Software Defined Radio:
State-of-the-Art & State-of-the-Future

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www.nparc.org & www.facebook.com/pages/New-Providence-Amateur-Radio-Club-NPARC/246739605343910

Updated for the Tri-County Radio Association (TCRA), February 16, 2015
www.w2li.org & www.facebook.com/groups/600921446630849

Software Defined Radio: State-of-the-Art & State-of-the-Future

This presentation was inspired by two, standing-room-only forums at the 2014 ARRL National Centennial Convention, but the content extends well beyond those two presentations alone:

“SDR Advances and the Future of SDR”

by Stephen Hicks, N5AC, FlexRadio VP of Engineering

Amateur use of Software Defined Radio (SDR) has gained substantial momentum in the last few years. Many new and exciting SDR radios are being introduced every year from a variety of vendors. This session explores new, emerging and future SDR technologies, demonstrating the secrets behind the technologies, how they advance Amateur Radio, and how the audience can use each technology to increase their operational effectiveness. The session concludes with an exploration of where SDR technology is likely to take Amateur Radio and what it means for today’s operators.

“Software Defined Radio for Beginners”

by Stephen Hicks, N5AC, FlexRadio VP of Engineering

This introduction to Software Defined Radio (SDR) explores the architectural and operational differences in traditional and software defined radios. The early foundations of SDR are used to briefly demonstrate the basics of SDR. Following this, an exploration of different SDR technologies and their capabilities will be discussed with an emphasis on educating the audience on how the technologies work and how they can use each technology to achieve their operational (on the air) goals.

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Software Defined Radio: State-of-the-Art & State-of-the-Future

The ARRL forums were not recorded. HRN by Gary Pearce KN4AQ conveys their flavor:

Ham Radio Now Episode 36: FlexRadio - SDR Architectures for Digital Communication
with Stephen Hicks, N5AC, FlexRadio VP of Engineering, http://youtu.be/xCdxAmMsoC4

Ham Radio Now Episode 61: Software Defined Radio Basics with FlexRadio
with Greg Jurrens K5GJ, FlexRadio VP of Sales & Marketing, http://youtu.be/yj44qGVjIkw

Ham Radio Now Episode 115 from the DCC: FlexRadio 6000 Update
with Stephen Hicks N5AC, FlexRadio VP of Engineering, http://youtu.be/UyXZn5ppYpk

Ham Radio Now Episode 146: FlexRadio 6300 Intro at Dayton
with Greg Jurrens K5GJ, FlexRadio VP of Sales & Marketing, http://youtu.be/SQkaLJiK92w

Ham Radio Now Episode 164 a&b: FlexRadio Open API & Waveform API at the DDC
with Stephen Hicks N5AC & Steve Bible N7HPR, http://youtu.be/LuWaStI0GgI & http://youtu.be/lOvBo6Lq_Jk

Ham Radio Now Episode 187: The "Accidental" Company; The Making of FlexRadio at the DDC
with Gerald Youngblood K5SDR, FlexRadio Founder, President & CEO, http://youtu.be/HBlkinewdHM

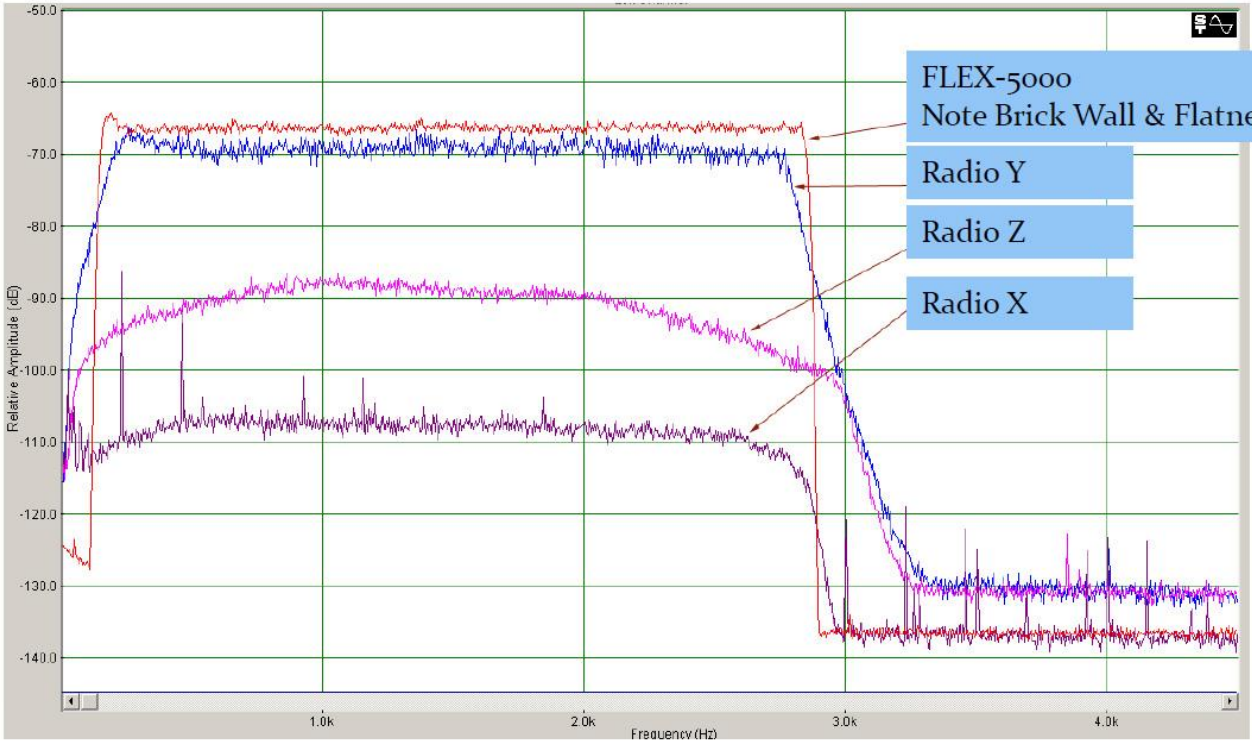
What Is A Software Defined Radio?

- Modulation and Demodulation modes in software, so they are changeable and new ones can be added.
- Signal Processing in Software, so it is changeable and expandable.
- Control Surface, whether a computer display or physical encoders, is Reconfigurable in software.
- Can Add New Features and Capabilities with new controls to operate them completely in software.
- Radio is Controlled by Software and is very likely networked. An API may be available.

What Are The Benefits Of A Software Defined Radio?

- Everything previously mentioned is reprogrammable in software. Flex RF Tracking Notch Filter™ is one example. Others later.
- Added features and added receivers only require more processing power, not physical components.
- “Small Pipe” designs allow full receive and transmit operation from smartphones or tablets, as well as computers.
- Tremendous dynamic range makes AGC and variable gain obsolete.
- Ideal component simulation with better performance. Example: Analog filters are ~2-30 poles. Digital can be ~100-2000 poles. See next slide.
- FPGA (Field programmable gate array) designs → Massive computing power → Sophisticated, high-performance designs. See following slide.

Digital Brick Wall SSB Filter: A Nearly Perfect Shape Factor



The digitally-implemented Flex-5000 2.8 KHz wide SSB Filter shows nearly ideal “brick wall” skirts compared to analog designs.

The top of the curve is nearly flat compared with a 12 dB hump in one analog design.

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Computing Power Cost Versus Time And Technology

The Flex-6700 Xilinx Virtex-6 FPGA technology is far more cost effective per GFLOP of processing power than a state-of-the-art desktop PC!

Name	Year	Cost	# GFLOPS	Cost/GFLOP
Cray-1	1976	$5M	0.08 GFLOPS	$62M/GFLOP
Cray-2	1985	$17M	3.9 GFLOPS	$4.3M/GFLOP
Cray X1	2002	$2.5M	205 GFLOPS	$12K/GFLOP
Intel i7-Hex Core	**2012**	**$3.3K**	**4-8 GFLOPS**	**$412-825/GFLOP**
Flex-6700	2012	$7K	121 GFLOPS	$57.84/GFLOP

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Transceiver And Receiver Architectures

- Multi-Conversion (Triple Or Dual Conversion Superheterodyne)

Car radios; TVs; Older Scanners; Elecraft K2 & K3 transceivers; most Icom, Kenwood, Ten-Tec and Yaesu transceivers ($100-$12K)

- SDR VHF/UHF >1 MHz Bandwidth Digital Receivers And Transceivers

DVB-T Dongles [R820T or E4000 receiver, RTL2832U USB demodulator] ($15), HackRF transceiver ($299), usable with the Ham It Up v1.2 Upconverter ($45 + optional $20 case)

- SDR Direct Conversion (One Analog Down Conversion To “Audio” Baseband)

Flex-5000 ($2,799 discontinued), Elecraft KX3 ($1K) optional PX3 panadapter ($500)

- SDR Direct Sampling With A “Large Pipe” Interface (Sampling At Antenna)

TAPR HPSDR (~$2K-3K), TAPR Hermes ($895), Apache Labs ANAN-100B ($1850), HiQSDR

- SDR Direct Sampling With “Small Pipe” Interface → VERY Powerful FPGA

Flex-6300 ($2,499), Flex-6500 ($4,299), Flex-6700 ($7,499)

Multi-Conversion (Triple Or Double Conv Superheterodyne)

The diagram shows Triple Conversion stages which have three sources of distortion.

