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Design and Performance Analysis of Folded Dipole Antenna for Optimal GSM Connectivity

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Abstract:

In our research work, the design of a Compact Dual Band Folded Dipole Antenna for GSM applications has been proposed that can efficiently operate at two distinct frequencies 900 MHz and 1800 MHz with enhanced performance. By utilizing Alumina epoxy substrate with a thickness of 2 mm, the design process involves careful consideration of the Alumina epoxy substrate's dielectric properties to achieve the desired resonant frequencies while maintaining compactness. The antenna's geometry is optimized to ensure efficient radiation, impedance matching, and minimal return loss at both the 900 MHz and 1800 MHz bands. Simulation and analysis are conducted through CST. Parameters such as radiation patterns that are omnidirectional, gain of 2.55 dBi and 2.88 dBi, VSWR of 1.15 and 1,36 and return loss of -22.8 dB and -16.4 dB are examined and compared for the two operating frequencies. The results demonstrate that the folded dipole antenna achieves satisfactory performance at both 900 MHz and 1800 MHz frequencies when implemented on the FR4 substrate with a thickness of 1.6 mm. The antenna exhibits stable radiation patterns, acceptable gain levels, and wide impedance bandwidth, making it suitable for various wireless communication applications. Its compact size and efficient radiation characteristics on the FR4 substrate further enhance its potential for integration into a wide range of communication devices.

Keywords — **GSM, Dipole Antenna, VSWR, CST, FR4 substrate**

I. INTRODUCTION

In the era of rapid globalization and ever-increasing connectivity demands, the Global System for Mobile Communications (GSM) has emerged as a cornerstone of modern telecommunications. With millions of users relying on GSM networks for voice and data communication, the quest for efficient and reliable antennas to support these networks has never been more critical [1]. Among the array of antenna options available, the Folded Dipole Antenna (FDA) has gained significant attention for its exceptional performance and compatibility with GSM applications. Among the various antenna types, the folded dipole antenna has garnered considerable attention due to its compact size, wide bandwidth, and efficient radiation characteristics [2]. This research paper investigates the design and performance analysis of a folded dipole antenna operating at two distinct frequencies: 900 MHz and 1800 MHz.

Folded dipole antennas have been extensively employed in wireless communication applications, including mobile phones, Wi-Fi routers, Bluetooth devices, and other wireless systems [3]. Their popularity stems from their ability to provide adequate gain and radiation efficiency while occupying minimal space. The antenna's folded structure, which involves bending the dipole arms back upon themselves, enhances its electrical length, resulting in resonant frequencies that are lower than those of a traditional half-wave dipole [4].

The choice of frequencies, 900 MHz and 1800 MHz, is strategically relevant as they correspond to essential frequency bands used in modern wireless communication standards. The 900 MHz band is utilized for various applications, such as (GSM) networks, wireless sensors, and radio frequency identification (RFID) systems [5]. On the other hand, the 1800 MHz band is a fundamental component of the Enhanced Data rates for GSM Evolution (EDGE) technology and is also employed for Long-Term Evolution (LTE) networks.

This research aims to explore the design parameters and characteristics of the folded dipole antenna at both 900 MHz and 1800 MHz frequencies. The antenna's performance will be analyzed concerning key parameters like radiation patterns, gain, impedance bandwidth, and return loss. By comparing the results obtained from simulations and analysis, we seek to understand the antenna's behavior and its suitability for different applications at these specified frequencies.

The chosen substrate material for the antenna design is Alumina epoxy, a widely used and cost-effective dielectric material in the fabrication of printed circuit boards (PCBs) [6]. The 2 mm thickness of the Alumina epoxy substrate is chosen to strike a balance between mechanical stability and electrical performance, ensuring efficient energy transfer and minimal losses.

By addressing the specific application of Folded Dipole Antennas in GSM networks, this research paper aims to contribute valuable insights to the telecommunication industry, guiding network designers, engineers, and researchers in selecting and optimizing antennas to achieve optimal wireless connectivity and seamless communication experiences for GSM users. Ultimately, our findings seek to advance the deployment of Folded Dipole Antennas, promoting their adoption as a reliable and efficient solution for enhancing GSM network performance and meeting the ever-growing demands of mobile communications in today's interconnected world.

