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Socket Design and Handler Integration for High-Volume Over the Air Testing of 5G Applications

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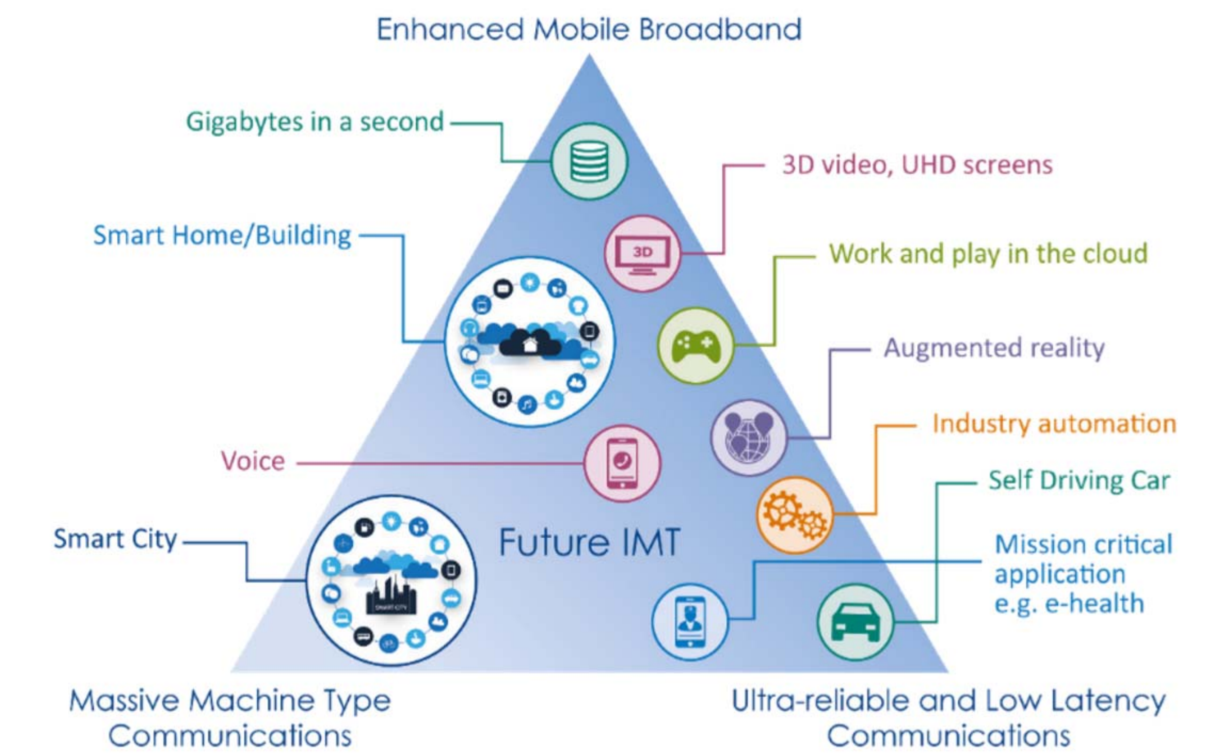
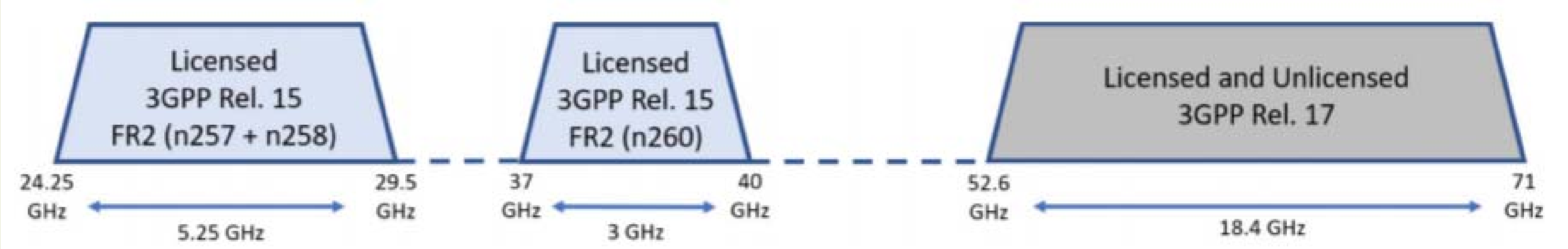
Contents

5G Frequency Bands and Applications

USA	600 MHz, 700 MHz, 2.5 GHz, 3.3-3.8 GHz, 4-5 GHz, 24-28 GHz, 37-40 GHz, 47-50 GHz
Mexico	2.5 GHz
South Korea	3.3-3.8 GHz, 28 GHz
Japan	3.6-5 GHz, 28 GHz
China	2.5 GHz, 3.3-3.8 GHz, 4.9 GHz, 24-28 GHz
Taiwan, China	3.3-3.8 GHz
India	3.3-3.8 GHz
Australia	3.3-3.8 GHz
EMEA	600 MHz, 700 MHz, 3.3-3.8 GHz, 24-27 GHz
Russia	3.3-3.8 GHz

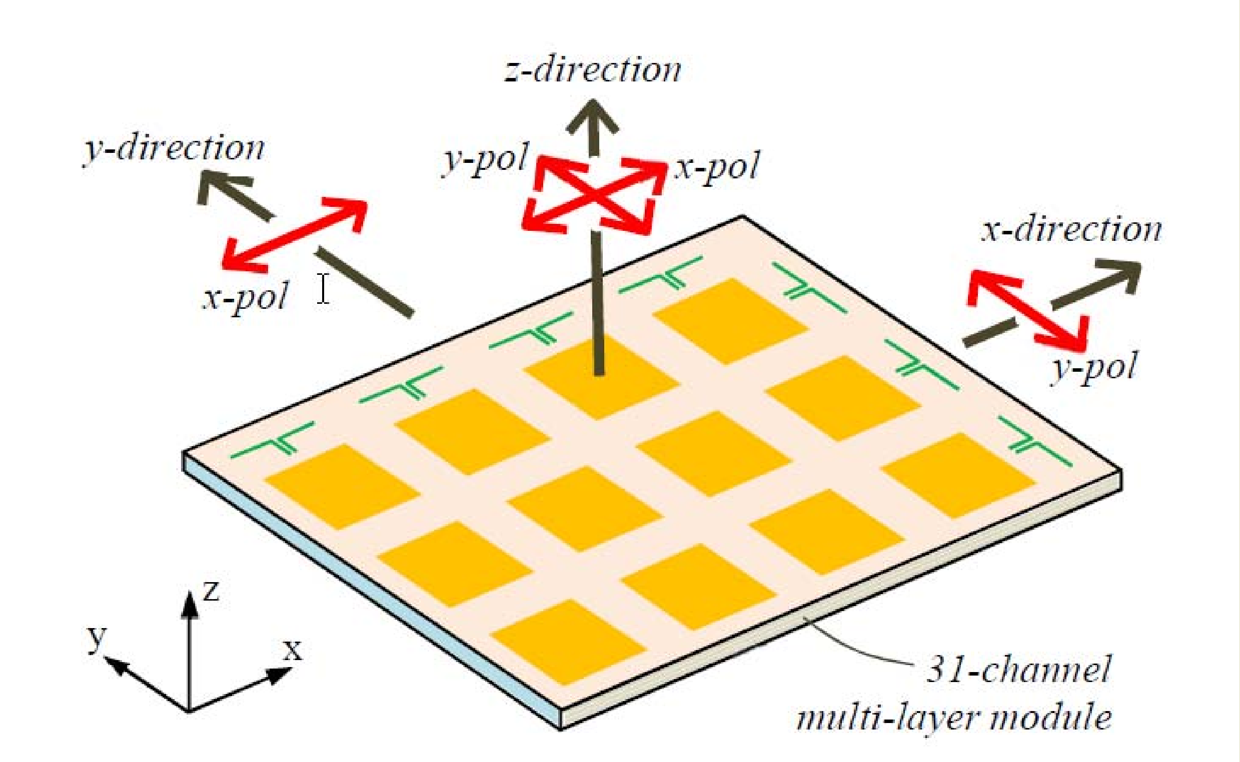
Source: GSA Report July 2019

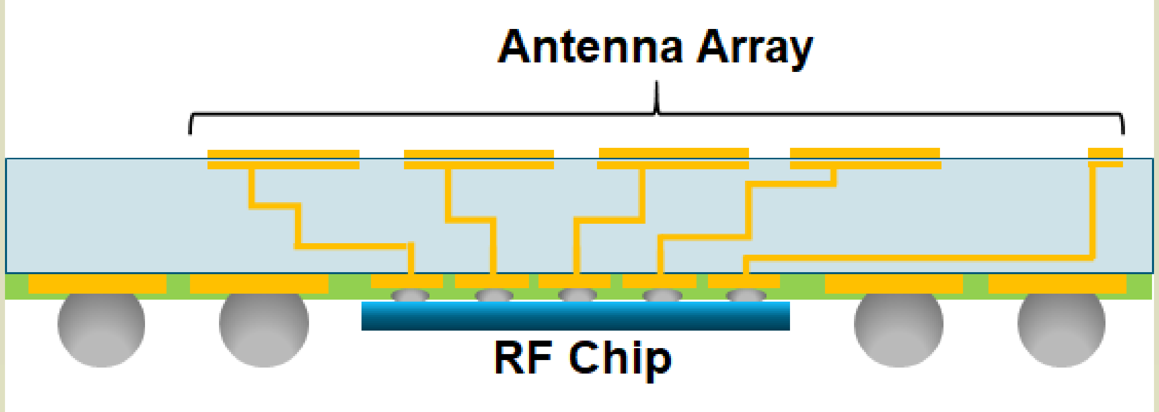




5G-NR OTA Testing Challenges

- 5G-NR AIP modules came in different sizes and configurations.
- They are composed of multiple dual-polarized patch antennas for top firing and in some configurations also dipole antennas for side firing.
- A 5G-NR cellphone will contain multiple modules and they might also not be all equal in terms of antenna configuration.





