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Automatic Tracking Filter for DDS Generator

Reduce spurious responses from a digital synthesizer with this filter.

The design of a receiver local oscillator has several levels of difficulties, especially over an extended frequency range. In a VLF – HF receiver (0.01 to 30 MHz), with a 10.7 MHz IF, the range of the frequency of the local oscillator would be between 10.71 and 40.7 MHz. With DDS technology it is now possible to have a particularly stable oscillator covering that range of frequencies.

The DDS AD9851, by Analog Devices, allows for very good performance. It exhibits frequency stability, low phase noise and a wide range frequency from the low frequencies to 60 MHz, so it is very well suited for this application. There is, however, a down side. The spectrum of the signal generated by this wide range DDS is not particularly clean, and the several spurious responses in the receiver mixing process produce many birdies. Although the spurs are weak (equivalent to a 0.5 µV
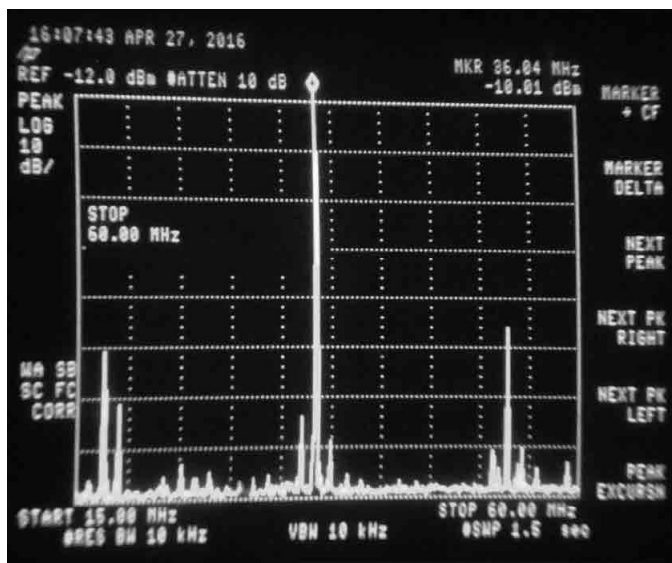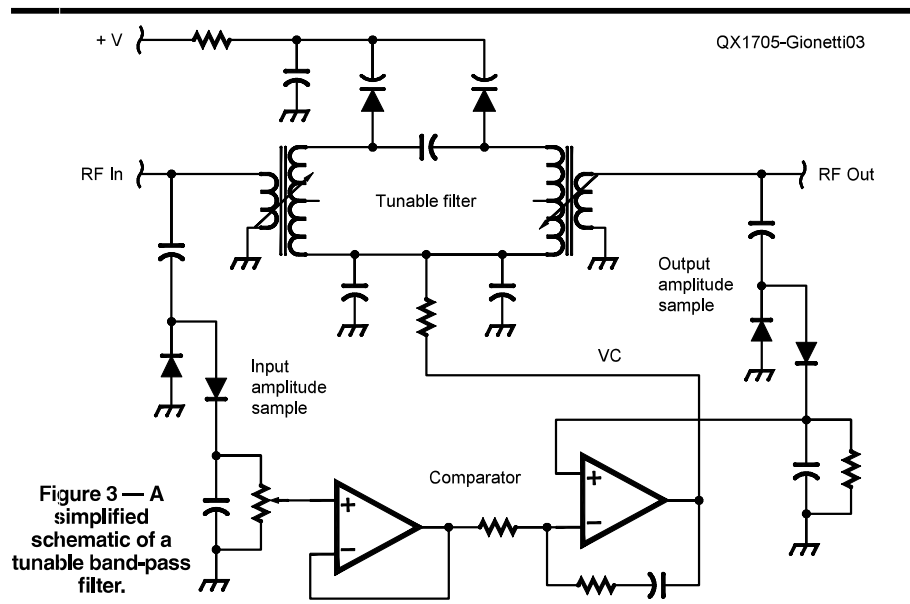
QX1705-Gionetti03

+ V

RF In

Tunable filter

RF Out

Input amplitude sample

Output amplitude sample

VC

Comparator

Figure 3 — A simplified schematic of a tunable band-pass filter.

