DOUBLE DIPOLE ANTENNA FOR DUAL-BAND WLAN APPLICATIONS

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ABSTRACT: *A double dipole antenna design is proposed for wireless local area network (WLAN) applications. Two parallel dipoles are used to facilitate operation in both the standard WLAN frequency bands (IEEE 802.11b and IEEE 802.11a) simultaneously. The lower band dipole is rhombus shaped and radiates above a planar ground plane, while radiation from the rectangular higher band dipole is directed through the use of a passive director. The antenna is characterized in terms of impedance bandwidth, gain and radiation patterns through simulations and measurements. The design addresses the need for dual-band operation, while delivering directional radiation patterns with adequate gain, low cross-polarization and a good front-to-back ratio. The 2.4/5 GHz WLAN bands are covered with an impedance bandwidth of 17.8% and 26.4% respectively, for a VSWR better than 2:1.*

Key words: *rhombus; dipole; dual-band; planar antenna; WLAN.*

1. INTRODUCTION

The recent growth in the ambit of modern wireless communication has increased the demand for multi-band antennas that can satisfy the requirements pertaining to WLANs (Wireless Local Area Networks). The development of dual-band antennas that can cover the 2.4 GHz (2.4 – 2.484 GHz) band and the 5 GHz (5.15 – 5.85 GHz) band for the IEEE 802.11b and IEEE 802.11a WLAN standards respectively are thus highly desirable. Printed planar antennas are popular due to their reasonable good performance, ease of integration and low cost. This is corroborated with the numerous monopole [1-6], dipole [7, 8] and a variety of other antenna variations [9-12] presented in the open literature over the last few years. Some of the key characteristics of a successful dual-band WLAN antenna design are the size of the antenna, the bandwidth, the gain, as well as stable radiation patterns over the WLAN frequency bands.

The monopole designs [1-6] are generally for use as omni-directional radiators, although the planar nature of the ground plane (and also other factors) does have a negative impact on the omni-directionality of the antennas – usually more on the higher band performance than on the lower band performance. Monopole antennas have the advantage of small dimensions, but also exhibit relatively narrow impedance bandwidths. A variety of methods have been used to obtain dual-band operation with sufficient bandwidth, which include the use of meander lines [1, 2] and shaped monopole sections [3-6].

The dipole designs (radiating above a planar ground plane) in [7, 8] have reasonably good directional patterns with higher gains and are thus more aimed at applications where end-fire radiation patterns are a prerequisite, e.g. for a WLAN access point. The folded half-wave dipole design [7] has average gains of approximately 3.6 dBi and 4.7 dBi respectively in the two WLAN frequency bands. The modified quasi-Yagi design [8] has an average gain of approximately 4.0 dBi in both the frequency bands. The geometry pertaining to the folded half-wave dipole antenna [7] has the advantage of being self-balancing and thus eliminating the need for a balun. The structure consists of three printed folded dipoles co-linearly arranged above a planar ground plane with a microstrip feeding network. The dipoles all resonate at different frequencies to cover the desired WLAN frequency bands. The modified quasi-Yagi design [8] on the other hand was presented with a broadband hook-shaped balun to balance the structure. This design also employs three dipoles, in a stacked or shunt connected configuration, with the longest dipole acting as the reflector, the midlength dipole as the director and the shortest dipole as the resonator.

Some of the other published dual-band antenna configurations include inverted-F radiators [9, 10], patch radiator variations e.g. [11], or so-called coplanar antennas [12]. The designs that employ parasitic patches to obtain wider bandwidths use either a stacked geometry or a coplanar geometry that increases the width of the antenna structure. Some of these structures are very compact (e.g. [11]), but at the cost of lower gain in especially the lower frequency band.

