Socket Design and Handler Integration Challenges in Over the Air Testing for 5G Applications

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Advantest

TestConX

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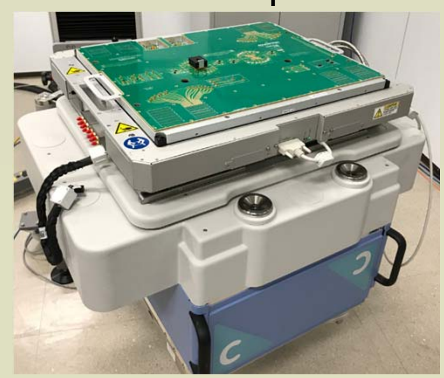
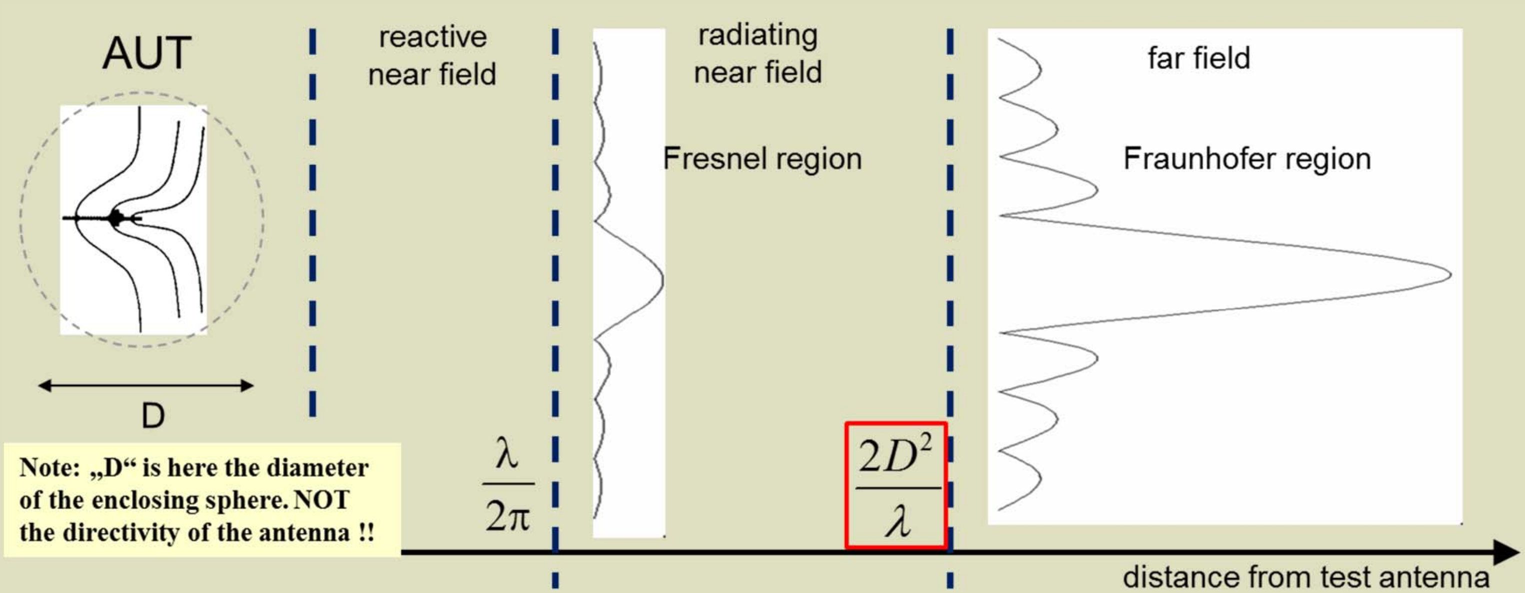
Contents

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



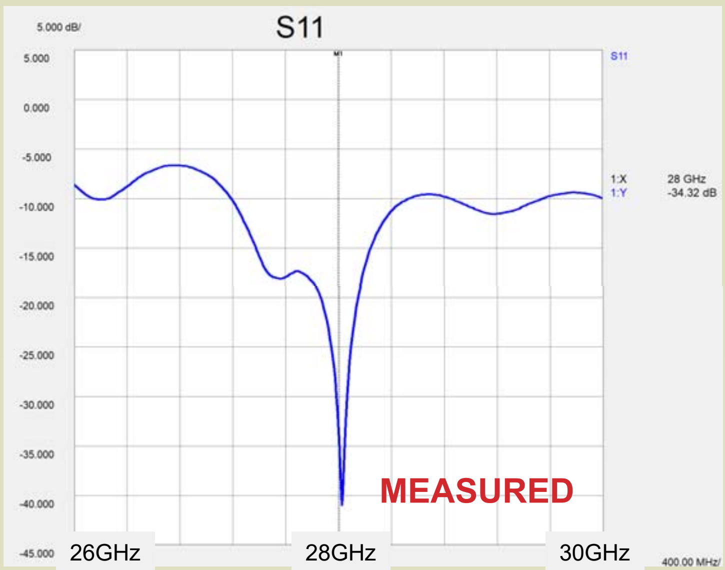
Near Field vs Far Field

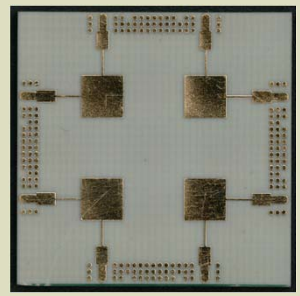


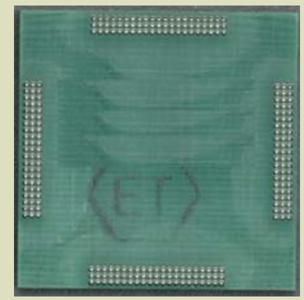
- far-field: angular variation independent of distance; locally plane waves
- reactive near-field: non-radiating fields dominate

