A C-band low noise downconverter for satellite TV reception

1. Introduction

A complete Ku-band (11 - 12 GHz) satellite TV receiver was described in two previous articles [1], [2]. The C-band low noise downconverter described in this article completes the receiving set enabling the reception of the 4 GHz satellite band using the same indoor IF receiver described in [2], since TV transmissions in the 4 GHz band use similar modulation formats: wideband FM modulation with a spectrum spreading waveform and FM audio subcarriers.

Although the technical problems like the profile accuracy of the parabolic reflector or the sensitivity/ noise figure of the RF front end are easier to solve at 4 GHz than at 11 GHz, only a few TV programs can be received in Europe with reasonably sized antennas. The easiest is certainly the Soviet Gorizont satellite at 14 degrees west. Each Gorizont satellite carries 6 transponders with an output power of 40 W each and usually one of them, connected to a high gain spot beam antenna, is used for television broadcast. The latter can provide a noise free TV picture with an antenna as small as 90 cm diameter. Unfortunately the spot beam antennas of other Gorizont satellites at 53 degreees east and 70 degrees east are oriented to the eastern parts of the Soviet Union and only provide weak signals to Europe. All the other geostationary communications satellites visible from Europe, like the Intelsat series, Arabsat or Telecom and other transponders onboard Gorizont satellites use low gain wide beam antennas to cover wide areas including the complete hemisphere visible from their geostationary orbit. The signal levels are 15 to 20 dB below the Gorizont spot beam transmission and even a 3 m diameter dish will only provide a rather poor quality picture.

The block diagram of the C-band outdoor unit is shown on Fig. 1. All the satellite signals beamed to Europe in the 4 GHz band are circularly polarized, either RHCP or LHCP. Since most TV transmissions are RHC polarized, including the strong Gorizont transmission, it is convenient to use a short, two turn helix as the feed for the parabolic dish reflector.
The satellite signal is first amplified in a two stage low noise amplifier equipped with GaAs FETs. The downconverter uses a 5.1 GHz fixed tuned local oscillator to make image rejection easy and avoid spurious responses. The 4 GHz satellite band, 3.6 Ghz to 4.2 GHz, is thus converted to 900 MHz to 1500 MHz, compatible with the published indoor unit and most commercially available ready built indoor receivers. Note however that the polarity of the FM video signal will be inverted compared to a 11 GHz downconverter with a 10 GHz LO!

The block downconverter module is followed by an IF amp to overcome the losses in the cable feeding the indoor unit. The IF amplifier is identical to that used in the Ku-band LNC (YU3UMV 019 module), therefore its description will not be repeated here.

2. 4 GHz helix primary feed

The construction of a helix primary feed for 4 GHz is shown on Fig. 2. A two turn helix with a pot shaped reflector has a suitable radiation pattern to illuminate a parabolic reflector with the f/D ratio around 0.4. The helix is made of brass (or copper) tape supported by an insulating structure. In practice, pieces of polyethilene dielectric of different size coaxial cables were used as support rods and spacers kept together with plastic (nylon) screws. The reflector is made of thin brass sheet. Its diameter, expressed in wavelengths, is 0.7 lambda and the rim is 0.2 lambda high.

The helix has a relatively high impedance at the feedpoint and a quarterwave coaxial transformer is used to match it to roughly 50 ohms. A fine match can be performed inside the low noise amplifier if required. The matching transformer is manufactured from a piece of 50 ohm semirigid cable. To raise its characteristic impedance to around 80 ohms the original outer conductor (copper tube) is removed. A dielectric sleeve is pushed on the original teflon insulation of the semirigid cable and the assembly is pushed in a 6 mm internal diameter copper tube. the copper tube is soldered to the reflector at one end and to a brass nut, screwed on the semirigid cable, at the other end.

