Leaky-wave Wires Antenna for Future D- Band 6G Communication Systems

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***Abstract*—Future communication generation such as 6G and beyond will be utilizing the terahertz band, as this range promises potential benefits such as a high data rate. However, designing different electronic components for 6G is complicated and has low fabrication precision due to its small wavelength. Additionally, the cost is also very high as compared to 5G components. These antennas feature high data rates, small size, and high bandwidth and are a critical component for the communication system. Therefore, in this study, an antenna design is proposed for the future sub-THz communication system that operates at D- band which is proposed for the 6G communication system. The simulation analysis shows that the proposed antenna has a high gain of 9.9 dBi at 120 GHz operating frequency and good performance characteristics for the complete D-band. The design of the proposed antenna is simple, low-cost, and does not require any complex fabrication, and can be the potential leaky-wave antenna for future 6G if properly excited.**

***Keywords*—Leaky-wave Antenna, D-band, 6G,**

I. Introduction

The hunger for high data rates is increasing day by day with the increase in the number of devices, users, and new technologies. Also, next-generation 6G requires a data rate exceeding 100 Gbps and one solution to obtain such speed is to utilize the THz range that offers availability of wide bandwidth. In comparison to 5G, 6G will operate at higher frequencies, with 100 to 300 GHz being the preferred range. Some services already use frequencies in this range, including radio astronomy, satellite Earth exploration, mobility satellite, and inter-satellite communications. Additionally, the FCC has also recommended the 95 GHz to 3 THz range for 6G communication systems [1]. Designing an antenna is a crucial part of any communication system. There are several antenna types are proposed for the sub-THz and THz range for efficient and low-loss propagation of such extremely high frequencies.

According to our knowledge, most of the publications are based on the microstrip patch antenna [2] and SIW technology [3] which are compact in size and other features. For high-frequency range, various antennas are proposed such as the Leaky-wave antenna [4], the slotted-waveguide antenna [5], and so on. For the D-band, a patch antenna array is proposed on PCB [6], a THz leaky wave antenna is proposed using a parallel plate waveguide [7], and a simple 3D printed leaky wave THz antenna [8]. Horn antennas are also popular in the THz range due to their very high gain as a corrugated horn antenna is proposed and designed based on the silicon platelet technology and has a gain of 19 dBi [9]. However, their design is quite complex, high precision fabrication is required due to their small size and are quite expensive. Therefore, a simple, low-cost, and leaky-wave antenna is proposed in this paper for efficient propagation of sub-THz waves for future 6G proposed D-band. Designing and choosing the efficient feeding mechanism in these leaky waves is still challenging due to its size, therefore feeding mechanisms are not included in the study while analyzing the performance of the proposed leaky wave for such an extremely high-frequency range.

II. THz Antenna Design

The proposed sub-THz antenna design is shown in Fig. 1. The antenna design consists of four metallic wires that are twisted around the Teflon rod. The twisting rate of each wire is set at 520°.

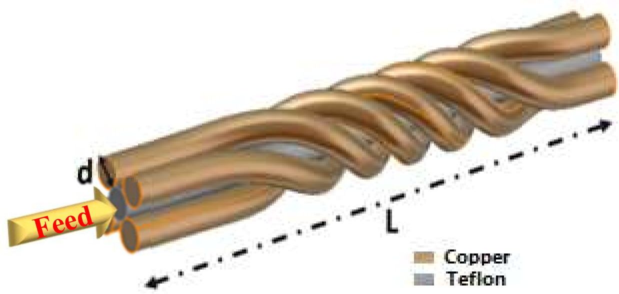

Fig.1 Proposed Leaky Wave Antenna.

The proposed antenna design has a length (L) of 20 mm, and the diameter (d) of copper wires and Teflon rod is 1 mm while the electrical length of the waveguide is about 10λ. The proposed leaky-wave antenna is simulated in CST Microwave Studio 2022 using a time domain solver for the proposed D-band allocated for future 6G communications. The proposed antenna structure is straightforward and does not require any additional complex fabrication.

