ON BOARD SATELLITE RECEIVER FOR EXPERIMENTAL SLOW RATE DATA COMMUNICATION

Design Report

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Abstract:

In this contribution a new developed satellite receiver for very slow data operation is described. The receiver is developed as a part of PCSAT2 satellite project of US Naval Academy that has to be placed on ISS and includes a PSK31 transponder for multi-user communications among others. The article describes base advantages of the slow rate PSK31 operation and the design and measurements of the final version of the receiver with respect to high reliability and low power consumption.

Description of realization

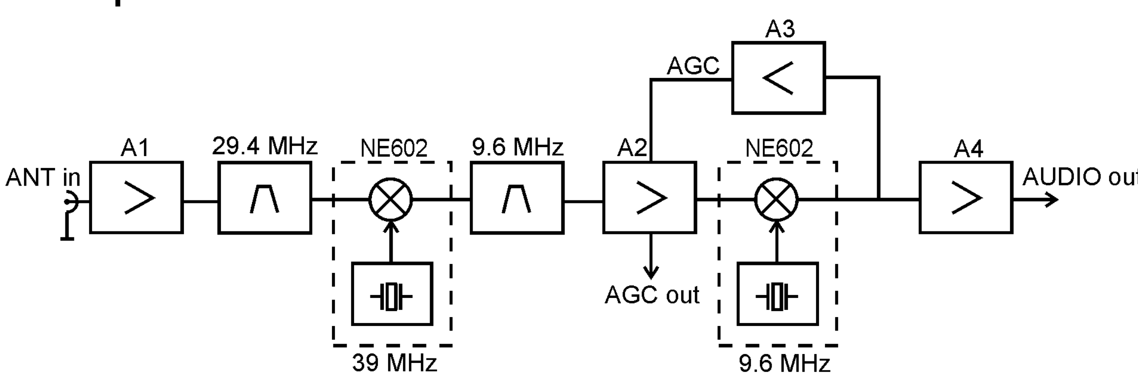

Fig. 1: Block diagram of the receiver

The receiver was developed for a space application. For this receiver special parameters were being required. These parameters are as follows:

- **Low current consumption** less than 15 mA for 5 V supply voltage. This is achieved by using a special low power consumption parts.
- **Gain** greater than 120 dB.
- **Excellent sensitivity** less than 0,2 μV for 10dB (S+N)/N ratio at 3 kHz bandwidth
- **High reliability according to space qualification**
- **High immunity to rf signals outside the pass-band**

The block diagram of the receiver is in fig. 1. The antenna's signal is injected to "ANT in" (connector SMA 50 Ω). The amplifier A1 that includes an NPN 1 GHz wideband transistor BFS17 in a plastic SOT23 package amplifies the input signal. The selectivity of an input amplifier is achieved by the resonant circuit (band-pass filter), which has the bandpass on frequency 29.4 MHz. An amplified input signal is mixed with a local oscillator 39 MHz signal. The NE602 is a low-power VHF monolithic double-balanced mixer with an input amplifier, an on-board oscillator, and a voltage regulator. It is intended for high performance, low power communication systems. The guaranteed parameters of the NE602 make this device particularly well suited for cellular radio applications. The typical value of a DC current drain is 2.4 mA, a conversion gain (at 45 MHz) is about 18 dB, and a noise figure 5 dB. The intermediate frequency is chosen by a bilithic filter (2MLF 9.6 – 3 Tesla), which works on frequency 9.6 MHz with bandwidth 3 kHz. An absorption loss of the filter is 1 dB.

The IF signal is amplified in the IF amplifier A2 for radio receivers (TAA981). A nominal current drain of the amplifier is 3.8 mA and a power gain is greater than 65 dB. The amplifier includes an input for a voltage control feedback and an AGC level output "AGC out". The output signal from A2 is injected to the NE602. The local oscillator of the second mixer works on 9.6 MHz. The dual operational amplifier MC34072 includes A3 and A4. The level of AGC operation is set by the gain of A3 and the level on 600 Ω audio output is set by A4. This conception of the transceiver fulfills the required conditions (low current consumption, high gain etc.) that are noted above.

The printed circuit is soldered in a shielding box. Power supply, the "AUDIO out", and the "AGC out" pins are made by capacitor bushing. The capacitors are also soldered to the box. SMA connector is fixed by the help of tetra screws. The transceiver is made on a two-sided FR4 substrate. It has excellent dimensional stability and it is resistant to all solvents and reagents hot or cold. The thickness of the substrate is 1.5 mm. Actual dimensions of the board are 63.3 × 52.6 mm. Photos of the transceiver are in fig. 2 (top) and fig. 3 (bottom).

