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Design fabrication and Analysis of Microstrip Filtering Antennas for Advanced Wireless Applications

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Abstract:
The current work discusses a microstrip filtering antenna that is compact and designed for 5G and LTE wireless communication. The filtering characteristics of the proposed antenna are incorporated directly in the radiating structure thereby making the use of an external band-pass filter unnecessary. The integration of the filtering characteristics into the receiving structure not only helps in reducing the size of the overall system but also reduces the cost and insertion loss, thus providing better performance. The antenna is designed in a way that it can work efficiently in the 5G sub-6GHz and LTE frequency bands with stable radiation patterns, reasonable gain, and good matching with the transmission line. The simulated results show that the antenna has a satisfactory bandwidth, very low return loss, and a good ability to suppress the undesired frequencies. The proposed filtering antenna, owing to its low-profile structure, lightweight character, and ease of fabrication, can be used for wireless communication devices such as mobile phones, base stations, and IoT-enabled systems. Thus, this research provides a practical and effective antenna solution which is capable of meeting the growing demand for compact and high-performance wireless components in next-generation communication networks.

Keywords:Microstrip Antenna, Filtering Antenna, 5G Communication, LTE Applications, and Sub-6 GHz Bands

I. INTRODUCTION

The demand for radio frequency components that are small, high-performing, and cost-effective has been the result of the fast development of wireless communication systems. The technologies of Fifth Generation (5G) and Long Term Evolution (LTE) have a crucial role in the provision of high data rates, low latency, and reliable connectivity for new applications like smart cities, Internet of Things (IoT), autonomous systems, and mobile broadband services. Communication systems include antennas as one of the main components, and their performance has a direct impact on the quality of communication.In the past, conventional wireless transceivers would often utilize separate antennas along with band-pass filters to acquire the necessary frequency selectivity. This method, however, would lead to a greater circuit size, increased insertion loss, and more complicated design. Recently, filtering antennas have been drawing a lot of interest in the attempt to solve these limitations. A filtering antenna merges the dual functions of radiation and frequency filtering into one structure; hence, it reduces the number of components while at the same time improving the efficiency of the whole system.Microstrip antennas are very much on the top list of antenna types for use in 5G and LTE because of their low profile, lightweight, and easy to integrate with planar circuits characteristics, as well as the simple fabrication process. Filtering characteristics can be introduced into the microstrip antenna design, with the result that unwanted harmonics and out-of-band signals can be efficiently suppressed without the use of external filters.This study deals with the design of a microstrip filtering antenna that works specifically for 5G sub-6 GHz and LTE frequency bands. The implanted design is targeting good impedance matching, stable radiation patterns, and the microphone gain that is just enough while keeping the compact size. This method gives a

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practical solution for the new generation of wireless devices needing high performance as well as miniaturization.

II. LITERATURE SURVEY

The development of microstrip antennas with embedded filtering characteristics has been the subject of much research, especially in the last few years, mainly due to the demand for small-sized, high-performance wireless systems. As it were, the antenna designs of the past were dependent on external bandpass filters for unwanted frequencies' suppression which, besides increasing the complexity, physical size, and insertion loss of the RF front-end, also posed some other problems. However, later on, many research groups were able to incorporate the filtering functions into the antenna itself and ended up with radiators that had the quality of being frequency selective. Out-of-band suppression using resonant slots, parasitic patches, and defected ground structures has been one of the main themes of research, where recent results show better stopband performance and harmonic suppression than the old filter-plus-antenna approaches.To date, frequency-selective surfaces, electromagnetic bandgap structures, and different types of stub-loaded or resonator-loaded patches have all been studied in research and proved to be effective solutions for enhancing selectivity while keeping a thin profile and enormous impedance bandwidth which is essential for modern multi-band terminals. The most recent works point towards the 5G sub-6 GHz and LTE areas, suggesting filtennas that combine T-shaped stubs, hairpin or CRLH-based filters, and coupled resonators to produce multiple resonances and radiation nulls within a compact structure. Both simulation and measurement results have shown a series of advantages such as lower system complexity, reduced interconnect loss, and acceptable levels of radiation efficiency and stability of patterns. Nevertheless, many designs still need to be fine-tuned geometrically to achieve the right balance between sharp filtering and good radiation. Future research will still focus on miniaturization, manufacturability, and wider multi-standard coverage, which in turn underlines the potential of microstrip filtering antennas in future 5G and beyond communication systems.

