Modern High-performance Narrowband Equipment for 10GHz

Part 3 The G3WDG-003 Transmit Converter

Designed by

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Introduction

Over the past few years there has been a trend away from traditional waveguide techniques for amateur narrowband equipment at 10GHz. Equipment using GaAs FETs in microstrip circuits offers higher power levels, better receiver performance and is arguably easier to build. Construction techniques follow lower frequency practice rather than "plumbing", although care and attention to detail are still required if good results are to be obtained.

A number of GaAs FET-based designs for 10GHz have appeared in amateur literature, for example [1]. These have tended to use relatively expensive GaAs FETs and the cost of construction has been too high for many amateurs. Recently a large quantity of GaAs FETs have become available on the UK surplus market at a fraction of the cost of "new" devices. The GaAs FETs in question were manufactured by the Plessey 3-5 Group for use in 11GHz satellite TV LNBs and have excellent performance. The low cost of these led the author to develop a number of new designs for 10GHz.

The designs are intended for home construction without the need for either difficult construction methods or elaborate test equipment. They have all been duplicated with relatively little difficulty by a number of independent constructors. Wherever possible, low cost components have been identified and designed-in, but in some cases it has been necessary to use more expensive components. The specified parts MUST be used throughout or the hard work put in by the designers to make the designs reproducible will have been wasted! All the special components, with the exception of the GaAs FETs, are available from the Microwave Committee Components Service. Problems were encountered during the design-proving phase when some constructors had not used the correct grade of GaAs FETs in some locations. The different surplus GaAs FETs available are NOT interchangeable!

Like the modules described in Parts 1 and 2, this module also requires a drive input of approximately 5-10mW in the 2.5 to 2.6GHz region. The exact frequency of the drive depends on the particular application. A suitable oscillator/multiplier, the G4DDK-004 design [2] has already been described, giving the required level of output in this range, and PCBs for that design are available through the Microwave Committee Components Service (G4DDK PCB 004). Subsequent to the original article, a number of minor modifications were made to some of the circuit values [3] which raised the output to 10mW or more, sufficient to drive the present designs. The modifications have been incorporated into the PCBs currently available (Issue B).

The three designs are:

1. A x4 multiplier/amplifier chain (G3WDG-001) which can provide 50 to 100mW output anywhere in the 10 - 10.5GHz band. It can be used as the basis of a simple CW/FM narrowband transmitter, a beacon or personal signal source, as an ATV transmitter or as a packet radio link transmitter. This was described in Part 1.

2. A down-converter (receiver), G3WDG-002, to 144 - 146MHz incorporating a x4 multiplier chain to generate the local oscillator signal, a dual-diode mixer and two stages of low-noise pre-amplification before the mixer. The design also incorporates a low-noise post-mixer amplifier at the intermediate frequency. The front-end noise figure of several prototypes has been measured at less than 3dB . It is possible to improve this figure by using an external pre-amplifier.

3. The present design, a linear up-converter (transmitter), G3WDG-003, from 144 -146MHz to any 2MHz segment in the 10GHz band. It incorporates a x4 multiplier chain, a GaAs FET mixer and four amplifier stages to reach an output power of at least 50mW. A further power amplifier stage is under development using a Mitsubishi power GaAs FET and the prototype is giving over 200mW output.

By providing the 002 and 003 modules with a common 2.556GHz local oscillator source and suitable transmit/receive changeover arrangement, the result is a complete "state-of-the-art" linear transverter.

It is a good idea, for those not yet skilled in the art of microwave PCB construction, to work through these module designs in the order described since this represents a steady progression from a relatively simple to quite a complex design. If you can successfully build and align the G3WDG-001 design, then you are well on the way to building your own state-of-the-art high performance receive converter or linear transverter at a fraction of the cost of comparable commercial equipment.

General circuit features and components.

All three designs are built on ptfe-glass board and, in the main, surface-mount "chip" devices (SMDs) are used, although some more familiar "ordinary" components are also used. The "heart" of the units is the widespread use of GaAs FETs as active multipliers, amplifiers and, where required, as mixers. Microstrip circuitry is used to provide the correct operating impedances for the GaAs FETs and the circuits have been designed to cover the whole of the 10GHz band from 10.0 to 10.5GHz. A reliable method for grounding the source leads of the GaAs FETs was developed to ensure that the designs would be reproducible. Earlier attempts using copper foil "wrap-arounds" failed because the inductance of such connections was too variable.

Where high selectivity is required, to discriminate between harmonics or to reject image frequencies, this is provided by the use of small "pill-box" tuned cavity resonators soldered to the board. Coupling from the microstrip lines into and out of the resonators is accomplished by the use of probes. This technique has been common in German amateur microwave designs for some time, for example [4], and avoids the use of critically dimensioned and spaced printed microstrip filters which are almost impossible to make with enough accuracy. It will be noted that a high drive oscillator frequency has been chosen (around 2.5GHz), also in order to minimise the stringency of filtering. The drive source chosen gives output at the required level, with all unwanted products at least -40dBc or better: this minimises the filtering requirement at the final signal frequency and makes the use of single, simple cavity resonators possible wherever such selectivity is needed.

Similar principles have been adopted for all three designs, each GaAs FET amplifier stage providing a gain of about 10dB. Matched input and output circuits are realised by the use of microstrip lines. Rather than attempt to etch very narrow (high impedance) microstrip lines, where these are necessary, easier construction results from the use of short lengths of thin wire soldered to the lines and pads on the surface of the board.

It is recommended that the PCBs available from the Microwave Committee's Components Service be used for these designs. Both the board material and the dimensions of the microstrip lines are critical to the success of this type of circuit. The other critical components, such as the ceramic chip capacitors, resistors and the resonators, are also available. Virtually all the other components are available from easily accessible amateur sources.

ONLY the recommended components should be used and only first-grade KNOWN components employed - substitution from the "junk-box" or components "salvaged" from other microwave equipment is just not acceptable!

It is strongly recommended that, whichever module is to be constructed, the PCB is installed in a tin-plate box or an alternative, specially made sheet-metal (brass or copper) enclosure of similar size and form. By so-doing, not only is the somewhat flexible board housed rigidly, but is also well screened and thermally insulated to some degree. The finished, boxed unit(s) should be housed in a rigid outer case to provide mechanical and thermal stability - the "boxes within boxes" approach which has been advocated for high performance microwave equipment, almost regardless of frequency.

The use of other than SMA connectors for input and output is not recommended. The 12V power supply (or any other ingoing supplies) should be well decoupled by 1nF to 10nF solder-in feedthrough capacitors or Filtercons. The power supplies must be stabilised to the voltages given in the circuit diagrams: if these voltages are exceeded, or the gate bias voltage fails, the GaAs FETs can be damaged, if not instantaneously destroyed. By incorporating resistors in the drain circuits a degree of current -limiting protection is afforded. Nevertheless, it is well worth spending time on this aspect of the circuits, using only generously rated and reliable components in the bias circuits.

Care and attention to detail is essential AND your soldering techniques must be good! Components should be mounted in the order given and the GaAs FET devices should always be the last components to be soldered into place, taking the usual precaution of grounding together the constructor, the body of the soldering iron and the case/groundplane of the PCB whilst soldering them in place. In this way the risk of damage by static discharge is minimised or eliminated.

The G3WDG-003 transmit converter: circuit description and operation.

The circuit is shown in Fig. 1, the layout of the board and components in Fig. 2 and their values in Table 1.

Referring to the circuit diagram of the G3WDG003 transmit converter, Fig. 1, the 2556MHz LO signal is fed to a MMIC amplifier IC1 which provides about 5.5dB gain. The output from this goes into a printed Wilkinson divider, which splits the signal into two, well isolated, outputs. One output is connected to J2, which is intended to provide the LO signal for the G3WDG002 receive converter. The gain from J1 to J2 is about 2.5dB, allowing proper operation of the unit with LO

powers in the range 5-15mW. The input circuit to the MMIC is modified from that used in the G3WDG001, in that a 1pF shunt capacitor has been added. This improves the input VSWR from about 5:1 to less than 1.5, and is a useful modification for existing G3WDG001 units (decreases 2.5GHz drive requirement by about 2.5dB and stops resonant cable length effects).
The other output from the Wilkinson is fed to the x4 multiplier stage F1, via a matching network L2/L3. The multiplier is identical to that used in the G3WDG001 and 002 modules, and details may be found in the booklets for these modules.
The 10224MHz output from FL1 is fed to the gate of F2 together with the 144MHz signal from J3 via C9/L6. F2 acts as an upconverter, and is provided with both variable gate bias (VR2) and drain bias (VR3) to optimise the conversion efficiency. These adjustments interact to some extent (see below). The output from F2 contains three main signals, the LO at 10224MHz, the wanted 10368MHz signal and the image at 10080. FL2 selects the wanted output.
The remaining circuitry is a four stage amplifier containing further bandpass filtering (FL3 and FL4) to clean up the output signal. The value of the drain resistor R14 is optional, 47 or 10 ohms. The use of 10 ohms may increase power output by a small amount in some cases.
The board layout is shown in Fig. 2. Note that C12, the negative rail decoupling capacitor, is not shown as it is fitted on the reverse side of the board.

