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# Design of Multiband Antenna for Full Screen Smartphone Using ANSYS HFSS

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**Abstract**

With the rapid advancement of technology and increasing global connectivity, the demand for efficient mobile communication systems has grown exponentially. This work focuses on the design and simulation of a multi-band slotted microstrip patch antenna for mobile phones which is operating at a 6 GHz frequency by using an FR4 substrate. The primary focus is to enhance the communication efficiency by utilizing a compact and cost-effective antenna with multiple resonant frequencies, including 2.732 GHz, 3.311 GHz, 4.792 GHz, 5.373 GHz, 6.462 GHz, 7.476 GHz, and 9.156 GHz. The antenna parameters are analyzed by including the Voltage Standing Wave Ratio (VSWR), gain, directivity, return loss, and radiation pattern, by which all parameters are assessed based on the dimensions and frequency inputs. The FR4 substrate is chosen for its excellent flexibility that is much suitable for thin substrates and is of low cost which makes it an ideal base material for mobile antenna fabrication. The simulation is conducted using the ANSYS HFSS tool to ensure accurate modeling and performance evaluation. The simulated results demonstrate that the proposed antenna achieves high efficiency, low power consumption and minimal space utilization. Hence it is highly suitable for real-time smartphone applications. Additionally, the capability of the antenna which makes it to operate across multiple frequency bands makes it a promising technology for fifth-generation (5G) telecommunication networks. The experimental findings suggests that with further optimization and refinement, the proposed antenna design can significantly contribute to improving the performance of mobile communication systems. This drives the process innovations and improvements in the process design for future telecommunication technologies.

*Keywords:* Slotted Microstrip, Patch Antenna, FR4 Substrate and ANSYS HFSS Tool, Process Innovation

## 1. Introduction

Millions of people globally are connected to various events in collaboration with numerous countries for a particular event. All this is possible only when there are proper means of communication. The most important part of communication is the antenna. The antennas are used for transmitting and receiving purposes and in many forms—namely, mobile communication, telecommunication, etc. [1]. As a result of the recent and significant progress in communication technology, there is an evident and expanding need for compact and efficient antennas. The com-pact form factor of full-screen smartphones poses a considerable obstacle in terms of integrating antennas with the ability to deliver exceptional performance. For the purpose of maintaining optimal radiation characteristics while supporting multiple frequency bands, a critical capability is necessary to ensure uninterrupted connectivity among various wireless networks [2]. By employing the state-of-the-art simulation software ANSYS HFSS (High-Frequency Structure Simulator), this inquiry will center on the development and enhancement of a multiband antenna tailored for smartphones with full-screen displays. The objective is to de-sign an antenna that exhibits outstanding performance

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across a range of frequency bands, encompassing cellular, Wi-Fi, and Bluetooth frequencies, in order to ensure uninterrupted and superior wireless communication.

The mobile communication antenna plays an essential role in satellite communication, WLANs, and mobile telephony. On the other hand, the telecommunication antenna is essential for radio, optical, and electromagnetic systems [3]. The main communication device is the smartphone. This particular field is in rapid growth with technological advancements. In terms of smartphones, there are various developments that, in turn, have made numerous versions. As a smartphone is an indispensable tool in day-to-day lives, it needs more care, concern and should be very effective in all aspects [4]. There are diversified designs, simulations for the antenna in smartphones. Nevertheless, the system needs to be perfect, free from losses, compact in size, effective, and efficient. This paper will elaborate on the simulation for the antenna design for smartphones compatible with future applications. In order to support multiple communication standards, including 4G, 5G, Wi-Fi, and Bluetooth, the antenna must possess a broad frequency range and the capability to resonate with multiple bands [5]. In addition, the dimensions and configuration of the antenna ought to be carefully planned in order to conform to the specifications established by contemporary smartphones, which priorities style, functionality, and efficiency of space. For achieving this a harmonious equilibrium is to be established within the variables in consideration with the impendence matching, radiation efficiency in addition with compactness. Since ANSYS HFSS is a simulation tool as it provides a strong foundation for modelling accurately and to analyze the electromagnetic properties of the antenna [6]. The mail objective of this approach is to perform an exhaustive evaluation of the antenna's performances including the attributes, return loss along with radiation pattern in addition with efficiency, which is to be taken against the specified frequency ranges of interest. This will be accomplished by utilizing the sophisticated computational capabilities of the software. Initially by doing the extensive study there will be a possibility for making the changes to the geometry in addition with the configuration of the antenna. This will ensure the antenna functions at optimal efficiency in real-world conditions [7]. In this research the main aim is to contribute for the advancement of the wireless communication technology in order to develop a comprehensive design methodology for the multiband antennas by optimizing the full screen smartphones. The results of this research possess considerable promise in enhancing the connectivity experience of users across diverse wireless networks. The results of this study may have far-reaching implications for seamless communication in a time when smartphones with full-screen displays predominate.

