State of the Art and Development of High Gain Planar Gap Waveguide Antennas at Chalmers University of Technology

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***Abstract*—Gap waveguide technology was invented by Prof. Kildal. The non-conductive connection between the upper and the lower plates makes this technology advantageous over conventional rectangular waveguides and microstrip lines in millimeter-wave and THz regime. This paper reviews the recent developments of high gain planar array antennas using the gap waveguide technology at Chalmers University of Technology, as a memory of Prof. Per-Simon Kildal.**

I. INTRODUCTION

Gap waveguide technology was invented by Prof. Kildal in 2008 [1]. The main contribution from this invention is to make the manufacture of devices and antennas with separate plates without requiring the difficult conductive connection between the top and the bottom plates at millimeter waves and THz regime. The theory behind this possibility is to create a wave stop in a gap between a PEC plate and a PMC plate realized with texture structure. This technology is a disruptive one, which disrupts conventional rectangular waveguides, microstrip line, existing packaging, diffusion bonding, dip-brazing and wire-bonding for MMIC, etc. at mm-waves and THz-waves.

This paper reviews the state of the art and the recent developments of high gain planar array antennas using the gap waveguide technology at Chalmers University of Technology, collaborated with Gapwaves AB, as a memory of Prof. Kildal.

II. GAPWAVE PLANAR ARRAY ANTENNAS

The coming 5G wireless communication systems employs Massive MIMO concept, where backhaul systems use millimeter wave point-to-point high gain antennas for mass data transfer with a requirement of low-cost manufacturability. The consumer market prefers flat antennas. The following gapwave planar antennas aim to offer the best possible solutions to the demands.

A. Slot Antenna Array fed by Inverted Microstrip Gap Waveguide

Microstrip line has a big advantage for low cost manufacture but a big ohmic loss due to lossy dielectric substrate at mm-waves. Gap waveguide technology offers a possibility to have inverted microstrip line, which reduces the ohmic loss significantly, and at the same time, keep the manufacture cost relevantly low. A 16 × 16 slot array antenna has been fed by a feeding network made of inverted microstrip gap waveguide [2], as shown in Fig. 1. This antenna consists of four layers: radiating slot layer, a groove gap cavity layer, a distribution feeding network layer and uniform pin layer with a transition from standard WR-15 waveguide to the IMGW. The inverted microstrip gap waveguide antenna array is designed at 60GHz frequency band. The radiating slot layer, a groove gap cavity layer, and uniform pin layer were fabricated using cost-effective Electrical Discharging Machining (EDM) technology, and the distribution feeding network layer was fabricated by the PCB technology, a low cost manufacturing. The measurements show that the antenna has a gain above 28 dBi, the efficiency above 40% covering 54-64 GHz frequency range.

B. Ka-Band Antenna Array with Integrated Diplexer

Gap waveguide technology provides a possibility to integrate high gain planar antenna with other circuitry to have a compact and cost effective solution for mmW systems. As one example, a high gain slot array antenna at Ka-band has been integrated with a diplexer into its corporate-feed network, which avoid extra inter-connection between the antenna and the diplexer for reducing the insertion loss and manufacture cost [3], as shown in Fig. 2. A novel 7th order hybrid diplexer-splitter realized by the gap waveguide technology has a natural compatibility for its direct integration with the feed-network of the 16×16 slot array antenna. The whole antenna module with diplexer is made by three distinct metal layers without requiring conductive contacts between them due to the stop band created by the the gap waveguide technology. The whole diplexer-antenna has two channels: 28.21 GHz and 29.21 GHz, with 650 MHz bandwidth for each. A measured radiation pattern of a manufactured prototype of the diplexer-antenna agreed well with the simulated one, presenting a good performance. The measured input reflection coefficients for both channels are below -13 dB. The measured antenna efficiency, including all the losses in the antenna and the diplexer, is above 60% in the pass channels.