Types of AiP Packages

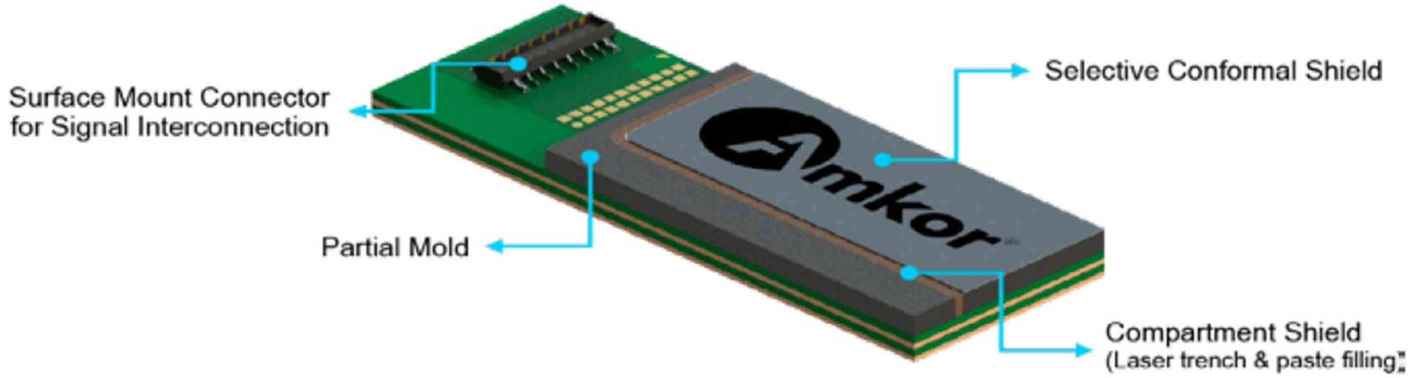
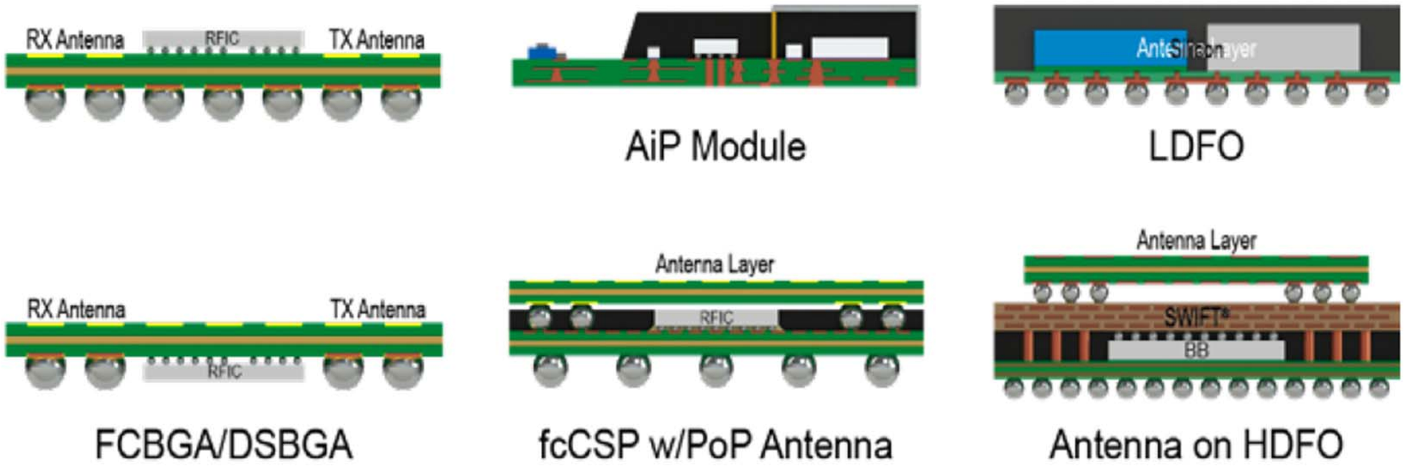
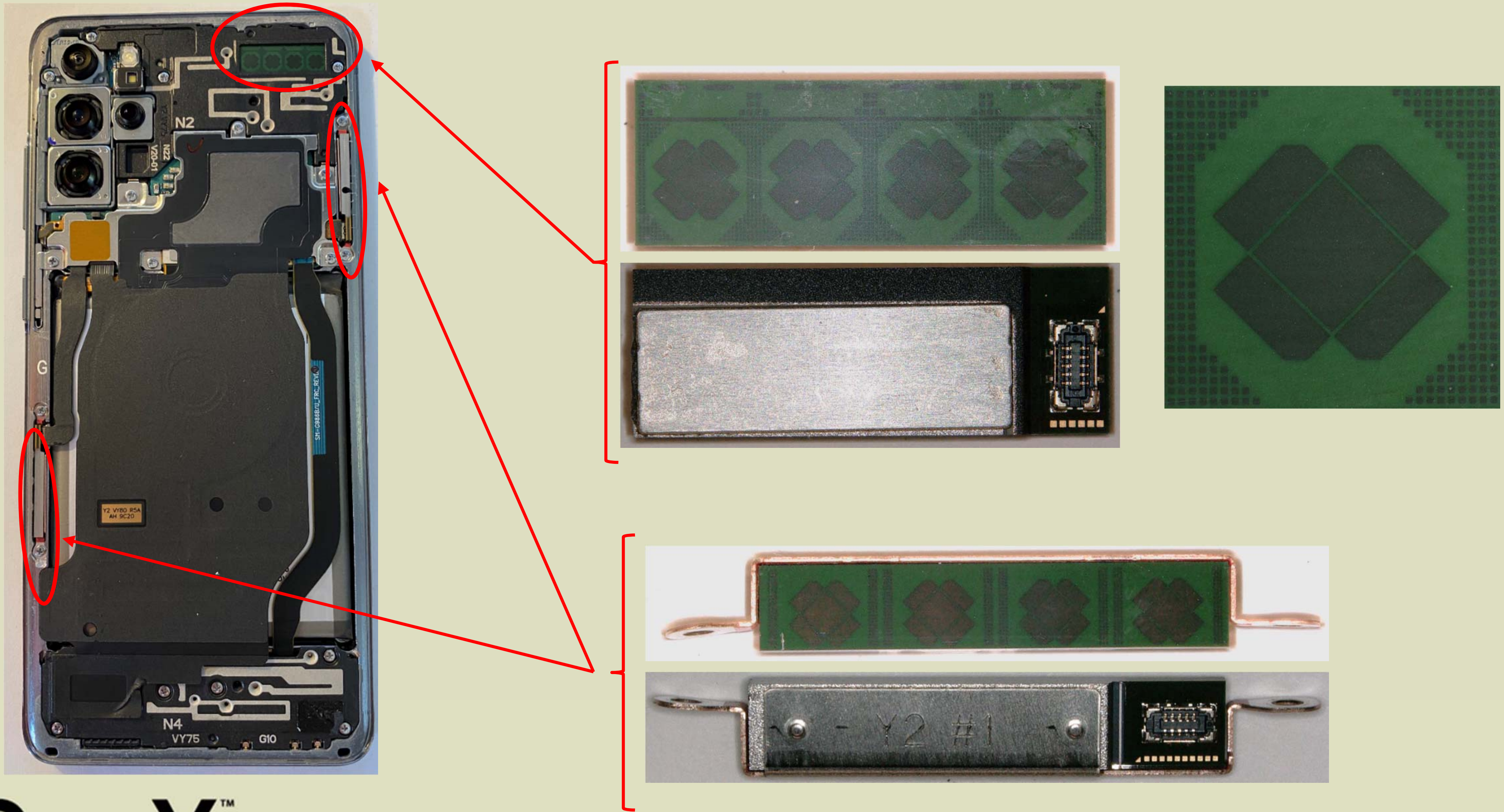


Figure 3: With an AiP design, the antenna is not a separate device, but is integrated in the device package.



Source: *Curtis Zwenger, Vik Chaudhry [Amkor Technology],* "Antenna in package (AiP) technology for 5G growth , Chip Scale Review March/April,2020

AiP Example: Samsung S20 + 5G



5G-NR OTA Testing Challenges

- The 3GPP standard defines the following OTA test methods for 5G-NR:
  - Direct Far-Field
  - Indirect Far-Field (e.g. Compact Antenna Test Range, CATR)
  - Near-Field to Far-Field Transformation

- For high-volume production of antenna-in-package (AIP) modules with ATE, lower cost approaches are needed.

Direct Far-Field

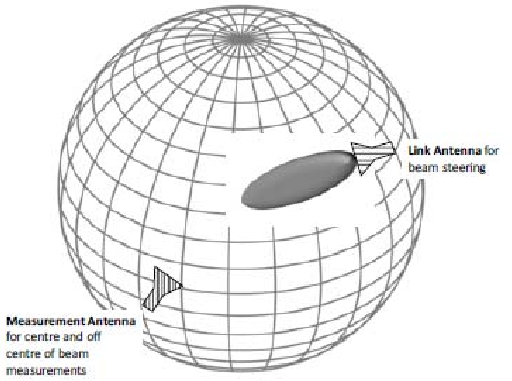


Figure 5.2.1.1-1: DFF measurement setup of UE RF characteristics

Indirect Far-Field

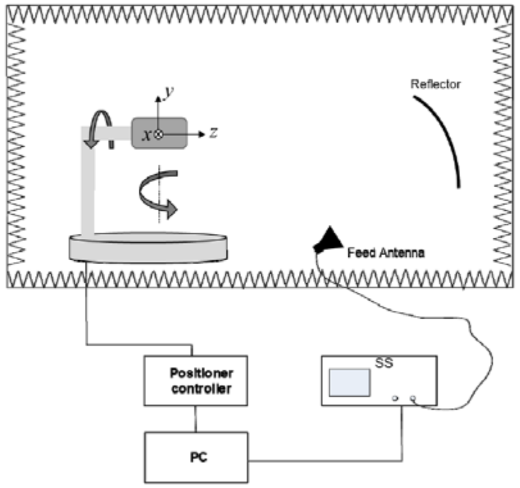


Figure 5.2.3.1-1: IFF method 1 (CATR) measurement setup of UE RF characteristic

Near-Field to Far-Field Transformation

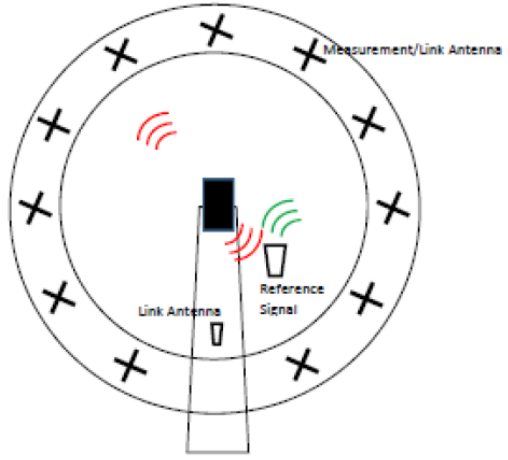
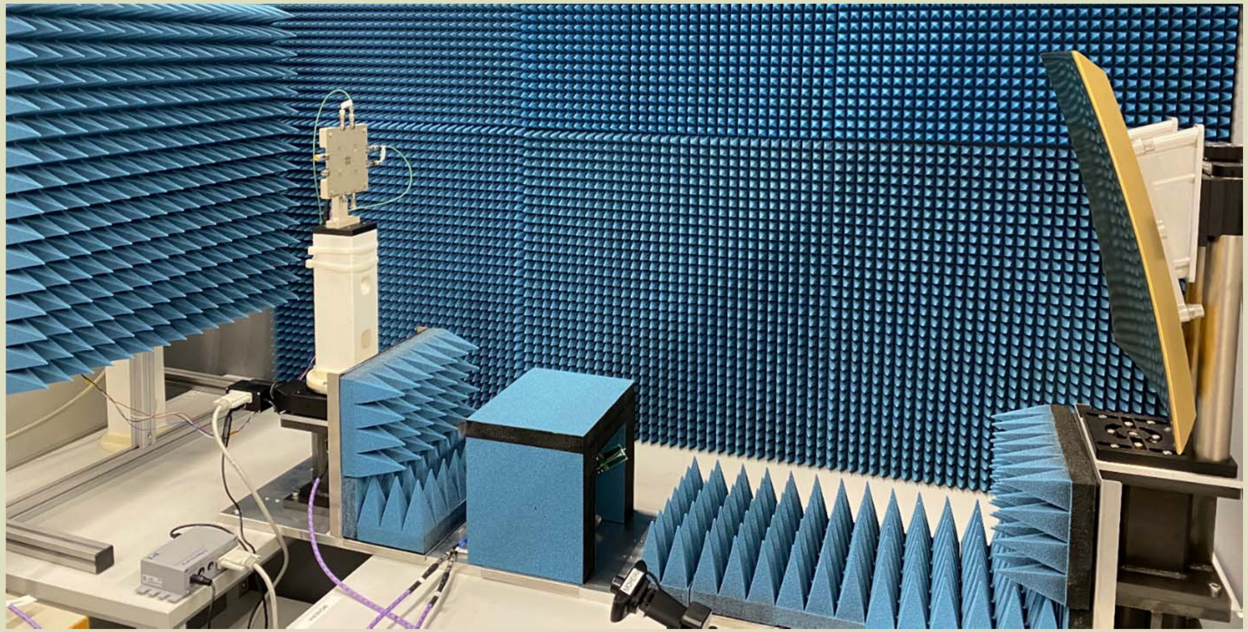
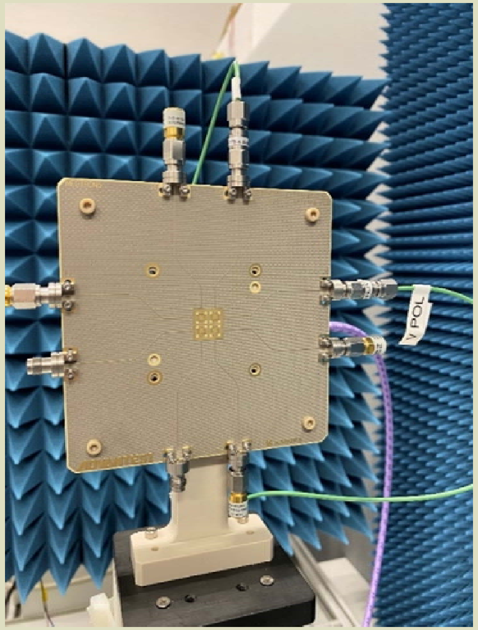


