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Development and Calibration of a Low-cost AESA Module for Weather Sensing at X-band

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Phased Array Radars (PAR) are based on Active Electronically Scanned Array (AESA) antenna apertures enabling nearly instantaneous beam steering. Being not constrained by the inertial steering of mechanical parts, only the electronics settling time acts as a limiting factor, leading to a beam repositioning latency ranging around just a few microseconds. AESA technologies clearly bear potential to reach the goal of providing volumetric weather maps with a faster update time and therefore contribute to improving forecasting accuracy.
Crucial for the actual instantiation of this technology is the development and validation of engineered solutions suitable to originate a data quality similar to their mechanically-steered counterparts while targeting reduction of ownership cost.
Favorably, technological breakthroughs leading to increased functional integration on dice can finally empower electronic designs requiring a drastically reduced board surface. A compact PCB layout with a lower number of layers, tracks and parts count is an essential condition for streamlined assemblies. Additionally, inexpensive FPGAs and related COTS ICs have been found capable to generate control signals with sufficient timing accuracy and dynamic to drive the core AESA ICs like beamformers and transceivers.
An AESA front-end capable of steering up to four channels, the so-called ARM (Active Row Module), has been developed to ensure actual feasibility and evaluate the achieved performance.
Central for reaching the required data quality by means of cross-polarimetric discrimination in excess of 30 dB, a specialized antenna design based on feed-probe rotation has been validated.
Furthermore, to ensure compliancy of the aperture radiation diagram at steering conditions (namely, sidelobe levels and similarity of beam aperture across polarizations) an automated calibration methodology has been developed to compensate for chipsets and board specific imbalances.
Similarly to fully-fledged AESA implementations featuring multiple digital channels, actual radiation performance thoroughly depends on array calibration. However, while digital architectures allow for precise adjustments of the radiated power per each channel (via controlling of DACs and potentially per each radiator), the same does not hold true for single-channel analog beamformers, where analog multiport networks excite transmitting ICs and combine the received echo. Originating from the cost-compromised nature of analog beamforming architectures, an additional source of complexity therefore requires proper addressing via a calibration process relying on ICs characterization and selection of the most appropriate steering states per each hardware implementation.
Initial results show suitability of properly calibrated analog beamformers for the generation of polarimetric weather products.

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