The negative bias generator used to supply the gate bias for the FETs uses the same PCB as that used in the G3WDG-001 module (G4FRE-023). The circuit is shown in Fig.3 and the board layout in Fig. 4.

Construction of the G3WDG-003 transmit converter.

It is strongly recommended that the following procedures are followed in detail, and in the order described for both this and the subsequent design:-

1. Fit grounding PCB pins and filter locating pins (see later) and solder in place.

2. Solder the filters into position. Leave the tuning screws and lock nuts in position to avoid unwanted debris accidentally falling into the cavities.

3. Locate the PCB into its box and trim to a neat fit if needed, particularly in the corners of the box where there are joints. The PCB material will cut quite easily with a sharp scalpel blade and straight-edge. Locate the groundplane 17mm from the top of the open box and mark its position. Locate and mark the SMA socket centre-pin clearance holes. Drill the holes and de-burr. Locate, drill and de-burr holes for any feedthrough components needed for power supplies. Tack-solder the corner seams of the box and make sure that the lids are a neat fit. Adjust as necessary. Check also that the board will fit neatly. When satisfied, solder the corner seams fully. Solder the SMA connectors and the feedthroughs in position.

4. Relocate the PCB so that the input and output tracks touch their respective socket spills, tack-solder the PCB in place and, when satisfied that it is correctly located, solder all round the groundplane and solder the SMA socket spills to their respective tracks. This completes the mechanical construction of the module.

5. Fit wire inductors as specified in the parts list (Table 1), into position, ensuring that the wires lie flat to the board.

6. Fit all chip components using the mounting techniques described later. You will need a pair of fine-pointed tweezers to handle these small devices and, maybe, the assistance of a magnifier!

7. Fit all components which have leads, ensuring that static-sensitive devices (IC, FETs) are put on the board last of all to minimise the risk of damage to the devices.

Note:- It is best to apply the supply voltage to the board BEFORE fitting the FETs, to check that both the +8V and -2.5V voltages are present and correct on the respective tracks/pins. On completion of this test, disconnect power and solder in the devices only if everything checks out correctly.

Individual "build" techniques.

1. PCB-pin grounds.

Place the PCB-pins in the holes with the pin heads on the track side and the body of the pins sticking up through the groundplane, with the exception of the twelve filter-locating pins (see below). Place the head of a pin on something hard and flat and press the board until the head butts up against the track side of the board.

Solder by starting with the iron at the top of the pin; tin the pin generously and, while applying more solder to the joint, flow the solder down the pin and onto the groundplane to ensure good pin to groundplane contact with no dry joints. Trim the pin back using flush-cut cutters. Repeat until all grounding pins are fitted. Do not solder the heads of the ground pins on the track side, as this makes fitting the chip components more difficult later on.

2. Fitting the filters

This is potentially the most difficult soldering operation on the board! Details of the cavities are given in Fig. 5(a), together with the dimensions of the coupling probe pins. First prepare the PCB by fitting the twelve PCB-pins which mark the filter cavity positions. These pins are fitted from the groundplane side through to the track side. Solder the pins to the pads provided on the track side and cut off excess pin length after soldering. Do not solder the pins to the ground plane side. The board is now ready to take the cavity filters.

Pre-heat each cavity in turn, with its tuning screw and locknut assembly in position. Heat it by placing on a hot plate (eg. a 3 to 6mm thick sheet of aluminium placed over a gas ring) and heat until 60/40 tin/lead solder melts very easily on touching it to the cavity wall near the base (open end). Quickly transfer the hot cavity, using pliers to grasp the tuning screw, to the board, position it between the three guide-pin heads on the groundplane side of the board and apply fine (22 SWG or finer) solder at the junction of the board and filter to fix the cavity in place. Ensure the cavity does not jump outside the guide pins whilst soldering, ensure a continuous small fillet of solder all round the cavity, but do not apply too much solder. Allow the cavity to cool without disturbing it. When it has cooled fully, fit the PCB-pins which probe through the board and into the cavity, having pre-cut them to the length shown in Fig. 5(a). Note that the lengths are significantly different for the LO and signal filters: make sure you fit the right pins in the right places! Some constructors prefer to use silver loaded solder for this operation and for fitting the chip components as it makes the soldering easier and cleaner. Suitable solder is available from Blue Rose Electronics. (See Appendix 2 for address).

3. Inductors

For inductors using enamel covered wire (ECW), cut the required length of wire then scrape/chip the enamel from the last 1-2mm of each end using a scalpel blade. Tin each end.

For inductors using one strand of a standard multi-strand wire, tin one end and fit to the board as shown in Fig. 5(c): solder first at position 1, then at position 2 as close as possible to the apex of the triangle, then at position 3. If any excess wire remains at 1 or 3, trim off carefully with a scalpel blade.

4. Chip components

To fit chip components across two circuit tracks or pads, adopt the following procedure for best results: (see Fig. 6)

a. Lightly tin one of the tracks or pads. b. Fit component and reflow solder to make a solder fillet at the tinned side - the tip of the tweezers may be used to hold the chip in position whilst the solder solidifies. Use as little solder as possible to form a very small fillet. c. The component should now be secure: tin the other track and make a solder fillet on the second side of the chip component to complete the mounting. d. Resolder the first joint if required, using a little fresh solder.

As an alternative to using tweezers, a simple spring loaded clamp as shown in Fig 8 may be used to advantage.

This procedure ensures that the components are flat to the board, good contact is made and the best circuit performance is achieved.

5. Static-sensitive components

Components such as ICs and FETs should always be fitted last to minimise the risk of static damage. The GaAs FETs have the gate lead bevelled for identification, as shown in Fig. 5(b). Grounding of the two FET source leads is via PCB-pin ground "pads " fitted as shown in Fig. 7. Cut the source leads to minimum length, but note that before handling static-sensitive devices, you should make sure that you and the handling implements (eg. tweezers) are grounded together: it is often a good idea to work on a grounded sheet of aluminium foil spread on the work surface, resting the wrists on the foil, with the board and implements also on the foil when not in use. You may find, if using surplus GaAs FETs, that one source lead is already trimmed short. Cut the other to a similar length so that no more than half of the heads of the Veropins are covered by the leads.Lightly tin one of the source grounding pins, and hold the device in position using tweezers or the clamp shown in Fig. 8. Make sure the FET is the right way round! Next, tack the device in position by reflowing the solder on the tinned grounding pin, making sure the device is flat on the pins and not sitting up on a bump of solder. It is best for this operation to apply the iron to the side of the pin head and not to the lead of the GaAs FET (this is why the leads are trimmed short), to minimise the chance of a dry joint. Using the same technique, solder the other FET source applying fresh solder to the point where the cut end of the lead touches the top of the veropin, not to the iron. Then go back and remake the first joint using a little fresh solder. The use of the Blue Rose 26swg silver loaded solder is highly recommended for this operation. (Dry source joints were a problem in one of the early prototypes resulting in only 8mW output power from the unit, so it is worth taking care at this stage!). Finally, bend the gate and drain leads down to the board as close to the body of the FET as possible (Fig 7c) and solder to the tracks. Make sure that the solder fillet starts at the point where the lead touches the track, to prevent any unwanted lead inductance.

Alignment with simple test-gear

Once completed, the PCB should be carefully examined for poor joints, accidental solder bridges and other forms of short circuit. Once satisfied that all is well, the alignment procedure may begin. You should already have checked before mounting the FETs and other semiconductors that the correct supply voltages will appear on the positive and negative supply rails when a 12V supply is connected to the input feedthrough capacitor.