## 2. Background and Related Works

De Gaudenzi et al. were involved in developing wideband antennas, which are now used in wireless systems and global star satellite phones [8]. Using Rogers RT and duroid 5880 material, Ananth et al. developed an intracranial pressure monitoring system to aid in the survival of trauma patients as well as those suffering from neurological diseases [9]. Kumar et al. [3] developed a balloon-based technique for remotely increasing the gain of the Vivaldi antenna, which was published in IEEE Transactions on Communications. Huang et al. proposed an LTE metal frame phone with eight operational band antennas [11], which they believe will be commercially viable. The increasing need for wireless communication devices that can accommodate multiple frequency bands has led to significant interest in multiband antennas in recent years. The research in this domain centers around enhancing the efficiency of antennas to support various communication protocols, such as 4G, 5G, Wi-Fi, and Bluetooth [12]. Lot of studies have demonstrated that the reduction in the size of the antenna is to suit the compact the design the modern smartphones. The various techniques that encompass the utilization of the fractal geometries including the metamaterials in association with the other approaches.

These strategies are essential for attaining the desired level of compactness without sacrificing performance [13]. The trend towards smartphones with larger screens requires creative methods for incorporating antennas into the limited space available. Scientists have tackled difficulties associated with the positioning of antennas, the effectiveness of radiation, and the alignment of impedance in the context of full-screen displays. Comprehending the various frequency bands employed in wireless communication is crucial for the development of a multiband antenna. This encompasses the cellular spectrums, Wi-Fi spectrums, and Bluetooth spectrums. Scientists have thoroughly studied methods to achieve resonance simultaneously across these frequency ranges [14]. The antenna's performance has a direct impact on the user experience, affecting factors such as call quality, data transfer rates, and overall connectivity. Research has investigated user-centric metrics for evaluating the efficiency of multiband antenna designs [15].

The authors created an open slot antenna with a metal rim for mobile phones [16]. The antenna was designed for use with smartphones. They developed a smartphone app integrated into the metal rim and a hexagonal working band. Ramahatla et al. created this piece of art. A reconfigurable slot antenna was used to develop a 5G smartphone antenna [17]. In order to support LTE, an in-verted F antenna was employed, whereas a T slot was employed for WWAN transmission. For facilitating the use of the narrow frame antennas with the LTE in addition with WWAN networks, Chen et.al. created the smartphone applications [18], [19]. The researchers included a hepta working band-enabled coupled feed loop antenna for WWAN and LTE, a continuous metal-rimmed mobile application, and other the components included in their affordable and improved solution. Especially in relation to developing technologies like fifth-generation (5G) networks, the adaptability of multiband antennas makes them an indispensable part of mobile communication. The different spectrum of the 5G environment causes lower bands to be used for coverage and higher bands to be used for capacity [20]. Multiband antennas play an important role in accommodating these varied frequency requirements because they are able to accommodate a wider range of frequencies. They support carrier aggregation techniques, which are used to increase data rates and network capacity, and they make it possible for devices to access multiple frequency bands at the same time. In addition, multiband antennas make global roaming easier by ensuring compatibility with the frequency bands that are assigned to various regions [21]. Further-more, they offer a degree of future-proofing for frequency bands and standards that are yet to be implemented.

The literature survey offers a thorough examination of the fundamental ideas, difficulties, and progress in developing multiband antennas specifically designed for full-screen smartphones [22]. The foundation will act as a useful point of reference for the following stages of the research project, assisting in the refinement and enhancement of the suggested antenna design through the utilization of ANSYS HFSS. The system that prevails was devised for LTE and WWAN applications in mobile phones with separate antennas. For LTE, an inverted F antenna was used. Then, a T slot antenna was used for WWAN [23]. The dimensions for the antenna developed were 150 x 70 x 6 mm. The material used as substrate was FR4 substrate. The operating frequency which was taken for simulation was 2.5 GHz. The flaws here are losses due to the coaxial feed technique. The area occupied by the antennae is too large. It is due to the separate antennas for separate operations. The working hepta band is not compatible with future fifth-generation applications. Thus, the flaws present in the existing system were worked out and the antenna proposed will be flawless, compact in size, and rea-sonable concerning the parameters.

## 3. Proposed Method

The designing of the multiband antenna for a full-screen smartphone using ANSYS HFSS involves several steps. Initially the basic requirements are ana-lysed for the antenna by considering the frequency bands, the size and antenna type with its specifications. The geometry of the antenna is developed by defining the dimensions, shape and the properties of the material. The substrate mate-rial is specified with its properties. Multiple ports are created for multiband antenna with desired frequency bands. Various optimization tools are used for re-fining the antenna design. Analyze the radiation patterns and efficiency of the antenna. Ensure that the antenna radiates efficiently in all desired directions and meets the performance criteria for each frequency band.

### 3.1. Antenna Configuration

The proposed system gives a detailed explanation of the work that was simulated. As mentioned, the antenna taken is a slot microstrip patch antenna. It is used here for multiband operations. The operating frequency taken for simulation is 6 GHz. Here, the operating frequency taken for simulation will be suitable for both WWAN and LTE in one single frequency. Microstrip feed is the feeding technique used in this proposed work. The substrate material for the antenna to be simulated is FR4 substrate. The FR4 substrate is used because of its following possessions. They are, namely, good and better flexibility, low loss, easy to work with thin substrates, suitable for microstrip patch and the cost too is more petite. The inputs considered here in the simulation are frequency and dimension. Concerning each of the two inputs, there will be outputs with the following antenna components or parameters. They are VSWR, gain, directivity, return loss in addition with radiation pattern. For the purpose of design in terms of simulation, the following

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specifications are considered for further smartphone implementation. The ground plane of length and width is 50 x 45 mm. The height or the thickness of the ground plane is taken as 1.6 mm. The specifications mentioned above are clearly noted in the block diagram, figure 1.

