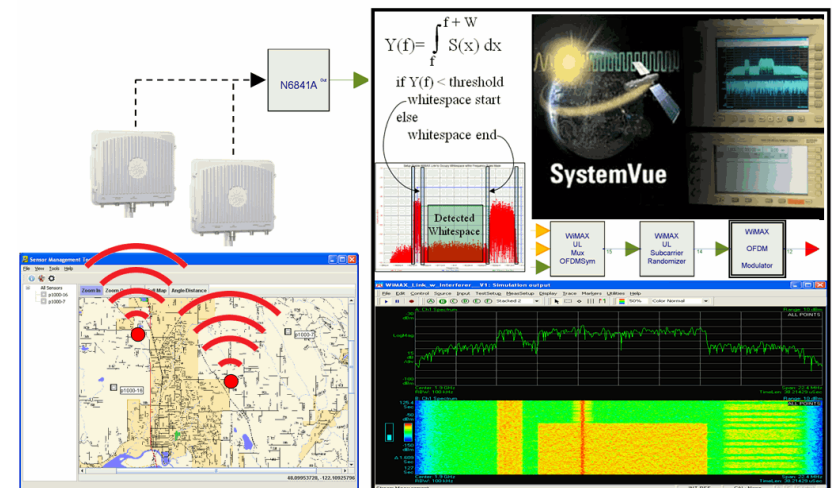


Modeling Cognitive Radio Performance in High Spectral Density Signal Environments

David Leiss,
Steve Sanelli
Agilent
Technologies

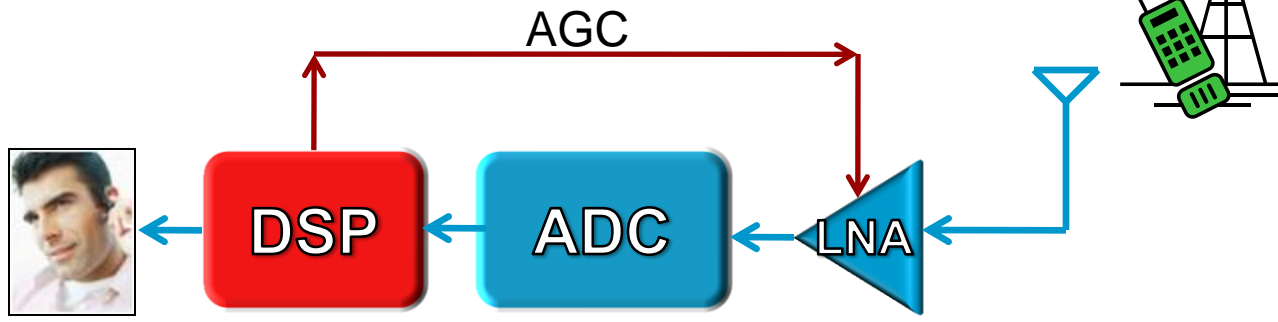
Techniques for Modeling a Direct Conversion Receiver when Multiple Measured and Simulated Signals are Applied.



Agenda

- The “Ideal” Direct Conversion Receiver
- A Basic Example of ADC Undersampling
- ADC Undersampling Equations & Examples
- Spectral Domain Analysis with Multiple Waveforms
- Spectral Domain ADC Undersampling Results
- Cascaded Spectral Analysis
- Wideband Direct Digital Radio – Measured Signals
- Cognitive Radio Simulation
- Cognitive Radio Algorithm Development & Testing

The “Ideal” Direct Conversion Receiver

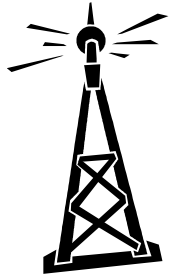


Advantages:

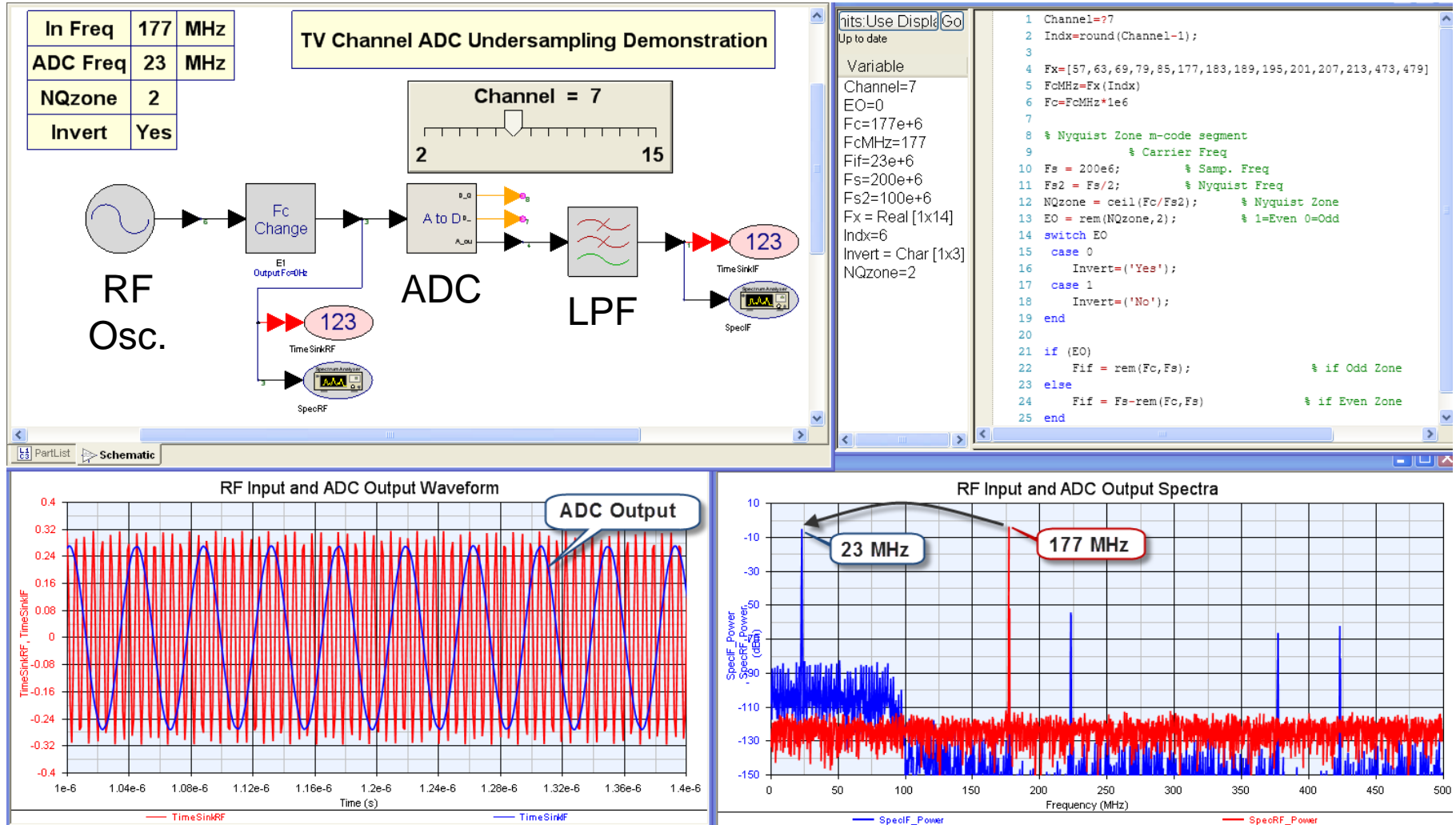
- A Minimal of Parts
- A Minimum of RF Parts
- No Mixers
- No RF/IF Filters
 - Filtering done in DSP
- Wide Bandwidth
 - DC to Daylight! ☺
- The Ultimate in Flexibility

Disadvantages:

- DSP Processing Speed
 - Interference ☹
- It's a noisy a world out there!
- ADC Dynamic Range
 - LNA Dynamic Range



A Basic Example of ADC Undersampling



ADC Undersampling Equations & Examples

% Nyquist Zone m-code segment

```
Fc = 834.78e6;           % Carrier Freq
Fs = 170e6;              % Sample Freq
Fs2 = Fs/2;              % Nyquist Freq
NQzone = ceil(Fc/Fs2);    % Nyquist Zone
EO = rem(NQzone,2);       % 1=Even 0=Odd
```

if (EO)

