Ultra-Wideband Array in PCB for Millimeter-Wave 5G and ISM

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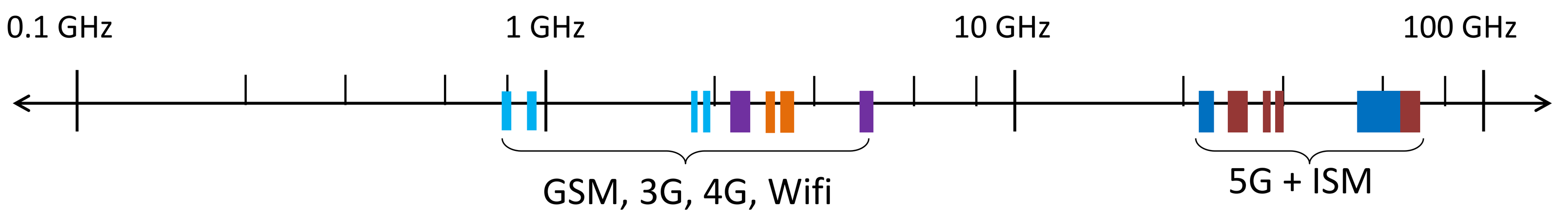
INTRODUCTION

Growing mobile data consumption has prompted the exploration of the millimeter-wave spectrum for large bandwidth, high speed communications. However, the allocated bands are spread across a wide swath of spectrum:

- Fifth generation mobile architecture (5G): 28, 38, 39, 64–71 GHz
- Industrial, Scientific, and Medical bands (ISM): 24, 60 GHz

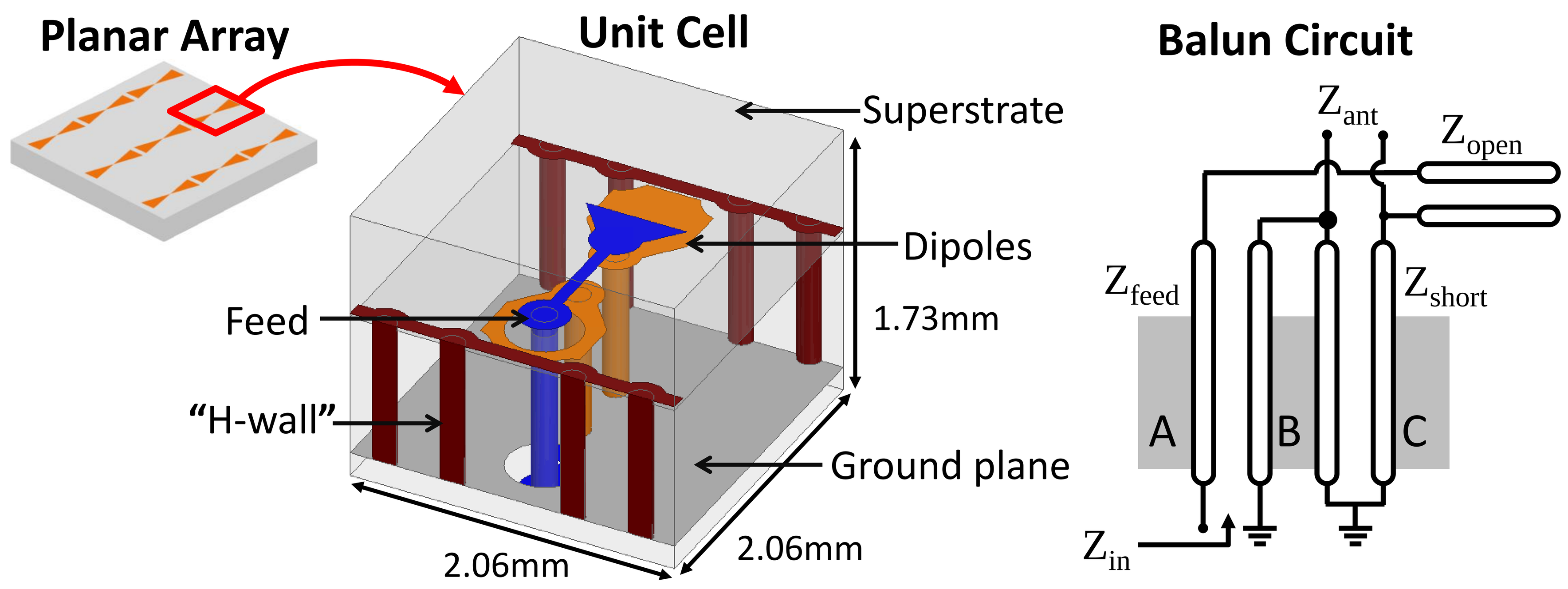
Moreover, high gain phased arrays are required to overcome the significant path loss associated with these frequencies. Further, it is necessary to incorporate several of these applications in a single, small size and low cost platform.

