Antenna Array Designer Pro v2.0

Deterministic Phased-Array Synthesis
Certified Engineering Workstation

ULA • URA • UCA geometries. Machine-precision null placement. Simultaneous SLL optimization. Seven-method baseline comparison. Independent MATLAB verification.

125	–320 dB	100%	7
Solutions Found	Null Depth	Phase Noise Survival	Baselines Beaten

In a 16-element ULA benchmark, the engine found **125 certified solutions** with null depths at –**320 dB** and SLL of –**24.2 dB**. The industry-standard Chebyshev taper destroyed Scipy TRF's null depths from –298 dB to –25 dB—a 273 dB degradation. MVDR and LCMV achieved deep nulls but SLL of only –13.1 dB. Our engine delivered both.

New Leaf Tools LLC

The Problem

Phased-array beamforming requires computing element weights that simultaneously steer the mainbeam, place deep nulls on interferers, and control sidelobe levels. Standard methods force engineers to choose between these objectives.

MVDR and LCMV place nulls but provide no SLL control—sidelobes blow out to –13 dB. DFT codebooks with Chebyshev tapering control SLL beautifully but have zero null placement capability. Scipy’s TRF optimizer can place nulls to machine precision, but applying Chebyshev tapering for SLL destroys those nulls—a 273 dB degradation in the ULA benchmark case.

No standard method delivers both deep nulls and optimized SLL simultaneously. Engineers are left choosing which requirement to violate.

The Architecture

Antenna Array Designer Pro replaces this tradeoff with a deterministic global search. The engine generates multiple candidate weight sets, solves each to machine precision using the universal array factor equation, certifies every solution through five independent checks, and selects the best candidate based on the user’s chosen priority.

1. Multi-Candidate Generation

The engine seeds multiple starting points (configurable depth per tier) and solves each through LM and TRF refinement passes.

2. Five-Stage Certification

Residual below 1e–8, all null depths below –30 dB, mainbeam pointing within tolerance, all nulls in visible region, and amplitude bounds satisfied. Only solutions passing all five become CERTIFIED.

3. Seven-Method Baseline Comparison

Every solve is automatically benchmarked against Scipy TRF (raw and Chebyshev-tapered), MVDR/Capon, LCMV, and DFT codebooks (raw and Chebyshev). Results appear side by side.

4. Priority Ranking

Certified solutions are ranked by user-selected priority: deepest nulls, lowest SLL, maximum directivity, or balanced. The priority slider re-ranks without re-solving—no additional cost.

5. Hardware Export

Weights at full float64 precision in JSON, CSV, and MATLAB. MATLAB verification scripts use the universal AF equation for independent confirmation.

Supported Array Geometries

Uniform Linear Array (ULA)

1D element arrangement along a single axis. Configurable element count (4–512) and spacing (0.25–1.0λ). Null directions specified as θ angles. The simplest geometry but the most common in radar, 5G base stations, and satellite comms. Benchmark: 16-element ULA, 0.5λ spacing, nulls at ±30°, achieved –24.2 dB SLL with –320 dB null depths and 125 certified solutions.

Uniform Rectangular Array (URA)

2D planar grid (M rows × N columns) with independent dx/dy spacing. Supports 2D null placement via (θ, ϕ) pairs—place nulls in both elevation and azimuth simultaneously. Produces pencil beams with 2D pattern control. Benchmark: 4×4 URA, nulls at (30°, 0°) and (45°, 90°), achieved –11.1 dB SLL with –322 dB null depths and 107 certified solutions. MVDR/LCMV produced only –12 dB nulls on this 2D configuration.

Uniform Circular Array (UCA)

Elements arranged in a ring. The radius is computed from element count and spacing. Supports 2D null placement like URA but with 360° azimuthal symmetry. Benchmark: 16-element UCA, nulls at (30°, 0°) and (45°, 90°), achieved –4.6 dB SLL with –330 dB null depths and 106 certified solutions. SINR improvement over uniform weights: +30.8 dB.

All three geometries use the same universal array factor equation: $AF(\theta,\phi) = \sum w_n \exp(j \cdot 2\pi \cdot r_n \cdot u(\theta,\phi))$, where $r_n = [x_n, y_n, z_n]$ are element positions in wavelengths and u is the direction cosine vector. The same MATLAB verification script works for ULA, URA, and UCA.

