THE SOFTWARE DEFINED RADIO

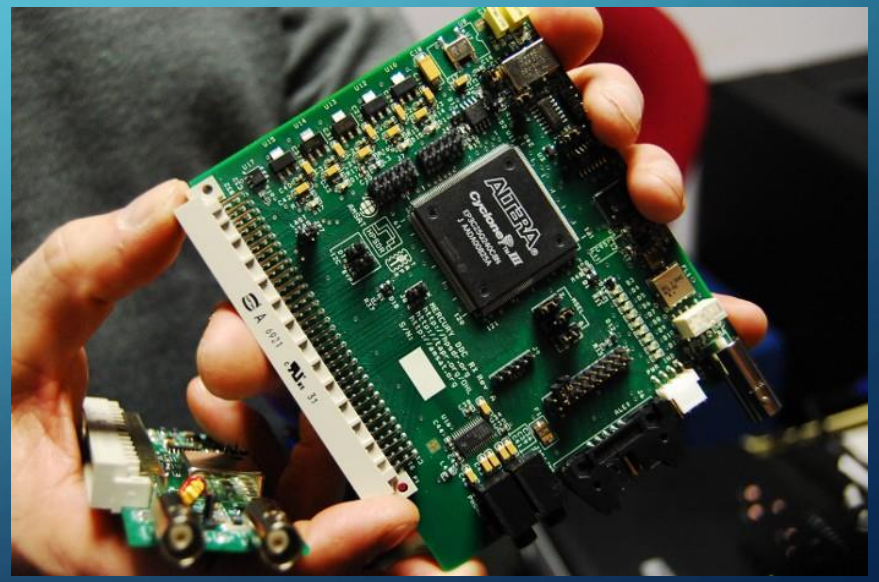
A DISRUPTIVE TECHNOLOGY

SDR IS THE TECHNOLOGY OF REPLACING RADIO HARDWARE WITH SOFTWARE

By KR9U

AGENDA

- How SDR has changed radio technology
- Benefits of SDR receivers and transmitters
- Challenges moving forward
- The CW Skimmer tool



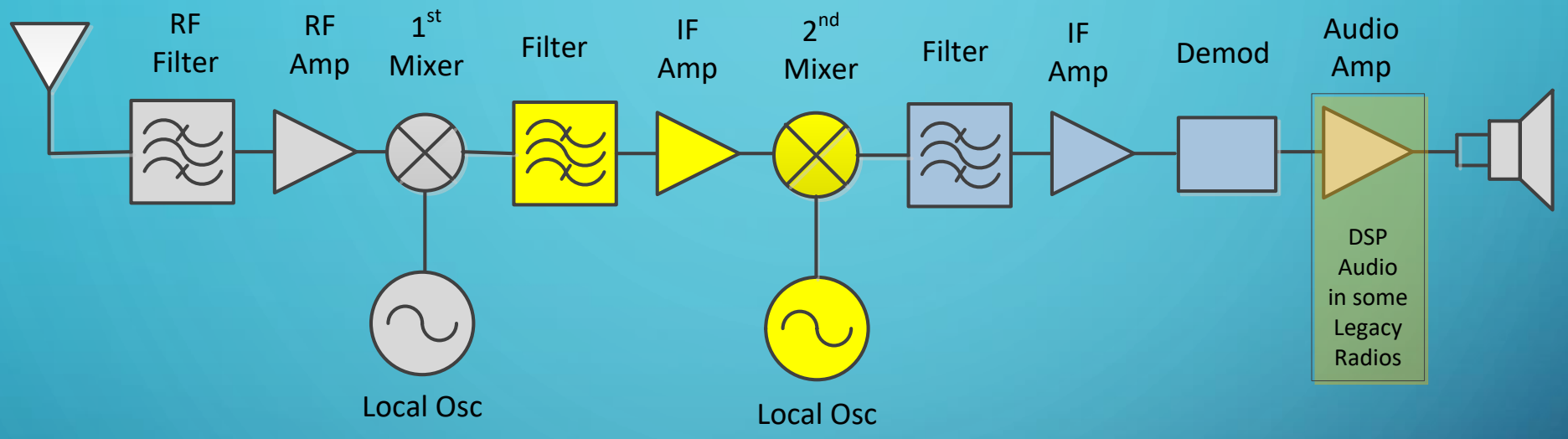
BENEFITS OF DIRECT SAMPLING RADIO

- Flexible
- Reduced Obsolescence
- Enhances Experimentation
- Brings Analog and Digital World Together

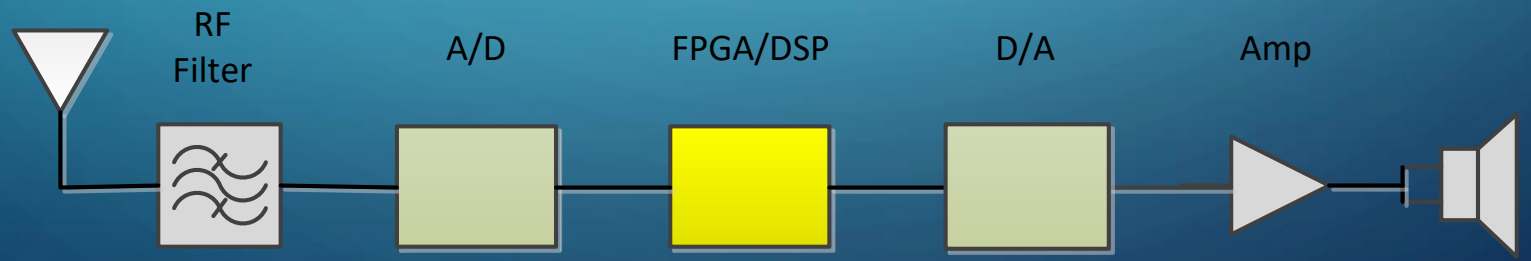
DIGGING DEEPER

- Dramatic simplification of block diagram & signal paths vs legacy designs
- Elimination of legacy subsystems (and their attendant impairments)
  - Mixers (IMD, noise, spurs)
  - Analog local oscillators (phase noise/reciprocal mixing, spurs)
  - IF “roofing” filters (PIM, phase distortion, insertion loss, IF leakage)
- Aging is less of a problem
- Greatly reduces environmental issues
  - Temperature
  - Humidity
  - Vibration

