TESTING METHODS AND ERROR BUDGET ANALYSIS OF A SOFTWARE DEFINED RADIO

By Richard Overdorf

SDR Considerations

Data rates

- Voice
- Image
- Data
- Streaming Video

Environment

- Distance
- Terrain
- High traffic/Low traffic

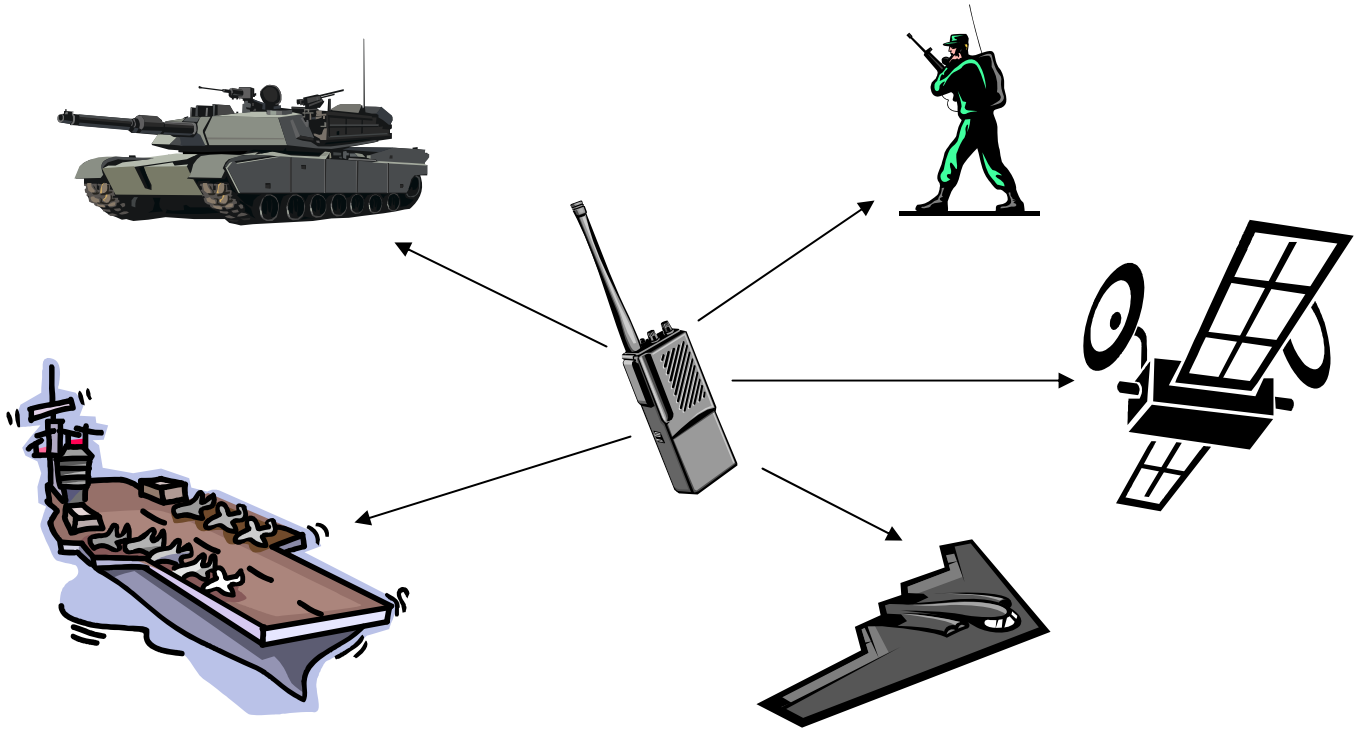
Priority

SDR's Flexibility

Interoperability

- One radio with ability to communicate with everyone.

