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ATE Challenges on Sub-6G PA

Norris Wang, Wei Xu,
Takumi Hayashi, & Zhiqiang Bai
ADVANTEST

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Introduction

Background

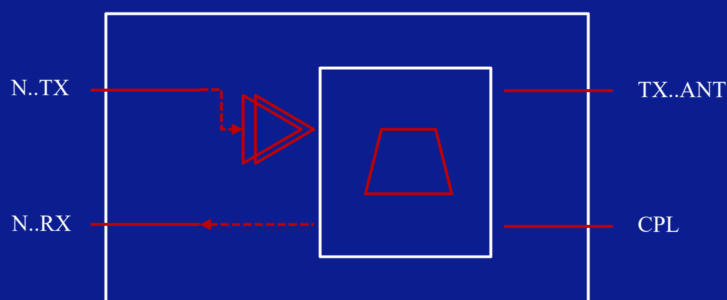
- Sub-6G RF TRX system is hot-spot in 5G communication. Compared to mm-wave band(*FR2), Sub-6G(*FR1) band has a lower power consumption and larger cover range. Compared to 3G/4G Front End Module (FEM), Sub-6G FEM also brings challenges like obvious occupied band-width increase (10M/20MHz->100/200MHz), higher order modulation (64QAM -> 256QAM) while the efficiency of Sub-6G Power Amplifier is reduced fiercely.

- In real sub-6G PA cases, one largest challenge is the thermal degradation which is caused by extremely low PAE(Power Added Efficiency). In the slides, it will show how to overcome difficulties to reduce cost and improve stability without hardware change.

- In the other hand, strict correlation criteria are necessary in both engineering and production. Consistency and continuity need achieve among testers to guarantee the Quality. By dedicated calibration design, all these Challenges are tackled.

Introduction

- Device information



- Device Band Support:

Band	Downlink/Uplink(GHz)
N77	3.30 – 4.20
N78	3.30 – 3.80
N79	4.40 – 5.00

Introduction

- Device information

Test item	N77/N79
Idle ICC	L/M/H
Active ICC	L/M/H
ACLR	L/M/H
EVM	L/M/H
PAE	L/M/H
Insert loss	L/M/H
Gain	L/M/H
Power Out	L/M/H
CPL	L/M/H
Switch time	

Different Gain Mode from Low to High.

Each test item will be tested in different modulation waveforms.

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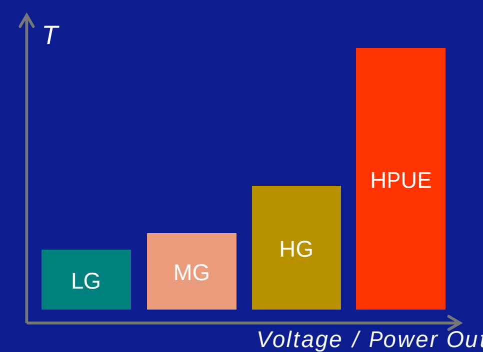
Engineering

- Overview of test program
  - Part of the test condition of RF test items

Test items	Voltage	RF power
	LG/MG/HG/HPUE	
Idle ICC	0.8~5.0V	-
Active ICC	0.8~5.0V	> 25dBm
ACLR/Gain/EVM	0.8~5.0V	> 25dBm



From the test condition, it shows the device temperature rise quickly with the voltage and power out. Compared to 3G/4G PA TX module(TXM), in most of the case, device PAE is very low, just half of 3G/4G PA devices. In the following slides, it is shown deeply influence on the correlation.

3G/4G PA PAE: **Much better** >> Sub-6G PA PAE: Extremely low

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Engineering

- Correlation
  - Environment compare

Equipment	ATE
DC	DPS64/DPS128 – V93K
RF	WSRF – V93K
Socket	Exists
PCB	LB – Quad Sites
Connection	RFIM6(V93K)->SMP->LB->Socket
Control	PS1600 – V93K
Attenuator	Attenuator

ATE test environment established on the latest ADVANTEST SmarTest8 (SW) and V93000 tester (HW).

