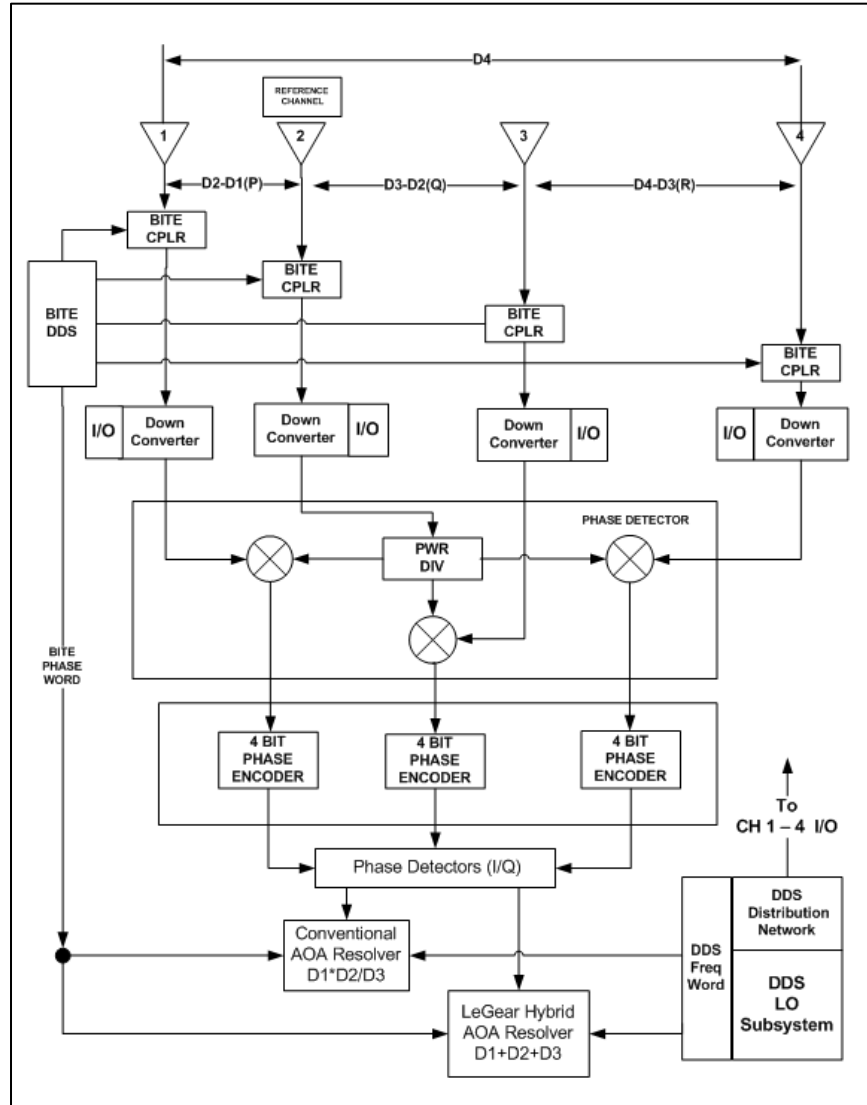


**RF Interferometer
AOA Resolvers
Past and Present
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Abstract

This paper examines how RF Interferometer angle-of-arrival (AOA) resolvers determine AOA accuracy across the spatial field of view. Using the spacing term $\lambda / (2\pi D \cos(\text{AOA}))$ as the foundation, the analysis shows how individual baselines contribute to the phase-slope behavior that produces the characteristic accuracy curve. A ratio-based resolver using $D1 \cdot D2 / D3$ highlights the effects of removing numerator baselines, while a hybrid summation method demonstrates how combined spacing contributions maintain stable AOA estimation even when one baseline is disabled. The accompanying block diagram illustrates the signal flow from RF inputs to phase detectors, to the AOA resolver blocks.



Typical block diagram showing the signal flow to the AOA resolvers

DOA / AOA Disclaimer

All direction-of-arrival (DOA) and angle-of-arrival (AOA) results presented in this paper are derived from analytic spacing expressions and resolver-level calculations. The accuracy curves reflect the geometric behavior of the D1, D2, and D3 baselines and the resolver structures used to combine their phase measurements. No hardware measurements, empirical DOA/AOA performance data, or calibrated system results are included. The figures illustrate expected behavior based solely on baseline spacing and resolver method, and are not intended to represent tested or certified operational accuracy.