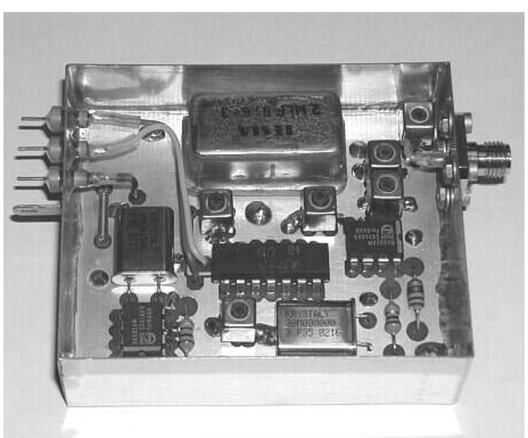

Fig. 2: Photo of the transceiver (top)

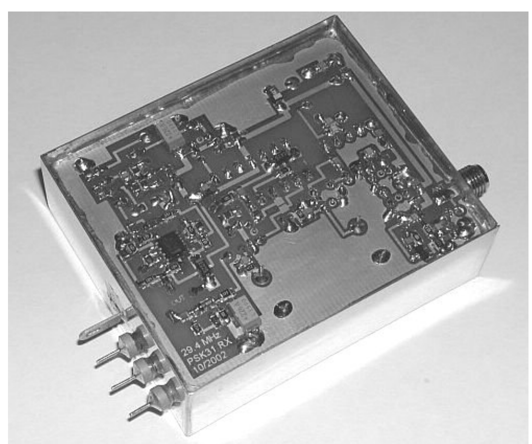

Fig. 3: Photo of the transceiver (bottom)