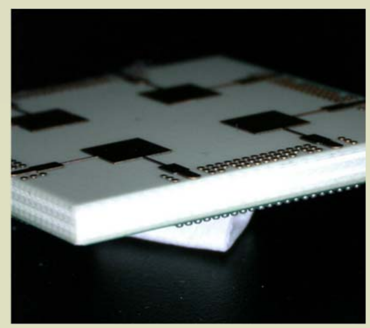
Creating an OTA ATE DUT Test Vehicle

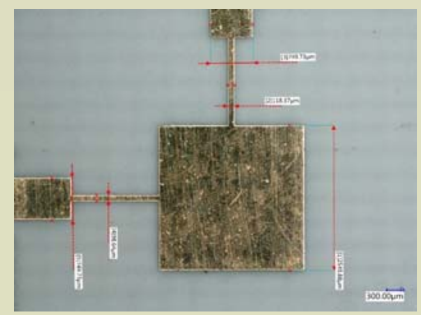
- **A "dummy" DUT (surrogate package) was developed with a 2x2 dual polarized antenna array tuned for 28 GHz.**
- **Dielectric material was Rogers 4350 (10 mil thick), BGA pitch is 0.4 mm, DUT thickness (including solder balls) is 1.9 mm.**



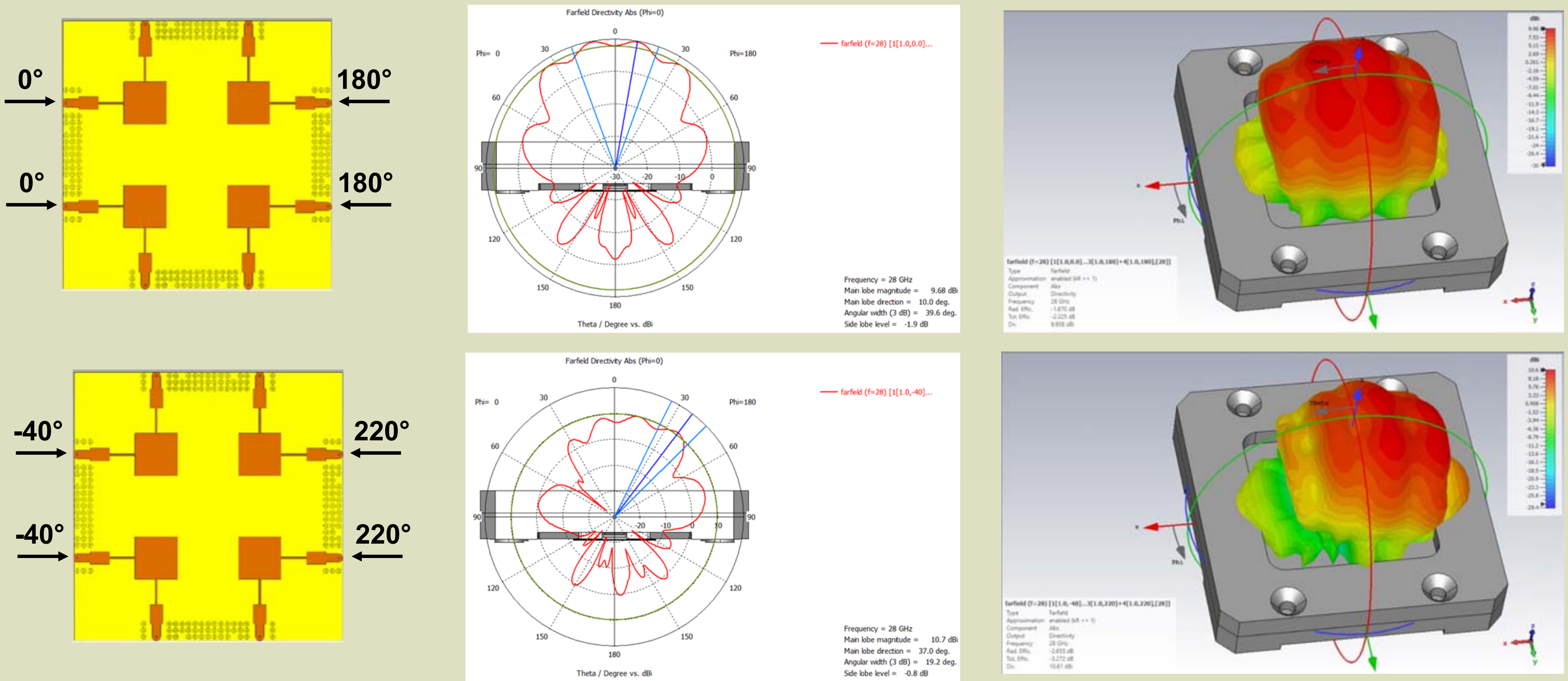








Antenna Far Field Beamforming Simulation



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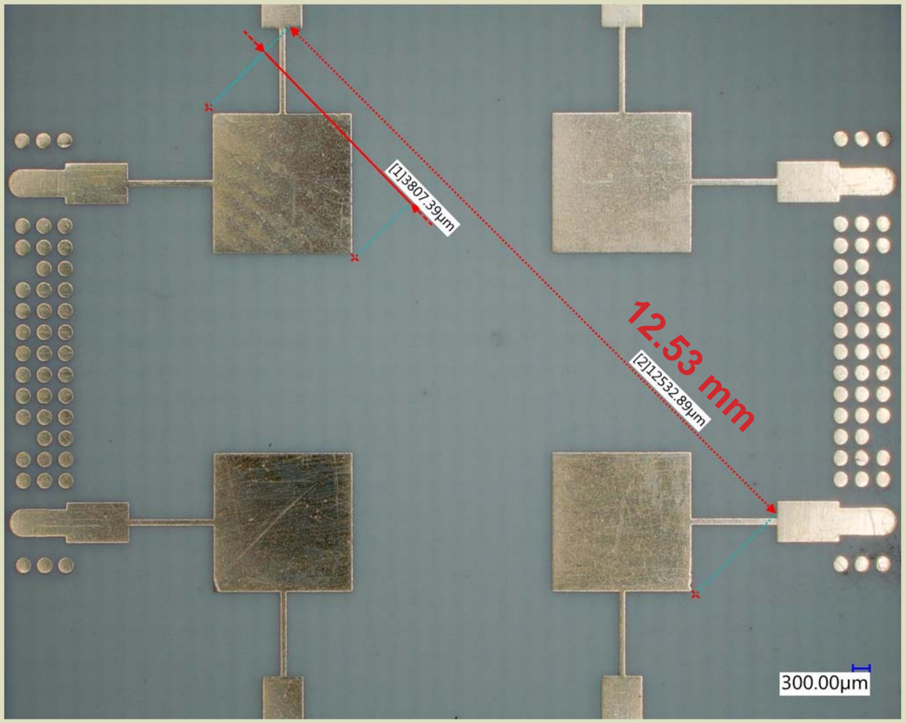
Computing the Far Field Distance



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

