Software Defined Radios
An Architectural Viewpoint

Tune In Excitement!™

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President

FlexRadio Systems®
Software Defined Radios

Three Architectures

- Direct I/Q Conversion – PC DSP
- Wideband ADC – FPGA/PC DSP
- Legacy Multi-conversion Analog – DSP Chip Firmware

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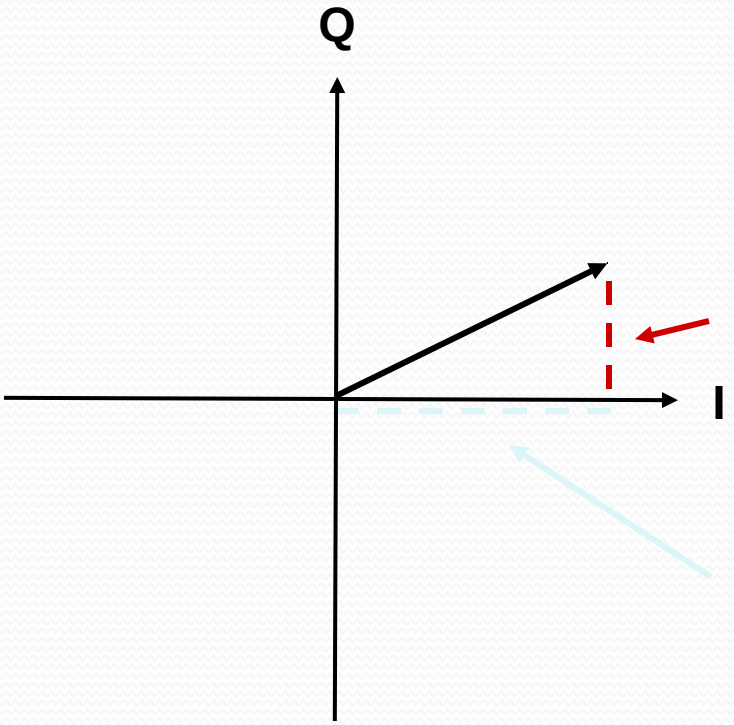
Quadrature Modulation & Demodulation



Q“-Imaginary

I“-Real

$C^2 = A^2 + B^2$

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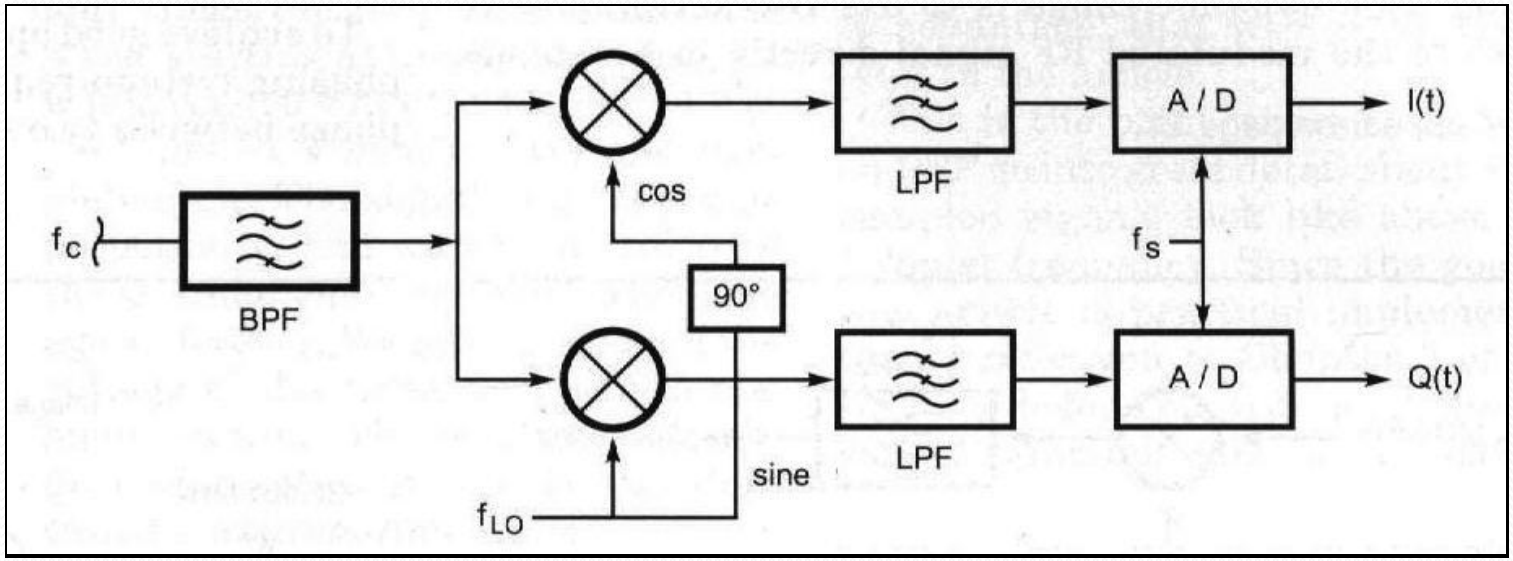
Quadrature Sampling Architecture



$$BW = 2 * \frac{f_s}{2} = f_s$$

Quadrature Sampling Doubles Bandwidth

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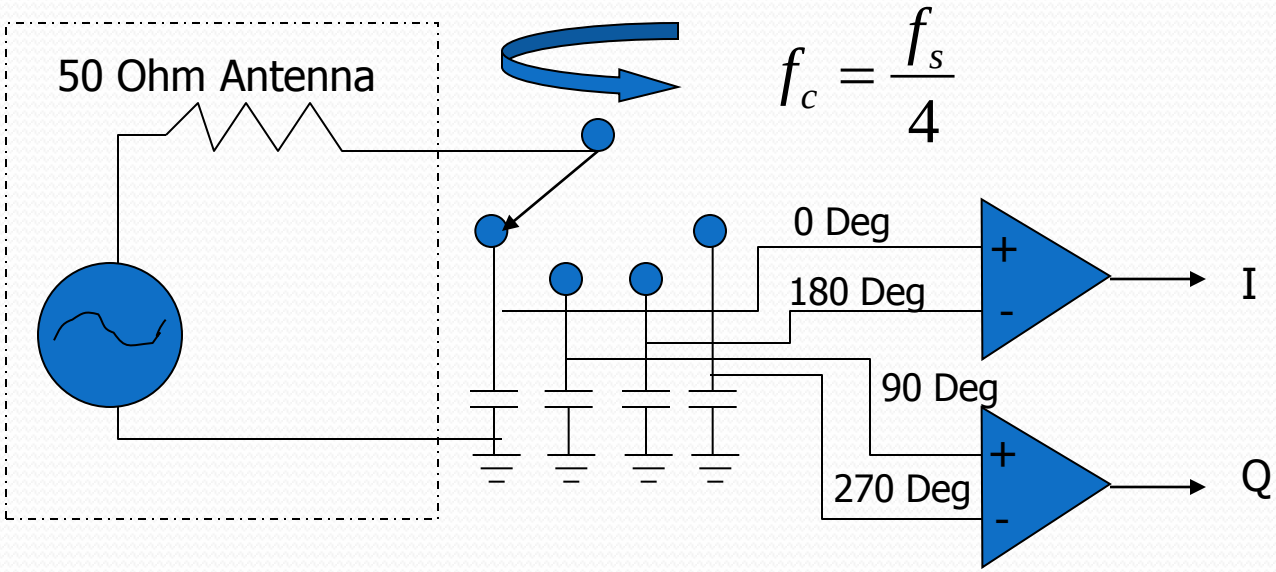
Quadrature Sampling Detector



