23cm VLNA

Very Low Noise Amplifier for 1.3GHz

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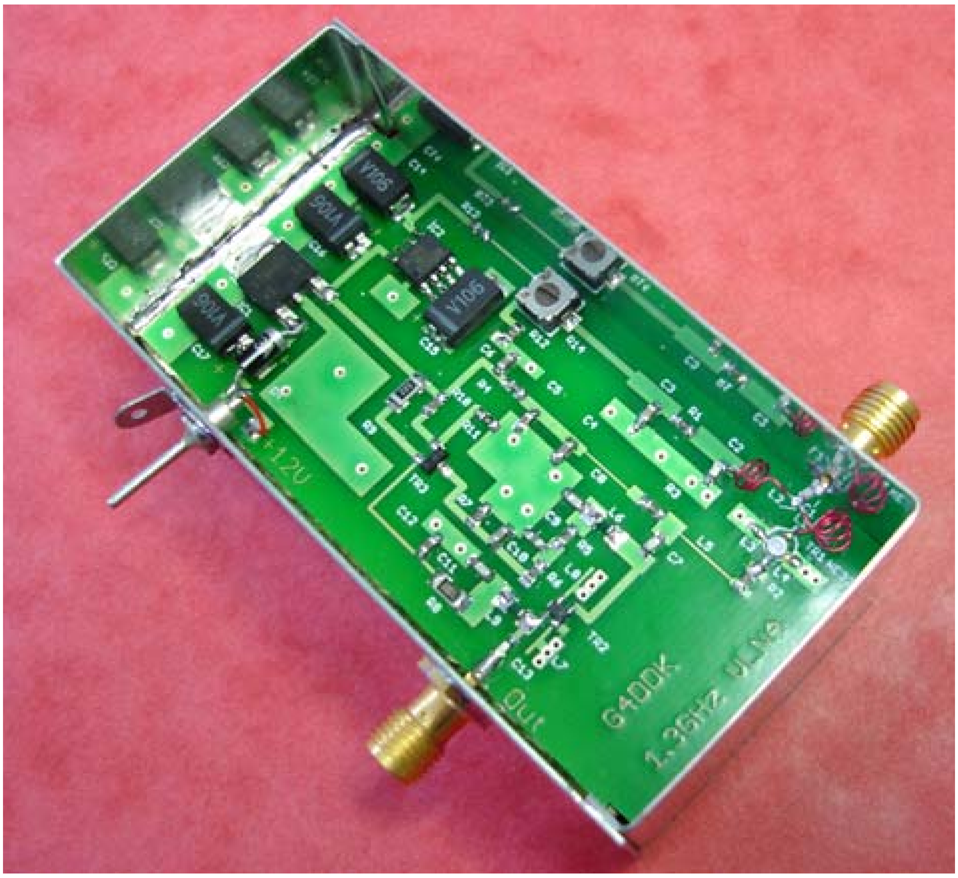

Introduction

One of the most effective 1.3GHz low noise pre-amplifier designs of recent years was designed by Tommy Henderson, WD5AGO. Tommy's design uses an NE32584/86 HEMT followed by an ATF10135 MESFET with ‘air spaced’ input ‘T’ matching to minimize parasitic losses from the substrate that the pre-amplifier is built on. The same technique was also used by W5LUA in his successful 2.3GHz low noise pre-amplifier design [2]. The WD5AGO 23cm pre-amplifier is used extensively by 23cm EME operators around the world.

Last year it became apparent how difficult it was becoming to obtain ATF10135 MESFETS. They had been discontinued for some years prior to this and supplies have been quickly drying up. This caused me to look at an alternative second-stage device. I chose to use the ATF54143 GaAsFET from Avago. As this is a very different device to the 10135, it was found necessary to change the bias arrangement and matching between stages.

WD5AGO's 23cm pre-amplifier achieves between 0.3 and 0.33dB noise figure with about 30dB gain, according to the article [1] and also verified by numerous measurements.

