RF Loopback Testing Concepts and Results

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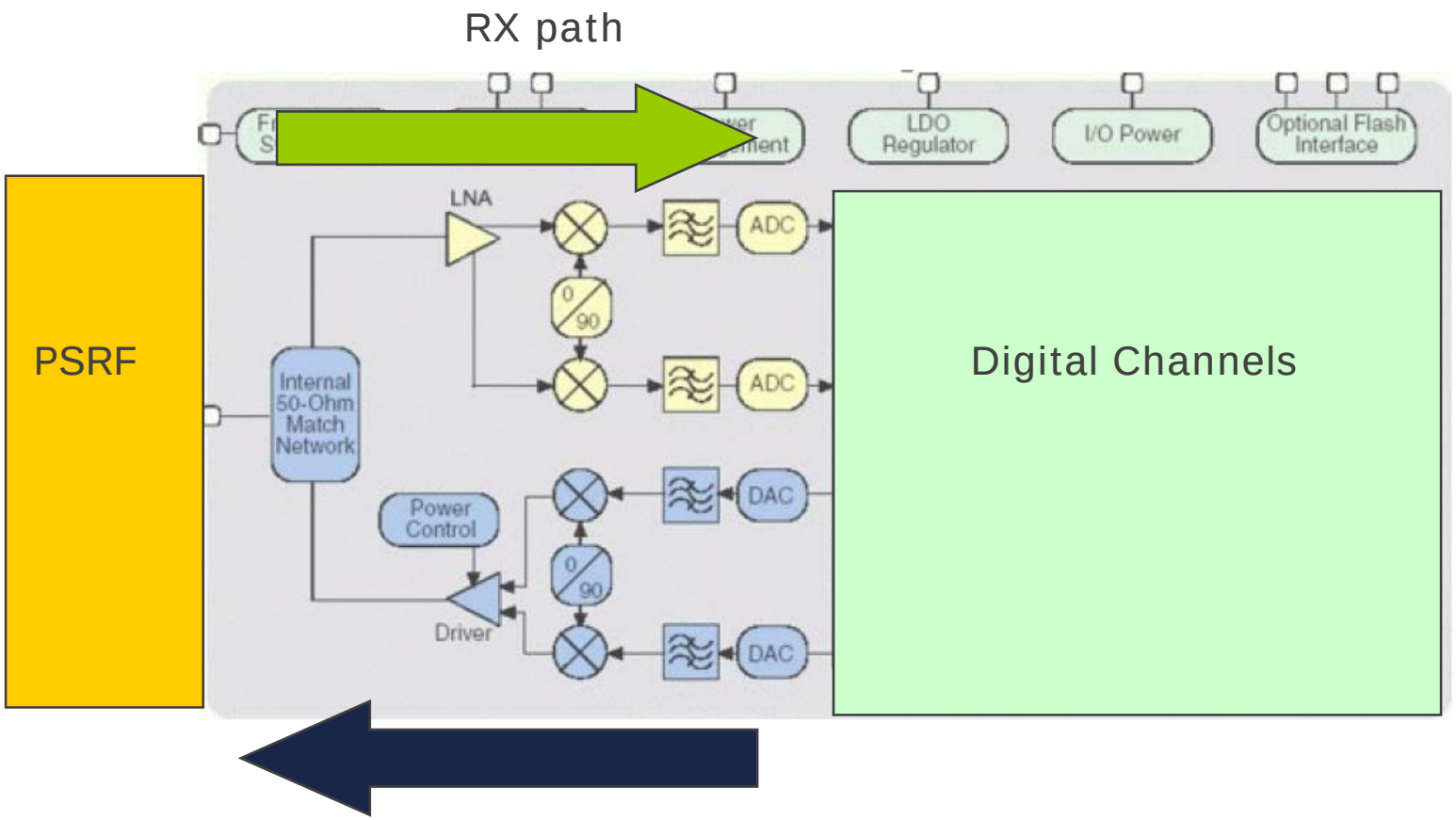
Agenda

- What is Dig-Dig RF test
- Implementation on a Dual-Band 802.11n 2x2 device
- Correlation - V93K Port Scale RF (PSRF) to RF-Loopback
- Test Time (TT)
- Implementation Issues
- Developments in RFBIST
- Thanks
- Next Steps – Questions?