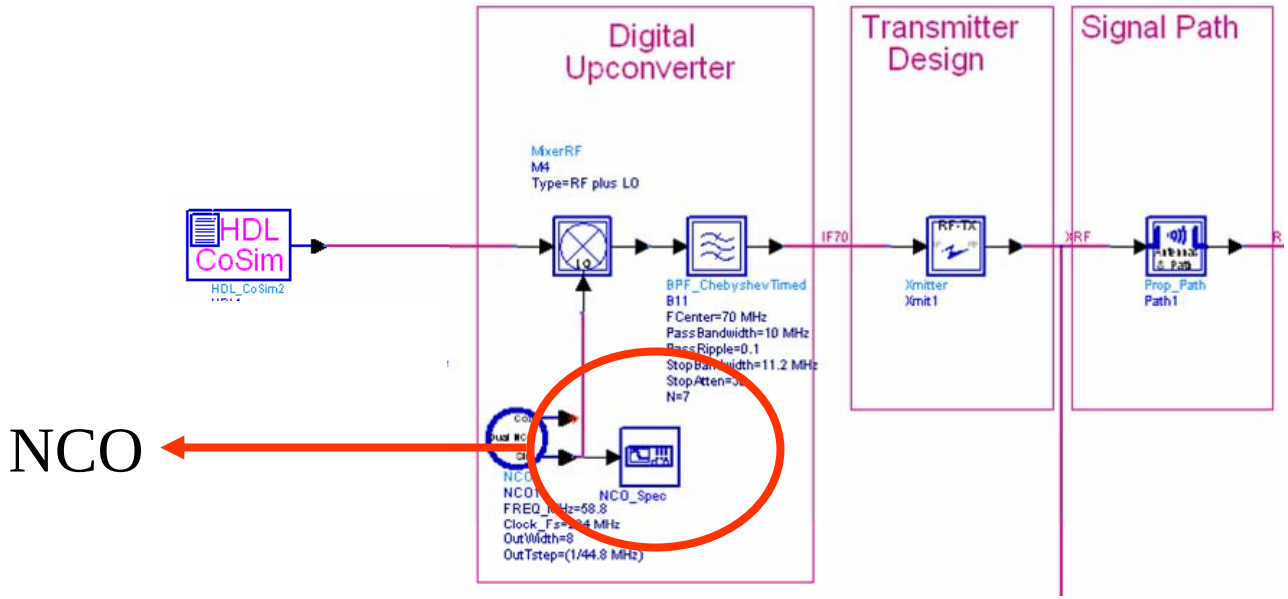
Upgradable



Frequency Configurable – Cognitive Radio

Front ends that are configurable require one of the following

- Very wide bandwidth
- Flexible front-end



SDR Testing

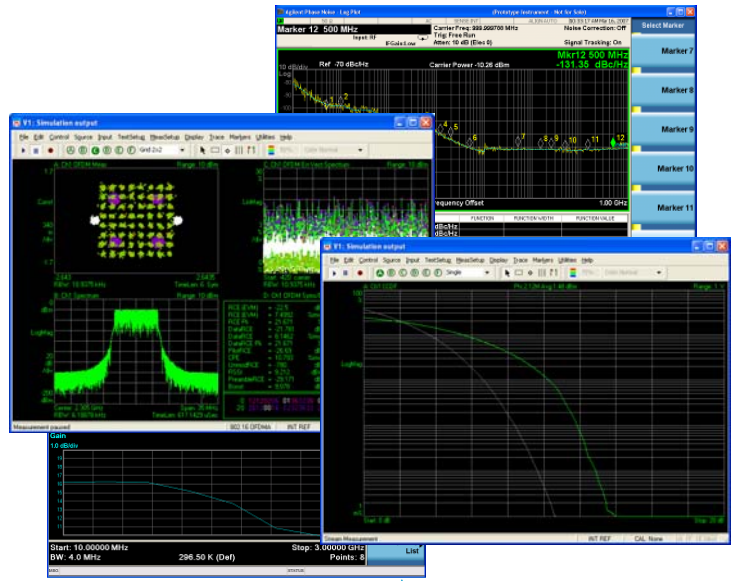
Analog vs. Digital Words

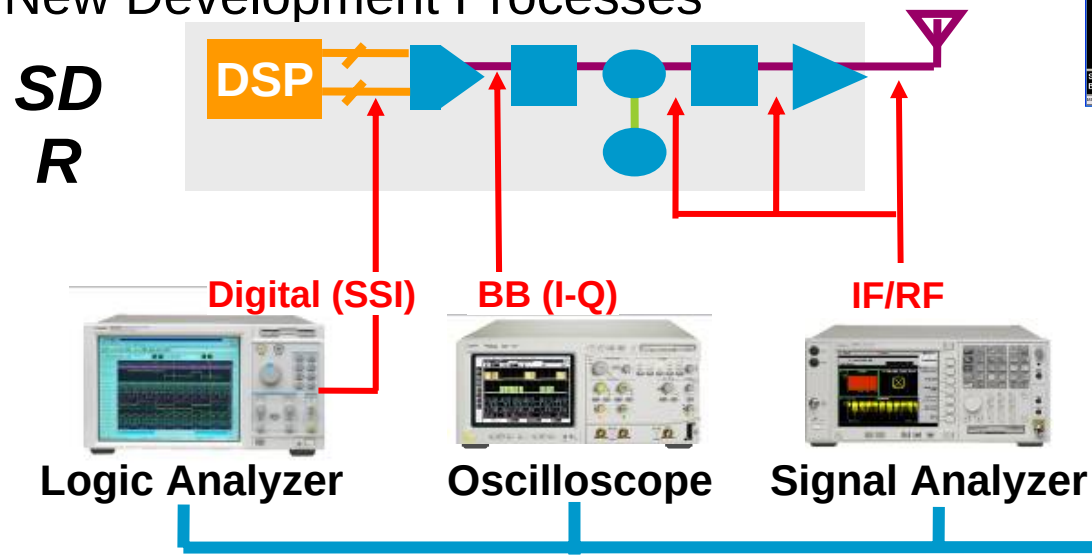
Different Signal Formats

Internal FPGA Signals

Cross Format Analysis

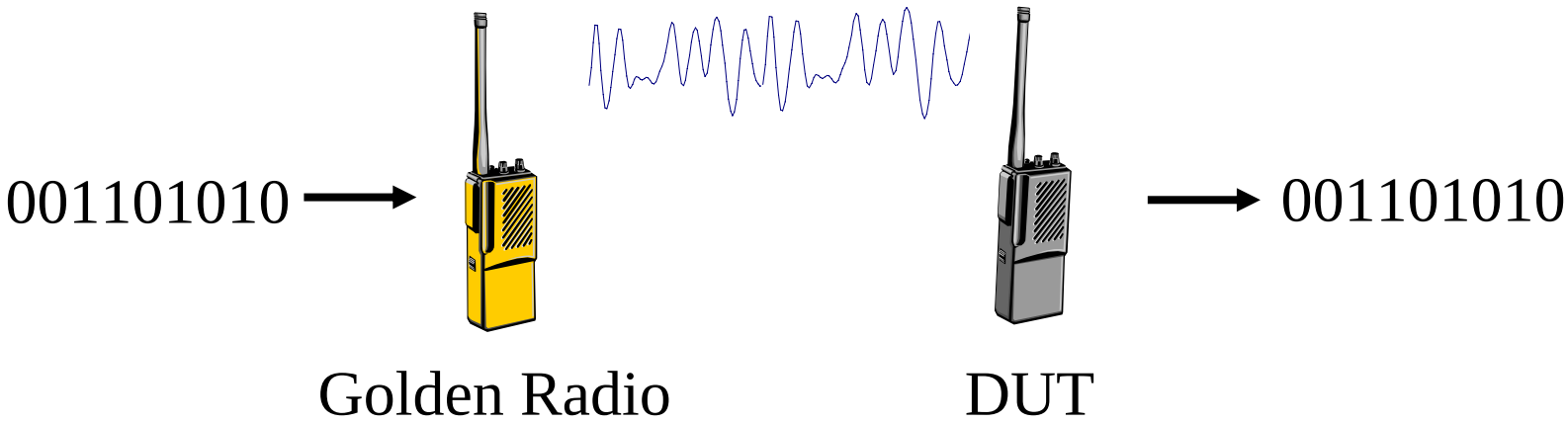
New Development Processes





Golden Box Testing

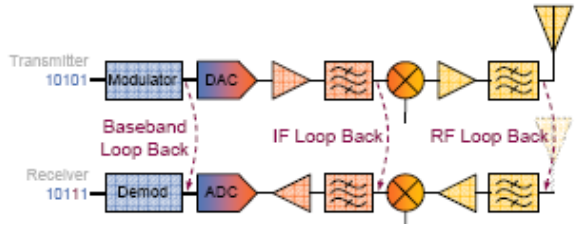
- Quantitative data is not available
- Makes statistical process control difficult
- Inability to separate impairments
- Can easily “mask” other problems with radio
- Can lead to interoperability issues



What is “Residual” BER?