Regarding the Icom IC-7600 (below), the Icom website states: “When compared to a typical triple-conversion system, the double-conversion system is more difficult to implement, but it dramatically reduces signal distortion and provides a high-fidelity RF signal to the DSP processor.”

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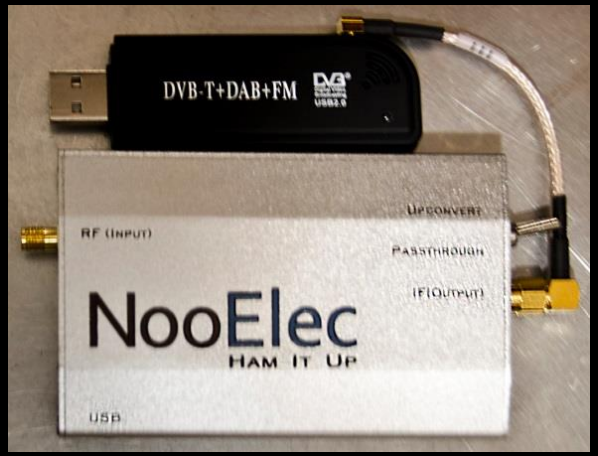
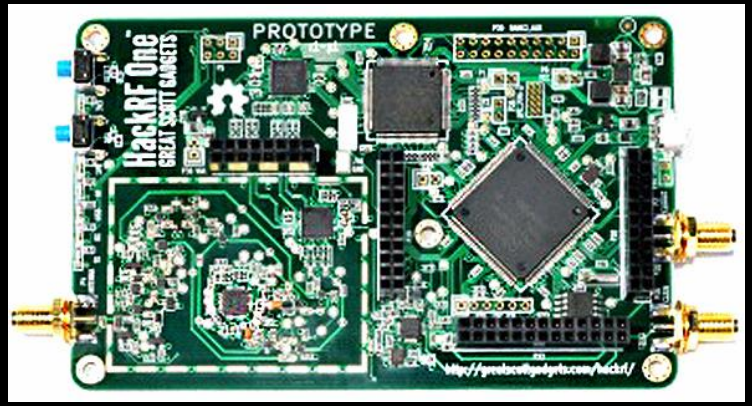
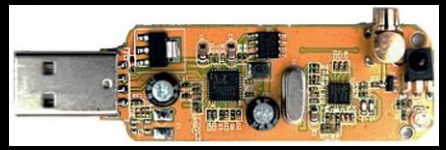
VHF/UHF >1 MHz Bandwidth Digital Transceivers & Receivers







A category for SDR things not easily classified, cell phone towers, too.

- DVB-T USB dongles, originally designed for European digital TV, cover 30-50 MHz to 1.2-2.2 GHz with 2.8 MSPS rates, 8 bit.
- The HackRF covers 10 MHz to 6 GHz with 20 MSPS rates, 8 bit. Mike Ossman SDR video series at: http://greatscottgadgets.com/sdr.
- The Ham It Up board v1.2 upconverts signals by 125 MHz, providing coverage of the ham HF bands for the above units.

Great for security studies, Wi-Fi, Bluetooth, GPS, 4G, radar, police, fire, 800 MHz trunking, aircraft ACARS flight paths, NOAA weather maps, radio astronomy, FM radio, rig monitoring and much more!

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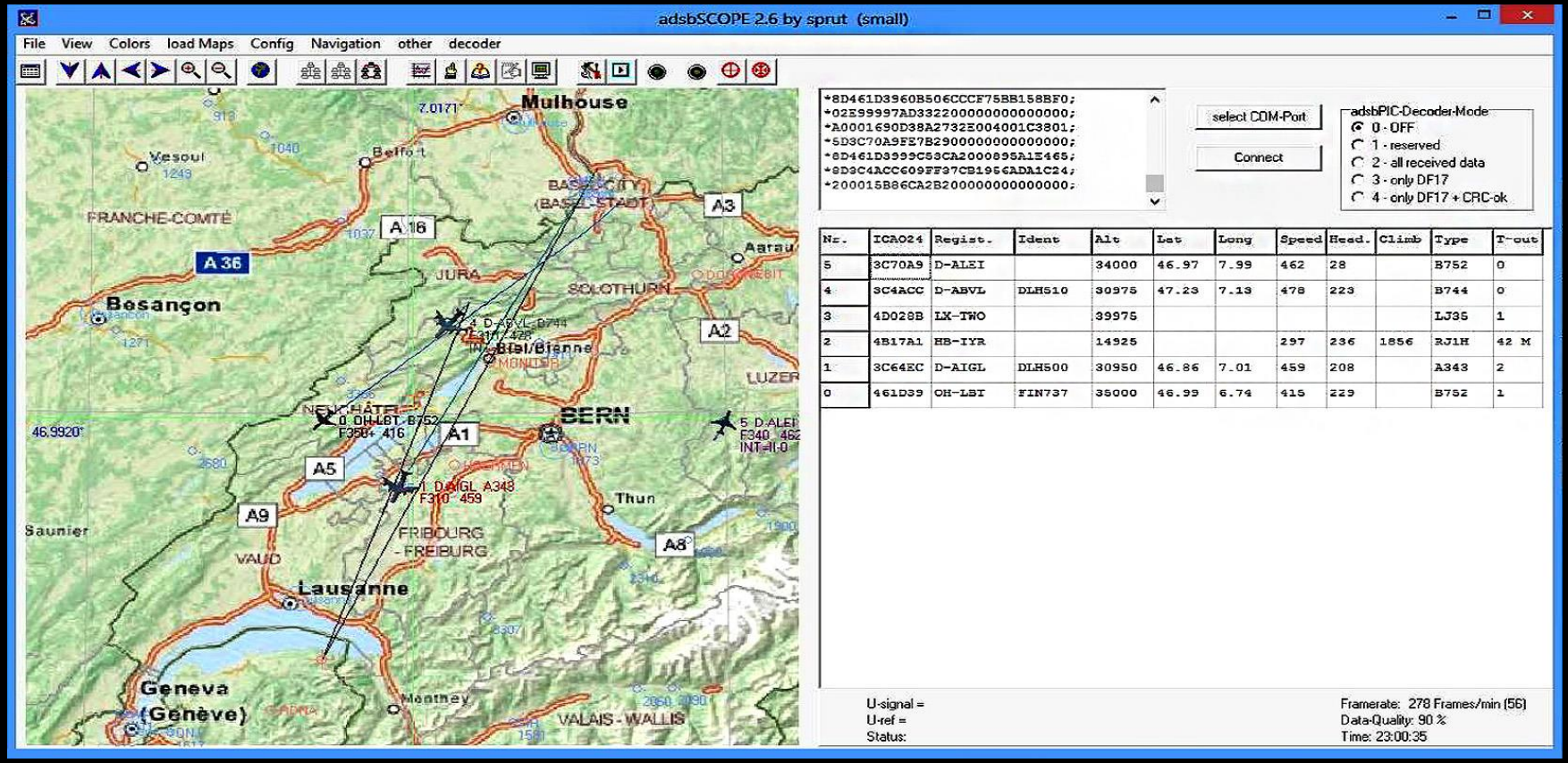
Aircraft Flight Tracking: A ‘Gee-Whiz’ Application Of $15 DVB-T Dongles



Nr.	ICAO24	Regist.	Ident	Alt	Lat	Long	Speed	Head.	Climb	Type	T-out
5	3C70A9	D-ALEI		34000	46.97	7.99	462	28		B752	0
4	3C4ACC	D-ABVL	DLH510	30975	47.23	7.13	478	223		B744	0
3	4D028B	LX-TWO		39975						LJ35	1
2	4B17A1	HB-IYR		14925			297	236	1856	RJ1H	42 M
1	3C64EC	D-AIGL	DLH500	30950	46.86	7.01	459	208		A343	2
0	461D39	OH-LBT	FIN737	35000	46.99	6.74	415	229		B752	1