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

ANTENNA ARRAY

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

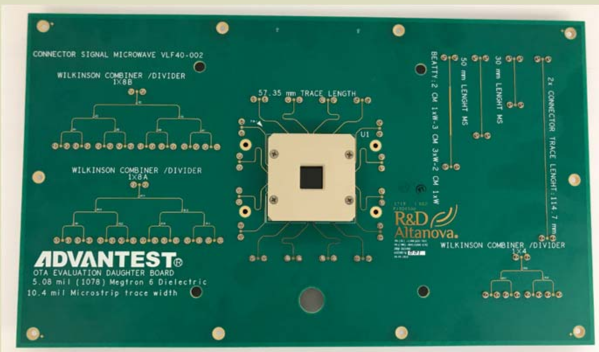
SINGLE ANTENNA

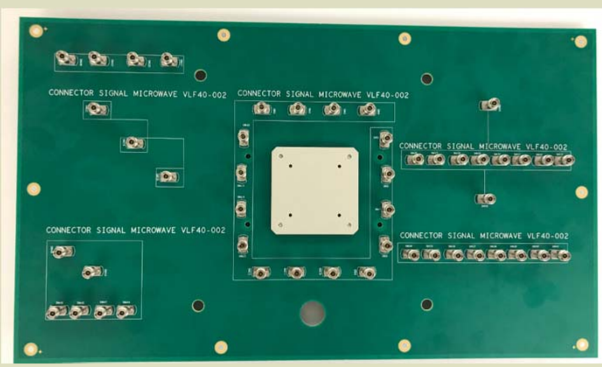
$$\text{Far-Field} \approx \frac{2 \times D^2}{\lambda_{0(28\ GHz)}} \approx \frac{2 \times (4)^2}{10.71} \approx 3 \text{ mm}$$

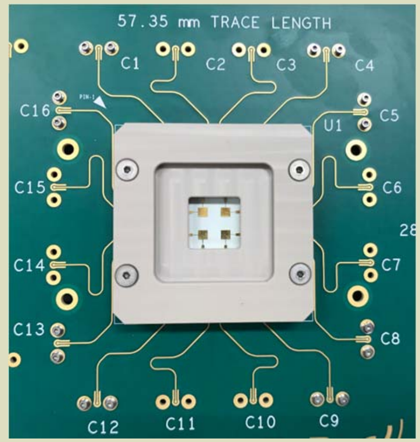
… though this is not a useful distance as any (conventional) probe antenna will strongly de-tune the patch feed impedance, leading to (potentially non-linear) variation of transceiver characteristics

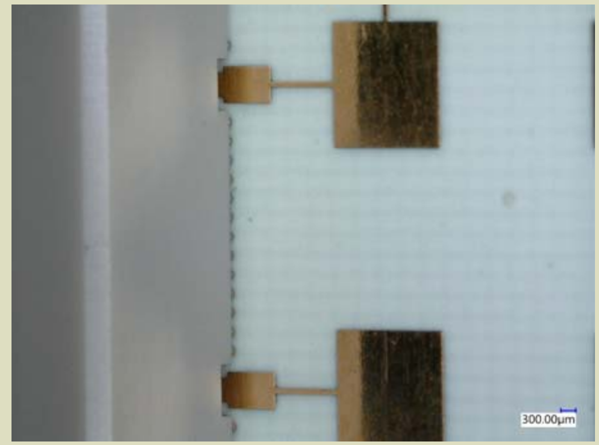
OTA ATE Test Vehicle: The DUT Test Fixture

