

SUPER WIDEBAND MULTIPLE INPUT AND OUTPUT ANTENNA ANALYSIS OF SIMULATED AND EXPERIMENTALLY VALIDATED RESULTS

¹Bhagya Lakshmi Medaka, ²Kiranmai Potnoori, ³Rachakonda Sudhakar, ⁴Vangeti Shanmitha

^{1,2,3}Assistant Professor, ⁴UG Student, ^{1,2,3,4}Department of Electronics and Communication Engineering, Rishi MS Institute of Engineering and Technology for Women, Kukatpally, Hyderabad.

ABSTRACT

The tiny planar MIMO antenna for extreme wide band applications is presented in this research. The MIMO antenna that is being shown consists of two identical patches mounted on the same substrate. The MIMO antenna's dimensions are 0.17 x 0.20 x 0.006 mm³ at the lowest resonance of 1.30 GHz. The F4B substrate, which has a dielectric constant of 2.65 and has a percent impedance bandwidth and bandwidth ratio of 187% and 30.76:1, was used to create the SWB antenna. By sandwiching a T-shaped corrugated strip between two antenna elements, the mutual coupling between the antenna components is reduced. The suggested MIMO antenna has a maximum diversity gain of 10 dB, low mutual coupling of 20 dB, low envelope correlation coefficient of 0.02, efficiency of >80%, and low reflection coefficient of 10 dB in the SWB frequency range (1.30 GHz–40 GHz). The presented antenna is a good candidate for SWB applications. The designed antenna has been experimentally validated, and the simulated results were also verified.

Keywords: ultra wide-band and super wide band planar monopole antenna, MIMO antenna, S parameters

INTRODUCTION

Both long- and short-range communication can benefit from using planar monopole antennas with ultra- and super-wideband (UWB and SWB) capabilities. SWB antennas have a bandwidth (BW) ratio larger than 10. Wideband antennas of various sizes have been developed for SWB and UWB applications. The massive size and dimensions of these wideband antennas provide a significant problem. The suggested wideband antenna is 0.56 x 0.56 mm² in size and resonates for a broad range (2.67 GHz–10 GHz). Similar to this, a 0.43 x 0.84 mm² coplanar waveguide (CPW)-fed antenna has been created for use in UWB applications. Most wideband antennas that have been previously constructed have huge dimensions, low BW percentages, and high lowest resonance frequencies. For example, the dimensions of the SWB antenna designed is $2.0\lambda \times 2.0\lambda$ mm², with a 5:1 BW ratio and a %BW of 164%. With the number of users of wireless communications on the rise, the data rate requirements are dynamically increasing. For example, presently WLANs offer data rates up to 54.0 Mbps with an envisaged increase up to 600 Mbps in the near future. The audio/video streams, such as those in high-definition television, require 1 Gbps transmission. To improve the channel capacity, as in 5 G technology, multiple-input multiple-output (MIMO) antenna is a good choice that can offer massive data transmission rates. MIMO is a multiplexing technology that utilizes multiple antennas at both receiver and transmitter ends resulting in improved communication performance at both ends. On the other hand, UWB/SWB is another technology that can provide massive data transmission rates by utilizing a very wide frequency band. Extensive research has been conducted in UWB and SWB antennas. More advanced technology needs to be used when the required data rate reaches 1 Gigabyte per second. A combination of MIMO and extremely wideband technology such as UWB and SWB may offer a viable solution. In this paper, we have designed a SWB MIMO antenna that provides an extremely wideband impedance matching from 1.30 GHz to 40 GHz. The designed wideband MIMO antenna exhibits percent impedance BW and BW ratio of 187% and 30.76:1 respectively. The maximum peak gain of the MIMO antenna linearly increases and reaches 10.9 dB. The

average peak gain within resonating band is 6.7 dB and diversity gain is about 10 dB. The tapered feed line technique has been employed to enhance the impedance matching. The T- shape corrugated strip is placed among antenna elements to reduce mutual coupling. The mutual coupling is < -20 dB within the resonating band (1.30 GHz–40 GHz), and the envelope correlation coefficient (ECC) is less than 0.02. To best of our knowledge very few highly isolated MIMO antennas with lowest resonance frequency of 1.3 GHz and highest resonance frequency of 40 GHz has been designed for SWB application.