III. Simulation Results

The simulation return loss and VSWR results for the proposed four-wire wounded leaky-wave antenna are shown in Fig. 2.

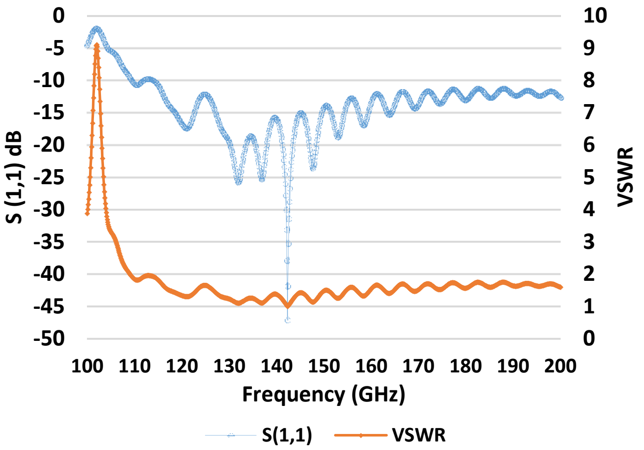

Fig. 2. Return Loss and VSWR for proposed Leaky Wave Antenna.

The leaky-wave antenna achieves a return loss below -10 dB throughout the complete D-band 115 GHz to 180 GHz having a center frequency at 142 GHz, accomplishing a very wideband of 65 GHz. The VSWR value for the proposed band is between 1 and 2. The radiation patterns and the gain of the proposed antenna are shown in Fig. 3. The proposed leaky wave antenna utilizes the Teflon rod as a waveguide, while four wires twisted around the rod create the helical patterns of the electric field that enhances the radiation of the antenna. The maximum gain of 9.9 dBi is achieved through the proposed leaky-wave antenna and maximum power is radiated to the forward side.

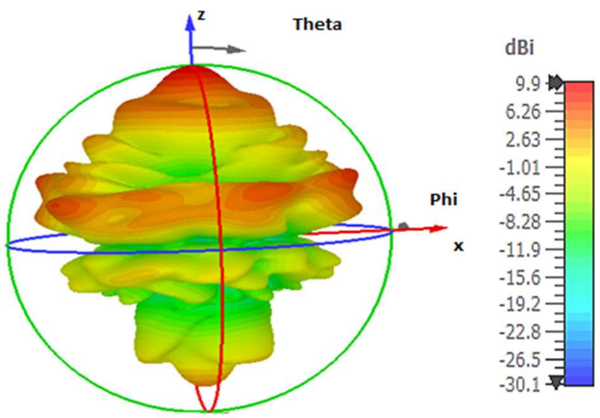

Fig. 3. Gain of proposed Leaky-wave Antenna in 3D

The gain of the proposed antenna is better compared to many single-element patch antennas and not too high as compared to the recent high-precision fabricated and costly horn antennas [9]. The radiation of the antenna is quite high in one direction and is suitable for directional applications.

The proposed antenna is also analyzed for efficiency, and it is found that the efficiency of the antenna is about 99% which is very high as compared to another sub-THz leaky-wave antenna such as 87% [10] and 97% [11]. The reason for such high efficiency is the feeding mechanism which will no doubt bring down the efficiency of the antenna.

Feeding an antenna in sub-THz is quite challenging due to its miniature size and fabrication. Therefore, feeding the proposed leaky wave is not included in the current study. However, it is our next step to analyze different feeding techniques for efficient coupling.

IV. CONCLUSION

Designing an antenna for future extremely high frequency is a great challenge, therefore a leaky-wave antenna is proposed in this study, and it is shown that an antenna made up of copper wires and a Teflon rod can be used to design a sub-THz antenna with a simpler design, fabrication and low-cost advantages. This antenna can be used in indoor Wi-Fi applications such as convention halls and auditorium halls, focusing the signals toward the audience while minimizing signals towards the other wall end. However, feeding such narrow and small sub-THz devices is still a great challenge that needs to be explored further.

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