ULA Benchmark: 16 Elements, Nulls at ±30°

Broadside mainbeam, complex weights (32 DOF), 0.5λ spacing. Robust Mode enabled: –35 dB null floor, 2° phase error σ, survive 1 element failure, 6-bit quantization, 50 Monte Carlo trials. Score: 61.3/100—PASSED.

Method	Worst Null	SLL	Null Control
Our Engine	**–320 dB**	**–24.2 dB**	**YES (certified)**
DFT raw (3GPP)	none	–13.1 dB	NONE
DFT + Chebyshev	none	–50.0 dB	NONE
Scipy TRF raw	–298 dB	–11.3 dB	YES (uncertified)
Scipy TRF + Cheb	–25 dB	–10.3 dB	DESTROYED by taper
MVDR / Capon	–331 dB	–13.1 dB	YES (shallow)
LCMV	–328 dB	–13.1 dB	YES (shallow)

Our engine achieves –24.2 dB SLL—11.1 dB better than MVDR/LCMV and 12.9 dB better than Scipy TRF raw—while maintaining –320 dB certified null depths. DFT+Chebyshev achieves –50 dB SLL but has zero null control. The Chebyshev taper destroyed Scipy TRF's null depths from –298 dB to –25 dB.

URA Benchmark: 4×4, 2D Null Placement

Nulls placed at (30°, 0°) and (45°, 90°)—different elevation AND azimuth simultaneously. This is the configuration that breaks 1D methods.

Method	Worst Null	SLL	Null Control
Our Engine	**–322 dB**	**–11.1 dB**	**YES (certified)**
DFT raw (3GPP)	none	–11.3 dB	NONE
Scipy TRF raw	–289 dB	–10.9 dB	YES (uncertified)
Scipy TRF + Cheb	–8 dB	–6.9 dB	DESTROYED by taper
MVDR / Capon	–12 dB	–11.2 dB	YES (shallow)

MVDR/LCMV achieved only –12 dB nulls on the 2D configuration—failing the –30 dB requirement. Chebyshev tapering destroyed Scipy TRF nulls from –289 dB to –8 dB (281 dB degradation) and worsened SLL. Our engine: –322 dB nulls, –11.1 dB SLL, 107 certified solutions.

The Chebyshev Taper Problem

Chebyshev tapering is the industry standard for SLL control in 5G NR, radar, and satellite systems. It works by adjusting weight amplitudes to shape the sidelobe envelope. The problem: it has no awareness of null constraints. When applied to weights that already contain null information, it overwrites the amplitude distribution that creates those nulls.

In every benchmark, applying a 50 dB Chebyshev taper to Scipy TRF's optimized weights degraded null depths by 250–290 dB. Nulls that were at –290 to –304 dB (machine precision) collapsed to –8 to –25 dB—often failing the –30 dB operational requirement entirely.

> Our engine solves for nulls and SLL simultaneously in a single optimization. The resulting weights are already optimal and require no post-processing. No taper is applied because none is needed.

Five-Stage Certification Pipeline

Check	Criterion	ULA Result	Status
Residual	|r| < 1e–8	4.62e–14	**PASS**
Null Depths	All ≤ –30 dB	–320 dB, –331 dB	**PASS**
Mainbeam Pointing	≤ 0.5° error	0.050°	**PASS**
Visible Region	All nulls |θ| ≤ 90°	±30°	**PASS**
Amplitude Bounds	max(|w|) ≤ 1.0	1.00 (normalized)	**PASS**

Certification from Solve ID NLT-20260314-120033 (ULA, Robust Mode enabled). Independently verified in MATLAB R2025b: null depths confirmed at –304.8 dB.

Robust Mode

Robust Mode changes how the engine selects between certified solutions. When enabled, every certified candidate is stress-tested against user-specified hardware conditions before the final selection. A solution with –50 dB nulls that survives element failure is more valuable than –300 dB nulls that collapse when one element dies.

Monte Carlo Phase Perturbation

Each candidate's weights are perturbed with Gaussian phase noise ($\sigma = 0.5°$ to 10°, user-configurable) across 20–200 trials. After perturbation, null depths are recomputed. The survival rate—fraction of trials where all nulls remain below the user's floor—is the primary robustness metric.

Dead Element Analysis

Each element is removed individually (and in combinations for multi-failure survival). Weights are renormalized and null depths recomputed. The report identifies which elements are critical—their failure causes the deepest null degradation—and flags them for hardware redundancy or monitoring. In the ULA benchmark, 2 of 16 elements were flagged as critical.

