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Add-Ons for 4GHz Frequency Generator

Norbert Kohns, DG1KPN

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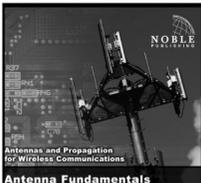
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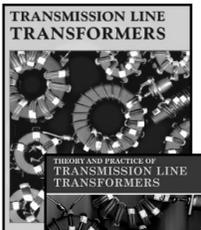
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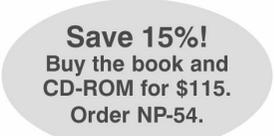


Transmission Line Transformers

Jerry Sevick

This book remains the definitive text on the subject of transmission line transformers for high frequencies.

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Theory and Practice of Transmission Line Transformers

Jerry Sevick

Sevick divides TLTs into four classes: TLTs with ratios of 1:1, 1:4, less than 1:4 and greater than 1:4. The first two sections in this course cover 1:1 baluns and 1:4 baluns and ununs, as discussed by Guanella and Ruthroff. Additional sections review TLTs with ratios less than 1:4 and greater than 1:4, such as 1:6, 1:9, 1:12. The course concludes with a discussion of information on diode mixers

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For those subscribers who wanted more constructional articles, this issue is for you. All but one article is for the keen constructor.

If you want a copy of the Key Word catalogue for PUFF 2.1 it will be on the web site in pdf format by the time you receive this magazine.

I had a surprise visit from my Italian agent, Franco Rota from R F Elettronica, in August. He was on holiday in the UK en-route to Scotland. It was great meet up with him, he is very active in the RF electronics industry in Italy. He has convinced me to join him at the Friedrichshafen amateur radio fair in 2004 so I hope to meet many existing subscribers there and find some new subscribers.

73s - Andy



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Norbert Kohns, DG1KPN

Useful add-ons for the 4GHz frequency generator (wobbler)

Described by Wolfgang Schneider, DJ8ES in
VHF Communications 1/2002

Making the 4GHz frequency generator described by Wolfgang Schneider, DJ8ES [1], led me to develop some add-on modules useful for frequency stability and ease of operation.

1. General

As regards the add-on circuits for the frequency generator up to 4GHz, they can be broken down into the following assemblies:

- Voltage regulator circuit board, matched to HP 8555A YIG oscillator
- Electronic span switching (universally applicable)
- Electronic sweep-time switching (universally applicable)
- Analogue calibration of output frequency in relation to LCD display

2. Assemblies

2.1. Voltage regulator circuit board

The frequency generator requires three

stabilised circuits that are supplied by the power supply assembly (Fig 1). The 78S12CT fixed voltage regulator (IC1) stabilises 12VDC at 1.5 Amperes. For the YIG oscillator, +20VDC and -10 VDC are also needed, and these are regulated by means of the adjustable LM 317 (IC5) and LM 337 (IC2) voltage regulators. Both voltages can be precisely adjusted using precision potentiometers.

Suitable transformers can be found (for example) in relatively old video recorders, which usually have several voltage outputs. We need an input voltage of approximately 15V AC (1.5A) for the 12VDC output, plus 24VAC and 14VAC (200mA) for the +20VDC and -10VDC outputs. The voltage regulators are each provided with a heat sink in order to carry away the heat loss.

The layout is shown in Fig 2, and the component drawing in Fig 3. Once the circuit has been assembled, the 12VDC output should be tested first, and then R3 is used to adjust the +20VDC and R4 to adjust the -10VDC. For IC1, the type 78S12CT voltage regulator should preferably be used, since this can supply a higher level of current!

The AC inputs and DC outputs are also easily accessible on the circuit board using various connectors. A fully assembled specimen can be seen in Fig 4.

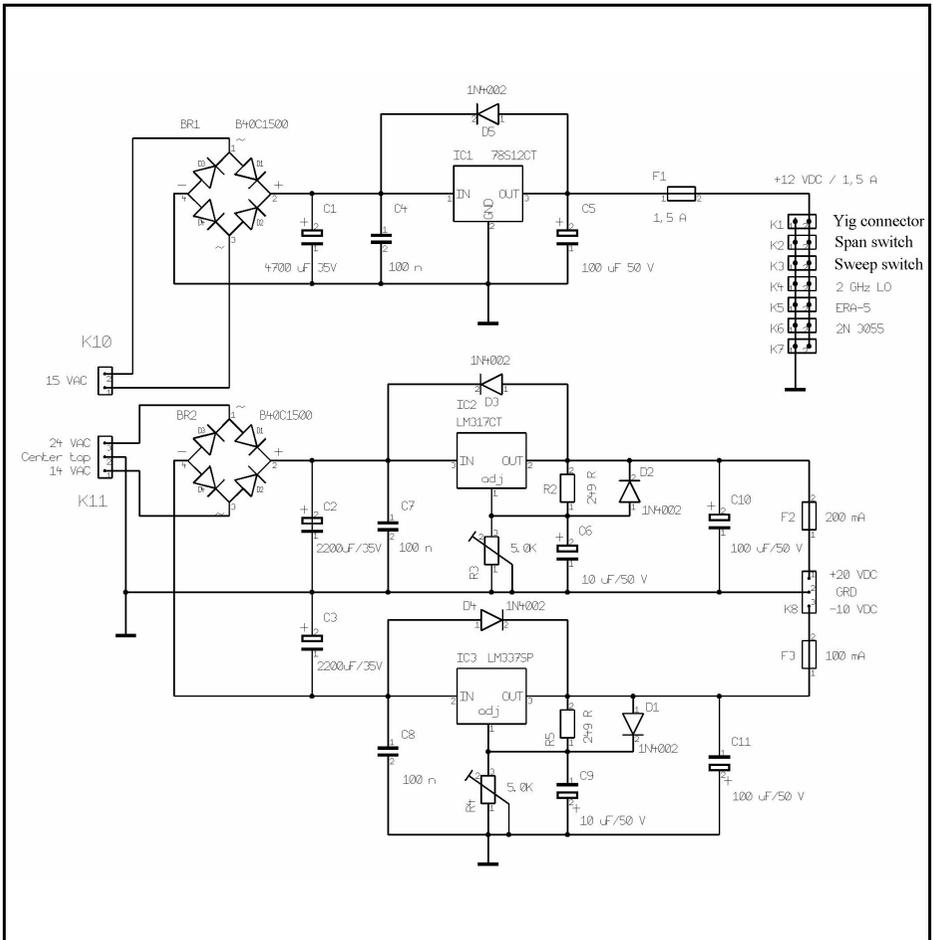


Fig 1: Circuit diagram of YIG voltage regulator.

Components list for power supply assembly:

- D2 1N4002
- R2,R5 249Ω
- R3,R4 5.0kΩ
- BR1,BR2 B40C1500
- C1 4700μF/35V
- C10,C11 100μF/50V
- C2,C3 2200μF/3V
- C4,C7,C8 100nF
- C5 100μF/50V
- C6,C9 10μF/50V
- D1,D3-D5 1N4002

- F1 1.5A
- F2,F3 100mA
- GEH2-4 KÜHLK104
- IC1 78S12CT
- IC2 LM337SP
- IC3 LM317CT
- K1-K7,K10 Attachment strip, single-row, 2-pin
- K8,K11 Attachment strip, single-row, 3-pin
- S1 1.5A
- S2,S3 200mA

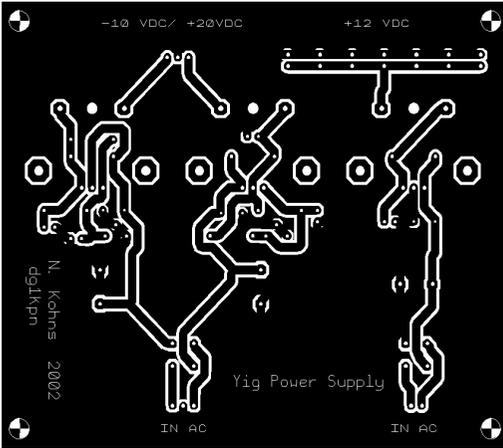


Fig 2: PCB layout for YIG voltage regulator.

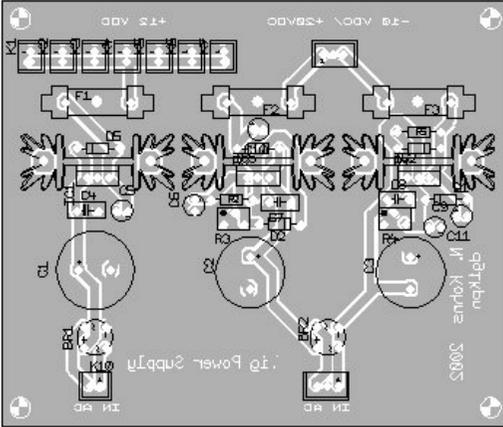


Fig 3: Component layout for YIG voltage regulator.