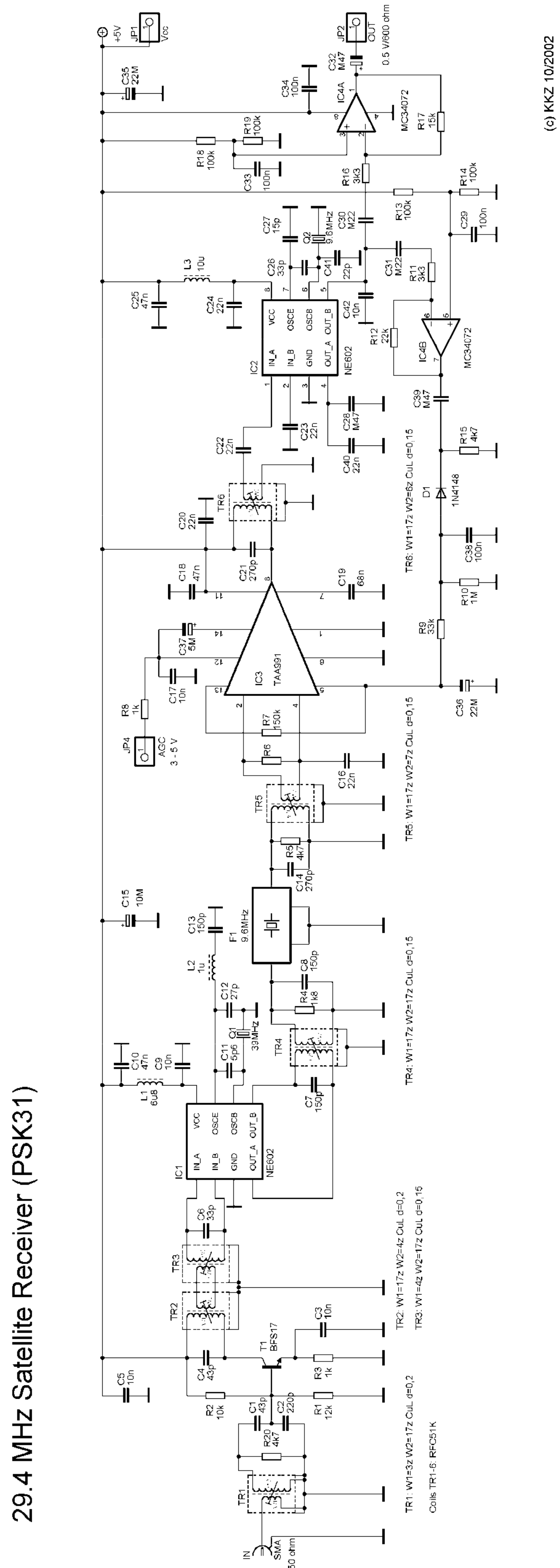

Fig. 4: Schematic of the receiver

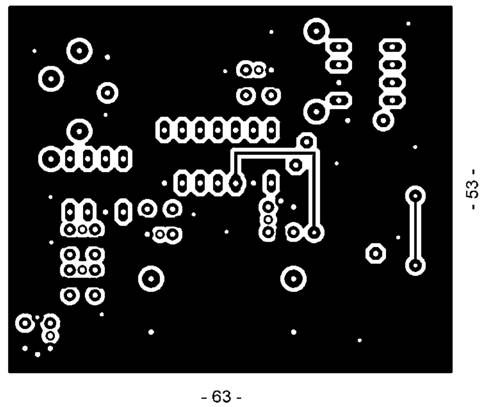

Fig. 5: Top layer layout

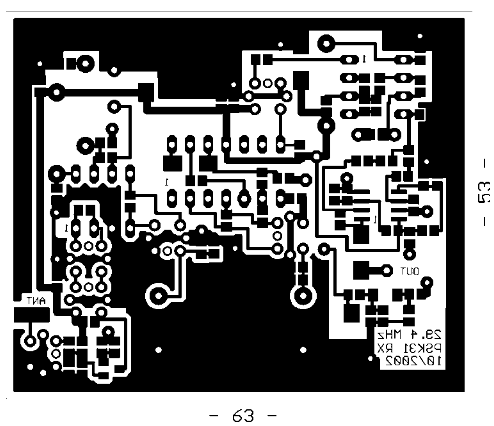

Fig. 6: Bottom layer layout

Substrate specifications:

Material FR-4, double-sided, thickness 1.5 mm, surface CuAg.

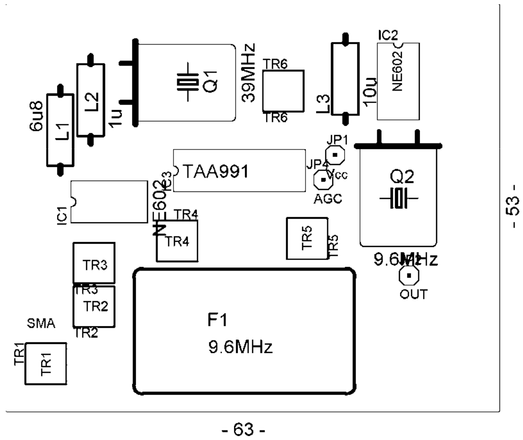

Fig. 7: Top layer of components

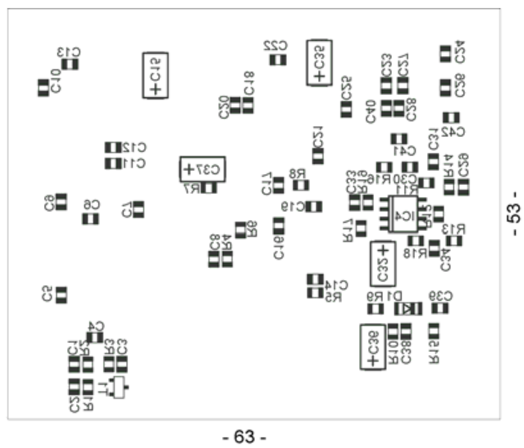

Fig. 8: Bottom layer of components

Shielding box:

Material SnFe metal, thickness 0.3 mm.