THE DUT TEST FIXTURE

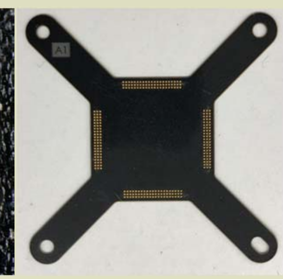






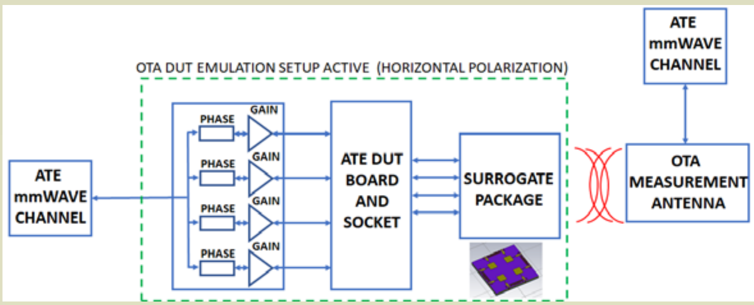


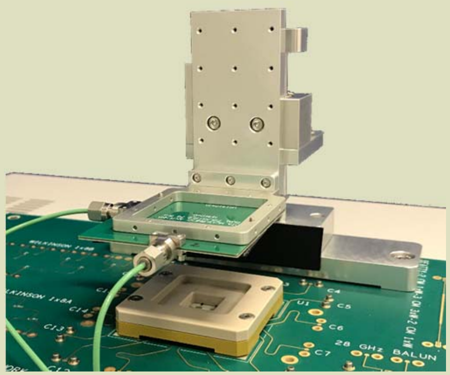
SOCKET



Creating an OTA ATE Test Vehicle

BEAM FORMING SETUP

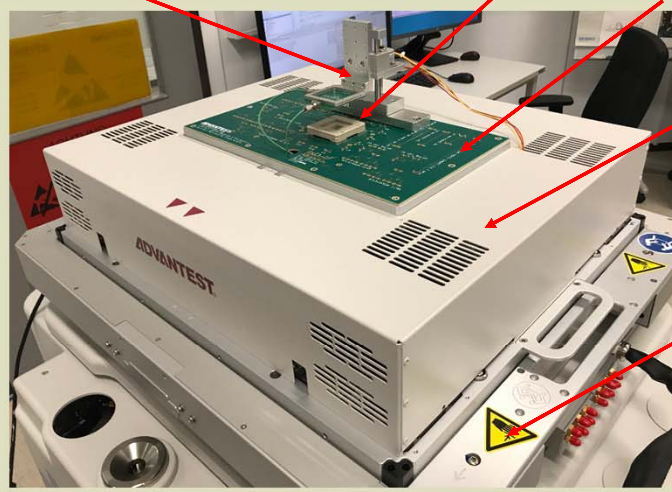




Motorized Manipulator With Measurement Antenna Holder

Socket with Surrogate Package

ATE DUT Test Fixture



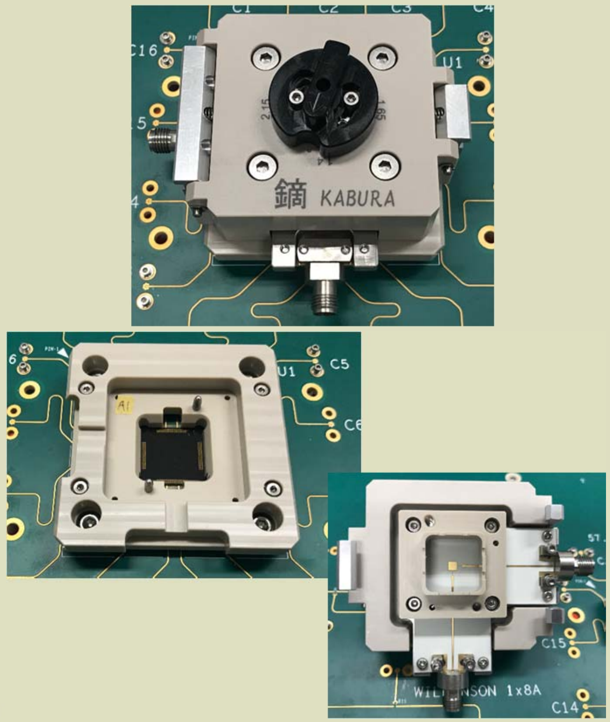
Garage Space for Additional Passive and Active Components