To this end, we have developed a scanning, Ultra-Wideband (UWB) array which covers all 5G, ISM, and other mm-W bands from 24–72 GHz. Critically, this is accomplished using mass-production Printed Circuit Board (PCB) fabrication.



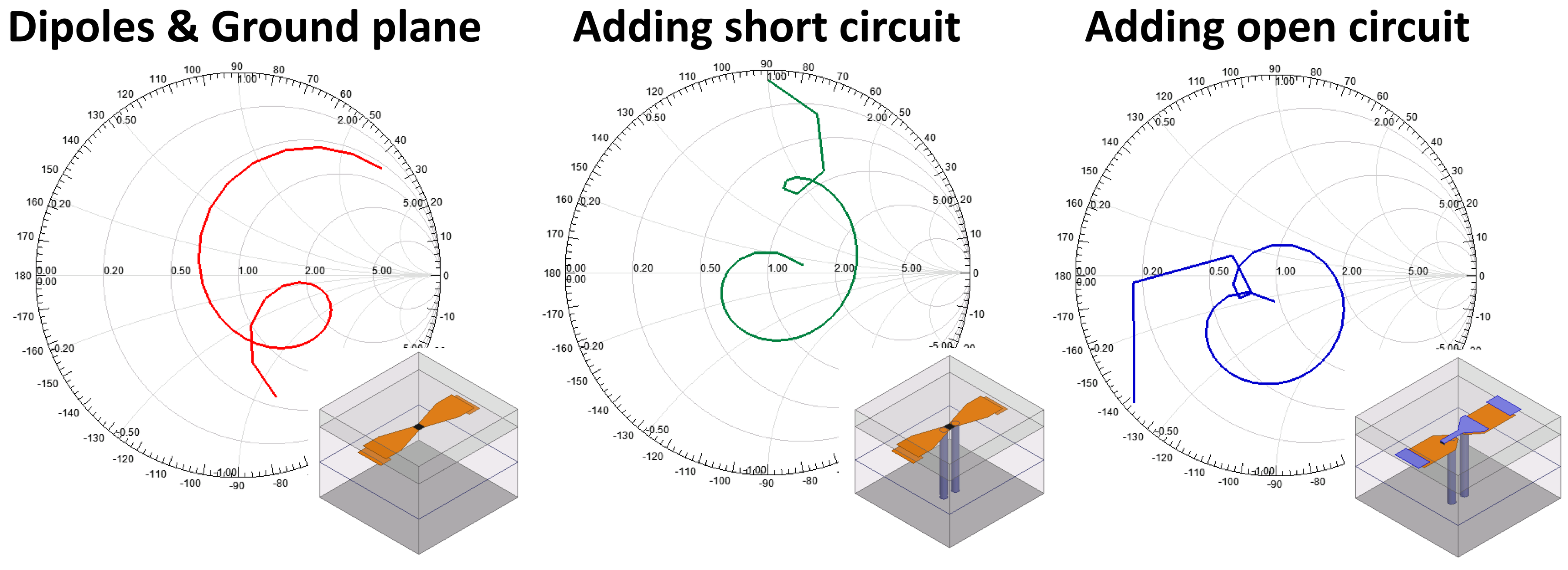
DESIGN

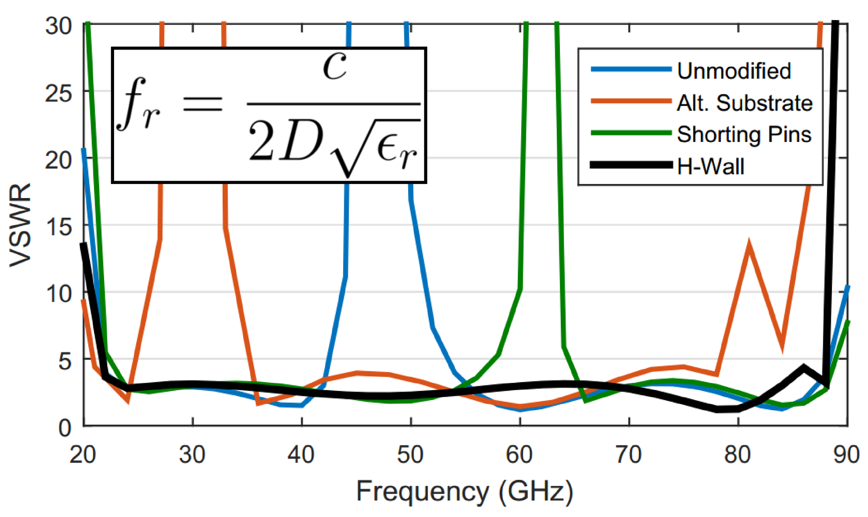
The complete array is fabricated as a single PCB. Tightly coupled dipoles are fed from an integrated balun, implemented using vias. Elements are fed from an unbalanced transmission line beneath the groundplane.