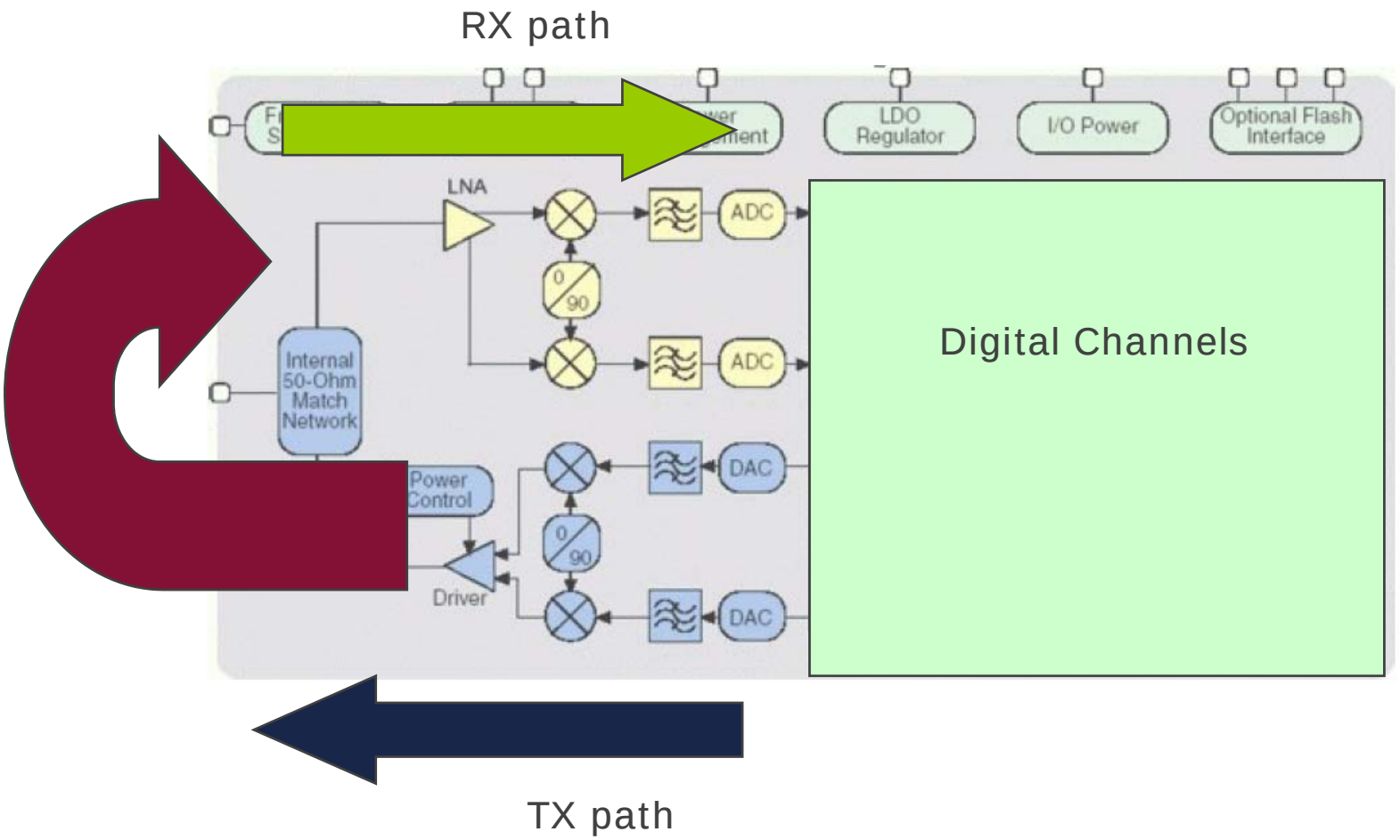
What is Dig-Dig RF test?

- This is a simple RF loopback test
  - Device TX connected to device RX though a external TML or internal connection scheme
- There is no RF sub-system hardware needed
  - Need ATE with DPS and standard PE channels (PS1600)
- The theory of operation
  - An IF frequency is generated inside the DUT through direct digital frequency synthesis
  - This is up-converted to an RF signal through the TX chain
  - Then looped back to the RX before the antenna
  - The (A or G band) RF signal is then down-converted to an IF signal through the RX path
  - The IF signal is then processed by the internal ADCs and digitally captured with standard digital tester channels
- Use model
  - An RF ATE system may be needed to verify key RF (PA, Ant. – LNA) parameters before lots reach finished goods
  - Wafer sort is ideal for implementing Dig-Dig RF loopback testing while reducing incremental cost per test second

Digital-RF test



Dig-Dig RF test



Implementation on a Dual-Band 802.11n 2x2 Device

Loopback Gain

Objective: This test provides a quick way to measure the performance of both Tx and Rx path of the chip.