Compared to application or evaluation environment, ATE test environment works with **higher density, shorter time, worse heat dissipation, multiple RF connectors and attenuator**.

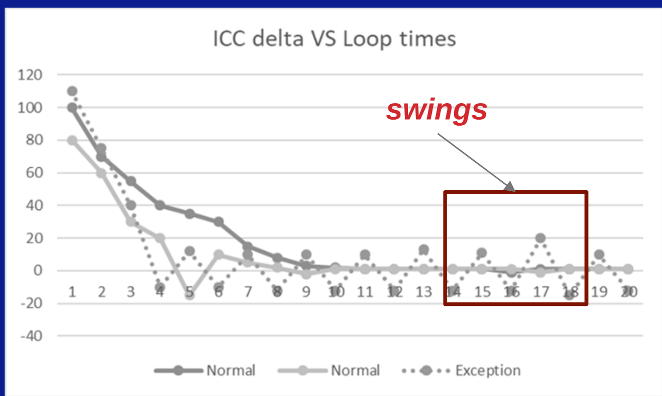
Engineering

- Correlation
  - Engineering correlation criteria from evaluation:

Test item	Criteria
Idle ICC	<10mA
Active ICC	<20mA
ACLR	ACLR1<0.3dB(~30dB) ACLR2<1dB(~40-60dB)
EVM	<0.1%
Gain	<0.3dB
Power Out	<0.2dB

Engineering

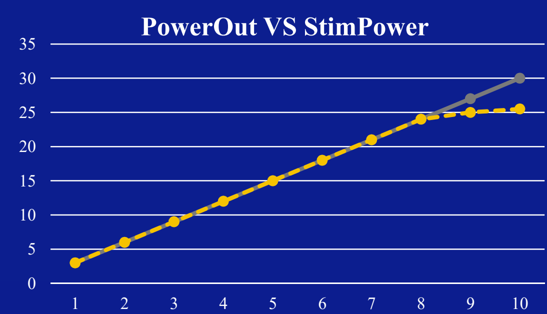
- Correlation
  - ICC calibration can not reach convergence



1. It supposes that target Power Out and target Active ICC can meet our calibration requirement error within twenty times modification of Outloss.
2. Most of Gold Units behave like that less than 10 times. Normal GUs ICC delta will reach to the minimum gap less than 1mA.
3. There are exceptional GU. The exception GU start swings around the [-20,20]mA.

Engineering

- Correlation
  - ICC calibration can not reach convergence



This slope works well when PA device is in “Linear Area”. However if the Power Out is close to “Non-Linear Area”(NLA), this formula doesn’t work.
Solution: set the adjust of stim power to constant when close to NLA:

```
If (adjust >= 0){
     stim power + =  0.15dB}
Else{
     stim power - =  0.1dB}
```

It will help *Active Icc* close to target Current from one side and avoid swings.

Engineering

- Correlation
  - Same Frequency Calibration Outloss Difference

Frequency	Real Loss	Normal Loss	Abnormal Delta
N77, N79	Around 3dB	Around 3dB	>5dB

As it shows, the PA has different Gain power mode and different waveforms. It could use different power mode target Power Out and Active ICC as reference. However Out Loss result is with much difference as above.

It's found that ICC/Target Out calibration has an important necessary condition: Calibration result should be getting at considerable PAE . Lower PAE means even with different Power Out, their Active ICC are close to same value.

Engineering

- Correlation
  - Overcome Heat dissipation problem of PA

In some cases, PA Active current was over than 1A without any additional heat dissipation method. Some version of Reg config IDLE ICC was very large, too. Compared to EVB, Idle ICC (quiescent current) in socket can not keep a stable current.