$$BW = \frac{1}{\pi n R_{ant} C_s}$$

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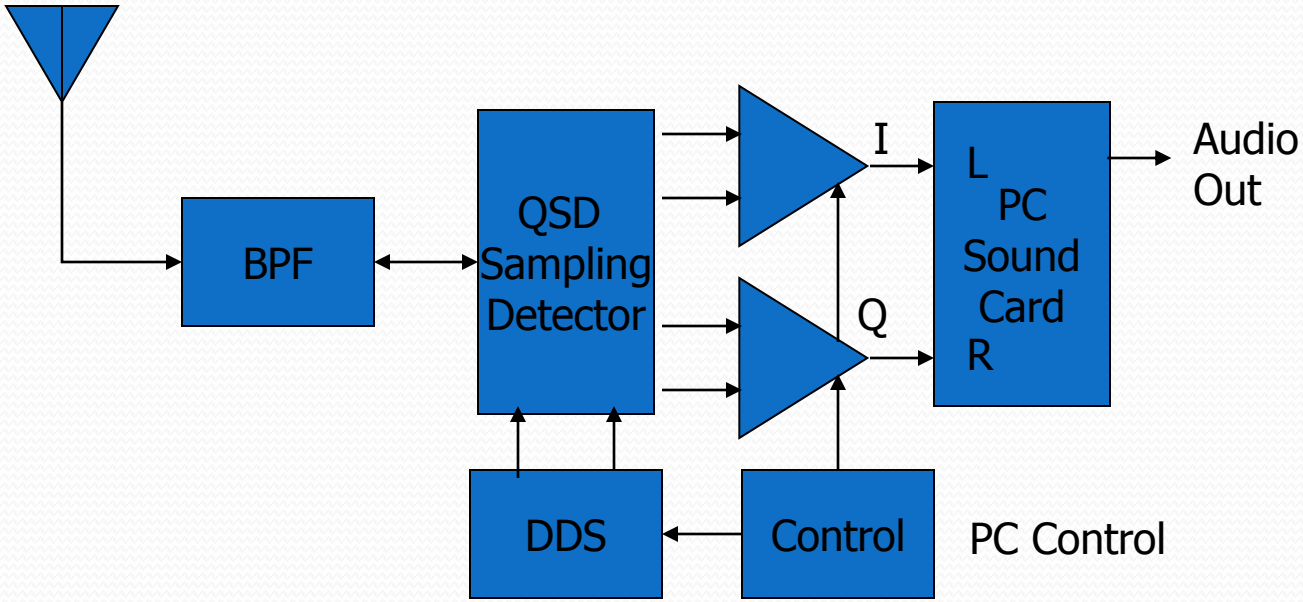
SDR-1000 Quadrature Sampling Receiver



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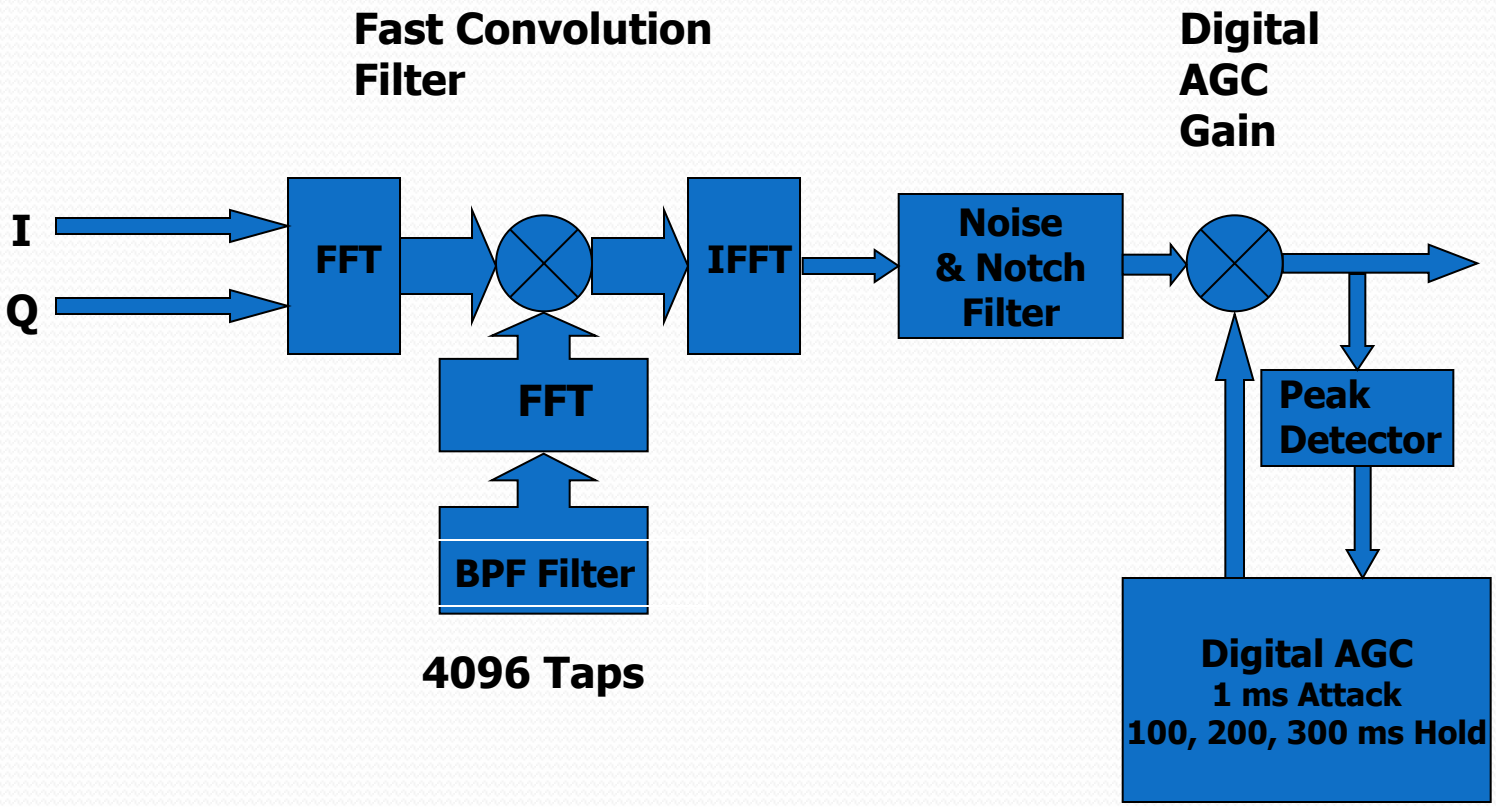
Basic Software Receiver Architecture



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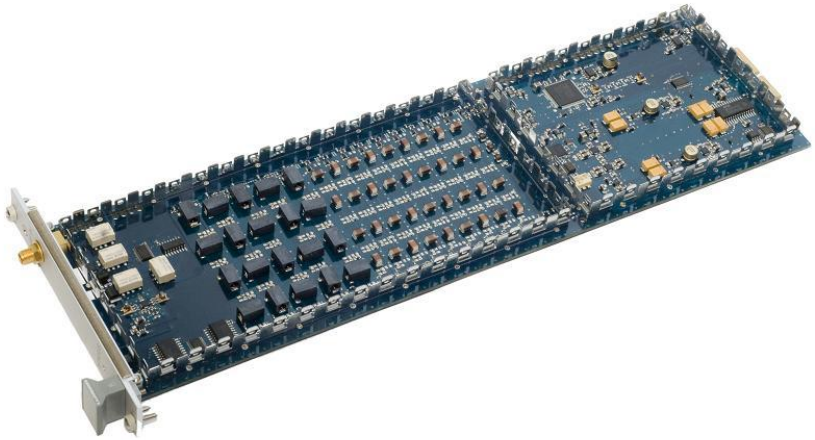
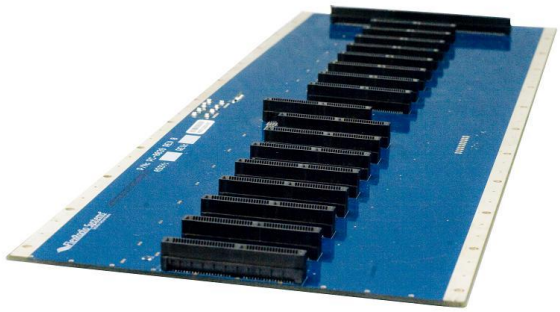
CDRX-3200 32 Channel Synchronous Receiver

- 32 Fully Independent Receivers
- Synchronous to GPS System
- 1 ns Time Stamping
- 200 kHz Channels
- 100 kHz – 100 MHz Tuning
- IMD DR3: >105 dB @ 100 Hz
- Phase Noise: < -150 dBc/Hz
- GigE Streaming I/Q Data
- 7U Chassis, 100W Total