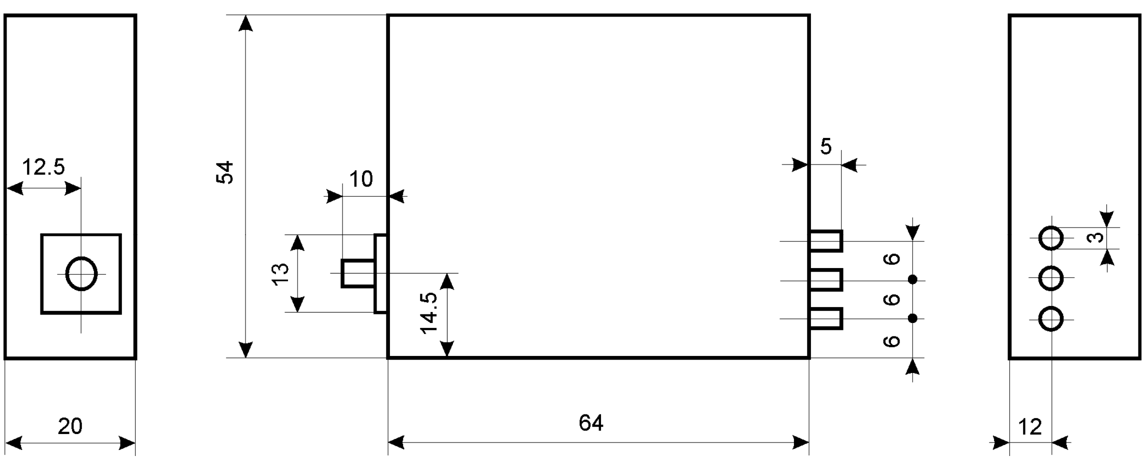

Fig. 9: Shielding box dimensions [in millimeters]

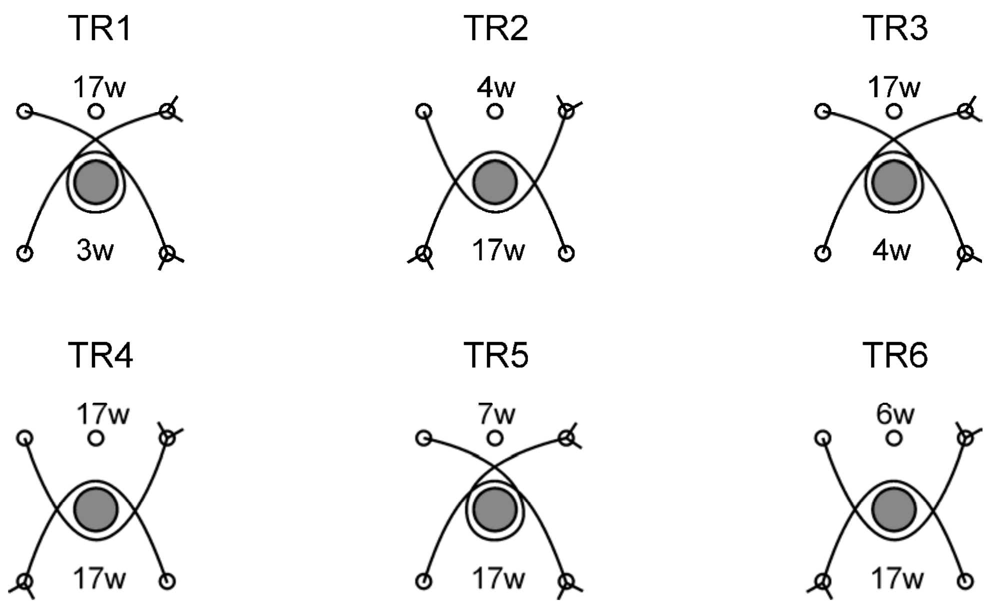

Fig. 10: Coil winding

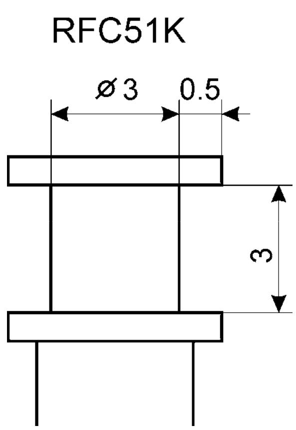

Fig. 11: RFC51K coil dimensions

Partlist

Part	Value	Package
C1, C4	43p	0805
C2	220p	0805
C3, C5, C9, C17, C42	10n	0805
C6, C26	33p	0805
C7, C8, C13	150p	0805
C10, C18, C25	47n	0805
C11	5p6	0805
C12	27p	0805
C14, C21	270p	0805
C15	10M	CT6032
C16, C20, C22, C23, C24, C40	22n	0805
C19	68n	0805
C27	15p	0805
C28, C39	M47	0805
C29, C33, C34, C38	100n	0805
C30, C31	M22	0805
C32	M47	CT6032
C35, C36	22M	CT6032
C37	5M	CT6032
C41	22p	0805
D1	1N4148	SOD80C
F1	2MLF9.6-3	
IC1, IC2	NE602	DIL08
IC3	TAA991	DIL14
IC4	MC34072	SO08
IN	SMA	SMA F PP
JP1, JP2, JP4	1n	Capacitor Bushing
L1	6u8	SMCC
L2	1u	SMCC
L3	10u	SMCC
Q1	39 MHz	HC18U-H Krystaly H.K.
Q2	9.6 MHz	HC18U-H Krystaly H.K.
R1	12k	0805
R2	10k	0805
R3, R8	1k	0805
R4	1k8	0805
R5, R15, R20	4k7	0805
R7	150k	0805
R9	33k	0805
R10	1M	0805
R11, R16	3k3	0805
R12	22k	0805
R13, R14, R18, R19	100k	0805
R17	15k	0805
T1	BFS17	SOT23
TR1 – TR6		RFC 51K