Superheterodyne Receiver



Direct Sampling Receiver



GENERAL SDR ADVANTAGES

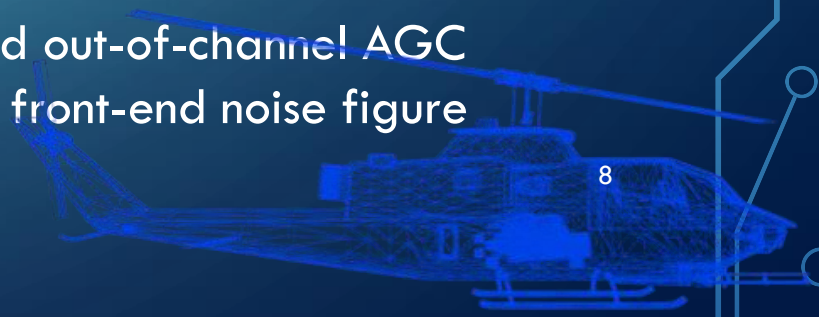
- Signal management is entirely in digital domain
  - Hardware alignment points (trimmers etc.) virtually eliminated
  - Easily configurable interfaces to other equipment
  - Greatly reduced component count
  - Reduction in cabinet size, weight, number of PCB modules
  - Significant reliability improvement & cost reduction

SDR DYNAMIC RANGE CONSIDERATIONS

- The ADC clip level (the input level at which the output is all ones) sets an absolute limit on the signal level which can be applied to the input. At the clip level, the ADC stops encoding the analog input.
- A typical ADC clip level (measured at the antenna input) is -3 dBm (S9 + 70 dB). Thus, the ADC will clip when the total instantaneous power of all applied signals is -3 dBm.
- The ADC is exposed to all RF signals in the RF passband. The passband width is limited by a preselector (BPF) which can be switched out in some designs for wideband reception. Certain SDR models are not fitted with preselectors.
- The optimum operating point for a direct-sampling SDR receiver is where the band noise is at or just above the receiver's noise floor, to maximize ADC dynamic range.

SDR DYNAMIC RANGE

- The input power limit imposed by ADC clipping requires a different approach to AGC design in a direct-sampling SDR as opposed to a legacy receiver.
- In a legacy superhet/IF-DSP receiver, the AGC levels average audio output over a wide range of RF input levels, and prevents overload of downstream mixers and IF stages.
- In a direct-sampling SDR, the AGC can adjust the ADC input level via a voltage-controlled RF attenuator to keep the ADC below clip level when a strong signal is present in the detection bandwidth. (Some SDR's have an ADC clip indicator.)
- Strong signals outside the detection channel can drive the ADC into clipping.
- The operator can also set the ADC input level via a manual RF gain control to keep the ADC below clip level. If the front end has sufficient gain reserve, sensitivity will not be excessively degraded.
- The Rockwell Collins SDR airborne radio design has in-channel and out-of-channel AGC loop to keep the ADC within its linear range whilst preserving the front-end noise figure in the presence of strong out-of-band signals.



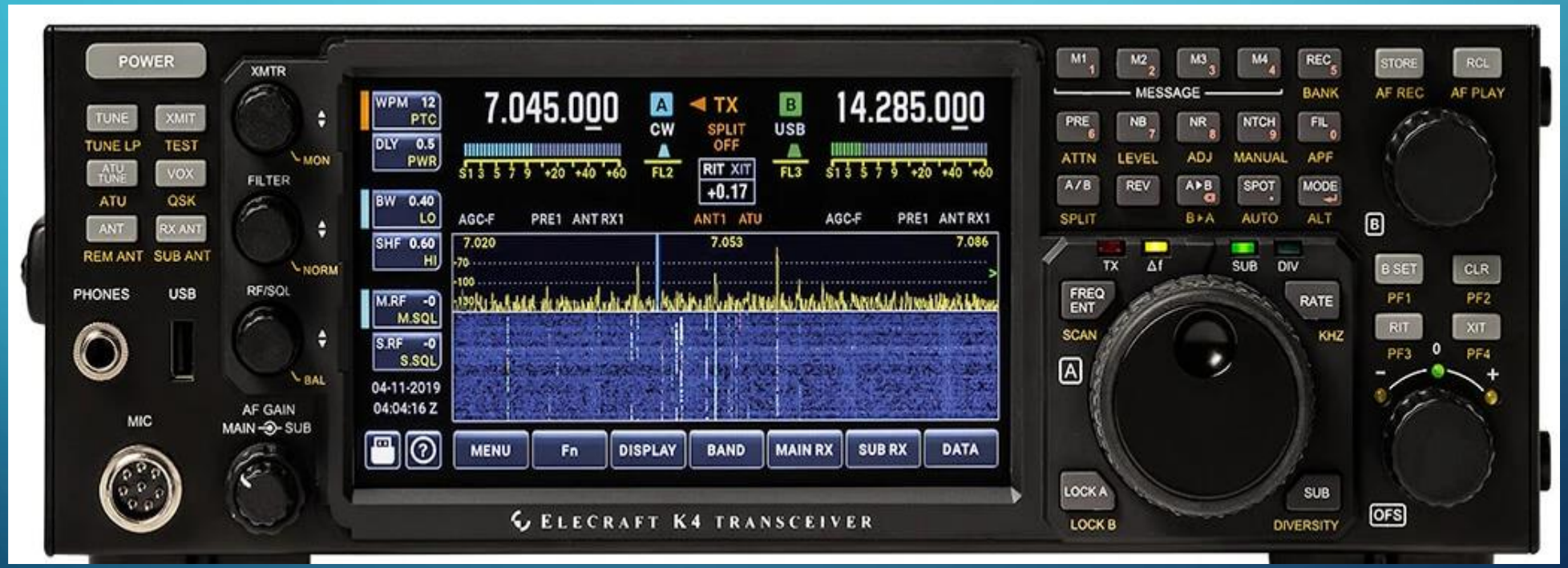
TRANSMITTER CONSIDERATIONS

- SDR transmitter has several significant advantages over a legacy transmitter:
  - The audio/baseband signal leaving the audio ADC or codec remains in the digital domain until it leaves the DAC as RF drive to the PA chain. Thus, signal processing adds no noise or distortion to the signal.
  - As the ADC and DAC clocks are the primary phase-noise contributors, a design with low-noise clocks can almost eliminate transmitted phase noise from the transmitted signal.
  - The removal of mixers & LO's eliminates spurs and phase noise from these sources.
  - Transmit latency in CW mode can be greatly reduced by keying the carrier in the FPGA rather than in the DSP (or external PC). This greatly improves QSK operation.
  - Analog IF filters, with their potential for phase distortion, are eliminated.
  - The parts count is much lower than that of most legacy transmitter architectures.
  - Fewer alignment points than a legacy design.

