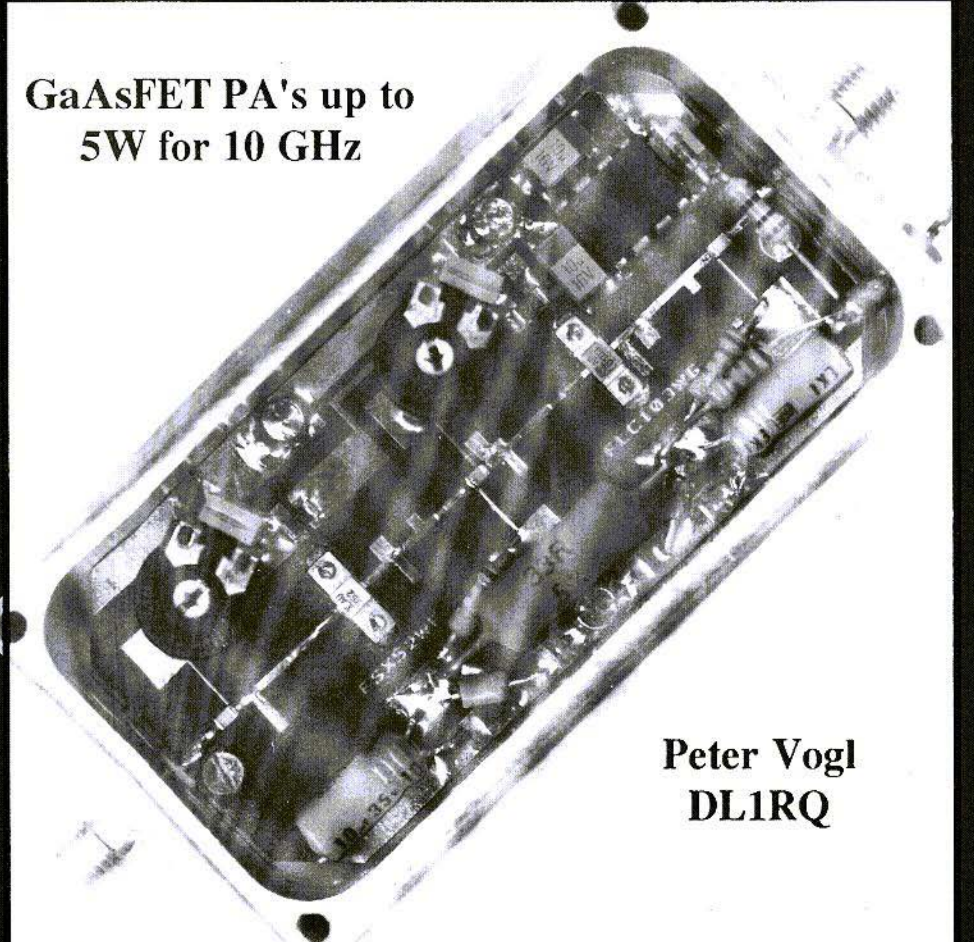
A Publication for the
Radio Amateur Worldwide

Especially Covering VHF, UHF
and Microwaves

VHF COMMUNICATIONS

Volume No.27 . Spring . 1/1995 . £4.00



VHF COMMUNICATIONS

A Publication for the Radio Amateur Worldwide

Especially Covering VHF, UHF and Microwaves

Volume No. 27 . Spring . Edition 1/1995

Publishers: KM PUBLICATIONS, 5 Ware Orchard, Barby, Nr.Rugby, CV23 8UF, United Kingdom.

Tel: 01788 891883
Fax: 01788 891883
Email:
100441.377@compuserve.com

Editors: Mike Wooding G6IQM

Advertising Manager: Mike Wooding G6IQM

VHF COMMUNICATIONS: The international edition of the German publication UKW-Berichte is a quarterly amateur radio magazine especially catering for the VHF/UHF/SHF technology. It is owned and published in the United Kingdom in Spring, Summer, Autumn and Winter by KM PUBLICATIONS.

The 1994 subscription price is £15.00. or national equivalent. Individual copies are available at £4.00, or national equivalent each. Subscriptions and orders of individual copies of the magazine should be addressed to the national representative, or - if not possible - directly to the publishers. All other enquiries should be addressed directly to the publishers.

Back issues, kits, as well as the blue plastic binders are obtainable from your national representative or direct from KM Publications.

Translated by: Inter-Ling Services, 62, Caldecott Street, Rugby, CV21 3TH, U.K.

Printed in the United Kingdom by Cramphorn Colour PrintersLtd., 15c Paynes Lane, Rugby.

Please address your orders or enquiries to your country representative., whose address is shown in the adjacent column.

AUSTRIA - Verlag UKW-BERICHTE, Terry D. Bittan, POB 80, D-91081 BAIERSDORF, Germany. Telephone: (9133) 47 0. Telex: 629 887. Postgiro Nbg: 30455-858. Fax: 09733 4747.

AUSTRALIA - W.I.A., P.O. Box 300, SOUTH CAULFIELD, 3162 VIC, Australia. Telephone: 528 5962.

BELGIUM - UKW-BERICHTE, P.O. Box 80, D-91081, BAIERSDORF, Germany. Tel: 09133 47 0. Postgiro Nbg: 30455-858 ; Fax: 09133-4747

DENMARK - KM PUBLICATIONS, 5 Ware Orchard, Barby, Nr.RUGBY, CV23 8UF, U.K. Tel: +44 788 890365. Fax: +44 788 891883

FRANCE - Christianne Michèl F5SM, SM ELECTRONIC, 20 bis Avenue des Clairions, F-89000 AUXERRE, France. Telephone: (86) 46 96 59

FINLAND - PETER LYTZ OH2AVP, Ylükartanonkuja 5 A 9, SF-02360 ESPOO, Finland

- SRAT, pl 44, SF-00441 HELSINKI, Finland. Telephone: 358/0/5625973.

GERMANY - UKW-BERICHTE, P.O. Box 80, D-91081 BAIERSDORF, Germany. Tel: 09133-7798-0. Postgiro: 30455-858

GREECE - C+A ELECTRONIC, P.O. Box 25070, ATHENS 100 26, Greece. Telephone: 01 52 42 867. Fax: 01 52 42 537.

HOLLAND - KM PUBLICATIONS, 5 Ware Orchard, Barby, Nr.RUGBY, CV23 8UF, U.K. Telephone: +44 788 890365. Fax: +44 788 891883

ITALY - ADB ELETTRONICA di Luchesi Fabrizio IW5ADB, Via Vecchia Romana 266, 55100 ANTRACCOLI (LUCCA), Italy. Telephone: 0583 952612.; Fax: 0583 91109

NEW ZEALAND - Peter Mott, AUCKLAND VHF GROUP Inc., P.O. Box 10 138, AUCKLAND 1030, New Zealand. Telephone: 0-9-480-1556

NORWAY - HENNING THEG RADIO COMMUNICATION LA4YG, Kjøiaveien 30, 1370 ASKER, Norway. Postgirokonto: 3 16 00 09

POLAND - Z.Bienkowski SP6LB, ul. Staszica 14/2, 58 560 JELENIA GÓRA 9, Poland. Tel: 514 80

SOUTH AFRICA - HI-TECH BOOKS, P.O. Box 1142, RANDBURG, Transvaal 2125, South Africa. Tel: (011) 886-2020.

SPAIN & PORTUGAL - JULIO A. PRIETO ALONSO EA4CJ, Donoso Cortès 58 5º-B, MADRID-15, Spain. Telephone: 543.83.84

SWEDEN- WAVELINE COMMUNICATION AB, Vipevägen 6, S-216 11 MALMÖ, Sweden. Tel: 40 16 42 66; Fax: 40 15 05 07

SWITZERLAND - TERRY BITTAN, PSchKto, ZÜRICH, Switzerland.

UNITED KINGDOM - KM PUBLICATIONS, 5 Ware Orchard, Barby, Nr.RUGBY, CV23 8UF, U.K. Telephone: (0)1788 890365; Fax: (0)1788 891883.

U.S.A. - WYMAN RESEARCH Inc., RR#1 Box 95, WALDRON, Indiana 46182, U.S.A. Telephone: (317) 525-6452.

- Henry Ruh, ATVQ MAGAZINE, 3 North Court Street, Crown Point, IN.46307, U.S.A. Tel: (219) 662 6395. Fax: (219) 662 6991

ELSEWHERE - KM PUBLICATIONS, address as for the U.K.

ISSN 0177-7505

Contents

SEE THE ENCLOSED FLYER GIVING EXCITING NEWS ABOUT BACK ISSUES OF VHF COMMUNICATIONS

KM Publications, 5 Ware Orchard, Barby, Rugby, CV23 8UF, UK

Telephone: (0)1788 890365; INT: +44 1788 890 365; FAX: (0)1788 891883
Email: 100441.377@compuserve.com

Denys Roussel, F6IWF

Modifying Satellite Receiving Systems for 10 GHz FM ATV Operation

Because of the wide bandwidth of the 3 cm band : 500 MHz this band is ideal for local amateur TV links. Only this band enables duplex or multiway TV transmissions when many amateurs want to transmit TV simultaneously

Local TV repeaters can be conceived up with several outputs in the 10 GHz band, and many high-speed digital links can take place.

The goal is to occupy the band to make it as popular as the 2 meter band for phone communications. Otherwise, we risk loosing a part of the 3cm band in the future.

To make links, the obstacle is the material. In VHF Communications 2/1992 I described a transistorised TV transmitter stabilised by dielectric resonator. I still have to describe the receiver to complete the system.

For cost and facility reasons, I chose to modify commercial equipment instead of building the whole system.

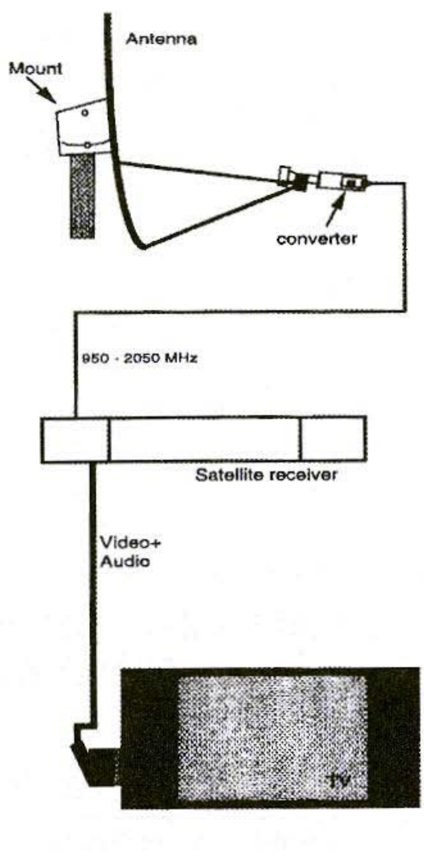


Fig.1: A Typical TVRO Installation

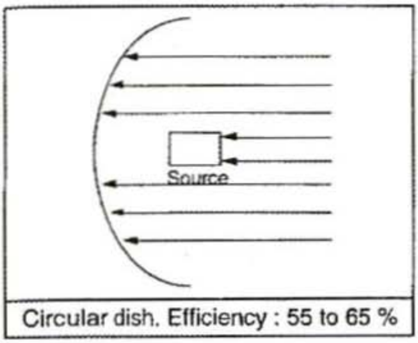


Fig.2a: Efficiency of a Circular Dish

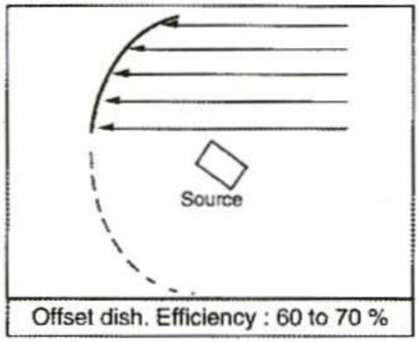


Fig.2b: Efficiency of an Offset Dish

A satellite TV receiving system (Fig.1) is composed of:

- An antenna which picks up energy from the satellites. In Europe, TV satellites are in the band 10.95 - 12.75 GHz with IERPs near 50dBW. The size of the antenna is about 50 to 85 cm.
- A Low Noise Converter or LNC (or Low Noise Block LNB) which amplifies (50dB) and converts satellite signals from frequencies in the band 10.95-12.75 GHz to an intermediate frequency of 950 to 1750, or 2050 MHz. These converters are very sensitive (NF 1.2dB) and mounted directly on the antenna just behind the feed-horn to reduce losses, before amplifying. The band 950 - 2050 can be easily transmitted via a coaxial cable thanks to the high conversion gain of the LNB/ LNC
- A satellite receiver which selects and demodulates FM TV channels in the 1st IF band 950-2050 MHz. The 2nd IF is on 479.5 MHz and the bandwidth is 27 MHz. Generally, the video performances of these receivers is very good.

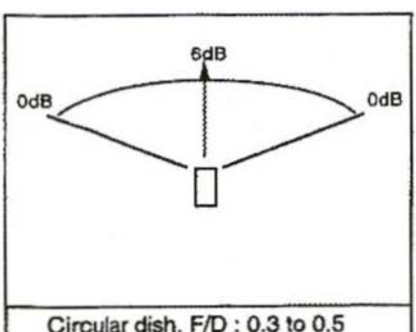


Fig.3a: Tube Feeding a Circular Dish

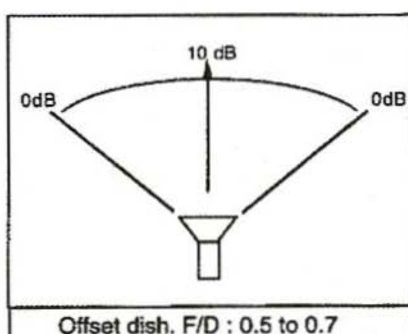


Fig.3b: Horn Feeding an Offset Dish

Now, prices of TVRO equipment are very attractive, especially for "old" systems with one polarisation, which are sold well below the normal purchase price. These systems are very simple to convert to our 10 GHz band and are a better way to start on 10 GHz TV FM with a modern design.

1. THE ANTENNA

Antenna can take different aspects and there are essentially two types, Dishes and Flat antenna

Flat antenna are made by an array of dipoles matched by printed strip-lines. They are characterised by a small bandwidth and therefore not suitable for our needs. On the other hand, dishes are very convenient because of the aperiodic property of the reflector. As 95% of dishes are now in offset technology, we will consider only this type.

An offset reflector is in fact a piece of a circular dish (Fig.2a). The offset dish provides a better efficiency especially with small diameters because the size of the source is important in comparison with the reflector. As the receiving part is the projection of a wave cylinder on a parabolic form, the offset dish is not circular but elliptical (Fig.2b).

Characteristics of an Offset Dish

1.1 The Diameter

The diameter is equal to the diameter of the wave cylinder received by the dish. It is measured on the short axis of the ellipse. The size of the dish and the efficiency determines the gain of the antenna for a chosen frequency. For reference the gain of an offset at 10.5 GHz is as follows:

∅ in cm	Gain in dBi
50	33
60	34.5
70	36
80	37

It is not recommended to exceed 80cm because of the small aperture angle of high gain dishes and difficulties in aligning them to the transmitter source.

1.2 The F/D ratio

The F/D ratio (F = focal length; D = diameter of the dish) is contained between 0.5 to 0.7 (Fig.3b) instead of 0.3 to 0.5 (Fig.3a) for circular dishes. The consequence is that the feed is not the same.

While a single tube of 23mm inside the diameter is sufficient to illuminate a reflector of F/D = 0,4, offset antennas demand a small horn (gain about 10dB) to respect the illumination law.

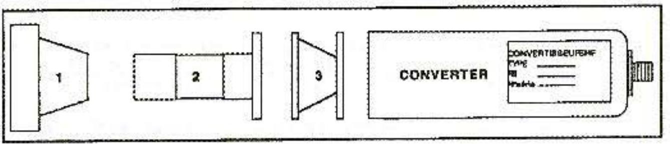


Fig.4: The Component Parts of an LNB

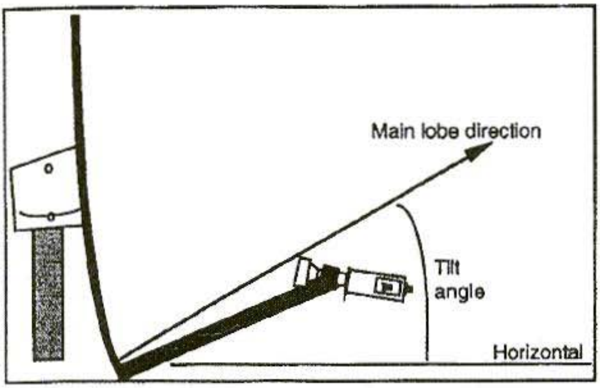


Fig.5: The Tilt Angle of an Offset Dish

Generally, 3 parts make up the source (Fig.4) :

1 Feed-Horn
2 Waveguide
3 Waveguide interface to adapt the input of the converter

Actually these parts are often in one piece, therefore it is difficult to utilise the source.

1.3 The Tilt Angle

An important characteristic of these offset antenna is that the receiving axis is not perpendicular to the plane of the dish border. The main lobe and this perpendicular are at an angle called the "tilt angle" (Fig.5). For amateur use the main lobe should be horizontal., therefore it is necessary to tilt the reflector down to bring the beam into the horizon.

1.4 The Materials

Dishes are made from metal (steel or aluminium) or from moulded metallised fibreglass. The advantage of composite material is the robustness which make this very suitable for portable use (insensitive to shocks during transportation).

For a fixed installation an aluminium antenna is preferable because the lower weight on the mast. Be careful of the painted steel antenna which are often less resistant to corrosion, especially with mesh dishes which have already 0.5 to 1dB lower gain than solid ones.

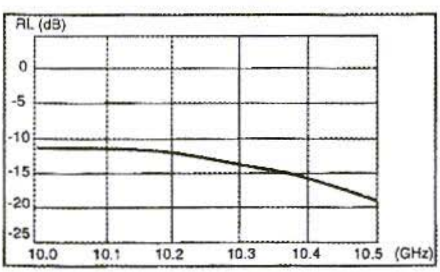


Fig.6a: Typical Return Loss of a Tonna 759220 Feed

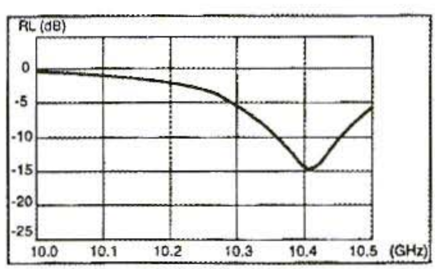


Fig.6b: Typical Return Loss of a C120 Feed

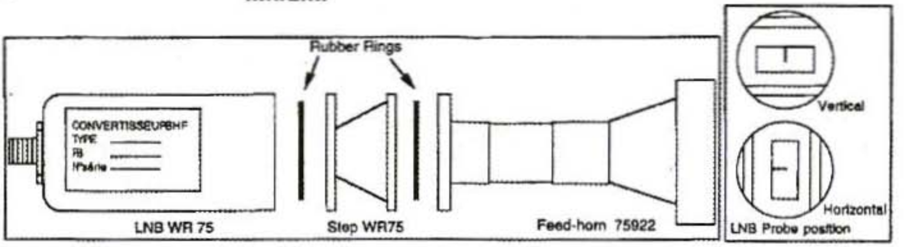


Fig.7: Mounting a WR75 LNB onto a Tonna 759220 Feed-Horn

1.5 Choice of a Commercial Model

My choice is an antenna from the TONNA products range which is very popular in France. This well known company in the amateur radio field, also build very fine satellite TV receiving systems.

An advantage is the existence of a feed-horn with a waveguide diameter of 22mm. This feed was primarily intended to accommodate a circular / linear polariser for TDF 1 or TVSAT reception. The return loss is better than 12dB on the 10.0 to 10.5 GHz range (Fig.6a). The source mounting is possible on all the TONNA antennas. Actually, the waveguide to the horn is C120 (17.475mm) and works as a high pass filter with a cut-off frequency of 10.4 GHz (fig.6b) and as such is unusable for our needs.

The best models for amateur use are the Tonna 49cm in fibre glass and the TONNA 68 cm in aluminium.