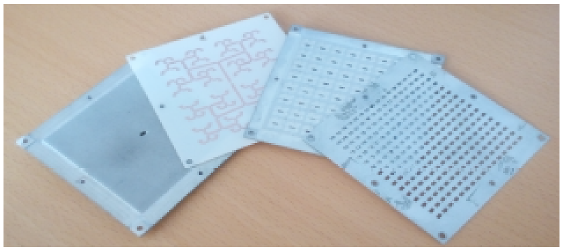

Fig. 1. Photograph of the fabricated 16×16 slot array antenna fed by inverted microstrip gap waveguide.

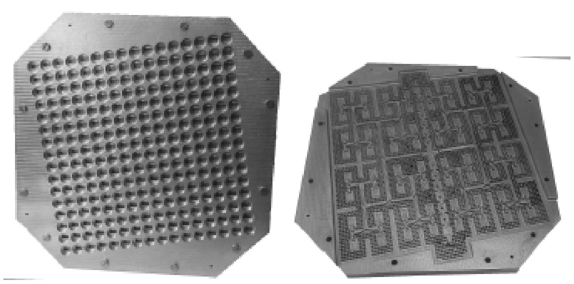

Fig. 2. Photograph of the fabricated integrated diplexer-antenna array module.

C. Dual-Polarized Slotted-Waveguide Antenna

Dual polarized planar antenna array is demanded but a big challenging task. Gap waveguide technology has a unique solution to this challenge. A wideband and a dual polarized slot antenna at V-band (57–66 GHz) based on Gap Waveguide concept has been designed and prototyped [4], as shown in Fig. 3. The antenna consists of three layers. The first one is the feeding layer for polarization 1, the second layer is feeding layer for polarization 2, and the third layer (top layer) is the radiation layer shared by the two polarization radiation. This offers flexibility for antenna functions and performance separated for each polarization, and reduce the complexity of the manufacture since all three layers can be fabricated separately, and the assembly of the antenna does not require the conductive contact between the layers. Simulated results shows both impedance bandwidth and radiation pattern bandwidth greater than 15% for both polarizations.

D. V-Band Planar Array Antenna Using Half-Height Pin Gap Waveguide

Gap waveguide technology can have different forms with the same idea in behind. A gap stop band. A new form of pins, the so called half-height pin, has been applied to design of a wideband, high gain, and high efficiency 8×8-element slot array antenna for 60GHz band, as shown in Fig. 4. The antenna has good performance with 14% bandwidth of the 10 dB return loss, 26 dBi realized gain and close to 80% aperture efficiency. The antenna has less difficulty in manufacturing because of new pin form and therefore is suitable for the low cost mass production of mm-Wave antennas.

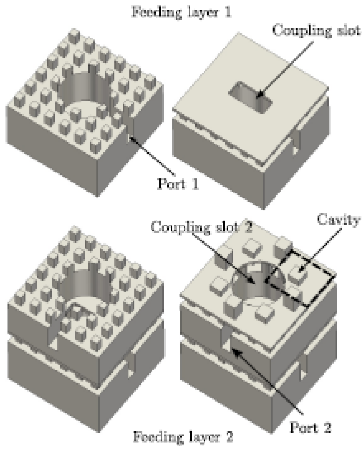

Fig. 3. Feeding layer of the single-layer slot antenna using RGR transitions.

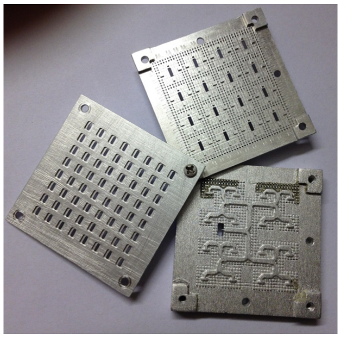

Fig. 4. Feeding layer of the single-layer slot antenna using RGR transitions.

III. CONCLUSIONS

Gap waveguide technology offers a great potential for mm-waves antenna systems with an easy integrability with MMICs. More gap waveguide antennas, including multiple steerable beam antennas for massive MIMO systems, will come soon in near future. The invention from Prof. Kildal has paved a solid basis for further developing this technology at mmW and even up to THz.

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