FLEX 6600M


FlexRadio Systems
FLEX-6600M
XVTR ANT1
MENU
XVTR ANT1
14.303.600
14.262.500
MOX
TUNE
ATU
F1
F2
F3
TX MENU
A MENU/CLR
B MENU/CLR

ELECRAFT K4


POWER
XMTR
TUNE
XMIT
TUNE LP
TEST
ATU TUNE
VOX
ATU
QSK
ANT
RX ANT
REM ANT
SUB ANT
PHONES
USB
MIC
FILTER
MON
NORM
RF/SQL
BAL
AF GAIN
MAIN SUB
WPM 12
PTC
DLY 0.5
PWR
BW 0.40
LO
SHF 0.60
HI
M.RF -0
M.SQL
S.RF -0
S.SQL
04-11-2019
04:04:16 Z
7.045.000
A
CW
TX
SPLIT
OFF
RIT XIT
+0.17
B
USB
14.285.000
FL2
FL3
AGC-F
PRE1
ANT RX1
ANT1
ATU
7.020
7.053
7.086
MENU
Fn
DISPLAY
BAND
MAIN RX
SUB RX
DATA
ELECRAFT K4 TRANSCEIVER
M1
M2
M3
M4
REC
MESSAGE
BANK
STORE
RCL
AF REC
AF PLAY
PRE
NB
NR
NTCH
FIL
ATTN
LEVEL
ADJ
MANUAL
APF
A/B
REV
A▸B
SPOT
MODE
SPLIT
B▸A
AUTO
ALT
TX
Δf
SUB
DIV
FREQ ENT
SCAN
RATE
KHZ
B SET
CLR
PF1
PF2
RIT
XIT
PF3
PF4
LOCK A
LOCK B
SUB
DIVERSITY
OFS

ICOM IC-7300

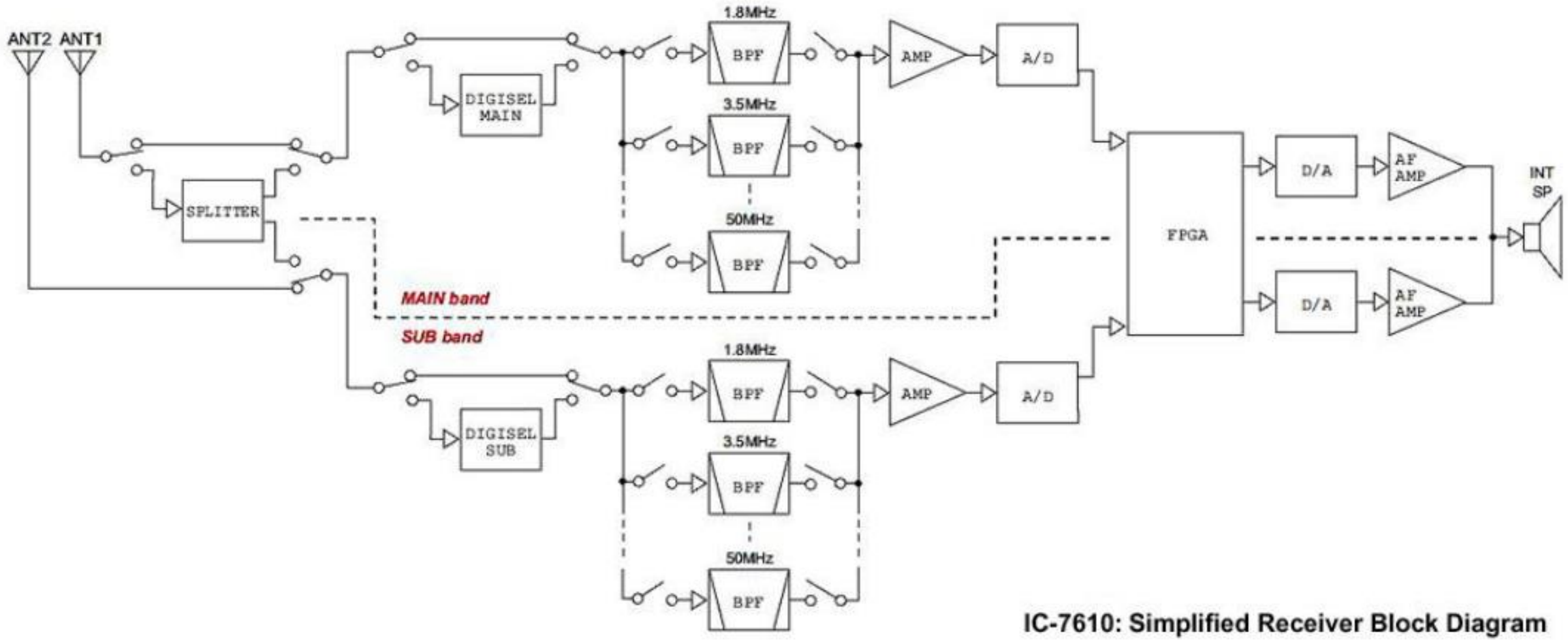

POWER
TRANSMIT
TUNER
VOX/BK-IN
PHONES
MIC
TWIN PBT CLR
P.AMP ATT
NOTCH
NB
NR
AF RF/SQL
ICOM
HF/50MHz TRANSCEIVER IC-7300
TX
LSB
FIL2
13:33
VFO A 1
7.073.00
7.030
7.200
7.04 7.06 7.08 7.10 7.12 7.14 7.16 7.18
ATT OFF
HOLD
AUDIO SCOPE
0 1.0 2.0 3.0 4.0kHz
LEVEL:-30dB
300ms/Div
ATT
HOLD
LEVEL
TIME
EXPD/SET
MULTI
RIT
ΔTX
CLEAR
SPLIT
A/B
V/M
MPAD
XFC
TX/RX
AUTO TUNE
MENU
FUNCTION
M.SCOPE
QUICK
EXIT
SPEECH

ICOM IC-7610


IC-7610
HF/50MHz TRANSCEIVER
ICOM
POWER
TRANSMIT
TIMER
TUNER
PHONES
MAIN:AF-RF/SQL
TX/RX
NB
NR
SUB:AF-RF/SQL
ANT 1
P.AMP 2
ATT OFF
IP+ OFF
AGC FAST
VOX OFF
COMP OFF WIDE
10:10 30
UTC 1:10
DUAL-W
TX
VFO
LSB
FIL2
7.070.000
1 7.035.00 LSB
CW
14.025.000
2 14.050.00 CW
SPECTRUM SCOPE
FIX
MAIN
Grid 25k/10dB
7.000
7.200
14.000
14.350
<MENU1>
EDGE
HOLD
CENT/FIX
MAIN/SUB
DUAL
EXPD/SET
MULTI
1.8
3.5
7
10
14
18
SPLIT
21
24
28
DUAL-W
GENE
50
MAIN/SUB
XFC
CHANGE
TWIN-PBT
CLR
FILTER
APF/TPF
KEY SPEED
PITCH
RIT
ΔTX
CLEAR
RIT/ΔTX
SPEECH
MENU
M.SCOPE
MP-W
MP-R
AUTO TUNE
QUICK
EXIT
REC