The recommended way of tuning up the module without resorting to laboratory test equipment is to align a given stage while monitoring the drain current of the following stage, which acts as a power indicator. The gate bias of the monitor FET should be set to give a drain current in that FET of approximately 1mA. The procedure is to make temporary connections to the drain resistor of the following stage using thin flexible wires, which are then connected to an analogue multimeter. Digital multimeters are much more difficult to read and should be used as a last resort! For example, when optimising the setting of VR1 and FL1 while aligning the multiplier stage, the multimeter is connected across R6 and VR2 is set to give a drain current of 1mA in F2. Adjustments are then made to R6 and FL1 for maximum current. In some cases the increase in current may be small and the adjustments need to be made carefully, especially the tuning screws.

It helps if all tuning screws are preset to approximately the right penetration, ie with 7.5mm of thread below the bottom of the locknut. When adjusting the tuning screws, particularly FL2-4, the locknut should be kept reasonably tight with a spanner while turning the screw with a screwdriver (like setting tappets!), or the filter loss may be very high. The final tuning may be done using the locknut tightness as a fine adjustment, but take care that the correct tuning point is with the locknut quite tight, or again the filter loss may be higher than normal. After the unit is tuned up, it may be necessary to cut the heads off the tuning screws to fit the bottom lid. The easiest way to do this is to remove the screws one at time, cut off the excess thread and head, make a slot in the top for screwdriver adjustment, refit and then tune up. (It is possible of course to precut the screws before tuning up, but constructors have found it easier in the initial stages to have a proper screw head.)

1. Connect a 50 ohm load or >10dB attenuator to J2, and a 10GHz power indicator to J4 (eg coax-waveguide transition and waveguide diode detector).
2. Set the gate bias on all stages to cause all FETs to be pinched off (zero drain current).
3. Set gate bias of multiplier to 1mA using VR1.
4. Apply 2.5GHz drive to J1 (5mW minimum). The drain current of F1 should increase.
5. Using F2 as a power meter as described above, adjust FL1 and then optimise VR1.
6. Temporarily remove 2.5GHz drive and DC power, and transfer the test leads to R8. Set VR3 to its centre position and after restoring DC power set the current through Q2 to 0.5mA with VR2.

Reconnect 2.5GHz drive and apply 1mW of 144MHz to J3. The mixer current should increase incrementally on application of the drive signals. Next, using F3 as the power indicator, adjust FL2. This is the most difficult stage in the alignment, as there are three peaks as the filter resonates to 10080, 10224 and 10368MHz. Finding the correct one may take a little time. The correct setting is with the tuning screw at the smallest penetration, and the power should disappear when 144 drive is removed. If the 10080 peak is selected by mistake, it is possible to carry on with the alignment and all will appear normal except that no-one will hear you (unless their 002 is on the wrong image!)

7. Next, optimise VR2 and VR3 for maximum power. The adjustments interact, so its necessary to loop until the best combination is found.

8. The same procedure should be followed to align the rest of the stages. Before starting optimisation, drain currents of the amplifier stages should be set to 15mA. After optimisation the current can be at whatever value resulted, with no risk of damage to the device. Finally, some power should be seen at the output, and a wavemeter should be used to confirm that the output is on 10368MHz as desired.

9. The final stage in the alignment is to go around all the adjustments again for maximum output power at J4. In case the unit is into significant compression with 1mW 144MHz drive, adjustments will be easier if the 144MHz drive power is reduced. Prototype power outputs have been greater than 50mW, but it may be possible to achieve more by tuning the microstrip lines with small pieces of copper or brass foil. Areas to try first are around F6 and the line between F2 and Fl2. Remove DC power before soldering the foil in position.

10. Check the level of output from J2. This should be 2-2.5dB higher than the drive power applied (below 10mW). At higher drive powers, IC1 will go into compression but this does not matter as plenty of drive will be available for the receive converter.

11. The performance should then be checked with the lids on. None of the prototypes built with the specified components have oscillated with properly fitting lids, the only effects seen being a small increase in the level of the 10080MHz and 10224MHz image and LO signals, and a small drop in output power (about 1dB). These effects should cause no problems in most applications. It is possible to maintain "lid-off" performance, however, by fitting a piece of lossy rubber (2 x 1" piece) to the lid enclosing the track side of the pcb. This is fitted in the centre of the lid, long dimension parallel to long dimension. A thin smear of "Evostick" forms a very good adhesive. Suitable lossy rubber is available from the Microwave Committee Components Service. The only case of instability with the lid on encountered during the development of the G3WDG003 unit was with one prototype which used copper tuning screws, instead of the silver plated brass ones supplied. (Copper tuning screws result in about 1dB lower filter loss, which increased the gain of the amplifier chain). This unit was made stable by fitting a piece of lossy rubber to the lid as described above, and reducing the gain of the F4 stage by inreasing the negative gate bias slightly. This reduced the gain of the amplifier chain sufficiently to stop the oscillation, at no expense of output power (the 144MHz drive level was increased to compensate).

DC operating conditions

	NO SIGNAL			SIGNAL			
FET	Vg	Vd	Id	Vg	Vd	Id	NOTE
1	-1.6	7.45	1.6	-1.7	3.7	16	
2	-1.9	7.0	0.3	-1.9	1.3	15	2.5GHz only
2	-1.9	7.0	0.3	-1.9	6.9	0.4	144MHz only (-4dBm)
2	-1.9	7.0	0.3	-1.9	1.3	0.4	both applied
3	-0.7	7.3	12.5	-0.7	7.3	12.5	
4	-0.4	6.6	27.0	-0.4	6.6	27.0	
5	-0.4	6.2	36.0	-0.4	6.2	36.0	
6	-0.4	7.35	54.0	-0.4	7.35	54.0	10R drain resistor

NOTES

1.Vg = gate voltage, Vd = drain voltage, Id = drain current (mA)
2. Values were taken from one prototype, and will differ (possibly significantly) from unit to unit, and should be taken as a rough guide only.

Summary

The G3WDG003 is the final module needed to complete a high-performance 10GHz amateur band transverter. When combined with a 144MHz transceiver, 10GHz antenna and a suitable changeover relay, the system is capable of outstanding performance. However, even better results may be obtained by adding a HEMT preamplifier and power GaAsFET PA. Suitable modules are currently under development.

References

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[2] "An oscillator/multiplier chain for the frequency range 2.0 to 2.6GHz", S.T.Jewell, G4DDK. Radio Communication, August 1990, RSGB

[3] "An update on the G4DDK-004 board", S.T.Jewell, G4DDK. Microwave Newsletter, 08/89 (February 1990). RSGB

[4] "10GHz transverter module - portable", J. Dahms, DC0DA, Belgian VHF/UHF Convention, November, 1988.

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Typeset

G3PFR and R.Mudhar (SWL).

