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Printed Dipole Antennas and Array Configurations for Advanced Wireless Communication Systems

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Abstract

"This study introduces a single micro strip antenna element with an extended bandwidth and its customized arrays for wireless applications. Addressing the need for a broader frequency range, the antenna incorporates an integrated balun for optimal feeding. The standalone antenna element operates effectively within the 34GHz to 46GHz frequency spectrum, boasting a reflection loss of less than -10dB and achieving a gain of 2.1 dBi. Furthermore, an 8-element linear antenna array has been carefully designed to minimize mutual coupling among the elements. This issue is effectively mitigated through the use of a rectangular stub. By adopting the array approach, two significant benefits are realized: not only does the antenna's overall gain experience enhancement, but the scanning angle also widens significantly. The approach presented here showcases the innovation of utilizing both individual antenna elements and arrays to meet the demands of wireless applications. The results expand the bandwidth and scanning capabilities of the proposed antenna system, highlighting its potential significance in modern wireless communication scenarios."."

Introduction

In the contemporary wireless communication landscape, the utilization of millimeter wave bands has become ubiquitous due to their expansive bandwidth, efficient operation, cost-effectiveness, and broad spectrum. Over the past few decades, planar printed antennas have emerged as pivotal tools for directional beam control through phase manipulation of each individual element. Among the repertoire of planar printed antennas, several hold significant influence, including the Yagi-Uda antenna, Printed Dipole antenna, and Angled Dipole antenna [1]. The Yagi-Uda antenna finds application in X-band phased arrays, the Printed Dipole antenna is a micro strip feed line for Ka-band phased arrays, and the Angled Dipole antenna is employed in active phased array setups. Notably, the Printed T Dipole antenna, a subtype of the planar printed dipole, garners prominence within wireless networks. This antenna is often fed through an integrated balun [2], an electrical device that transforms balanced and unbalanced signals. While it operates effectively across microwave frequencies with broad bandwidth, its main drawback lies in its relatively larger size [3]. A Dipole antenna, crucial in generating radiation patterns, is extensively employed in radio and telecommunications applications. This antenna consists of two identical conductive elements, separated by a feeding mechanism as depicted in Fig. 1. The interaction between voltage and current leads to electromagnetic wave generation, subsequently resulting in radiation [4]. The dipole antenna's impedance is chiefly determined by the length of its radiating element. In this paper, we delve into the application of printed dipole antennas within wireless communications [5]. To enable operation across a broad spectrum, the dipole antenna is fed through an integrated balun. A beam-forming angle of 45 degrees is chosen to compact the antenna's size. The primary objective is to mitigate mutual coupling between antenna elements, a task facilitated through the insertion of a stub between them to nullify unwanted signals. The comprehensive design and analysis of the antenna system are undertaken using the High-Frequency Structure Simulator (HFSS), an electromagnetic design and simulation tool. In summation, this paper sheds light on the utilization of planar printed antennas for beam control in millimeter wave bands, underscoring their vital role in contemporary wireless communication systems.