The Icom IC-7610

Receiver Block Diagram



IC-7610: Simplified Receiver Block Diagram

IC-7610 ADC CHARACTERISTICS

- Uses the 16 bit, 130 Msps, LTC2208 ADC, NF ≈ 23 dB.; ∴ MDS = -124 dBm for BW = 500 Hz (CW).
- The differential ADC driver (e.g. LTC6401-20) has 20 dB gain and 6 dB NF. The calculated NF of the LTC6401 driving the LTC2208 is 8 dB. Allowing 5 dB insertion loss for the preselector, system NF ≈ 13 dB., ∴ system MDS = 134 dBm . This is comparable to the MDS of a legacy transceiver .
- Two low-noise RF preamps can be selected ahead of the ADC driver to lower the NF even further.
- The LTC6401 IMD spec ≈ -100 dBc, so the ADC driver should not significantly degrade the ADC's IMD performance.
- Uses Dithering (user selectable), an on-chip function of the LTC2208. When active, dithering de-correlates IMD products generated in the ADC. It can lower IMD levels significantly, at the cost of a slight increase in NF: About 3 dB.
- Many direct-sampling SDR receivers feature a user-accessible dither switch. Nothing comparable exists in any legacy radio

TOP SDR TECHNICAL CHALLENGES

- Dynamic Range
- Different AGC schemes
- ADC/DAC Speed
- Smart Radio Algorithms

THE CW SKIMMER

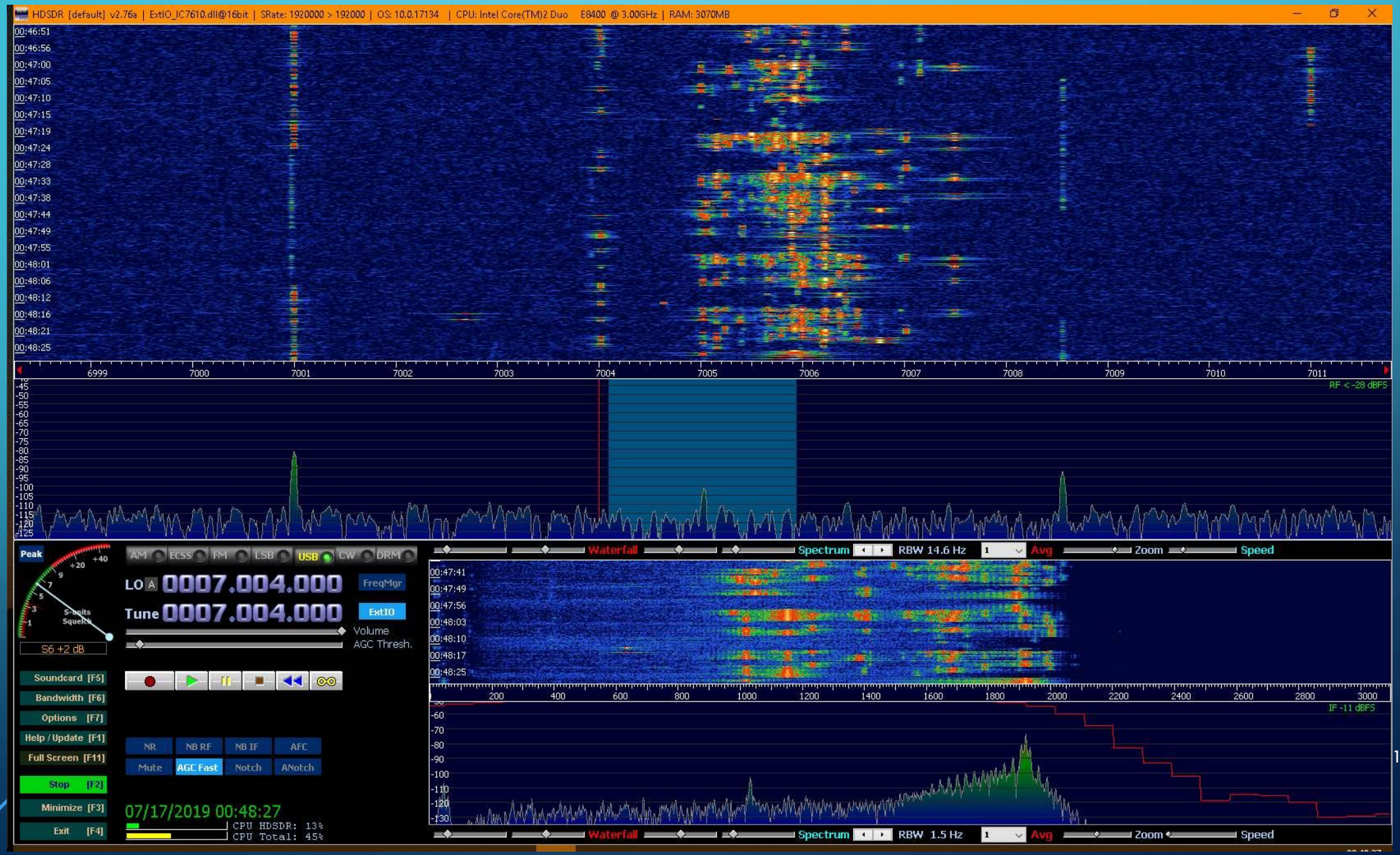
BY VE3NEA

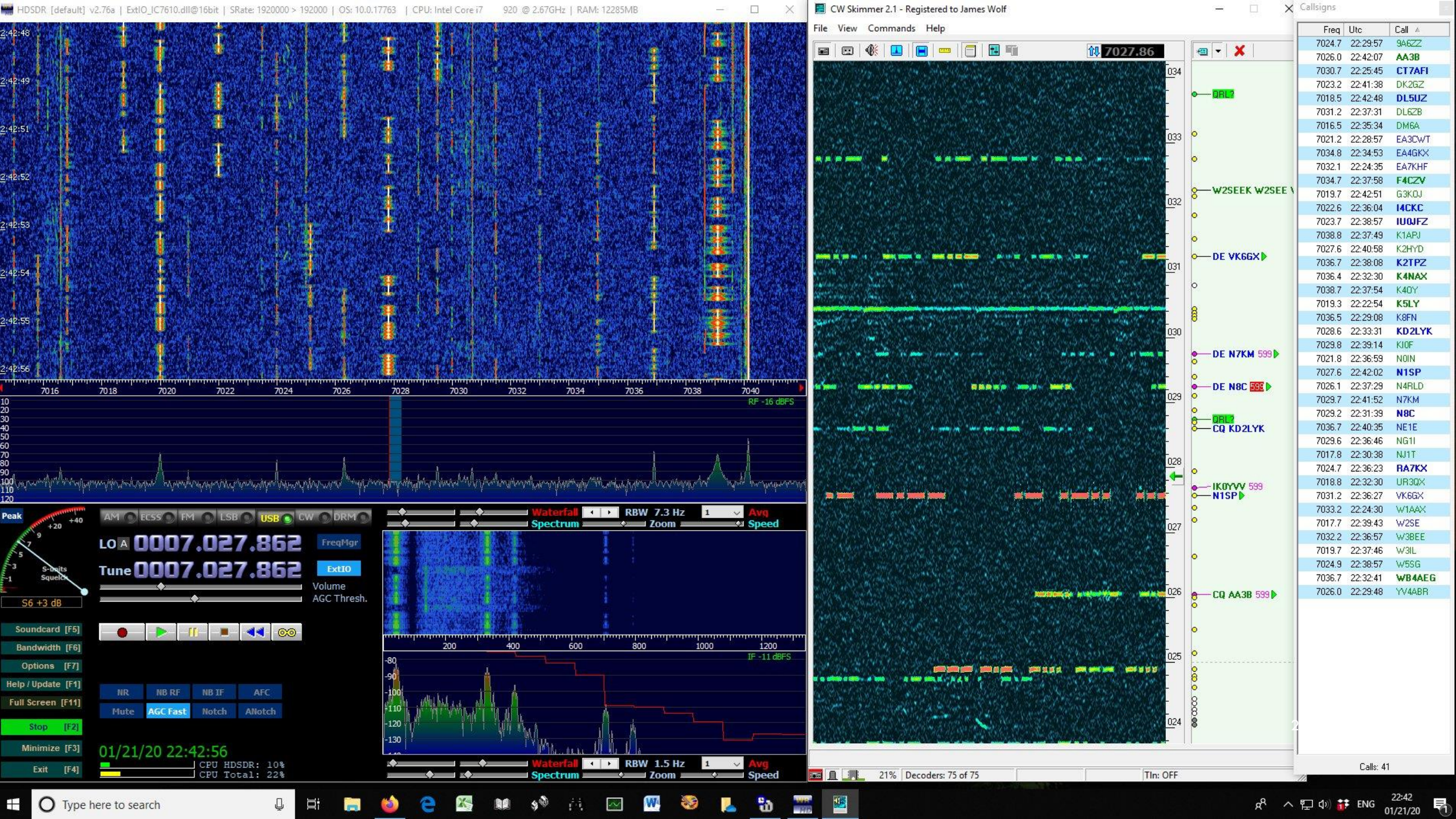
- CW decoding algorithm based on the methods of Bayesian statistics.