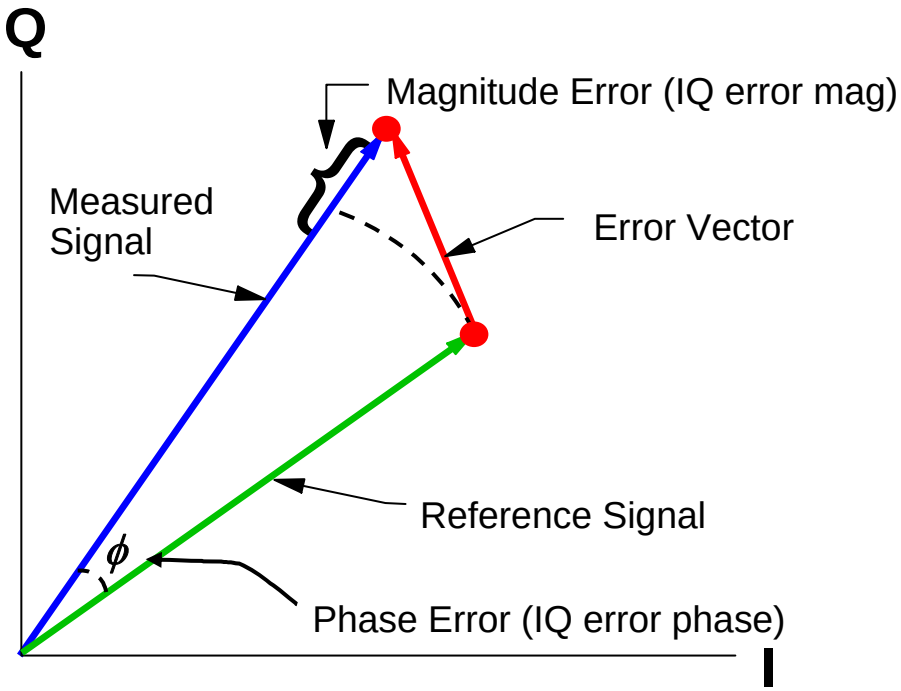
BER Testing Methods

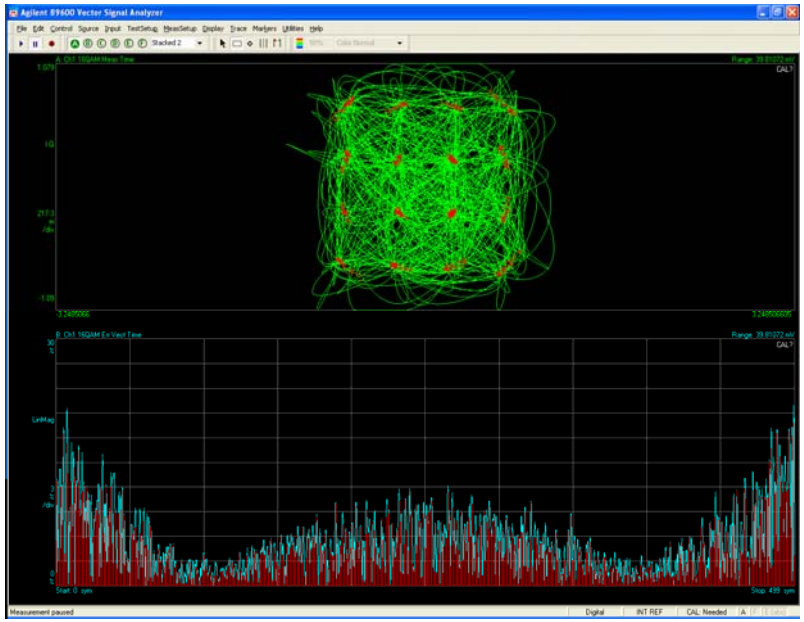
- Loopback Testing



  - 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

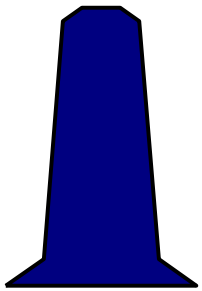
EVM





Error Vector Magnitude

Waveforms

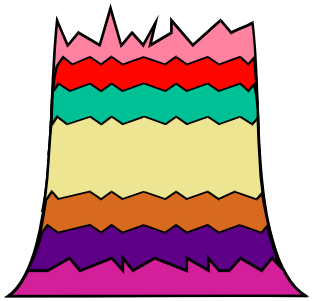


SCM

Development

Flexibility

Troubleshooting

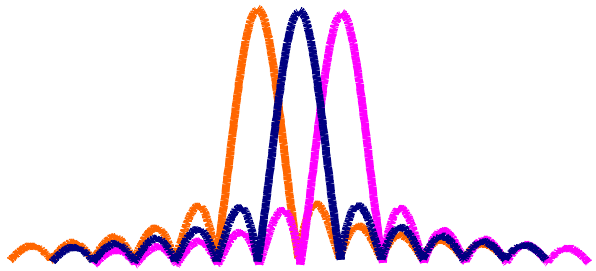


CDMA

Security

Ability to carry multiple users

Transmit more efficiently

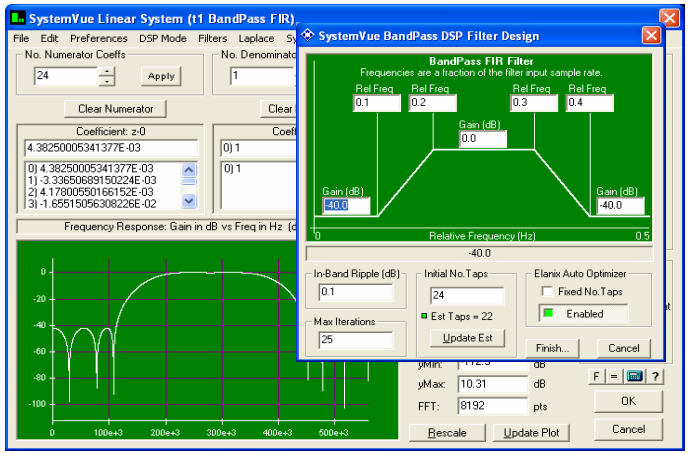


OFDM

Robust in the presence of SCM interferes

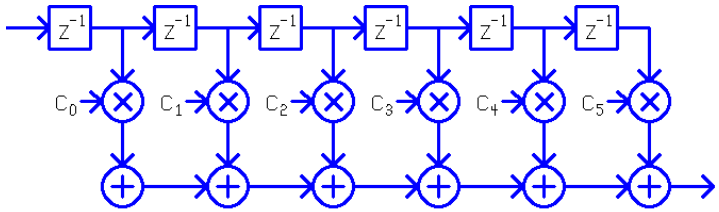
Adapt and handle challenging channels

Digital Impairments



Agilent System Vue Filter Design tool

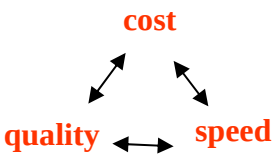
FPGA resources vs signal quality



Filters

Filter ripple, rolloff, filter rejection

- Better filter requires more filter taps
  - More taps means more multiplies
    - Multiplies increase word length
      - Overflows
      - Truncation reduces DR
      - Rounding requires additional operations



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

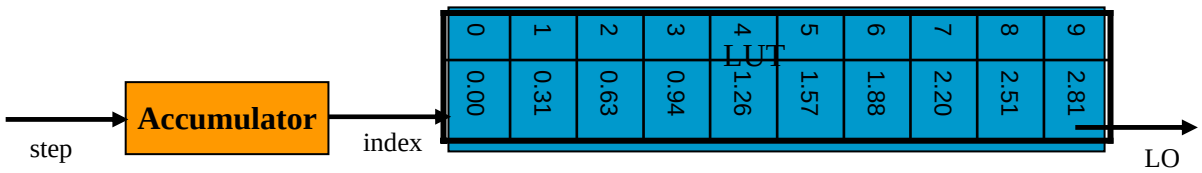
Overflows: distort signals and will reduce BER/EVM

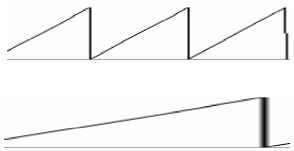
Truncation: reduces DR, reduced S/N effects EVM/BER

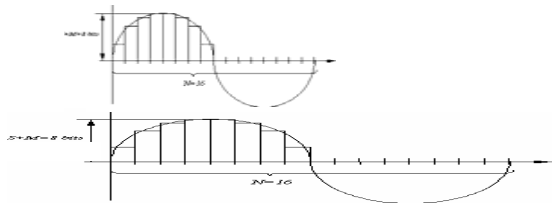
Insufficient rejection or rolloff: cross channel interference reducing BER/EVM in co-channels