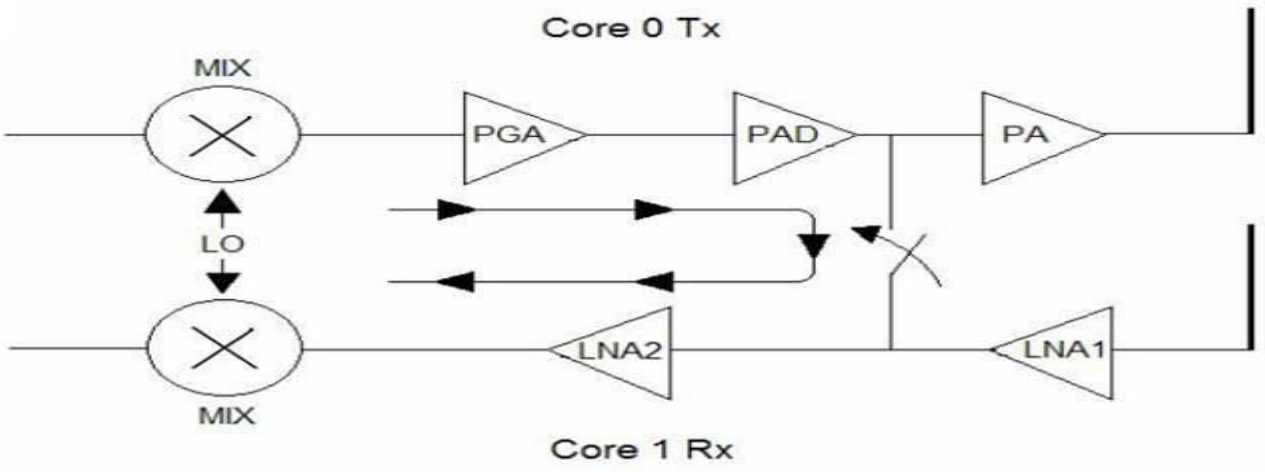


Fig 3.1.9.1: Loopback Block Diagram

Test Procedure:

- 7 standard measurement channels in G-band and A-band
- A tone is sent out from the DUT
- The loopback path is activated
- The received signal is measured

