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High Gain and Fixed Broadside Leaky Wave Antenna with Quasi-Optical Feed for D-Band Communication

Usman Shehryar* (1), Ashraf Uz Zaman (1), Jian Yang (1)
(1) Chalmers University of Technology, Gothenberg, Sweden, https://www.chalmers.se

1. Introduction

The demand for communication services has led to the exploration of higher frequency bands, including the D-band (110 GHz to 170 GHz) for wireless backhaul/access networks [1]. However, electromagnetic waves at this frequency experience significant path loss in free space, making it necessary to improve antenna efficiency. An ideal antenna for high frequencies should have low loss, high directivity, large bandwidth, compact size, and need to be suitable for mass production.

Reflector antennas are well suited to provide directional beams at high frequencies, but they can be expensive to integrate into a system due to strict feeding requirements and incompatibility with volume limitations. Alternatively, single or multiple layer slotted waveguide arrays can be used to achieve highly directional beams. However, at higher frequencies (e.g.145 GHz), traditional waveguide based corporate feed networks used for each radiating element excitation become more complex, causing increased losses and reflections in the structure and creating challenges for tolerances and assembly [2]. Additionally, scalability to larger arrays becomes an issue, with a decrease in effective bandwidth.

The use of Leaky wave antennas (LWAs) has become popular for achieving high gain, directive and broad bandwidth radiation at the sub-THz range, with a relatively simple and low-profile structure. This study presents a two-layer LWA aperture that can offer fixed broadside radiation with a directivity of 30-32 dBi over the 140 GHz - 150 GHz band. The aperture is excited with a low loss, geometrically simpler quasi-optical feed and can be easily expanded to larger arrays.

2. Antenna Description

Figure 1. shows the antenna system which is composed of three parts: feeding part (integrated horns), quasi-optical system and a radiating part. The radiating and feeding parts are placed in two different stacked parallel plates connected by the optimized quasi-optical system.

The proposed radiating aperture consists of a periodic array of 14 continuous transverse slots (CTS) that are symmetrically arranged into two 1 x 7 slot arrays that are excited from the center. The CTS widths and periodicity are optimized to provide a uniform amplitude and phase distribution across the aperture for broadside radiation. This configuration also minimizes beam squinting and reduces grating lobes by exciting two symmetrical subarrays from the center, resulting in constructive interference of their radiation patterns. A corrugated surface is placed below the aperture to reduce the guided wavelength within the parallel plate and to prevent the grating lobe problem [3].

The feeding component of the system comprises an H-plane integrated horn that is positioned in the focal plane of the parabolic reflector. The size and number of horns used are determined by the length of the CTS aperture to generate a high-quality plane wave. These horns are designed to generate a TEM wave with a cylindrical wave front. The horns are tapered in a specific manner to adjust the parabolic profile, which helps to minimize spill-over and increase the efficiency of radiation. The quasi-optical system proposed in this study comprises of a parabolic reflector that connects two stacked parallel plates. Several coupling slots are located in the common plate, which facilitates the coupling of energy from quasi-TEM mode that propagates in the feeding layer to the radiating aperture. The parabolic reflector plays a critical role in converting the cylindrical phase wave front to a plane wave.

The combination of integrated horns and a quasi-optical reflector in this straightforward feeding topology provides several advantages over traditional corporate feeding networks, including reduced complexity, lower losses and reflections, and the ability to excite a large CTS aperture using a smaller number of waveguide inputs. Furthermore, the bandwidth remains consistent even when scaled to larger arrays, and scalability is easily achieved. Additionally, this feeding topology allows for the realization of antenna arrays with fewer stacked layers.

