Time-domain performance of patch-loaded band-reject UWB antenna

M. Koohestani, N. Pires, A.K. Skrivervik and A.A. Moreira

A previous study of a novel technique to design a band-reject UWB monopole antenna by using patch loading is extended. Frequency-domain measurements have confirmed that the antenna designed using this technique rejects the interfering signal at the two intended narrowband frequency ranges. Moreover, the antenna radiation pattern distortion is negligible except at the notched bands. A study of time-domain characteristics based on the antenna pulse response and system fidelity factor is presented. The time performance has been extracted from frequency-domain measurements using a standard method. The obtained time-domain results promise the suitability of the proposed technique to design band-reject antennas useful for future UWB system applications.

Introduction: In recent years, there has been a considerable research effort to develop band-reject UWB antennas in industry and academia [1–5]. The use of such antennas helps designing UWB systems by reducing their complexity and/or weight. UWB systems overlay with existing narrowband radio services and are usually based on impulse ratio (IR) or orthogonal frequency division multiplexing (OFDM) modulation methods [6, 7]. Using band-reject antennas in IR improves the quality of UWB communication links in WLAN environments by increasing the signal-to-noise ratio and helping the system to behave better with practically no additional fabrication cost. For OFDM, it can be useful as it prevents nonlinear distortion caused by a high power interfering signal that can, for instance, saturate the first stages of a receiver.

A recent technique has been proposed to create two stopbands near 5 and 8 GHz in an UWB monopole antenna. It consists of gluing a metallic patch printed on a small single-layer piece of substrate over the antenna primary patch [5]. Albeit the desired frequency-domain performance has been achieved, the introduction of notches can lead to distortion in the time-domain behaviour. This Letter extends the previous study to assess the impact of the proposed technique on the antenna's time-domain behaviour. The fidelity factor is the most used parameter to characterise the time performance of an antenna. Simulations and measurements have been conducted in the time-domain to verify the suitability of the proposed technique.

Measurement setup and simulation: Fig. 1 illustrates the measurement setup, making use of two identical patch loaded antennas for transmitting (Tx) and receiving (Rx). The Tx antenna is fixed and the Rx antenna rotates in the azimuth plane ($\varphi = 0°$, $90°$, and $180°$; $\theta = 90°$). The chosen distance between the antennas is 40 cm, which was checked to be large enough to validate the far-field approximation.

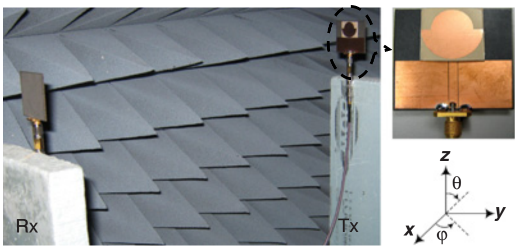

Fig. 1 *Measurement setup inside an anechoic chamber*

Numerical simulations have been carried out using CST MWS™ transient solver. To completely meet the FCC's emission limit, the CST default Gaussian pulse signal, shown in Fig. 2*a*, with spectrum corresponding to the 3.1–10.6 GHz frequency range was used. It was found that, as illustrated in Fig. 2*b*, the radiated power spectral density (PSD) of this pulse fully complies with the FCC indoor and outdoor power spectrum mask.

The method recently presented in [8] was used in the measurement procedure, in order to obtain the antenna time behaviour. The desired transmitted pulse was defined in Matlab™ and a fast Fourier transform (FFT) was performed to obtain its frequency response. The received signal in the frequency domain has been obtained after multiplying the FFT with the measured antenna transfer function. The Rx time signal was then calculated by using the inverse Fourier transform (IFFT). Finally, the system fidelity factor was computed through the cross-correlation between the Tx and Rx pulses [8, 9].

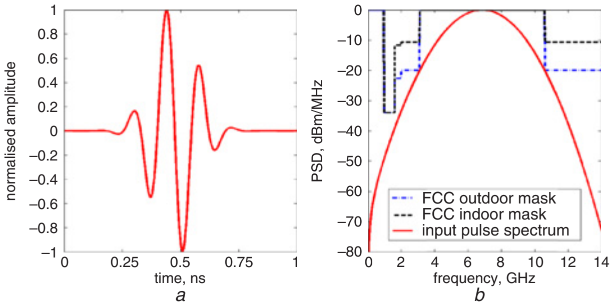

Fig. 2 *Normalised input pulse and FCC power mask*

a Normalised input pulse
b FCC mask and PSD of complying input pulse

Experimental results: The magnitude and phase of the measured and CST simulated S_{21} are shown in Fig. 3. It can be seen that outside the rejection bands the magnitude is reasonably constant and the unwrapped phase is almost linear. However, there is a decrease in S_{21} magnitude and a jump in phase at the notch bands. A good agreement between the measurements and simulations was obtained, although a small shift of the notch frequency band has been observed in the measured results. The small null in $|S_{21}|$ corresponds to the slight phase jump at the lower notch band. The maximum measured decrease of S_{21} magnitude for different φ (0°, 90°, and 180°) at the lower notch band is 20.5, 14.6 and 8.2 dB, respectively, while at the higher notch band it is about 32, 35 and 50 dB. It should be noted that the antenna S_{21} without patch loading has a null at the higher notch band, but applying the technique decreases its level by 2.4, 5.5 and 20 dB for the considered orientations, respectively.