The new 23cm VLNA prototype measured 0.26dB NF with 35dB gain using the 'Martlesham' HP8790A and HP346A noise head. The same pre-amplifier measured 0.25dB/34dB at RAL RT 2007 and 0.26dB/34dB by WW2R. I took one to the CSVHF 2007 meeting where Tommy measured it at 0.25dB NF and 35dB gain. G3LQR regularly measures 0.5dB more sun noise on his 23cm EME system with this pre-amplifier than with his original WD5AGO pre-amp.

The pre-amplifier is best suited to 23cm EME use, as it is rather wide band. It should prove useful across 1 - 2GHz and especially at 1420MHz (Hydrogen line). The ATF36077 is particularly good at 1420MHz, with a slightly lower NF here than at 1.3GHz,although this requires that the input inductor (L1) IS CHANGED TO 2.5 TURNS.

Commercial, silver-plated, plated-through-hole (PTH) PCBs and kits for the 23VLNA are available from the author.

Circuit description

The circuit schematic is shown in Fig 1.

The component list is shown in table 1.

The input circuit consists of a 'T' match with suitable low loss capacitors and inductors. Fig 2 shows the input arrangement. Low noise matching is achieved by slowly adjusting the spacing of the turns of L1. Careful adjustment is critical to achieving lowest NF. Lowest NF will not coincide with maximum gain. Maximum gain will occur at about 1200 - 1240MHz when the NF is lowest at 1296MHz. The strange positioning of the turns of L1 are important and the adjustment is critical.

Input impedance match is improved by the use of source series inductance. This is already designed into the PCB, so you don't need to worry about tuning this parameter.

Except where indicated, 0603 size surface mount components are used on the board in order to minimize component parasitics. This has proven most successful and it is a genuinely good reason to move towards 0603 or even 0402 size parts in all designs above 1GHz.

Negative bias for the NE325 is provided by an 7660 DC-DC inverter IC. R14 allows a range of adjustment, from approximately -0.3 to -0.65V. Tr1 drain voltage (to ground) should be adjusted to approximately +2.3 volts by adjusting R14. The drain current will be around 12 to 13mA. Do not get too hung-up about this value at this stage. After adjusting L1 to lowest noise figure it will be necessary to go back and adjust R14 to give the lowest noise figure. This will be in the range 11 to 14mA. The drain voltage will be 2.6v at 11mA. Stability and noise figure seem to optimise with slightly higher drain volts than might be expected (2.0V). This is normal for this design at L band.

Active bias was chosen for Tr2 as the drain current is set quite high, at 65mA, to achieve a good dynamic range. At this elevated current I felt that active bias would help to maintain circuit performance. This is provided by Tr3, a BC807 PNP transistor .

The whole unit runs from a 5 volt, 500mA regulator IC that uses a surface mount (D-Pak) 78M05 regulator soldered to the PCB ground plane as the heat sink. A TO92 packaged 78L05 will not supply enough current without over-dissipating.

D1 is there to ensure that an accidental reversal of the supply doesn’t destroy the pre-amplifier. The Trucap tantalum capacitors, especially C17, seem to be very sensitive to even small reverse voltages. If you do accidently connect up the supply with reveresed polarity, the preamp should survive, although C17 may need to be changed to ensure longer term reliability. This is probably true for many tantalum capacitor manufacturers.

The RF absorber material IS PART OF THE DESIGN and must be used if the full performance of the pre-amplifier is to be achieved.

Construction

The PCB is designed to fit into a popular 74 x 37 x 30mm tin plate box .

It is advisable to solder the four 10uF Tantalum capacitors and 78M05 voltage regulator to the board before this is soldered into the tinplate box as the capacitors near the 78M05 will be found difficult to solder afterwards. Do watch the polarity of the tantalum capacitors.

Prepare the tinplate box, drilling holes for the SMA RF connectors and the DC feed-through capacitor. The layout is shown in figure 3.

The input connector hole should be 10mm below the top rim of the box. The output connector hole should be level with the pre-amplifier output track. The feedthrough capacitor hole should be 10mm below the rim of the box and on the same box wall as the output connector.

Mark a line 10mm below one rim of the box (a vernier caliper is ideal for this). This is the ground-plane position. Seam-solder the PCB into the box, taking care to ensure it is level and then soldered all the way round including on the component side at the regulator end of the box. It will be necessary to file small cut-outs in two corners of the PCB in order to clear the seam overlaps in the box. These should be in diagonal corners as shown in figure 3.

