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Design Two Port Microstrip Patch Array Antenna for Ultra-Wideband Applications

[1]Amit Kumar, [2]Dr. Ram Milan Chadhar
M. Tech. Scholar, School of Electronics and Communication Engineering, Faculty of Engineering & Technology, MPU, Bhopal, India[1]
Assistant Professor, School of Electronics and Communication Engineering, Faculty of Engineering & Technology, MPU, Bhopal, India[2]

Abstract: - Ultra-Wideband (UWB) communication systems require antennas that provide wide impedance bandwidth, high gain, low mutual coupling, and stable radiation characteristics while maintaining a compact and low-profile structure. Among the available antenna technologies, microstrip patch array antennas are widely preferred due to their lightweight design, low fabrication cost, ease of integration with microwave circuits, and compatibility with modern wireless communication systems. This paper presents the design of a two-port microstrip patch array antenna for UWB applications. The proposed antenna consists of two symmetrically arranged microstrip patch elements configured as an array to enhance gain and improve radiation performance while supporting dual-port operation. The antenna geometry and feed network are optimized to achieve broad impedance bandwidth, good impedance matching, and high isolation between the two ports. Performance parameters including return loss (|S11|), mutual coupling (|S21|), Voltage Standing Wave Ratio (VSWR), gain, radiation pattern, bandwidth, and radiation efficiency are analyzed through electromagnetic simulations. The proposed design demonstrates improved bandwidth, enhanced gain, and reduced port-to-port interference, making it suitable for high-speed wireless communication, radar imaging, Internet of Things (IoT), medical imaging, and short-range sensing applications. The compact structure and reliable performance indicate that the proposed two-port microstrip patch array antenna is a promising candidate for next-generation UWB wireless communication systems.

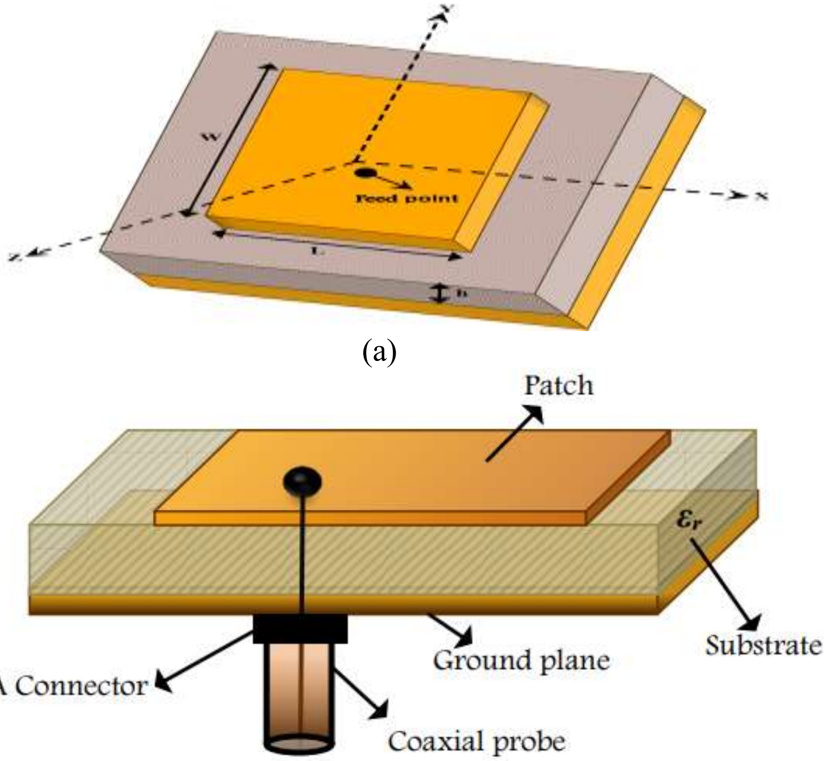
Keywords:-Microstrip Antenna, Partial ground plane, Ultra-wide band

