Low-cost Sub-THz Dielectric Grating Antennas

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Background

- The **sub-THz frequency band (>100GHz)** has attracted increasing interest for emerging applications such as **high-resolution radar**, **imaging**, and **high-data-rate wireless communications**.
- For antennas, sub-THz systems commonly rely on **on-chip antennas (AoC), horn antennas, or AoC-plus-lens solutions**.
- However, **AoCs** have very **low gain (<0 dBi)**, **silicon lenses** are **expensive** and **bulky**, and **horn antennas** have **large vertical height**.

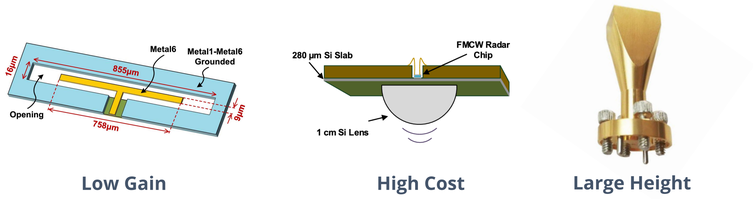


Fig. 1 Comparison of sub-THz antennas

- These limitations led to new demand for low-cost, high gain and low-profile sub-THz antennas.

Solution

- Among the off-chip antennas, **dielectric antennas** have gained increasing attention due to their **negligible conductive loss** and **favorable performance** at **millimeter-wave** and **sub-THz frequencies**.
- In terms of fabrication, the most used fabrication method is **computer numerical control (CNC)** machining. The **micrometer-level** precision demands highly specialized 3D CNC equipment, which is expensive, occupies a large footprint as Fig.2 (left) shows.

Fig. 2 Comparison of **3D CNC (left)** and **2.5D CNC (right)** machine

- One alternative is **2.5D milling** using PCB manufacturing machines. These machines offer excellent **in-plane (XY)** accuracy, often reaching **micrometer-level precision**, while being relatively **low-cost** and **compact**, making them suitable for **in-house deployment** in RF laboratories.

Antenna Design

- The proposed **antenna array** consists of **three main parts**: **power dividers**, **dielectric grating array**, and **waveguide-to-dielectric waveguide transition**, as Fig. 3 shows. The overall dimensions of the proposed antenna are **69 mm × 7.5 mm × 1.2 mm**.

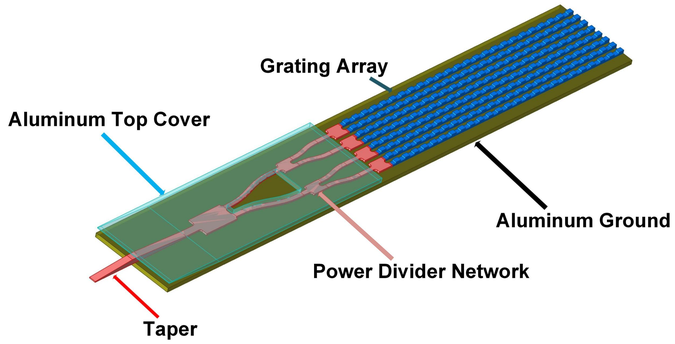


Fig. 3 The proposed antenna array

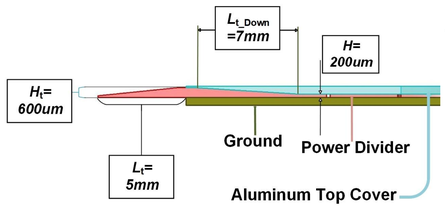


Fig. 4 Dimensions of taper

- To excite the proposed antenna array, a **WR-5** rectangular **metal waveguide** operating from 140 GHz to 220 GHz is employed as the input feed. Then the **dielectric waveguide** section is designed to **be inserted into** the WR-5 waveguide to enable efficient electromagnetic coupling. Fig.4 shows the sideview of feeding structure.

- To form an antenna array, the **power distribution network** is used, which consists of **three stages** of **1-to-2** power dividers. The first stage employs a 1-to-2 **multimode interference (MMI)** power divider, while the second and third stages use **Y-branch-like** power divider structures as the "**Y**" in Fig.5.