Use small gauge solder (28swg - nothing larger) and a fine-pointed small soldering iron to solder all the components onto the board. The component layout is shown in figure 4. Regular 22swg solder is GUARANTEED TO MAKE A MESS OF THE BOARD! Suitable solder can be obtained from Rapid Electronics of Colchester as a SMD rework kit. Regular 22SWG solder is probably best used only to assemble the box and for seam soldering the PCB.

The PCB is shown in fig 5.

Solder C1 onto the spill of the input connector. Solder L2 so that one end is on the track pad, as shown, and the other end is soldered carefully to the free end of C1. Solder L1 so that the **bottom** end lead is free to be soldered to Tr1 gate. The spill of the input connector must be cut down so that it protrudes no more than 1mm inside the box.

D1 can be soldered direct between the feedthrough capacitor and the (cathode - bar) PCB land or soldered onto the board in the place indicated, with a wire connection between the diode anode and the feedthrough.

Solder in the two GaAs FETs in after the initial setting up.

Initial Setting up

Connect +12v to +16v to the feed through capacitor. Check the output of IC1 for +5V at its output.

Check that the output of IC2 is -5V

Check that the variable resistor R14 adjusts the output voltage at the free end of L1 down to about -0.7 to -0.3v

If any of these tests fail, check for incorrect component values or bad joints.

Solder the GaAs FETS into place, ensuring correct lead orientation, especially the leads of Tr2. It is best to use a small insulated soldering iron to prevent static damage. Touch the soldering iron to the tin plate box before soldering the GaAs FET leads.

Correct the power supply to the box and adjust R14 so that Tr1 drain voltage is 2.3v. Also check that Tr2 drain voltage is about 3.0V.
With L1 still close-wound, measure the noise figure. Now carefully bend the first two (top) turns up and away from the remaining turns. The turns should be spaced as shown in figure 2. Re-measure the noise figure. It should now be very low. Now CAREFULLY adjust the spacing of these two turns for the lowest NF. Care here will be rewarded. Now go back and adjust R14 to obtain the lowest noise figure. The drain current (as measured as the voltage drop across R2, R3 and R4 in series = 223R) should be in the range 11 to 13mA. This applies to the NE325. The ATF36077 may be slightly different.

RF absorbent material should be stuck to the inside of the lid of the tin plate box. If using the supplied piece of ARC material, remove the protective paper from the rear of the absorber. Stick the absorber towards the end of the lid nearest the amplifier section. Putting the lid in place should not result in any increase in noise figure or loss of gain. This stuff is MAGIC!

The magnetic field absorber material supplied with the kit has been carefully selected to ensure stability.

Results

These should already speak for themselves. The input third order for the NE325 version is about -8dBm. Whilst this is not outstanding, the gain of the pre-amplifier will degrade the overall dynamic range of the pre-amplifier and transceiver or transverter combination. Careful attention to system gain distribution will allow you to achieve a very sensitive receiver with a useful dynamic range when used with, e.g. a TS2000X or LT23S.

Where strong out-of-band signals are a problem, the very low noise figure of the pre-amplifier will allow the use of a low-loss inter-digital filter in the antenna lead, without increasing overall system noise figure too significantly.

Caveat Emptor

Very low noise figures are notoriously difficult to measure with any accuracy. No specific noise figure is claimed for this pre-amplifier. I have quoted the numbers measured at different VHF/Microwave events and with different noise figure measuring equipments and operators. Since the pre-amplifier is offered as a kit, the noise figure and gain achieved will depend on the individual constructor's ability with the soldering iron and patience in setting up the pre-amplifier.

The pre-amplifier can be operated without a lid and the stability will be good. However, without the high quality commercial magnetic field absorber material inside the tin plate box lid, putting this in place is guaranteed to degrade performance. Foam absorber, such as 'CMOS' foam, will not work very well in this application. Please use the right material. It is as much a part of the design as the FETs used!

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For the printed version............................

Updates and further construction details are published on my web page at www.g4ddk.com
Follow the links from Technical Content.

