70cm UHF Transceiver with DRA818U Module

Documentation
Bill of Material
Parts

Keywords: DRA818U, transceiver, TRCV, handheld amateur radio, homemade, homebrew, 70cm transmitter, avr microcontroller

Preface:

A homemade handheld 70 cm amateur radio transceiver on a perfboard sounds like a challenge. With the SMD module DRA818U it looked feasible to me. All RF related functions are integrated in this module. The internet shows plenty of test circuits but never a complete transceiver including controller and antenna on a single board. When I found a small whip antenna with a SMB connector for 440 MHz I started realizing this project on a perfboard.

Contents

1 Design Goals

My goal was the design of a transceiver capable for direct or via repeater communication. Frequency and volume control in the fashion of commercial transceivers. A LCD for frequency and menu display and four keys for basic control.
Since the RF power of the DRA818U is 30 dBm (1 watt) only, the more important is a good antenna matching especially for a handheld device. Designing and verifying the performance of a whip antenna mounted on a perfboard was one of the main goals.
The known problem of the poor harmonic suppression had to be solved. A low pass filter between the module and the antenna is mandatory in order to suppress the harmonics and to comply with the national law.
Components had to be found for PCB mounting. Power from a single rechargeable li-ion cell of 3.7 V for the complete transceiver was a basic desire.

Specification:

Operating frequency	:	430 – 440 MHz
RF output power	:	1 W
Modulation	:	narrowband fm (NFM)
Frequency deviation	:	2.5 kHz max
Suppression of harmonics	:	> 60 dB
Battery power	:	3.7 V from a single lithium ion cell

Software and control elements

Key1	:	Toggle channel step 12,5 or 25 kHz
Key2	:	Squelch in 8 steps
Key3	:	Toggle 7.6 MHz shift ON/OFF
Key4	:	Burst tone 1750 Hz (while PTT is pressed)
Pot1	:	Volume control
ENC	:	Rotary encoder for channel selection
Key	:	PTT
LCD Display	:	2 lines with 16 characters for channel and menu

2 The DRA818U Module

What is inside this compact transceiver module? The core is the RDA1846 from RDA microelectronic providing the digital signal processing (DSP) for the TX and RX part. A microcontroller takes care of the RDA1846, the RF power amplifier, the audio process and squelching circuits. The UART provides the communication with the external controller.

For a transceiver all RF related functions are concentrated in this SMD module. I am using the “U” type standing for UHF-band. The manufacturer DORJI Applied Technologies specifies the frequency band from 400 to 470 MHz. The dimensions are 36 mm by 19 mm. Further technical data see [1]. Very comfortable is the supply voltage range von 3.3 to 4.5 Volts. This matches the voltage of a single lithium ion cell perfectly. See figure 1 and 2.