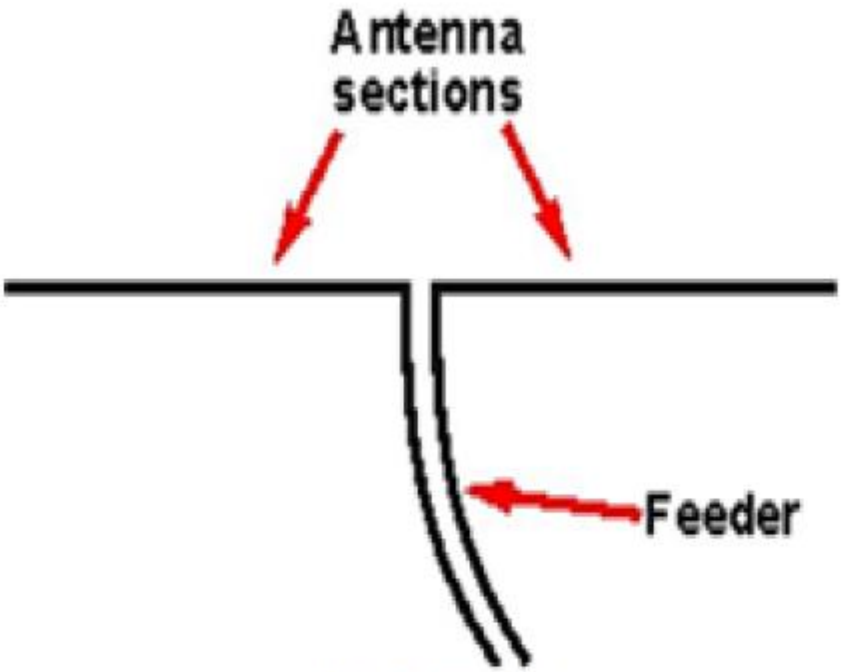

Fig. 1: Dipole Antenna.

Single element antenna design

"In this paper, we undertake the design of a single-element antenna with specific measurement requirements. Figure 2 portrays the geometry of the printed dipole antenna, which was conceived on both sides of a Rogers RT/Duroid 5880 substrate possessing a permittivity of 2.2 and a thickness of 0.254mm. The antenna features a 50-Ω micro strip line feed along with an integrated balun. In this

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design, the top layer constitutes the substrate, while the bottom layer encompasses both the micro strip and ground plane. The dipole antenna is fed using a slotted line characterized by a characteristic impedance ranging from 116Ω to 130Ω. Given the antenna's operation across a wide range of frequencies, there is a potential for impedance mismatch. To counteract this issue, a balun is employed. The balun functions as a bridge between the micro strip and the feed line, visualized as 'Dr' and appearing in a rectangular shape. Achieving optimal impedance matching involves the meticulous adjustment of the rectangular slot and the feed line where the balun is connected. The antenna's configuration is realized using Ansys HFSS, ensuring precise impedance matching and a gain within the range of 26GHz to 38GHz. The following parameters define the antenna's design: Wgnd = 10, D1 = 0.84, D2 = 0.7, D3 = 0.5, Dr = 0.6, Lr = 0.8, Dcps = 0.4, Wd = 0.6, Ld = 1.6, l1 = 1.4, l2 = 1.8, l3 = 2, l4 = 0.4, n = 0.2, gap = 0.3, and Sd = 0.4. The undertaken modifications and design considerations lead to an antenna that operates cohesively within the specified frequency range while ensuring impedance matching and optimal performance."

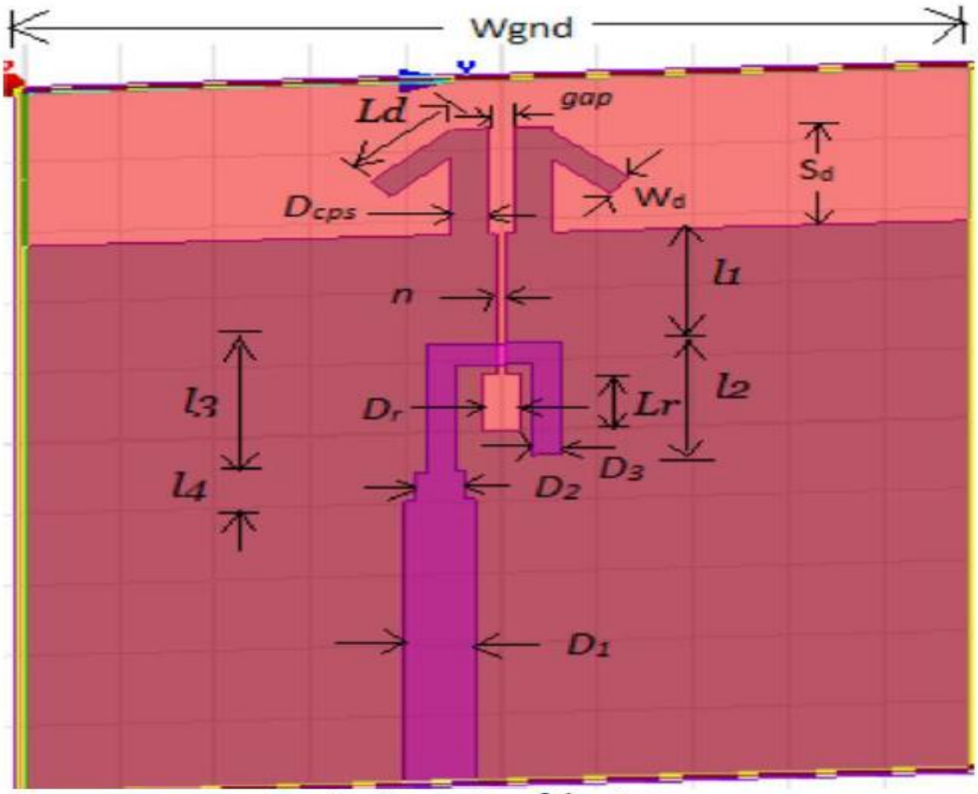

Fig. 2: Geometry of the Antenna.