1.6 Construction of a Feed-Horn

For other antenna it is always possible to replace the C120 source with another one. As conical horns are not very easy to build, it is easier to make a square source (Fig.8). The illumination law of offset antenna requires about 10 dB gain feed.

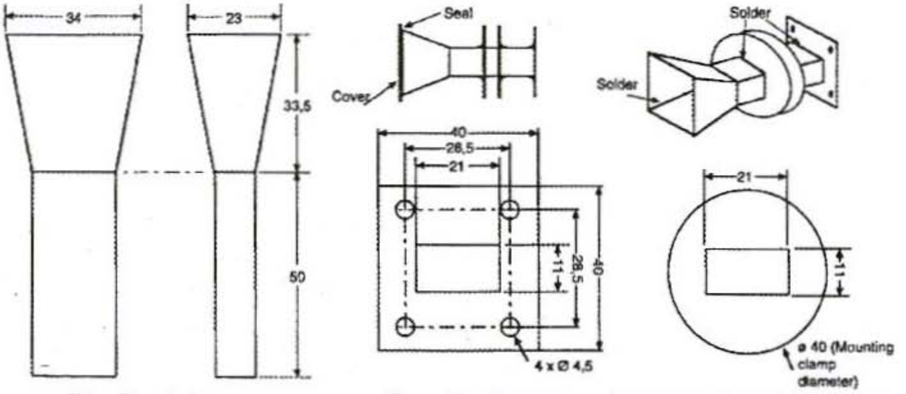


Fig.8: Construction Details for the Feed-Horn

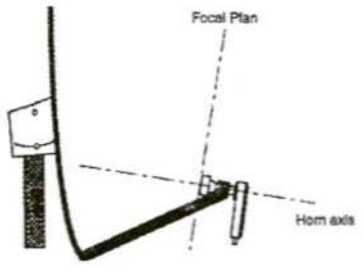


Fig.9a: Determine the Source Axis and the Focal Plane of the Original LNB

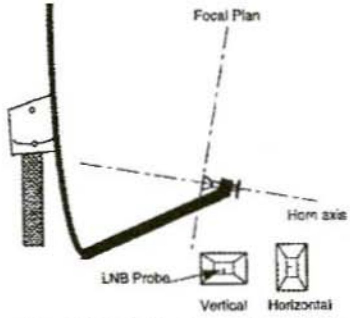


Fig.9b: Maintain the original Axis Position and the Focal Plane when fitting the New Feed

As microwave antenna are intended to be used outdoors it is necessary to provide a waterproof feed. The cover should be made from UV-resistant plastic and transparent to microwaves.

The best material to use is PTFE but it is difficult to seal. Generally, light-coloured or transparent plastics are good for microwaves, but bad for UV. Dark or black ones are good for UV but not for microwaves.

Manufacturers use different PTFE combinations to guarantee UV, water proofing and sealant effectiveness.

Make some tests to find a suitable material. It is also possible to try a thin glass window, which accepts the silicone mastic very well and is completely UV-proof.

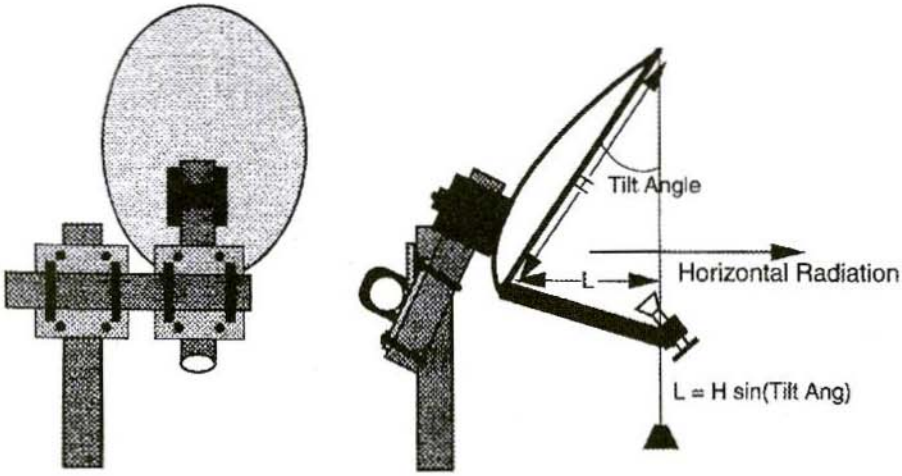


Fig.10: Mounting and Positioning the Offset Dish for Horizontal Radiation

1.7 Putting a new Feed in the correct place

It is necessary to keep the axis of the previous source and the focal plane (Fig.9a).

The position is not very critical, plus or minus 5 mm forward or back gives almost identical results (Fig.9b).

All measurements made on small dishes showed higher the efficiency of offset antennas.

1.8 Adjustment of Antenna Direction

As satellite dishes are rarely pointed on the horizon line, manufacturers design antenna mounts with elevation angles from nearly 15 to 50°, however, for land links we need 0°.

To ascertain the value of the tilt angle, put the antenna onto a vertical mast, set the reflector perfectly vertical with a plumb-line and read the value on the mount. Tilt the antenna down by this angle. As mounts are not generally designed to to tilt down to 0° a special mechanical assembly is necessary (Fig.10a).

Pre-setting of the antenna can be made with a ruler and a plumb-line fixed to the top of reflector (Fig.10a). For fine tuning, use a beacon or a transmitting station located a few kilometres away and adjust for maximum signal.

This antenna modification was intended for wideband TV use, but it is also possible to use it for SSB or any mode of transmission.

2. THE LNB

In this article we are concerning ourselves only with single polarisation LNBs/LNCs.

2.1 Principles

The "LNB" (Low Noise Block) also called LNC (Low Noise Converter) or SHF converter is designed as follows (Fig.11):

It is composed of :

1) An Antenna: A 1/4 wave probe in a WR75 cavity. The low cut off frequency of this guide is 10 GHz.

2) A very Low Noise Amplifier: The noise figure is below 1dB and the gain 25 to 30dB in three stages. The frequency range is adapted to the

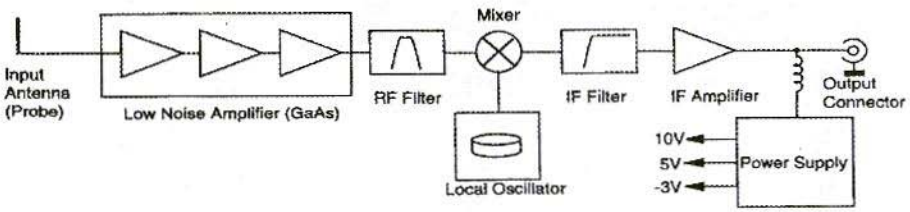


Fig.11: Functional Block Diagram of the LNB

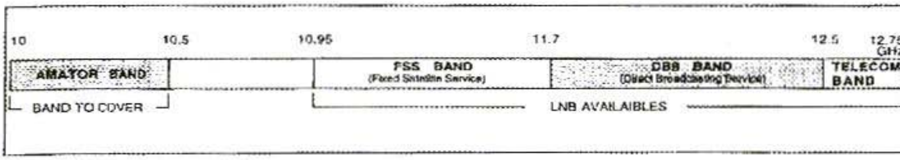


Fig.12: The Amateur Band in relation to the LNB Bands

input specification of the LNB. The first stage is nowadays an HEMT GaAs transistor to achieve the best NF.

3) The RF Filter: A strip line band pass filter is used to suppress the image frequency band. This filter is helped very often by rejectors which are placed between the amplifier stages. In some older designs there is no band pass filter, but a high number of rejectors cut for the best image rejection.

4) A Local Oscillator: For small size and low price, the LO is made from a dielectric resonator. The phase noise and stability are sufficient for TV transmissions. For the bands 10.95 - 12.75 GHz, LO is always below the output frequency.

5) The Mixer: It is generally a diode mixer with 1 or 2 diodes. The loss is around 6dB. Active GaAsFET mixers can also be found in some converters.

6) IF Amplifier : The mixer is followed by a high pass filter and a low noise amplifier (NF 2dB, Gain 3OdB). The IF amplifier is often a monolithic IC with one or two transistors.

7) Power Supply: Generally, the power supply includes a 10 V regulator for the IF stages, a 5V regulator for the local oscillator and input amplifier and a -3V inverter to polarise the GaAsFETs. The main supply is picked up from the output coaxial cable, 13V is necessary for good regulation of the derived supplies.

Some models use a 12V regulator, which means that the power supply should be not less than 15 V, which is difficult to obtain when using the system in portable mode. Therefore it may be preferable to obtain a 10V model.

2.2 Which model of LNB for easy modification?

The problem is to shift the operating band of the LNB to cover the amateur band: 10 - 10.5 GHz (Fig.12).

1) FSS LNB

The design frequency range of this unit is near the amateur band and it is the reason why first tests where made on these converters.

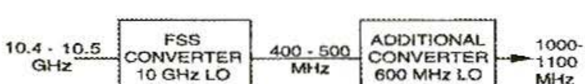


Fig.13: The FSS LNB with additional up-converter

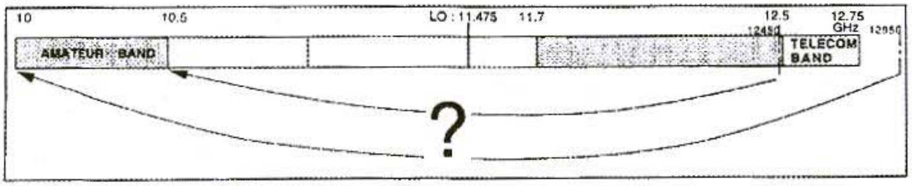


Fig.14: The relationship between the Amateur Band and the Telecom Band

- The bandwidth of input amplifier is sufficiently wide to work on 10 GHz without tuning.
- The band pass filter must be tuned using copper strips.
- The LO frequency is 10.0 GHz.

With some older LNBs, there was no high pass filter before the IF amplifier. I used this LNB a few years ago with only small changes to the RF filter to receive the band 10.4 - 10.5 GHz with a 400 - 500 MHz receiver. Later an upconverter was built to enable the use of a standard satellite receiver operating in the 1000 - 1100 MHz band (Fig.13).

Because of the poor availability of such LNB's I tried to shift the LO frequency down. By placing epoxy washers under and above the dielectric resonator, and opening totally the cavity above the resonator, it possible to move the frequency down to about 9.4 GHz, which enables you to cover the band 10.35 - 10.5 with a 950 - 1100 MHz IF.

As it is not possible to receive the bottom part of the 3cm band, and because of degraded stability with the resulting LO modification, this solution was ruled out.

2) DBS LNB

Not suitable to modify.

3) TELECOM LNB

These LNB's where designed to receive French satellites TELECOM 1 or German KOPERNICUS. Both satellites now demand dual polarisation, but there are still high stocks of these LNBs available in single polarisation.

How do you cover the 10.0 - 10.5 GHz amateur band with this 12.5 - 12-75 GHz converter (Fig.14)?

The principle is to keep the same LO frequency (Fig.15)!

Using the LO in supradyne mode, the 10 - 10.5 GHz band is converted to 1.475 - 0.975 GHz. As these frequencies are contained in the normal output range of the LNB no changes are necessary to the IF section. Modifications concern only the RF Amplifier, Filter and the Mixer.

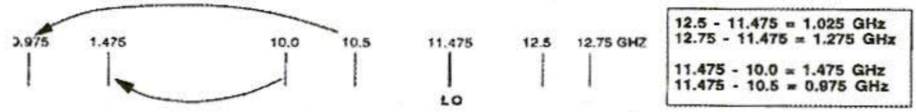


Fig.15: Keeping the LO the same, the IF is within the LNB's output range

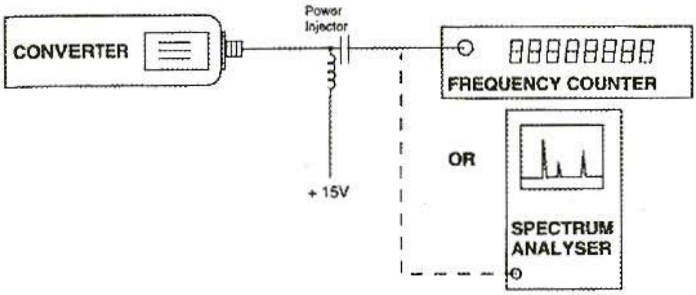


Fig.16: Using the LNB as a converter for SHF Frequency Measurements

To keep the same LO frequency is a enormous advantage, manufacturers tune the LO with an accuracy of better than +/- 500 kHz at room temperature.

The LNB becomes the first 3cm measurement set of the shack, with a frequency meter/counter it is possible to know our working frequency to a accuracy of better than +/- 1 MHz. This process can also be used to extend a limited range Spectrum Analyser to the 10 GHz band (Fig.16).

The only disadvantage of this technique is the spectrum inversion. The conversion inverts the modulation sense (FM transmissions). Invert the video signal at the output of the receiver to give the right polarity.

To modify the input amplifier and mixer is simple and easy to reproduce; devices are already wide band designs, and by carefully positioning some copper stubs you are able to retune the system for best gain with low noise figure at our frequencies of interest.

The RF filter modification requires a special design, but it is also easy to reproduce thanks to using photographic transfer technology to manufacture the printed circuit board.

Although Telecom LNB's normal operating frequency band is the most removed from the amateur 3cm allocation, it is by far the best and most economically modified unit for 10 GHz ATV.

2.3 Design of a 10.0 - 10.5 GHz Filter

This filter was designed and optimised using the Touchstone program. Input and output impedances are fixed to 50Ω. The PCB is made from 0.79mm

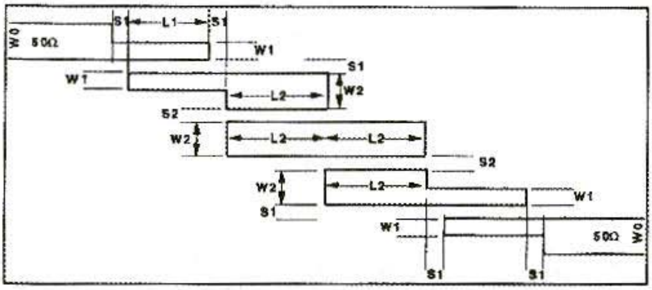


Fig.17: Strip Line Design for the 10 GHz Filter

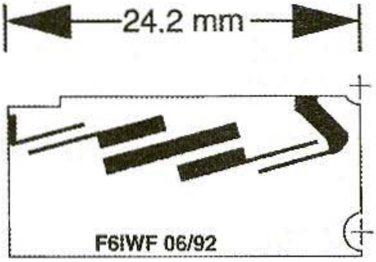


Fig18: Printed Layout for the 10 GHz Filter PCB

double-sided Teflon-glass with an $\varepsilon_r = 2.55$.

The line dimensions are as follows (Fig.17):

WO = 2.16 mm
Wl = 0.25 mm
W2 = 1.1 mm
Sl = 0.6 mm
S2 = 0.75 mm
Ll = 4.3 mm
L2 = 4.7 mm

The overall size of the PCB is 24.2 x 10.8 mm. To reproduce the filter, photo-reduce the layout shown in Fig.18 to the final size shown and photo-print the substrate. The etching is quite difficult because of the small width of the lines and it is recommended to etch several boards simultaneously and select the best one afterwards. Final trimming of the lines is possible with a very sharp scalpel.

2.4 Modifying a Commercial LNB

All the modification processes were guided with the same purpose: to enable anybody to have a good TV receiving unit on 10 GHz without the need for special measurement equipment, such as a Spectrum Analyser or Microwave Frequency Meter, following step by step the modifications. Thus, as stated earlier, the 10 GHz SHF converter becomes the first measuring instrument of the shack.

The model chosen for this description was the NJR 8170 F from NJRC. This converter is imported into Europe by the Nichimen Corporation and distributed in France by TONNA Electronique (part number 750130). This LNB is not very small and is easy to modify, all functions are clearly separated and identifiable without difficulty (Fig's.19a to 19e).

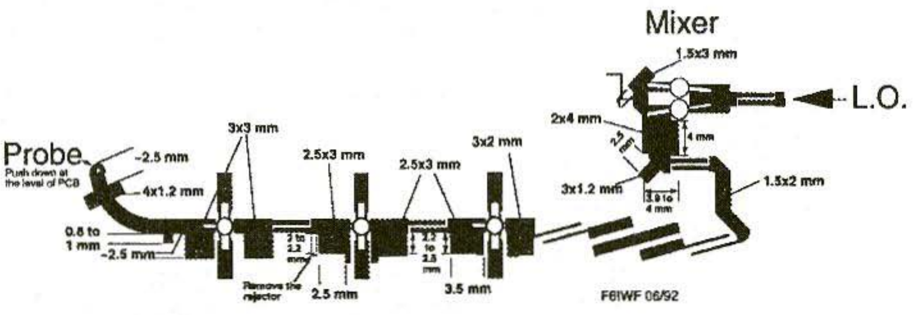


Fig.19a: The Sizes and Positions of the Stubs

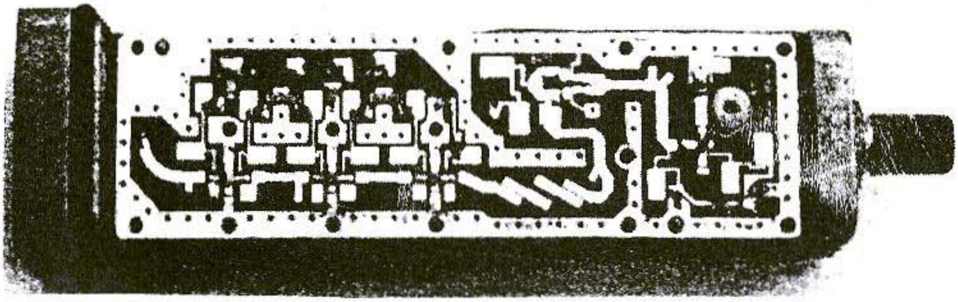


Fig.19b: The Circuit before Modification

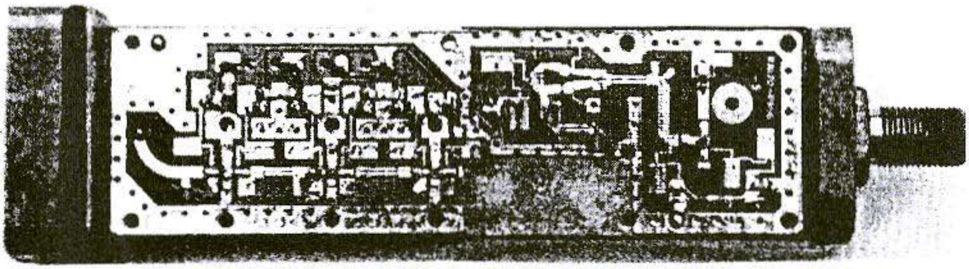


Fig.19c: The Filter has been Removed

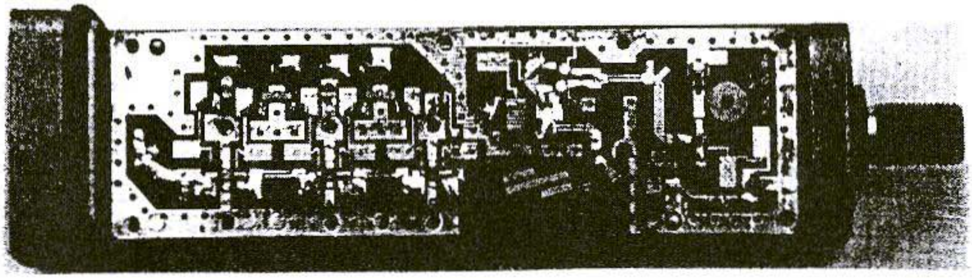


Fig.19d: The LNB with the new Filter and Stubs in place

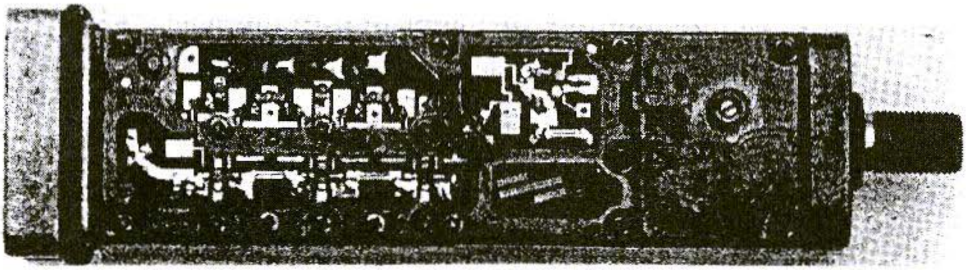


Fig.19e: The Completed Modified LNB

1) Remove the nut from the LNB and take off the housing. You can see the IF assembly and a cover which screens the RF section, and the Dielectric resonator cavity. *Do not turn the oscillator tuning screw as it is important to keep to the factory accuracy.*

2) Remove and keep the cover screws. Use a very good screw-driver and lay the LNB on a flat surface to push very hard to release the screws. You can see the three input stages, the band pass RF filter and the diode mixer.