Digital Impairments

FPGA resources vs signal quality







NCO – Numerically controlled oscillators

Frequency resolutions

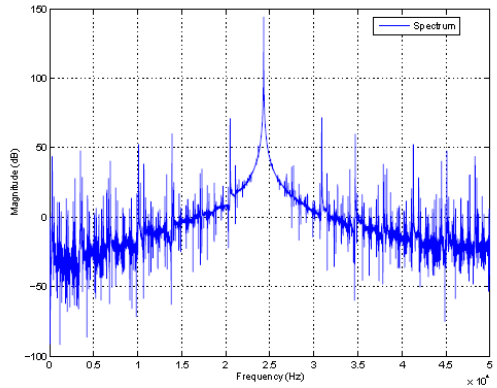
•Improve with larger LUT size

Amplitude Quantization spurs

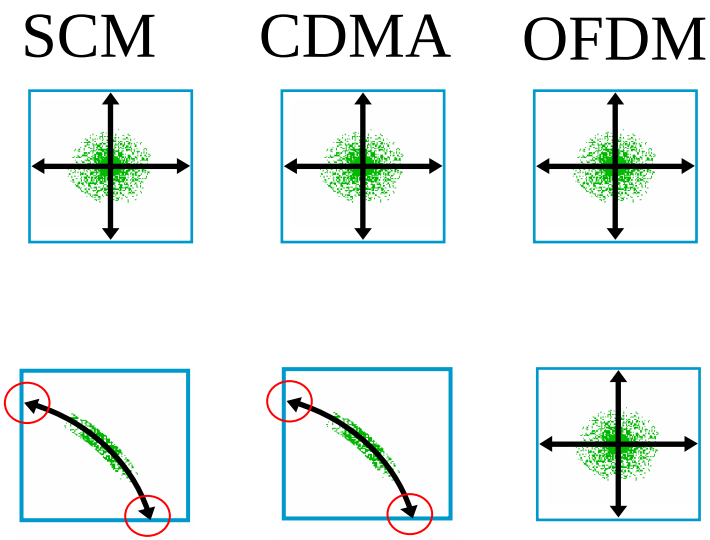
• Improve with greater word length or dithering

Phase truncation (quantization)

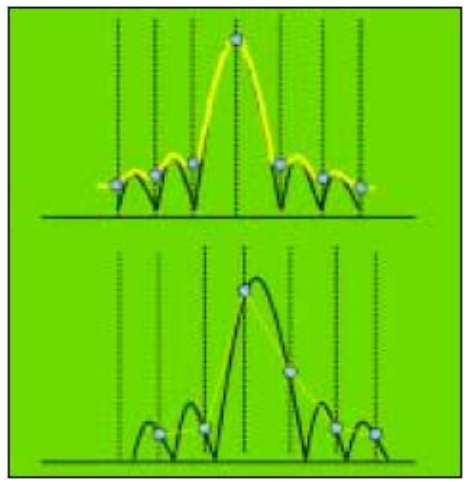
•Improve with enhanced dithering techniques or greater LUT resolution



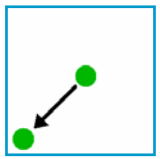
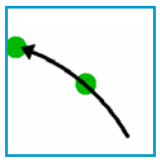
Noise Effects



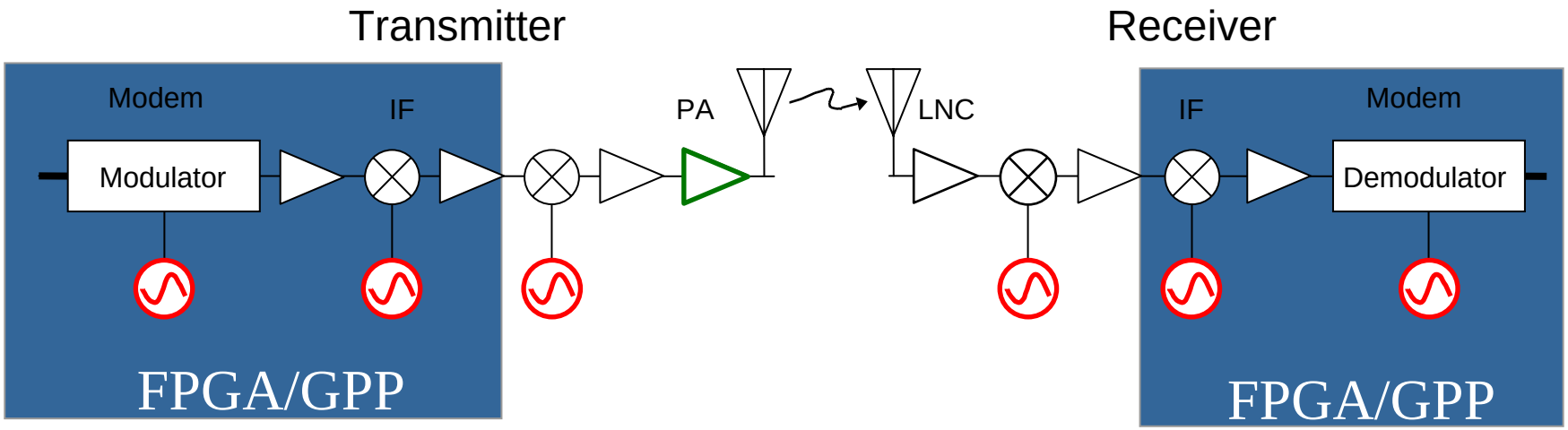
- **Phase Noise in OFDM**
  - Results in each subcarrier interfering with other sub-carriers
  - Modulates each sub-carrier to the point that they no longer look like simple sinusoids within the FFT interval
  - Causes the nulls of the sin(x)/x spectrum to fill in, creating interference between every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



Other Impairments

		Primary	Secondary
Channel Loss		Range	Natural Barriers
Interference		Spurious	Power Supply
AM/AM Distortion		PA	ADC Quantization
AM/PM Distortion		PA	PA Leveling Stability
Delay Distortion/ISI		BB Filters	IF Filters

System Budget Concept

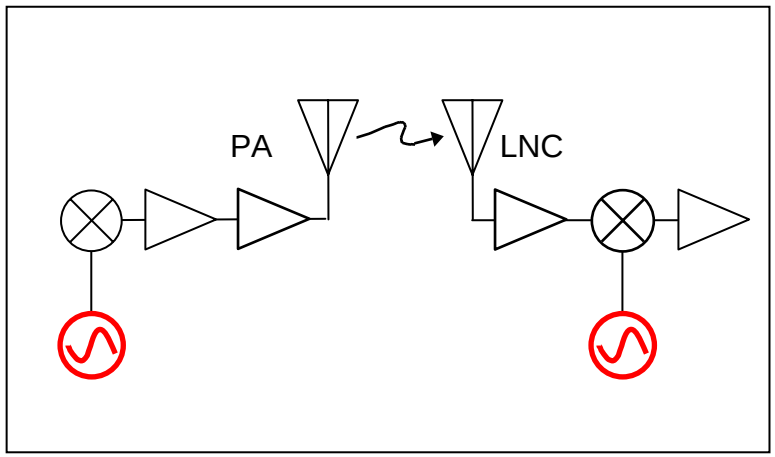


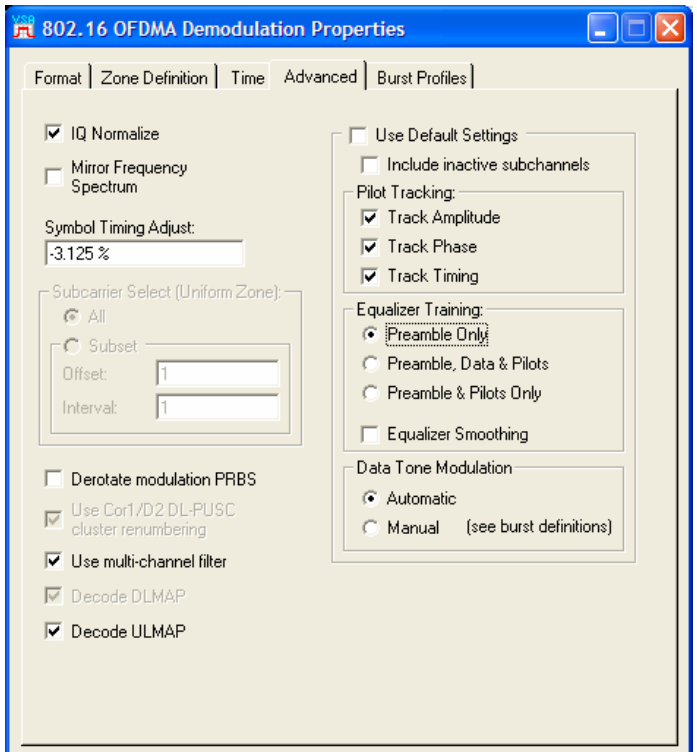
- Allows the engineer to separate the modulator, transmitter, receiver, and demodulator issues
- Helps ensure interoperability between different receivers or transmitters
- Essential for assuring customer premises equipment units will not dribble years after the base station is installed
- Gives the 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

