Tech-ni-shn

Testing RTL-SDR V4, V3 (+ Spyverter), Airspy HF + Discovery & Mini

Sensitivity — Check S+N/N at different levels. Change S+N/N to S/N
Noise figure — Calculate Noise Figure from theoretical MDS and Sensitivity tests

Equipment used
RTL-SDR V4, V3 (+ Spyverter)
Airspy HF+ Discovery SDR, Airspy Mini
SDRSharp (SDR#) on a PC
0.5 to 470 MHz RF Signal Generator -70 dBm to -132 dBm (See Aliexpress/Amazon, etc)
or another signal source such as a TinySA or a commercial signal generator
RF cables, attenuators (30 dB) & misc adapters
TinySA Ultra Spectrum Analyser (ZS405 model)

Using a minimal setup, I am testing the sensitivity of RTL-SDRs, Spyverter, AirSpy HF+ Discovery and Airspy Mini. Note the test equipment is not calibrated, but levels are verified. Readings should be taken as indicative, not absolute

I proceeded to test the 0.5 to 470MHz Signal generator for signal level. I had previously found that the output level was ~1.5 dB lower than the displayed level. I rechecked this at 136MHz and 11 MHz and the level difference was fairly consistent down to about -104 dBm. At -105 dBm it seems to change again possibly due to a different internal attenuator being used. I also verified that an additional fixed 30 dB attenuator was close to 30 dB. The 30 dB fixed attenuator enables me to go down to -134/-135 dBm without having the 1.5 dB offset change. **NOTE. The generator output level drops significantly below 5 MHz;**

I had modified the Signal generator to run off 8x AA size NiMh cells, making it portable.

I am testing the SDRs at ~136MHz, then at HF frequencies ~11 MHz where applicable. One will later be used for tests at frequencies including 9 and 10.7 MHz

The Signal generator is connected via the fixed 30 dB attenuator on the RF input of the SDRs as I test them.

The SDRs are run using the SDR# software, which is downloaded from the Airspy website www.airspy.com

Ensure one has the latest versions of SDR#, which have the RTL-SDR versions incorporated in the software.

First off the RTL-SDR V4. Terminate the input with a 50Ω termination or a 30 dB attenuator.
Start up SDR# with the RTL-SDR connected, it should automatically find the RTL-SDR.
Set the frequency to 136MHz and Mode to USB 2400 Hz Bandwidth Order 500

Click the right facing arrow/triangle on the left side of screen to start the program.
One should see the display noise move, and may even hear noise if the volume is set higher

Switch the AGC to off, and set the gain to Maximum (49.6 dB)in the menu under the gear wheel
Go to the left menu, and set to diagnostic mode, which should bring a Signal Diagnostics screen up.
Tick the little Enabled window

Click rebuild and wait 15 secs (which is what mine defaults to), and it will come up with a number in the power window. Mine was -56.77dB. Press acquire and that display will reset to zero. This may need to be done multiple times as things may drift a little

If one injects a signal, then the display will give reading of (Signal + Noise)/Noise or S+N/N
At high S+N/N then the readings are close to S/N readings which will be calculated later.

We will take a number of measurements at different levels to endeavour to get a consistent reading.

With -70dBm input, through the 30 dB attenuator, then the S+N/N reading is 30.5dB
With -80dBm input, through the 30 dB attenuator, then the S+N/N reading is 20.4dB
With -90dBm input, through the 30 dB attenuator, then the S+N/N reading is 10.7dB
With -100dBm input, through the 30 dB attenuator, then the S+N/N reading is 3.3dB

The Signal to Noise can be calculated by 10 log ((10^((S+N/N)/10))-1)
For example taking the 3.3dB S+N/N
divide that by 10 to give 0.33dB
$10^{0.33}$ is 2.14. Subtract 1 from that gives 1.14
10 log 1.14 is 0.57 dB

See charts below. The S/N values are calculated

MDS can be calculated by taking the actual level A and subtracting the S/N (B) from that.
MDS (Minimum discernable signal is normally quoted to be 0 dB S/N or 3dB S+N/N

RTL-SDR V4	136 MHz	SSB Bandwidth	2400 Hz		
Set level dBm	Actual level	Actual Level -30dB (A)	S+N/N dB	S/N dB (B)	MDS dBm
-70	-71.5	-101.5	30.5	30.5	-132
-80	-81.5	-111.5	20.4	20.4	-131.9
-90	-91.5	-121.5	10.7	10.3	-131.8
-100	-101.5	-131.5	3.3	0.57	-132.1

From the tests it can be seen that the MDS is around -132dBm.
If one uses the formula 30 + 10 log kTB (seen in my first full video), then using 2400 Hz, 290°Kelvin and 1.38 $x10^{-23}$ then the MDS for 0 dB Noise figure at room temp of 17C is -140.1 dBm

Then the difference between them is in the region of 8 dB which is the Noise Figure.

