Ultra-Wideband Phased Array 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

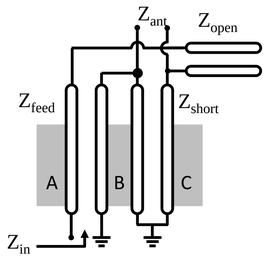
Moreover, high gain phased arrays are required to overcome the significant path loss associated with these frequencies. Further, it is necessary to incorporate several of these applications in a single, small size and low cost platform.

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.

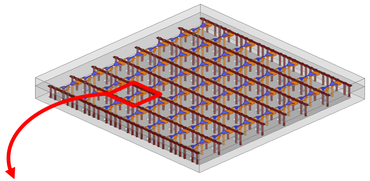
DESIGN

Compared to previous work (<18 GHz), the primary challenge at 70 GHz is realizing a wide range of impedances in the balun, while maintaining fabrication tolerances, and avoiding spurious resonances. The array elements are designed co-planar to the fabrication panel, such that the complete array can be fabricated as a single PCB. The coupled dipoles are paired with an integrated balun, implemented using vias through the panel. Elements are fed from an unbalanced transmission line, beneath the groundplane.

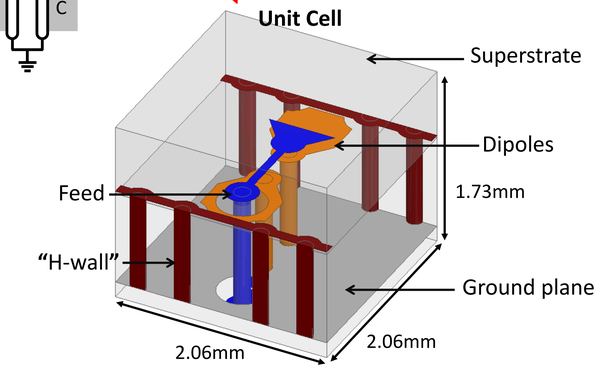
Balun Circuit



Sample Array



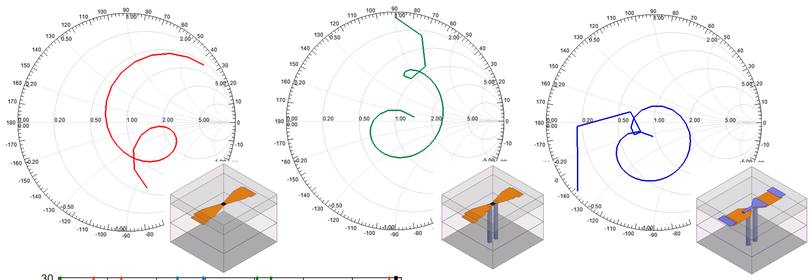
Unit Cell

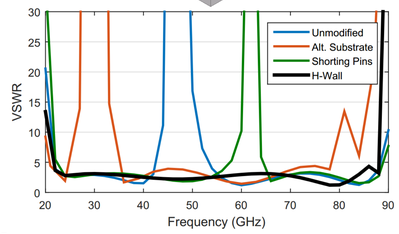


SIMULATION

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

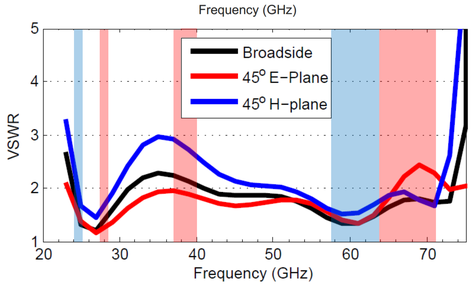
Dipoles & Ground plane | **Adding short circuit** | **Adding open circuit**





"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.



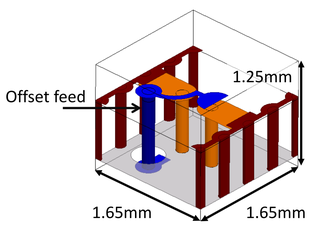
Final Design Performance

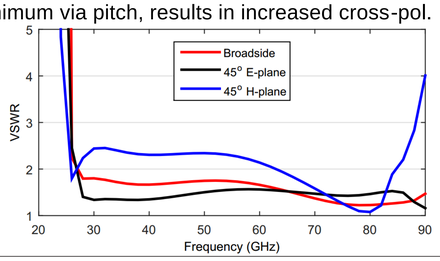
- ISM and 5G bands highlighted
- VSWR < 2.2 Broadside, E-Plane
- VSWR < 3 H-Plane
- Polarization purity > 50dB

SCALABILITY

The array is designed within the fabrication limitations, and can be scaled to higher frequencies with only minor modifications. Below, we demonstrate such a design to include Ka-band, 76 GHz and 86 GHz satellite backhaul bands:

- 26–90 GHz with VSWR < 2 (Broadside and E-plane)
- Compatible with PCB fabrication
- Offset feed necessary due to minimum via pitch, results in increased cross-pol.

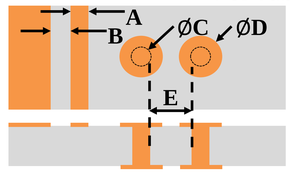




PROTOTYPE FABRICATION

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.

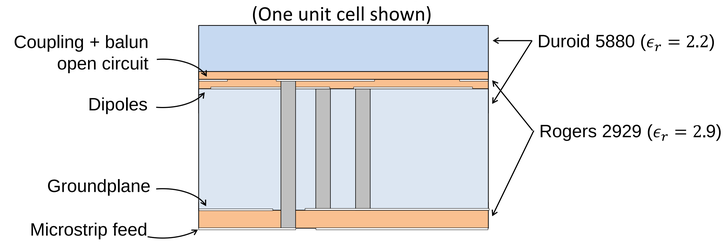
PCB Fabrication Limits:



Dimension	Min. (μm)	Min. (mil)	Tolerance
A	75	3	±25%
B	75	3	±25%
C	150	6	±10%
D	300	12	±10%
E	250	10	±20%

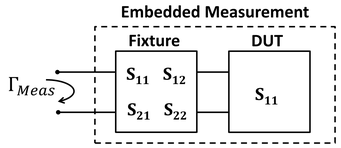
The design consists of four copper layers, and four dielectric substrates. The fabrication sequence is shown below (substrates in blue, bond layers in orange). A 5x5 prototype array is being fabricated.

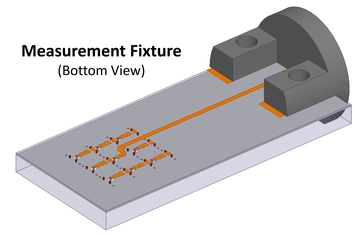
Fabrication Stack-Up:



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.





CONCLUSIONS

UWB phased arrays are needed to consolidate future communications applications on small platforms. Mass-market adoption requires low-cost PCB fabrication.

We demonstrated an array design simultaneously supporting all six mm-W 5G and ISM bands, which is compatible with PCB processes. This array is currently being fabricated; gain pattern and return loss measurements will be conducted.

THE OHIO STATE UNIVERSITY

ElectroScience LABORATORY

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