Miroslav Gola, OK2UGS

FM Receiver For 137 - 141MHz (A double conversion superhetrodyne with pll)

1. Introduction

Receiving information from FM meteorological satellites has become an interesting hobby for thousands of radio enthusiasts all over the world. Those of you who have already tried internet searches using such keywords as NOAA, METEOSAT, 137.5MHz, WEFAX , Meteor etc. , will undoubtedly confirm that they have found hundreds of links to pages of receiver manufacturers, re-sellers, professional users and particularly ham enthusiasts.

You will find among others, a link to the homepage of Radek Václavík OK2XDX, which is devoted to these issues [1]. His article on a downconverter for Meteosat reception was published also in the VHF Communications issue 4/1999 [28,29].

It is worth noting that on 1st April 2000 we commemorated the 40th anniversary of the first transmission of images from the satellite TIROS 1. The pictures were of rather low quality, nevertheless, they started an era of space research of the Earth's surface. The resolving power of todays images is currently of the order 1 pixel = 1 m. You can find more detailed information on the internet pages of the NOAA agency http://www.earth.nasa.gov/history/tiros/tiros.html.

Quite and few hams tried successfully in the seventies to construct receivers. These obviously did not have the technical specification that can be achieved with modern components. Images were not generated using high quality decoding programs for personal computers, simply because they did not exist at that time. The images were "decoded" using of technology of the seventies; plotting on oscilloscope with medium afterglow and then photographing using an instant Polaroid camera [9].

2. Looking at earth from space

Satellites NOAA (USA - National Oceanographic and Atmospheric Administration) and METEOR, OKEAN, RESURS (Russia) are the focus in this article. They are flying on polar orbits around the Earth at the distance of approximately 800 - 1200 kilometres passing over the same place at approximately same time every day [23]. Satellites pass the North or South pole on each orbit, that is why their orbits are called polar. It is possible to determine their trajectory precisely using "Keplerian elements", which describe the current orbit of the given satellite. Calculation of the exact time of a satellites orbit, from the mo-

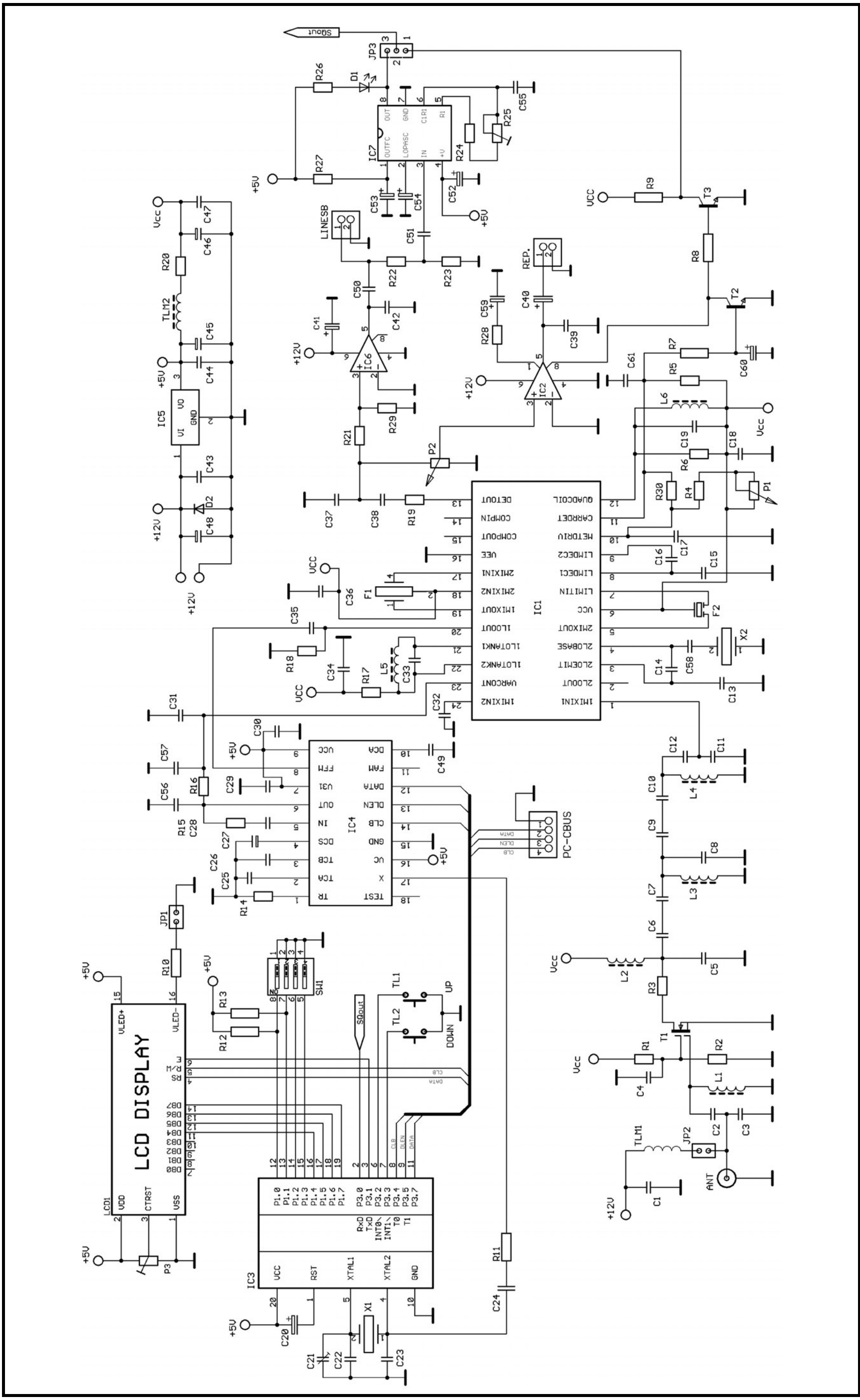

Fig 1 : Circuit diagram of receiver.

ment when it appears at the horizon till the moment when it disappears behind the horizon, can be made nowadays using many programs for personal computers. I most frequently use a simple Windows program called SatWin [10, 24]. A version of SatWin was also written for MS-DOS and can be run on older personal computers of the DX486 type. Both these programs can be downloaded free of charge together with up-to-date Keplerian elements at the following address: http://www.emgola.cz/. You will also find other information about the activities of satellites plus the signals that you can receive and decode using the receiver described in the following article. Pictures are transmitted continuously from polar satellites without beginning or ending. When the satellite appears over the horizon, the edge of the pictures is slightly cramped, gradually resolution of details in the picture improves. At the end of orbit the signal gets weaker and the picture begins to disappear in noise as the satellite slips behind the skyline.

Inclination is the angle made by the plane of satellites orbit and equatorial plane. A satellite that passes over both poles (on so called polar orbit) has the inclination of 90°. The inclination of American satellites NOAA 10-16 is 98°, their period is approximately 102 minutes and height of satellite is approximately 820 - 850 kilometres.

Signals from the satellites are in WEFAX format (Weather Faximile). This is an old, but still useful, system for transmission of black and white visual information using a standard audio channel where a change of amplitude of the 2400Hz sub carrier represents the level of the video signal brightness. Maximum modulation (black) is not zero, but approximately 5%, white is then approximately 87%. This audio signal is frequency modulated on the main carrier, e.g. 137.50MHz for the satellite NOAA 15. After demodulation by the FM receiver we therefore obtain an amplitude modulated tone of 2400Hz. This signal is sent to the input of standard sound card in a PC and processed by a software decoder such as JVComm32 which can be downloaded from http://www.jvcomm.de/. JVComm32 even handles bad quality demodulated signals due to the efficient digital filters. The result of this processing is shown in Fig 12 as picture displayed on a computer monitor.

