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MIMO Antenna for UWB Communications

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Abstract

Design of ultra-wideband antennas is challenging in the stringent requirements that are often conflicting to achieve a wide impedance bandwidth while maintaining high radiation efficiency, uniform gain and compact size. A Multiple-Input Multiple-Output (MIMO) antenna system can enhance the overall antenna performance but at having to overcome new challenges such as reducing the mutual coupling and the correlation between the elements. A printed circular disc compact planar antenna is selected in this work due to its UWB performance and compact size for the MIMO antenna system. A parametric analysis is carried out to achieve an optimal design. The system developed consists of two elements with an overall size of 59 × 27 mm. The designed antenna system operates over the whole of the UWB bandwidth from 3.1 to 10.6 GHz with radiation efficiency up to 85% and reflection coefficients less that −10 dB. The envelope correlation is less than −60 dB throughout the UWB band while the diversity gain approaches 10 throughout the entire UWB bandwidth and Total Active Reflection Coefficient (TARC) between the antenna elements is less −11 dB. Thus the proposed MIMO antenna outperforms similar antenna systems reported in the literature.

Keywords

Antenna Efficiency, Diversity Gain, MIMO Antenna, Total Active Reflection Coefficient (TARC), Ultra-Wideband (UWB) Antenna

1. Introduction

UWB is a radio technology that can be used for transmitting and receiving a large amount of data over an ultra-wide frequency band with very low power and for short distances [1]. It has some advantages like high data rate, low equipment cost, multipath immunity and finally ranging and communication at the same time is possible. In all wireless communication systems, the antenna has an essential role since it is the means by which the signals are converted from electrical to electromagnetic wave form and vice versa. The design of an UWB antenna is subject to numerous challenges such as achieving a wide impedance bandwidth and keeping high radiation efficiency. This has been the subject of many studies [2]-[16]. Also meeting the equipment physical constraints like size and portability is another challenge. Research results have proven that some of these challenges can be resolved by adopting a MIMO antenna system. The multiple antenna system increases the diversity gain, multiplexing gain or array gain and thus enhances the overall antenna performance [3]-[11] [16]. However there

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are some challenges in designing a MIMO antenna for a technology like UWB including reduction of the mutual coupling and the correlations between the elements. The objective in this work is to design a MIMO antenna for UWB communication suitable for many applications in a wireless personal area network (WPAN) that outperforms antenna systems reported in the literature. The main antenna parameters considered are 1) the bandwidth which is expected to extend over the entire UWB 3.1 to 10.6 GHz with reflection coefficients better than −10 dB; 2) the radiation pattern which is to be omnidirectional; 3) the radiation efficiency that is to exceed 70%; 4) the gain over the UWB bandwidth that is to be uniform; 5) the Total Active Reflection Coefficient which accounts for both coupling and random signal combination and offers a better representation of a MIMO antenna efficiency and varies between 0 and 1 with the latter as the desired value; 6) the envelope correlation; and 7) the diversity gain.

2. Methodology

A time domain solver package was utilized to carry out the design and simulation of the MIMO antenna. The antenna performance including bandwidth, radiation pattern, efficiency, gain, mutual coupling between the MIMO antenna elements, the envelope correlation and diversity gain are examined using the software. In addition, a script was developed to determine the TARC between the antenna elements. A parametric analysis was carried out to obtain an optimal geometry and configuration subject to the design constraints shown in **Table 1** [1].

The configuration of the MIMO antenna system is shown in **Figure 1**.

Table 1. MIMO antenna design requirements [1].