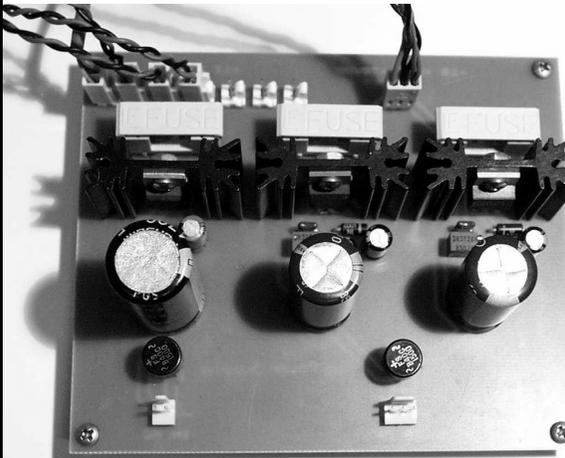


Fig 4: Completed YIG voltage regulator.

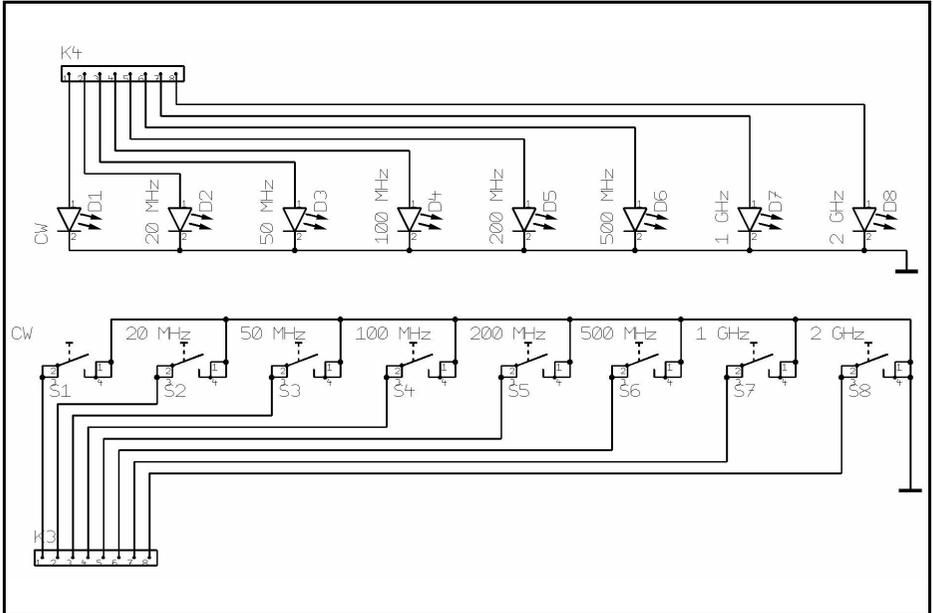


Fig 5: Circuit diagram of electronic span control keys and LEDs.

2.2. Electronic span switching

Electronic switching is rather more elegant than a mechanical rotary switch. Since an additional micro-controller

should not be used, two “old acquaintances” are selected from TV engineering. The SAS 560S and SAS 570S integrated circuits provide all that is required for an eight-stage switch with two levels. The ranges are switched using eight miniature keys.

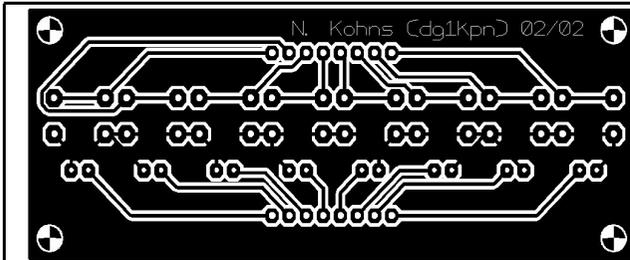


Fig 6: PCB for electronic span control keys and LEDs.

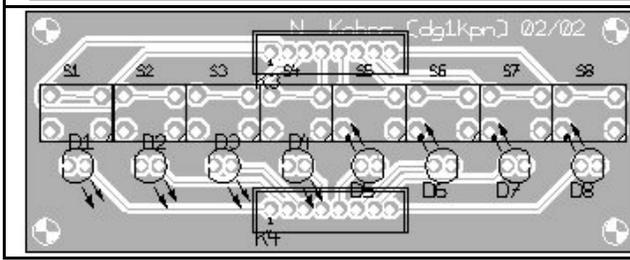


Fig 7: Component layout for electronic span control keys and LEDs.

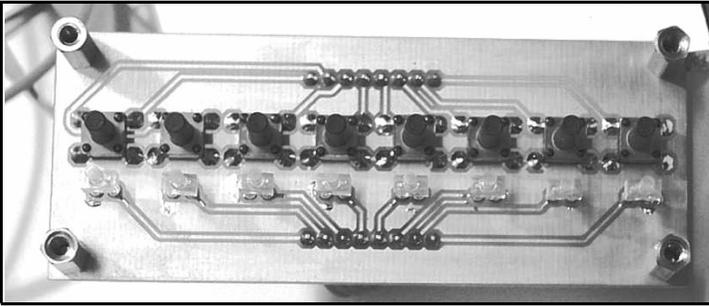


Fig 8:
Completed
electronic span
control keys
and LEDs PCB.

The circuit itself consists of two circuit boards, the span control keys (Fig. 5) and the YIG mode control (Fig. 9). The single-sided span keys control circuit board contains the keys and the associated status LEDs (Figs 6 - 8).

Span keys components list:

- D1-D8 LED, low current, red
- K3,K4 Attachment strip,

S1-S8 single-row, 8-pin
Miniature key

The double sided YIG span mode control circuit board (Figs 10 - 13) contains the two SAS-ICs, the eight miniature relays (5Volt version) and two MOS 4066s. The relay contacts here guarantee a low on resistance in comparison to the MOS 4066.

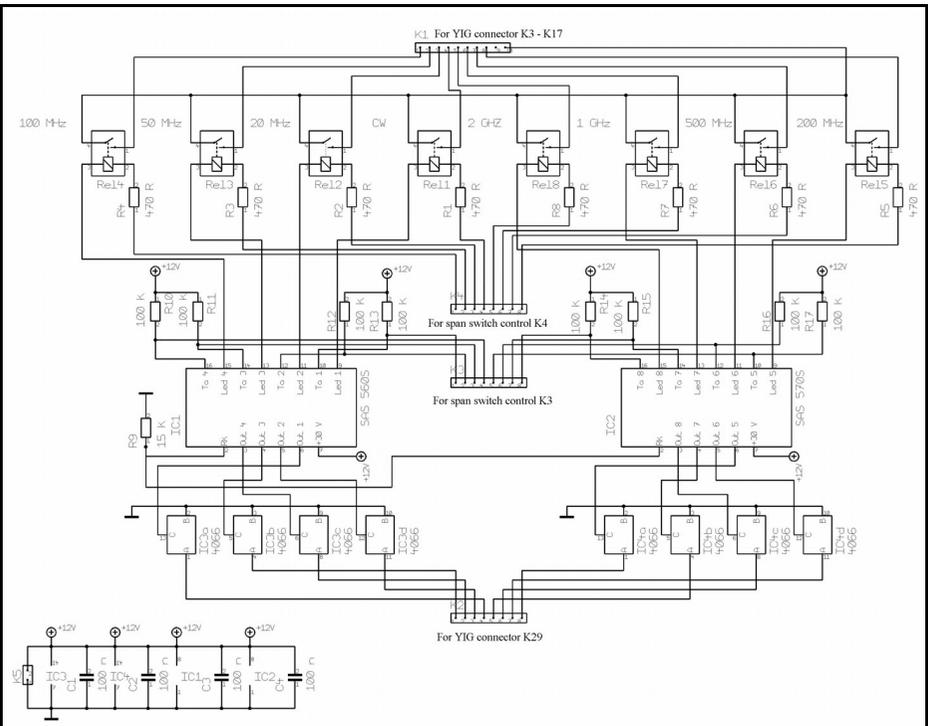


Fig 9: Circuit diagram of span switching YIG mode control.