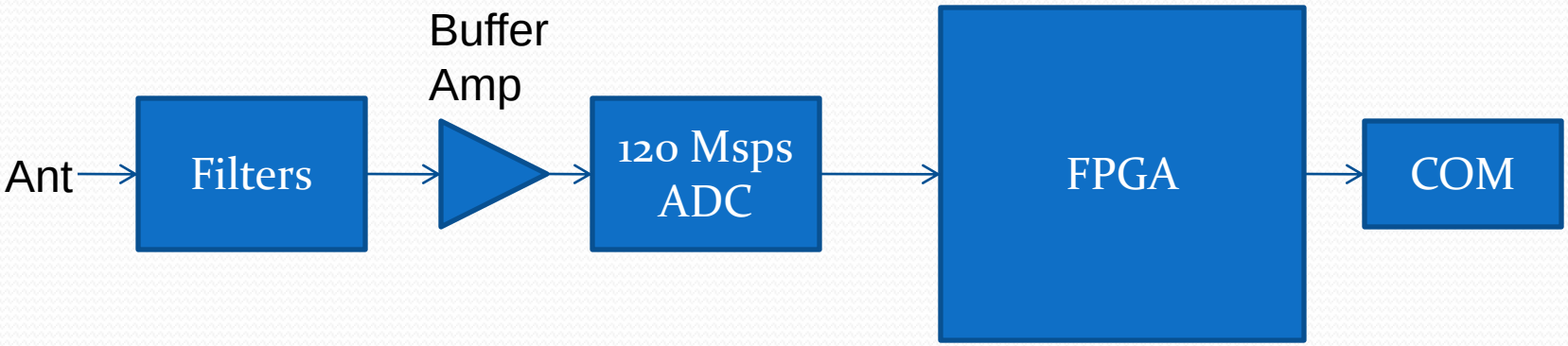
CDRX in the Raw





CDRX-3200 In The Rack

Wideband Sampling SDR



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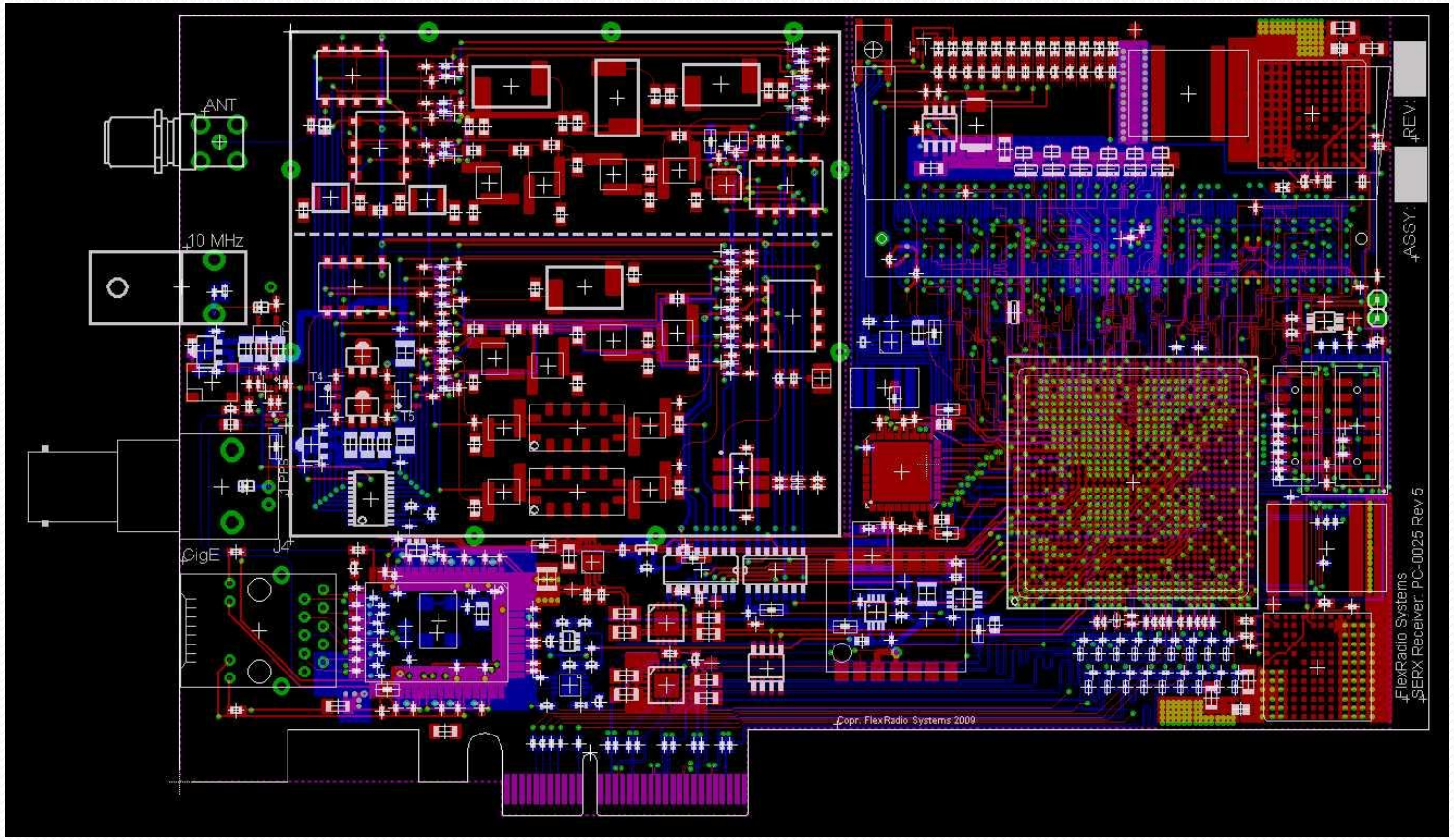
SERX-16 Survey Receiver

- 180Msps Direct Sampling Receiver
- 16 Streaming 250kHz Channels
- Polyphase Down Sampling DDCs
- DDCs Combine for Reconstruction
- Real-time FFT (256–8192 bins)
- DDC look-back up to 4.3 seconds
- >90dB Wideband SFDR
- Phase Noise: <-150 dBc/Hz
- RX Bands: HF & Low VHF
- 70MHz and 140MHz 25 MHz BW IF
- Optional full wideband I/Q stream
- PCI Express x4 Lanes (GigE Opt.)
- Virtex-5 SX95T FPGA

SERX-16 Survey Receiver

180 Msps Direct Sampling RX



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Direct Conversion vs. High Speed Sampling SDRs

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Analyzing ADC Signal Chains

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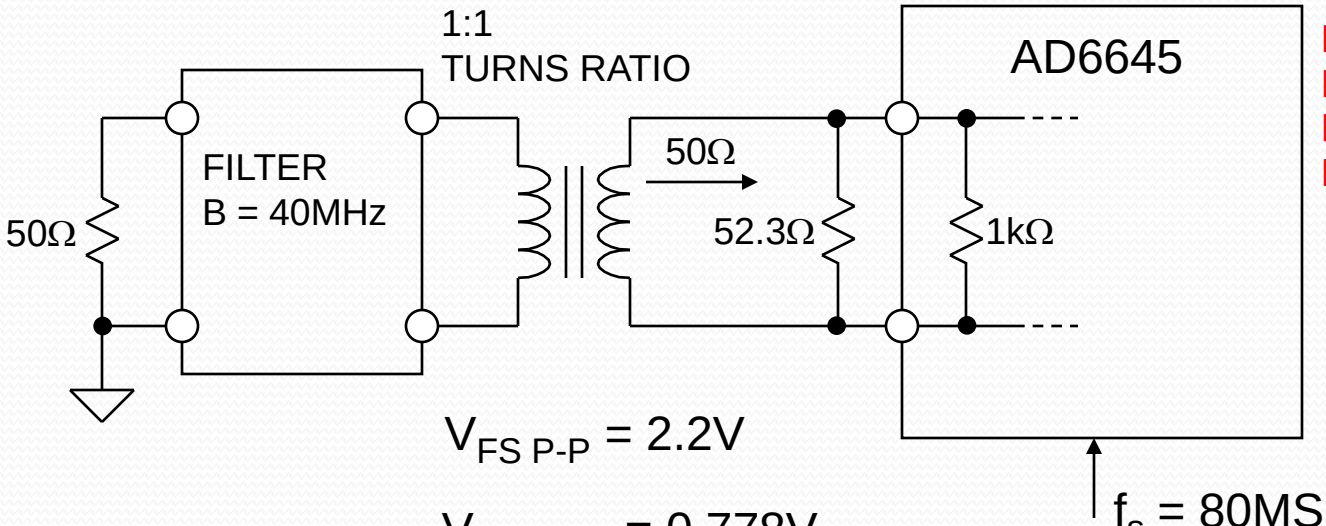
Example Calculation of Noise Figure Under Nyquist Conditions for AD6645