Figure 1 — A DDS Carrier 36 MHz, with unfiltered "birdies" above and below the carrier.

Figure 2 — A DDS Carrier 36 MHz, with "birdies" reduced by the band-pass filter.
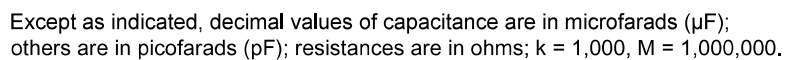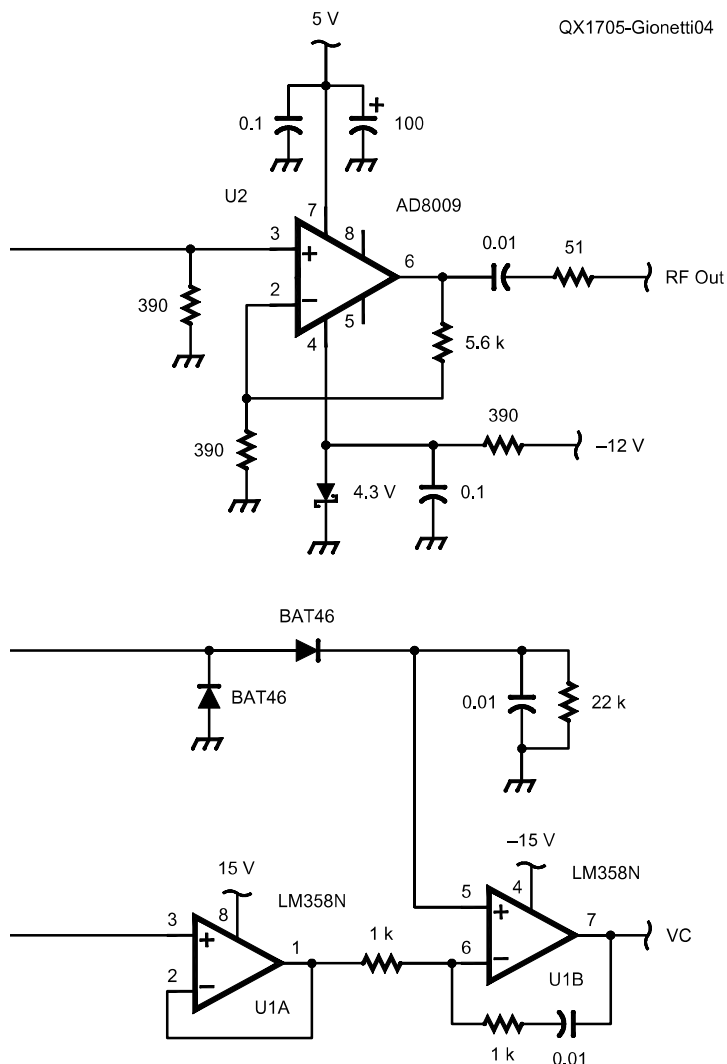
L1A, L1B – 4.5-9.0 μH
L2A, L2B – 1.5-3.5 μH
L3A, L3B – 0.90-0.22 μH
L4A, L4B – 0.45-0.75 μH

+ 15 V
6.8 k
0.1
MV104   MV104
1N4148   L1A   L1B   1N4148
220   2.2 pF   220
B1   B1
0.0001   0.0001
0.1   0.1
220
VC

RF In
0.01   33
0.001
BAT46
+ 15 V
6.8 k
0.1
MV104   MV104
1N4148   L2A   L2B   1N4148
220   1   220
B2   B2
0.01   0.01
0.1   0.1
220
VC

+ 15 V
6.8 k
0.1
MV104   MV104
1N4148   L3A   L3B   1N4148   0.01
220   1   220
B3   B3
0.01   0.01
0.1   0.1
220
VC

BAT46

+ 15 V
6.8 k
0.1
MV104   MV104
1N4148   L4A   L4B   1N4148   0.01
220   1   220
B4   B4
0.01   0.01
0.1   0.1
220
VC

150   1 k   1 k
4.7 k
1 mH   1 mH
10 k
0.01   R1

Except as indicated, decimal values of capacitance are in microfarads (μF);
others are in picofarads (pF); resistances are in ohms; k = 1,000, M = 1,000,000.

