SW Test Workshop

Semiconductor Wafer Test Workshop

5G: THE NEXT DISRUPTIVE TECHNOLOGY IN PRODUCTION TEST

Daniel Bock, Ph.D.
Mike Bishop
Jeff Damm

FormFactor™

Michael Engelhardt
Michael Hemena
Robert Murphy
Balbir Singh

intel®

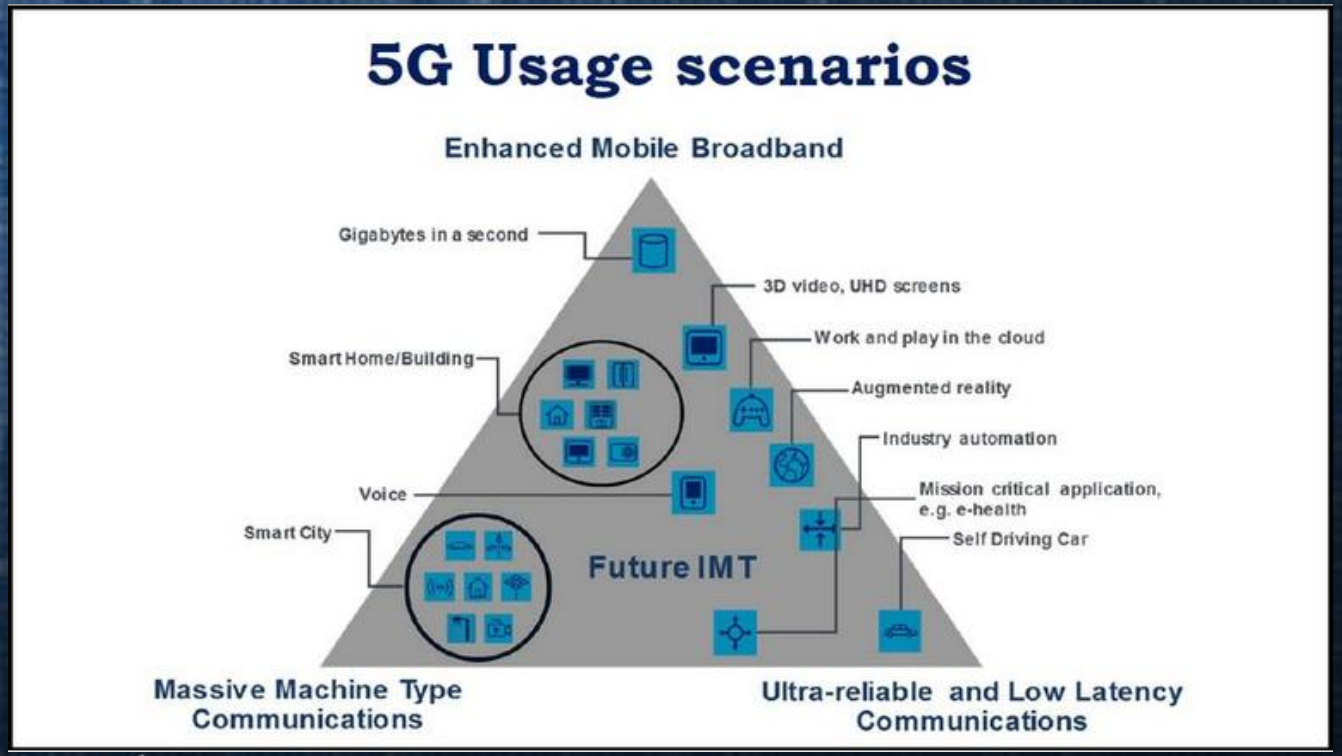
June 3-6, 2018

Introduction

- ***The development of 5G / WiGig products are creating a unique challenge for high volume production testing of the radio devices.***
- ***These devices operate at multiple frequencies throughout the 24 GHz to 86 GHz range, well beyond the 6GHz RF capabilities of most existing production ATE 's.***
  - *Design of the test solution requires creation of up/down converter circuits to reach 5G frequencies.*
- ***These devices may incorporate phased array beam-forming antennae for improved gain.***
  - *Beam-forming requires that a single DUT have a large number of RF, with many chips including more than 24 RF channels*
  - *Multi-DUT x8 test cell could require more than 256 RF channels.*
- ***The test solution for 5G devices as well as future WiGig products, will require testing of BGA, WL-CSP and DIE using both conducted and radiated methods in a full test cell.***
  - *The final HVM test solution design needs to have low installation cost and high volume test capabilities.*
- ***Results will be presented that illustrate initial testing of both conducted and radiated methods on test devices.***

What is 5G?

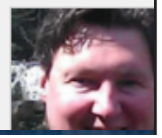
- *'It is a capital improvement project the size of the entire planet, replacing one wireless architecture created this century with another one that aims to lower energy consumption and maintenance costs. Sure, you'll download movies faster on your phone, but that's not the real reason 5G's arrival is being accelerated'. – Scott Fulton III, ZDNet*
- 5G will include:
  - *Fixed wireless data connectivity*
  - *Edge computing services*
  - *Machine-to-machine communications*
  - *Video delivery services*



Who is 5G?

- All of the major players in semiconductor are working on pathfinding devices
- 5G is broadly seen as a paradigm shift and market entry opportunity

DT Poised for 5G Launch as Huawei Antennas Go Up in Berlin



Digi and Ericsson tested live 5G connections showing the evolution from 4G

Facebook's New Focus On 5G and Golden Opportunity for Entrepreneurs

WIRELESS TECHNOLOGY

U.S.-China Competition Over 5G Likely to Increase, Even Without Trade War

Qualcomm Has Made It Cheaper To License Its 5G Technology

MACOM and STMicroelectronics to Bring GaN on Silicon to Mainstream RF Market

Like 0 Share Tweet Share

February 06, 2018 16:07 ET | **Source:** STMicroelectronics N.V.

- *Combines manufacturing scale, supply security, and surge capacity from ST with MACOM's GaN on Silicon RF power products to address m consumer, automotive, and wireless basestation programs*
- *ST licenses MACOM's technology to supply GaN on Silicon RF power products*
- *Anticipated breakthrough cost structure and power density of GaN on Silicon would enable 4G/LTE and massive MIMO 5G antennas*

Nokia, Telia and Intel carry out 5G manufacturing trials

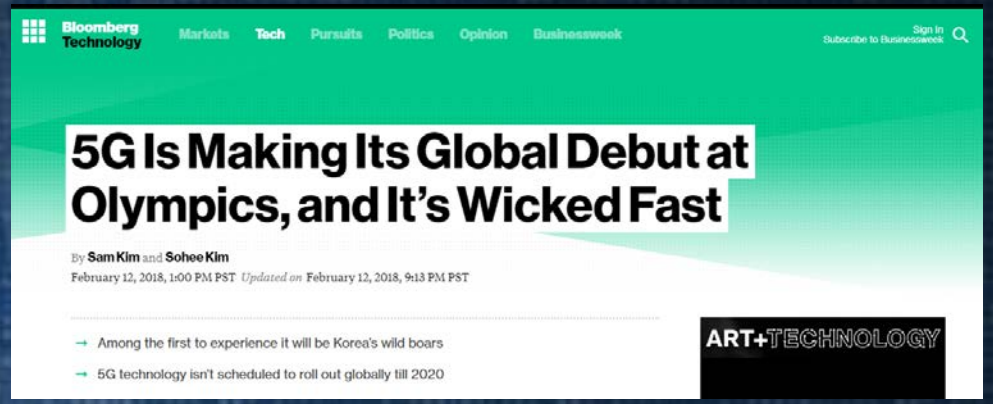
0

13 April 2018 | Natalie Bannerman

Nokia, Telia and Intel have successfully carried out an industrial trial using 5G to improve the time sensitive applications and enhance productions in manufacturing.

5G Field Trials Olympics

- **Intel and Korea's mobile carrier KT were showcasing some of the possibilities at the 2018 winter Olympics:**
  - Provided tablets equipped with faster speeds in "spectator zones"
  - Buses with no drivers
  - 360 degree VR in real-time for figure skaters



- **Japan 2020 Summer Olympics is expected to have the largest commercial deployment of 5G – Intel w/ NTT Docomo partnering**
  - Intel is promising 8k 360 degree video streams

What are we seeing with 5G devices?

- **The efforts to develop 5G fall under 3 main categories:**
  - –Spectral Efficiency: Better use of the RF spectrum for greater bandwidth over farther distances of communication
    - 30 GHz, 40 GHz, and 60 GHz bands are being added
  - –Energy Efficiency: Reduce power usage for lower cooling costs and longer lifetimes of battery operated devices
    - Beamforming for antenna gain, requiring more antenna channels
  - –Utilization: Infrastructure overhaul with more distributed, high speed digital devices
    - More high speed devices with a larger number of base stations

What does 5G Production Test Require?