Transmission of images from NOAA satellites are composed of lines lasting 0.5 second, which correspond with data from sensors. They provide one picture of the Earth surface containing data from two channels. Channel A transmits picture in the visible spectrum (VIS) and channel B transmits picture in the infrared spectrum (IR). Each line contains time multiplexed data from both channels and is composed of separation tones interlaced with picture modulation. Data from channel A is preceded by and short impulse of 1040Hz and similarly data from channel B are preceded by and short impulse of 832Hz. Each line also contains a calibration sequence. Thanks to this the decoding program can display only the chosen type of picture. You will find more detailed information at http://www.noaa.gov/. You will find up-to-date information about Russian satellites METEOR, OKEAN, RESURS at http://sputnik.infospace.ru/. These satellites have higher orbit than that of NOAA satellites (1200 km). For example inclination of satellites METEOR is 82° and their period is 115 min. The system of picture transmission from METEOR satellites is compatible, however slightly different, from that of NOAA satellites. Modulation is similar, but pictures contain only one photo with higher resolution. Edges of lines contain sets of phasing lines (alternately black and white), the lines mark end of picture and greyscale. Pictures in the infrared spectrum do not contain the greyscale. The pictures are also inverted as in comparison with NOAA pictures. Photos from NOAA satellites show warmer places by darker shade and colder places are brighter. The

NOAA 11	137.62MHz	Not operating
NOAA 12	137.50MHz	
NOAA 13	137.62MHz	
NOAA 14	137.62MHz	
NOAA 15	137.50MHz	
NOAA 16	137.62MHz	Not operating
NOAA 17	137.62MHz	
NOAA beacons	136.77 and 137.77MHz	
METEOR 2-21	137.40MHz	
METEOR 3-5	137.30MHz	
OKEAN-O	137.40MHz	
RESURS O 1.1	137.85MHz	

Table 1 : Not all the satellites given are always active. Some of them are still flying on polar orbits, but their transmitters have been switched off. Some others do not transmit due to a failure, e.g. the modern satellite NOAA 16 only transmits in the mode HRPT at the frequency 1.698 GHz due to a defect. This is the fate of all artificial satellites, when they fail they can only be repaired using very costly methods. Not all the satellites are as important as the Hubble space telescope, which was repaired by the space shuttle that we watched with excitement and admiration.

See http://noaasis.noaa.gov/NOAASIS/ml/status.html

pictures from METEOR use inverse scale warm seas are white and cold cloud formations are black.

It is also possible to decode visual information from the receiver any time. To do this it is necessary to save the received modulated signal as a WAV sound file on a high quality recorder (we had the best results with SONY Minidisk). If you take holidays in distant countries, it is recommended that you use a portable and easily mounted Quadrifillar Helix antenna, see [19], take the receiver described below and a Minidisk. During your trip you can record exotic pictures from any of the meteorological satellites. When you return you can decode the saved WAV sound files in the same manner as during direct reception.

3.

Description of the receiver RX-137-141MHz

The receiver RX-137-141MHz has been designed for high quality reception of signals form polar meteo-satellites NOAA, METEOR, OKEAN and others. It is compatible with the converter from 1691MHz to 137.50MHz which is suitable for reception from geo-stationary satellite METEOSAT 7 [14, 23].

Looking at the Table 1, you will find that satellites in polar orbits transmit signals in the range of 137.30-137.85MHz, therefore a very narrow frequency range is sufficient. We have chosen, for practical reasons, a lower frequency of 137.00MHz and an upper frequency of 141MHz. No meteorological satellites transmit at frequencies above 137.85MHz but the frequency of

Frequency range:	137 - 141MHz, smoothly in steps of 10kHz
Function SCAN:	137.00 137.30 137.40-137.50 137.62 137.85-141.00MHz,
Intermediate frequencies:	10.7MHz and 455 kHz
Input sensitivity:	0.4µV (rms-typ.) for 12dB SINAD
Output signal:	2400Hz amplitude modulated (black 5% and white 87%)
Display:	LCD single line, 16 displayed characters
Current consumption:	70mA, (with converter LNC1700 250-500mA)

Table 2 : Specification of the receiver.

141MHz will make it possible to use the converter for the METEOSAT 7 satellite. This makes it possible to process information from both channels, the first channel (1691MHz) converts to 137.50MHz and the second channel (1694.50MHz) converts to 141.00 MHz.

The circuit diagram of the receiver is shown in Fig 1. It was originally developed for the nearby ham frequency range of 144-146MHz [3]. The circuit of the receiver is designed for wideband FM (bandwidth 30kHz). The low-frequency WEEFAX signal is sent from the output to the PC sound card. The frequency synthesiser PLL and LCD display are controlled by an ATMEL micro-computer.

The receiver is a double conversion superhetrodyne. Design of the receiver has been significantly simplified by using an MC 3362P (IC1) integrated circuit made by Motorola [5], which comprises all main elements of modern FM receiver. All that is required to connect to the MC3362P is an input band-pass filter, a resonant circuit for the first mixer oscillator, 2 ceramic filters for 10.7MHz and 455kHz, a quartz crystal oscillator for the second mixer, a resonant circuit for the demodulator and few other passive components. We will thus obtain an excellent receiver with a rather simple circuit and with supply voltage of 2-5V [12].

3.1 Input circuits of the receiver

The signal from the antenna (or from the converter) go to a capacitance divider C2-C3 (input impedance adjustment). The divider together with L1 forms the first tuned circuit, the “hot end” of which is connected to T1 a dual gate MOS-FET, preferably “low-noise” type BF982. T1 ensures sufficient amplification of the input signal. Resistor R3 suppresses the tendency of input amplifier to oscillate, but it does reduce overall amplification. The signal from resistor R3 is further filtered by a band-pass filter L2-C5, L3-C8, L4-C11+C12 with the bandwidth of approximately 4MHz. Critical coupling between the band-pass filter circuits is determined by serial connection of SMD capacitors C6 + C7 and C9 + C10. The signal passes through the capacitance divider C11+ C12 to the input of the first mixer in IC1 with mixing signal from oscillator (L5, C33).

3.2 PLL Oscillator

The stability of the oscillator for the first mixer is achieved using a PLL with reference frequency of 4MHz. IC4 is a Philips SAA1057 single chip synthesiser designed for tuning of VHF FM radio receivers with medium frequency bandwidths [4, 6]. It was produced in 1983, but surprisingly enough it is still available on the market and at very good price. In the circuit shown in Fig 1 the synthesiser can be tuned from 110MHz to 150MHz with steps of 10kHz using a maximum tuning voltage of 4.5V. The tuning voltage (max. 5.5V) is taken from the power supply to the pin 7 of IC4. R14, C25 and C26 are the passive components of the phase detector, C27 filters the internal stabilised voltage. The stability of the PLL is determined by the filter connected to pins 5 and 6 of IC4, R15, R16, C28, C31, C56, C57 determine the time constant of active low-pass filter. It is important here to pay special attention to recommended values of components. The tuning voltage from the PLL is connected to the pin 23 of IC1 to an internal varicap diode. The output from the first oscillator of the circuit in IC1 (oscillator buffer) is connected through the coupling capacitor C35 to pin 8 (FFM), the input pre-divider of the synthesiser IC4. In the majority of applications of the SAA1057 the reference frequency is determined by a 4MHz internal oscillator controlled by external quartz crystal connected to pin 17 (X). In our circuit we have chosen an economic option and used a common quartz crystal for the reference frequency of both PLL and ATMEL micro-computer [7]. The quartz crystal X1 is part of the oscillator in IC3 and the reference frequency for IC4 is connected through the capacitor C24 and resistor R11.

For the first mixer we have chosen frequency one intermediate frequency (10.7MHz) lower than the signal frequency. The synthesiser therefore generates frequencies from 126.3MHz to 130.3MHz for a reception frequency range from 137.0MHz to 141MHz. The synthesiser frequency can be finely tuned with use of trimming capacitor C21. The control word for setting the dividing ratio of the divider is accepted by the synthesiser IC4 through the inputs CLB, DLEN, DATA from the micro-processor IC3 via a three wire data bus, C-BUS, which is also connected to the connector PC-BUS for other uses.

