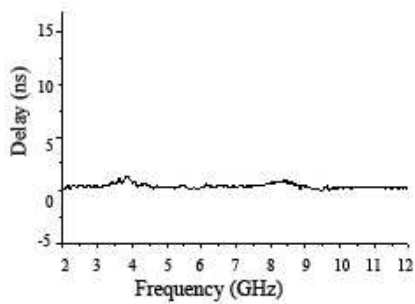


**Figure 10.** (a)  $E$ ,  $H$ -plane ( $y$ - $z$  in Figure 1) radiation pattern of antenna without band-notch, (b)  $E$ ,  $H$ -plane radiation pattern with band-notch, (c) gain of the two antennas.

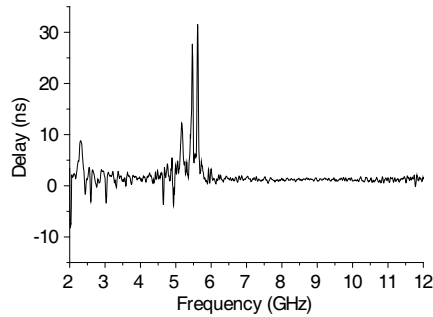
#### 4. TIME DOMAIN MEASUREMENTS

The E shaped slot producing the notch was optimized in various dimensions for the best impulse response, taking care that it did not affect the return loss. The slot gap, width and height were varied and input impulse was given while simulating the model as shown in Figures 13 and 14.

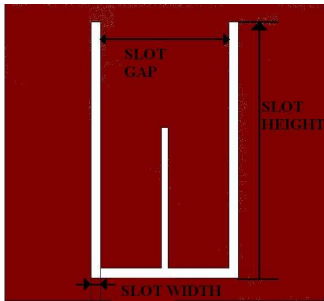
The simulation comparisons for impulse response of the antenna revealed that best response was given when the slot gap was very narrow as shown in Figure 15. Return loss simulation showed that for the best impulse response configuration the notch existed from 5 GHz



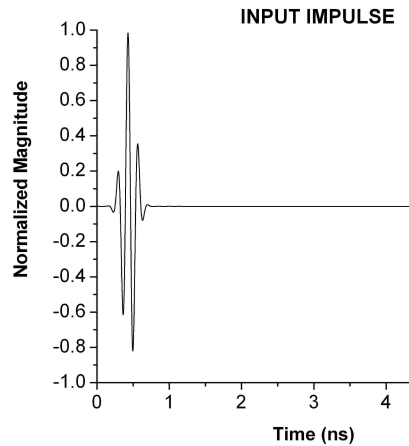
**Figure 11.** Group delay for UWB antenna.



**Figure 12.** Group delay for notch antenna.



**Figure 13.** Various dimensions used for optimization.

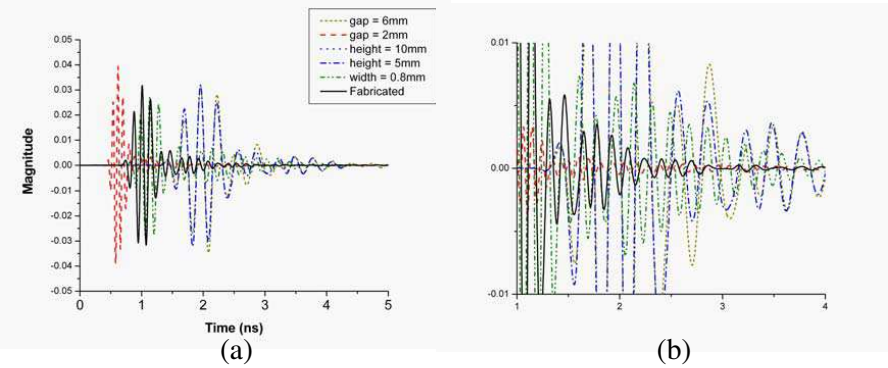


**Figure 14.** Input impulse.

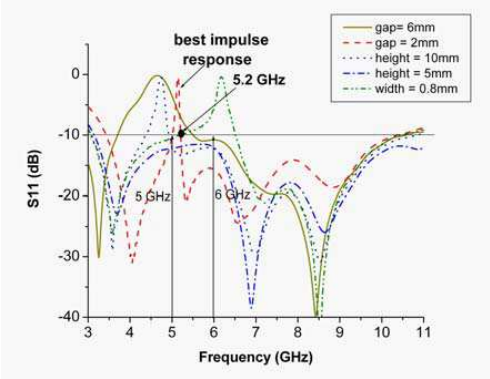
to 5.25/5.3 GHz, thereby decreasing the band rejection capability of the proposed antenna. The proposed antenna dimensions showed the second lowest levels of ringing amongst the various configurations compared. Tradeoff was achieved between return loss and impulse response with the dimensions as given in Figure 2.

