EVALUATION OF HIGH-FREQUENCY SUBSTRATES FOR ANTENNA DESIGNS

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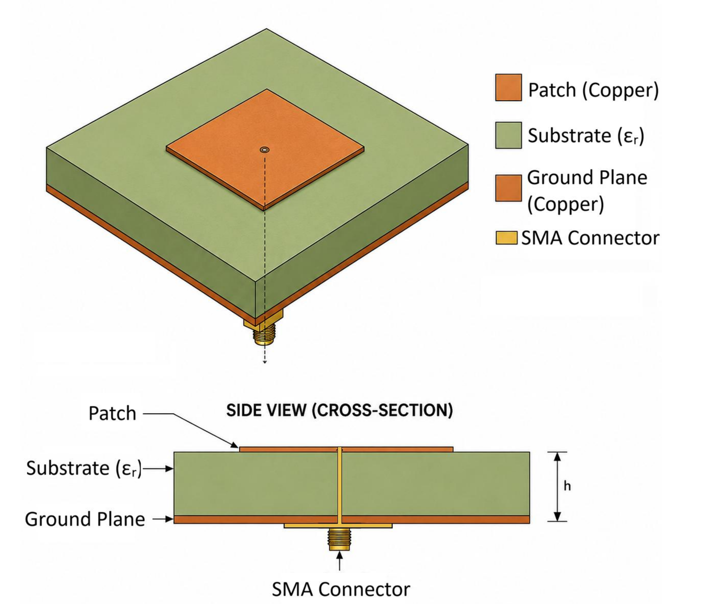
BLUE ORIGIN

Introduction

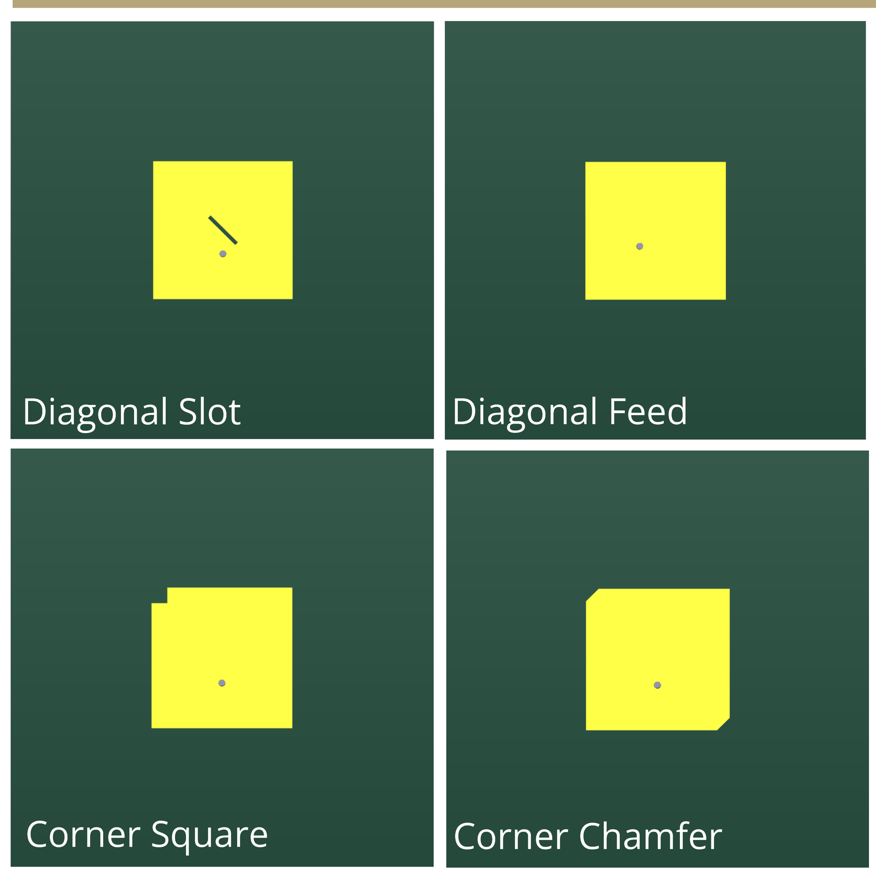
Wireless systems require antennas that balance performance, manufacturability, and cost. RF substrate selection strongly affects bandwidth, gain, efficiency, and circular polarization performance.

Blue Origin is interested in how commercially available RF substrates impact 2.45 GHz patch antennas. **20 circularly polarized patch antennas** were designed and evaluated. The designs span **5 RF substrates** and **4 perturbation geometries**.