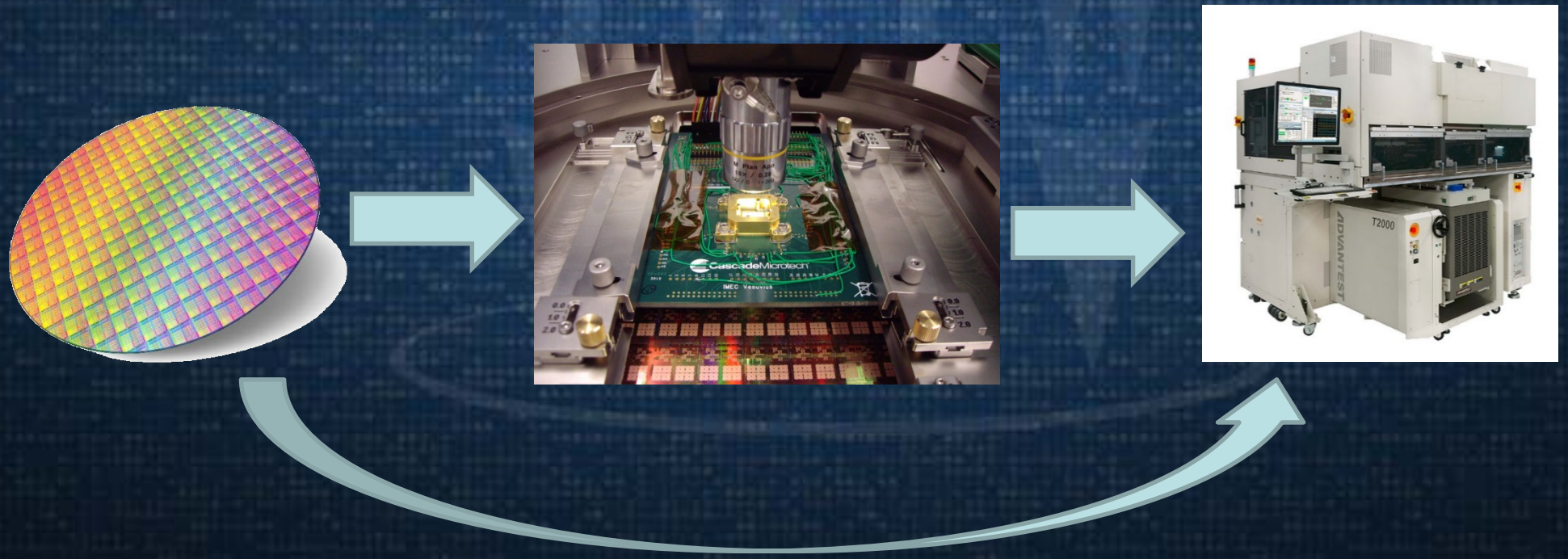
- **5G components testing will require:**
  - New test equipment:
    - Higher frequencies than current ATE testers are capable of measuring
    - Higher number of channels
  - Time of test as low as possible with high throughput
    - Parallel test (multi-site)
  - High Accuracy
    - Good Signal integrity at high RF frequency
    - Prevent packaging bad devices due to yield

Possible 5G Wafer Test Methods

Test Method	Wafer Test Cost	Functional Test Coverage	Full RF Bandwidth Test	Probe Card Complexity
Full Channel				
Loopback				
Baluns, Switches, Combiners				
DC Test				
Antenna Coupling				
No Wafer Test				

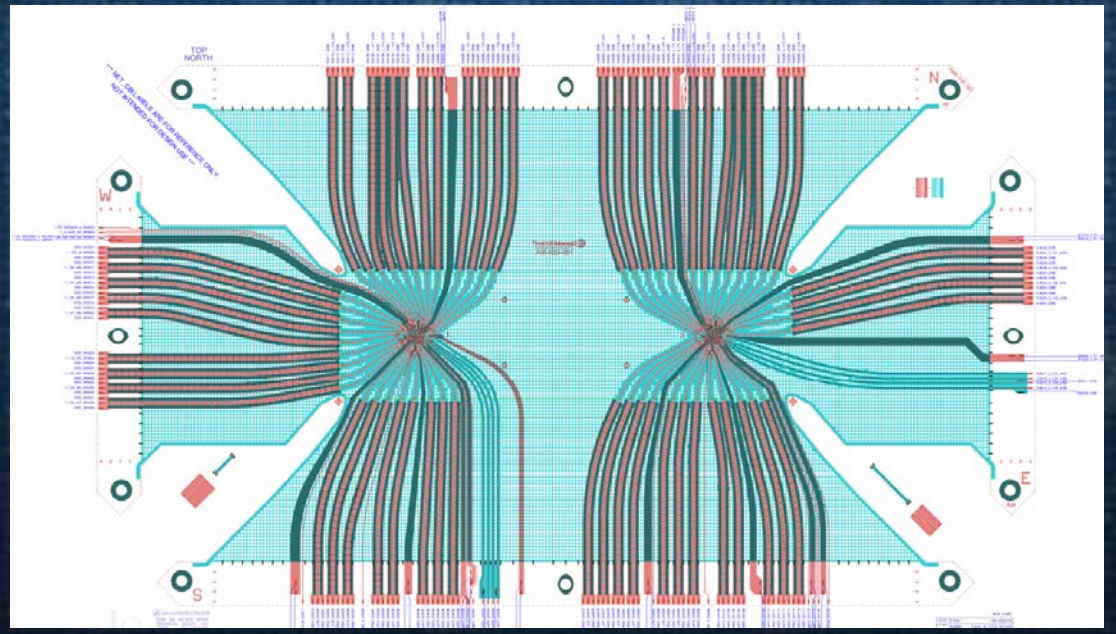
Wafer Test vs Final Test

- *Advantages:* Reduces lost cost from packaging bad parts when there is low yield; final test cannot do parallel test
- *Disadvantages:* Adds in cost to final product; additional time in the process flow prior to packaging; if yield is low, than a lot of packaged parts are thrown away



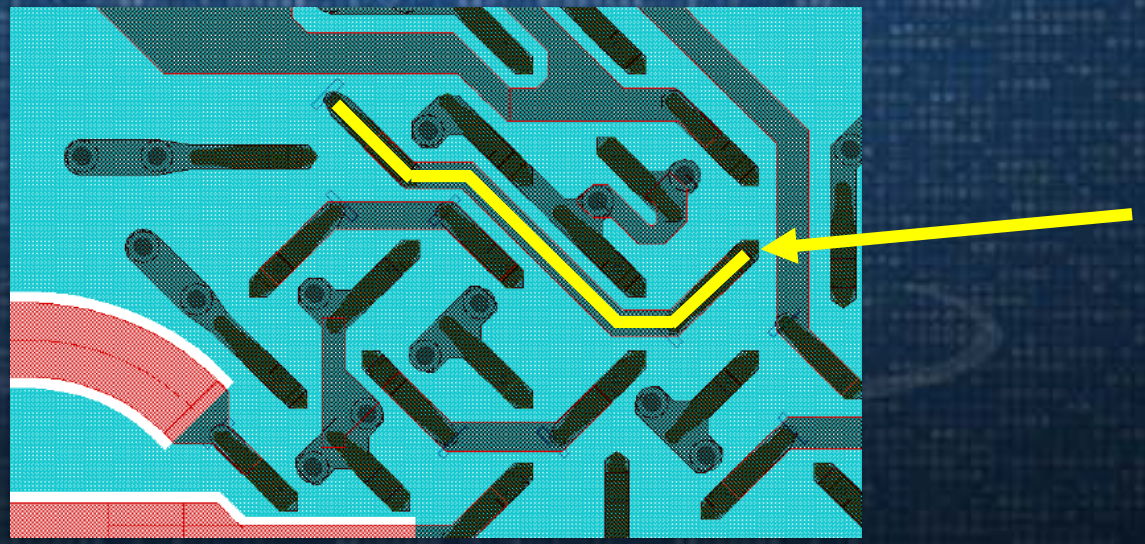
Full Tester Channel Count

- *Advantages:* Full test coverage and very fast
- *Disadvantages:* Very expensive tester; high channel count required; space transformation difficulties likely with the high number of I/O