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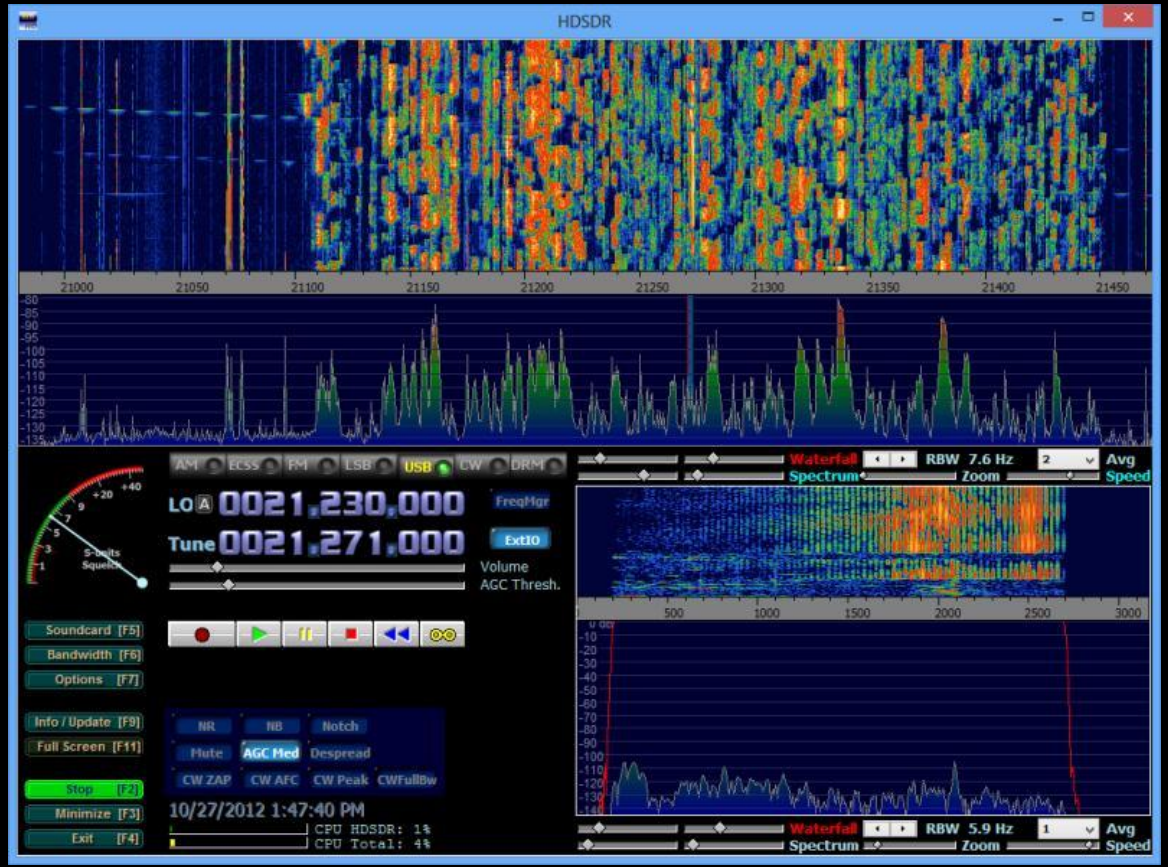
HDSDR Software Runs With Almost All SDR Hardware



The top waterfall display scrolls upward with time displaying signals in colors ranging from blue to red for increasing signal strength. Below that is spectral amplitude versus frequency. On the bottom right these displays are repeated with different frequency and time scales.

An S-Meter and frequency readouts (L0 and Tune) are on the middle left. Below that are various buttons and sliders, some of which open drop-down menus, thereby accessing the transceiver control functions.

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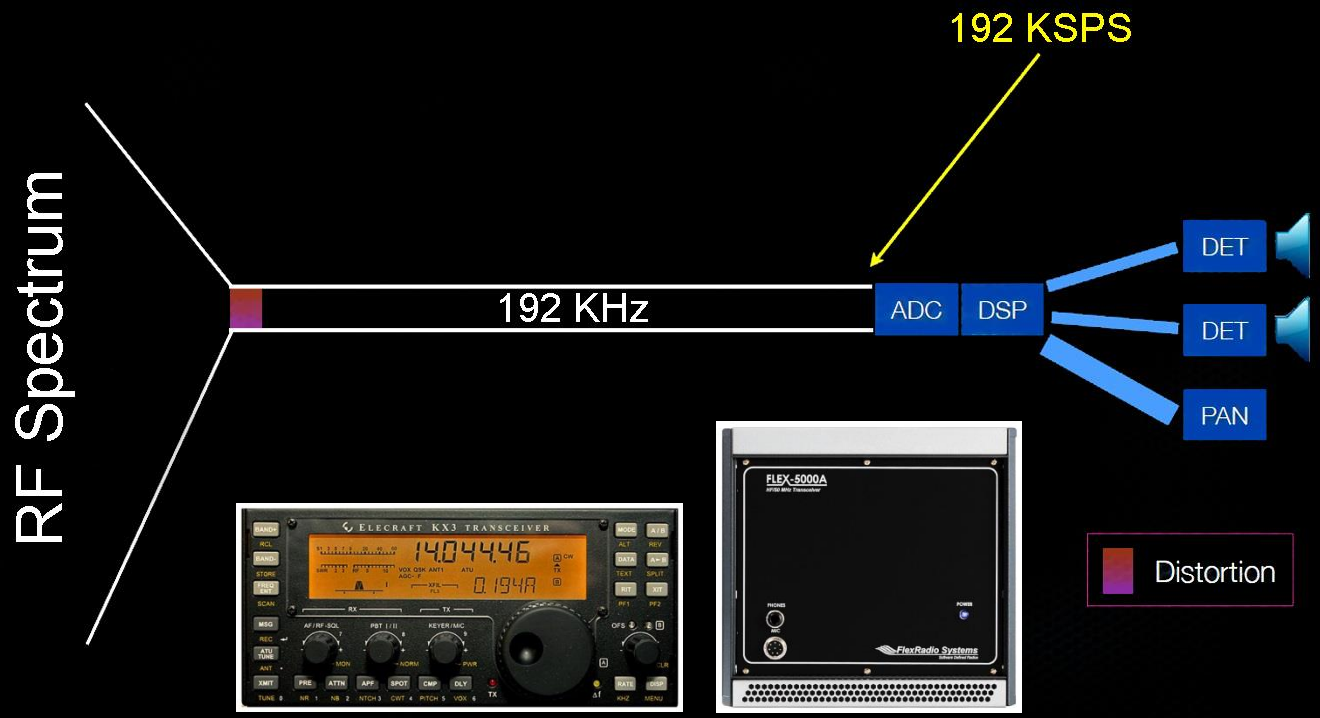
SDR Direct Conversion (One Down Conversion To Baseband)



With only one analog down conversion before digitizing the signals, there is less opportunity to introduce distortion than in the multi-conversion design.

The Elecraft KX3 (left) and Flex-5000 (right) are examples of Direct Conversion SDRs.

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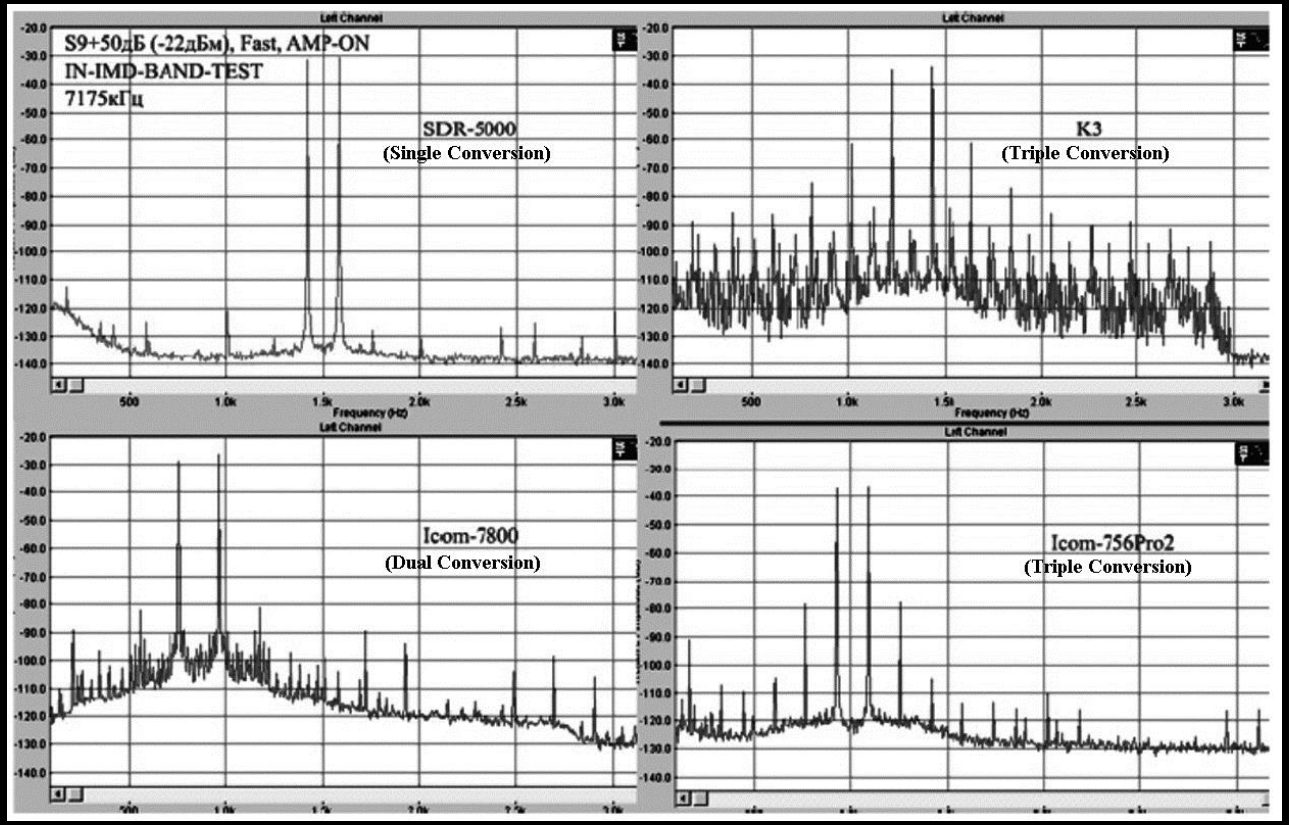
Sherwood Engineering IMD Tests On Four Transceivers



Two frequencies separated by 200 Hz induce Inter-modulation Distortion (IMD) spurs at second and third harmonic frequencies.