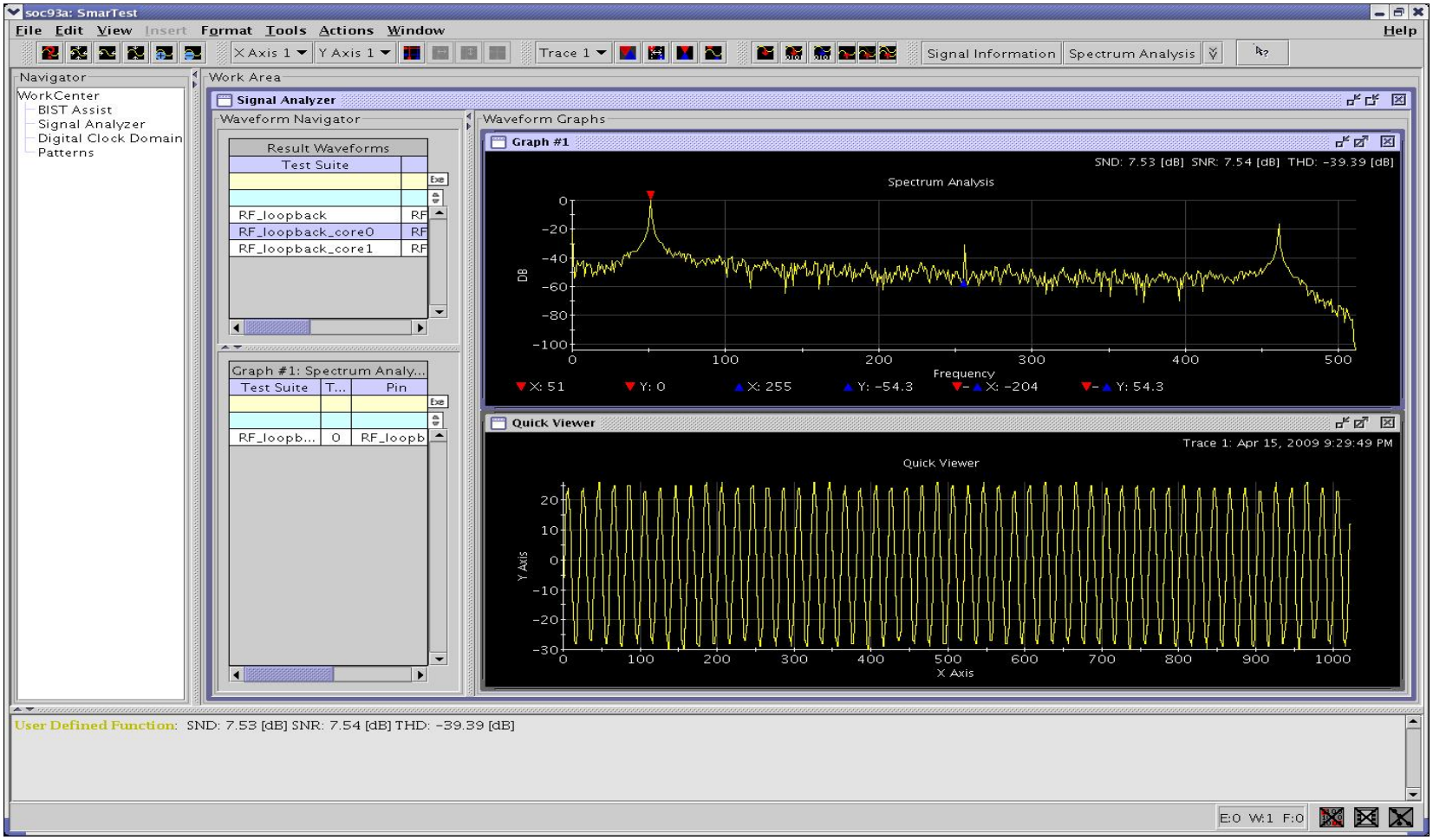
Implementation Issues

- RF DFT implementation on target device
  - Number of radio cores
  - ADC outputs accessible with ATE digital channels
  - Test modes
- Coherent sampling and resolution bandwidth
  - Incoherency is solved thru DSP windowing the sample data
  - Large number of sample points are captured for better bin resolution
- Debug and Test Validation
  - Still need PSRF for characterization and PA testing
  - RF paths loopback path may require calibration and correction

RF-Loopback Package Characterization Data

RF loopback @ 2.4G r0 power	-21.67 dB
RF loopback @ 2.4G r0 frequency	3.984 MHz
RF loopback @ 2.4G r1 power	-16.55 dB
RF loopback @ 2.4G r1 frequency	3.984 MHz
RF loopback @ 5.5G r0 power	0.33 dB
RF loopback @ 5.5G r0 frequency	2.031 MHz
RF loopback @ 5.5G r1 power	-3.86 dB
RF loopback @ 5.5G r1 frequency	2.031 MHz

RF-Loopback G-band (TX – RX) Device Measurement



Correlation - PSRF to RF-Loopback

G-band TX gain step test done with RF-loopback was compared with the results from the our V93K Port Scale RF system

PSRF	RF-loopback
Gain delta I = -5.65	Gain delta = -5.76
Gain delta Q = -5.62	Gain delta = -5.63
Gain delta I = 9.89	Gain delta = 10.05
Gain delta Q = 10.06	Gain delta = 9.99
Gain delta I = -4.50	Gain delta = -4.67
Gain delta Q = -4.82	Gain delta = -4.67
Gain delta I = -6.87	Gain delta = -7.06
Gain delta Q = -6.92	Gain delta = -7.02
Gain delta I = 5.15	Gain delta = 5.36
Gain delta Q = 5.22	Gain delta = 5.30

All measurements in db

Test Time Results

- With careful design and implementation a RF loopback test can replace RF ATE testing for
  - TX + RX Gain test, single tone
  - TX + RX Filter test, 2 tones
  - TX + RX Gain step test

- Test time collected for a production device
  - TX Gain test
  - RX Gain test
    - 300 to 400ms total
  - RF loopback is 150-200 ms
    - Depending on the number of captures