Fif = rem(Fc,Fs); % if Odd Zone

else

Fif = Fs-rem(Fc,Fs) % if Even Zone

end

Fc = 834.78 MHz and Fs = 170 MHz

NQzone = 10 Nyquist Zone

EO = 0 Spectral Inversion

Fif = 15.22 MHz Aliased Frequency

GSM Signal

Fc = 1934 MHz and Fs = 170 MHz

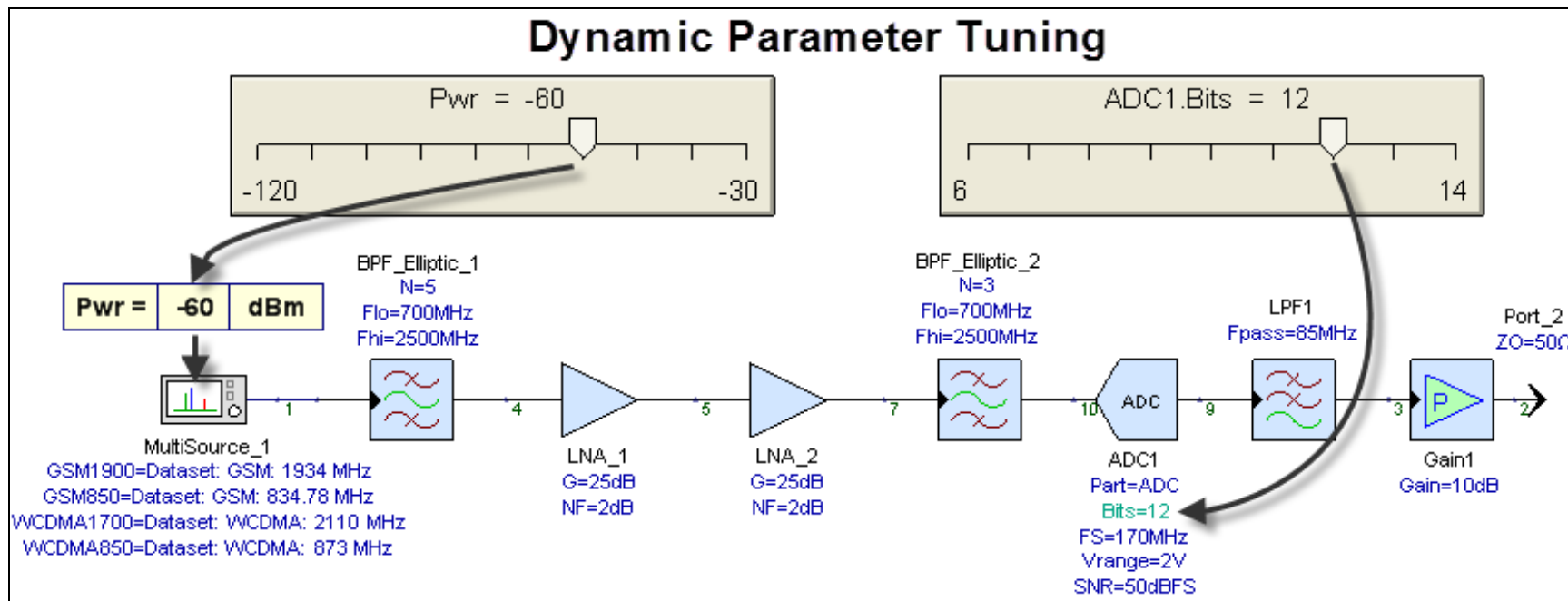
NQzone = 23 Nyquist Zone

EO = 1 No Spec. Inversion

Fif = 64 MHz Aliased Frequency

WCDMA Signal

Spectral Domain Analysis with Multiple Waveforms



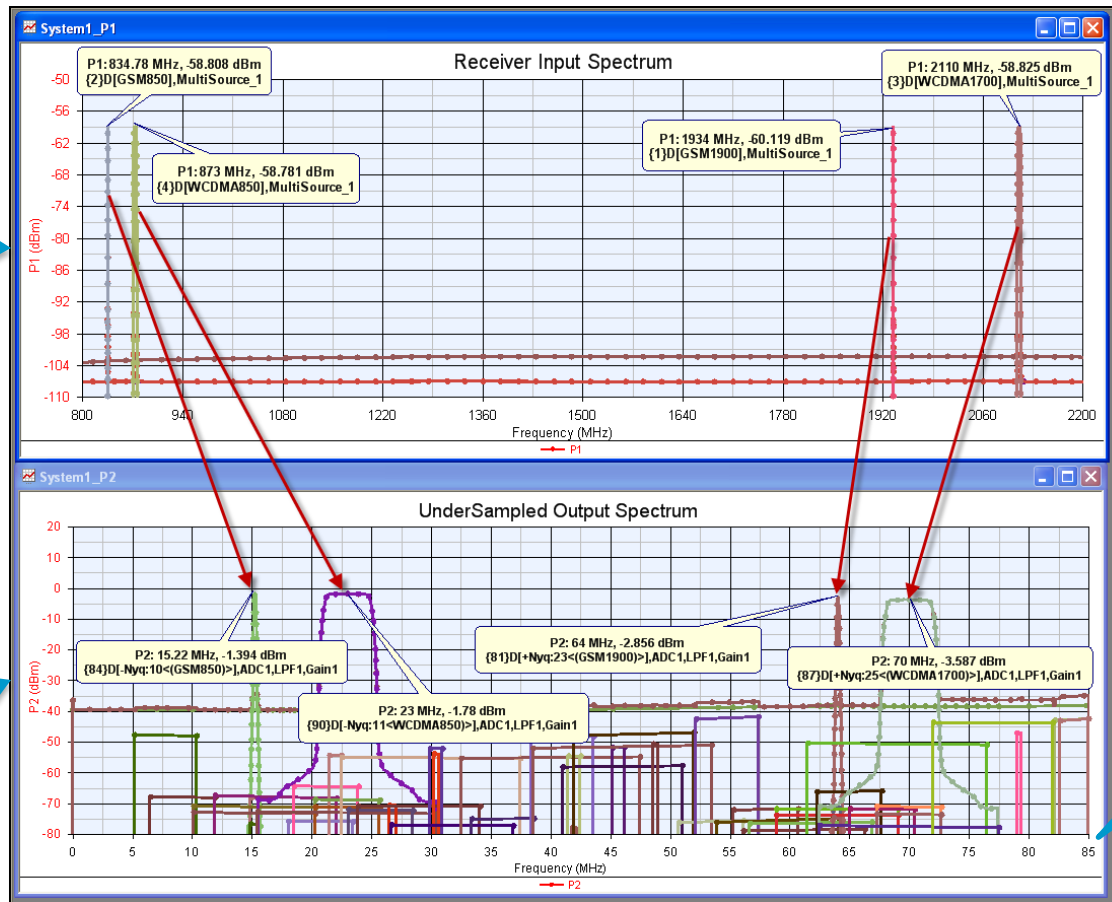
Applied Waveforms:

GSM - 1934 MHz
GSM - 834.78 MHz

WCDMA - 873 MHz
WCDMA - 2110 MHz

Spectral Domain ADC Undersampling Results

Signals at the ADC Input map into the first Nyquist Zone (DC – 85 MHz)



Input RF
Spectral
Domain
Waveforms

ADC Output
Aliased
Spectral
Domain
Waveforms

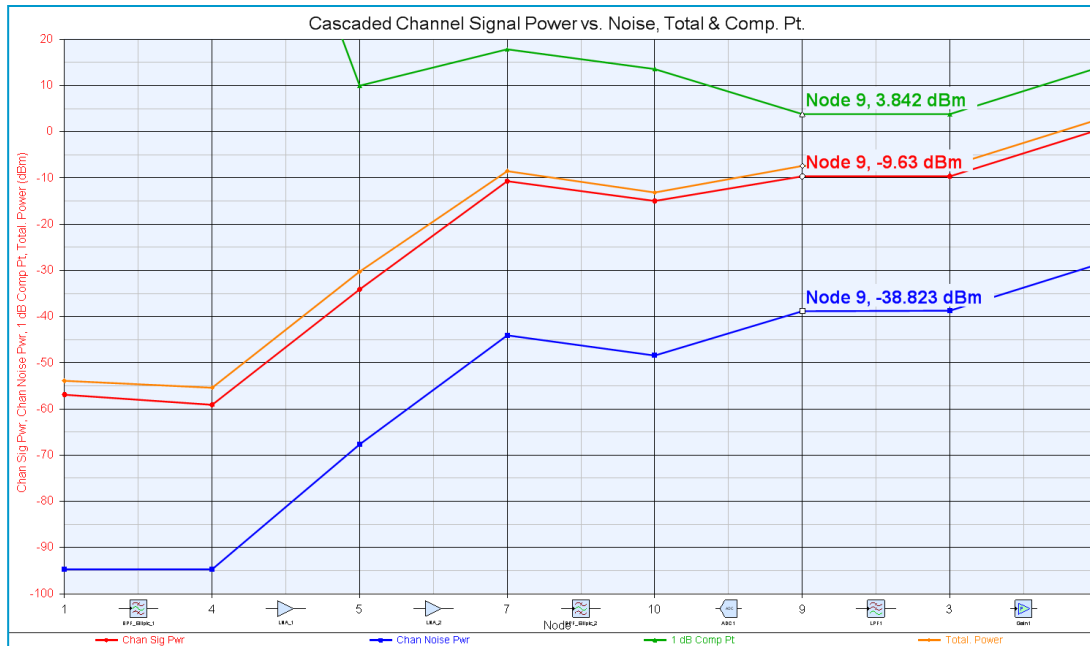
The ADC
Sampling
Frequency
is 170 MHz
in these
examples

ADC $F_s/2$
(85 MHz)