Figure 4 — Schematic diagram of multiple band-pass filters.

A Technical Solution

Strong attenuation of the spurious signals can be achieved by placing a band-pass filter tuned to the DDS frequency between the output of DDS and the mixer Local Oscillator (LO) port. Figure 1 shows the measured spectrum of the DDS generating a carrier at 36 MHz without a filter. Figure 2 shows the same spectrum with the 36 MHz carrier, now filtered by a band-pass filter.

When changing the DDS frequency, the band-pass filter center frequency should be tuned to the new frequency to maintain effectiveness. This tuning operation should automatically follow changes in the DDS frequency.
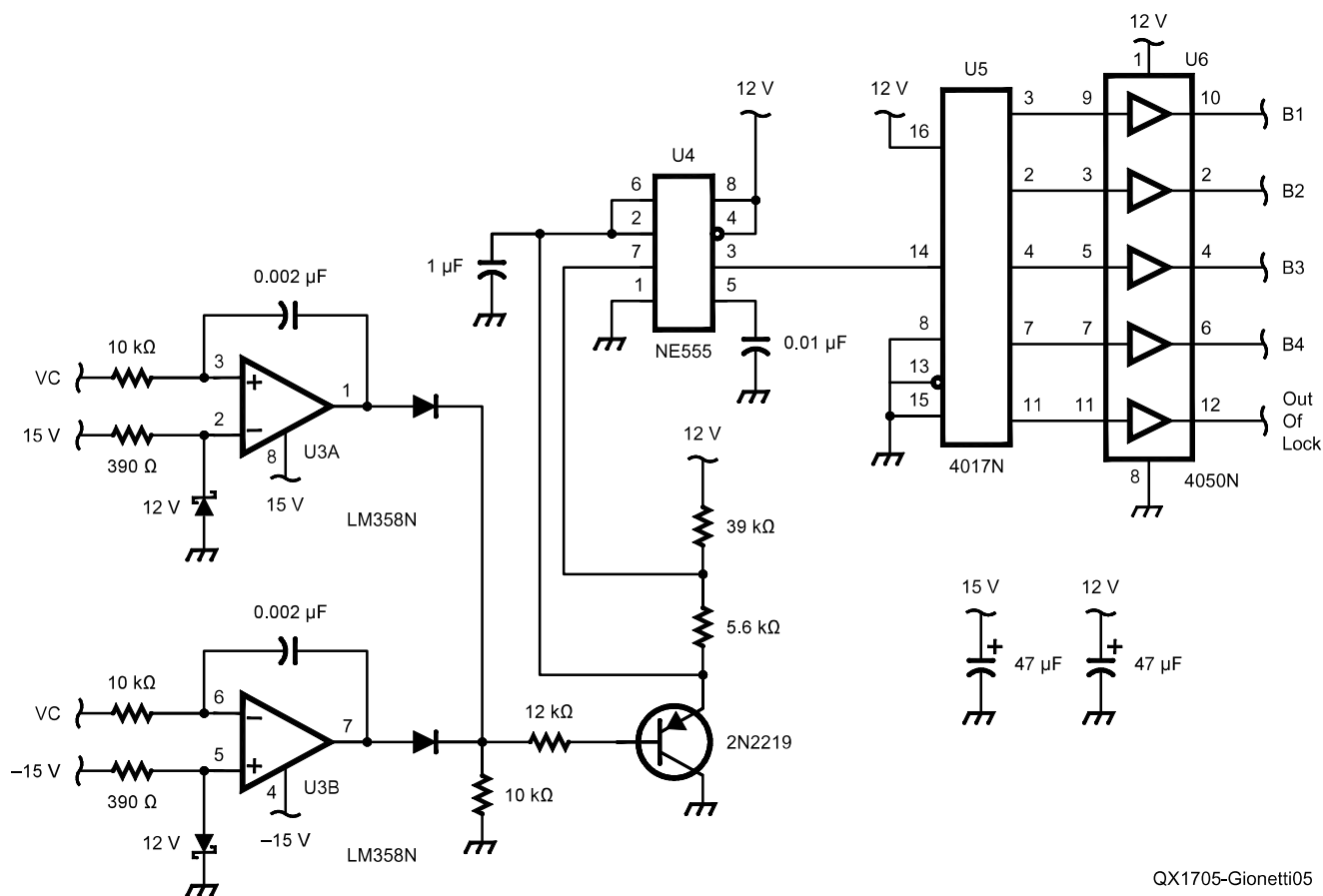
After several attempts I implemented the following solution. Compare the level of the input signal with the signal level at the output of the filter, then tune the filter to maximize the output. If we use varicap diodes to tune the filter, the tuning is done by means of a dc voltage that can be obtained by an op-amp that compares the rectified input and output RF signals. So with a relatively simple circuit it is possible to implement an Automatic Tracking Filter.