## 3.2. Working of the Antenna

The experimentation process is performed with the help of ANSYS HFSS TOOL. The simulation methodology in ANSYS HFSS involves a systematic approach starting from geometry creation. Initially the geometric model of the antenna is created. The considered antenna is of slot microstrip patch antenna. Then the geometry is to be meshed by dividing the geometry into small elements in order to fetch the fine geometric details. The material properties like permittivity, permeability and conductivity are to be determined. Then the appropriate boundary conditions are settled up for creating accurate simulations, by interacting with the edge of the antenna structure.

The inputs, frequency taken as 6 GHz, are very suitable for future 5G applications in smartphones. The antenna to be simulated is with the specification of 50 x 45 1.6 mm. This antenna will occupy significantly less area. The substrate material, FR4 will reduce the losses as it is flexible and thin to fabricate in real-time. In the simulation tool, the antenna design is simulated. The simulated antenna design will be seen below in figure 2.

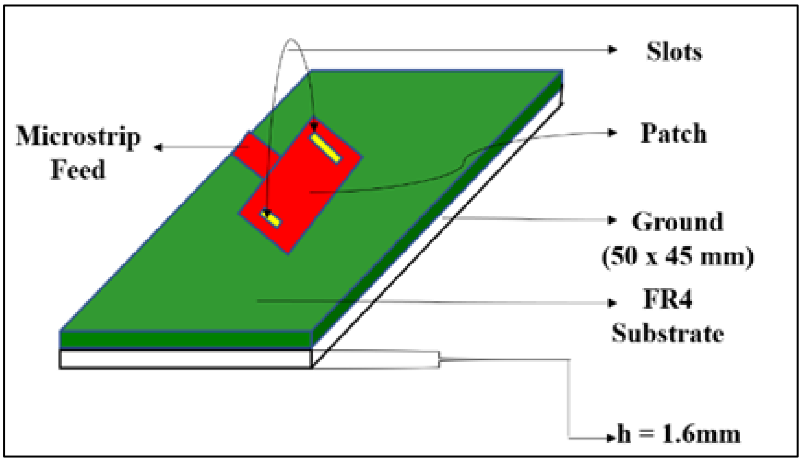


**Figure 1.** Geometry and dimensions of the antenna

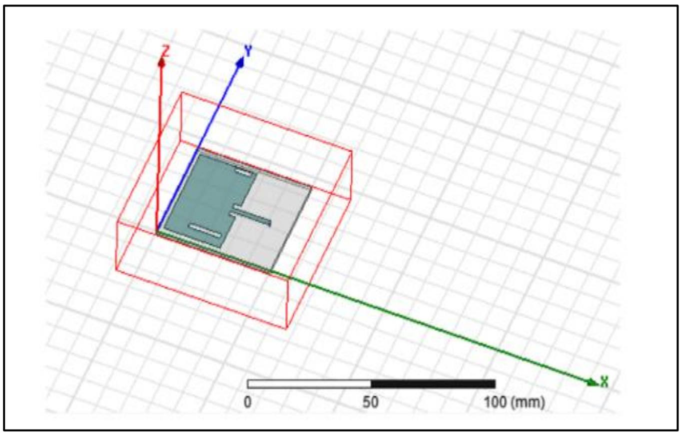


**Figure 2.** Design of simulated antenna

For simulating the behavior of the antenna, the excitation sources are defined for representing the various input signals. Here it includes voltages, currents, waveguide ports and lumped port excitations. Then the solver sittings are being configured for getting the simulate results in efficient and accurate manner. Then, to obtain the results of the parameters, the simulation process is carried out. After completing the simulation, the analysis of the results is being done by plotting VSWR, Gain, Directivity, Return loss, and Radiation pattern.

 

## 3.3. Overview of Proposed System

The overview of the proposed method for antenna simulation is illustrated in figure 3. FR4 was selected as the substrate material because of its many advantageous characteristics, including the fact that it is inexpensive, suitable for thin substrates and patch antennas, and simple to work with. The material of choice for the proposed antenna in cellular phones is FR4, which is chosen because it possesses a number of properties that are desirable. The results are guaranteed to be accurate and reliable since the simulation is run using the ANSYS HFSS tool.

There are anticipated to be a number of benefits associated with the utilization of this antenna in mobile devices. According to the results of the simulation, the device is compatible with low power consumption and demonstrates efficient utilization of space during the fabrication process. The capability of the suggest-ed antenna to minimize space and maximize power consumption, which are two important considerations, makes it very appealing for use with mobile devices. Considering the 5G networks the virtual antenna is considered to be a better choice because of the efficiency and performance.