Update

Since designing this pre-amplifier I have become aware that the NE32584 has also been made obsolete. However, there are plenty of these devices still available on the surplus market. However, even these will become harder to find in the future. For this reason I have investigated alternative devices to be used in the pre-amplifier. The Avago ATF36077 works well in this circuit, although noise figure will be very slightly worse than with the NE32584/86 at 1296MHz. For terrestrial use the difference will not be noticeable.

For those who are able to source their own NE325 devices, the kit is offered without Tr1. If you need an active device then the ATF36077 can be supplied at extra cost.

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schematic

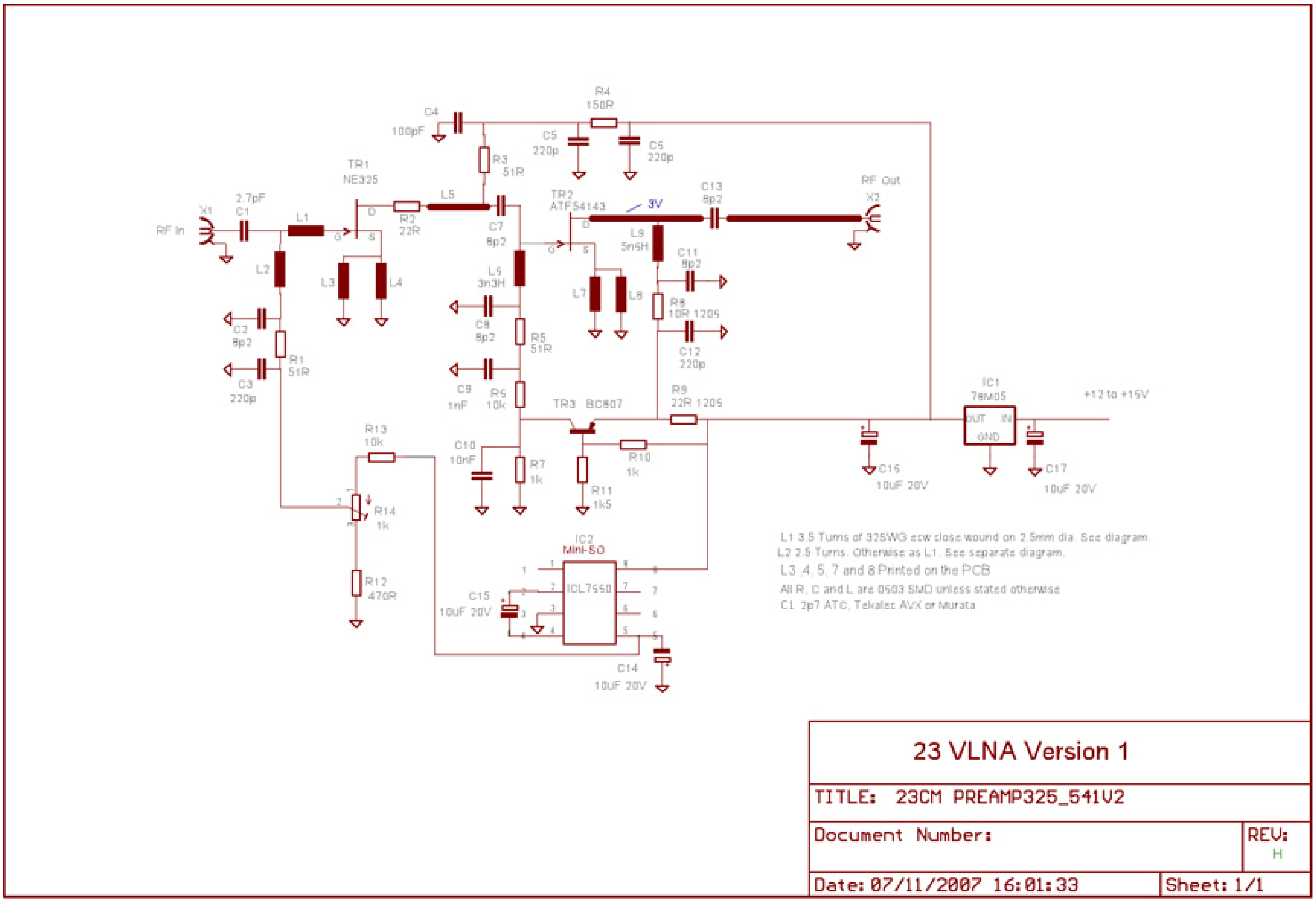

Figure 1 Schematic of the 23cm VLNA

Updated schematic as of 7 November 2007

Note, R15 is not shown on the schematic. It was an alternative value resistor for R13, as explained in the text.
as from Kit 281 R15 will not be provided and R13 will continue to be 10k. However, R4 will be changed to 150R (as now shown above) to allow a
slightly lower Vds at 11 - 14mA Id.