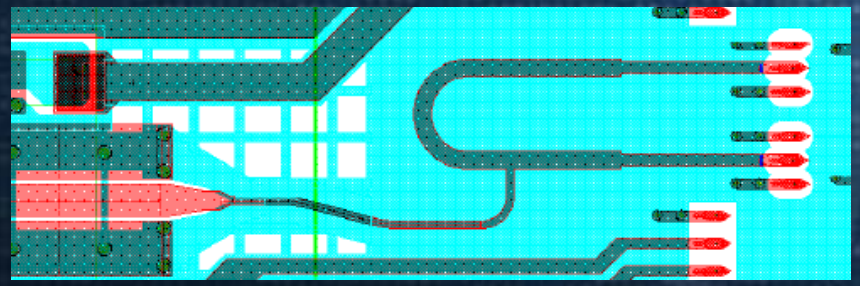
Probe Head Loopback

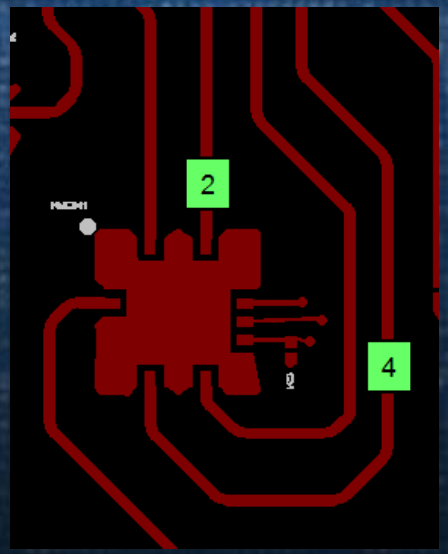
- *Advantages:* Does not need high number of channels and minimal space transformation
- *Disadvantages:* No access to die by tester and depends upon the DUT to know if it fails; and routing requires no crossing

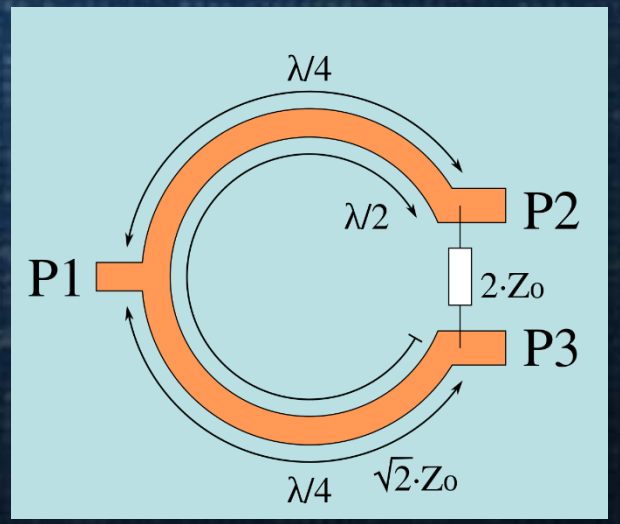


Baluns, Switches, Combiners

- *Advantages:* these are known methods of reducing total channel count in a tester, and there are some COTS parts available
- *Disadvantages:* Can have minimal effect in space transformation, increased loss compared to direct connection, and most parts can only operate up to maybe 50 GHz

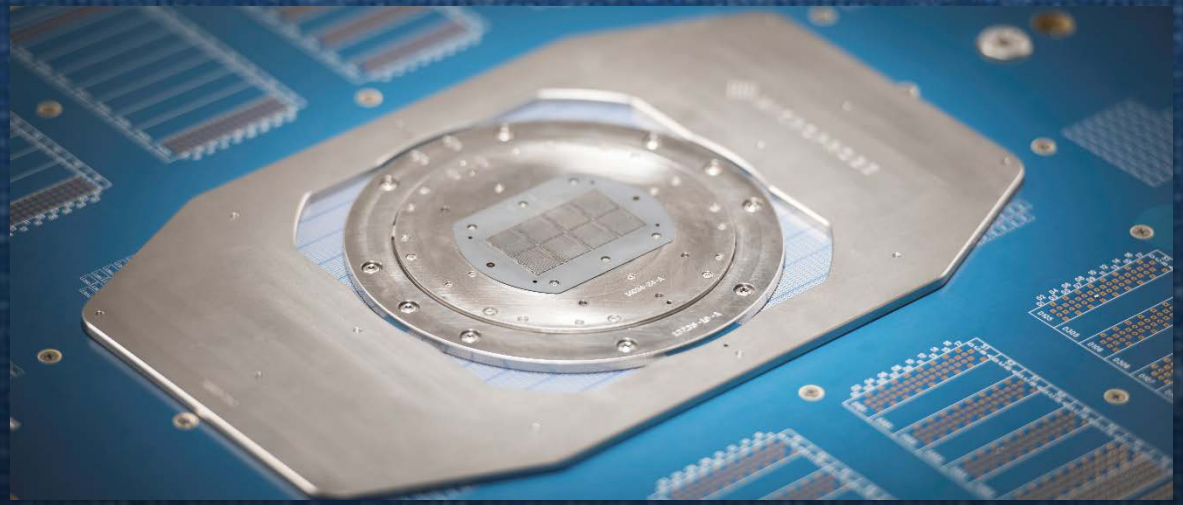






DC Test

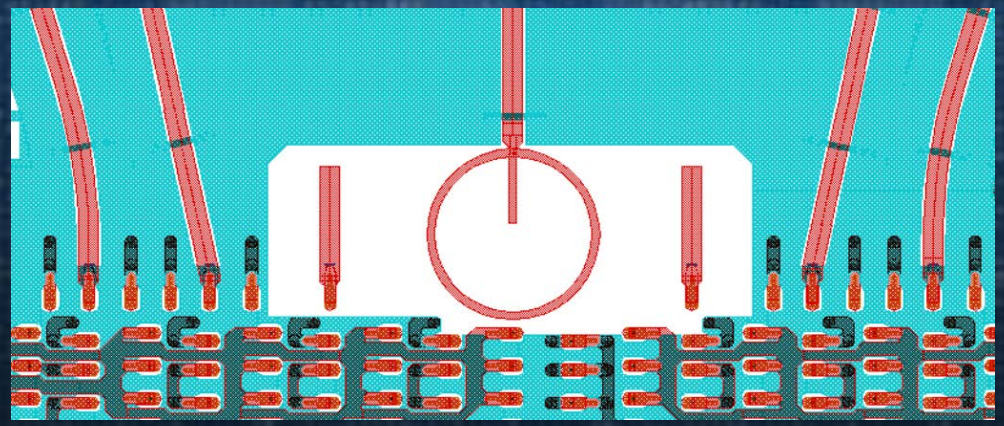
- *Advantages:* Lower cost tester; does not need impedance control for cheaper interconnects
- *Disadvantages:* does not test actual part operation; checks connectivity only, not KGD



MF80 Probe Card

Antenna Coupling

- *Advantages:* can be used to reduce total channel count (4:1 combining); mimics OTA test
- *Disadvantages:* more loss than conducting measurements, need open space in the area to fit an antenna large enough

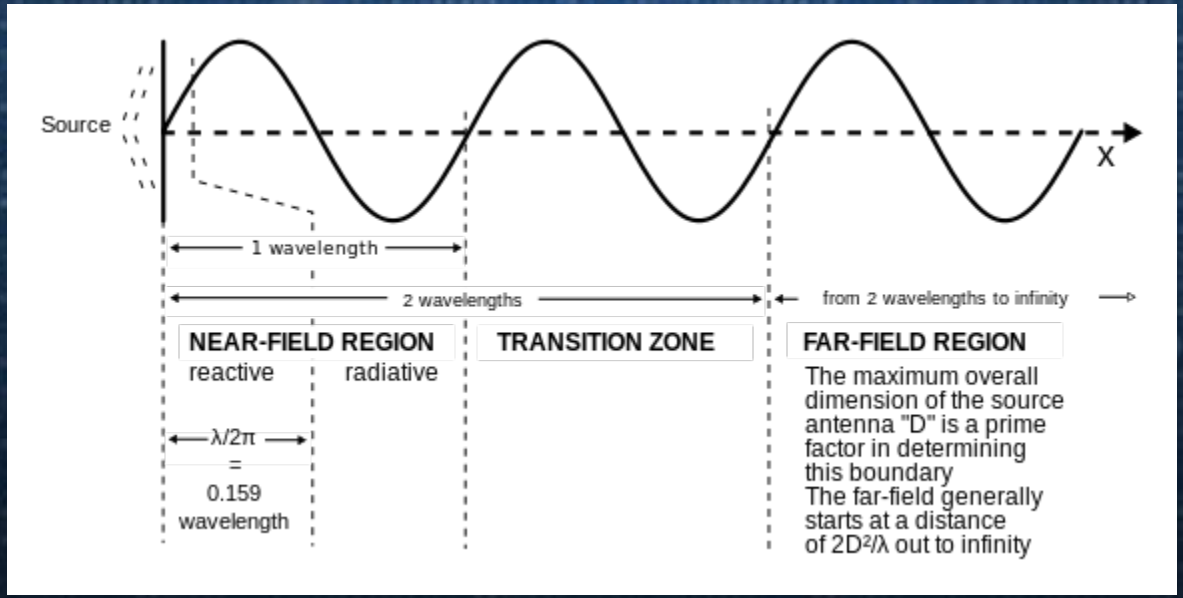


Wafer Test Methodology Summary

Test Method	Wafer Test Cost	Functional Test Coverage	Full RF Bandwidth Test	Probe Card Complexity
Full Channel	🔴	🟢	🟢	🔴
Loopback	🟢	🔴	🟢	🟡
Baluns, Switches, Combiners	🟡	🟢	🟢	🔴
DC Test	🟢	🔴	🔴	🟢
Antenna Coupling	🟢	🟡	🟢	🟡
No Wafer Test	🟢 / 🔴	🔴	🔴	🟢

