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Archive

Challenges of Over The Air (OTA) Testing with ATE

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Shanghai ▪ October 29, 2019

Contents

- Over The Air (OTA) Testing Challenges
- Creating an OTA ATE Test Vehicle
- Measurement Results
- Near Field OTA Challenges
- Reactive Near Field Probing
- Conclusions

ATE Challenges for 5G Applications

- 5G is seen as the next major driver of mobile applications
- But 5G presents significant new challenges for ATE:
  - Frequency range from 24 GHz to 44 GHz (might change!!)
  - Modulation frequencies in the range of 800 MHz
  - Devices with antennas integrated in package require over the air (OTA) testing at packaged level
- Silicon vendors would like to keep the testing infrastructure modifications as small as possible
- Costs of test is critical for 5G applications

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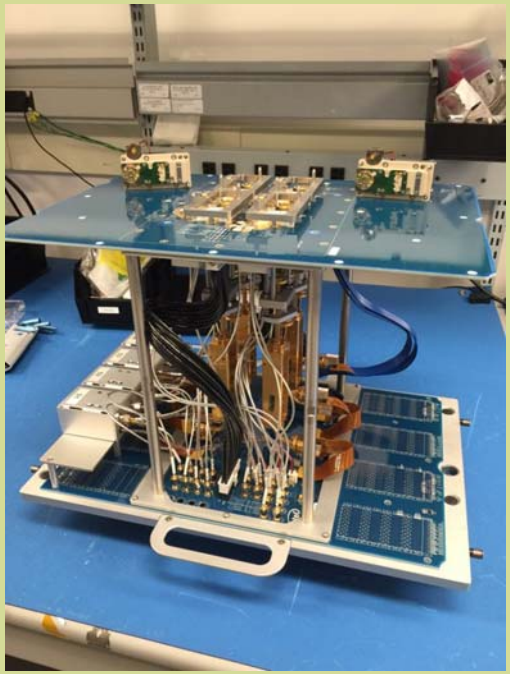
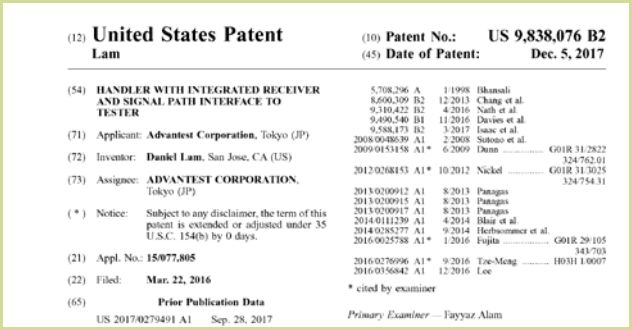
Previous Advantest Projects on OTA



ADVANTEST HAS BEEN WORKING ON OTA PROJECTS WITH CUSTOMERS SINCE 2013



(12) **United States Patent**
Lam

(10) **Patent No.: US 9,838,076 B2**
(45) **Date of Patent: Dec. 5, 2017**

(54) **HANDLER WITH INTEGRATED RECEIVER AND SIGNAL PATH INTERFACE TO TESTER**

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(72) Inventor: **Daniel Lam**, San Jose, CA (US)

(73) Assignee: **ADVANTEST CORPORATION**, Tokyo (JP)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **15/077,805**

(22) Filed: **Mar. 22, 2016**

(65) **Prior Publication Data**

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* cited by examiner

Primary Examiner — Fayyaz Alam

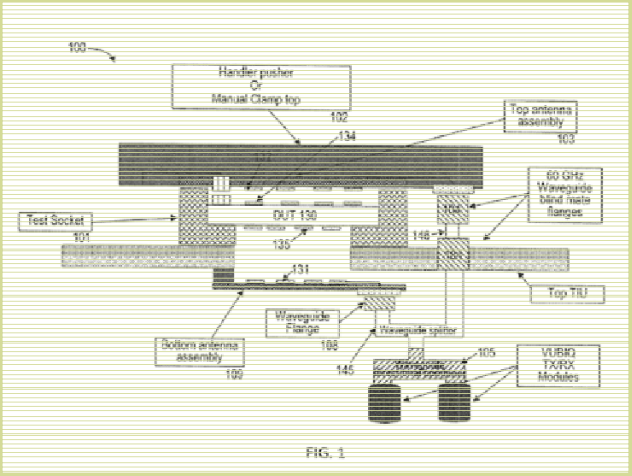

FIG. 1

Challenges of Over The Air (OTA) Testing with ATE

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REFERENCE: [1]

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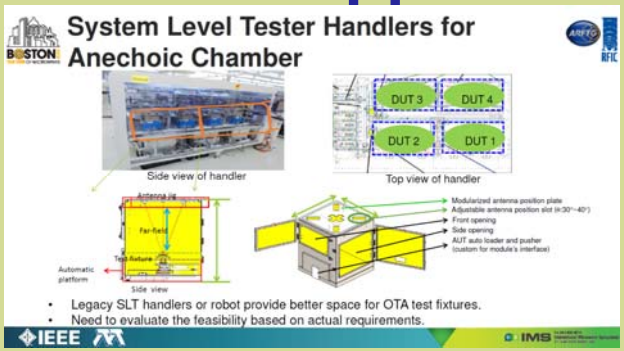
Current OTA ATE Measurement Approaches

Anechoic Chamber

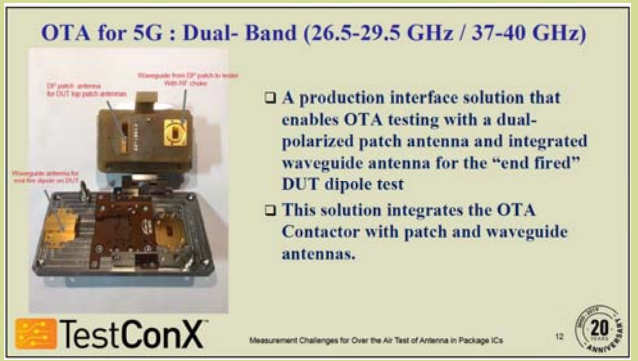
- Far Field Measurement
- Closer to System Level Test (SLT) than classic RF ATE.
- Integration on a standard ATE production test cell very challenging.
- Test Time?



Harrison Chang et al., "From Assembly to Testing, Characterization of Low Cost Organic Substrate for mm-Wave AiP Application", IEEE IMS 2019.

OTA Single Measurement Antenna Socket

- Measurement Antenna very close to DUT (usually in the radiating near field region).
- Easier integration on current ATE Test Cell environment.



Aaren Lonks, "Measurement Challenges for Over the Air Test of Antenna in Package ICs", TestConX 2019.

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REFERENCE: [2,3]

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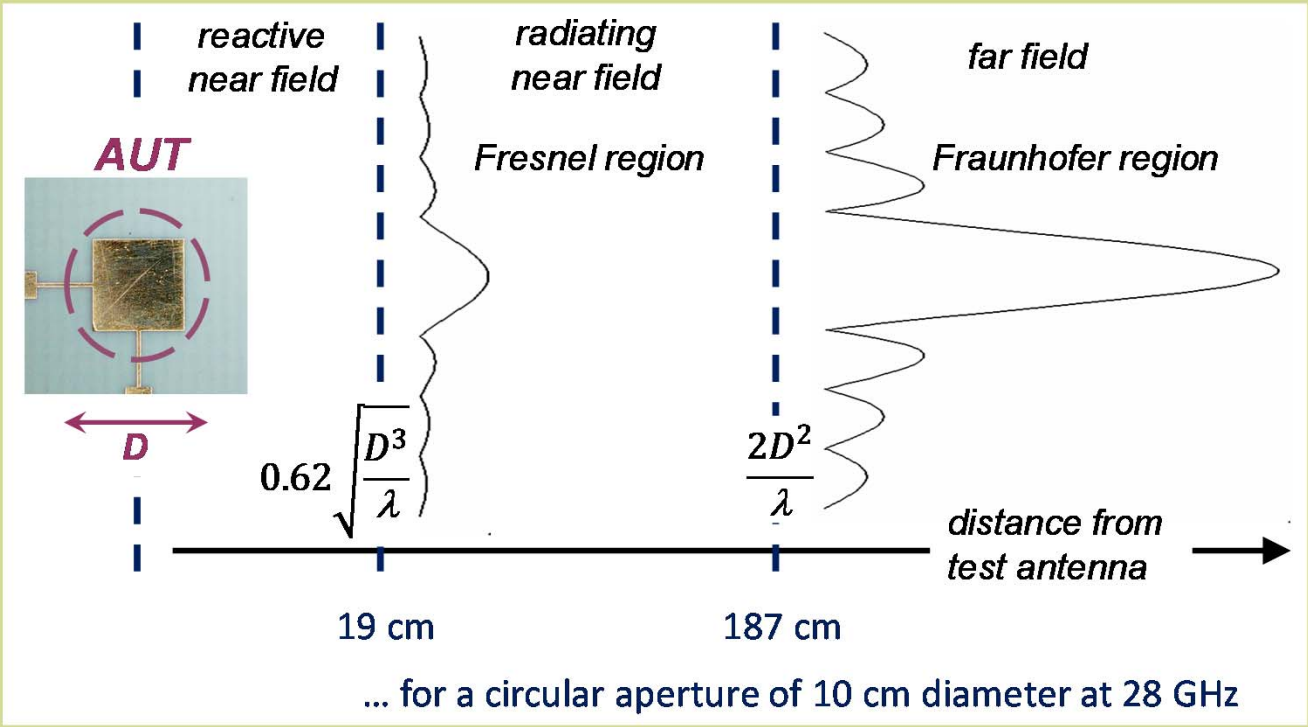
Near Field vs Far Field Measurements



AUT- Antenna Under Test

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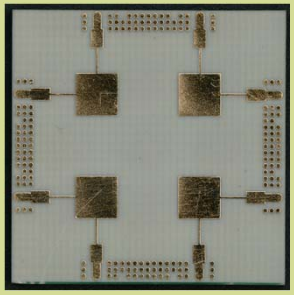
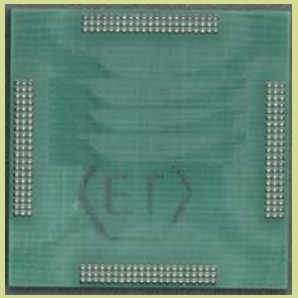
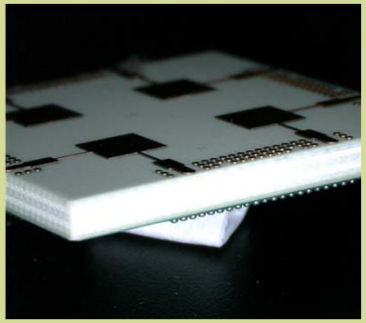
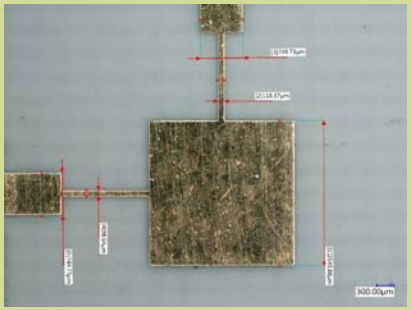
Creating an OTA ATE DUT Test Vehicle