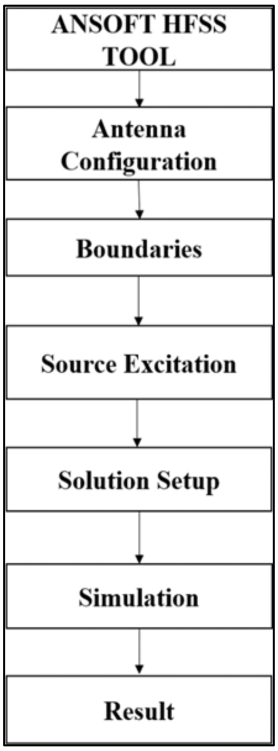


**Figure 3.** Overview of Proposed System

Based on the parameters that were simulated and acquired, it is clear that the work which was developed with the assistance of a slotted microstrip patch antenna at a frequency of 6 GHz, with dimensions of 50 x 45 x 1.6 mm, is suitable for applications that will be used in smartphones of the next generation. The future use of 5G depends upon the frequency band which is of 6GHz is now becoming more and more important since it is easily available and could support high data rates. It is appropriate for use in both urban and suburban environments since it finds a mix between coverage and capacity. In addition to this, the band is currently being investigated for the benefits that attained in Wi-Fi 6E, which further intensifies the most significant applications of the smart phones. The inclusion of the 6GHz ranged frequency is much suitable for the antenna which makes it to be compactable with the Wi-Fi and the other 5G standards which are in recent development trends that ensures the typical antenna design. It is essential for this antenna to have the capability of supporting multiple frequency bands, including resonance at 6 GHz, in order to support the various frequency bands that are utilized in 5G networks. The various resonant frequencies that is intended to reach the carrier aggregation considerably the most necessary component of the 5G technology by considering the raising data rates. Furthermore, the design has been tuned for frequencies below 6 GHz, which is essential for attaining 5G communications comprehensive coverage.

## 3.4.Fabrication Process

The proposed multiband slotted microstrip patch antenna is fabricated by using a standard printed circuit board (PCB) manufacturing process. The layout of the antenna is transferred to a copper-clad FR4 substrate through the process of photolithography after the initial design of the antenna's geometry is carried out with the assistance of computer-aided design (CAD) software. Etching processes particularly the chemical etching process are used to create the slots and the patch. After the fabrication of the microstrip feed line, the ground plane is then constructed on the reverse side of the substrate. The antenna is then cleaned so that any defects may be located and investigated. For improving the resistance of the antenna based on the environmental factors for increasing the durability of the same, a protective coating is applied. Automated manufacturing techniques, such as laser etching and automated assembly, can be utilized to streamline the fabrication process for real-time applications. These techniques can improve the precision and efficiency of the fabrication process, ensuring consistent performance and high-volume production.

**4. Results and Discussion**

In this section the analysis and the outcomes of the implementation results are obtained from crafting the patch antenna using ANSYS-HFSS. Here the Gain, VSWR value, Directivity, return loss and Radiation pattern was obtained. The following images are the simulation results for the proposed antenna.

## 4.1. Measurement of VSWR

It is the parameter that emphasizes the quality of the impedance match. Further, it also symbolizes that the signal is reflected prior to the signal, which has to be radiated by the antenna. The results for VSWR for the proposed antenna using ANSYS HFSS TOOL provides the values like 1.6 at 2.7 GHz, 1.5 at 3.3 GHz, 1.21 at 4.8 GHz, 1.7 at 5.4 GHz, 1.45 at 6.5 GHz, 1.5 at 7.5 GHz, and 1.7 at 9.2 GHz, can be seen in figure 4.

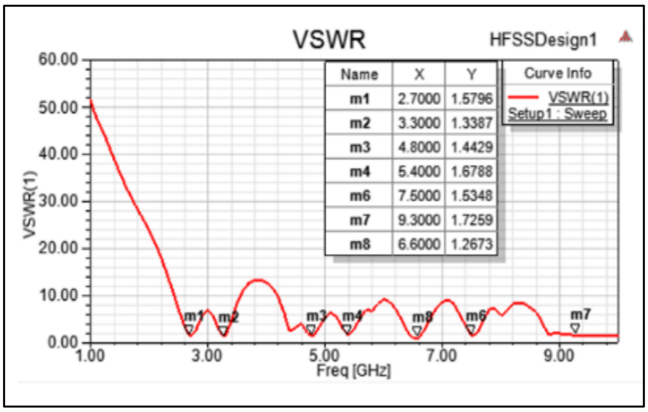


**Figure 4.** VSWR of the simulated antenna: Analyzing Voltage Standing Wave Ratio (VSWR) Performance in Simulated Antenna Systems

The VSWR is a measure of how well the antenna is matched to the transmission line. A good match occurs when the VSWR is close to 1, and a poor match occurs when the VSWR is high. The x-axis of the graph is the frequency in giga-hertz (GHz), and the y-axis is the VSWR. The red line shows the simulated VSWR of the antenna design, and the blue line shows the ideal VSWR of 1. The graph shows that the VSWR of the antenna design is below 2 for most of the frequency range. This means that the antenna is well matched to the transmission line, and it will transmit and receive signals efficiently.

## 4.2. Measurement of Gain

The antenna's focus and power-emitting capabilities can be described by this parameter. The Gain obtained from this simulated antenna is very accurate as it possesses 3.12 db. There are precise results in regard to the proposed antenna, which can be seen as shown in figure 5.