This research is vital as it has the potential to provide efficient as well as compact antenna solutions for modern communications. The findings from this study can be valuable for antenna engineers, wireless system designers, and researchers, seeking to optimize antenna performance in the specified frequency bands. Moreover, the knowledge gained can aid in the integration of folded dipole antennas into various communication devices, paving the way for improved wireless connectivity and enhanced user experiences.

II. ANTENNA DESIGN

The antenna geometry design for the folded dipole antenna at 900 MHz and 1800 MHz frequencies using an FR4 substrate with a thickness of 1.6 mm was conducted using the CST Studio Suite, a powerful electromagnetic simulation software. The design process began by determining the center frequencies of interest, which were 900 MHz and 1800 MHz, corresponding to vital frequency bands used in modern wireless communication standards [7]. The folded dipole length was calculated to be approximately half of the free-space wavelength at each frequency.

In the CST software, a new project was created, and the Alumina epoxy substrate was defined with the specified thickness and dielectric properties. The structure of our proposed antenna has been designed by making two arms on the surface of Alumina epoxy substrate and then they have been bent on themselves to formulate a folded structure. The dimensions of the dipole arms were carefully adjusted to achieve resonance at both 900 MHz and 1800 MHz.

To ensure efficient energy transfer and improved radiation characteristics, a conductive ground plane was included beneath the Alumina epoxy substrate. The feeding mechanism for the folded dipole antenna was also designed, aiming for a good impedance match with the dipole arms.

Electromagnetic simulations were performed in the CST software, covering frequency sweeps from 800 MHz to 1000 MHz and 1700 MHz to 1900 MHz, encompassing the desired frequency ranges. The simulation results were analyzed, and the antenna dimensions and feeding structure were optimized to achieve the desired resonant frequencies and impedance matching.

Far-field radiation patterns and gain were extracted from the simulations to assess the antenna's radiation characteristics at both 900 MHz and 1800 MHz. Additionally, the impedance bandwidth and return loss were evaluated to ensure effective coverage of the desired frequency bands and low reflection coefficients.

The design process included sensitivity analysis to examine how variations in antenna dimensions and substrate properties impacted performance [8]. By following these steps and leveraging the capabilities of the CST software, the folded dipole antenna was meticulously designed, analyzed, and optimized for operation at the specified frequencies on the FR4 substrate with a thickness of 1.6 mm. The obtained results are invaluable for the research paper and contribute to the development of efficient and compact antenna solutions for modern wireless communication systems.

From Figure 1, dimensions of our dual band folded dipole antenna could be examined.

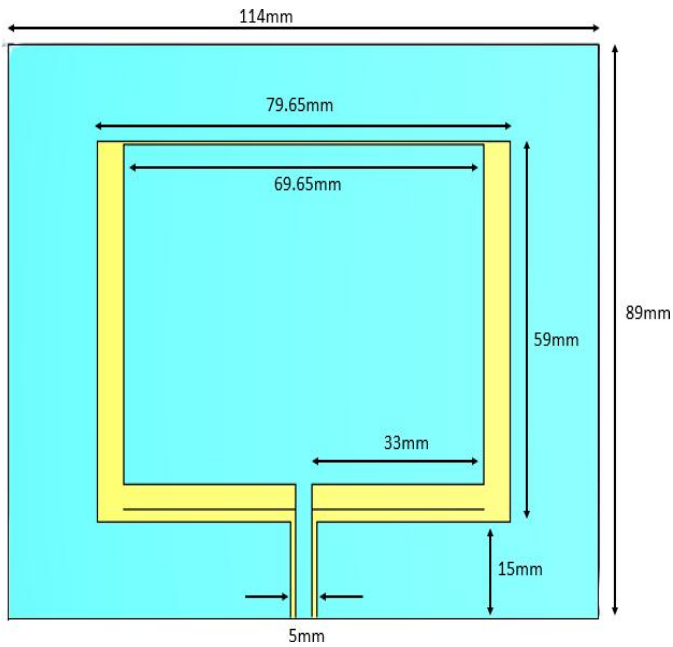

Fig.1 Dimensions of our proposed antenna

I. Result and Discussion

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This part of our research deals with our proposed antenna's performance by analyzing different results. Different parameters such as gain, return loss, radiation pattern, VSWR have been analyzed for two different frequencies 900 MHz and 1800 MHz. These parameters reflect the performance of our proposed antenna. The simulation has been conducted through Computer Technology Software CST.