- **A "dummy" DUT (surrogate package) was developed with a 2x2 dual polarized antenna array tuned for 28 GHz.**
- **Dielectric material was Rogers 4350 (10 mil thick), BGA pitch is 0.4 mm, DUT thickness (including solder balls) is 1.9 mm.**









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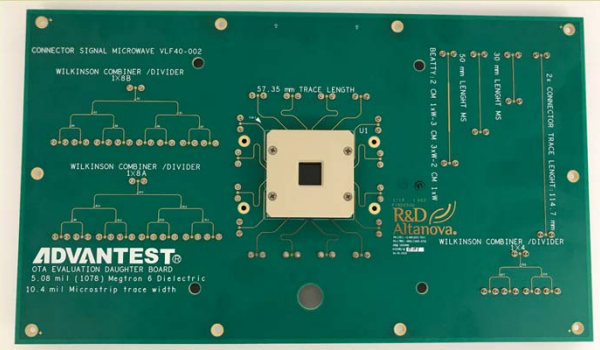
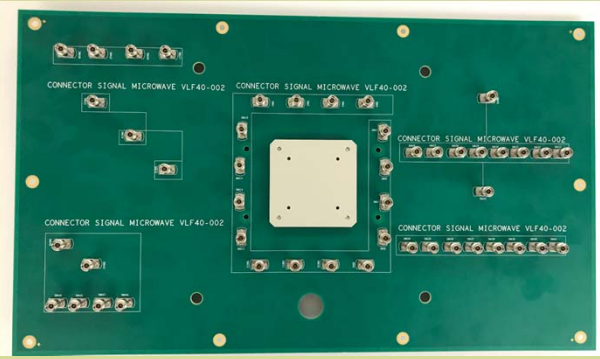
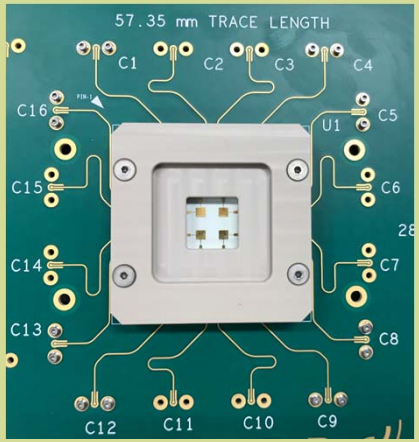
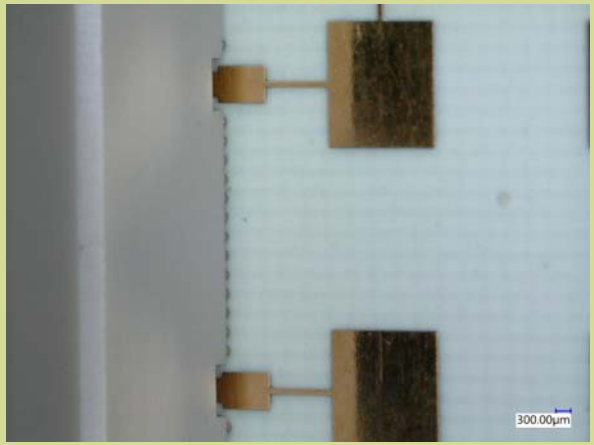
OTA ATE Test Vehicle: The DUT Test Fixture

THE DUT TEST FIXTURE

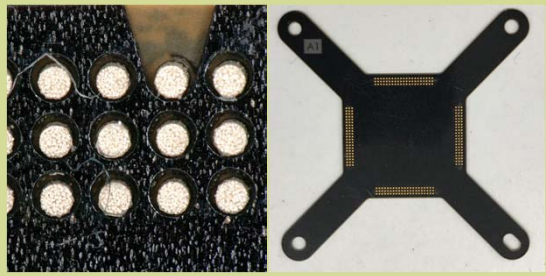








R&D/ALTANOVA INVISIPIN SOCKET



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REFERENCE: [4]

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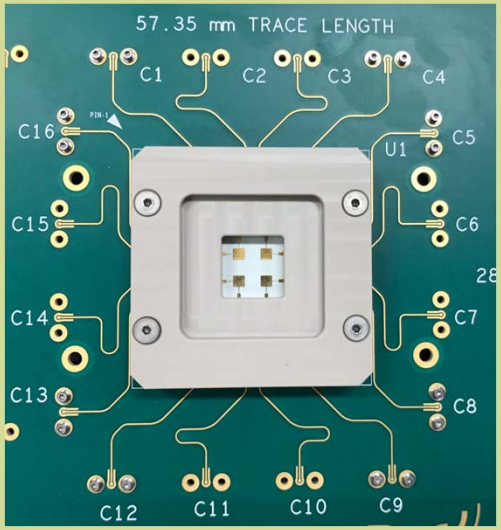
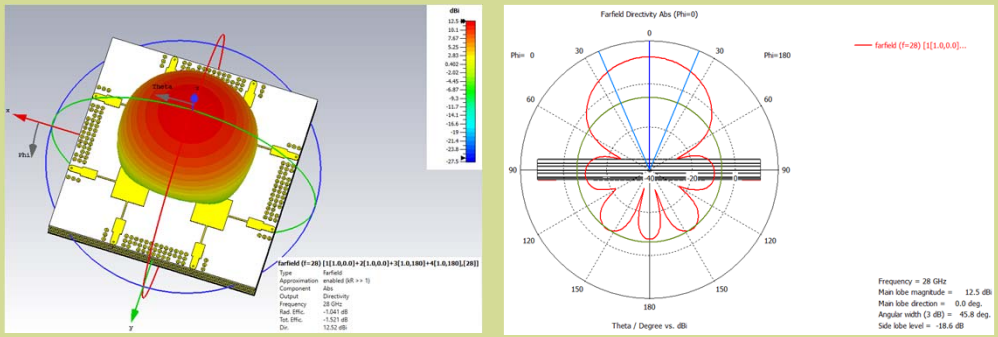
Socket Lid Impact

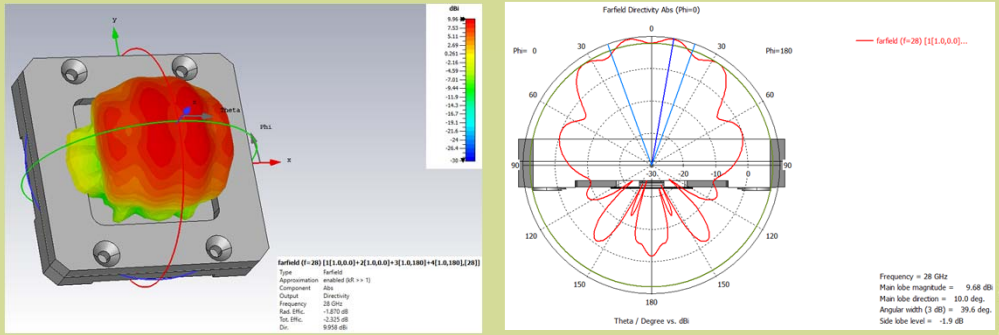
- Even when using an anechoic chamber for OTA testing, a socket with a lid is needed.
- The lid impacts the antenna array performance.
- Lid made of PEEK.



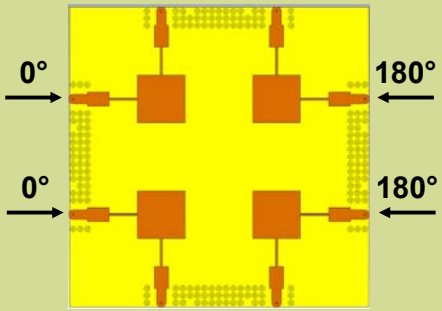
ANTENNA ARRAY SIMULATION WITHOUT LID

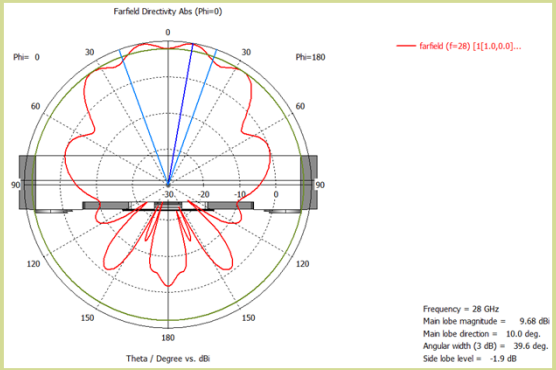


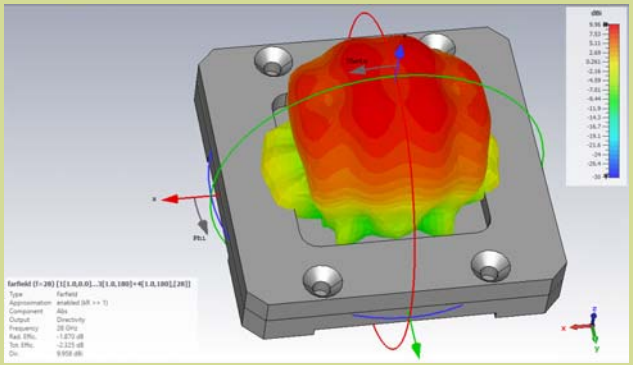
ANTENNA ARRAY SIMULATION WITH LID

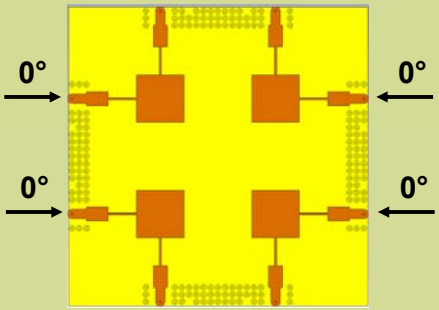


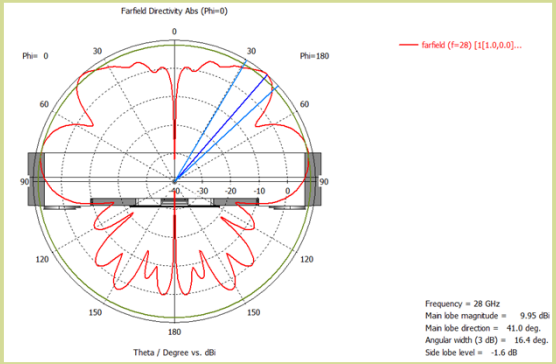
Antenna Far Field Beamforming Simulation