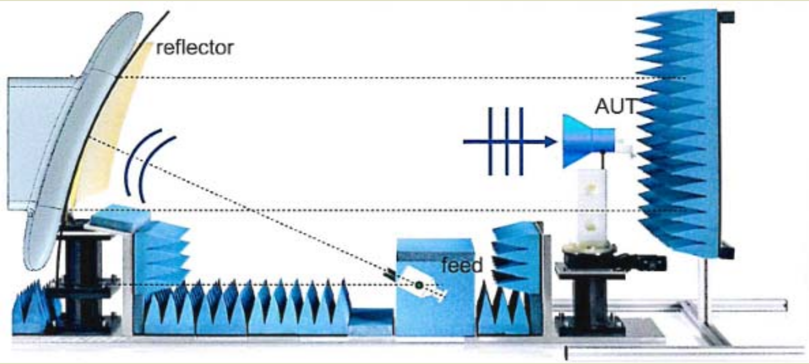
Figure 5.2.4.1-1: Typical NFTF measurement setup of EIRP/TRP measurements

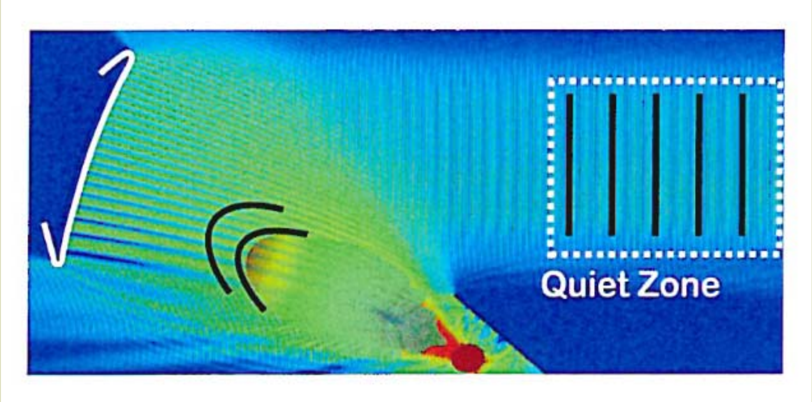
Figures from the 3GPP TR 38.810 V16.1.0 (2018-12) document

Indirect Far-Field 5G Compliant Reference Measurement Setup at Advantest R&D





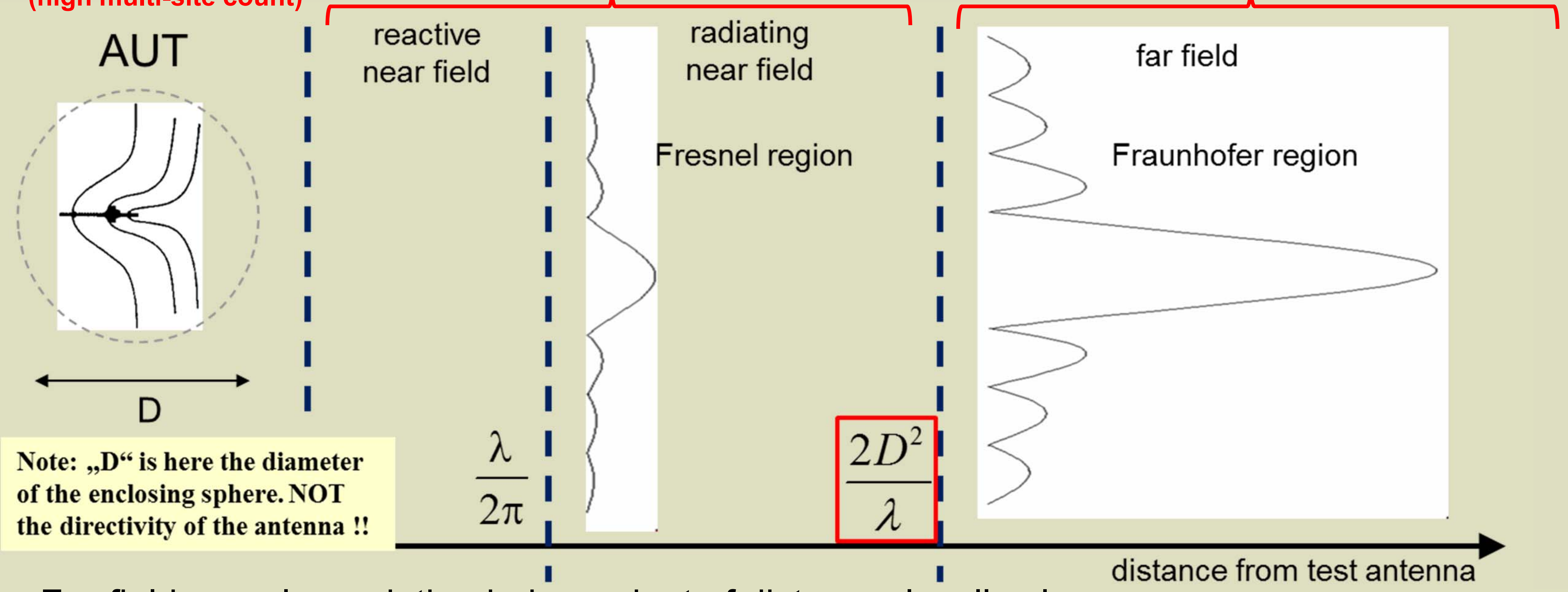




Near-Field vs Far-Field

This is not a good region for OTA testing. But its mechanical dimensions makes multi-site integration in a standard test cell possible (high multi-site count)

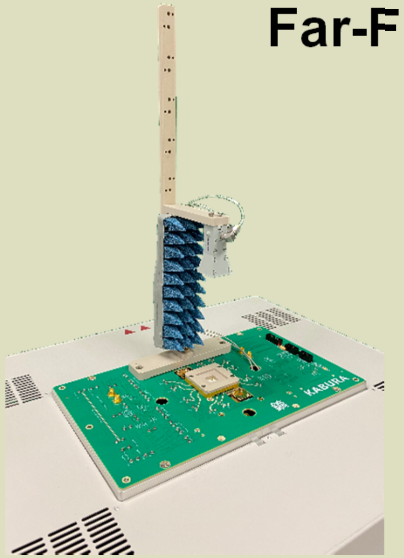
This is the best region for OTA testing. But its mechanical requirements makes multi-site integration challenging

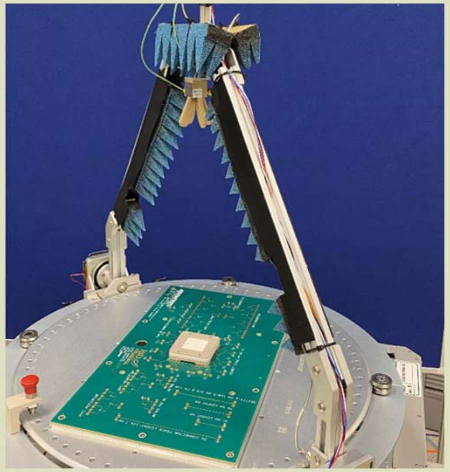


- Far-field: angular variation independent of distance; locally plane waves
- Reactive near-field: non-radiating fields dominate

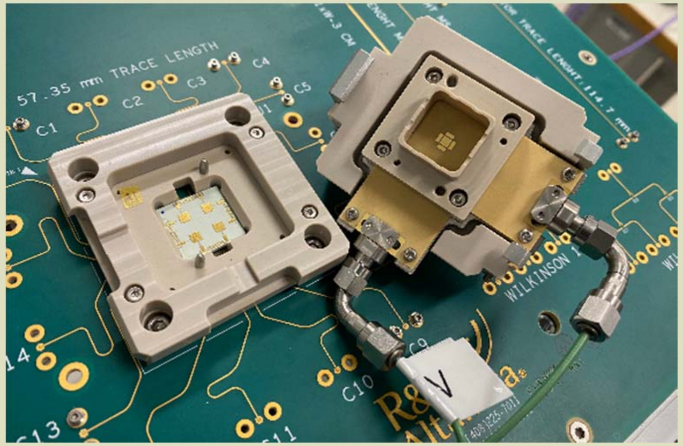
ATE OTA Testing Options with V93000 WSMM CC