In this paper, a new double dipole antenna design is proposed for WLAN applications – see Figure 1. The lower band dipole is rhombus shaped and radiates above a planar ground plane, while radiation from the rectangular higher band dipole is directed through the use of a passive director. The antenna is characterized in terms of impedance bandwidth, gain and radiation patterns through simulations and measurements. The 2.4/5 GHz WLAN bands are covered with an impedance bandwidth of 17.8% and 26.4% respectively, for a VSWR better than 2:1. The new design is in fact a major re-design of a previously published double rhombus antenna. The original antenna [13] consisted of two parallel quasi-rhombus-shaped dipoles fed by a microstrip line, was intended for phased array applications, operated over an ultra-wide frequency band (5.7 to 17.8 GHz), and was designed for manufacture on a high permittivity ($\varepsilon_r = 10.2$) substrate. The same basic configuration (with two rhombus-shaped dipoles) was initially re-designed for dual-band operation in the 2.4 GHz and 5 GHz WLAN bands, and for implementation on a low-cost low-permittivity substrate. The antenna gain in the higher band was found to be quite low. By using a rectangular dipole with a director as the higher band radiator the gain in the higher band could significantly be improved. The new antenna structure is shown in Figure 1. The stable end-fire radiation patterns with good front-to-back ratio, good cross-polarization and average measured gains better than 4.0 dBi in both bands, offer a competitive alternative compared to the folded dipole [7] and modified quasi-Yagi antenna [8] that also produce directional radiation patterns. The new double dipole design is approximately the same size in surface area (but with a different aspect ratio) than the folded dipole array in [7], but is easier to manufacture because it does not require any via-holes. The modified quasi-yagi [8] antenna is slightly more compact than the newly designed double dipole antenna, but the new design has slightly better average gain and front-to-back ratio, judging from the simulated results presented in [8].

2. ANTENNA DESIGN

All simulations were conducted with the aid of the commercial software package CST Microwave Studio®. The proposed dual-band antenna was designed to be etched on Rogers RO4003C substrate with a dielectric constant of 3.38 and a height of 0.813 mm. All the design parameters of the antenna are indicated in Figure 2, which shows only the copper tracks on the upper side of the substrate. The two dipole halves of each dipole are printed on different sides of the substrate and therefore ensure that the structure is more balanced. The lengths (L3 and L5) of the two dipoles control the two primary resonances and the rhombus shape (effectively defined by W2 and W3) of the lower band dipole has the advantage of reducing the size of the antenna compared to a normal dipole antenna. The rhombus shape of the dipole also facilitates multi-current paths which differ in length to ensure that the bandwidth is increased by achieving densely spaced multi-resonances. A truncated ground plane acting as a reflector is printed on the bottom lower side of the substrate, which is also utilized as ground for the microstrip feed line of the antenna. The antenna is designed for a 50 Ω system, and a tapered microstrip feed line is used to help improve the impedance matching. This part of the geometry is indicated as section 1 in Figure 2. Section 2 is a matching parallel transmission line section connecting the microstrip feed line to the lower band dipole. The length and width (L1 and W1) are also parameters to be optimized. L1 + L2 is the spacing between the planar ground and the lower band dipole, and L4 the spacing between the lower band and the higher band dipole. The position, width and length of the passive director are defined by d, Wd and Ld respectively. The antenna was optimized through a series of simulations to obtain the best configuration in terms of the desired antenna characteristics. All of the final dimensions indicated in Figure 2 can be seen in Table I, with the size of the overall structure equal to 90 x 96 mm^2.

TABLE I Physical Dimensions of the Proposed Double Dipole Dual-Band Antenna [units: mm]

L1	L2	L3	L4	L5	Lf	Ld	W1	W11	W2	W3	W4	W5	Wf	Wd	d
19.0	4.3	25.0	3.0	9.5	39.0	17.0	1.4	0.7	4.2	2.5	0.6	2.5	1.4	1.0	3.5

3. RESULTS AND DISCUSSION

Figure 3 shows the simulated and measured reflection coefficient associated with this design. The simulated results indicated that the antenna was to operate from 2.30 – 2.75 GHz in the lower band (17.9 % bandwidth) and from 4.56 – 5.95 GHz in the upper band (26.4 % bandwidth), assuming 2:1 as acceptable VSWR. The measured results correlated very well with the simulated results, with a matched lower band of 17.8% (2.32 – 2.77 GHz) and an upper band of 34.8% (4.25 – 6.03 GHz). These results are more than adequate to cover the specified WLAN bandwidths with the lower band only requiring a bandwidth of 3.44% and the upper band 14.41 %.