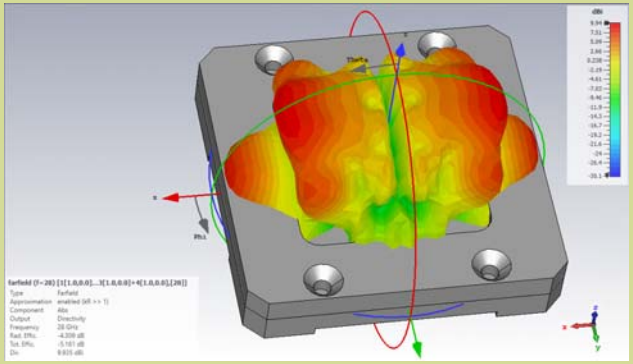












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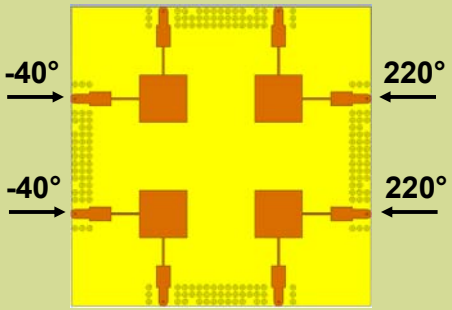
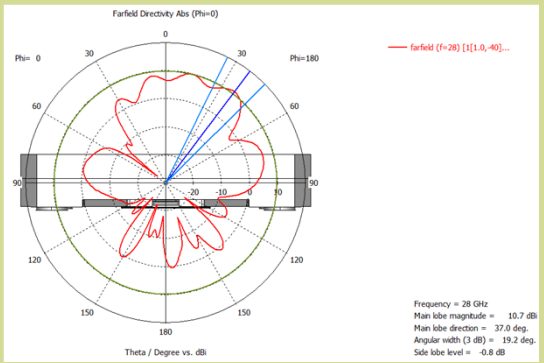
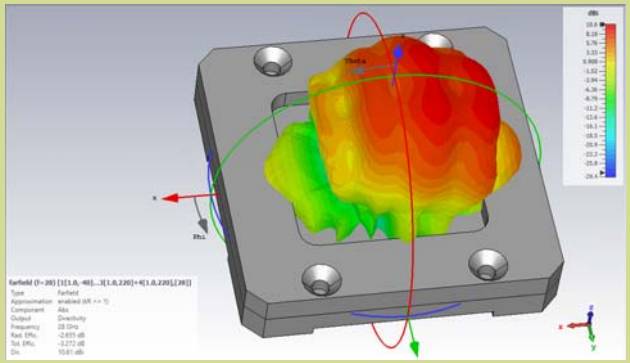
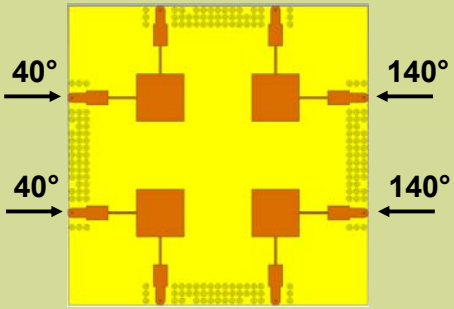
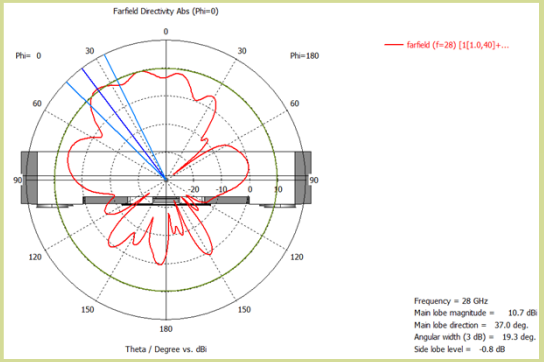
Antenna Far Field Beamforming Simulation

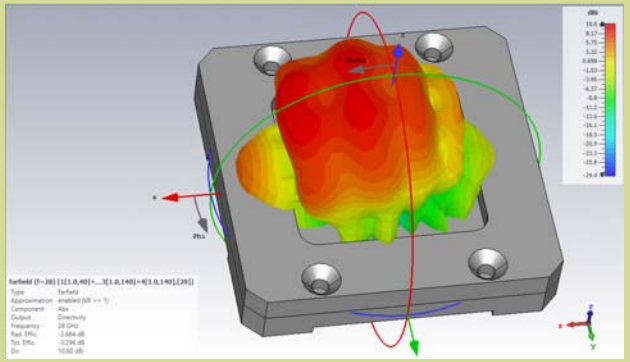












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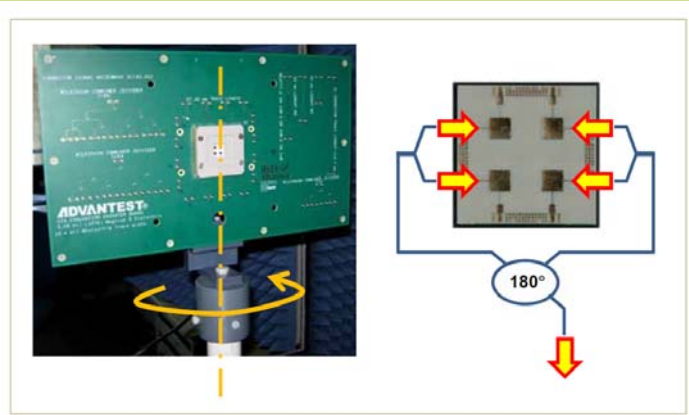
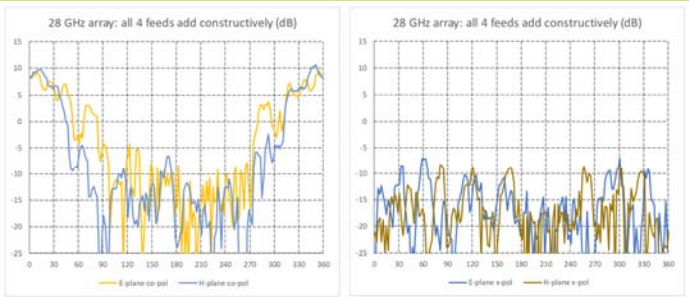
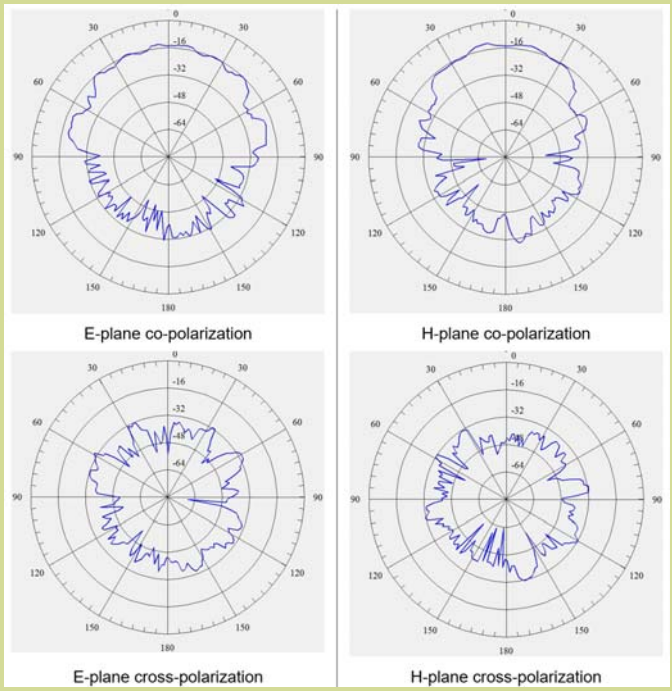
Anechoic Chamber Measurements





Pattern measurements: Co-polarization (left) and cross-polarization (right)



Far Field Measurements of Surrogate Package Correlate with Simulations and Design Targets

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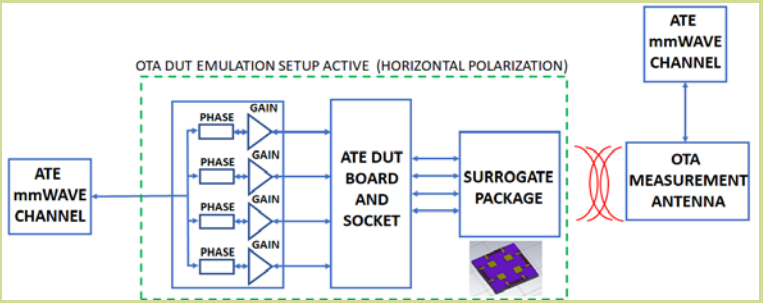
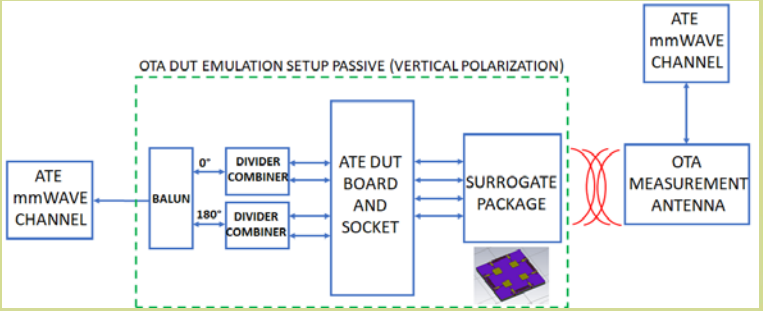
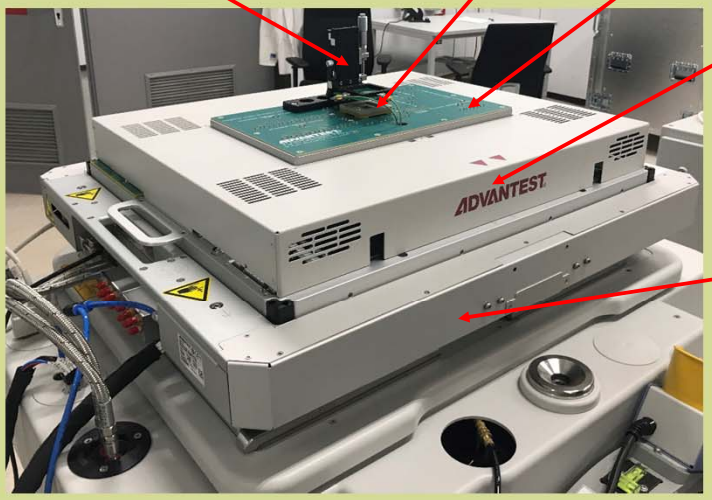
Creating an OTA ATE Test Vehicle