RF Design vs. DSP

Many times you can cut costs by implementing tracking and equalizing

Cost come in development and DSP power

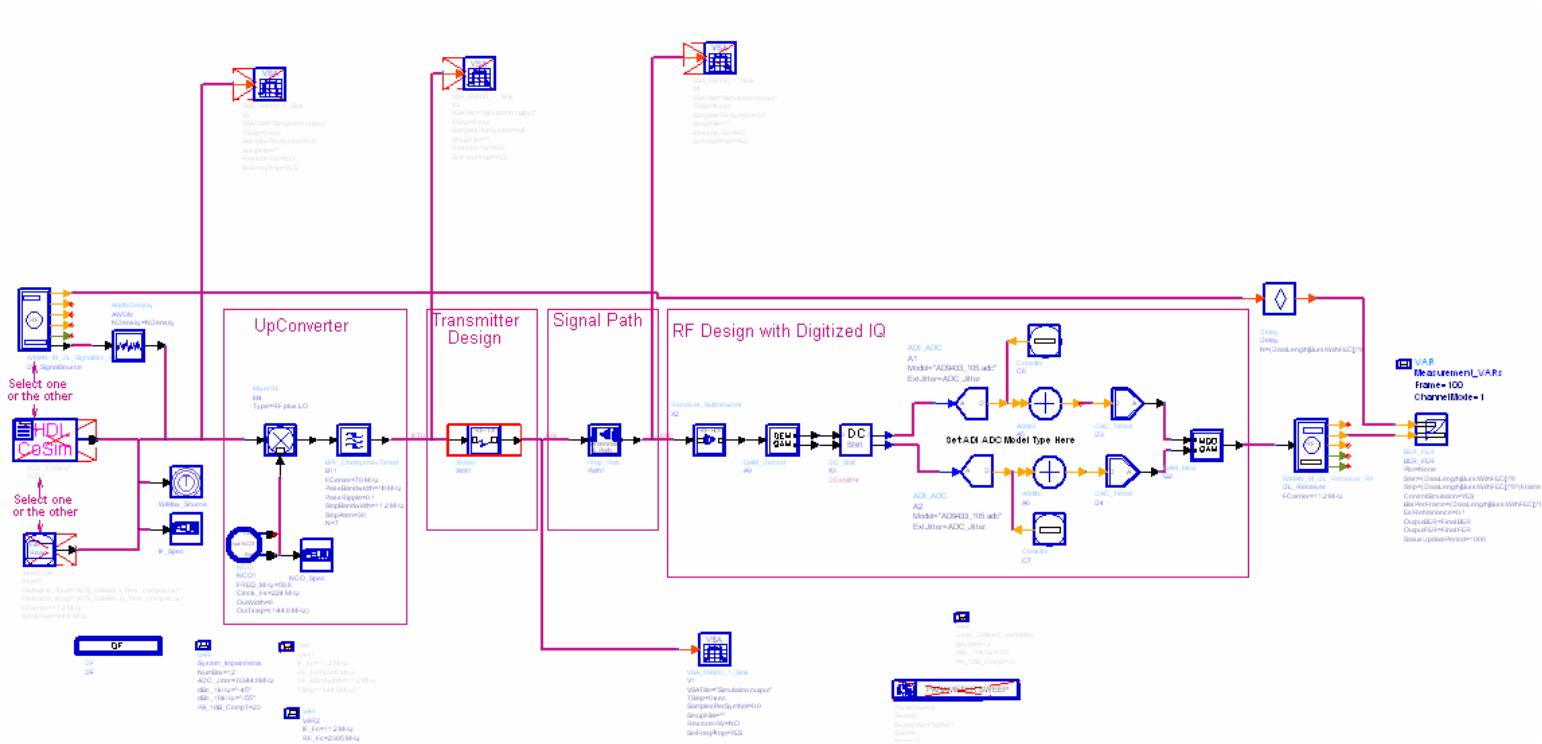




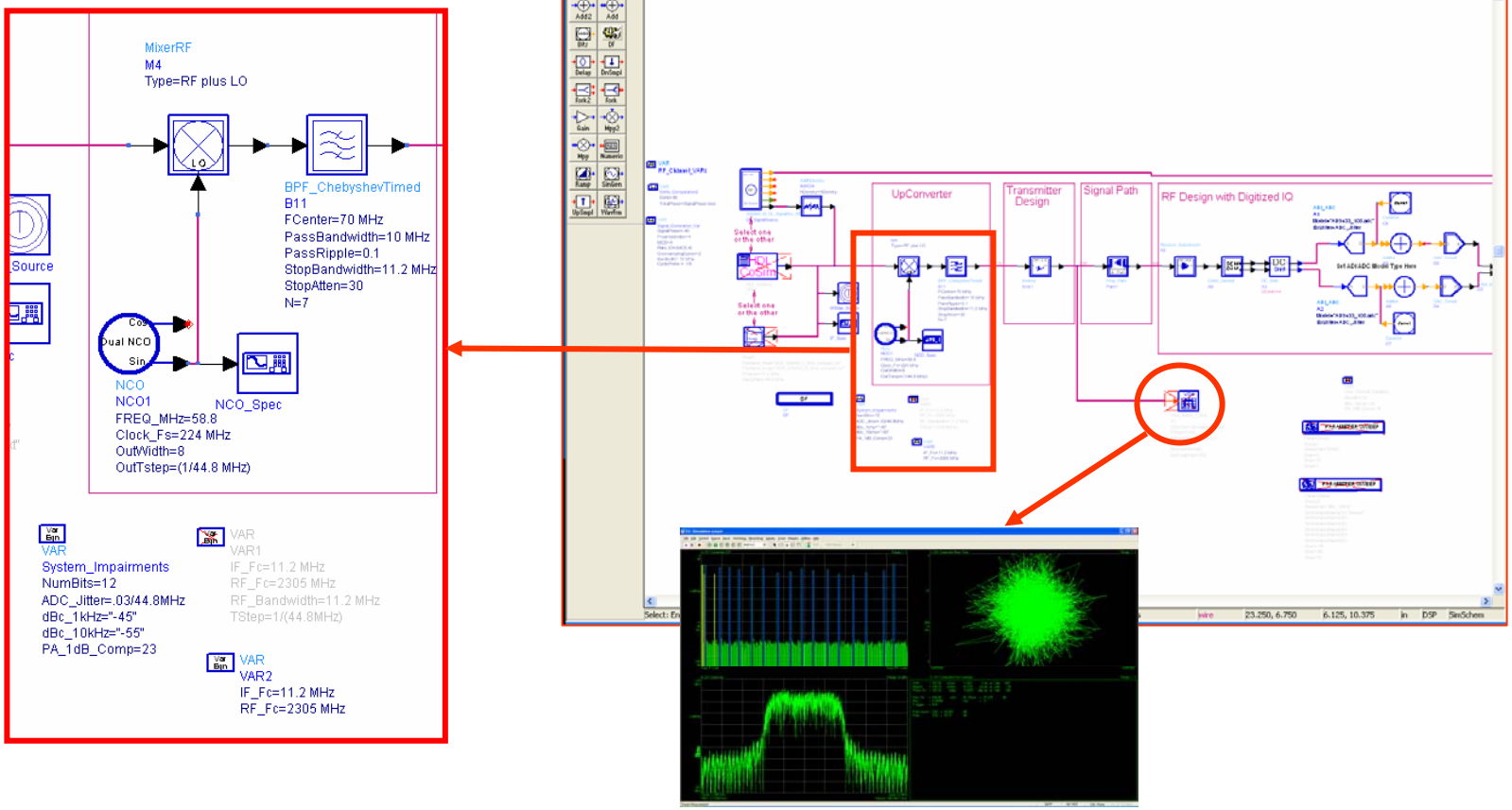
Testing Impairments in SDR

ADS model to input multiple waveforms

