

Technical Note 1

RTL-SDR Sensitivity for AIS System

RTL-SDR [1] is a software defined radio that uses a DVB-T TV tuner dongle. Its manufacturer does not provide the necessary details to know the sensitivity for AIS System. In order to include this, a rather comprehensive study on this device would be required. As reference, the chip used by the RTL-SDR received is the RTL2832U. Its datasheet can be found on [2] from which the following parameters have been extracted.

Table 1-2 : Electrical AC Parameters

Parameters	Condition	Units	Min	Typical	Max
Input Return Loss ¹	S11	dB		-10	
Operation Frequency Range		MHz	42		1002
Voltage Gain		dB	85		95
AGC Range		dB		104	
Noise Figure	@ Max Gain	dB		3.5	
IIP3	LNA Max Gain	dBm		-7.5	
	LNA Min Gain	dBm		+35	
Image Rejection		dBc		65	
Phase Noise	1K	dBc		-91	
	10K	dBc		-98	
	100K	dBc		-109	
CSO	110 Channel at 75dBuV	dBc		-67	
CTB		dBc		-65	
Multiple Crystal Frequency Spurious	Refer to RF-In	dBm		-120	
RF in to Loop through gain ¹		dB		0	
Loop through Return loss ¹		dB		-13	
Sensitivity	FFT:8k,QPSK,CR:1/2	dBm		-97.5	
	FFT:8k,16QAM,CR:1/2	dBm		-91.5	
	FFT:8k,64QAM,CR:3/4	dBm		-81.5	
Adjacent Channel Rejection	FFT:8k,64QAM,CR:7/8	dBm		-79.5	
	Analog Interference at DVB-T Signal	dBc		-47	
Max. Input Power	FFT:8k,64QAM,CR:7/8	dBm		+10	
IF Output Level	Swing	Vp-p		1	2
	Impedence		Differential 2kΩ/5pF		
PLL Locking time		ms			5

From the table, it can be observed, that its sensitivity value is given to enable DVB-T signal demodulation given that these devices were manufactured initially for this mentioned purpose. From the table we can read that for an FFT 8K QPSK, CR=1/2, the sensitivity value is of -97.5dBm and a Noise Floor (NF) of 3.5dB. The value of C/N is chosen from [3] in Table A.1.

Table A.1: Required C/N for Non-Hierarchical transmission
to achieve a BER = 2×10^{-4} after the Viterbi decoder

Constel- lation	Code rate	Required C/N (dB) for BER = 2×10^{-4} after Viterbi QEF after Reed-Solomon (see note 2)			Bitrate (Mbit/s) (see note 3)			
		Gaussian Channel (AWGN)	Ricean channel (F ₁)	Rayleigh channel (P ₁)	$\Delta/T_U = 1/4$	$\Delta/T_U = 1/8$	$\Delta/T_U = 1/16$	$\Delta/T_U = 1/32$
QPSK	1/2	3,5	4,1	5,9	4,98	5,53	5,85	6,03
QPSK	2/3	5,3	6,1	9,6	6,64	7,37	7,81	8,04
QPSK	3/4	6,3	7,2	12,4	7,46	8,29	8,78	9,05
QPSK	5/6	7,3	8,5	15,6	8,29	9,22	9,76	10,05
QPSK	7/8	7,9	9,2	17,5	8,71	9,68	10,25	10,56
16-QAM	1/2	9,3	9,8	11,8	9,95	11,06	11,71	12,06
16-QAM	2/3	11,4	12,1	15,3	13,27	14,75	15,61	16,09
16-QAM	3/4	12,6	13,4	18,1	14,93	16,59	17,56	18,10
16-QAM	5/6	13,8	14,8	21,3	16,59	18,43	19,52	20,11
16-QAM	7/8	14,4	15,7	23,6	17,42	19,35	20,49	21,11
64-QAM	1/2	13,8	14,3	16,4	14,93	16,59	17,56	18,10
64-QAM	2/3	16,7	17,3	20,3	19,91	22,12	23,42	24,13
64-QAM	3/4	18,2	18,9	23,0	22,39	24,88	26,35	27,14
64-QAM	5/6	19,4	20,4	26,2	24,88	27,65	29,27	30,16
64-QAM	7/8	20,2	21,3	28,6	26,13	29,03	30,74	31,67

NOTE 1: Figures in italics are approximate values.
NOTE 2: Quasi Error Free (QEF) means less than one uncorrected error event per hour, corresponding to BER = 10^{-11} at the input of the MPEG-2 demultiplexer.
NOTE 3: Net bit rates are given after the Reed-Solomon decoder.

In this table, for the QPSK modulation, Code Rate of 1/2 and a Gaussian Channel (AWGN), the necessary value of C/N is of 3.5dB. The sensitivity can be calculated and have an estimative value throughout [4].

$$Sensitivity(dBm) = 10 \log_{10}(KTB) + NF + \frac{C}{N} + 30$$

Including the adequate values: $K=1.38e-23$ J/K, $T= 290$ K, $B= 8$ MHz, $NF = 3.5$ dB, $C/N = 3.5$ dB, a sensitivity = -97.9 dBm, is obtained. As it can be observed, the value is very close to the one indicated by the manufacturer. In this case, with a margin error of 0.4 dB.

The AIS system has a bandwidth of $B=25$ KHz and a relation Signal to Noise $C/N = 10$ dB [5]. For this reason, and by using the same formula a sensitivity value = -116.5 dBm is obtained.

References:

- [1] <http://www.rtl-sdr.com/rtl-sdr-tutorial-cheap-ais-ship-tracking/>
- [2] http://rtlsdrblog.rtlsdrblog.netdna-cdn.com/wp-content/uploads/2013/04/R820T_datasheet-Non_R-20111130_unlocked.pdf
- [3] European Standard ETSI EN 300 744 “Digital Broadcasting (DVB); Framing structure, channel coding and modulation for digital terrestrial television”.
- [4] Beasley J., Miller, G., Modern Electronic Communication (Eighth Edition), Ed. Phl.
- [5] http://www.comarsystems.com/slr_300n.html

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