BEAM FORMING SETUP



PASSIVE SETUP





MANIPULATOR WITH MEASUREMENT ANTENNA HOLDER

SOCKET WITH SURROGATE PACKAGE

ATE DUT BOARD

GARAGE SPACE FOR ADDITIONAL PASSIVE AND ACTIVE COMPONENTS

ADVANTEST WSMM CC ATE mmWAVE MEASUREMENT SYSTEM

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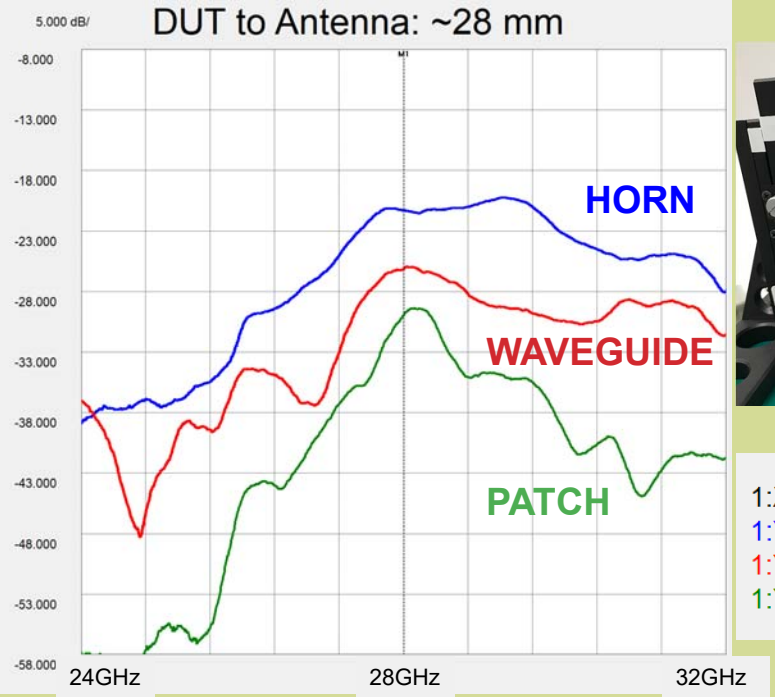
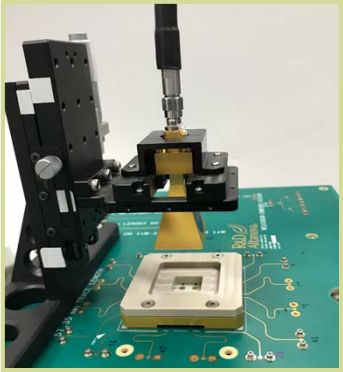
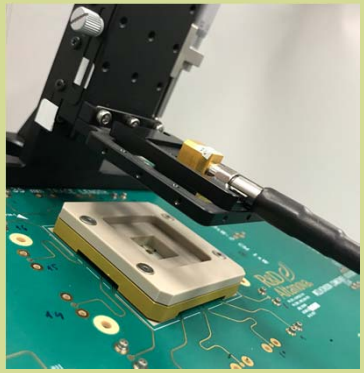
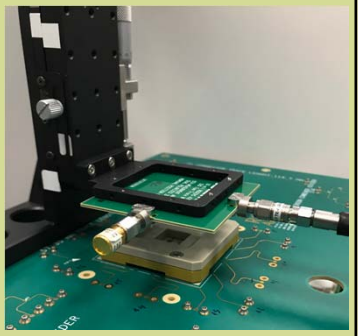
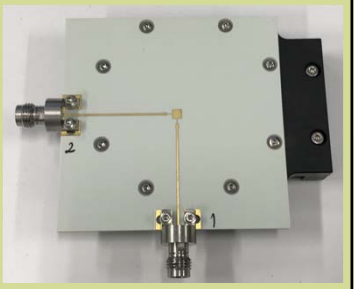
OTA Measurement Antenna Options



	HORN	OPEN WAVEGUIDE	PATCH ANTENNA
			
			

1:X	28 GHz
1:Y	-21.3 dB
1:Y	-26.08 dB
1:Y	-29.9 dB

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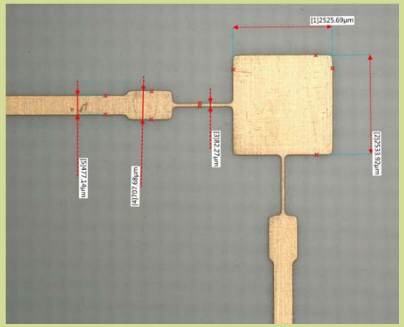
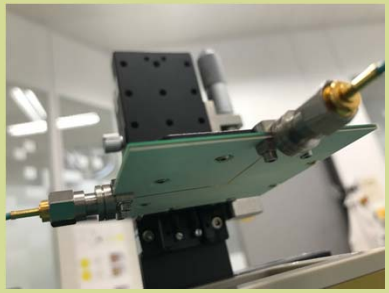
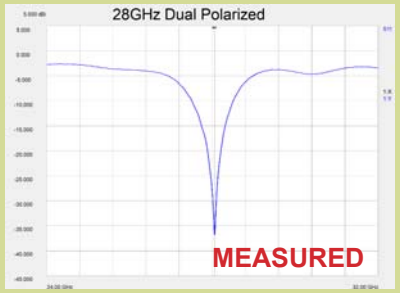
Patch Measurement Antenna Example

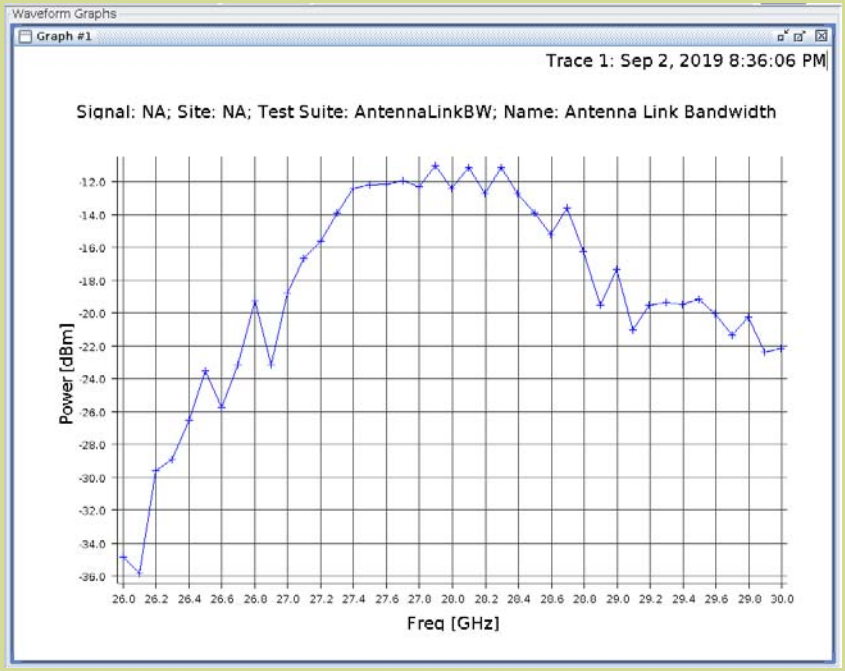
- **Exact same design as used on the "dummy" DUT package.**
- **Rogers 4350B, 28 GHz Dual Polarized.**







DISTANCE DUT TO MEASUREMENT ANTENNA: ~9mm



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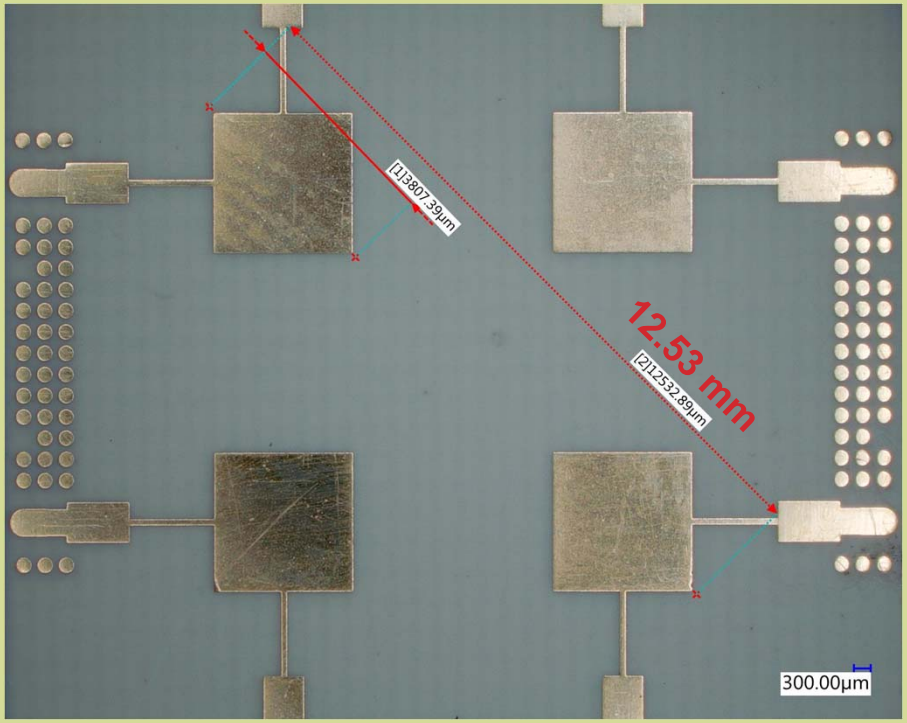
Computing the Far-Field Distance



$$\lambda_0 \approx \frac{300}{F_{(GHz)} \times \sqrt{\varepsilon_R}} (mm)$$

$$\lambda_0(28\,GHz) = 10.71 \text{ mm}$$

ANTENNA ARRAY

$$\text{Far-Field} \approx \frac{2 \times D^2}{\lambda_{0(28\,GHz)}} \approx \frac{2 \times (13)^2}{10.71} \approx 32 \text{ mm}$$

SINGLE ANTENNA

$$\text{Far-Field} \approx \frac{2 \times D^2}{\lambda_{0(28\,GHz)}} \approx \frac{2 \times (4)^2}{10.71} \approx 3 \text{ mm}$$