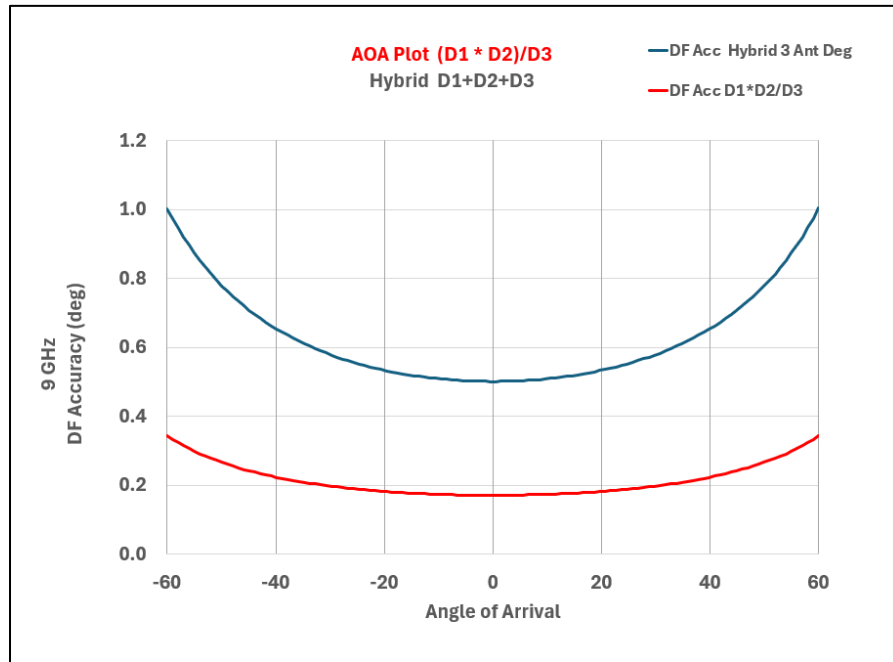


Figure 1

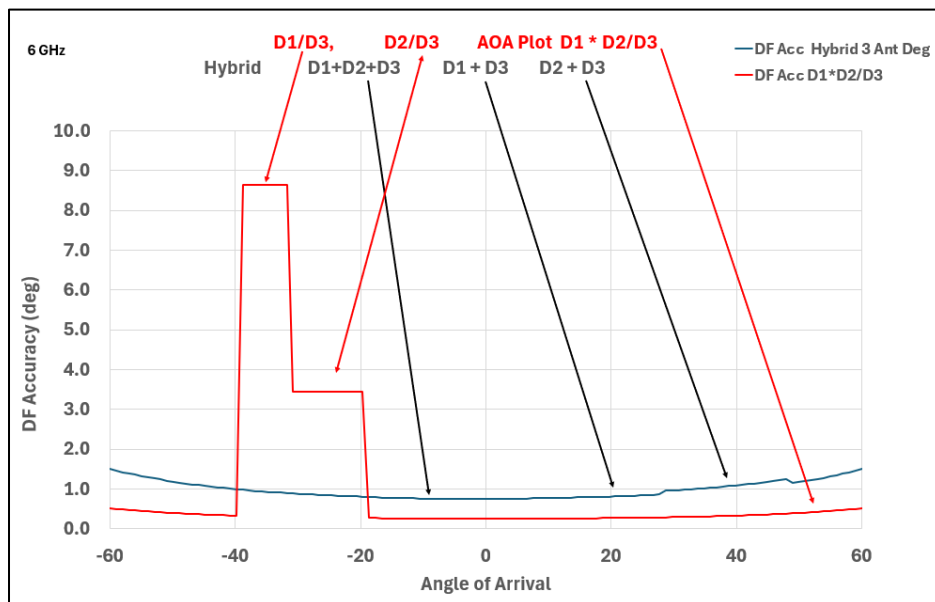


Figure 2

Appendix Modern AOA Resolver Architecture

Introduction

This appendix presents the modern architectural elements that extend classical interferometer-based AOA resolvers into high-accuracy, wideband, multi-baseline systems. While the main paper traces the historical development of fractional and hybrid methods, the material here documents the contemporary techniques—mathematical, digital, and physical—that enable present-day resolver performance. These enhancements include improved baseline-combination strategies, real-time software-based error monitoring, frequency-anchored ADC scaling, hardware symmetry reinforced by chamber-derived profiling, and parallel hardware/software resolver comparison for DOA integrity. Together, they form a unified architecture that preserves accuracy across operating conditions and represents the current state of the art in AOA resolver design.