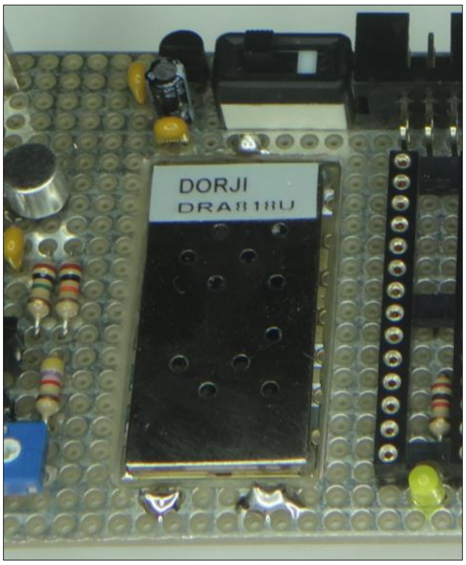


Figure 1: Photo DRA818U

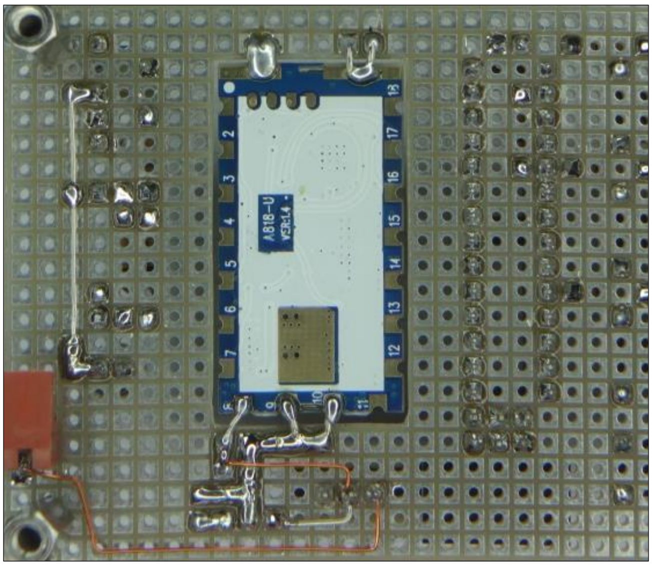


Figure 2: Photo DRA818U solder side

3 Software

A hard- and software design of a microcontroller, LCD, encoder and 4 keys did already exist. The supply voltage of these parts is 3.3 V. These parts are of low current consumption and easy to supply from a single lithium ion cell. The software handling the keys, the LCD and the encoder had to be modified in order to support the functions of a transceiver. The encoder controls the frequency channel selection. The LCD of two lines shows the current frequency and other transceiver functions. The four keys take over basic functions.

When rotating the encoder, the ENCODERA signal causes an interrupt at the INTA pin. In the interrupt routine the rotation direction is determined and a counter value is incremented or decremented. A flag indicates the main routine for update. See figure 3, schematic 70cm transceiver.

If one of the four keys is pressed, a pin change interrupt of the controller activates the corresponding interrupt routine in which the individual key is decoded. A flag indicates a service in the main routine. Every 100 ms the main loop is initiated by a compare match interrupt of timer 1.

The output compare function of timer 0 is used for generation of a 1750 Hz burst signal for a repeater access.

3.1 Serial Communication to the DRA818U

A serial telegram configures the DRA818U module. The default data format is: 8 data bits, 1 stop bit, no parity and 9600 kbps data rate. All commands in ASCII codes start with “AT” and end with “<CR><LF>”. The main command defines the following functions:

GBW	Channels space
TFV	Transmit frequency
RFV	Receive frequency
Tx_CTCSS	CTCSS transmit
SQ	Squelch
Rx_CTCSS	CTCSS receive

AT+DMOSETGROUP=GBW,TFV, RFV,Tx_CTCSS,SQ,Rx_CTCSS<CR><LF>

Details are describes in the datasheet [1]. With each frequency change the full command is sent to the DRA818U. The response information from the module is ignored by the software. In the appendix is a cross reference table for the CTCSS frequency.

4 Schematic of the 70cm Transceiver

4.1 ATmega328P and Periphery

The controller (IC1) is well known from Arduino projects. I choose the two line display EA-DOG-M (DIS1) because of the 3.3 V supply voltage and its SPI interface. Only four pins of the controller are necessary for the data exchange. The encoder (U$2) and the four keys (S2~S4) built the digital part. The voltage regulator (IC2) produces a stable 3.3 V from the lithium ion cell of about 3.5 to 4.2 V. LED1 flashes while the controller is running.

4.2 DRA818U and Periphery

The transistor Q1 amplifies the audio signal from the electret microphone. R2 adjusts the gain. R14 and C23 build a low pass filter for the 1750 Hz burst tone. R15 reduces the amplitude to about 10 mV at MIC_IN at the DRA818U module. Between the ANT pin and the antenna is the low pass filter 550 MHz [7]. Further details with measurements see below. LED2 (green) is lit if a signal is detected. LED3 (red) is lit while transmitting. S7 is the PPT.

4.3 Audio Power Amplifier

IC3 is an audio amplifier for low supply voltage. The two channels operate in a bridge configuration. Output power is about 500 mW into a 8 Ω speaker. R10 controls the volume. R10 is the volume control.