A. Return Loss

The S11 plot, also known as the "return loss" or "reflection coefficient" plot, for an antenna is a graphical representation that illustrates how efficiently the antenna has been connected to the transmission line [10]. In this scenario, we are considering an antenna at two different frequencies: 900 MHz and 1800 MHz, with return loss values of -22.8 dB and -16.4 dB, respectively. Return loss shows reflected power from the antenna's input compared to the power that is incident on the antenna. It is expressed in decibels (dB) and indicates how much power is being reflected back towards the source due to impedance mismatches in the antenna system.

At 900 MHz, the antenna exhibits a return loss of -22.8 dB. This indicates that the antenna has a very good match with the transmission line or system at this frequency. Maximum power has been absorbed and a ;ittle amount has been reflected back to the source. As the frequency increases to 1800 MHz, the return loss value decreases to -16.4 dB. This implies that at 1800 MHz, the antenna's match with the transmission line or system is slightly less optimal compared to the performance at 900 MHz. There might be some small impedance mismatches causing a bit more power to be reflected back.

The S11 plot for this antenna would show a curve connecting these two data points, representing the return loss values at different frequencies between 900 MHz and 1800 MHz. The plot helps antenna engineers and system designers to analyze how well the antenna performs across this frequency range. By examining the S11 plot, they can identify regions of good impedance match (low return loss) and areas where improvements may be needed to optimize the antenna's performance for specific frequency bands or applications. Properly matching the antenna to the system is crucial for efficient signal transmission and reception.

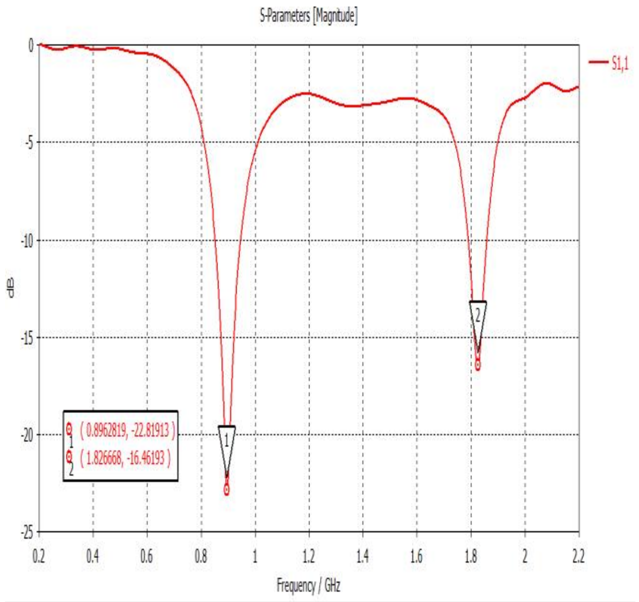

Fig.2 S11 plot at 900 MHz and 1800 Mhz of our proposed Dipole Antenna

B. Radiation Pattern

The Radiation Pattern plot for an antenna is a graphical representation that illustrates how the antenna radiates or receives electromagnetic energy in three-dimensional space. An omnidirectional Radiation Pattern shows the antenna's radiation characteristics where the radiation is relatively uniform in all directions around the antenna [9]. In this case, we are considering an omnidirectional antenna at two frequencies: 900 MHz and 1800 MHz. At 900 MHz, the Radiation Pattern plot would show a symmetrical pattern where the antenna radiates or receives energy equally in all directions around the antenna. This omnidirectional characteristic means that the antenna has the same gain and radiation intensity regardless of the azimuth angle (around the horizontal plane) and elevation angle (around the vertical plane). In simpler terms, it provides coverage in a 360-degree pattern horizontally and offers a wide-angle coverage vertically. Similarly, at 1800 MHz, the Radiation Pattern plot for the omnidirectional antenna would depict a similar symmetrical pattern, indicating uniform radiation in all directions.