$$V_{FS\ P-P} = 2.2V$$

$$V_{FS\text{-}RMS} = 0.778V$$

$$P_{FS} = \frac{(0.778)^2}{50} = 12.1mW$$

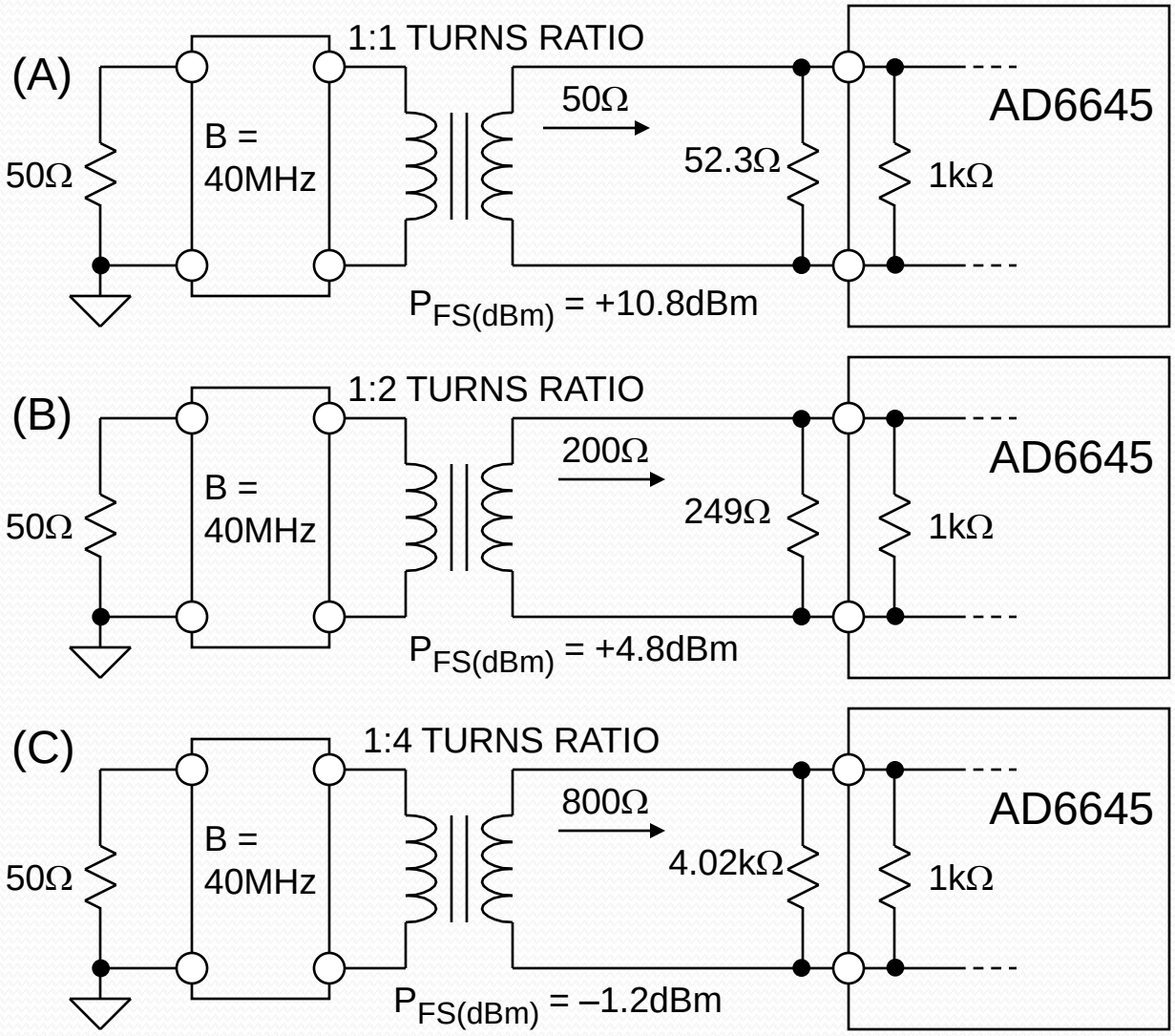
$$P_{FS(dBm)} = +10.8dBm$$

$$NF = P_{FS(dBm)} + 174dBm - SNR - 10\log_{10}B$$

$$= +10.8dBm + 174dBm - 74dB - 10\log_{10}(40 \times 10^6)$$

$$= 34.8dB$$

Using RF Transformers to Improve Overall ADC Noise Figure



- $V_{FS\ P\text{-}P}$ = 2.2V
- f_S = 80MSPS
- SNR = 74dB
- Input 3dB BW = 250MHz

NF = 34.8dB

NF = 28.8dB

NF = 22.8dB

ADC 1 Hz DR Comparisons

	AK5394	PCM4222		ADS5483-135	ADS5485-200	LTC2208-130	ADC - L	ADC - A	Unit
Overload Vpk	2.4	2.8		1.5	1.5	1.125	1.125	1	**Vpk**
Overload Vrms	1.6968	1.9796		1.0605	1.0605	0.795375	0.795375	0.707	**Vrms**
30 MHz SNR (@ 0 dBFS)	121	121		79.2	75	77.7	77	75	**dB**
2X BW for Audio Fs/2	40,000	40,000		135,000,000	200,000,000	130,000,000	160,000,000	210,000,000	**Hz**
Overload dBm @ 50 Ohms	17.6	18.9		13.5	13.5	11.0	11.0	10.0	**dBm**
1:1 NF	27.6	28.9		30.0	32.5	29.2	29.0	28.8	**dB**
Noise Power dBm/Hz	-146.4	-145.1		-144.0	-141.5	-144.8	-145.0	-145.2	**dBm**
1 Hz Dynamic Range	164.0	164.0		157.5	155.0	155.8	156.0	155.2	**dB**