Graphics

G4DDK, G4FRE and G3PFR

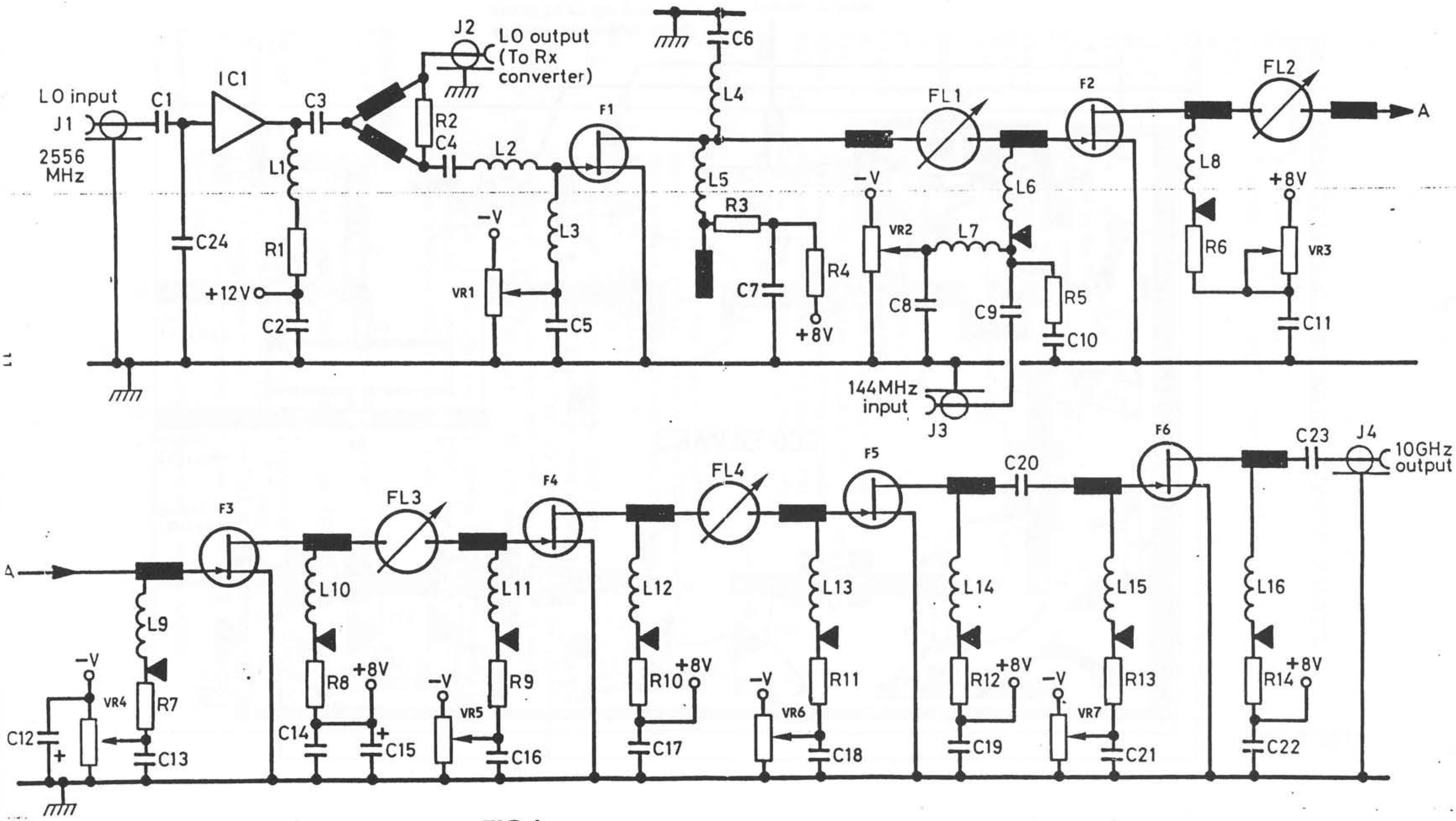


FIG 1
G3WDG 003 10GHz Transmit Converter Circuit Diagram

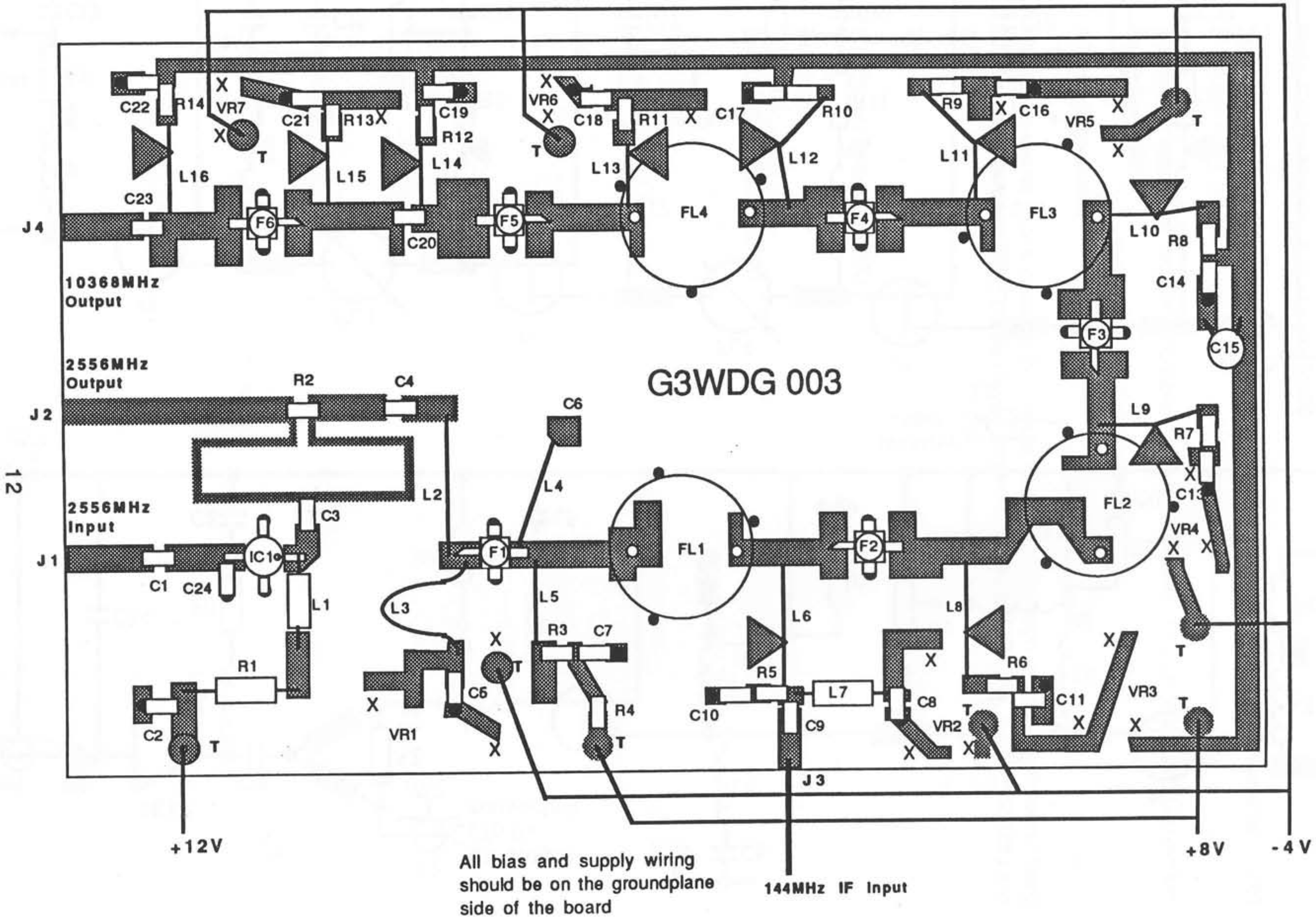
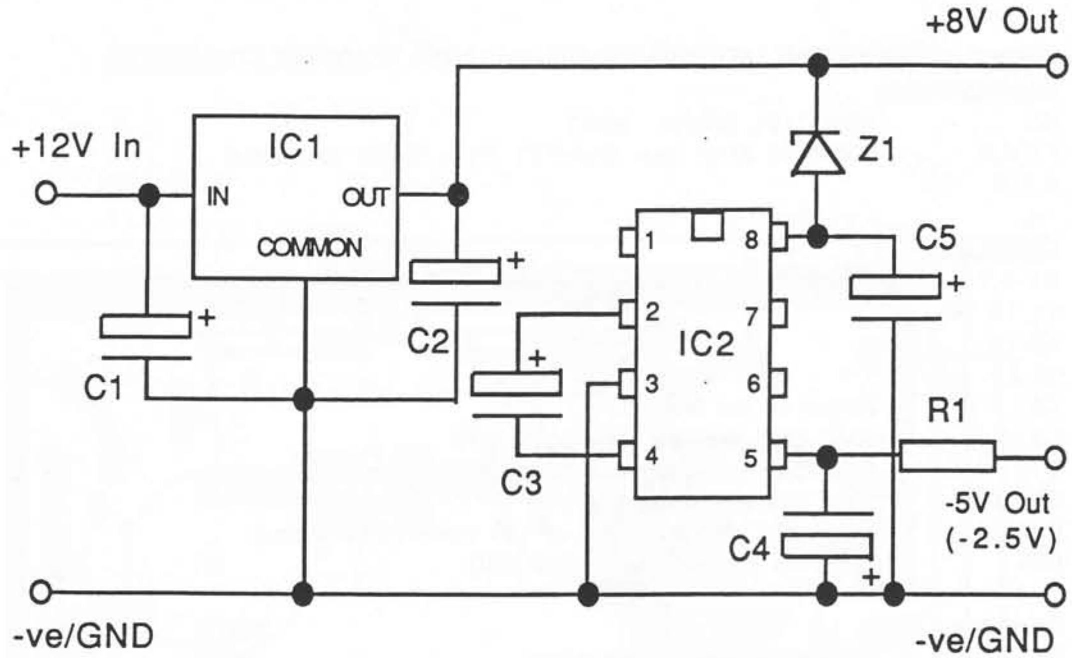