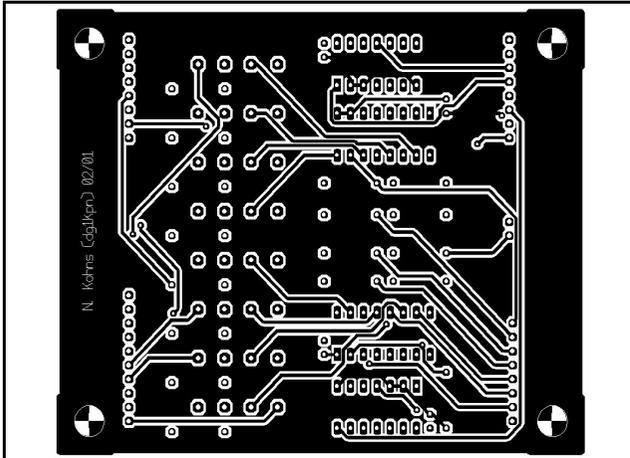


Fig 10: Top side of PCB layout for span switching YIG mode control.

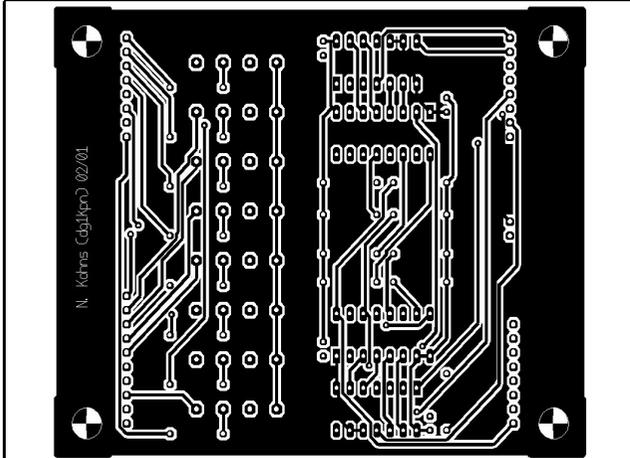


Fig 11: Bottom side of PCB layout for span switching YIG mode control.

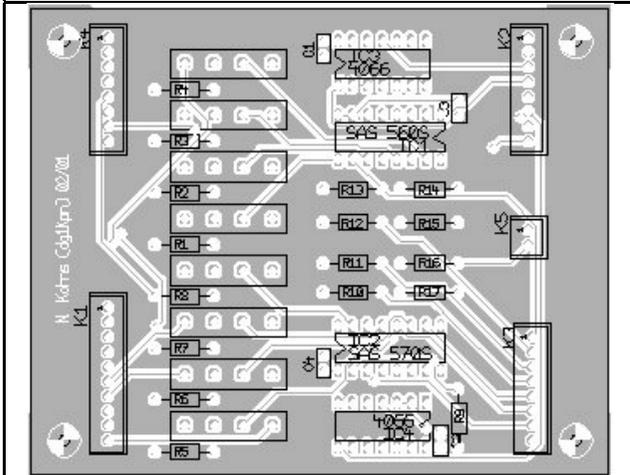


Fig 12: Component layout for span switching YIG mode control.

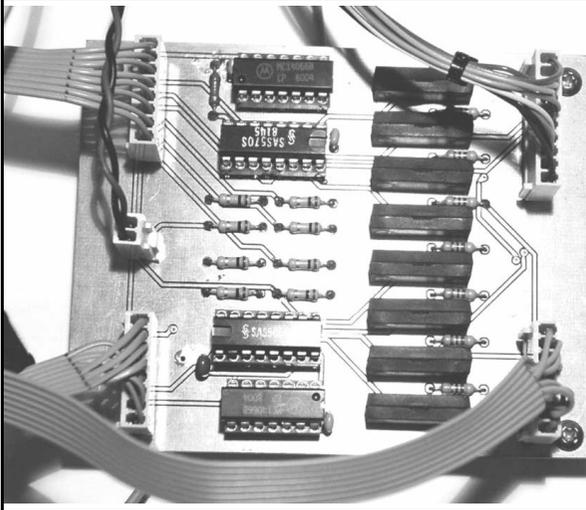


Fig 13: Completed span switching YIG mode control PCB.

Components list for span mode control:

| | |
|--------|--------------------------------------|
| C1-C4 | 100nF |
| GEH1 | P-EURO/2 Circuit board |
| IC1 | SAS 560S |
| IC2 | SAS 570S |
| IC3,4 | 4066 |
| K1 | Attachment strip, single-row, 10-pin |
| K2-4 | Attachment strip, single-row, 8-pin |
| R1 | 470 Ω |
| R10-17 | 100k Ω |
| R2-8 | 470 Ω |
| R9 | 15k Ω |
| Rel18 | Relay, SIL 7271-D 5V |
| D1-8 | 4148SMD diodes |

When the power supply (12VDC) is fed in, IC1 (SAS560S), has an internal reset, switches the 12Volts from Pin 7 to the LED1 output. The first relay, Rel-1 (CW) thus responds through R1 and D1 (on the Key Control) and LED-1 lights. The internal resistors of Rel-1, R1 and LED-1 (Low-Power Version) restrict the current to approximately 10mA, with 5Volts being released through the relay and certainly causing it to respond.

Diodes should be soldered to the coils of

the eight relays, so that the SAS-ICs are not destroyed if the individual relay opens. They can be soldered directly between the coil connections on the bottom face of the circuit board without any problems (pay attention to polarity).

At the same time, Out-1 switches SAS560S to 12Volts. IC3 (4066) acts as a level switch to earth. The outputs of IC3 and IC4 switch the corresponding pin on K29 of the YIG control to earth, which correspondingly alters the display of the span on the LCD display. Make sure that the signal circuits of the YIG span mode control (connectors K1 and K2) are correctly linked to the corresponding connectors on the YIG control circuit board (K29 and K9 to K17). Depending on which key is pressed, the associated LED lights and the corresponding outputs on one of the two SAS-ICs are activated.

2.3. Electronic sweep-time switching

The sweep-time control and sweep keys circuit boards operate together in a similar way. Since only four different logic level switching states are required here, the SAS 560S plus a CMOS 4066 is

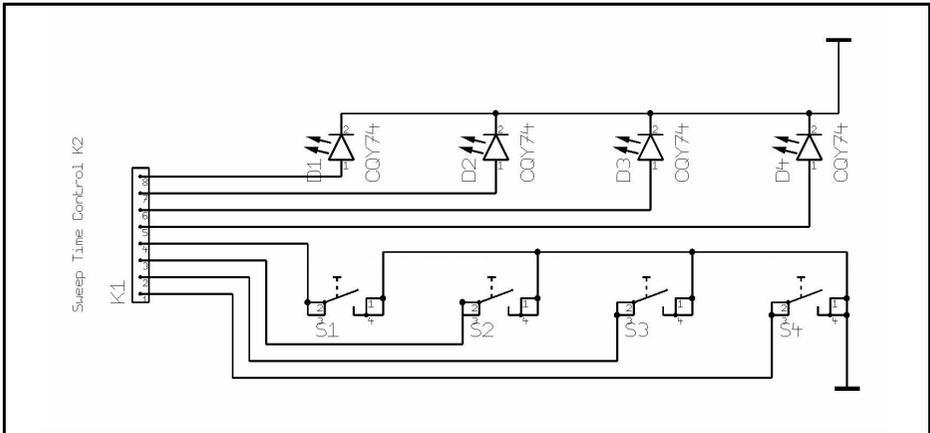


Fig 14: Circuit diagram of electronic sweep time keys.

adequate. The circuits are shown in Figs 14 and 18.

Components list for sweep-time keys assembly:

- D1-D4 LED, low power, red
- S1-S4 Miniature key.

Pin 1 of the connector K1 remains blank, since the longest selectable sweep time (1.3 seconds) is attained if all the pins of K5 (YIG control) remain open (high level). With the three remaining outputs on K1 (sweep-timer), pins 2, 3 and 4, depending on requirements, we can select between the available sweep times

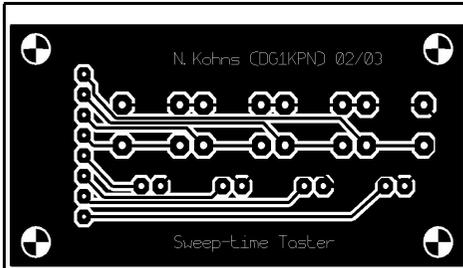


Fig 15: PCB layout for electronic sweep time keys.

