



ADCs for Software Radios

Presented by:

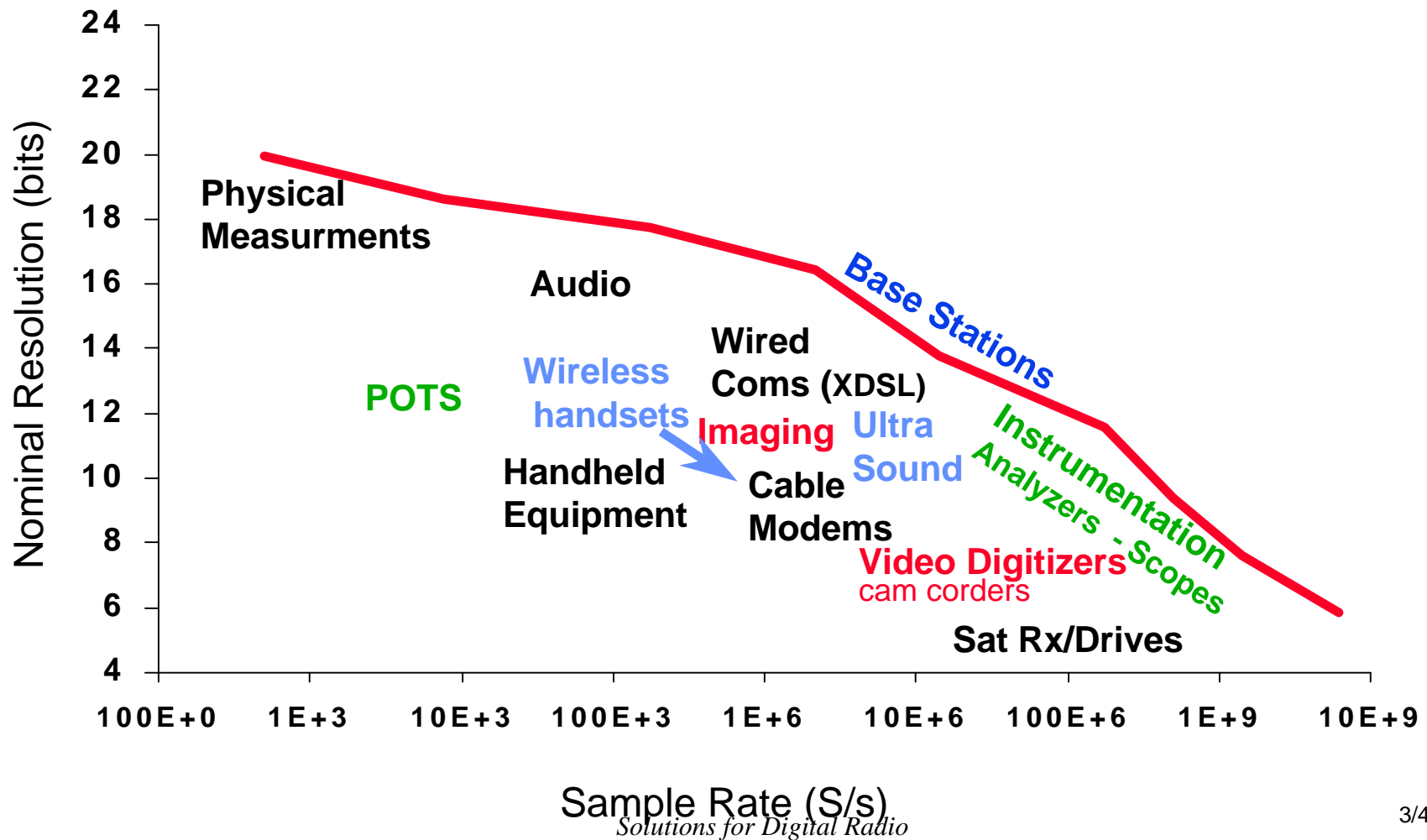
Tom Gratzek

Analog Devices Inc.

Greensboro, NC

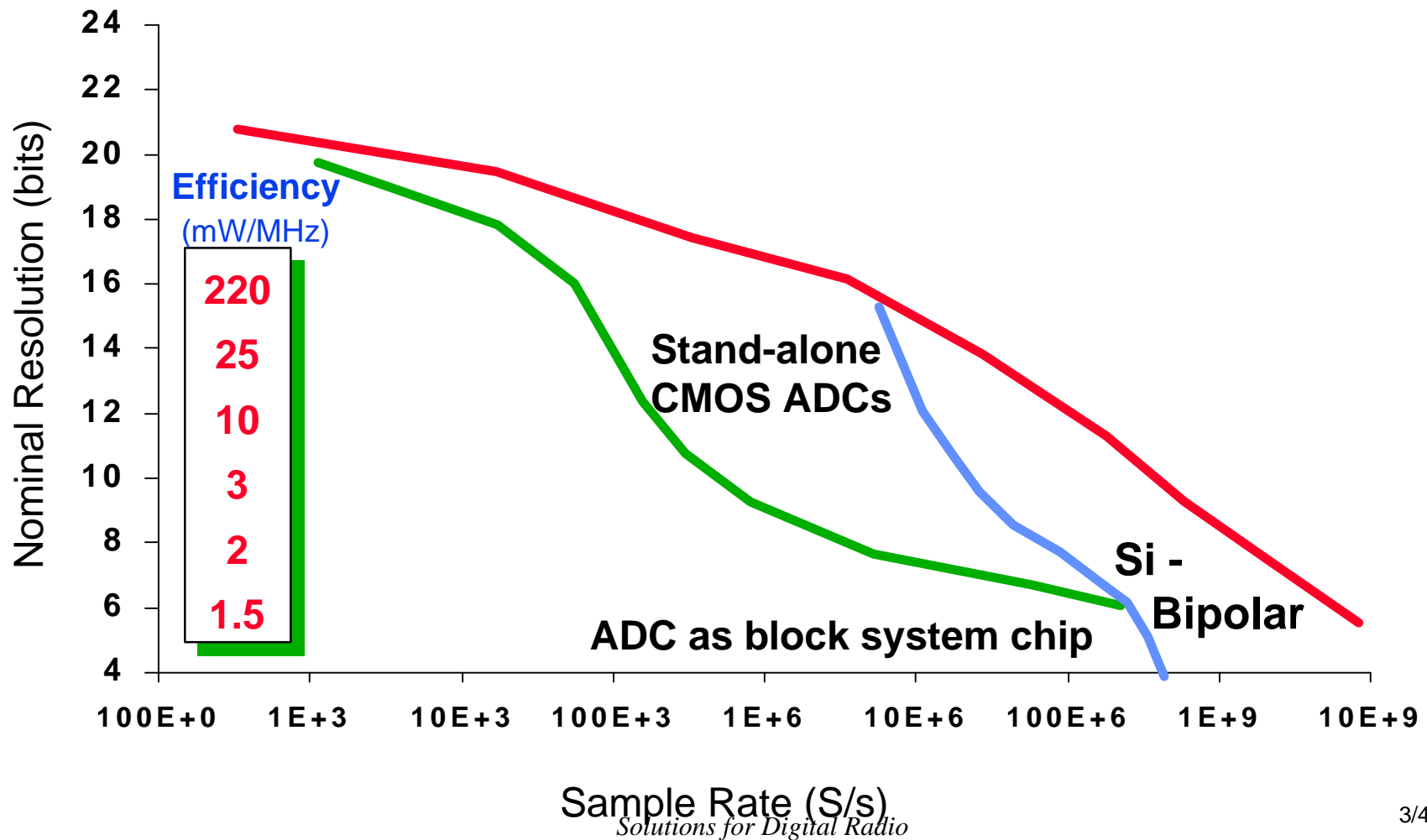
336-605-4233/tom.gratzek@analog.com

Commercial Application Drivers



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Fabrication Processes



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ADC Technology Trends



- Applications drive technology development
- At volume, ADC function moves to SOC block
 - disk drives, pro audio, ADSL, cable modems, NB radios, scanners, digital cameras
- Technology Development Trends (12 bit 20MSPS)

<u>Year</u>	<u>P. Diss.</u>	<u>Tech.</u>	<u>Dyn. Perf.</u>	<u>Cost</u>	<u>Application</u>
84	20 W	Board	60 dB	\$4K	Radar
88	5 W	Hybrid	62 dB	\$1K	Missiles
92	2 W	bipolar	63 dB	\$200	Instruments
96	0.4W	CMOS	65 dB	\$20	Medical
98	0.2W	core	65 dB	\$2	Image. ASIC

ADC: Not all created equal



- Critical specifications for radio applications
- Dynamic range - correlates with # of bits?
 - SNR, Harmonic distortion, SFDR
 - may only roughly correlate with nominal # of bits
 - Aperture jitter - limits at high input frequency
- Sample rate - must obey Nyquist criteria
 - IF sampling performance
 - must understand channel bandwidth vs. IF

What Kind of Software Radio?



- Software radio - adaptive bandwidth & modulation?
 - Narrowband PCS
 - 25, 12.5, 6.25 KHz BW by same radio
 - Must provide service for 1 month on single A Cell
 - Tune at RF, Sigma Delta ADC, extremely low power
 - Programmable base station (Macro)
 - Multiple channels in licensed band (15 MHz)
 - Various types of signals in band (IS-136, CDMA, GSM)
 - Tune and filter in digital domain
 - ADC linearity often limits receiver performance