The comparisons between time response for various configurations and its zoomed view are given in Figure 15. While their return loss simulation results are shown in Figure 16.

The pulse which is used to test the antennas is shown in Figure 17(a) and its spectrum (properly defined in [8], but here only



**Figure 15.** (a) Time response comparisons. (b) Zoomed view of ringing.



**Figure 16.** Return loss comparisons.

relative values are important) in Figure 17(b). Details about the generating circuit have been given in [8]. The spectrum (here and subsequently) is calculated through FFT in the oscilloscope used to measure the time-domain waveform, and frequently shows a spurious peak at D.C. which can obviously be ignored for signals received through antennas.

The antennas were kept 15 cm apart. The input pulse was sent to one of the antennas and the received pulse on the other antenna was recorded using Agilent DSA91304A Digital Serial Analyzer, as in Figure 18.

The received pulse and the spectrum for the UWB antenna without band-notch are shown in Figure 19 and the received pulse



and spectrum for the UWB antenna with band-notch are shown in Figure 20. It can be seen from Figure 16 that the effective pulse-duration is just below 2 ns, which is appropriate for data transmission upto 500 Mbps, while the spectrum is quite satisfactory — the only

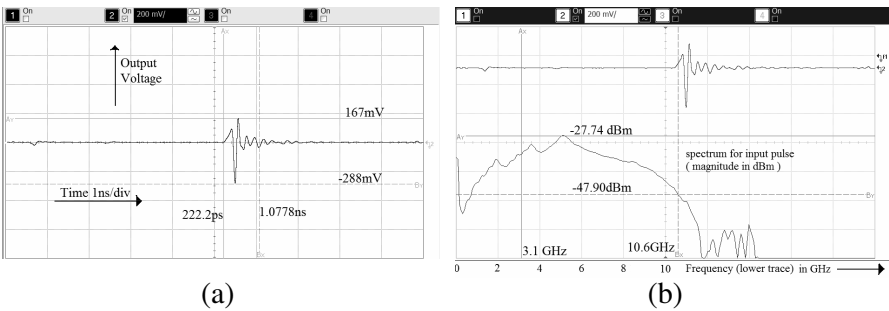


Figure 17. (a) Waveform and (b) spectrum of the UWB pulse.

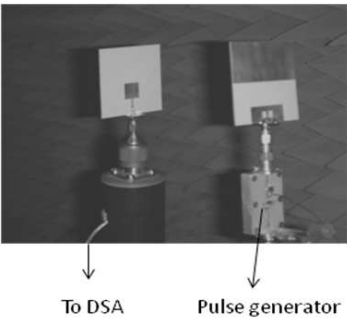


Figure 18. Photograph of time domain measurement setup.

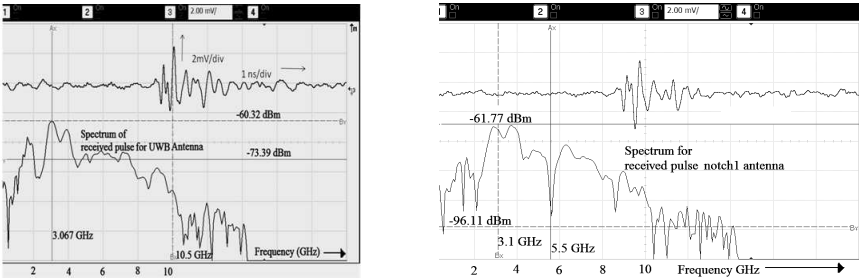


Figure 19. Received pulse and spectrum for UWB antenna without notch.

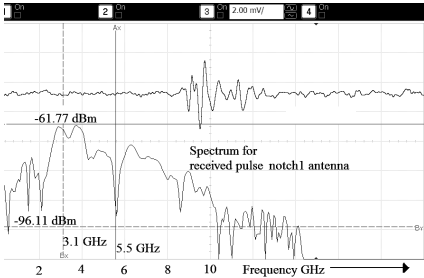


Figure 20. Received pulse and spectrum antenna with notch.

deficiency being a fall in the power level at higher frequencies. Actually it is not just the antenna which can be considered in isolation — the properties of the pulse generator play an equally important role.

## 5. CONCLUSION

A low cost, easy to fabricate UWB antenna with band-notch has been proposed in this letter. Other than the usual return loss and radiation pattern measurement, transmission measurements in frequency domain and pulse-shape measurement in time domain have been carried out. It has been shown that the antenna satisfies the standardized UWB spectral shape, and also maintained a short pulse-duration when UWB pulses are transmitted and received using it.

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