APECS

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This research aims to design pulse-detecting antennas, quantify, classify, and localize ESD pulses in clean and complex environments (e.g., placement machinery), and enable robust CDM-type ESD testing at the chiplet level during manufacturing steps. It further seeks to detect CDM events during production at frequencies and magnitudes arising from chiplet stacking, serving as early indicators of failed charge-voltage suppression, and to characterize chiplet ESD behavior for System Efficient ESD Design. The research also includes shared hardware and signal-processing assets (current sensors, antennas, probes) and the development of ESD/EMC training materials for online and onsite delivery with laboratory components.

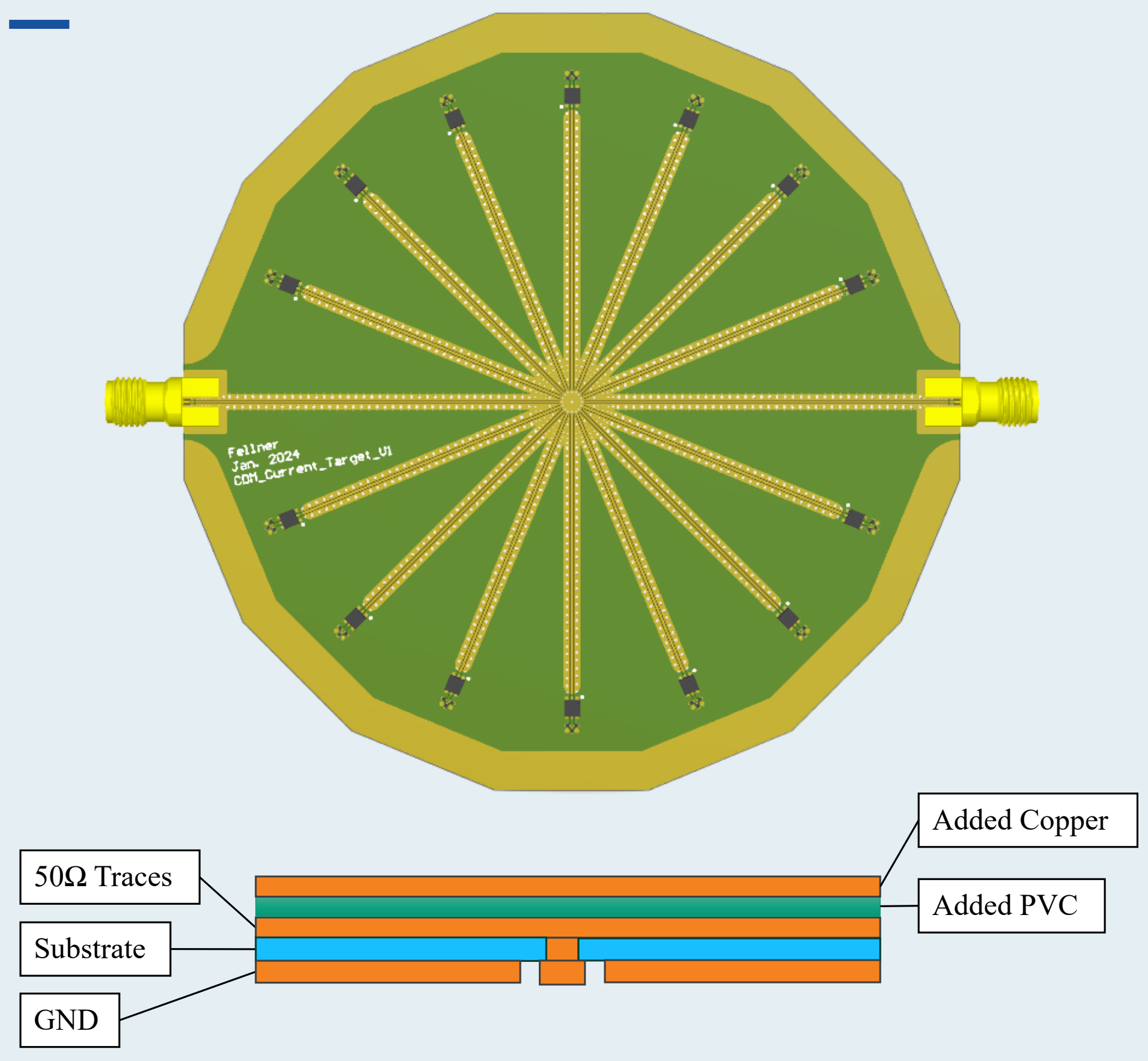
Transmission Line Based Current Target