ADC Errors effect Receivers



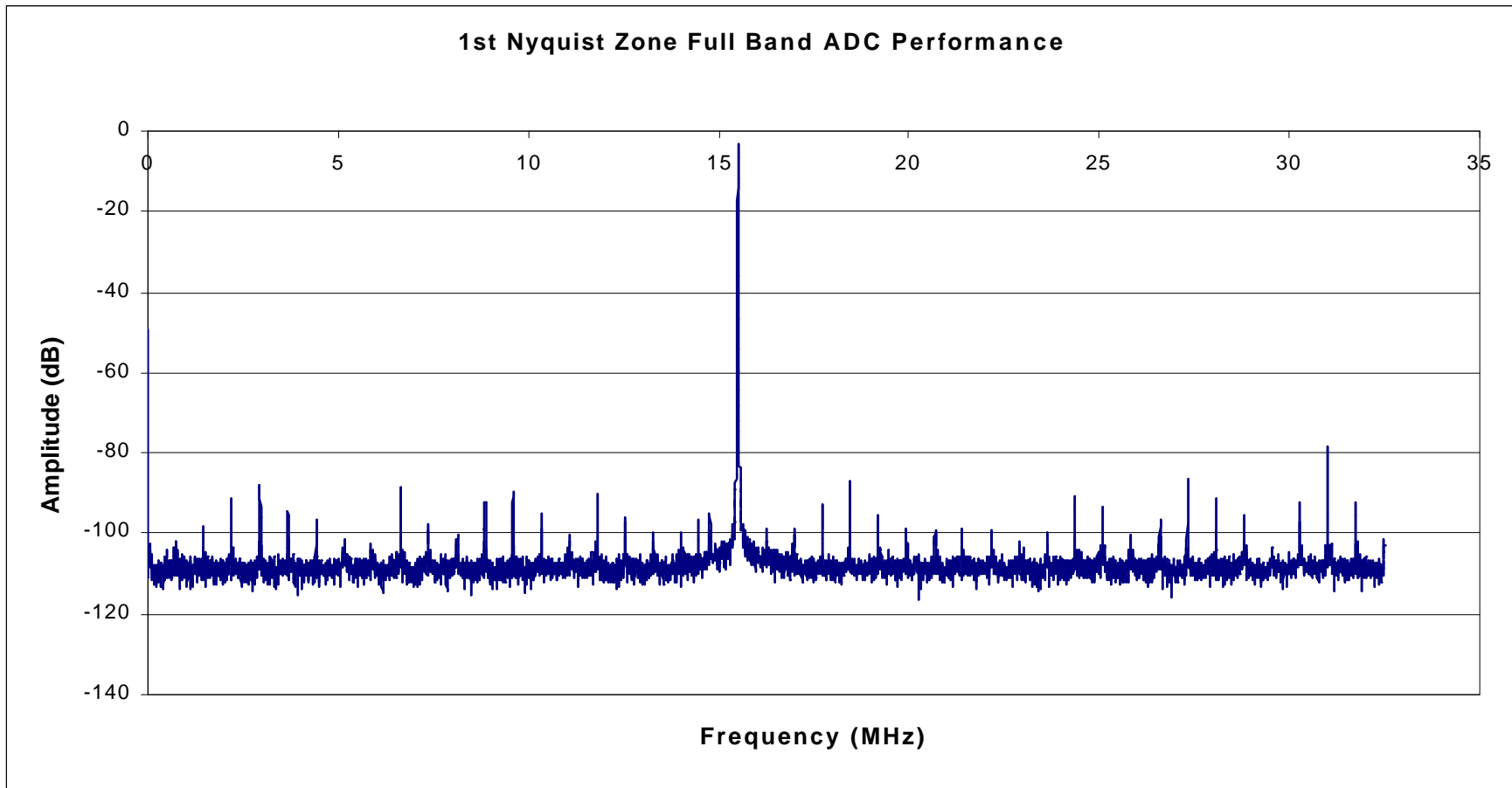
- **Static Errors**
 - non linearity in encoder transfer function
 - can create harmonics in frequency domain
- **Dynamic Errors**
 - sampling jitter - increases noise at high A_{in}
 - T/H linearity - increase in noise & harmonics
- **Noise**
 - sampling, component, thermal

ADC *error avoidance* Techniques



- **Oversampling** -
 - decreases noise in band of interest (*improves SNR*)
 - facilitates digital filtering/ “processing gain”
- **Dither** -
 - smooths the encoder transfer function reducing spurs (requires excellent T/H at high A_{in})
- **IF sampling** -
 - can move harmonics out of analysis bandwidth
 - can filter amp harmonics with IF filters & reduce analog component count

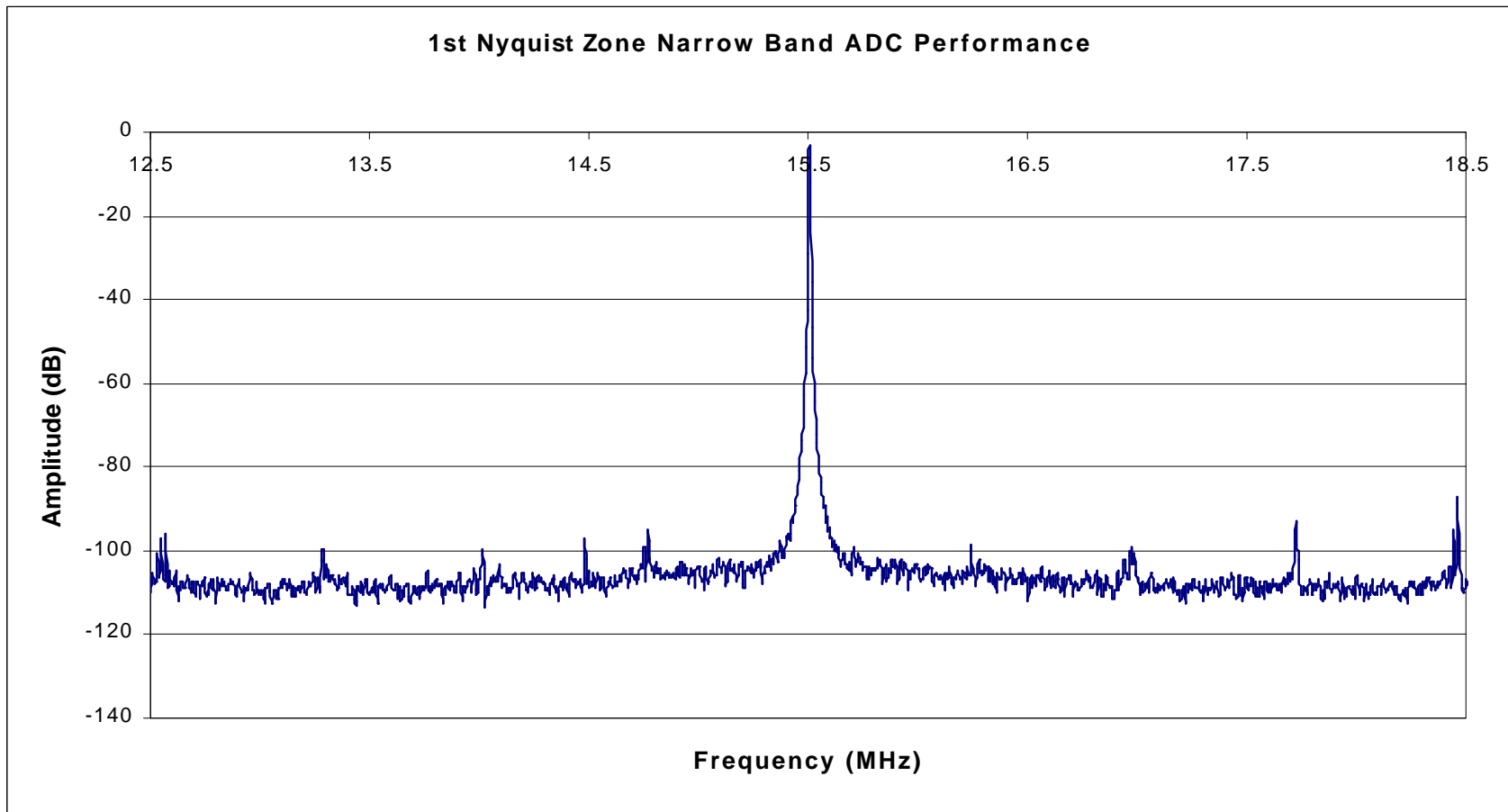
AD6640: -80 dBfs Spurs



Sampling rate = 65MSPS; dc to 32.5MHz; A_{in} = 15.5 MHz

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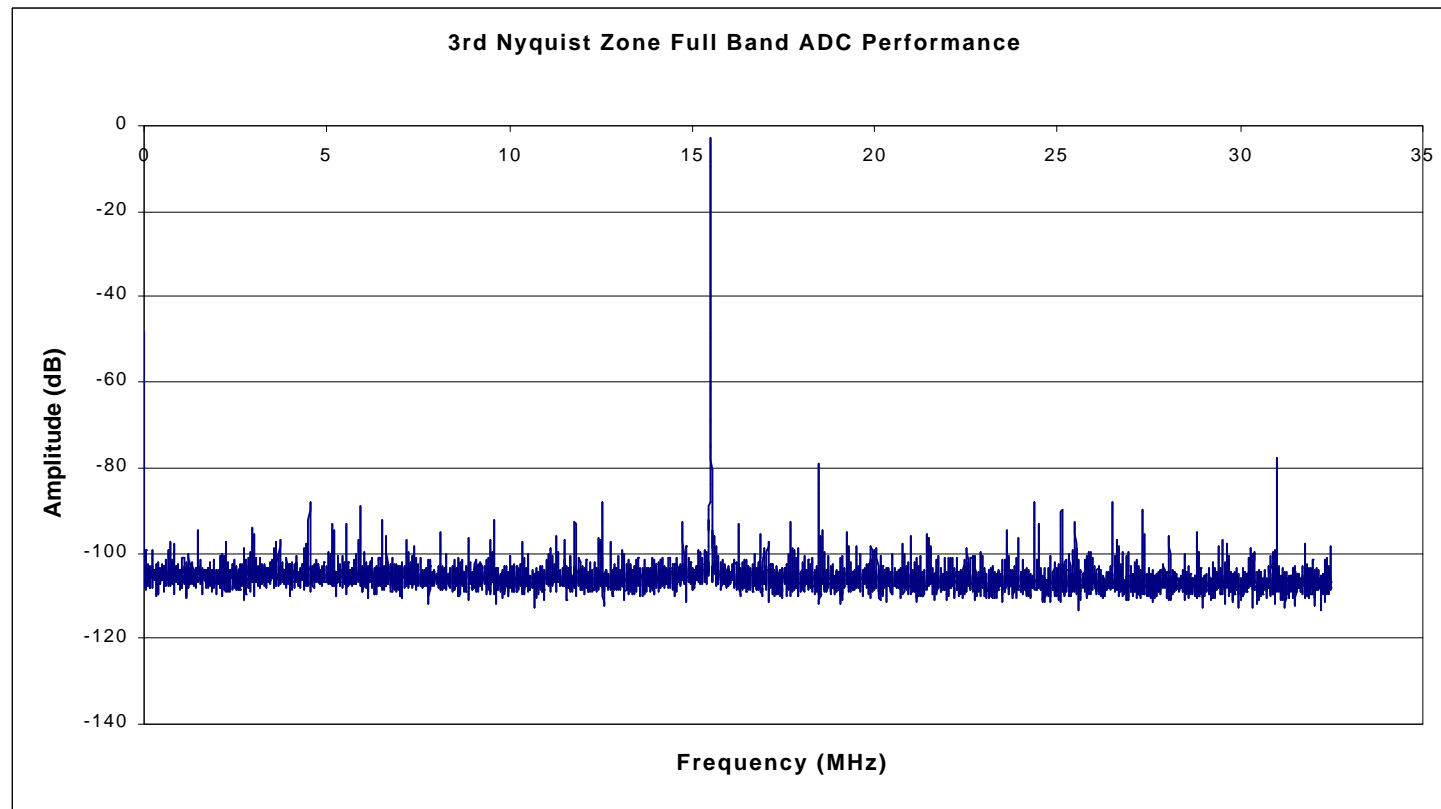
AD6640-1st Nyquist Performance



