Ultra Low Noise Signal Source for Testing HF Receivers

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The Ultra Low Noise Signal Source (Source later in text) generates clean CW signal in 40m HF amateur band with calibrated power and ultra low phase noise.

The source can be used for testing HF receivers and measuring their parameters such as RMDR, IMD3 DR, BDR. It can also be used for S-meter checking/calibration and other purposes that require clean and stable CW signal.

Table 1 Specifications

Parameter	Min	Typical	Max
Frequency[1], kHz	7151	7153	7155
	7138	7140	7142
Output power, dBm	+4.5	+5	+5.5
Phase noise, dBc/Hz			
1kHz offset		-163	
10kHz offset		< -180[2]	
Supply voltage,V	3.5		6
Dimensions[3], mm		57x50x15	

[1] There are two versions of the source for the two different 40m frequencies
[2] Calculated from the XTAL filter frequency response, oscillator phase noise and thermal noise
[3] Including output connector

The Source is based on the ultra low noise crystal oscillator powered by ultra low noise LDO. These combination already provides the low enough level of the phase noise for measuring even the highest performance HF receivers. The crystal filter at the oscillator output further lowers the phase noise at large enough offsets (larger then +-1kHz), and also suppresses any out of band signals. So when you combine two such Sources for IMD DR measurements the combiner requirements for sources decoupling are greatly relaxed. Even with the simple resistors combiner it is possible to measure IP3 of up almost +50dBm.

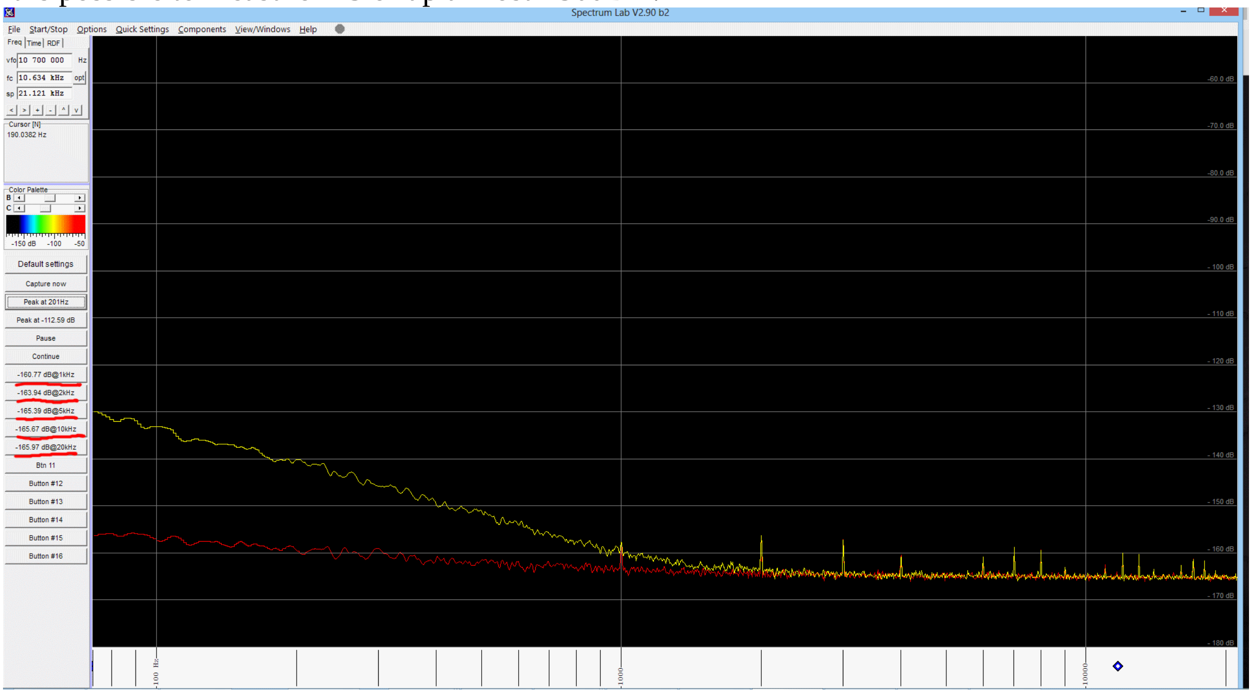

Fig.1 Source phase noise test (yellow line) and the test set noise floor (red line)

The Source phase noise measurement results is shown on Fig.1. It can be clearly seen that combined Source and test floor phase noise is 3dB higher then the test set noise at 1kHz offset, so at this offset the Source noise is at least 3dB lower then combined one (-163dBc/Hz). At 10kHz offset the XTAL filter will provide more than 20dB attenuation, with the thermal noise (-177dBm/Hz) and Source output power (+5dBm) in mind we can safely assume that the Source phase noise will be below -180dBc/Hz.