The simulated and measured normalized radiation patterns are shown in Figures 4 to 7. Stable directional radiation patterns were achieved with low cross-polarization levels. The maximum front-to-back ratio in the lower band is close to 10 dB, and even better in the higher band. The simulated and measured boresight gain is shown in Figures 8 and 9, for the lower band and higher band respectively. The average measured gain in both frequency bands were better than 4 dBi, and corresponds reasonably well with the simulated gain.

4. CONCLUSION

A new double dipole antenna design is presented for dual-band WLAN operations. The lower band dipole is rhombus shaped and radiates above a planar ground plane, while radiation from the rectangular higher band dipole is directed through the use of a passive director. The design addresses the need for dual-band operation, while delivering directional radiation patterns with adequate gain, low cross-polarization and a good front-to-back ratio. Both frequency bands specified by the IEEE 802.11b and IEEE 802.11a WLAN standards are adequately covered, and the measured results corresponded well with the simulated results, confirming the validity of the design.

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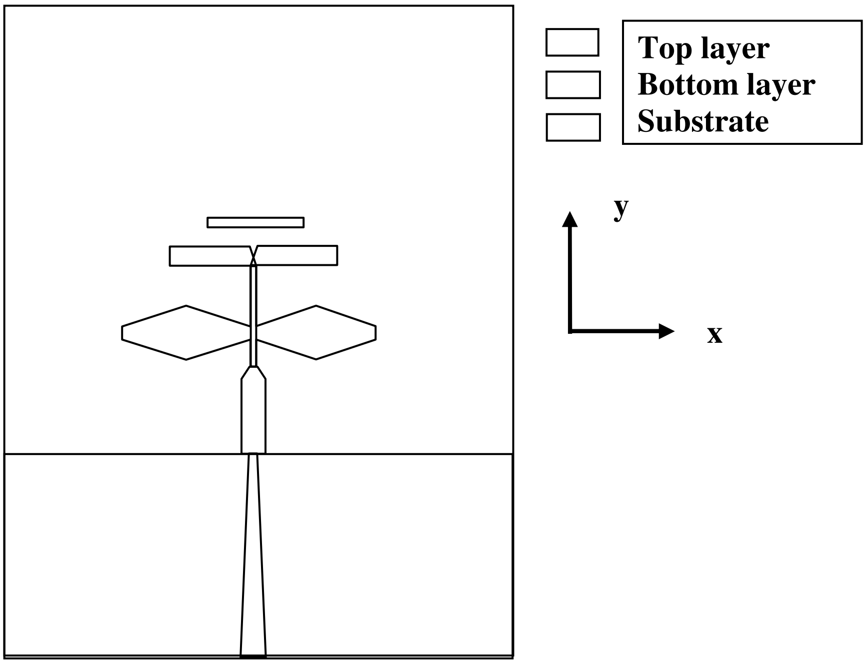

Figure 1: Double dipole antenna configuration.