Far-Field



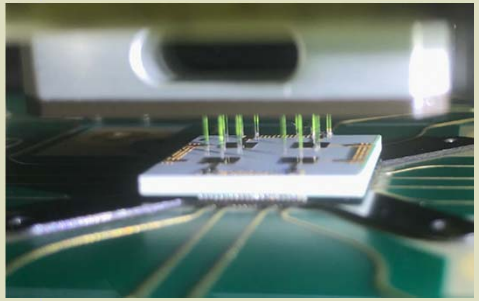


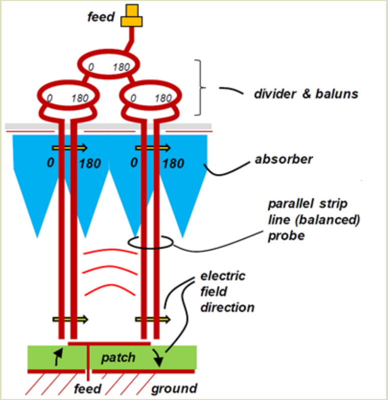
Radiating Near-Field

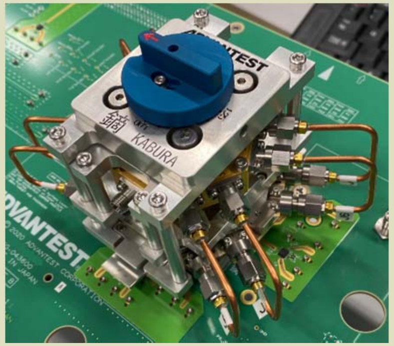


Reactive Near-Field

Patent Pending







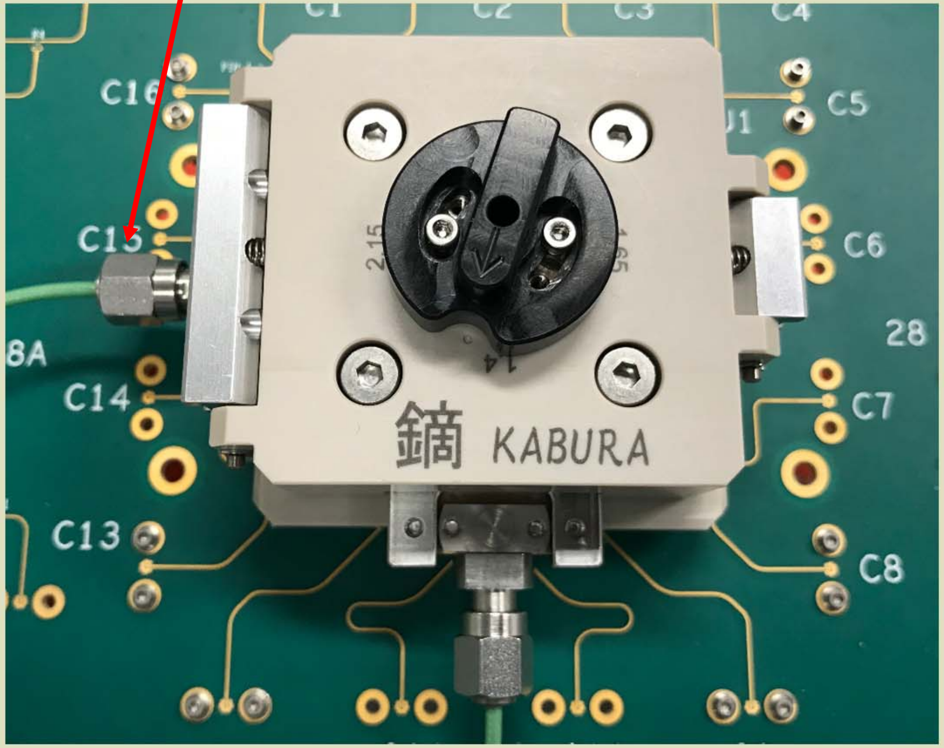
OTA Test Strategies

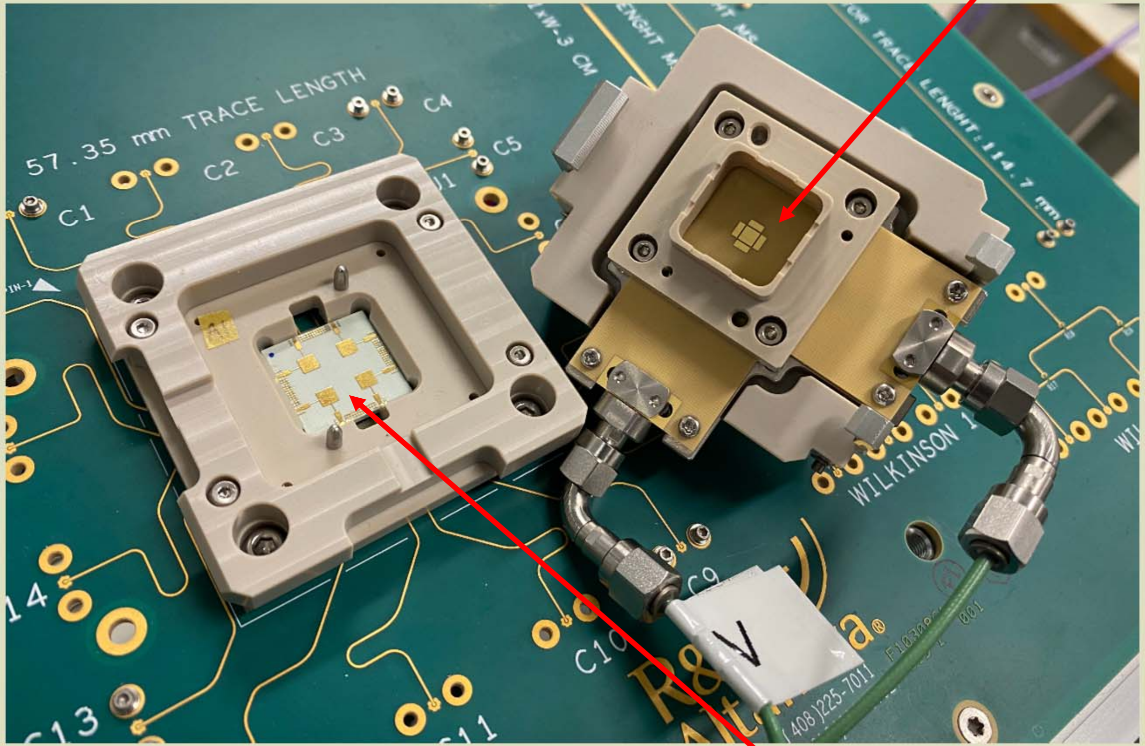
OTA Test Strategy	Advantages	Disadvantages
Far-Field Antenna	• Far-field measurement. • DUT antenna array is not impacted (detuned) by the measurement antenna. • Easiest setup to correlate with measured data using 3GPP compliant methods.	• Integration in standard ATE test cell difficult due to mechanical dimensions. • Multisite implementation is more 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 might have an impact on the DUT antenna performance (detuning and standing wave effect). • Possible different distances between the measurement antenna and DUT antenna array elements. • If "golden device" calibration is 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.
OTA Loopback	• Very low cost.	• Failure coverage depends on implementation approach and available BIST structures. • Power/phase calibration very challenging.

Low-Cost Radiating Near-Field Manual OTA Socket

28 GHz signals from measurement antenna to ATE measurement system

24 to 30 GHz dual polarization patch measurement antenna





DUT to measurement antenna distance of ~11mm

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

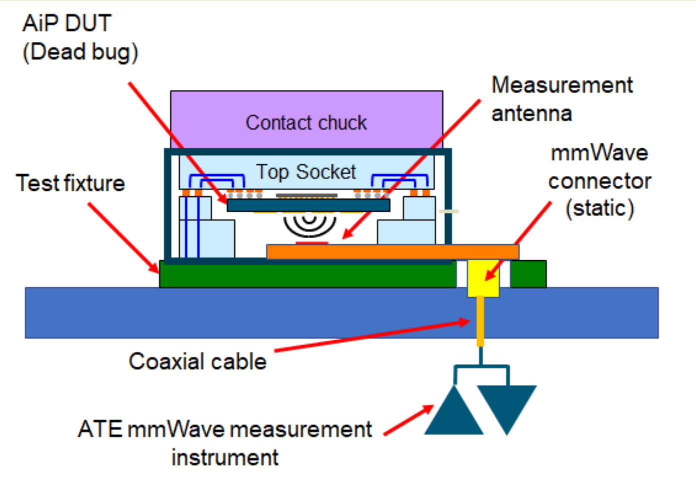
Radiating Near-Field OTA: Measurement Antenna Options

Antenna Type	Advantages	Disadvantages
Open Waveguide	• Full metal design allows precise manufacturing control and performance invariance to temperature.	• Larger size than a PCB antenna can result in a more complex mechanical integration.
Dual Polarized Patch Antenna	• Small size and low cost. • Allows separate polarization measurements.	• Requires two measurement resources or a switch. • PCB manufacturing variations.
Circular Polarized Patch Antenna	• Small size and low cost. • Only requires one measurement resource.	• Cannot measure the two linear polarizations independently. • Performance impact due to PCB manufacturing variations and temperature.
Dipole Antenna	• Direct measurement of DUT dipole antenna arrays.	• Performance impact due to PCB manufacturing variations and temperature.

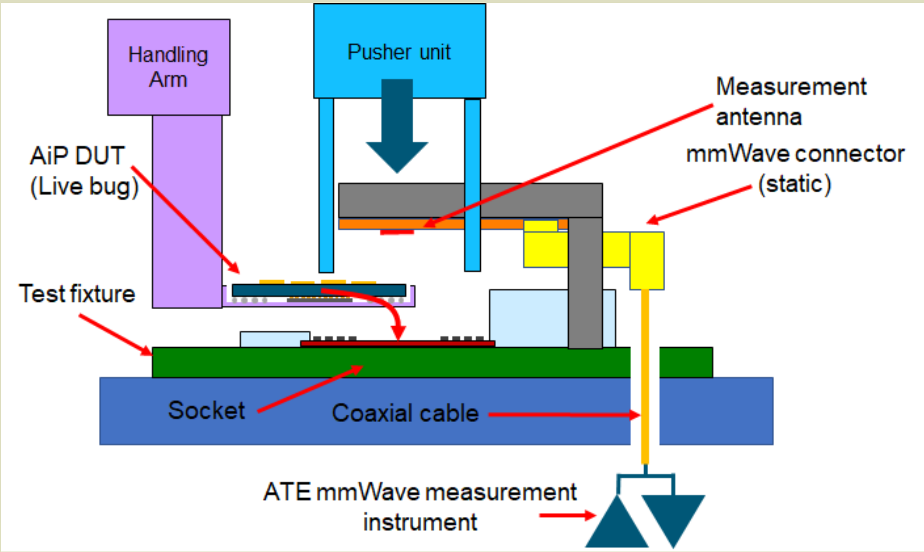
Near-Field OTA Handler Integration Options

- 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.