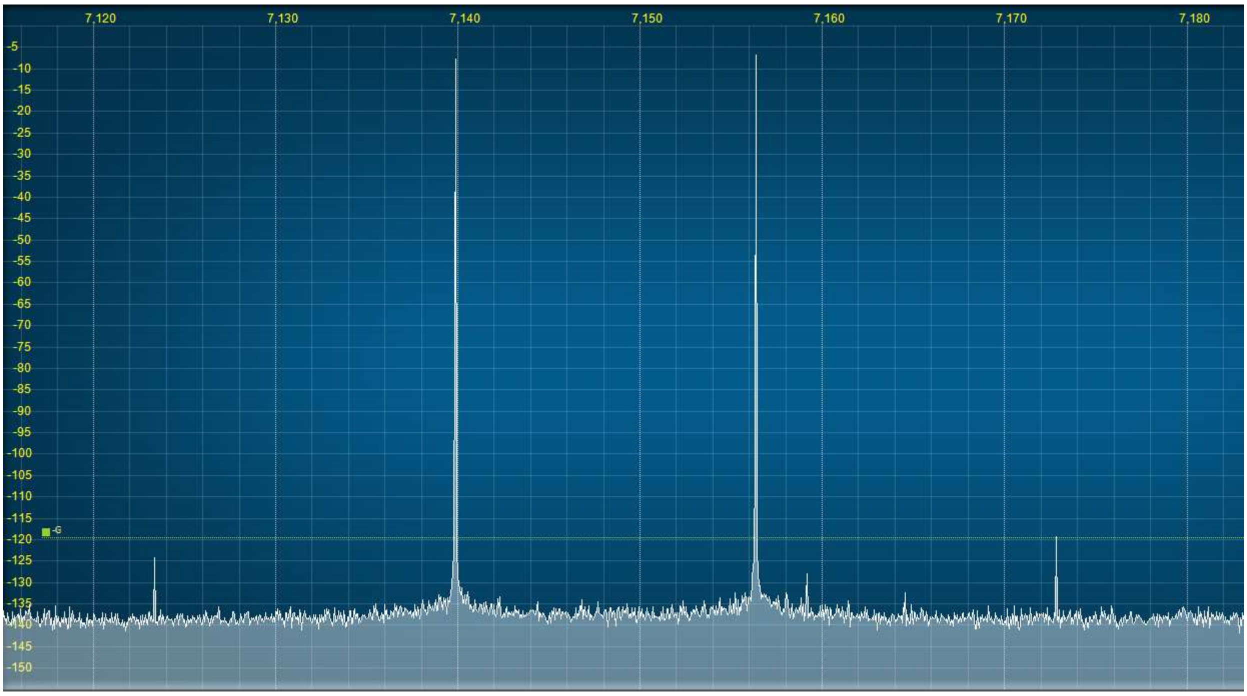

Fig.2 The IMD3 measurements of the direct sampling SDR receiver. Two sources were combined using the simple resistors combiner, but it was possible to measure +48.5dBm IP3 value (-7dBm test signals and -118dBm largest IMD3 product).