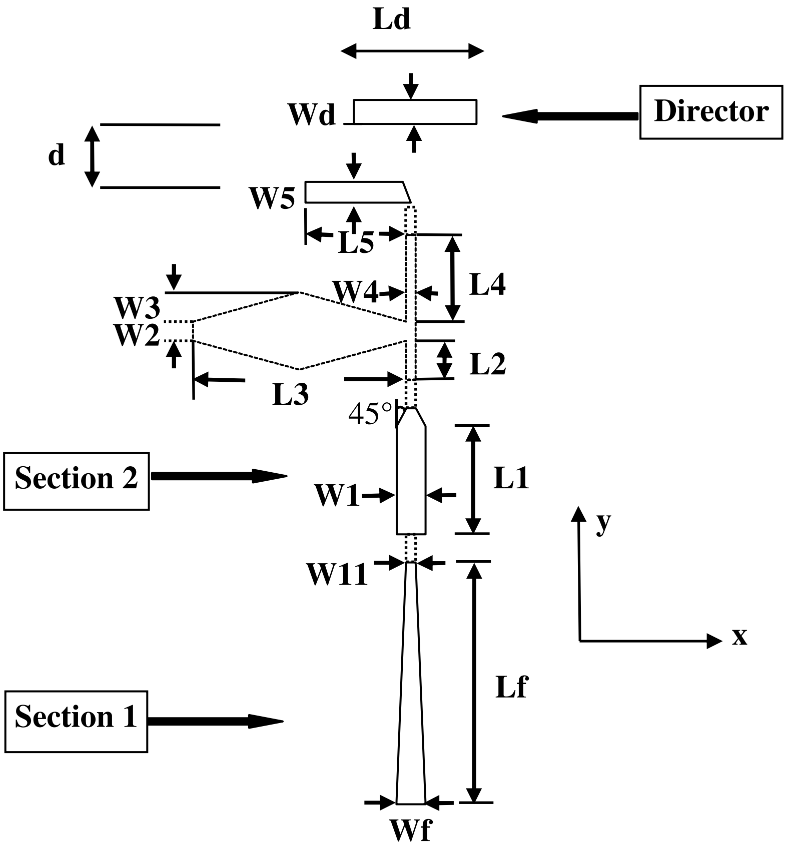

Figure2: Upper layer of the antenna showing the design parameters.

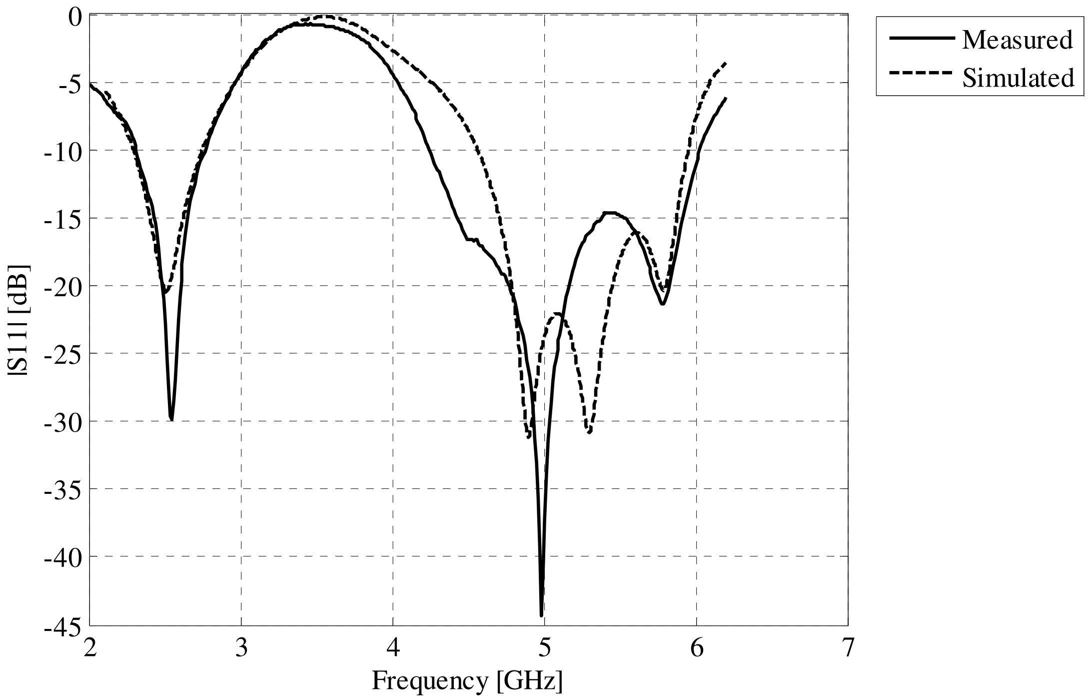

Figure 3: The simulated and measured reflection coefficient of the antenna.