- Simultaneous decoding of up to 700 signals can be decoded in parallel if a wideband receiver is used.
- A waterfall display, with a resolution sufficient for reading Morse Code dots and dashes visually.
- The callsigns are extracted from the decoded messages, and the traces on the waterfall are labeled with stations' callsigns.
- The extracted callsigns can be exported as DX cluster spots via the built-in Telnet cluster server.
- A DSP processor with a noise blanker, AGC, and a sharp, variable-bandwidth CW filter; an I/Q Recorder and player.

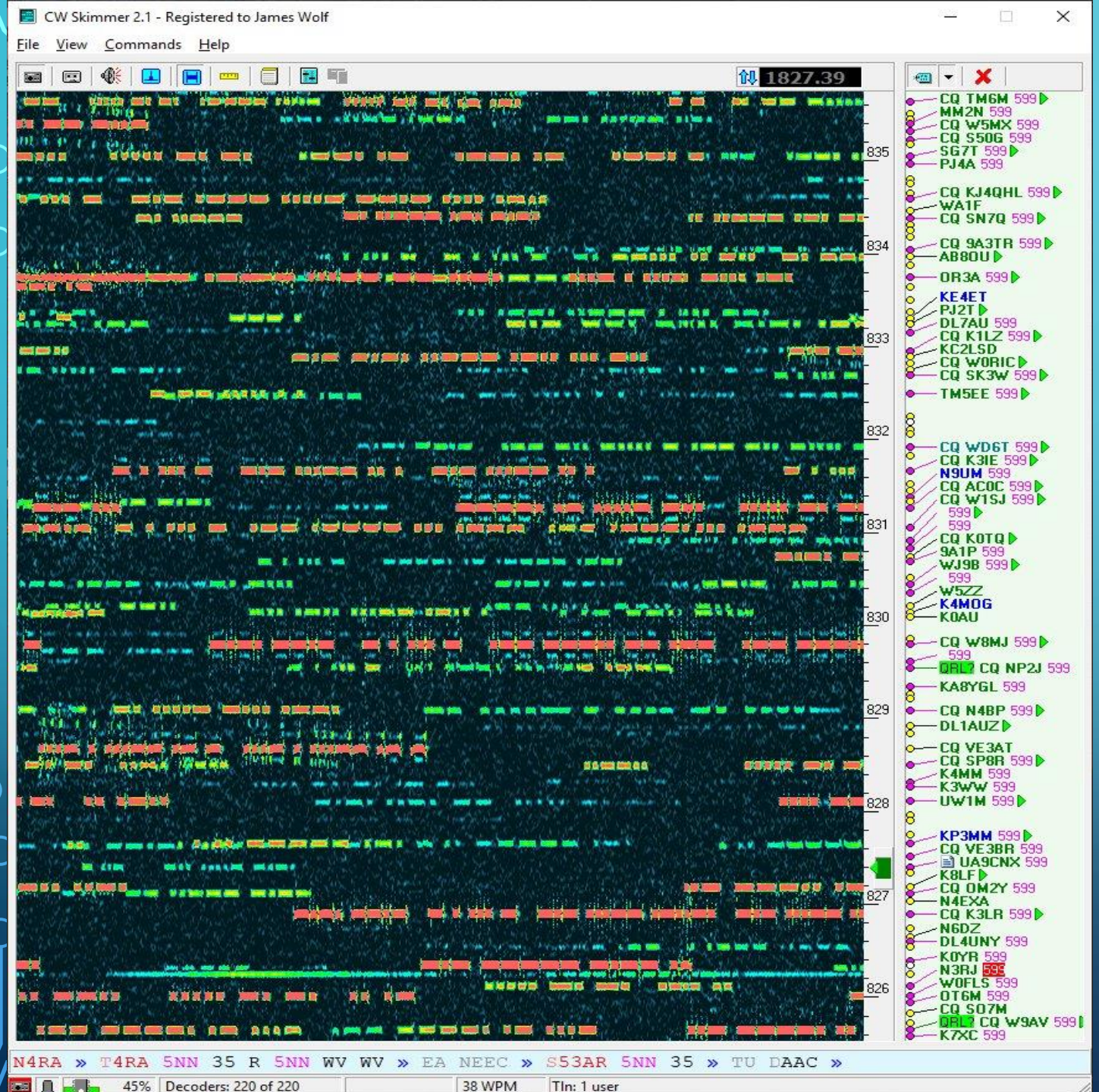
MORE CW SKIMMER

- Can be used with audio from a current receiver, or with Software Defined Radio (SDR) hardware.
- CW Skimmer will enable operators to be aware of everything that is going on across large swaths of any band.
- You can pick out individual signals and enhance their readability by putting them through a tight audio DSP filter, or
- Click on a station and move your transceiver to its frequency.
- It looks at the entire swath of spectrum it can “hear”, identifies CW signals, and decodes them all. Meanwhile, it looks at the decoded text and works to identify stations newly arrived on the band, stations calling CQ, etc.
- It generates a time-stamped list of these stations and their frequencies, and makes them available via Telnet to your logging program, or via the Internet to the hub server of the reverse beacon network (more on this below).