… though this is not a useful distance as any (conventional) probe antenna will strongly de-tune the patch feed impedance, leading to (potentially non-linear) variation of transceiver characteristics

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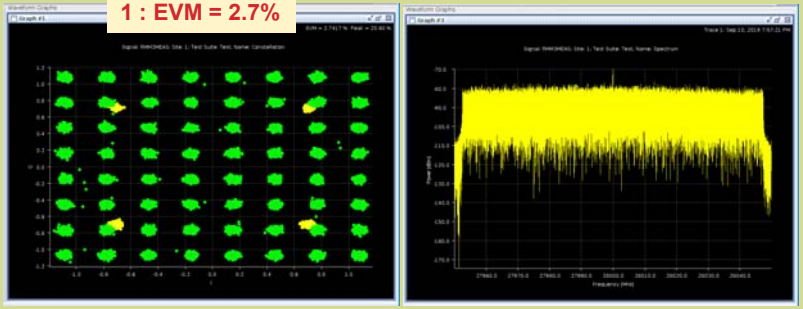
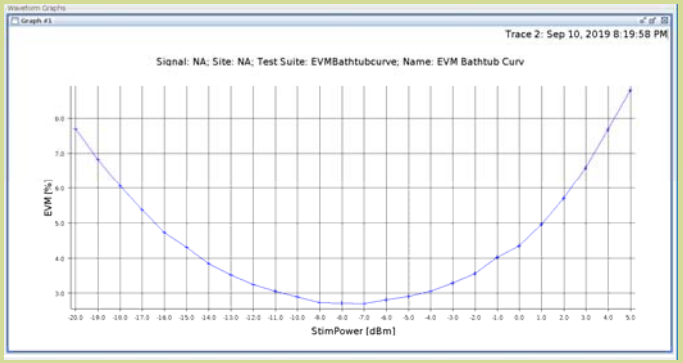
OTA Patch Measurement Antenna Example

DISTANCE DUT-MEASUREMENT ANTENNA: ~9mm

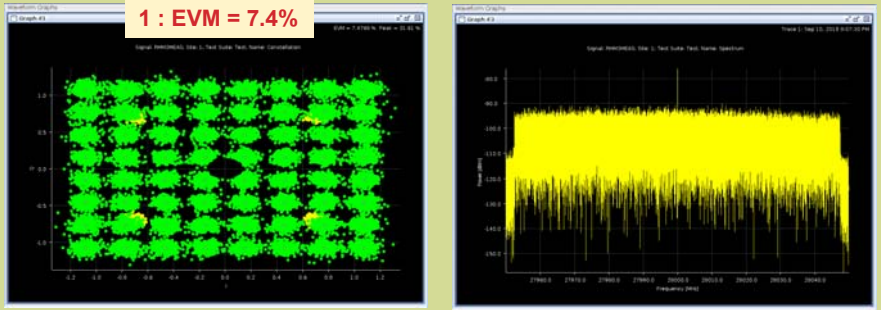
1 : EVM = 2.7%

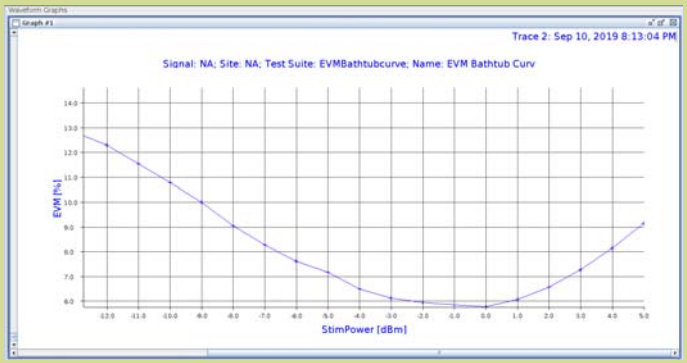




DISTANCE DUT-MEASUREMENT ANTENNA: ~16mm

1 : EVM = 7.4%





- **28 GHz 5G QAM64 WAVEFORM (100 MHz)**
- **SAME STIM POWER USED IN BOTH CASES**

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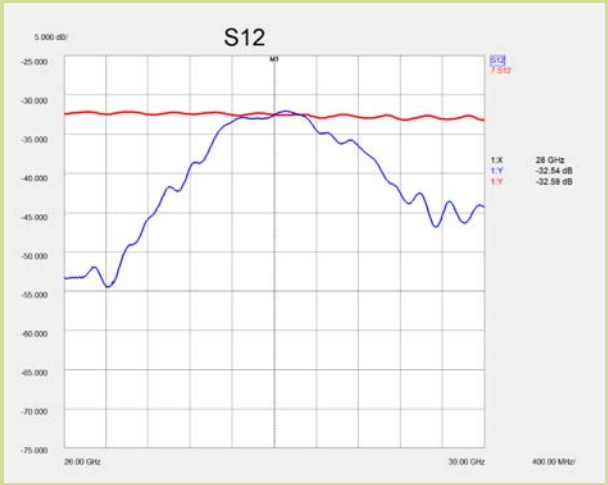
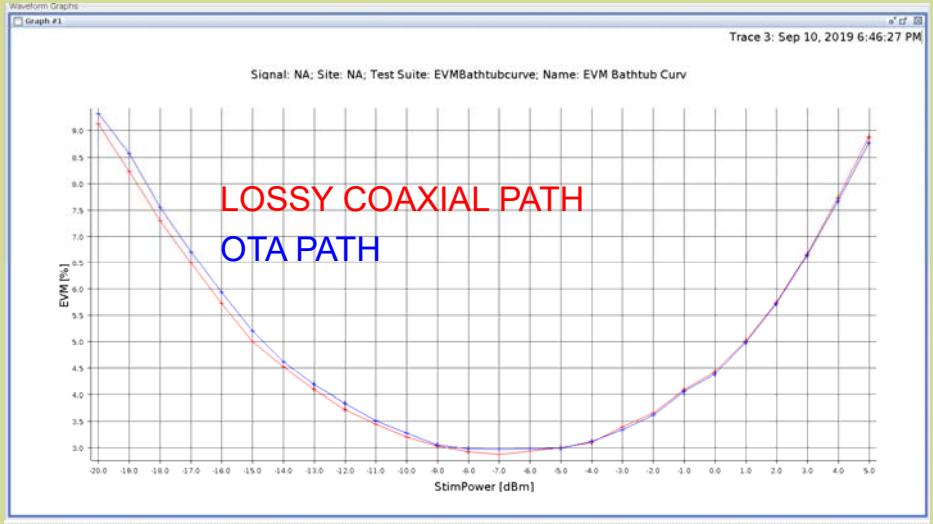
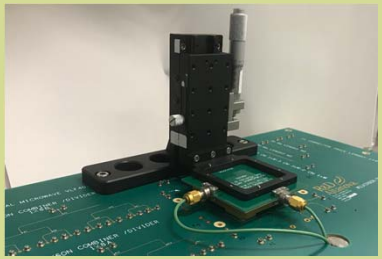
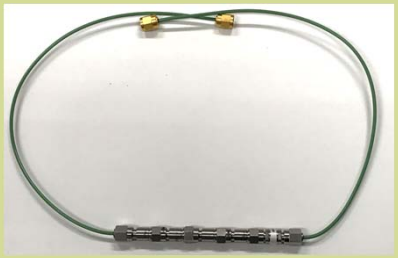
OTA vs Conductive









- A coaxial loopback path was created with attenuators to achieve the same loss at 28 GHz as the OTA measurement path (antenna to DUT distance: 16 mm).
- The results show that in this case the EVM results correlate between the OTA and conductive testing.

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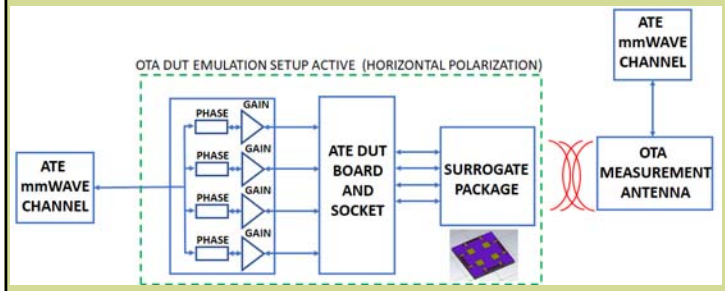
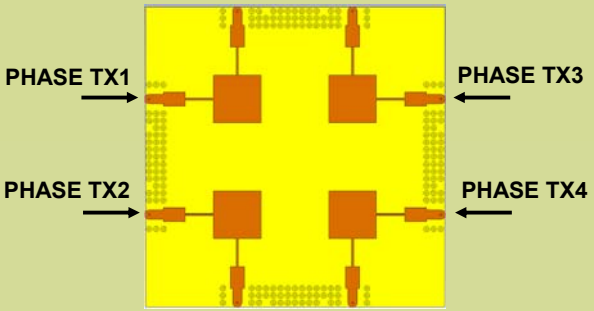
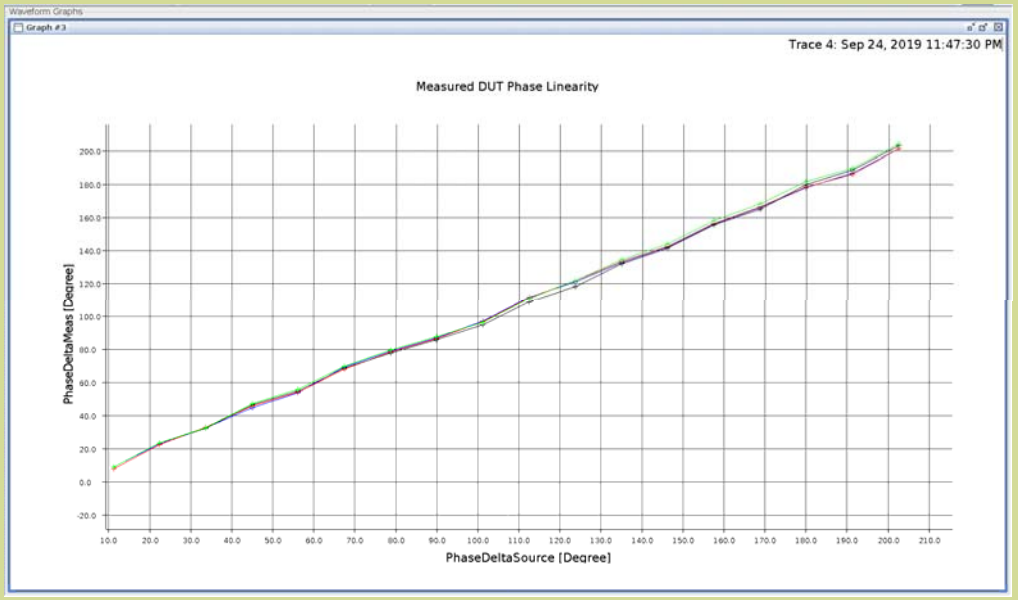
DUT Antenna Phase Measurement



- With the presented setup it is possible to measure the phase linearity of each antenna phase element control.
- But this measurement must be made serially.