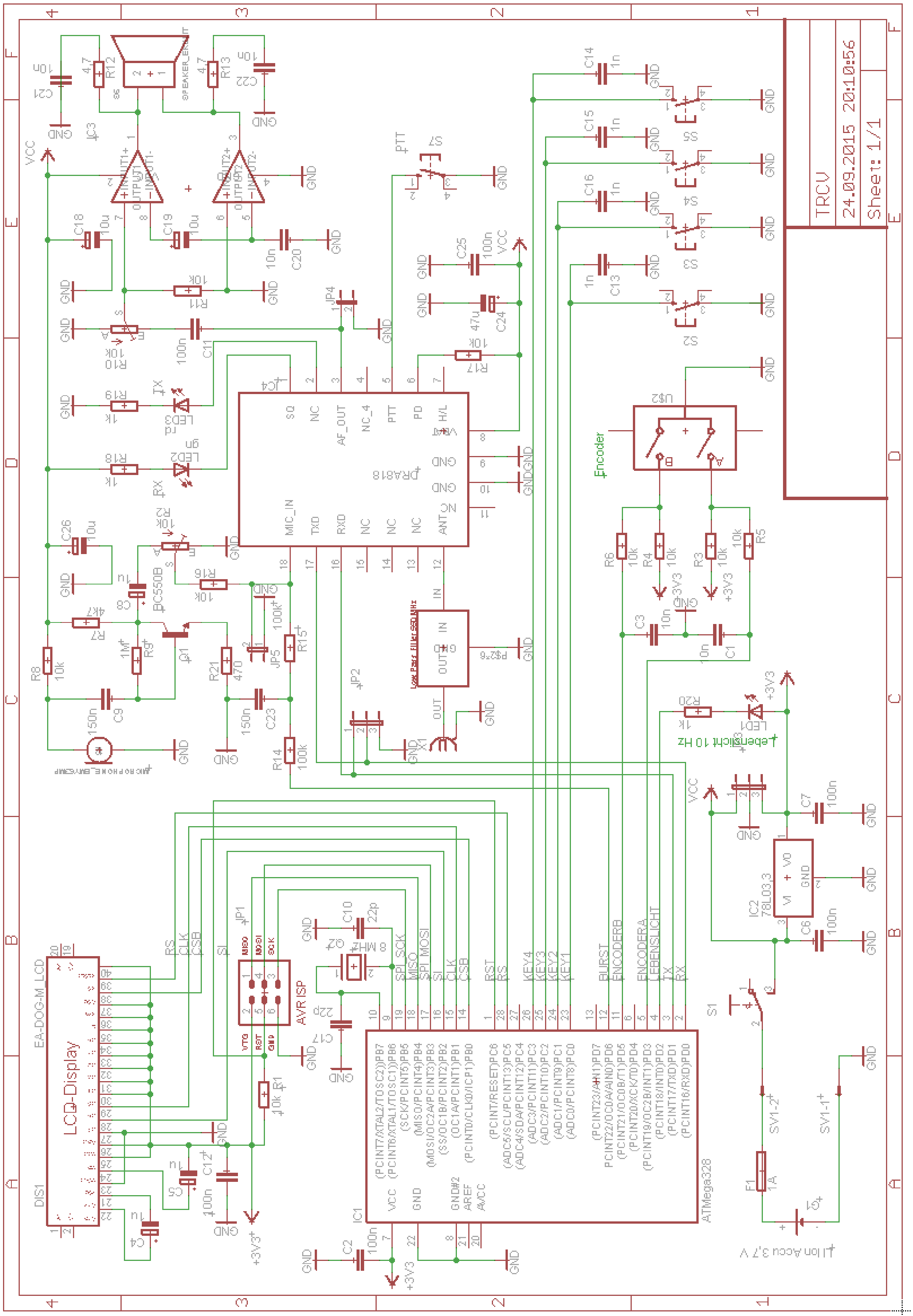


Figure 3: Schematic 70cm Transceiver

5 Transmitter Measurements

5.1 Output Power

At a frequency of 438 MHz and a battery power of 3,8 V the power was measured at the antenna connector.

Power measured:	9,8 dBm
Attenuator:	19,89 dB
Total:	29,69 dBm

The RF output power at the SMB connector is 0,93 W. See figure 4 with the measurement setup. Losses in the adapters were neglected.

