



SDR 101 Ham Radio University 2021

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About N2RJ

Licensed 1997 - Trinidad and Tobago

Licensed 2001 - Brooklyn NY USA

Occupation: IT systems engineering team lead

Ham radio has nurtured my gift of technical curiosity and has enabled me to learn tech and engineering. My ham radio Elmers were Tony Lee-Mack, 9Y4AL (teacher), and Steve Mendelsohn, W2ML.

I got involved in ham radio in school, through the influence of a teacher.

I am proud to help and serve the amateur radio community as a director of ARRL and district chair for YLRL.



Note on radios

- I am a Flex radio user, but that does not mean that these techniques cannot be applied to other radios. I will be mostly talking about my experiences, and showing how I operate on the FlexRadio platform
- This talk is not specifically endorsed nor sponsored by any radio manufacturer

My radio story

- I've enjoyed DXing ever since I was a child - SWLing, listening to different countries, cultures but most importantly enjoying "radio for radio's sake"
- I have learned so much
 - About my station
 - About propagation
 - About the world

Other things I've done/do

- Emcomm/ARES
 - Primarily in an urban environment
- Homebrew/kits
- Drones/sUAS
- Contesting
- Ragchews

What is an SDR?

- An SDR replaces some or all of the components of an analog radio with software
- Specifically RF components
 - Detector
 - Modulator
- Direct Sampling takes the RF out of the air and converts it to digital bits
- “Baseband” SDRs take RF downconverted to baseband
 - I/Q signals

Today's SDR landscape

Software defined radios are the new kid on the block but in reality they've been around for a while now.

What is different is adoption. We find the mainstream radio manufacturers adopting Direct Sampling SDR technology, and the "boutique" ones going mainstream.

The tipping point has been reached. SDR is mainstream.



What can an SDR offer you?

1. Visibility - SEE the spectrum
2. Performance - the best performing radios today are typically SDRs.
3. Integration - everything can talk to everything
4. Remote operation - SDRs enable you to be there, even when you are not.

Visibility

See the spectrum

Visibility

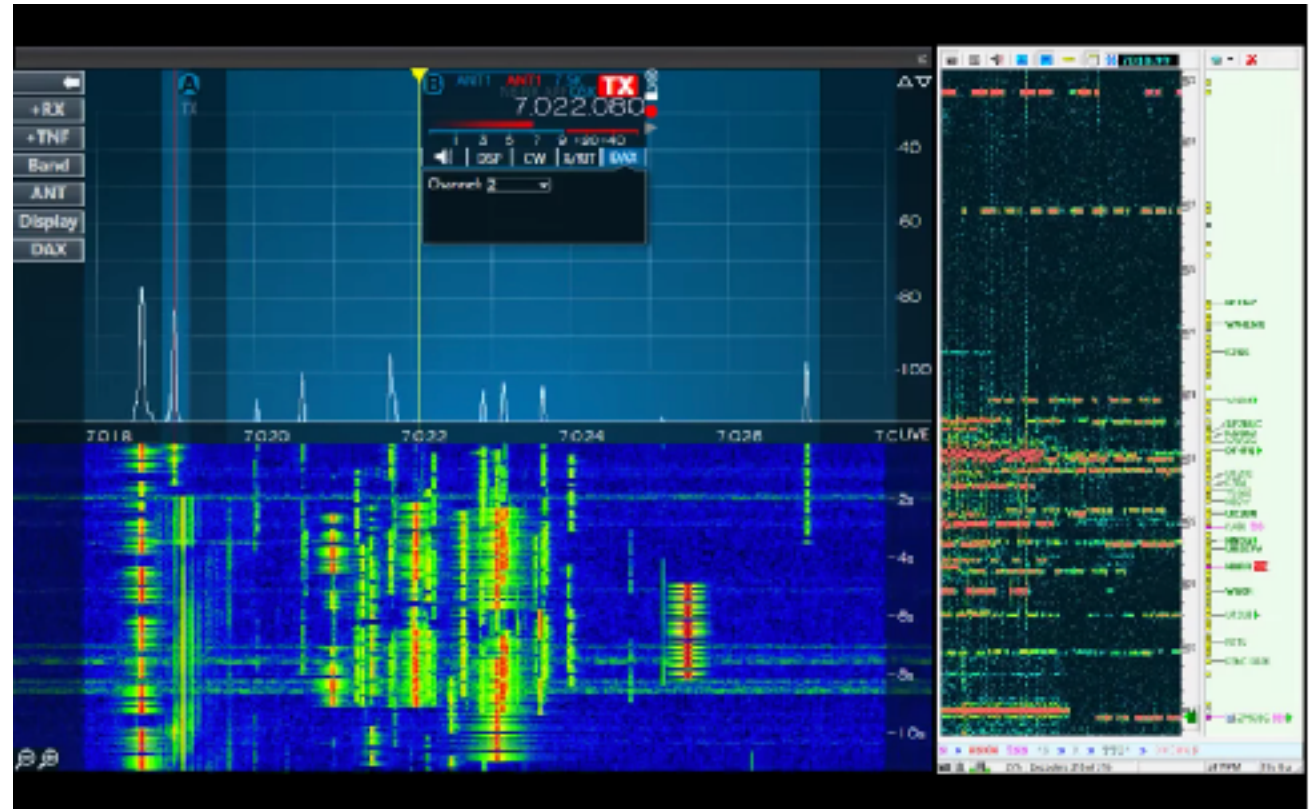
This one is straightforward. SDRs typically have sophisticated band scopes. They can show you what is happening well beyond what you can hear.



Visibility with decoding

SDRs can also feed entire bands and multiple bands to decode popular modes.

Today we can decode Morse code and digital modes.