Considering the velocity factor of teflon insulated coaxial cables, the transformer should be around 14 mm long. Since it is difficult to find a teflon sleeve of the required internal and external diameters, polyethilene can also be used in spite of its slightly higher dielectric constant. In practice, a piece of RG-214 coax cable dielectric is used. The copper tube is heated by the soldering iron to the melting point of polyethilene and the dielectric is forced into the tube. When the tube cools back to room temperature, the central hole in the dielectric is carefully enlarged using a series of sharp drill points at low speed to match the diameter of the teflon insulation.

The parabolic reflector is a mirror and it reverses the sense of a circularly polarized wave. If the satellite transmission is RHCP, the polarization at the focal point of the reflector is LHCP and a LHCP primary feed is required. It is easy to determine the polarization of a helix antenna: a RHCP helix is wound like a right hand screw and a LHCP helix is wound in the opposite direction, like a left hand screw.

3. Low noise amplifier for 3.6 - 4.2 GHz

Considering the noise figures of available mixers, a gain of roughly 20 dB is required from the low noise amplifier to avoid that its noise figure is degraded by mixer noise. At 4 GHz, two amplifier stages equipped with GaAs FETs are sufficient to provide the gain required.

The circuit diagram of the 4 GHz low noise amplifier is shown on Fig. 3. The matching of the transistors is very simple: two inductive stubs at the input and two capacitive stubs at the output. The interstage match is acheived selecting the correct length of the 50 ohm microstrip. Of course, additional tuning stubs can be added to improve the performance of the amplifier on a particular frequency, to compensate for the transistor tolerances or antenna mismatch, like described in [1].

Except for the obvious changes due to the different frequency range, the bias network is identical to that used in the 11 GHz amplifier. Each of the two source leads of each FET is bypassed to ground by a leadless ceramic disc capacitor and the current through each transistor has to be adjusted selecting the source resistor. In the prototype, a CFY18 was used in the first stage and a CFY19 in the second. Since the S-parameters of these transistors are similar at 4 GHz, a cheaper CFY19 could be used in the first stage and an even cheaper CFY13 in the second with a just slightly degraded overall noise figure.

The microstrip circuit is etched on a 0.79 thick, Er = 2.6 glassfiber-teflon printed circuit board (Fig. 5). The circuit is installed in a custom made case with a piece of microwave absorber foam attached to the cover to prevent resonances, just like the 11 GHz amp.

The amplifier requires little if any tuning. A component that may cause problems are the 6.8 pF coupling capacitors. In the prototype, the smallest available ceramic capacitors (lead spacing 2.5 mm) were installed with the shortest possible leads.

4. Block downconverter 3.6 - 4.2 GHz to 0.9 - 1.5 GHz

The circuit diagram of the block downconverter is shown on Fig. 4. It incluudes a GaAs FET mixer, a local oscillator at 5.1 GHz and an IF amplifier stage.

The mixer is built with a single FET (T4). Both the RF and LO signals are applied to the gate of T4 and the IF signal is taken from the drain. The RF and LO signals are combined in a selective network including lambda/4 traps, followed by a matching networkfeeding the gate of T4. The drain stub operates like a lambda/4 short circuit at RF and LO frequencies and as a capacitor at IF frequencies forming a low-pass, matching network with L1 feeding the first IF amplifier stage (T5).

The 5.1 GHz local oscillator uses a cheap silicon bipolar transistor BFQ69 (T3). The frequency of the latter is mainly determined by the base and emitter stubs. The collector stub is used to adjust the amount of power delivered to the mixer stage. A bipolar transistor oscillator at microwave frequencies requires a bias regulator (T6) to stabilize the current through the oscillator transistor and improve the phase noise performance.