How do commercially available RF substrates compare across patch antenna performance, manufacturability, and cost tradeoffs?



Patch Topologies & Design Requirements

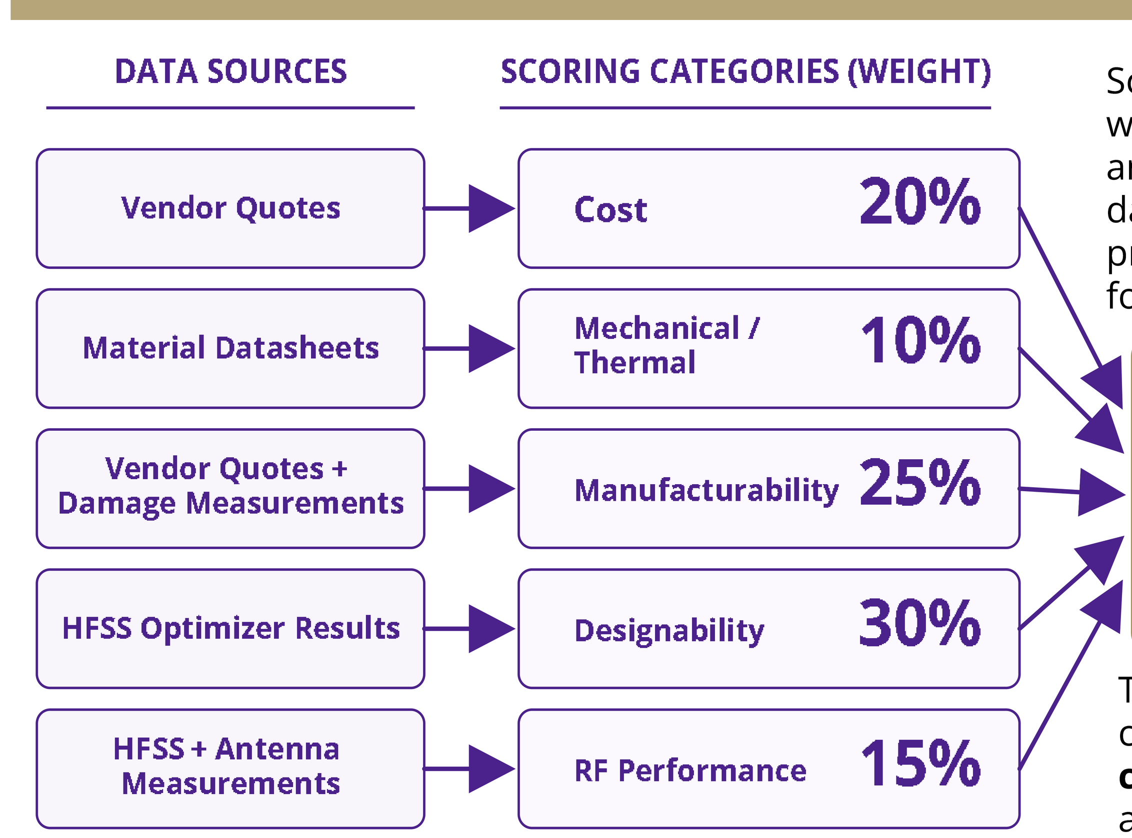


ANTENNA PERFORMANCE SPECIFICATIONS

METRIC	REQUIREMENT
Frequency Band	2.42 – 2.48 GHz
Polarization	Left-Hand Circular
Axial Ratio	< 3 dB at boresight
Boresight Gain	≥ 4 dBic
Coverage	LHCP gain > -12 dBi over hemisphere
Size	≤ 6 in × 6 in
Feed	SMA probe feed

Four circularly polarized patch antenna geometries were evaluated using identical design requirements.