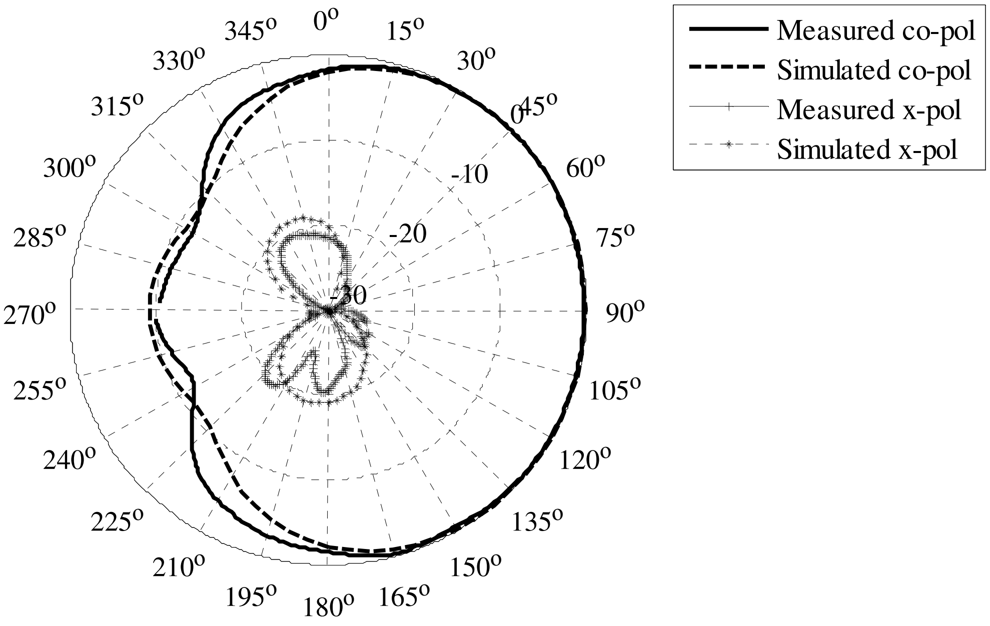

Figure 4: The simulated and measured radiation patterns in the H-plane (yz-plane) at 2.44 GHz.

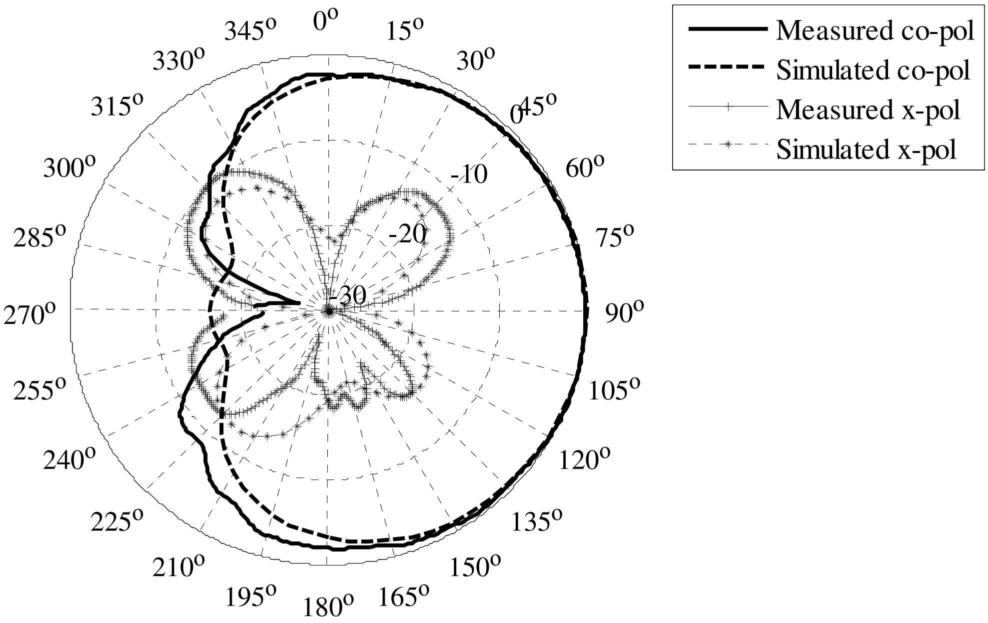

Figure 5: The simulated and measured radiation patterns in the H-plane (yz-plane) at 5.55 GHz.