Charged Device Model (CDM) events exhibit very fast rise-times (< 20 ps) and short pulse widths (< 50ps), making failure thresholds rise-time dependent and imposing strict requirements on current measurement such as high-voltage rating, pulse-current capability, low resistance, and high bandwidth/low inductance. Conventional targets have limited bandwidths: IEC 61000-4-2 up to 4 GHz; 1 Ω disk resistors up to 13 GHz.

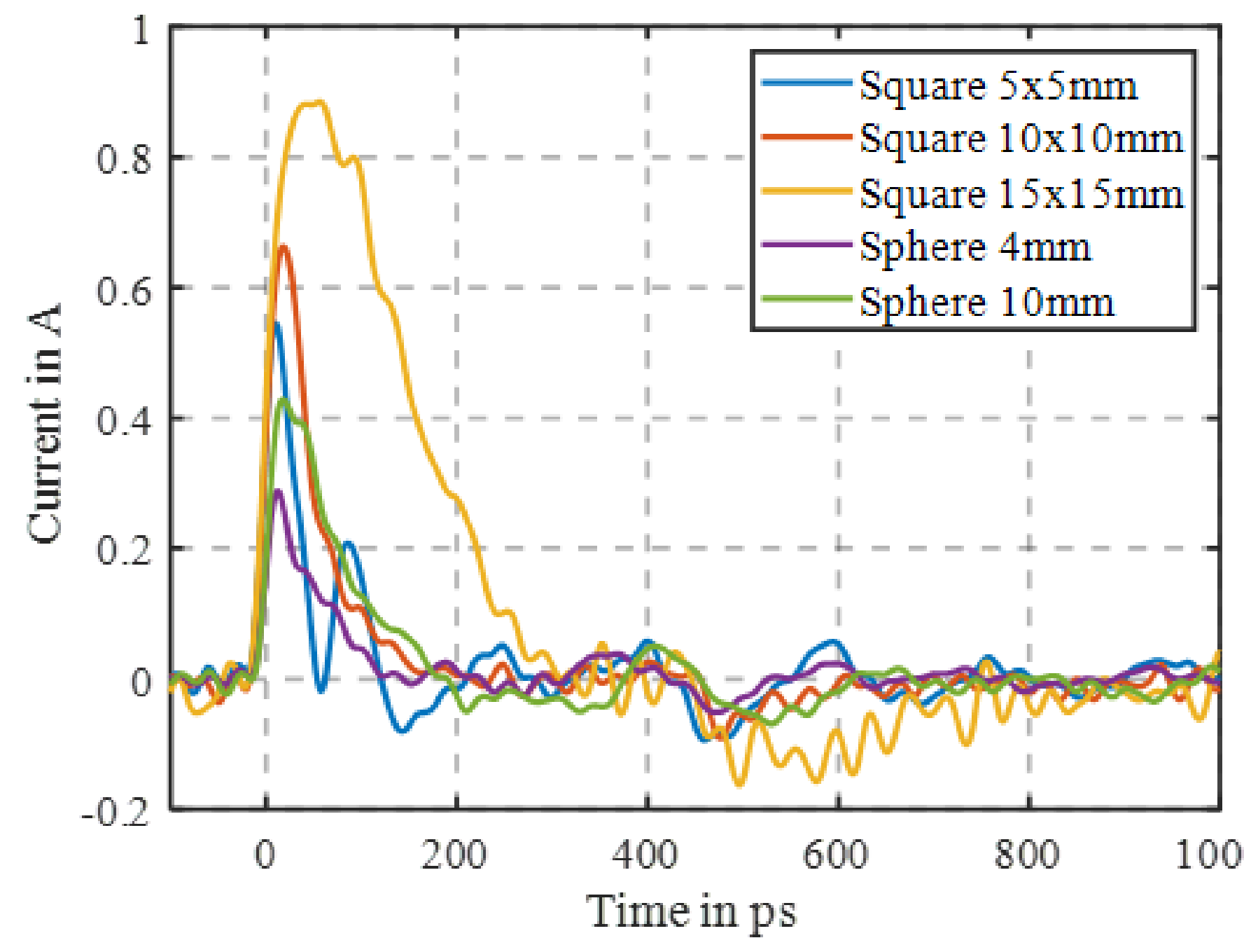
To overcome these limitations, a transmission-line current target using 16 parallel ground-referenced coplanar waveguide (GCPWG) lines was designed, with key parameters including trace width/gap, center pad diameter, substrate thickness, and terminations via 14 SMT attenuators (DC–43.5 GHz) plus two SMA connectors for validation. CST simulations used waveguide ports on all traces and at the center, enabling impedance extraction from S11 and verification via TDR.