ADVANTEST WSMM CC ATE mmWave measurement system

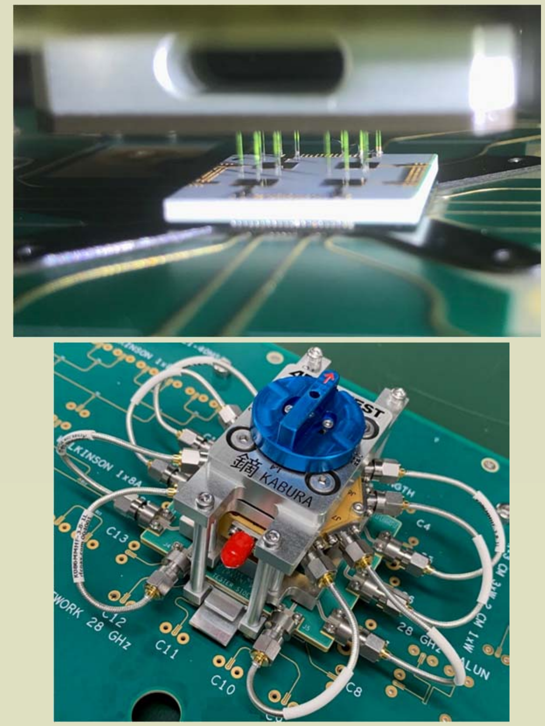
OTA Testing Options

Far Field

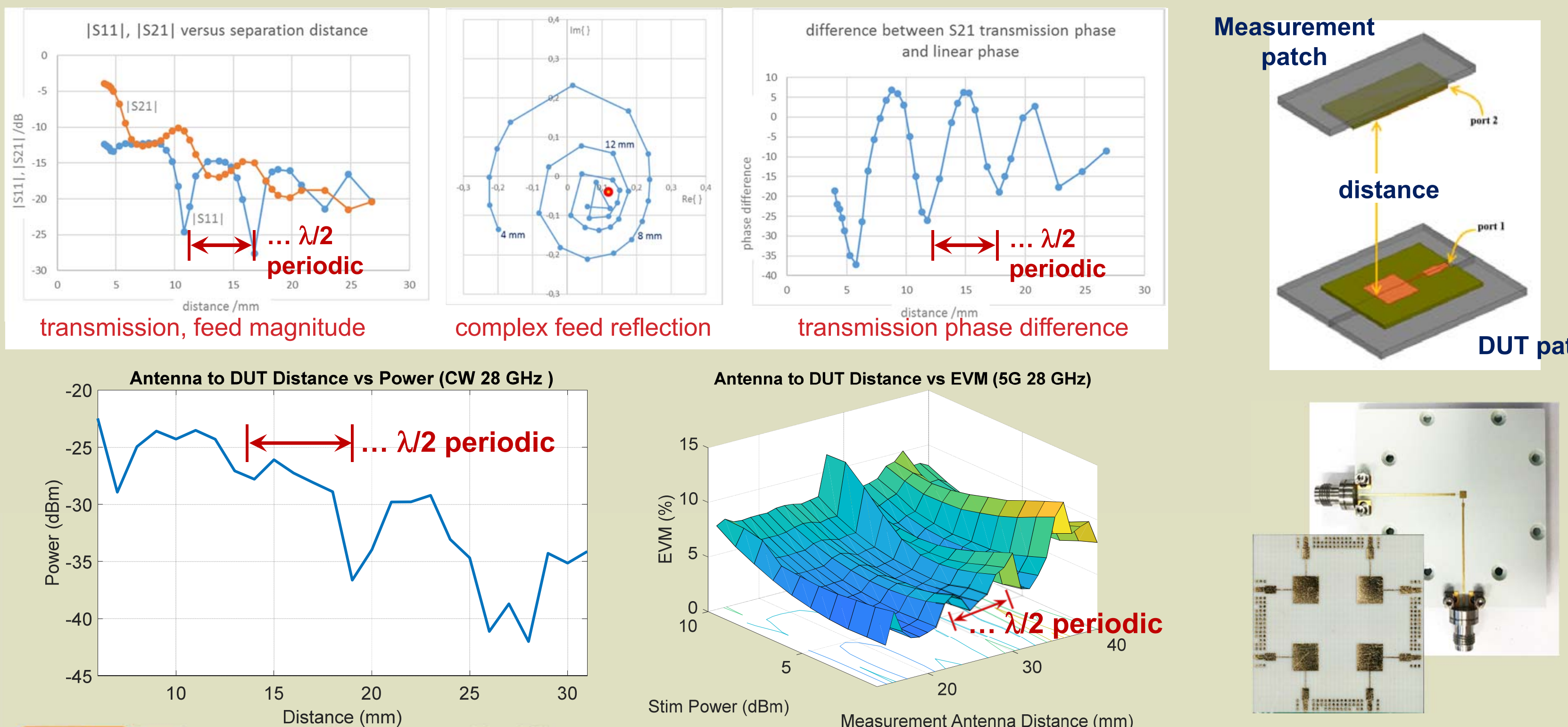
Radiating Near Field



Reactive Near Field



Radiating Near Field OTA Challenges



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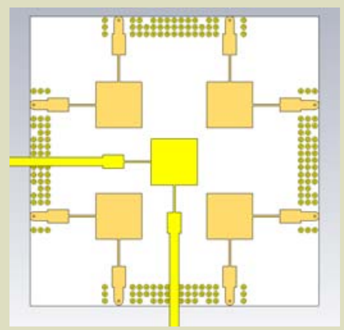
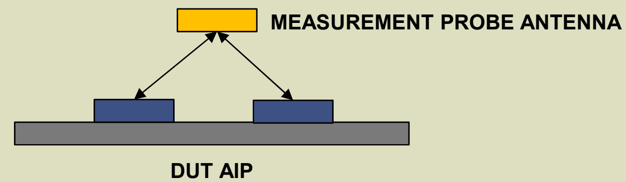
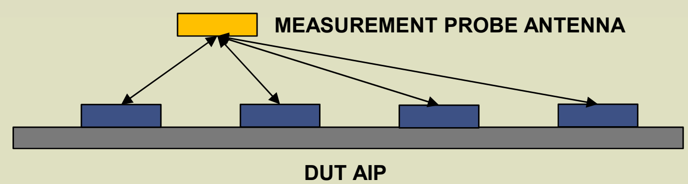
Radiating Near Field OTA Challenges

- 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.





