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

		Required C/N (dB) for BER = 2×10^{-4} after Viterbi QEF after Reed-Solomon (see note 2)			Bitrate (Mbit/s) (see note 3)			
Constel-lation	Code rate	Gaussian Channel (AWGN)	Ricean channel (F_1)	Rayleigh channel (P_1)	Δ/T_U = 1/4	Δ/T_U = 1/8	Δ/T_U = 1/16	Δ/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].

$$Sensitivity\ (dBm) = 10log10(KTB) + NF + \frac{C}{N} + 30$$

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.

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.

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