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2.1. Return loss

For any antenna, S11 parameters (Return Loss) are to be taken into consideration and for the proposed antenna the return loss obtained at operating frequency i.e38GHz is 15 dB and the fig.3 represents the Return loss of the antenna.

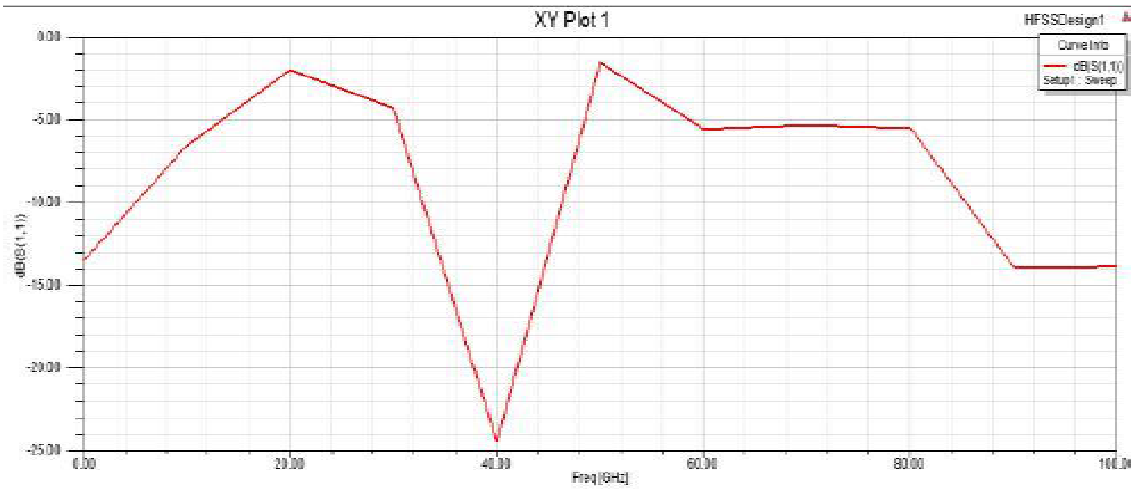

Fig. 3: Frequency vs. |S11| Plot.