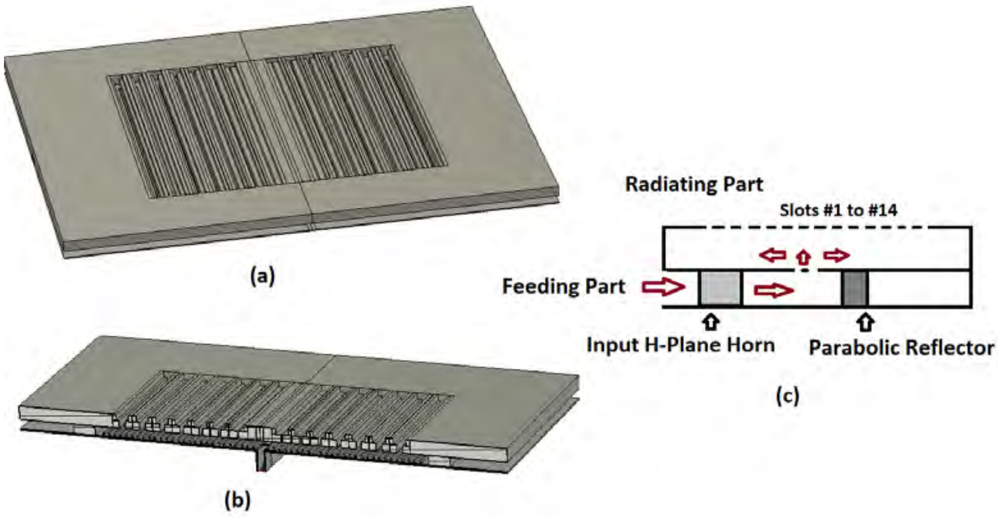

Figure 1. (a) Antenna Aperture (b) Cross-sectional view of Radiating Aperture
(c) Feeding Part and Parabolic Reflector interfaced with Radiating Aperture

3. Simulation Results

The proposed structure is simulated in CST 2021. The simulation results including E and H-Plane radiation patterns over the desired band are shown in Figure 2. Broadside radiation is achieved in the 140 GHz - 150 GHz. The directivity w.r.t frequency is also shown in the Figure 2. The directivity achieved has a value of 30 – 32 dBi over the 140 GHz - 150 GHz.

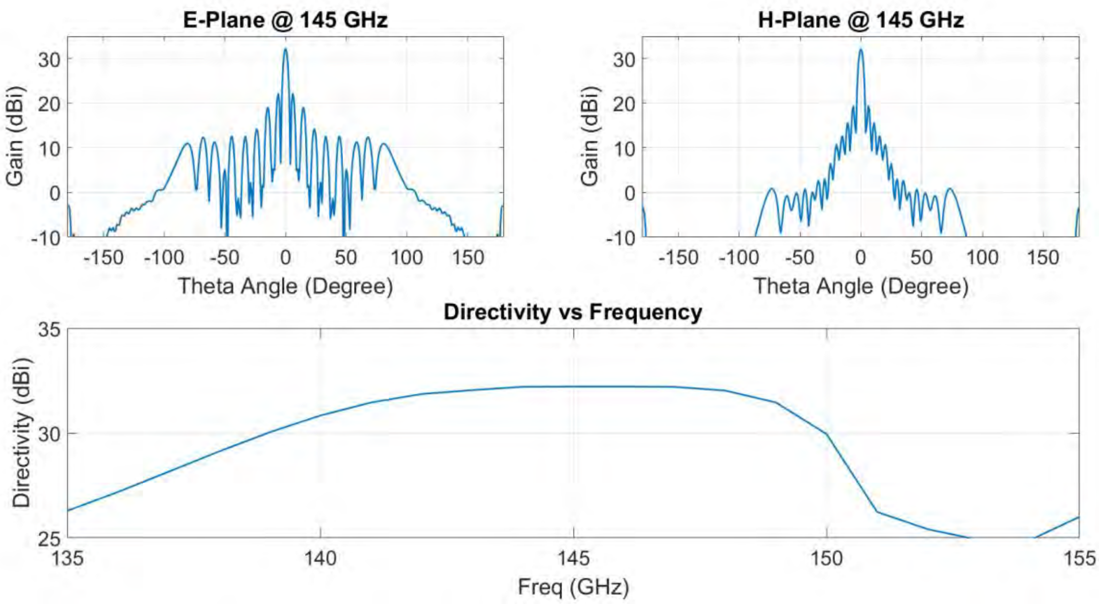

Figure 2. E and H -Plane radiation pattern at 145 GHz and Directivity over frequency range

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