3) Remove and keep the screws of the shielding piece. These screws are longer than the cover ones.

4) Position the new RF filter and carefully cut the LNB printed circuit with a very sharp cutter. Use a metal ruler if necessary. Clean the area with acetone or similar cleaning agent.

5) Place the new filter and connect input and output with a piece of thin copper strip (1.5 x 2 mm). You can find this copper tape from the shielding of good TV coax cable. If there is varnish on the transistor lines, scrape it off.

6) Position and solder with a low-power soldering iron pieces of copper tape as shown in the photo and drawing. Remove the second stage input rejector with a cutter (dotted line on Fig.19a).

7) Reduce the length of the stub on the gate of input stage to 0.8 - 1 mm.

8) Push down the iron tip onto the RF probe soldered joint to drive it in at the same level as the PC board.

9) Put back the shielding piece and tighten all screws

10) You can try your 10 GHz LNB before putting back the cover and housing. Do not forget the rubber rings.

This modification takes less than 1 hour and is easily reproducible thanks to the diagrams. No tuning is necessary to provide good results.

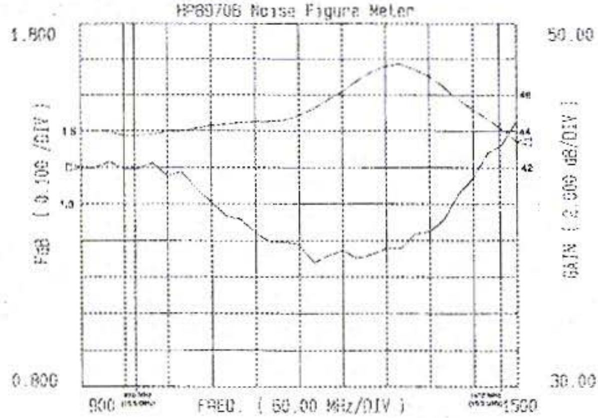


Fig.20: Measurement Curves for the Tuned Converter

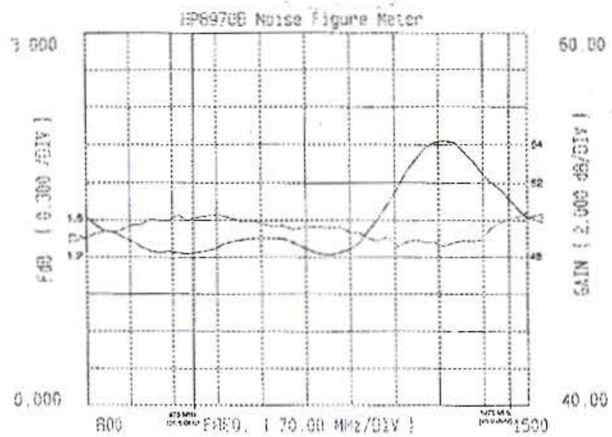


Fig.21: Measurement Curves for the Untuned Converter

2.5 Results

I compared two modified units. The first was tuned with the help of a Scalar Analyser HP8757C and an HP8970B Noise Figure Meter.

The second was made simply by repeating exactly the operations realised on the prototype without any tuning.

The results are very similar. On the tuned model, the Noise Figure is below 1.5dB and the gain is more than 44dB with a peak of 48dB near 10.13 GHz (IF = 1345 MHz). The minimum NF is 1.2 dB.

On the copy model, the Noise Figure is below 1.6 dB and the gain is more than 48dB with a peak of 52dB, near 10.12 GHz (IF = 1355 GHz). The minimum NF is 1.3dB.

The plots (Fig's.20 and 2) are not to the same scale because of measurements were not realised at the same time.

The gain difference between two converters is not very important and is mainly attributable to the gain spreads of the active devices, the important thing is the Noise Figure. The gain serves only to compensate for loss in

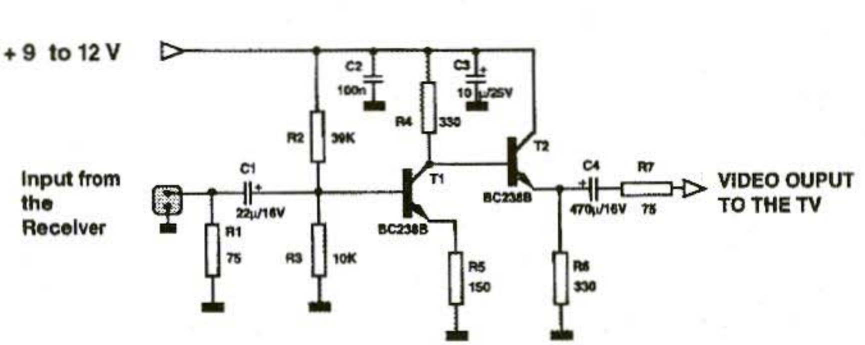


Fig.22: A Video Inversion Interface

the coaxial cable to the receiver, 45dB is more than enough to compensate for 30 meters of standard TV coaxial cable.

The peak of gain is at the same place on both converters because of the filter. This peak fits with the best NF because of the better masking of mixer losses at this frequency. The image frequency rejection is better than 32 dB.

In practice, the new receiving system was compared to an old one made from a diode cavity mixer without an amplifier (NF about 8dB). The results are quite impressive, the C/N in the same conditions passing from 3.5dB (very bad picture) to 10dB (normal picture) as confirmed by calculation sheets.

The accuracy of the local oscillator enables you to tune transmitters without the need for a Spectrum Analyser or other laboratory equipment. Keep 25 MHz from the band edges when tuning the central transmitting frequency and remember, that because of supradyne conversion, the output frequency (IF) decreases when the input increases, and vice versa.

3. THE RECEIVER

If you have already a satellite receiver, of course you can to use it. If it has the facility to invert the video you only need to connect the 10 GHz converter to receive off-air pictures. If there is no video inversion you must to build a small interface to invert it :

If you want to buy a system choose a receiver with:

- Video inversion (called C.Band capability), preferably programmable for each channel by software
- Display of the frequency (IF or LNB input).
- Fully tuneable and storable audio subcarriers, the best is 5.00 to 9.00 MHz in 10 kHz steps.
- "Not de-emphasise" auxiliary base band output (called MAC base band) for high speed digital transmissions

If you specialise in portable operation you can often locate models that operate from a 12 V supply.

You can also choose to construct your receiver, I did it but I do not recommend this solution now for cost reasons. A home made system is only interesting if you project a special use, such as to switch on a transmitter for a repeater.

5. CONCLUSION

The modification of TVRO Satellite systems is a good solution to enable relatively simple and cost effective operation Amateur TV on the 10 GHz band.

Electrical Performance:

- A good noise figure (<1.5 dB) is achieved without help of noise figure meter.

- Excellent stability and accuracy of the Local Oscillator thanks to the Dielectric Resonator Oscillator which is factory tuned.
- Benefit of all the facilities provided by satellite LNB (High gain, Power supply from output coax cable, etc.).
- High gain and efficiency of the antenna.

Mechanical Performance:

- The antenna is intended for outdoor use and as such is ready prepared for the elements.
- The LNB is completely weatherproof (very difficult to realise by the amateur).

Price:

- It is really difficult to construct such a system at the same price of commercial models. The unit price of all the microwave transistors included in the LNB is higher than a single polarisation LNB.

Availability:

- Satellite dishes and LNB's are available more easily than microwave components.

Facility:

- The modification of a Satellite converter can be realised by any Radio Amateur without the need of special equipment.

Time:

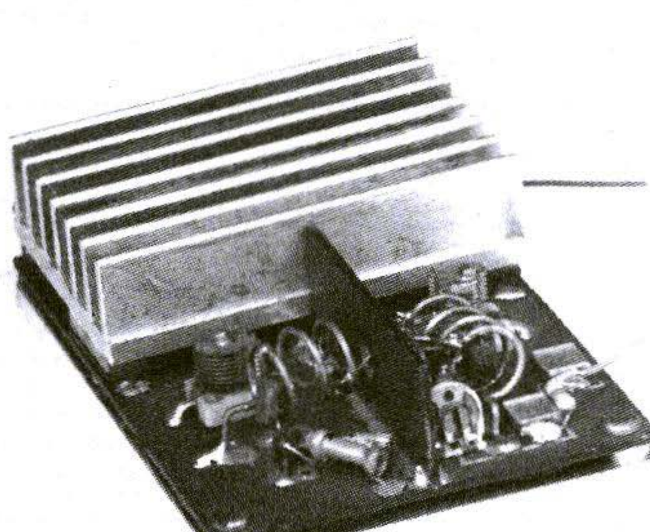
- The modification of a satellite receiving system can be completed very quickly. It is without comparison to the necessary time required to completely build completely a system

Carl G. Lodström, SM6MOM/W6

A Bi-Directional Amplifier for 2m

The unit described here is a small piece of equipment that can make life more enjoyable when using a 2m transceiver from a vehicle or whenever 12 V is available. It may also be useful where a long cable is needed to reach an antenna, permitting the use of RG-58 instead of the more expensive RG-8. If you live on a low floor in a high rise building, the unit could be remotely powered by a solar-charged battery, the charge/discharge being controlled by a remote relay. Or more simply, the unit could be mast-head mounted for greatest efficiency and powered from the transceiver end.

I built this project in early 1982 and have not changed it since and it is in regular service. Thirteen years later there may very well be better power modules than the BGY 35. Interesting to note that the 1/94 issue of VHF Communications arrived yesterday with the DJ8ES article about a hybrid power amp.



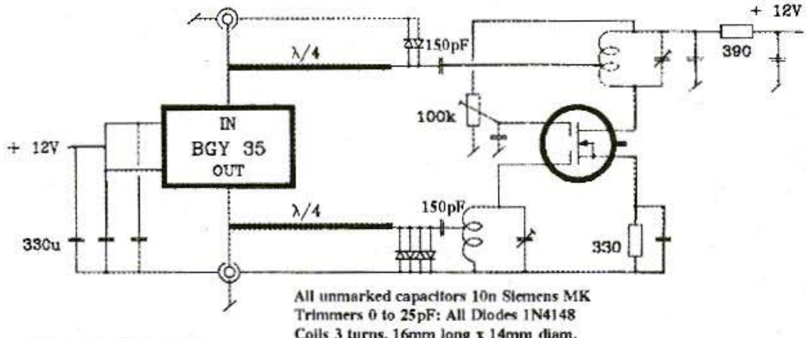


Fig.1 Circuit Diagram

The concept is one of isolating two bi-directional amplifiers by using 1/4 wave transmission lines. Regular 1N4148 diodes across the far ends of the transmission lines act as short circuits for larger signals. For the small signals involved in receiving, they become "invisible."

The transceiver power output at the modules must be less than 0.3W or the input of the power amplifier module will be destroyed. If your transceiver delivers more than required and allowing for the coaxial cable losses the power input to the module is still greater than 0.3W, add a few resistors on the power module input to attenuate the power to a safe level. The output power level for the 0.3W drive is in excess of 20W.

The receive pre-amplifier may not be exactly state-of-the-art, but it does have 17dB gain, which would be helpful to most modern 2m transceivers, whose actual on-air performances often expose the adventurous nature of manufacturers specifications writers! The 40673 RF transistor used in the preamplifier circuit is somewhat antique and better performance may be had by modernising this circuit. The purpose of this article is to demonstrate the concept, but if the preamplifier is not required it can be replaced with just two cross-connected diodes to ground! No extra receive gain, but no Tx/Rx relay or switching diodes to operate either.

One drawback of the system is that the first stage in this power module operates in class B, generating noise. However, measurements made using my IC-2AT transceiver showed that the normal input level of 0.18µV required for 20dB quieting, became 0.25µV due to this noise source with V_{B1} of the power module connected to 12V, which is acceptable. Permanent connection of V_{B2} on the power module to 12V does not generate noise and consumes no current unless the unit is driven.

The 1/4 wave transmission lines are 322mm lengths of RG174 cable.

An extra heat sink was later machined to press fit over the smaller one shown in the photograph. The small one shown was satisfactory only for short transmission times of a minute or so. With a larger heatsink much longer overs are possible.

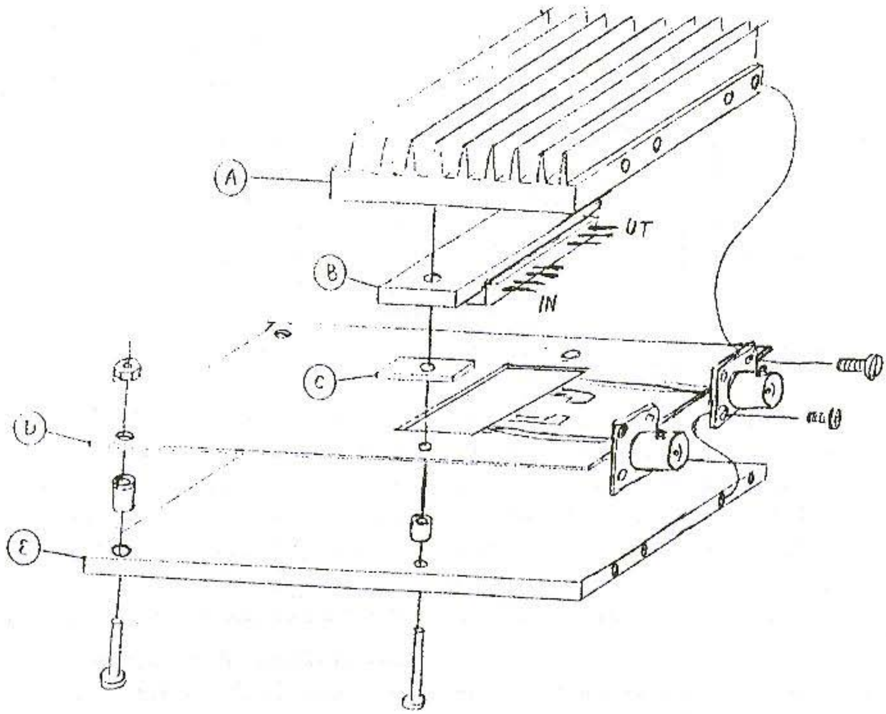


Fig.1: Mechanical Details
A = Heatsink; B = BGY 35 Power Module; C = Spacer. 1mm thick;
D = Double-sided Galss Fibre PCB 1/16 thick; E = 4mm Alum Sheet

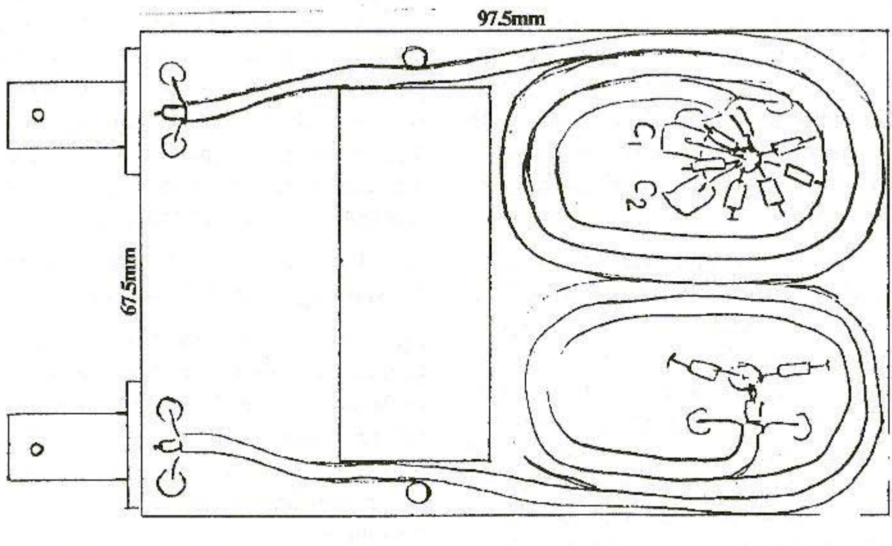


Fig.2: Layout of the 1/4 Wave Transmission Lines

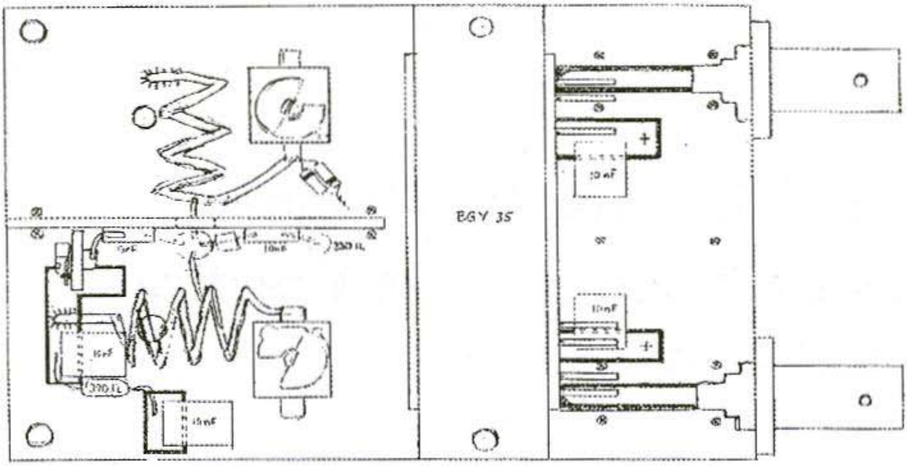


Fig.4: Component Layout

Carl G. Lodström, SM6MOM/W6

The Detector for Complex Impedances - Some Practical Additions

In the years gone since 1991 I have gathered some more practical experience with the Detector for Complex Impedances I descibed then (1).

1. SUGGESTED ADDITIONS

The kind of detectors that are the easiest to use are no doubt the kind where the diodes are grounded, all facing the same way. A differential amplifier can then handle the polarities, as in Fig.7 of (1). The only difference is that the 10k resistors would be in series with the 5M6 resistors, and the amplifiers inputs connected to the junction between them. This difference is immaterial to the operation.

Weak capacitive coupling to the line is sufficient. The device has plenty of sensitivity anyway.

The gain of the amplifiers may be left fixed since the oscilloscope or X-Y plotter has plenty of gain adjustment itself. It may be convenient to make the gain of one of the channels adjustable by some ±20%, just to make up for possible different coupling to the detectors, variations in different detector heads and loss along the transmission line.

The purist may also want reversing switches on the amplifier inputs, and between the outputs, so that the display can be flipped right side up and left/right to agree with normal orientation of a Smith chart. Smaller rotation can be had by means of adding a bit of extra cable between load and detector.

For use with different frequency heads, it may be advantageous to build the amplifiers in another box, using 5-pin 180° DIN audio plugs for interconnection. Ready made shielded cables of this kind are inexpensive and easily obtained from the local hi-fi store.

The detector head will then only have to contain the transmission line, four diodes and resistors, the 10k resistor in Fig.7 of (1), (a few kΩ to keep the RF from reaching the cable) and a DIN receptacle.

The "real" resistances limiting the bias current in the diodes to a few μA are in the other unit, near the amplifiers. Before they connect together to +15V (or -15V, whichever way you prefer to have the diodes) they connect to a balancing potentiometer with the wiper to + or - 15V. Another switch can be added for this polarity selection.

The balancing potentiometers, one for each channel, can very favourably be a joy stick, of the kind used in radio controlled aeroplanes.

2. CONSTRUCTION DETAILS

Since I used a tomato soup can for the detector, what is more logical than to use a cocoa can for the joy stick and amplifier?

