Leaky-Wave Antenna Based on Modified Aperture Half-Mode Substrate Integrated Waveguide

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***Abstract*—In this paper, we will introduce a novel leaky-wave antenna based on the half-mode substrate integrated waveguide. By modifying the aperture of the proposed antenna, the side-lobe level of the radiation pattern in the E-plane is reduced up to -19 dB. The operating band of the antenna is from 27 to 29 GHz that is one of the allocated 5G bands. The radiation efficiency is increased to 53% by partial removal of the dielectric layer that leads to the reduction of the scanning speed. Hence, the frequency sensitivity of the radiation pattern decreases. The length, width, and height of the antenna are 70mm, 11.5mm, and 0.127mm, respectively. The small size of the antenna makes it a suitable candidate for circuit integration.**

***Keywords*— antenna, leaky-wave, side-lobe level, substrate integrated waveguide.**

I. Introduction

Leaky-wave antenna (LWA) is a radiating structure that enables leakage of a traveling wave propagating through the structure. The radiation in LWA occurs via the discontinuities on the surfaces of the structure [1]-[3]. LWAs are classified among high gain antennas with wide impedance bandwidth.

After the introduction of substrate integrated waveguide (SIW), designers are leaning toward the adoption of the SIW LWAs. Low cost, ease of fabrication, and compact size are among the advantages of SIW [4]-[8]. Removing half of the upper copper cladding of SIW will make the structure more compact. This new structure is called half-mode substrate integrated waveguide (HMSIW) [9]-[14] that is the basis of the proposed design in this paper. In the HMSIW LWA, the radiation occurs from both the open aperture [9]-[13] and the slots on the surface of the structure [14]. In the proposed antenna, radiation occurs from the open aperture of the structure.

Recent allocation of 5G bands by regulatory bodies such as ITU and FCC has generated a great deal of focused activity in the research community [15]-[17] to enable relevant technologies for these allocated millimeter-wave frequency bands. Providing high data rates in dense environments, covering continuously vast number of wireless devices, and reducing the power consumption are among the main objectives of 5G wireless systems [15]-[17]. Hence, using steerable high gain antennas becomes crucial for efficient communications. Compactness, low cost, high gain, frequency scanning capability, and simple feed network are among the features that make HMSIW LWAs a suitable candidate for 5G applications such as internet of things (IoT) [17], vehicle to vehicle communications [17], satellite on-the-move [18], space communications [18], and point-to-point communications.

A convenient technique to control the radiation pattern of the HMSIW LWA is to taper the sidewall [11], [12]. In [11] by tapering the sidewall the side-lobe level (SLL) was reduced. In [12] tapering the sidewall causes the generating of desired nulls in the radiation pattern. Tapering the phase constant is another method that can be implemented for SLL reduction [13]. For the first time, we propose tapering the open aperture of the HMSIW LWA to reduce SLL. Tapering the dielectric layer in a similar way as the top copper cladding leads to improvement of the radiation efficiency as well. The structure of the proposed antenna is presented in section II and the simulation results are investigated in section III.

II. Structure of the Antenna

The proposed design is based on Rogers RT/Duroid 5880 substrate with 0.5 Oz copper cladding. The proposed antenna is presented in Fig. 1. The length, width, and height of the antenna corresponding to 70 mm, 11.5 mm, and 0.127 mm, respectively. A tapered sidewall in addition to the tapered microstrip feeding lines is used to improve the impedance matching.

III. Simulation Results

The Preliminary simulations have been carried out using Ansys HFSS 18.2. The S-parameters diagrams are presented in Fig. 2. According to Fig. 2, the proposed antenna exhibits a return loss better than -10 dB over the 2.6 GHz bandwidth ranging from 26.6 to 29.2 GHz.

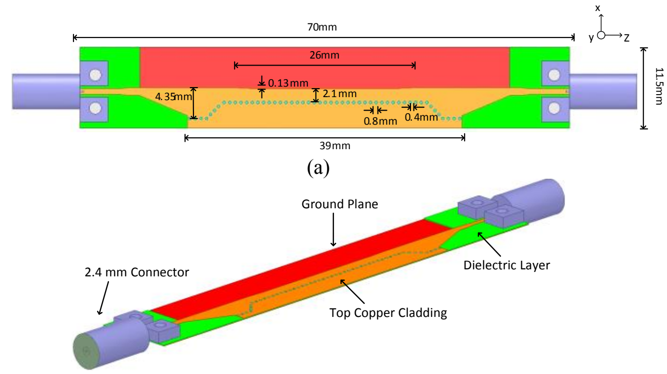


Fig. 1. Schematic of the proposed antenna. (a) Top view, (b) 3D view.

The radiation patterns (gains) of the antenna at different frequencies are presented in Fig. 3. Fig. 3 indicates that by sweeping the frequency, the main lobe of the radiation pattern will rotate and antenna beam will scan space. Meanwhile, since we remove part of the dielectric layer, the effective dielectric constant gets closer to one which leads to reduced frequency sensitivity of the radiation pattern. In other words, by sweeping the frequency, the antenna scans space at a slower pace.

According to Fig. 3, the proposed antenna scans space with high gain and low SLL. The realized gain, SLL, and main lobe angle of the antenna in the E-plane at the center frequency, 28.5 GHz, corresponding to about 10 dB, -19 dB, and 55^0, respectively. The simulation results confirm that the proposed antenna has better SLL compared to [9]-[14]. The reported SLL in [11] is lower than the corresponding value in the presented design. However, in [11] authors only consider the radiation pattern in the upper hemisphere. In contrast, in the presented paper we consider the radiation in both upper and lower hemispheres.

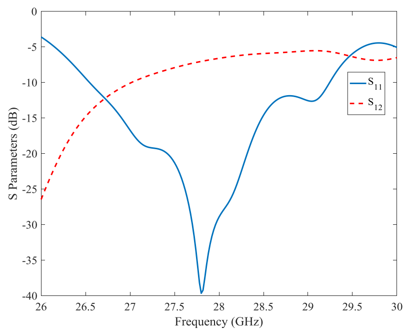
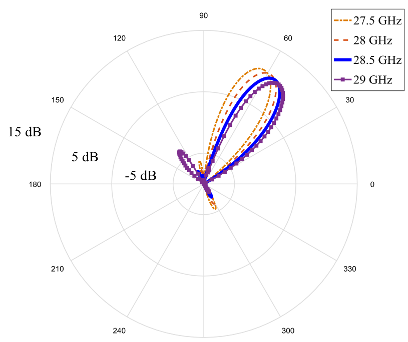
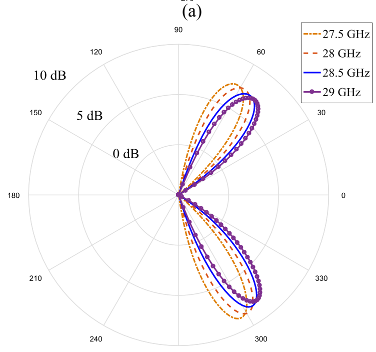


Fig. 2. S-parameters diagrams.



(a)



(b)

Fig. 3. Radiation patterns (gains) of the proposed antenna. (a) E-plane, (b) H-plane.

IV. Conclusion

In this paper, a novel HMSIW LWA for the 5G wireless system was introduced. The proposed antenna offers the unique ability of 3D frequency-scanning in real time. This feature was achieved by scanning in both E- and H- planes simultaneously. Moreover, by tapering the open aperture of the HMSIW structure, the SLL and radiation efficiency were improved. Therefore, the proposed antenna scans space with high gain and low SLL.

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