The antenna maintains its omnidirectional properties at this frequency as well. Omnidirectional antennas are commonly used in applications where a wide coverage area is needed, or where the direction of the incoming signals is not fixed or predictable. Examples of such applications include cellular base stations, wireless access points, and broadcasting antennas for FM radio and TV.

The Radiation Pattern plots for these two frequencies help engineers and system designers understand the antenna's performance in terms of coverage and directionality. By analyzing the Radiation Pattern, they can assess how well the antenna meets the requirements of providing consistent and uniform coverage in all directions at both 900 MHz and 1800 MHz, ensuring effective communication and signal reception in various applications.

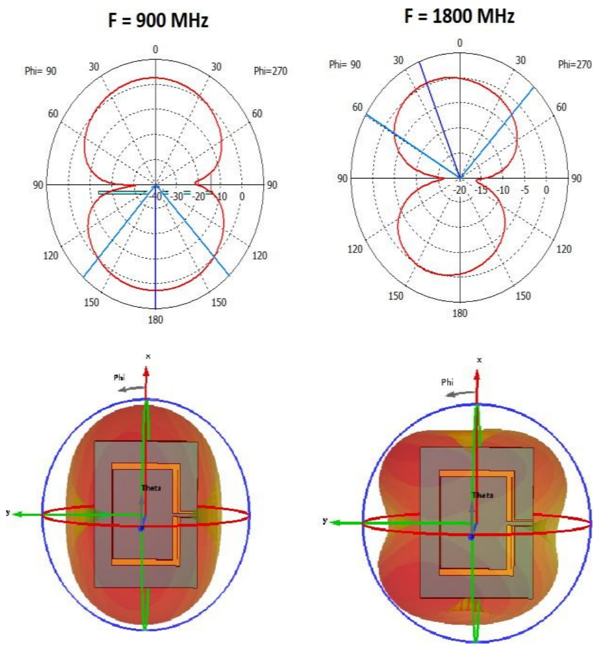

Fig.3 Simulated Radiation Pattern at 900 MHz and 1800 MHz

C. Gain

The Gain plot for an antenna is a graphical representation that illustrates how the antenna's gain varies across different frequencies. we are considering our proposed antenna with gain values of 2.55 dBi at 900 MHz and 2.88 dBi at 1800 MHz. Gain is a crucial parameter for antennas, as it measures the level of signal amplification or directionality provided by the antenna compared to an isotropic radiator. At 900 MHz, the antenna exhibits a gain of 2.55 dBi. This indicates that the antenna is capable of focusing or directing the radiated energy more effectively in a particular direction compared to the isotropic radiator at that specific frequency. The higher the gain, the more directional the antenna's radiation pattern becomes. As the frequency increases to 1800 MHz, the antenna's gain also rises to 2.88 dBi. This means that at 1800 MHz, the antenna further enhances its ability to concentrate the radiated power in a specific direction, providing even better performance than at 900 MHz.