3.3 Intermediate frequency

The first mixer oscillator is 10.7MHz lower than the input signal. The difference component (f_{IN}-f_{OSC}) is the intermediate frequency signal of 10.7MHz being amplified by the amplifier in IC1 and fed to the ceramic filter F1, this is a common type muRata 10.7MHz/180 kHz. The filtered signal is fed to the second mixer where it is mixed with the signal of a quartz crystal oscillator with the frequency of 10.245MHz (X2). The resulting difference component is filtered by ceramic filter 455kHz (F2) with a bandwidth is 30kHz. Due to frequency swing of the WEFAX signal's modulation of +/-17kHz the width of F2 should be approximately 40-50kHz. Unfortunately, the only ceramic filter available is the muRata/455/B. We have found that the narrower width of the filter has an unrecognisable impact on quality of the final image. Modulation of the first oscillator can have a substantial influence on the quality of decoded image. That is why increased attention must be paid, in this project, to the feedback loop of the PLL.

The signal after the filter F2 is amplified in the internal limiter with the output to the quadrature demodulator, which uses the resonance circuit L6-C19. In order to ensure only minor signal distortion after demodulation the linear characteristic of the demodulator must have width of at least 40kHz. For this reason we have chosen the value of the damping resistor of 39k. For use with the METEOSAT satellite a bandwidth of approximately 20kHz is sufficient.

3.4 Low-Frequency output

The demodulated low-frequency signal is a tone of 2.4kHz that passes through a simple filter, formed by R19, C37, C38, which suppresses undesirable products. After the filter the signal is divided into two parts, one to the potentiometer P2 which feeds the low-frequency amplifier IC2 with output to the loudspeaker, the other to the pre-amplifier IC6 for the 2.4kHz tone decoder circuit IC7, and also to the output for the PC sound card.

3.5 2400Hz tone decoder

A tone decoder [13] was included in the receiver after considering possible modifications to the software for the original receiver from [2, 3, 8]. From the table of orbit times for individual satellites and frequencies at which they transmit, it is apparent that the receiver must scan the band from 137 - 141MHz and stop only at signals with modulation by a tone of 2400Hz and not at incidental interference. We have chosen a simple algorithm; the receiver performs a test after switching on and stops at the first channel having a signal modulated by tone of 2400Hz. When the satellite disappears behind the horizon the signal modulated by a tone gets lost in the noise and the receiver begins scanning again. It stops at the next signal with 2400Hz tone modulation. The tone decoding is reliably accomplished by the integrated circuit NE(SE)567 (IC7). As soon as a signal appears on the input of the tone decoder, it is compared with the frequency of the internal oscillator. When a tone is detected the output, pin 8, of IC7 is set to the a low level and diode D1 is lit. The frequency of internal oscillator is set roughly by the capacitor C55 and accurately to the value of 2400Hz by the trimming resistor R25. The logic signal on pin 8 of IC7 is connected via the jumper JP3 to the input of the microprocessor SQ OUT which controls mode of automatic searching for signals in the received bandwidth (SCAN). The jumper JP3 can be used to select control of automatic scanning for signals either on the basis of presence of 2400Hz tone, or by active squelch.

3.6 Squelch

A side effect of receiving weak FM signals or operation of the receiver beyond the tuned station is an unpleasant noise in loudspeaker. That is why squelch (SQL) forms an integral part of any FM receiver. It interrupts the low-frequency signal to the amplifier at absence of sufficient level of input signal.

The DC component of LF signal from the pin 10 (MetDriv) of IC1 is fed through R4 to the potentiometer P1, which is used to set the sensitivity threshold of the squelch. When the slider of potentiometer P1 is in the extreme left position the squelch is disabled. Turning the potentiometer clockwise increases the level at which the squelch switches off. Pin 11 of IC1 is carrier detect which is used to control the squelch switch having a voltage of approximately 0V for a signal without noise or a voltage of approximately 2.8V for no signal, or a signal with increased noise level. This is inverted by transistor T2 and fed to pin 8 of the loudspeaker amplifier IC2 that mutes the signal path when the squelch is active

When the squelch is switched off the collector of the transistor T2 and pin 8 of IC2 have voltage of 1.25V, and the low-frequency is not muted. When at constant signal is received at the antenna and the potentiometer P1 is turned clockwise, we will reach a state where the squelch activated i.e. a voltage 0V appears at the collector T2 and the low-frequency path is muted. When signal voltage on the receivers input increases slightly the squelch deactivates and opens the low-frequency path.

The squelch signal has been used also for automatic scanning of signals. We have added transistor T3, which inverts the squelch signal which can be connected to the input P3.0 (SQ OUT) of the microprocessor IC3. The processor program then takes care of the rest (see the chapter Setting-Up Of The Receiver for more details).

Note: If you do not like the small hysteresis of squelch, connect pins 10 and 11 of IC1 using a resistor of 2 - 5M (R30) and connect a ceramic 100nF capacitor (C61, preferably SMD) between pin 11 and GND. Another option to soften the squelch rise time is to use an electrolytic capacitor C60.

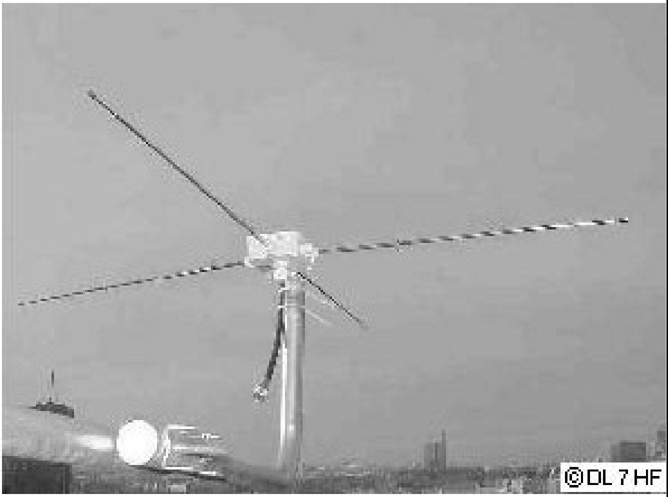

Fig 2 : General view of a Turnstile antenna.

4.

Experiment with an AFC circuit

During the design of this receiver described in [2, 3, 8] experiments were made for AFC. This tuned the frequency of the reference oscillator using the DC component of the voltage from the quadrature demodulator at pin 13 of the IC1. This was connected to the inverting input of an operational amplifier TL071 with it's output connected to a pair of varactor diodes, KB105G, which replaced the trimming capacitor C21 in the circuit of reference oscillator. Thanks to the very good stability of PLL we did not notice any change in quality of the final image when AFC was used, that is why we decided to exclude the AFC circuit in order to make the design as simple as possible. For people interested in AFC, the circuit diagram is available at the authors homepage.

In relation to the use of AFC, it is appropriate to mention Doppler shifting of frequency. This phenomenon is observed if a signal source, in our case a meteorological satellite, is approaching, you perceive it's frequency as higher, and when it moves away, you perceive its frequency as lower than it in fact is. The magnitude of the Doppler shift for orbital satellites is a maximum of 5kHz which is still in the pass-band of the filters and does not cause visible distortion of final image.

5.

Antenna

A requirement for assuring high quality reception of signals from meteorological satellites is the use of a high quality antenna. Polar meteorological satellites are rotation stabilised and transmit circular polarisation. It is therefore impossible to use ordinary Yagi or ground plane antenna. When you listen to the signal from the loudspeaker it seems to be noise free, however when you observe the picture after it is decoded you will see that it is unusable. Anyone can build high quality antenna. Two basic types are used: Turnstile and Quadrifillar Helix.