Figure 3 shows a simplified diagram of the circuit. The filter maintains its resonance even when the frequency is changed quickly. Tracking, however, can be lost when the bandwidth limits are exceeded. The next filter in the filter bank then must be changed to re-establish the tracking.

We want the DDS to cover a receiving range from 0.01 to 30 MHz, so the band-pass filter must be able to track over the 30 MHz from 10.7 to 40.7 MHz. To do this we require a filter bank of at least four filters (Figure 4) having some overlap between them, to cover the entire frequency range. The first band-pass filter tunes between 10 and 16 MHz and uses a band select control voltage at B1 from the control circuit of Figure 5. The second tunes between 15 and 23 MHz, and is controlled by band select voltage on line B2. Figures 6 and 7 show no filtering and filtering respectively for a 16 MHz carrier. The third tunes between 21 and 30 MHz with the band select voltage on line B3. Figures 8 and 9 show no filtering and filtering respectively for a 26 MHz carrier. Finally, the fourth filter tunes between 28 and 42 MHz and is selected by the B4 control voltage.

Automatic Switching

The automatic switching of the several band-pass filters in the filter bank is done with a comparator U3 in Figure 5. The comparator controls the maximum and

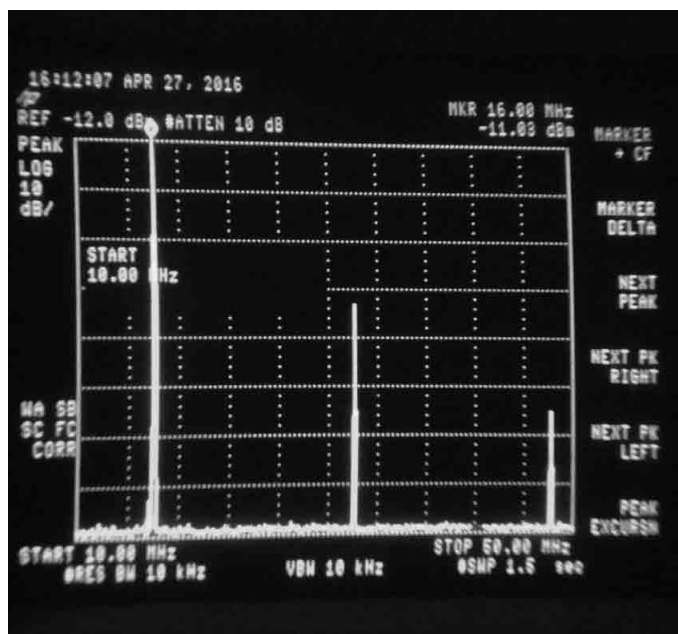Figure 5 — Schematic diagram of the control circuitry.

