# TESTING METHODS AND ERROR BUDGET ANALYSIS OF A SOFTWARE DEFINED RADIO By Richard Overdorf

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# **SDR Considerations**

#### Data rates

- Voice
- Image
- Data
- Streaming Video
   Environment
- Distance
- Terrain
- High traffic/Low traffic
   Priority





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# **SDR's Flexibility**

Interoperability

• One radio with ability to communicate with everyone.

Upgradable



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# **Frequency Configurable – Cognitive Radio**

Front ends that are configurable require one of the following

- Very wide bandwidth
- Flexible front-end



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# **SDR Testing**



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### **Golden Box Testing**

- •Quantitative data is not available
- •Makes statistical process control difficult
- Inability to separate impairments
- •Can easily "mask" other problems with radio
- •Can lead to interoperability issues



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### What is "Residual" BER?



**Agilent Restricted** Month ##, 200X

# **BER Testing Methods**

- Loopback Testing
- Easy Measurement...
- Measures Overall Performance
- Issues in Loopback BER
  - Some impairments are additive across the wireless system.





- Loop-back tests remove impairments, leading to false results.
- System budgets are essential for interoperability.
- Bit Error Ratio Tester (BERT)
- Agilent ADS
- Signal Sources digital/analog/RF



EVM





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## Waveforms



SCM

Development

Flexibility

Troubleshooting



CDMA

Security

Ability to carry multiple users

Transmit more efficiently



### OFDM

Robust in the presence of SCM interferes

Adapt and handle challenging channels

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# **Digital Impairments**

SystemVue Linear System (t1 BandPass FIR),	
File Edit Preferences DSP Mode Filters Laplace Sy	🗞 SystemVue BandPass DSP Filter Design 🛛 🛛 🔀
No. Numerator Coeffs No. Denominato	BandPass FIR Filter Frequencies are a fraction of the filter input sample rate.
Clear NumeratorClear	Rel Freq         Rel Freq         Rel Freq           0.1         0.2         0.3         0.4
Coefficient: z-0         Coeff           4.38250005341377E-03         0) 1           D) 4.38250005341377E-03         0) 1	Gain (dB) 0.0
1) -3.33650689150224E-03 2) 4.17800550166152E-03 3) -1.65515056308226E-02	Gain (dB) 40.0
Frequency Response: Gain in dB vs Freq in Hz (d	H Relative Frequency (Hz) 0.5
	-40.0
-20	In-Band Ripple (dB) Initial No.Taps Elanix Auto Optimizer
-40	Max Iterations Est Taps = 22 Enabled
	25 Update Est Finish Cancel
-80 - 08-	yMm: 112.3 dB F = 100 ?
-100	FFT: 8192 pts OK
0 100e+3 200e+3 300e+3 400e+3	600e+3 Bescale Update Plot Cancel

#### **Filters**

Filter ripple, rolloff, filter rejection

- Better filter requires more filter taps
  - More taps means more multiplies
    - •Multiplies increase word length

Agilent System Vue Filter Design tool

- Overflows
- Truncation reduces DR

#### FPGA resources vs signal quality



**Ripple:** typically removed by receiver equalizer but can effect signal quality

**Overflows:** distort signals and will reduce **BER/EVM** 

**Truncation:** reduces DR, reduced S/N effects EVM/BER

**Insufficient rejection or rolloff:** cross channel interference reducing BER/EVM in co-channels



• Rounding requires additional operations



# **Digital Impairments**

#### FPGA resources vs signal quality



#### NCO – Numerically controlled oscillators

Frequency resolutions

•Improve with larger LUT size

Amplitude Quantization spurs

• Improve with greater word length or dithering

Phase truncation (quantization)

•Improve with enhanced dithering techniques or greater LUT resolution



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### **Noise Effects**

**Noise Figure** 



**Phase Noise** 



#### Phase Noise in OFDM

- Results in each subcarrier interfering with other subcarriers
- Modulates each sub-carrier to the point that they no longer look like simple sinusoids within the FFT interval
- Causes the nulls of the sin(x)/x spectrum to fill in, creating interference between every subcarrier and its neighbors



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# **Other Impairments**

**Channel Loss** 

Interference

AM/AM Distortion

**AM/PM Distortion** 

**Delay Distortion/ISI** 

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Primary	Secondary
Range	Natural Barriers
Spurious	Power Supply
PA	ADC Quantization
PA	PA Leveling Stability
<b>BB</b> Filters	IF Filters

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# System Budget Concept



- Allows the engineer to separate the modulator, transmitter, receiver, and demodulator issues
- Helps ensure interoperability between different receivers or transmitters
- Essential for assuring customer premises equipment units will not dribble years after the base station is installed
- Gives the ability to upgrade modem and ensure that the current RF will support it
- Budgeting helps control costs
- It mathematically relates key analog metrics to digital bit errors used to evaluate the system

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## **RF Design vs. DSP**

Many times you can cut costs by implementing tracking and equalizing Cost come in development and DSP power



802.16 OFDMA Demodulation Properties		
Format Zone Definition Time Advance ✓ IQ Normalize Mirror Frequency Spectrum Symbol Timing Adjust: -3.125 %	ced Burst Profiles Use Default Settings Include inactive subchannels Pilot Tracking: I♥ Track Amplitude I♥ Track Phase I♥ Track Timing	
C Subset     Offset:     I Interval:     I	Equalizer Training: Preamble Only Preamble, Data & Pilots Preamble & Pilots Only Equalizer Smoothing	
	Data Tone Modulation Automatic Manual (see burst definitions)	
Decode ULMAP     Decode ULMAP		

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# **Testing Impairments in SDR**

ADS model to input multiple waveforms

#### Variable impairments



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# **Impairments – Using ADS**



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## Using EVM to trouble shoot the radio



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## Phase Noise effects on CDMA and WiMAX

• Example of effects of BER in a SDR



#### \*Waveforms are NOT equal in data throughput

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#### **BER vs 2<sup>nd</sup> LO PN vs Amp gain for WiMAX**



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# How to Test Impairments in SDR

#### 89601A

SD

R

- Digital Impairments
- IQ impairments
- IF/RF impairments

DSP

Logic Analyzer

Digital (SSI)



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## **Phase Noise Measurements Techniques**

- •Spectrum analyzer technique
- •Phase detector techniques
  - discriminator method
  - PLL/reference source method



#### **Direct Spectrum**





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## **Other Measurements**

#### • CCDF

•Peak to average power measurement

•Fully characterize the power statistics of a digitally modulated signal

•Vital in setting signal power specifications for mixers, filters, amplifiers

#### • ACP

- •Test for leakage into other channels
- •Inter-modulation products
- •Phase Noise
- SEM
  - •Test for unwanted emissions







### **Conclusions and Review**

The dynamic nature of SDR requires in depth testing

Multi-dimensional system budgeting is highly recommended to drive down costs

Beneficial to have tools that work from start of design to deployment