Dead Bug

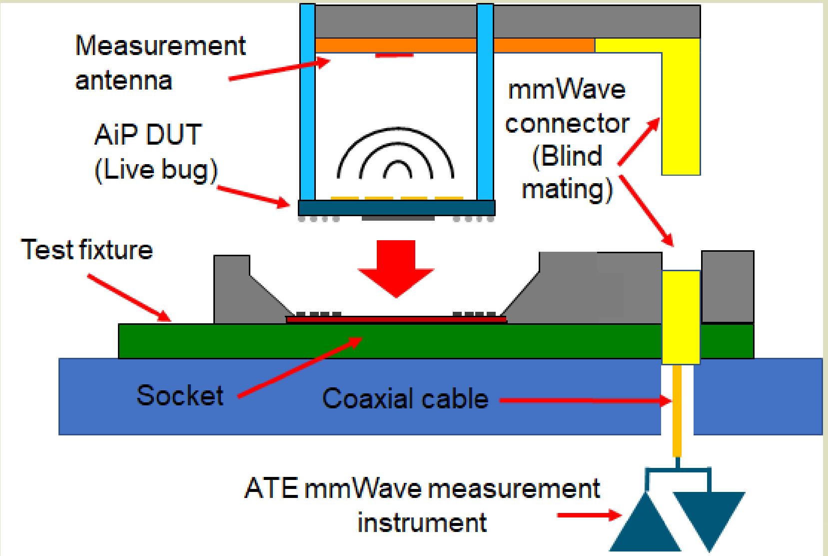


Live Bug Without Measurement Antenna Disconnect

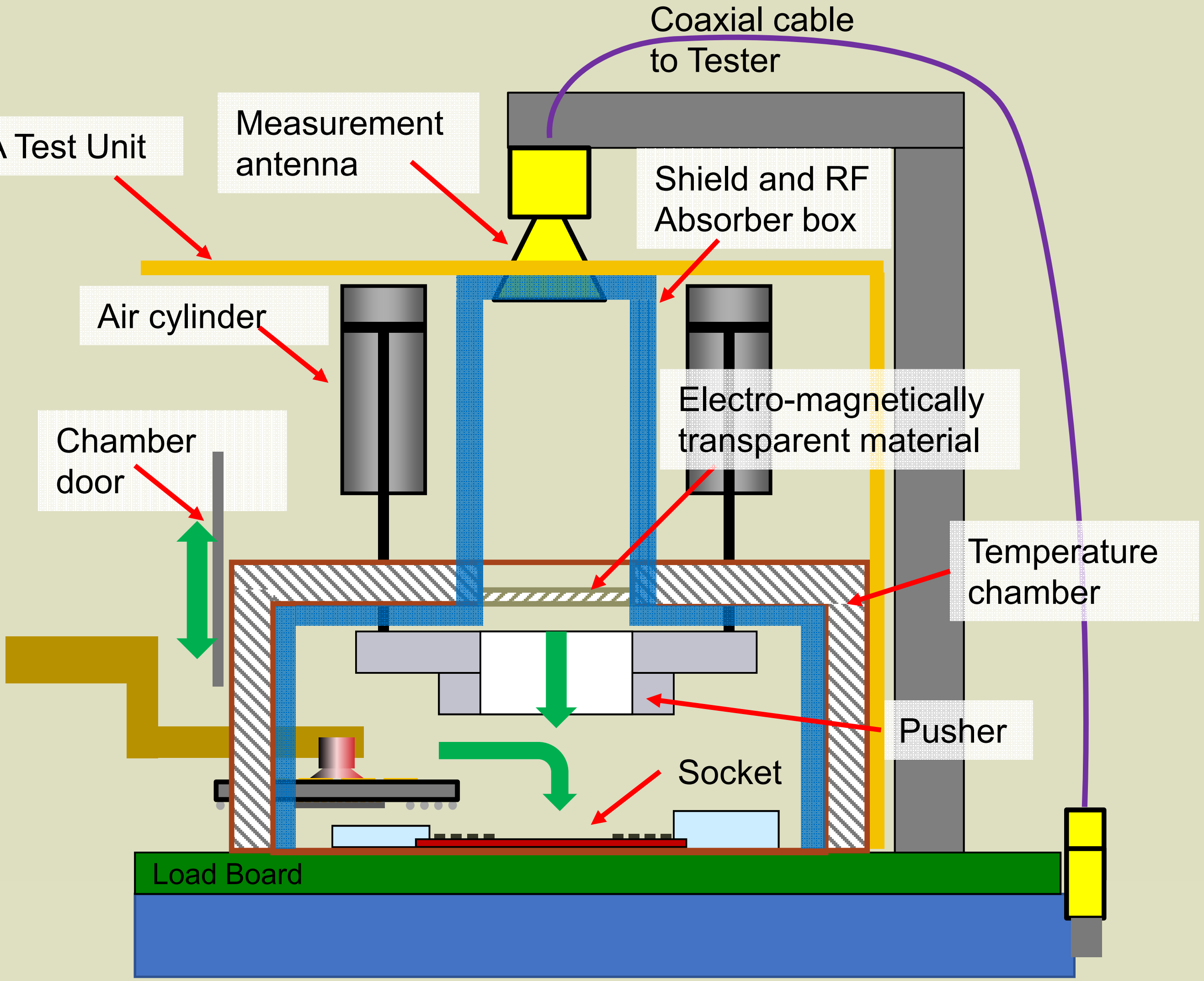


(not possible for reactive near-field)

Live Bug With Measurement Antenna Disconnect



Far-Field OTA Handler Integration



- Apply temperature to whole anechoic chamber is not realistic
- Apply temperature only to small area around DUT and socket
- Can be integrated to Advantest M4841
- Can also be integrated into non-Advantest handlers.

M4841 Tri-temp Handler

OTA Handler Integration Options

Good | Acceptable | Bad

Item	Near-field Dead bug	Near-field Live bug without measurement antenna disconnect	Near-field Live bug with measurement antenna disconnect	Far-field Live bug without measurement antenna 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. **Not usable for reactive near-field OTA.**	Antenna is mounted on the handler plunger. Requires a high reliability blind mating mmWave interconnect (e.g waveguide)	No measurement antenna disconnect. Does not require a high reliability blind mating mmWave interconnect.
Electrical side contactor	Need 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	Standard socket design
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	Temperature chamber or Temperature controlled air blow
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	Small. But far-field measurement approach makes multi-site very complicated.
Contact motion	Normal Z motion	Need Y-Z motion, 4x2 layout is difficult	Normal Z motion	Need Y-Z motion
Device handling	Need flip mechanism	Need special handling arm	Need special device pickup structure for plunger	Need special handling arm
Handling arms for Contact area	Only contact arm. Can be integrated to standard handler	Need device in/out arm and contact arm. Can be integrated to standard handler with modification	Only contact arm. Can be integrated to standard handler	Need device in/out arm and contact arm. Can be integrated to standard handler with modification

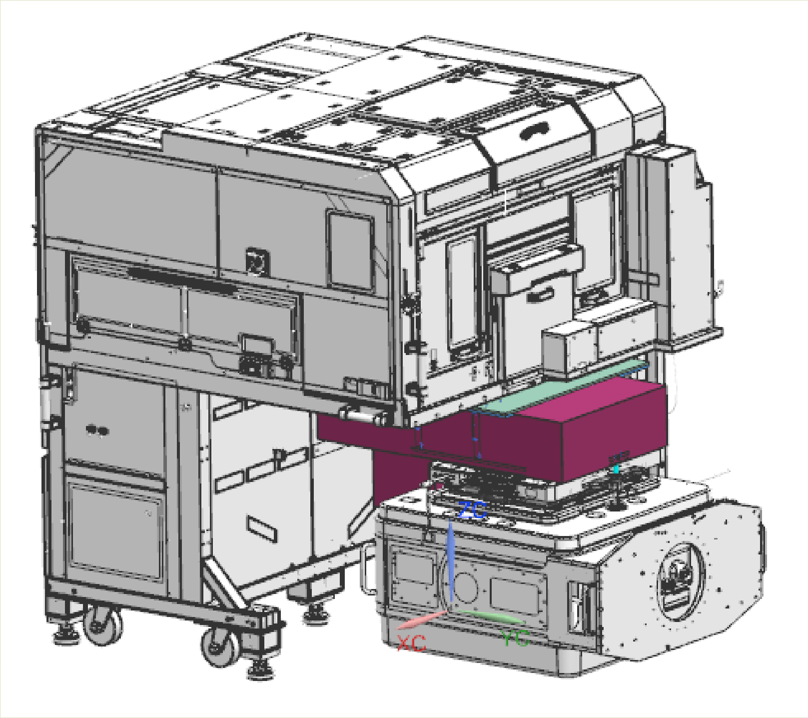
Far / Radiating Near-Field OTA Handler Integration

Concept:

- OTA Test Unit can be attached to existing handler without mechanical modification.

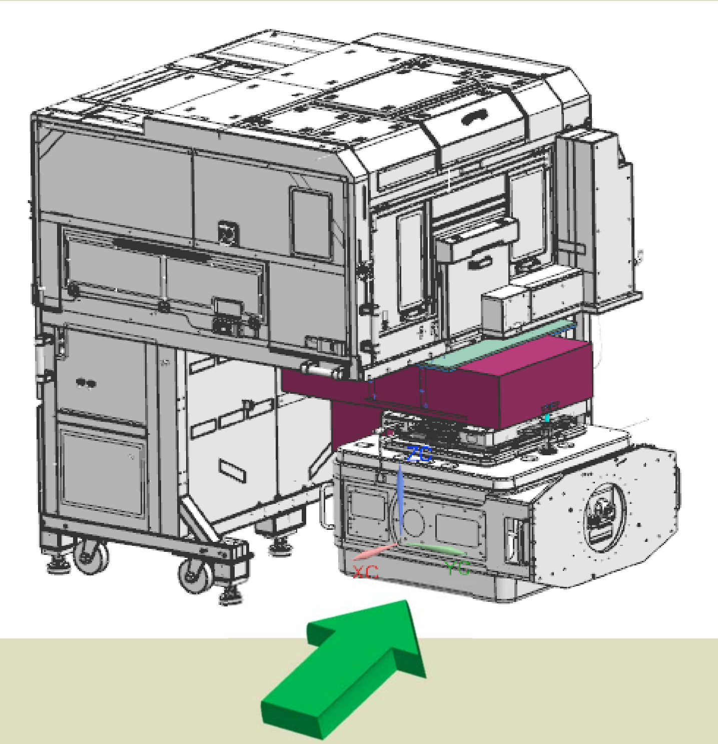
- Parallelism
  - Far-Field : x2
  - Near-Field : x8