Visibility with overlays

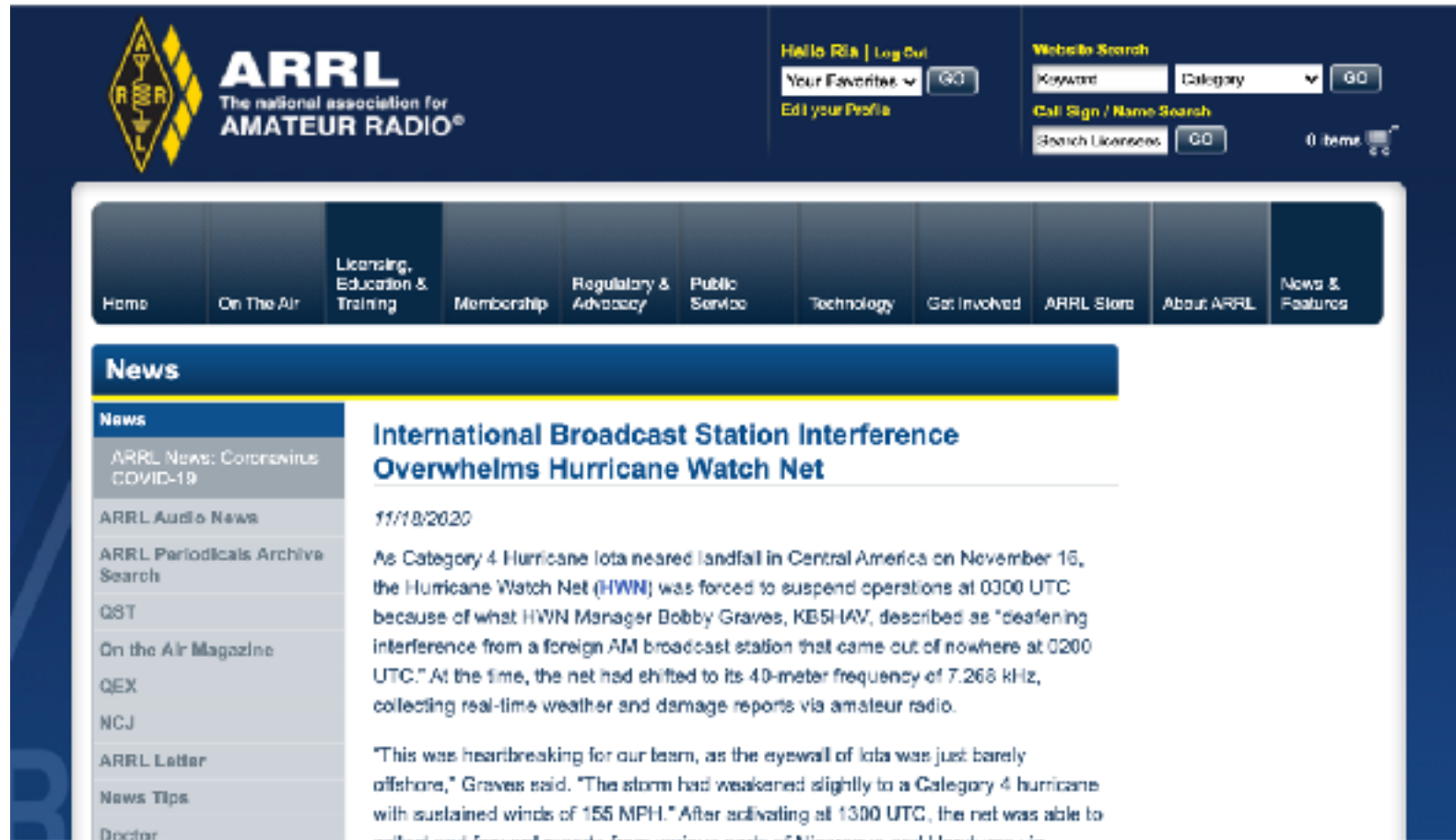
Some SDRs offer the ability to overlay information on the panadapter display. This can be fed from a DX telnet cluster or other information source.

This can enable point and click or point and tap DXing



Visibility for Emcomm

- Scout out clear spots
- See who is interfering
- Filters including TNF



The screenshot shows the ARRL website interface. At the top left is the ARRL logo with the text "The national association for AMATEUR RADIO®". To the right of the logo are user options: "Hello Ria | Log Out", "Your Favorites" with a dropdown arrow and a "GO" button, and "Edit your Profile". Further right is a "Website Search" section with "Keyword" and "Category" input fields, a "GO" button, and a "Call Sign / Name Search" section with a "Search Licenses" button and a "GO" button. A shopping cart icon shows "0 items".

Below the header is a navigation menu with the following items: Home, On The Air, Licensing, Education & Training, Membership, Regulatory & Advocacy, Public Service, Technology, Get Involved, ARRL Store, About ARRL, and News & Features.

The main content area is titled "News" and features a sidebar on the left with a "News" section containing links to "ARRL News: Coronavirus COVID-19", "ARRL Audio News", "ARRL Periodicals Archive Search", "QST", "On the Air Magazine", "QEX", "NCJ", "ARRL Letter", "News Tips", and "Doctor".

The main article is titled "International Broadcast Station Interference Overwhelms Hurricane Watch Net" and is dated "11/18/2020". The article text reads: "As Category 4 Hurricane Iota neared landfall in Central America on November 16, the Hurricane Watch Net (HWN) was forced to suspend operations at 0300 UTC because of what HWN Manager Bobby Graves, KB5HAW, described as 'deafening interference from a foreign AM broadcast station that came out of nowhere at 0200 UTC.' At the time, the net had shifted to its 40-meter frequency of 7.268 kHz, collecting real-time weather and damage reports via amateur radio. 'This was heartbreaking for our team, as the eyewall of Iota was just barely offshore,' Graves said. 'The storm had weakened slightly to a Category 4 hurricane with sustained winds of 155 MPH.' After activating at 1300 UTC, the net was able to collect and forward reports from various parts of Mississippi and Louisiana via..."

