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Archive

RF Module Test Challenges

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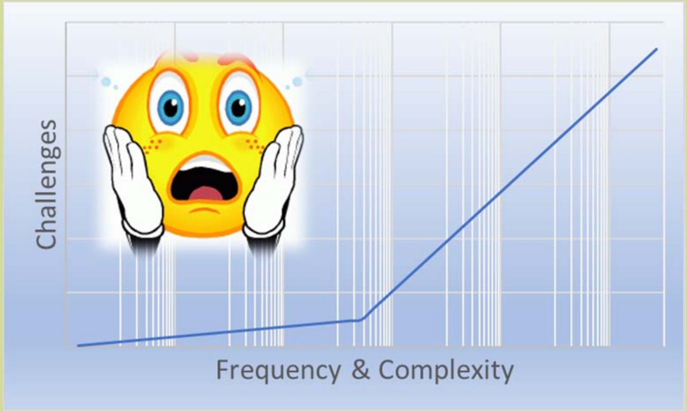
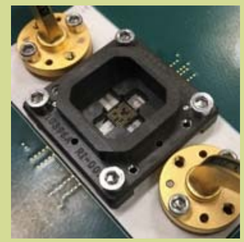
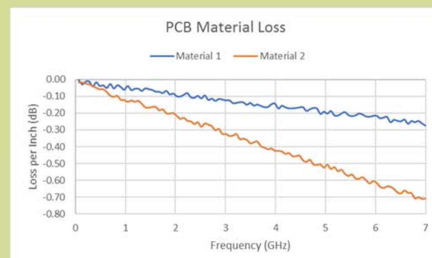


Where Are We Today? – Sockets & Load Boards

- Sockets
  - The RF test socket - our friend for 30+ years
  - Socket manufacturers have pushed performance to 10 GHz and beyond, but with great performance comes great cost
  - Cleaning and maintenance challenges
- Load Boards
  - The old standbys: FR-4, MEGTRON 6, …
  - Multiple factors drive selection: Cost, circuit design, spec tolerances, temperature, power dissipation, …
  - Material selection has significant impact on signal loss at high frequencies



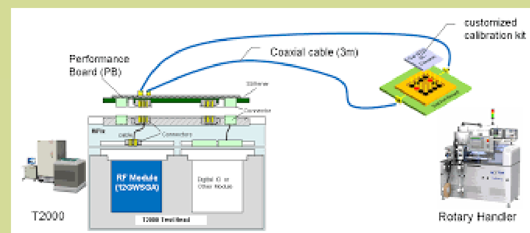


Where Are We Today? – Frequencies

- Frequencies typically < 6 GHz
- Key applications driving volume
  - Mainstream LTE Cell Phone: < 2.7 GHz
  - GPS Receiver: < 1.6 GHz
  - RF Remote Control: < 900 MHz
  - WLAN/Bluetooth/ZigBee/…: < 5 GHz
- 5G initial deployments will be < 6 GHz
- Test contacting at < 6 GHz is a solved problem

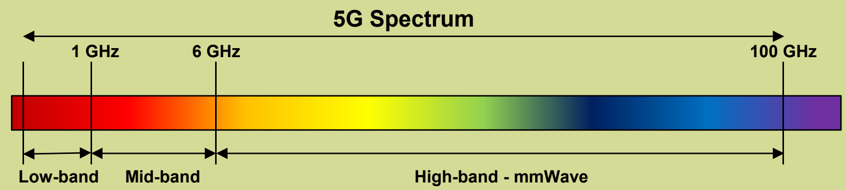
Where Are We Today? – Handling

- Standard handler configurations adapted for RF
- RF shielding and socketing requirements can impact cost, parallelism, and UPH
- Lower parallelism allows for flexibility on integrating RF test equipment
- System RF calibration process must be carefully designed



Key Trends – Frequencies ↑

- Frequencies are going up to 100GHz
- 5G frequencies are priority in the Test industry
- 28GHz and 39Ghz are key for the cellular providers
- Unlicensed frequencies are being explored
- Radar (non- automotive) applications are enjoying some relevance