Distance to Antenna – Near field vs. Far-field

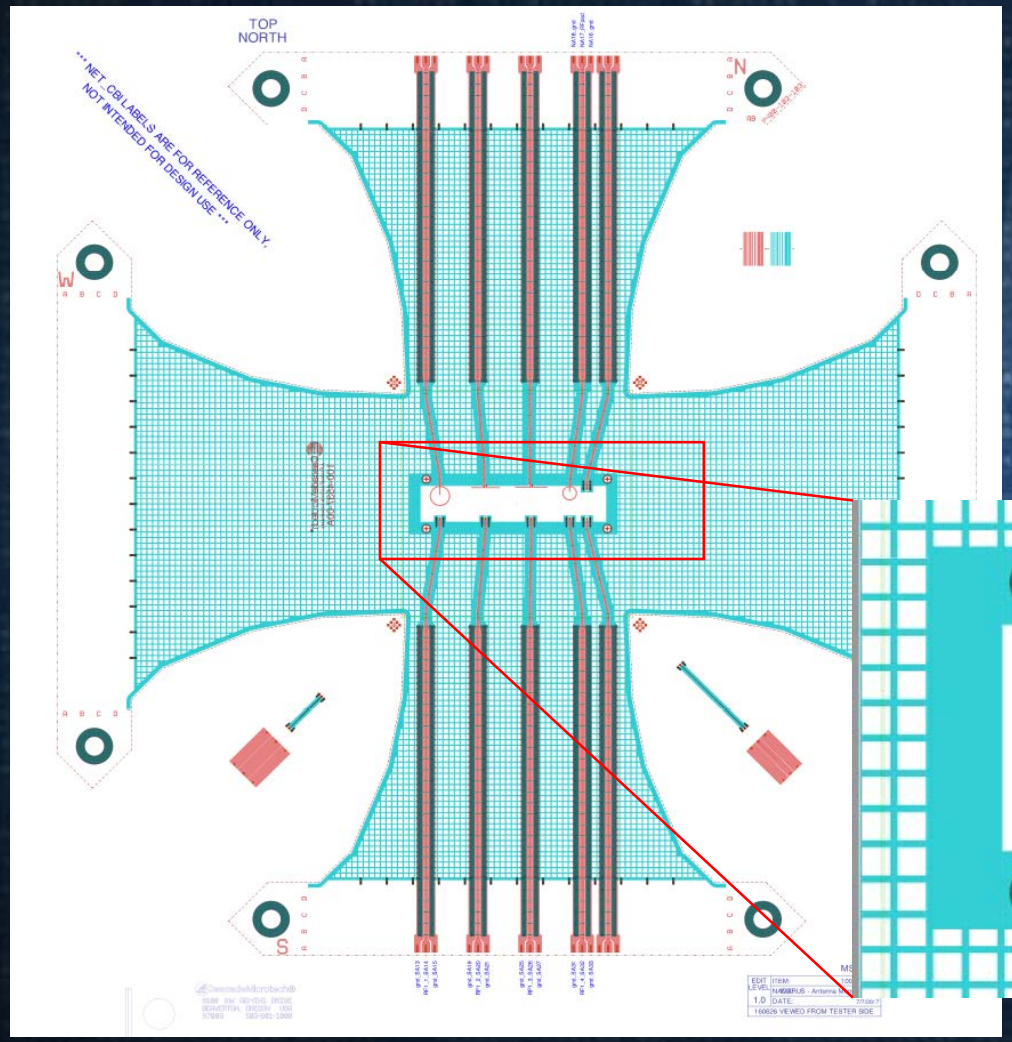
- **The membrane is so close, does it need to be a full antenna?**
  - The distance from the antenna will be well below one wavelength (30 GHz λ = 10 mm), so the field distribution will depend upon the distance from the antenna



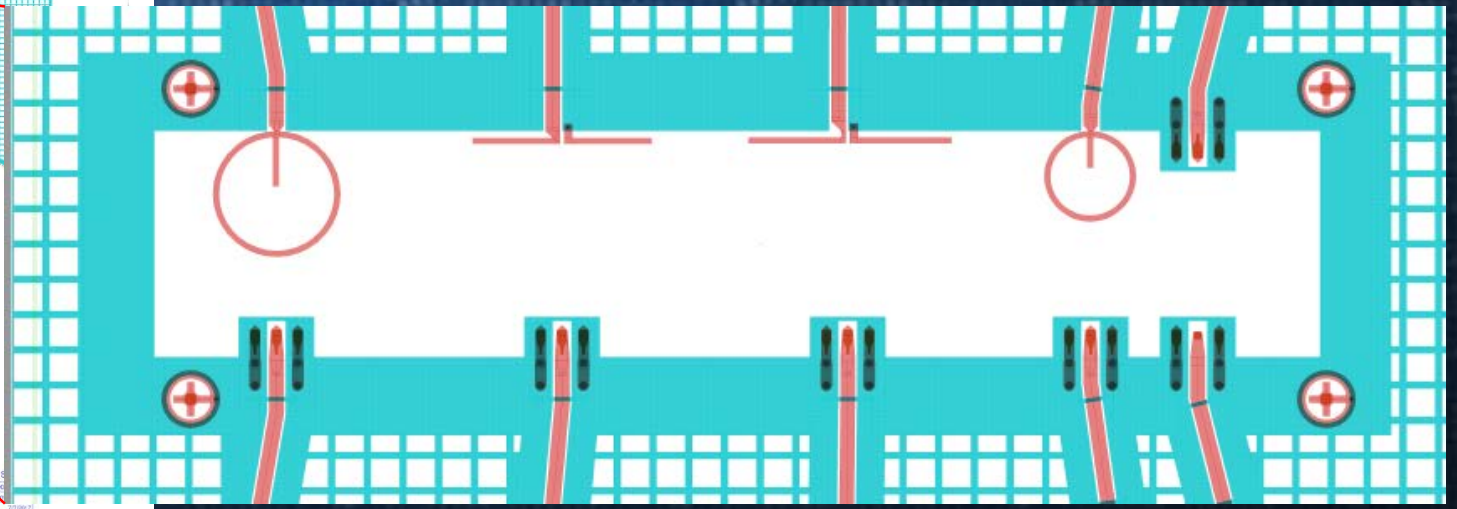
Antenna Uses in RF wafer test

- **Interrogate on die antennas**
  - It can be used for packages with antennas added
  - Can a bump or pad be interrogated?
  - Can it help with the high channel count to reduce the number of RF channels being measured?