The round lid on this can allows for its rotation. The joy stick is mounted to it, so the movement of the pin agrees with the movement of the display without having to twist the cables entering the bottom of the can.

My own "in-house-standard" for ±15 supply is the 240° DIN connector. The two remaining pins will conveniently carry the amplified and buffered signal back to the power supply in one cable,

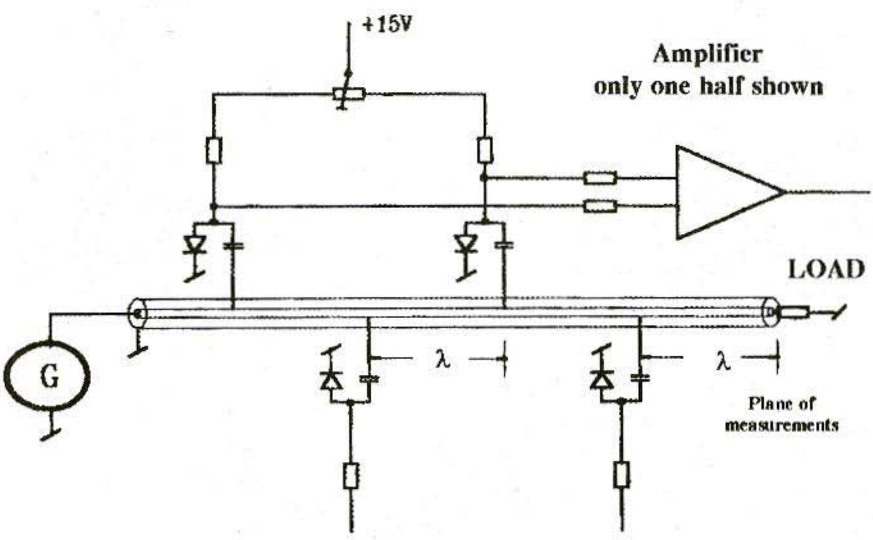


Fig.1: Suggested Circuit Modification

where they can be retrieved for the scope or plotter. In some instances the scope can provide the ±15V as well.

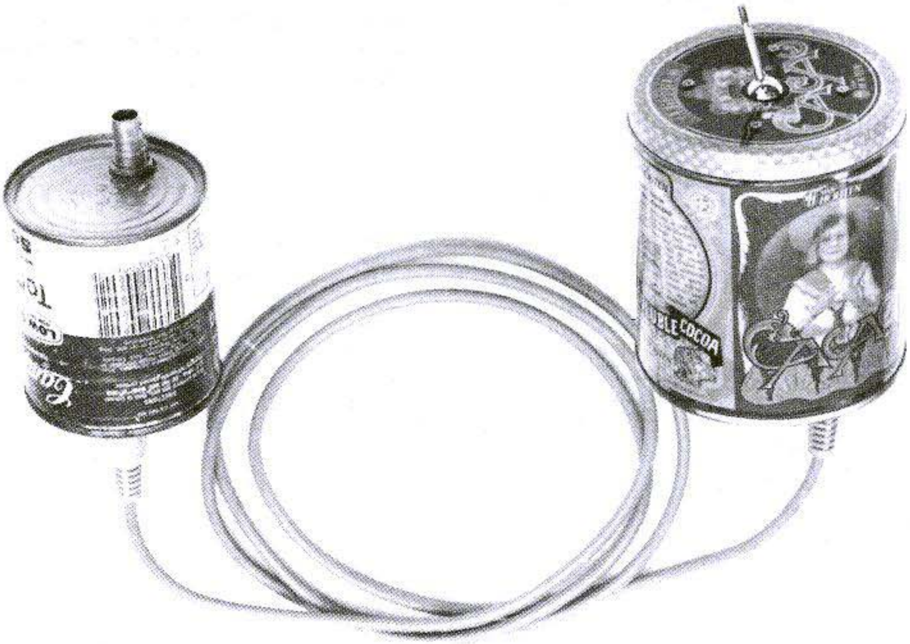
The AD 524 is a superb instrumentation amplifier, but they cost a bit too. I used the less expensive AMP-02 (also from Analog Devices) here. The selectable gain of 1-10-100-1000, the Sense and Reference pins, the input and output offset pins of the AD 524 are not needed. Gain is here set to a fixed 100X with a 510Ω resistor on each amplifier, and the offset is taken care of by means of the variable balance of bias currents.

Since the amplifiers are to feed the capacitances in the audio cable, it is a good idea to add at least some 100Ω in series with each output for stability. A much larger value will provide an intentional lowpass filtering of the output signal if there is no particular reason for to see very fast changes in the reflection coefficient.

By the way, since I wrote (1) I have got a copy of relevant pages describing the bridge in Fig. 3. of (1) Thanks Don/ W6OHZ! It is a Thurston bridge.

3. LITERATURE

(1) C.G.Lodström, Measurement Arrangements for Complex Impedances.
VHF Communications 2/91 pp. 93-101.



Ing. Jiri Otypka, CSc

Calculating the Focal Point of an Offset Dish Antenna

It is assumed that readers know how to calculate the focal point of a symmetrical parabolic antenna.

Offset antennae are a different matter. The popular belief here is that the focal point can not be established by simple means. However, this is not correct.

To establish the focal point of an offset antenna, we need to measure three parameters instead of two: the large and small elliptical axes and the maximum antenna depth.

The bulk of an offset antennae is formed by a three-dimensional space (Fig.1a).

The similarity of offset antennae is determined by two parameters, but no explicit expression is available.

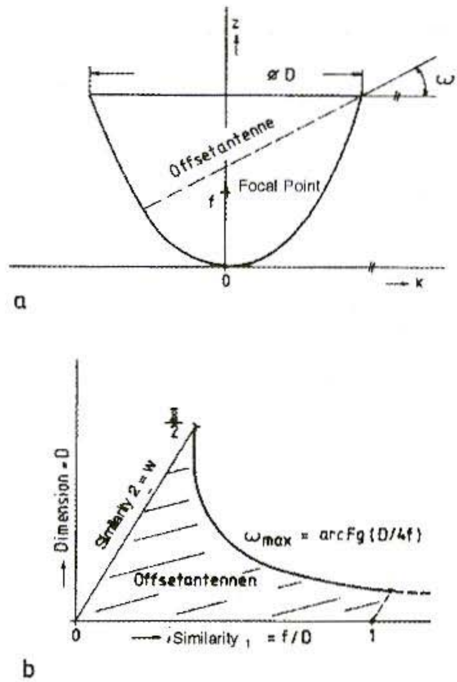


Fig.1: a. Definition of Offset Antennae
b. Similarity of Offset Antennae

The principle of offset antennae is described below, and the parameters and marginal conditions required to establish the focal point are given.

A listing of a small BASIC program is also included, together with some checking calculations.

Fig.2 shows an offset antenna with an even lateral face. It emerges as a section of a cylindrical paraboloid which is divided by a cut.

With a little effort, we can prove that:

1. Penetrating the plane and the surface of the circular paraboloid gives an ellipse
2. Projecting the penetration onto a plane running at right angles to the axis generates a circular line.

These important findings make it possible to establish the correction angle for the edge of the offset antenna:

$$\omega = \text{arctg} \quad u \qquad (1)$$

where

An equation can also be derived for the co-ordinate, x1:

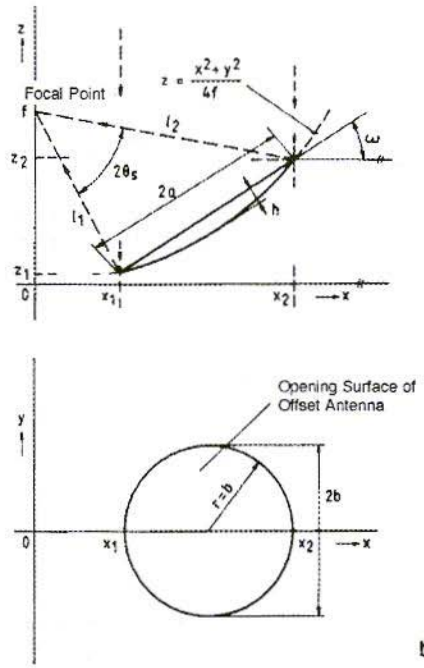


Fig.2: Offset Antennae with Even Lateral Faces in Two Views

For the focal point, the position is as follows:

The correction angle can be derived from equations (1) and (2) if it has not already been given by the manufacturer.

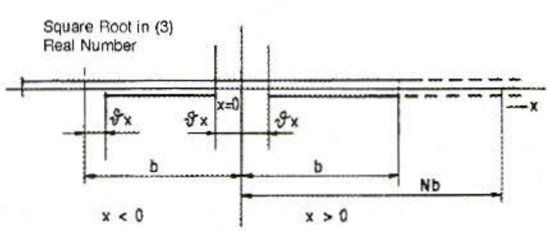


Fig.3: Aid to Solution of Equation (3)

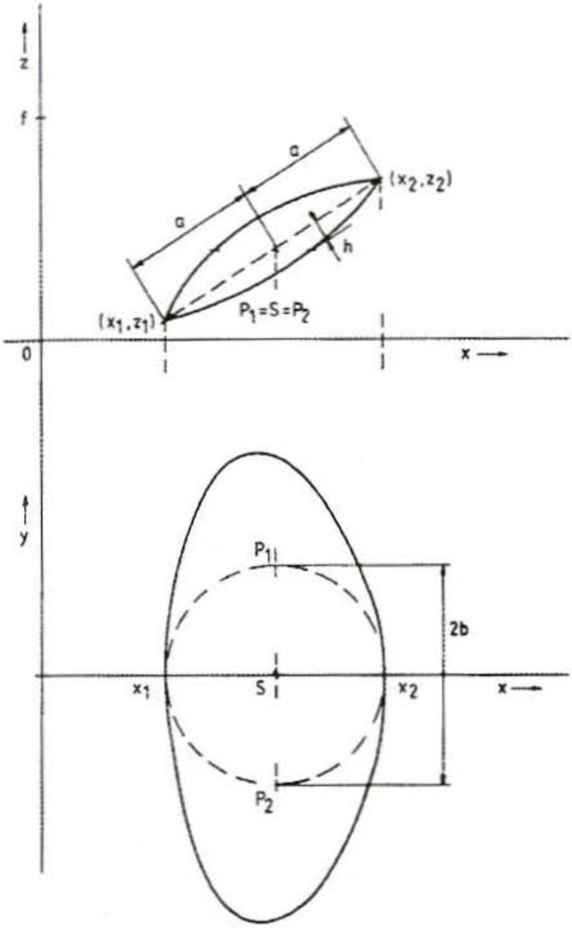


Fig.4: Optimised Offset Antennae with Uneven Lateral Faces

There is a simple method by which it can be calculated from the reflector width. It is more difficult to solve equation (3). It can be solved, for example, using the small BASIC program, or with a programmable pocket calculator.

First we must delineate the areas on the x axis which lead to unambiguous solutions for equation (3) for $f > \phi$ together with $z_2 > z_1$. Fig.3 shows the interval selection for the solution of the equation by means of interval halving.

We begin in the range $x < \phi$, which emerges as the penetration of the two intervals referred to. If no solution is found, the search is continued in the range $x > \phi$.

It is advantageous to select the interval δx - b. It can be shown that in (3) a (+) in front of the root for $x > \phi$ never leads to a solution.

If no solution has been found, the areas outside the brackets, which have so far been established as the standard accuracy, G = 0.001 (in the program),

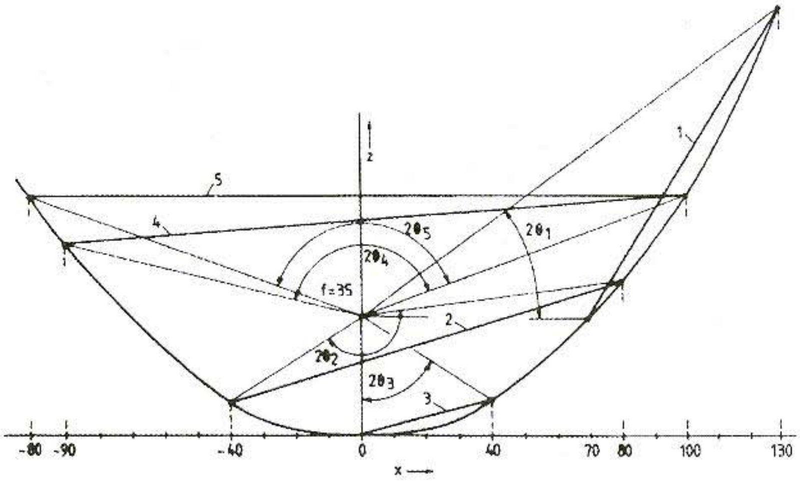


Fig.5: Examples of Offset Antennae with the same Focal Distance

δx = accuracy, b = DX (in the program) or N = 1 (δx - Nb), are expanded.

We now select a G < 0.001 or N > 1. The co-ordinate x1 is established with an accuracy of $\pm \delta x$.

In order to obtain a narrower major lobe in the directional diagram of the offset antenna, antennae are manufactured which do not have an even surface (Fig.4). These antennae also have a plane of symmetry y = ϕ, 2a and t can be measured in this plane.

The interval 2b can be measured in a plane which runs vertically to the plane y = diameter and which contains the points (x_1, z_1) and (x_2, z_2). To put it another way, for any even section selected through the surface of a rotation paraboloid, the points (x_1, z_1) and (x_2, z_2) can be obtained, which make it possible to measure the lengths 2a, 2b and t.

All the parameters can indeed be measured on a punched-out offset antenna. There remains only the problem of the correct classification of points (x_1, z_1) and (x_2, z_2), which are in the plane of symmetry.

In theory the classification is clear, but in practice there are always problems, so appropriate manufacturers' markings would be of assistance.

The point (x_1, z_1) lies at a position on the edge where the curvature of the section in the plane y = ϕ is greater than the curvature at point (x_2, z_2).

In many cases, only after precise antenna measurements can it be determined that the two points have been transposed. Fig.5 shows some examples for offset antennae. Here a focal length of 35 mm. is selected, and then some calculations are carried out.

The relevant parameters and results are shown in table form.

```
10   REM OFFSETANTENNE FOCAL POINT
20   REM J.OTYPKA, 1987
30   PI=3.141593
40   INPUT "2A (MM) = ;A
50   INPUT"2B(MM) = ;B
60   INPUT " T (MM) = " ;T
70   REM  SYMMETRICAL PARABOLIC
     ANTENNA ?
80   IF A<>B THEN GOTO 130
90   XI=-A/2: X2=A/2
100  F=A^2/16/T
110  Z1=T: Z2=T
120  OM=0: GOTO 710
130  REM ACCURACY G: DX=G*B/2
140  REM STANDARD G=.001
150  INPUT"STANDARD ACCURACY (Y/N)?";AO
160  REM X1MAX=N*B/2
170  REM STANDARD N=I
180  INPUT "N STANDARD (Y/N)?" ;BO
190  DX=.001*B/2
200  X1MAX=B/2
210  IF AO="J" THEN GOTO 240
220  INPUT"ACCURACY(1)=";G
230  DX=G*B/2
240  IF B0="J" THEN GOTO 270
250  INPUT " N (1) = " ; N
260  X1MAX=N*B/2
270  REM OUTPUT PARAMETERS
280  AB=A/B
290  U-SQR(AB^2-1)
300  REM CORRECTION ANGLE
310  OM=ATN(U)*18000/PI
320  OM=INT(OM)/100
330  POM=AB*T
340  X1MIN=-.5*POM/U+DX
350  X0MIN=-B/2+DX
360  IF X1MIN > X0MIN THEN GOTO 380
370  X1MIN=X0MIN
380  DEF FN F(X,K)=U/(B/2+X)-(X*U+POM+
     K*SQR((X*U+POM)^2-X*X*U^2))/(X*X)
390  REM SOLUTION EXISTS FOR X1<O ?
400  K=3
410  K=K-2
420  DMIN=FN F(X1MIN,K)
430  D0=FN F(-DX,K)
440  IF SGN(DMIN)=SGN(D0) AND K=I
     THEN GOTO 410
450  IF SGN(DMIN)=SGN(D0) THEN GOTO 530
460  X1=X1MIN
470  F1=DMIN
480  X2=-DX
490  F2=D0
500  GOSUB 990
510  XI=X3
520  GOTO 660
530  XI=DX
540  FL=FN F(X1,-1)
550  X2=X1MAX
560  F2=FN F(X2,-I)
570  IF SGN(FI)<>SGN(F2) THEN GOTO 620
580  AO="N"
590  BO="N"
600  PRINT "EXPAND LIMITS!"
610  GOTO 210
620  REM SOLUTION FOR XI>0
630  K=-I
640  GOSUB 990
650  XI=X3
660  REM PARAMETERS SOUGHT
670  F=(B/2+X1)/2/U
680  ZI=XI*XI/4/F
690  X2=XI+B
700  Z2=X2*X2/4/F
710  L1=SQR(X1*X1+(F-Z1)*(F-Z1))
720  L2=SQR(X2*X2+(F-Z2)*(F-Z2))
730  DZ=(L1^2+L2^2-A^2)/2/L1/L2
740  REM ACS:750-800
750  IF DZ<> THEN GOTO 770
760  DZ=90:GOTO 810
770  ACS-ATN(SQR(1/DZ/DZ-1))
780  IF DZ>0 THEN GOTO 800
790  ACS=3.141593-ACS

800  DZ=INT(ACS*18000/PI)/100
810  PRINT
820  PRINT "OFFSET ANTENNA
     PARAMETERS: "
830  PRINT
840  PRINT "2A (MM) ;A
850  PRINT"2B (MM) = ;B
860  PRINT"DEPTH (MM) = ";T:PRINT
870  PRINT "CORRECTION ANGLE
     (DEGREE) = " ;OM
880  PRINT"FOCAL POINT LENGTH F (MM) = F
890  PRINT"X1 (MM) = " ;X1
900  PRINT"Z1 (MM) = " ;Z1
910  PRINT"X2 (MM) = " ;X 2
920  PRINT"Z2 (MM) = ";Z2
930  PRINT"L1 (MM) = ";L1
940  PRINT"L2 (MM) = ";L2
950  PRINT"ANGLE 2DZ (DEGREE) = "DZ
960  PRINT
970  STOP
980  REM INTERVAL HALVING
990  X3=(X1+X2)/2
1000 DF=ABS(X1-X2)
1010 IF DF<DX THEN GOTO 1100
1020 F3=FN F(X3,K)
1030 IF SGN(F3)<>SGN(FI) THEN GOTO 1070
1040 XI=X3
1050 FI=F3
1060 GOTO 990
1070 X2=X3
1080 F2=F3
1090 GOTO 990
1100 RETURN
```

Table: GW BASIC Program Listing

If we use the BASIC program, we must initially increase the intervals after entering the standard parameters. The standard accuracy has been retained, N has been defined as N = 2, and finally N = 3 has been selected, which led to a solution. In the second case, it was not necessary to alter the standard parameters.

In the third case, in which the section ran through the impermissible area $x1 = \phi$, the intervals had to be increased again. So G = 0.00001 was selected and x1 calculated. The area around $x_1 = \phi$ can be avoided if the input parameter is altered "infinitesimally".

In practice, this case presents no difficulties, and so no special researches or calculations were needed.

In the fourth case, a higher accuracy was selected for x_1, from x = 0.1 mm. to x = 0.01 mm.. If we lay down that 2a = 2b, we are pre-setting the values of a symmetrical parabolic antenna, which is shown in Fig.5.

In accordance with the principles set out above, here are some explicit examples of the application of the program:

1. Establishing focal point:
   a. For correct placing of radiator
   b. Determining phase centre of radiator used
2. Modification or copying of given parabolic antennae

LITERATURE

Otypka, J.:
Urceni ohniska ofsetore anteny
Sdelovaci technika, c. 8, 1992

Index of Volume 26 (1994)

AMATEUR TELEVISION

SATELLITE RECEPTION

(see also the ANTENNA TECHNOLOGY section on page-31)

2m BAND

70cm BAND

24cm BAND (see also the ANTENNA TECHNOLOGY section on page-31)

MISCELLANEOUS

Matjaz Vidmar, S53MV

A DIY Receiver for GPS and GLONASS Satellites Part-4

In this part of the series complete construction details will be shown for the GPS RF Module and the IF Converter, the GLONASS RF Module and IF Converter and the GLONASS PLL Synthesiser Converter.