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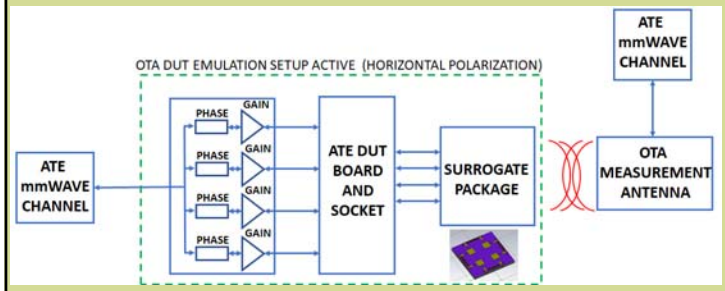
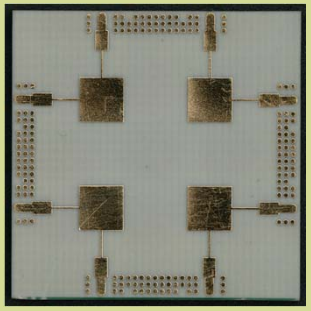
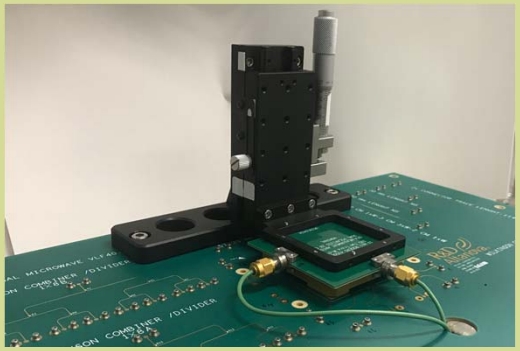
BeamForming Measurement

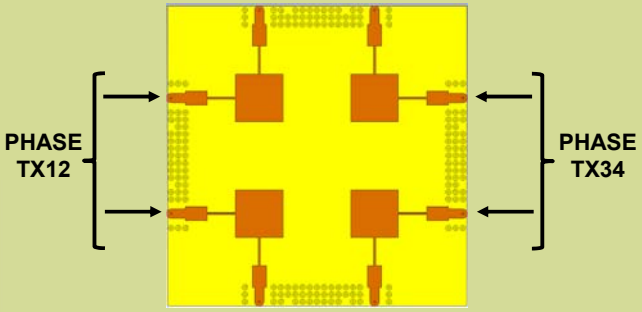


DUT

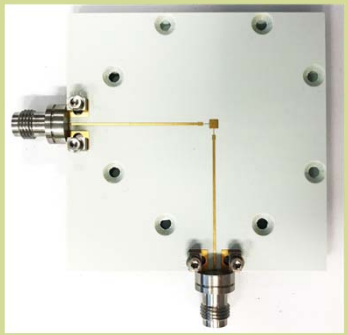


DUT TO MEASUREMENT ANTENNA DISTANCE ~9 mm

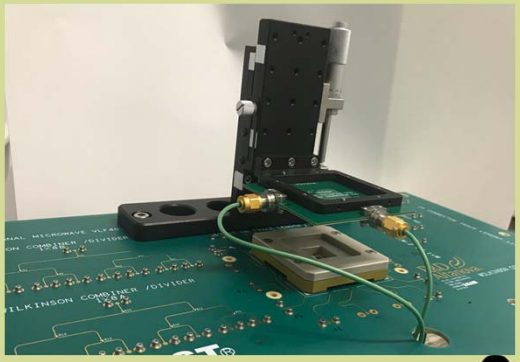




MEASUREMENT ANTENNA



DUT TO MEASUREMENT ANTENNA DISTANCE ~36 mm



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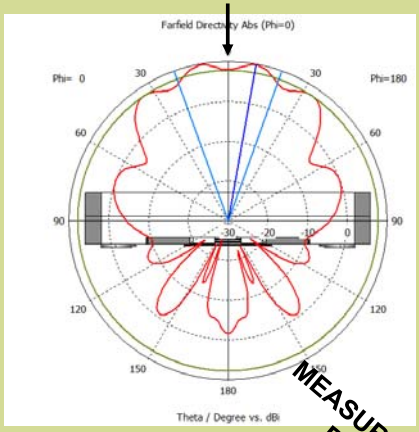
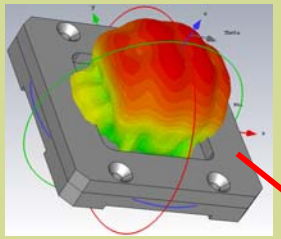
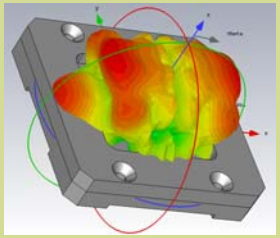
MEASUREMENT POINT

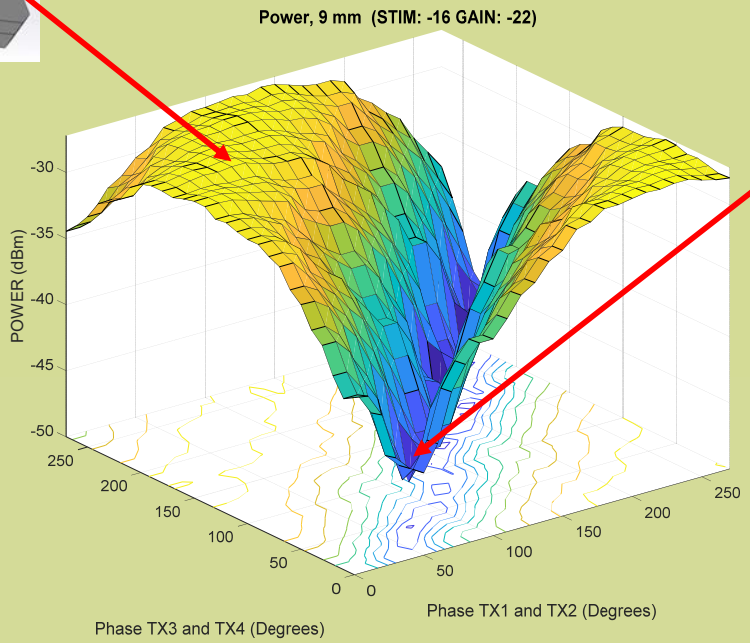


BeamForming Measurement

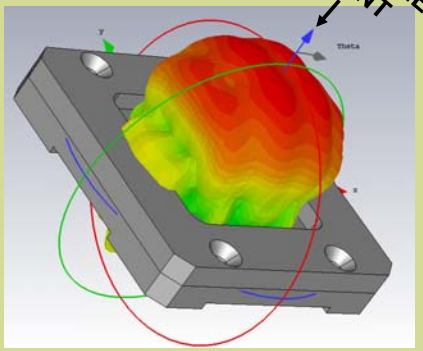


Boreside Direction Receive Power as a Function of Feed Phase of Array Elements





MEASUREMENT POINT



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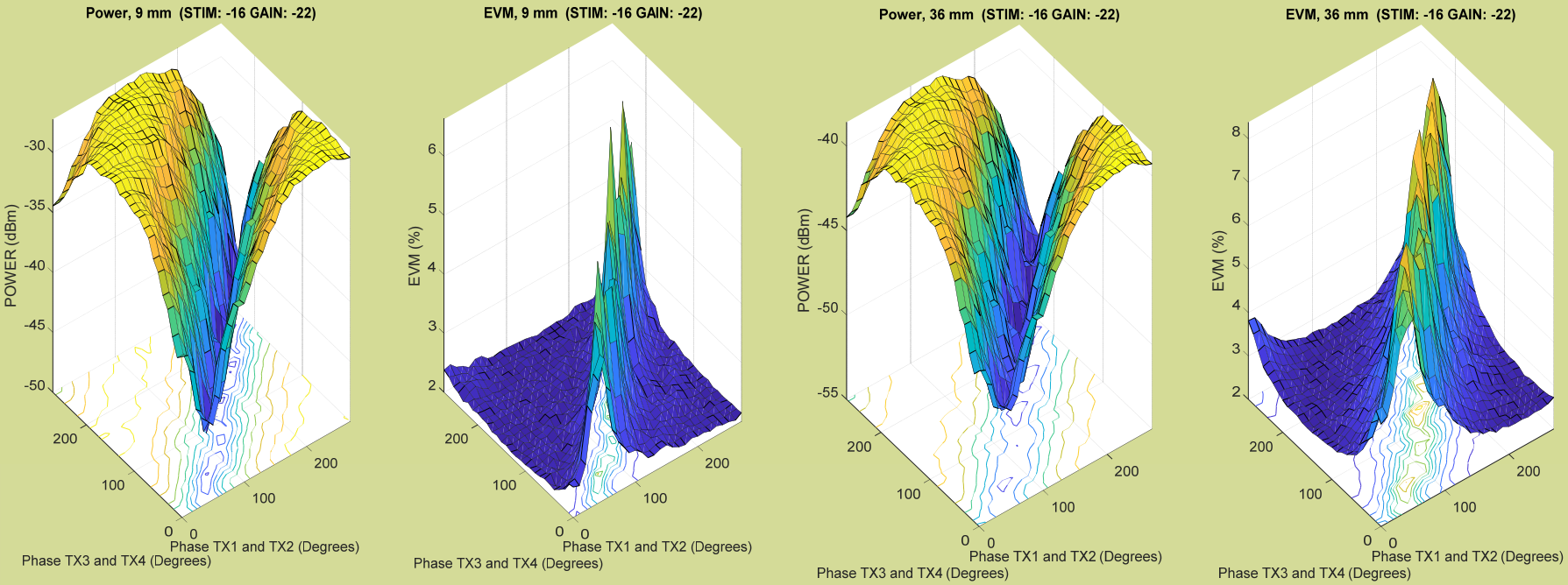
BeamForming Measurements