The impact of the groundplane and integrated balun is shown, demonstrating how the balun serves to increase bandwidth as an additional matching stage:

Dipoles & Ground plane | **Adding short circuit** | **Adding open circuit**

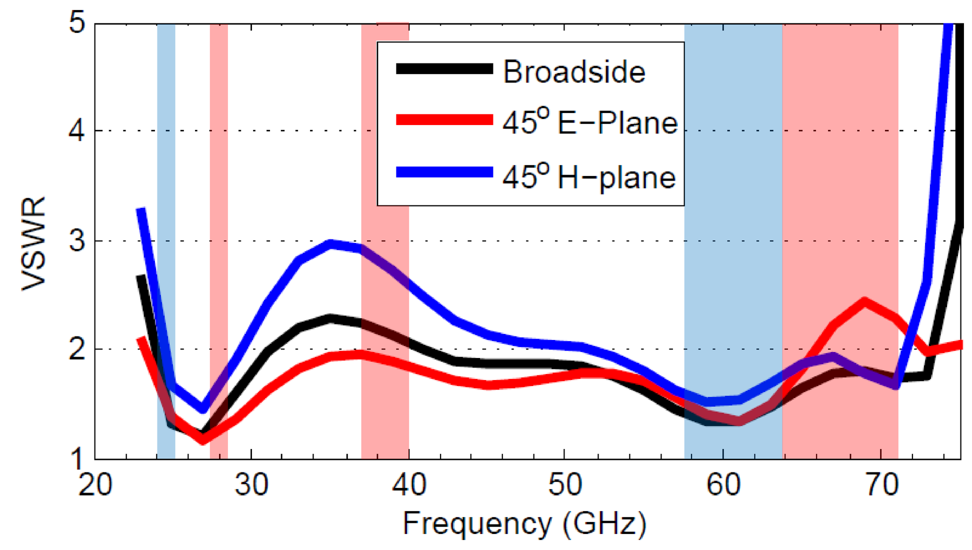




"H-Wall" for Resonance Mitigation

Destructive resonances occur between neighboring elements in the substrate. These are mitigated with a conducting via fence perpendicular to the dipoles.