Sampling rate = 65MSPS; 12.5 to 18.5MHz; A_{in} = 15.5 MHz

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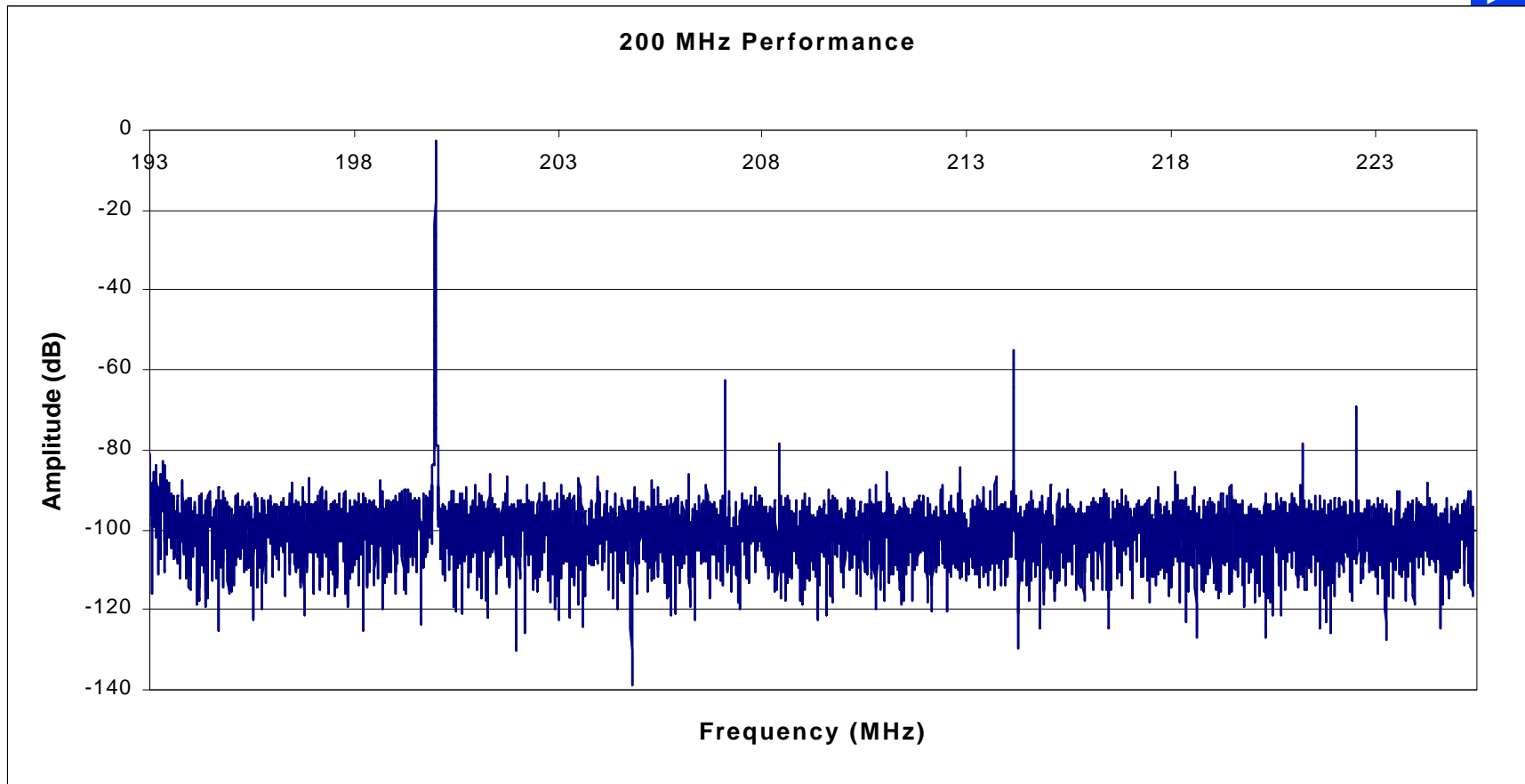
AD6640 3rd Nyquist Zone



Sampling rate = 65MSPS; 65 to 97.5 MHz; A_{in} = 80.5 MHz

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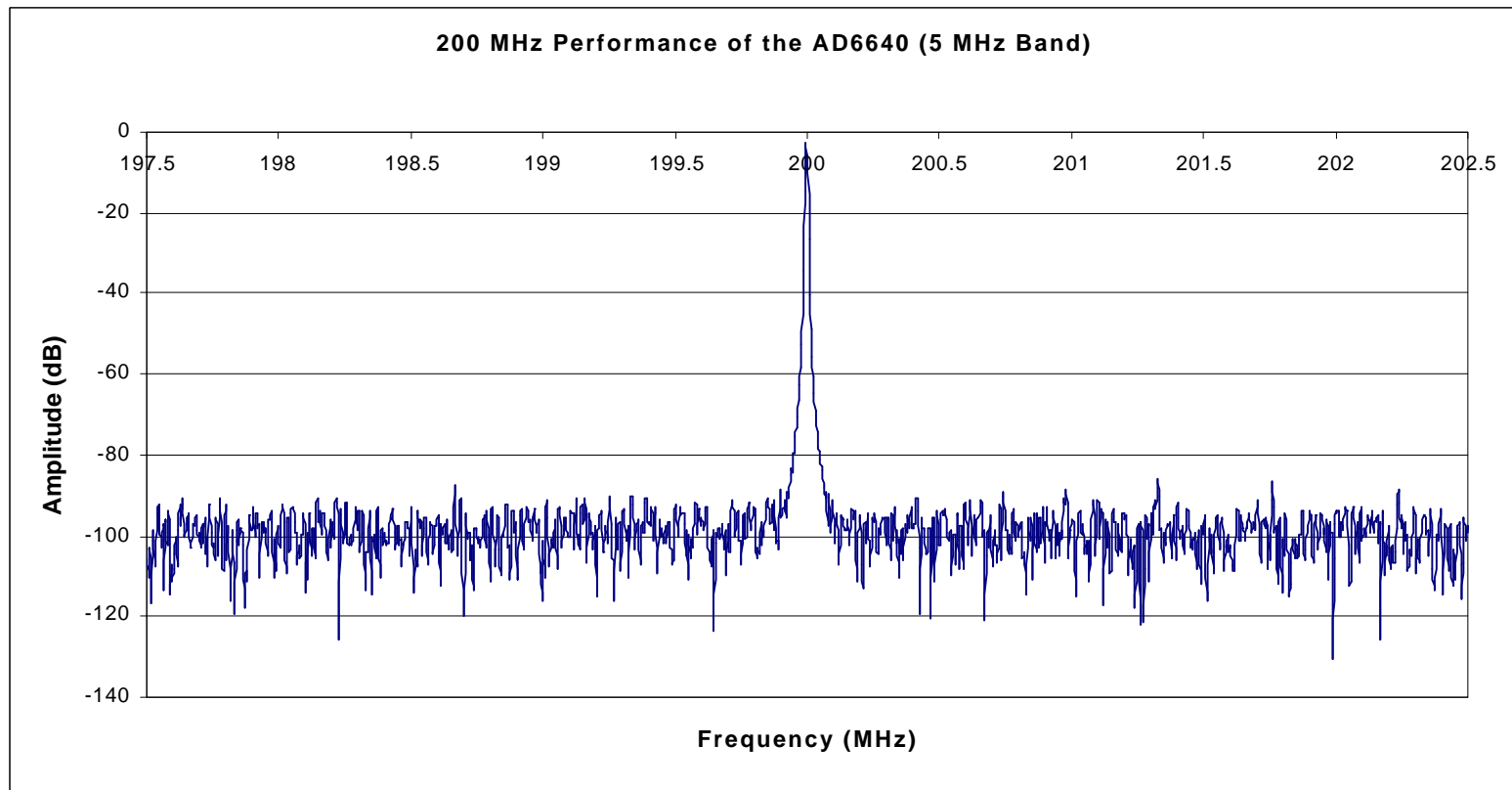
AD6640: 7th Nyquist Zone



Sampling rate = 65MSPS; 193 to 225MHz; A_{in} = 200 MHz

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7th Nyquist Zone - Zoom



Sampling rate = 65MSPS; 197.5 to 202.5 MHz; A_{in} = 200 MHz

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Processing Gain & Oversampling

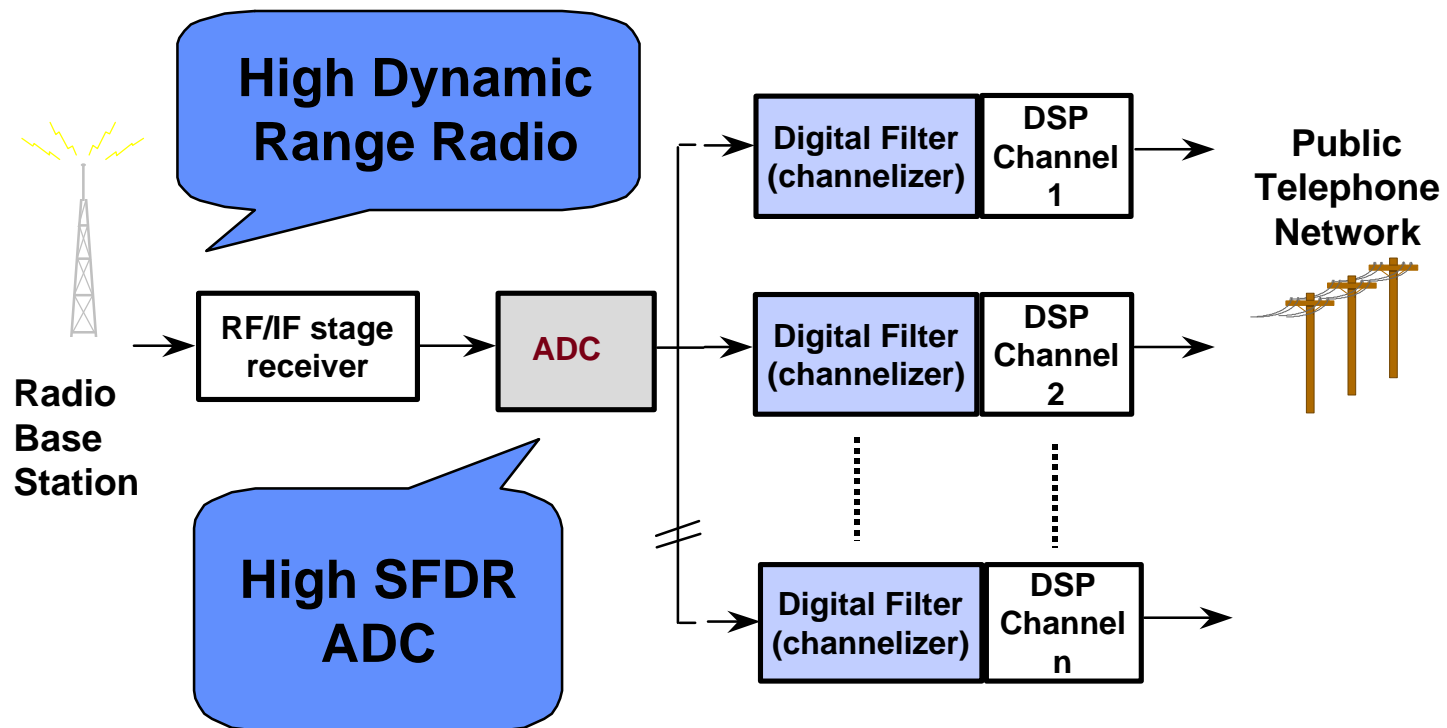


<u>Standard</u>	<u>Chan. BW</u>	<u>Symbol Rate</u>	<u>Samp. rate</u>	<u>Proc.Gain*</u>
IF Sampling				
IS-136	30 KHz	48.6 Kbit/sec	9.72 MSPS	22 dB
GSM	200 KHz	270.83 Kbit/s	6.5 MSPS	12 dB
CDMA	1.23 MHz	1.228 Mbits/s	19.66 MSPS	9 dB
Wide band				
IS-136	30 KHz	48.6 Kbit/sec	58.32 MSPS	29 dB
GSM	200 KHz	270.83 Kbit/s	65 MSPS	22 dB
CDMA	1.23 MHz	1.228 Mbits/s	58.98 MSPS	14 dB
3G	5MHz	4.096 Mbits/s	65.53 MSPS	9 dB