I. INTRODUCTION

The advancement of contemporary wireless communications has increased significantly owing to utilization of the wireless systems at enormous scale. The wireless system comprises of enormous assortment of equipments such as radar, navigation, landing system, direct broadcast T.V, space communications, small mobile units like laptops, cellular phones and so on. Today, we appreciate substantially more profit by the wireless system, therefore significant contributions of antennas should not be underestimated. These wireless systems are fundamentally based on electromagnetic (EM) waves which are transmitted and received through an antenna. Accordingly, an antenna is the prime element of wireless system, therefore it's impossible to design a wireless system without antenna. The system requirements can be reduced along with improved system performance through better design of antenna. The recent trend in commercial and communication devices has been to develop such kinds of antennas that are smaller, reliable and capable of sustaining great performances over an enormous spectrum of frequencies [1].

However, it was not before 1970 when the research publications started to flow with the appearance of design equations. In 1886, Henrich Hertz designed a radio system, in the transmitting side, it generates electric current and spark by an induction coil executing at 8-meter wavelength and a square loop antenna at the receiving side. The first antenna which was used in radio broadcasting transmitters of high power and Trans-Atlantic communication system is rendered by Marconi in 1885. Marconi comes to be an astrologer of wireless, his great contribution towards the development to the community prevailed as memorandum ebullience scholar in the laboratory. Practical antennas improvement hustled exceptionally quicker with the accessibility of good substrate having low loss tangent, great thermal and mechanical properties, upgraded and progressed photolithographic procedure [2, 3].

The current advancements in wireless communication technology and remarkable growth in the wireless communication market, which made wireless devices affordable and more reliable. Researchers have devoted their investigations to construct novel design or modification to the standard antenna to produce either broad bandwidth or diverse frequency activity in a solitary component. In spite of, such of these modifications bear drawbacks corresponding to the size, height of the substrate or overall dimension of the individual element, and the enhancement in bandwidth typically suffers from deterioration of the other characteristics [4].



(a)

(b)

Figure 1: Basic Configuration of microstrip antenna (a) Top view (b) Side view

Because of these, the requirement of compact, portable, low cost and light weight antenna has increased regularly [5, 6]. MSA has drawn maximum attention to improve performance and supports high mobility for wireless devices. MPAs have diversified applications such as aerospace vehicle, missile, space telemetry including commercial areas i.e. mobile-satellite-communications, direct broadcast satellite (DBS) systems, global positioning system (GPS), remote sensing and hyperthermia, etc. In its simplest form, MPA comprises of a radiating patch and ground plane that are detached by the dielectric substrate and fed at an appropriate location of the patch as shown in Fig. 1.

II. PARAMETRIC OPTIMIZATION

The design parameters that govern the input impedance are substrate height, feed-point location and gap width.

2.1 Effect of Feed Point Location

For three different feed-point locations from the center of the patch, there is variation in the VSWR with frequency, shown in Fig. 2. With increase in frequency, the input impedance moves in a clockwise direction in the smith chart [7, 8]. As x moves from 1mm (feed-point is shifted to the edge), the input impedance loci shifts in the right direction on the smith chart implying that the impedance is increasing. A perfect match of 50 ohm feed-line is obtained for 4.75 mm along –x direction, which gives a bandwidth of 3.21 GHz for VSWR 2.