The microstrip circuit of the block downconverter module is also etched on a 0.79 mm thick Er = 2.6 glassfiber-teflon laminate (Fig. 6). The oscillator transistor (T3) is installed in a 5 mm diameter hole drilled in the laminate although it does not make any connection to the ground plane. The hole should be then tapped with a piece of copper foil to provide a ground plane for the transistor. Three low inductivity 470 pF leadless ceramic disc capacitors are used in the circuit: on each source lead of T4 and on the emitter stub of T3. The 2.2 pF capacitor is special too: it is made of a small piece of thin (0.15 mm thick) glassfiber teflon laminate. L1 is identical to the equivalent inductivity in the 11 GHz converter [1] and L2 is a lambda/4 choke for the IF frequency.

The block downconverter microstrip printed circuit board is also installed in a custom made case including a rim of thin brass sheet soldered around the PCB and a cover of aluminium sheet with a piece of microwave absorber foam.

The block downconverter module requires a few adjustments. As first, the frequency of the local oscillator (T3) should be checked. To tune the oscillator the length of the base stub should be adjusted acting on the open end. The lambda/4 traps usually do not require adjustments. To match the input of T4 a tuning stub (a piece of copper foil) has to be added and adjusted to optimize the conversion gain. The mixer test point can be used to monitor the LO signal level supplied to the mixer.

5. Conclusion

The converter described in this article was mainly used to receive the Soviet Gorizont satellite at 14 degrees west. The EIRP of this transmission is estimated around 46 dBW. Using an 1.2 m diameter dish reflector many other TV signals could be detected in the 4 GHz satellite band down to an EIRP level as little as 22 - 24 dBW. Of course, no TV picture could be obtained from such weak signals, but the characteristic field frequency hum was heard connecting an audio amplifier to the receiver video output. Synchronization of the picture on the TV monitor was possible at signal levels around 30 - 33 dBW EIRP, corresponding to Gorizont global and hemispheric beam transmissions and Intelsat zone beam transmissions. A larger antenna, between 2.4 and 3 m diameter, could provide useable but not yet noise free pictures from these transmissions.

Using the described downconverter with the indoor unit described in [2], two small problems were noted. First, one of the harmonics of the local oscillator of the second tunable downconverter (YU3UMV 020 module) may fall in the received satellite band causing an interference. This can hardly be observed receiving Ku band satellites at 11 GHz, but at 4 GHz the harmonics are much stronger. Fortunately the interference can only be observed when the indoor unit is very close to the antenna, during adjustments and experiments. When the distance between the indoor receiver and the antenna exceeds 10 m or when there is a concrete wall in between any interference disappears suggesting that additional shielding of the indoor receiver second tunable downconverter is unnecessary.

Second, the Gorizont FM audio subcarriers have a much wider deviation than most Ku-band TV transmissions and the audio subcarrier demodulator should be modified to avoid distortion. Finally, the Gorizont audio signal is companded and requires an audio expander to obtain a good audio quality.

The 4 GHz band actually offers much less than the 11 GHz band in Europe, yet it is very interesting for the TV DX-er, especially if a larger parabolic antenna is available. Another frequency band has yet to be explored: the segment between 2.5 and 2.69 GHz is also allocated to satellite TV distribution at higher TX power levels. Some satellites are already operating in the 2.6 GHz band, like Insat or Arabsat while other third world nations are planning their own TV broadcast satellites in this frequency band. In particular, the Arabsat satellites carry a 50 W transmitter in the 2.6 GHz band and the antenna footprint includes southern Europe.

[1] M. Vidmar, "A Ku-band Low Noise Downconverter for Satellite TV", VHF Communications 4/86

[2] M. Vidmar, "Satellite Television Receiver Indoor Unit", VHF Communications 1/87