Antenna parameter	Value
VSWR bandwidth	3.1 - 10.6 GHz
E and H radiation pattern	Omnidirectional
Radiation efficiency	>70%
Gain	Smooth over UWB bandwidth
Phase	Linear
Size	Small

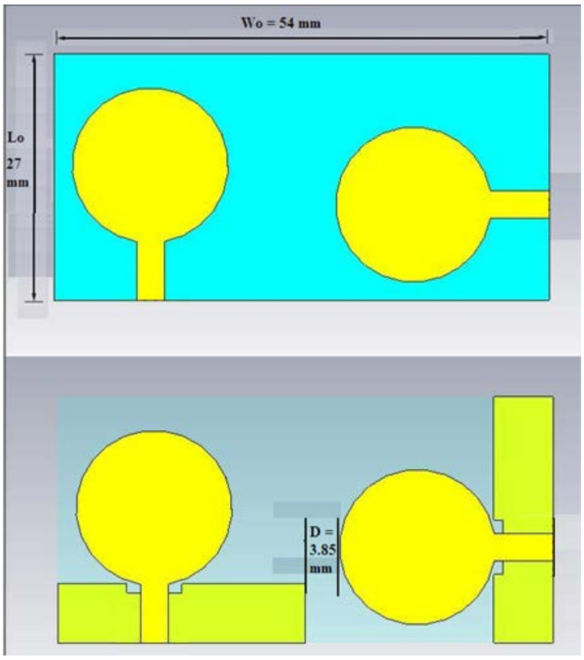

Figure 1. Structure of the MIMO antenna.

3. Results

3.1. S-Parameters of the MIMO Antenna

The overall dimension of the optimised MIMO antenna is (width × length) = 59 × 27 mm. The bandwidth extends from 3.1 GHz to 10.6 GHz as shown by the scattering parameters plots in **Figure 2** that are less than −10 dB. This indicates that the developed antenna supports about 100% of UWB BW, unlike the antenna reported in [1]. The simulation results also show that mutual coupling is less than −24 dB over the same bandwidth.

3.2. Radiation Patterns of the MIMO Antenna

Figures 3-5 depict the E and H radiation patterns of the MIMO antenna at three frequencies: 3.7, 7.8 and 9.7 GHz. It is observed that these radiation patterns are close to omnidirectional in most of the coverage areas.

3.3. Gain and Radiation Efficiency

The gain and radiation efficiency were observed throughout the supported UWB bandwidth (3.1 to 10.6 GHz)

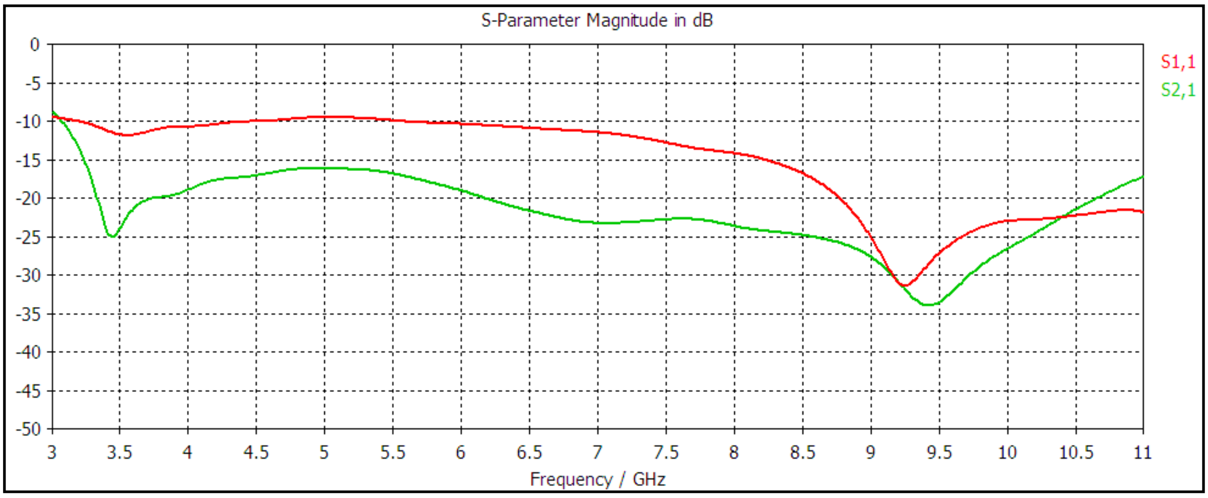

Figure 2. S_{11} and S_{21} of the MIMO Antenna.