Measurements were repeated at 11 MHz
Note. Check the mode is USB as it resets to a different mode (AM), when the frequency is changed.

Similar tests are repeated on the other SDRs

RTL-SDR V4	11 MHz	SSB Bandwidth	2400 Hz		
Set level dBm	Actual level	Actual Level -30dB (A)	S+N/N dB	S/N dB (B)	MDS dBm
-70	-71.5	-101.5	23.9	23.9	-125.4
-80	-81.5	-111.5	14.1	13.9	-125.4
-90	-91.5	-121.5	5.3	3.8	-125.3
-100	-101.5	-131.5	1	-5.9	-125.6

The MDS for 11 MHz is ~ -125.4 dBm and Noise figure is about 14.7 dB.
This is made up of triplexer losses, mixer losses/gain, mixer noise figure and noise in later stages.

RTLSDR V3	136MHz	SSB Bandwidth	2400Hz		
Set level dBm	Actual level	Actual Level -30dB (A)	S+N/N dB	S/N dB (B)	MDS dBm
-70	-71.5	-101.5	35.1	35.1	-136.6
-80	-81.5	-111.5	24.7	24.7	-136.2
-90	-91.5	-121.5	14.6	14.4	-135.9
-100	-101.5	-131.5	5.9	4.6	-136.1

MDS is ~-136 dBm, and Noise figure is about 4 dB
When using the Spyverter The Bias needs to be turned on as well as the Shift for -120MHz

RTLSDR V3 +Spyverter	11MHz	SSB Bandwidth	2400Hz		
Set level dBm	Actual level	Actual Level -30dB (A)	S+N/N dB	S/N dB (B)	MDS dBm
-70	-71.5	-101.5	22.3	22.3	-123.8
-80	-81.5	-111.5	12.7	12.5	-124.0
-90	-91.5	-121.5	4.5	2.6	-124.1
-100	-101.5	-131.5	Too lower level	Readings not	Stable

The MDS is ~-124 dBm and Noise Figure about 16 dB

AirSpy HF+D	136MHz	SSB Bandwidth	2400Hz	Preamp off	
Set level dBm	Actual level	Actual Level -30dB (A)	S+N/N dB	S/N dB (B)	MDS dBm
-70	-71.5	-101.5	31.2	31.2	-132.7
-80	-81.5	-111.5	20.9	20.9	-132.4
-90	-91.5	-121.5	11.3	11.0	-132.5
-100	-101.5	-131.5	3.4	0.75	-132.25

The MDS is ~ -132.5dBm and Noise figure about 7.5 dB

AirSpy HF+D	136MHz	SSB Bandwidth	2400Hz	Preamp on	
Set level dBm	Actual level	Actual Level -30dB (A)	S+N/N dB	S/N dB (B)	MDS dBm
-70	-71.5	-101.5	31.4	31.4	-132.9
-80	-81.5	-111.5	21.4	21.4	-132.9
-90	-91.5	-121.5	11.5	11.2	-132.7
-100	-101.5	-131.5	3.7	1.3	-132.8

The MDS is ~ -132.8 dBm so Noise figure is about 7.2 dB

AirSpy HF+D	11MHz	SSB Bandwidth	2400Hz	Preamp off	
Set level dBm	Actual level	Actual Level -30dB (A)	S+N/N dB	S/N dB (B)	MDS dBm
-70	-71.5	-101.5	35.1	35.1	-136.6
-80	-81.5	-111.5	25.1	25.1	-136.6
-90	-91.5	-121.5	15.1	15.0	-136.5
-100	-101.5	-131.5	6.1	4.9	-136.4

The MDS is around -136.5 dBm, so Noise figure is about 3.5 dB

AirSpy Mini	136MHz	SSB Bandwidth	2400		
Set level dBm	Actual level	Actual Level -30dB (A)	S+N/N dB	S/N dB (B)	MDS dBm
-70	-71.5	-101.5	32.6	32.6	-134.1
-80	-81.5	-111.5	22.4	22.4	-133.9
-90	-91.5	-121.5	12.6	12.4	-133.9
-100	-101.5	-131.5	4.3	2.3	-133.8

The MDS is around -133.9 dBm, so Noise figure is about 6.2 dB

SDR @ 2400Hz BW	Frequency	MDS dBm	Noise figure dB	
RTLSDR V4	136 MHz	-132.0	8	
RTLSDR V4	11 MHz	-125.4	14.7	
RTLSDR V3	136MHz	-136.0	4	
RTLSDR V3 + Spyverter	11 MHz	-124.0	16	
AirSpy HF+ Discovery Preamp off	136 MHz	-132.5	7.5	
AirSpy HF+ Discovery Preamp on	136MHz	-132.8	7.2	
Airspy HF+ Discovery	11 MHz	-136.5	3.5	
Airspy Mini	136 MHz	-133.9	6.2	