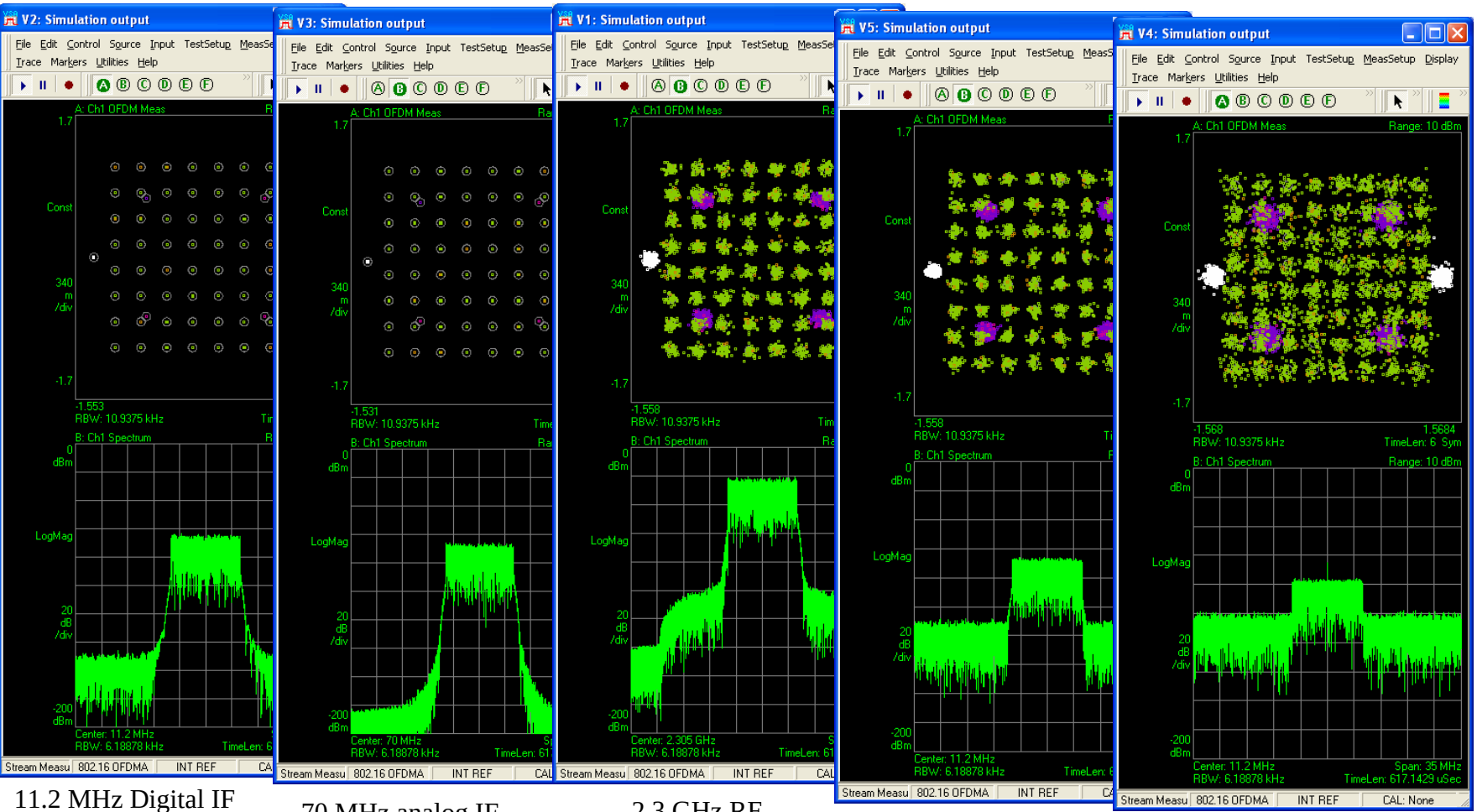
Variable impairments



Impairments – Using ADS



Using EVM to trouble shoot the radio



11.2 MHz Digital IF

70 MHz analog IF

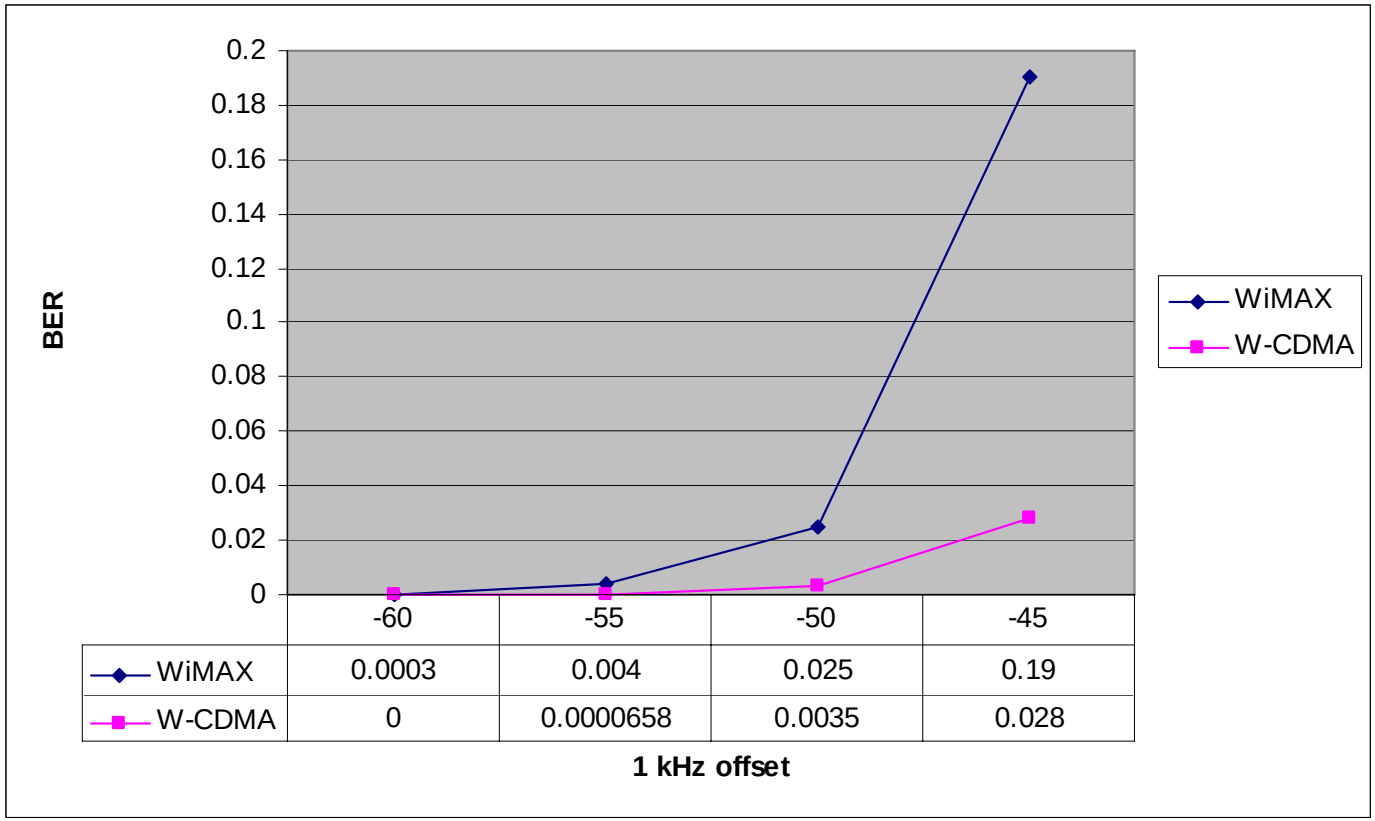
2.3 GHz RF
5.4 EVM

11.2 MHz IF
5.7 EVM

Digital IQ
9.2% EVM

Phase Noise effects on CDMA and WiMAX