The turnstile consists of two crossed dipoles (Fig. 2) phased for circular polarisation. This antenna should be situ-

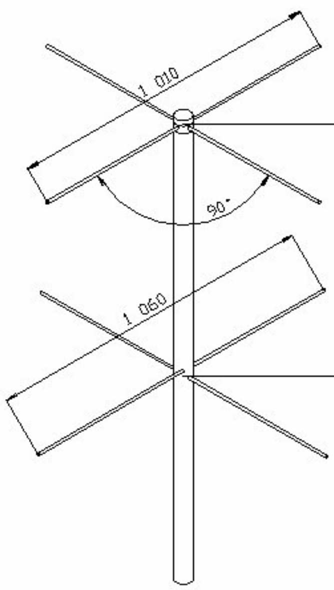

Fig 3: Practical design of a turnstile antenna.

ated as high as possible above the horizon, preferably above the house roof or in an open air space. Experiments made with a turnstile antenna located on the balcony of a blockhouse, satellites flying over at a low elevation angle were shielded by building or balcony. In short, it is only possible to receive signals that are "seen" by the antenna. Instructions for building several types of turnstile antennas are on the authors homepage. Drawings describing the construction of a simple antenna made from plastic tube and 8 - 12 mm aluminium tube are given in the literature [18].

We have tested the antenna shown in Fig 3 with the receiver. The antenna was installed on a roof at 40m above the ground and gives high quality signal reception. The feeder connection for circular polarisation is shown in Fig 4. Fig 5 shows the polar diagram for this antenna, particular attention should be paid to the dipole to refelctor spacing because it changes the polar diagram, the author chose 3/8λ.

The manufacture of the Quadrifillar Helix antenna, which is shown in Fig. 6 can be done only in a well equipped machine shop. This antenna has slightly better reception of signals and moreover it can be used also in moving objects, such as yachts cruising in Mediterranean Sea. The article [20, 21] contain many descriptions of simpler mechanical constructions suitable, however, only for a short-term seasonal use, or for antennas made of copper heating tubes. If the distance of your receiver from the antenna will exceed 10m, I would recom-

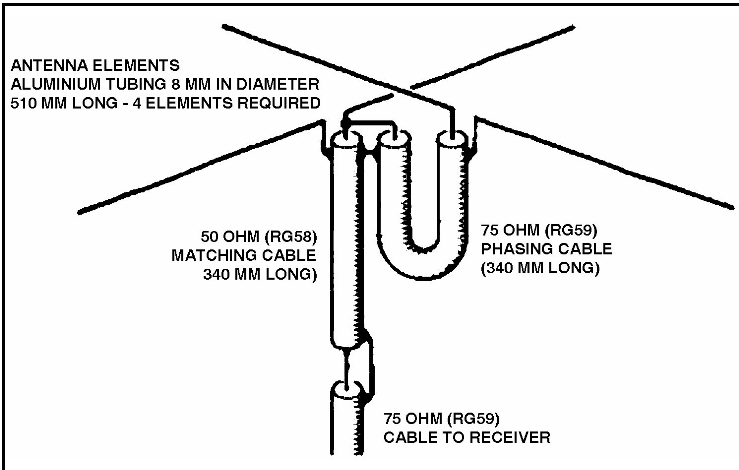

Fig 4: Details of feeder for turnstile antenna.

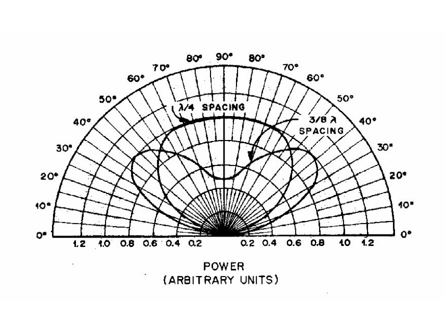

Fig 5: Polar diagram for turnstile antenna.

mend use of selective pre-amplifier for frequency range of 137MHz, preferably using bipolar transistor. Experience has shown that summer storms have a rather bad impact on MOS-FET transistors. In an environment with industrial interference it is often desirable to use a band pass helix filter in front of the pre-amplifier.

6.

Power supply for the receiver

The receiver requires a stabilised power supply adapter with a voltage of 9 - 12V. It is highly that you pay special attention to the selection of a power supply adapter. If you have an oscilloscope, look at it's output when on load at 150mA and check that there is no ripple. The low-frequency amplifiers IC2 and IC6 are fed directly from the adapter. The other supply voltages, 5V for receivers circuits and 5V for synthesiser and microprocessor, are stabilised by IC5 (LM7805). The supply voltage for the analogue part of the receiver is also isolated by choke L6. The input of the power supply is protected against reverse polarity by diode D2. Bridging jumper JP2 enables the use the feeder cable to supply the antenna pre-amplifier or Meteosat converter. This requires a higher capacity power supply

Fig 6 : General views of Quadrifillar Helix antennas.

adapter, for connection of the OK2XDX Meteosat converter [16], I recommend a power supply adapter of 12V/500mA.

7.

Construction of the receiver

Building the receiver is very simple, it can be done by any beginner, who has a knowledge of rf techniques, and is able to use a multimeter. If care is taken there will be no need for special rf measurement equipment. The secret of success is to put the correct value components in the right place on the printed circuit board and solder them in properly.

If you build the receiver from the EMGO kit you will have all of the components needed. First of all visually check the components against the parts list. The values of the resistors and capacitors can be checked, the resistors can be measured and the markings checked on the capacitors. Do not forget that the marking 470 on some capacitors does not mean 470pF, but 47pF. It is important that you pay special attention to this initial measurement of components and visual inspection, including printed circuits. After first construction guide was published [3] I agreed, out of curiosity, to complete several almost finished kits. Although these receivers seemed to be assembled, they did not work. In all the cases I found that this was caused either by mistakes, negligence or bad soldering of components. After minor repairs all of the receivers worked perfectly.

After visual inspection of the printed circuit board (PCB) fit the four pillars in the corners, they will simplify the insertion of components (Fig 7). Start by fitting the 9 SMD capacitors and one SMD resistor using a small quantity of 1mm diameter SnPbCu solder. Next insert and solder the remaining resistors, capacitors, semiconductors and the connectors for the loudspeaker and power supply starting with small components and continue with larger ones. Sockets are used for the integrated circuits IC3 and IC4. Before soldering the two quartz crystals, X1 and X2, fit a 0.5mm paper pad and removed it after soldering. Similarly the 5 TOKO coils with metal covers should be fitted into PCB with small space of about 0.5 mm., this prevents the case shorting to other tracks on the PCB. The tank circuit of the discriminator, L6, also has a metal cover and should be fitted approximately 0.5mm above the PCB. If L6 does not contain a capacitor, fit C19. Finally fit the switch SW1 and JP3 and connectors LINESB and LINEREP. If you use your own printed circuit board and it does not have plated through holes, do not forget to solder the top and bottom of components leads and fit fed through wires where required. Fit the pre wound coils L1 to L5 for the input band-pass filter, these are high quality coils made by Japanese manufacturer TOKO.

If you manufacture the coils yourself, you must wind 2.75 turns of 0.215mm enamelled copper wire on 5mm formers. Solder the wire ends to the metal pins on the bottom of the former and cover the coil with a droplet of beeswax. Turns on all the coils must go in the same direction (e.g. clockwise). Insert the coils to the PCB and check orientation before soldering. Put a metal cover over the former approximately 0.5 mm above the printed circuit board. Finally fit ferrite cores made of N01 (150MHz) into the formers.

The following components will be fitted during set-up using rf measuring equipment: capacitors C11, C12, ceramic filters F1 and F2, integrated circuits IC1 (microprocessor AT89C2051 with the program RX137DIP4X) and IC4 (PLL SAA1057). If you do not have rf measuring equipment, insert all the components in accordance with the component layout.