A practical implementation mounts the four identical RF-to-IF converter LRUs on a common ground plane. This suggestion is not a mechanical design, but an architectural indication of how symmetry, uniform thermal behavior, and consistent RF return paths can be maintained while preserving the modular advantage of replacing a single converter without disturbing the remaining channels.

Fractional and Hybrid Resolver Behavior

Modern AOA resolver performance begins with how baseline spacing information is used. The fractional resolver isolates the geometric influence of individual baselines by forming ratios such as $D1/D3$ or $D2/D3$. When one numerator baseline is removed, the accuracy curve shifts accordingly, revealing how each spacing contributes to the estimate. This relationship-based method sharpens accuracy near boresight but becomes more sensitive when any contributing baseline weakens or drops out.

The hybrid resolver merges all spacing-dependent contributions before computing the angle. If one baseline is disabled, the calculation continues normally; accuracy decreases, but the curve remains smooth because the remaining baselines still contribute. This combined-response approach maintains stable behavior across the field of view, especially toward angular limits where individual baseline influence diminishes. Both methods rely on the same underlying spacing behavior, but their different combination strategies produce the distinct accuracy characteristics shown in the plots.

Parallel Hardware/Software AOA Error Monitoring

A contemporary extension to interferometer processing uses a software-based AOA resolver operating in coincidence with the hardware resolver. The four-channel RF-to-IF downconverters are implemented as individual LRUs, each physically identical in internal component mounting and electrical length. In the modern configuration, these LRUs are mounted together on a common ground plane, ensuring uniform thermal behavior, consistent RF return paths, and stable mechanical alignment.

Using individual LRUs also provides practical cost savings. When a converter chain drifts, fails, or degrades, you can replace the defective module directly without removing or rebuilding the entire assembly.

This modularity reduces maintenance time, lowers lifecycle cost, and keeps the resolver architecture aligned with field-service realities while preserving the symmetry required for high-accuracy AOA performance.

Anechoic-chamber calibration removes any residual amplitude or phase variance and produces per-channel correction terms. The hardware resolver applies these corrections and also stores them in the software model as channel-specific lookup tables. During operation, the hardware and software resolvers run in parallel from the same digitized IF data stream. The software model implements the same underlying AOA algorithm but with higher numerical precision and full use of the calibration LUTs, allowing it to serve as an independent reference solution.

Real-time comparison of hardware and software DOA estimates provides an effective integrity monitor: large deviations, branch-selection errors, or ambiguity faults in the hardware resolver are immediately detectable. Because the software model explicitly incorporates calibrated channel variances, any gross hardware anomaly—such as drift in one LRU, connector degradation, or sudden gain/phase discontinuity—appears as a divergence between the two resolvers. This parallel-resolver method transforms calibration from a static factory process into continuous performance tracking, enabling early drift detection and preserving high-accuracy AOA performance throughout the system's life.

LeGear Frequency-Anchored ADC Scaling

Wideband operation introduces another challenge: the mid-phase detector's slope increases with frequency, risking ADC window overrun. The LeGear resolver addresses this by using a DDS-generated frequency word to compute a compression factor applied to the detector waveform before digitization. This keeps the waveform within the ADC's dynamic range without clipping or wrap distortion. After conversion, the FPGA applies the inverse expansion factor, restoring the correct geometric slope before mid-phase extraction.

Paired with the parallel AOA reference model, this DDS-anchored scaling loop adds a second layer of stability. The scaling preserves geometric slope across the band, while the parallel model identifies slow drift or bias. Together, they form a resolver architecture that maintains accuracy under wideband operation, hardware aging, and environmental variation.

Hardware Symmetry and Chamber-Derived Profiling

Physical symmetry is essential for predictable resolver behavior. In the modular architecture, the four RF-to-IF downconverter chains are implemented as **individual LRU modules**, each built with identical internal component geometry and identical RF path length.

All four LRUs are **mounted on a common ground plane**, ensuring uniform dielectric loading, thermal behavior, and RF return paths across the assembly. This approach preserves channel-to-channel symmetry while providing a practical maintenance advantage: a defective converter can be replaced individually without disturbing the remaining channels or removing the entire assembly.

A comprehensive chamber profile—mapping phase, amplitude, and angle across the band—anchors this symmetry. Loading the profile into system memory frees the FPGA from computing static corrections, allowing it to focus on real-time DDS-based scaling, radian-accurate vector math, and asynchronous scan scheduling for the nested Goodwin geometries.

With modular symmetry and chamber profiling combined, the receiver behaves like four matched lengths of coax, enabling the resolver to operate at its theoretical limits while retaining the life cycle cost benefits of LRU-based construction.