Radiation pattern

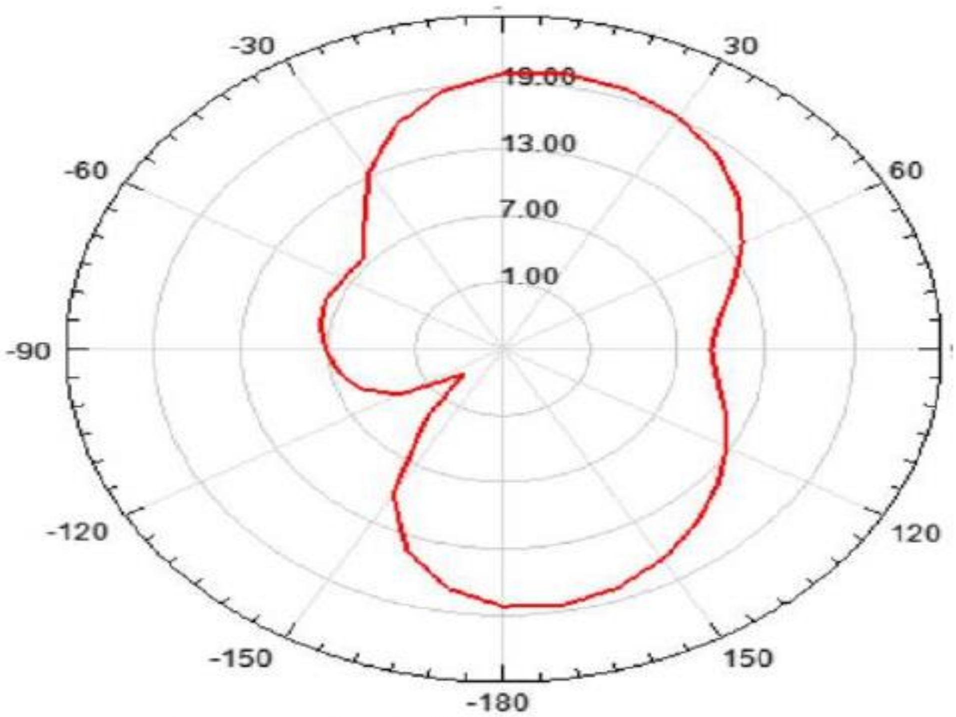

Fig. 4: Radiation Pattern of the Antenna.

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2.3. Gain of the antenna

Fig.5 represents the 3D plot of gain and for the designed antenna the obtained gain is 2.1 db.

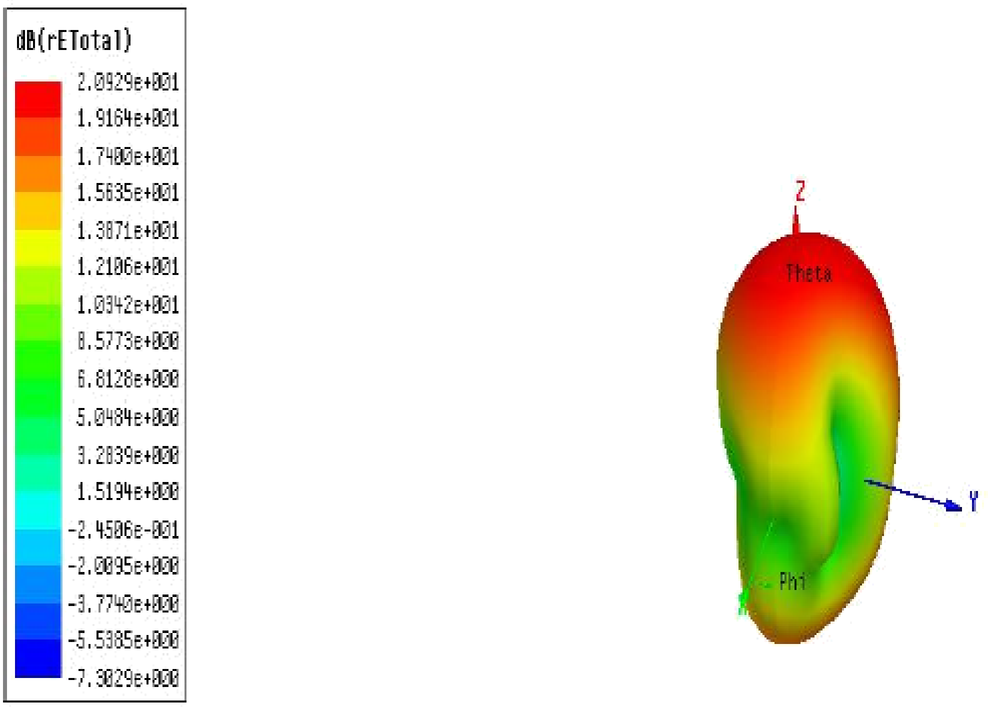

Fig. 5: Gain of the Antenna.

Characteristics of antenna arrays

The congregation of single element radiators in geometrical con-figuration under some conditions are known as antenna arrays. Among the different antennas such as linear, planar and circular we do use planar array antenna as it provides larger aperture so that by changing each element of antenna in an array the direc-tional beam can be controlled. Some major aspects that are to be taken into consideration while designing antenna arrays are that i) Geometrical specifications ii) Mini-mum spacing between the elements and iii) Excitation phase.