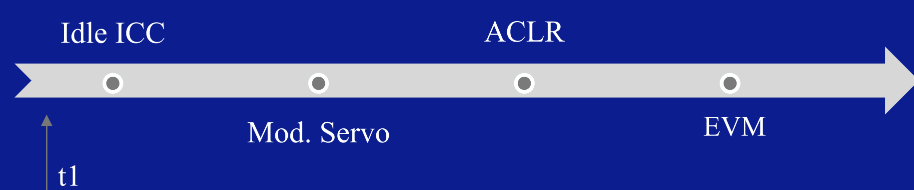
Test condition	EVB - ATE
Loop test 50 times	0-10mA
Debug stop 1s test	~100mA
Power off 3s then test	0-10mA

Generally RF PA is typical Class-(A/B/C) amplifier. Bias current is one of the most important index. If the quiescent current is not same, it means that the test conditions are completely different and the nonlinear effect is enhanced. It is difficult to do correlation.

Engineering

- Correlation
  - Overcome Heat dissipation problem of PA

When the temperature of the conductive particles increases, the thermal motion intensifies, and in the PN junction of the semiconductor, conductive particles becomes more and more uncontrolled, resulting in some reduction in the quiescent current bias.



The register configuration and level setting were completed at time t1. The following three test items are not set configure. In other words, PA has been heating and processing performance degradation since t1 Idle ICC test.

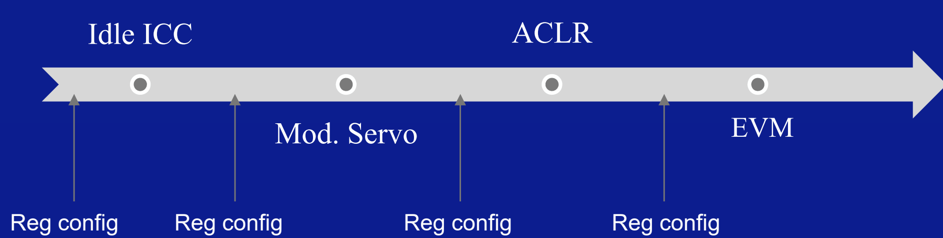
Engineering

- Correlation
  - Overcome Heat dissipation problem of PA

    Solution:

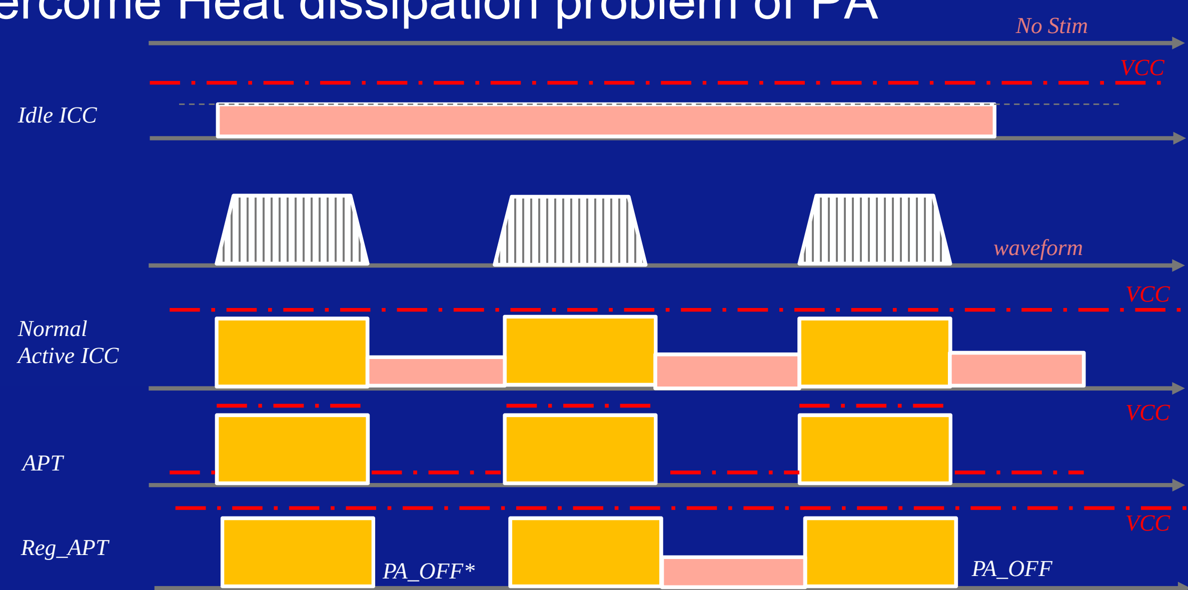
    After finishing the RF Meas action, configure PA OFF register immediately, which takes about ms level of time. It helps reduce PA temperature before the following test items.