Fit the components onto the front panel (Fig 10) including the support plate for the LCD display and its fixings to the receivers main PCB. First fit the buttons TL1 and TL2 to the panel from the front and the 100k trimming resistor, for setting of display contrast, to the panel from the back. If you use a back lit LCD display, you must also fit the 120Ω limiting resistor. The panel will be fastened to the receivers PCB by soldering at the bottom corners, at places without a protecting layer of solder mask. This is strengthened by installation of two the potentiometers P1 and P2, and the angular connector. After checking that the panel is perpendicular to the receivers PCB you can solder all terminals of potentiometers and angular connector. Insert the 16 pin connector into the top part of the panel from the front and solder it from the back. Finally insert the LCD display form the front and solder its

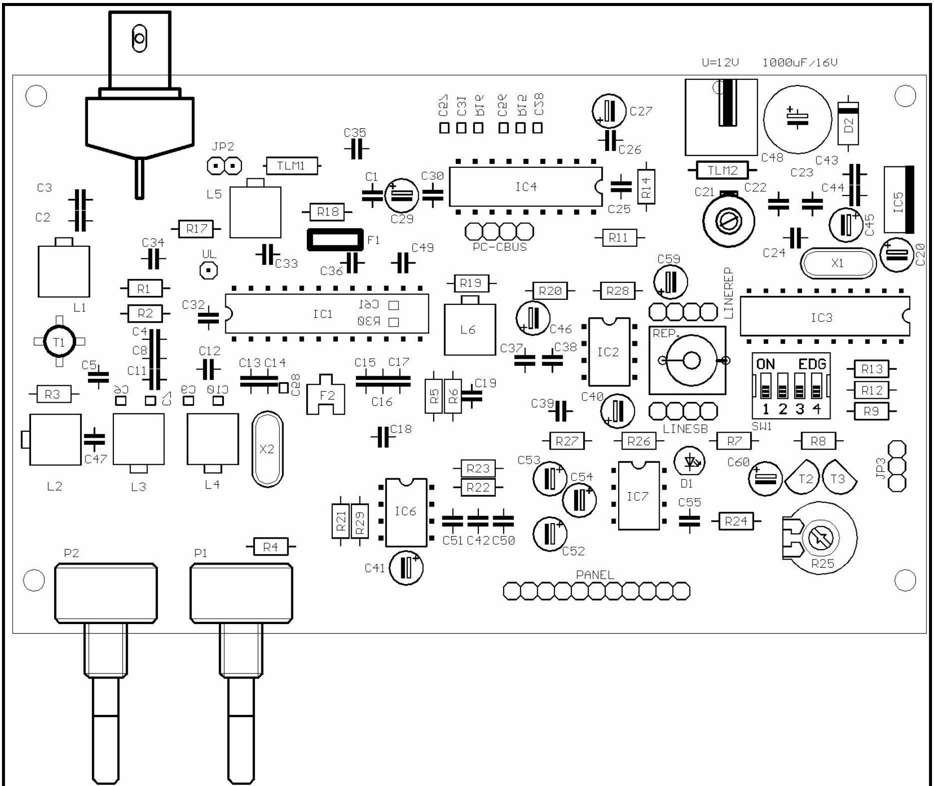

Fig 7 : Componet layout of the main receiver PCB.

16 pins to the front panel. Secure the potentiometers P1 and P2 by fitting the shaft nuts.

After putting the receiver RX-137-141 into operation you can fit it into a suitable plastic or metal box with apertures for the display and controls. The antenna and power supply connectors are at the rear of the box. Fig 13 shows the receiver mounted in a suitable box.

8.

Setting-up of the receiver

Connect a stabilised power supply, of 9 - 12V, to the input connector U12. Ensure the centre connector is positive and the outer is ground. Using a voltmeter measure +5V at the stabilised output of IC5. If there are problems with the noise properties of the receiver, check the stabilised voltage using an oscilloscope. If there is noise on the supply the stabiliser must be replaced.

The procedure for commissioning and tuning of the rf components will depend on the instruments available to the individual constructors [22]. The receivers board is already fitted with all components except the intermediate frequency filters F1 and F2. Do not fit the microcomputer IC3 and synthesiser IC4 into their sockets. Turn the potentiometer P1 (SQL) completely to the left, this will put the squelch out of operation. Do not

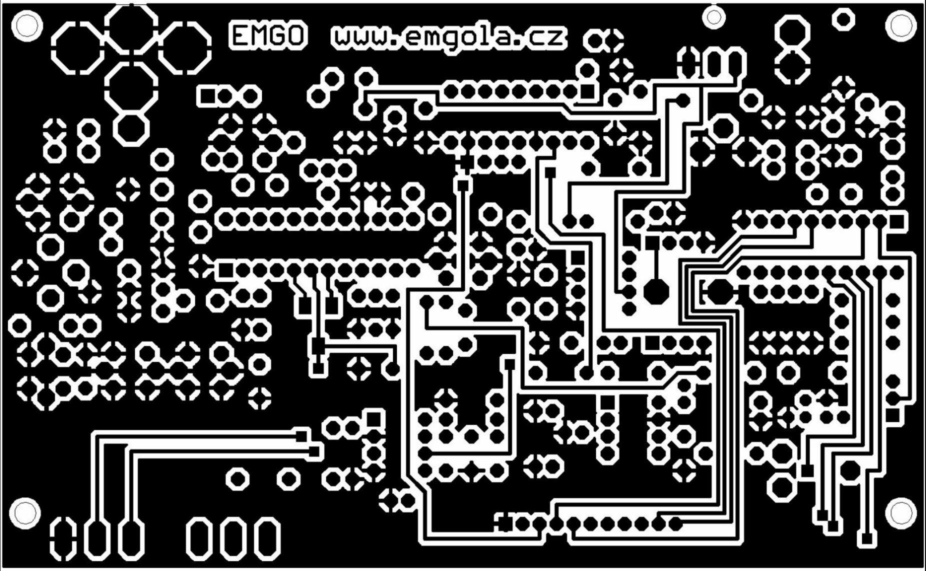

Fig 8 : Top side of the main receiver PCB.

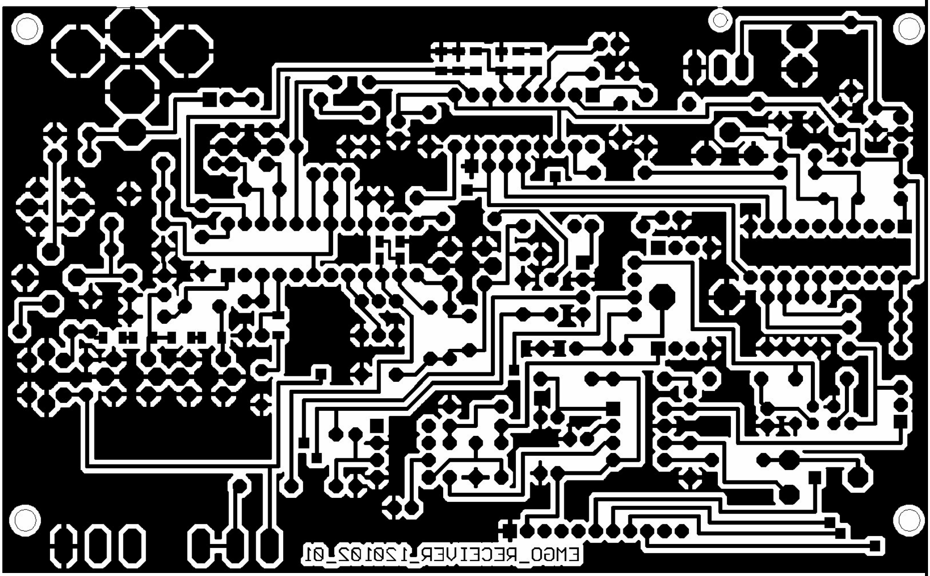

Fig 9 : Bottom side of the main receiver PCB.