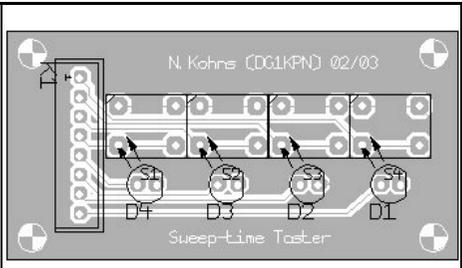


Fig 16: Component layout for electronic sweep time keys.



Fig 17: Completed electronic sweep time keys PCB.

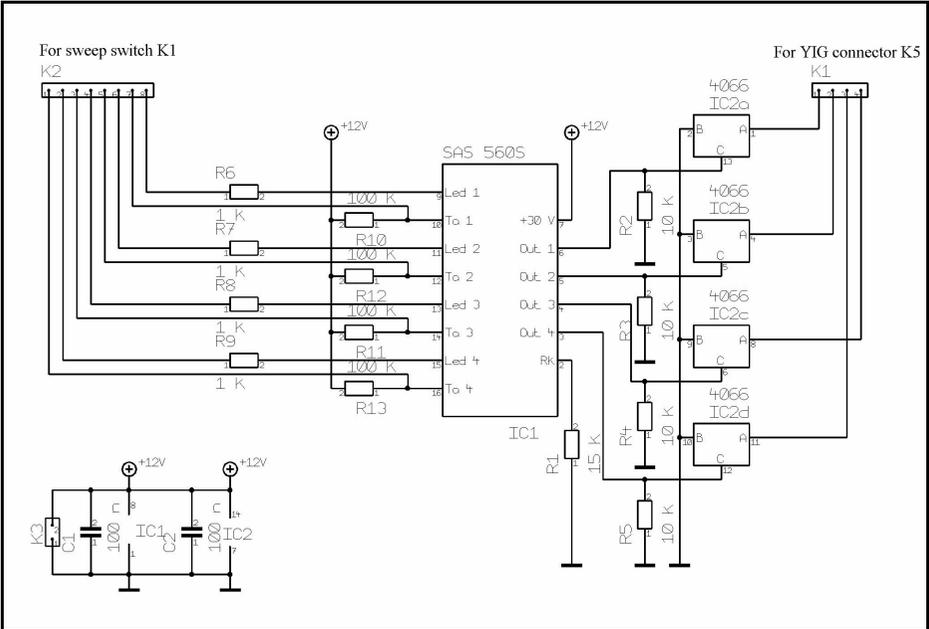


Fig 18: Circuit diagram of sweep time control.

on K5 (YIG control). These are 650ms, 330ms, 168ms, 88ms and 47ms.

The earth surfaces of the sweep keys and span keys control must be separately connected to earth.

Components list for sweep-time control assembly:

C1,C2 100nF
 IC1 SAS 560S

IC2 4066
 K1 Attachment strip, single-row, 4-pin
 K2 Attachment strip, single-row, 8-pin
 K3 Attachment strip, single-row, 2-pin
 R1 15kΩ
 R10-R13 100kΩ
 R2-R5 10kΩ
 R6-R9 1kΩ

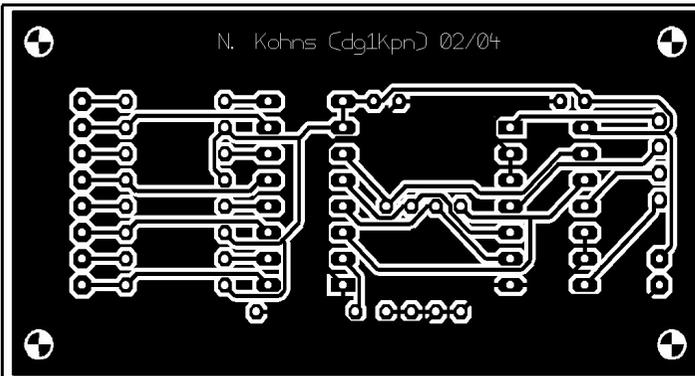


Fig 19: PCB layout for sweep time control.

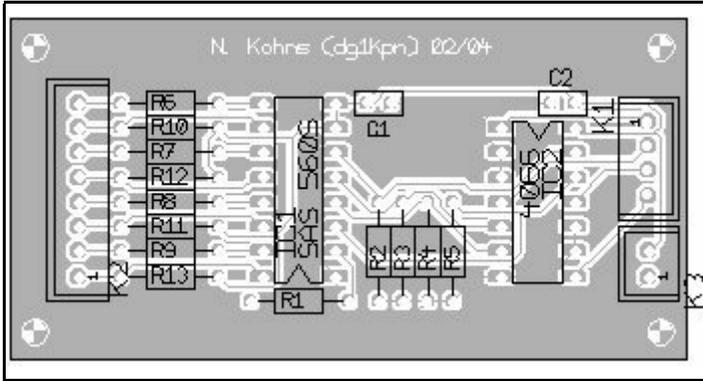


Fig 20:
Component layout for sweep time control.

2.4. Analogue calibration of output frequency

The software must normally be matched individually to each YIG, so that the frequency displays correspond to the actual YIG frequency. If we use the same YIG as in the circuit from DJ8ES, the deviation is not too great. In the present circuit, the mean deviation was approximately 30MHz.

The YIG frequency correction circuit can eliminate this fault. As can be seen from

the wiring diagram (Fig 22), the circuit influences the control voltage for the YIG (basic 2N3055), in that it can be increased (offset) or decreased around an adjustable constant level. Moreover, the gain is adjustable, which influences the gradient of the control voltage.

To keep the temperature drift in the circuit as low as possible, the ICL8069 voltage reference, which supplies a very stable 1.2Volts, is used when the offset voltage is generated. Likewise, for reasons of stability, only metallic film resistors with 1 per cent tolerance are used.

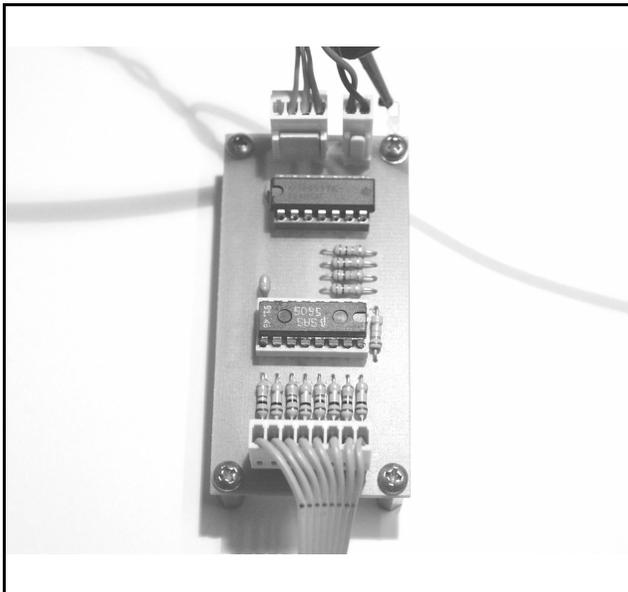


Fig 20: Completed sweep time control PCB.

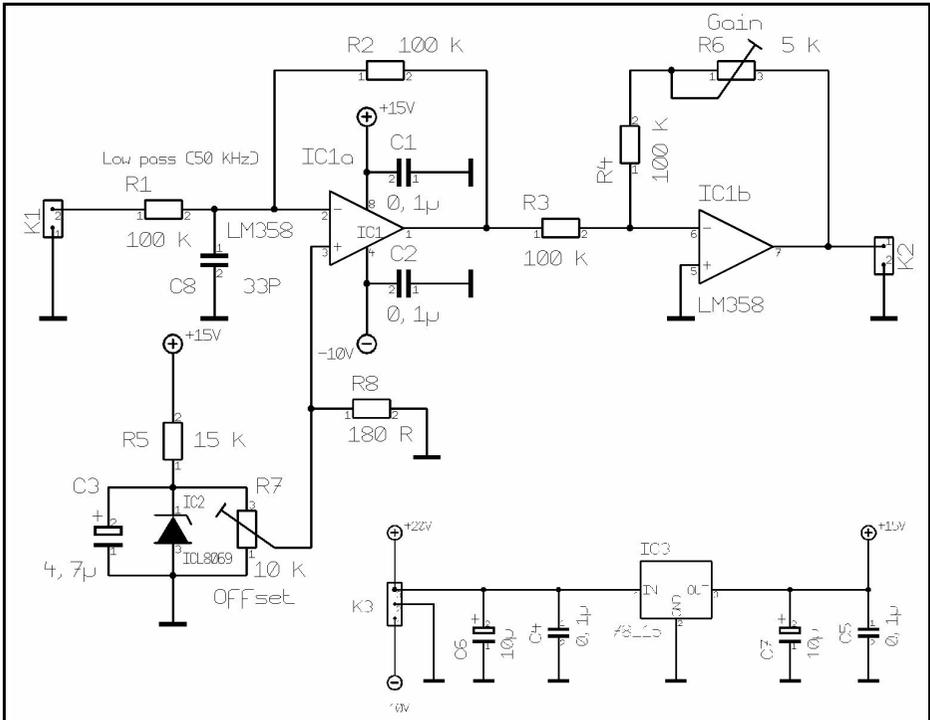


Fig 22: Circuit diagram of YIG frequency correction.