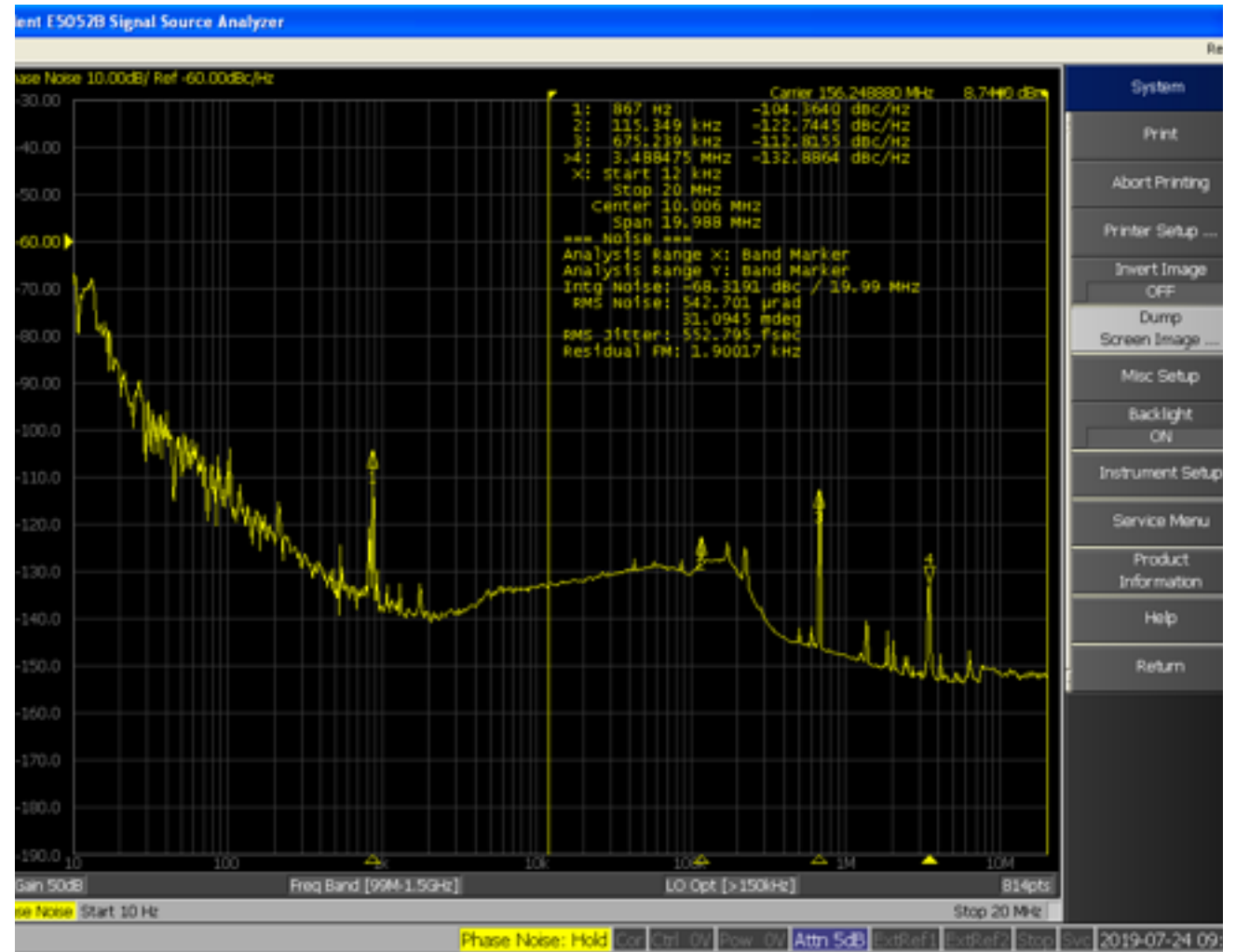
Performance

When you place signals in the analog domain, they are affected adversely by environmental factors in our electrically noisy world.

When signals are in the digital domain, they are isolated from these environmental factors.

Therefore you will find that things like noise floor and dynamic range are substantially better on an SDR

Additionally, with direct sampling SDRs you will find that less reliance on analog mixers means less phase noise.



Performance

Rob Sherwood, NCOB has been doing tests of receivers (and now transmitters) for a long time. His rankings are generally considered to be the metric that the community looks for their receivers to be measured by. You can see that a good number of the top performers are SDRs. But as with anything, there are caveats.

In particular, receivers are measured for their ability to pick out weaker signals interspersed between smaller ones. However, anything above 80-90dB 3rd order dynamic range is more of a numbers game

Receiver Name	1st Order Dynamic Range (dB)	2nd Order Dynamic Range (dB)	3rd Order Dynamic Range (dB)	4th Order Dynamic Range (dB)	5th Order Dynamic Range (dB)	6th Order Dynamic Range (dB)	7th Order Dynamic Range (dB)	8th Order Dynamic Range (dB)	9th Order Dynamic Range (dB)	10th Order Dynamic Range (dB)	11th Order Dynamic Range (dB)	12th Order Dynamic Range (dB)	13th Order Dynamic Range (dB)	14th Order Dynamic Range (dB)	15th Order Dynamic Range (dB)	16th Order Dynamic Range (dB)	17th Order Dynamic Range (dB)	18th Order Dynamic Range (dB)	19th Order Dynamic Range (dB)	20th Order Dynamic Range (dB)
SDR#1 (RTL-SDR)	120	110	100	90	80	70	60	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70
SDR#2 (HackRF)	115	105	95	85	75	65	55	45	35	25	15	5	-5	-15	-25	-35	-45	-55	-65	-75
SDR#3 (BladeRF)	110	100	90	80	70	60	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80
SDR#4 (SDRplay)	105	95	85	75	65	55	45	35	25	15	5	-5	-15	-25	-35	-45	-55	-65	-75	-85
SDR#5 (SDR-Lite)	100	90	80	70	60	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90
SDR#6 (SDR-Bugs)	95	85	75	65	55	45	35	25	15	5	-5	-15	-25	-35	-45	-55	-65	-75	-85	-95
SDR#7 (SDR-Sharp)	90	80	70	60	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100
SDR#8 (SDR-KIT)	85	75	65	55	45	35	25	15	5	-5	-15	-25	-35	-45	-55	-65	-75	-85	-95	-105
SDR#9 (SDR-Kit2)	80	70	60	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100	-110
SDR#10 (SDR-Kit3)	75	65	55	45	35	25	15	5	-5	-15	-25	-35	-45	-55	-65	-75	-85	-95	-105	-115
SDR#11 (SDR-Kit4)	70	60	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100	-110	-120
SDR#12 (SDR-Kit5)	65	55	45	35	25	15	5	-5	-15	-25	-35	-45	-55	-65	-75	-85	-95	-105	-115	-125
SDR#13 (SDR-Kit6)	60	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100	-110	-120	-130
SDR#14 (SDR-Kit7)	55	45	35	25	15	5	-5	-15	-25	-35	-45	-55	-65	-75	-85	-95	-105	-115	-125	-135
SDR#15 (SDR-Kit8)	50	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100	-110	-120	-130	-140
SDR#16 (SDR-Kit9)	45	35	25	15	5	-5	-15	-25	-35	-45	-55	-65	-75	-85	-95	-105	-115	-125	-135	-145
SDR#17 (SDR-Kit10)	40	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100	-110	-120	-130	-140	-150
SDR#18 (SDR-Kit11)	35	25	15	5	-5	-15	-25	-35	-45	-55	-65	-75	-85	-95	-105	-115	-125	-135	-145	-155
SDR#19 (SDR-Kit12)	30	20	10	0	-10	-20	-30	-40	-50	-60	-70	-80	-90	-100	-110	-120	-130	-140	-150	-160
SDR#20 (SDR-Kit13)	25	15	5	-5	-15	-25	-35	-45	-55	-65	-75	-85	-95	-105	-115	-125	-135	-145	-155	-165