- With one (1) RF loopback test we had 40-50% reduction in RF test time

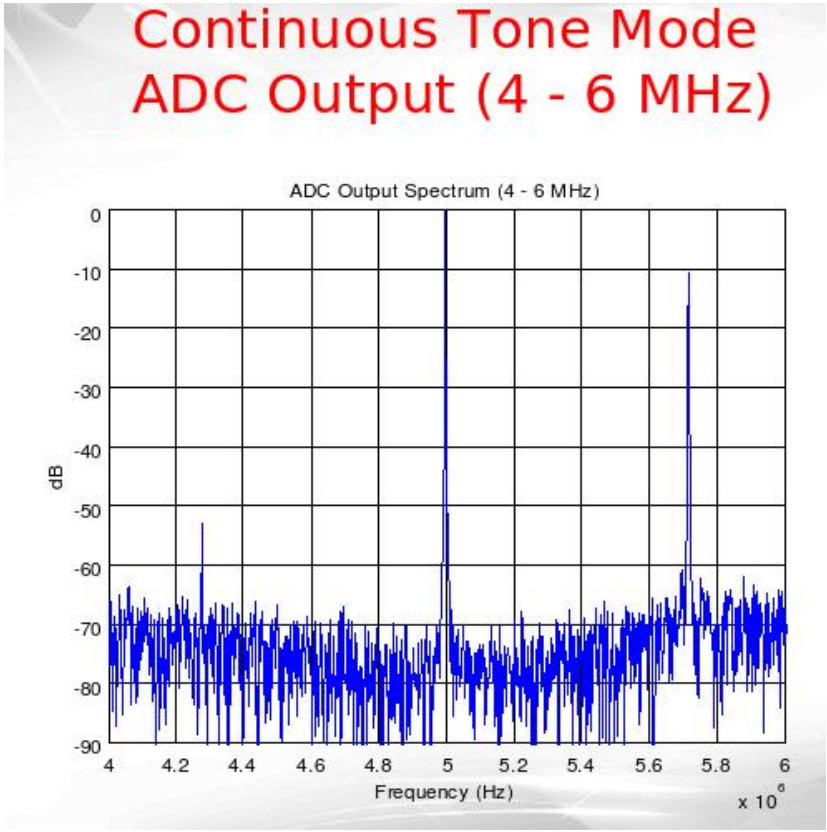
RFBIST Development

- Definition of RFBIST
  - Loopback BER
    - TX generates GFSK symbols. DSP modulator generates symbols, transmit through TX path, picked up via LNA, received via RX, ADC converted and demodulated
    - A BER counter internal to the DSP API sets pass/fail flags per lane
  - Phase noise power measurement
    - It generates a “pass” / “fail” flag based on programmable threshold
  - SNR Test
    - Measure the SNR of the receive path
- Future development areas include TX-RX EVM

RFBIST modes

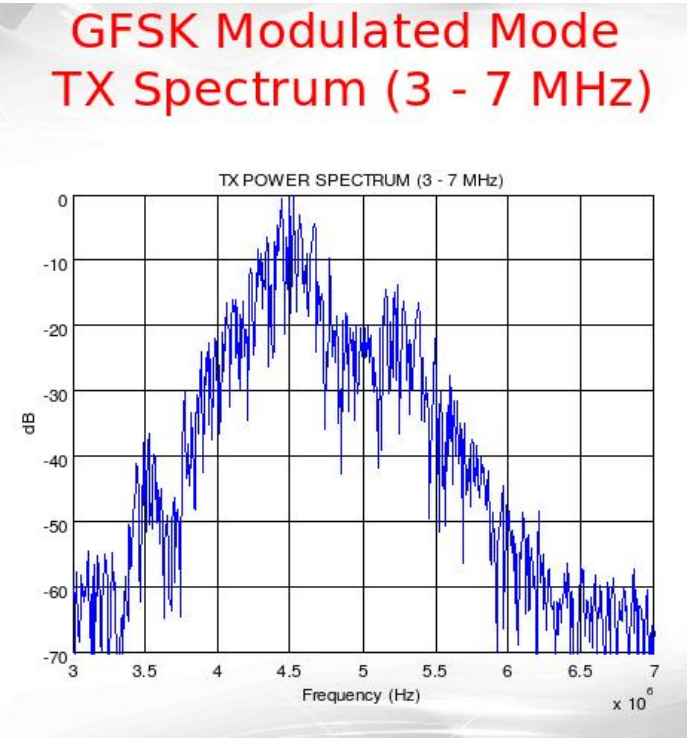
- SNR test

  A 5MHz tone is generated from TX modulator and looped back to RX. The SNR of the tone is measured at the ADC output.