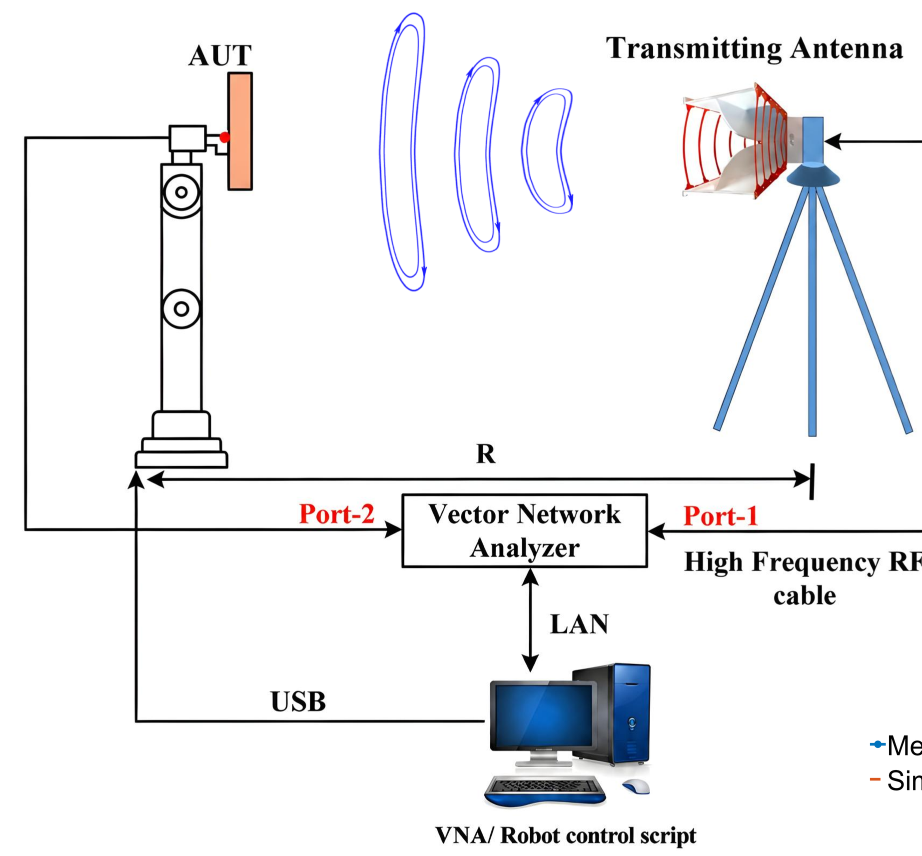
Substrate Scoring Framework

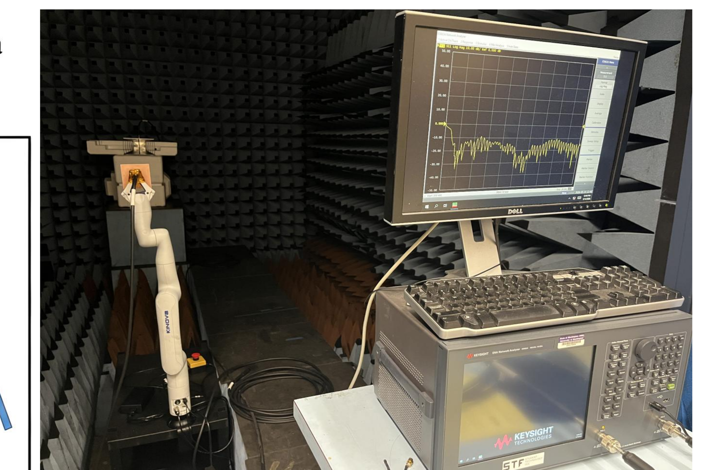


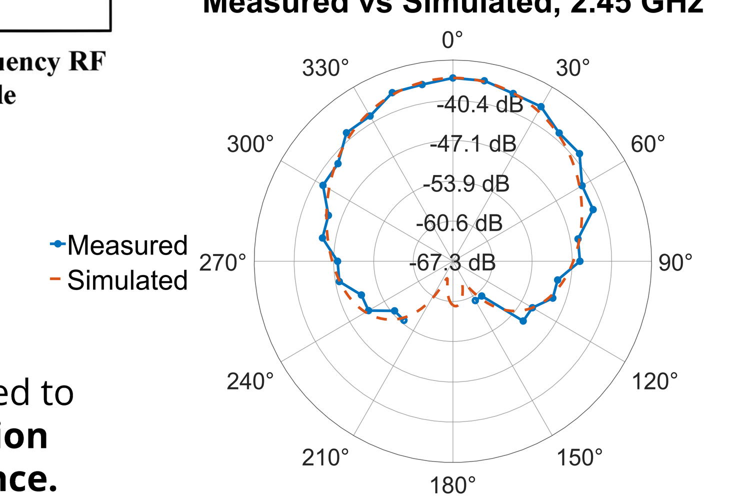
Scoring categories were weighted based on confidence and consistency of collected data. Defined sub-metrics produced normalized 0–5 scores for each category.

The weighted combination of category scores was used to **compare substrate tradeoffs** across performance, manufacturability, and cost.