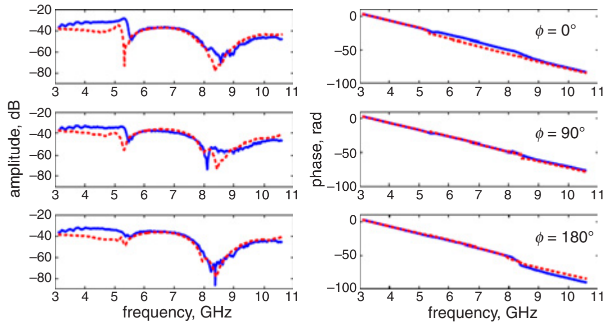

Fig. 3 *S_{21} magnitude and phase: simulated (dash-red), measured (solid-blue)*

The system fidelity factor has been calculated from measurements by using the Rx and Tx pulses, shown in Fig. 4. To evaluate the effect of the patch loading a comparison is made with the unloaded antennas; Table 1 summarises the obtained measurement and simulation results for both patch loaded and unloaded antennas. Based on the simulation results, it is observed that applying patch loading decreases the fidelity factor, as expected. From the measurements, it can be seen that for $\varphi = 0°$ and $90°$ the fidelity value decreases by about 21% and 10%, respectively. At $\varphi = 180°$, the parameter value increases due to the different radiation patterns of the patch loaded against unloaded antennas. Patch loaded antennas have higher directivity at $\varphi = 180°$, which leads to an increase in the system fidelity factor. A good agreement between the simulated and measured fidelity factor results was obtained except at $\varphi = 0°$. At $\varphi = 0°$, the decrease of S_{21} magnitude in simulation for the lower notch band is much more pronounced (~18.3 dB) than in measurements which may be related to the fabrication imperfections, especially alignment problems when gluing the patch padding. This causes a large jump in phase (~6 rad), as shown in Fig. 3, which leads to a sensible difference in the calculated system fidelity factor (~22%) when comparing simulation and measurement results. Nevertheless, both simulation and measurement results show clearly a decrease in fidelity when the patch is glued. Owing to the impedance mismatching at the notched bands, small ringing distortions in the time-domain are observed in simulations and measurements.

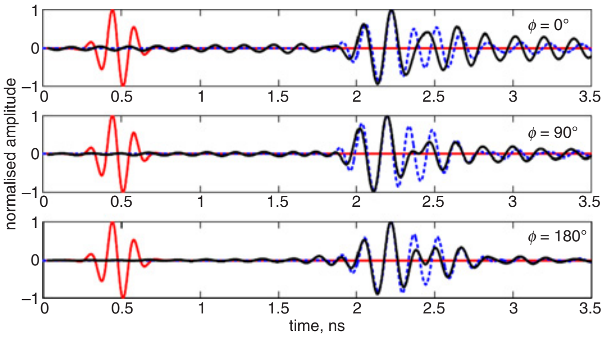

Fig. 4 *Tx and Rx signals: input (solid-red), simulated (dash-blue), calculated from measurements (solid-black)*

Table 1: System fidelity factor for CPW-fed UWB monopole antennas with and without patch loading

ϕ	Fidelity factor			
	Without patch loading		With patch loading	
	Simulated	Measured	Simulated	Measured
φ = 0°	0.827	0.750	0.755	0.533
φ = 90°	0.859	0.804	0.767	0.701
φ = 180°	0.827	0.718	0.785	0.751

Conclusion: Time-domain performance of a band-reject UWB monopole antenna, which uses a previously proposed patch loading technique, has been studied and presented. The time performance has been extracted from frequency-domain measurements using a standard method and is presented in terms of pulse response and system fidelity factor. Both simulation and measurement results show a small ringing distortion in the transmitted pulse and a decrease in the system fidelity factor when patch loading is applied. These results indicate that using the proposed technique leads to suitable designs of band-reject antennas for UWB system applications.

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One or more of the Figures in this Letter are available in colour online.

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References

1 Bahadori, K., and Rahmat-samii, Y.: 'A miniaturized elliptic-card UWB antenna with WLAN band rejection for wireless communications', *IEEE Trans. Antennas Propag.*, 2007, **55**, (11), pp. 3326–3332
2 Hong, C.Y., Ling, C.W., Tarnand, I.Y., and Chung, S.J.: 'Design of a planar Ultrawideband antenna with a new band-notch structure', *IEEE Trans. Antennas Propag.*, 2007, **55**, (12), pp. 3391–3397
3 Jiang, D., Xu, Y., Xu, R., and Lin, W.: 'Compact dual-band-notched UWB planar monopole antenna with modified CSRR', *Electron. Lett.*, 2012, **48**, (20), pp. 1250–1252
4 Nguyen, D.T., Lee, D.H., and Park, H.C.: 'Very compact printed triple Band-Notched UWB antenna with quarter-wavelength slots', *IEEE Antennas and Wirel. Propag. Lett.*, 2012, **11,** pp. 411–414
5 Koohestani, M., Pires, N., Skrivervik, A.K., and Moreira, A.A.: 'Band-reject ultra-wideband monopole antenna using patch loading', *Electron. Lett.*, 2012, **48**, (16), pp. 974–975
6 Chiani, M., and Giorgetti, A.: 'Coexistence between UWB and narrow-band wireless communication systems', *Proc. IEEE*, 2009, **97**, (2), pp. 231–254
7 Zhuo, L., Feng, Z., Zheng, Z., Weixia, Z., Bin, L., and Chong, Z.: 'Analysis on coexistence of UWB with IEEE802.11n', IEEE Int. Symp. on Electromagnetic Compatibility (EMC), Fort Lauderdale, FL, USA, 2010, pp. 807–812
8 Quintero, G., Zurcher, J.-F, and Skrivervik, A.K.: 'System fidelity factor: a new method for comparing UWB antennas', *IEEE Trans. Antennas Propag.*, 2011, **59**, (7), pp. 2502–2512
9 Allen, O.E., Hill, D.A., and Ondrejka, A.R.: 'Time-domain antenna characterizations', *IEEE Trans. Electromagn. Compat.*, 1993, **35**, (3), pp. 339–346