HDSDR - AN SDR CONTROL PROGRAM



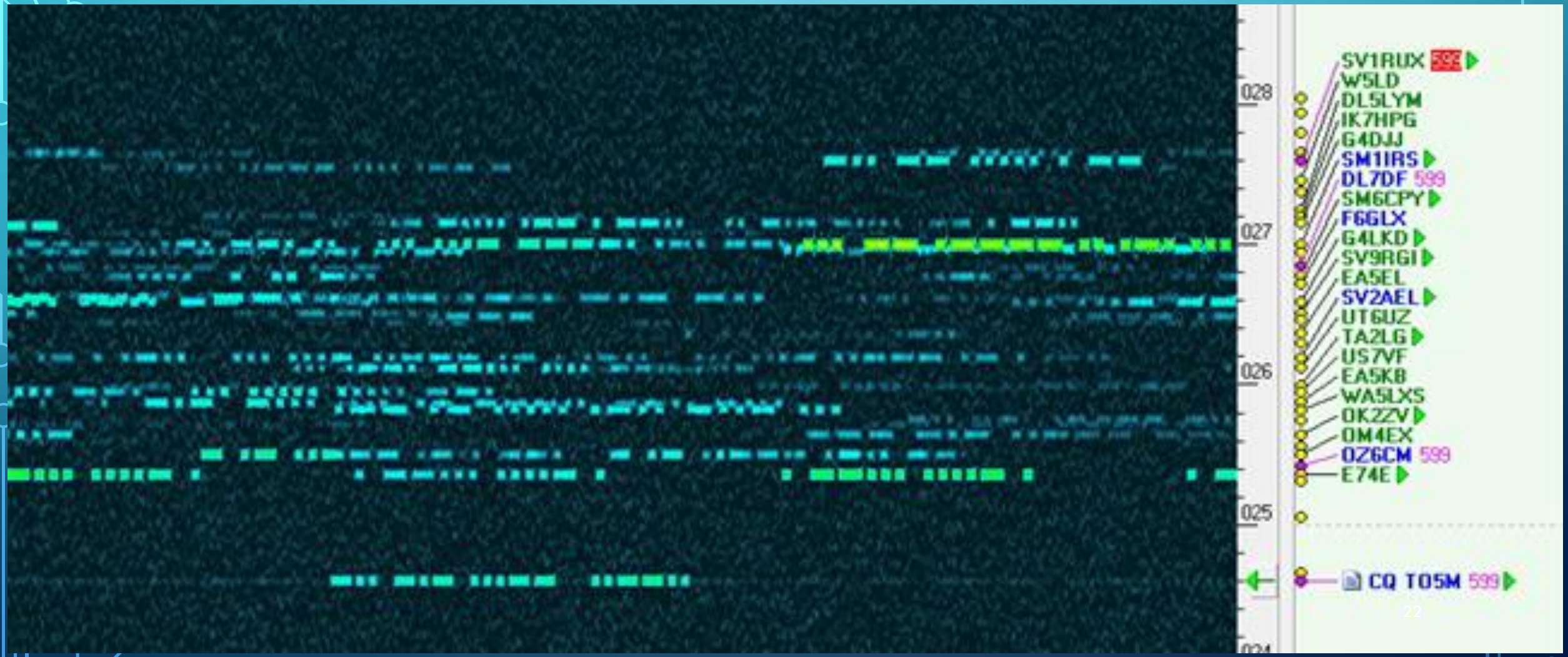

HDSDR [default] v2.76a | ExtIO_IC7610.dll@16bit | SRate: 1920000 > 192000 | OS: 10.0.17763 | CPU: Intel Core i7 920 @ 2.67GHz | RAM: 12285MB
7016 7018 7020 7022 7024 7026 7028 7030 7032 7034 7036 7038 7040
RF -16 dBFS
AM ECSS FM LSB USB CW DRM
LO A 0007.027.862
Tune 0007.027.862
FreqMgr
ExtIO
Volume
AGC Thresh.
Soundcard [F5]
Bandwidth [F6]
Options [F7]
Help / Update [F1]
Full Screen [F11]
Stop [F2]
Minimize [F3]
Exit [F4]
NR NB RF NB IF AFC
Mute AGC Fast Notch ANotch
01/21/20 22:42:56
CPU HDSDR: 10%
CPU Total: 22%
Waterfall RBW 7.3 Hz Avg
Spectrum Zoom Speed
IF -11 dBFS
Waterfall RBW 1.5 Hz Avg
Spectrum Zoom Speed
CW Skimmer 2.1 - Registered to James Wolf
File View Commands Help
7027.86
QRL?
W2SEEK W2SEE
DE VK6GX
DE N7KM 599
DE N8C 599
QRL?
CQ KD2LYK
IK0YVV 599
N1SP
CQ AA3B 599
21% Decoders: 75 of 75
TIn: OFF
Callsigns
Freq Utc Call
7024.7 22:29:57 9A6ZZ
7026.0 22:42:07 AA3B
7030.7 22:25:45 CT7AFI
7023.2 22:41:38 DK2GZ
7018.5 22:42:48 DL5UZ
7031.2 22:37:31 DL6ZB
7016.5 22:35:34 DM6A
7021.2 22:28:57 EA3CWT
7034.8 22:34:53 EA4GKX
7032.1 22:24:35 EA7KHF
7034.7 22:37:58 F4CZV
7019.7 22:42:51 G3KOJ
7022.6 22:36:04 I4CKC
7023.7 22:38:57 IU0JFZ
7038.8 22:37:49 K1APJ
7027.6 22:40:58 K2HYD
7036.7 22:38:08 K2TPZ
7036.4 22:32:30 K4NAX
7038.7 22:37:54 K4OY
7019.3 22:22:54 K5LY
7036.5 22:29:08 K8FN
7028.6 22:33:31 KD2LYK
7029.8 22:39:14 KI0F
7021.8 22:36:59 N0IN
7027.6 22:42:02 N1SP
7026.1 22:37:29 N4RLD
7029.7 22:41:52 N7KM
7029.2 22:31:39 N8C
7036.7 22:40:35 NE1E
7029.6 22:36:46 NG1I
7017.8 22:30:38 NJ1T
7024.7 22:36:23 RA7KX
7018.8 22:32:30 UR3QX
7031.2 22:36:27 VK6GX
7033.2 22:24:30 W1AAX
7017.7 22:39:43 W2SE
7032.2 22:36:57 W3BEE
7019.7 22:37:46 W3IL
7024.9 22:38:57 W5SG
7036.7 22:32:41 WB4AEG
7026.0 22:29:48 YV4ABR
Calls: 41
Type here to search
ENG
22:42
01/21/20