NEAR FIELD **FAR FIELD**

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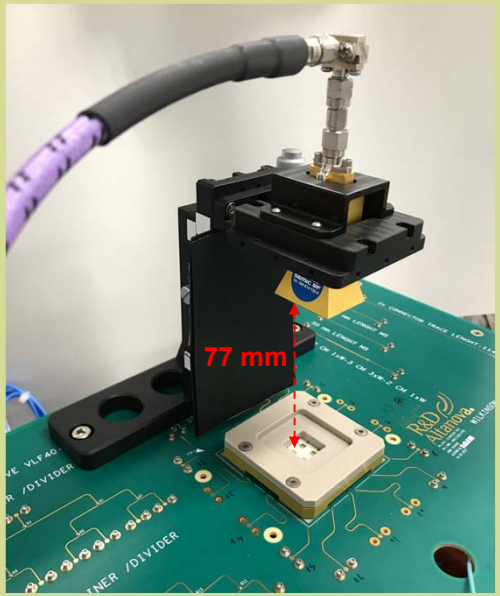
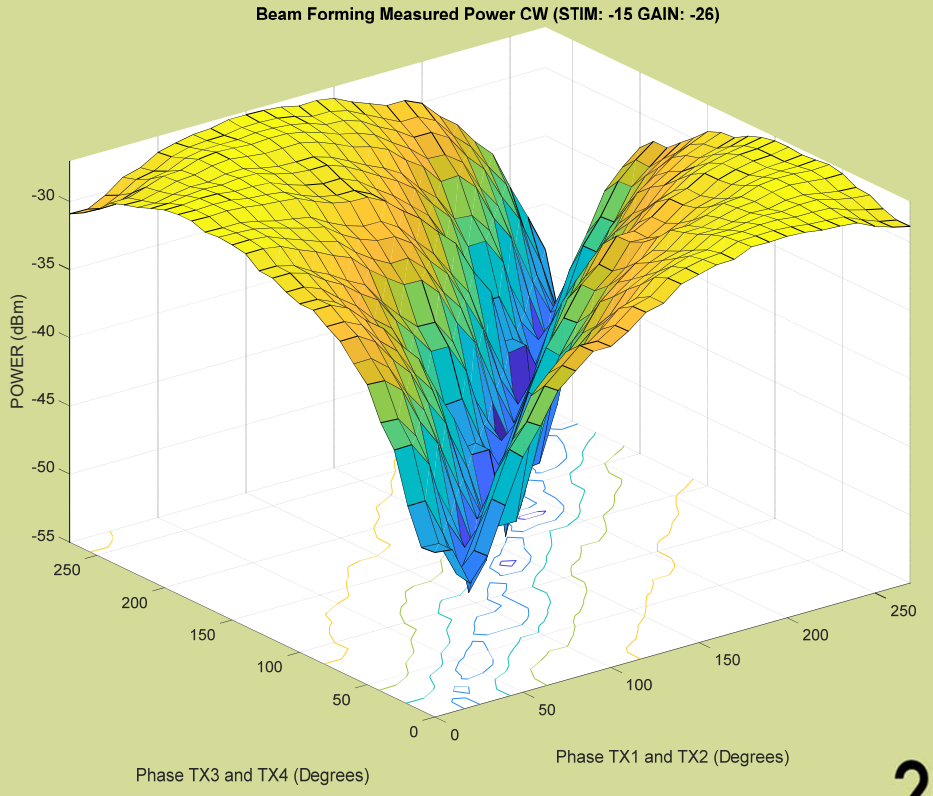
BeamForming Measurement



FAR FIELD WITH HORN ANTENNA



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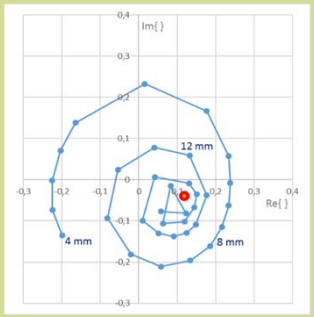
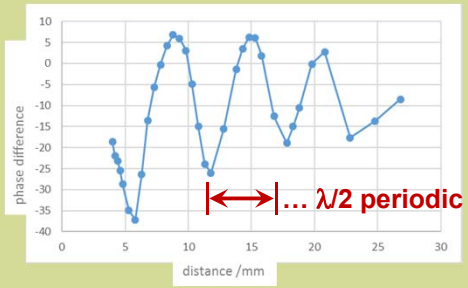
Near Field OTA Challenges

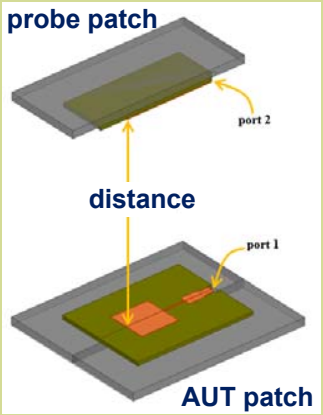
Probe (patch) antenna causes standing wave, leading to AUT feed impedance de-tune and periodic (λ/2) variation of transmission characteristics.

Simulation:

- Complex feed reflection coefficient over distance
- Transmission phase w.r.t. linear phase over distance

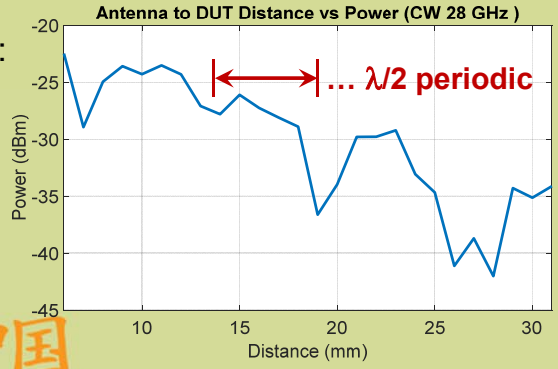


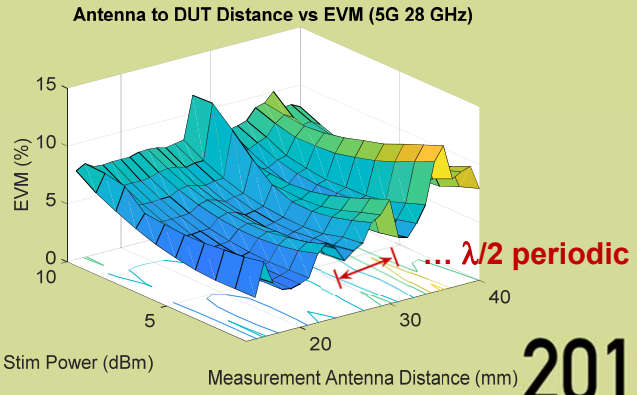




OTA test vehicle measurement:

- Transmission magnitude over distance
- EVM over distance (and over signal magnitude)





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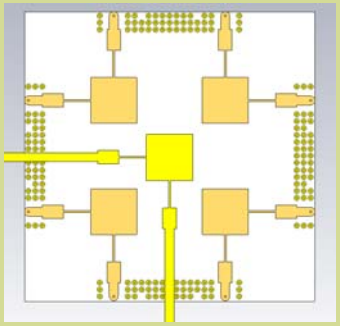
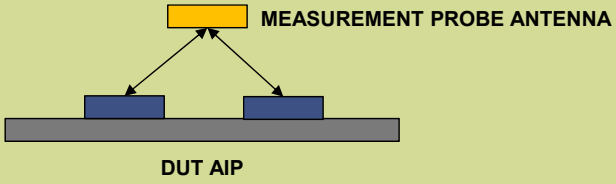
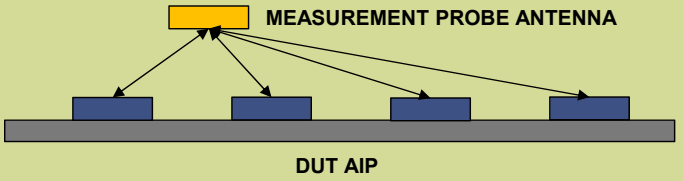
Near Field OTA Challenges

- The presented DUT antenna array and measurement antenna have a **symmetric configuration**
- This setup gives a too optimistic result because the measurement antenna distance to each DUT array antenna is the same.





- Any **realistic application** will have varying distances to different array elements, leading to the **test of some elements to fail** because of standing wave pattern resp. resonances between array and probe.



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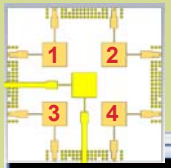
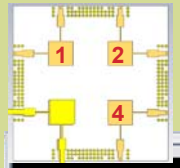
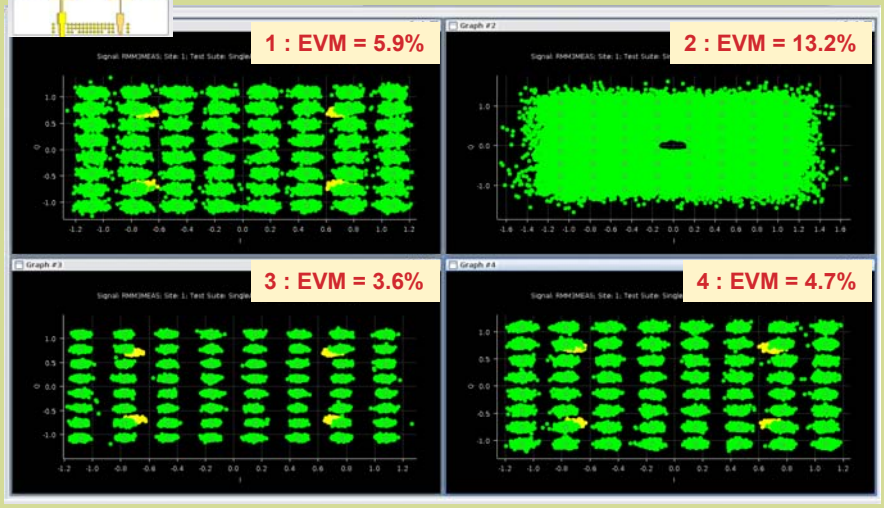
Issues with Single Measurement Antenna Approach



MEASUREMENT PROBE ANTENNA
SYMMETRICALLY CENTERED



MEASUREMENT PROBE ANTENNA
OFFSET FROM CENTER



distance from array plane to measurement probe antenna = 9 mm (0.84λ)