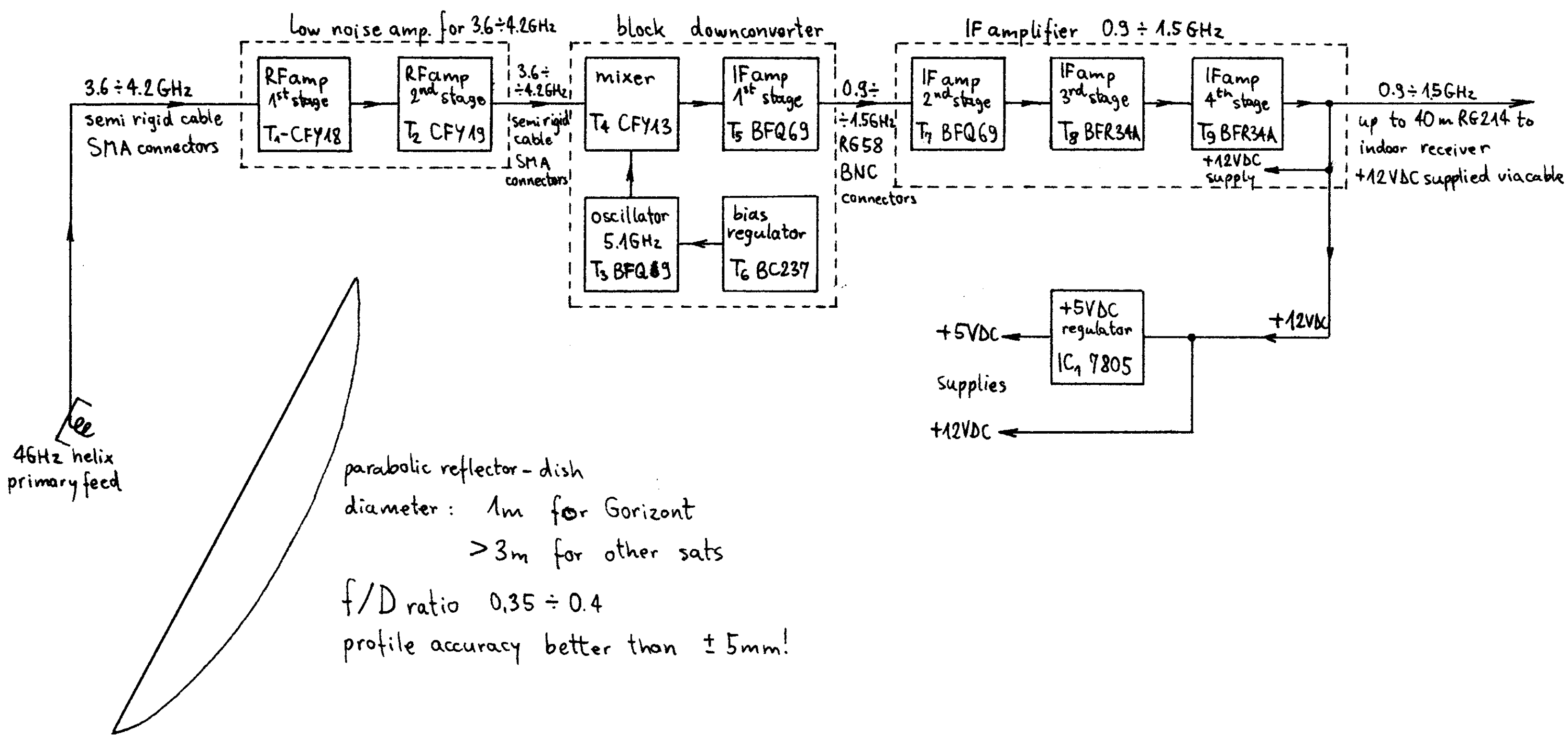

Fig. 1. – Block diagram of the C-band satellite TV receive only station – outdoor units.