The single-sided circuit board (Fig 23) also has two SMD components on the solder side.

Components list for YIG frequency correction assembly:

- C1,C2,C4,C5 0.1µF
- C3 4.7µF
- C6,C7 10µF
- C8 33pF
- GEH2 P48X37
- IC1 LM358
- IC2 ICL8069
- IC3 78L15, voltage regulator
- K1,K2 Attachment strip, single-row, 2-pin
- K3 Attachment strip, single-row, 3-pin
- R1-R4 100kΩ
- R5 15kΩ
- R6 5kΩ

- R7 10kΩ
- R8 180Ω

The +20 and -10VDC of the voltage regulator circuit board provide the power supply. The circuit is simply looped in between K18 and K19 of the YIG control and the base of the 2N 3055 transistor.

3. Calibration

First, the span is set to CW and the fastest sweep time is selected. (To reach the output frequency faster, we can switch to a wider span. For fine frequency adjustment, switch back to CW.)

The frequency is set to 1.8GHz in the LC display, using the shaft encoder. The

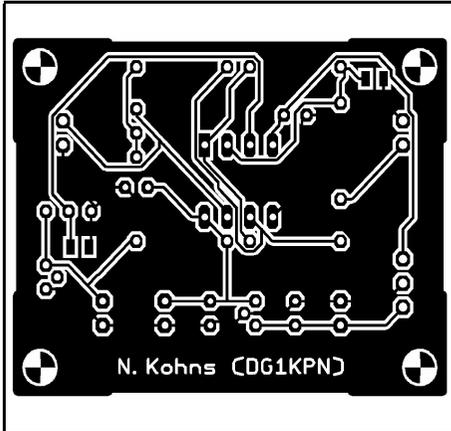


Fig 23: PCB layout for YIG frequency correction.

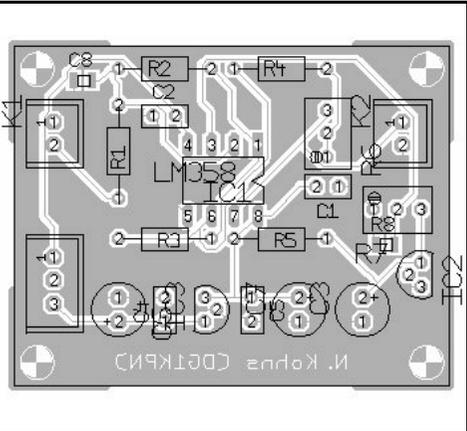


Fig 24: Component layout for YIG frequency correction.

output frequency is measured with a precise frequency counter, and R7 from the YIG frequency corrector is used to set the display on the frequency counter to precisely 1.8GHz. Then we use the shaft encoder to set the frequency to 3.8GHz in the LC display. R6 from the YIG frequency corrector is used to set the display on the frequency counter to precisely 3.8GHz.

These settings are repeated alternately until the two cut-off frequencies on the

display and the frequency counter agree.

4. Literature

[1] Wolfgang Schneider, DJ8ES, Frequency generator (wobbler) up to 4GHz, Pp. 2 - 16, VHF Communications 1/2002

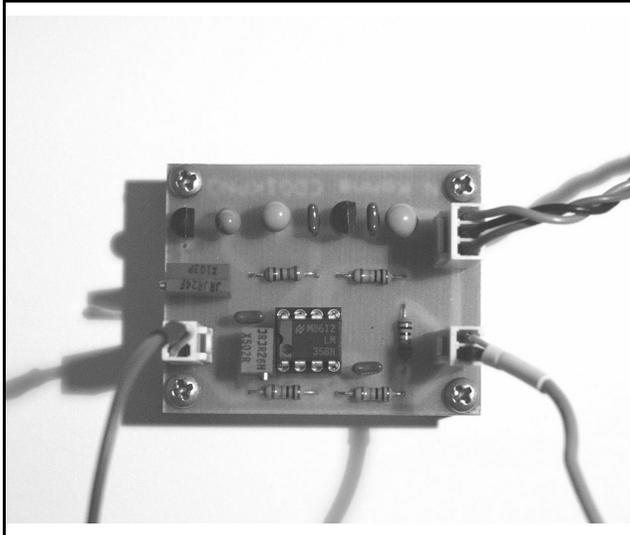


Fig 25: Completed YIG frequency correction PCB.



Konrad Hupfer, DJ1EE

L Band power amplifier for AO-40 Uplink

Amateur radio satellites offer many options for experimentation. The AM-SAT-OSCAR 40 (AO-40) satellite is currently in orbit. In addition to operating on other bands, it has an uplink in the L Band, 1296MHz. However, the power required for satisfactory radio contact is above the output of a normal transceiver, which makes it necessary to use a suitable power amplifier. A concept for such an RF power amplifier is shown below.

1. General

The experiences of many AO-40 users have demonstrated that a PEP power of approximately 50W at the input of a circular radiating antenna with approximately 20dB gain is sufficient for the L Band uplink, even using squint angles. Looked at from the point of view of cable losses it makes most sense to generate the power at the point where it is used: directly at the antenna power feed.

The amplifier described here has the following characteristics:

- $P_{pep} = 50W$
- $U_{ds} = 28V$
- $G = 12dB$

- $I_q = 300mA$

The direct mounting of an L Band helix or a patch antenna on the rear of the reflector offers the ideal solution.

The reflector plate of an antenna (e.g. made from 3mm aluminium) having the normal area of approximately 400cm², is not quite adequate for a heatsink at ambient temperatures of > 25°C. One remedy can be an additional “chimney”, consisting of approximately 1mm thick aluminium plate, with an associated cover. This additional cooling makes it possible to obtain thermally stable functioning, even in summer, for normal SSB mode with a PEP of approximately 55Watts.

2. The amplifier

The L Band amplifier uses a fairly standard circuit (Fig 1). Printed line transformers are used to transform the relatively low complex input and output impedances of the L-DMOS transistor used (UPF 1060P from ULTRA RF). These transformers are made on the familiar material RO 4003, substrate thickness 0.79 mm, $\epsilon_r = 3.35$, using stripline technology.

The general calculations for transforma-

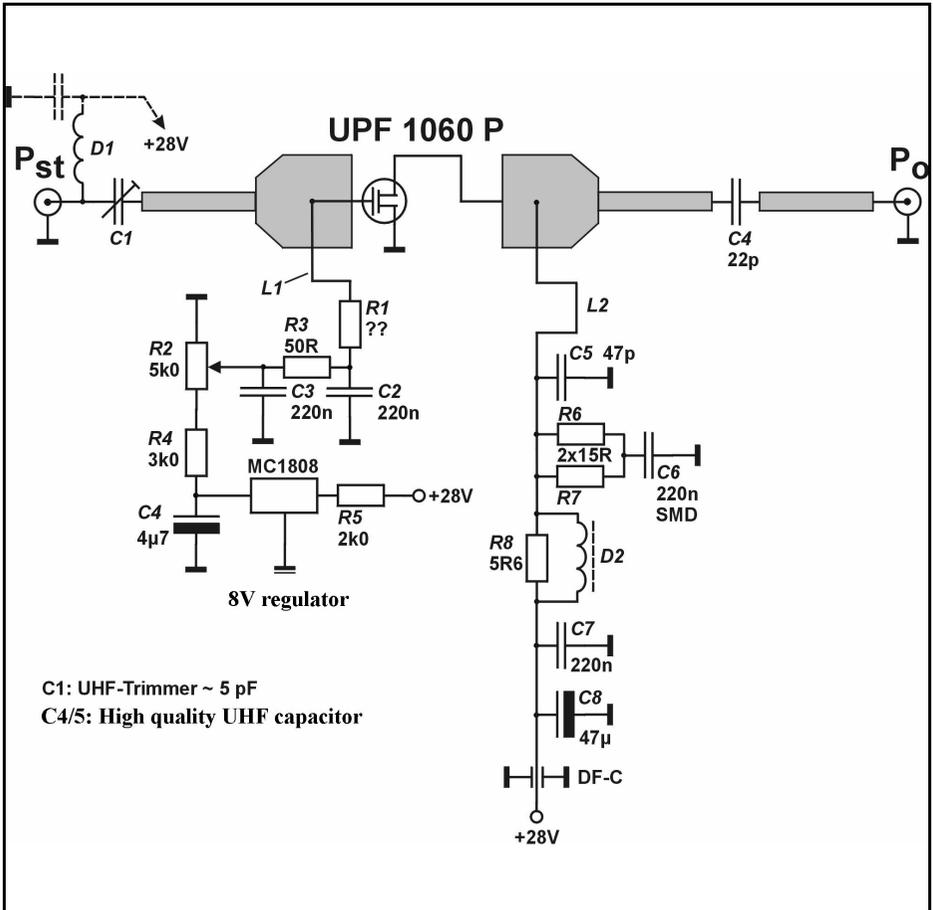


Fig 1: Circuit diagram of L band amplifier.