Measurement Setup





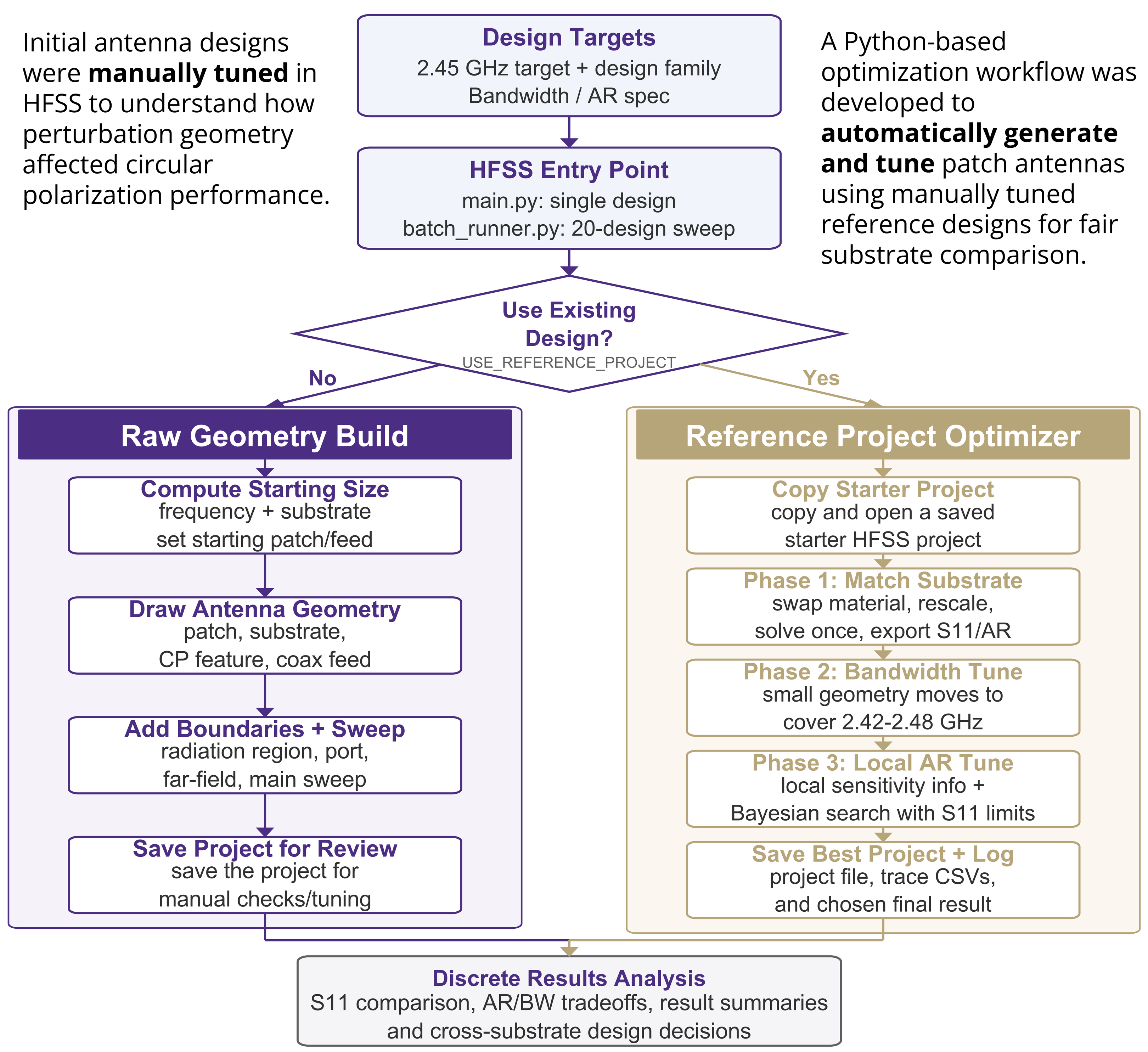


A Kinova robotic arm and Keysight VNA were used to collect antenna measurements including **radiation patterns, S11, axial ratio, and gain performance.**