Band	Range	Licensed	Shared	Unlicensed
Low-band	< 1 GHz	600 MHz US 700 MHz EU		
Mid-band	1-6 GHz	AWS (Band 66) 2.5 GHz 3.3-4.3 GHz 4.4-4.99 GHz	3.5 GHz CBRS US 3.7-4.2 GHz US 5.9-7.1 GHz US	5-5.9 GHz
High-band	> 20 GHz	24.25-29.5 GHz 27.5-28.35 GHz 37-38.6 GHz 38.6-40 GHz	37-37.6 GHz 57-71 GHz	64-71 GHz

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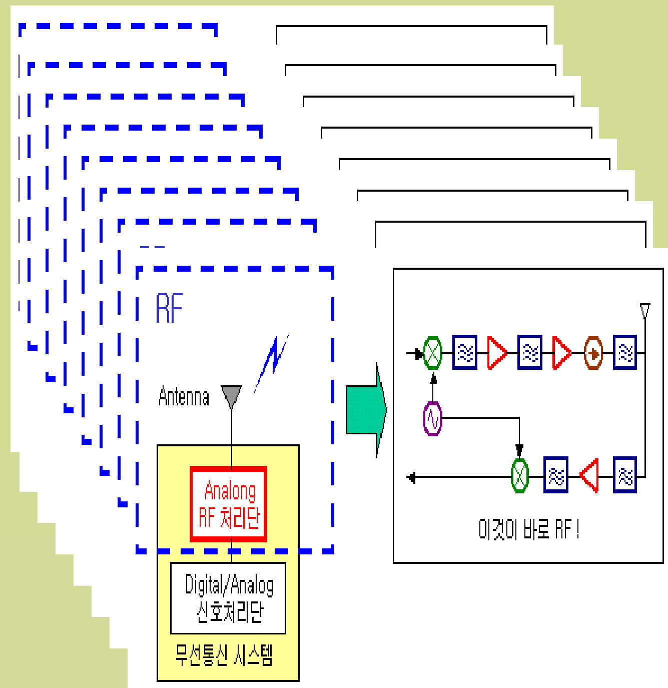
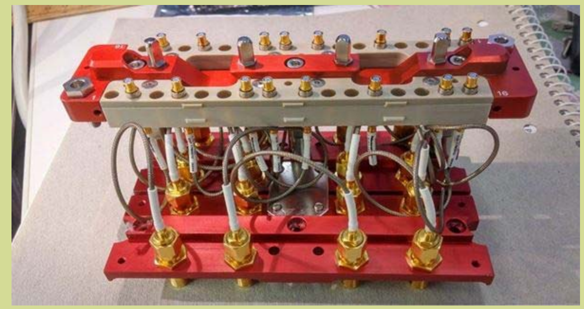
Key Trends – Complexity ↑

- RFCMOS Devices achieve significantly more complex functions at higher frequencies at lower cost
- Complexity is in many areas - high port counts, higher frequency, multi-band, I/O functionality (transmit/receive on same port)
- Other useful features at these frequencies are implemented - devices with antennas built-in reduce interconnecting cost along with smaller packages
- Traditional contacting socket/load board methods of ATE testing are less applicable and require innovation at the test cell to solve the issues of signal integrity/validity



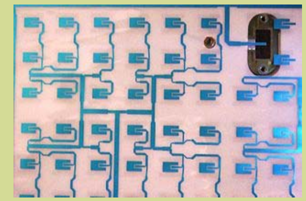
Key Trends – Connection Choices

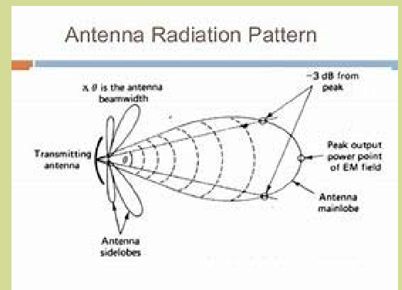
- System complexity – multi-site in “direct contacting” environment is manageable but constrained by space
  - Higher frequencies/functions will require many connections that keep getting smaller as frequency goes
  - Reliable blind mate is possible using 1.85mm and 1.35mm blind mate are not proven in ATE
  - Cabling is more lossy at higher frequencies and many cables/connections make the load board complex
  - Waveguide is a consideration in automotive radar cases
- Cost-effective testing involves many combinations – over the air or direct contacting – consider actions carefully to avoid expensive schedule slips
- Good socket (pogo pin, elastomeric, a hybrid) and load board design solves some issues
- What is done now will evolve as 5G matures