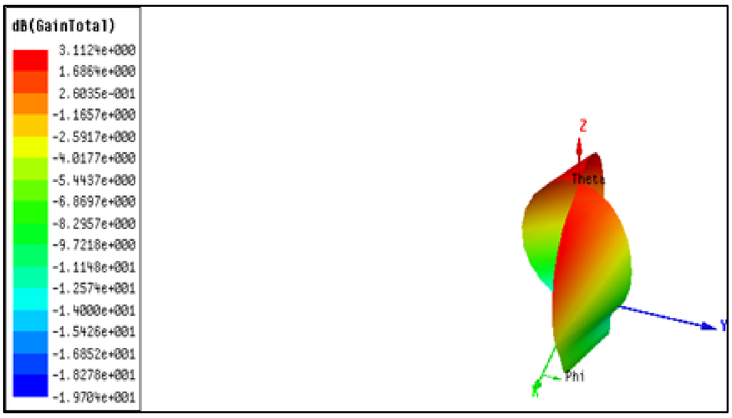


**Figure 5.** Simulated gain of microstrip antenna arrays at different frequencies

The x-axis shows the frequency in gigahertz (GHz) and the y-axis shows the gain in decibels (dB). The different colored lines represent different antenna con-figurations. The black line shows the gain of a single patch antenna, the blue line shows the gain of a 2x2 array of patch antennas, and the green line shows the gain of a 4x4 array of patch antennas. The gain obtained is very accurate as it possesses 3.12 db. The Radiation pattern is the antenna pattern that is procured by the radio waves of the antenna.

## 4.3. Measurement of Directivity

Directivity is the property of an antenna that describes the focused concentration of its radiation pattern in a particular direction when it is oriented according-ly. The antenna parameter in question is a contributing factor to the overall gain of the antenna. The plot on the right displays the directivity of the proposed antenna, which was acquired. Directivity is an antenna parameter that is a component of gain. There are precise results in regard to the proposed antenna, which can be seen in figure 6 for directivity, and figure 8 for radiation pattern.

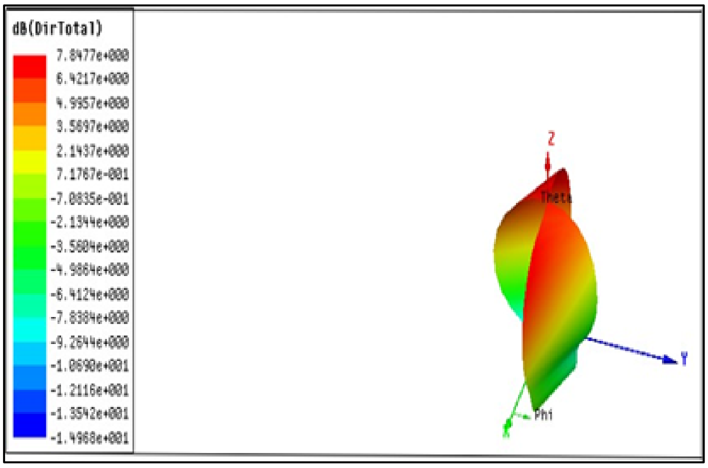


**Figure 6.** Color intensity plot of the directivity pattern of a rectangular microstrip patch antenna array

The color intensity plot in the image shows the directivity of the antenna array in the dB scale, where 0 dB corresponds to the strongest directivity. The colors range from blue (weakest directivity) to red (strongest directivity). The plot also has a number of concentric circles, which represent the different angles at which the directivity is measured. The text labels along the edge of the plot show the values of these angles in degrees.

## 4.4. Measurement of Return Loss

The Return loss for antenna, in general, should be less than -10 db. Then only there will be no losses in the system. The acquired results of the proposed antenna in terms of return loss are -12.58 dB at 2.7 GHz, -13.78 dB at 3.3 GHz, -16.17 dB at 4.8 GHz, -11.27 dB at 5.4 GHz, -29.80 dB at 6.5GHz, -13.75db at 7.5GHz and -12.08db at 9.2GHz, can be seen in figure 7.