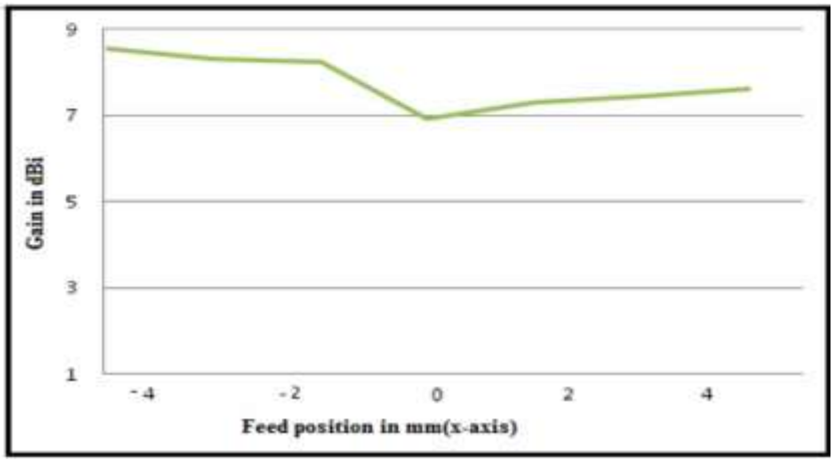


Figure 2: Gain variations of microstrip antenna

2.2 Effect of Gap Width

Gap width governs the interaction between the coupled patch and the main patch. Increase in the gap width decreases the size of the impedance loci, because the interaction between the resonators decreases. Also the impedance loci shift toward the left side of the smith chart is shown in Fig. 3(a) and (b). Further increase in the gap width decreases the size of the impedance loci and the loop disappears for larger gap width. In this case, the gap width is varied from 0.007Ʒ to 0.03Ʒ. The optimized value of 0.007Ʒ gives good bandwidth thereby increasing the interaction between the co-patch and the main patch [9].

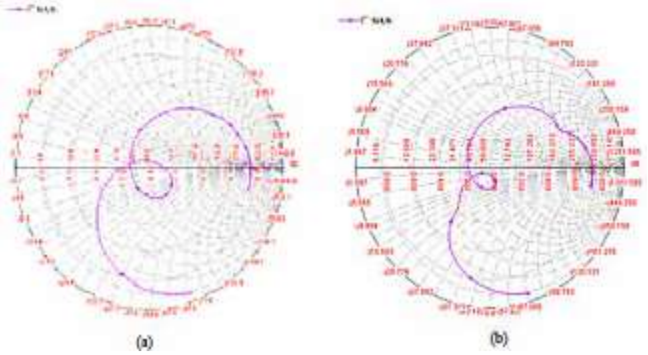


Figure 3: (a) Smith chart for optimized gap width (b) Smith chart for increased gap width

2.3 Effect of Slot

Cutting slots in the radiating patch reduces the resonant frequency. Slot is considered as capacitive reactance on the patch. For a given slot length, resonance frequency decreases with increase in slot width. The increase in slot width increases the impedance linearly. For maximum slot length (15mm), the resonant frequency variations are minimum and maximum for minimum slot length (5mm). Slot loaded microstrip antenna is analyzed using equivalent circuit concept, in which the capacitive reactance of the slot on the patch counteract the inductive reactance of the probe. Fig. 4 shows the variation of bandwidth for various slot lengths [10, 11].

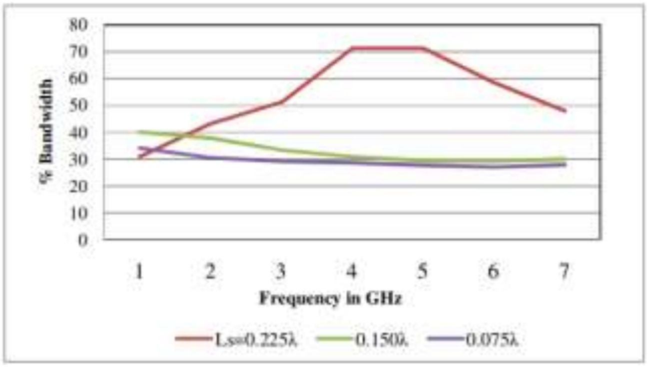


Figure 4: Bandwidth variations for various slot lengths

2.4 Effect of Height, h

With increase in height h, from 0.08Ʒ to 0.09Ʒ the fringe fields from the edges increase, which increases the extension length and hence the effective length, thereby decreasing the resonance frequency. The bandwidth of the antenna increases from 1.575 GHz to 3.21 GHz, for the optimized height 0.09Ʒ. The increase in the probe inductance of the feed moves the input impedance in clockwise, thereby introducing inductive shift [12].