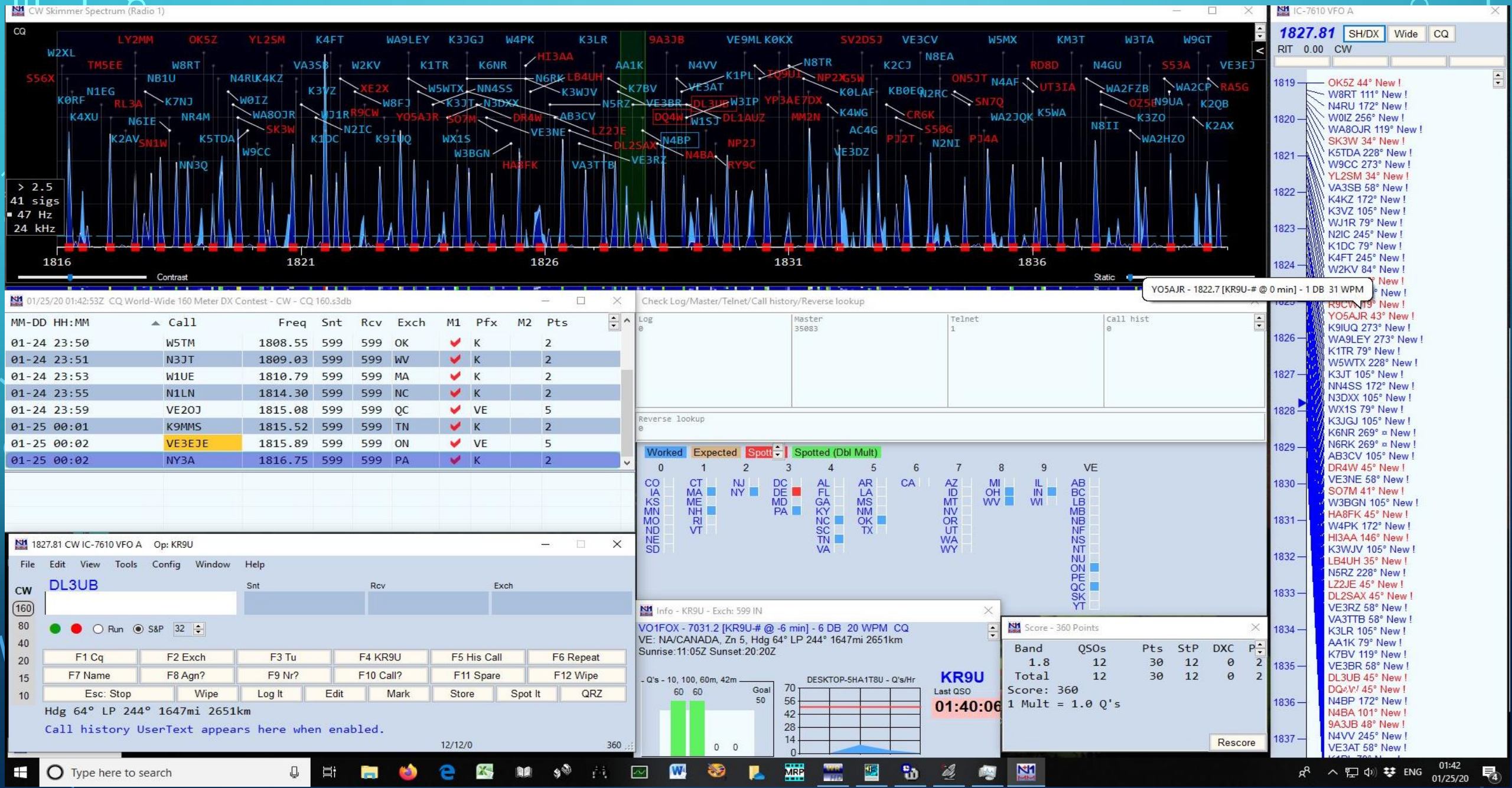
CW SKIMMER IN THE 160 METER CONTEST 10 kHz BW

Use of a CW skimmer puts a single operator in the assisted category in many major contests