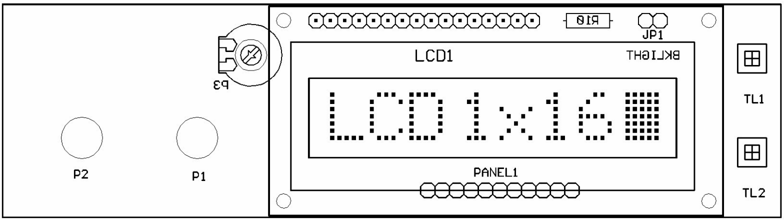

Fig 10 : Component layout of the display PCB.

connect the shorting pin on the switch JP3. For tuning L1 - L4 at the receivers input and the demodulation discriminator L6 it is best to use a wobbler. Almost same result can be achieved using an rf generator (even an improvised test oscillator 137 - 141MHz with one transistor) a counter and a simple rf diode probe connected to an analogue voltmeter.

Connect a signal with frequency of 455kHz, preferably frequency modulated by tone of 1kHz, with frequency swing of 30kHz to pin 7 of IC1 using a 1nF capacitor. Connect an oscilloscope to pin 13 of IC1 and tune L6 for maximum amplitude of demodulated signal. By adjusting the value of R6 (a lower value will broaden the linear part of the curve) at least 30kHz of linear demodulation can be achieved. If a signal generator without frequency modulation is used, adjust it in steps 1kHz and plot a graph of the voltage at pin 13 of IC1. It is also possible to determine the value of R6 experimentally by monitoring the image quality (minimum noise, the highest loudness, sharpness of image details, etc.). The recommended value of R6 is 33-56K.

The next step is to fit filter F2 and connect the output signal from a wobbler generator or analyser to the receivers antenna input, connect the wobbler to pin 19 of IC1. This will enable the input selectivity to be adjusted without being affected by capacity of the signal source. Shunt the input coil L1 using a 50Ω resistor and tune the band-pass filter L2, L3 and L4 to approximately the centre of the band (139MHz) and set the width of band-pass to 4MHz. If you do not intend to use the METEOSAT converter with your receiver, set the input band-pass filter to centre at approximately 137.6MHz. If it is necessary modify C6, C7 and C9, C10 (0.5-1pF) in order to adjust the coupling of the resonant circuits to critical or slightly supercritical. Remove the shunt resistor from L1 and also tune it to the centre of the selected received band, i.e. to 139 or 135.6MHz.

Now fit filter F1 and to insert the synthesiser and microcomputer ICs into their sockets. Switch on receivers power supply and use the trimming resistor on the front panel to set the LCD display contrast so that characters are legible. If turning of trimming resistor to both extremes does not help and no characters appear on LCD display, use an oscilloscope to check communication between PLL IC4 and microprocessor IC3 (pins 8 (CLB), 9 (DLEN) and 11 (DATA) TTL levels). Push any button on the display panel and look for a sequence of impulses, when microprocessor sends new data to the PLL synthesiser. If this is unsuccessful, check that the microprocessors reference oscillator is working.

With the LCD display showing a frequency of 137.5MHz, connect a voltmeter to the pin 23 of IC1 or even better to the test point “UL” and check that the first oscillator PLL is functioning cor-

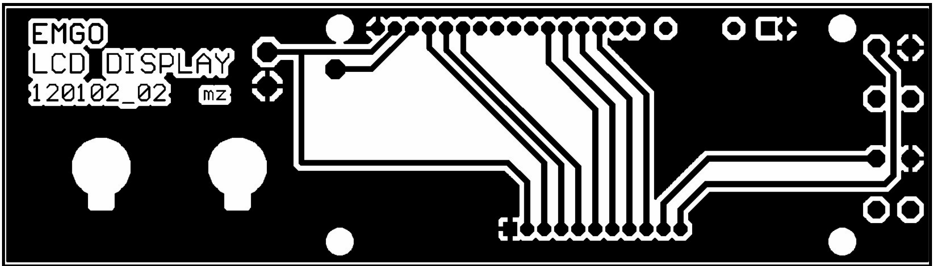

Fig 11 : Top side of the display PCB.

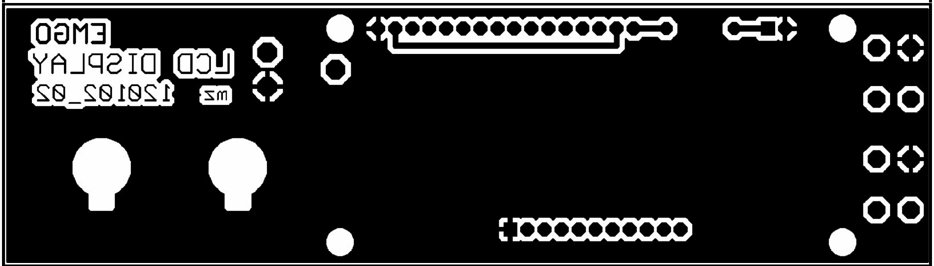

Fig 12 : Bottom side of the display PCB.

rectly. Start by adjusting the core of L5 using a non-metallic screwdriver and watching the voltmeter for changes in the control voltage of the PLL. The measured voltage should not remain fixed at either extreme, i.e. 0.2V or 4.3V. If the PLL is working, the tuning voltage should vary smoothly between 0.2V and 4.2V as the position of the core in L5 is changed.

Fig 13 : Completed receiver in a plastic case.

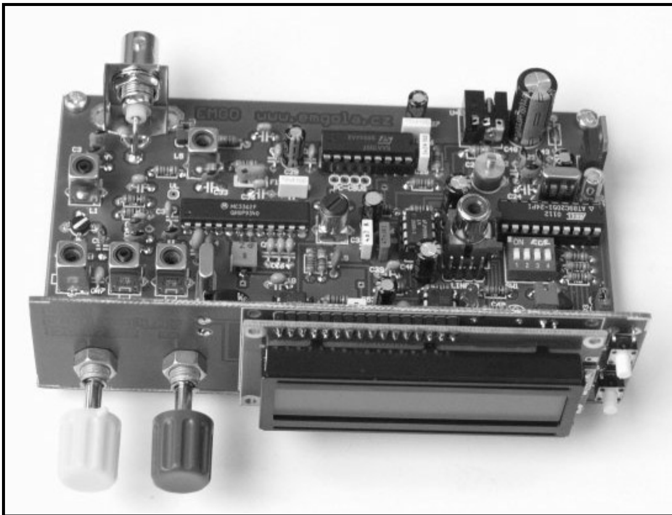

Fig 14 : Picture of the completed receiver.

If you have wound your own coil L5, you may have to adjust the value of C33. If the tuning voltage reaches the maximum of 4.2V with the core almost unscrewed (minimum inductance), reduce the value of C33 by one step. If the tuning voltage reaches the minimum of 0.2V with the core completely screwed in (maximum inductance), increase the value of C33 by one step. In order to avoid such problems we recommend the use of the specified TOKO coil.

For example, for a received frequency 137.50MHz - satellite NOAA 15 (oscillator of the receiver oscillates at 126.80MHz) set the voltage at the junction of R16, C31 to approximately 2.5V by adjusting the core of the L5. Check the exact frequency of the oscillator using a counter and tune it by slight changing the trimming capacitor C21.