Performance - ARRL Lab tests

ARRL lab also tests SDRs, with generally high performance as well.

ARRL has developed the metric called "RMDR" or "Reciprocal Mixing Dynamic Range" which also measures the ability to hear weak signals among adjacent strong ones.

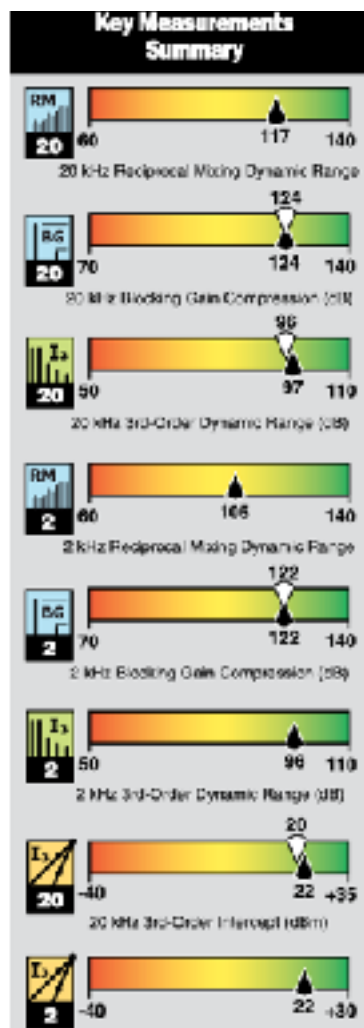


Table 1
Apache Labs ANAN-100D, serial number 32186

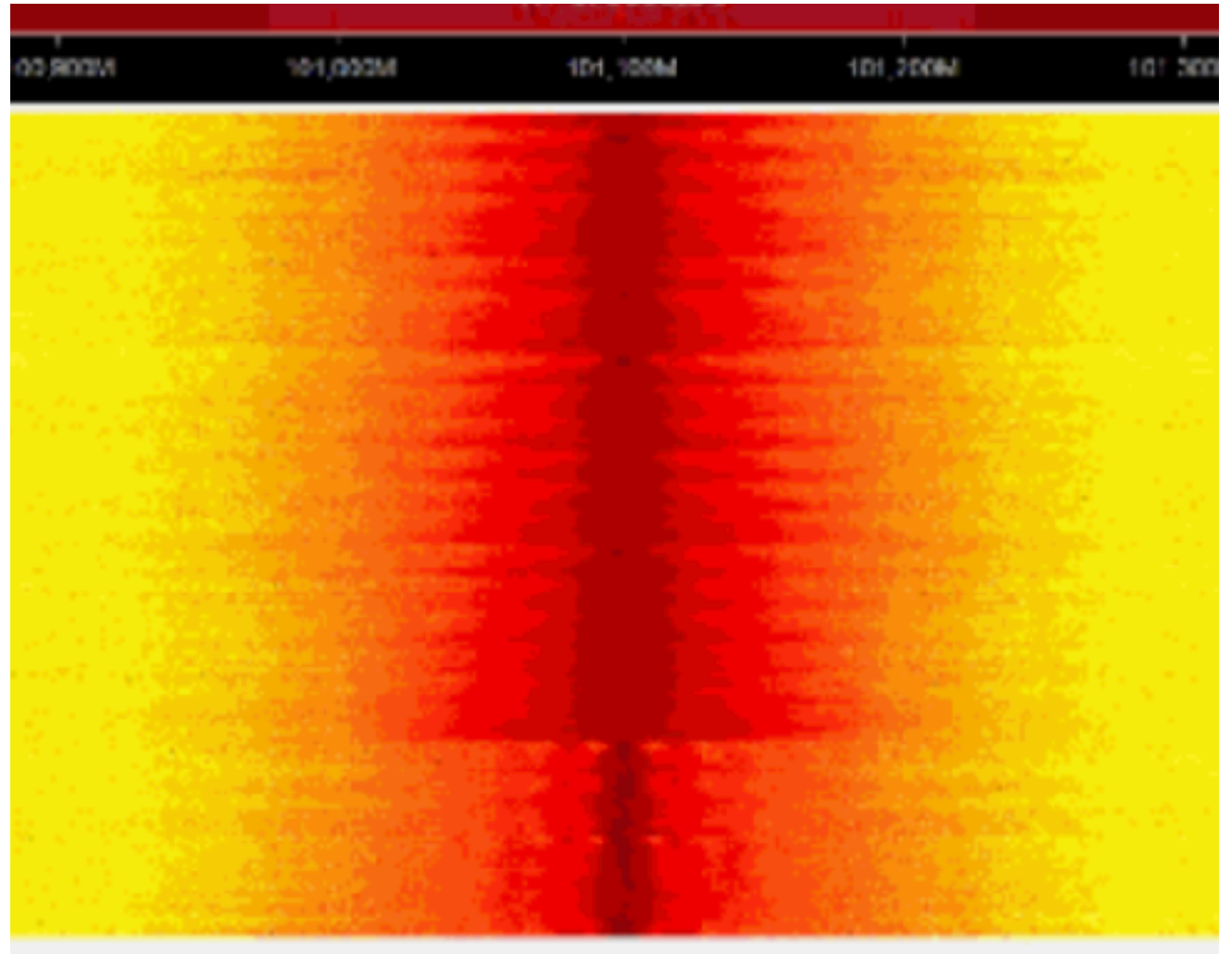
Manufacturer's Specifications		Measured in the ARRL Lab			
Frequency coverage: Receive, 0.01 – 55 MHz; transmit, 150 – 6 meter amateur bands.		Receive, 0.100 – 61.440 MHz; transmit, as specified.			
Power requirement: Not specified.		At 13.8 V dc: transmit, 15 A (typical); receive, 2.1 A. Operation confirmed at 11.7 V dc (0.85 W RF output).			
Modes of operation: SSB, CW, AM, Digital, RTTY, FM.		As specified.			
Receiver		Receiver Dynamic Testing			
Minimum discernible signal (MDS): –138 dBm.		Noise floor (MDS), 500 Hz DSP BW: 0.137 MHz –130 dBm 0.476 MHz –130 dBm 1.0 MHz –135 dBm 3.5 MHz –135 dBm 14 MHz –136 dBm 50 MHz –144 dBm			
Noise figure: Not specified.		14 MHz, 12 dB; 60 MHz, 8 dB.			
Spectral sensitivity: Not specified.		100 kHz screen bandwidth, parallel, –135 dBm; waterfall, –142 dBm.			
AM sensitivity: Not specified.		10 dB (S+N)/N, 1-kHz, 30% modulation, 8 kHz DSP BW: 1.0 MHz 1.16 µV 3.98 MHz 1.16 µV 50.4 MHz 0.96 µV			
FM sensitivity: Not specified.		29 MHz, 0.47 µV; 62 MHz, 0.20 µV.			
Blocking gain compression dynamic range: Not specified.		Blocking gain compression dynamic range, 500 Hz DSP BW: 20 kHz offset 0/2 kHz offset 3.5 MHz 124 dB 124/122 dB 14 MHz 124 dB 124/122 dB 50 MHz 116 dB 116/116 dB			
Reciprocal mixing dynamic range: Not specified.		14 MHz, 20/5/2 kHz offset: 117/110/105 dB.			
ARRL Lab Two-Tone IMD Testing* (500 Hz DSP bandwidth)					
Band	Spacing	Measured IMD Level	Input Level	Measured IMD DR**	Calculated IP3
3.5 MHz	20 kHz	–135 dBm –97 dBm	–30 dBm –19 dBm	95 dB	+9 dBm +20 dBm
14 MHz	20 kHz	–135 dBm	–30 dBm	97 dB	+11 dBm