As the number of conversions decreases from three (ur, lr) to two (ll) to one (ul), the spurs lie further and further below the main peak amplitude.

Not shown is the similar reduction of the phase noise, important for reducing background noise from strong adjacent signals.

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SDR Direct Conversion (One Conversion To Baseband)

A (recently-discontinued) Flex-5000 is shown on display at the ARRL Testing Labs. It covers 10 KHz to 60 MHz. A Firewire interface transfers data with sampling rates of 192 KHz per receiver to the computer. Sometimes sufficient computer processing power or Firewire interface incompatibilities are issues.

An Elecraft KX3 covers 310 KHz to 54 MHz + 2m with dual receive over +/- 15 KHz. Its optional PX3 Panadapter can span up to 200 KHz. A computer is not required, however receiver IQ outputs are available to drive a computer-based audio interface and the PX3.

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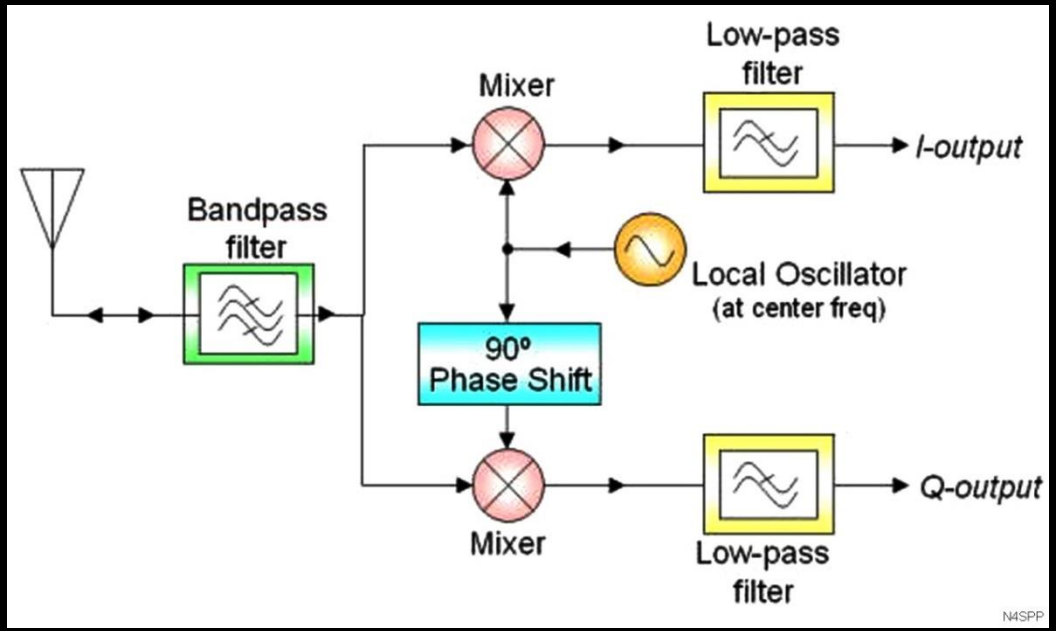
SDR Direct Conversion Receive Simplified Block Diagram



This illustrates down-converted, baseband IQ signals for the SDR being generated by analog hardware. Hardware following this converts them into the digital domain, most often sampling at 192 KHz or 96 KHz:

- A pair of ADCs is connected to a DSP or FPGA within the box for full local analysis (Elecraft KX3),
- The outputs of digitizers within the box are sent to a computer over USB, Firewire (Flex-5000), or Ethernet, OR
- Very frequently a stereo audio interface attached to a computer digitizes the signals (a secondary Elecraft KX3 mode).

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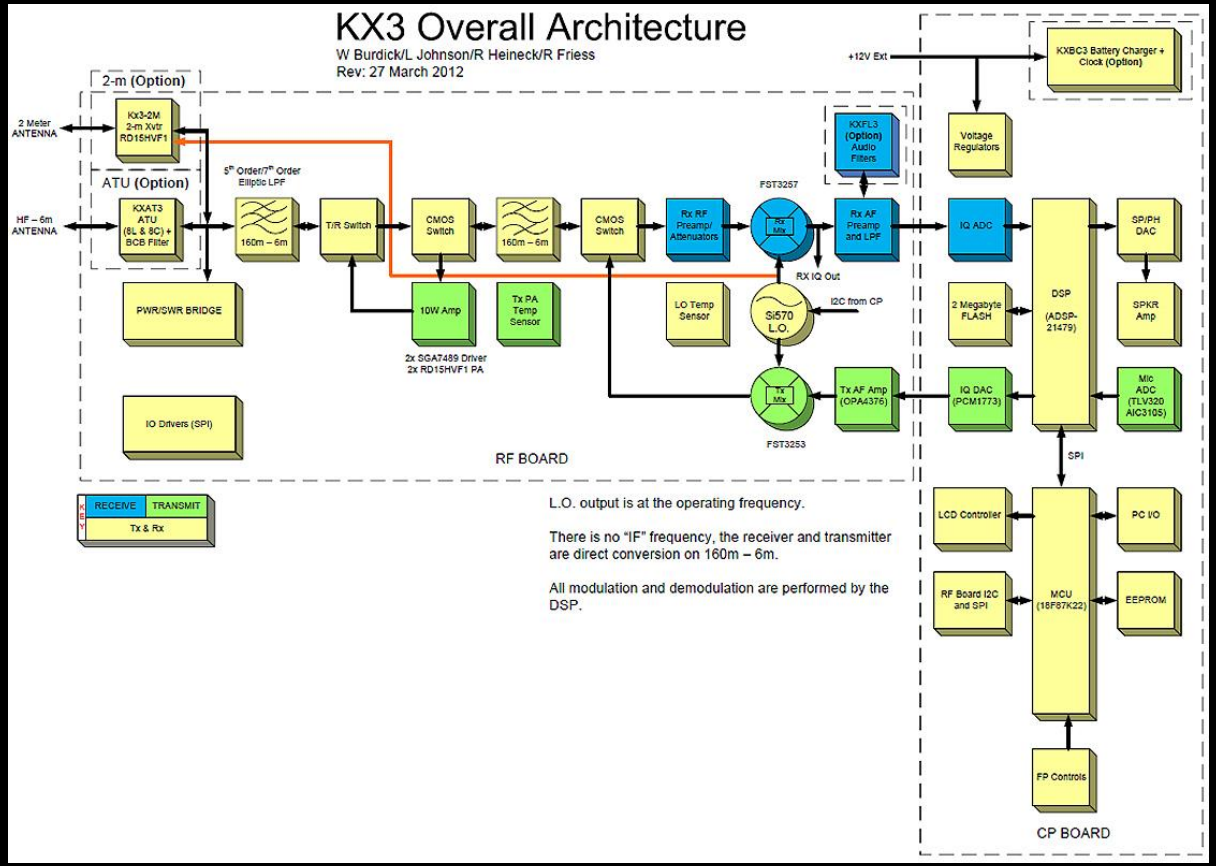
Elecraft KX3 Block Diagram (SDR Direct Conversion)