Parameters	Values (mm)
PDL_1	4.2
PDW_1	2.5
PDL_2	1.4
PDW_2	1.4
PDL_3	1.5
PDW_3	1.5
W_1	0.5
W_2	0.45
L_1C	8
L_2C	4

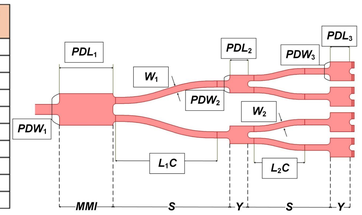
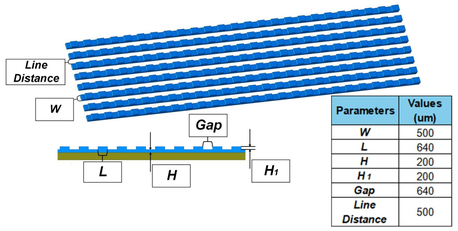


Fig. 5 Top view and dimensions of power divider network

- **S-bend** dielectric waveguides are used to interconnect adjacent stages. The **slope** of the S-bend is **zero** at both the **beginning** and the **end**, theoretically providing a **smooth waveguide transition** and minimizing modal perturbations and field tumbling.

- For radiation part, an **eight-element** parallel **dielectric grating antenna array** is employed. Each dielectric grating waveguide has a **width of 500 μm**, The **total height** of each dielectric grating antenna is only **400 μm**, consisting of a 200 μm dielectric waveguide height and a 200 μm grating step height.



Parameters	Values (um)
W	500
L	640
H	200
H_1	200
Gap	640
Line Distance	500

Fig. 6 Dimensions for dielectric grating array

Simulation Results

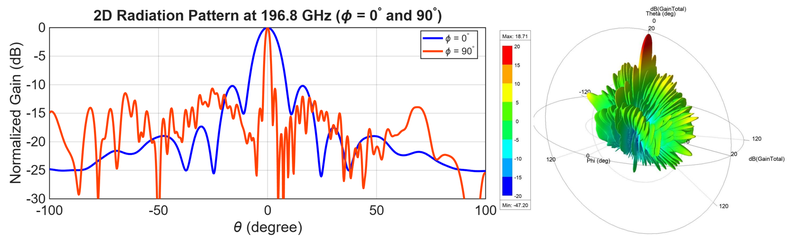


Fig. 7 Simulated **2D (left)** and **3D (right)** radiation pattern

- Fig.7 shows the 2D and 3D radiation pattern, which indicates that the **center operating frequency** of the proposed antenna is approximately **196.8 GHz**, where the peak **gain** is **18.71 dBi.** The 2D pattern shows that the **3-dB beamwidth** is 2.4° at $\Phi = 90^\circ$and 10° at $\Phi = 0^\circ$, indicating a highly directive radiation characteristic.

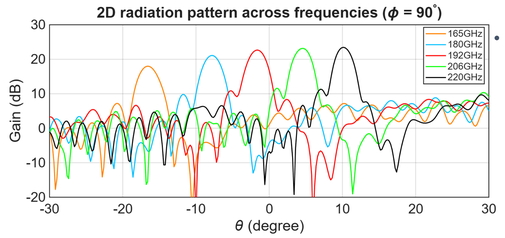


Fig. 8 2D radiation pattern across frequencies at $\Phi = 90^\circ$

- The grating antenna is a type of leaky-wave antenna (LWA), which the beam location is frequency dependent, as Fig. 8 shows, the beam direction shifts from -17° To 10° .It also demonstrates the **55 GHz** operating **bandwidth** from 165 GHz to 220 GHz.

- In conclusion, this work presents a **fully planar dielectric grating antenna array** operating in the sub-THz frequency range and compatible **with low-cost 2.5D milling fabrication**. The proposed design eliminates the need for tall structures or expensive quasi-optical components, demonstrates the feasibility of **rapid, in-house fabrication** of **high-performance sub-THz dielectric planar antennas**.

Publication:
Zhuoran Wu, Hossein Naghavi, "A Low-Cost Dielectric Grating Planar Array Antenna for Broadband Sub-THz Systems," in 2026 IEEE International Symposium on Antennas and Propagation (IEEE AP-S), under review..

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