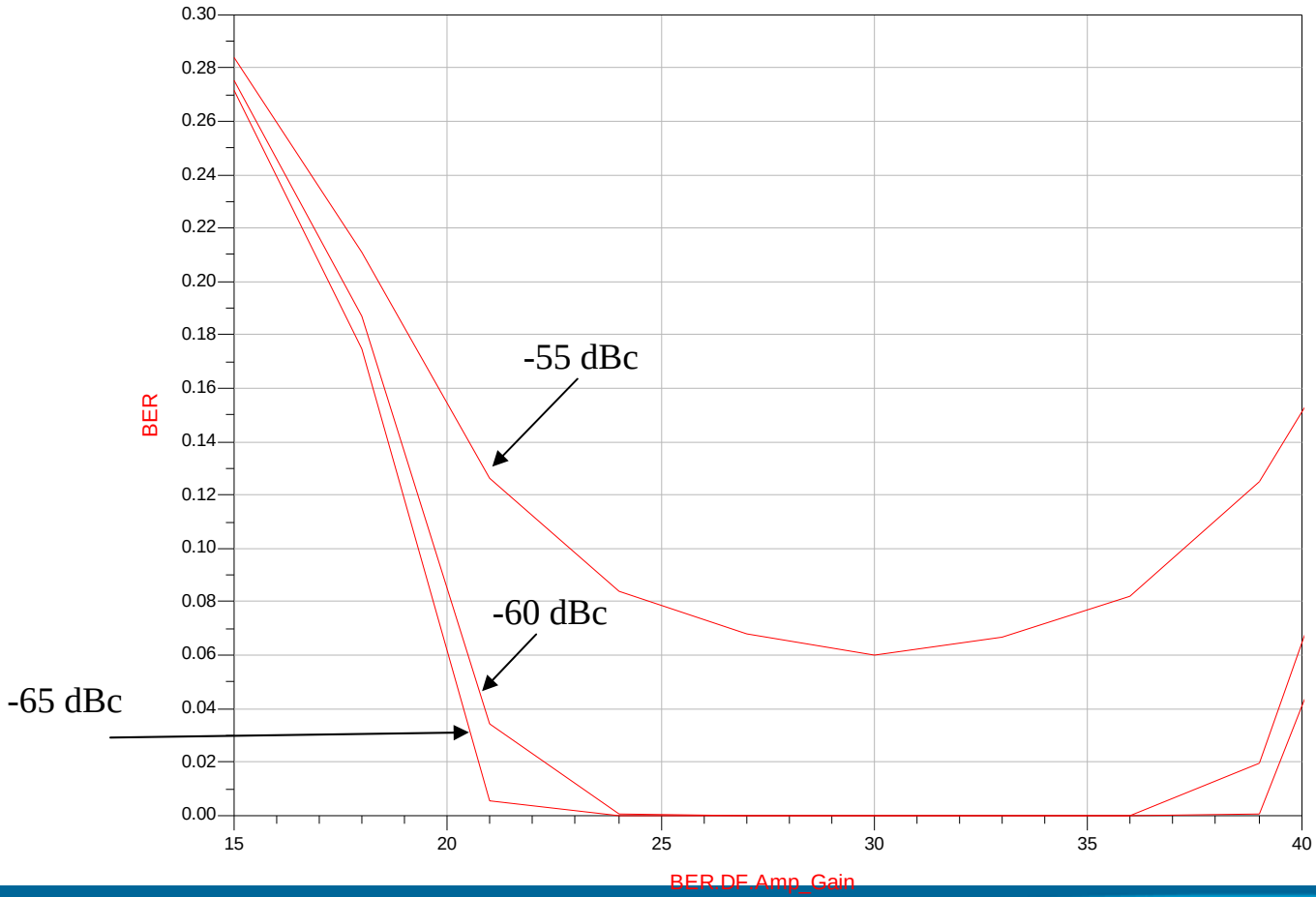
- Example of effects of BER in a SDR

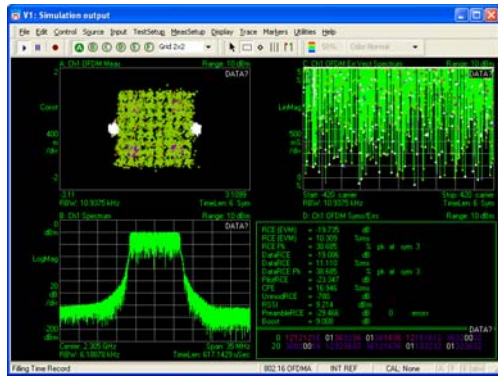


	-60	-55	-50	-45
WiMAX	0.0003	0.004	0.025	0.19
W-CDMA	0	0.0000658	0.0035	0.028

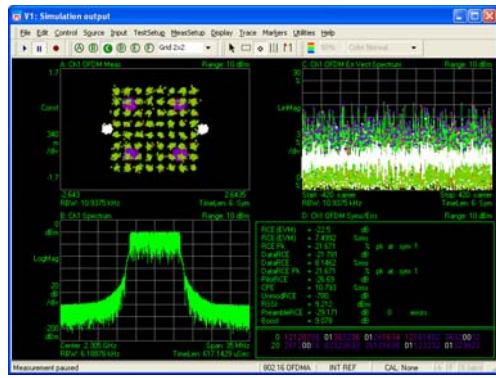
***Waveforms are NOT equal in data throughput**