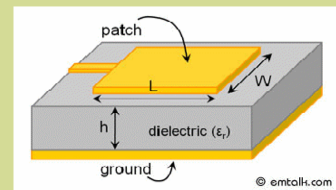


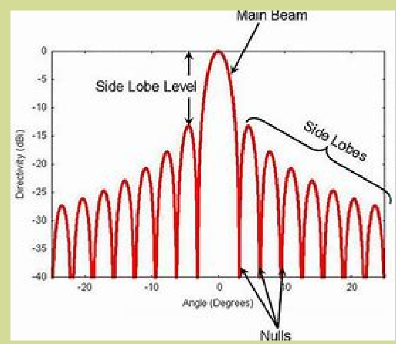
Key Trends – Over-The-Air

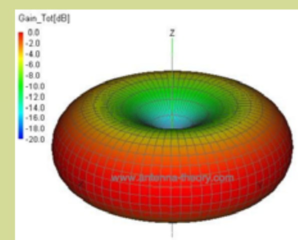
- Over the Air (OTA) testing means devices have antennas incorporated into the package
- In the test environment, antennas are bidirectional
  - Patch, dipole, horn and combinations of any/all are possible
  - Measurement equipment and devices have antennas
  - Measurements are influenced by all hardware and environment (internal and external to the test cell)
- Traditional antenna test environments and antenna types may not be suited to high volume production
- Far field and near field constraints drive the test cell configuration and dictate results made
- What is an “acceptable” result?
- What is sufficient test?
- Is testing accurate – calibration for example?





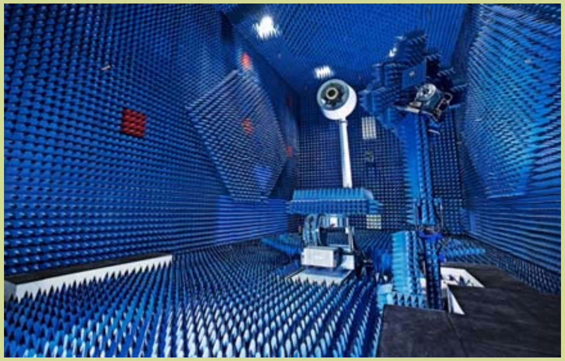






Key Trends – Over-The-Air

- OTA breaks traditional ATE in many ways
  - Physical space and time is *always* a premium in ATE – an enclosure is large and likely single site
  - *Cost control* is still a requisite – no cheap enclosures
  - Characterization should lead to high volume – not more of same, but to better ideas about needed test
  - Some approaches may *be too expensive* and *too slow* – adding robotic handlers, single site, standard test methods, complex antenna results conversions
- The "measurement hardware", test specifications, and "acceptable" specifications require new ideas for millimeter devices with antennas



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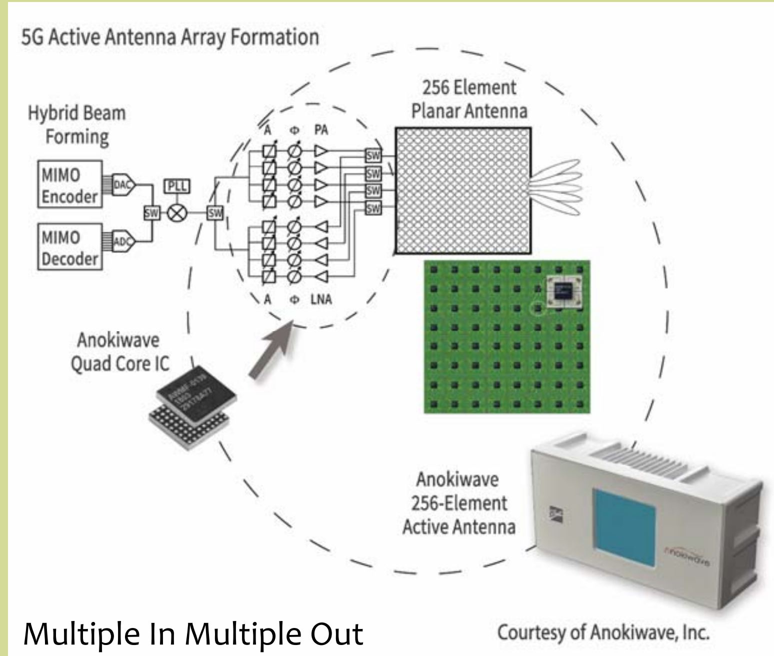
Key Trends – Antenna Arrays