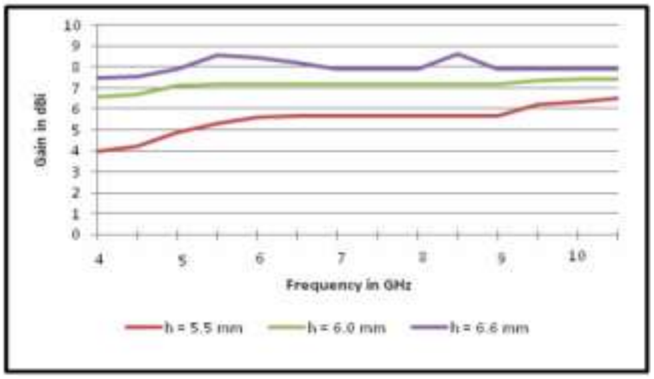


Figure 5: Gain variations of microstrip antenna

2.5 Effect of Width, W

Patch width affects the bandwidth to a larger extent [13]. A larger patch width increases the bandwidth, radiated power and the radiation efficiency. Patch width is chosen greater than the patch length, with good excitation. It is observed that the patch width various from 0.45Ʒ<W

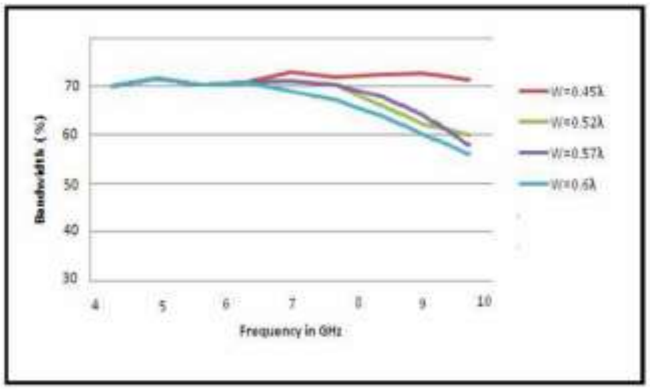
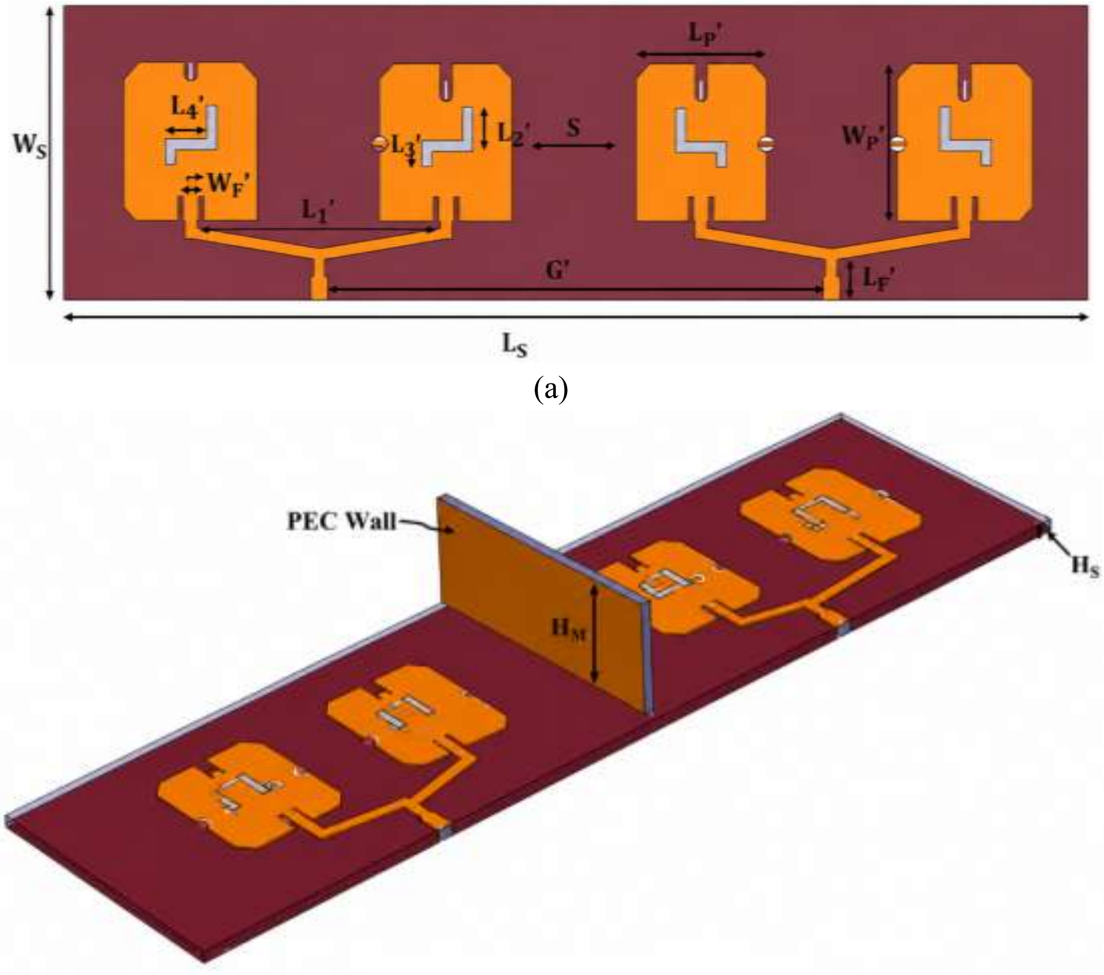