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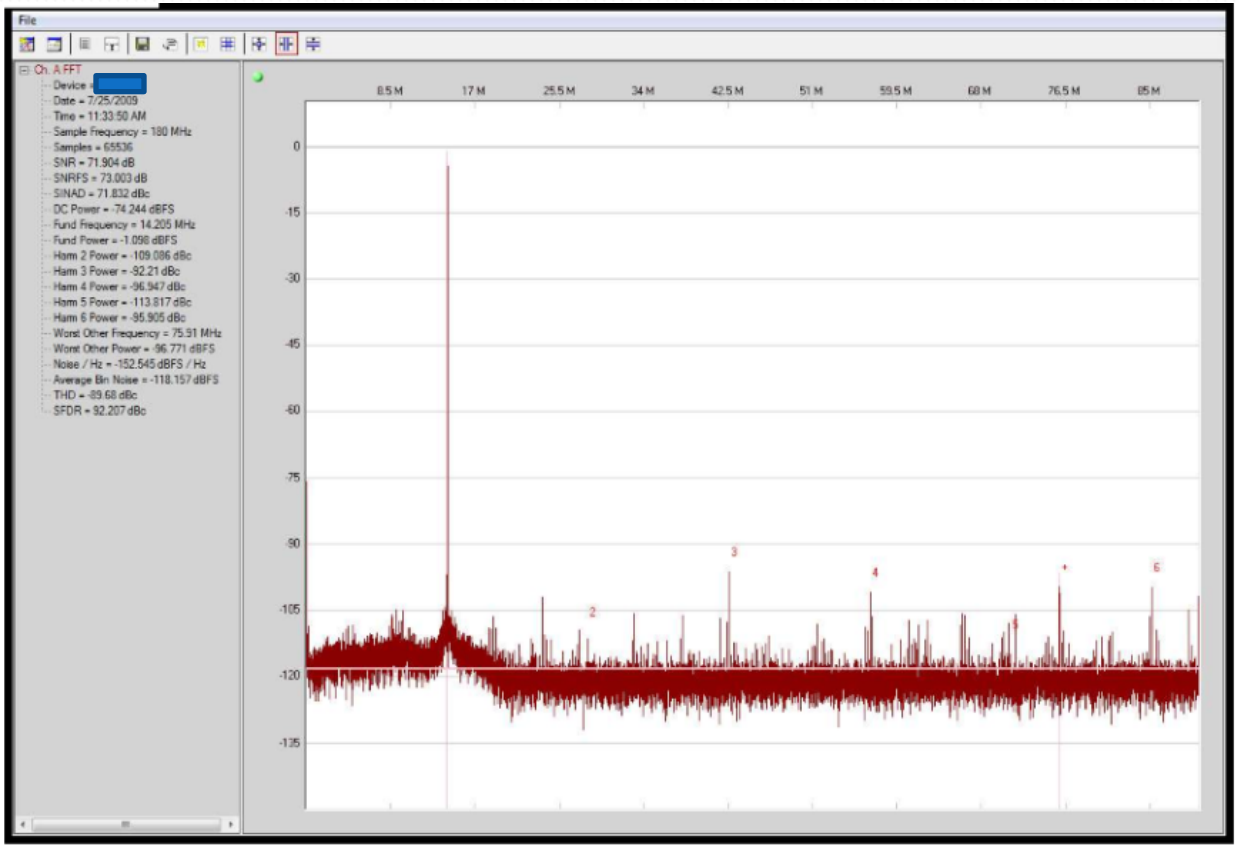
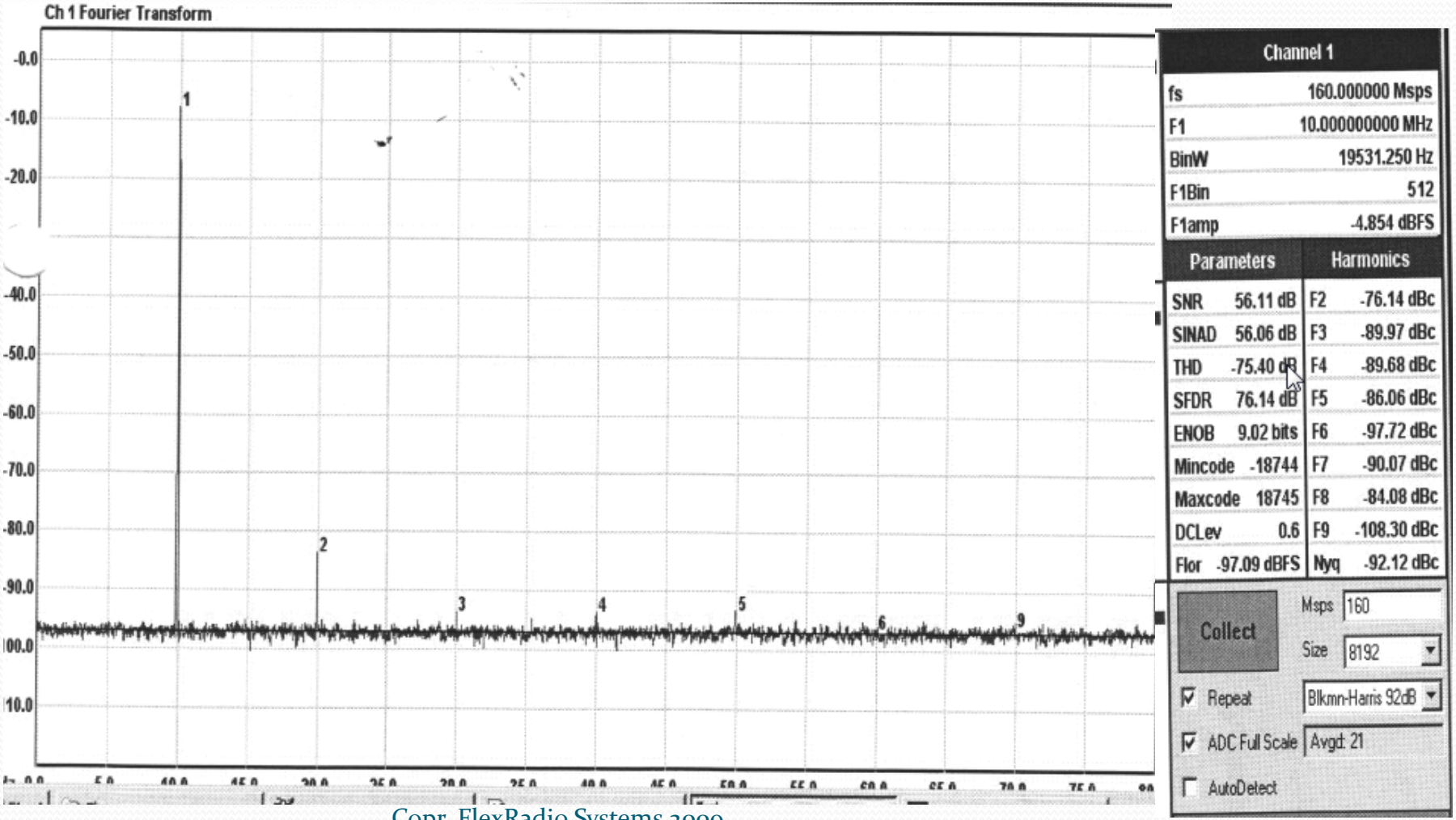
SERX: 92 dBc SFDR @ -1 dBFS 180 Msps



LTC6400-20 & 160 Msps LTC2209 SFDR



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Measured QSD/Baseband vs. High Speed ADCs

QSD/Baseband

- SFDR ADC Limited: 110 dB
- BDR: ~129 dB
- IIP3: ~ +31 dBm
- IMD DR3: ~107 dB
- Limited SFDR Change
- Bandwidth – 200 kHz
- Image centered at DC

LTC6400-20 & LTC2209

- SFDR ADC Limited: ~90 dB
- BDR: ~123 dB
- IIP3: ~ +30 dBm
- IMD DR3: ~110 dB
- SFDR Decreases w/Freq.
- Bandwidth Fs/2
- Image at Nyquist

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Eliminating the Direct Conversion Image… SDR Magic!

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Four Channel Signal Combiner For WBIR Testing

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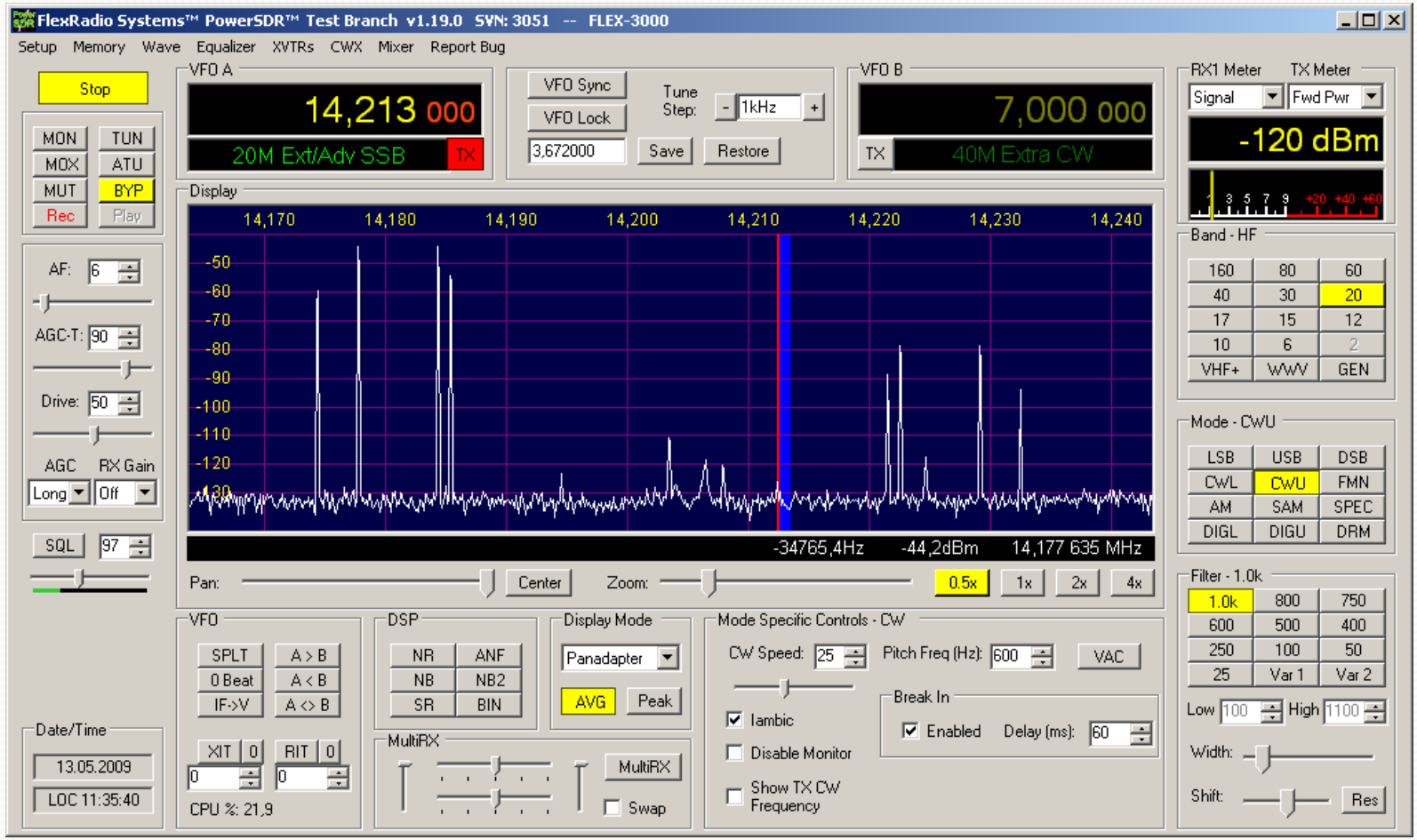
WBIR Off – Now you see them