4. The RF and IF Stages of the GPS and GLONASS Converters.

4.1 The Antenna

The Quadrifilar Backfire Antenna used by the Author for this project was described in part-3b of this project in VHF Communications 4/1994, pp.197 - 200.

4.2. Low-Noise Amplifier

This unit, which is common to both the GPS and the GLONASS receive converters was described fully in VHF Communications 2/1992, pp. 90 - 96 and is available as a separate kit from KM Publications *(see the advertisement on page 17 of this issue)*.

4.3. GPS RF Module

The GPS receiver only requires a single-frequency (1575.42 MHz) downconverter and its design is relatively straightforward. The GPS downconverter includes two modules: a RF module built in microstrip technology and an IF strip built on a simple, single-sided printed circuit board.

The circuit diagram of the GPS RF module is shown on Fig.19. The GPS RF module includes three RF amplifier

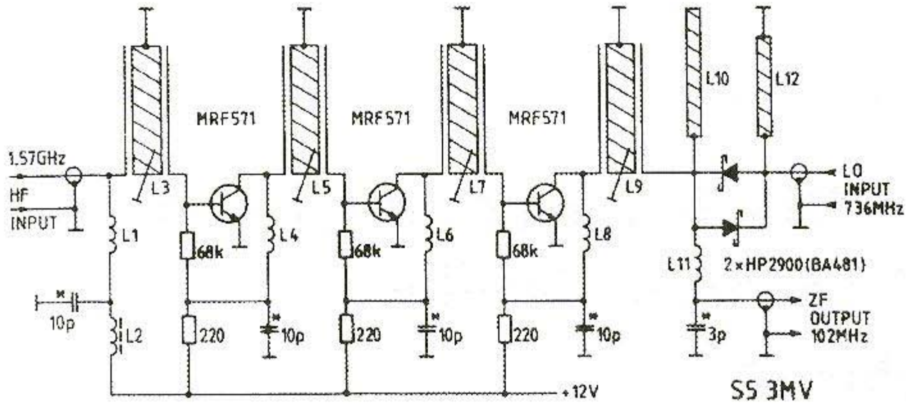


Fig.19: GPS RF Module

stages and the first downconversion mixer. The amplifier stages are identical and use silicon MRF571 transistors. Much of the gain provided by these transistors is lost in the microstrip filters, since the latter are etched on a lossy but inexpensive glass fibre-epoxy laminate.

The first downconversion to 102 MHz is performed by a harmonic mixer using two anti-parallel Schottky diodes HP2900, BA481 or similar. Such a mixer has a higher noise figure than conventional diode mixers, especially when using the suggested low frequency diodes. On the other hand, the required local oscillator signal is at 736 MHz, only half of the frequency required for the downconversion (1473 MHz).

The RF module circuit includes a network to supply with +12V the GaAs FET preamplifier through the RF cable. On the other hand, the +12V supply voltage for the RF module itself is taken out of the IF converter, after

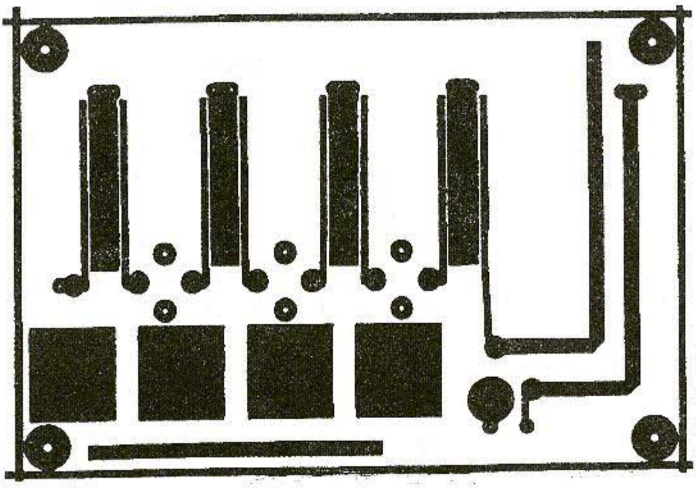


Fig.20: GPS RF Module, upper side (top view)

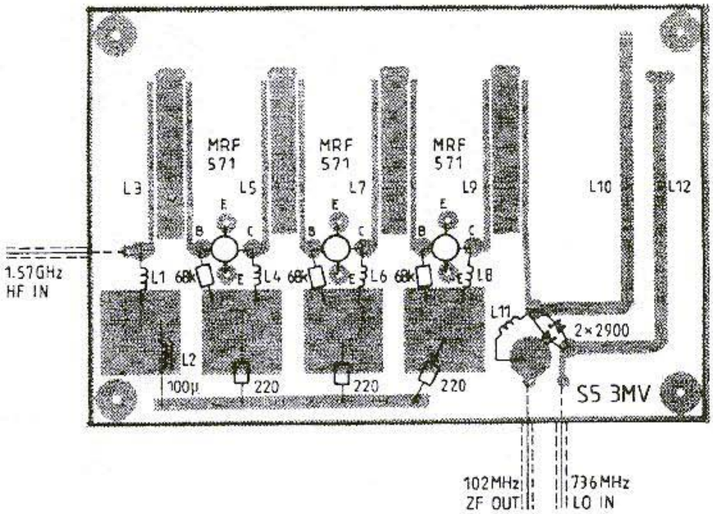


Fig.21: GPS RF Module Component Overlay

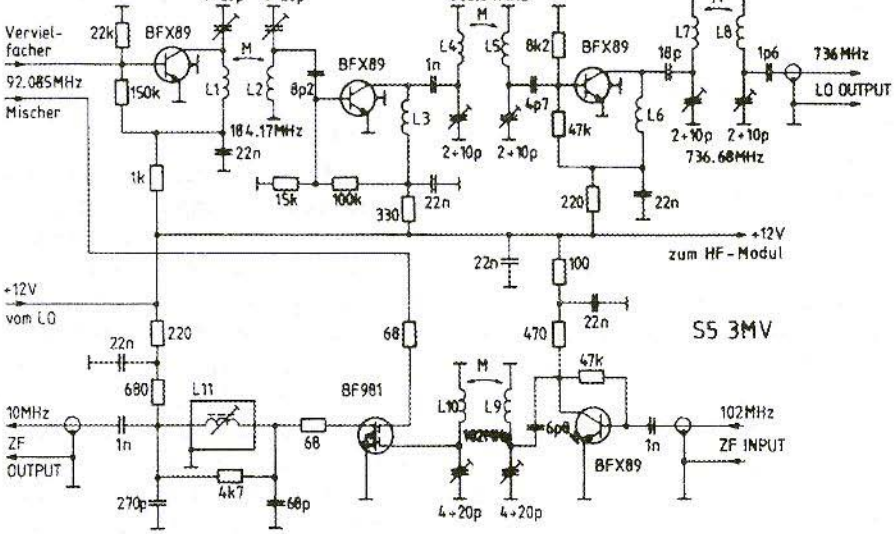


Fig.22: GPS IF Converter Multiplier and Mixer

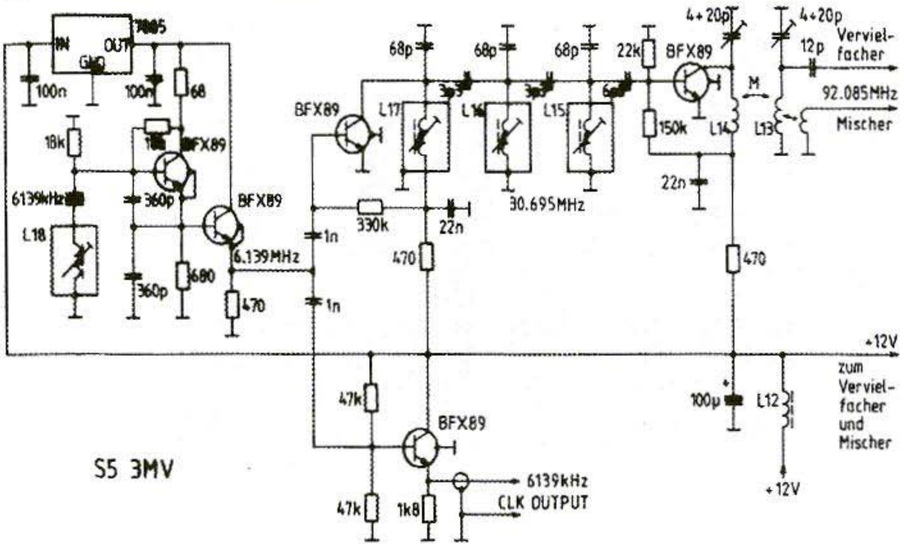


Fig.23: GPS IF Converter Local Oscillator

being filtered by a choke and a 100uF capacitor. The RF module is built in microstrip technology on a double-sided board made of 0.79mm thick glass fibre-epoxy. The upper side is shown on Fig.20 while the lower side is not etched. The location of the components is shown on Fig.21. Before installing the components, L3, L5, L7, L9 and L12 should be grounded by soldering small Unshaped pieces of wire at the marked locations.

L1, L4, L6, L8 and L11 are quarter-wavelength chokes. These are made from about 6cm of 0.15mm thick copper enamelled wire, tinned for about 5mm at each end. The remaining wire is wound on a 1mm inner diameter and the finished chokes are small self-supporting coils. on the other hand, L2 is a commercial 100uH "moulded" choke.

It is recommended to use thin Teflon coax like RG-188 for the internal RF wiring of the GPS receiver. The braid of the cable should be soldered directly to the microstrip groundplane while the central conductor reaches the upper tracks through a hole in the printed-circuit board. To avoid shorts, the copper plating around this hole on the groundplane side should be carefully removed using a much larger (3mm) drill tip.

The GPS RF module needs some adjustments of the striplines and these are best performed after all of the receiver hardware is assembled. L3, L5, L7 and L9 usually need to be trimmed shorter by about 1mm at the open end to achieve the maximum gain at 1575 MHz. On the other hand, L10 and L12 may need some small pieces of copper foil (about 7mmx7mm) at different locations along these striplines to achieve the best noise figure from the diodes actually used in the mixer.

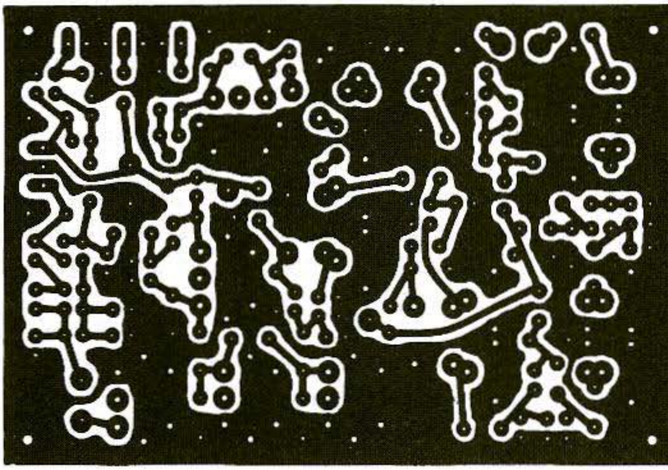


Fig.24: GPS IF Converter, bottom view

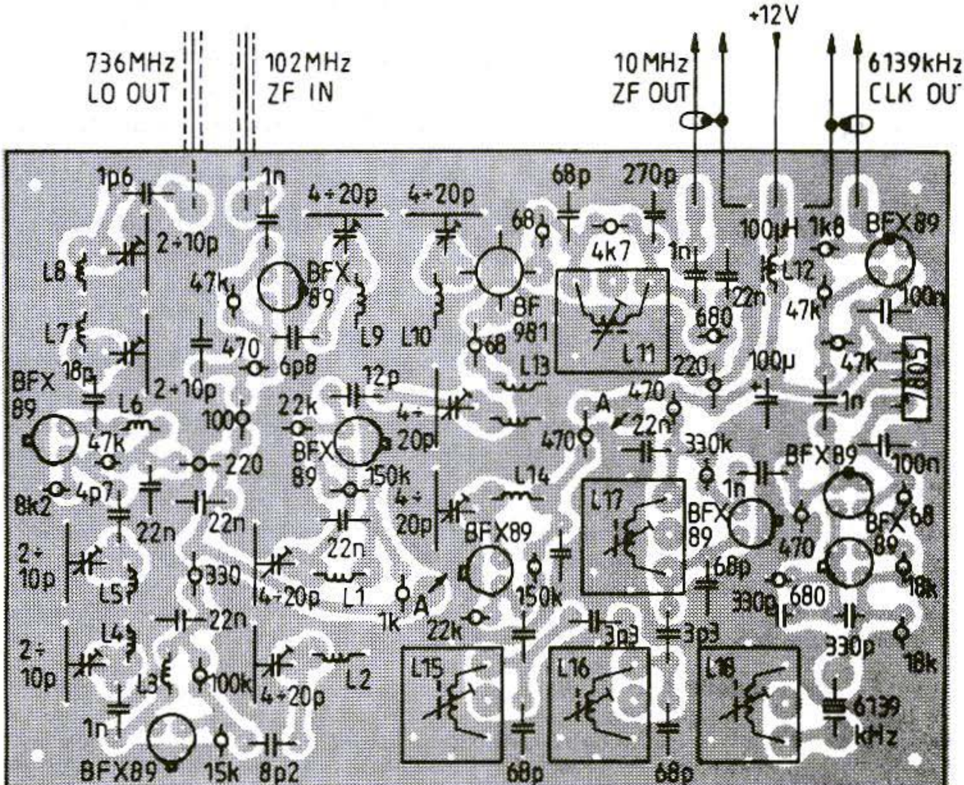


Fig.25: GPS IF Converter Component Overlay

4.4. GPS IF Converter

The GPS IF strip includes a second downconversion to 10 MHz, signal amplification and limiting at 10 MHz and the generation of all required local oscillator and clock signals from a single master frequency reference.

The second downconversion to 10 MHz and the LO frequency generation is included in the GPS IF converter module shown on Fig.22 and Fig.23. The GPS IF converter module includes a 6139 kHz crystal oscillator (Fig.23). This frequency is used both for signal sampling and suitably multiplied for both downconversions. Since the required short term stability is very high, in the I.E-9 range, to be able to demodulate the 50 BPS PSK navigation data, the crystal oscillator has its own supply regulator 7805 and is followed by two buffer stages.

The crystal oscillator output frequency is first multiplied by five to obtain 30.7 MHz and then by three to obtain the 92 MHz required for the second downconversion. Three additional frequency-doubler stages are required to obtain the first downconversion signal at 736 MHz from the available 92 MHz signal. The design of all multiplier stages is similar and is using two tuned circuits in each stage except for the first stage, where three tuned circuits are necessary due to the higher multiplication factor.

The 102 MHz IF signal is first amplified (BFX89) and then filtered (L9 and L10). The second mixer is a simple dual-gate MOSFET mixer (BF981). The selectivity provided by the tuned circuits at 102 MHz (L9 and L10) and at 10 MHz (L1) is already comparable to the GPS C/A-code signal bandwidth (2 MHz)In fact, L11 already requires damping resistors to achieve the required bandwidth.

The GPS IF converter is built on a single-sided board as shown on Fig.24. The location of the components is shown on Fig.25. Due to the limited space all of the resistors are installed vertically. The capacitors are conventional ceramic discs (except for 10OuF) with a pin spacing of 5mmCapacitive trimmers are plastic foil types of 7.5mm diameter: green 4-20pF and yellow 2-10pF. There is also a wire jumper marked with "A".

The BFX89 is used as an universal RF transistor in this module and has many possible replacements: BFY90, BFW30 etc. The four leads of the BF981 MOSFET are bent so that the device is inserted in the printed-circuit board with the marking towards the board. The 7805 regulator does not require a heat sink provided that it is-a TO-220 version.

The GPS IF converter includes several inductors. Most of them are air-wound, self-supporting coils wound with copper enamelled wire of either 0.5mm or 1mm diameter. The turns of these coils are not spaced and the leads go straight through the printed-circuit board without any additional bending or forming. In these way the coils themselves have about 1/4 of a turn less than specified in the following paragraph.

L1 and L2 have 3 turns each of 1mm wire wound on a 4mm inner diameter. L3 has 5 turns of 0.5mm wire wound on a 3mm inner diameter. L4 and L5 have two turns each of 1mm wire wound on a 3mm inner diameter. L6 has 3 turns of 0.5mm wire wound on 3mm inner diameter. L7 and L8 have one single turn (or "U" loop) of imam wire with a 3mm inner diameter. L9 and L10 have 5 turns each of 0.5mm wire on a 4mm inner diameter. Finally, L13 and L14 have 6 turns each of 0.5mm wire wound on a 4mm inner diameter. L13 has an additional coupling loop of one single turn around the main winding.

L11, L15, L16, L17 and L18 are wound on standard cores for IF transformers (Toko or Mitsumi) with the external dimensions of 10mm x 10mm. L11 should have about 4.5uH and in practice this means 15 turns of 0.15mm diameter copper enamelled wire on a 10.7 MHz IF transformer core set including a fixed central ferrite core, an adjustable ferrite cup, various plastic support parts and a metal shielding can. L15, L16 and L17 should have about 0.4uH and in practice have 6 turns of 0.15mm diameter copper enamelled wire on a 36 MHz IF transformer core set including a plastic support with a central adjustable ferrite screw, a plastic cap and a metal shielding can.

The exact value of L18 depends on the crystal used and the frequency required. In all of the prototypes built inexpensive computer crystals designed for 6144 kHz were used. These require quite a large inductivity to be pulled 5 kHz down to about 6139 kHz. An inductivity around 40uH is required for this shift. The exact value depends much on the crystal used and the parasitic capacitances of the circuit. Since the performance of the GPS receiver depends on the stability of this master crystal oscillator, also L18 needs to be very stable. Therefore a 36 MHz IF transformer core set is recommended and the latter requires about 60 turns of 0.08mm diameter copper enamelled wire.

Finally, L12 is a 100 uH "moulded" choke.

The GPS IF converter has several connections. The two coax cables carrying IF and LO signals to the RF module and the +12V supply wire for the RF module are all soldered directly to the bottom side of the IF converter module. The 10 MHz IF output, the 6139 kHz clock output and the +12V supply voltage are available on a 7-pin connector obtained from a piece of a good-quality IC socket with round contacts.

The GPS IF module requires several adjustments, but the crystal oscillator should be adjusted first to roughly 6139 kHz. Then the multiplier chain should be adjusted. Each multiplier stage should be adjusted to provide the maximum signal at the required frequency to the next stage. The levels of the RF signals can be easily monitored with a DC voltmeter, since they are rectified by the BE junction of the next stage. Without any RF input, the DC voltage is set to about 0.7V across the BE junction. When the multiplier chain is operating correctly, this voltage should decrease down to about zero and may even become negative

If the transistor base goes more negative than -0.5V, RF transistors may be damaged and this should be avoided by decreasing the values of the coupling capacitors.

Of course, the voltmeter required for these adjustments should only be connected through a RF choke to avoid disturbing the RF circuit. A 10kohm resistor may also be used as a RF choke. In this way all of the multiplier stages can be adjusted except the last one to 736 MHz, since no BE junction follows this stage. The level of the 736 MHz signal is monitored in a different way, by connecting a DC ohmmeter to the IF output Of the mixer. The higher the LO signal level, the lower the resistance measured by the ohmmeter.

The signal circuits (L9, L10 and L11) are best adjusted after the receiver is completely assembled, since the following IF amplifier has a S-meter output. A grid-dip meter can be used as a signal source at 102 MHz. The trimmers in parallel to L9 and L10 tune almost to their maximum capacity and L10 may sometimes require an additional capacitor in parallel. The final adjustment of the signal circuits is best performed on a real GPS signal obtained from a directional antenna (a 15 turn helix or a small dish) pointed to a GPS satellite.

Finally, the crystal oscillator should be adjusted to the exact frequency required by the software. For the current version V122 the exact frequency is 6139.050 kHz, but this may change in the future. The exact frequency is specified in the program listing.