Caveat - dynamic range

An SDR can suffer from overload pretty quickly. This is why the top performers generally have analog filters before the ADC.

Clipping in the analog world isn't as nearly as bad as in the digital world. Once you reach the top in digital, you are at the top. There is no wiggle room.

Some traditional radio manufacturers have the SDR after a traditional front-end to mitigate this.



Integration

The connected shack

Integration and the connected shack

Today the average ham station is not just a radio and a paper logbook. Today's ham shack is centered around the radio AND the computer. Not just for digital modes but for logging, contesting and automation.

A lot of this can be “blamed” on the rise of WSJT, but also things were trending in that direction anyway.

Software such as N1MM+, DXLog and others are best used with a connection to the radio. Software defined radio implementations tend to be rich in connections.



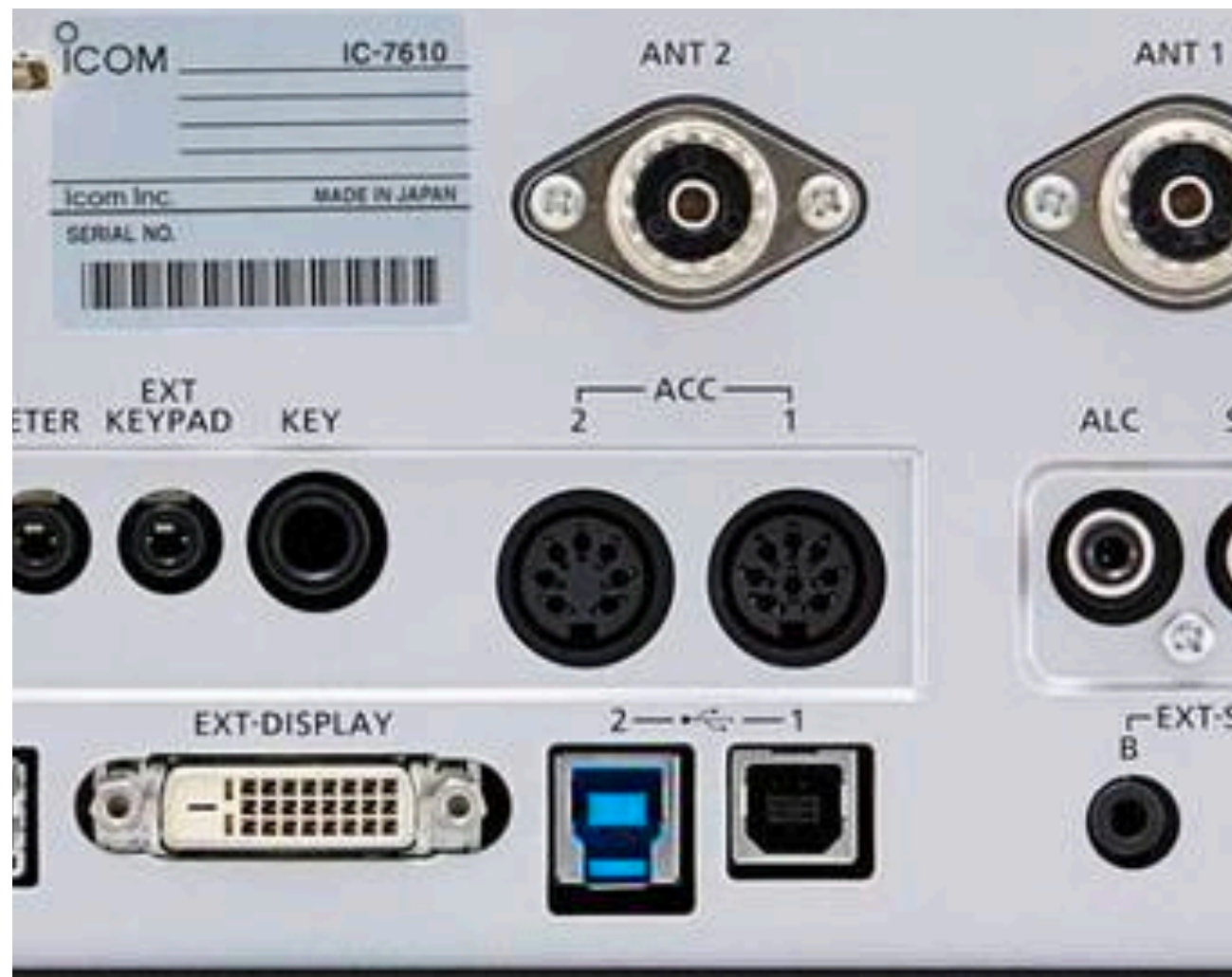
Why Integration matters

- Concentrate on the mission