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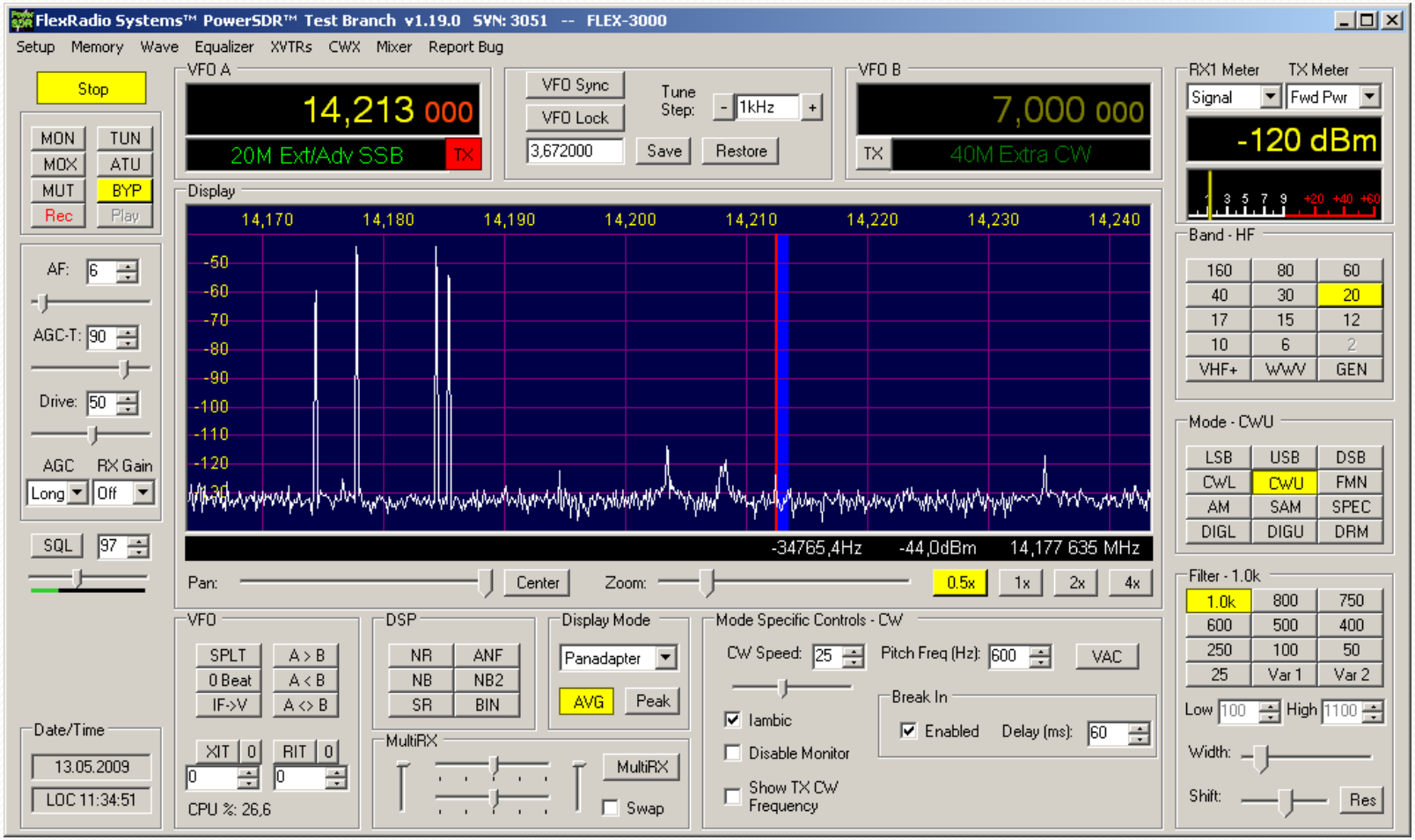
WBIR Magic! Now you don't



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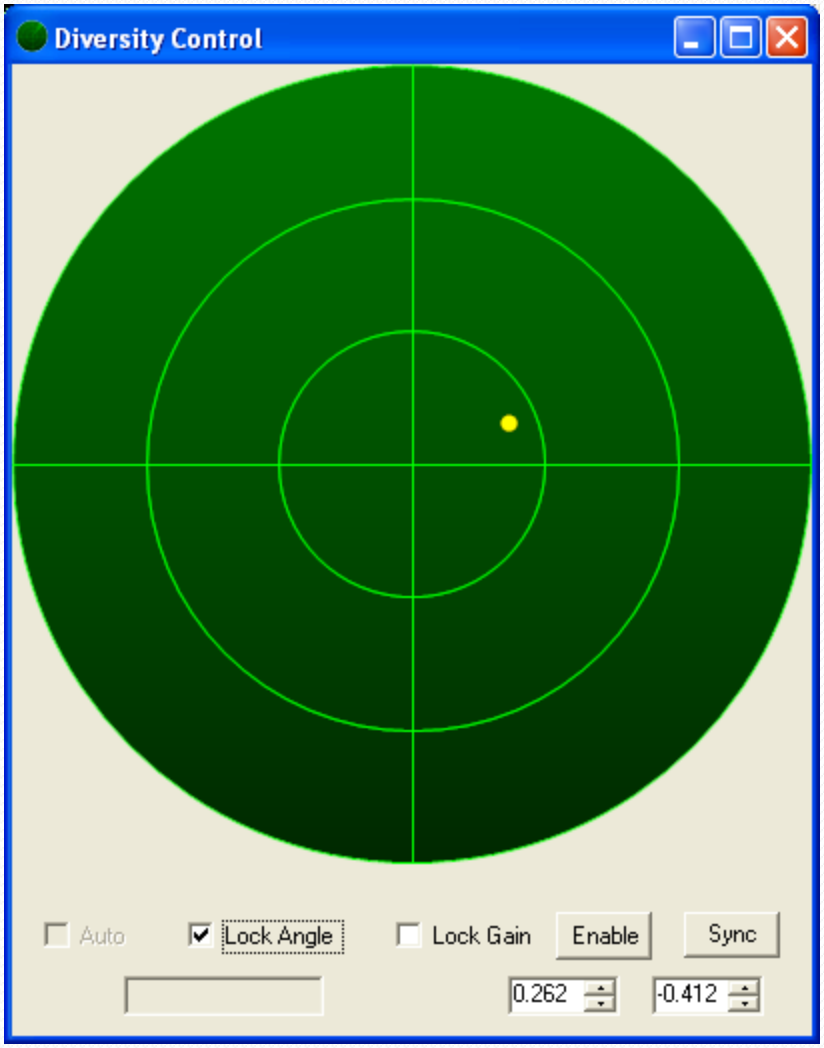
Synchronous Diversity Reception Radar



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Software vs. Firmware Defined Radios

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Contrasting Software & Firmware Defined Radios

SDR

- PC CPU Follows Moore's Law
- Unlikely PC Obsolescence
- Totally Flexible User Interface
- Interactive Code/Debug
- GPL Open Source

FDR

- DSP IF – Fixed Performance
- Likely DSP Obsolescence
- Limited Disp/Ctrl Flexibility
- Special Hardware ICE Debug
- Open/Closed Source Issues

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Moore's Law Keeps Making PC Based SDRs Better