FIG 2

144MHz to 10GHz up-converter unit G3WDG003 PCB component layout

Table 1 COMPONENT LIST FOR G3WDG 003 10GHz TRANSMIT CONVERTER

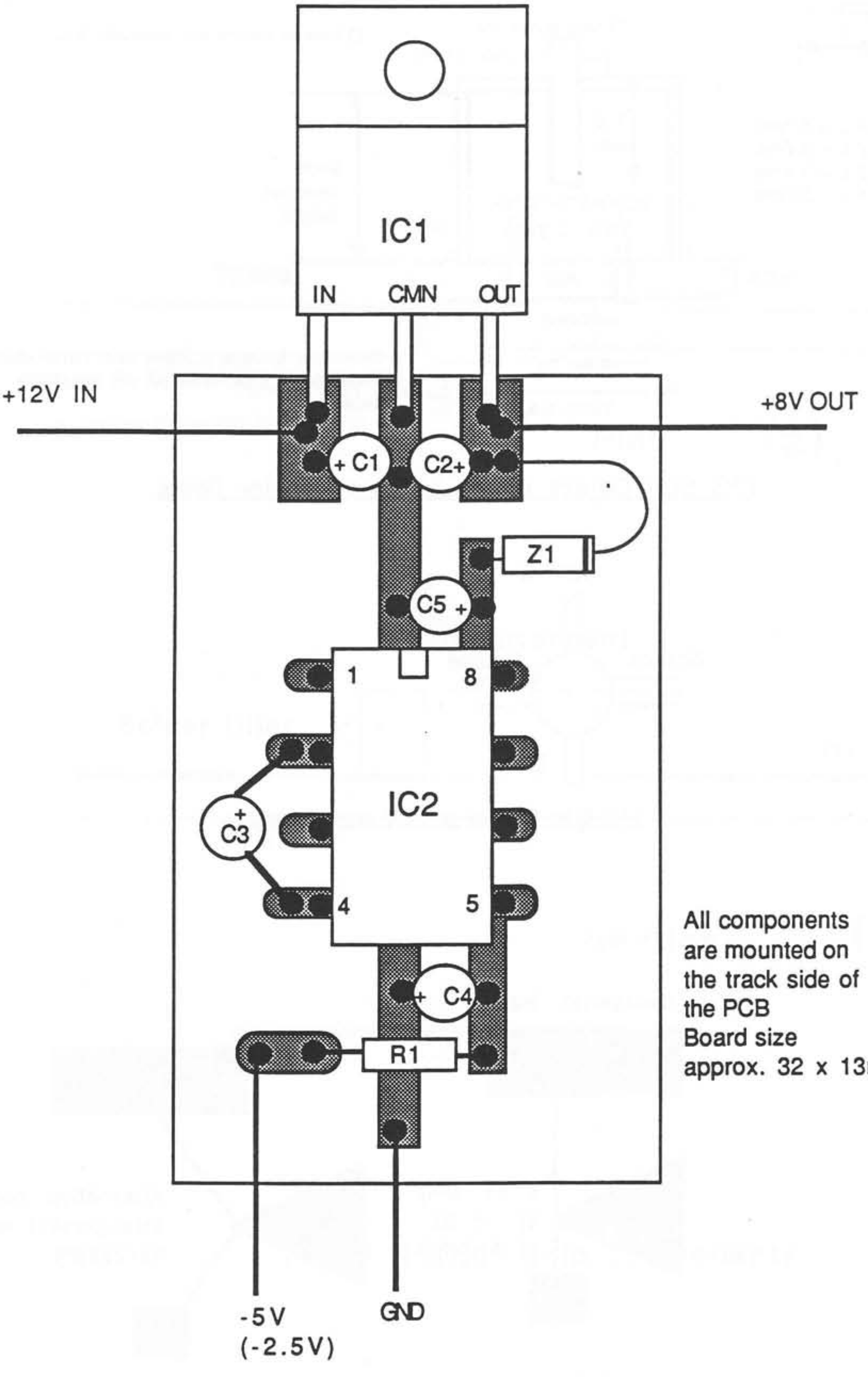
Semiconductors	
IC1	MSA 1104, MAV11 MMIC
F1,2,3, 4,5,6	P35-1108 Black spot GaAsFET (from Birkett of Lincoln)
Capacitors	
C1-5,7, 11,13,14, 16-19, 21,22	220pF Chip capacitors, size 0805 Surface mount device (SMD)
C6	Printed on the PCB
C8,9	10nF Chip capacitor, size 0805 SMD
C10	22pF Chip capacitor, size 0805 SMD
C12,15	10uF Tantalum bead, 10V Wkg
C20,23	2.2pF ATC Porcelain 100 or 130 series (0.050" size)
C24	1pF Chip capacitor, size 0805 SMD
Resistors	
R1	100R Axial lead, 1/2W rating
R2	100R Chip resistor, size 0805 SMD
R3,5-13	47R Chip resistor, size 0805 SMD
R4	220R Chip resistor, size 1206 SMD or 1/4W axial lead
R14	47R or 10R Chip resistor, size 0805 SMD (see text)
VR1,2 4to7	10k Skeleton cermet potentiometer horizontal mounting. Suitable types, Allen Bradley 90H, Bournes VA05H or 3309, Philips Comps. OCP10H.
VR3	2k2, Type as above
Inductors	
L1	6 Turns of 0.315mm diam. ecw, close wound, 2mm diameter, self supporting, 1mm above the PCB. Lead length 2mm.
L2	16mm length of 0.315mm diam. ecw, tinned 1mm each end, soldered flat to the PCB as shown.
L3	As L2 but 19.5mm long
L4,5	Straight length of 0.315mm diam. ecw, tinned 1mm each end and soldered flat to the PCB between the tracks as shown.
L6,8-16	Straight length of 0.2mm diam. (approx.) silver plated or tinned copper wire, soldered between the tracks and radial stub as shown. A single strand of braid from a miniature coaxial cable such as RG174/U is suitable.
L7	4.5 Turns of 0.315mm diam. ecw wound through the centre of an FX1115 ferrite bead. Alternatively use a 10uH radial lead miniature choke such as Toko type 348LS100 (Bonex, stock number 438100)
Miscellaneous	
FL1 to 4	Cavity resonators, see diagram. Overall probe length 4.7mm for FL1 and 3.4mm for FL2 to 4
Veropins	1mm diam. single ended, (RS stock number 433-854) (59 required)
Sockets	SMA two hole mounting. (Farnell stock number GE65137A). Or PCB mounting type with the lugs removed. (RS stock number 403-752) 4 required, although the IF input could be SMB or SMC (Conhex)
Tinplate box	size 74 x 111 x 30mm available from Piper Comms. (0235 834328) as type 7760
Feedthrough capacitors	1000pF solder-in type, 2 required (Bonex stock number 032102)



Component list for the regulator circuit

IC1	uA7808
IC2	ICL7660PCA
Z1	3V0 or 3V3, 400mW zener diode
R1	1k5 1/4W metal film
C1	1uF Tantalum bead, 16V Wkg
C2	0.1uF Tantalum bead,10V Wkg
C3	22uF Tantalum bead,10V Wkg
C4	22uF Tantalum bead,10V Wkg
C5	10uF Tantalum bead, 10V Wkg
PCB	G4FRE-023

Fig 3 Regulator circuit



All components are mounted on the track side of the PCB
Board size approx. 32 x 13mm