Figure 6 — DDS carrier at 16 MHz without filtering.
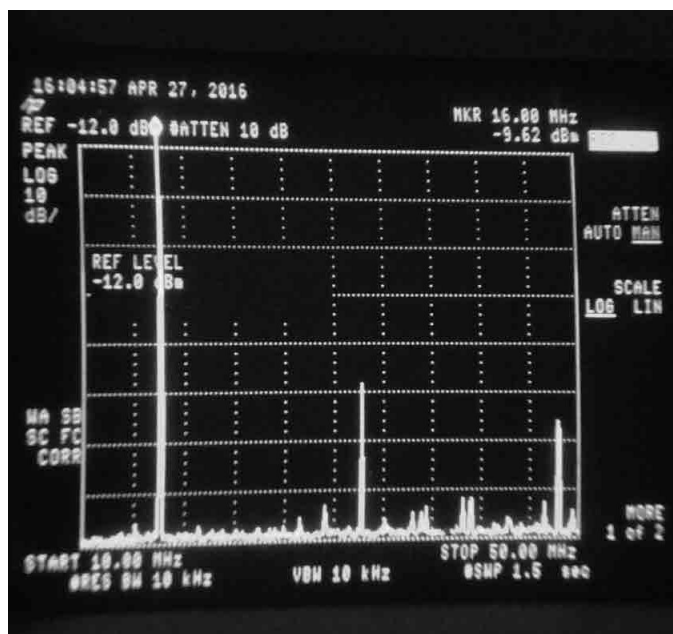

Figure 7 — DDS carrier at 16 MHz with band-pass filtering.
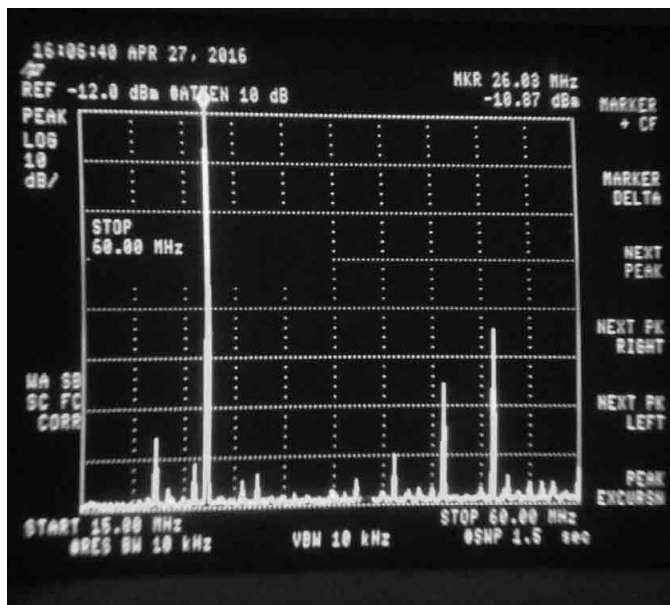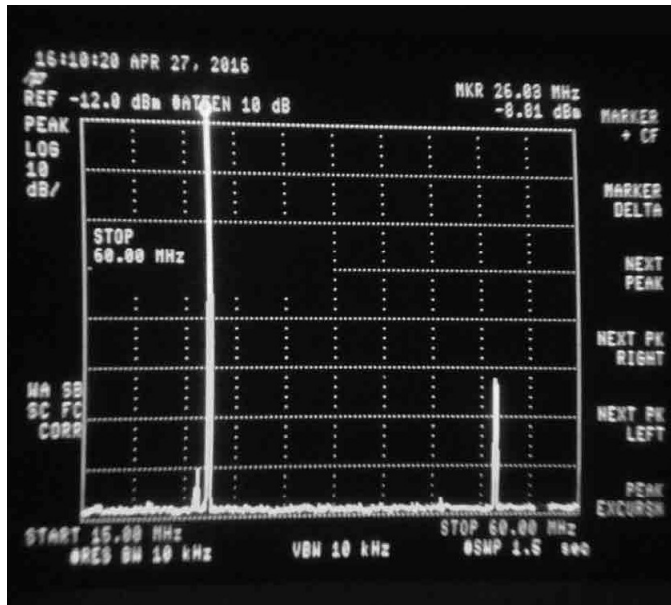
Figure 8 — DDS carrier at 26 MHz without filtering.