Figure 4: Photo setup power measurement

5.2 Frequency Accuracy

At a default frequency of 438.800 MHz I measured the transmitting frequency with a precision counter. The reading was 438.800300 Hz. The offset of 300 Hz in relation the bandwidth of 12.5 kHz FM transmitter is negligible. The relative error is 0.68 ppm. Due to temperature increase while transmitting for about 10 s I observed a drift of about 10 Hz.

5.3 Verification of the Low Pass Filter

From prior transmitter measurements the requirement of a low pass filter became mandatory. I choose a Mini-Circuits PLP-550+ [7] available at [2].
With a network analyzer I verified the insertion loss at the TX frequency and at the expected frequency of the 2nd harmonic. I soldered two coaxial cables with SMA connectors onto the leads of the filter. See figures 5. Figure 6 is a screenshot from the network analyzer. I expected the isolation even higher when the filter is soldered onto a perfboard with a ground top layer.

Insertion loss	at 435 MHz is	< -0,47 dB
	at 880 MHz about	< - 56 dB

Figure 5: Photo low pass filter

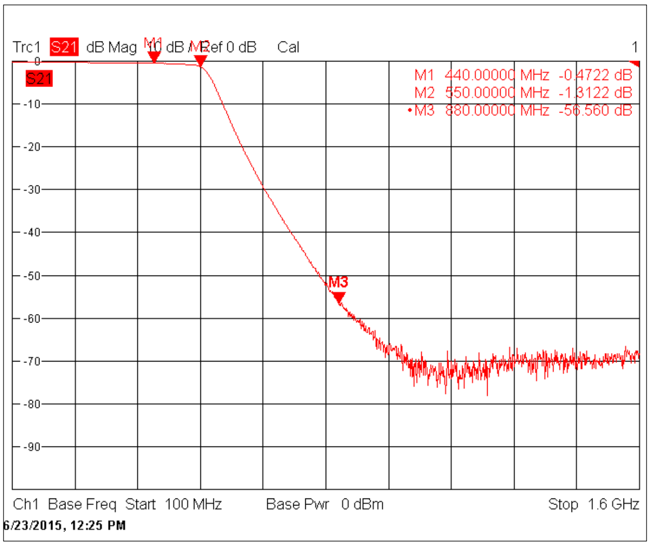
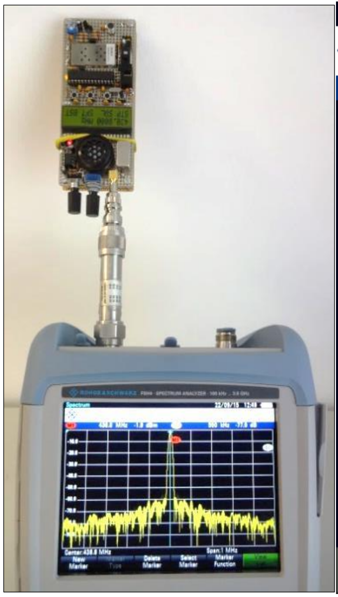


Figure 6: Screenshot network analyzer

5.4 Transmitter Harmonics

For verification of the harmonic suppression I used the measurement setup of figure 7 with PPT pressed continuously with a rubber band. A 30 dB precision attenuator between the transmitter and the analyzer protects the input of the analyzer. The 1. harmonic at 435.000 MHz produced an RF level of – 1.7 dBm. The 2. harmonic at 870 MHz was measured with a suppression of 73.5 dBc. The 3. harmonic was not detectable.