SWB Antenna Design: In this section, a planar monopole antenna is designed for SWB application. The schematic diagram of single SWB antenna is shown in Figure. The designed planar monopole antenna possesses a half circular disc shape radiator and rectangular shape ground. The planar monopole antenna is etched on F4B substrate having 1.5 mm thickness. To achieve optimum matching the designed antenna is fed with tapered micro-strip feed. The tapered feed line enhances the impedance bandwidth. The single element has wide impedance matching from 1.7 GHz to more than 40 GHz. To verify the designed SWB antenna, the E- plane co- and cross polar radiation pattern is depicted. At lower resonance frequencies co- polar pattern is greater than cross-polar with Omni-directional behaviour such as at 5 GHz and 10 GHz. At higher resonance frequencies the Omni-directional pattern becomes distorted and nulls are created. Because of this distortion, at some angles, the co-polar pattern is less than cross-polar pattern. It happens in mostly wideband antenna because of the excitation of hybrid modes at higher frequencies.

Results MIMO Antenna Design: Two monopole antenna elements with circular shape radiator are chosen as shown as design I in Figure. The S-parameters for design I are depicted in Figure. The design I shown in Figure exhibits impedance mismatching for many frequencies, so the circular shape radiator was modified to a semi-circular shape radiator, shown as design II in Figure. The simulated impedance matching for semi-circular shape radiator monopole antenna is shown. The design II has comparatively better impedance matching than design I, where the coupling among antenna elements is very high as shown in Figure b. As the tapered feed line provides wideband impedance matching, the rectangular micro-strip feed line is modified to tapered feed line.

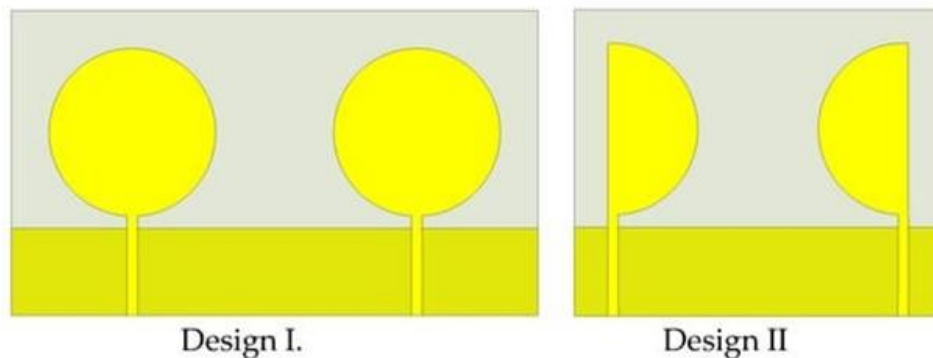


Figure. SWB MIMO antenna.