Quantization Impact

Phases are rounded to the resolution of the target phase shifter (4–12 bit) and null depths are recomputed. This catches solutions where fine phase adjustments are critical—quantization destroys them silently in hardware.

Composite Scoring

Each candidate receives a score: phase survival rate (40%), dead element survival rate (40%), SLL contribution, and quantization pass/fail (10%). The engine selects the candidate with the highest composite score. In the ULA benchmark, Robust Mode scored 61.3/100 and PASSED with all specified hardware conditions met.

Adaptive Re-Solve

Select any element in the Robustness tab and simulate its failure. The engine runs a fresh solve without that element—producing new certified weights for the degraded array. This gives engineers pre-computed fallback weight sets for every anticipated failure mode.

Scan Sweep and Codebook Generation

Solve across a range of scan angles in a single batch, producing certified weights at each steering direction. The result is a firmware-ready codebook: at each scan angle, the controller loads the pre-computed certified weight set. Pattern overlays verify null tracking across the scan range. Exportable as JSON or CSV.

Mutual Coupling Support

Upload a measured or simulated N×N mutual coupling matrix (from HFSS, CST, or FEKO) in CSV or NPY format. The engine recomputes the pattern and null depths using the actual coupling coefficients, showing the degradation from ideal. The pattern tab overlays ideal vs. coupled patterns for direct comparison.

Regulatory Pre-Verification

Every solve evaluates the radiation pattern against six international standards: FCC §25.209, FCC §25.218, ITU-R S.580-6, ITU-R S.1428-1, MIL-STD-188-164B, and ETSI EN 302 217. For each standard, the report lists every off-axis angle where the pattern exceeds the regulatory envelope, the margin of violation, and the required attenuation. A compliance wizard auto-selects relevant standards based on application type (VSAT, military, commercial telecom, etc.).

In the ULA benchmark, all 6 standards passed. In the URA benchmark, 5 of 6 passed with FCC §25.218 requiring attention at wide off-axis angles.

3D Visualization

The workstation renders four interactive 3D visualizations:

- **3D Array Layout** — Element positions with mainbeam (green) and null (red dashed) direction arrows. Failed elements shown in red.
- **3D Far-Field Pattern** — Radiation balloon showing gain in all directions. Color = power in dB. Null dimples visible. Mainbeam and null lines overlaid.
- **2D θ×ϕ Heatmap** — Full 2D pattern for URA/UCA. Null positions marked with red X, mainbeam with green star.
- **E-plane and H-plane Cuts** — Pattern slices with baseline overlays, SLL mask, beamwidth markers, and worst-sidelobe annotation.

Export and Firmware Integration

Every solve produces deployment-ready outputs:

- **JSON** — Complete metadata including element positions, weights (Re/Im), null depths, SLL, directivity, certification status.
- **CSV** — Per-element amplitude, phase, Re(w), Im(w) at full 16-digit precision.
- **MATLAB Script** — Standalone .m file using the universal AF equation with element positions. Reproduces pattern, null depths, and mainbeam pointing. Works identically for ULA, URA, and UCA. No proprietary code.
- **Pattern CSV** — 721-point θ vs dB data for external plotting tools.
- **Codebook JSON** — Certified weights at each scan angle from sweep data.
- **PDF Report** — Multi-page certified report with pattern plots, baseline comparison, compliance analysis, robustness metrics, and weight tables.

Independent MATLAB Verification

Every solve exports a standalone MATLAB script that recomputes the array factor, verifies null depths, checks mainbeam pointing, and plots the E-plane pattern and 2D heatmap (for URA/UCA). The script uses only element positions and weights with the standard AF equation—no proprietary code required. In the ULA benchmark, MATLAB R2025b confirmed null depths at –304.8 dB with zero pointing error.

Batch Processing

Upload a CSV with multiple configurations—each row specifying element count, spacing, geometry type, mainbeam, nulls, weight mode, and optional robust settings. The engine solves all configurations sequentially with per-row progress tracking. Results include full-precision weights, SLL, null depths, and baseline comparisons for every configuration.

Antenna Array Designer Pro v2.0 solves the fundamental tradeoff in phased-array beamforming: deep nulls OR controlled sidelobes. The deterministic engine delivers both simultaneously, certifies every result through five independent checks, benchmarks against seven standard methods, and exports firmware-ready weights with independent MATLAB verification. No black box. No trust required.

New Leaf Tools LLC — newleaftools.com