Fig 4. Regulator layout

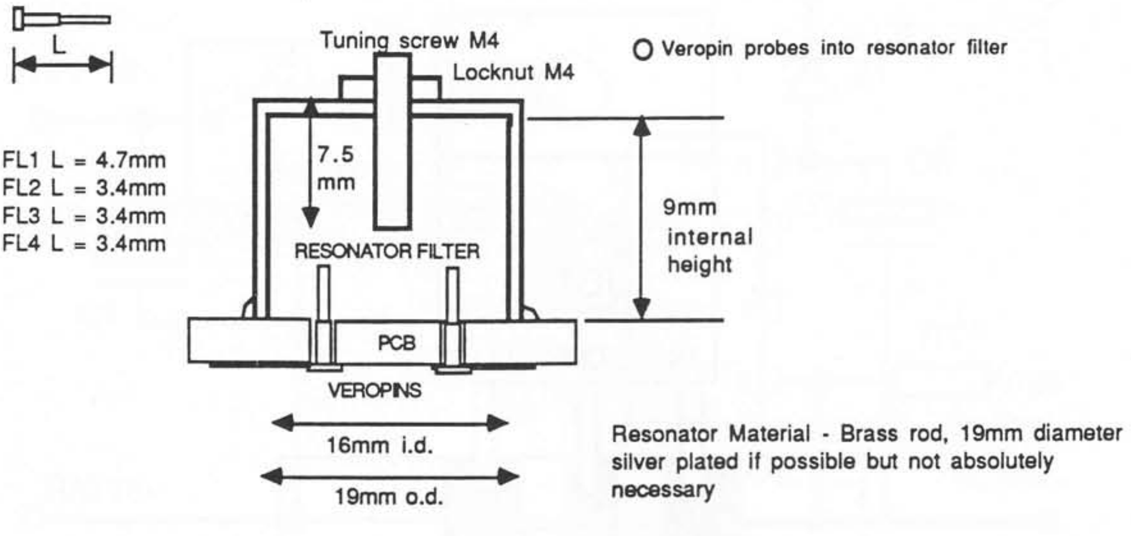


FIG 5(a) Details of the cavity resonator filters

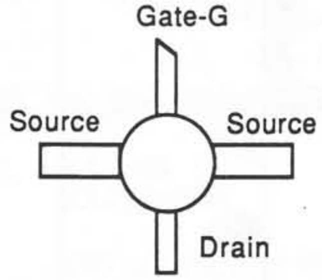


FIG 5(b) Details of FET connections

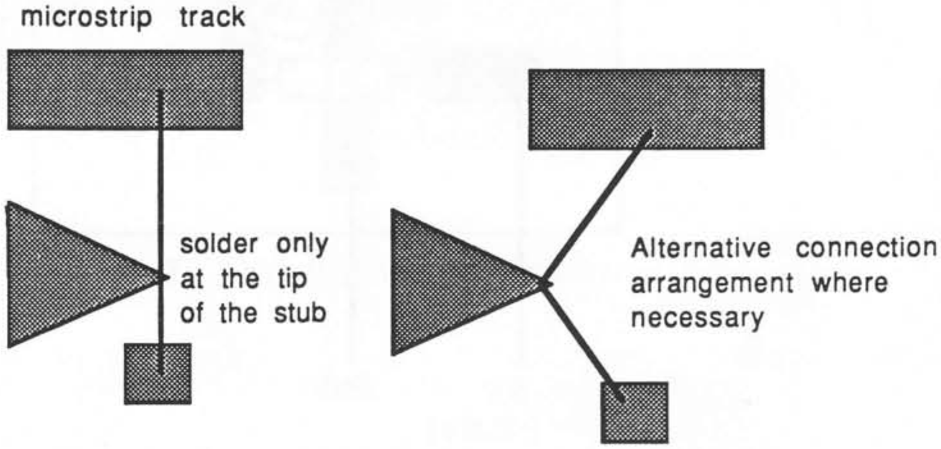
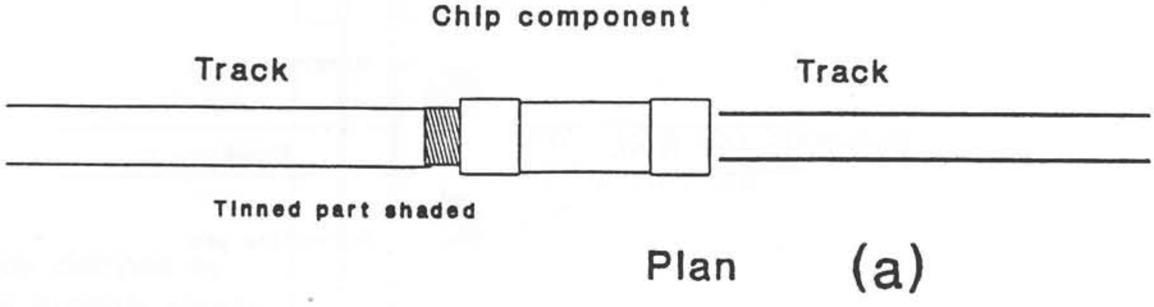


FIG 5(c) Details of the radial stub connections to the bias chokes



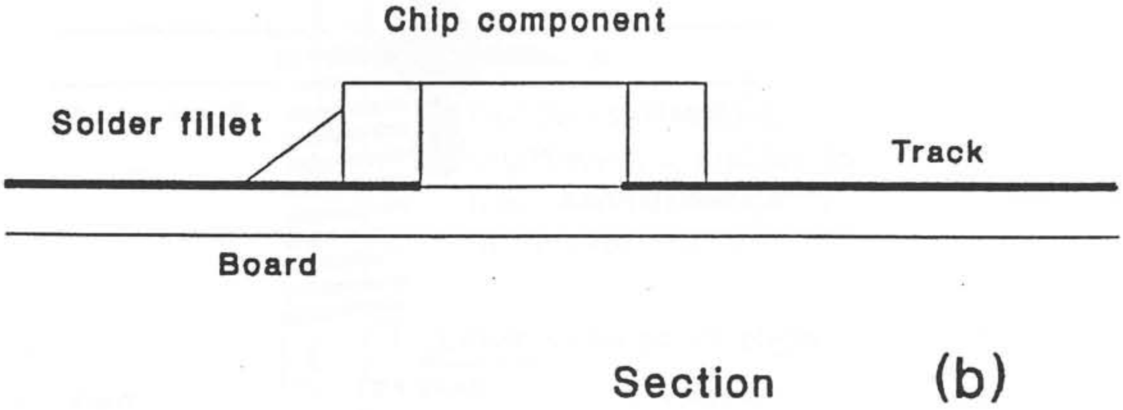


Fig. 6 Fitting chip components

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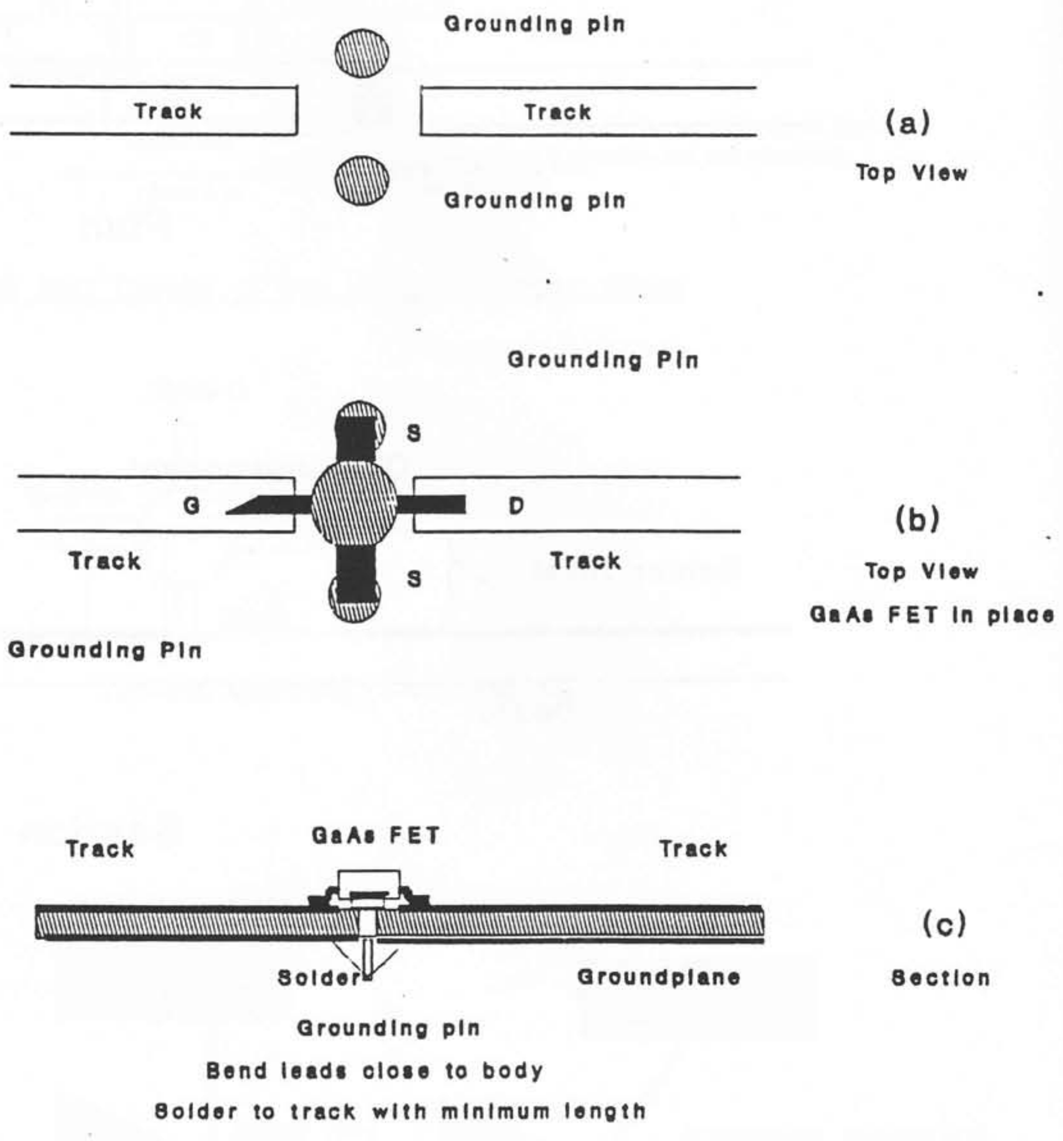