Layout of Test

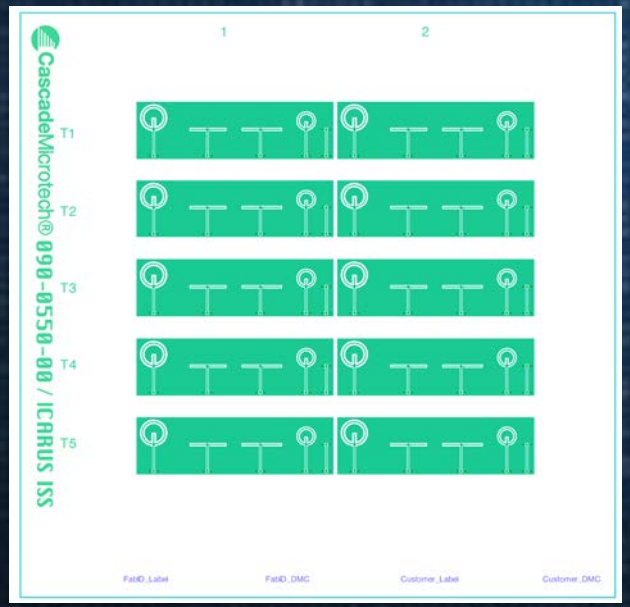


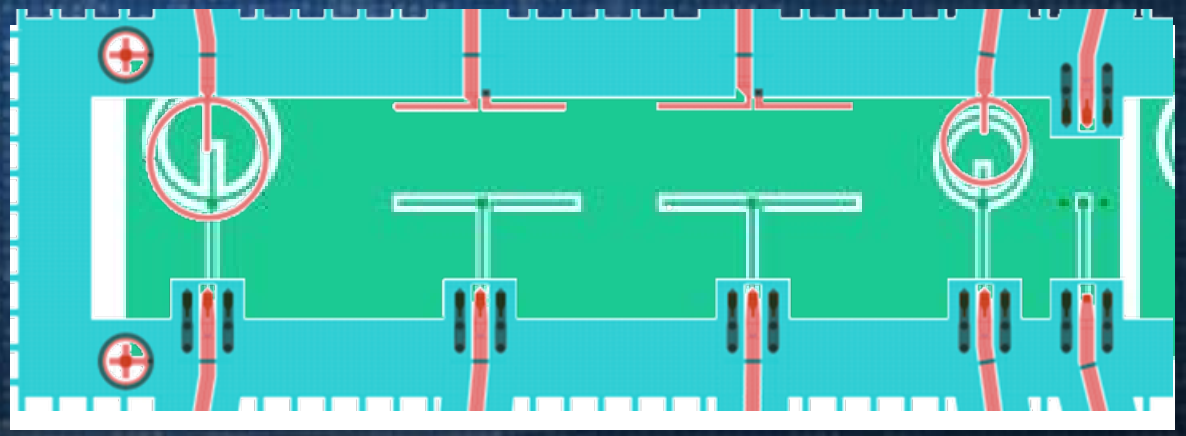
- The test layout has 2 dipoles, and 2 ring antennas
- It also has a pad for transmission with no antenna on the DUT



ISS for reception

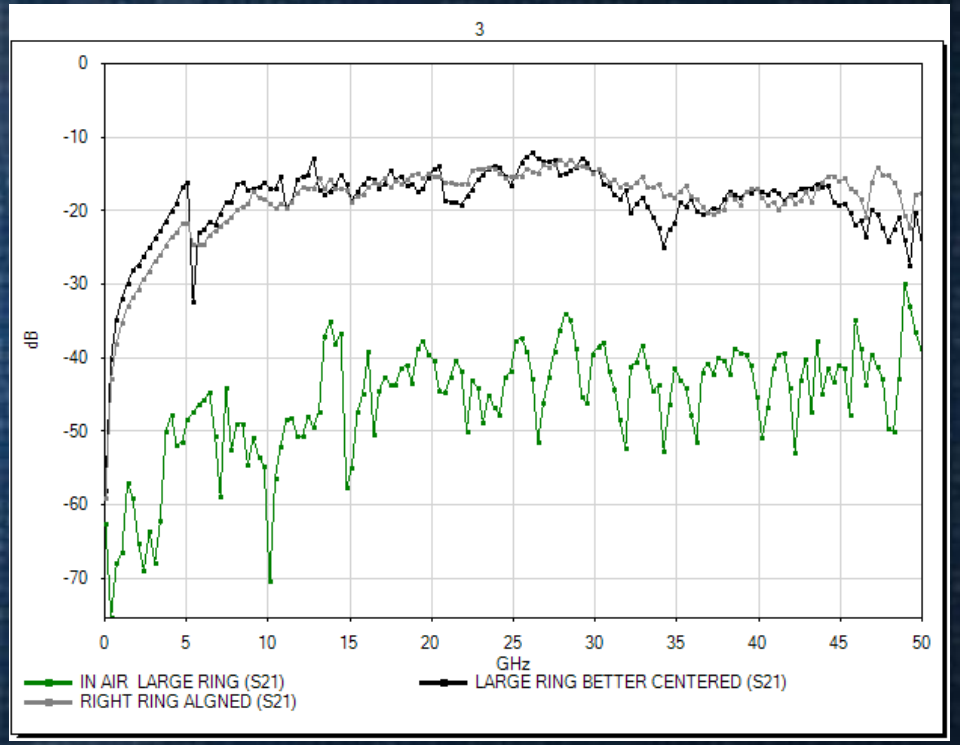
- An ISS was made for reception of the signals, which would then go back to the membrane using a GSG pair at the and of the transmission line





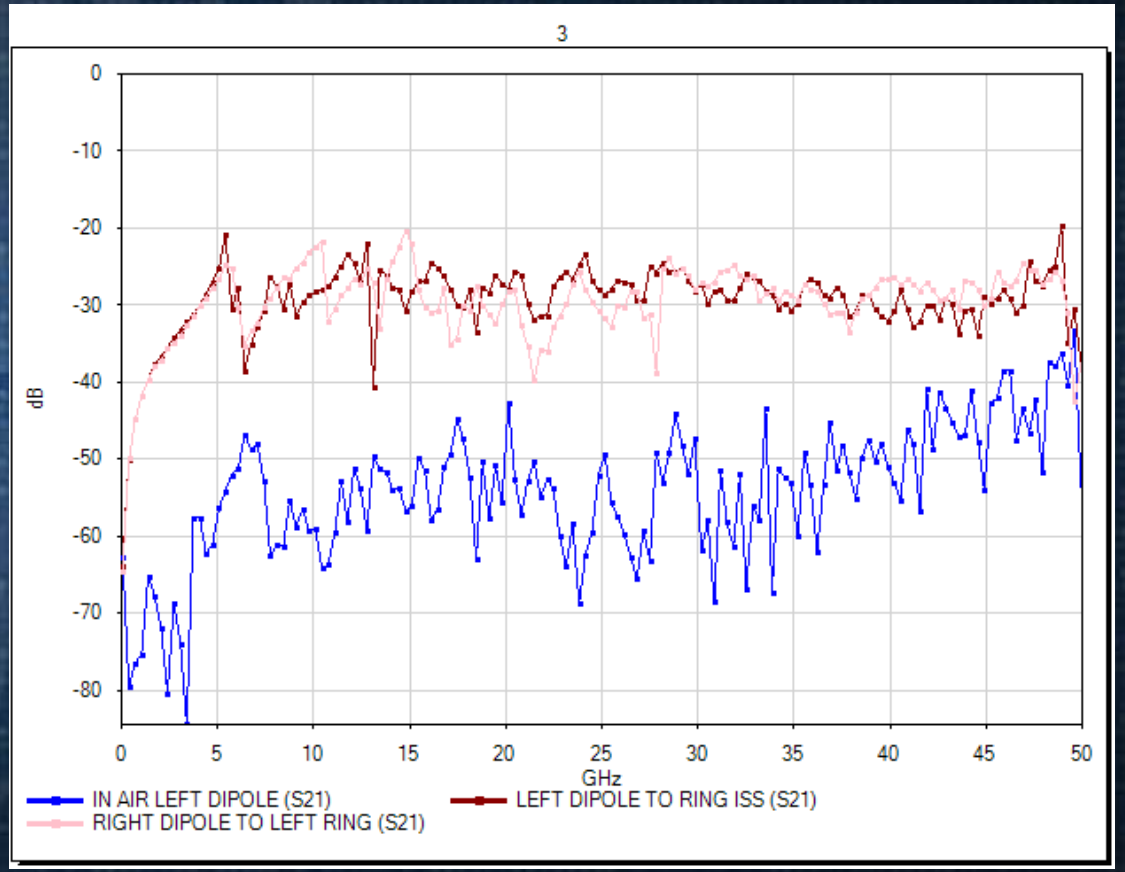
IL measurement of the large/small ring

- **Looking at transmission of the two rings, the amount of energy on IL is about 20 dB higher than the noise**
  - Noise is measured in the air, not in contact with the ISS for reception
  - The bandwidth is very wide because of the near field coupling in a wafer probing application