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Component list

23VNLAV1 Parts list

Device		Package	Description
C1	2p7 ATC,Tek or AVX	C-EUC0603	CAPACITOR,
C2	8p2	C-EUC0603	CAPACITOR,
C3	220p	C-EUC0603	CAPACITOR,
C4	100pF ATC	C-EUC0603	CAPACITOR,
C5	220p	C-EUC0603	CAPACITOR,
C6	220p	C-EUC0603	CAPACITOR,
C7	8p2	C-EUC0603	CAPACITOR,
C8	8p2	C-EUC0603	CAPACITOR,
C9	1nF	C-EUC0603	CAPACITOR,
C10	10nF	C-EUC0603	CAPACITOR,
C11	8p2	C-EUC0603	CAPACITOR,
C12	220p	C-EUC0603	CAPACITOR,
C13	8p2	C-EUC0603	CAPACITOR,
C14	10uF 20V	CPOL-EU139CLL-2R	Tantalum CAPACITOR,
C15	10uF 20V	CPOL-EU139CLL-2R	Tantalum CAPACITOR,
C16	10uF 20V	CPOL-EU139CLL-2R	Tantalum CAPACITOR,
C17	10uF 20V	CPOL-EU139CLL-2R	Tantalum CAPACITOR,
R1	51R	R-EU_R0603	RESISTOR,
R2	22R	R-EU_R0603	RESISTOR,
R3	**51R**	R-EU_R0603	RESISTOR, **Value correction.**
R4	100R	R-EU_R0603	RESISTOR,
R5	51R	R-EU_R0603	RESISTOR,
R6	10k	R-EU_R0603	RESISTOR,
R7	1k	R-EU_R0603	RESISTOR,
R8	10R	R-EU_R0603	RESISTOR,
R9	22R	R-EU_R1206	RESISTOR,
R10	1k	R-EU_R1206	RESISTOR,
R11	1k5	R-EU_R0603	RESISTOR,
R12	470R	R-EU_R0603	RESISTOR,
R13	10k	R-EU_R0603	RESISTOR,
R14	1k	R-TRIMM4G/J	Trim resistor
R15	4k7	R-EU_R0603	RESISTOR,

L1 3.5 Turns of (32SWG) ecw 1 close wound on 2.5mm dia. self supporting. See diagram.
L2 2.5 Turns. Otherwise as L1. See separate diagram.
L3/4 Printed on PCB
L5 Printed on PCB
L6 3n3 SMD 0603 Inductor
L7/8 Printed on PCB

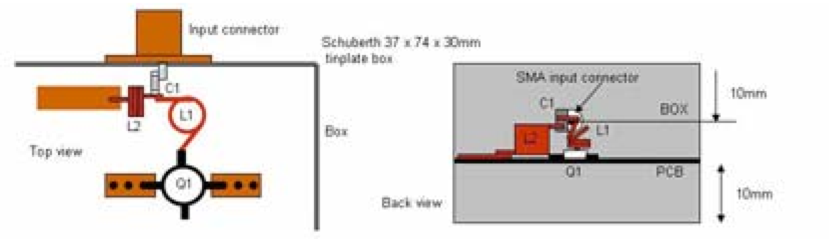
L9 5n6 SMD 0603 Inductor

Tr1 NE32584/86 or ATF 36077 NE325 Widely available, but no longer listed by NEC
Tr2 ATF54143 SOT343 Avago Enhancement mode Pseudomorphic HEMT
Tr3 BC807 SOT23 PNP bipolar

IC1	78M05	D-PAK	Voltage regulator
IC2	ICL7660	SOIC8	Voltage inverter
D1	1N4001	Leaded diode or SMD	