Figure 6: Bandwidth variations of microstrip antenna

III. ANTENNA DESIGN

In an aperture coupling feed (ACF) microstrip patch antenna, separate dielectric substrate is used for the feed network and the patch antenna. Since all layers adhere to conformal printed circuit technology, fabrication is thus made simple. However, alignment between layers and correct selection of aperture size and position will be critical in controlling the antenna impedance. The natural existence of small gaps between the layers of dielectric substrate can significantly change the input impedance values.



(a)

(b)

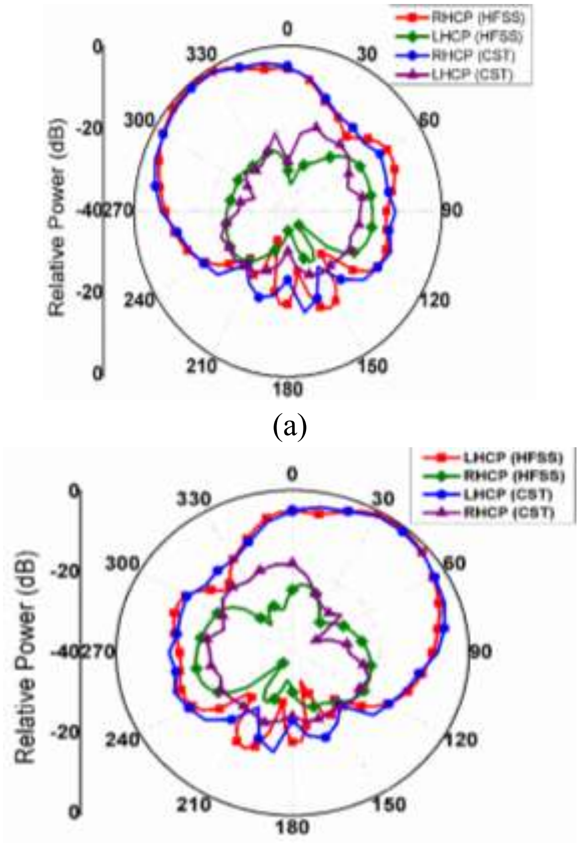
Figure 7: Two Port Microstrip Array Antenna (a) Top View (b) 3D View

The proposed modified MIMO antenna design is developed by introducing several structural changes to improve impedance matching, isolation, bandwidth, and radiation performance while maintaining a compact geometry. The rectangular radiating patches are modified by incorporating chamfered (truncated) corners and small U-shaped notches at the upper edges. These modifications increase the effective current path, resulting in better resonance characteristics and wider operating bandwidth. Additionally, small circular slots are introduced on the side edges of the inner and outer antenna elements, which help suppress unwanted surface currents and reduce mutual coupling between adjacent antenna elements, thereby enhancing port isolation.