- Once you get one software application working you can easily get others working
- Winlinkers already know this, but it's not intuitive unless you get into it!
- I'll be giving the full treatment to system integration at QSO Today ham radio expo in March 2021

Integration - less wiring

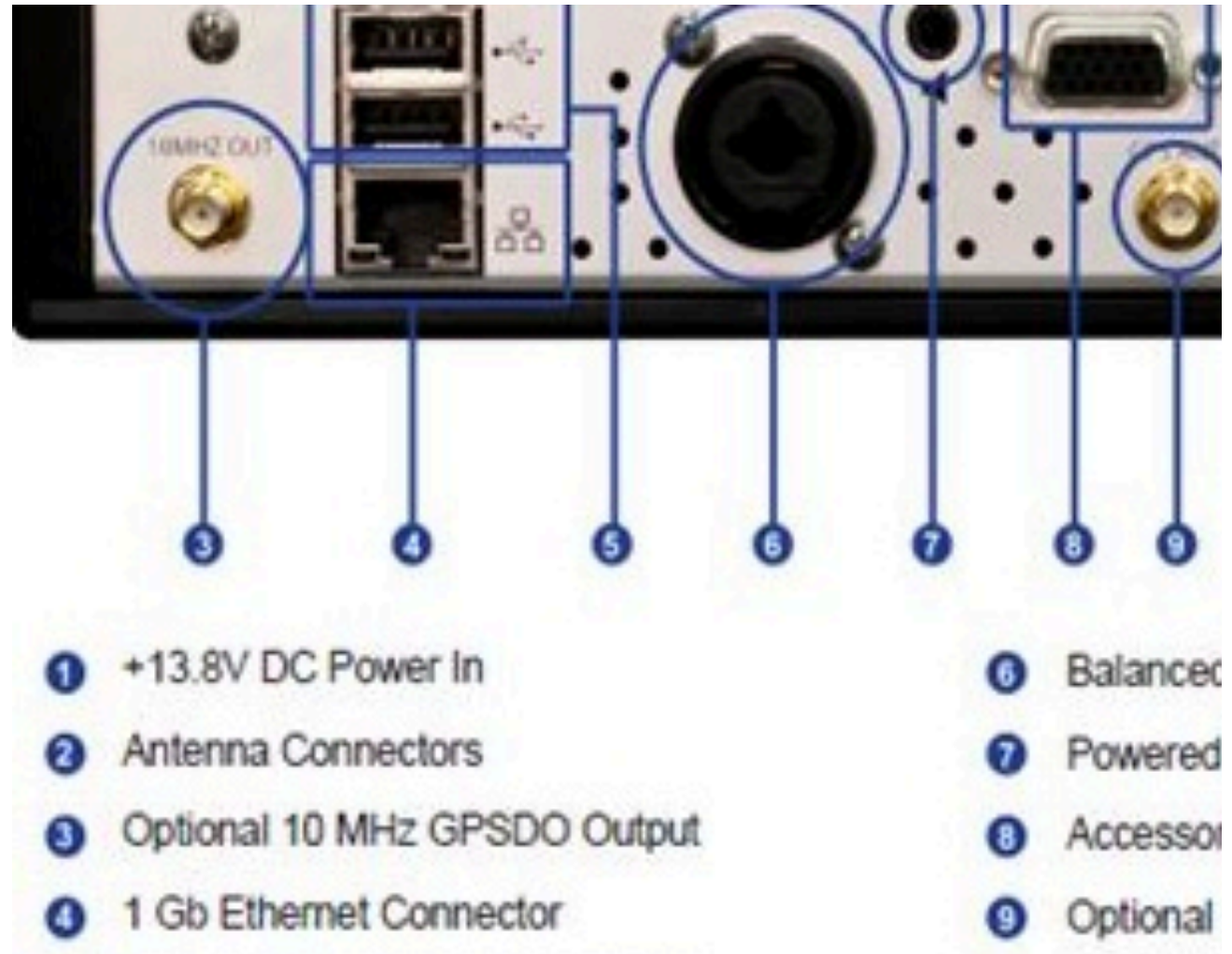
Better Integration also means less wiring. This can increase reliability and offer greater capability to integrate, even over the Internet.

Many radios today, SDR and non SDR come with USB connections that carry many signals on one bus.



Ethernet ports

Many SDR radios today, especially computer controlled ones come with an ethernet port. This can enable less cable clutter and remote operation.



Remote operation

When your world is your shack

No human being can be everywhere at once

- My life does not revolve around ham radio. I have family and other commitments.
- However, I still manage to work rare ones and fill up my logbook with DX, and put pretty plaques on the wall. How can this be?