    This solution is called as “Reg APT” since it looks like “APT” with a little difference.



Engineering

- Correlation
  - Overcome Heat dissipation problem of PA



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Production

- Release Correlation

Multiple Prog Versions — Between Prog versions

Multiple Testers — Between Testers and Sites

Strict correlation and production quality are guarantee!

Test item	Criteria
Idle ICC	<10mA
Active ICC	<20mA
ACLR	ACLR1<0.3dB(~30dB) ACLR2<1dB(~40-60dB)
EVM	<0.1%
Gain	<0.3dB
Power Out	<0.2dB

Dedicated solution is necessary to guarantee strict correlation and production quality.

Production

- Release Correlation
  - How to maintain the robustness of test results

GU groups selection: Select GU groups with high consistency to replace a single GU.

Using the GU group to simultaneously calibrate on the quad site and multi-testers to ensure stability and greatly improve efficiency.

GU reference iteration: The golden lot data tested during first release is used as the golden data.

In case program version updated, the reference value of the GU group is also iterated synchronously to ensure the consistency of the test data.

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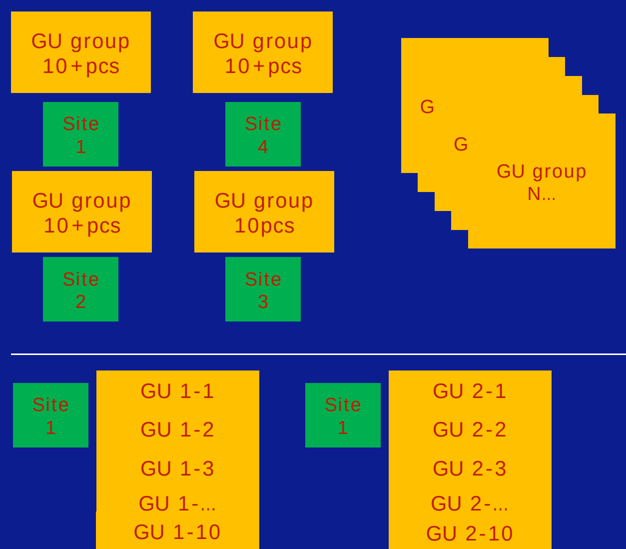
Production

- Release Correlation
  - How to maintain the robustness of test results



Group Gu calibration between testers and sites. Great efficiency and stability.

All these operations will be done by Software and Tester automatically.

Each site with more than 10 pcs calibration GUs

Each GU will run on one site more than 10 times.

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Production

- Release Correlation
  - How to maintain the robustness of test results

Production

- Release Correlation
  - How to maintain the robustness of test results

    Golden Lot samples must be well preserved.

    Generally the test results of 1000+ chips should not change significantly.

    Golden Lot report produced by each program version and different tester should be same.

> Despite of addition test items as well as the hardware degradation, it guarantees Consistency and continuity by using group GU and GU value iterations.

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Conclusion

According to the above real cases, by Advantest 93K SMT8 test platform, it solves :

- ➢ Device heating testing
- ➢ Current Non-convergence
- ➢ Calibration difference

And

- ✓ Improving Hardware re-usage
- ✓ Guaranteeing consistency and continuity

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