- Temperature : LT to HT

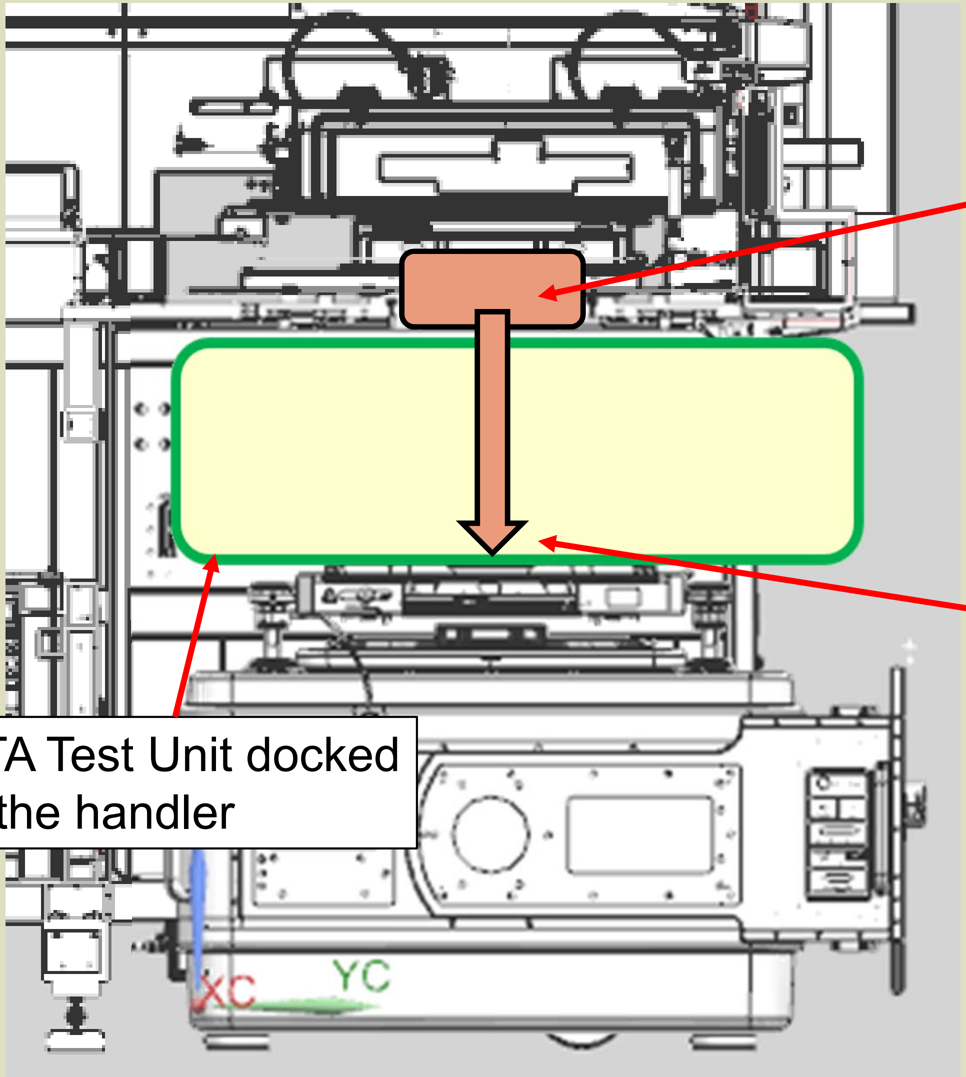


Advantest OTA Test-Cell

Far / Radiating Near-Field OTA Handler Integration



Side view



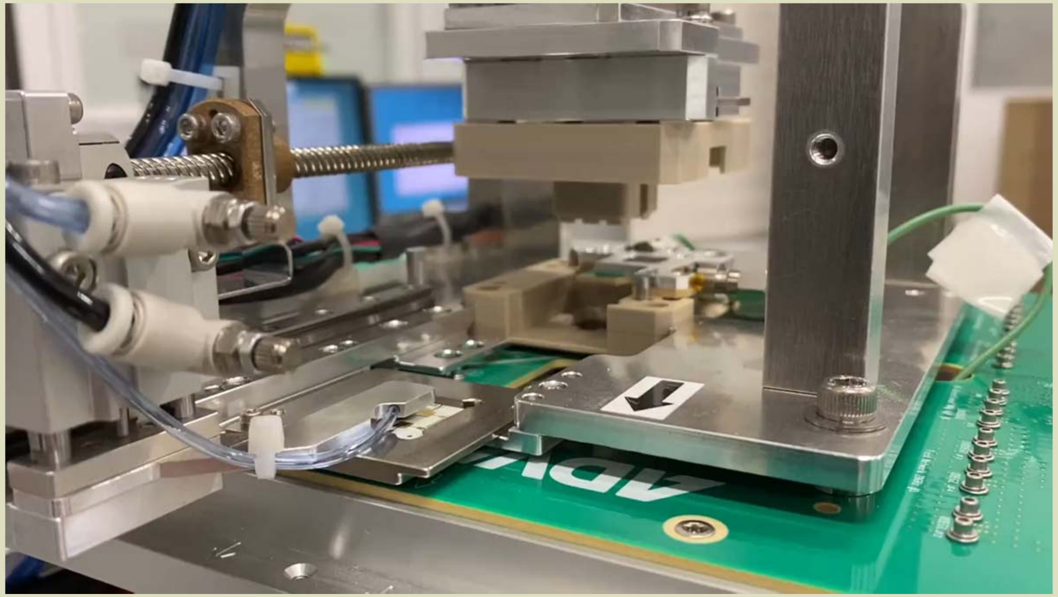
Receive devices from contact arm of the handler

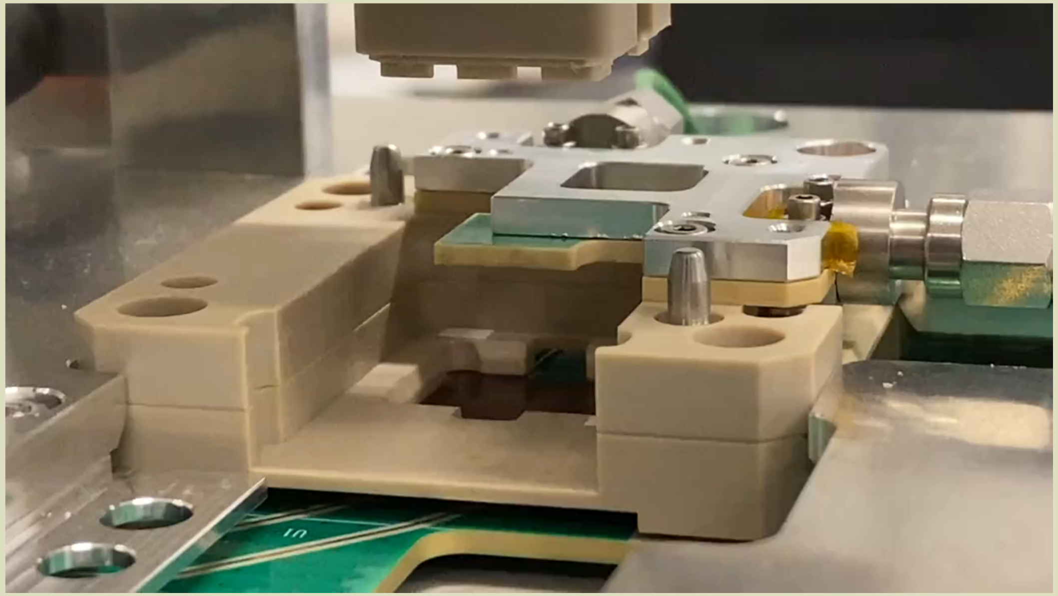
Plunge devices to the socket and execute OTA test

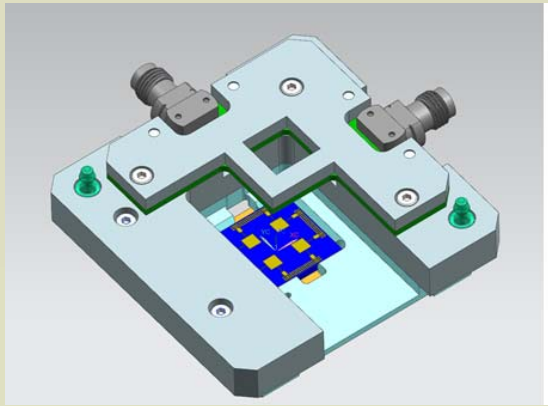
OTA Test Unit docked to the handler

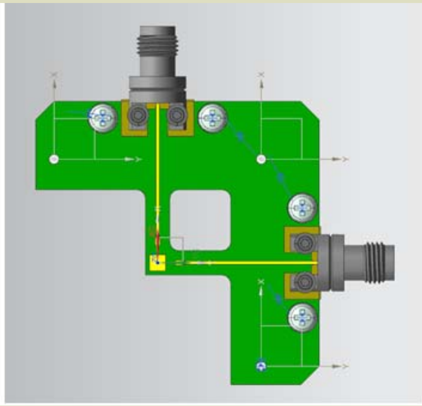
Side view

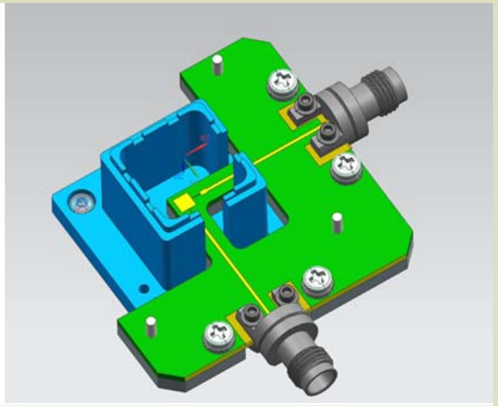
Handler Integration Prototype: Radiating Near-Field Without Antenna Disconnect