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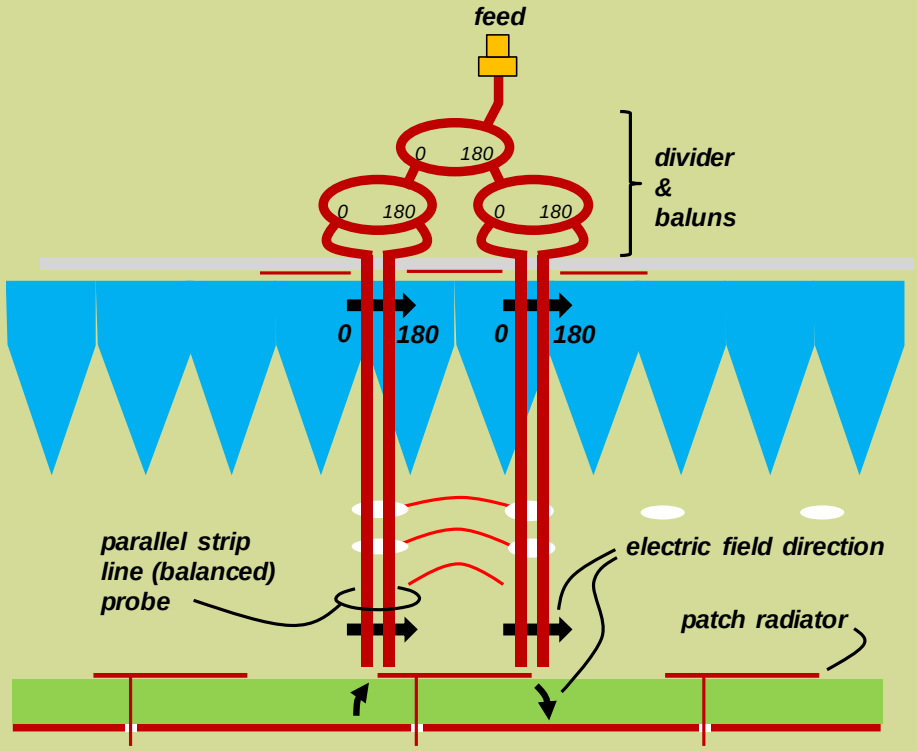
Reactive Near Field Probing

- Probing the radiation of a single radiator of an antenna array by means of a wire-probe pointing into the reactive field of the radiator.
- The wire-probe should not affect the radiator (i.e., radiator feed impedance left unchanged).
- The wire-probe must collect only small part of the electromagnetic field.
- The wire-probe should be routed such that radiated fields are not affected (E must be perpendicular to the wires etc.).



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REFERENCE: [5]

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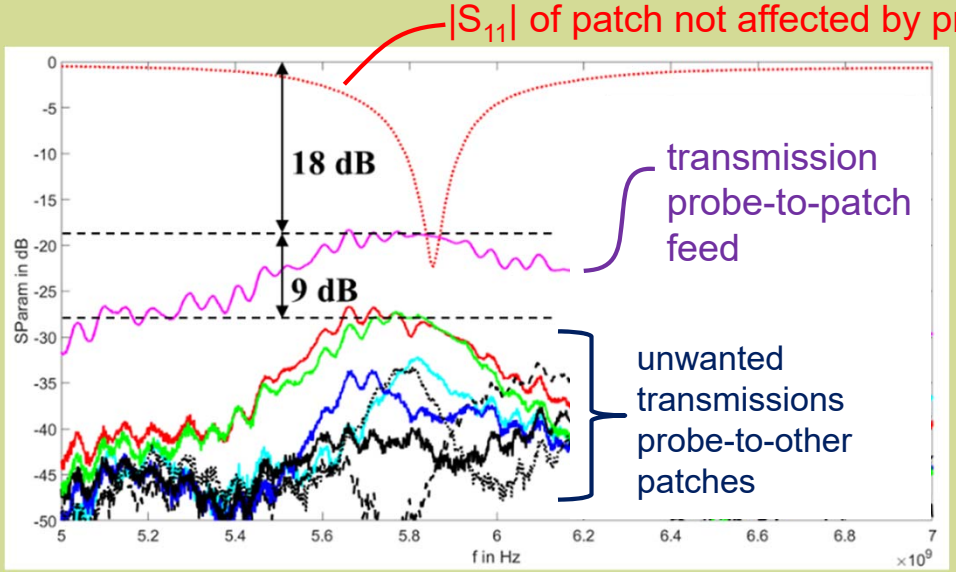
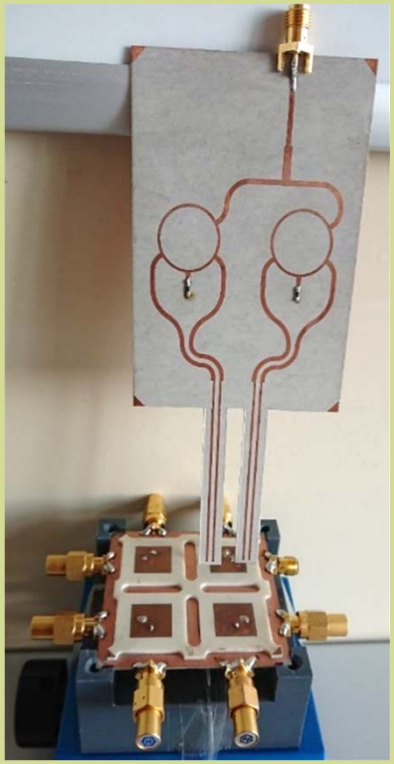
Reactive Near Field Probing

- Probing patch antenna radiators – low-frequency prototype
- Dual-linear polarized patch 2x2 array @ 5.8 GHz
- Probe is open-ended two-wire transmission line





REFERENCE: [5]

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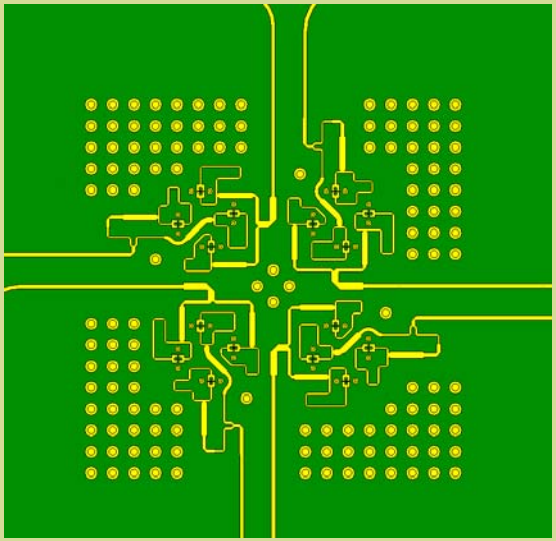
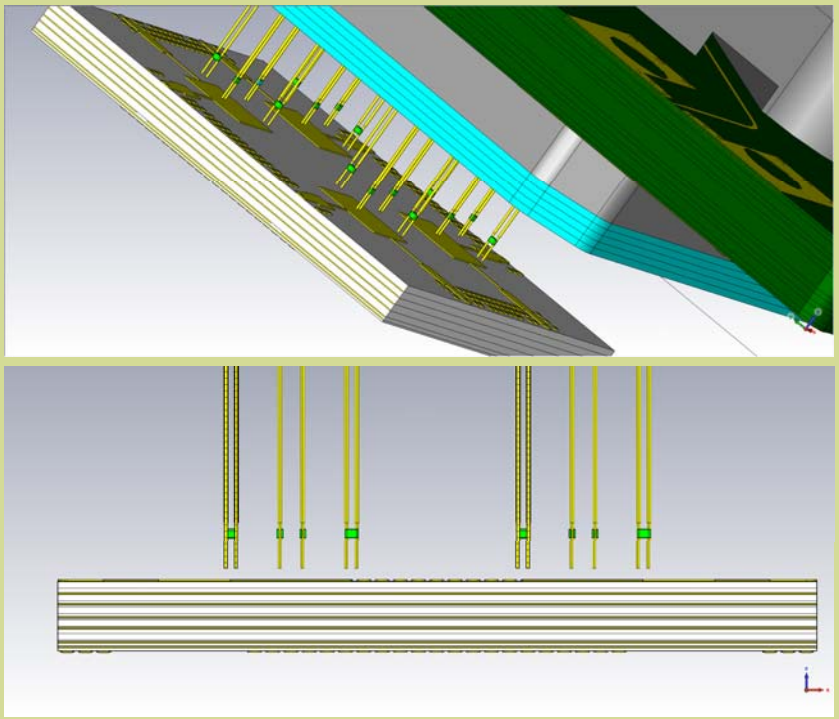
Reactive Near Field Probing

- Allows measuring each individual antenna in the array in parallel if enough ATE resources are available.
- Array size does not have an impact since the coupling is the same for each antenna.





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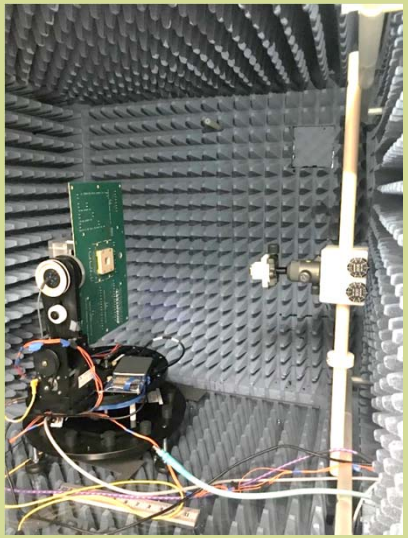
Evaluation Approach

- **The presented evaluation setup provides a pragmatic approach to test different OTA approaches to test a DUT with AIP and correlating with anechoic chamber measurements.**
- **Can be used with a pre-existing evaluation board for anechoic chamber characterization.**
- **After a given OTA methodology is evaluated and chosen, the remaining implementation is just a mechanical challenge.**

PASS/FAIL CORRELATION



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Conclusions

- If a near field OTA strategy is chosen it is important to understand its limitations.
- A new OTA approach based on probing the reactive near field was presented that addresses some of the near field OTA limitations.
- The presented ATE OTA setup allows to easy evaluation of different OTA measurement approaches with different geometries.
- After verifying that the chosen OTA test methodology works and has the needed failure coverage, it then becomes only a mechanical problem to implement it in a productive solution for a high-volume ATE test cell.

Acknowledgments

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- We would like to thank Markus Rottacker and Kosuke Miyao from Advantest for supporting this project.
- We would like also to thank Don Thompson from R&D/Altanova for the help on the surrogate package design and manufacturing.

References

- [1] Daniel Lam, “Handler with Integrated Receiver and Signal Path Interface to Tester“, Patent No . : US9,838,076B2, Dec . 5 , 2017.
- [2] Harrison Chang et al., ”From Assembly to Testing, Characterization of Low Cost Organic Substrate for mm-Wave AiP Application”, IEEE IMS 2019.
- [3] Aaren Lonks, “Measurement Challenged for Over The Air Test of Antenna in Package ICs”, TestConX 2019.
- [4] Don Thompson, Jose Moreira and Giovanni Bianchi, “PCB Test Fixture and Socket Challenges for mmWave Applications”, BITS 2016.
- [5] Jan Hesselbarth, Georg Sterzl and Jose Moreira, “Probing Millimeter-Wave Antennas and Arrays in their Reactive Near-Field“, European Microwave Conference 2019.

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