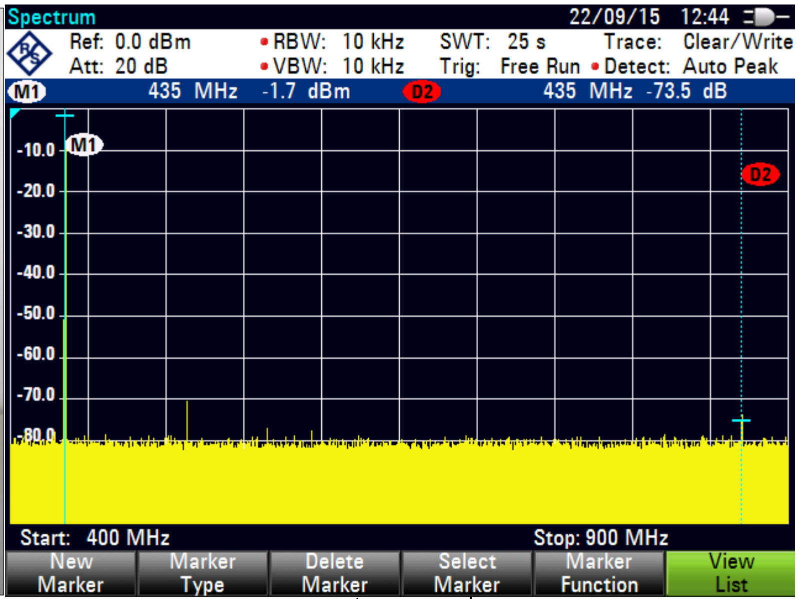


Figure 7: Photo setup   Figure 8: Screenshot 1st and 2nd harmonic

The German Amateur Radio Law [5] regulates in § 16 section (4) the allowed emissions of harmonic. In detail the German Authority for Telecommunications publishes the present limits in Table 1 [6].

Richtwerte in Sendemode		
Frequenzbereich	**Erforderliche Dämpfung unerwünschter Aussendungen gegenüber der maximalen PEP des Senders [1)]**	**Alternativ zulässige maximale Leistung unerwünschter Aussendungen eines Senders [1)]**
1	**2**	**3**
0,15 MHz - 1,7 MHz	60 dB	0,25 µW (-36 dBm)
1,7 MHz - 35 MHz	40 dB	
35 MHz - 50 MHz	$40\,\text{dB} + 129{,}1 \cdot \lg\frac{f}{35}\,\text{dB}$ mit f ... Frequenz in MHz	
50 MHz - 1000 MHz	60 dB	
>1000 MHz - 40 GHz	50 dB	1 µW (-30 dBm)

Table 1: Extract from [6]

In the 70 cm amateur radio band either total power of the harmonics or the carrier suppression is defined. With the result of 73 dBc the requirement of columm 2 with a suppression of > 60 dB is fulfilled. In fact the column 3 as well.

6 Receiver Measurements

6.1 Audio Frequency Response

With a signal generator I produced a RF signal with 2.5 kHz deviation. Modulated from an external audio generator I injected this signal with an amplitude of -70 dBm into the transceiver. With the probe of an oscilloscope on the AF_OUT pin 3 of the DRA818U I measured the frequency response. See figure 9. I did not select any filters of the SETFILTER command.