Measurements

Power consumption of the receiver is 13 mA for +5 V supply voltage. The chart on fig. 12 shows receiver sensitivity as dependence of the output signal to noise ratio on the 29.4 MHz input voltage at 3 kHz and 60 Hz bandwidth. The sensitivity for SNR = 12 dB is 0.2 μV and the resulting gain of the all receiver is 128 dB which is higher then the minimal required gain 120 dB and a noise figure of the all RX is 6 dB.

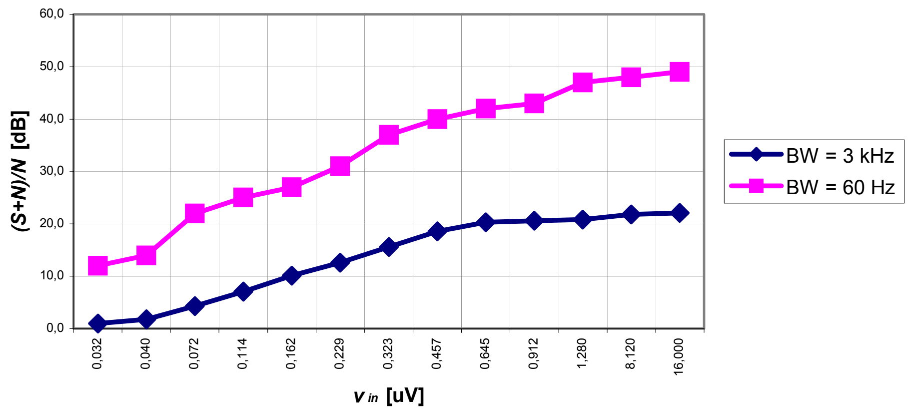

Fig. 12: Sensitivity of the satellite receiver

The image rejection is better than 70 dB for SNR > 12 dB and image frequency f_i = (29.4 + 2 · 9.6) MHz. Because the receiver will be placed in a transponder with transmit frequency 145.825 MHz, there is needed get the immunity on this frequency. The maximal level of the 144.825 MHz signal is 1.4 mV for 0.14 μV of the 29.4 MHz signal. It was measured for noise increase on an audio spectrum analyzer.

The high gain IF amplifier has AGC that provides approximately 500 mV RMS on the audio output of the receiver. The output voltage dependency and voltage on the AGC output versus input voltage shows the chart on fig. 13.

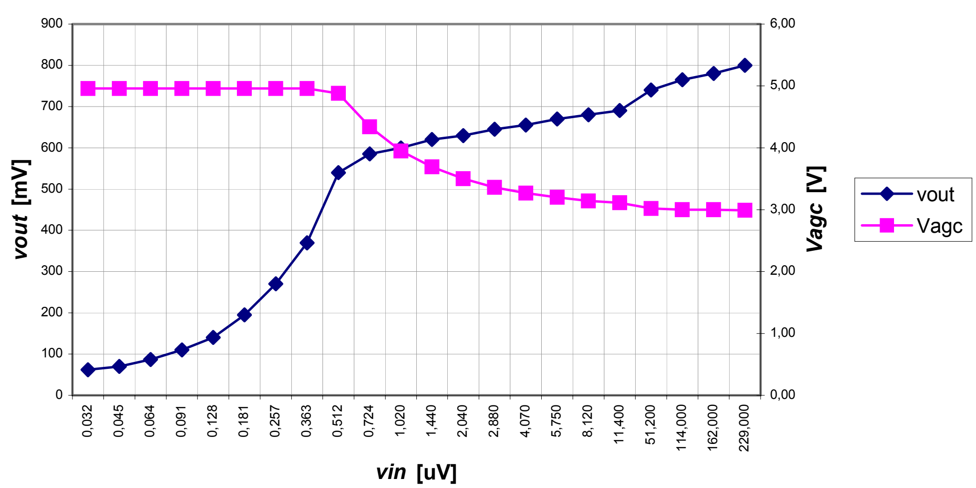

Fig. 13: AGC output voltage and output voltage versus input voltage of the satellite receiver