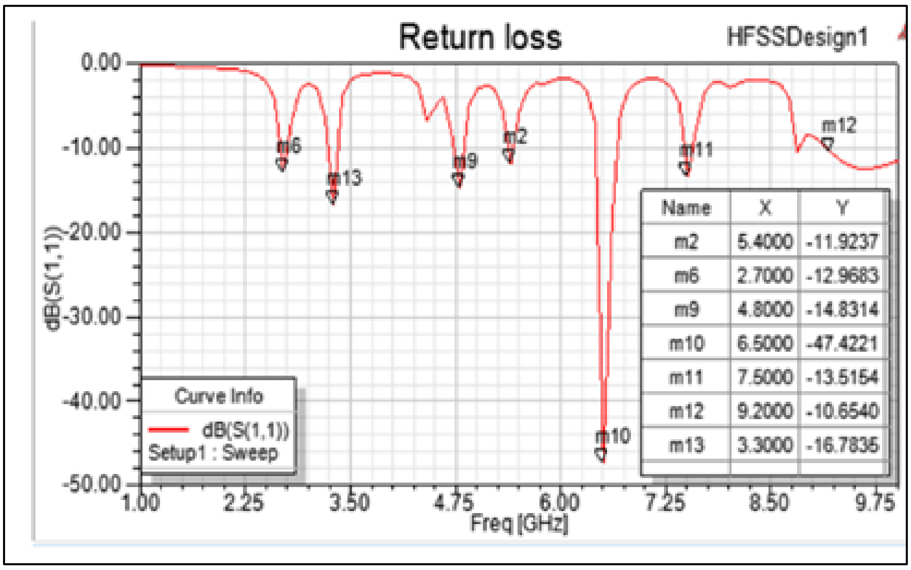


**Figure 7.** Comparison of Return Loss for Different Antenna Elements in HFSS Design

The x-axis of the graph represents the frequency in gigahertz (GHz), and the y-axis represents the return loss in decibels (dB). The graph shows multiple curves, each corresponding to a different antenna element in the array. The curves are labeled with numbers, such as "m6" and "m12". These labels likely correspond to the positions of the antenna elements within the array.

## 4.5. Measurement of Radiation Pattern

The radiation pattern refers to the specific pattern of electromagnetic waves emitted by an antenna. The figure 8 below displays the simulated radiation pattern of the antenna.

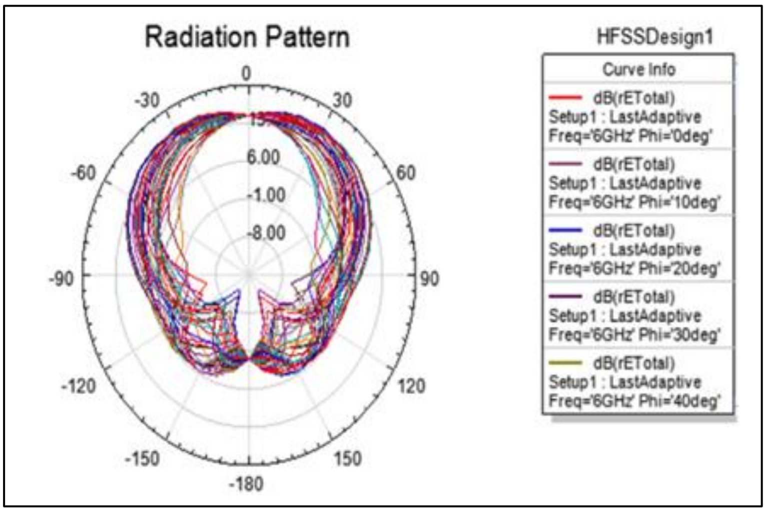


**Figure 8.** Radiation Pattern of a Pyramidal Horn Antenna at 6 GHz

The figure 8 shows the radiation pattern of a pyramidal horn antenna at a frequency of 6 GHz. The color intensity plot indicates the relative strength of the radio waves emitted by the antenna at different angles. The concentric circles represent the different angles at which the radiation is measured. The strongest radiation is emitted in the direction straight ahead from the antenna (0 degrees), and the radiation weakens as the angle increases.

### 4.5.1. Radiation Pattern – E plane

The above figure 9 consists of a plane that possesses the electric field vector and direction of maximum radiation. Thus, it is termed to be as E plane. The color intensity plot in the image shows the directivity of the antenna array in the dB scale, where 0 dB corresponds to the strongest directivity. The colors range from blue (weakest directivity) to red (strongest directivity). The plot also has a number of concentric circles, which represent the different angles at which the directivity is measured. The text labels along the edge of the plot show the values of these angles in degrees.

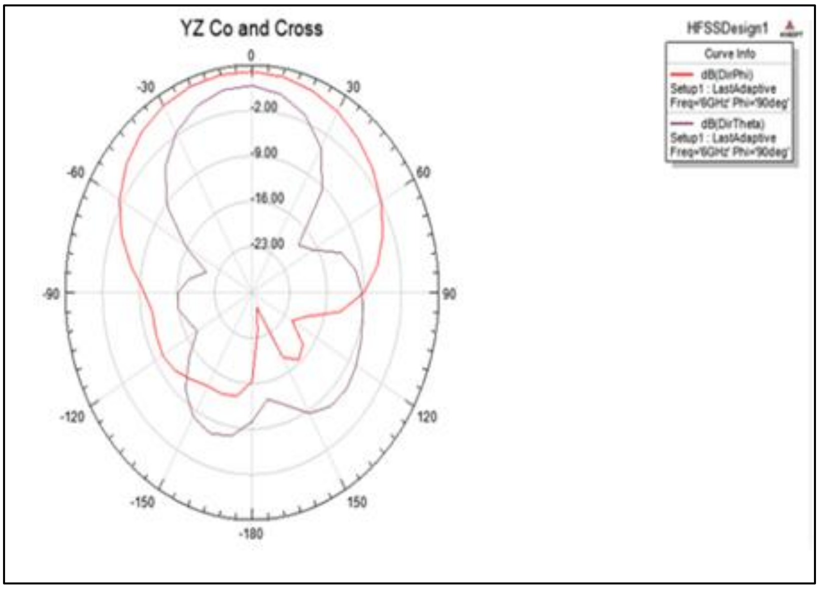


**Figure 9.** Color intensity plot of the directivity pattern of a rectangular microstrip patch antenna array

### 4.5.2. Radiation Pattern – H plane

The following figure 10 consists of a plane that emphasizes the magnetic field vector and direction of maximum radiation.