** Assumes 1 sample/symbol*

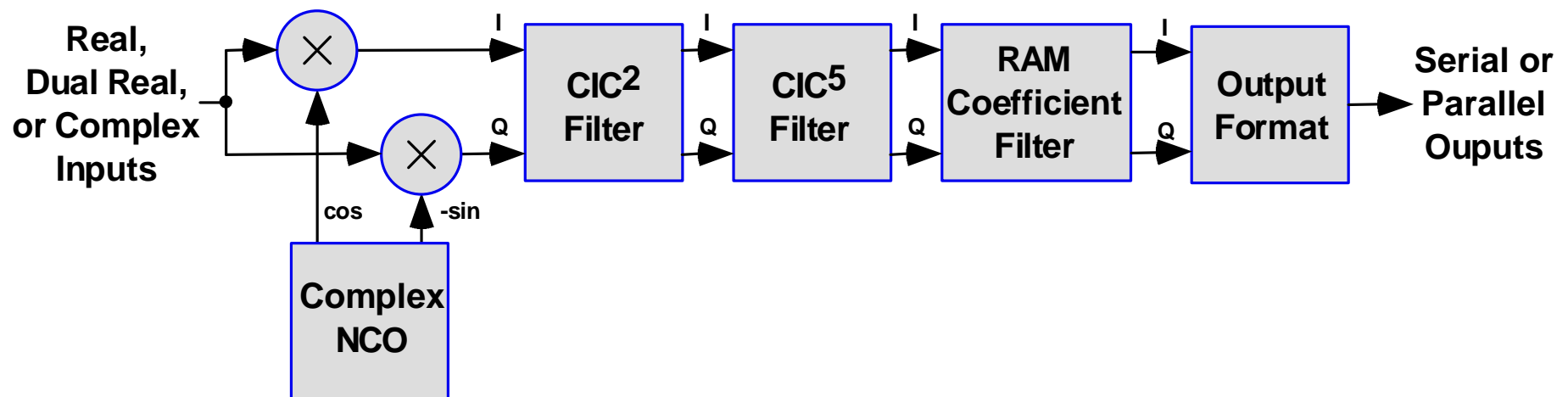
Processing Gain = $10 \log (\text{Sample rate}/2^* \text{ channel BW})$

Multi-Channel RX Challenges



AD6620 Functions

NCO and Filter Stages



AD6620

Dual Channel Decimating Receiver

Accepts real or complex input words: provides tuning and decimation filtering

65 MSPS Single channel inputs or 32.5 MSPS Dual Channel Mode

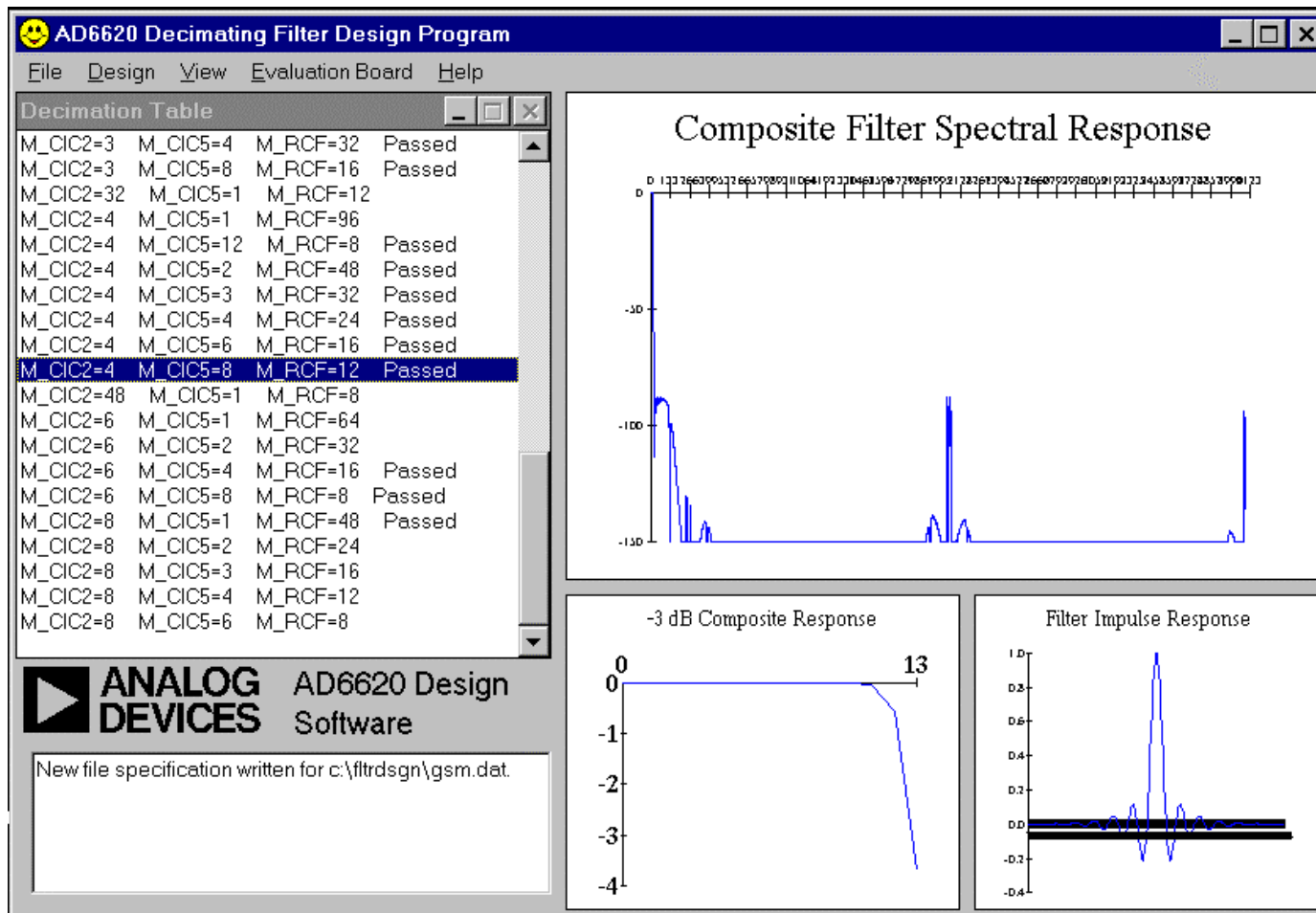
NCO worst spur better than -105dBc; 0.02 Hz tuning resolution

CIC2 Fixed Coefficient Filter decimates 1 to 16; CIC5 Fixed Coefficient Filter decimates 1 to 32

Programmable RAM based FIR filter with programmable decimates 1-32

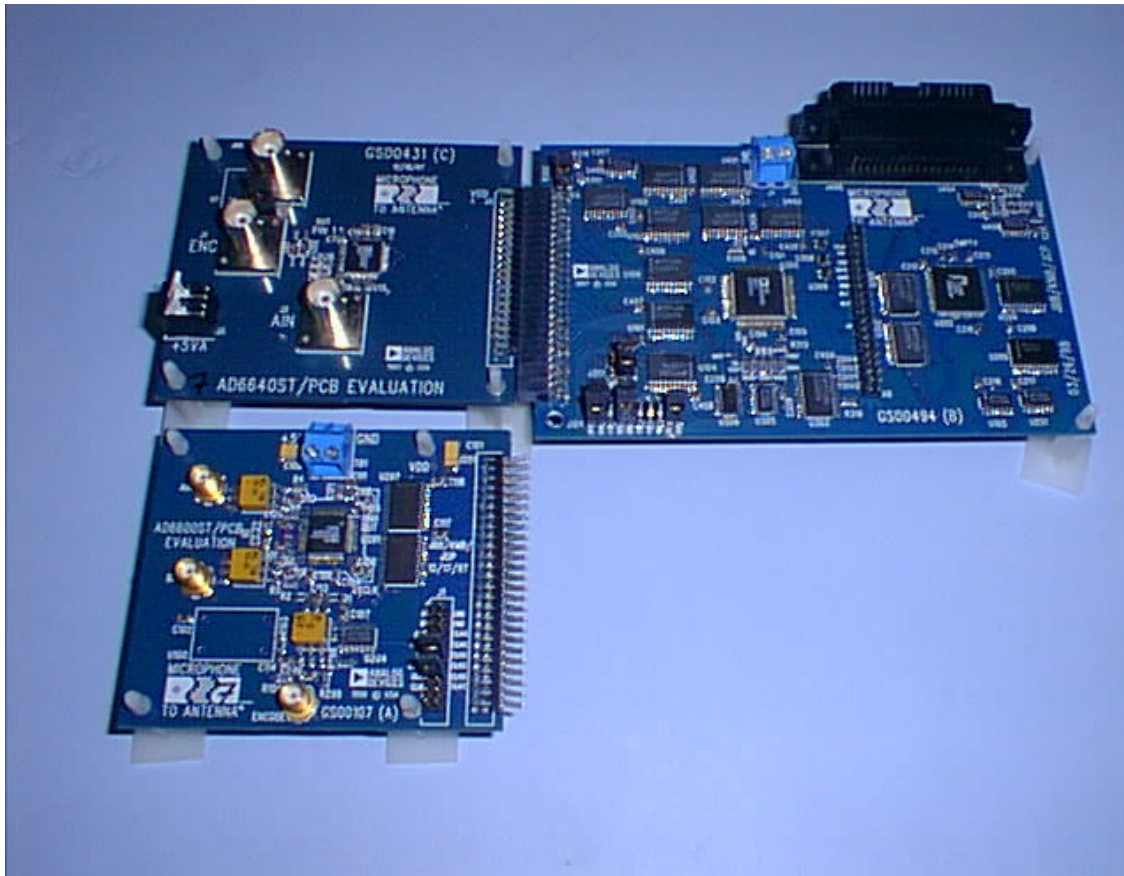
1700 Million Operations per second at 250 micro-watts/MOP

