HETEROGENEOUS INTEGRATION ROADMAP

2019 Edition

Chapter 17: Test Technology

Section 01: RF Test

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Section 1: RF Test

Key Test Trends

Table 1: RF Test Requirements

Year of Production	2018	2019	2020	2025	2030
Leading Edge (Note 1)					
Mobile Devices (General Radio) (Note 13)					
Carrier Frequency (GHz)	8	8	8	8	8
Number of simultaneously active RF Ports per Die (Note 11)	12	16	16	16	16
Total number of RF Ports per Die (Note 11)	48	64	64	64	64
Modulation RF SSB BW (MHz) (Note 2)	80	80	80	80	80
Amplitude Accuracy (dB) (Note 3)	<0.25	<0.25	<0.25	<0.25	<0.25
ACLR (dB) (Note 4)	77	80	80	80	80
Phase Noise (dBc/Hz @ 100kHz offset @ Fc=1GHz) (Note 12)	-143	-146	-146	-146	-146
Error Vector Magnitude 3G/4G (Note 5)	0.5%	0.5%	0.5%	0.5%	0.5%
IIP3 (dBm) (Note 6)	36	36	36	36	36
OIP3 (dBm) (Note 6)	60	60	60	60	60
Infrastructure/Focused applications (Radar, WiGig, Backhaul)					
Backhaul Carrier Frequency (GHz) (Note 7, 9) 115 is W band.	115	115	115	115	115
Collision Avoidance Radar Carrier Frequency (GHz) (Note 8)	81	81	81	81	81
Modulation RF SSB BW (MHz) (Note 10)	1760	1760	1760	1760	1760
Amplitude Accuracy (dB) (Note 3)	<0.5	<0.5	<0.5	<0.5	<0.5

Manufacturable solutions exist, and are being optimized
Manufacturable solutions are known
Interim solutions are known
Manufacturable solutions are NOT known

Notes for Table 1:

1. Leading Edge versus Volume: This distinction is to serve two purposes. One purpose is to approximate an adoption cycle from when new technologies emerge and require characterization vs. volume production, while a second is to highlight that certain test methodologies may be required in characterization (typically more complete), while production test may rely on simplified conditions.
2. The leading-edge modulation bandwidth increased significantly from year 2010 to year 2011 to cover proposed wireless standards such as WirelessHD. 1760 MHz driven by WiGig @ 57-66GHz.
3. Amplitude accuracy below 0.5 dB requires de-embedding, which adds significant cost.
4. For WCDMA @ 5MHz offset channel.
5. Error Vector Magnitude (EVM) testing is very prevalent in high volume manufacturing today. The challenge in a table such as this is that each standard (WLAN, WiMAX, W-CDMA, etc) has a different requirement. The values represented here are a blended average of EDGE, and W-CDMA variants (HSDPA, HSUPA, etc).
6. OIP3 / IIP3: These are (best for the chain) figures of merit for distortion performance (O = Output, I = Input). Generally speaking, systems with larger peak to average power excursions require higher linearity. Examples are systems employing code division multiple access (CDMA) technologies and Orthogonal Frequency Division Multiplexing (OFDM) systems.
7. 40/100 GHz Point to point connectivity (WW freq. allocations differ by country)
8. 75-81 GHz for collision avoidance RADAR & Other sensors, IEEE 802.11ad (WW freq. allocations differ by country)
9. 66-67 and 76-86 GHz is for backhaul point to point
10. 1760 MHz is for WiGig
11. Device is defined as a single IC (not chip set or other). Testing can be done with less simultaneously ATE active ports.
12. DUT Requirements of the source
13. Cell Phone 5G base station (standard not finalized) 28 & 40 GHz carrier. Wafer level OK (BW is a challenge and number of ports is high). Package level with antenna is still a challenge
14. 40 GBPS @10 GBPS 4 twisted pairs -- 4 twisted pair (10 GBPS)

Short Term Trends (<5 years)

Mobility

The mobility area of the table is a dynamically evolving topic. LTE and LTE-advance have emerged as the world-wide 4G standard for all mobility devices and UWB was never commercially adopted. WiGig has taken the place of UWB. The market was driven by evolving existing standards to larger bandwidths like WCDMA to LTE-Advance and 802.11a/b/g/n to 802.11ac WiFi to drive faster data rates. The primary drivers of consumer mobility devices are smartphones and tablets that use LTE/LTE-advance and WiFi as predominant standards.

The Mobility portion of table has been reworked to reflect those changes. RF SSB BW remains constant at 80MHz (driven by 802.11ac). The WiGig is in place in the near future, requiring a 1760 MHz modulation as reflected in the tables.

The system sensitivity, driven by better phase noise and less spectral growth from non-linear distortion, drives adoption of higher density modulation standards to carry forward faster data rates. As the number of QAM constellations increase, the EVM accuracy that plots the amplitude and phase error also needs to improve.

The RF port count per device increases to 64 over time because frequency allocations are non-standard across the globe and the need for backwards compatibility to the many existing digital communication standards need to be fulfilled.

The Internet of Things (IoT) is a market that is high-volume cost-driven, more than a test technology driver. It primarily consists of huge numbers of RF sensors that transfer data into a global data distribution center which will then communicate to the outside world and internet. Data processing will be used to identify trends and make the data meaningful to the world. There are two schools of thought for the data transfer for IoT: 5G speed could make this attractive for the massive amounts of data. On the other hand, if cellular phones quickly adopt the 5G standard, then there will be 4G infrastructure capacity available at a cheaper cost for IoT data transfer.