Cascaded Spectral Analysis

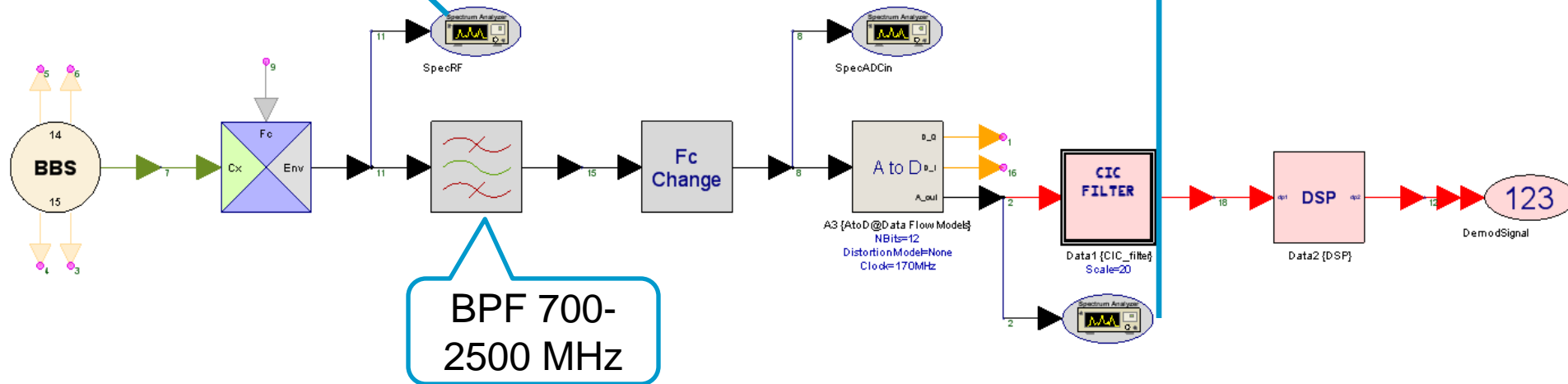
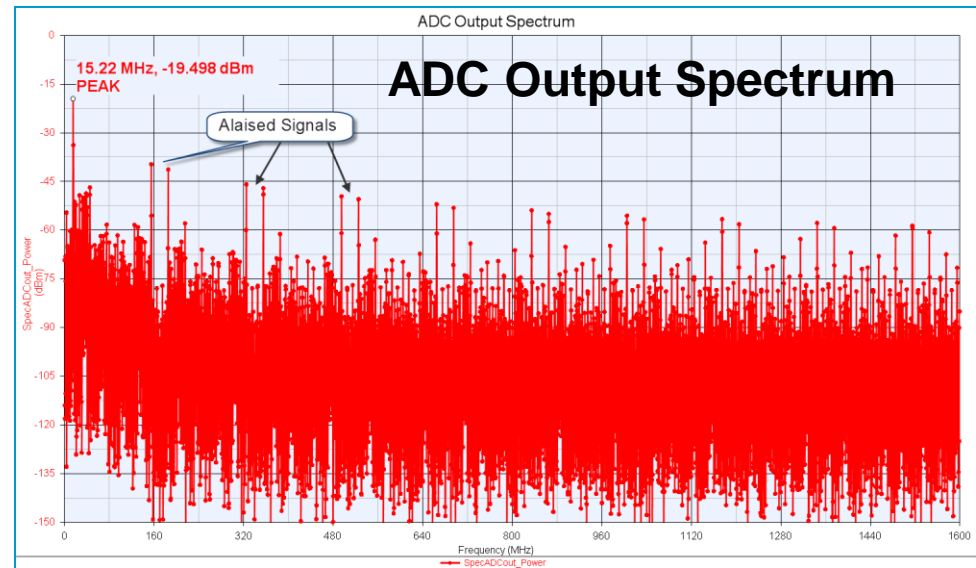
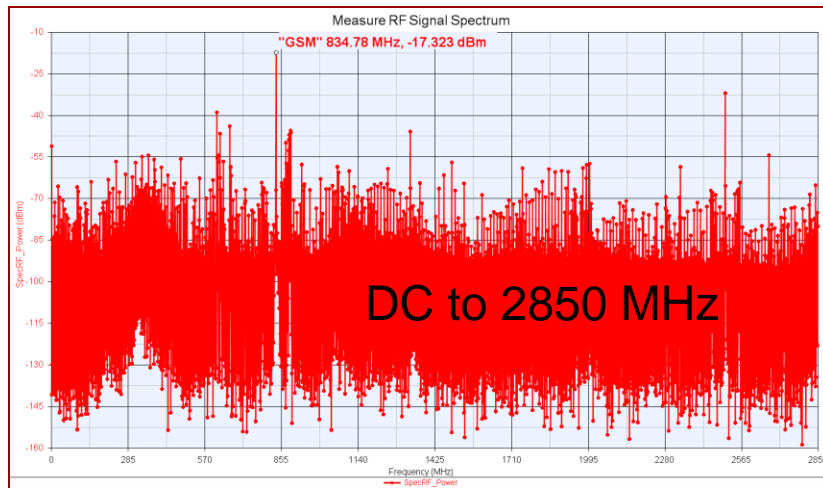
Part Name	Freq (MHz)	Stage DR (dB)	Tot Pwr (dBm)	Channel Pwr (dBm)	Casc. NF (dB)	Added Noise (dB)
MultiSource_1	834.78	153.89	-53.89	-56.909	0	0
BPF_Elliptic_1	834.78	155.39	-55.39	-59.09	2.181	2.181
LNA_1	834.78	40.242	-30.242	-34.094	4.238	2.058
LNA_2	834.78	26.5	-8.5	-10.674	4.42	0.182
BPF_Elliptic_2	834.78	113.129	-13.129	-14.96	4.329	-0.091
ADC1	15.22	11.352	-7.373	-9.63	8.603	4.274
LPF1	15.22	107.375	-7.375	-9.631	8.715	0.112
Gain1	15.22	97.375	2.625	0.369	8.715	12.53e-6