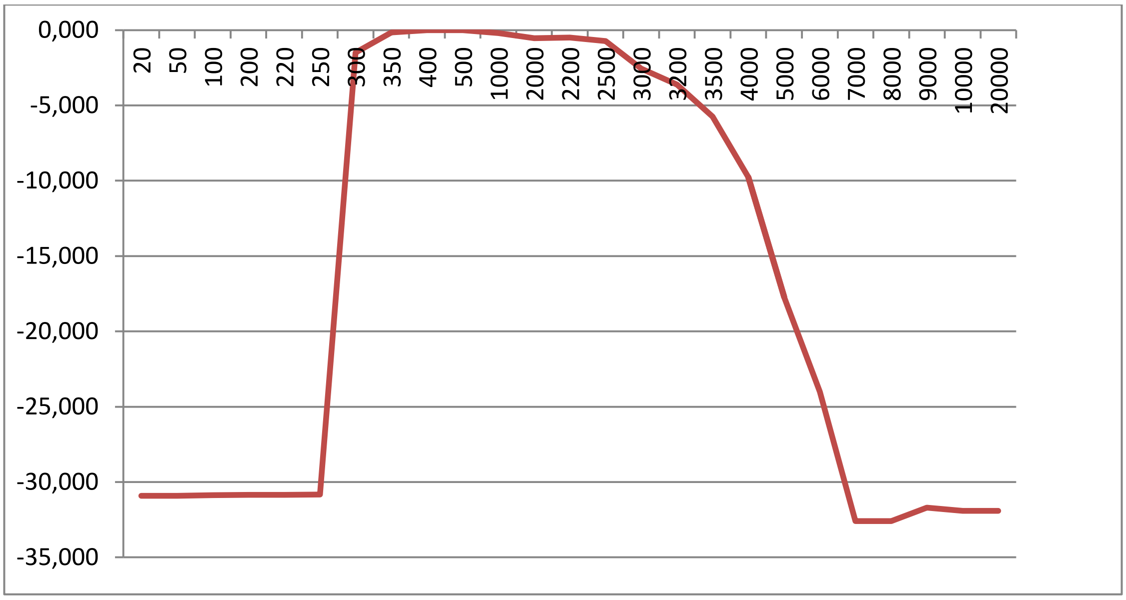


Figure 9: Audio frequency response

The audio bandwidth is about 300 to 3200 Hz. The DSP in the RDA1846 suppresses the audio below 300 Hz for the CTCSS tones. The rising slope is remarkable. The dynamic range is probably better than in my measurement.

7 Integration of the Antenna

With a network analyzer I verified matching of the “rubber ducky” whip antenna. Therefore a SMB connector was positioned at the upper edge of a perfboard were the position in the final design would be. See figures 10 and 11. The perfboard has a ground layer on the top which was used for the antenna. Figure 11 shows the return loss with the board in a typical transmitting or receiving position for a handheld transceiver. This result was satisfying and no further matching improvements were necessary. The matching was found to be stable and the diagram did not change significantly with different positions of the hand.

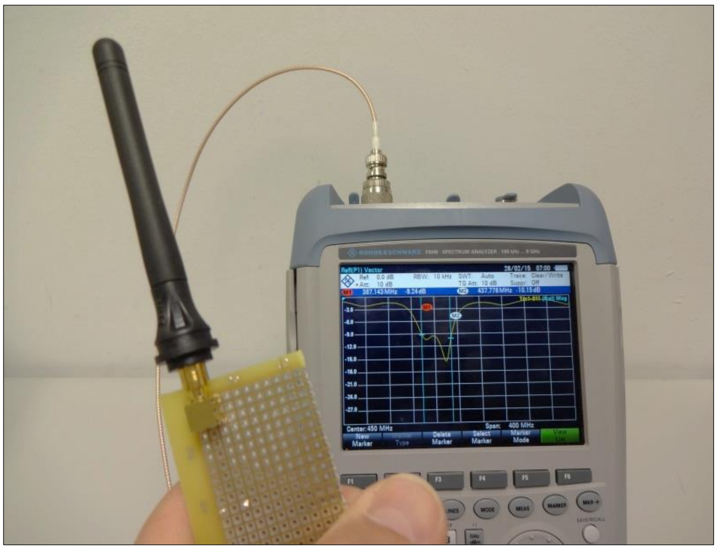



Figure 10 and 11: Photos of antenna matching test

Later with the dimensions of the final board the matching was checked again. In a range from 386 to 440 MHz the return loss was better than -10 dB. See photo and screenshot in figure 12 and 13.