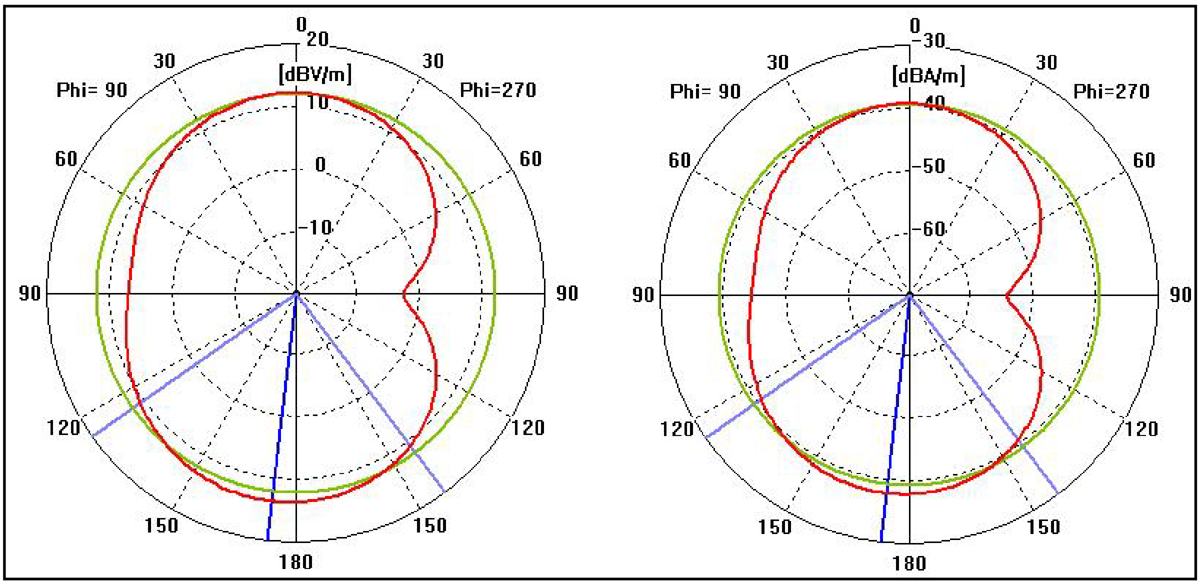

Figure 3. E-Field (left) and H-Field (right) at 3.7 GHz.

