Scalable 3D-printed antenna array with liquid cooling for Ka-band

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RF Sampo

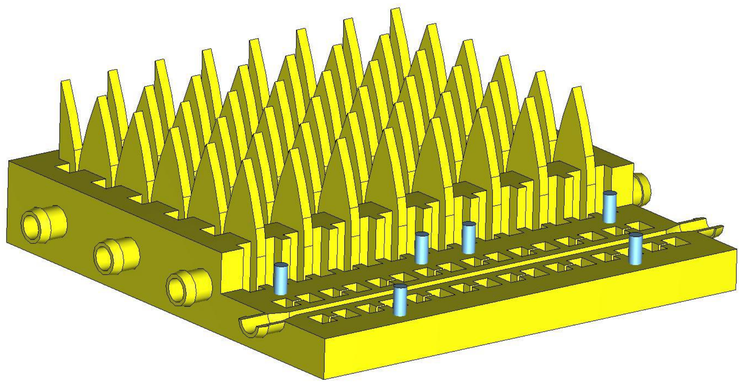
- Veturi program
- Business Finland

Introduction

- High-frequency antenna arrays have challenges in RFIC integration as the antenna-element size and inter-element distance are reduced to a level comparable to the RFIC size:
  - **heat** generated by the RFICs in a small, concentrated area and
  - **limited space** available for RFIC.

Antenna array

- 8x8 array, 3D printed of metal (steel)
- Cooling channels inside Vivaldi elements
- Surface mounted antenna structure
- RFICs and antenna on the same side of the PCB
- The antenna design covers 24 – 29.5 GHz band.

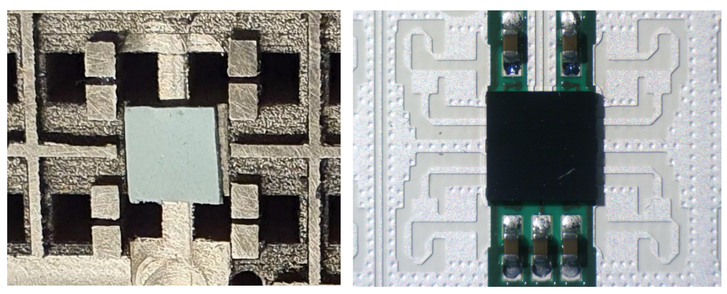


Antenna model.

Feed network.

RFIC integration

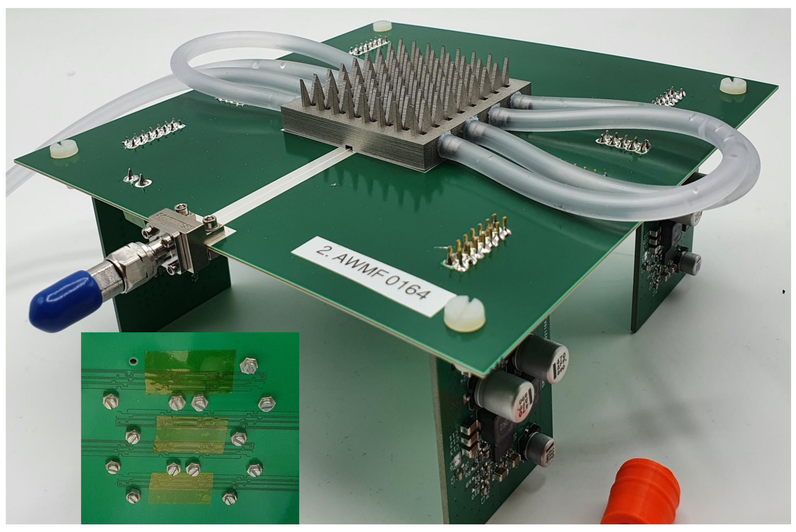
- Two commercial four-channel beam-former RFICs from Anokiwave are used:
  - AWMF-0158 (24.25-27.5 GHz)
  - AWMF-0164 (26.5-29.5 GHz).
- 16 RFICs are feeding the 64 single-polarized antenna elements.
- Baluns for the differential feeding of the Vivaldi elements are implemented.
- The antenna array is mounted on top of the PCB with the flip-chip RFICs.
- Flexible heat-transfer pads are placed between the antenna and the RFICs. The cooling channels are right on top of the RFICs.