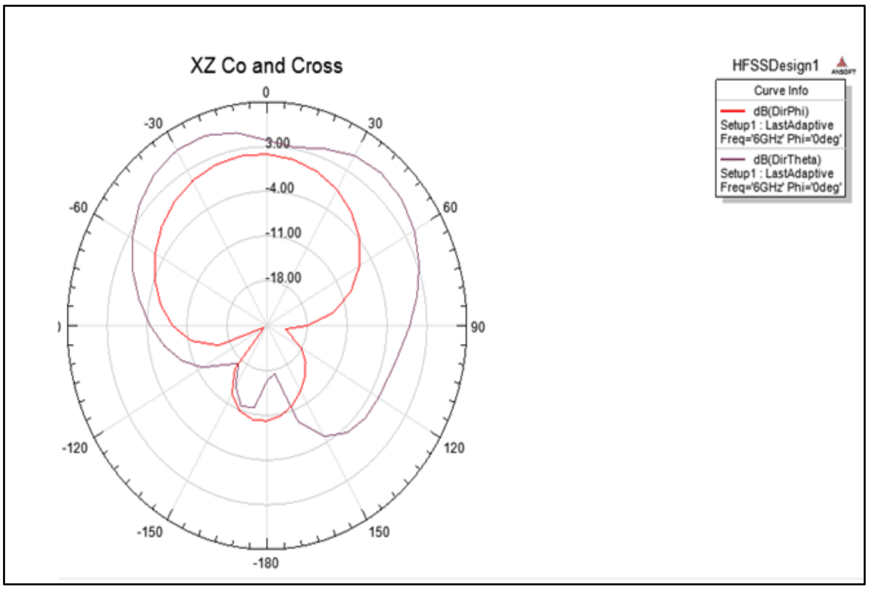


**Figure 10.** Color Intensity Plot of Dipole Antenna Directivity at 2.4 GHz

Plotting the radiation pattern of a dipole antenna at a frequency of 2.4 GHz, figure 10 seems to be a color intensity chart. Although it radiates electromagnetic waves in all directions, the antenna is a type where the angle determines the intensity. Plot color intensity shows the relative strength of the emitted waves; warmer colors indicate stronger emissions and cooler colors indicate weaker emissions. The concentric circles represent the different angles at which the radiation is measured, and the text labels along the edge of the plot show the values of these angles in degrees.

### 4.6. Integration Considerations and Potential Interference

For integrating the proposed multiband antenna into full-screen cellphones in effective manner the evaluation of the potential for the interferences are mandatory in consideration with other components. The antenna's close proximity to the battery, speakers, and display increases the likelihood of electromagnetic interference. This interference will affect not only the functioning of these parts but also the antenna's performance. There are lot of methods available for lowering the possibility of interference. Initially the separation of the antenna from the sensitive to electromagnetic interference components is done using electromagnetic shielding methods. Then the maximization of the placement and the orientation of the antenna within the smartphone chassis is done for reducing the major effects that is happened because of coupling. Finally, a thorough testing and simulation process should be done to assess the antenna performance under the presence of other components. Particularly, the attention is given more to the charging ability of the battery and the controlling of the displays touch screen might influence the radiation pattern and impedance matching that the antenna employs. Moreover, it is important to evaluate the speakers' acoustic performance to guarantee that the antenna does not produce undesired distortion or noise by them. The development of mobile device communication technologies is expected to depend much on the proposed antenna. Design enhancement and the optimizations are needed for achieving this process. Table 1 presents the details on the acquired values and limits following antenna design. Applications especially connected to wireless communication will find great relevance in this material.

**Table 1.** Statistical Results of Proposed Multiband Antenna

| Parameter | Obtained Value |
|---|---|
| Operating Frequency | 6 GHz |
| Resonant Frequencies | 2.7 GHz, 3.3 GHz, 4.8 GHz, 5.4 GHz, 6.5 GHz, 7.5 GHz, 9.2 GHz |
| VSWR (Average) | 1.52 dB |
| Return Loss | < -10 dB |
| Gain | 3.12 dB |
| Directivity | Optimized for mobile applications |
| Substrate Material | FR4 |
| Fabrication Compatibility | High (Compact, Low Power Consumption) |
| Simulation Tool Used | ANSYS HFSS |
| Application Compatibility | WWAN, LTE, 5G |

There are multiple resonant frequencies that range from 2.7 GHz to 9.2 GHz that are exhibited by the antenna, which operates at a frequency of around 6 GHz. The fact that it has a return loss of less than -10 dB and an average Voltage Standing Wave Ratio (VSWR) of 1.52 dB indicates that it has good impedance matching qualities. A gain of 3.12 dB is displayed by the antenna, which has been tuned to be suitable for directivity in mobile applications. The product is manufactured on a FR4 substrate and is designed to have a high level of fabrication compatibility. It places an emphasis on its small size and low power consumption. The performance of the proposed antenna is better in performance when compared to the previous methods which is shown in table 2.