Fig. 7 Mounting GaAs FETs

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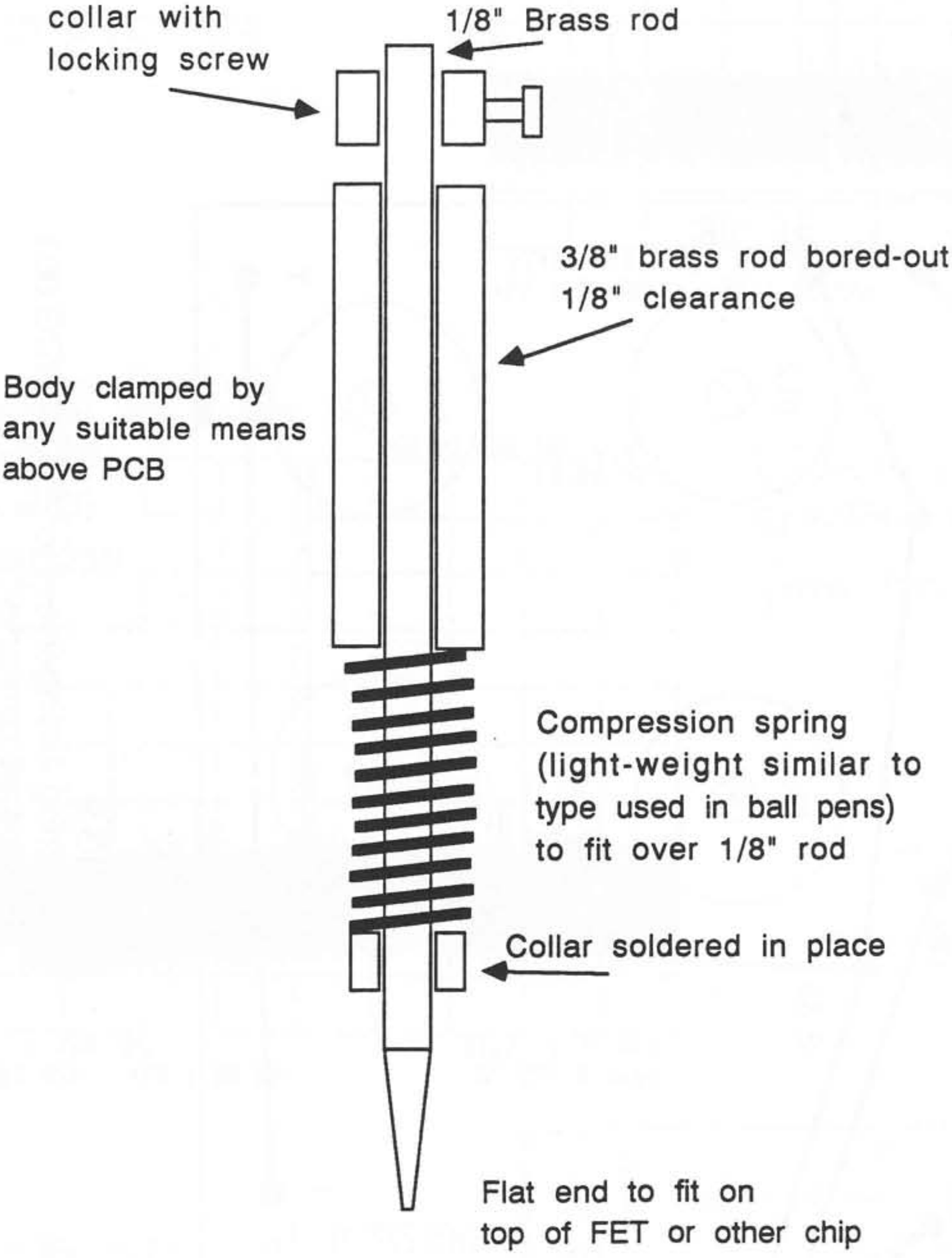


FIG 8
Simple homemade clamp arrangement to hold chip devices in place during soldering

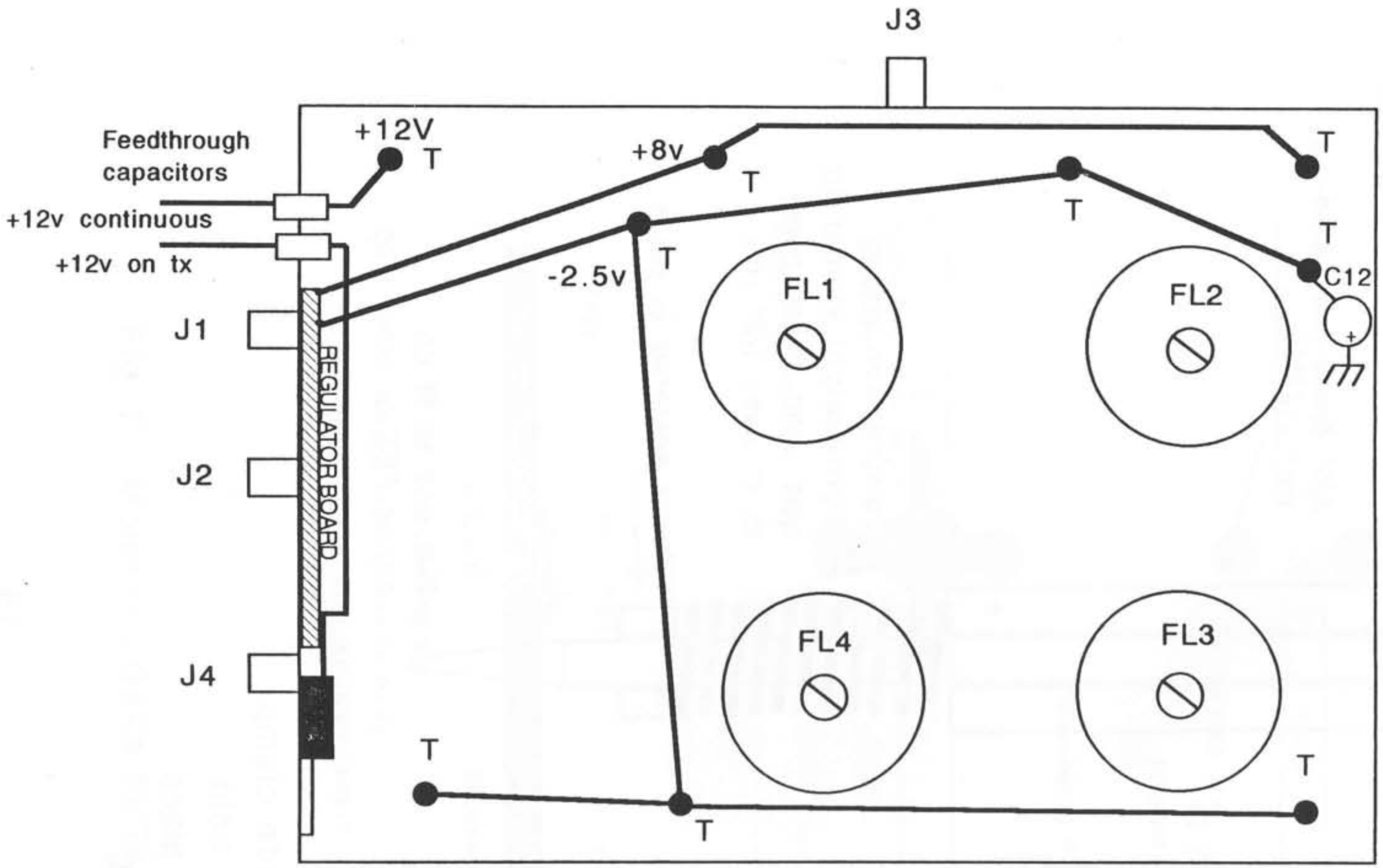
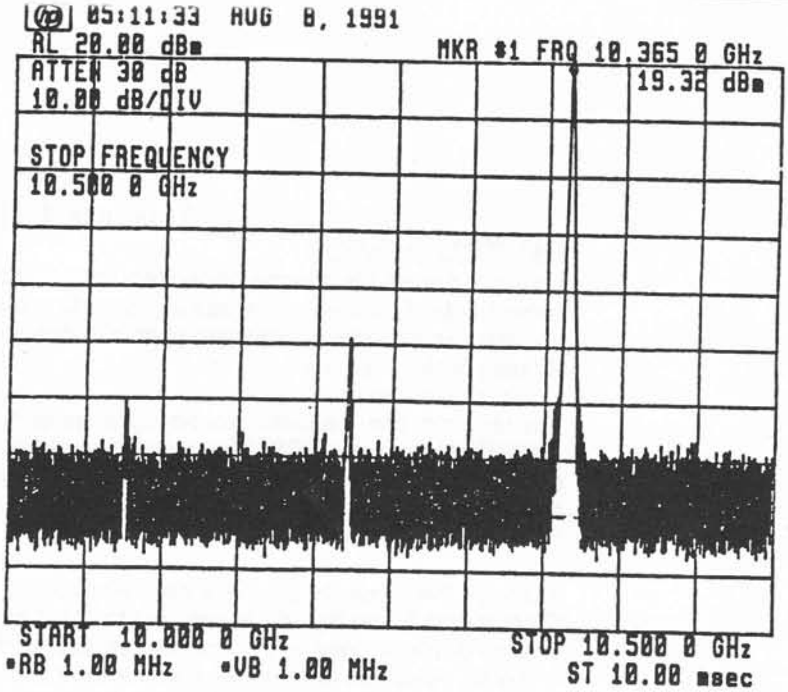
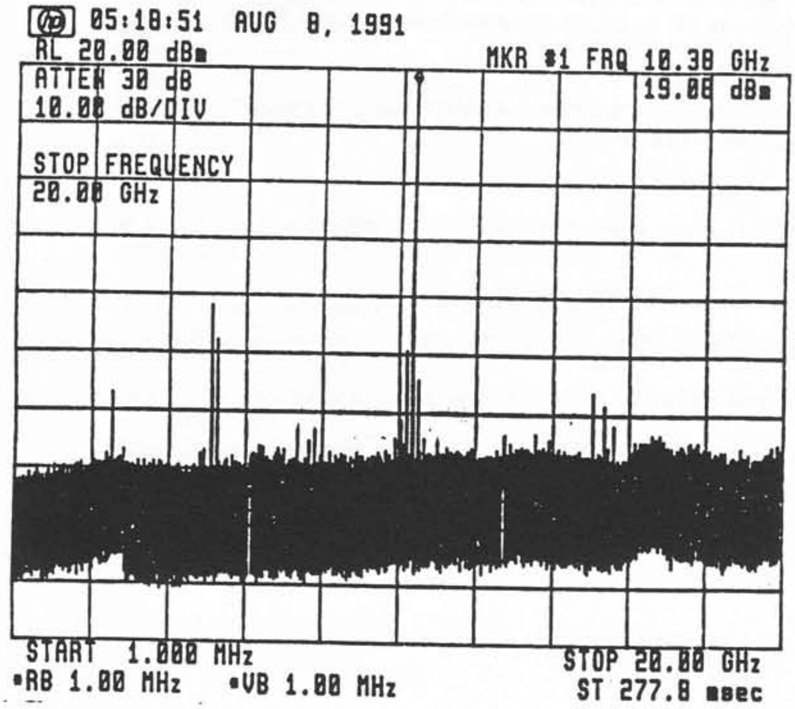