Heat-transfer pad on the 3D-printed antenna and the RFIC on the PCB.

Prototypes

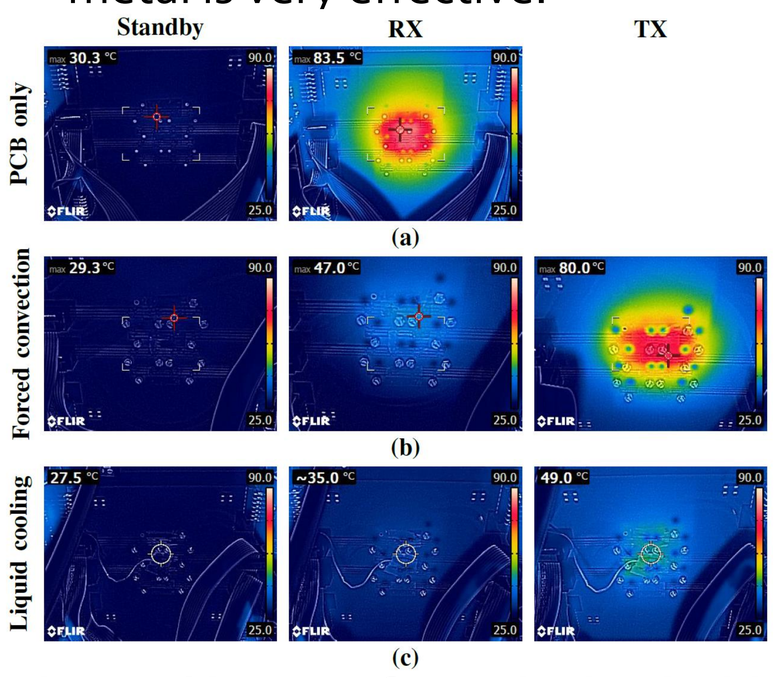
- Two prototypes are built for two different bands. The antenna structures are identical.
- Water cooling is implemented; flow is 4.5 l/h in the experiments.



Antenna prototype and backside of the PCB (inset).

Thermal performance

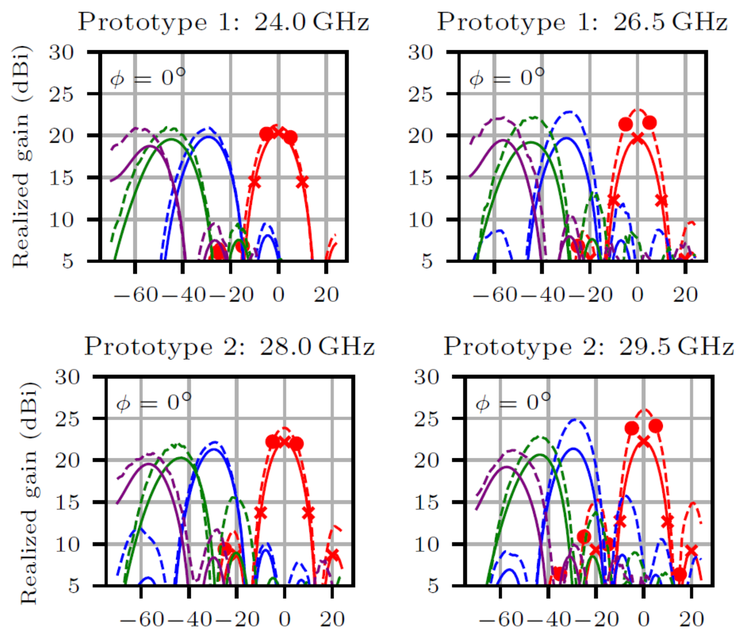
- Power consumption of RFICs and, therefore, the power dissipation varies with different operation modes:
  - transmit mode ~25 W
  - receive mode ~13 W.
- Liquid cooling integrated in the metal is very effective.



Thermal images from the back side of the PCB: a) PCB without antenna, b) forced convection (fan), and c) liquid cooling.

Beam steering

- Realized-gain patterns for different beam steering angles are measured verifying good antenna performance.



Measured (dashed) and simulated (solid) realized gain patterns of the two prototypes, when the beam is steered to 0°, 30°, 45°, and 60° in the E-plane.

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