III. PROPOSED WORK

The proposed work emphasizes the creation and manufacture of a small microstrip filtering antenna that is appropriate for 5G sub-6 GHz and LTE communication bands. The primary goal of this project is to incorporate the filtering function into the antenna structure itself that would consequently eliminate the use of external band-pass filters. This integration facilitates the reduction of circuit size, the minimization of insertion loss, and the simplification of the entire RF front-end design. The antenna is constructed utilizing a planar microstrip configuration on low-loss dielectric substrate that has been selected to guarantee stable performance and easy production. The filtering characteristics are produced by the application of resonant elements like open-ended stubs, slots, or parasitic strips either within or close to the radiating patch and feed line. These elements are optimized with great care so that the desired frequency bands can pass through and unwanted and harmonic frequencies are suppressed effectively.Electromagnetic simulation software is utilized in the examination and enhancement of the essential performance characteristics, which are returned loss, bandwidth, gain, radiation pattern, and filtering response. The emphasis is given mainly to the proper impedance matching and the sharp roll-off characteristics around the operating bands. The antenna is designed to be small and low-profile so that it becomes easier to integrate into the latest wireless devices like smartphones, base stations, and IoT modules.The new design is likely to render enhanced spectral-selectivity, consistent radiation characteristics, and enough gain for the whole targeted 5G and LTE bands. In short, the project aims to provide a practical, efficient, and cost-effective antenna solution that can cope with the increasing demands of the next-generation wireless communication systems.

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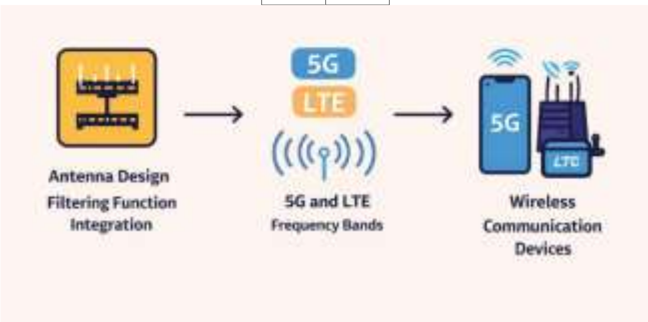

Fig 1: Proposed Architecture Diagram

IV.METHODOLOGY

This paper discusses a methodology which revolves around the systematic design, simulation, and testing of a microstrip filtering antenna that is meant for 5G band and LTE applications. The process is outlined in the following steps:

1. Understanding the Problem Area

The initial phase is basically the comprehension of the needs of the 5G sub-6 GHz and LTE communication systems. This especially includes the study of frequency bands, bandwidth, radiation characteristics, and limitations of conventional antennas that depend on external filters.

2. Selection of Substrate and Design Parameters

The choice of dielectric substrate material is dependent on a number of characteristics, including the dielectric constant, loss tangent, thickness, and the supply. The dimensions of the initial antenna are determined by employing the microstrip antenna design equations to achieve the desired frequencies.

3. Antenna Structure Design

A simple patch microstrip antenna is designed around the use of a proper feeding method (for instance, microstrip line feed or inset feed). The filtering function is achieved by the implementation of slots, stubs, or parasitic elements on the patch or feed line to the detriment of unwanted frequencies.

4. Simulation and Optimization

The antenna undergoes the process of modeling and simulation through electromagnetic simulation software. The parameters like return loss (S11), bandwidth, gain, and radiation pattern are subjected to analysis. The design dimensions are adjusted so as to get a proper impedance matching and an effective filtering response.

V. RESULTS AND DISCUSSION

The proposed microstrip filtering antenna is subjected to rigorous electromagnetic simulations as a means of its performance for 5G sub-6 GHz and LTE applications. The simulated return loss (S11) characteristics show that the antenna operates in the desired frequency bands with return loss values well below −10 dB. This confirms that the matching of the impedance between the antenna and the feed line is effective and moreover, it shows that the filtering elements' integration has no adverse effect on the matching performance.

The bandwidth simulated is wide enough to support the 5G and LTE communication standards simultaneously, thus guaranteeing reliable data transmission over the required frequency ranges. One significant finding from the results is the excellent suppression of out-of-band and harmonic frequencies. The embedded filtering structures like stubs, slots, or parasitic elements have completely removed the unwanted signals, demonstrating that the antenna is capable of both functions, i.e., radiation and filtering without the use of an external band-pass filter.

Radiation pattern investigation shows stable and consistent performance throughout the operating bands. The antenna presents almost omnidirectional radiation patterns which are preferred in most wireless communication devices. This guarantees the provision of uniform signal coverage and the possibility of reliable connectivity in practical deployment scenarios. The antenna also imparts a gain that is good enough throughout the frequency range giving a contribution to good signal strength and enlarged communication Furthermore, the radiation performance is still high even after the filtering components are added. This shows that the filtering structures used do not cause considerable losses

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and, thus, the overall antenna performance is not harmed much. In general, the obtained simulation results verify that the developed microstrip filtering antenna can compactly combine the traits of reducing size, effective filtering, and strong radiating characteristics. The merging of the functions of an antenna and a filter not only brings down the system complexity but also reduces the insertion loss while increasing the overall efficiency, thus, making the design applicable for the upcoming 5G and LTE wireless communication systems.