SIMULATION



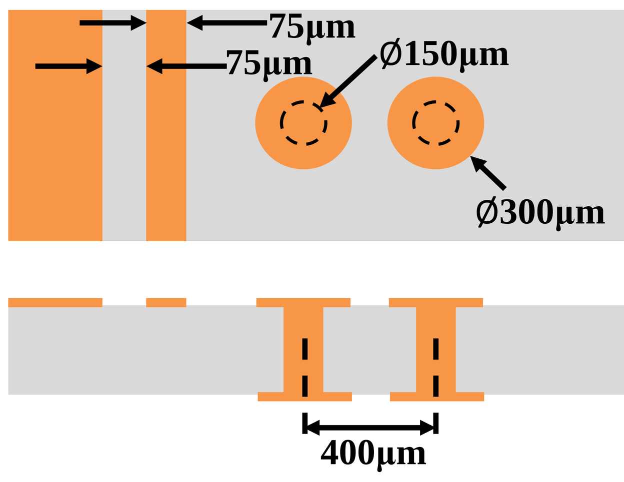
Final Design Performance

- ISM and 5G bands highlighted
- 24–71 GHz bandwidth
- VSWR < 2.2 Broadside, E-Plane
- VSWR < 3 H-Plane
- Polarization purity > 50dB

FABRICATION

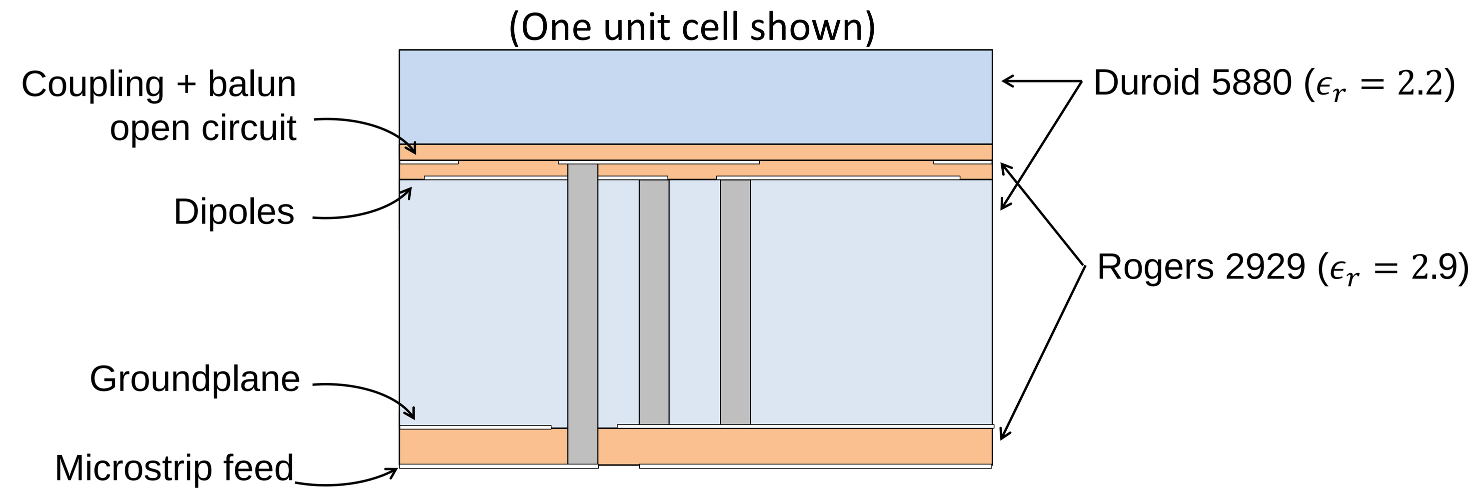
The most challenging aspect of the design is accounting for the fabrication limitations inherent in the PCB process. This includes the copper trace width and spacing, and particularly the via separation, all of which are a significant fraction of a wavelength at the design frequency.

PCB Fabrication Limits:



The design consists of four copper layers, and four dielectric substrates (substrates in blue, bond layers in orange). A 5x5 prototype array is being fabricated through commercial vendors.