The majority of constructors will probably not have a wobbler or rf signal generator at their disposal. Nevertheless even the modest ham shack equipped with just a probe, a multimeter and "common sense" it is possible to tune the input circuits to the lowest possible noise in the output LF signal. You just have to make a test Colpitts oscillator, working at 137.5 MHz. If you do not have a suitable circuit, I will gladly send it to you together with a PCB. You can then tune the resonance circuits, by the following method, to a minimum noise in the output signal. It is not necessary to make direct connection of test oscillator to the receivers input. it is sufficient to insert a cut wire into the antenna connector, a paper clip formed to an "L" shape will do the job. Set SW1-DIP4 to 137.5MHz and tune the frequency of test oscillator to this frequency, i.e. when the noise disappears from the receivers loudspeaker (or at least its intensity is considerably reduced). By touching the coil of test oscillator you can introduce "frequency modulation". At pin 13 of IC1 you can see the signal using an oscilloscope, or by listening to the loudspeaker. First adjust the core of L6 for the lowest noise in LF signal and the loudest volume. Then tune the input circuit, L1 - L4, and gradually shorten the improvised wire antenna (or move the test oscillator away) to give the lowest noise in low-frequency. Do not use a metal screwdriver, make a non-metallic screwdriver from a piece of hard wood (preferably bamboo), or from suitable plastic material.

Note: set the squelch off using potentiometer P1 set to its minimum value.

	Receive freq.	Oscillator freq.	Switch
K0	137.500MHz	126.800MHz	all OFF
K1	137.300MHz	126.600MHz	SW1 ON
K2	137.400MHz	126.700MHz	SW2 ON
K3	137.500MHz	126.800MHz	SW3 ON
K4	137.620MHz	126.920MHz	SW4 ON

Table 3 : Switch settings for synthesiser.

When this procedure is complete you can listen for received signals and set the correct squelch level. The synthesiser PLL must be set up before the alternative tuning method is used.

Connect a 137 - 138MHz turnstile antenna [17] to the receiver's input and set the frequency for the NOAA or METEOR satellites by using either switch SW1-DIP4 or buttons TL1/TL2. These satellites should soon appear, consult the current orbit timetable to verify the times. The switch SW1-DIP4 serves as simple memory to store pre-set frequencies after switching on of the receiver. When all the switches are set to the position OFF, the PLL tunes the oscillator frequency to 126.80MHz, thus the received frequency is 137.500MHz (satellite NOAA15). Set the required frequency for the receivers oscillator by switching some of the four switches of the selector switch SW1-DIP4x to the position ON. Table 3 shows the setting of the 4 switches, however all 16 combinations in binary code can been used.

To commission of the low-frequency part of the receiver all that is required is to set the gain of the amplifier for the loudspeaker and sound card using an oscilloscope, or by just listening to the audio output. Set the amplification of IC2 to the required value by adjusting R28 (3R3=74dB, 10R=70dB, 33R=54dB, 105R=44dB, 820R=34dB) with C59 100uF. Set the tone decoder IC7 by adjusting R25 so that the LED diode D1 lights up whenever a tone of 2400Hz is detected in the received signal. The optimum input sensitivity of the decoder has been chosen during development. Should you have any reason to change it, choose different ratio of resistors R22 and R23. The output from pin 8 is connected using a jumper on JP3 to the input SQOUT of microcomputer. SQOUT can also be connected to the collector of transistor T3, which has a logical value depending on the setting of the squelch and on magnitude of input signal.

8.1 The Receivers control function

With a jumper on JP3 position 2-3 (TON), after switching on the receiver will perform a first test for the absence of low logical level on SQOUT. The test is then repeated and if a 2400Hz signal above the set threshold level is detected on any channel, the processor stops tuning. When the signal disappears i.e. when the satellite sinks behind horizon, the test re-starts and re-tunes until another signal is captured. Tuning can be interrupted by pressing the push button UP (TL1) or DOWN (TL2), the receiver is set to the frequency according to the selector switch SW1-DIP4. It is then possible to tune manually from 137 - 141MHz in steps of 10.0kHz. Simultaneous pressing and holding of both push buttons restarts scanning again. The LCD display will show the current received frequency in MHz. With a jumper on JP3 position 1-2 (SQL), the squelch output is connected to the input of processor SQOUT. The scan function still operates but is now controlled by the level of the squelch, and not the presence of a 2400Hz tone.

9.

How to connect a LF output of the receiver to your personal computer

After demodulation the receiver's low-frequency output is an amplitude modulated tone of 2400 Hz, which can be

Fig 15 : JVComm32 in action.

processed by several methods. WEFAX signals used to be processed on older computers without a sound card using JVFAX 7.1a. (operating system Microsoft MS-DOS 3.0-6.22). For those who would like to reminisce, you can study this issue on the web [19]. You will find a description of simple method, which consists of converting the amplitude modulation to frequency modulation. The maximum change of brightness is then expressed by a change of frequency of approximately 1500 - 2300Hz. This signal is connected to the computer's serial port using a simple comparator (EasyInterface) and processed by JVFAX 7.1a. Thanks to the negligible price of obsolete computers you can make a receiver and decoder at minimum cost and have continuous receiption of pictures form meteo-satellites.

Modern fast computers with sufficiently big operation memory give us a possibility to use the most advanced programs. The demodulated 2400Hz signal is connected directly to the input of sound card.

9.1 Program for decoding of WEFAX signals using JVComm32

Decoding of pictures by personal computers is supported by many modern programs [26]. I have tested a demonstration version of JVComm 32. This is an elegant program without the need for an EasyInterface, just connect the low-frequency output of the receiver to the LINE input of your sound card. I finally bought a full licence for use of this program [27]. This program can be, however, only be used on a powerful PC working under Windows 95/W98/W2000/W-NT. The following paragraph describes reception of an image and its decoding by JVComm32 version 1.0 or 1.1.

In 1998 the German author of the JV-FAX, Eberhard Backeshoff, DK8JV (e-mail address: feedback@jvcomm.de and homepage at http://www.jvcomm.de/) wrote JVComm32 for decoding of WE-FAX, FAKSIMILE SSTV and other modern modes, he continues to enhance it and extend it. The program requires a common 16-bit sound cards with it’s LINE input connected to the low-frequency output of the receiver. A disadvantage of this program is that it requires at least a 75MHz Pentium PC with 16MB of memory, operating system Windows 95, W98 or Windows NT 4.0 and high quality graphic card (High or True Colour) with resolution at least 800 x 600 pixels. JVComm32 on the other hand can work at the background and allows simultaneous processing of received images (viewing, cropping, sending to your friends by e-mail, etc.). The author, nevertheless, recommends for multitasking at least 90MHz Pentium and 32 MB of memory as a minimum.

Connecting the receiver to the input of computer sound card is very easy. From connector LINESB of the receiver connect the low-frequency signal to the connector LineIn or microphone input of the sound card. Fig15 shows JVComm32 in action, when a map is received in background for, the pictures received from the satellite NOAA are loaded from the folder, Picture files, to the desktop:

9.2 Description of software

Configuration of the program for reception of satellites NOAA or METEOSAT is very simple. Set the mode to NOAA or METEOR, and the Interface type to Sound Card. The help with this program is also very user friendly, you will find all the details of setting and operation.

10. Kits

The author has produced kits for hams for several years and therefore knows very well that successful completion of a project is often hindered by tiny problem. No matter how good a verbal description is, it’s information capability is always much lower than visual and/or audio information. That is why kits are supplied with a CD containing complete information. Kits contain a set of printed circuit boards and parts. Fully assembled and tuned modules are also available for a slightly higher price.

You can get more detailed information at the following contacts:

emgo@vuhz.cz or emgo@iol.cz or http://www.emgola.cz/

11. Literature

[1] Ing. Radek Václavík OK2XDX, Pøíjímaè and interfejs WXSAT (pøíjem snímkù z orbitálních meteosatelitù) [Receiver and interface WXSAT (receipt of images from orbital meteorological satellites)]. A-Radio Praktická elektronika, series of articles in issues Nos. 2-6/1997.