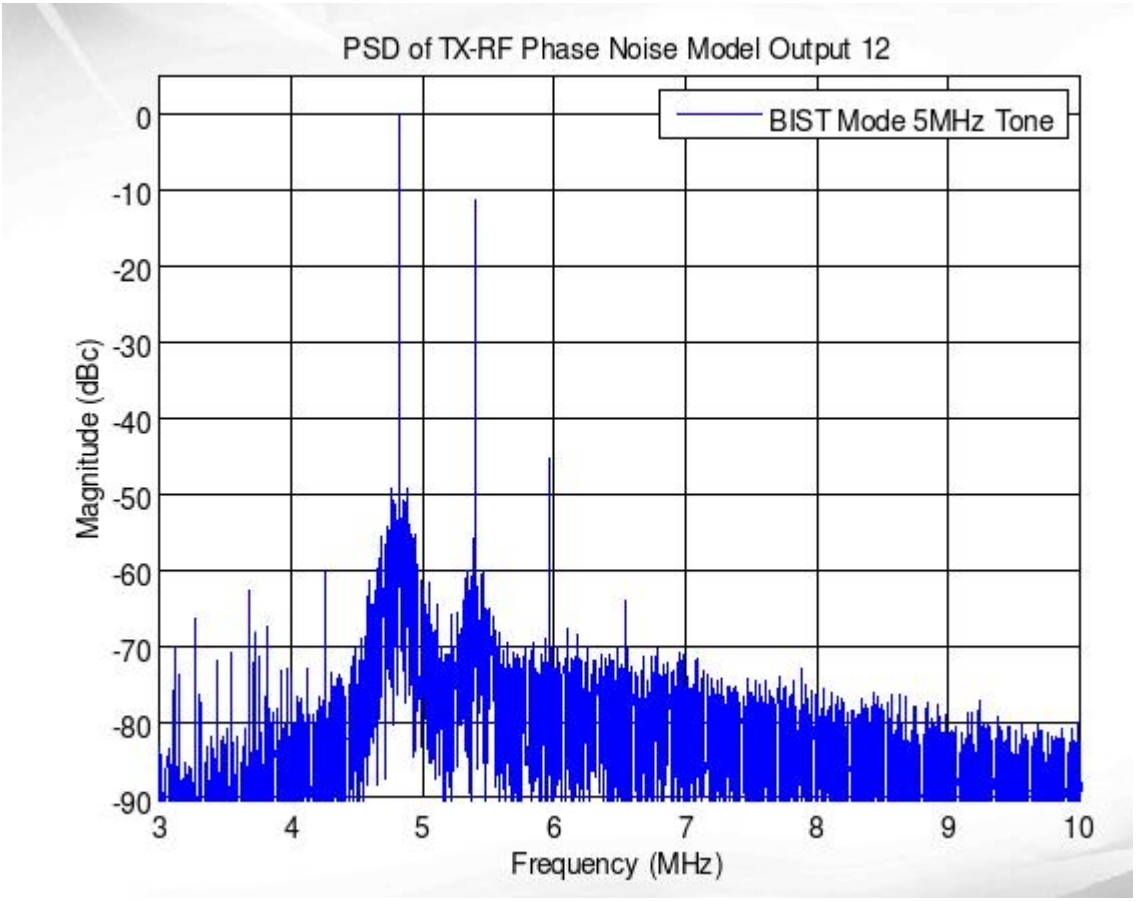
RFBIST Mode

- GFSK modulated signal
  - A GFSK modulated signal with an IF of 4.5MHz is generated from the TX modulator and looped back to RX. The transmit and receive bits are compared to measure error count. An error count of “0” is a pass



RFBIST Mode

- Phase Noise Test



Potential Benefits

- Reduce test time and ATE resource requirements at wafer sort for RF class SOC devices
- Straight forward IP re-use
  - Source code is portable via Verigy's Universal Test Method's (UTM)
  - SVN deployment for revision control
  - Device family IP blocks
- HVM devices can be tested on a digital system in parallel for high throughput
  - High multi-site efficiency - ~96%
  - Using hidden upload on digital capture decreases TT
- Test Time Reduction (TTR) requires only DC and digital functional tests to be optimized
- RFBIST development has the potential to reduce RF sub-system requirements at wafer and final test

Thanks

- To the team at Advantest/Verigy
- Don Ong at Broadcom
- Everyone at SVTC 2011

Next Steps – Questions?

- Deployment models
- HVM trials
- Production Qualification
- RF-Loopback EVM development
- UTM IP library development