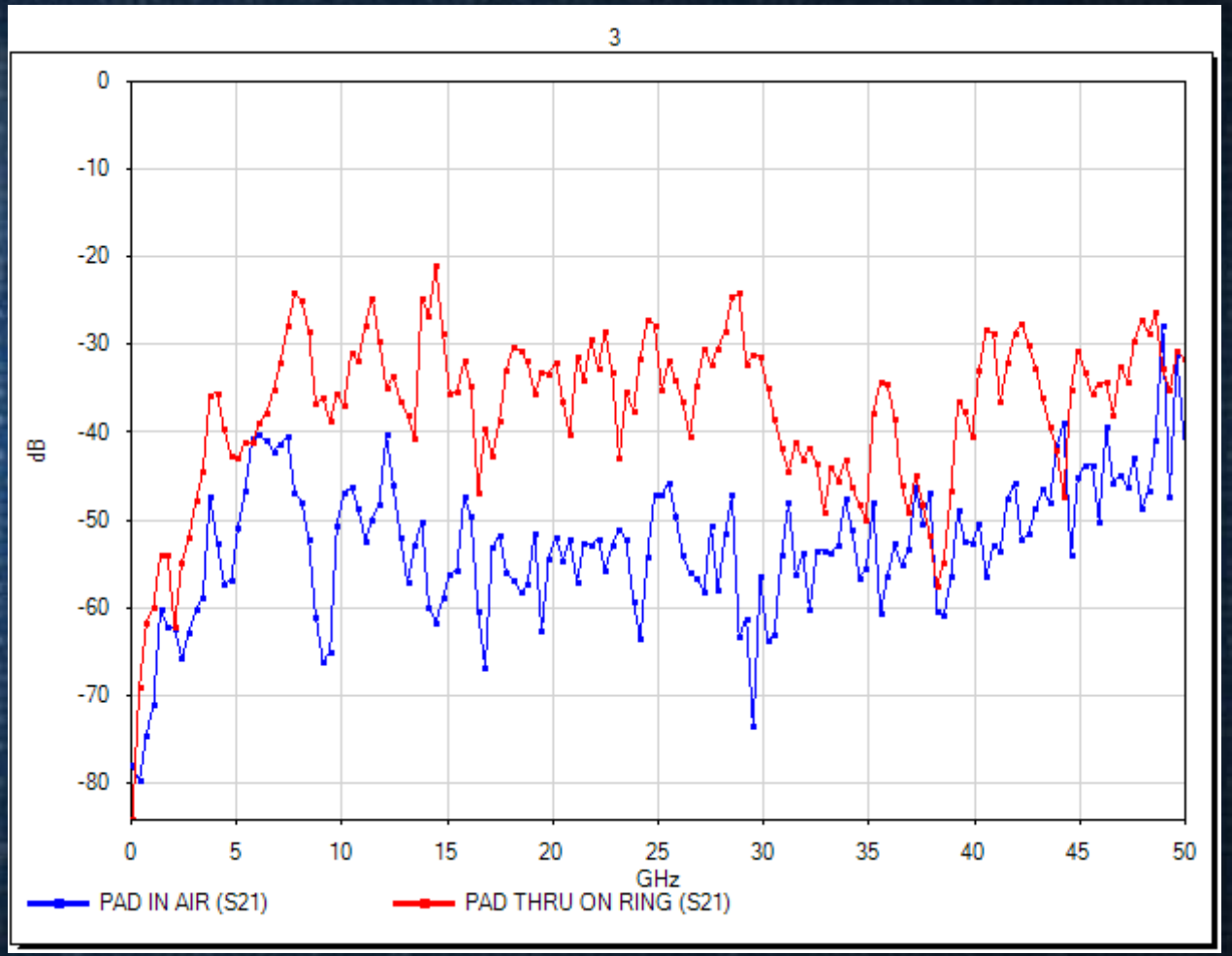
IL measurement of the large/small dipole

- **Looking at transmission of the two dipoles, the amount of energy on IL is about 20 dB higher than the noise**
  - Noise is measured in the air, not in contact with the ISS for reception
  - The received signal is ‘noiser’ than that of the ring antenna



IL from pad on ISS to Ring

- **The IL where the pad on the ISS is used with the ring antenna is used for reception, the signal is seen**
  - However, the reception is not as clean across frequency as seen on the other transmissions



ATE Testing of mm Wave at Intel

- **Test Setup**
  - Advantest 93000 PSRF ATE System was used to generate an up-converted 38 GHz signal and measure a down-converted 38GHz signal
  - SIU PCB (Wafer Sort Interface Unit) with mm Wave UDC (UP/Down Converters)was developed using off the shelf components.
    - The UDC up converts an IF signal from the ATE resulting in CW signal that was in the 38GHz band.
    - Similarly the UDC down converts a signal from the DUT to a signal that was within the measurement range of the ATE (< 6GHz)

Membrane Probe-head mmWave Testing on SIU

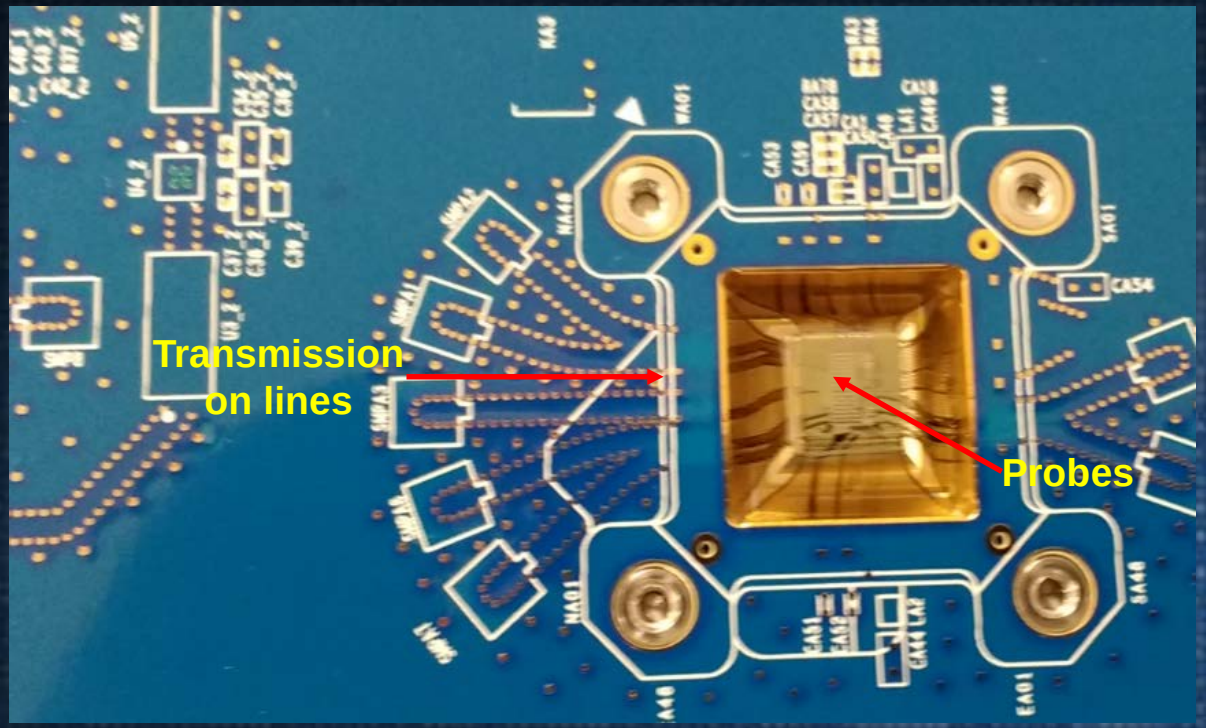
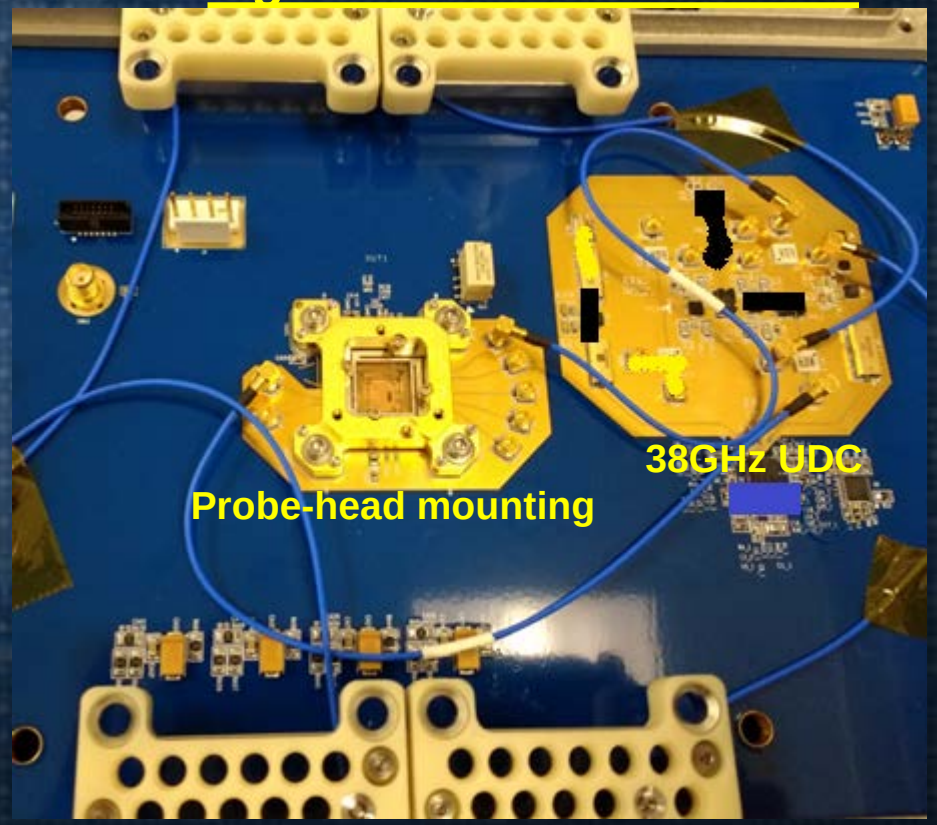