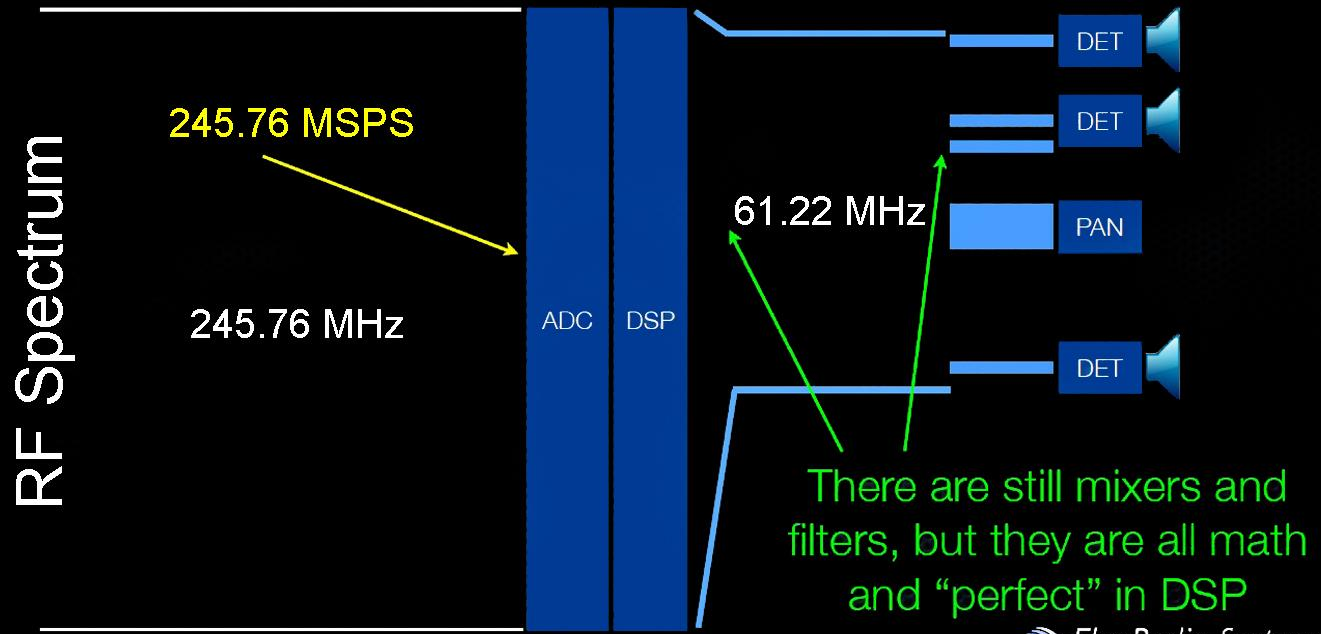
Unlike many other Direct Conversion SDRs, the high-performance Elecraft KX3 incorporates a powerful ADSP-21479 32-bit floating point DSP and an 18F87K22 MCU so it can work independently of a PC.

Many designs stop at the IQ signals relying on an audio interface, the PC and a program such as HDSDR for the digital signal processing. The KX3 can do that too, having receive IQ outputs for a PC and the PX3 panadapter.

SDR Direct Conversion Characteristics

- Greatly improved linearity compared to Superheterodyne designs.
- Distortion is minimized with only one mixer. The clear signal sounds better and creates less operator fatigue since it has less in-band distortion.
- They have a high dynamic range and lower phase noise.
- The panadapter displays reasonably-wide bandwidths up to 192 KHz. However, Direct Sampling designs are capable of far wider bandwidths.
- They require small amounts of power. They excel in portable applications.
- Near-in images can’t be rejected with traditional band reject filters.
- Specialized Automated WBIR (Wideband Image Rejection) software eliminates the image rejection problem, nulling images to the noise floor.

Direct Sampling (No Analog Conversions-ADC At The Antenna)



In SDR Direct Sampling designs, the signal is digitized at the antenna, so there are no analog conversion stages to introduce distortion.

Processing of the data may be at the computer ("Large Pipe") or within the box ("Small Pipe") .

The Flex-6700 (shown above) is a Direct Sampling "Small Pipe" transceiver, the current state-of-the-art.

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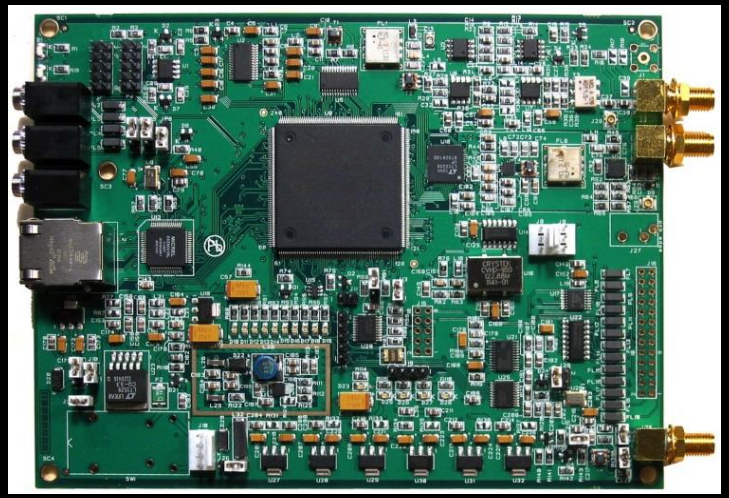
SDR Direct Sampling With A “Large Pipe” Interface



TAPR (Tucson Amateur Packet Radio) HPSDR boards (upper left) were integrated into one TAPR Hermes board (upper right) for cost reduction. The power amplifier, LPF, antenna tuner/ switching board is not shown.

An Indian company, Apache Labs, now manufactures the TAPR Hermes board, later incorporated into the ANAN-100D (below), and advanced spinoffs such as the Angelica board and ANAN-200 series.

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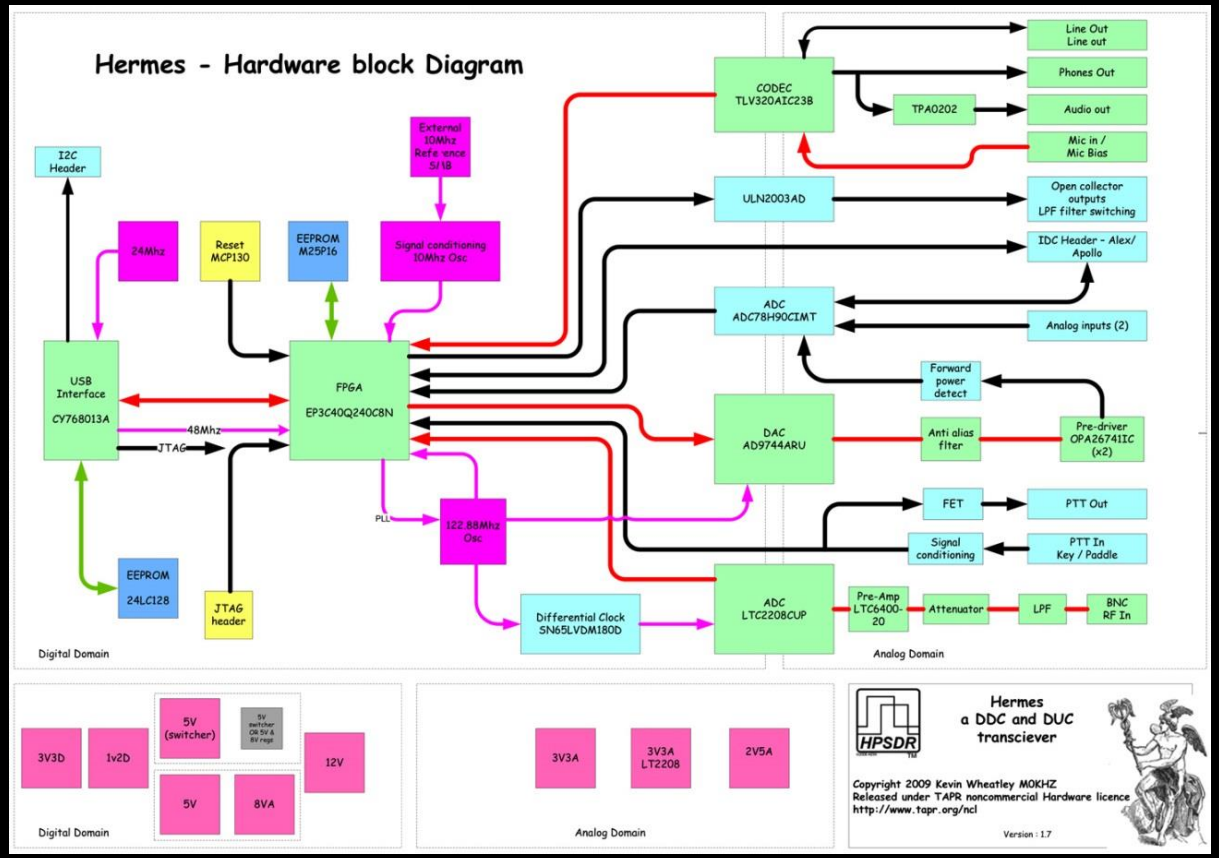
TAPR Hermes Block Diagram (Direct Sampling “Large Pipe”)



The TAPR Hermes 8-layer PCB is full-duplex, covering 10 KHz to 55 MHz, supporting 7 independent receivers each displaying 48, 96 or 192 KHz of spectrum. It uses a 122.88 MHz master clock for a 16-bit ADC.