The manufactured PCBs initially showed excessive trace impedance and reflections. Tuning to 50 Ω with a PVC layer and copper reference improved matching but introduced around 5 dB deviation at 15 GHz, higher loss, and SMA mismatch. A controlled setup (approach mechanics, conductive suction-cup charging/positioning, gold-plated samples with elevated center pin) measured discharges with pulse widths of 35 ps to 400 ps, low ringing, and no target-induced reflections. The rise-times decrease with sample area, reaching 16.3 ps for a small sphere, with significant spectral energy above 10 GHz and beyond 15 GHz for a 5×5 mm sample. De-embedding shows increasing target impedance with minor signal impact at increasing frequencies. The concept is validated with rise-times down to ~15 ps, and its relevance grows as CDM target levels decline with continued scaling and heterogeneous integration.

Current Target



25+ GHz current target for the measurement of chiplet CDM discharges



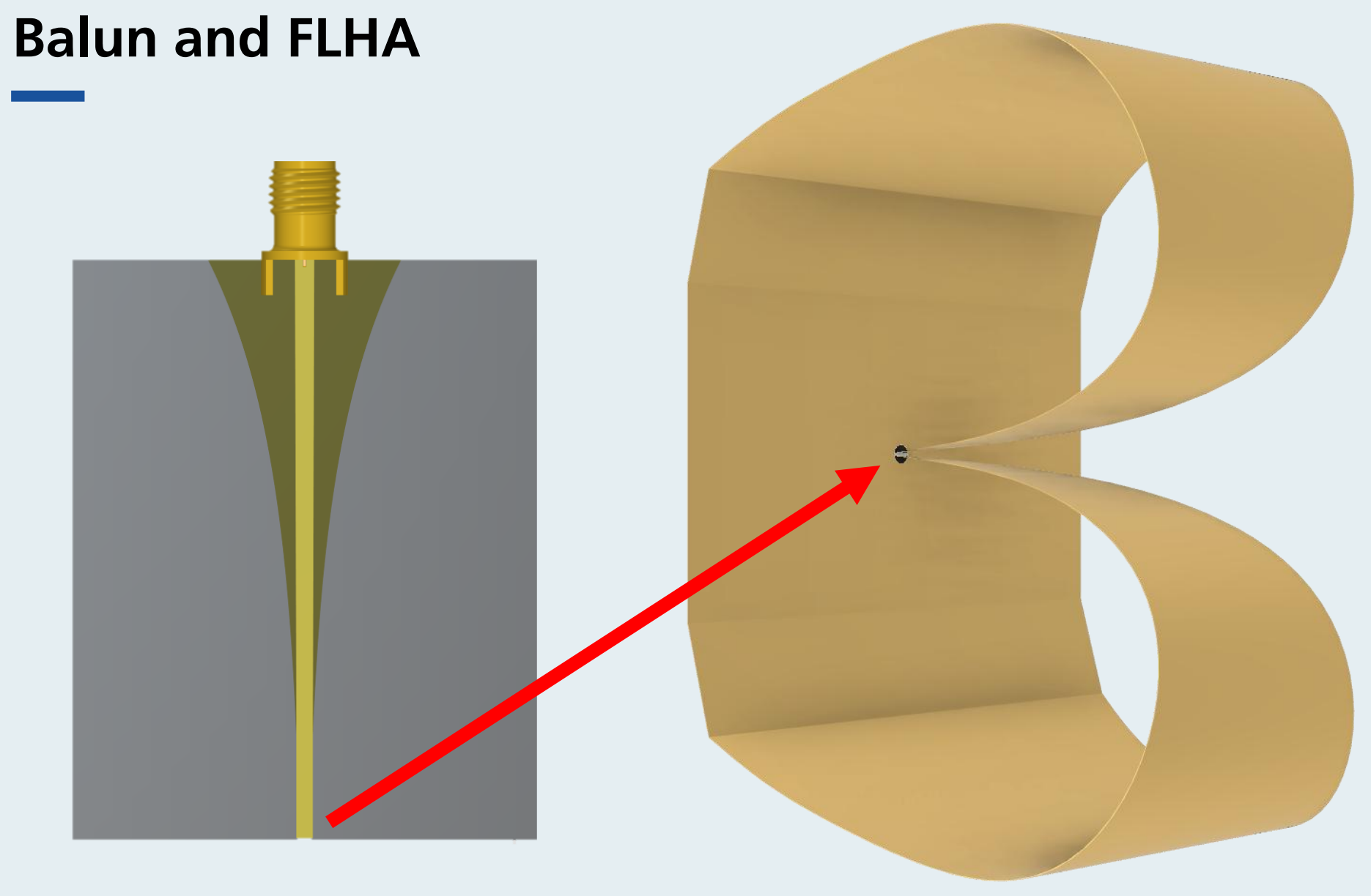
CDM Time domain CDM measurements from the 25 GHz target

Folded Long-Hexagon Antenna

Conventional EMI setups require multiple antennas across bands. To enable single-antenna coverage, a folded long-hexagon antenna (FLHA) with an improved feed derived from a folded rhombic topology was designed for 400 MHz–65 GHz operation.

The FLHA is constructed using a brass long-hexagon with inward-bent wings. A tapered-trace PCB balun converts the 50 Ω unbalanced 2.92 mm connector to a balanced 70 Ω output at the wing tips, improving impedance matching, preserving symmetry, and enhancing launch robustness. The balun sits in a 3D-printed holder that provides mechanical strength, allows proper cable torquing, and facilitates mounting of the antenna.