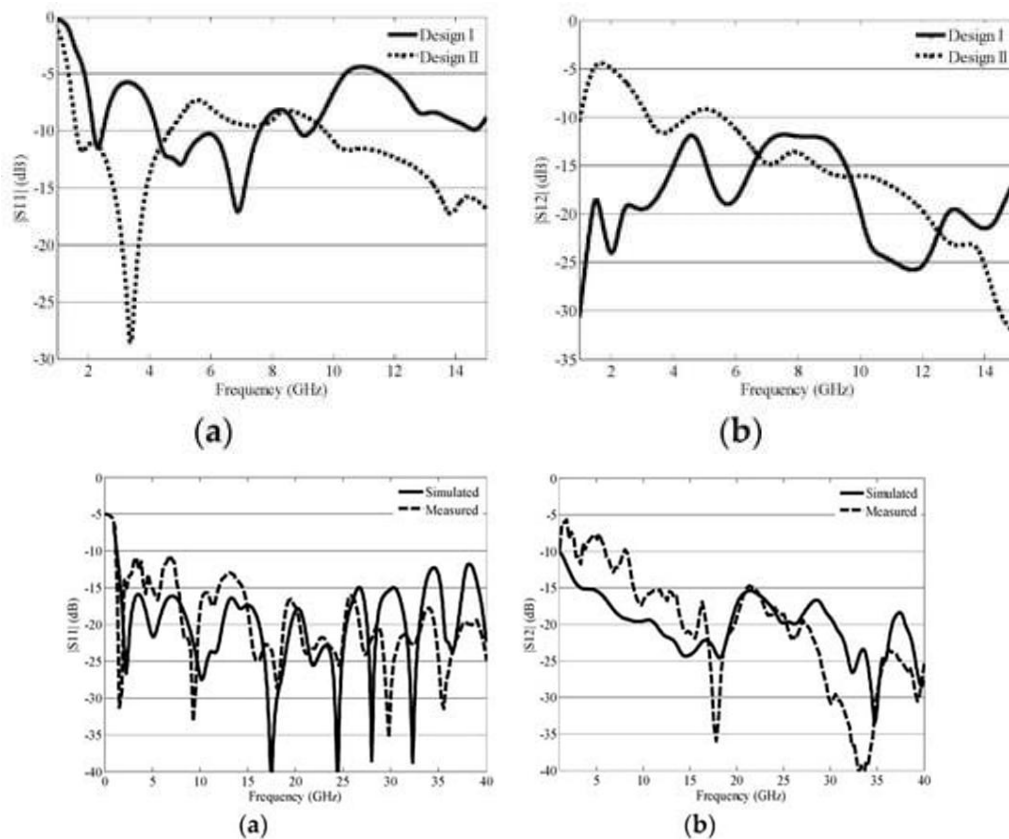


Figure. S-parameters (a) S_{11} and (b) S_{12} .

Simulations were carried out using Microwave studio computer simulation technology (CST) software. Finally, schematic design shown in Figure was fabricated on F4B substrate with a permittivity of 2.65 and a thickness of 1.5 mm. The measurements were made by using a two-port Agilent N5245A PNA-X network analyzer. The measured and simulated scattering parameter of the manufactured antenna are given in Figure 6a,b. As can be seen, the measured scattering parameters validate the simulated scattering parameters. The impedance matching S_{11} is given in Figure. From Figure it is clear that S_{11} is less than -10 dB for the 1.3 GHz to 40 GHz. In addition, the measured and simulated S_{12}/S_{21} is less than -10 dB; however, at some frequencies it increases, signifying that the isolation is very low at lower frequencies. Very little discrepancy is observed between the measured and simulated results owing either to the fabrication tolerance/manufacture accuracy or to the SMA connector.

Wideband Isolated MIMO Antenna: The decoupling setup provides negative coupling, which cancels out the coupling caused by the adjacent excited antenna element, thus reducing the mutual coupling among the antenna elements. The mutual coupling is mostly caused by surface waves and space waves. Power dissipation takes place among the antenna elements because of parasitic resistance whose occurrence cannot be ignored. The decoupled structure complicates the structure of antenna. However, to increase the isolation, a number of MIMO antennas employ the decoupled structure. Parasitic elements are mostly used to enhance isolation as they produce an opposing coupled field that diminishes the coupling between the antenna elements, thus eliminating the RF current in the adjacent antenna element. The BW, the decoupling range, and the surface current coupling can be controlled by designing an appropriate parasitic element. In this work, a corrugated T-shape strip parasitic element is selected to suppress the mutual coupling among antenna elements at lower frequencies as well as at higher frequencies. By placing the corrugated T-shape parasitic element, the impedance matching is not affected, as it is less than -10 dB in the desired frequency range (1.3 GHz–40 GHz). The coupled radiation

leads the current on the adjacent antenna therefore the designed isolated structure receives the coupling fields and transforms them in surface current leading to an increase in isolation. To examine the effect of the isolated structure, the surface current distributions at 5, 10, and 15 GHz. The surface current distribution shows the isolation of MIMO antenna with loaded corrugated T-shape parasitic element. The surface current is mainly concentrated on the corrugated T-shape parasitic element which reduces the induced current on the neighbouring antenna. In all cases, the left side monopole patch antenna was excited to see the impact of corrugated T-shape parasitic element, where the other element was terminated with a matched load. Bulleted lists look like this: In order to confirm the suitability of the designed antenna for MIMO applications, it is important to realize a low ECC. The ECC is a measurement of how much the communication channels are isolated or correlated with each other. The following formula is used to calculate ECC. An ECC value of 0.5 has been set as a suitable value for diversity conditions. The ECC for the proposed MIMO antenna has been calculated from the scattering parameters using Equation (1) and a plot of ECC versus frequency. The average ECC of the proposed MIMO antenna is 0.0073. Over the resonating band, the ECC is less than 0.02; however, the ECC slightly increases to 0.023 at 3.5 GHz. Diversity gain (DG) is another important parameter to measure the performance of the antenna. DG was calculated using Equation (2) and a plot of DG versus frequency, it is clear that the DG is varying around 10 dB at all resonance frequencies. The peak gain with and without corrugated T-shape parasitic element. The peak gain of the MIMO antenna increases; however, the gain of the decoupled structure is less than that of the MIMO antenna with no decoupling structure. The efficiency is varying around about 90%.