- Over the Air testing brings system level testing to the forefront requiring antenna expertise along and substantial mechanical effort
- Packaged devices with antennas (AIP) located on side, top, or bottom lead to a host of test issues - frequency plans, radiation leaks, complex load boards
- Array device tests must consider all parameters like self-heating, contact resistance, and orientation
- High mmw port count will drive test hardware cost
- Many antennas of several types make effective test strategies complex – OTA and traditional chamber approach are limiting – jamming, multisite, EMI/EMC must be factored in to overall test cell planning



Key Trends - Handling

- An OTA Environment will likely include
  - Dedicated handlers for parts, custom change kits, or robots to handle modules
  - A socket and load board with the features required for the signals and transparency to all device frequencies
  - A load board to route all the other signals required such that it will not interfere with the "over the air"
- Reference antennas in the test system may end up being positioned in many possible orientations to meet device requirements.
- Several different types may be required for the interface to the device since device antennas may not be just one type
- Companies considering high volume test may want multi-site. These techniques are not refined due to hardware limitations, possible interference among the devices, and overall cost.
- A test cell will be expensive - innovative approaches must be considered

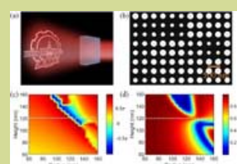
<6 GHz → mmWave – Form Factors

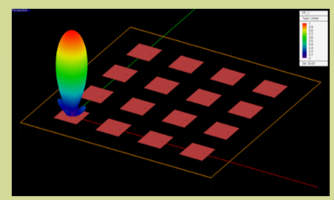
<6 GHz – Form factor

- Module's "like a chip"
- Standard handler

mmWave – Form factor

- Many custom 3D non standard form factors
- Standard handler not viable -> Robotics?
- Do we need to manipulate the package in 3D

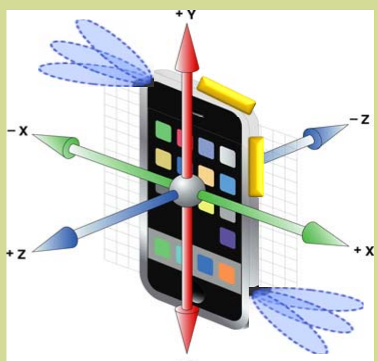




<6 GHz → mmWave - Calibration

<6 GHz - Calibration

- Connected: more pins, more BW, more parallelism
- Lower cost
- Bandwidth
- # RF pins



mmWave - Calibration

- How to calibrate when the antenna "IS THE PACKAGE"
- OTA and antennas and multi-dimensional movement has not been a requirement before in HVM testing

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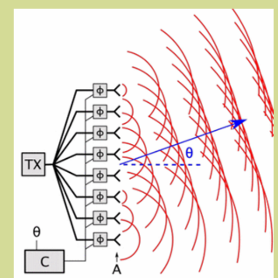
<6 GHz → mmWave – Beam Forming/Steering

< 6 GHz – Beam forming/steering

- Has not been a requirement
- MIMO tests implemented using traditional methods – OK
  - 93K Wave Scale and T2000 12GWSGA solution exists for MIMO

mmWave – Beam forming/steering

- Beam forming and beam steering have never been a production test requirement
  - Requires antenna expertise (very short supply)
  - Requires OTA HVM expertise (perhaps look to automotive radar solutions?)
  - Innovative solutions being studied



Conclusions

<6 GHz

- Load boards
  - Required several years for industry to production"ize" < 3 GHz RF load boards – especially RF parallel testing
  - Helped with 6 GHz, but was still tougher
- RF Connector and socket technology had to adjust
- Calibration was and continues to be a challenge
- For sub 6 GHz the challenges can categorized as "more of the same"

mmWave

- New socket technology needed
- Load board, socket, and connector technologies are improving and adapting to increasing frequency
- Manipulating and handling 3D custom form factors require robotics along with RF interfacing
- AiP, OTA, calibration and testing, and Beam forming/steering will be critical and disruptive idea will win the markets
- Solutions to these issues are being studied now

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