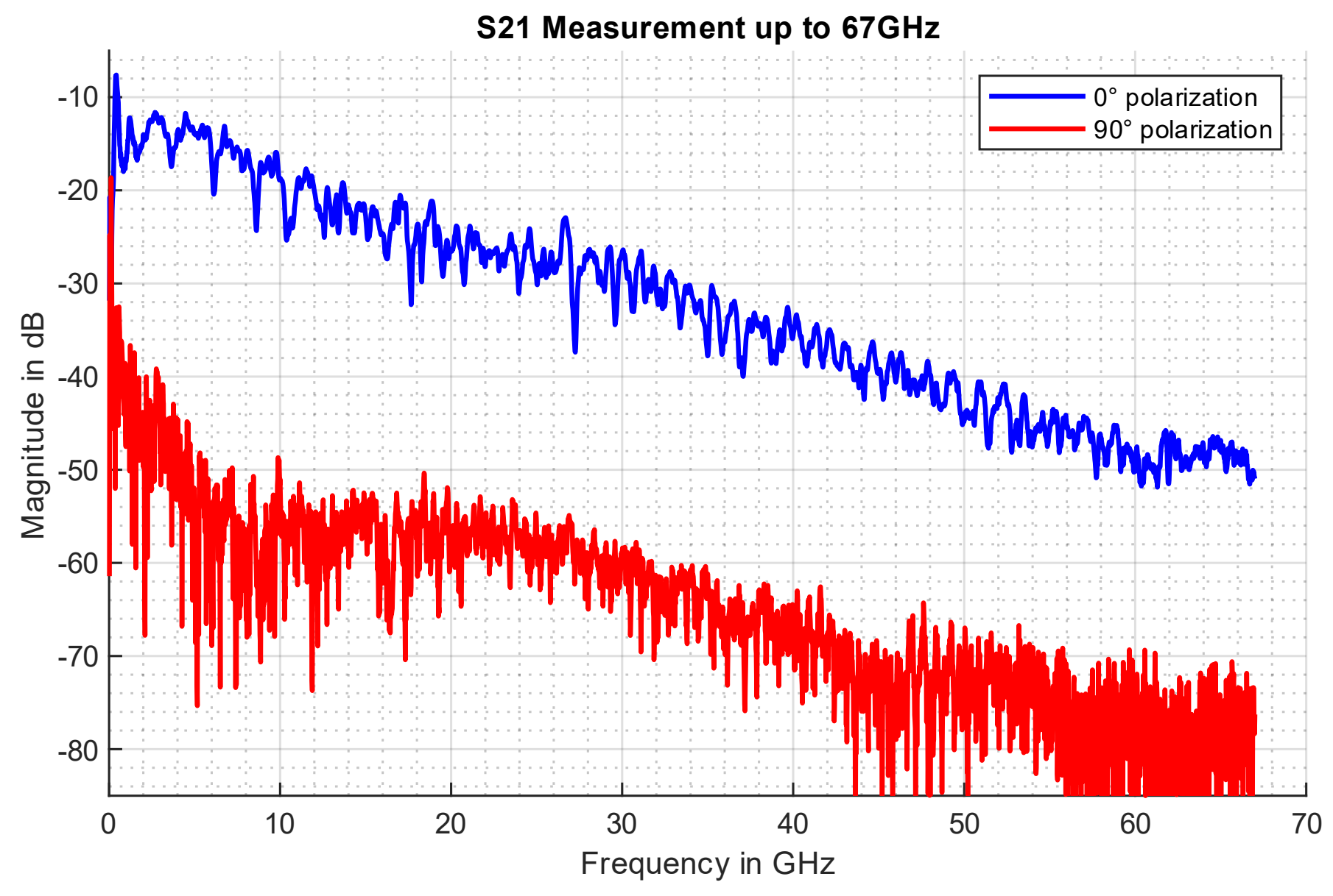
Balun and FLHA



FLHA antenna with balun

CST simulations show good correlation with measurements in the balun region with some deviations at the section interfaces. At the upper band, the antenna becomes electrically large, making full-wave simulation resource-intensive and challenging.