SDR-1000 Development System

SDR-1000 Project Began

SDR-1000 Shipped

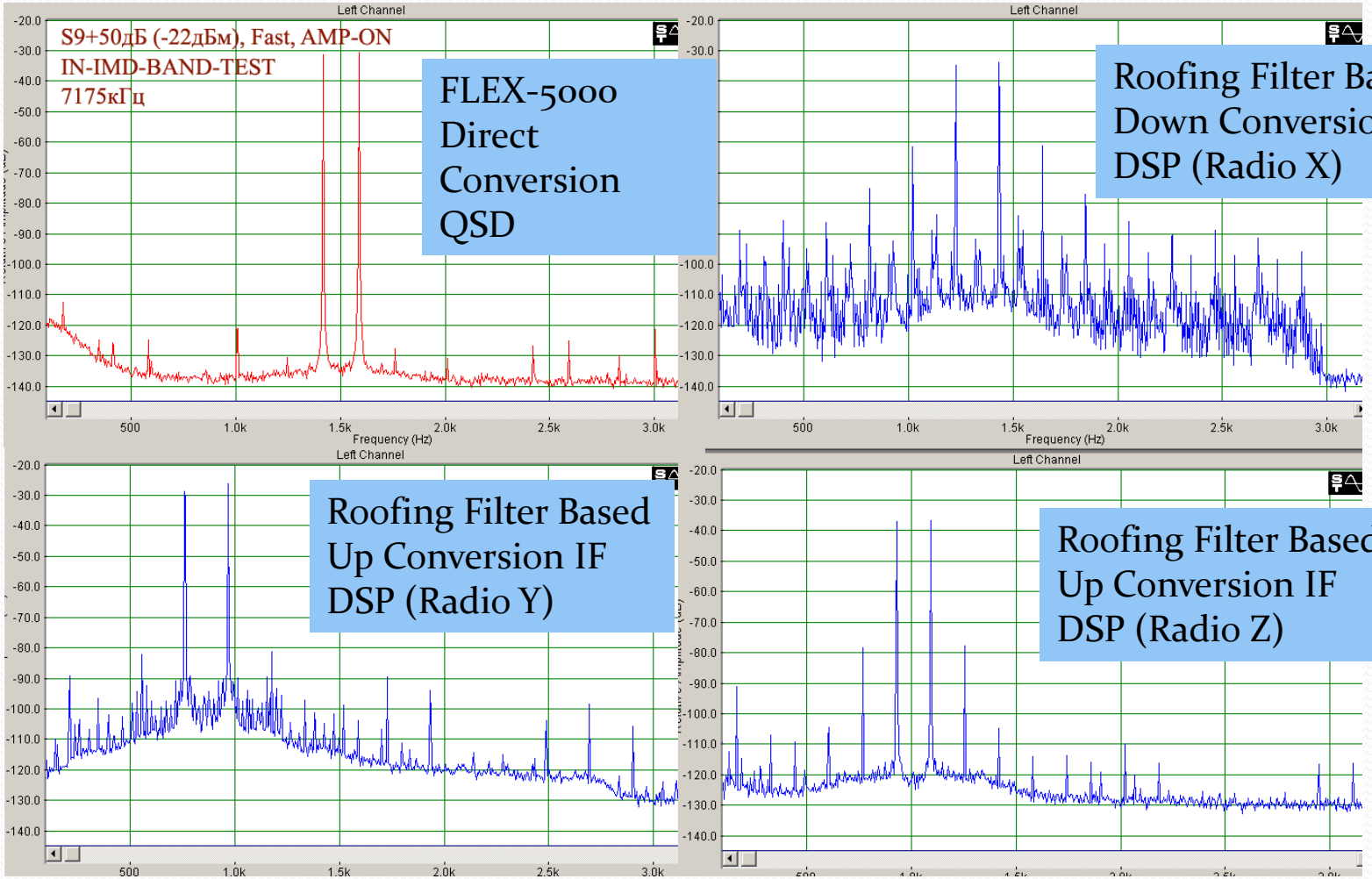
FLEX-5000 Shipped

FLEX-3000 Shipped

FLEX-1500 Shipped

Processor	Transistor count	Date of introduction	Manufacturer	Process
Intel 4004	2,300	1971	Intel	10 µm
Intel 8008	3,500	1972	Intel	10 µm
Intel 8080	4,500	1974	Intel	6 µm
Intel 8088	29,000	1979	Intel	3 µm
Intel 80286	134,000	1982	Intel	1.5 µm
Intel 80386	275,000	1985	Intel	1.5 µm
Intel 80486	1,180,000	1989	Intel	1 µm
Pentium	3,100,000	1993	Intel	0.8 µm
AMD K5	4,300,000	1996	AMD	0.5 µm
Pentium II	7,500,000	1997	Intel	0.35 µm
AMD K6	8,800,000	1997	AMD	0.35 µm
Pentium III	9,500,000	1999	Intel	0.25 µm
AMD K6-III	21,300,000	1999	AMD	0.25 µm
AMD K7	22,000,000	1999	AMD	0.25 µm
Pentium 4	42,000,000	2000	Intel	180 nm
Atom	47,000,000	2008	Intel	45 nm
Barton	54,300,000	2003	AMD	130 nm
AMD K8	105,900,000	2003	AMD	130 nm
Itanium 2	220,000,000	2003	Intel	130 nm
Cell	241,000,000	2006	Sony/IBM/Toshiba	90 nm
Core 2 Duo	291,000,000	2006	Intel	65 nm
AMD K10	463,000,000/758,000,000[1]	2007	AMD	65 nm
Itanium 2 with 9MB cache	592,000,000	2004	Intel	130 nm
Core i7 (Quad)	731,000,000	2008	Intel	45 nm
POWER6	789,000,000	2007	IBM	65 nm
Six-Core Opteron 2400	904,000,000	2009	AMD	45 nm
Six-Core Core i7	1,170,000,000	2010	Intel	32 nm
Dual-Core Itanium 2	1,700,000,000[2]	2006	Intel	90 nm
Six-Core Xeon 7400	1,900,000,000	2008	Intel	45 nm
Quad-Core Itanium Tukwila	2,000,000,000[3]	2010	Intel	65 nm
8-Core Xeon Nehalem-EX	2,300,000,000[4]	2010	Intel	45 nm

200 Hz In-Band IMD Comparisons



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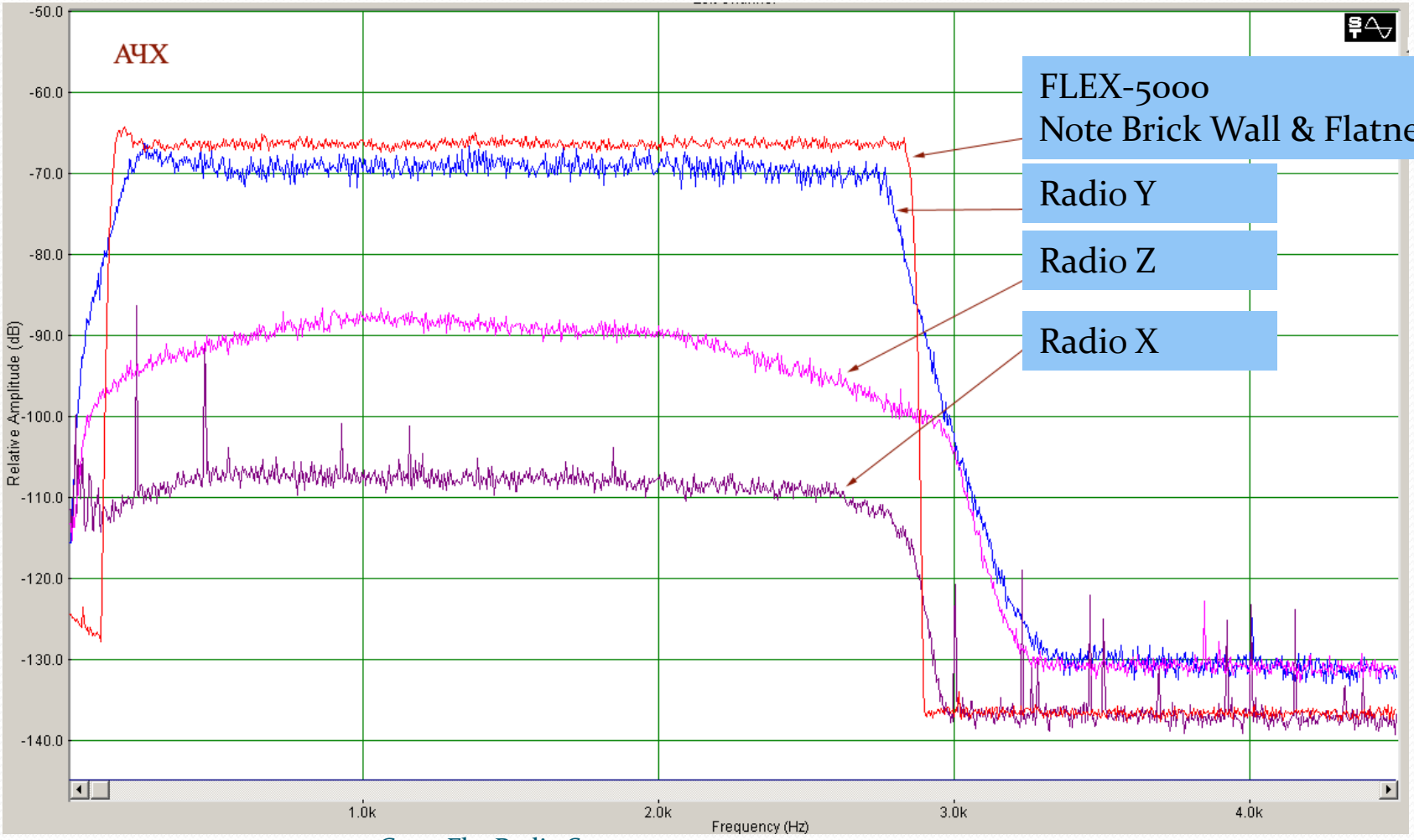
Filter Shape Factor