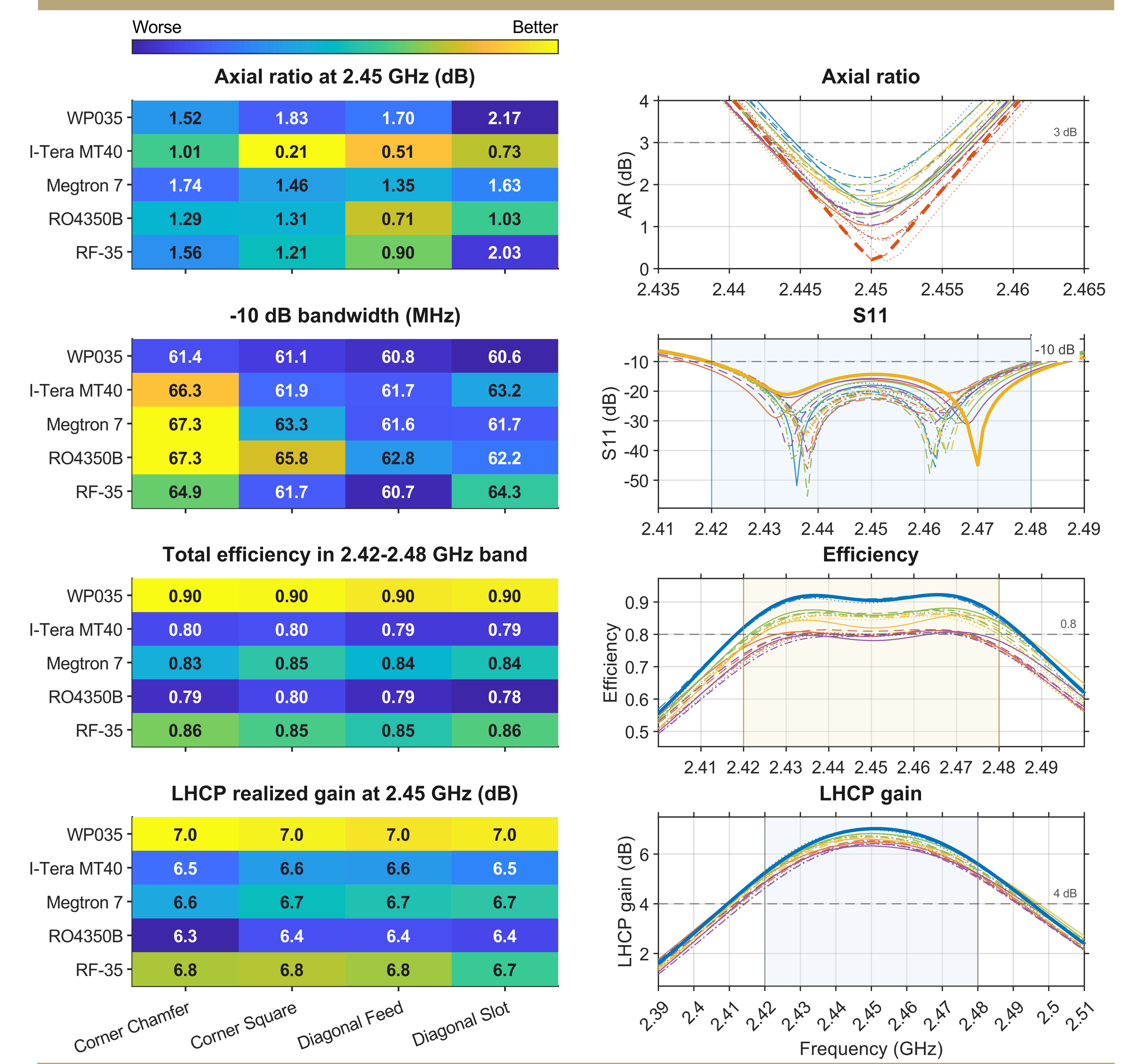
HFSS Design Workflow

Initial antenna designs were **manually tuned** in HFSS to understand how perturbation geometry affected circular polarization performance.

A Python-based optimization workflow was developed to **automatically generate and tune** patch antennas using manually tuned reference designs for fair substrate comparison.



Optimizer Simulation Results



Substrate Score Results

Material	Manufacturer	Designability	Manufacturability	Cost	RF Performance	Mech / Thermal	Final Weighted Score
RO4350B	Rogers	4.0	5.0	5.0	4.5	3.9	4.5
I-Tera MT40	Isola	4.3	4.1	2.6	4.5	3.8	3.9
RF-35	Taconic	4.0	3.4	2.9	1.8	2.9	3.2
Megtron 7	Panasonic	3.9	2.0	2.5	3.1	3.6	3.0
WP035	Garlock	3.9	1.8	1.9	0.0	3.4	2.4

Future Research

The scripts that were developed are reusable across a wide range of RF substrates and antenna design parameters but can be expanded to encompass other parameters such as frequency and substrate thickness. Future work using industry-standard PCB manufacturing processes instead of LPKF milling could provide more consistent and applicable results. Adding more antenna features, such as superstrate layers on top of patch material, may introduce more interesting engineering challenges.

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