BER vs 2nd LO PN vs Amp gain for WiMAX





-55 dBc

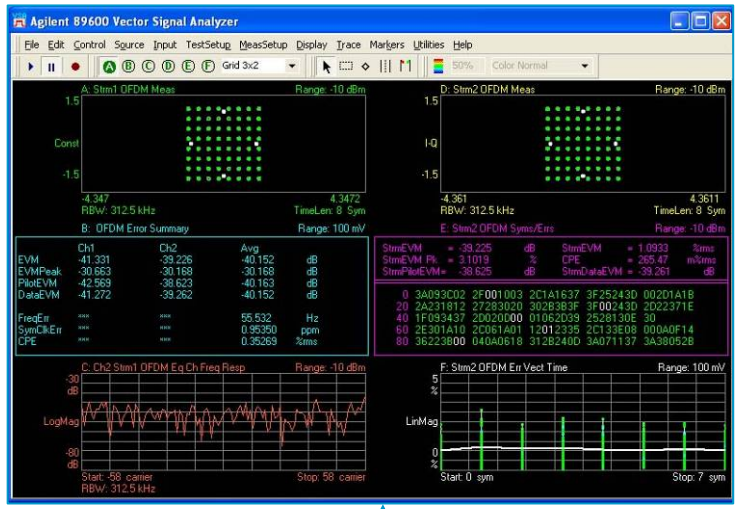


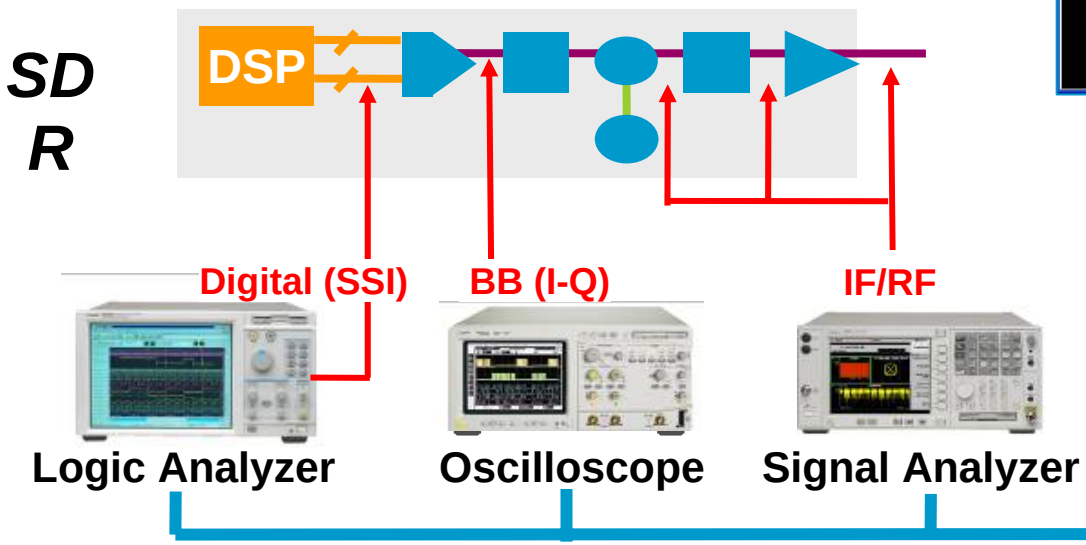
-65 dBc

How to Test Impairments in SDR

89601A

- Digital Impairments
- IQ impairments
- IF/RF impairments

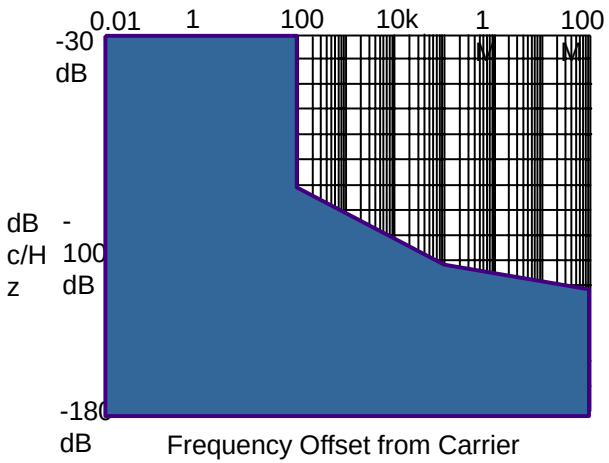




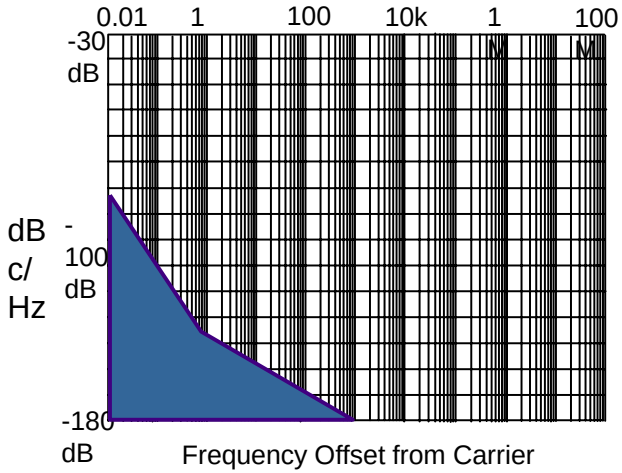
Phase Noise Measurements Techniques

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

Direct Spectrum

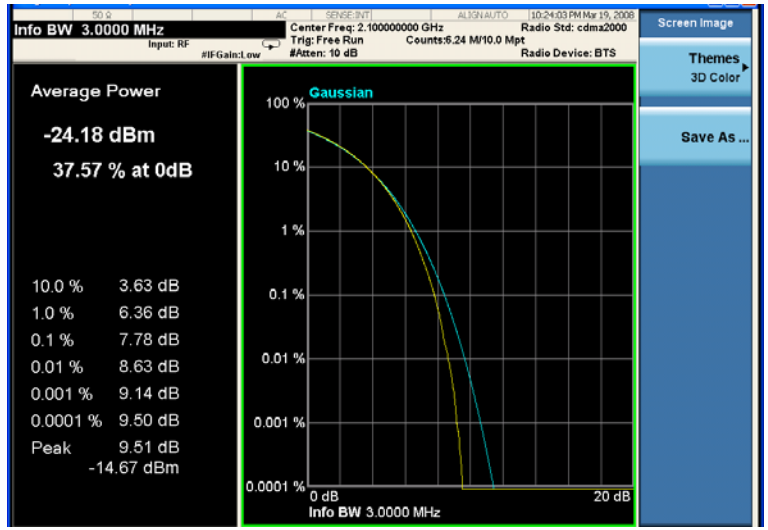


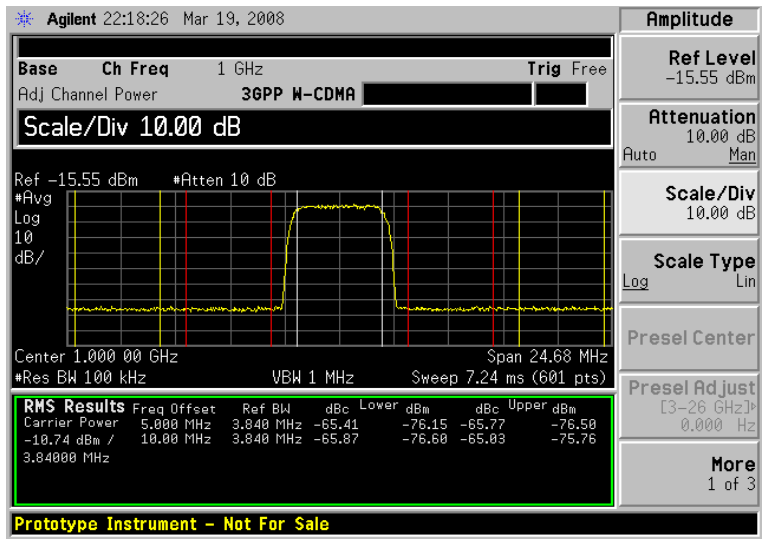
Phase Detector



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