Design Filter Using AD6620 software



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Modular Evaluation Boards

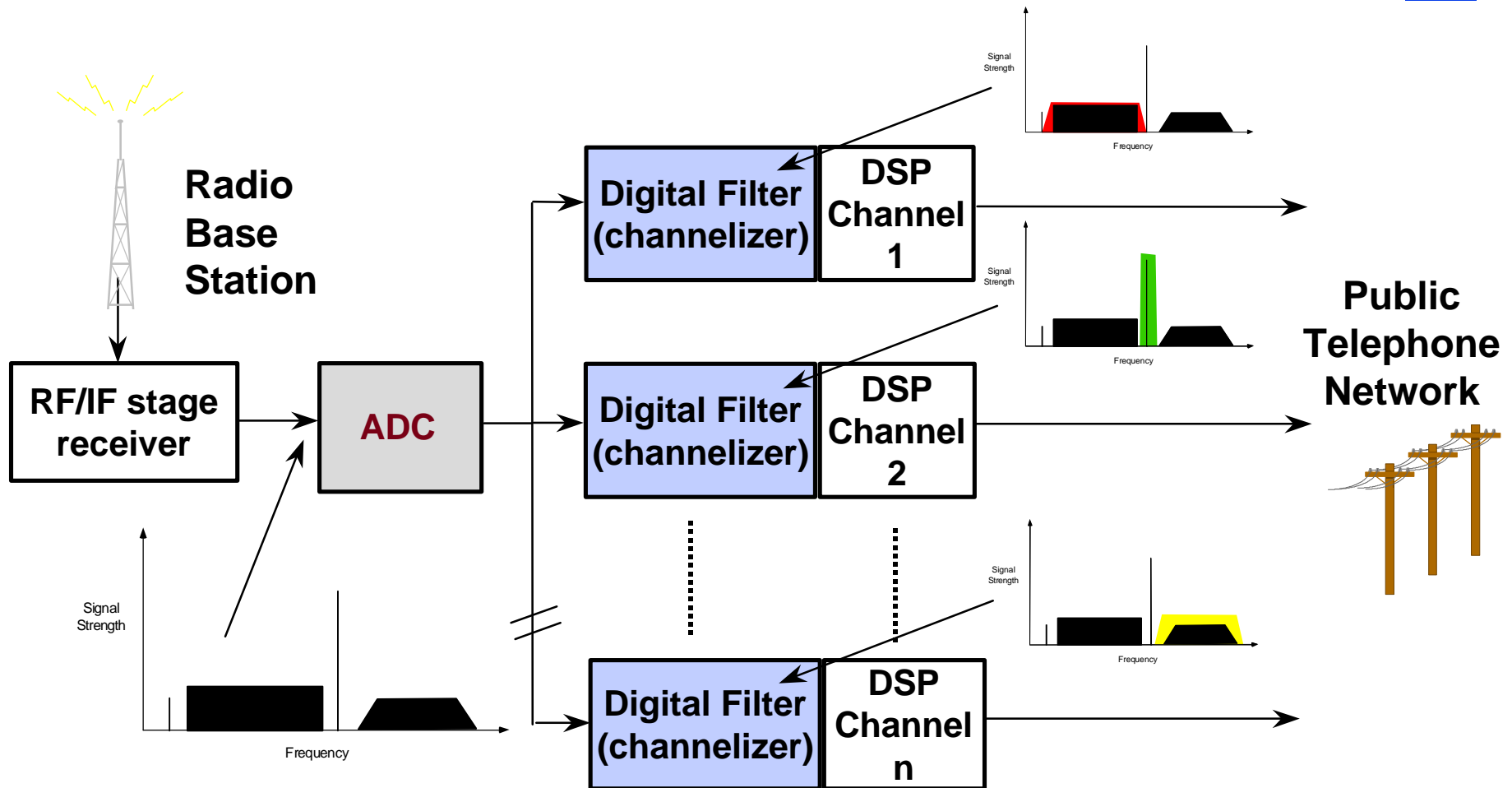


**AD6640 -
12 bit 65MSPS
IF Sampling ADC**

**AD6620
Receive Signal Processor**

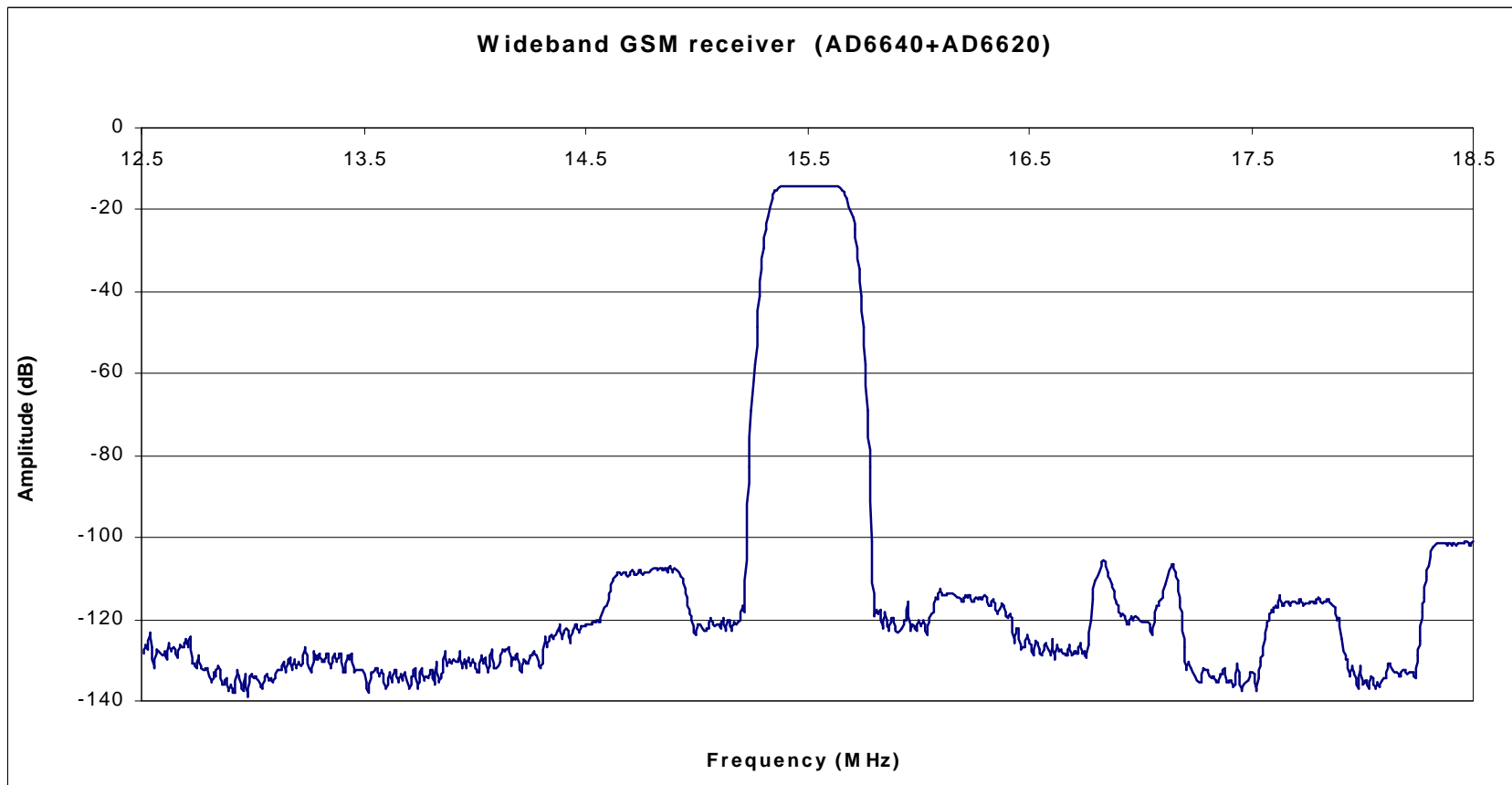
**AD6600 -
Diversity Receiver ADC**

Multi-carrier Receivers Overview



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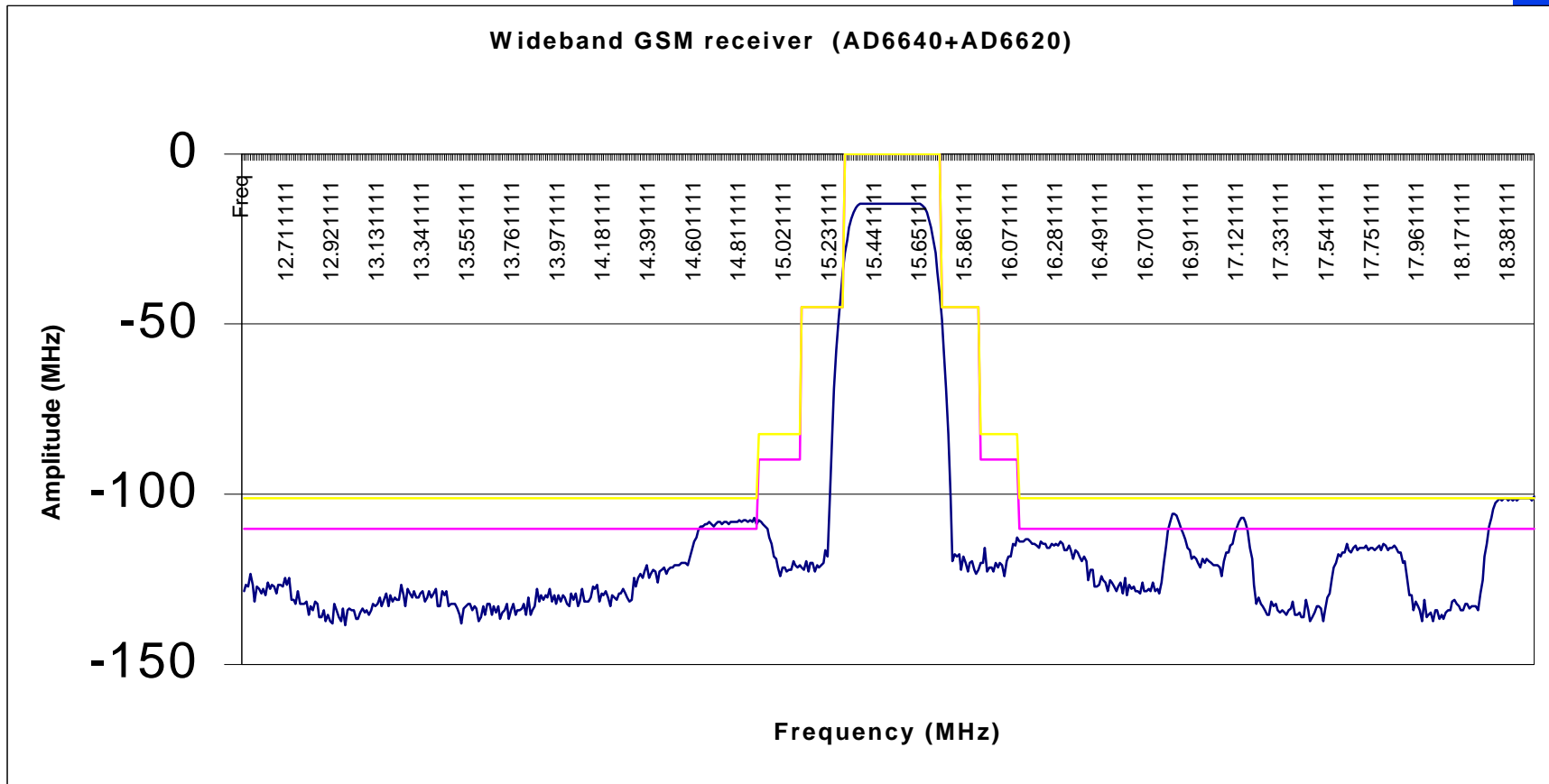
AD6640 + AD6620: GSM