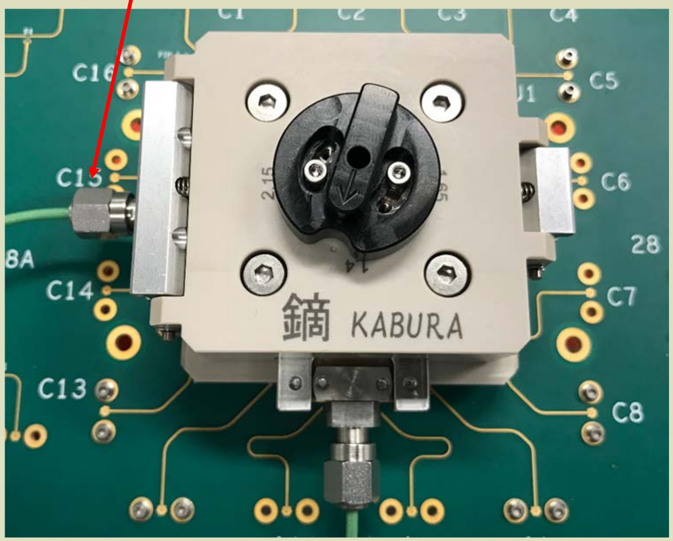
- Any **realistic application** will have varying distances to different array elements, leading to the **test of some elements to fail** because of standing wave pattern resp. resonances between array and probe.

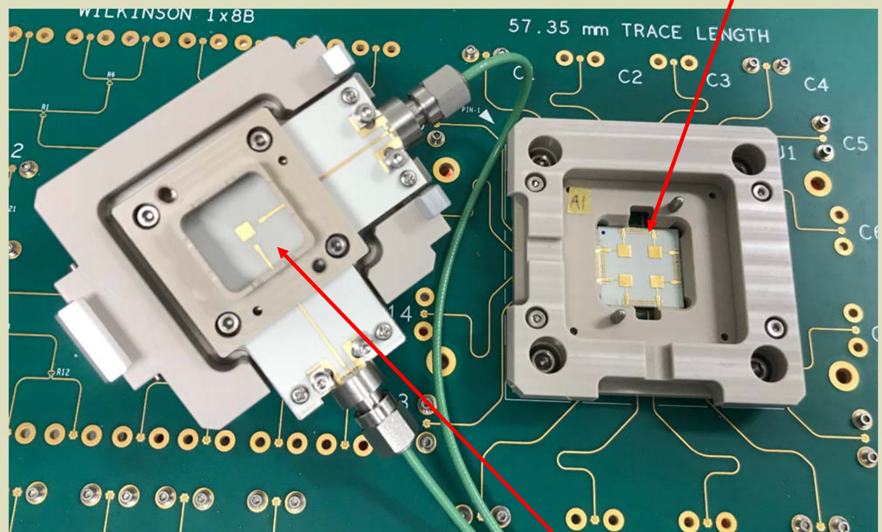


Low Cost Radiating Near Field OTA Socket

28 GHz Signals from Measurement Antenna to ATE Measurement System

DUT (surrogate package) on an elastomer type socket (0.4 mm pitch)

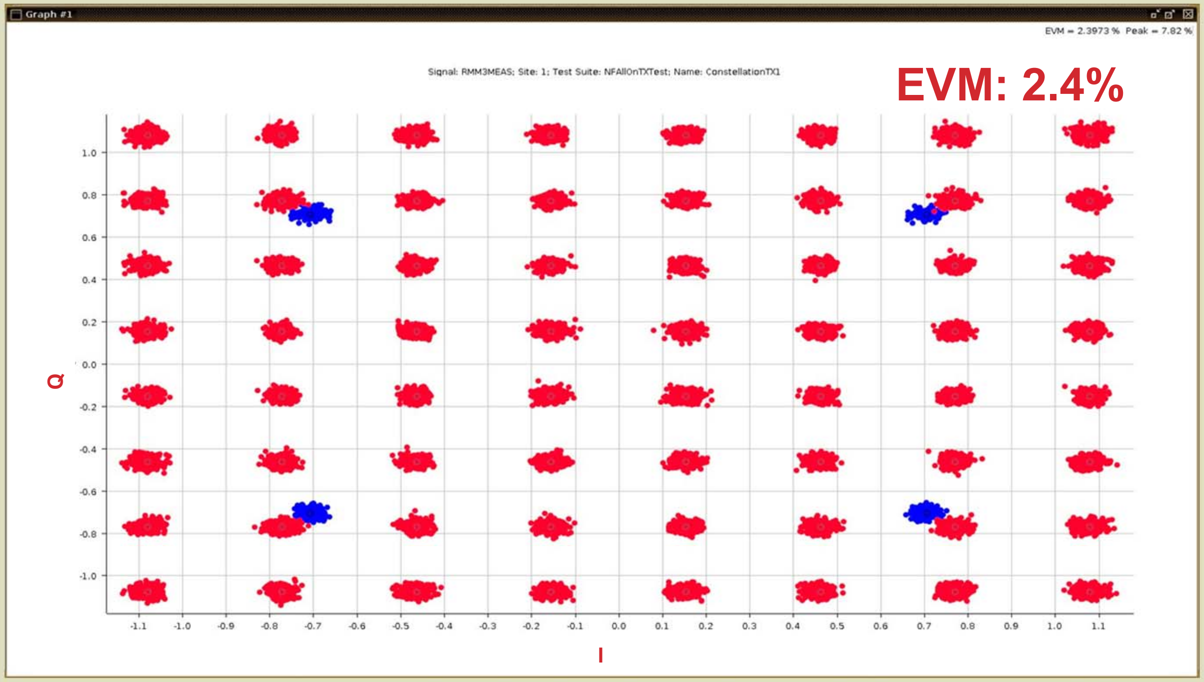


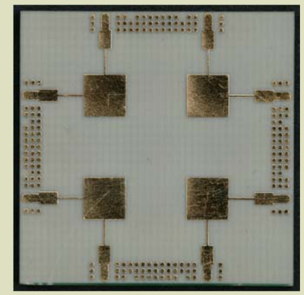


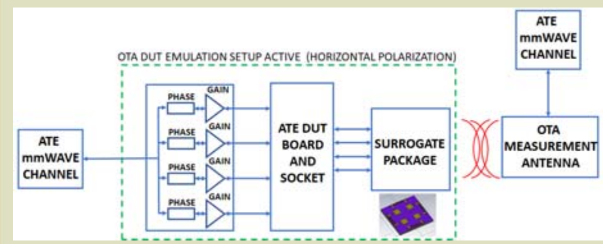
28 GHZ dual polarization patch measurement antenna