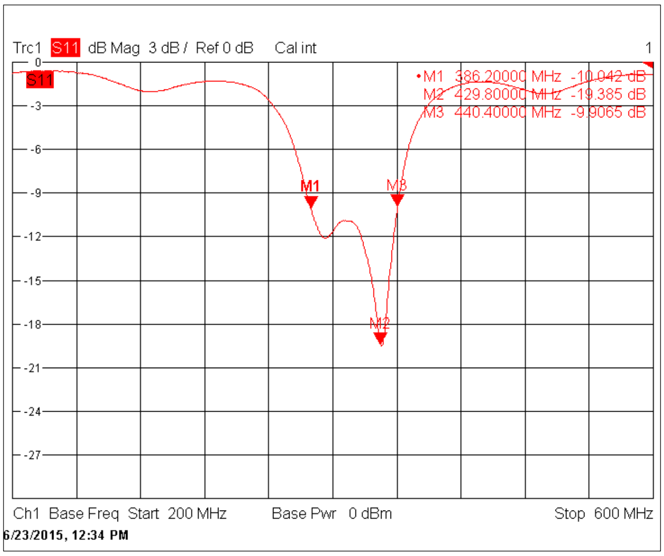



Figure 12: Antenna feeding Figure 13: Screenshot return loss antenna

8 Construction on a Perfboard

Component positioning of the DRA818U module was difficult. Due to the different grid pattern of the perfboard and the footprint of the module a positioning onto the soldering side was impossible. The component side with the ground layer makes shorts circuits likely and a replacement very difficult Mounting the module upside down onto the top layer known as “dead bug” gives good access to the pads underneath but is mechanically unsuitable for a handheld device. My solution was to saw a hole of the size of the module into the perfboad and to connect it to the solder side.

For the RF connection from the DRA818U to the filter and further on to the antenna I used a thin coaxial cable. See figure 15. The dimension of the board was determined by the size of the LCD display and the amount of components to be placed. With four spacers I fastened a second board underneath. See figure 16, the lithium ion cell fits well between.

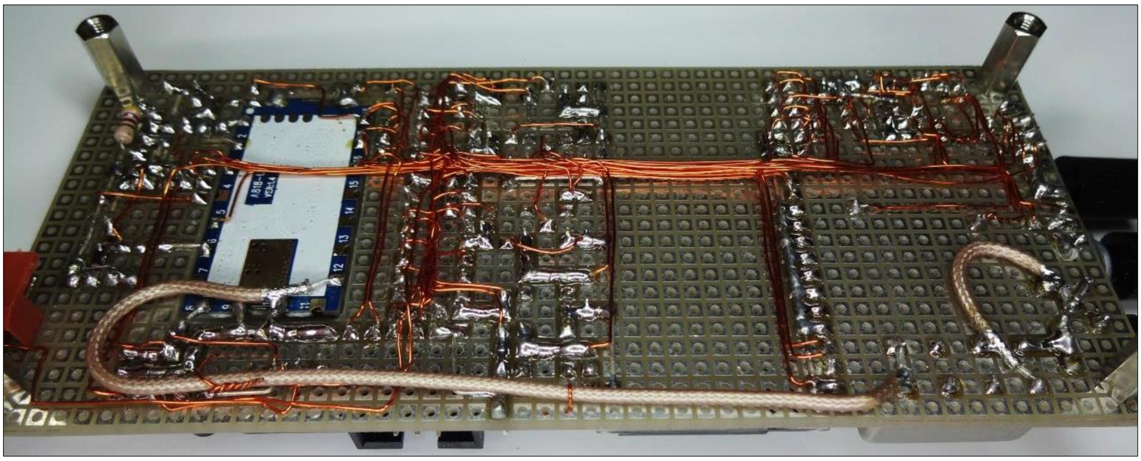


Figure 15: Photo solder side with coaxial cable

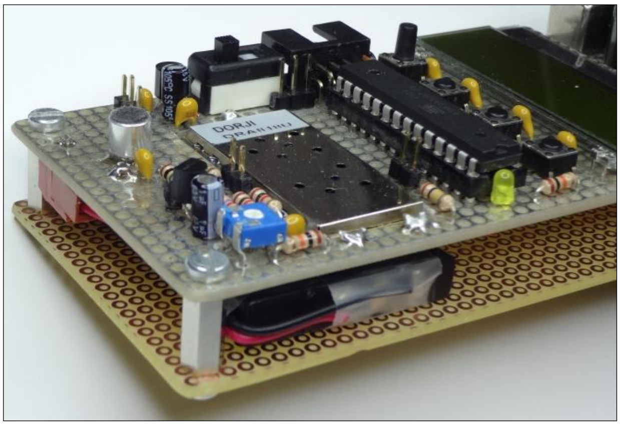


Figure 16: Photo side view li-ion cell

9 Conclusion

A perfboard with a ground top layer is essential for a proper matching and radiation of the antenna. The analog and digital part benefits from this layer.
The performance of this module is amazing, taking the physical dimensions into account. The RF power of 1 watt is well fed and matched to the whip antenna. This transceiver transmits and receives with narrow band FM with a 2.2 kHz frequency deviation. For best audio the repeater or other station should use a similar frequency deviation (NFM).