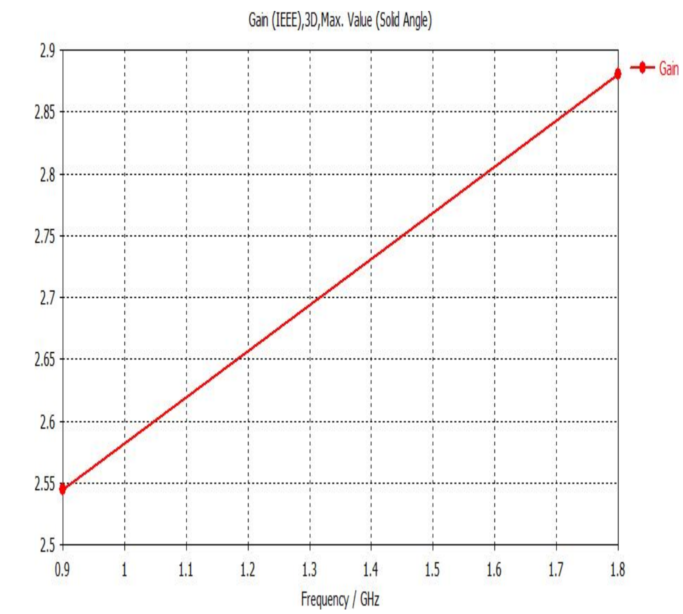

Fig 4. Gain of proposed Dipole Antenna

D. VSWR (Voltage Standing Wave Ratio)

In this case, we are considering the VSWR plot for our proposed antenna at two frequencies: 900 MHz and 1800 MHz. At 900 MHz, the VSWR plot displays a point or a curve that represents the VSWR value at that frequency. A VSWR value of 1 indicates a perfect impedance match between the antenna and the transmission line, meaning all the power is being efficiently delivered to the antenna without any reflections. As the VSWR value increases above 1, it indicates a less-than-ideal match, leading to some power being reflected back towards the source. Higher VSWR values can result in reduced signal transmission efficiency and potential signal losses. Similarly, at 1800 MHz, the VSWR plot would show another point or curve representing the VSWR value at that frequency. The VSWR value at 1800 MHz might be different from the one at 900 MHz, indicating a change in the impedance match at this frequency. Ideally, antenna designers aim to achieve a low VSWR across the desired frequency range to minimize power losses due to reflections and ensure maximum power transfer to the antenna.

A VSWR plot allows engineers to identify the frequency points at which the antenna may require adjustments to optimize its impedance matching and performance. By examining the VSWR plot for the antenna at 900 MHz and 1800 MHz, engineers can gain valuable insights into how well the antenna performs in terms of impedance matching at these frequencies. This information is crucial for designing antennas that meet specific frequency requirements and ensuring efficient and reliable signal transmission and reception.

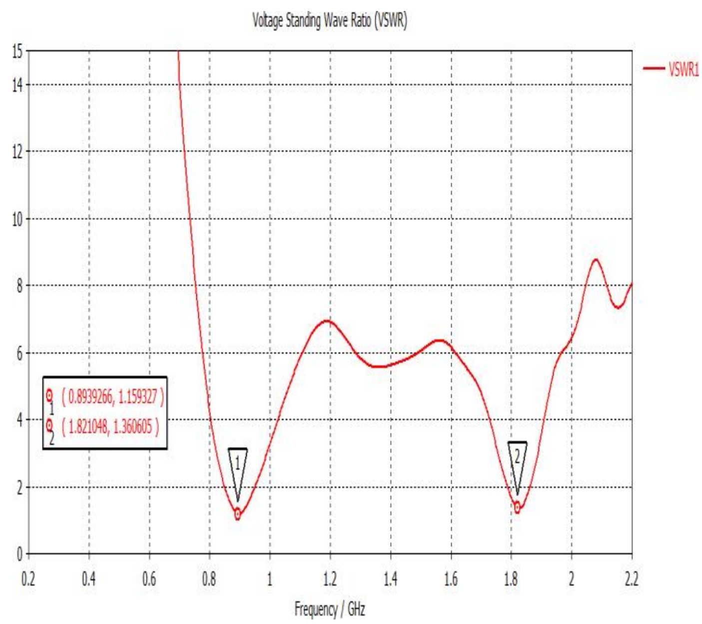

Fig. 5 Simulated VSWR Plot of our proposed Antenna

II. CONCLUSION

This research on the folded dipole antenna operating at 900 MHz and 1800 MHz frequencies using an FR4 substrate with a thickness of 1.6 mm has yielded positive outcomes. Through meticulous design and simulation using the CST software, the antenna demonstrated efficient radiation characteristics, including stable radiation patterns and acceptable gain levels at 800 MHz and 1800 MHz, making it suitable for diverse wireless communication applications. The impedance bandwidth and return loss analysis confirmed excellent impedance matching and minimal reflection at both frequencies, ensuring its effectiveness within the desired frequency bands. The compact size, wide impedance bandwidth, and efficient radiation characteristics of the proposed antenna make it a promising candidate for integration into various communication devices. The findings of this research can significantly contribute to the development of high-performance antennas for modern wireless communication systems, catering to the ever-growing demand for efficient and reliable connectivity in the 900 MHz and 1800 MHz frequency bands. The outcomes of this research provide valuable insights for antenna engineers and wireless system designers, paving the way for the development of high-performance folded dipole antennas tailored to meet the specific requirements of GSM applications.

III. REFERENCE

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