ADC Limits Dynamic Range

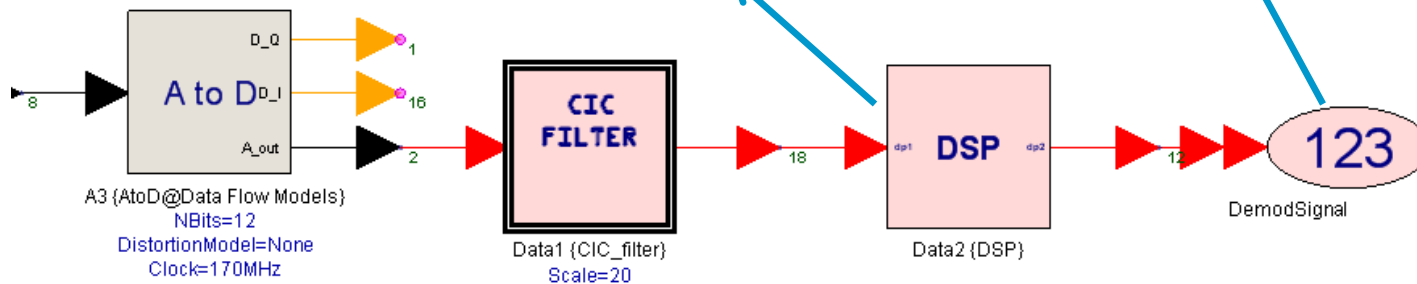
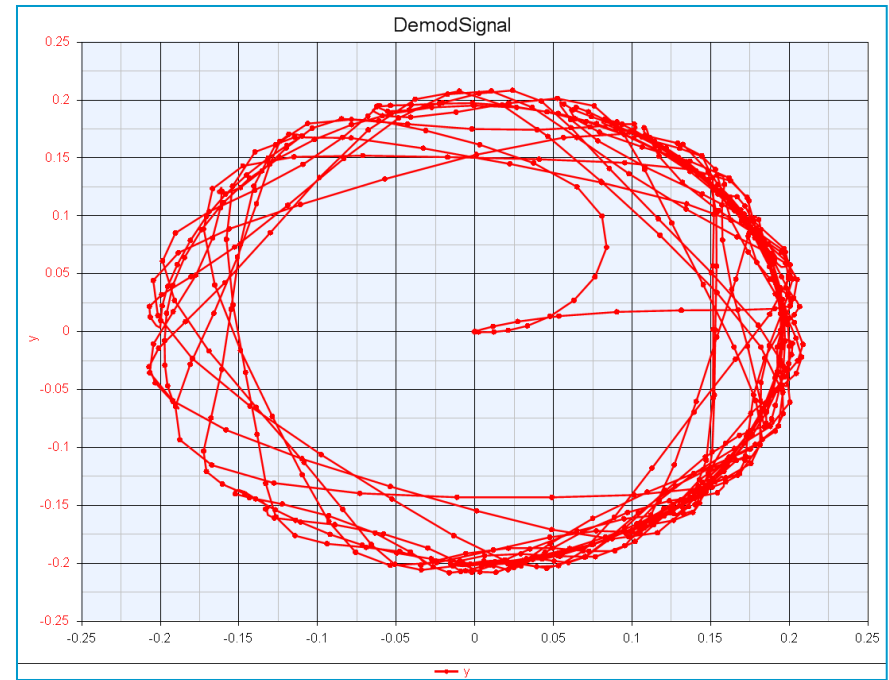
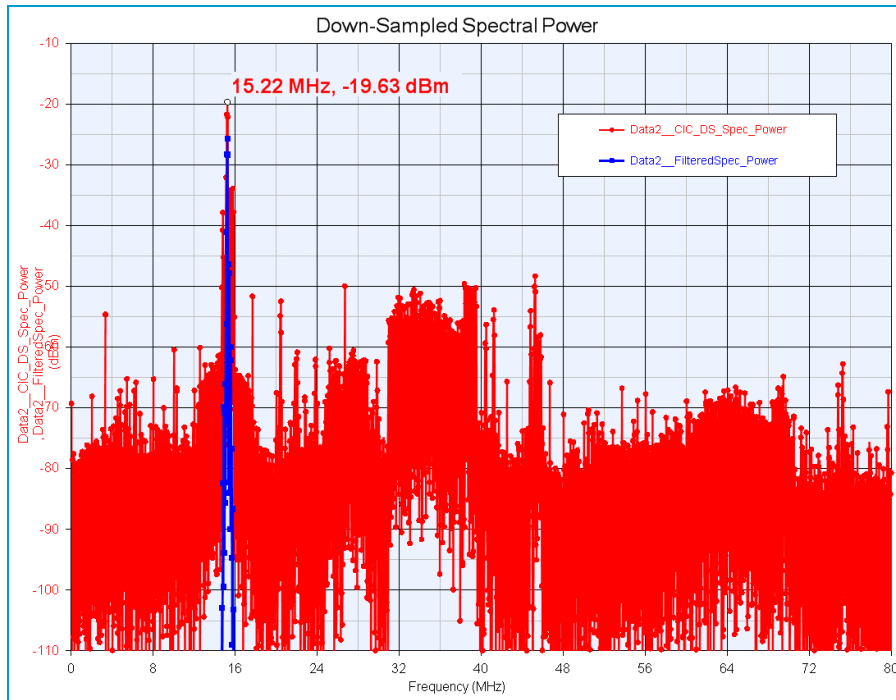