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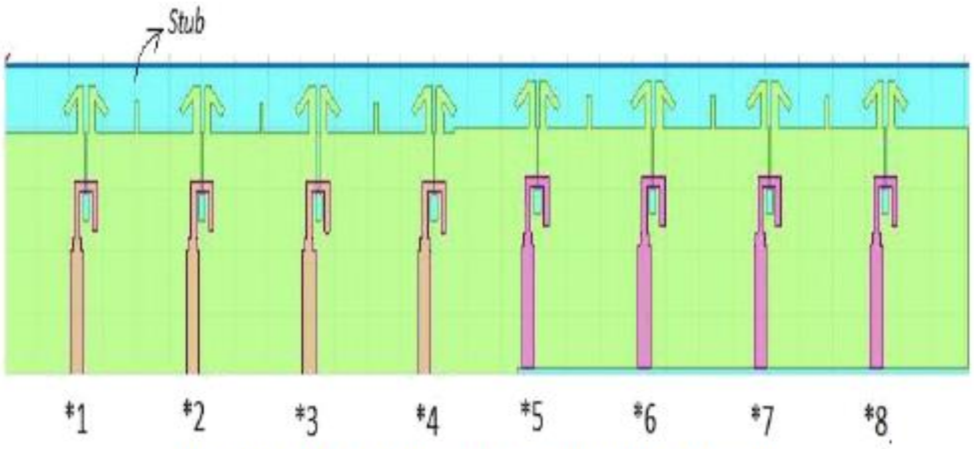

Fig. 6: Eight Element Linear Array Antenna.

Excitation phase

Excitation phase depends upon the design of the array antenna. Spacing between the elements play a major role in determining the excitation phase.

Fig.7 represents the overall gain for the eight element linear Antenna and it has a gain of 7.2dBi. Therefore, the overall gain and efficiency of the antenna increases by implementing array technique.

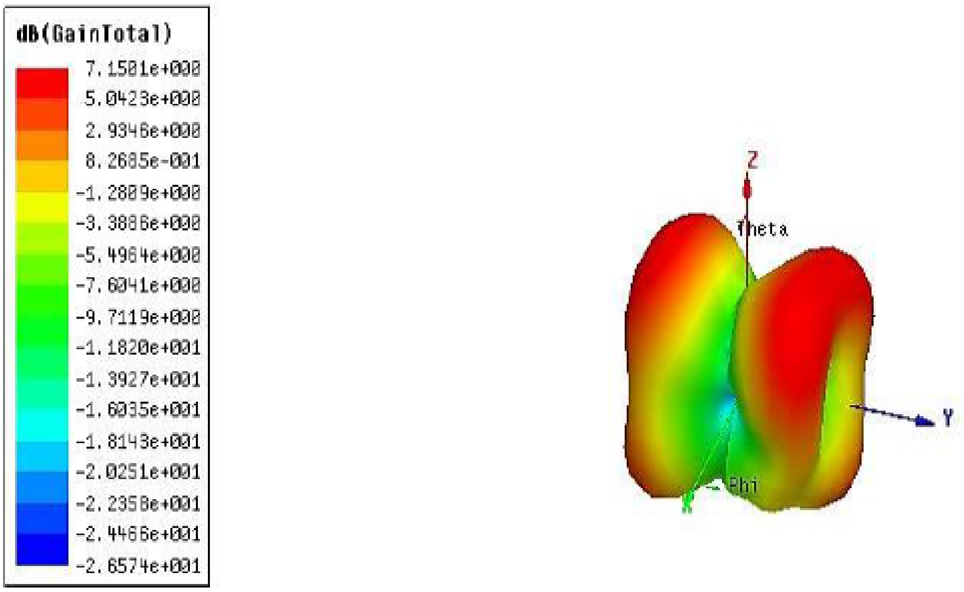

Fig. 7: Gain of the eight Element Linear Array Antenna.

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conclusion

"The introduced dipole antenna design not only boasts an expanded bandwidth but also exhibits a wide radiation pattern, showcasing its remarkable efficiency in radiating signals. In the pursuit of enhanced efficiency and increased gain, a cluster of antenna array elements has been carefully engineered. To mitigate the effects of mutual coupling, a center-to-center spacing distance of 4.8mm is utilized, further complemented by the integration of a micro strip stub to suppress mutual coupling. The incorporation of the array technique results in a comprehensive enhancement of the antenna's overall performance. Through these combined advancements and inherent benefits, the proposed antenna assumes a pivotal role within wireless communication systems and millimeter-wave applications. Its ability to provide broader coverage, improved gain, and efficient radiation establishes its significance in the realm of modern wireless communications."

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