10 Appendix

10.1 Measurement Equipment

Device	Type	Manufacturer
Signal Generator	SMH	Rohde&Schwarz
Spektrum Analyzer	FSH-4	Rohde&Schwarz
Network Analyzer	FSH-4	Rohde&Schwarz
Power Sensor	FSH-Z18	Rohde&Schwarz
Frequency Counter	M2412C	Anritzu
Oscilloscope	HM203-5	Hameg

10.2 Parts and Distributers

Distributor: Reichelt Elektronik [4]

Part number	Description
Semiconductors:	
ATMEGA 328P-PU	ATMega AVR-RISC-Controller, DIL-28
EA DOGM162L-A	LCD Display, DOG-Serie 3,3V Hintergrund grün/gelb, nicht Bel.
TDA 2822M	Amplifier, DIP-8
VAP VL004	Li-Ion Camcorder-Akku 3,7V 900mAh
AL-30P	Kunststofflautsprecher, Printanschluss
EMY-63M/P	Mikrofonkapsel, Printausführung
PX0408	SMB Antenne, IP68, 440 bis 470 MHz
GS 28P-S	IC-Sockel, 28-polig, superflach, gedreht, schmal
GS 8P	IC-Sockel, 8-polig, superflach, gedreht, vergold.
Perfboard:	
UP 832EP	Lochrasterplatine, Epoxyd, 160x100m
RE 201EP	HF-Europlatine, Epoxyd, verzinnt 160x100mm
Electro mechanicals:	
SMB EB2-L174	SMB-Print-Einbaubuchse 90° für RG174/U
TASTER 3305	PTT, Kurzhubtaster 6,6x7,4mm,Höhe:3,15mm,12V,horiz
SS 25136 NH	Switch, Schiebeschalter, gerade, RM 2,54, 1x EIN - EIN
RK11K112-LOG10K	ALPS Drehpoti., logarithm., 6mm, mono, 10K
STEC12E05	ALPS STEC12E Drehimpulsg., 24/24, horiz., OT

Distributor: FUNKAMATEUR online Shop [4]

PLP-550+	Low Pass Filter, 550MHz
DRA818U	UHF-Transceiver-Modul DRA818U (1 W/400-470 MHz)

10.3 CTCSS Cross Reference Table

The sub audio frequencies are in regard oft he TIA/EIA-603-D.:

CODE	Frequency	CODE	Frequency	CODE	Frequency	CODE	Frequency
0000	switched off						
0001	67	0011	97,4	0021	136,5	0031	192,8
0002	71,9	0012	100	0022	141,3	0032	203,5
0003	74,4	0013	103,5	0023	146,2	0033	210,7
0004	77	0014	107,2	0024	151,4	0034	218,1
0005	79,7	0015	110,9	0025	156,7	0035	225,7
0006	82,5	0016	114,8	0026	162,2	0036	233,6
0007	85,4	0017	118,8	0027	167,9	0037	241,8
0008	88,5	0018	123	0028	173,8	0038	250,3
0009	91,5	0019	127,3	0029	179,9		
0010	94,8	0020	131,8	0030	186,2		

10.4 References

[1] Dorji Applied Technologies:
http://www.dorji.com/pro/modules/Audio_voice_transceiver.html

[2] FUNKAMATEUR-Leserservice: Majakowskiring 38, 13156 Berlin,
Online-Shop: www.box73.de/product_info.php?products_id=3245

[3] Braun, S., DJ5AM: VHF-Transceiver mit minimaler Außenbeschaltung.
FUNKAMATEUR 64 (2015) H.2, S. 168-169

[4] Reichelt Elektronik GmbH & Co. KG, Sande,
www.reichelt.de

[5] Verordnung zum Gesetz über den Amateurfunk, §16 Technische und betriebliche Rahmenbedingungen,
http://www.gesetze-im-internet.de/afuv_2005/__16.html

[6] Authority for Telecommunications,
Verfügung Nr. 33/2007 "Amateurfunk, Richtwerte für unerwünschte Aussendungen"
http://www.bundesnetzagentur.de/DE/Home/home_node.html

[7] Mini-circuits Low Pass Filter PLP-550+