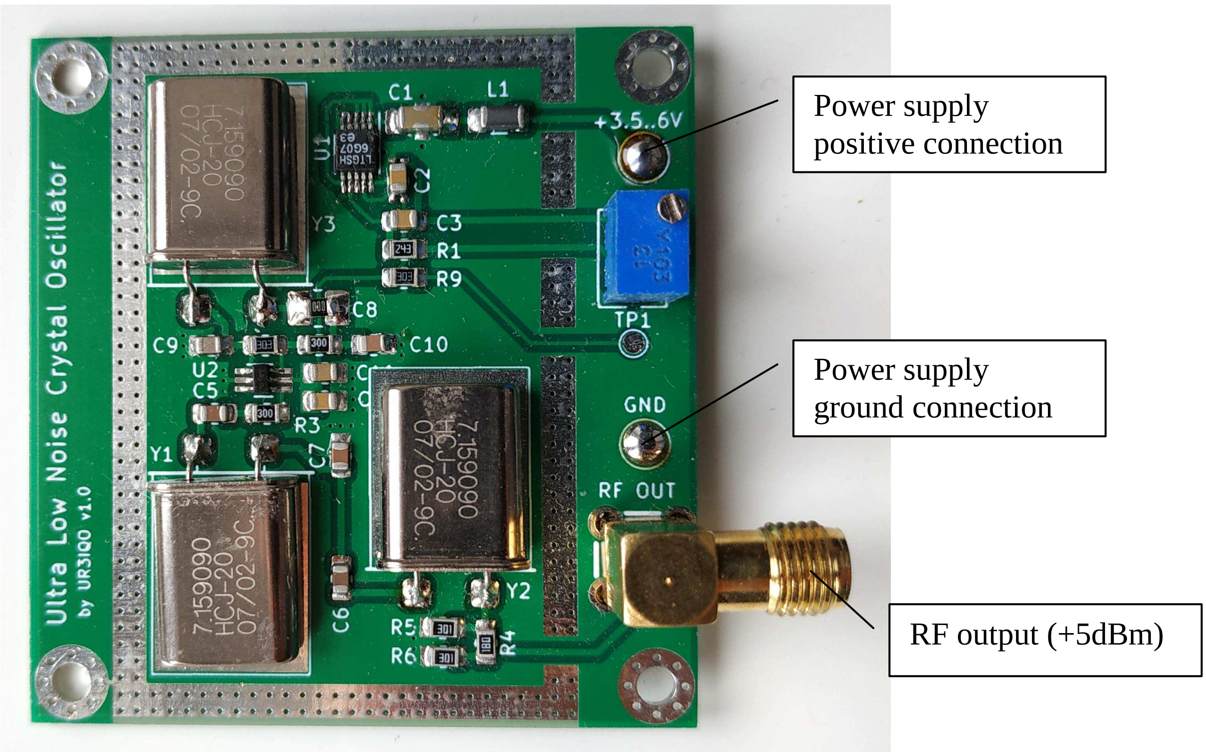

Fig.3 Ultra low noise signal source board

The Source supports wide supply voltages range (+3.5..6V recommended supply voltage range and +3.5..15V max), and contains ultra low noise, high PSRR voltage regulator, but it is desirable to use clean power supply. The very good variant is to use single 18650 Li cell or batteries.

Test setups for different measurements

Note: This section provides **ONLY BASIC and SIMPLIFIED** information of the Source use. Please consult ARRL Test Procedures Manual [1] or ITU documents for more complete information.

Note: For the most measurements you will need variable step attenuator and power combiner. They are not supplied with the Source.

S-meter calibration

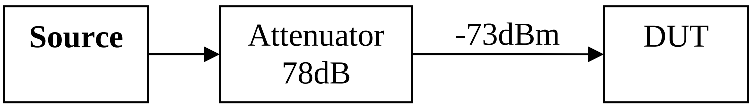

Fig 4. Test setup for the S-meter checking/calibration

The Source provides signal with calibrated power, so it can be used to calibrate receiver S-meter (or check its calibration). You will need 78dB attenuator to get -73dBm the standard S9 signal.

RMDR/BDR measurements

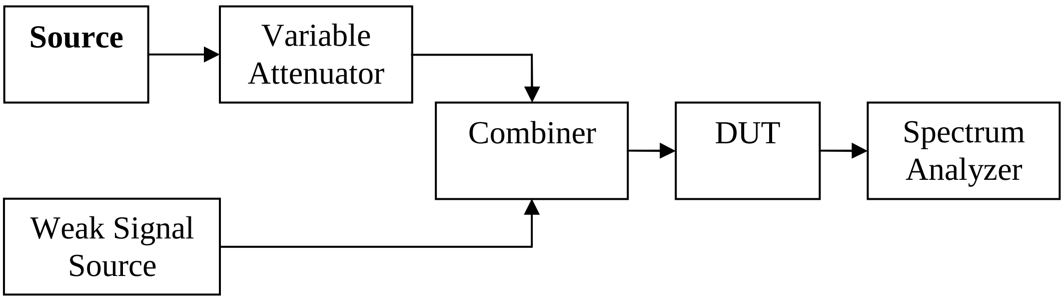

Fig 5. Test setup for the BDR/RMDR measurements

The Blocking Dynamic Range is the range between the DUT MDS and the level of the strong nearby offending signal that produces 1dB decrease of the weak desired signal. While the source of the offending signal should be exceptionally clean, there are no strict requirements for the weak signal source, so many signal generators can be used.

BDR (dB) = +5 (dBm) - Attenuator loss (dB) - Combiner loss (dB) - MDS (dBm) (1)

To measure BDR, apply a test signal from the Source to a DUT and increase its level (by decreasing variable attenuator value) until Weak Signal level at the DUT output will drop by 1dB. Then use formula (1) to calculate the BDR.