The feeding network is also redesigned by replacing the conventional straight microstrip feed with a tapered (V-shaped) corporate feed structure. This tapered feed provides a smoother transition of electromagnetic energy from the feed line to the radiating patches, leading to improved impedance matching and lower reflection coefficient (|S11|). The feed dimensions are optimized and represented by the modified parameters L1′, LF′, WF′, LP′, WP′, L2′, L3′, and L4′. Furthermore, the spacing between adjacent antenna elements, denoted by S, and the optimized inter-element gap G′ are carefully selected to minimize electromagnetic coupling while preserving compactness. As a result of these structural enhancements, the proposed antenna is expected to achieve higher gain (greater than 9 dBi), wider bandwidth, improved isolation (better than −25 dB), lower return loss, and enhanced radiation efficiency, making it suitable for high-performance 5G, B5G, and future 6G wireless communication applications.

IV. RESULTS AND DISCUSSION

Figure 8 presents the LHCP and RHCP radiation design got from port-1 and port-2 at 10.4 GHz in XZ plane. It is evident from Figure. 8 that the proposed recieving wire upholds the RHCP waves with port-1 and LHCP waves with port-2 at 10.4 GHz. Ports 1 and 2 also tilt the pattern by 300 percent, respectively. Figure 9 displays the gain variables. on was derived from CST and HFSS. It is evident from Figure. 9 that the operating band gain is approximately 12.0 dBi.



(a)

(b)

Figure 8: LHCP and RHCP pattern at 10.4 GHz in XZ plane (a) Port-1 (b) Port-2

The proposed antenna's envelop correlation coefficient (ECC) and diversity gain (DG) variations are depicted in Figure 10. ECC tells about the correlation between the antenna port, while DG communicates the mutli port antenna gain in blurring climate. For proficient MIMO, the worth of ECC ought to be under 0.2 while the DG is around 10.0 dBi. It is evident from Figure 10 that the proposed antenna's ECC and DG values are within the standard range.