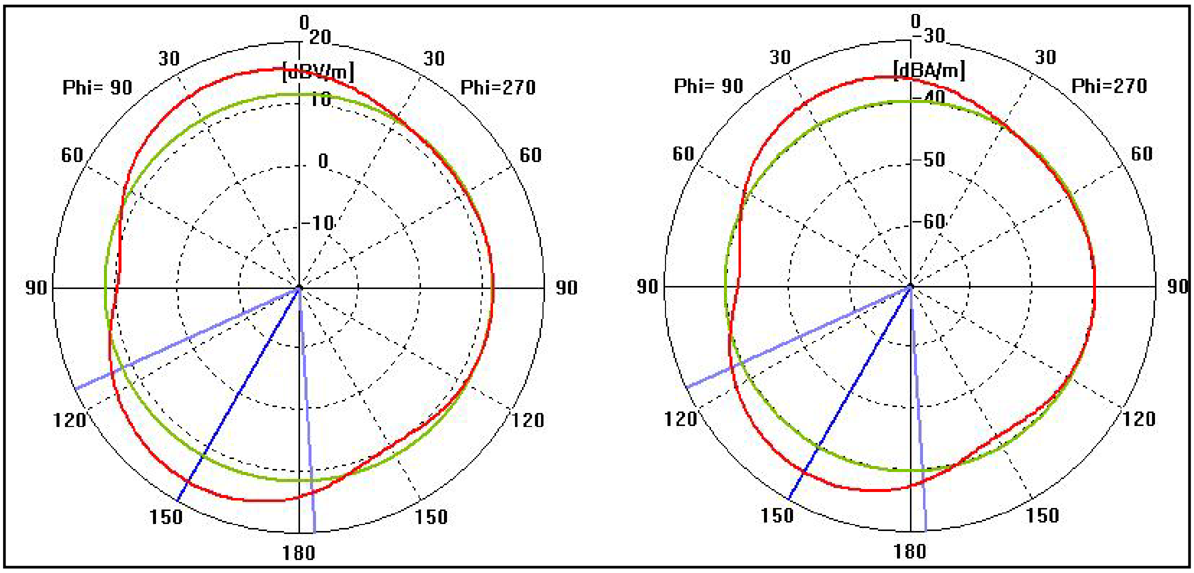

Figure 4. E-Field (left) & H-Field (right) at 7.8 GHz.

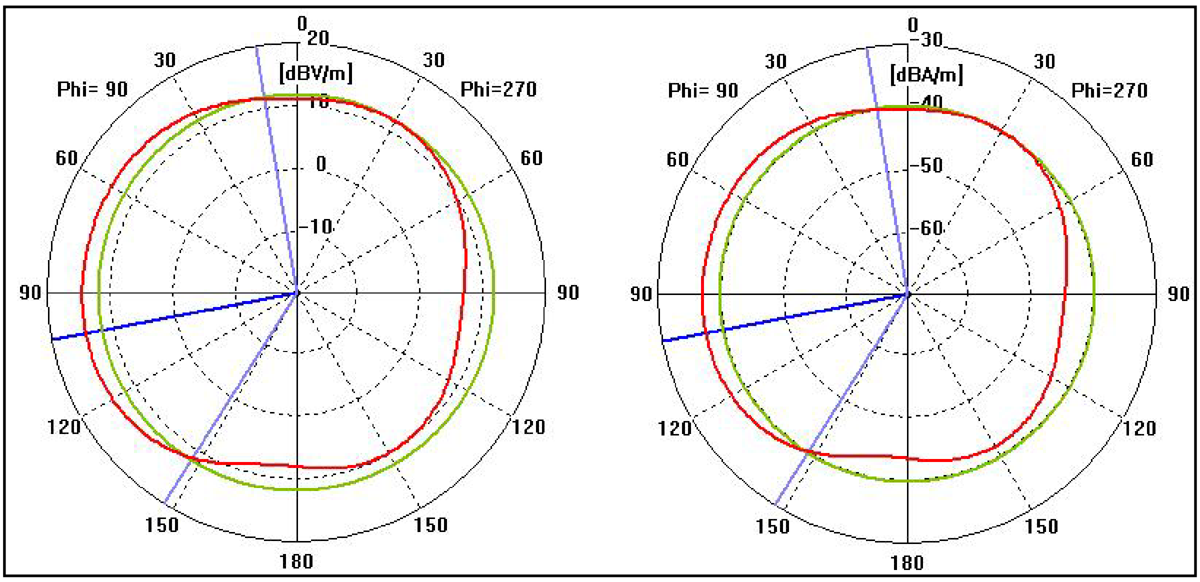

Figure 5. E-Field (left) and H-Field (right) at 9.7 GHz.

and the results are as shown in **Figure 6** and **Figure 7**.

From the **Figure 6** and **Figure 7**, it can be observed that the proposed UWB MIMO antenna has a good gain, but there is variation from 4.3 dBi at 3.1 GHz to 6.3 dBi at 10.6 dBi. The average antenna gain is 4.7 dBi. The antenna has good radiation efficiency, but with variation from 40% at 3.1 GHz to 83% at 6.6 GHz. The average radiation efficiency is 65%.