Note: For the measurements described in this section the receiver AGC system should be turned off and receiver gain should be set manually, so the receiver will operate within the linear part of amplitude characteristics.

The Reciprocal Dynamic Range is the range between the DUT MDS and the level of the strong nearby offending signal the produces 3dB increase of DUT noise.

RMDR (dB) = +5 (dBm) - Attenuator loss (dB) - Combiner loss (dB) - MDS (dBm) (2)

To measure RMDR, apply a test signal from the Source to a DUT and increase its level (by decreasing variable attenuator value) until DUT noise floor increases by 3dB. Then use formula (2) to calculate the RMDR.

Note: observe signal and noise levels at the DUT output using the spectrum analyzer to determine if the blocking or reciprocal mixing occurred.

When measuring RMDR the Weak Signal Source, Combiner and Spectrum Analyser are needed to check whether the blocking (the weak signal level will drop with the rise of the offending signal level) or reciprocal mixing occurs (in this case the noise power will rise with the rise of the offending signal level). If you are absolutely sure that RMDR is lower then the BDR the RMDR measurements can be done using the simplified setup:

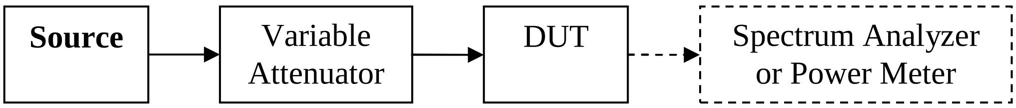

Fig 6. Simplified test setup for RMDR measurements

Note: A few radios provides precise signal power measurement capabilities. In such case, when the simplified setup is used, the Spectrum Analyzer or Power Meter might not be necessary (but the DUT should be capable of precise RMS power measurement of the passband signals/noise).

IP3/IMD3 DR Measurements

The IMD3 DR will determine the range of the signals levels the DUT will tolerate without generating no spurious signals due to 3rd order intermodulation.

Note: A simplified test setup and procedure will be described in this section for the full variant please consult ARRL Test Procedures Manual or ITU documents.

Note: You will need two Sources for two different frequencies to make IMD3 measurements

Note: For the measurements described in this section the receiver AGC system should be turned off and receiver gain should be set manually, so the receiver will operate within the linear part of amplitude characteristics.

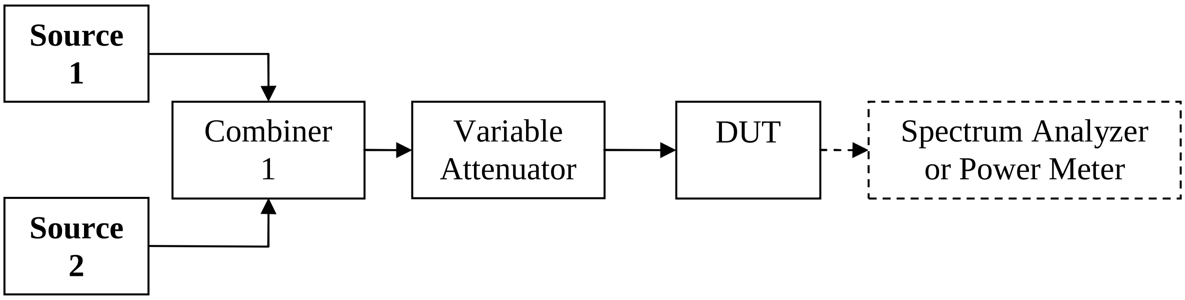

Fig 7. Simplified test setup for 3rd order intermodulation measurements

Two test signals of equal amplitude are combined in the passive Combiner and applied to the DUT through the Variable Attenuator. The receiver is tuned to the upper and lower IMD3 product frequency (2*f1 - f2 and 2*f2 - f1). The test signal levels are increased until the IMD3 product level combined with the DUT noise results in 3dB DUT output power increase. So the IMD3 product is equal to MDS. The IMD3 DR will be equal to:

DR3 (dB) = +5 dBm - Combiner loss (dB) - Attenuator loss (dB) - MDS (dBm)

Use the minimal DR3 from the two measured values.

For some receiver architectures (Direct Sampling Receivers) the IMD3 products does not follow cubical law, so the DR3 number is not the best way to describe its strong signal performance with several strong offending signals. In such cases a better way to present the IMD3 DUT performance it to measure the IMD3 products level for the different input test signals levels and show resulting table or plot the curve showing IMD3 level depending of the input test signal levels.

References

1. ARRL Test Procedures Manual, http://www.arrl.org/files/file/Technology/Procedure%20Manual%202011%20with%20page%20breaks.pdf