DUT to Measurement Antenna Distance of ~11mm

Radiating Near Field OTA Socket Results

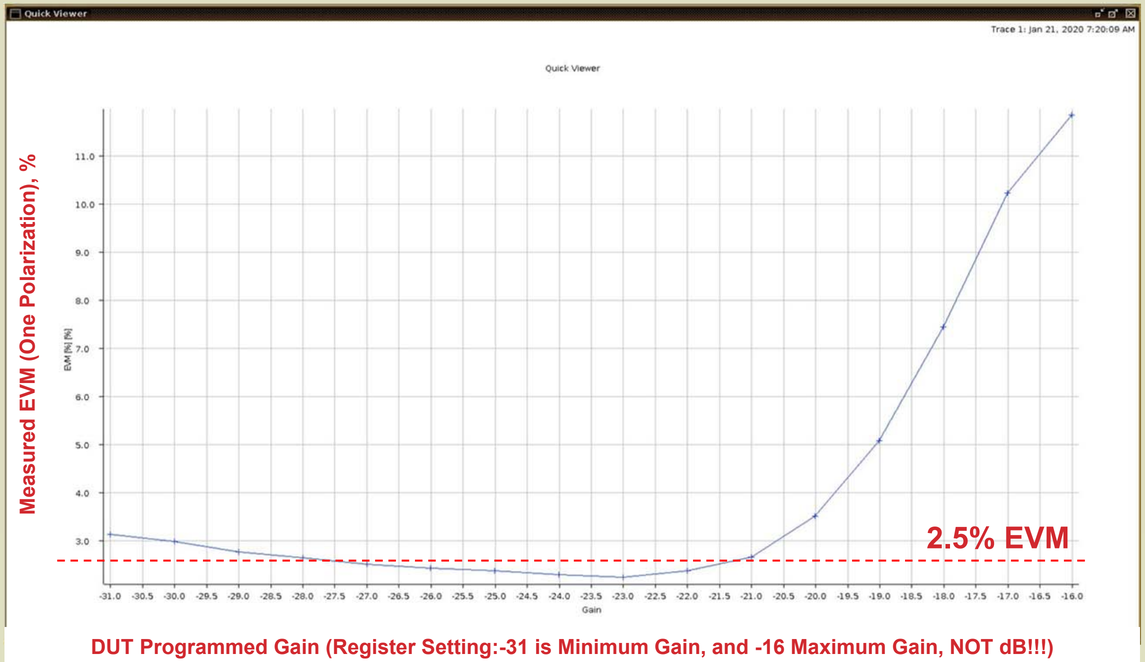


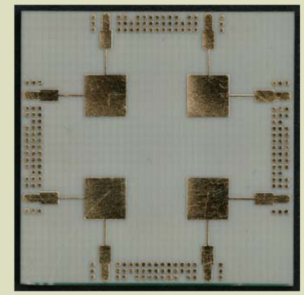


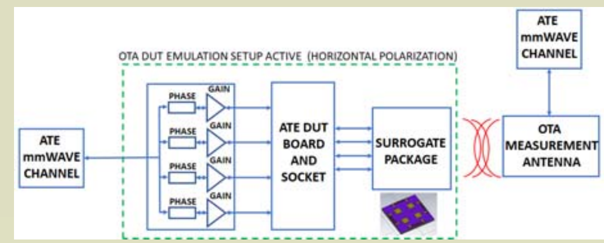


Measured with ATE System, 28 GHz 5G QAM64 Waveform (100 MHz)

Radiating Near Field OTA Socket Results







Measured with ATE System, 28 GHz 5G QAM64 Waveform (100 MHz)

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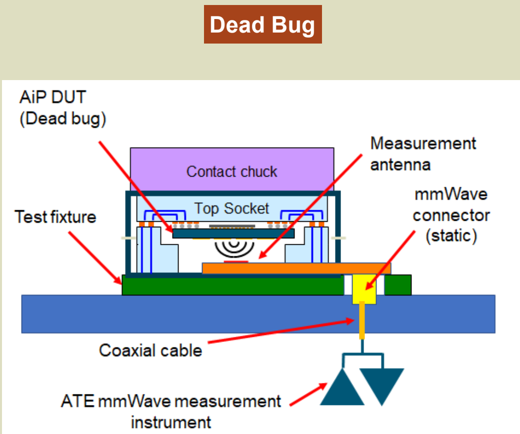
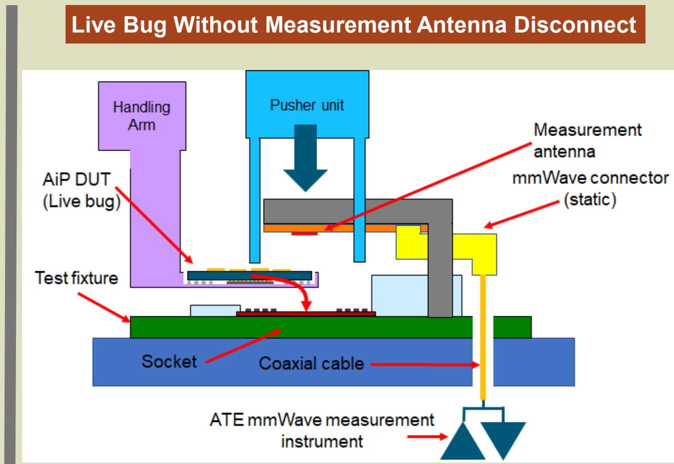
OTA Testing Options