The “Large Pipe” carries a high data rate to the computer for analysis, display and control.

Altera EP3C40Q240C8N FPGA code can be updated via Ethernet.

The power amplifier, LPF and antenna tuner/switching board is available separately.

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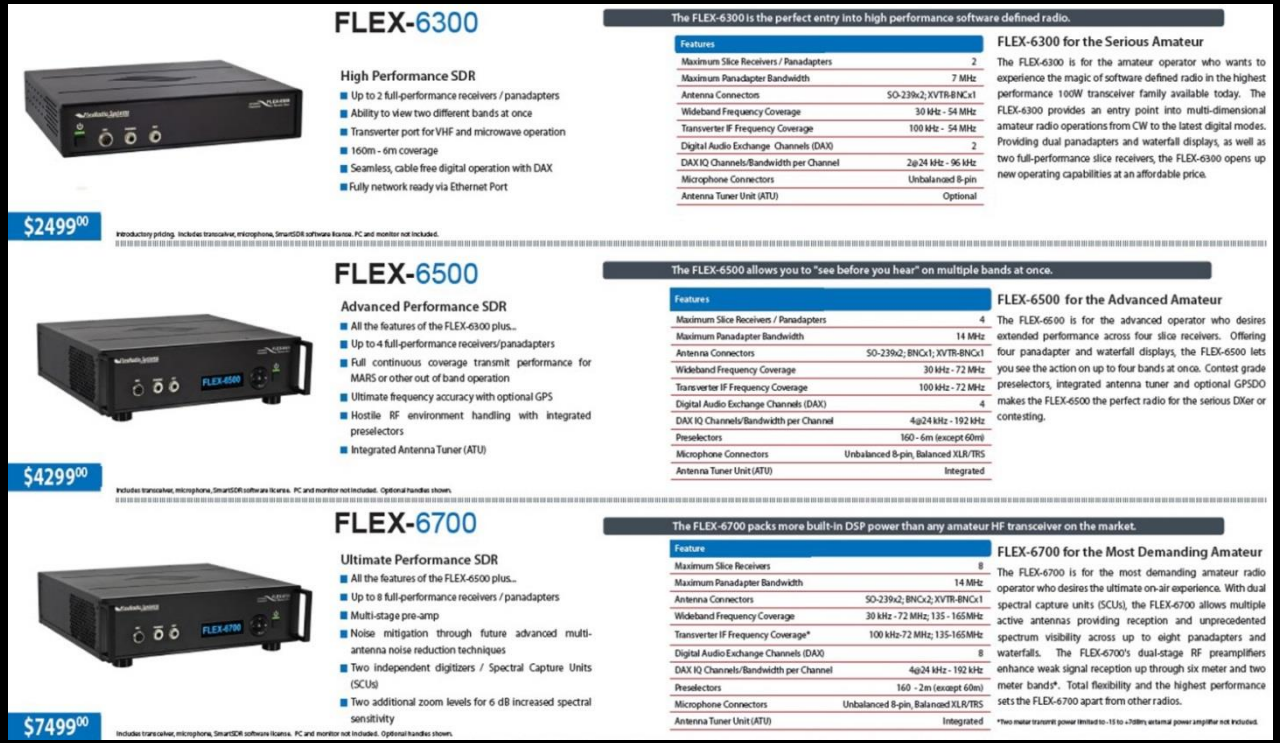
SDR Direct Sampling With A “Small Pipe” Interface



FLEX-6300

High Performance SDR

- Up to 2 full-performance receivers / panadapters
- Ability to view two different bands at once
- Transverter port for VHF and microwave operation
- 160m - 6m coverage
- Seamless, cable free digital operation with DAX
- Fully network ready via Ethernet Port

$2499.00

Introductory pricing. Includes transceiver, microphone, SmartSDR software license. PC and monitor not included.

The FLEX-6300 is the perfect entry into high performance software defined radio.

Features	
Maximum Slice Receivers / Panadapters	2
Maximum Panadapter Bandwidth	7 MHz
Antenna Connectors	SO-239x2; XVTR-BNCx1
Wideband Frequency Coverage	30 kHz - 54 MHz
Transverter IF Frequency Coverage	100 kHz - 54 MHz
Digital Audio Exchange Channels (DAX)	2
DAX IQ Channels/Bandwidth per Channel	2@24 kHz - 96 kHz
Microphone Connectors	Unbalanced 8-pin
Antenna Tuner Unit (ATU)	Optional

FLEX-6300 for the Serious Amateur

The FLEX-6300 is for the amateur operator who wants to experience the magic of software defined radio in the highest performance 100W transceiver family available today. The FLEX-6300 provides an entry point into multi-dimensional amateur radio operations from CW to the latest digital modes. Providing dual panadapters and waterfall displays, as well as two full-performance slice receivers, the FLEX-6300 opens up new operating capabilities at an affordable price.

FLEX-6500

Advanced Performance SDR

- All the features of the FLEX-6300 plus...
- Up to 4 full-performance receivers/panadapters
- Full continuous coverage transmit performance for MARS or other out of band operation
- Ultimate frequency accuracy with optional GPS
- Hostile RF environment handling with integrated preselectors
- Integrated Antenna Tuner (ATU)

$4299.00

Includes transceiver, microphone, SmartSDR software license. PC and monitor not included. Optional handles shown.

The FLEX-6500 allows you to "see before you hear" on multiple bands at once.

Features	
Maximum Slice Receivers / Panadapters	4
Maximum Panadapter Bandwidth	14 MHz
Antenna Connectors	SO-239x2; BNCx1; XVTR-BNCx1
Wideband Frequency Coverage	30 kHz - 72 MHz
Transverter IF Frequency Coverage	100 kHz - 72 MHz
Digital Audio Exchange Channels (DAX)	4
DAX IQ Channels/Bandwidth per Channel	4@24 kHz - 192 kHz
Preselectors	160 - 6m (except 60m)
Microphone Connectors	Unbalanced 8-pin, Balanced XLR/TRS
Antenna Tuner Unit (ATU)	Integrated

FLEX-6500 for the Advanced Amateur

The FLEX-6500 is for the advanced operator who desires extended performance across four slice receivers. Offering four panadapter and waterfall displays, the FLEX-6500 lets you see the action on up to four bands at once. Contest grade preselectors, integrated antenna tuner and optional GPSDO makes the FLEX-6500 the perfect radio for the serious DXer or contesting.

FLEX-6700

Ultimate Performance SDR

- All the features of the FLEX-6500 plus...
- Up to 8 full-performance receivers / panadapters
- Multi-stage pre-amp
- Noise mitigation through future advanced multi-antenna noise reduction techniques
- Two independent digitizers / Spectral Capture Units (SCUs)
- Two additional zoom levels for 6 dB increased spectral sensitivity

$7499.00

Includes transceiver, microphone, SmartSDR software license. PC and monitor not included. Optional handles shown.

The FLEX-6700 packs more built-in DSP power than any amateur HF transceiver on the market.

Feature	
Maximum Slice Receivers	8
Maximum Panadapter Bandwidth	14 MHz
Antenna Connectors	SO-239x2; BNCx2; XVTR-BNCx1
Wideband Frequency Coverage	30 kHz - 72 MHz; 135 - 165MHz
Transverter IF Frequency Coverage*	100 kHz-72 MHz; 135-165MHz
Digital Audio Exchange Channels (DAX)	8
DAX IQ Channels/Bandwidth per Channel	4@24 kHz - 192 kHz
Preselectors	160 - 2m (except 60m)
Microphone Connectors	Unbalanced 8-pin, Balanced XLR/TRS
Antenna Tuner Unit (ATU)	Integrated

FLEX-6700 for the Most Demanding Amateur

The FLEX-6700 is for the most demanding amateur radio operator who desires the ultimate on-air experience. With dual spectral capture units (SCUs), the FLEX-6700 allows multiple active antennas providing reception and unprecedented spectrum visibility across up to eight panadapters and waterfalls. The FLEX-6700's dual-stage RF preamplifiers enhance weak signal reception up through six meter and two meter bands*. Total flexibility and the highest performance sets the FLEX-6700 apart from other radios.

*Two meter transmit power limited to ~15 to ~70Wm external power amplifier not included.

The Flex-6000 series covers 30 KHz to 72 MHz + 2m with one or two 345 MSPS 16-bit ADCs and 2 to 8 slice receivers covering bandwidths up to 14 MHz each.

A powerful Xilinx Virtex-6 FPGA performs DSP functions on board:

- A “Small Pipe” of ~0.5 MBPS flows to the PC to display the graphic interface and provide control functions,

NOT a “Large Pipe” of:

- 77 MBPS to display and process 1 MHz bandwidths
- 770 MBPS to display and process 10 MHz bandwidths.