Figure 9 — DDS carrier at 26 MHz with band-pass filtering.

minimum voltages that the varicap diodes can reach, If these limits are exceeded, the output voltage of the comparator becomes positive and transistor Q1 is switched off. As soon as Q1 is off, U4 starts to oscillate and sends pulses to the input of a decimal counter U5. The counter outputs sequentially change with each counter output pulse.

The switching diodes of each band-pass filter are connected to an output of the counter U5 via a buffers U6. The filter is switched when the output of its buffer becomes positive. As soon as the filter is switched, the tracking is again acquired, at this point the comparator output goes low and Q1 short circuits the capacitor C1 across the collector-emitter pins, blocking operation of U4, and counter U5. This leaves a logic high at the output to which the filter is connected. This cycle is repeated at each change of frequency that corresponds to a loss of tracking.

Following the filter, an AD8009 amplifier stage U2 (Figure 4), compensates for the filter and switching diode losses, and matches the output impedance to 50 ohms.
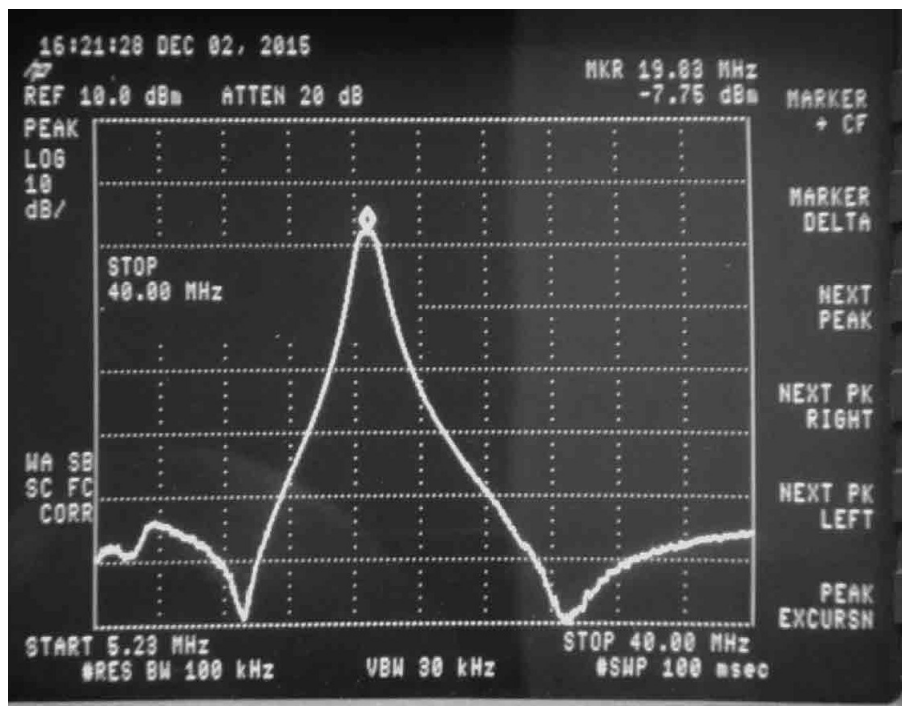

Figure 10 — Response of the band-pass filter tuned to 20 MHz.