Another important characteristic is the radiation pattern. The far-field radiation pattern in the H-plane and E-plane is depicted in **Figure** at six different frequencies (a) 5 GHz, (b) 10 GHz, (c) 15 GHz, (d) 20 GHz, (e) 30 GHz, and (f) 40 GHz. The proposed antennas exhibit nearly Omni-directional pattern in H-plane and bi-directional pattern in E-plane at lower frequencies from 1.3 GHz to 10 GHz. At higher frequencies, nulls are generated in both H- plane and E-plane. In addition, the proposed antenna has high co-polarization at lower frequency. While, at higher frequencies the co-polarization is lower than cross-polarization level, mainly because of (1) excitation of hybrid current distribution (2) horizontal component of the surface currents increases. Overall, the designed wide-band MIMO antenna exhibit nearly stable radiation pattern and matches the behaviour of the planar monopole antenna.

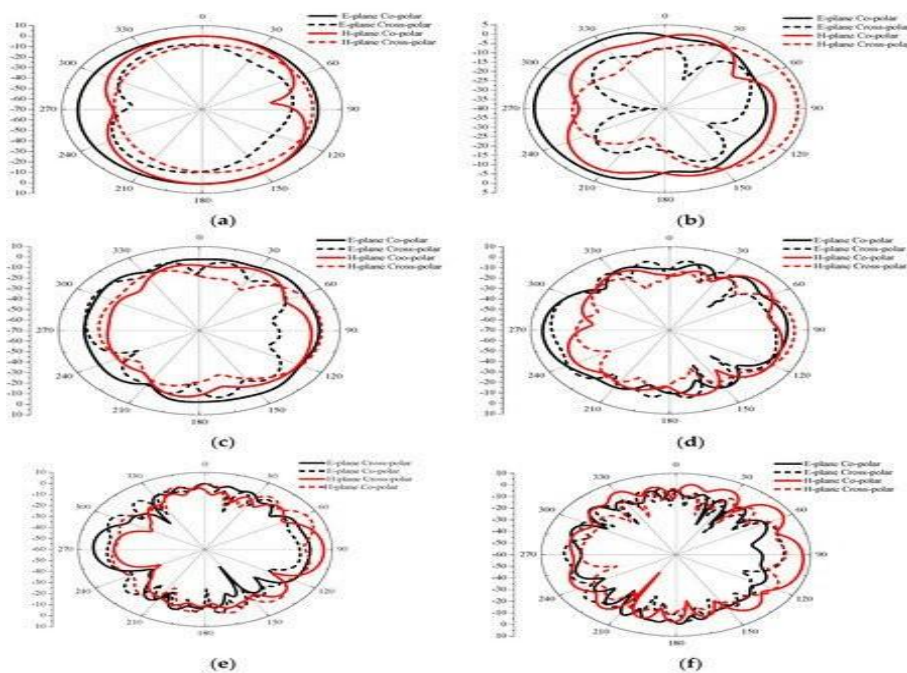


Figure. The co- and cross polar pattern in E-plane and H-plane at (a) 5 GHz (b) 10 GHz (c) 15 GHz (d) 20 GHz (e) 30 GHz, and (f) 40 GHz. It is clear that the proposed antenna has compact electrical dimensions, very large resonance frequencies with the lowest resonance frequency of 1.3 GHz, high isolation and less ECC etc. To best of our knowledge very few highly isolated MIMO antennas with lowest resonance frequency of 1.3 GHz and highest resonance frequency of 40 GHz has been designed for SWB application.

Conclusions: In this paper, a compact MIMO antenna has been designed for UWB/SWB application. The semi-circular shape radiator is fed with micro strip feed line. Micro strip feed line is modified to tapered feed line that provide extremely wideband resonance frequency range with lowest resonance frequency of 1.3 GHz. The proposed antenna exhibits high BW ratio, percentage BW, and has compact electrical dimension of $0.17\lambda \times 0.20\lambda \text{ mm}^2$. Moreover, the mutual coupling is successfully reduced in the wideband frequency range by placing a corrugated T-shape parasitic element without affecting the impedance matching. The decoupled MIMO antenna structure has a mutual coupling less than -20 dB , a ECC less than 0.02, and a diversity gain of 10 dB

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