Sampling rate = 65MSPS; IF = 12.5 MHz to 18.5 MHz
(noise floor increased due to lower decimation rate)

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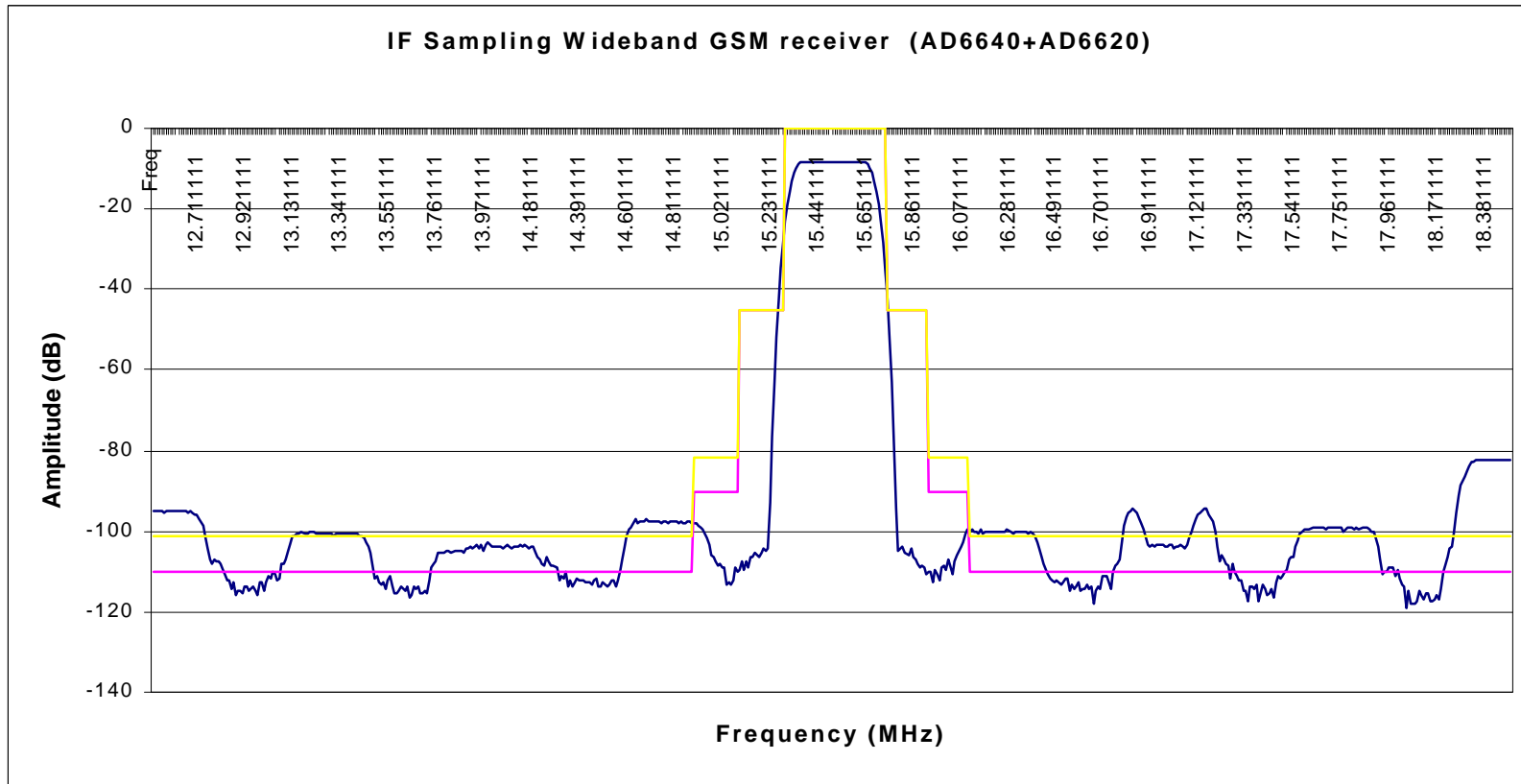
GSM:Pico Cell - Y/ Macro - N



Yellow - Pico Cell Mask; Purple - Macro Cell Mask;

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GSM Receiver: IF Sampling

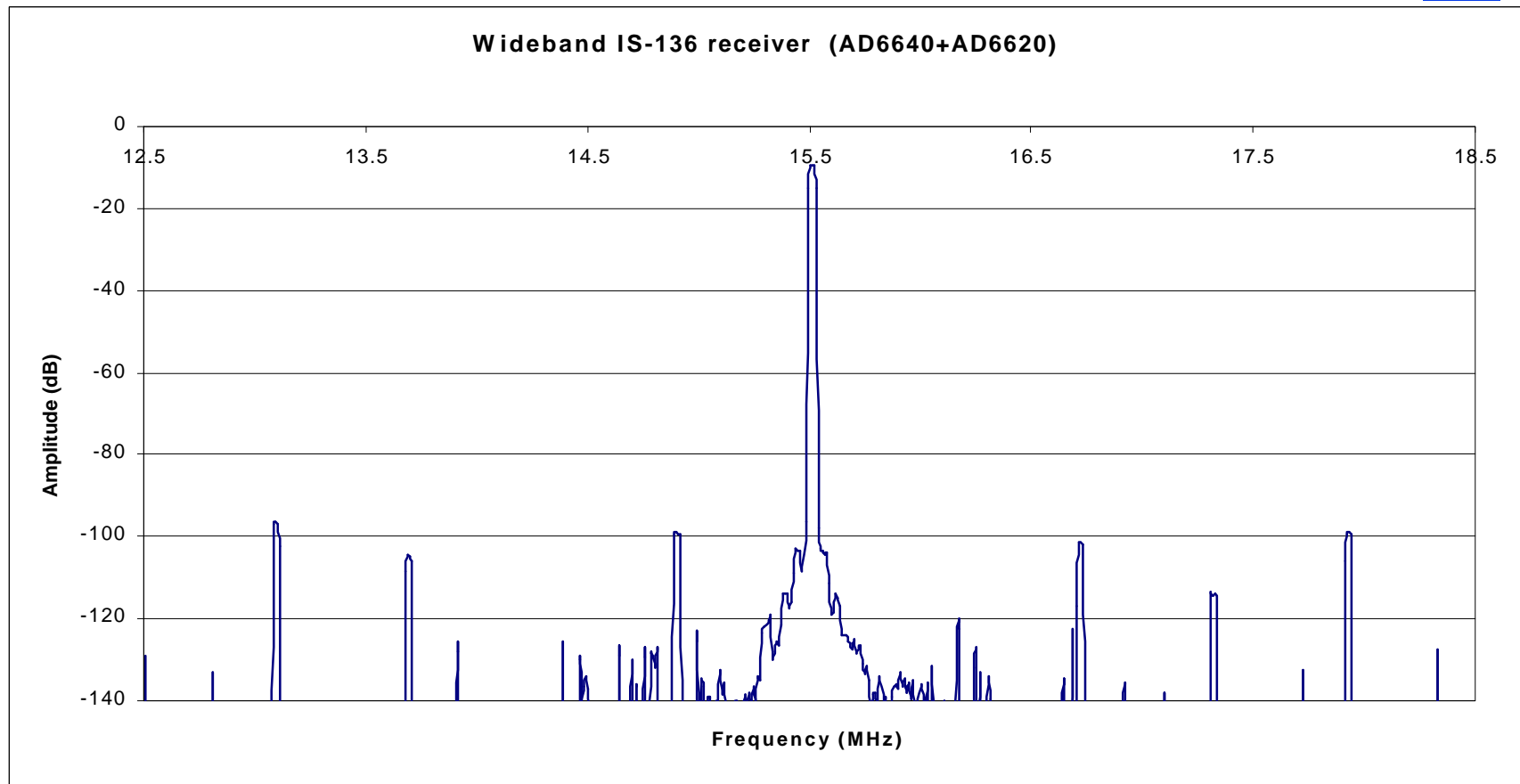


Yellow - Pico Cell Mask; Purple - Macro Cell Mask;

Sampling Rate: 65MSPS; A_{in} 77.5 to 83.5 MHz

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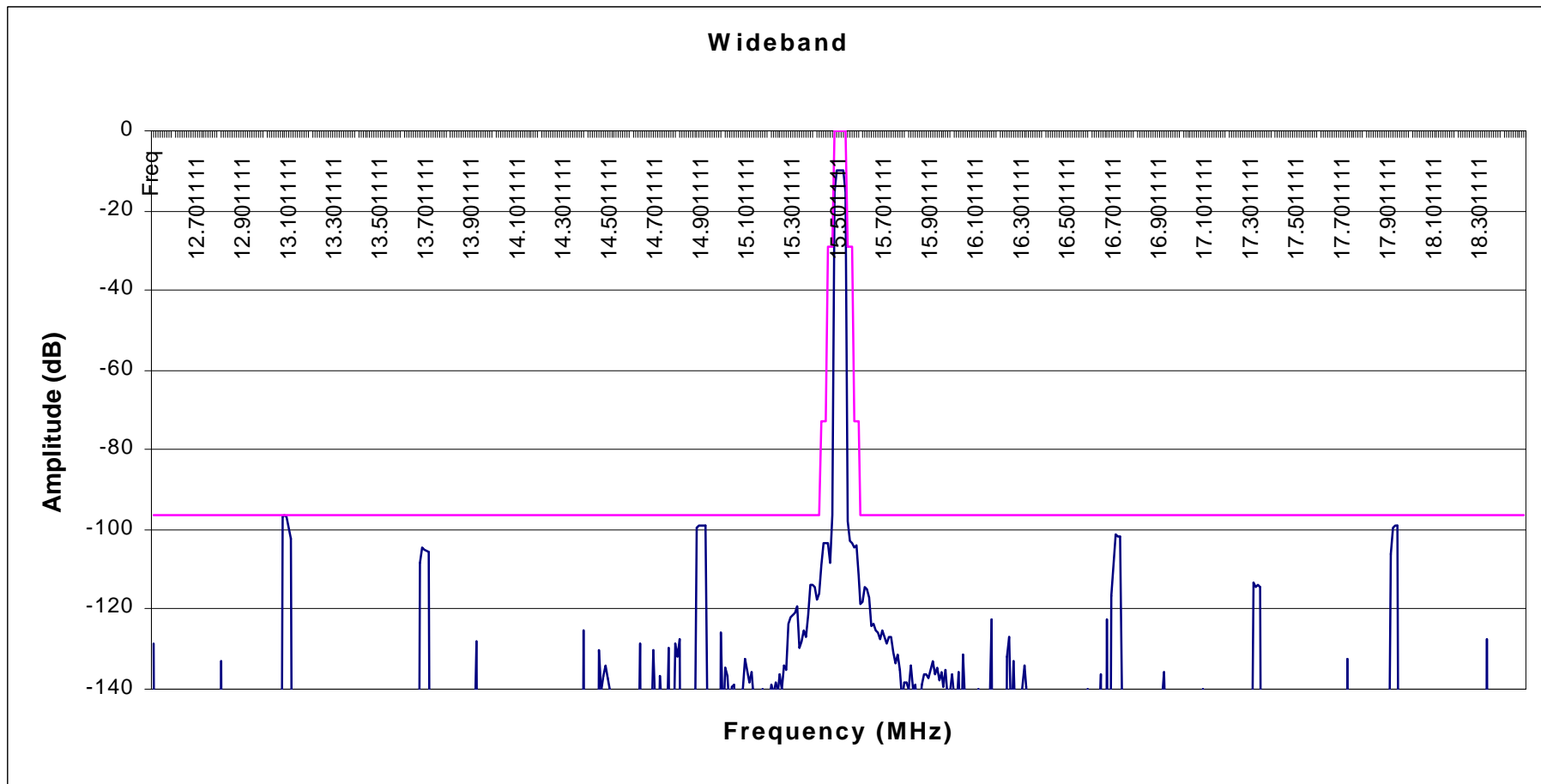
AD6640 + AD6620: IS-136