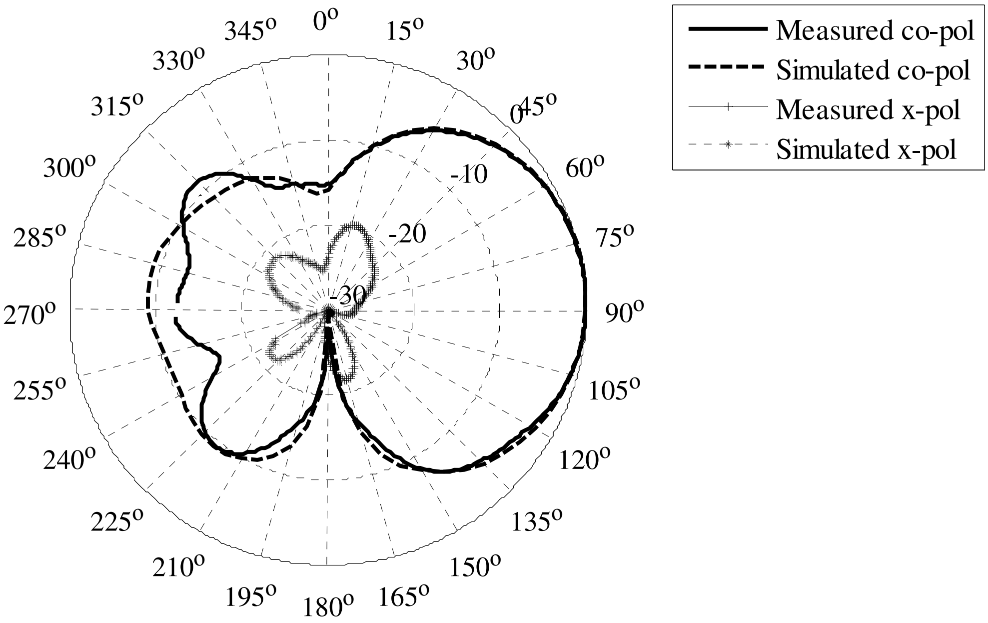

Figure 6: The simulated and measured radiation patterns in the E-plane (xz-plane) at 2.44 GHz.

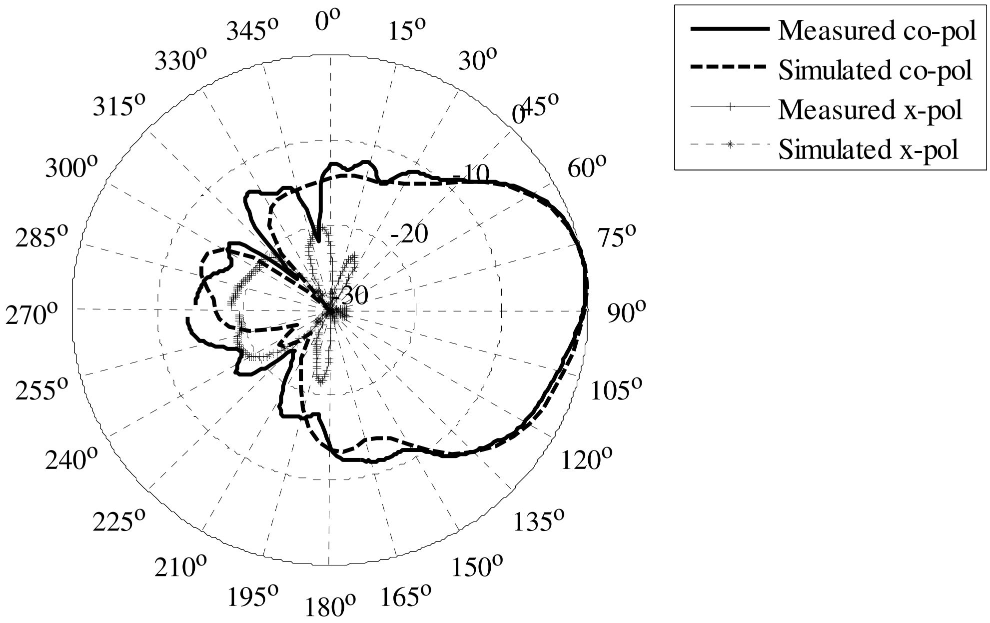

Figure 7: The simulated and measured radiation patterns in the E-plane (xz-plane) at 5.55 GHz.