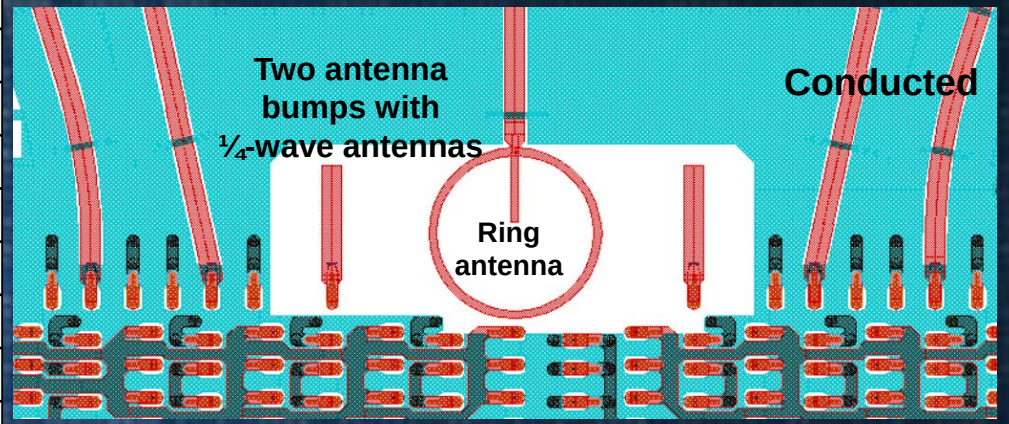
Figure 1: Wafer Sider of SIU

Figure 2: ATE Side of SIU



Repetability measuremnts at 38.56 GHz

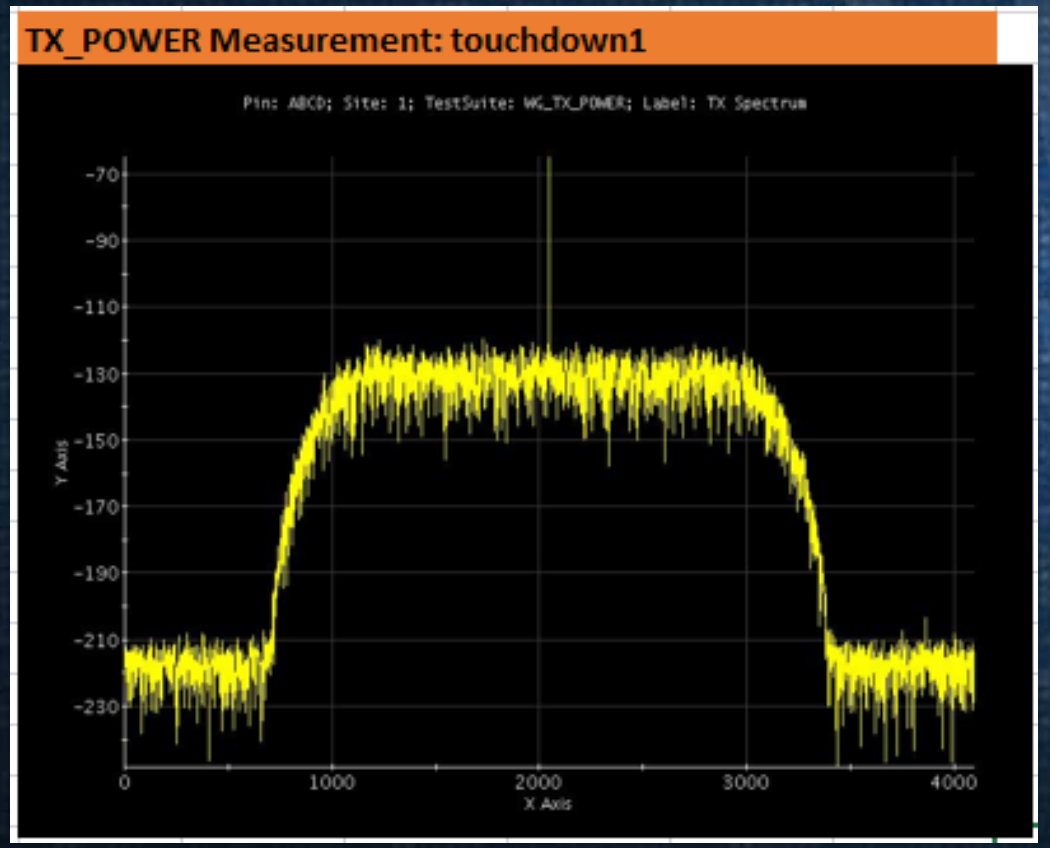
Probe touchdown	Transmit Power from Same DIE (dBm)		
	1/4λ to Ring Antenna	Ring Antenna only	Fully Conducted Path
1	-63.27	-86.67	-38.593
2	-63.169	-85.95	-38.594
3	-63.8	-86.68	-38.588
4	-63.825	-86.62	-38.589
5	-63.636	-85.63	-38.59
6	-63.687	-85.51	-38.597
7	-63.793	-86.62	-38.602
8	-64.043	-86.23	-38.61
9	-64.728	-85.14	-38.616
10	-64.673	-85.98	-38.615
11	-64.955	-86.69	-38.634
12	-64.866	-85.43	-38.649
13	-65.111	-85.95	-38.648
14	-65.785	-84.65	-38.698
15	-65.826	-84.25	-38.711
16	-65.854	-84.13	-38.757
17	-65.748	-84.32	-38.762
18	-65.831	-84.61	-38.766
19	-65.696	-84.21	-38.753
20	-65.692	-84.74	-38.778