3.4. Envelope Correlation, Diversity Gain and TARC

For this design the envelope correlation, diversity gain and TARC are also examined to check the MIMO performance. These are shown in **Figures 8-10** respectively.

From **Figure 8**, the envelope correlation appears too low and it is less than −60 dB throughout the entire supported UWB bandwidth.

The diversity gain in **Figure 9** on the other hand approaches 10 indicating uncorrelated antenna elements of

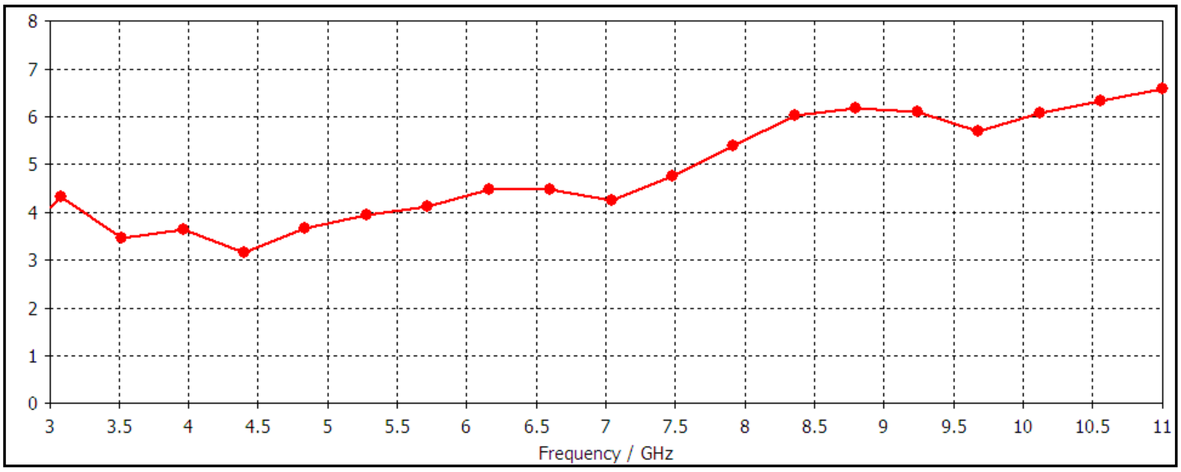

Figure 6. Frequency versus gain.

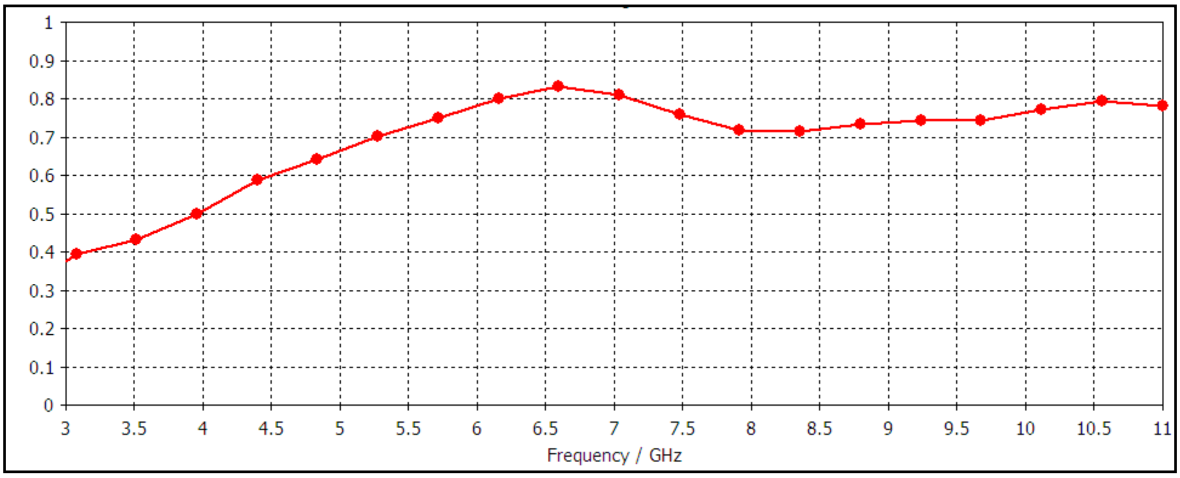

Figure 7. Frequency versus radiation efficiency.