37 X 74 X 30mm tin plate box		Schuberth.
Magnetic field absorbent material		ARC
Feedthrough capacitor		1000 – 2200pF solder-in
PCB	23VLNAV1	34.5 X 72 1.6mm RF4 1oz Cu

X1 CONNECTOR	BU-SMA-G	BU-SMA-G	FEMALE SMA
X2	BU-SMA-G	BU-SMA-G	FEMALE SMA CONNECTOR



Input circuit arrangement

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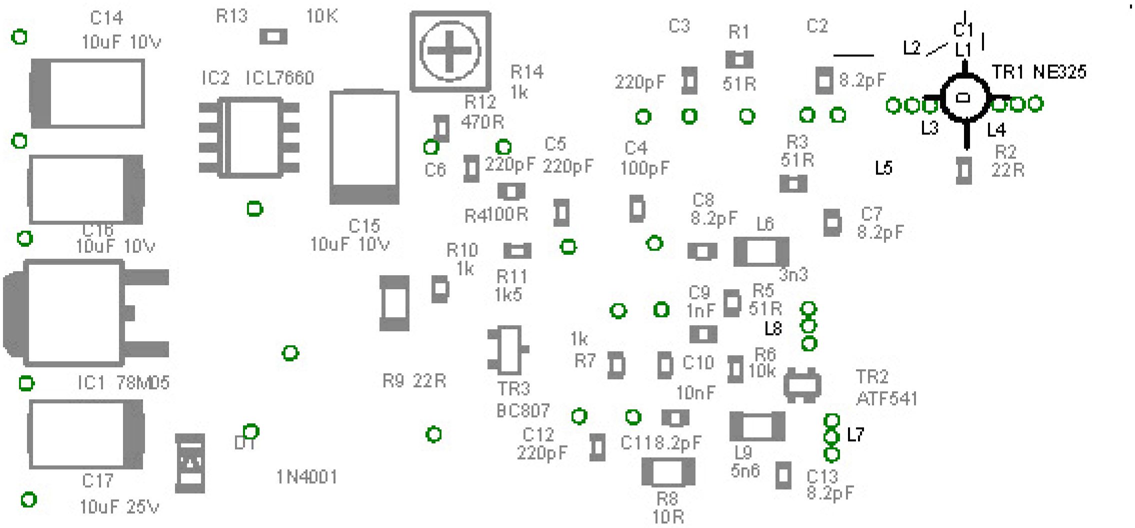
box layout



PCB

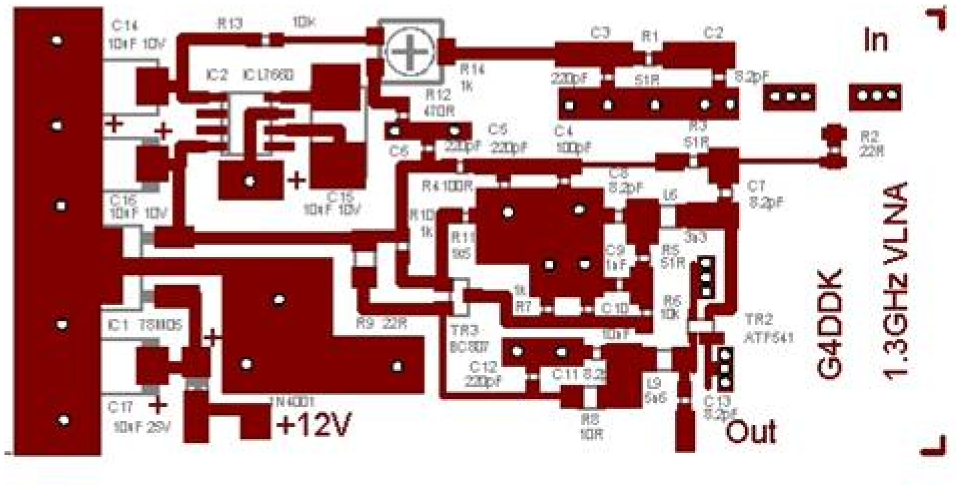


Fig 5. PCB layout for the 23cm VLNA