Remote operation for Emcomm

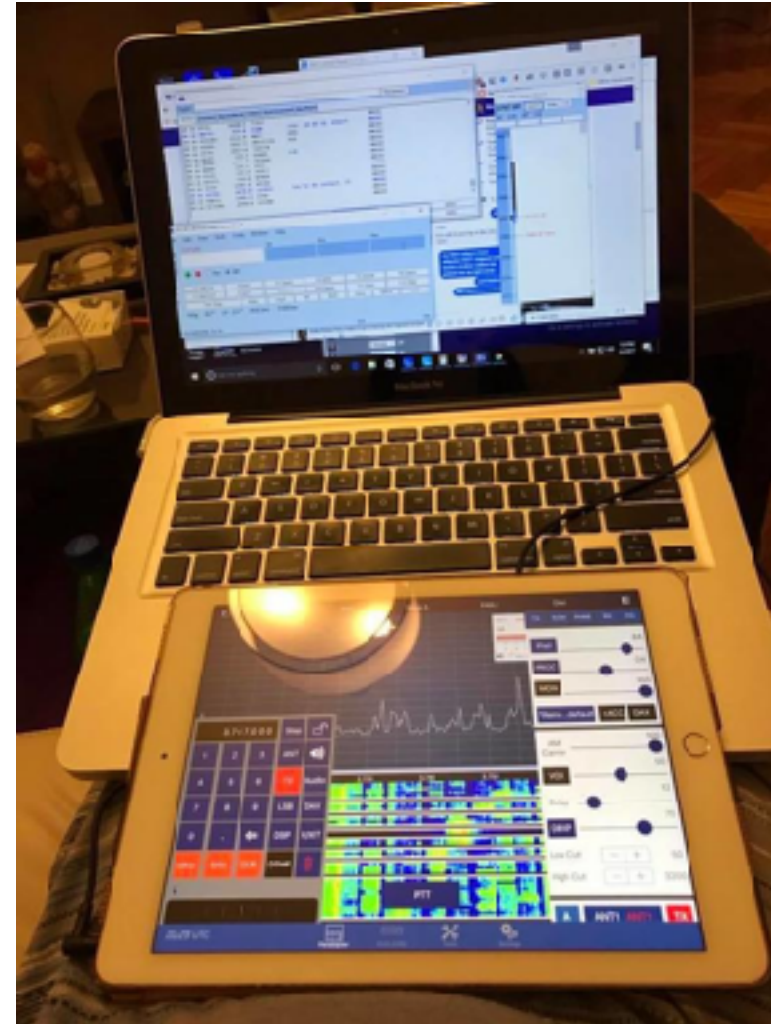
- Good location for radio, bad for operators
 - Radio on mountaintop, operators in city
- Solution: Remote operation
- Share radios with your crew
- Operate NCS easily with a powerful station
- The internet becomes your STL (Broadcasters know!)

Remote operation

Remote operation of your own station is a powerful tool to keep on the air even when you are away from home.

Several solutions to this exist - some turnkey, some not so turnkey

When the radio is software defined it is a lot easier, as these radios are based on data rather than analog signals, so they can be sent anywhere



What can you get for \$1?

Nothing!

But you can get a functional SDR receiver for \$21

Softrock is the granddaddy of cheap SDR

Needs a PC sound card but it works rather well.

Can be used for CW skimmer and monitoring of the band



Commercial solutions

These are based on RTL-SDR

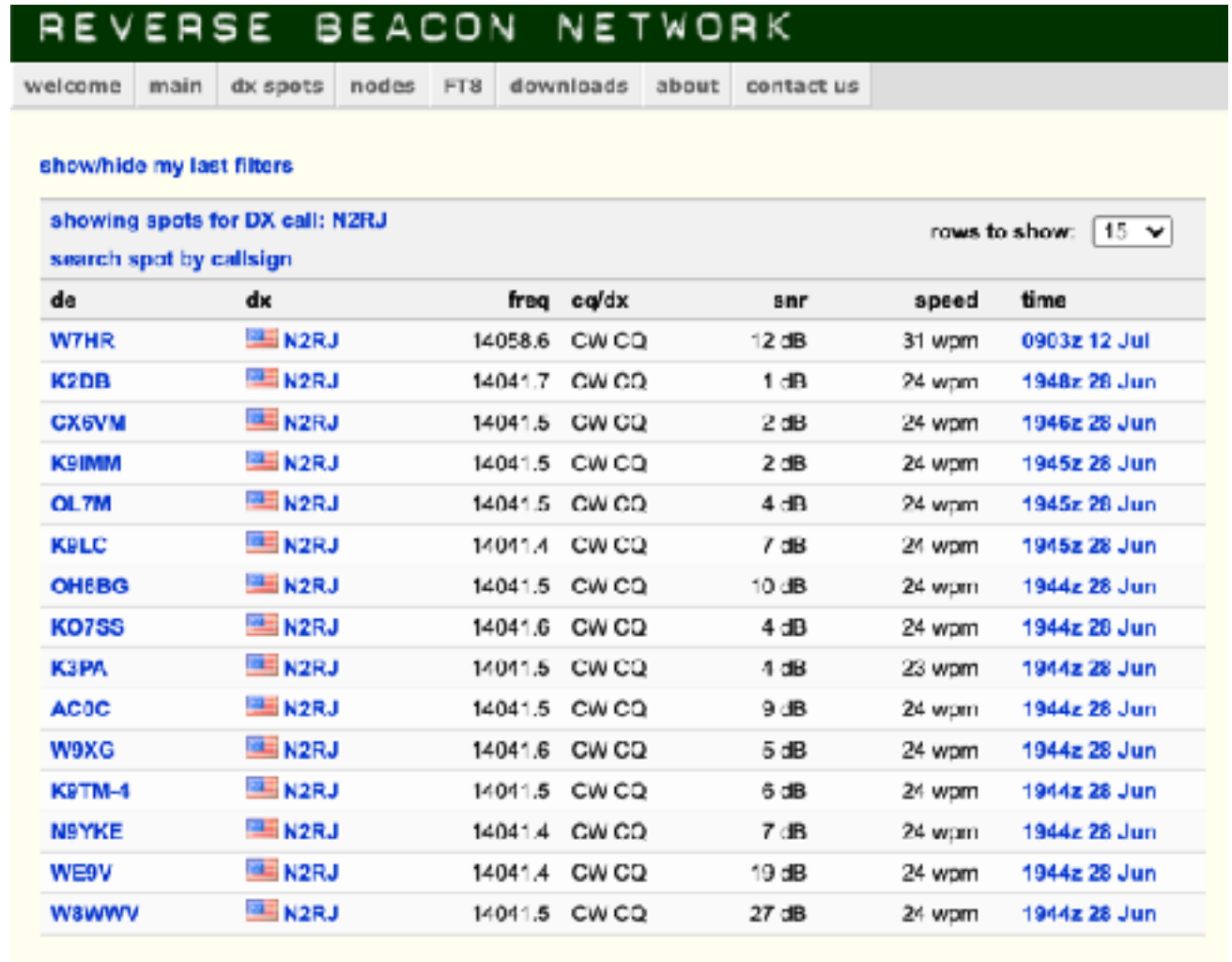


Are you getting out?