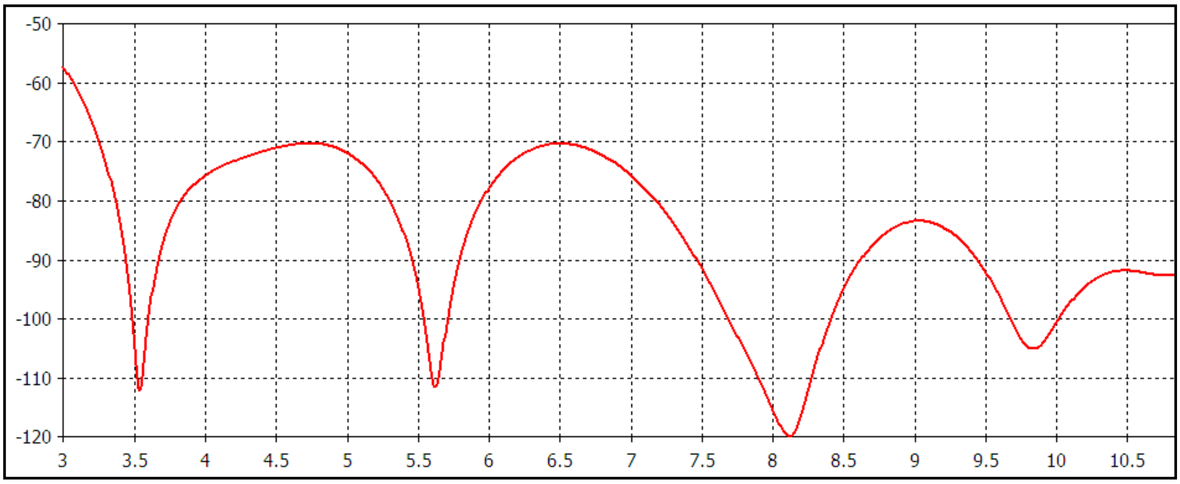

Figure 8. Envelope correlation (dB) of the of the MIMO antenna.

the MIMO antenna.

TARC is less than −11 dB throughout the supported impedance bandwidth as shown in **Figure 10**.