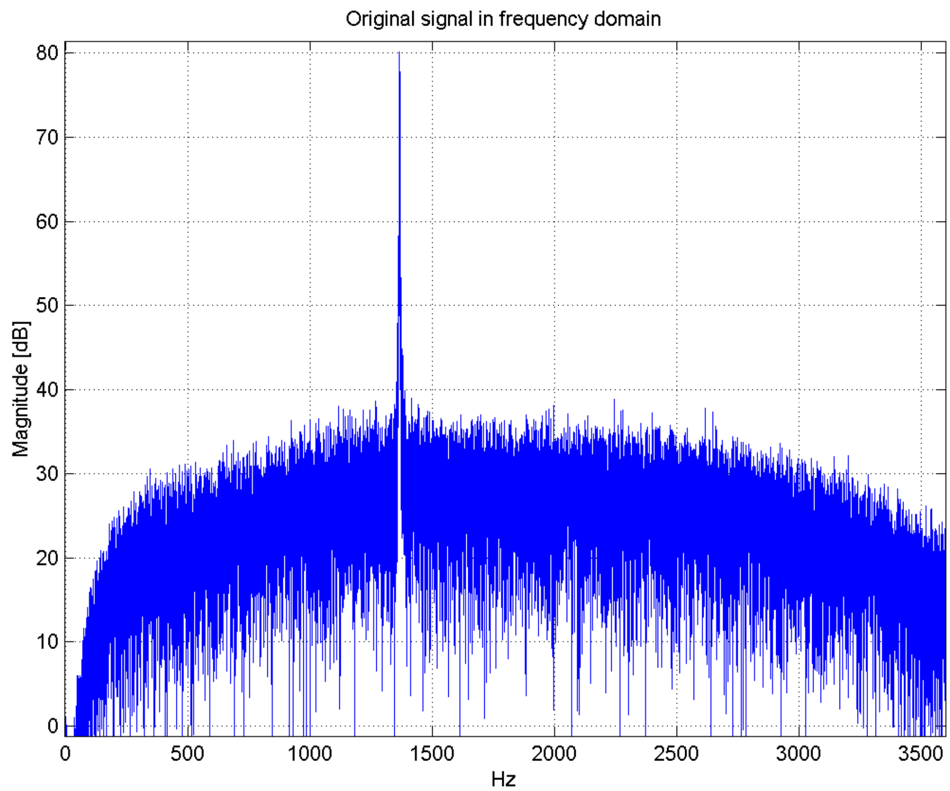

Fig. 14: Frequency spectrum of the signal on the audio output for the 0.3 μV input RF signal

The output audio signal is sampled by a soundcard with 44.1 kHz sampling frequency and 16 bits resolution. The spectrum of the signal, fig. 14, is counted in Matlab by FFT.

Changes

Added components during construction:

R20 (4k7)	improvement of a noise figure of the receiver (about 1 dB)
C42 (10n)	limiting of the output maximum frequency, improvement of the output SNR
C41 (22p)	fine tuning of Q2 (9601.5 kHz)

Changed components during construction:

C1, C4 (43p)	changed for correct tuning of TR1, TR3 (compounded from two capacitors)
C30, C31 (M22)	lower than original M47 for the higher output low cut-off frequency, fig. 15
C32 (M47)	lower than original 2M2 for the higher output low cut-off frequency, fig. 15
R17 (15k)	for setting the output audio level (0.5 V rms)
R12 (22k)	for setting the AGC bias level for the 20 dB output SNR
R6	isn't placed (only for an IF measurement)

Measurement instruments

RF generator Rohde&Schwartz 302.4012.22, 0.4 – 1040 MHz
RMS Voltmeter HP 3400A
Oscilloscope GOULD 3105 150 MHz
Digital Multimeter METEX M-3860D
Power Supply TESLA BK125
Audio Spectrum Analyzer on PC by WinPSK
RF generator ELSY SG2000
Attenuator 10, 20 dB
Noise figure measurement apparatus with nitrogen