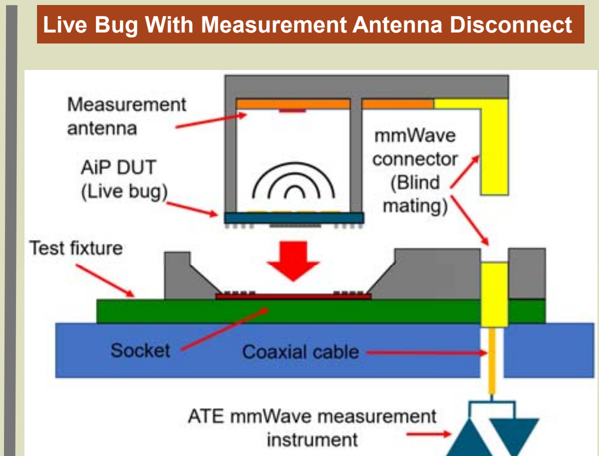
OTA Test Strategy	Advantages	Disadvantages
Far Field Antenna	• Far-field measurement • DUT antenna is not impacted by the measurement antenna • Easiest setup to correlate with measured data using 3GPP compliant methods	• Integration in standard ATE test cell difficult due to mechanical dimensions • Multisite implementation complex • High cost of test for volume production
Radiating Near Field Antenna	• Easy integration on standard ATE test cell • Easy multisite implementation • Low cost	• Measurement antenna (e.g. patch) will have an impact on the DUT antenna performance (standing wave effect). • Possible different distances between the measurement antenna and DUT antenna array elements • If "golden device" calibration used, results are critically dependent on "golden device" performance. No absolute measurements possible
Reactive Near Field Probe	• Probing measurement elements have a minimal impact on the DUT antenna • Each DUT radiating element is individually measured • Easy integration on standard ATE test cell • Easy Multisite implementation	• Complex design with high NRE and manufacturing costs • Long lead-time • Higher loss due to weak coupling of the probes to the DUT radiating elements

Handler Integration Challenges for OTA

- For discussion simplicity we assume a top firing (patch antenna array) only AIP DUT.
- Three different approaches are possible for the AIP DUT handling in a handler test cell setup: dead bug, live bug without measurement antenna disconnect and live bug with measurement antenna disconnect.







OTA Handler Integration Challenges

Good	Acceptable	Bad

Item	Dead bug	Live bug without measurement antenna disconnect	Live bug with measurement antenna signal disconnect
Measurement antenna connection	No measurement antenna disconnect. Does not require a high reliability blind mating mmWave interconnect.	No measurement antenna disconnect. Does not require a high reliability blind mating mmWave interconnect.	Antenna is mounted on the handler plunger. Requires a high reliability blind mating mmWave interconnect (e.g waveguide)
Electrical side contactor	Needs longer electric length and double the number of contacts due to top side contact, but for only DC/Digital and IF RF signals	Standard socket design	Socket design needs to include the blind mating mmWave interconnect for the measurement antenna signals
Thermal control	Temperature controlled air blow and socket temperature control	Temperature controlled air blow and socket temperature control	Temperature controlled air blow and socket temperature control
Socket size	Small. 80mm pitch x8 testing is possible	Small. 80mm pitch x8 testing is possible	Blind mating mmWave interconnect takes additional space limiting multisite implementation
Contact motion	Normal Z motion	Need Y-Z motion, 4x2 layout is difficult	Normal Z motion
Device handling	Need flip mechanism	Need special handling arm	Need special device pickup structure for plunger
Handling arms for Contact area	Only contact arm. Can be integrated to standard handler	Need device in/out arm and contact arm. Need dedicated handler	Only contact arm. Can be integrated to standard handler

Conclusions

- There are multiple options for OTA testing. There is no optimal choice. It depends on the test coverage requirements, cost of test requirements and where on the product life cycle stage one is (characterization, early production ramp, high volume production, etc.)
- The radiating near field approach has several drawbacks but is the easiest and lowest cost approach for OTA.
- Golden device appears to be the best approach to handle the calibration needs of a radiating near field OTA approach.
- The reactive near field approach addresses several of the disadvantages of the radiating near field approach. It was not discussed in this presentation but is explain in detail on the references provided at the end of this presentation.

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References

- Jan Hesselbarth, Georg Sterzl and Jose Moreira, "Probing Millimeter-Wave Antennas and Arrays in their Reactive Near-Field", European Microwave Conference 2019.

- Jose Moreira, Jan Hesselbarth, Krzysztof Dabrowiecki," Challenges of Over The Air (OTA) Testing with ATE", TestConX China 2019.

- Utpal Dey, Jan Hesselbarth, Jose Moreira, Krzysztof Dabrowiecki, "Over-the-Air Test of Dipole and Patch Antenna Arrays at 28 GHz by Probing them in the Reactive Near-Field", to be presented at 95th ARFTG Microwave Measurement Conference.

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