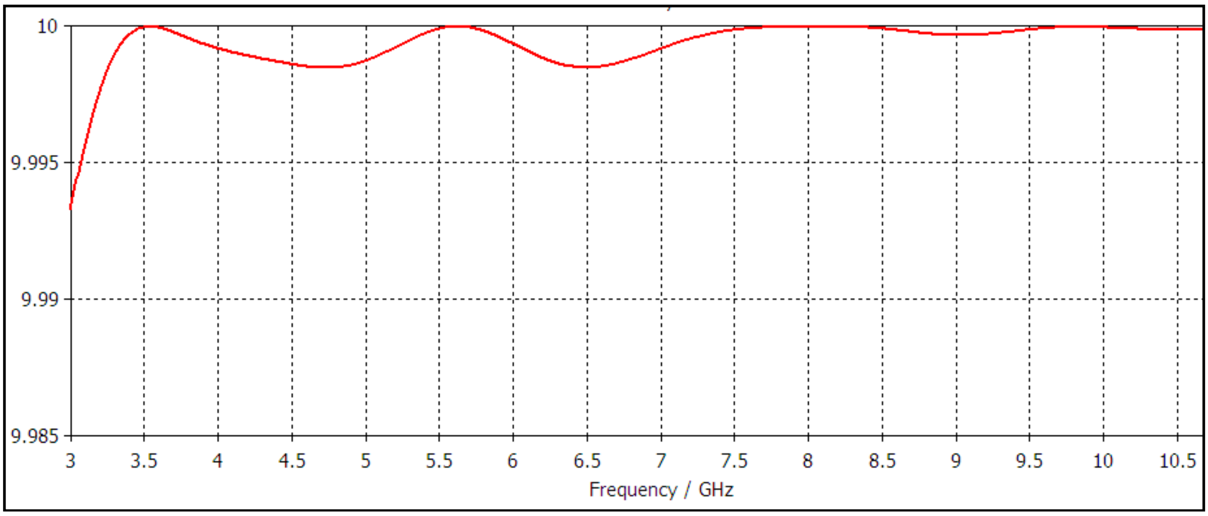

Figure 9. Diversity gain of the MIMO antenna.

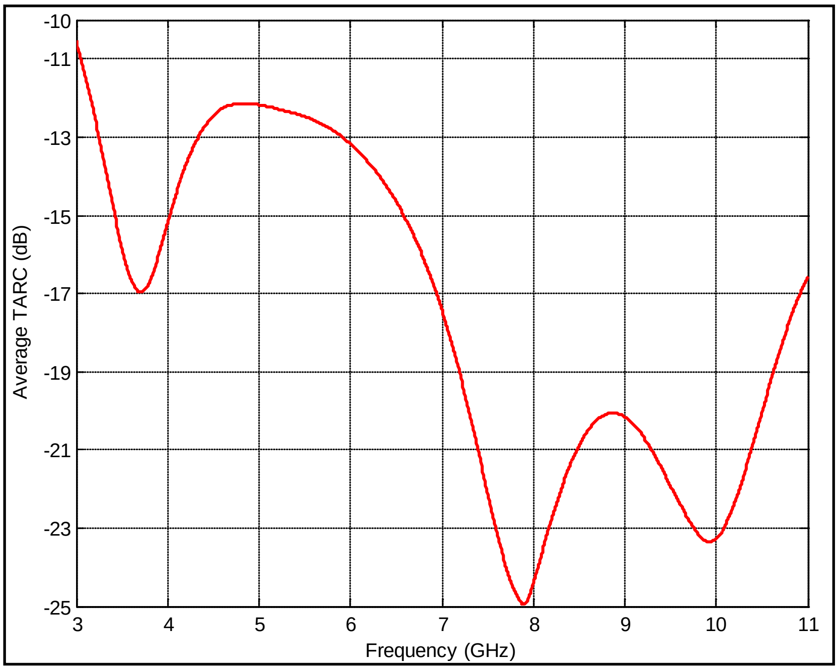

Figure 10. The average TARC of the MIMO antenna.

4. Conclusion

A UWB MIMO antenna system has been designed that is suitable for general purpose UWB MIMO applications and especially for integration with personal wireless-based devices that include mobile handset, laptops and tablet PC's. The emphasis was on developing MIMO antennas with low correlation between the elements and with a low profile. The basic element that has been used in the proposed design is circular monopole disc printed on in a block of FR-4 dielectric substrate with relative permittivity 4.6 and dimensions: width = 27 mm, length = 23.5 mm and thickness = 1.6 mm. Two elements were used and positioned orthogonal to each other with a separation of 8.85 mm. The simulation results have shown that the antenna system bandwidth extend over the entire UWB bandwidth (3.1 to 10.6 GHz). The mutual coupling between the elements is less than −24dB. The radiation pattern, gain and efficiency have been obtained and found that the developed antennas outperform the antennas reported in the literature. The MIMO antenna correlation coefficient has been found to be less than −60 dB with a diversity gain of 10 and TARC less than −11 dB.

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