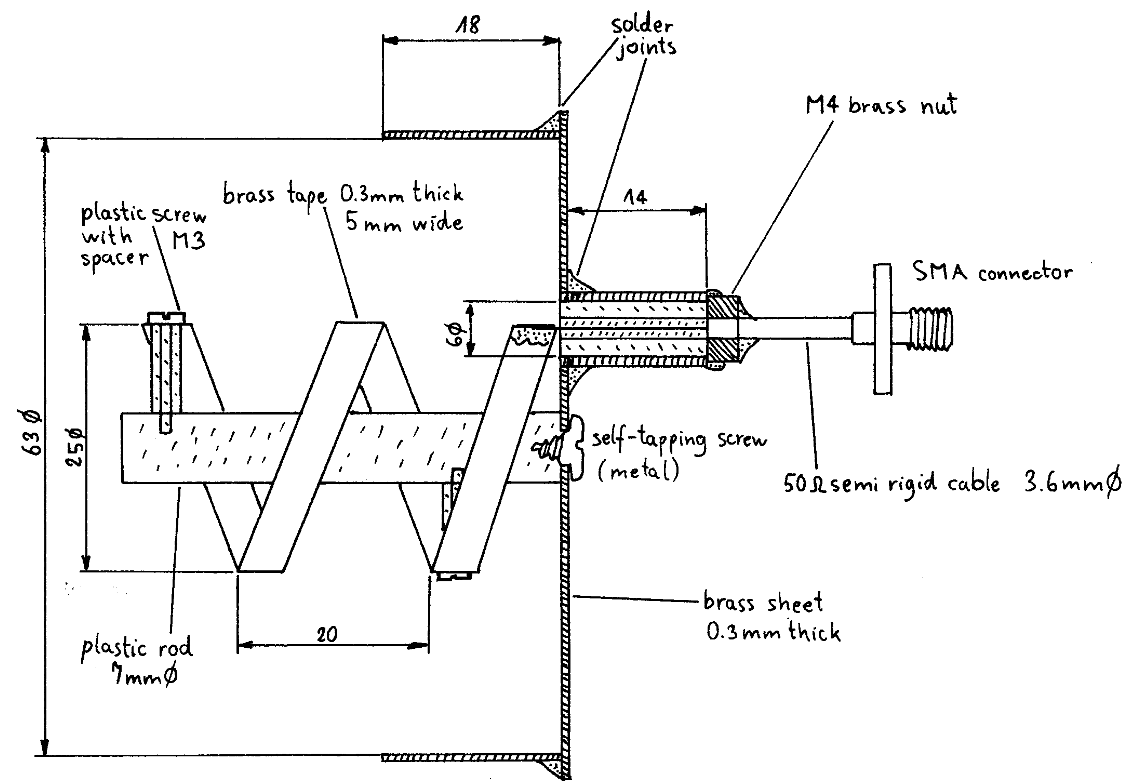

Fig. 2. - 4GHz helix primary feed.