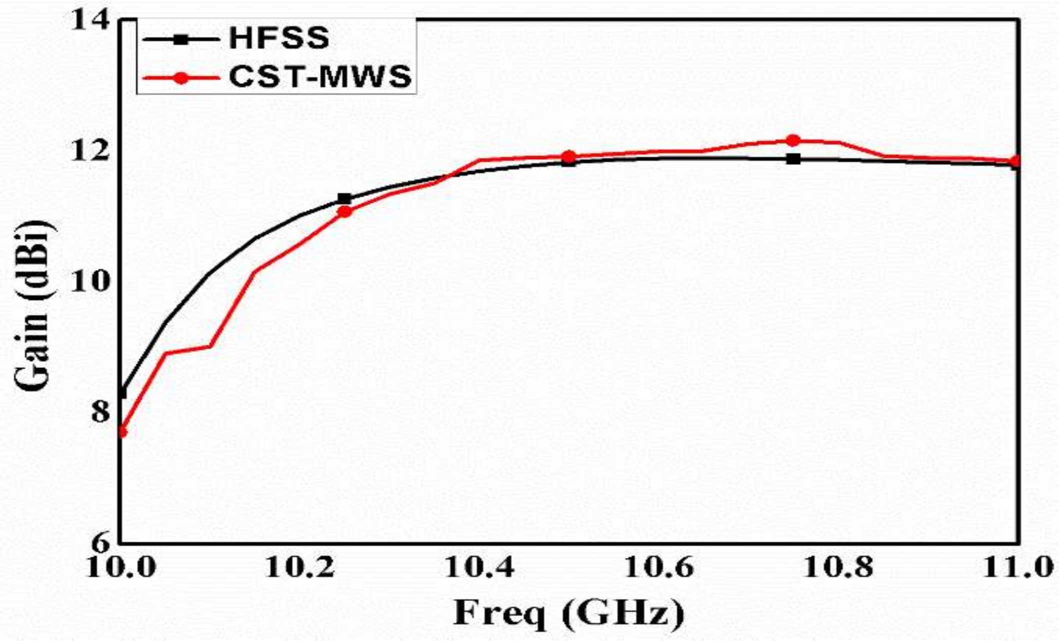


Figure 9: Gain Variation obtained from HFSS and CST-MWS

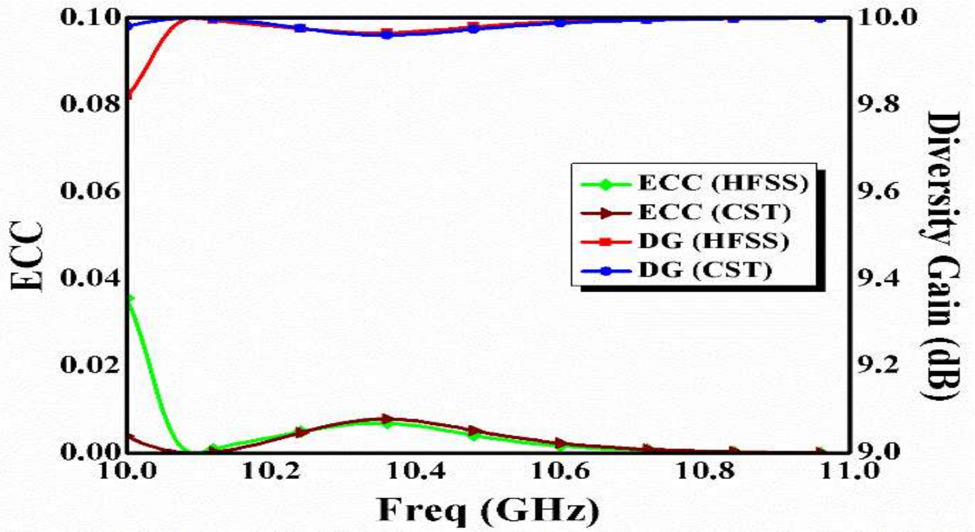


Figure 10: ECC and DG Variation obtained from HFSS and CST-MWS

V. CONCLUSION

This paper presented the design of a two-port microstrip patch array antenna for Ultra-Wideband (UWB) applications, focusing on achieving wide impedance bandwidth, enhanced gain, high port isolation, and stable radiation performance. The proposed array configuration effectively improves the limitations of conventional single-element microstrip antennas by increasing radiation efficiency and directivity while maintaining a compact, low-profile, and lightweight structure. The optimized feeding network and antenna geometry contribute to good impedance matching, low return loss, acceptable VSWR, and reduced mutual coupling between the two ports, ensuring reliable dual-port operation.

The performance analysis demonstrates that the proposed antenna satisfies the essential requirements of UWB communication systems, including broad bandwidth, improved gain, stable radiation patterns, and efficient signal transmission. These characteristics make the antenna suitable for a wide range of applications such as high-speed wireless communications, radar imaging, medical imaging, Internet of Things (IoT), wireless sensor networks, and short-range positioning systems.

Overall, the proposed two-port microstrip patch array antenna provides an effective solution for modern UWB wireless systems by combining compact size, high performance, and ease of fabrication. Future work may focus on further enhancing isolation using defected ground structures (DGS), electromagnetic band-gap (EBG) structures, or metasurfaces, as well as integrating artificial intelligence and machine learning techniques for antenna parameter optimization. The use of flexible substrates and reconfigurable designs can also be explored to meet the evolving requirements of next-generation 5G, Beyond 5G (B5G), and 6G wireless communication systems.

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