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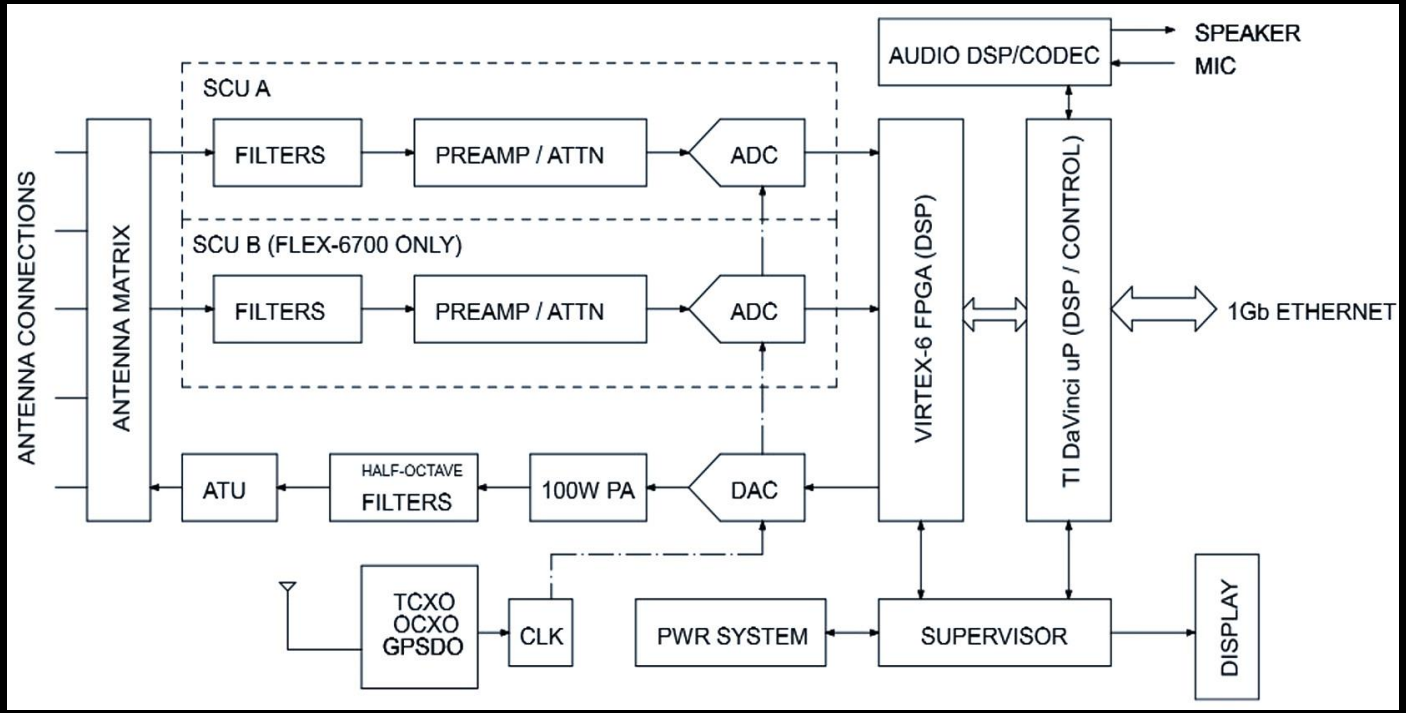
Flex-6000 Series Block Diagram (Direct Sampling “Small Pipe”)



The Gigabit Ethernet interface rapidly re-programs the Xilinx Virtex-6 XC6VLX130T FPGA and the TI TMS320C6A8167 DSP.

However, only a “Small Pipe” of ~0.5 MBPS is needed to display the real-time graphical interface and provide control functions for a smartphone, tablet or a computer.

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Direct Sampling Characteristics “Large Pipe” And “Small Pipe”

- Signal Distortion is minimized with the ADC at the antenna, yielding the best signal clarity of any design.
- N-Receivers and N-Panadapters with widely-varying bandwidths are available. We can view more bands with more receivers.
- The Dynamic Range is extremely high, allowing operation in the worst conditions.
- We have Extreme Flexibility through reprogrammibility. It is the ultimate SDR, as benefits continue to accrue into the future with upgraded software.
- Additionally, the low data rates of a “Small Pipe” design allow operation from smartphones and tablets, as well as reduced load upon a connected computer.
- Direct Sampling transceivers are technically challenging to design.

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Sherwood Labs Receive Performance Ranking - 12/9/2014

Rank	Company Model	Price	Design Architecture	Noise Floor [dbM]	Sensitivity [uV]	LO Noise [dBc/Hz]	Dynamic Range 3rd Wide Spaced [dB]	Dynamic Range 3rd Narrow Spaced [dB]
1	FlexRadio Flex-6700	$7,499	SDR	-118 -135*	2 0.25*	145 155	99	108
2	Hilberling PT-8000A r2.0	$15,168	Superhet Triple Conv	-128 -141*	0.45 0.11*	144 149	105	105
3	Elecraft KX3	$1,140	SDR	-123 -138*	0.9 0.09*	144	105	104
4	Yaesu FT DX-5000D	$5,700	Superhet Dbl/Trpl Conv	-123 -141*	1.1 0.13*	135	104	101
5	Elecraft K3	$2,540	Superhet Triple Conv	-130 -138*	0.33 0.19*	138	104	101
6	Microtelecom Perseus Receiver	$1,000	SDR	-123 -125*	0.8 0.6*	147	99	99
7	FlexRadio Flex-5000A	$2,799	SDR	-123 -135*	1.3 0.3*	123	96	96
8	Ten-Tec Orion II	$4,000	Superhet Triple Conv	-127 -133*	0.75 0.3*	126	95	95

*Measured with the preamplifier on, set to maximum gain.

Transceiver output powers range 100 to 200 watts, except the Elecraft KX3 which is 10 watts. The optional Elecraft KXPA100 100 watt amp costs $750.

Performances and prices are specified assembled with one optional roofing filter, no optional antenna tuners. The Microtelecom Perseus is receive only.

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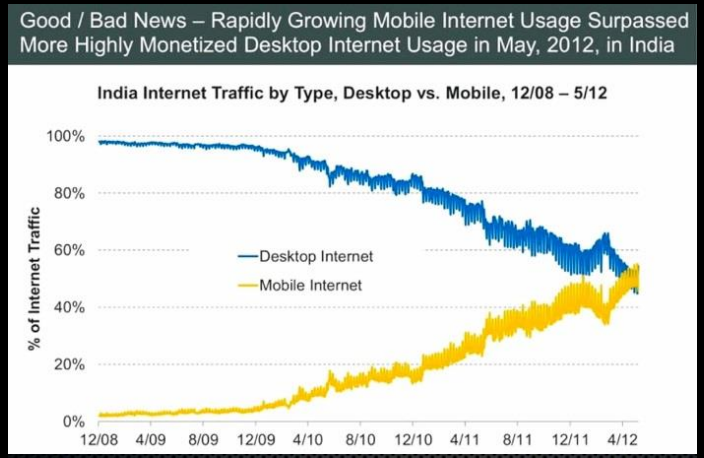
We Are Going Mobile And Want To Take Our Fun With Us!



In April 2012 50% of India's Internet traffic became mobile. USA lags their numbers by about two years.

Direct Sampling "Small Pipe" SDRs support powerful networking. The "Small Pipe" keeps the bandwidth manageable for smartphones and tablets. An iPad has already been integrated with the Flex-6000's.

A friend calls to say that Christmas Island station you have been after is on the air NOW! Try to rush home in time? NO! Work them from your smartphone!

In the future complete station control will be integrated into the SDR FPGA: linear amplifier control; antenna switching, tuning and rotation; logging software; etc. An API is already in place.

Contest Support And DX Chasing

Which bands are open and active? Watch them all with eight broadband spectral displays! A strongly-tuned antenna such as a SteppIR is only down 10 dB off-band. Still plenty of signal for all!

Found that rare DX station calling CQ? You have to QSY by the optimal amount to work it. Open a waterfall display to determine their reply strategy:

- Offset by a fixed frequency? Go there.
- Reply to the strongest station? Wait on their frequency until they finish.
- Rotate circularly between frequencies? You'll know which one is next.

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AE2JP

Auxiliary Interfaces And Remote Operations

The most universal complaint about SDRs which require a computer regards their slow, [mouse] “clicky” interface:

- At least two large contesting groups are devoting major engineering resources to contest-grade, nimble, efficient-workflow interfaces for Flex-6000 series SDRs. They have not made their results public!
- FlexRadio sells a FlexControl USB knob with three buttons, sometimes used in pairs by contesters.
- Contesters use Hercules USB DJ controllers as speedy SDR interfaces.
- The Elecraft K3/0-Mini + Remote Rig RRC-1258MkIIS boxes replicate the K3 front panel over the Internet. One company leases their (high-priced) antenna/K3 farm with them www.RemoteHamRadio.com. Similar physical SDR controllers (contest grade?) and SDR farms will be coming.
- http://websdr.org lists ~75 Internet-based, web browser-driven SDR receivers which permit simultaneous users to listen to and tune them.