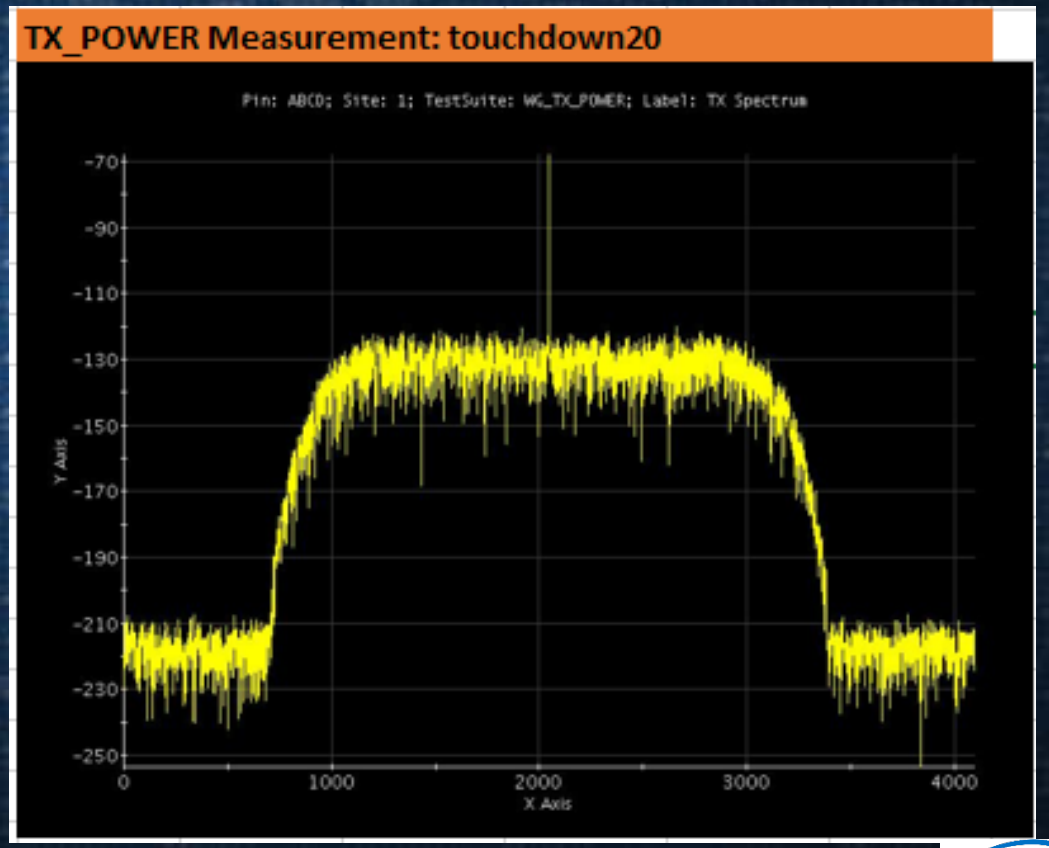


mm Wave Probe Connection: 2 to 1 combining with ¼-wave antennas

38 GHz CW Spectrum showing repeatability

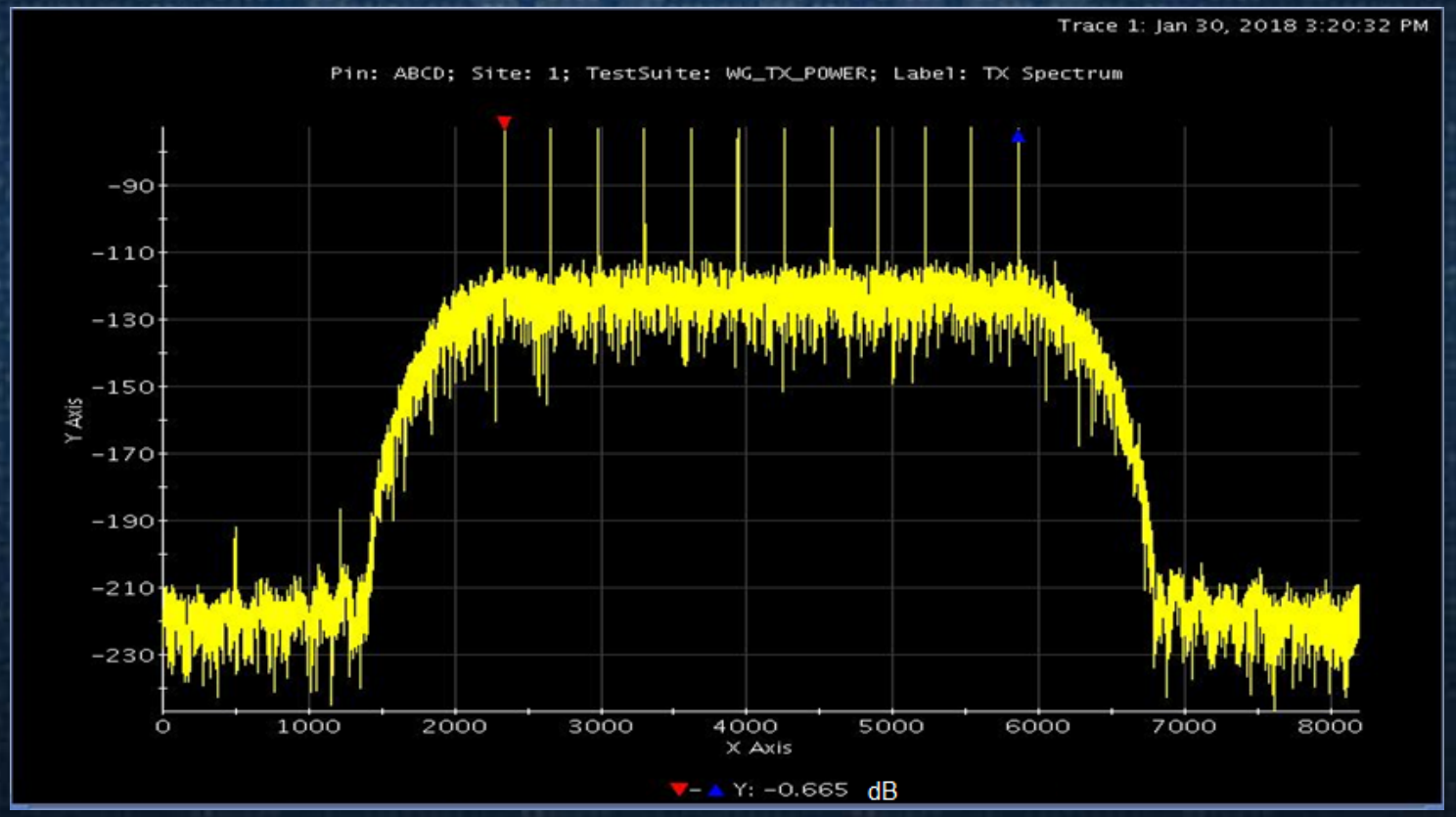
- This is CW Spectrum measured with the ¼-antenna





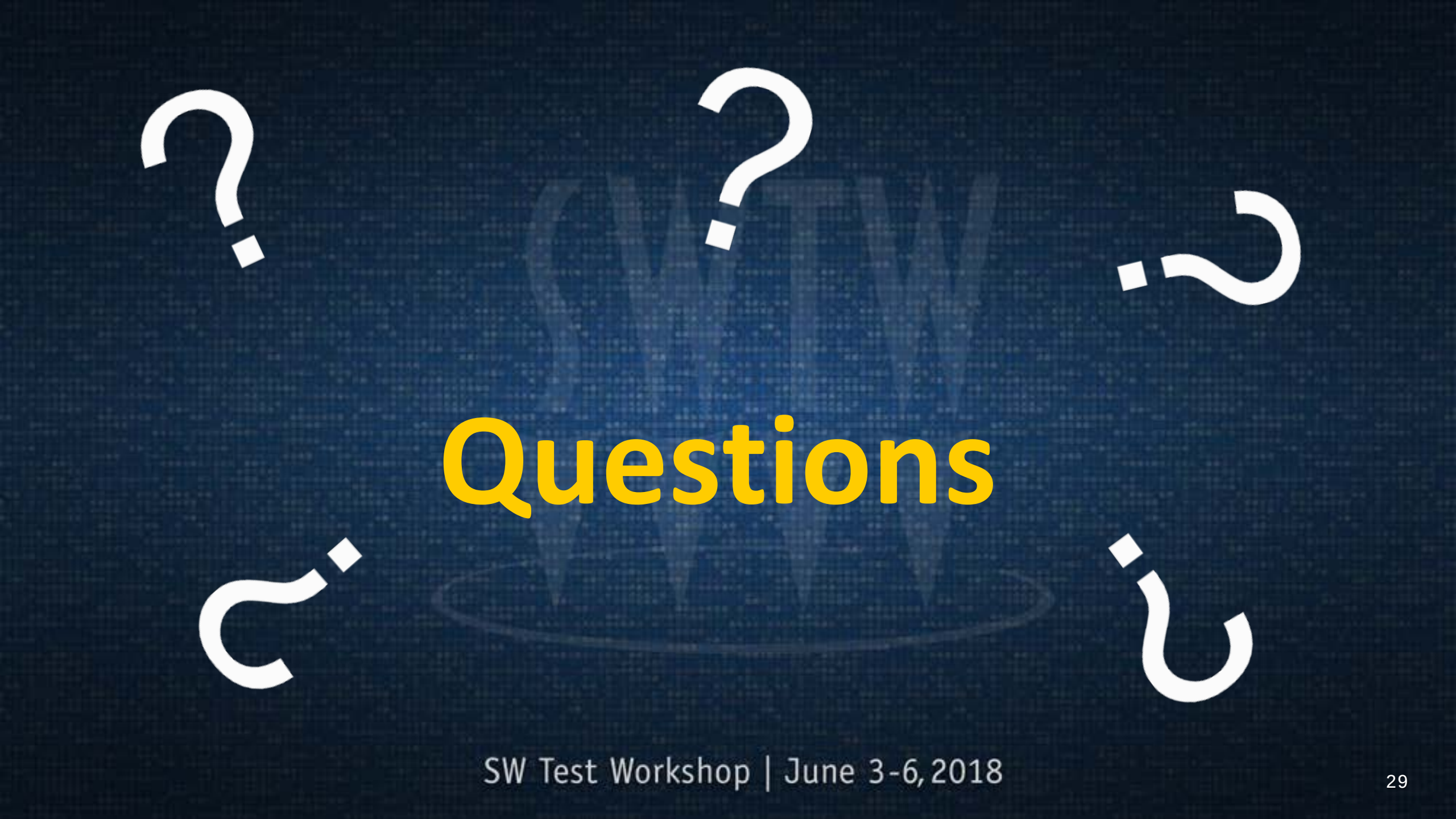
Multi-tone Spectrum's at 38 GHz

- **This spectrum is measured with the ¼-antenna**
  - 12 tone linearity using an IQ waveform



Summary

- **We have shown that using in membrane antennas is a feasible method for wafer production test**
  - It can reduce the total number of RF channels without expensive tester upgrades
  - Does not require large areas in the membrane
  - Has good signal integrity that will support 5G production test


Questions