4.5. GLONASS RF Module

The GLONASS receiver requires a tuneable downconverter across all of the 25 GLONASS channels spacing from 1602 MHZ to 1615.5 MHz, therefore its design is more complicated than the GPS counterpart. The GLONASS downconverter is divided into four modules for shielding purposes and differences in the construction technology: an RF module and a PLL synthe-

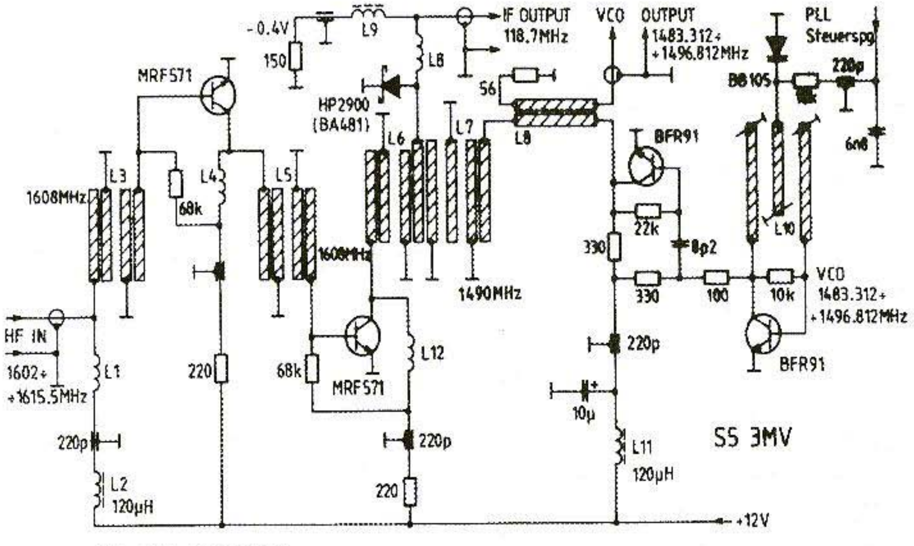


Fig.26: GLONASS RF Module

siser converter built in microstrip technology and an IF converter and synthesiser logic built on simple, single-sided printed circuit boards.

The circuit diagram of the GLONASS RF module is shown on Fig.26. The GLONASS RF module includes two selective RF amplifier stages, the first receiver mixer to the first (fixed) IF of 118.7 MHz, and a VCO followed by a buffer stage. The two RF amplifier stages are identical and use MRF571 transistors. Since the GLONASS RF module is built on a lossy, but thicker laminate than GPS, the losses in the RF filters are lower and two amplifier stages provide enough gain.

The VCO includes an amplifier (BFR91) and a highly-selective interdigital filter feedback network. Such a VCO can only cover a very limited frequency range (about 10% around the central frequency), but its phase noise is very low. The VCO is tuned by a BB105 varicap in the central finger of the interdigital feedback network.

The VCO is followed by a buffer stage with another BFR91A microstrip coupler takes part of the VCO output signal to drive the PLL circuits. The VCO and RF signals are then combined in an interdigital filter network to feed the mixer diode HP2900 or BA481.

The GLONASS RF module circuit includes a network to supply with +12V the GaAs FET preamplifier through the RF cable.

The GLONASS RF module is built in microstrip technology on a double-sided board made of 1.57mm thick glass fibre-epoxy. The upper side is shown on Fig.27 while the lower side is not etched. The location of the components is shown on Fig.28. Before installing the components, the resonators of L3, L5, L6 and L7 should be grounded by soldering short pieces of 1mm diameter copper wire at the marked locations. The transistors and diodes are installed in 6mm diameter holes in the printed circuit board.

L1, L4, L8 and L12 are quarter-wavelength chokes. These are made from about 6cm of 0.15mm thick copper enamelled wire, tinned for About 5mm at each end. The remaining wire is wound on a 1mm inner diameter and the finished chokes are small self-supporting coils. On the other hand, L2, L9 and L11 are commercial 12OuH "moulded" chokes.

RF interconnections inside the GLONASS receiver are made with thin Teflon coax like RG-188, installed just like in the GPS receiver front end. On the other hand, GLONASS microstrip modules include feedthrough capacitors to save space on the printed-circuit boards. The feedthrough capacitors are soldered to the microstrip groundplane from the bottom side. Some components, like chokes and resistors in the supply network, are also installed on the bottom side of the microstrip boards.

The GLONASS RF module only needs few adjustments, mainly to the VCO feedback network. To cover the desired frequency range, the central finger usually needs to be trimmed shorter by several mm. The two side fingers-may need adjustments if the VCO stops oscillating at band edges.

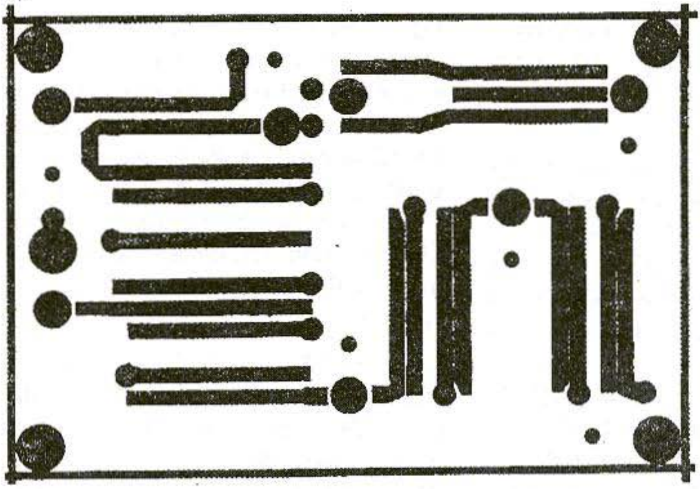


Fig.27: GLONASS RF Module, upper side (top view)

The remaining interdigital filters usually do not need any adjustments to provide the best performance in the desired frequency range. If the VCO is operating correctly, the mixer diode will provide a rectified voltage of about -0.4V across the 150ohm resistor.

4.6. GLONASS IF Converter

The GLONASS IF strip includes a second downconversion to 10.7 MHz, signal amplification and limiting at 10.7 MHz and the generation of the required local oscillator and clock signals from a single master frequency reference.

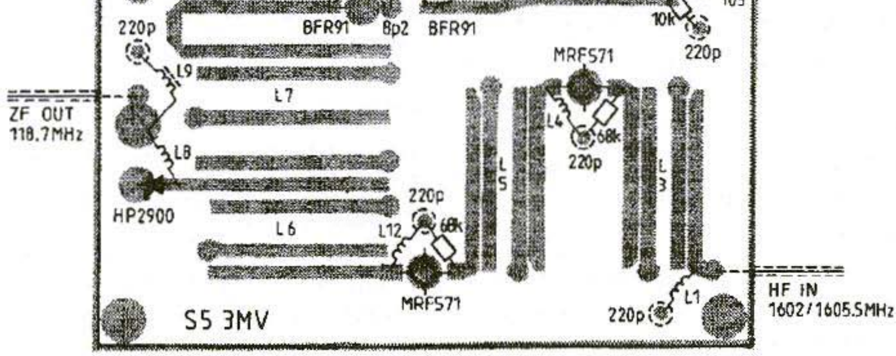


Fig.28: GLONASS RF Module Component Overlay

The second downconversion to 10.7 MHz and the LO frequency generation is included in the GLONASS IF converter module shown on Fig.29. The GLONASS IF converter module includes an 18 MHZ master crystal oscillator. This frequency is used, divided by four, for signal sampling, divided by 32 as the PLL reference frequency and suitably multiplied for the second signal downconversion and for the PLL downconversion. The GLONASS IF module only includes the oscillator and some multiplier stages. The dividers are located in the PLL synthesiser logic module and the last frequency multiplier is in the PLL synthesiser converter. Like in the GPS receiver, the required short term stability is very high, in the 1-E-9 range, to be able to demodulate the 50 BPS PSK navigation data Therefore the crystal oscillator has its own supply regulator 7805 and is followed by two buffer stages just like in the GPS IF converter module.

The crystal oscillator output frequency is first multiplied by three to obtain 54 MHz. This signal is then doubled to 108 MHz for the second downconversion and multiplied by three to obtain 162 MHz to drive the PLL synthesiser converter, using two separate multiplier stages fed by the same 54 MHz signal. The 162 MHz signal is further amplified in a buffer stage (BFR96) to drive the SRD multiplier in the PLL synthesiser converter.

Since the described GLONASS receiver includes a more complicated RP front-end than GPS, more filtering is required in all multiplier stages to avoid spurious frequencies. Therefore multiplier stages may have three or even more tuned circuits on their outputs. The 118.7 MHz IF signal is filtered (L9, L10 and L11) and amplified (BFX89). The second mixer is a simple dual-gate MOSFET mixer (BF981). The selectivity provided by the tuned circuits at 118.7 MHz (L9, L10 and L11) and at 10.7 MHz (L12) is already comparable to the GLONASS C/A-code signal bandwidth (1.2 MHz). In fact, L12 already requires damping resistors to achieve the required bandwidth.

The GLONASS IF converter is built on a single-sided board as shown on Fig.30. The location of the components is shown on Fig.31. Due to the limited space all of the resistors are installed vertically. The capacitors are conventional ceramic discs (except for 100uF) with a pin spacing of 5mmCapacitive trimmers 4-2OpF are a plastic foil type of 7.5mm diameter, marked with a green body. There is also a wire jumper marked with "A".

The BFX89 is used as an universal RF transistor as in the GPS IF converter. Also the BF981 is installed just like in the GPS IF converter module and a TO-220 case 7805 regulator is recommended so that no heat sink is required.

The GLONASS IF converter includes several inductors. Most of them are air-wound, self-supporting coils wound with copper enamelled wire of 0.5mm diameter. The turns of these coils are not spaced and the leads go straight through the printed-circuit board without any additional bending or forming. In these way the coils themselves have about 1/4 of a turn less than specified in the following paragraph.

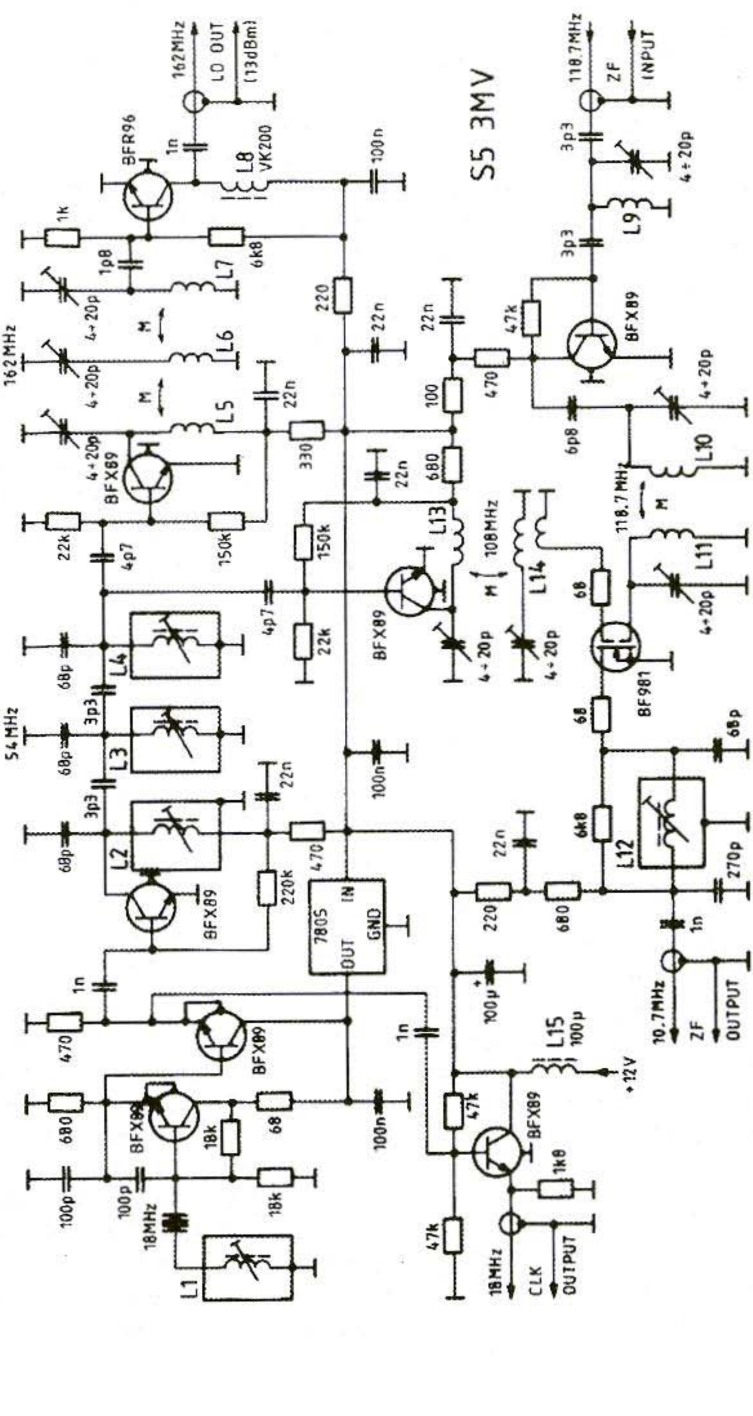


Fig.29: GLONASS IF Converter

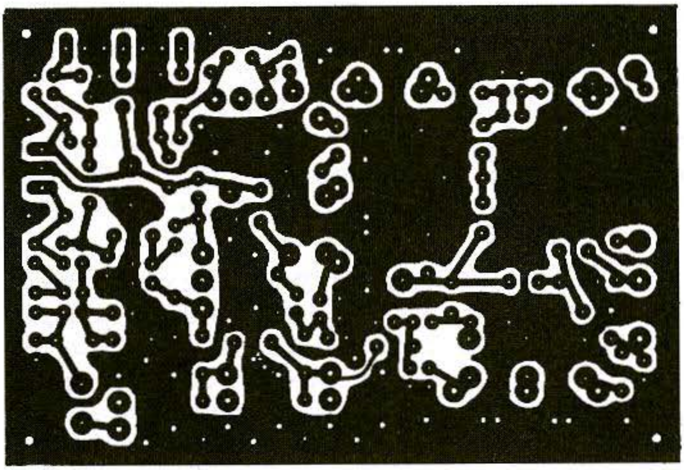


Fig.30: GLONASS IF Converter, bottom view

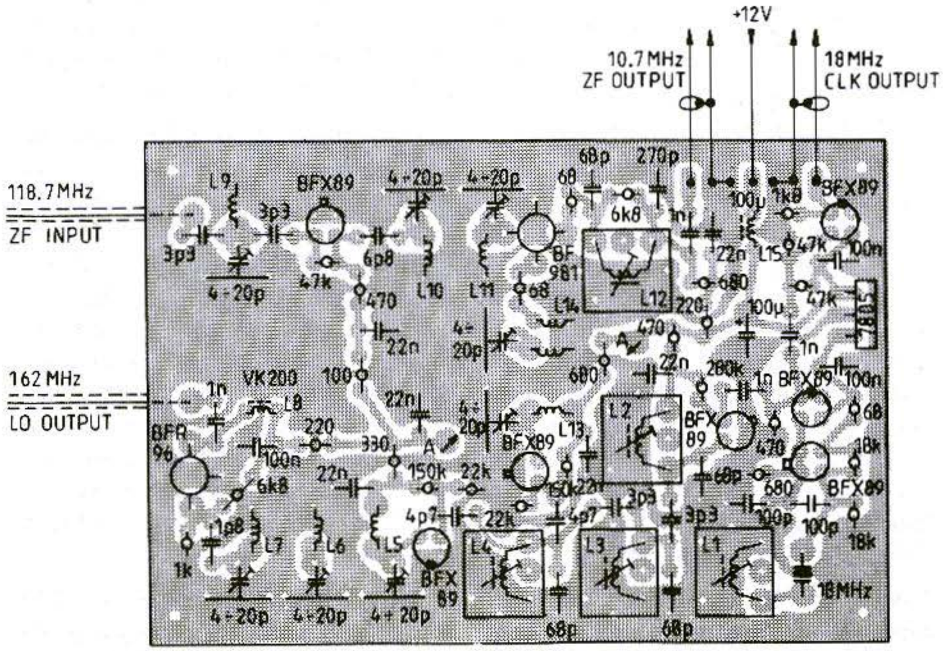


Fig.31: GLONASS IF Converter Component Overlay

L5, L6 and L7 have 4 turns each wound on a 3mm inner diameter. L9, L10 and L11 have 4 turns wound on a 4mm inner diameter. L13 and L14 have 5 turns wound on a 4mm inner diameter. L14 has an additional coupling loop of one single turn around the main winding. L1, L2, L3, L4 and L12 are wound on standard cores for IF transformers (Toko or Mitsumi) with the external dimensions of 1mm x 10mm.

L12 should have about 4.5uH and in practice this means 15 turns of 0.15mm diameter copper enamelled wire on a 10.7 MHz IF transformer core set including a fixed central ferrite core, an adjustable ferrite cup, various plastic support parts and a metal shielding can. L2, L3 and L4 should have about 0.13uH and in practice have 3 turns of 0.3mm diameter copper enamelled wire on a 36 MHz IF transformer core set including a plastic support with a central adjustable ferrite screw, a plastic cap and a metal shielding can.

The exact value of L1 depends on the crystal used and the frequency required. In all of the prototypes built inexpensive computer crystals designed for 18OOO kHz, series resonance, were used. These require a small inductivity in series to compensate for the feedback capacitors of the oscillator network. In practice about 2uH were required, corresponding to 16 turns of 0.15mm diameter copper enamelled wire on a 36 MHz IF transformer core set.

Finally, L8 is a VK200 "six-hole" ferrite choke and L15 is a 10OuH "moulded" choke.

The GLONASS IF converter module has several connections. The two cables carrying the 118.7 MHz IF from the RF module and the 162 MHz LO to the PLL synthesiser converter are all soldered directly to the bottom side of the IF converter module. The 10.7 MHz IF output, the 18 MHZ clock output and the +12V supply voltage are available on a 7-pin connector obtained from a piece of a good-quality IC socket with round contacts.

In the GLONASS IF converter module the multiplier stages should be aligned first, just like in the similar GPS module. However, only the output of the first multiplier stage to 54 MHz can be monitored as a dip of the following stage base voltage. The output of the 108 MHz multiplier may be observed as a dip in the drain voltage of the BF981 mixer, while the output of the 162 MHz multiplier may be measured as the rectified voltage by the SRD multiplier in the PLL synthesiser converter.

The signal circuits (L9, L10, L11 and L12) are best adjusted after the receiver is completely assembled, since the following IF amplifier has a S-meter output. A grid-dip meter can used as a signal source at 118.7 MHz. The trimmers in parallel to L9, L10 and L11 tune almost to their maximum capacity. The final adjustment of the signal circuits is best performed on a real GLONASS signal obtained from a directional antenna (a 15 turn helix or a small dish) pointed to a GLONASS satellite.

Finally, the crystal oscillator should be adjusted to the exact frequency required by the software. For the current version V39 the exact frequency is 18000.000 kHz, but this may change in the future.

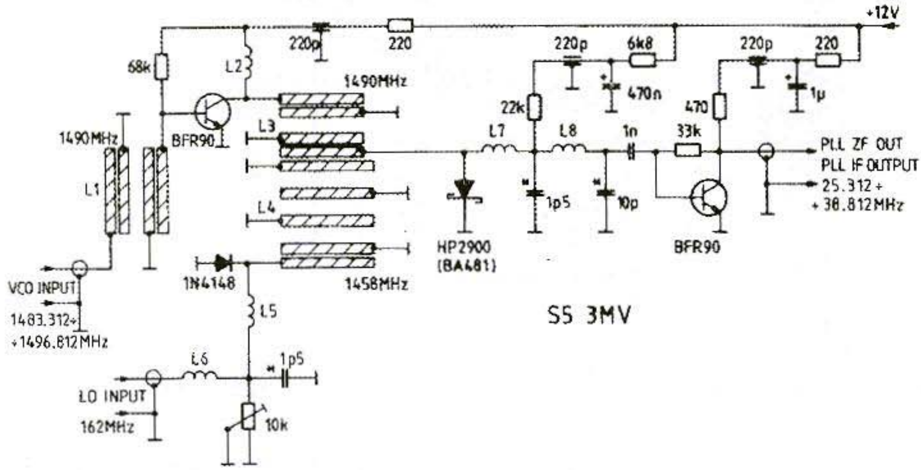


Fig.32: GLONASS PLL Synthesiser Converter

The exact frequency is specified in the program listing.