FIG 9
Wiring arrangement for the G3WDG 003 transmit converter

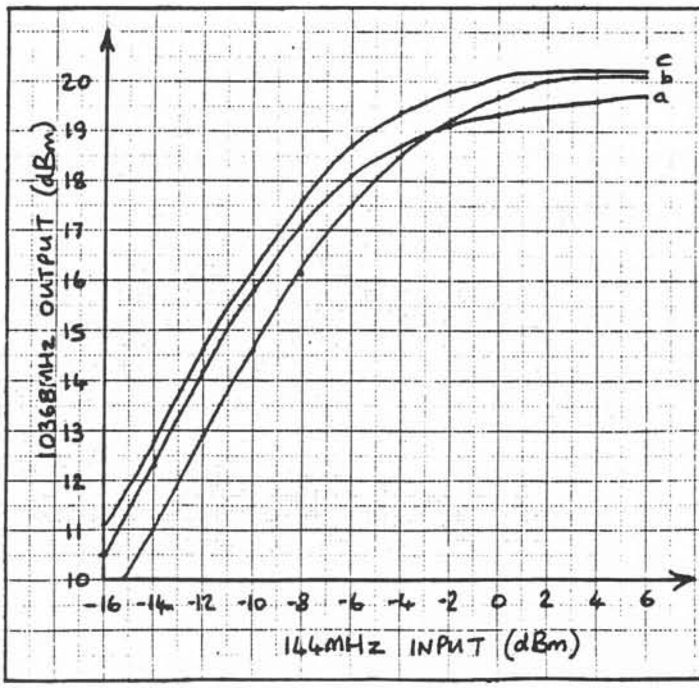
Output Spectrum of G3WDG003 from 10.0 to 10.5GHz Showing wanted signal at 10368 MHz, LO at 10224 and image at 10 080 MHz





Wideband output spectrum of G3WDG003 from 1MHz to 20GHz

Power output at 10368MHz versus drive power at 144MHz for three prototypes.



Appendix 1

G4FRE023 Regulator

Figure 3 shows the recommended regulator circuit for the transmit converter. The circuit consists of a 8V integrated circuit regulator to provide +8V for FET drain bias, and a negative voltage inverter circuit consisting of an ICL 7660 and associated components to provide the -5V gate bias.

The regulator may be built-up in any convenient form, but the G3WDG003 short kit includes a G4FRE023 regulator PCB. This may conveniently be housed within the upper part of the specified tin-plate box as shown in figure 9. Construction of the regulator is a little unusual in that the components are all mounted on the track side of the PCB. *No holes are required in the PCB.*

Although the regulator provides both +8 and -5V outputs, when connected to the G3WDG003 board the -5V is reduced to -2.5V across the bias potentiometers because of the voltage divider formed by R1 and the parallel combination of the bias pots. If the value of any of the six potentiometers is changed the bias voltage will change. This can be remedied by changing the value of R1 on the regulator board so that it equals the parallel value of the six potentiometers. It should be noted however that the ICL7660 inverter produces significant voltage spikes at the switching frequency. These are effectively suppressed by the filter consisting of R1 and C12. If the value of R1 is significantly reduced then the filter becomes less effective!

ICL 7660 and uA7808 ICs may be obtained from several different sources including RS Components, Farnell, STC Components and Maplin.

Appendix 2

Components

The "Modern High Performance Equipment for 10GHz" series of modules were designed specifically to use the surplus series of GaAs FETs available from Birketts of Lincoln. It may be possible to use alternative devices but this has not been tried by the author and no guarantee can be made for performance if components are substituted. Please note that the "3 for £1.99" devices from the same source are not suitable for this application.

The Microwave Committee Component Service short kit consists of:-

ITEM	QUANTITY
RF printed circuit board G3WDG003	1
DC printed circuit board G4FRE023	1
Veropins	59
Cavity filter + tuning screws	4
MSA1104 or MAV11	1
1pF Chip capacitor	1 (Dark green)
2.2pF chip capacitor (loose)	2
220pF chip capacitor	16
10nF chip capacitor	2
22pF Chip capacitor	1 (Blue)
47R chip resistor	11
10R Chip resistor (marked 100)	1 (Red)
100R Chip resistor (marked 101)	1
0.315mm wire	1
Booklet	1

To complete construction of the transmit converter you will need to obtain ALL of the remaining components in table 1, including the regulator components.

Several useful addresses for parts include:-

Microwave Committee Component Service, 314A Newton Road, Rushden, NORTHANTS, NN10 0SY. Tele 0933 411446.

Blue Rose Electronics, 538 Liverpool Road, Great Sankey, Warrington, WA5 3LU. Tele 0925 727848

Piper Communications, 4 Severn Road, Chilton, Didcot, OXON. Tele 0235 834328. Before 9pm, please.