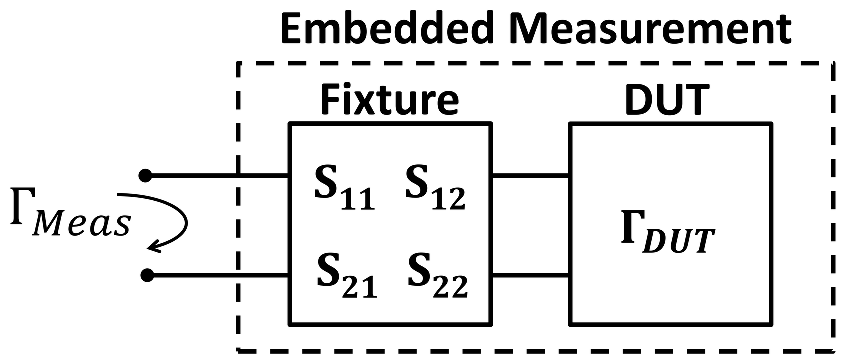
Fabrication Stack-Up:
(One unit cell shown)



DE-EMBEDDED MEASUREMENTS

At these frequencies, a test fixture is required to interface with the VNA. However, this fixture is large and significantly distorts the characterization of the antenna. Thus an isolated fixture is characterized and correspondingly removed from the embedded measurement.

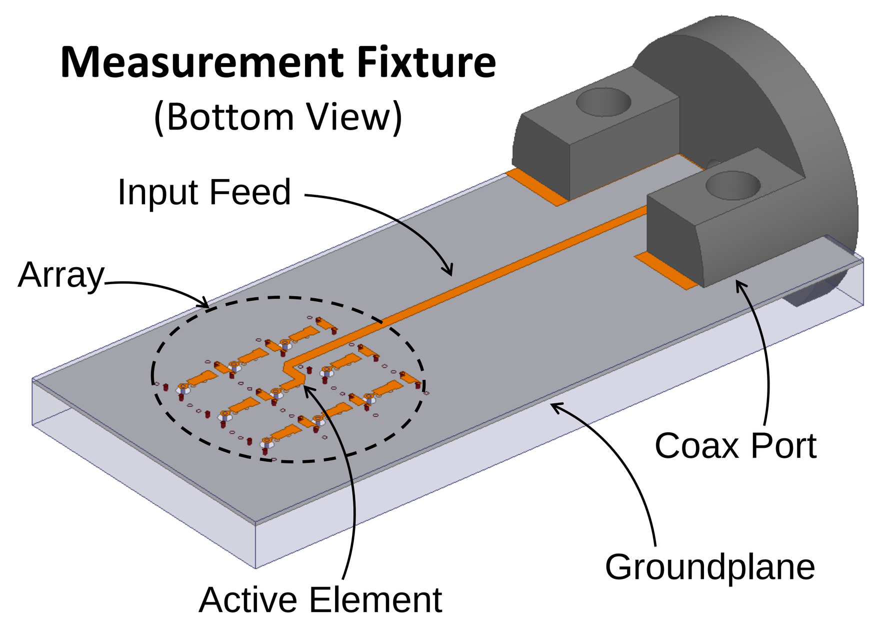
Embedded Measurement



$$\Gamma_{Meas} = S_{11} + \frac{S_{12}S_{21}\Gamma_{DUT}}{1 - S_{22}\Gamma_{DUT}}$$

$$\Gamma_{DUT} = \frac{S_{11} - \Gamma_{Meas}}{S_{11}S_{22} - S_{12}S_{21} - S_{22}\Gamma_{Meas}}$$

Measurement Fixture
(Bottom View)



CONCLUSIONS

UWB phased arrays are needed to enable emerging communications and sensing applications on small platforms. Mass-market adoption requires low-cost PCB fabrication.

We demonstrated an array design supporting all mm-W 5G and ISM bands, compatible with PCB processes. This array is in fabrication and will be measured to validate the concept.

ElectroScience LABORATORY

THE OHIO STATE UNIVERSITY

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