

G-band Frequency-Steering Antenna Array Design and Measurements

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Abstract

This paper discusses design of a micro-fabricated frequency-steered waveguide slot array and its radiation pattern measurements over a 130GHz to 180GHz frequency range. The array is designed in a reduced-height WR-5 waveguide, and the slot spacing, size and position are optimized using HFSS. The array was fabricated in the PolyStrata™ process by Nuvotronics, LLC. The measured return loss of the 20-element travelling-wave array is below 12dB from 130 to 180GHz. The radiation patterns agree well with simulations and exhibit about 1degree/GHz of scanning. The measurements were performed in a calibrated quasi-optical setup.

Summary

Beam steering antenna arrays have many applications, from object tracking and localization to landing systems. Beam steering can be obtained electronically, by controlling the relative phase shift between the array elements. This can be achieved by delay elements, as in the case of phased arrays, or by tuning the signal frequency, as in frequency scanned arrays [1–5]. The latter are usually easier to build than the former, but require a wider operating bandwidth. In this work frequency scanned arrays at G-band having a wide scanning angle are described. By operating at G-band, the overall size of the antenna can be reduced, thus making it suitable for space applications, where reducing the size and weight of the radar system is important.

The antenna array feed in this work are rectangular waveguides designed to operate close to cutoff where the dispersion is large. When the feed is dispersive, the phase velocity and thus the relative phase between elements changes with frequency and as a result the beam steers. The wave travels down the feed line and loses power at each element to radiation; this power loss is accounted for when the element excitations are determined. Thus, elements near the feed must couple weakly to the feed line, while elements near the load must couple strongly. The phase of each element is determined by the length of the feed line section between the elements, as well as the mutual coupling [1]. When the inter-element path length in a feed line increases, a small frequency change will result in a larger phase change between elements and so greater scanning can be achieved compared to a line with low dispersion.

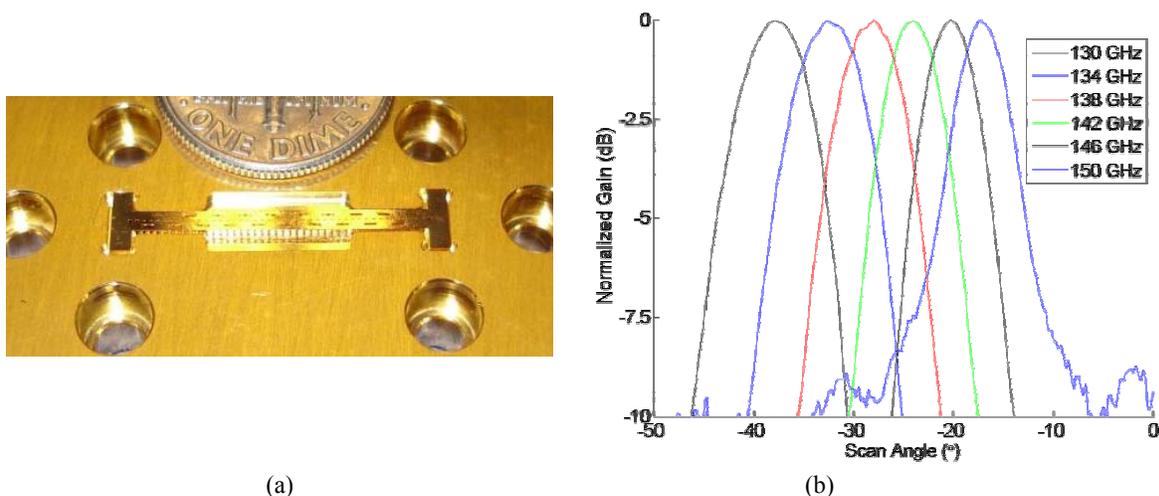


Figure 1. (a) Photograph of 20-element frequency-scanning array mounted on two standard WR-5 waveguide flanges. (b) Measured normalized radiation patterns between 130 and 150GHz.

Figure 1(a) shows a photograph of the 20-element waveguide slotted array with longitudinal slots. In order to achieve the greatest possible scan angle and the lowest gain variation over the scanning frequencies, several parameters, such as the length and width of the slots, the distance between each slot, and the position of the slots from the center of the waveguide were optimized. The array was fabricated in the PolyStrata™ process by Nuvotronics, LLC [6]. In the past, this process was mostly used for micro-coaxial circuit components and antennas, as outlined in [7] and to the best of our knowledge, this is the first such antenna array demonstrated with waveguides at this high frequency. The photograph shows the array mounted on a machined brass block which connects two standard WR-5 flanges for measurement purposes. The vertical adaptor from the slot waveguide feed to the WR-5 waveguides is designed using HFSS for best return loss, which was measured to be below 12dB over the 130-180GHz range. The measurement was performed with a network analyzer with G-band extenders.

The radiation patterns of the array were measured in a quasi-optical setup calibrated against a standard-gain WR-5 horn. One of the ports of the slot array was connected to a load (Custom Microwave, with VSWR better than 1.2) and the other port to a power detector. Two detectors were used for the measurements, since the array spans two bands, and no single detector covers both bands. Additionally, two multiplied sources were connected to the transmit standard gain horn antenna for the same reason. Figure 1(b) shows normalized patterns for the lower band, 130-150GHz. Similar patterns are obtained for the higher band (150-180GHz) and agree well with predictions. The details of the theoretical patterns, gain over steering angles and measurement calibration will be given in the final paper.

Acknowledgments

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