tion networks of this type can be found, among other places, in [1]. The printed matching networks are shown in Figs 2 and 3. Since the most important dimensions of the lines are shown, you can easily construct them yourselves.

The first specimens of the amplifier circuit boards were designed with Indian ink, using the age-old procedure, and then etched in the usual way. The undersides of the circuit boards naturally have a copper coating.

In the present circuit, for the sake of simplicity, no stabilisation is provided

for the 300mA zero signal current. It would also be expedient to incorporate temperature compensation, to be prepared for “extreme cases”. A cut out when excessive temperatures arise can also be recommended!

The DC wiring can be laid out as you wish, and/or in accordance with the mechanical size of the components used. This applies even to the M3 holes needed to fasten the circuit board (heat dissipation required for copper plate housing).

It can be seen from Figs 2 and 4 that, in addition to the transformer lines, some

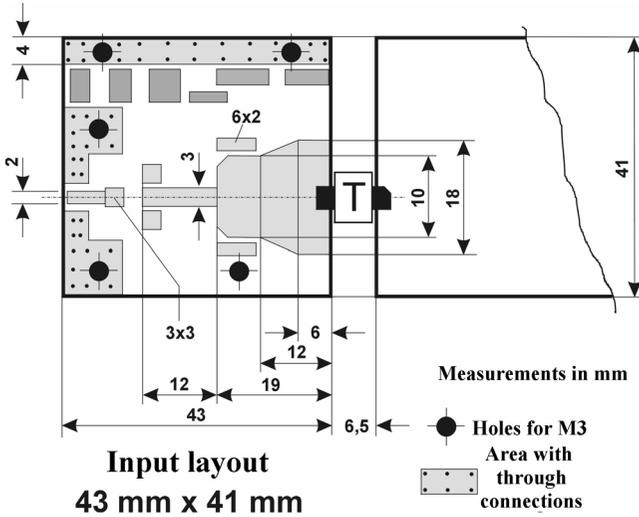
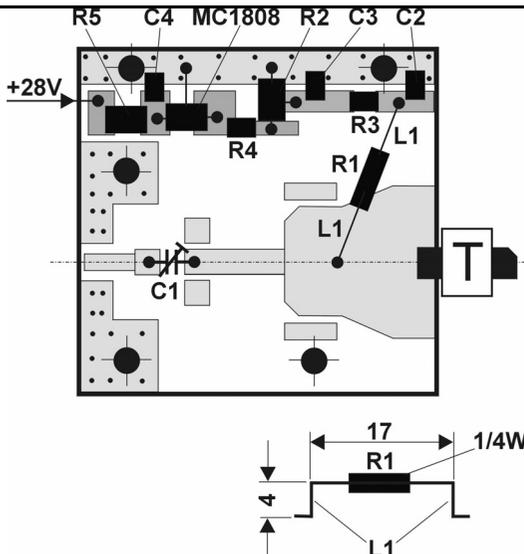


Fig 2: Input circuit layout showing measurements of matching networks.

small additional areas are also laid out. These are the so-called trim elements, used to fine tune the amplifier for the best input matching and/or for maximum output power and linearity. This is

needed to compensated for, for example, when similar transistors are used, divergences in the input and output impedances occur or there are tolerances in the mounting of the transistor.



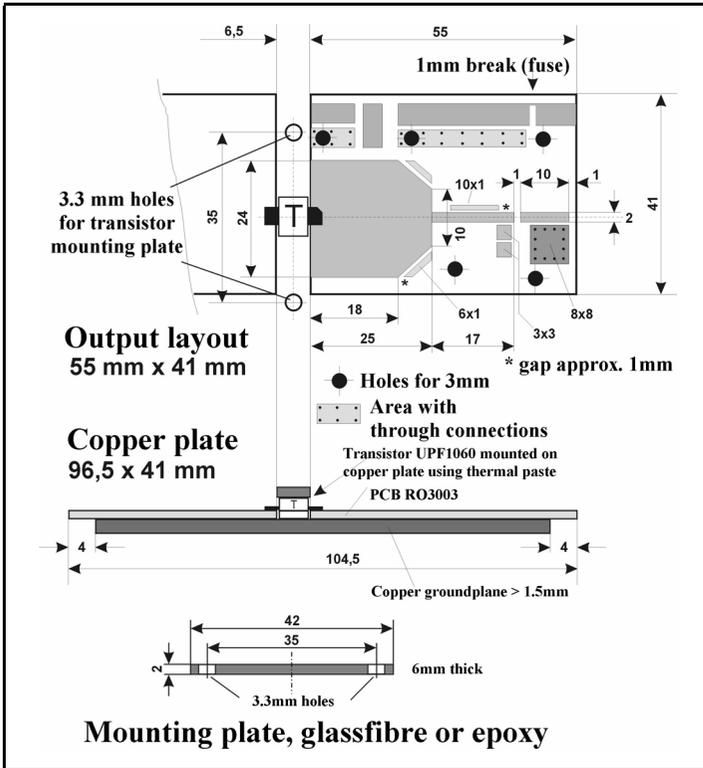


Fig 4: Output circuit layout showing measurements of matching networks and details of transistor mounting.

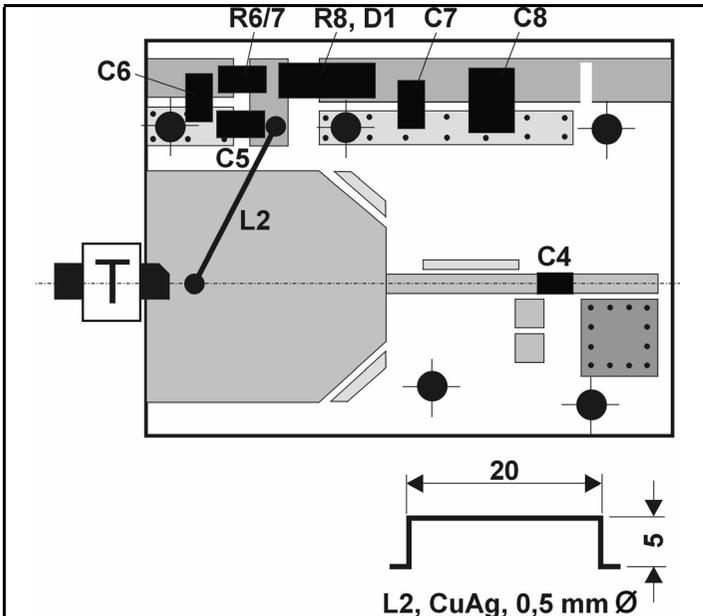


Fig 5: Component layout for output circuit showing details of L2.