WORKING A PILEUP



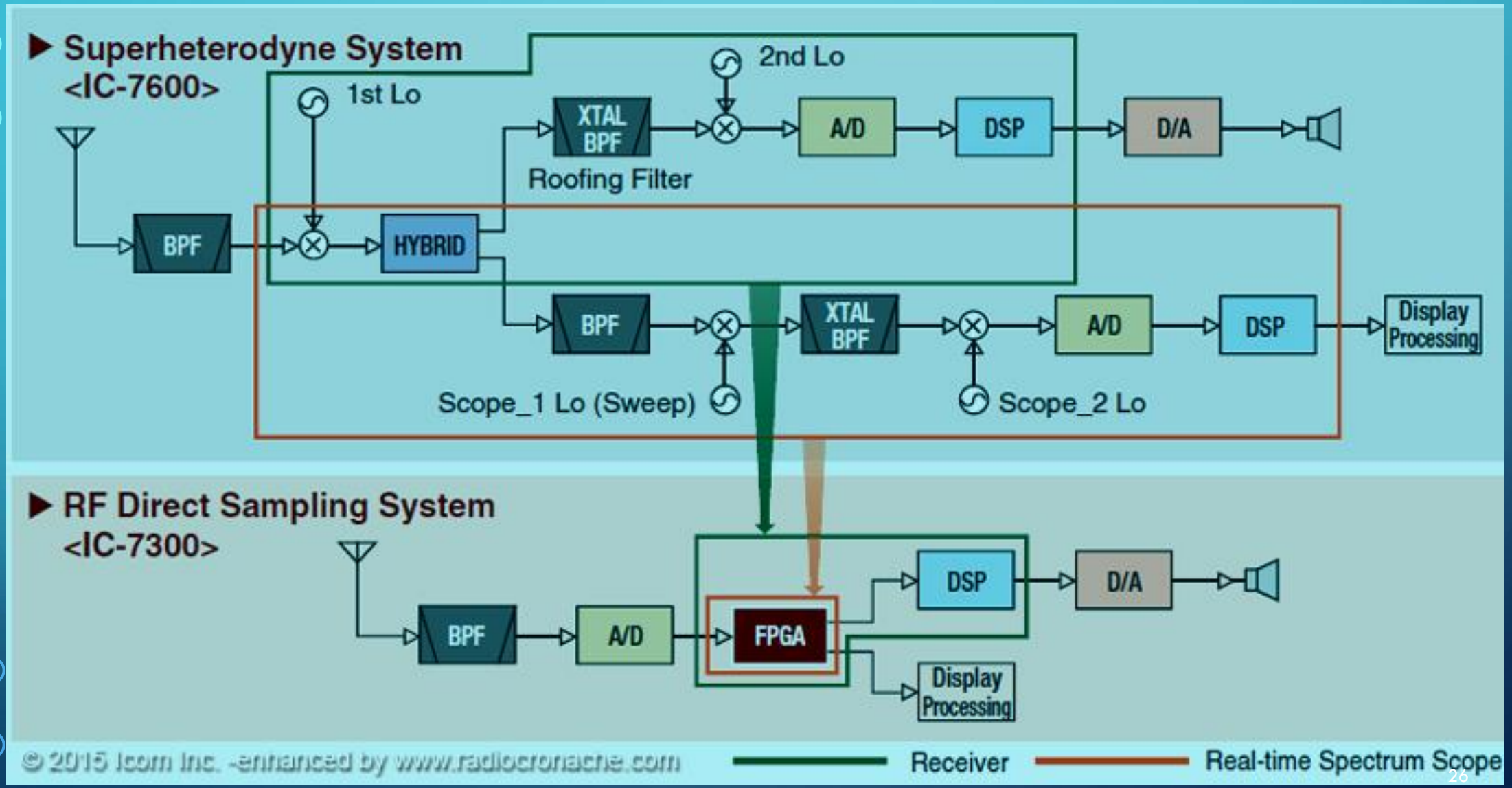
SKIMMER SPECTRUM DISPLAY IN N1MM



LOOKING AHEAD

- **Smart Radios** that configure themselves to perform the communications task requested (using different frequency bands, modes, etc.)
- **Cognitive Radios** that learn about their environment (e.g., other users nearby, interference, location, elevation) to optimally configure themselves to maximize efficiency and reduce interference.
- **Automated** plug and play systems
- **Spectrum** conservation

Questions ?


Superheterodyne System
<IC-7600>
1st Lo
2nd Lo
XTAL BPF
Roofing Filter
A/D
DSP
D/A
BPF
HYBRID
BPF
XTAL BPF
A/D
DSP
Display Processing
Scope_1 Lo (Sweep)
Scope_2 Lo
RF Direct Sampling System
<IC-7300>
BPF
A/D
FPGA
DSP
D/A
Display Processing
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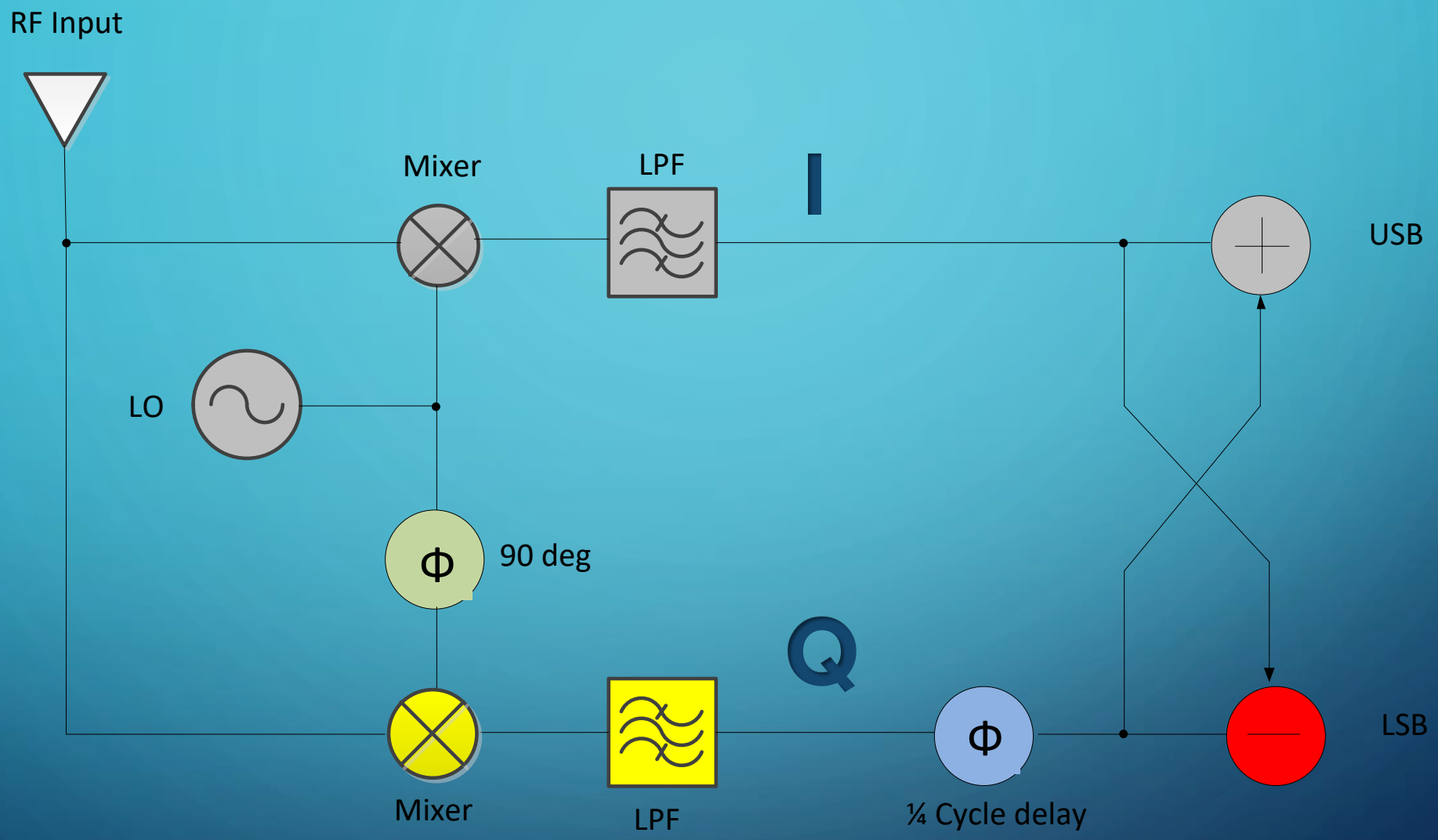
Receiver
Real-time Spectrum Scope


RF Input
Mixer
LPF
I
USB
LO
Φ
90 deg
Q
Mixer
LPF
Φ
¼ Cycle delay
LSB