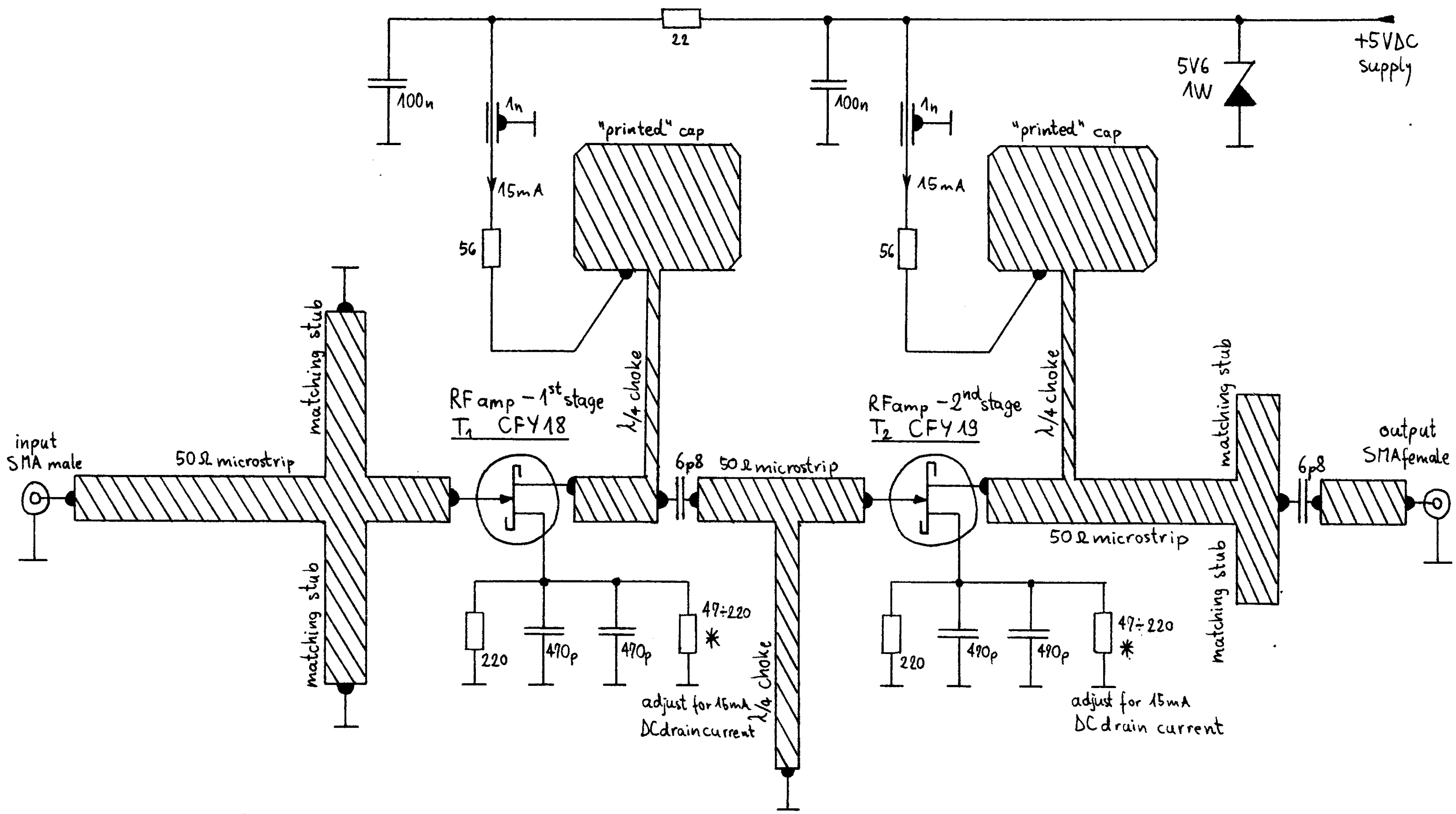

Fig. 3. – Low noise amplifier for 3.6 ÷ 4.2 GHz.