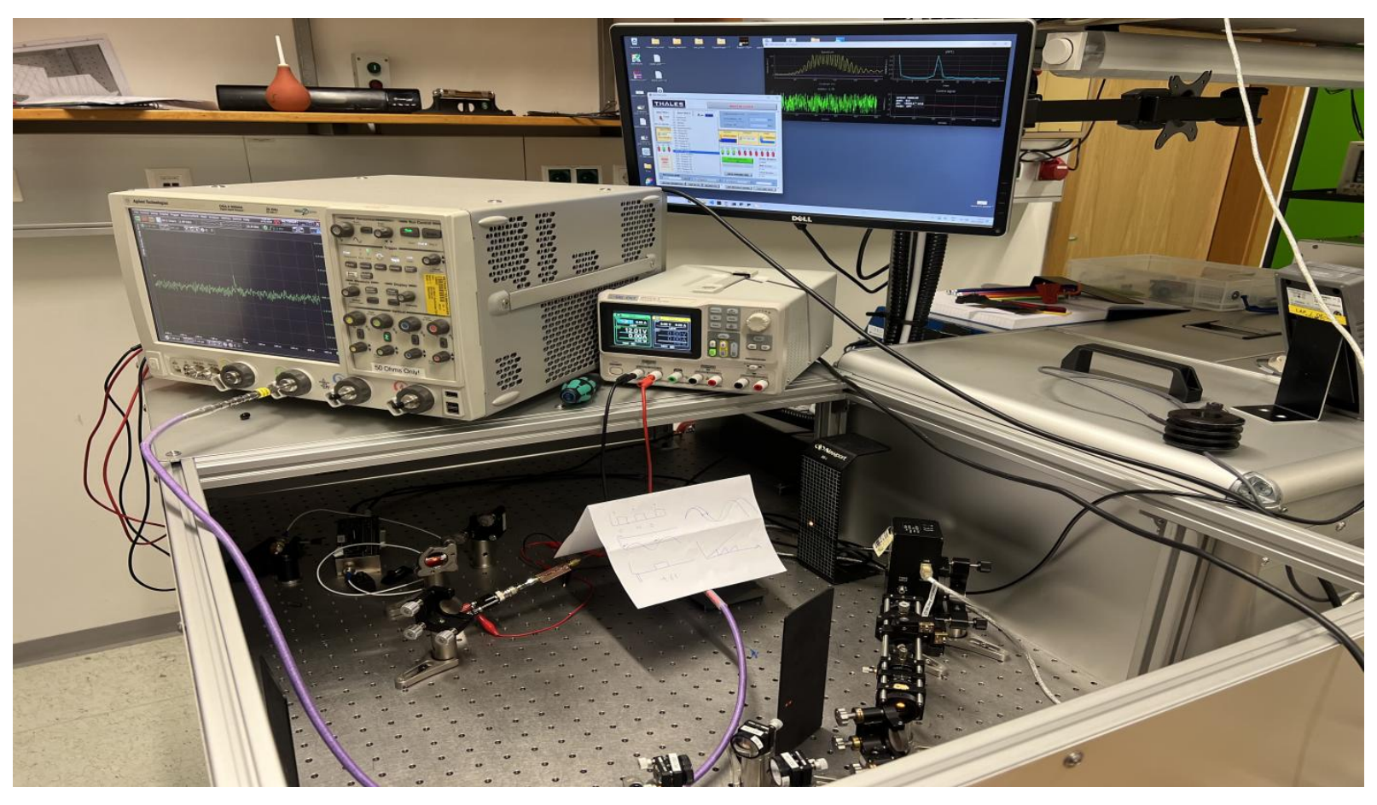
TDR confirms that the balun improves matching, yet residual reflections persist at the wing-tip transition, indicating a need for further transition optimization. Transmission measurements using two identical FLHAs at 70 cm distance show good S21 with an approximately linear roll-off at increasing frequency. When paired with the developed current target, the FLHA demonstrates a good response to CDM discharges, supporting its suitability for broadband ESD sensing.



S21 of two FLHA antennas using in plane and out of plane setups

Fast switches and CDM measurements

The goal is to create pulses with voltages of up to 500 V and rise times of 10 ps. An experimental study was performed to investigate advanced switching concepts for Charged Device Model (CDM) pulse generation using Transmission Line Pulse (TLP) methodologies. Several high-speed switching technologies are investigated, including HG reed switches, RF relays operated under dry conditions and with Galinstan-modified contacts. Furthermore, we are testing laser-triggered GaN-based switches and optically induced switches in air, as well as an RF power amplifier driven by an arbitrary waveform generator (investigated by FMFT). The competing solutions will be optimized, after which a decision will be made on the most suitable solution for CCTLP testing of the ESD robustness of chiplets. The primary objective was to assess pulse shape fidelity and repeatability, particularly in regard too rise time performance under CDM-relevant stress conditions. Picosecond-range rise-time waveforms were achieved with 67 GHz RF relays in dry conditions, which are suitable for advanced CDM emulation; however, pulse stability remains a challenge.



Optically induced switch test setup

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Additional information

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