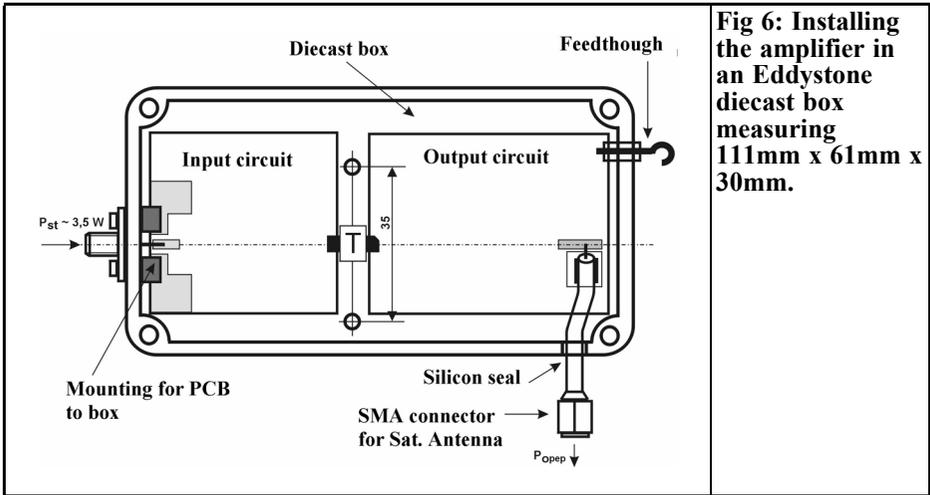


Fig 6: Installing the amplifier in an Eddystone diecast box measuring 111mm x 61mm x 30mm.

3. Mechanical and electrical assembly

The semiconductor type selected, UPF 1060 P, is a flangeless model, because of price. Figs 4, 6 and 7 show one possible assembly, using a 3mm thick carrier plate made from copper as a heat spreader! This mounting plate should be as level as possible on both sides; it should preferably be finished by surface milling on both sides! The individual circuit boards are soldered onto the copper plate using a hotplate. The distance of 6.5mm between

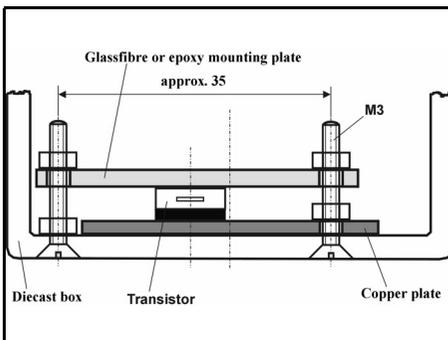


Fig 7: Details of transistor mounting using mounting plate.

the circuit boards should be adhered to, the copper surface must not be tinned in this area!

When the circuit boards have been assembled, the transistor is put in place, but initially without its connections soldered to the striplines. The module (copper plate with soldered-on circuit boards) is screwed into the housing, the base of which has been finished by surface milling! Sparing use a uniform application of heat-conducting paste between the transistor, the copper plate and the housing base. The transistor is now pressed onto the copper plate by means of a flexible implement (un-coated printed circuit material, fibreglass). You must naturally treat the equipment carefully! Now the connecting lugs can be soldered. (Figs 6 and 7).

The amplifier must now be mounted flat onto the chimney/radiation reflector installation in its housing for best heat dissipation. The holes required for M3 countersunk screws can be made in the reflector. Another solution is to cut M3 threads into the reflector and then screw the entire unit onto the reflector from the amplifier side. (Figs 8 and 9).

Various mechanical solutions can be made, depending on the application. For simplicity's sake, the power supply in this

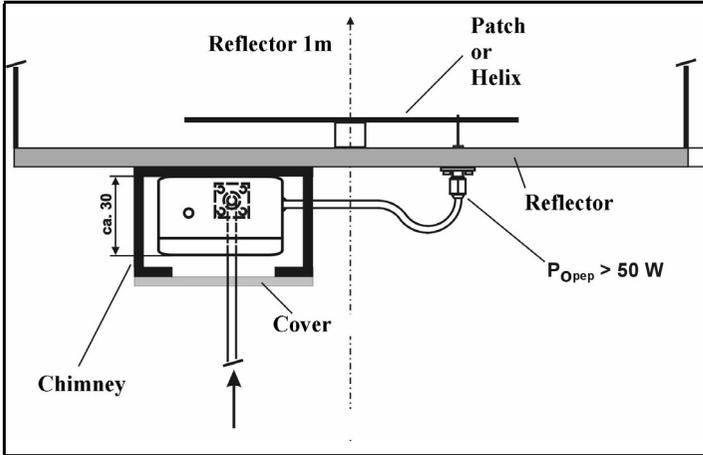


Fig 8: Mounting the amplifier on an antenna with cooling chimney approximately 150 x 200mm.

layout is provided using a lead-through filter mounted in the housing wall. The supply voltage of 28V can be fed through the coaxial feeder cable.

The entire structure should be painted white to keep the temperature as low as possible, even when the sun is shining!

The circuit has been assembled and tested many times. The characteristic, interpolated from the worst values of three amplifiers, is shown in Fig. 10. The typical measurements of the RF power amplifier for single-tone control are as follows:

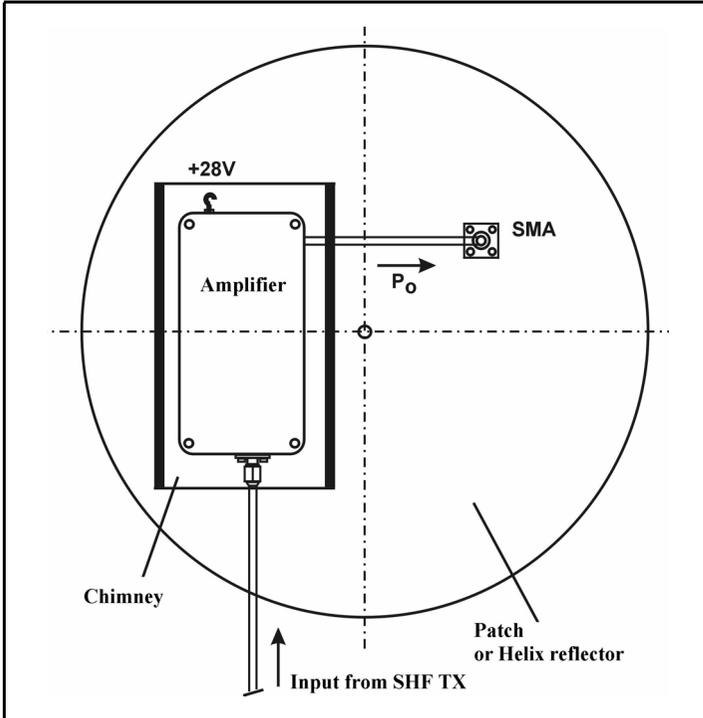


Fig 9: Rear view of mounting the amplifier on an antenna with cooling chimney approximately 150 x 200mm.

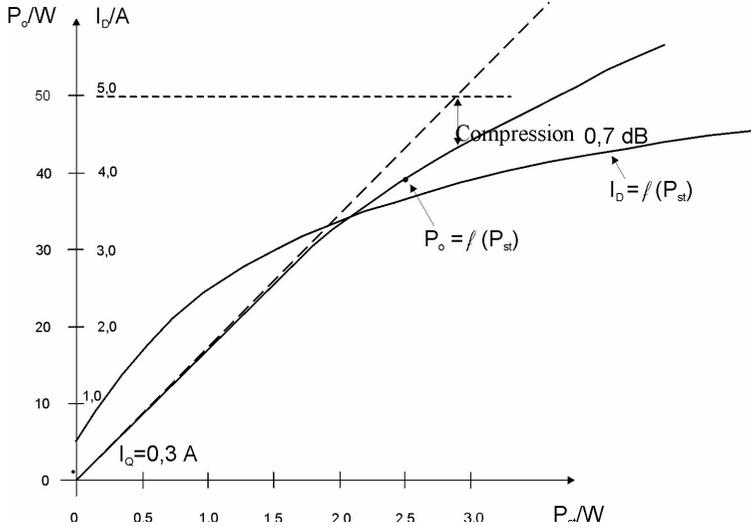


Fig 10: Transfer characteristics of the L band amplifier.

- $P_0 = 50\text{W}$ (with compression approximately 0.6dB)
- $J_D = 4.5\text{A}$
- $J_{DQ} = 300\text{mA}$
- $P_{st} = 3.2\text{W}$
- $G = 12\text{dB}$
- $\eta \geq 49\%$

Incidentally, this description should be merely a stimulus to constructing an RF amplifier; it should not in any way restrict my own ideas regarding design.

The author will be happy to supply any additional information regarding the practical execution of the amplifier and to exchange experiences.

Contact: Konrad.hupfer@t-online.de

4. Literature

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- [1] Matching an LDMOS power transistor at 1.3GHz with an output of 120W; Proceedings of Congress on VHF-UHF 2002; Munich Technical College, 9th. 10th March, 2002
- [2] DATA BOOK, Ultra RF Power, www.globes.de



Wolfgang Schneider, DJ8ES

Frequency / power standard for calibration

Measuring instruments such as frequency counters or wattmeters are among the standard tools of many active radio amateurs. This equipment is often required to monitor ones own radio station or as an aid in circuit design and assembly of RF equipment. To be able to test that this equipment is functioning correctly and to calibrate it, a frequency / power standard is an important tool.