4.7. GLONASS PLL Synthesiser Converter

A single-channel GLONASS receiver requires a fast-settling frequency synthesiser, since the receiver is continuously switching among different frequency channels. Besides this requirement the synthesiser should have a low phase noise. To limit group-delay variations the synthesiser should supply a variable frequency already to the first downtonverter. All these requirements ask for a PLL synthesiser with a frequency downconverter in the feedback loop, to decrease the divider modulo and increase the loop gain. Therefore, the GLONASS PLL synthesiser includes a VCO in the RF module,

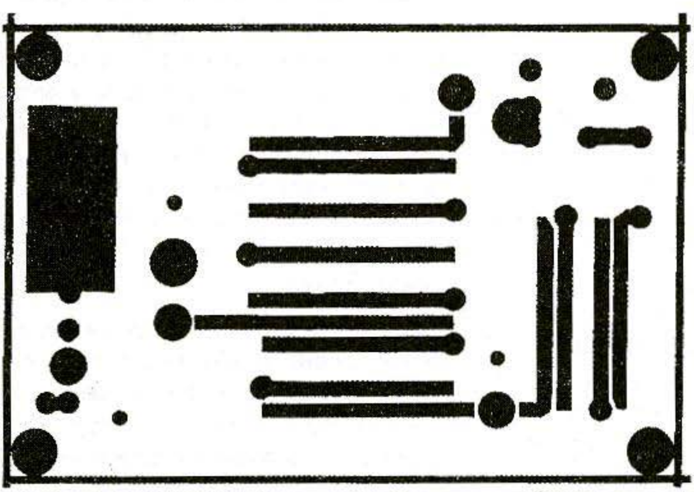


Fig.33: GLONASS PLL Synthesiser Converter, upper side (top view)

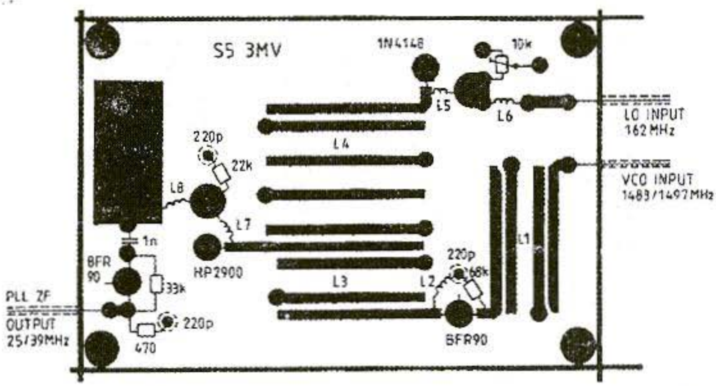


Fig.34: GLONASS PLL Synthesiser Converter Component Overlay

a downconverter and conventional PLL synthesiser logic like variable modulo dividers and a frequency/phase comparator.

The circuit diagram of the GLONASS PLL synthesiser converter is shown on Fig.32. The circuit includes another buffer stage for the VCO signal around 1490 MHz, a step-recovery diode (SRD) frequency multiplier by 9, to get 1458 MHz from the available 162 MHz, a mixer diode and an IF ampli4-:ier stage. The VCO buffer stage (BFR90) is required to avoid getting any unwanted spurious signals back in the GLONASS RF module.

The SRD multiplier uses a very inefficient silicon PN-junction diode IN4148. Other diodes like VHF TV tuner band switching diodes (BA182 or BA482) provide an up to 20dB stronger signal at 1458 MHz in the same circuit, but a higher signal level is not required here and it is even harmful, since it may get in the RF module and cause unwanted mixing products. In practice it is thus convenient to keep the 1458 MHz signal level low and drive the mixer diode into the non-linear region with the 1490 MHz VCO signal.

To avoid any spurious generation all signal levels are kept low. Even the buffered VCO signal amounts to only a few hundred mV on the mixer diode HP2900 (or BA481) while the 1458 MHz signal level is much lower. To operate efficiently at low signal levels the mixer diode receives a DC bias current.

The PLL IF signal then needs much amplification to reach the TTL level required by the variable-modulo counter. The first PLL IF amplifier stage (BFR90) is built in the PLL converter module. The following PLL IF amplifier stages are located in the PLL synthesiser logic module for shielding purposes, since harmonics of the PLL IF fall in the first IF (118.7 MHz) frequency range of the described GLONASS receiver.

The GLONASS PLL synthesiser converter is built in microstrip technology on a double-sided board made of 1.57mm thick glass fibre-epoxy. The upper side is shown on Fig.33 while the lower side is not etched. The location of the components is shown on Fig.34. Before installing the components, the resonators of L1, L3 and L4 should be grounded by soldering short pieces of 1mm diameter copper wire at the marked locations. The transistors and diodes are installed in 6mm diameter holes in the printed circuit board.

L2, L5, L7 and L8 are quarter-wave-length chokes. These are made from about 6cm of 0.15mm thick copper enamelled wire, tinned for about 5mm at each end. The remaining wire is wound on a 1mm inner diameter and the finished chokes are small self-supporting coils. L6 is a self-supporting coil with 3 turns of 0.5mm diameter copper enamelled wire wound on a 3mm inner diameter.

The microstrip filters in the GLONASS PLL synthesiser converter usually do not require any trimming. The 10kohm trimmer for the SRD bias current is usually set to 5kohmThe SRD multiplier will operate correctly if the rectified DC voltage by the lN4148 diode amounts to about 2V.

Peter Vogl, DL1RQ

GaAsFET Power Amplifier Stages up to 5 W for 10 GHz

The following article introduces two high-level output stages for 10 GHz. Both modules were developed by the author with a view to ease of copying and reliable long-term operation. Numerous examples of the 1W high-level stage have been running for some years (some of them installed on masts) and none has yet given rise to any problems.

1. INTRODUCTION

The last few years have seen the emergence onto the market of output GaAs FET's in the 5W range, which certainly do drain the "research budget" of a radio amateur, right down to the last penny. But "better 5 Watts in the GHz rucksack than a designer suit in the wardrobe". Thus the tried and tested existing circuit was expanded by a TIM 0910-4 from Toshiba, which was internally tuned to 50Ω. Five examples of the 5W version have been assembled so far. Long-term operation in the laboratory and utilisation by several competitors (figuratively left out in the cold and expeditions literally snowed up) have left the hope open that this high-level stage can also attain the operational reliability of the 1W version. In one example, at least, a faulty SMA relay triggered a ten-minute crash test with full power drive but open output. The transistor survived the experience, though the author was forced to part with the relay.

In spite of all efforts at reproducibility, I am obliged to admit that the cumulative total of the small tolerances in the component values and the assembly can eventually lead to significant individual deviations (-3 dB is normal) in the amplification and output power. But there is some comfort in the fact that, with patience, experience and good measurement facilities, a high-level stage can be trimmed to the rated values with a fine calibration using the "small disc method".

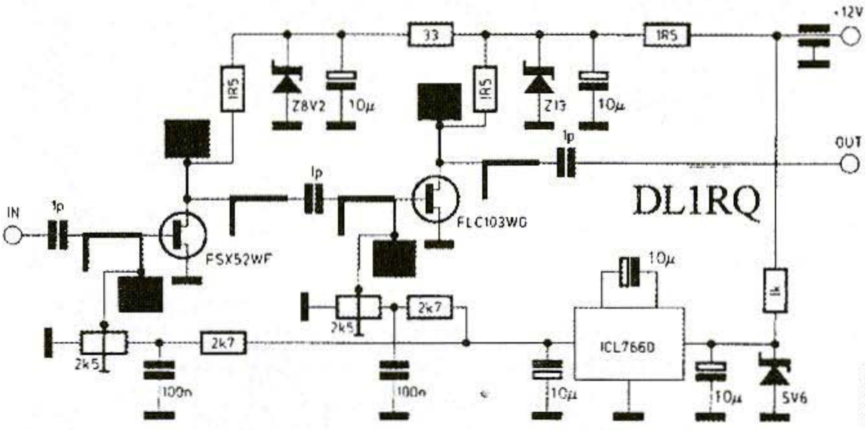


Fig.1: Circuit Diagram of the 1W Power Amplifier for 10 GHz

The following descriptions are intended to provide a stimulus to the interested radio amateur. No doubt further slight changes will occur as this concept is optimised further.

2. 1W HIGH-LEVEL STAGE FOR 10 GHz

2.1. Description

The wiring diagram (Fig.1) is comparable in structure to the author's two-part 5.7 GHz high-level stage, published in (1) and (2), down to the additional voltage inverter for the negative gate voltage. Good experiences with the reliable FSX52WF transistors (drive) and FLC103WG transistors (high-level stage) from Fujitsu led to trials at 10 GHz, which were immediately successful, although the FLC103WG is specified only for use up to 8 GHz by the manufacturer. 0805 model 1pF SMD capacitors were used as high-frequency coupling elements (2.0 mm. x 1.25 mm.). Research carried out only recently as part of a specialist project (3) showed that the SMD capacitors used by the author, with a series inductance of L_{Series} = 0.66 ±0.01 nH,

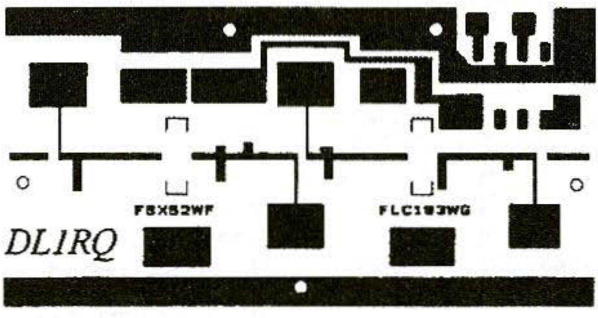


Fig.2: Board Layout of the 1W Version

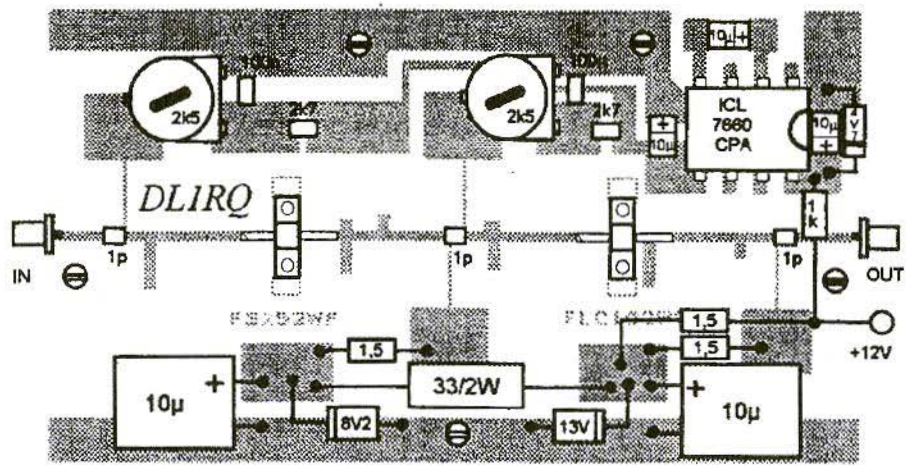


Fig.3: Component Layout of the 1W Version

differ from those components available by normal mail order, with L_{Series} = 0.72 ±0.02 nH. Unfortunately, the author was no longer in a position to identify the individual manufacturer. In any case, a rough calculation quickly shows that the series resonance frequency of these SMD capacitors lies around 6.0 GHz. So, at 10 GHz the coupling "capacitors" should be considered more as DC-disconnecting components with inductive behaviour. Naturally, this inductance clearly has an influence on the transformation by the calibration elements (at the cost of narrowing the band!).

The power supply was deliberately made simple. Stabilisation was provided through 1.3W Zener diodes, which simultaneously provided protection against overvoltage and false polarity. The 1.5Ω / 0.25W axial carbon film resistors fulfil their purpose as disconnection resistances and as safety resistances. A protective circuit in case the negative power supply failed was dispensed with following an involuntary 24-hour test without any minus voltage, which did not result in any damage to the semi-conductors.

2.2. Assembly

The assembly and board layout of an amplifier for microwaves are determined by two essential requirements:

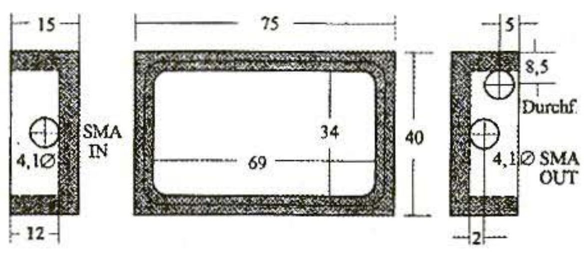


Fig.4:
Dimensions for the Milled Aluminium Housing in mm

Durchf = Connectors

- The high-frequency transition from the earth surface of the board to the source flange of the transistor must be as close to ideal and as smooth as possible
- The extraction of the transistor's lost heat must be as close to ideal as possible

A board with a sandwich construction has proved itself as a way of being able to fulfil both requirements simultaneously. The layout (Fig.2) is etched onto an RT/Duroid D-5870 board measuring 68.5 mm. x 34 mm. x 0.25 mm.. After pre-tinning of the earth surface, the board is soldered onto a 1.0 mm. thick copper plate under high pressure. Next, two oval grooves 0.75 mm. deep are milled, using a 2.5 mm. diameter bore groove milling cutter, for the source flanges of the transistors. When the five 2.1 mm. diameter holes have been made for the board to be screwed into the housing and for the contacts to be connected up, and when the tracks have been tin-plated (or silver-plated), the board is assembled as far as the two 10µF electrical capacitors (on the drain side) and the transistors (Fig.3). In order to guarantee good heat transmission between the copper plate and the milled aluminium housing (Fig.4), some heat-conducting paste is smeared over the aluminium base in the vicinity of the transistors. To ensure good transition between the high-frequency section and the earth in the input and output areas, silver conducting lacquer can be smeared there (very sparingly, of course). The partly-assembled board is now incorporated into the suitably prepared aluminium housing and screwed down by five M2 brass screws. When the connections to the feed-through capacitor have been completed, it is already possible to check the DC function. For this purpose, the two trimmers are pre-set to a gate voltage of about - 1.5 V.

The trickiest stage in the procedure is the soldering of the GaAsFET into the milled grooves. To this end, the aluminium housing is first heated, with the

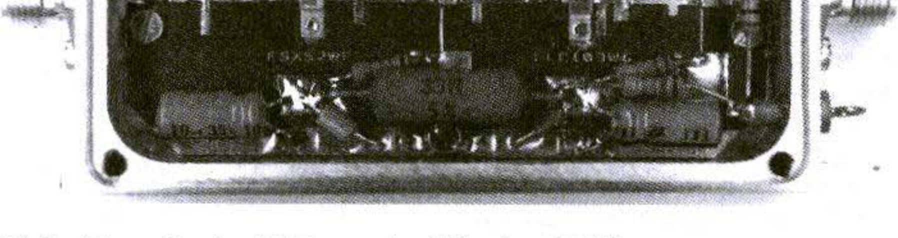


Fig.5: Example of a 1W Power Amplifier for 10 GHz

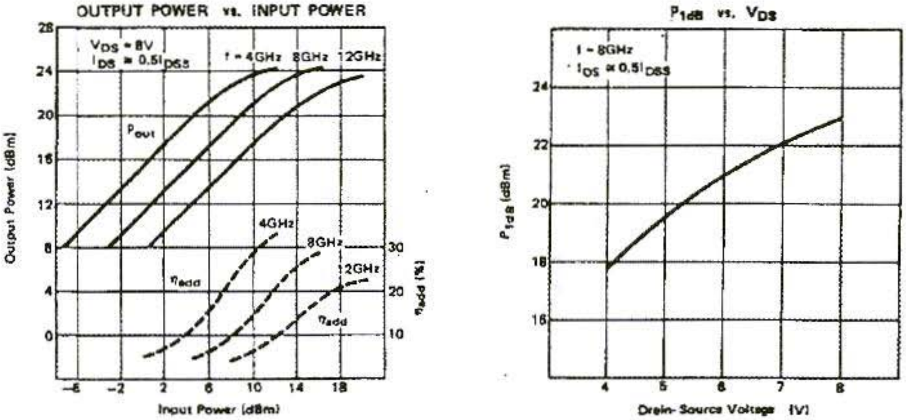


Fig.6: Power Data for the FSX52WF taken from the Fujitsu Data Sheet (5)

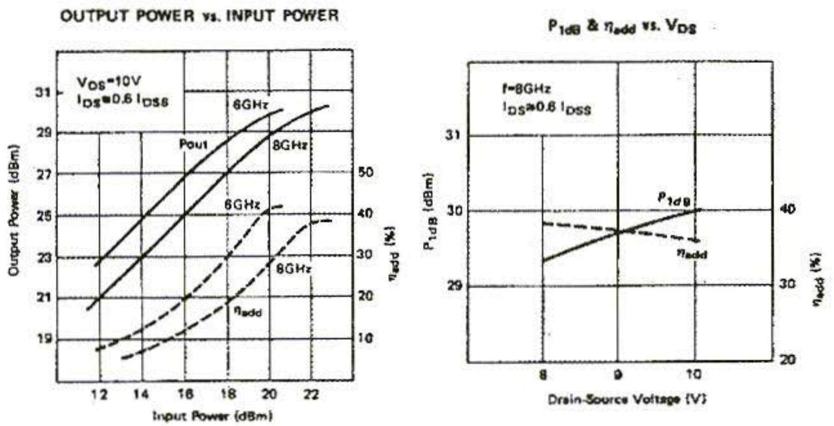


Fig.7: Power Data for the FLC103WG taken from the Fujitsu Data Sheet (5)

board inside it, to precisely 150°C. Each milled groove is then pre-tinned, using low-temperature solder with a melting temperature of 140°C. Excess tin is then removed using a de-soldering pump. The transistors are then placed in the grooves - all the relevant safety measures known must be taken. Normally, the tin binds very well with the gold-plated flanged base - something which can easily be tested by a visual check of the flanged bores. Naturally, this soldering process should be carried out as rapidly as possible. The housing is then immediately placed on a cold copper block or a large cooling body, so that the temperature quickly falls.

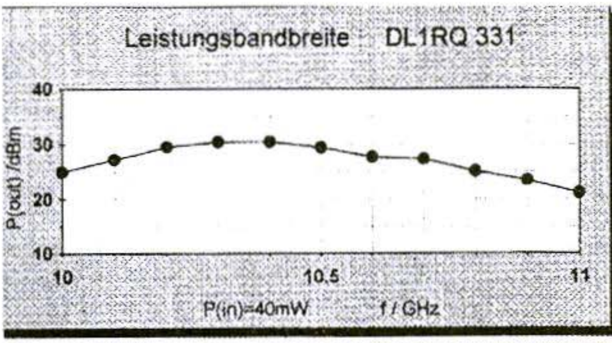
Drain and gate connections are soldered onto the stripline - all the relevant safety measures must be taken. The two 10µF capacitors on the drain side are fitted and the SMA flanged bushes are screwed on. The high-level stage is ready for fine calibration (Fig.5).

2.3. Calibration

First, the zero signal currents are set as follows:

For the FSX52WF at app. 70mA, this corresponds to a voltage drop of 105 mV, with a 1.5Ω protective resistor. For the FLC103WG, at app. 240mA, it corresponds to a voltage drop of 360 mV, with a 1.5Ω protective resistor.