Sampling rate = 65MSPS; IF = 12.5 MHz to 18.5 MHz
(noise floor reduced due to narrow IS-136 filter)

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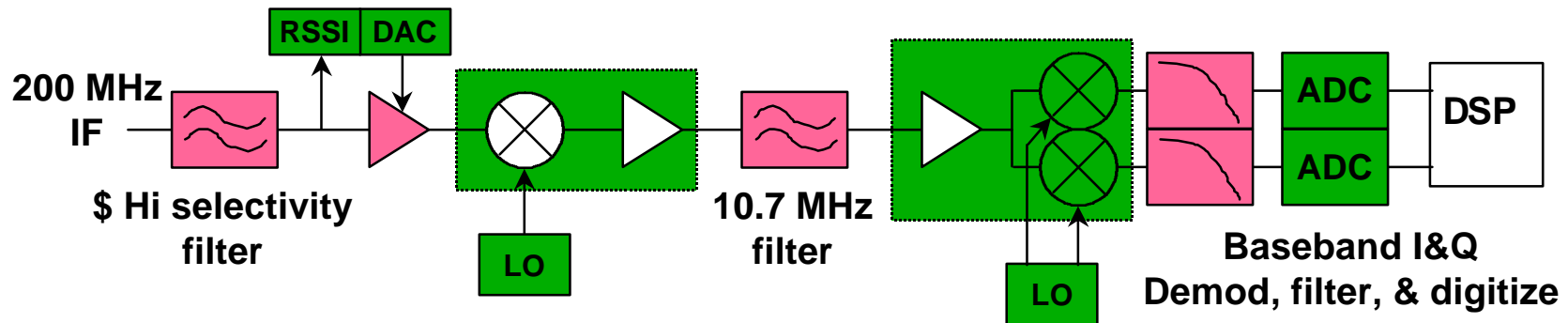
Meets IS-136 Specification



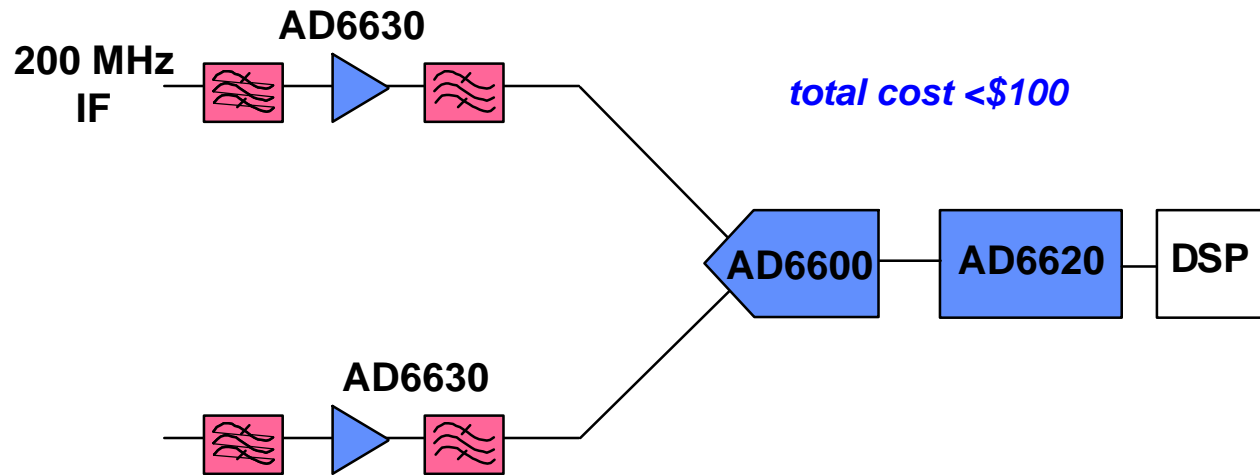
Sampling rate = 65MSPS; IF = 12.5 MHz to 18.5 MHz
(noise floor reduced due to narrow IS-136 filter)

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Narrowband Chipset comparison (*IF to digitizer(s)*)



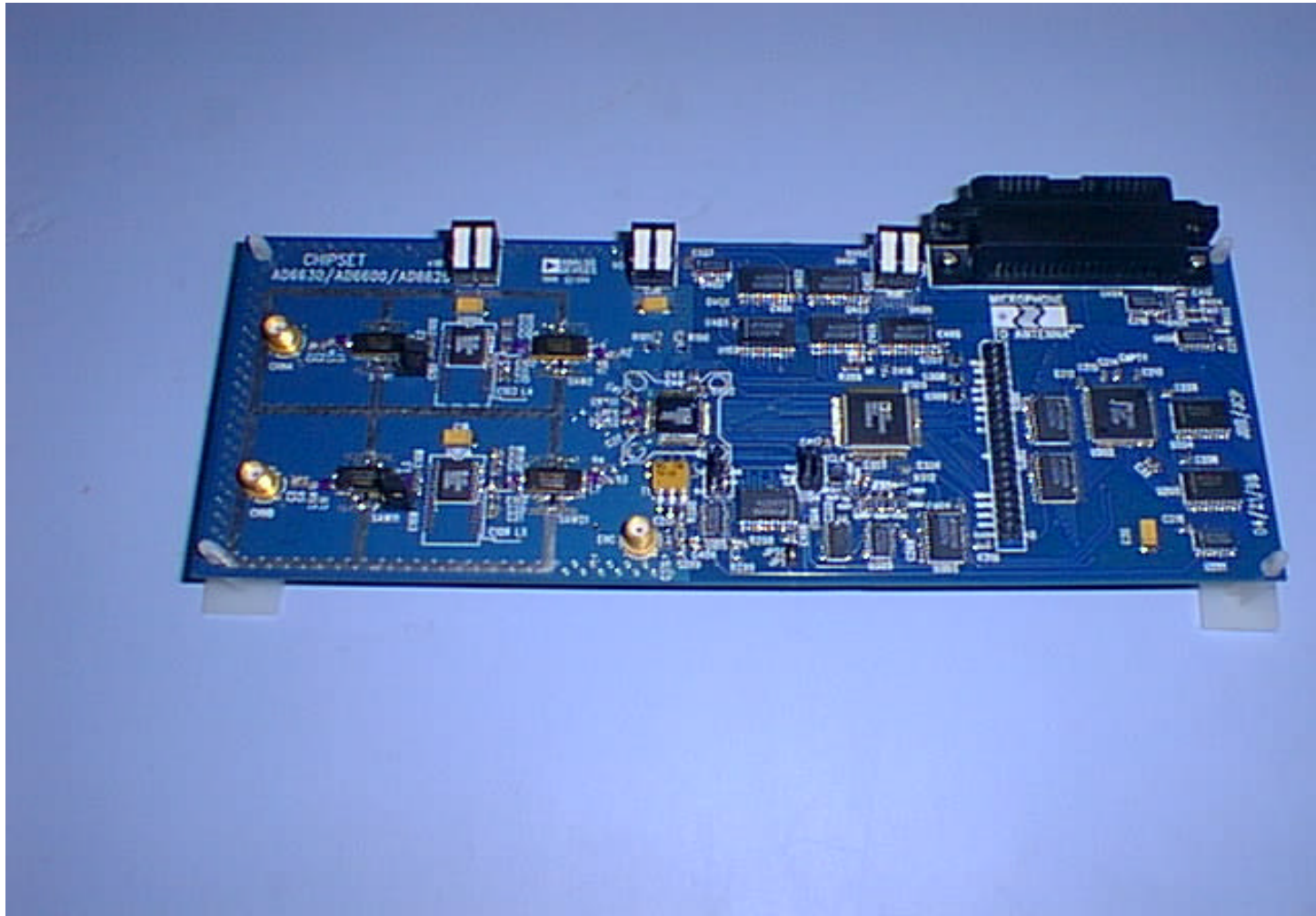
Traditional: Two channels required for diversity total cost = \$200+