[2] Günter Borchert DF5FC, Funkamateur 2/1995, str. 153 - 156 Der Wetterfrosch - ein 137 MHz Satellitenempfänger, continuation in Funkamateur 3/1995, p. 274

[3] OK2UGS.: Pøijímaè FM v pásmu 144 - 146 MHz s obvodem Motorola MC3362 [FM receiver for the band 144 - 146 MHz with the circuit Motorola MC3362]. A_Rádio_Electus99, pp.73-79

[4] Maršík, V.: Kmitoètová syntéza oscilátorového kmitoètu rozhlasových pøijímaèù [Frequency synthesis of oscillator frequency of radio receivers], Amatérské Radio B3/1987, p. 88.

[5] Motorola, Linear/Interface ICs Device Data, Vol.II, str. 8-82

[6] Philips Semiconductors, SAA1057 - Radio tuning PLL frequency synthesiser, November 1983.

[7] ATMEL, AT89C2051 8.bit Microcontroller with 1kbyte Flash, catalogue sheets August 1994.

[8] DF2FQ: VHF Empfanger, CQ DL 1/1994

[9] Borovicka, Jiri, OK1BI. Personal consultation history of receipts from the Meteosat, Antenna Turnstile

[10] Our location database includes most towns and villages in the entire world (over 2 million places!) http://www.heavens-above.com/

[11] OZ1HEJ, Pedersen, Michael: Receiver with LCD readout: http://ozon-.homepage.dk/eng/elcd.htm

[12] OK2UGS.: Pøijímaè FM v pásmu 144 - 146 MHz s obvodem Motorola MC3362 [FM receiver for the band 44 - 146 MHz with the circuit Motorola MC3362.]. Elektroinzert 5/97 p. 6.

[13] Philips Semiconductors: SE567 - Tone decoder/phase-locked loop, , 4/92

[14] OK2XDX.: http://www.qsl.net/ok2xdx/

[15] OK2UGS.: http://www.emgola.cz/Info.htm

[16] Ing. Radek Václavik, OK2XDX: Prakticka elektronika No. 7/1999 construction guide to building of converter LNC1700 MHz

[17] L. B. Cebik, W4RNL: http://www.cebik.com/turns.html The Turnstile An Omni-Directional Horizontally Polarized Antenna

[18] Martin DH7GL: http://www.emgola.cz/Ant_GLdipol/GL_dipol.htm

[19] Ruud JANSEN'S PA0ROJ: QFHA http://www.hshaarlem.nl/~ruud/ Skládací anténa na cesty za poznáním [Foldaway antenna for exploration trips]

[20] Steve Blackmore: QFHA http://www.pilotltd.net/qha.htm (step-by-step construction guide to building and QHFA)

[21] Borre Ludvigsen: http://abdallah-.hiof.no/~borrel/QFH/ QFHA - More pictures and construction picture above is one of the designs on this site.

[22] Josef Danes et al: Amatérská radiotechnika and elektrotechnika, 3. èást , Mìøení na pøijímaèích [Ham radio and electrical engineering, 3rd part, Measurement on receivers], pp. 190 254, Naše vojsko, Praha 1988.

[23] Gola, Miroslav: http://www.emgola.cz/jak_zacit_meteo.html

[24] Kucirek, Petr: Program SatWin pøedpovìdi doby pøeletù satelitù nad zvoleným územím [Program SatWin prediction of time of passages of satellites over the selected territory]

[25] Gola, Miroslav: http://www.emgola.cz/fapcsimile.html

[26] Eberhard Backeshoff, DK8JV e-mail address: , homepage

[27] Eberhard Backeshoff, DK8JV What does it cost and how can I get the full registered version?, http://www.jvcomm-.de/indexe.html

[28] Vaclavik, R, OK2XDX: Easy downconverter for Meteosat, VHF Communication 4/1999, page 196 - 207. http://www.vhfcomm.co.uk/

[29] Vaclavik, R, OK2XDX: Small receiver for Meteosat, VHF Communication 4/1999, page 208 - 217. http://www.vhfcomm.co.uk/

12.

Parts list

Capacitors

1pF	4	ceramic (SMD 0805)	C6,C7,C9,C10
3p3	1	ceramic	C2
5p6	1	ceramic	C12
6p8	1	ceramic	C3
10pF	1	ceramic	C33
12pF	3	ceramic	C5,C8,C11
1.8 - 22pF	1	trimming capacitor	CKT1 8-22pF C21
33pF	3	ceramic	C22,C23,C24
47pF	1	ceramic	C14
47pF	1	ceramic not included in L6)	C19 (used if
150pF	1	ceramic	C13
2n2	1	foil WIMA	C25
4n7	1	foil WIMA	C37
10nF	1	ceramics	C35
10nF	2	foil WIMA	C26,C49
47nF	5	ceramic	C4,C30,C32, C36,C39
47nF	1	foil WIMA	C38
100nF	9	ceramic	C1,C15,C16, C17,C18,C34, C43,C44,C47
220nF	1	foil WIMA	C31
330nF	1	foil WIMA	C28
2M2/50V	1	radial electrolytic	C20
10M/50V	1	radial electrolytic	C45
47M/12V	2	radial electrolytic	C27,C29
100M/10V	1	radial electrolytic	C46
100M/15V	1	radial electrolytic	C40
1000M/15V	1	radial electrolytic	C48

Resistors and potentiometers

2R2	1	R20
47R	1	R3
180R	1	R14
120R	1	R10 (for LCD with back light)
3k3	3	R8,R9,R11
4k7	2	R17,R18
10k	4	R5,R7,R16,R19
22k	1	R4
39k	1	R6 (39K - 56K see text.)
47k	2	R12,R13
50k/G pot	1	TP160, shaft 4mm P2
100k/N pot	1	TP160, shaft 4mm P1
100k	2	R1,R2
100k trim	1	PIHER PT6VK100 P3 (setting of contrast of LCD display)
180k	1	R15

Transistors and diodes

BF981	1	Dual gate MOS FET T1
BC238	2	NPN universal TO92 T2,T3
Red LED	1	Any LED diode D1
1N4007	1	Rectifier diode 1A D2

Integrated circuits

MC3362	1	RX FM 2x MF IC1
LM386	2	LF amplifier IC2,IC6
89C2051	1	With program RX137141DIP4LCD IC3
SAA1057	1	PLL up to 160MHz IC4
LM7805	1	Stabiliser +5V IC5
SE567	1	Tone decoder IC7
LCD-DV-16100		Single line display LCD1

Coils

7MC455kHz	1	TOKO 455kHz/600µH L6
Choke 560nH-1 µH	2	axial, TLM2
0.1µH inductance	5	TOKO or 2.75 turns, see text L1, L2, L3, L4, L5

Other

X-TAL 10.245MHz	1	Quartz X2
X-TAL 4.000MHz	1	Quartz X1
F 455 kHz/30kHz	1	Ceramic filter F2
10.7MHz	1	Ceramic filter F1
Socket DIL8	1	low Pro IC2
Socket DIL18	1	low Pro IC4
Socket DIL20	1	low Pro IC3
BNC connector	1	Antenna connector F
Spacer	4	M3x5 mm
Nut M3	4	Fe/Cd
Con. SCD-016A	1	power supply socket 12V-2.5mm
Con. SCP-2009C	1	power supply plug 12V-2.5mm
CINCH SCJ-0363	1	GM Elektronic, REP connector.
Switch DIP 4x	1	GM Elektronic, DIP1 connector.
Push butn. P-B1720	2	GM electronic, display board TL1. TL2,
Push butn. P-B1720	2	GM electronic, main PCB TL1
Knob	2	GM electronic, for 4mm shaft for P1 and P2
Pin S1G11W	1	GM Electronic, to connect the base of the receiver to LCD display
Loudspeaker	1	Conrad Electronic
PCB1 DISPL	1	138 x 37mm
PCB2 M-BOARD	1	138 x 88mm