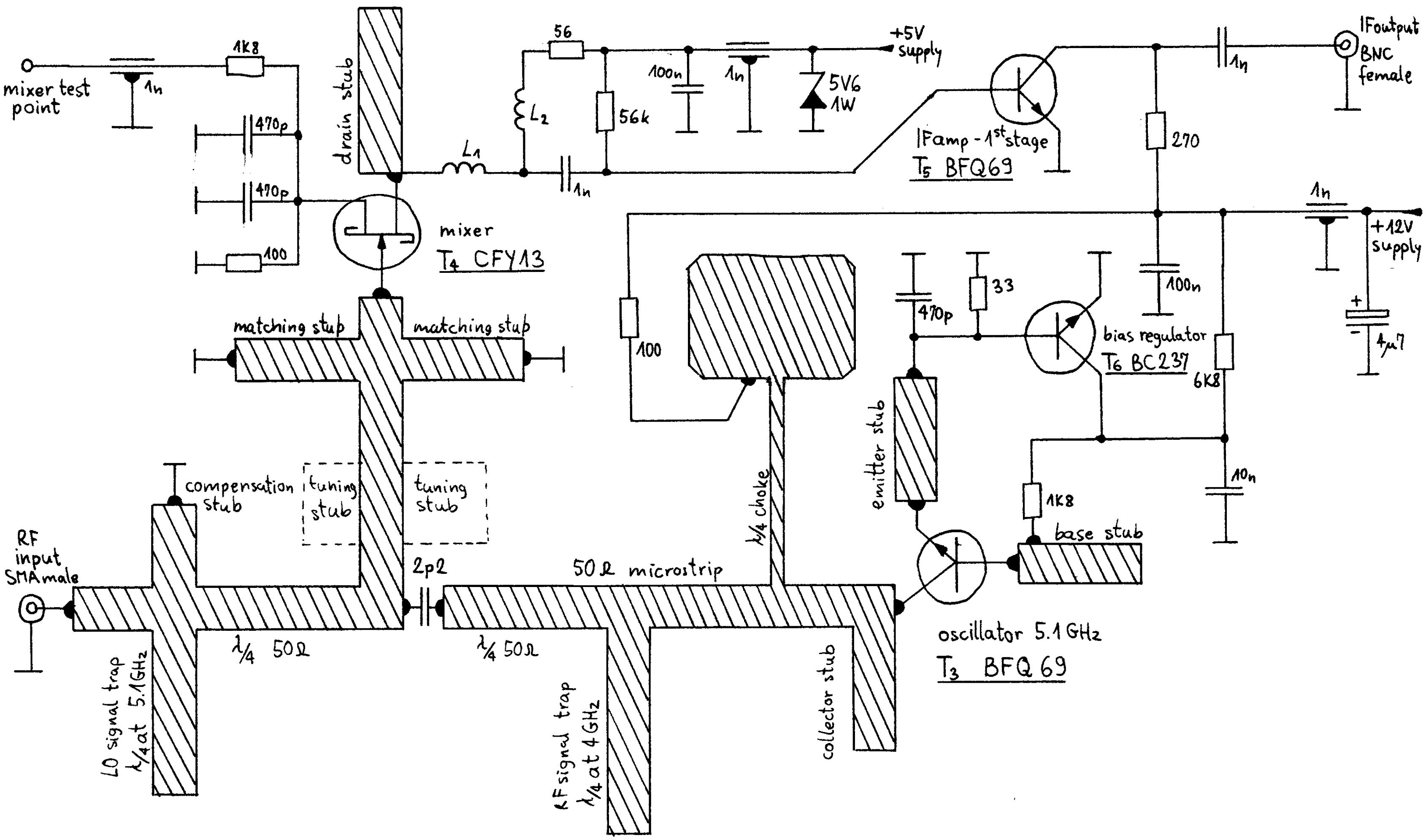

Fig. 4. – Block downconverter 3.6 ÷ 4.2 GHz to Ø.9 ÷ 1.5 GHz.

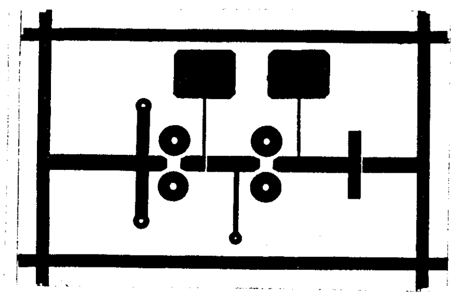

Fig. 5 - Two stage 4 GHz low noise amp PCB.

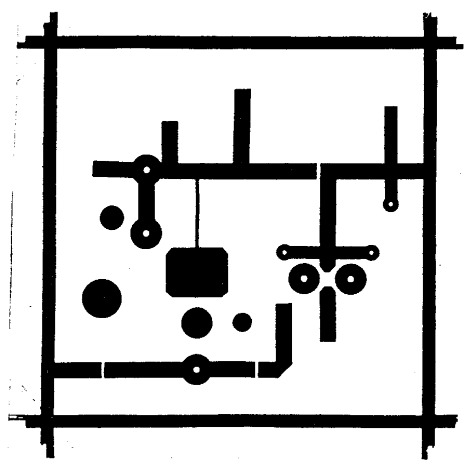

Fig. 6 - 4 GHz downconverter PCB.