total cost <\$100

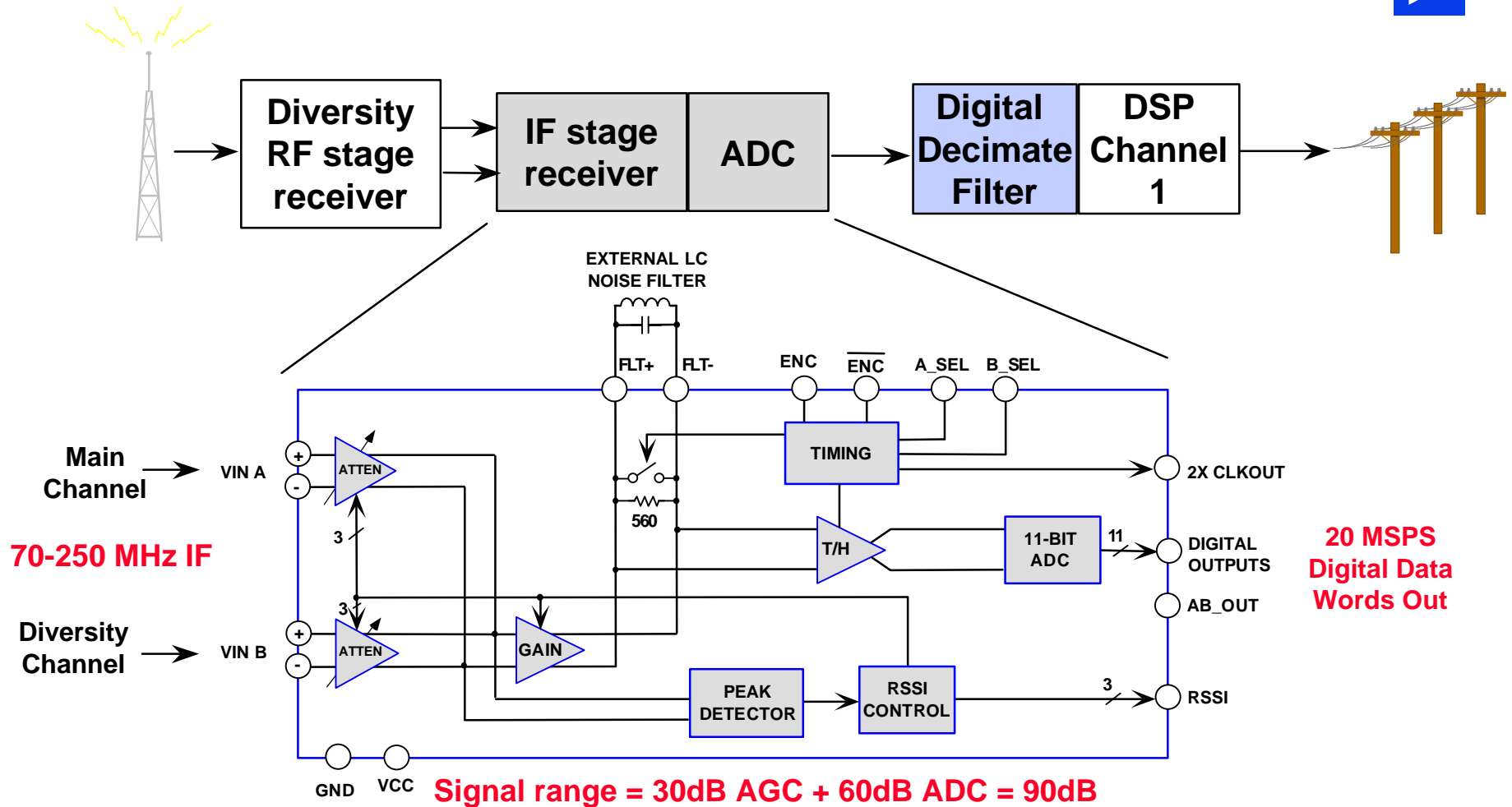
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GSM, IF sampling Ref. Design



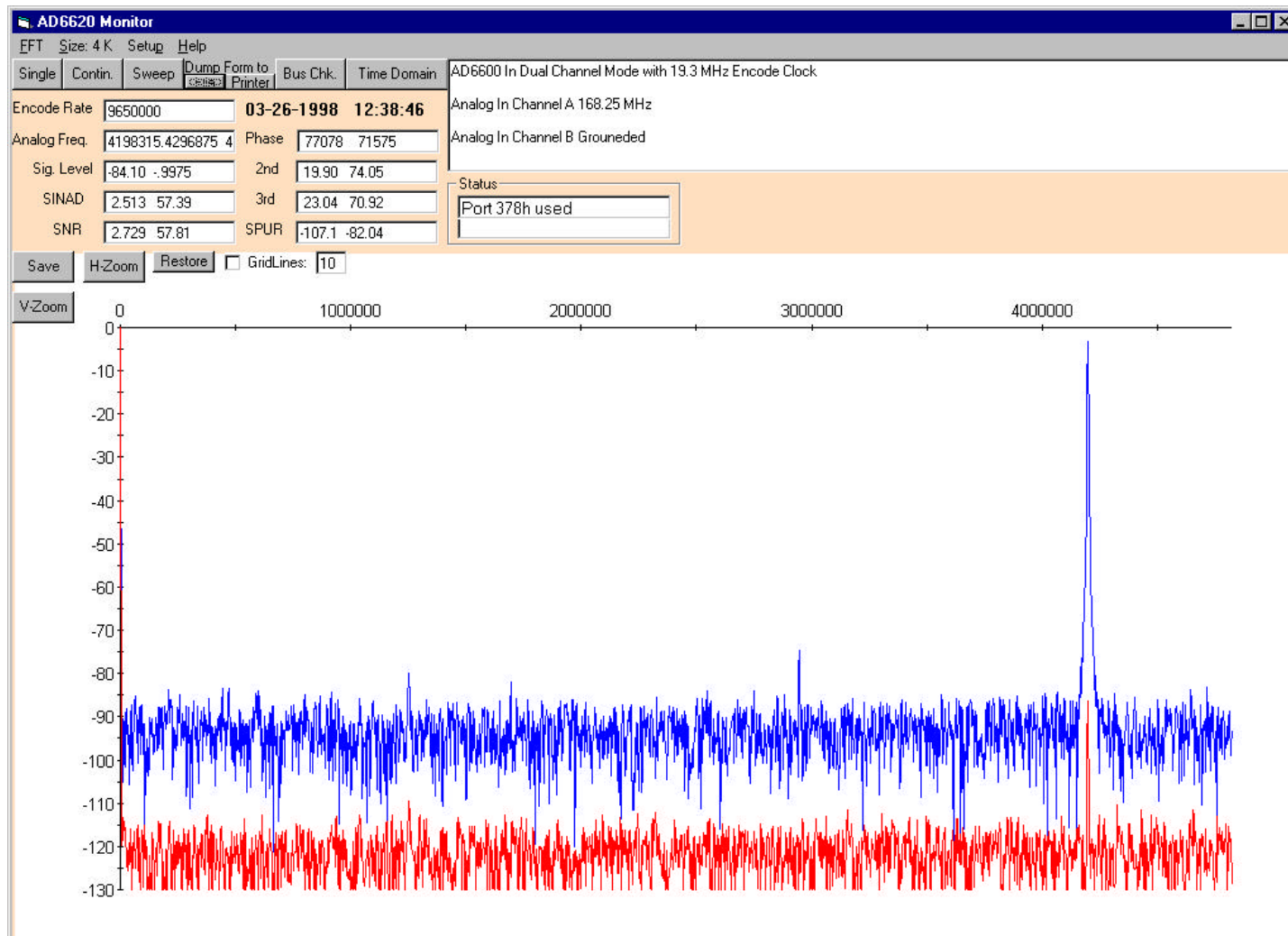
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“IF” Gain-Ranging Technology



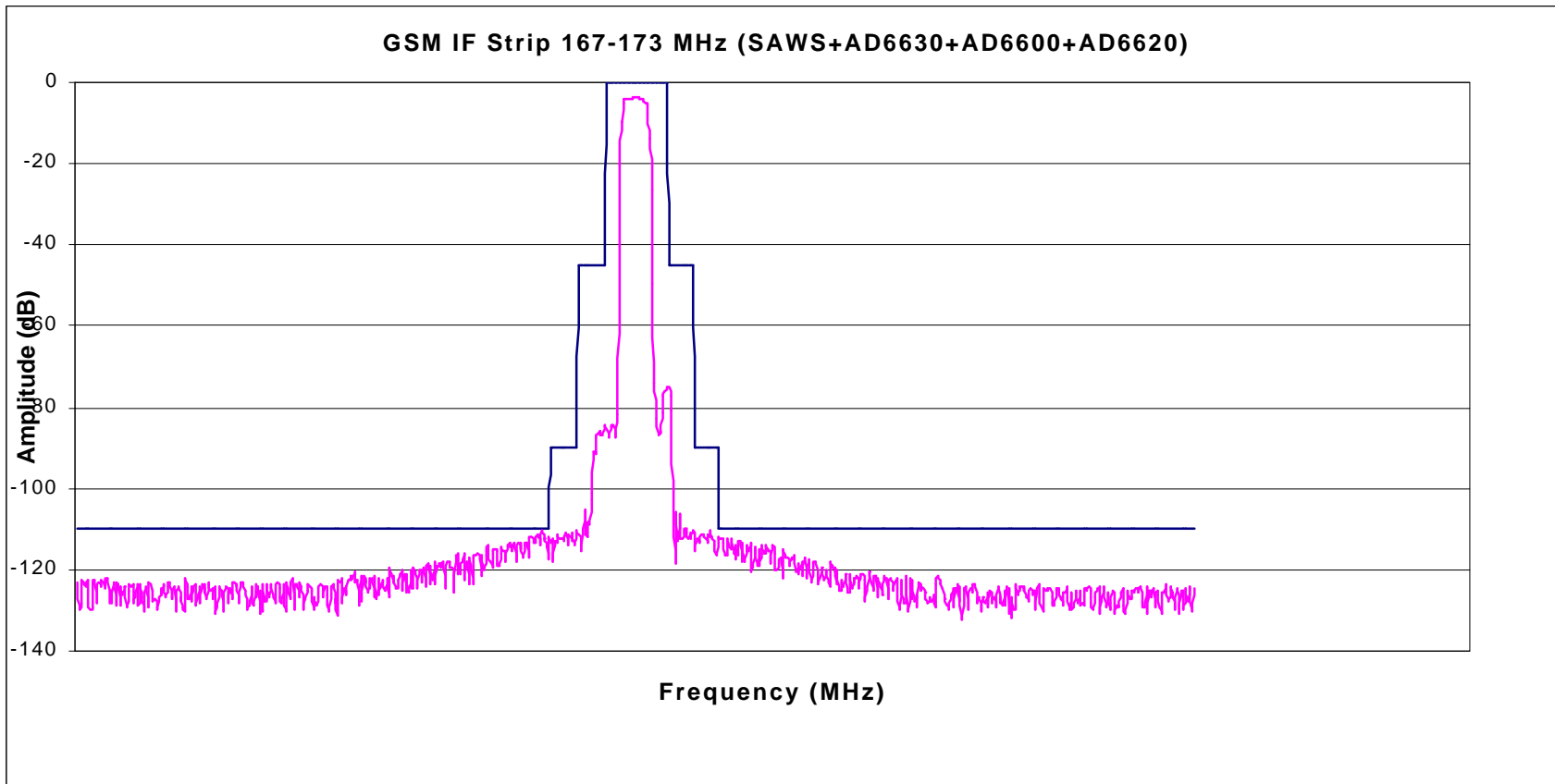
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Sampling 170 MHz IF



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IF sampling chipset: meets GSM requirements



Sampling rate = 6.5MSPS; IF = 167 MHz to 173 MHz

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Conclusions



- **ADC technology improving dramatically in many ways**
- **ADC manufacturers need volume applications to drive R/D investment**
- **System understanding drives ADC innovations**
- **Multi-mode, Multi Channel Rx chipsets available**
 - **performance limited by ADC**
- **IF Sampling Chipset (AD6600+6620+6630)**
 - **available and meets GSM requirements**
 - **requires some analog filtering**
 - **High IF sampling decreases “RF” costs**

More Information



- AD6640, AD6620, AD6630 and AD6600 chips, app notes and evaluation boards available from Analog Devices
- search at www.analog.com