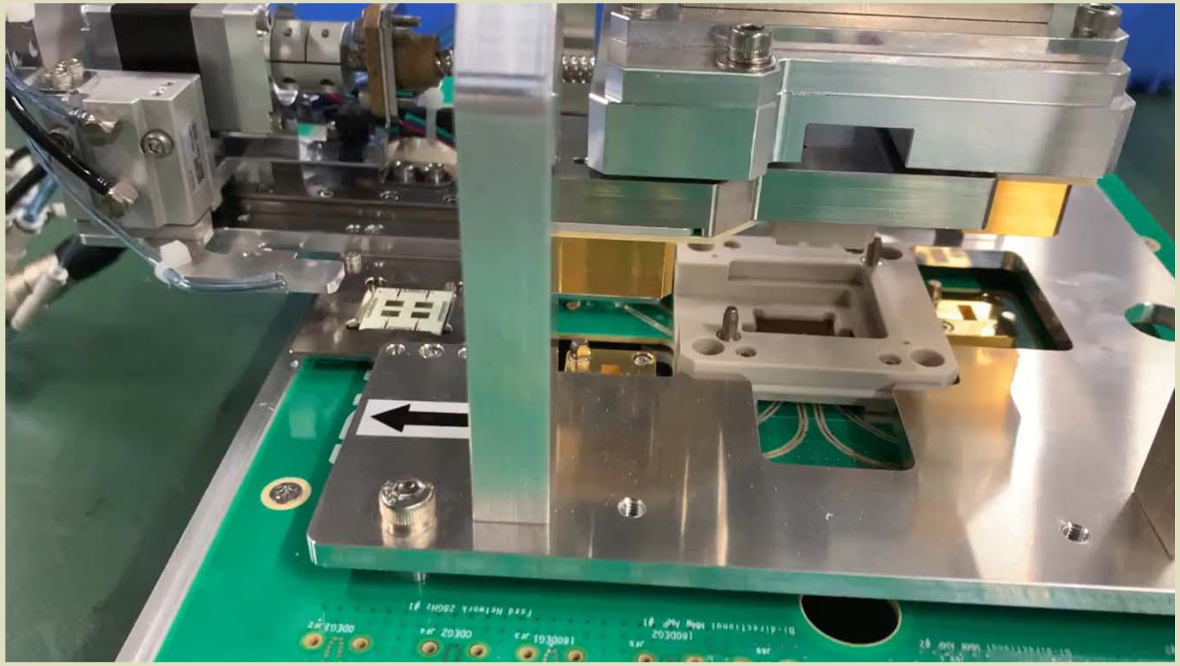


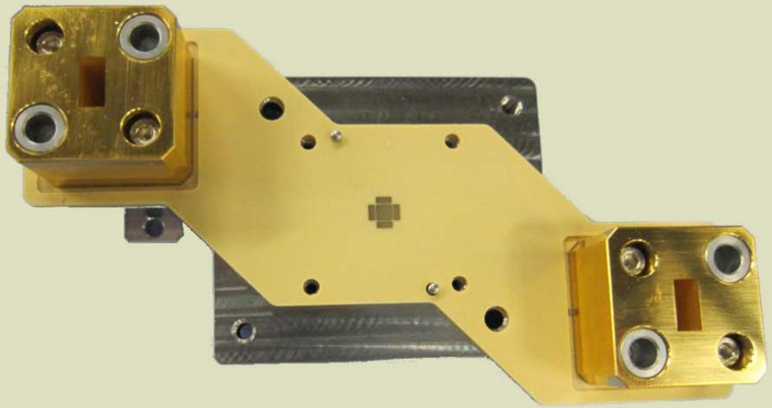






Handler Integration Prototype: Radiating Near-Field With Antenna Disconnect

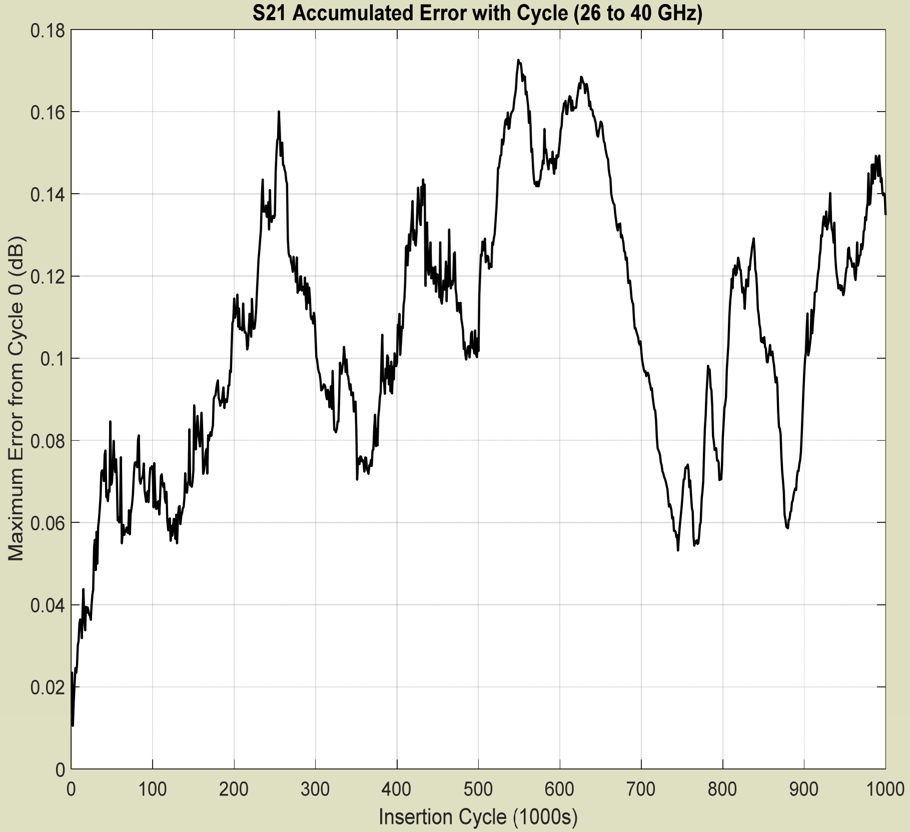


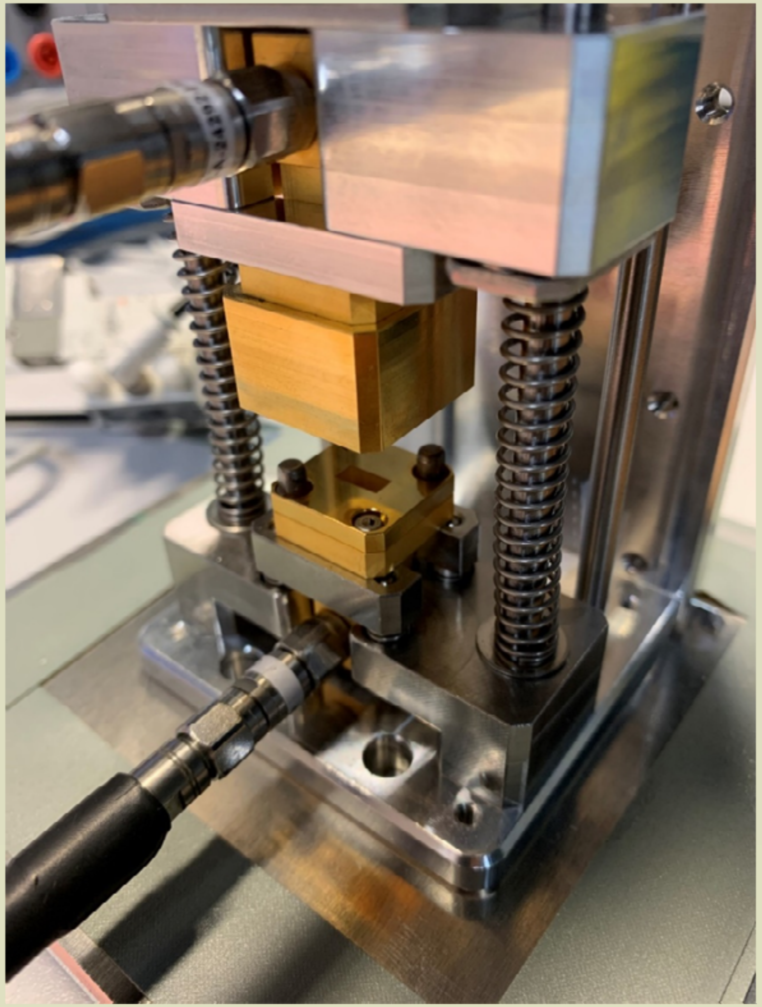


- WR28 based waveguide blindmating interface
- Advantest custom design for handler integration

Waveguide Blindmating Interconnect Reliability Testing Results

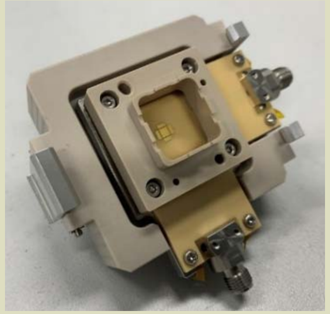
- For handler integration reliability is critical
- Results with 1 million insertions show better than +/- 0.1 dB variation on the insertion loss.

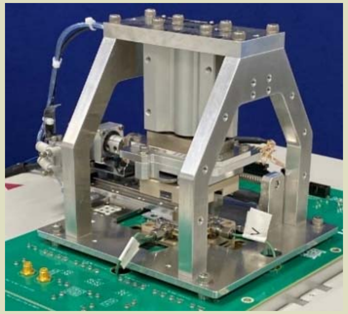


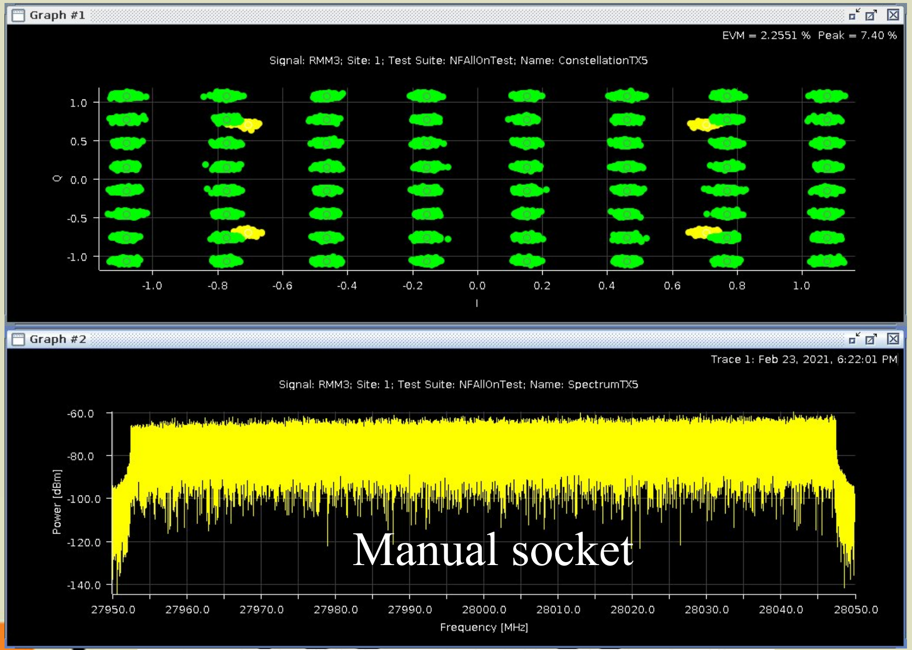


Example: Manual Socket to Handler Correlation

Because of handler integration pusher mechanical requirements, some changes are required on the antenna implementation but with careful design, good correlation can be achieved.








```
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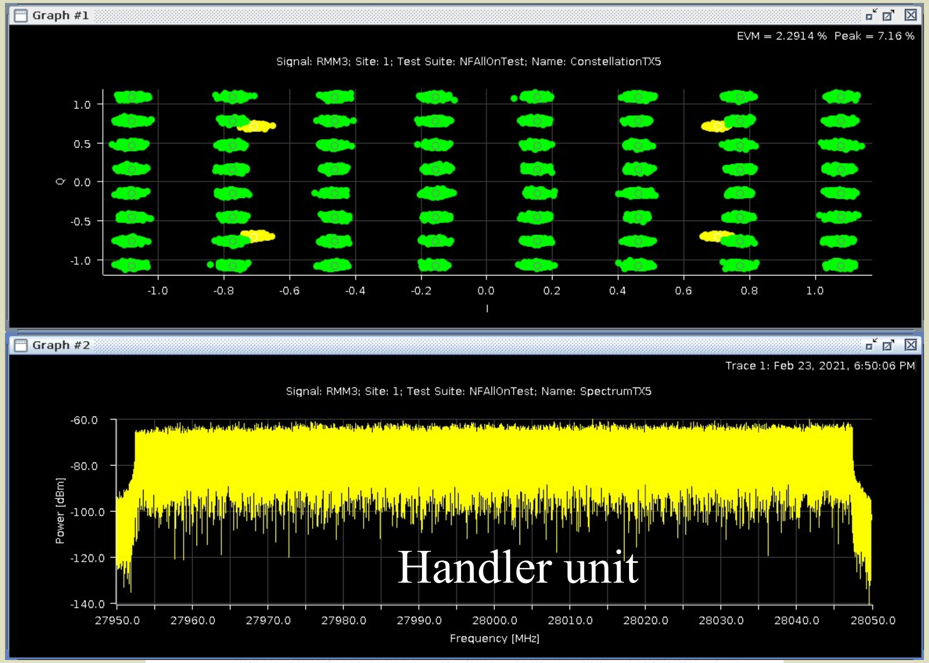
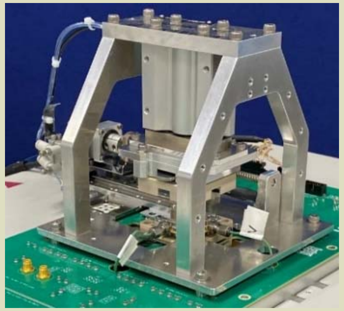
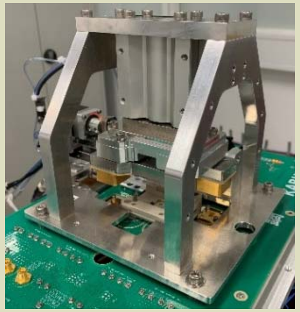
Site 1 -> [         Power,        EVM [%] ]
Site 1 -> [       -19.698,          2.255 ]
```

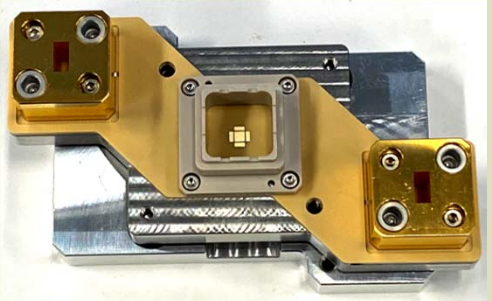


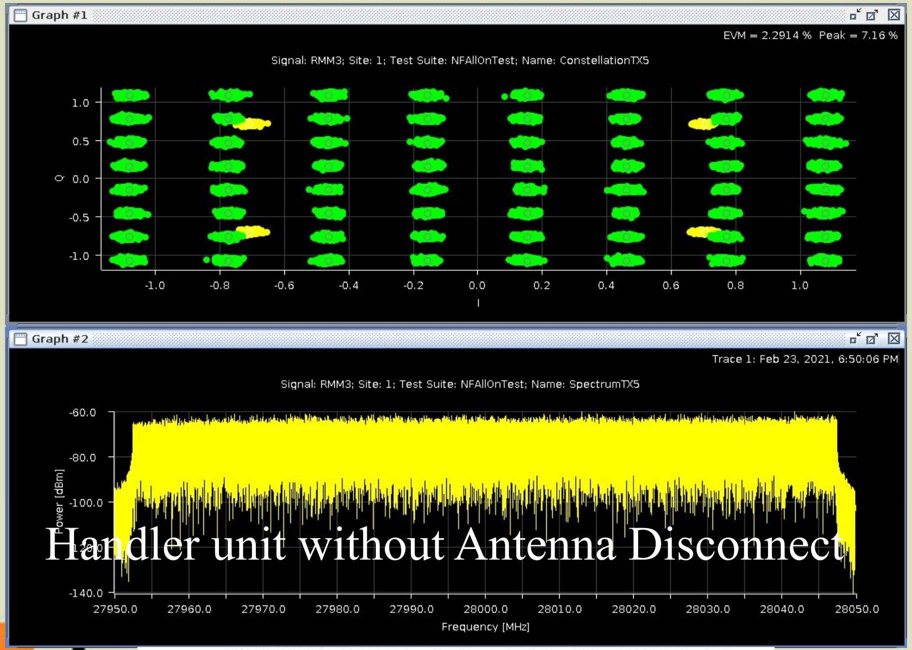

```
Freq:  28000 MHz, Stim: -15.00 dBm, Gain:   0
Site 1 -> [         Power,        EVM [%] ]
Site 1 -> [       -19.352,          2.291 ]
```