Wideband Direct Digital Radio – Measured Signals

Measured Wideband Spectrum

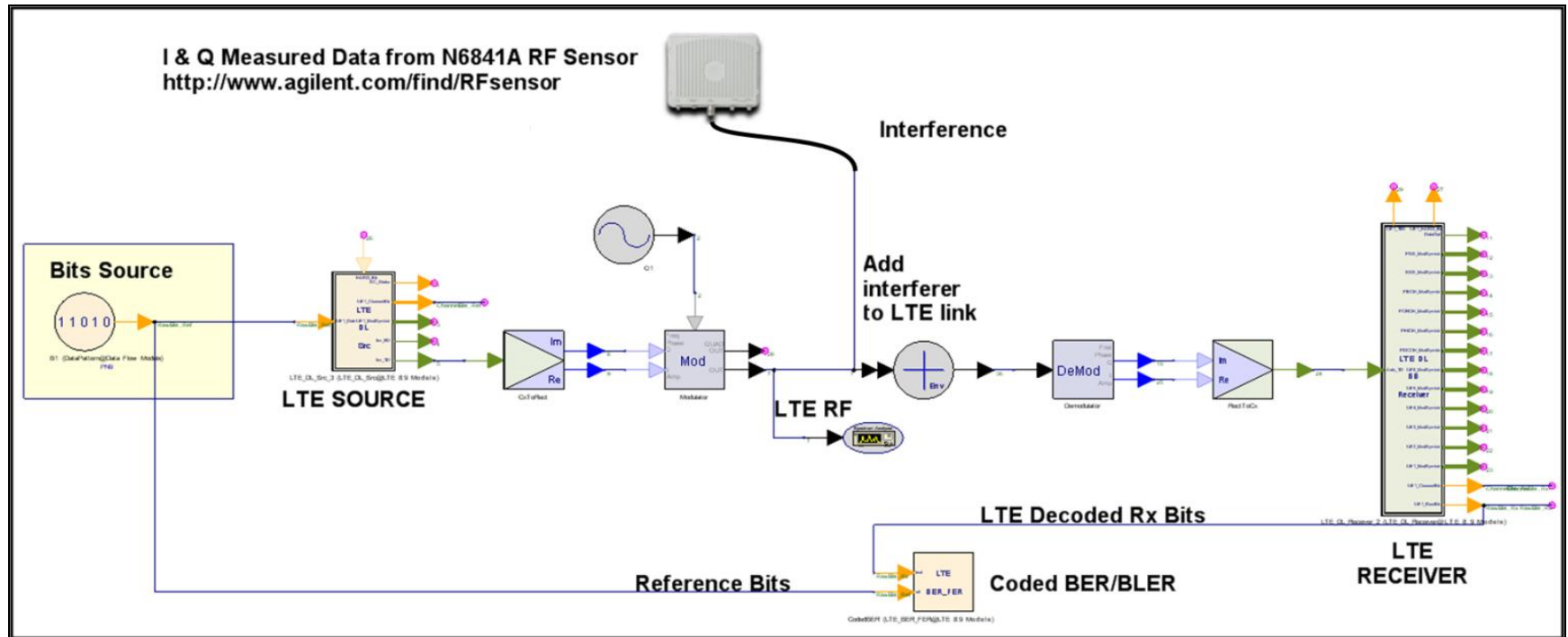


Wideband Direct Digital Radio – Processed Signals



Note: No attempt was made to decode the GSM signal for this exercise

Cognitive Radio Simulation

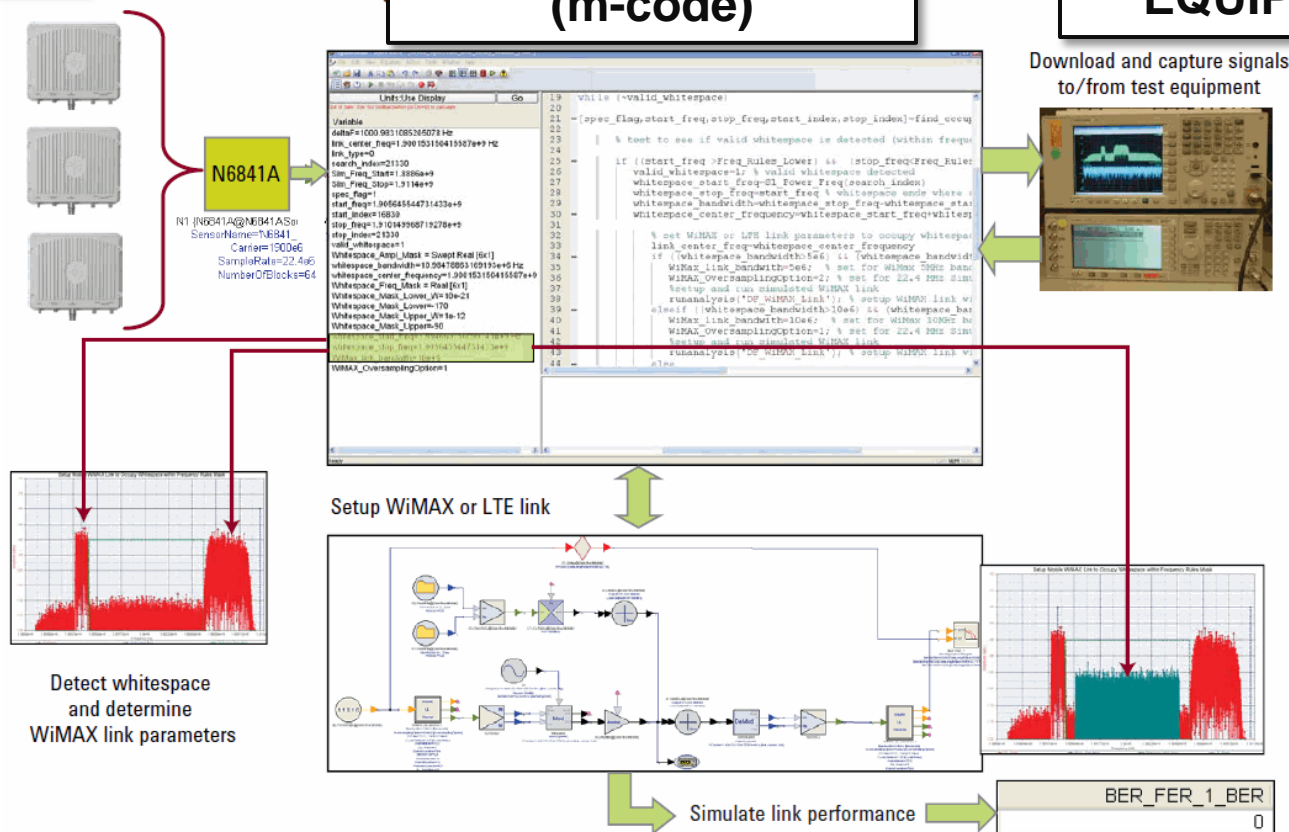


Cognitive Radio Algorithm Development & Testing

**REMOTE
RF SENSOR
PODS**

**ALGORITHM
ENVIRONMENT
(m-code)**

**LOCAL
STIMULUS /
RESPONSE LAB
EQUIPMENT**



Summary

- Provided a basic review of a direct conversion ADC under-sampled receiver.
- Showed techniques for rapidly evaluating receiver performance in the spectral domain. Identified the limiting component in the receiver.
- Evaluated a wideband direct conversion receiver. performance with applied measured signals covering DC to nearly 3 GHz.
- Evaluated Cognitive Radio and algorithm performance with a combination of environmental signal measurements, test equipment and simulation.

References and Additional Resources

Product Web sites:

SystemVue <http://www.agilent.com/find/systemvue>

RF sensors <http://www.agilent.com/find/rfsensor>

Whitepapers and application notes:

Cognitive Radio Algorithm Development and Testing:
<http://www.agilent.com/find/eesof-cognitive-whitepaper>

Software Defined Radio Measurement Solutions:
<http://cp.literature.agilent.com/litweb/pdf/5990-4146EN.pdf>

Solutions for Addressing SDR Design and Measurement Challenges
<http://www.agilent.com/find/sdr>
<http://www.agilent.com/find/powerofx>

Videos:

Web video of CR Testbed discussed in this paper:
<http://www.agilent.com/find/eesof-cognitive-whitepaper>

Thank You!