See how well you get out with internet connected SDRs.

Send a few CQs and then go to reversebeacon.net and see how you are being heard, and where.

This is a good way to see how your station compares to your peers...



The screenshot shows the Reverse Beacon Network website. At the top is a dark green header with the text "REVERSE BEACON NETWORK" in white. Below the header is a navigation menu with links: "welcome", "main", "dx spots", "nodes", "FT8", "downloads", "about", and "contact us". The main content area has a yellow background. It starts with a link "show/hide my last filters". Below that is a search bar with the text "showing spots for DX call: N2RJ" and a "rows to show:" dropdown menu set to "15". Underneath is a "search spot by callsign" label. The main part of the screenshot is a table with the following columns: "dx", "freq", "cq/dx", "snr", "speed", and "time". The table contains 15 rows of data, each representing a spot for the call N2RJ. Each row includes a "dx" column with a small US flag icon and the call sign, a "freq" column with a frequency value, a "cq/dx" column with "CW CQ", an "snr" column with a signal-to-noise ratio in dB, a "speed" column with a value in wpm, and a "time" column with a timestamp.

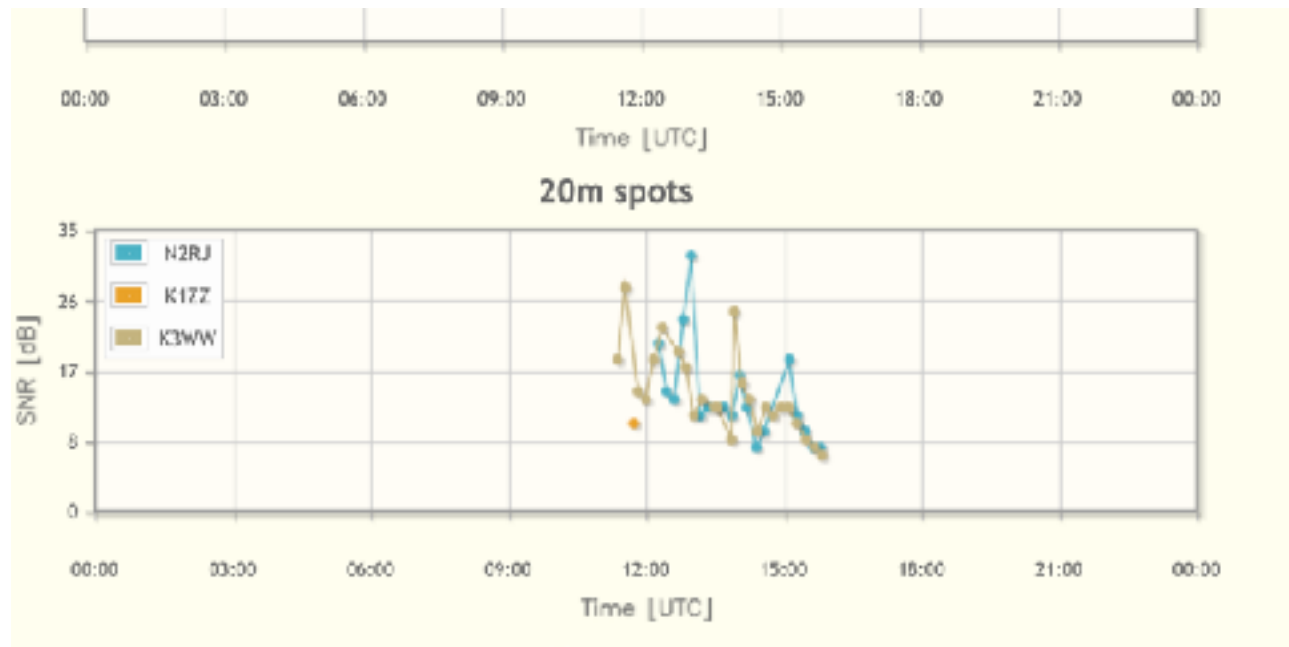
dx	freq	cq/dx	snr	speed	time
W7HR	14058.6	CW CQ	12 dB	31 wpm	0903z 12 Jul
K2DB	14041.7	CW CQ	1 dB	24 wpm	1948z 28 Jun
GX6VM	14041.5	CW CQ	2 dB	24 wpm	1946z 28 Jun
K9IMM	14041.5	CW CQ	2 dB	24 wpm	1945z 28 Jun
OL7M	14041.5	CW CQ	4 dB	24 wpm	1945z 28 Jun
K9LC	14011.4	CW CQ	7 dB	21 wpm	1945z 28 Jun
OH6BG	14041.5	CW CQ	10 dB	24 wpm	1944z 28 Jun
KO7SS	14041.6	CW CQ	4 dB	24 wpm	1944z 28 Jun
K3PA	14011.5	CW CQ	1 dB	23 wpm	1944z 28 Jun
AC0C	14041.5	CW CQ	9 dB	24 wpm	1944z 28 Jun
W9XG	14041.6	CW CQ	5 dB	24 wpm	1944z 28 Jun
K9TM-1	14011.5	CW CQ	6 dB	21 wpm	1944z 28 Jun
N9YKE	14041.4	CW CQ	7 dB	24 wpm	1944z 28 Jun
WE9V	14041.4	CW CQ	19 dB	24 wpm	1944z 28 Jun
W8WWV	14041.5	CW CQ	27 dB	21 wpm	1944z 28 Jun

Whose (signal) is bigger?

A neat little tool can tell you.

www.reversebeacon.net/analysis

Choose a spotter, and then enter callsigns.
Plot them on a graph.



Learn about
the **COOLEST**
Hobby in the world!



Ria's Shack

your #hamradio questions answered!



Ham Radio and electronics videos by N2RJ

[YouTube.com/RiaJairam](https://www.youtube.com/RiaJairam)

Questions?