With a 30mW drive at the desired frequency, an output of approximately 400mW (in the worst case) and of 1 Watt (in the ideal case) should be measurable. As already mentioned initially, the "small disc method" is normally of assistance. Small discs, measuring about 2 - 4 mm.^{2}, a few toothpicks to press down and push, a lot of patience and, above all, the greatest care in watching out for short-circuits



Typical Readings for the 1W Unit

Fig.8: Power Bandwidth

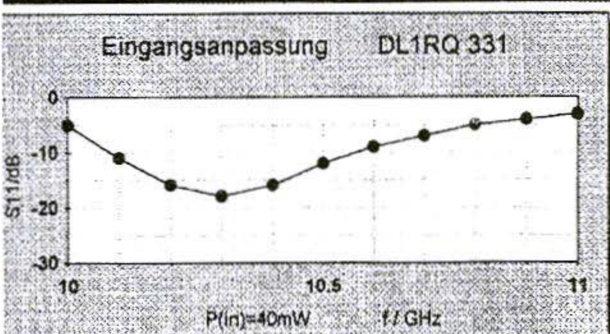


Fig.9: Input Matching

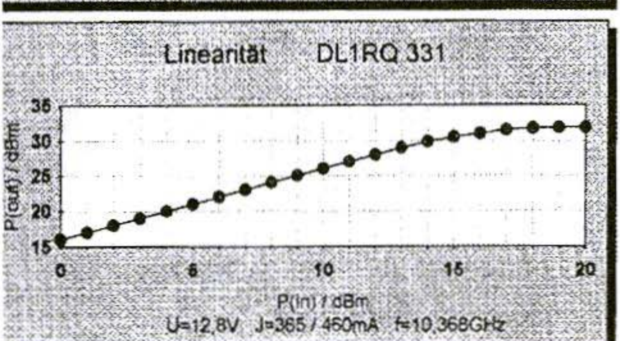


Fig.10: Linearity

will (hopefully) soon lead you to your goal. After calibration, an aluminium plate cover 1 mm. thick can be pressed into a matching edge milling. In the overwhelming majority of the high-level stages measured, almost no influence from the cover could be detected. Of course, there were just a few cases in which minimal self-excitation was detected when the cover was put on. This is seen as an astonishingly stable housing resonance, lying slightly above the calibration frequency, with a few milliwatts of power at the output. Even this undesirable oscillation disappeared with a low-powered drive. A strip of absorbent material about 5 mm. wide and about 10 mm. long, glued to the inside of the cover in the area above the FSX52WF, provided a reliable remedy here.

2.4. Data and Readings

A comparison of the output data from the semi-conductors (Fig.6 and Fig.7) with the readings from a typical high-level stage (Fig.8 - Fig.10) makes clear how successful the project is in practice.

3. 5W HIGH-LEVEL STAGE FOR 10 GHz

3.1. Description

The circuit diagram for the 5 Watt high-level stage (Fig.11) differs from the circuit diagram for the 1 Watt high-level stage due to the inclusion of the additional power pack with the

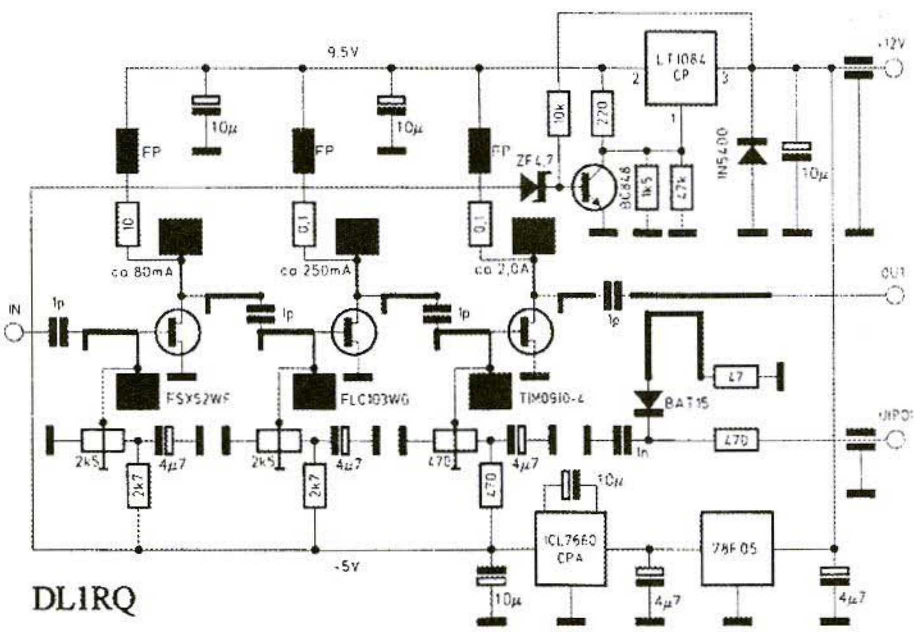


Fig.11: Circuit Diagram of 5W Power Amplifier for 10 GHz

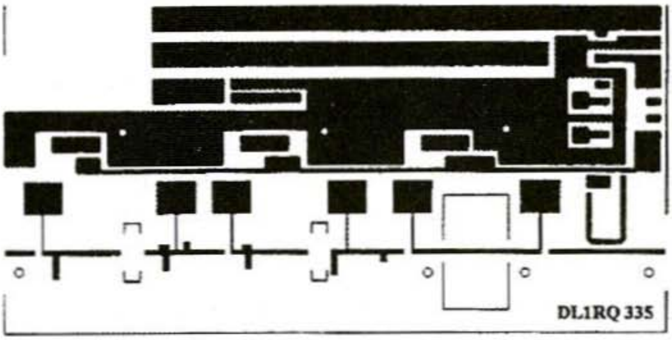


Fig.12: Board Layout of the 5W Version

TIM0910-4 Toshiba internally matched power GaAsFET and due to a more expensive power supply circuit, provided by DB6NT largely copied from (4). The LT1084CP 5-A low-drop regulator is permanently set to a drain voltage of 9.5 V, and is switched off through the BC848 transistor if the - 5 V voltage cuts out. The relatively high-resistance gate circuitry of the TIM0910-4 corresponds to a recommendation from the manufacturer. With high-frequency drive, it leads to an increase in UGS and thus to an artificial counter-coupling. In this way, undesirable oscillation can be avoided, in accordance with the manufacturer's recommendation. This explains the fall in the power consumption from app. 2.5 A without drive to app. 2.1 A with full drive. The first appearance of the gate current can also be detected in the linearity diagram (Fig.18) as a slight bend in the characteristic line at an output of app. 3 dBm. 2Watt. Cemented wire resistances of 10Ω or 0.1Ω are used as drain resistances. They have adequate inductance and the voltage drop on them can be made use of for the convenient measurement of the

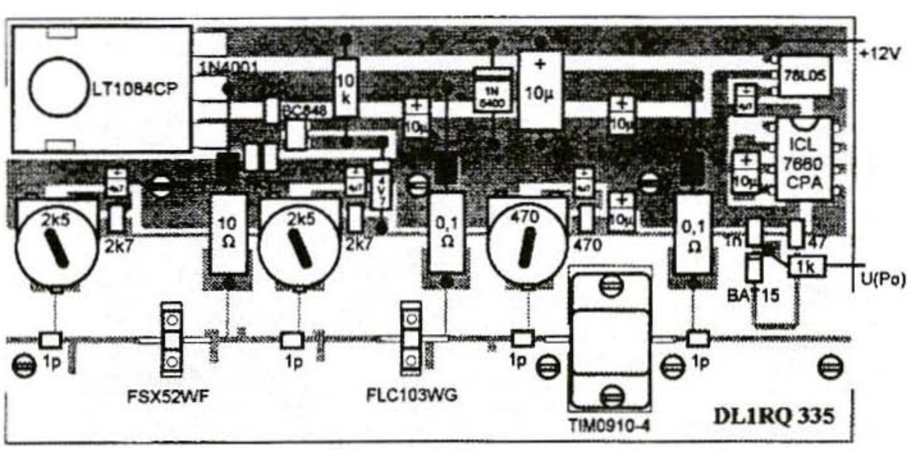


Fig.13: Component Layout of the 5W Version

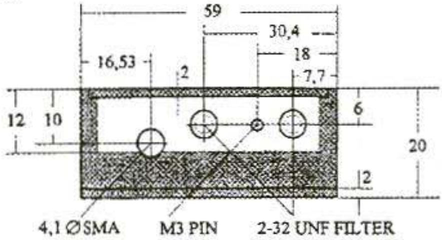


Fig.14: Dimensions of the Telemeter ZG4-2-N Housing in mm

drain current. The ferrite beads threaded on could be described as "hope beads", as they are connected with the hope that they contribute to the suppression of undesirable housing resonances. A Siemens directional coupler with a type BAT 15-098 low-barrier Schottky diode is provided for the monitoring of the output.

3.2. Assembly

There are some structurally determined differences between the assembly of the 5 Watt high-level stage and that of the 1 Watt high-level stage. The layout (Fig.12) is etched onto an RT/Duroid D-5870 board measuring 101.6 mm. x 50.8 mm. x 0.25 mm. (4 x 2 x 0.01 in.). The dimensions arise from the use of a finish-milled, nickel-plated type ZG4-2-N aluminium housing from Telemeter Electronic (6). Following the pre-tinning of the earth surface, the board is soldered to a 1.5 mm. thick copper plate under high pressure. Two 0.75 mm. deep oval grooves are then cut using a 2.5 mm. diameter bore groove milling cutter for the source flanges of the two drive transistors. Countersinking is carried out for the LT1084CP voltage controller, with a precisely fitting opening for the TIM0910-4 transistor, in accordance with the dimension specified in the layout. The two components are then screwed directly onto the 8 mm. thick housing base. This provides exactly the height required for the stripline for the TIM0910-4. Following the preparation of the seven 2.1 mm. diameter bores for the screwing down and through-plating of the board in the housing and the tin-plating (or silver-plating) of the tracks, the board is

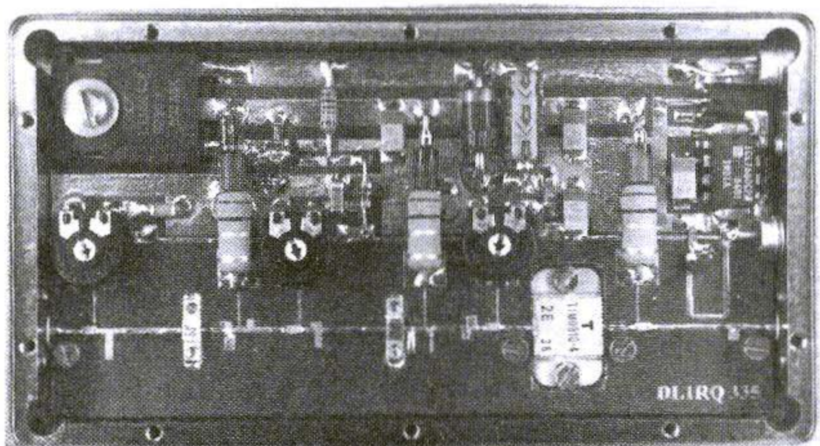
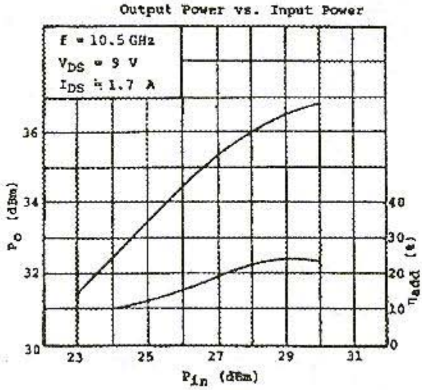


Fig.15: Example of a 5W Power Amplifier for 10 GHz



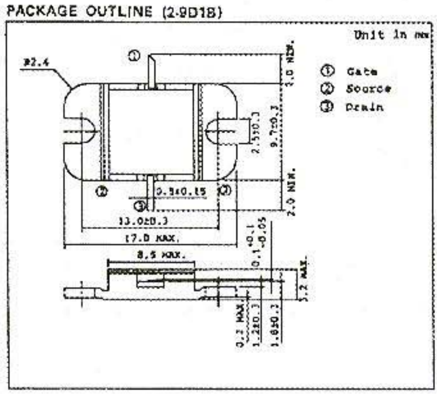
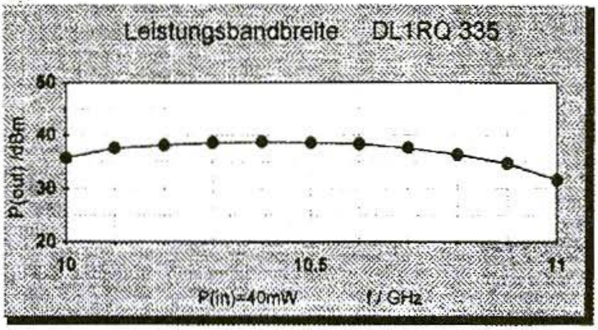


Fig.16: Power Data and Case Details for the Toshiba TIM0910-4 (7)

assembled, as far as the 10µF electrical capacitor (on the power supply bar), the LT1084CP and the three GaAs transistors (Fig.13). In order to guarantee good heat transmission between the copper plate and the housing, some heat-conducting paste is smeared onto the aluminium base in the area of the two drive transistors. Silver conductive lacquer can be smeared on to produce a good transition from the high-frequency section to the earth in the vicinity of the input, the output, the gate and the drain of the TIM0910-4. Of course, silver conductive lacquer must be applied extremely sparingly. Even a transient leak while the board is being screwed on can lead to considerable problems. (The author's prototype was tested without conductive lacquer. No difference could be detected from later versions with conductive lacquer!)

The partly-assembled board is now put into the housing, which has all the necessary bores, and is screwed down using seven M2 brass screws. When the LT1084CP has been incorporated (don't forget the little insulating discs!) and the connection to the feed-through capacitor has been completed, the DC function can be checked. All trimmers are pre-set to -1.5V for the gate voltage. The two drive transistors are soldered in just as already described for the 1Watt high-level stage. When the housing has cooled, the remaining components and the SMA bushes are mounted (with suitable Teflon collars). The final step is the incorporation of the "expensive bit", the TIM0910-4, into the opening provided in the board, using two M2 screws. Since a certain amount of lever action can not be excluded when the screws are tightened, the gate and drain lugs should not be soldered to the stripline until afterwards.

It is vital to bear in mind that, up until sometime early in 1993, Toshiba identified the drain lug by a chamfer. Since then, the gate lug has been chamfered. In case of doubt, a suitable Ohmmeter can be used for measurements. Battery-operated equipment with a low measuring voltage (< 0.5V) is suitable. The drain-source resistance is usually



Typical readings for a 5W Unit

Fig.17: Power Bandwidth

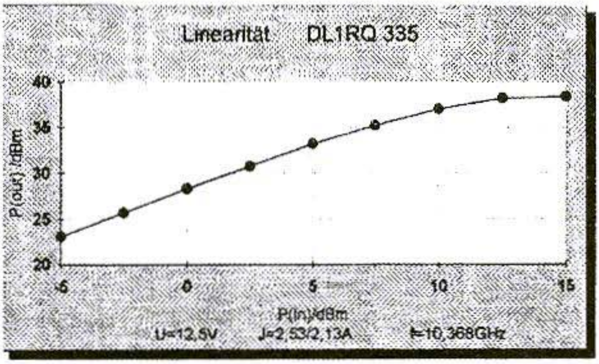


Fig.18: Linearity

markedly less than an Ohm. The gate-source resistance, by contrast, will be very high-ohmic - and this is irrespective of the polarity of the measurement voltage. Naturally, measurements must be carried out very carefully as static charges may be present. The author came to a decision as to whether to give preference during assembly to the best heat contact (by an abundant use of heat-conducting paste) or to the best high-frequency contact (by doing without the paste), in that (somewhat half-heartedly!) he applied less than a breath of this paste.

3.3. Calibration

First, the zero signal currents are set:

FSX52WF to approximately 80mA - this corresponds to a voltage drop of 800mV with a drain resistance of 10Ω; FLC103WG to app. 250mA - this corresponds to a voltage drop of 25mV with a drain resistance of 0.1Ω; TIM0910-4 to app. 2.0 A - this corresponds to a voltage drop of 200mV with a drain resistance of 0.1Ω. Should the readings not match the above values immediately, fine tuning should be carried out using the "small disc method".

3.4. Cooling

Estimating the cooling of the high-level stage we can calculate as follows:

App. Power loss for the TIM0910-4: $P_v = 9.5\ V * 2.1\ A \approx 20\ W$

The HF output is not taken into account!

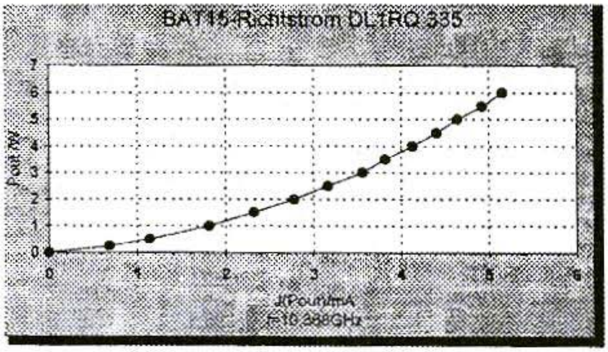


Fig.19: Relative Power Display using a BAT 15

Temperature differential between channel and flange:

$\Delta\varphi_{CC}$ = 3.5 K/W.20 W ≈ 70 K

i.e., a flange temperature of, for example, 60°C. gives a channel temperature of 130°C.. The maximum permissible channel temperature is 175°C.. If you want to "keep on the safe side", the high-level stage housing should be cooled in such a way that, even when the ambient temperature is at its most unfavourable (insolation!) a flange temperature of 60° C. will not be greatly exceeded at TIM0910-4.

I would like to thank all those who have contributed to this project. Special thanks go to my fellow radio-enthusiast Manfred Deutsch, DC4UI, who was always ready to help and advise me in selecting and testing components.

4. LITERATURE, REFERENCE SOURCES

(1) Peter Vogl: 6-cm. Transverters in Modern Stripline Technology; VHF-UHF Munich 1990, pp. 49-66

(2) Peter Vogl: 6-cm. Transverters in Stripline Technology, Part 2 (Conclusion); VHF Communications, 2/1991, pp. 69 - 73

(3) Roland Richter: Determination of Parasitic Inductances on Capacitors, Special Project at Dominicus von Linprun Grammar School Viechtach, 1994

(4) Michael Kuhne: Power FET Amplifier for the 9-cm. Band; VHF-UHF Munich 1992, pp. 50 - 58

(5) Fujitsu Distributor; Melatronic Nachrichtentechnik GmbH, Unterschleißheim

(6) ZG4-2-N Aluminium Housing; Telemeter Electronic GmbH, Donauwörth

(7) Toshiba Distributor; Tricom Mikrowellen GmbH, Freising

Publications:

UHF Compendium Pts.1 & 2; K.L.Weiner DJ9HO	£27.50
UHF Compendium Pts.3 & 4; K.L.Weiner DJ9HO	£27.50

Post & packing: UK +£4.50; Overseas +£8.00; Airmail +£12.00

An Introduction to Amateur Television; Mike Wooding G6IQM	£ 5.00
Slow Scan Television Explained; Mike Wooding G6IQM	£ 5.00
The ATV Compendium; Mike Wooding G6IQM	£ 3.50
TV Secrets Volume I; ATVQ Magazine	£ 7.50
TV Secrets Volume II; ATVQ Magazine	£17.95
Just a Few Lines (a history of the birth of the BBC)	£ 5.00
Back Issues of ATVQ Magazine (1992/1993/1994 - per volume of 4)	£12.00

Post & packing per book: UK +£0.80; Overseas +£1.25; Airmail +£2.75

VHF Communications:

SEE FLYER FOR SPECIAL OFFER DETAILS

1994 Subscription, Volume 26		£15.00
	by credit card	£15.75
1993 Volume 25		£13.50
	by credit card	£14.20
1993 per single issue		£ 3.75
	by credit card	£ 4.00
1980 to 1992 per full volume (4 issues)		£13.00
	by credit card	£13.60
Any single issue before 1993		£ 3.50
	by credit card	£ 3.70

Post & packing per issue: UK +£0.30; Overseas +£0.50; Airmail +£1.25

Post & packing per volume: UK +£0.80; Overseas +£1.50; Airmail +£4.00

Binders to hold 3 Volumes		£ 5.50
	by credit card	£ 5.80

Post & packing per binder: UK +£0.75; Overseas +£1.25; Airmail +£3.00

VISA / ACCESS / MASTERCARD / DELTA / EUROCARD / DINERS / AMEX / JCB

KM Publications, 5 Ware Orchard, Barby, Nr. Rugby, CV23 8UF

Tel: (0)1788 890365 Fax: (0)1788 891883

Email: 100441.377@compuserve.com