**Table 2.** Comparison with State-of-the-Art Methods

| Method | Operating Frequency | VSWR | Return Loss (dB) | Gain (dB) | Substrate Used | Advantages |
|---|---|---|---|---|---|---|
| Proposed Method (Multiband Slotted Microstrip Antenna) | 6 GHz (Multiband) | 1.52 | < -10 | 3.12 | FR4 | Compact, Low Power, High Efficiency, 5G Compatible |
| Traditional Microstrip Patch Antenna [21] | 2.4 GHz / 5 GHz | 2 | -8 | 2 | FR4 | Limited Bands, Less Efficiency |
| Slot Antenna for Mobile Applications [22] | 5 GHz | 1.8 | -9 | 2.5 | Rogers RT5880 | Higher Cost, Limited Frequency Bands |

| | | | | | | |
|---|---|---|---|---|---|---|
| Metamaterial-Based Antenna [23] | 6 GHz | 1.3 | -12 | 4.5 | Rogers RO4003C | Higher Gain, Expensive, Complex Design |

Four distinct antenna techniques comparatively a proposed multiband sloped microstrip antenna, a conventional microstrip patch antenna, a slot antenna for mobile applications, and a metamaterial-based antenna which have their performance and advantages shown in a comparative table 2. When evaluating these methods, the operating frequency, voltage standing wave ratio (VSWR), return loss, gain, substrate material, and primary benefits are taken into consideration. The proposed method stands out for several reasons, including its compactness and compatibility with 5G networks, as well as its multiband operation at 6 GHz, good voltage standing wave ratio (VSWR), and return loss. Although the conventional microstrip antenna is easier to understand, it does have some restrictions that must be taken into consideration. On the other hand, antennas that are based on slots and metamaterials have trade-offs in terms of performance, cost, and complexity. Table 2 highlights the fact that the choice of antenna is determined by the specific application requirements as well as the desired performance characteristics.

## 4.7. Cost-Benefit Analysis of FR4 Substrate

The FR4 is selected as a substrate material for the proposed antenna because of its cost-effectiveness, availability, and suitability for microstrip patch antennas. When comparing to the other substrate materials like Rogers RT5880 and Rogers RO4003C, FR4 has very less production cost and hence it is an attractive option for smartphone manufacturers. While Rogers materials offer superior electrical properties, such as lower dielectric loss and higher thermal stability, the cost difference can be substantial. The cost savings connected with FR4 can exceed the performance advantages of more costly materials in high volume smartphone manufacture. Moreover, FR4's mechanical characteristics like its flexibility and durability is making it suitable for the small and demanding surroundings of a smartphone. The material's ability to withstand mechanical stress and environmental variations is crucial for ensuring long-term reliability.

# 5. Conclusion

In this study, a multiband slotted microstrip patch antenna for full-screen smartphones was successfully designed and simulated. The antenna operates at a frequency of 6 GHz and exhibits multiple resonant frequencies, including 2.7 GHz, 3.3 GHz, 4.8 GHz, 5.4 GHz, 6.5 GHz, 7.5 GHz, and 9.2 GHz. The antenna exhibits some better performance characteristics like an average voltage standing wave ratio (VSWR) of 1.52 dB, a return loss of less than -10 dB, and a gain of 3.12 db. These characteristics make it suitable for future applications involving 5G and compatible with both WWAN and LTE networking. Because of its small size and FR4 substrate, which is complemented to each other the antenna is suitable for the smartphone integration. The simulation's positive outcomes notwithstanding call for some more research in a few other directions. For doing more research, a few more direction are needed for enhancing the capability of the antenna. Initially, it is essential to analyze the antenna's performance in dynamic environments, such as urban areas marked by significant interference. The simulated results will be validated through testing in the real world, which will also identify potential challenges.

When using a smartphone for an extended period of time, it is important to optimize the antenna in terms of its power efficiency and radiation pattern stability. Future research should focus on the creation of adaptive tuning mechanisms to preserve performance under a range of running environments. Furthermore, looking at the merging of the antenna with the most sophisticated signal processing methods including MIMO and beamforming will help to greatly increase its dependability and data throughput. The examination of the user hand effects and the proximity is much crucial to examine the other smart phone components when checking on the performance of the electromagnetic antennas. Finally for validating the practical applicability of the antenna, there is a need for conducting a comprehensive analysis of the antennas performance by integrating the prototype of the full screen smartphone. For this analysis the interference from the display, speakers and the battery are taken into consideration.

# 6. Declarations

## 6.1. Author Contributions

Conceptualization: R.K.M., K.S.K., T.A.K., R.N., A.J.J., and M.B.; Methodology: M.B.; Software: R.K.M.; Validation: R.K.M., M.B., and A.J.J.; Formal Analysis: R.K.M., M.B., and A.J.J.; Investigation: R.K.M.; Resources:

M.B.; Data Curation: M.B.; Writing Original Draft Preparation: R.K.M., M.B., and A.J.J.; Writing Review and Editing: M.B., R.K.M., and A.J.J.; Visualization: R.K.M. All authors have read and agreed to the published version of the manuscript.

## 6.2. Data Availability Statement

The data presented in this study are available on request from the corresponding author.


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The authors received no financial support for the research, authorship, and/or publication of this article.


## 6.4. Institutional Review Board Statement

Not applicable.

## 6.5. Informed Consent Statement

Not applicable.

## 6.6. Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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