Infrastructure/Automotive RADAR/Industrial

The popularity and acceptance of collision-avoidance radar detection systems and point-to-point backhaul is driving the second area of the table – Infrastructure/Automotive RADAR/Industrial. In the Automotive Radar space, the trend is towards more ports and multiple transmit and receive channels. Similarly with backhaul transceivers (802.11 AY, MU MIMO) the trend is towards more antennae and arrays (4 antennas per array and possibly as many as 64 arrays) as well as frequency increases upwards of 115 GHz.

In the 5G space, it is already out and becoming more prevalent and widely used. It is also driving the need for more RF ports with its antenna numbers ranging from a 2X2 antenna array up to 64. Another possible driver for 5G is that it is less able to penetrate walls and glass, so that could drive the repeater trend to mitigate this.

Difficult Challenges in the Short Term

- RF will much more frequently be embedded into products via SoC or SiP techniques. Combination of RF tests with (high-end) digital and mixed signal will be more common. RF test at the wafer level will increase. Next to the test system, there will also be emphasis on the tooling (load boards, sockets, and probe cards) to cope with signal integrity.
- More ports, multiple transmit and receive channels, more antennas and arrays will require more RF ports from ATE.
- In general, for some of the leading-edge frequencies and number of ports required, characterization and debug solutions are known, but will be a challenge in production. For example, the 802.11 AY band requires a 60 GHz carrier1 and W Band carriers are at 115 GHz. The newer standards for MU-MIMO are using 8X8 arrays2.
- There are some challenges specific to a production ATE environment including: Integrating waveguides into ATE for applications >65 GHz (mechanical and cost challenge), Integrating 3rd party components into the test-head or probe card for applications >60 GHz, and blind mate connector BW performance at 40-80 GHz.
- In the 5G space, there are more carrier bands/aggregation and more BW(IF - 2 GHz). Power management may become an issue both in terms of number of domains and cooling dissipation during test.
- Impedance standards and calibration methods for high frequency measurement at probe need to be created.

- The EMI environment of the test development setup may be substantially different than the environment on the production test floor, creating yield and correlation issues.
- Most SOC test requirements are still trending from RF-to-BB and vice-versa. RF-to-Digital or line-to-line is limited but widely discussed.
- The increase in performance and frequency in combination with the economics of test will put a strong focus on novel design-for-test and alternative test techniques to be developed in the coming years.
- OEM is conceptualizing RF BIST/loop-back test methodology, but functional and parametric tests still dominate the market.

Medium-Term Trends (6-10 years out)

In the backhaul transceiver space, phase array antennas will have a larger number of RF ports. For example, satellite apps in the 12-40 GHz range with MCMs combining front end integration: ASICs, ADC and DACs.

Other examples include backhaul: transceivers with 3 ports (RX, LO, TX) per band combined with multi-band for a total of as many as 9-11 ports; and 5G with a minimum 4 ports (2X2 antenna) and maximum of 64 ports for an 8X8 antenna.

With this increase in ports and IP blocks, there will be an increase of power needs in terms of the number of domains and wattage (heat).

Difficult Challenges in the Medium Term

- Test for phase-array transceivers will require cooling mechanism(s) during test.
- There will be a need to integrate temperature sensors into the handler, device (on die) and wafer probe. The higher the power, the faster the rate of change of temperature.
- There will be a requirement to integrate cooling into the handler and wafer chuck.
- COT challenges will be exacerbated for these solutions for cooling and number of RF ports.

LONG Term Trends (10+ years out)

- 6G future possible improvements include:
  - Integrate terrestrial wireless with satellite systems.
  - Ultra-dense cell networks, millimeter waves for user access, enhanced optical-wireless interface.
- Difficult Challenges in the Long Term
  - The definition of 6G needs to firm up for the challenges to be known.

Trends impacting the roadmap 2017-19

The model presented in this roadmap was generated in 2017 and there are areas that need to be looked into further for the next update.

- 5G both in the base station and appliances have been gaining significant momentum and will need to be integrated into the tables with more details about frequency bands, different modes, channel bandwidth, EVM requirements and number of channels.
- An additional 5G topic, but one that deserves its own space in the tables as well is the 5G antennae which are required for beam forming. Here the entries would include the frequency bands, array sizes, looking at phase shifts between the antenna elements in the array, and the number of RF ports required to test the array along with the other elements, such as a transceiver(s)

Summary

The number of RF ports increases significantly in categories such as backhaul transceivers and multi-band 5G. With the increase in ports also comes higher power consumption, leading to higher heat generation. The Mobility market continues to have higher cost pressures than the Infrastructure/Automotive RADAR/Industrial. ATE needs to follow these trends with more RF ports, more power options and ways to deal with heat generation, while maintaining or even decreasing the ATE costs.

References

https://www.keysight.com/upload/cmc_upload/All/20170608-A3-BrianSu.pdf
https://www.eetindia.co.in/news/article/new-wi-fi-standard-extends-mu-mimo-to-8x8-arrays
https://www.linkedin.com/pulse/beyond-5g-roadmap-6g-stephen-patrick/