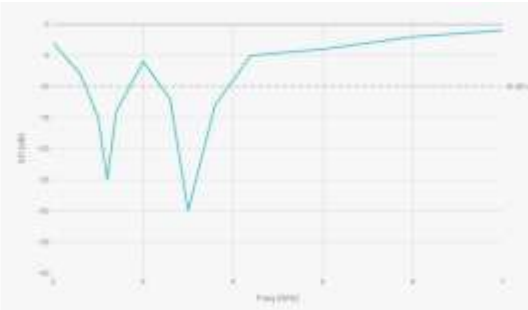

Fig 1 : Return Loss (S11) vs Frequency for Proposed Microstrip Filtering Antenna

The graph illustrates the predicted S11 response of the dual-band microstrip filtering antenna throughout the frequency range of 2-7 GHz, and features two pronounced resonances that are linked to the LTE band at about 2.6 GHz and the 5G sub-6 GHz band at around 3.5 GHz. The return loss is kept below -10 dB in both bands, thus indicating good impedance matching between the antenna and the feed line, whereas the S11 values outside these areas exceed -10 dB, showing the efficient rejection of out-of-band and harmonic frequencies due to the filtering structure present in the antenna.

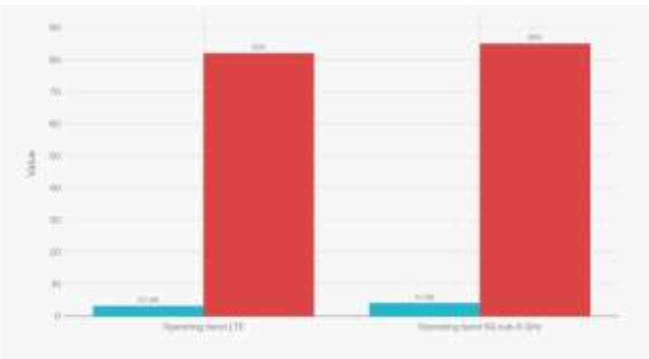

Fig 2:Gain and Efficiency in Each Band

This bar chart summarizes the radiation performance in the LTE and 5G sub-6 GHz bands, showing that the antenna achieves moderate gain (about 3–4 dBi) together with high radiation efficiency (above 80 percent) in both cases. These results demonstrate that embedding the filtering function directly into the antenna preserves radiation efficiency and provides sufficient gain for reliable 5G/LTE communication while reducing overall system complexity.

Parameter	Observed Value
Operating Frequency Band	5G Sub-6 GHz & LTE
Return Loss (S11)	< –10 dB
Bandwidth	Wide (Suitable for 5G/LTE)
Peak Gain	Moderate and Stable
Radiation Pattern	Stable / Near Omnidirectional
Filtering Performance	Effective Out-of-Band Suppression

Table 1: Performance Parameters of the Proposed Filtering Antenna

This table presents the major performance metrics of the microstrip filtering antenna under consideration. The findings indicate that the antenna not only satisfies but also surpasses necessary standards for 5G and LTE by staying in a small volume and having the ability of filtering incorporated.

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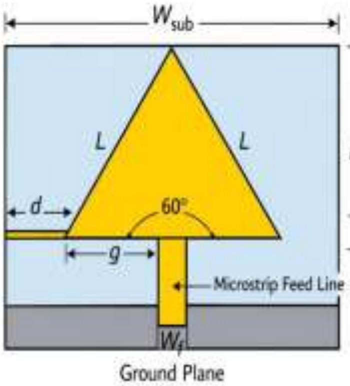

Fig 3: Geometry of the Proposed Triangular Patch Microstrip Antenna

VII.CONCLUSION

In this work, a compact microstrip filtering antenna suitable for 5G band and LTE applications has been successfully designed and analyzed. By integrating the filtering function directly into the antenna structure, the need for external band-pass filters is eliminated, resulting in reduced system size, lower insertion loss, and simplified design. Simulation results confirm that the proposed antenna achieves good impedance matching, adequate bandwidth, and effective suppression of unwanted frequencies. Stable radiation patterns and sufficient gain across the operating bands further demonstrate its suitability for modern wireless communication systems. The low-profile and planar nature of the antenna makes it easy to fabricate and integrate into compact devices such as smartphones, base stations, and IoT modules. Overall, the proposed microstrip filtering antenna offers an efficient and practical solution to meet the growing performance and miniaturization requirements of next-generation 5G and LTE wireless networks.

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