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Phoenix Thunderbird ARC 2014 ARRL Field Day: Best Ever!

Operating more than one transmitter per band on Field Day is a challenge. Phase noise of transmitters and the receiver combine to elevate the noise floor of the receiver unacceptably. Low phase noise SDRs can mitigate that problem.

PTARC ran 4A: One Flex-6700 and three Flex-6300's. Respective phase noises of -148 dBc/Hz and -140 dBc/Hz allowed a huge reduction of the in-band noise. The screen shot is from the Flex-6700 running CW. It, a (literally) red-hot PSK31 Flex-6300 and an SSB Flex-6300 are all on 20m, each running 100W with antennas within 400 feet of the others. The PSK31 station 40m Carolina Windom at 65 feet was inside ~3 wavelengths of the CW station 80m Carolina Windom also at 65 feet. The CW station saw ZERO increase in the noise floor outside +/-20 KHz of the PSK31 signal!

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Baldock UK Monitoring Station: An Invitation To Innovation

by Michael Wells, G7VJR, QST August 2014 p. 99

Also see http://stakeholders.ofcom.org.uk/binaries/enforcement/spectrum-enforcement/baldock.pdf.

Over the past decade or two, we have become experts in dealing with interference by using increasingly elaborate DSPs in our receivers that help us operate with the context of man-made noise and congestion. But we have only just begun to explore the possibilities of DSPs right at the input—that is, DSP sampling directly from an antenna (i.e. Direct Sampling). Now that we have the computer power at our disposal, this is becoming a hot topic.

The possibilities of this receiver architecture are remarkable. I was lucky enough to tour the UK's radio monitoring station at Baldock, Cambridgeshire, part of a network of listening posts that can be used to combat spectrum abuse, including on the HF bands. It has the capability of direction-finding signals, and through international coordination this can lead to fast, accurate location of rogue transmitters.

To my surprise, the antenna farm for the Baldock station is only a small field of ground-mounted monopoles! Each is connected to an independent DSP receiver and then to a computer. The timing and phase differences are analyzed in real-time, and then displayed as traces on a two-dimensional plot of azimuth and elevation.

This technology is within the reach of radio amateurs, an extremely powerful resource for our purposes.

Thoughts On Signal Processing

Power Amplifier Drive Adaptive Pre-distortion

Power amplifiers are one of the most non-linear components in modern transceivers. Analog LP filtering is required to meet FCC spurious emission regulations. If the I/O transfer function is measured, it is possible to pre-distort the input to linearize the output. HPSDR Pure Signal® developed by NR0V is the first iteration. Some speculate that LP filters may disappear. See http://video.openhpsdr.org/HRF2014/PureSignal1.2.mp4.

Higher Average Output Power On SSB Transmissions

SSB transmissions go out with 4.5 to 5 dB less average power than CW. Most voice compression and other audio processing schemes which significantly increase the average output power leave the audio sounding unacceptably artificial and mechanical. W9CRB provided FlexRadio with a new algorithm which they have coded and incorporated into the Flex-6000 series. It provides a 2.5 dB average power increase without sounding artificial.

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More Thoughts On Signal Processing

Receive Antenna Array Processing

Since the Flex-6700 has two ADCs, the inputs of two vertical monopole antennas can be combined in appropriate phases to provide a directional receive. Alternately, phase differences could provide directionality data for each signal received. An experimental version of HPSDR was written which does that. A second transmitter would allow directional output. How about a skimmer with directional information?

A Digital Voice Skimmer

Digital voice should be of sufficiently good quality for voice recognition tools. How about building a voice skimmer, similar to a CW skimmer? The fact that amateurs repeat information such as callsigns could improve the SNR.

An Everything Digital Skimmer

It should be possible to identify most all digital modes (PSK31, JT65, JT9, Olivia, Packet, RTTY, Hellschreiber, MFSK16, SSTV, BPSK, APRS, etc.) and decode them automatically.

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Thoughts On Noise And Interference Reduction

Keeping The Correlated Data

A separate antenna can be connected to each of two ADCs, both monitoring the same frequency. Actual received signals should be completely correlated. Uncorrelated components can be discarded as noise for a 3 dB SNR improvement.

Discarding The Correlated Data

If one ADC monitors a signal source and the other monitors a quiet portion of the band, then the signals should be completely uncorrelated. Correlated components would arise from broadband noise such as lightning, atmospheric disturbances, solar events or certain types of man-made interference. The correlated components can be discarded to improve the SNR.

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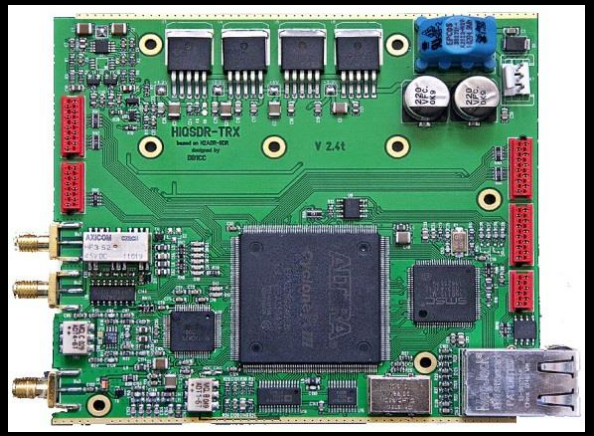
MIMO, Direction Finding And Beam Steering Musings



Multiple Input Multiple Output (MIMO) with digital domain phasing is ripe for amateur exploration, but expensive. A 4-square for directional receive has been built with toy-like DVB-T dongles for $60. A 4 x Flex-6500 4-Square costs a hefty $17.2K. Can we build four inexpensive, high-performance transceivers supporting only one slice receiver and transmitter each?

The HiQSDR is a Direct Sampling "Large Pipe" with a reasonably-priced Altera EP3C25Q240C8N FPGA, covering 30 KHz through 62 MHz using a 125 MHz 14-bit ADC and DAC (but 16 bits are nicer!). The data rate is 46.08 MBPS for a 960 KHz BW. Is it much cheaper than the $895 TAPR Hermes? Is it good enough? Combine units for a Field Day 4-Square? See http://hiqsdr.com/hiqsdr-wiki/, http://hiqsdr.com/download/presentation/HiQSDR_Vortrag_English.pdf, http://dl2stg.de/stefan/hiqsdr/index.html, http://james.ahlstrom.name/transceiver/, https://groups.yahoo.com/neo/groups/n2adr-sdr/info and http://www.arrl.org/files/file/QEX_Next_Issue/Jan-Feb_2011/QEX_1_11_Ahlstrom.pdf.

Another idea: Build the Hermes (or core processing of a Flex 6500, if needed) with four ADCs and four DACs. How much processing power do we actually need? What existing software is reusable? Writing from scratch is overwhelming. 4 x inexpensive Packer power amps sum to 140W. Interesting thoughts?

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State-of-the-Art & State-of-the-Future -- Part I

- SDR designs are converging on Direct Sampling which has no analog frequency conversions. It is scalable, has the highest performance and a small parts count. Powerful FPGAs (or DSPs) manage the high data rates in "Large Pipe" designs and even more powerful ones in "Small Pipe" designs.
- Direct 345.76 MHz Sampling, multiple receiver slices & ADCs, and a "Small Pipe" interface is the current state-of-the-art. Users rave that they are like nothing else! Multiple transmitters and more ADCs (MIMO) are the future.
- Networking is becoming a must. "Small Pipe" ~0.5 MBPS data rates enable mobile smartphone and tablet display and control. Super-powerful FPGAs, which permit this, are dropping in cost. The best-in-class design has 65% of the processing power unused and provides an API, allowing for upgrades, innovation and integration. User-created applications will flourish.

State-of-the-Art & State-of-the-Future -- Part II

- All transmission modes, analog or digital, will be identified, decoded and displayed, including voice and video. Correlation will improve decoding SNRs. A skimmer is one user interface for that data. New display paradigms are badly needed!
- Expanded physical control surfaces are coming for both networked and local use. Some will be generic and others rig specific. Contesters love nimble, workflow-optimized physical interfaces!
- Many innovations in noise reduction, noise correlation, signal processing, specialized filters, adaptive pre-distortion, frequency and phase stability, signal transport and integrated equipment control are underway.

State-of-the-Art & State-of-the-Future -- Part III

- MIMO, beam steering and direction finding will become common. We will know where signals come from with four, phase-coherent receivers and where our signals are going with four, phase-coherent transmitters. We will add the power of remote facilities to our own. Protocols are evolving.
- Not covered here: The government-championed VITA-49 protocol will widely transport RF (IF, Audio, too) over Internet sockets, facilitating soft instruments, interconnecting of our own multiple transceivers and interconnecting with remote facilities. The soft sound card already exists for DAX (Digital Audio Exchange)-like applications.
- Reasonably-priced, super-performance, incredibly-versatile SDR designs are increasingly becoming available to the amateur community!

Questions?