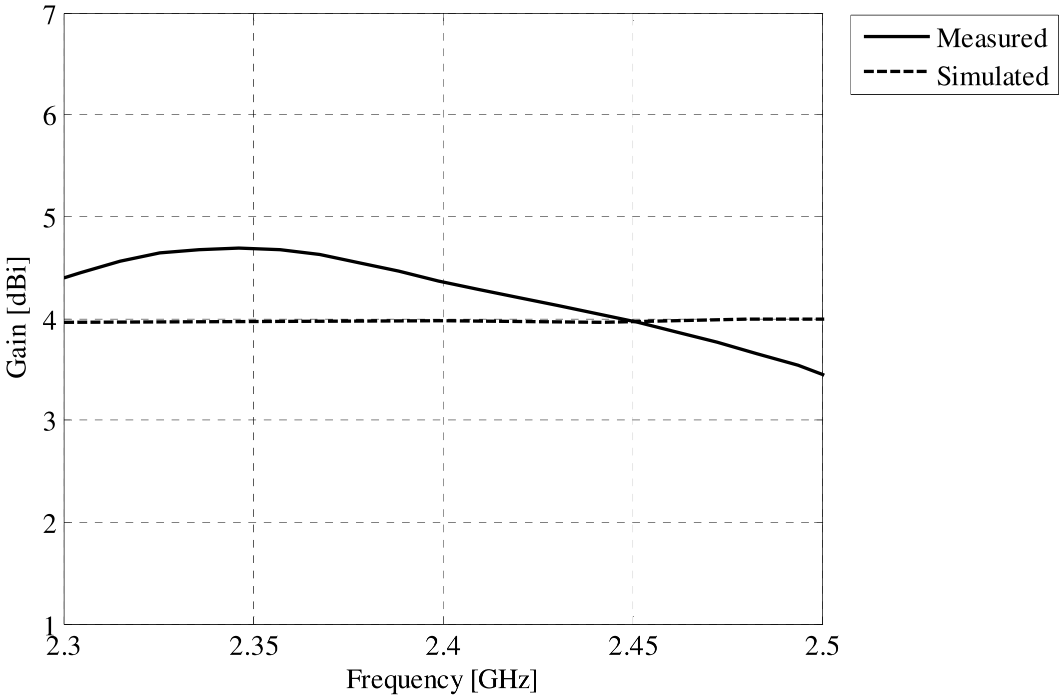

Figure 8: The simulated and measured boresight antenna gain in the low-band frequency range.

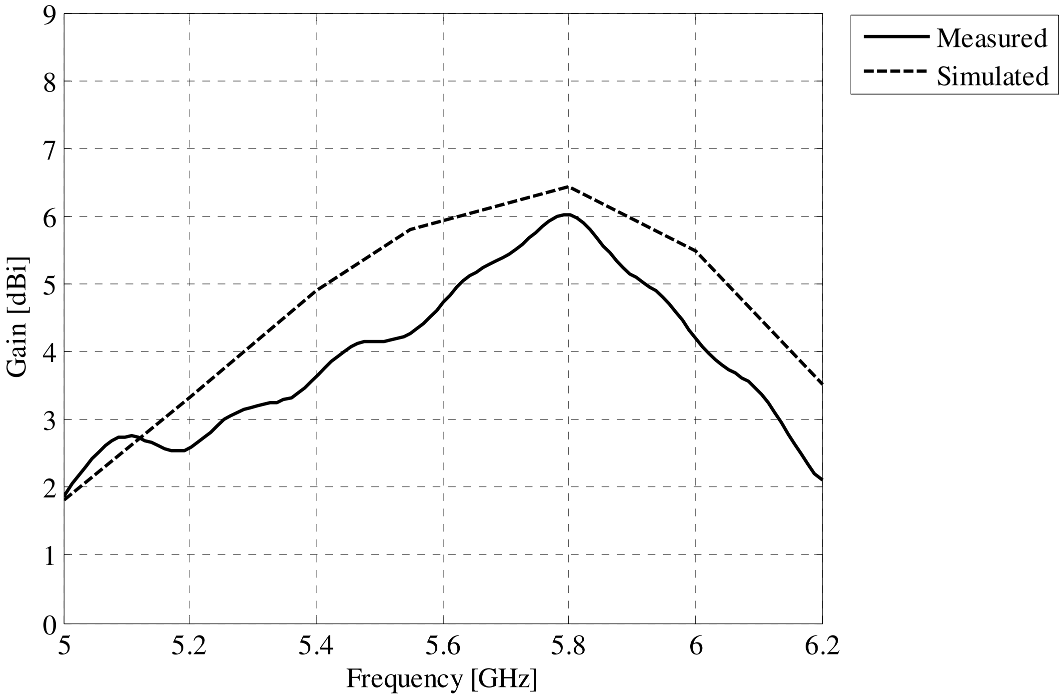

Figure 9: The simulated and measured boresight antenna gain in the high-band frequency range.