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New Products for 2010

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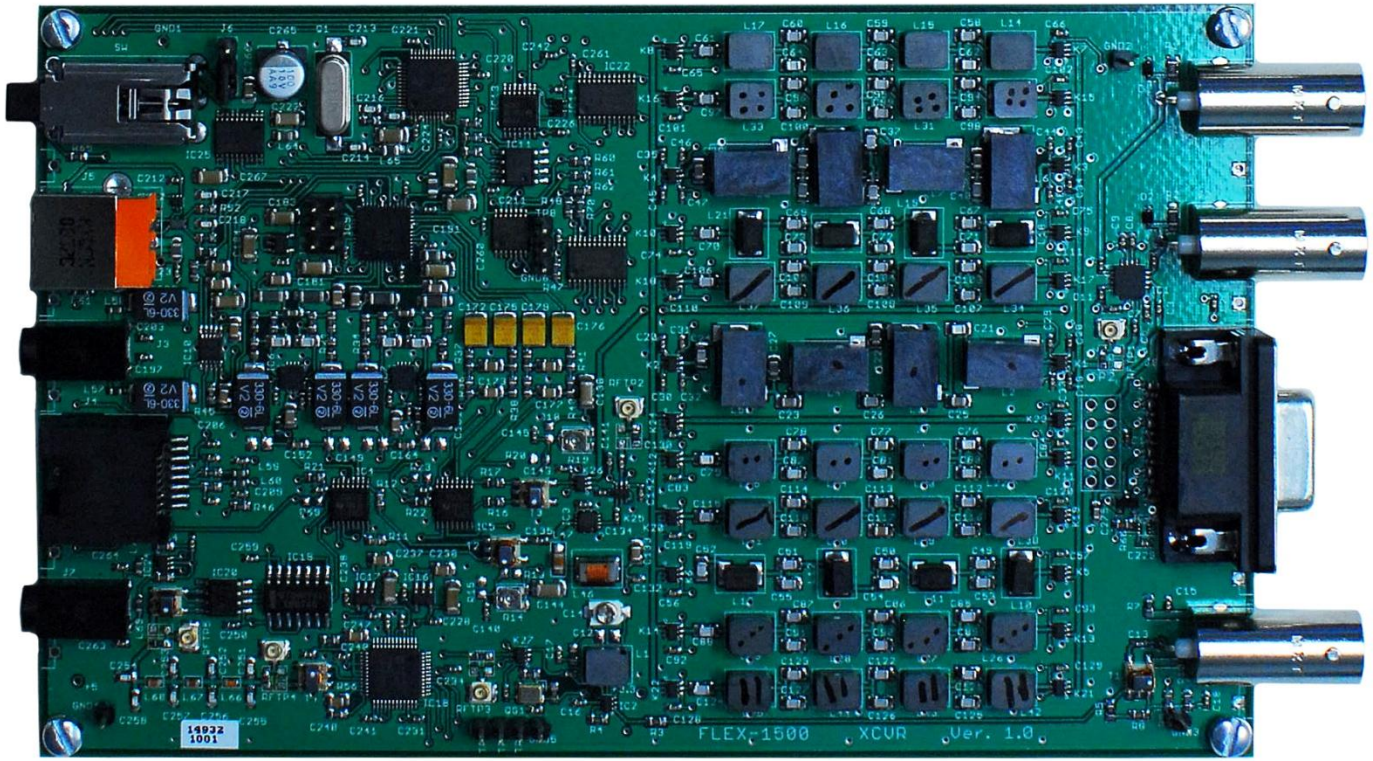
Introducing the FLEX-1500

- 160-6m
- 48 kHz Panadapter
- >80 dB IMD DR3
- All Mode
- 5W PEP & CW
- 0 dBm Transverter IF
- 10 MHz Ref. Input
- USB Interface
- Only 1.2 Pounds
- 4” W x 6” D x 2” H

FLEX-1500 Transceiver Board



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Introducing PowerSDR™ 2.0

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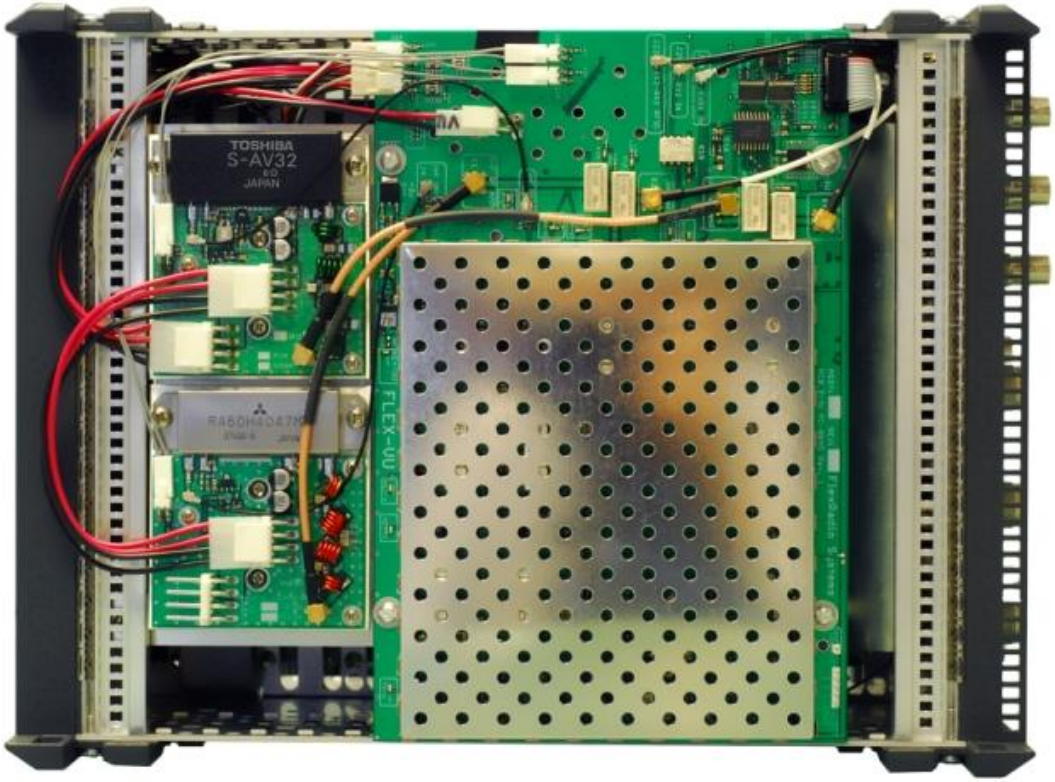
FLEX-VU5k VHF/UHF Upgrade for FLEX-5000



- 2 m and 70 cm
- All Mode Operation
- Cross Band Full Duplex
- Satellite Modes B & J
- 60W Output
- +17 dBm Option
- Reference Locked LOs
- Dedicated V & U BNCs

Radios that just keep getting better.™

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