Example: Antenna Connection Options Correlation



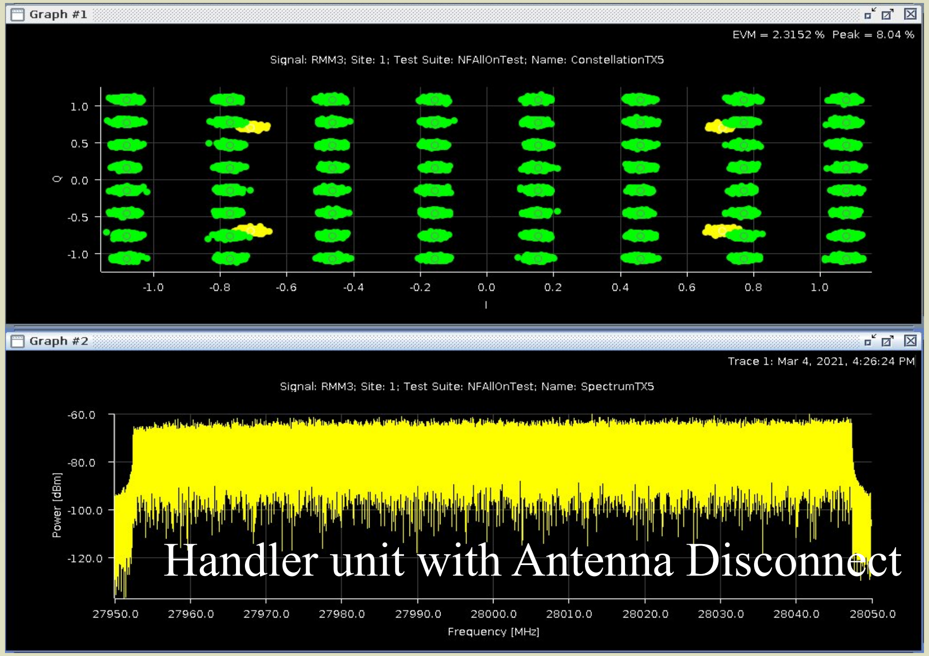







Handler unit without Antenna Disconnect

```
       Freq:  28000 MHz, Stim: -15.00 dBm, Gain:   0
Site 1 -> [          Power,         EVM [%] ]
Site 1 -> [        -19.352,          2.291 ]
```



Handler unit with Antenna Disconnect

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Site 1 -> [          Power,         EVM [%] ]
Site 1 -> [        -19.500,          2.315 ]
```

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 also where on the product life cycle stage one is (characterization, early production ramp, high volume production, etc…).

- Advantest has developed solutions for all OTA testing options.

- The radiating near-field approach has several drawbacks but is the easiest and lowest cost approach for OTA.

- Solutions for multi-site integration in a standard ATE test cell are available from Advantest.

Acknowledgments

- We would like to thank Sui-Xia Yang and Frank Goh from Advantest for their support on the application development.

- We would like to thank Markus Rottacker, Nakadate Atsushi, Marc Moessinger and Ikeda Hiroki from Advantest for supporting this project.

- We would like also to thank Prof. Jan Hesselbarth from the University of Stuttgart for his support.

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The Market Leader in Test Interface Solutions for the Most Challenging Applications

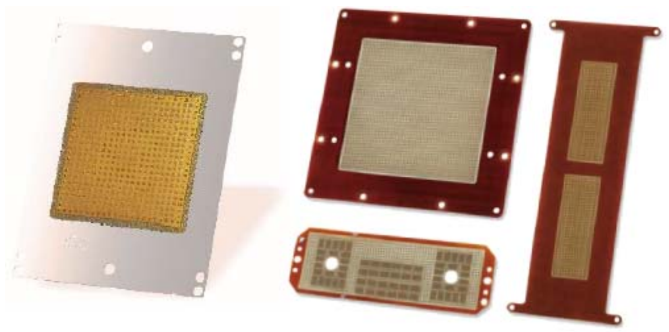
Mobility	Precision Analog & Sensors	RF	High End Digital	Automotive & Power

ISC Global No.1! Total Test Solution Provider!

GLOBAL INNOVATION

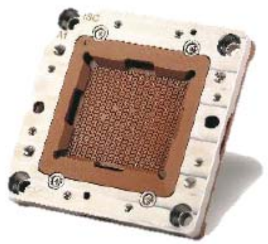
ELASTOMET SOCKET & INTERPOSERS

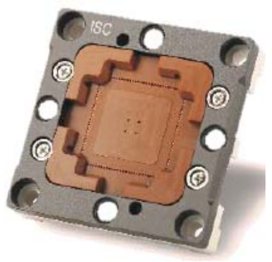
- High performance and competitive price
- High speed & RF device capability
- Various customized design to meet challenge requirement



POGO SOCKET SOLUTIONS

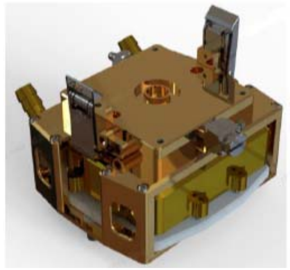
- Excellent gap control & long lifespan
- High bandwidth & low contact resistance





THERMAL CONTROL UNIT

- Extreme active temperature control
- Safety auto shut-down temperature monitoring of the device & thermal control unit
- Full FEA analysis & Price competitiveness



BURN-IN SOLUTIONS

- Direct inserting on the board without soldering
- Higher performance BIB solution

CONTACT
ISC CO., LTD

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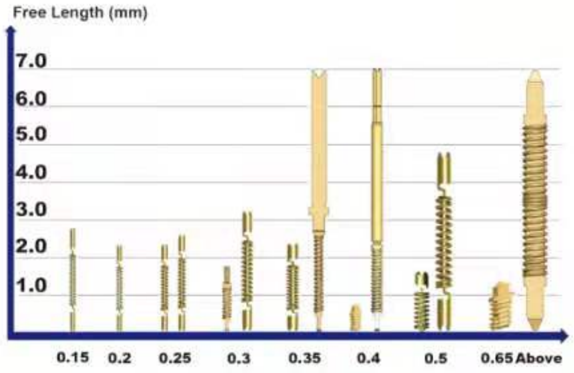
Seong-nam, Korea	Silicon-valley, CA	**Tel**: +82-31-777-7675 / **Fax**: +82-31-777-7699 **Email:** sales@isc21.kr / **Web:** www.isc21.kr

IWIN Co., Ltd. The test probe for high signal integrity at extremely high speed test

Spring probe by stamping



250 kinds of spring probe pin

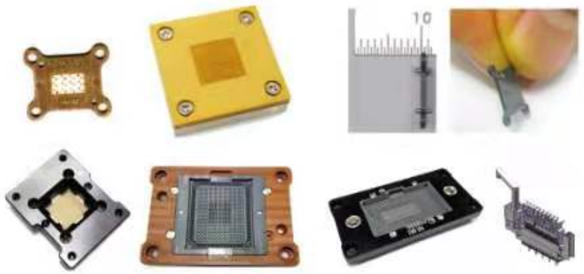
300 kinds of test socket (44,000 Pin count socket possible)

One piece spring probe

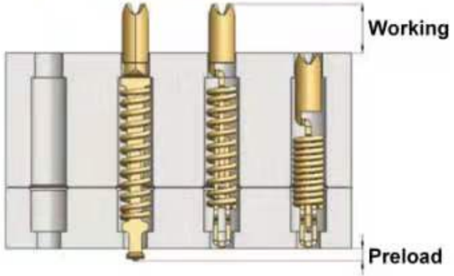
Three piece spring probe

High speed product → 0.63mm free length spring probe pin available

Finest Pitch → 0.15mm Pitch



Spring probe by stamping

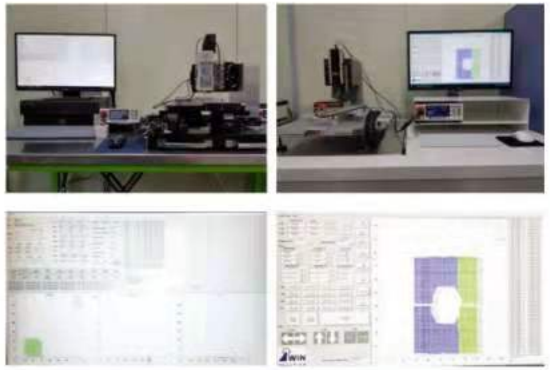


Patented

Pitch(mm)	Free Length(mm)	Current Carrying(Amps)
0.15/0.2/0.25	2.17~	0.5~
0.3	1.5~	1.5~
0.35	2.08~	1.8~
0.4	0.8~	2.5~
0.5	1.5~	3.0~
0.65	1.13~	9.0~
0.8	3.14~	3.0~

Automation

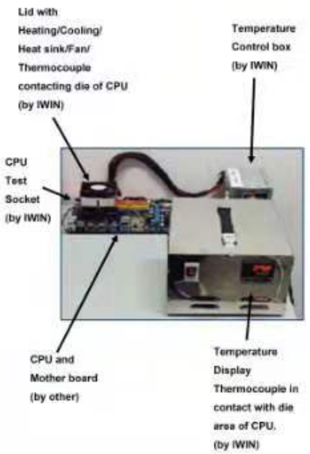
Pin assembly and Quality control



Top Figure: Socket CRES, Force, Stroke test
Bottom Figure: Data displayed

Top Figure: Socket CRES test
Bottom Figure: Data display 5,903 pins socket

Socket and Lid



Pin assembly

(Fully automated machines)

- Stamped piece parts attached to a reel fed into the assembly machine

- Assembled pins can be attached to a reel, or, supply in separate for socket assembly.

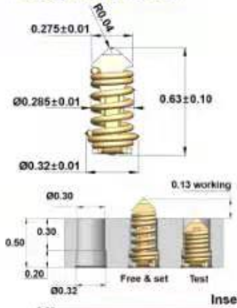
Spring probe pins for High speed

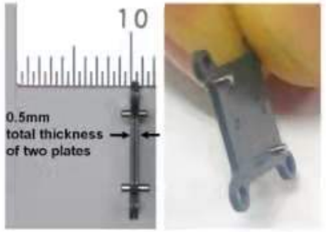
Extremely short spring probes by stamping

One piece spring probe

Three piece spring probe

Design approach





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High Performance Probe solution