Calibration and Results

Calibration is quick and you should not have any critical issues. The first step is the calibration of filters. Remove U1 and U6, which are mounted in sockets. Then,

[1] — Connect a +12 V source to the B1 (pin 10 of U6) output to select the first band-pass filter.

[2] — Connect +10 V to the VC line to bias the varicap tuning diodes.

[3] — Connect a sweep generator to the input of the band-pass filters, adjust the cores of input and output coils L1A and L1B to have a symmetrical response curve at 10 MHz, as seen in Figure 10.

[4] — Connect -12 V to the VC line and verify that the filter is tuned at 16 MHz.

Repeat this procedure for the other three band-pass filters at 15 and 23 MHz, 21 and 30 MHz, 28 and 42 MHz.

After completing the filter calibrations, reinsert the two ICs U1 and U6, and connect the DDS generator. With the trimmer R1, set the level of comparator reference voltage on the U1B. Starting from the highest frequency, adjust potentiometer R1 until tracking begins. This can be monitored with

a voltmeter on the VC line.

Including the Automatic Tuning Filter between the DDS and the receiver mixer has reduced birdies by more than 80%.

Figure 11 shows an internal view of the tracking filter.

Additional Applications

Automatic Tuning Filter can also be used to automatically tune HF transmitter driver filters. The B1 – B4 control outputs can be used to automatically switch the band filters of a HF receiver.

Riccardo Gionetti, IØFDH was first licensed in 1974. He studied at University of Rome "La Sapienza - E. Fermi Institute"and received a degree in physics, specializing in cybernetics and electronics. He also attended additional technical courses in radar technology, microwave measurements, EMC, IR sensors, and electronic warfare. Riccardo worked for 10 years in a telecommunications company and for 30 years has held several positions in the Italian defense industry. In the last 10 years he was responsible for Applied Research and Technology for radar sensors and missile subsystems.

Riccardo has published over 50 technical articles and papers in professional and Amateur Radio venues, and is co-author of a handbook "HF Power Linear Amplifier Design", (in Italian) and is author of a course on "Tactical Radio Communications". He is now in retirement enjoying experimenting and building his own equipment. Riccardo's main interests are VLF, HF, VHF receivers and transceivers, RF power amplifiers, instrumentation and the restoring of old radios.
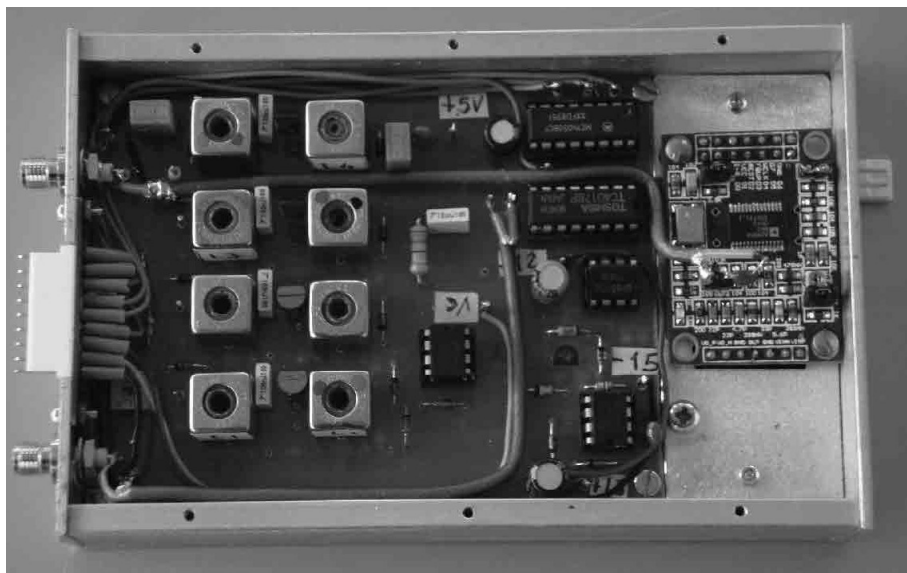

Figure 11 — Internal view of the tracking filter.