The following article describes the basic considerations for the circuit concept and assembly of such a standard.

1. Considerations regarding circuit design

The aim of this article is to create a frequency / power standard for calibrating simple frequency counters and wattmeters (mW meters) with a diode detector or a bolometer head. Important considerations for this concept are, manageable implementation cost and technical comprehensibility (not only for experienced technicians).

In order to satisfy the requirements of the shortwave, ultra shortwave and UHF/VHF users at the same time, a compromise must be found with regard to the

output frequency. The range around 50MHz is suitable here for both the shortwave amateur and the GHz components usually designed for broadband use. For example, commercial diode detectors may well be specified for up to 18GHz (or beyond!), but can not be used at low frequencies, i.e. ≤ 10 MHz.

On the other hand detectors developed, e.g. as do-it yourself projects, supply usable results only up to a few 100MHz. This is also true for resistance bridges in bolometer heads.

From the description, “frequency / power standard for calibration purposes”, in addition to the precise frequency a precisely defined output level must also be available. Normal mW meters are designed for up to 100mW (+20dBm). This output should also be used for this project. Lower power levels can easily be created without any problem by means of a downstream attenuator. An attenuator that can be switched in 1dB steps is an interesting option [1].

Oven stabilised oscillators (OCXOs) are practically tailor-made for generating a high precision frequency output. The characteristics of such an OCXO are far beyond everything the radio amateur is used to from the measurement equipment available to him or her. For example, the short-term frequency stability of an HP10544A is specified at $1 \times 10^{-11}/s$ (1Hz at 100GHz), with a long-term sta-

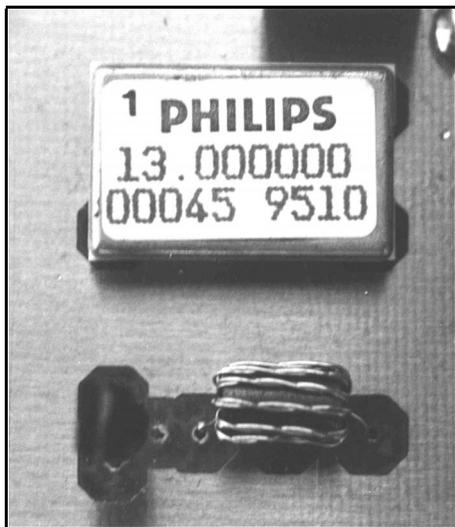


Fig 1: Picture of the TCXO in a 15mm x 25mm housing.

bility of $<5 \times 10^{-10}$ /day. Normal frequency counters, with a crystal as the internal oscillator for the gate time control offer only 10^{-6} Hz/1s here (1Hz at 1MHz). The short-term stability, and thus the accuracy of measurement of the frequency counter, is thus worse by a factor of 100,000!

Of course, the price of such oscillators is a deterrent to many people. Even in flea markets, you have to pay more than 100 Euros for used OCXOs of this type. For new oscillators, the price would certainly reach four figures.

Alternatively, temperature compensated oscillators (TCXOs) are also available. It is true that their frequency stability is lower than that of a good OCXO, but, with a short-term stability of approximately 1×10^{-8} Hz/1s (1Hz at 100MHz), is still better by two powers of ten than what many of us can reckon with today.

If a higher frequency precision is required, then the link to a high quality frequency standard can be made without any problem, using a PLL control circuit.

A controlled amplifier must be used in order to obtain the defined power level of

100mW. The precision of this power level is only dependent on the reference used.

One consideration is the thermal behaviour of the control circuit. However, because components are available at favourable prices, this problem is much easier to solve than the one relating to frequency stabilisation.

Starting from the assumption that such a frequency / power standard is usually used at room temperature, this calibration aid can be created at an acceptable price.

2. Approach to a solution

Highly stable oscillators are currently available based on GSM technology but an interesting product, manufactured by Philips, is available at a favourable price. The TCXO (Fig. 1) oscillates at 13.0000MHz. Various measurements have given a short-term stability of $\pm 2 \times 10^{-8}$ Hz/1s for the frequency.

The precise oscillation frequency can be finely adjusted using a control input, by means of a tuning voltage (0.5V). In Fig. 2, the frequency response is plotted against the voltage feed.

The oscillator frequency of 13MHz is, at first glance, unusual. If the frequency is quadrupled to 52MHz, the nominal frequency for the frequency / power standard is generated. The TCXO frequency divided by 13 gives 1MHz. The oscillator can be easily synchronised with a high quality frequency standard, for example, 10MHz by means of a PLL.

The frequency of 52.0000MHz generated in this way can achieve the defined output level of 100mW. The amplifier must be able to deliver this output reliably and should still have a few dB in reserve. A small part of the output signal is rectified and fed back to a PIN diode

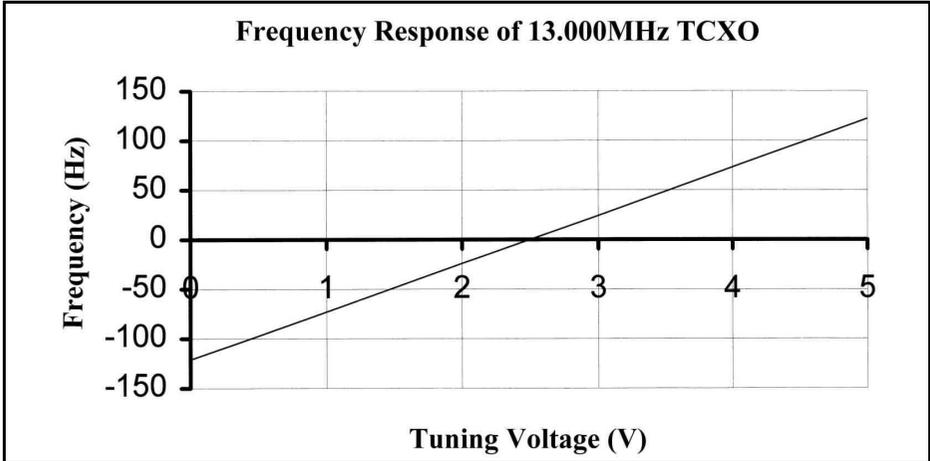


Fig 2: Frequency change of the TXCO with change of tuning voltage.

regulator connected in series to the amplifier.

3. The TCXO assembly

The core of the TCXO assembly is the temperature compensated quartz oscillator (IC1) for 13MHz. At an operating voltage of just 6V, this TCXO supplies an extremely stable output frequency with a level of approximately 0.3Vss.

The short-term frequency stability of the

oscillator is better than $\pm 2 \times 10^{-8}$ Hz/1s. The precise frequency is finely adjusted with the R5 trimmer (2 kΩ). The possible tuning range is shown in Fig. 2.

Only a small part of this wide tuning range (± 3 Hz) is used for this application. The resistance combination R2/R3 is used to pre-set the frequency. The process to determine the necessary resistance values, depending on the power supply and, naturally, the specimen mean variations of the TCXO module, is described in detail in the following instructions for assembly and putting into operation.

The TCXO is followed by the buffer

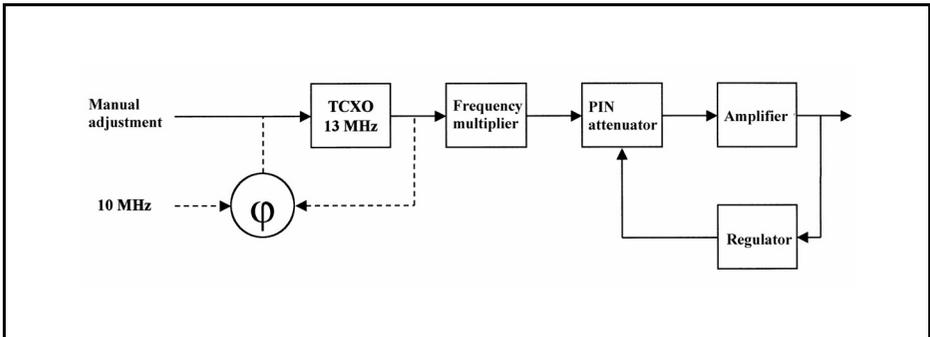


Fig 3: Block diagram showing the concept of the frequency / power standard.

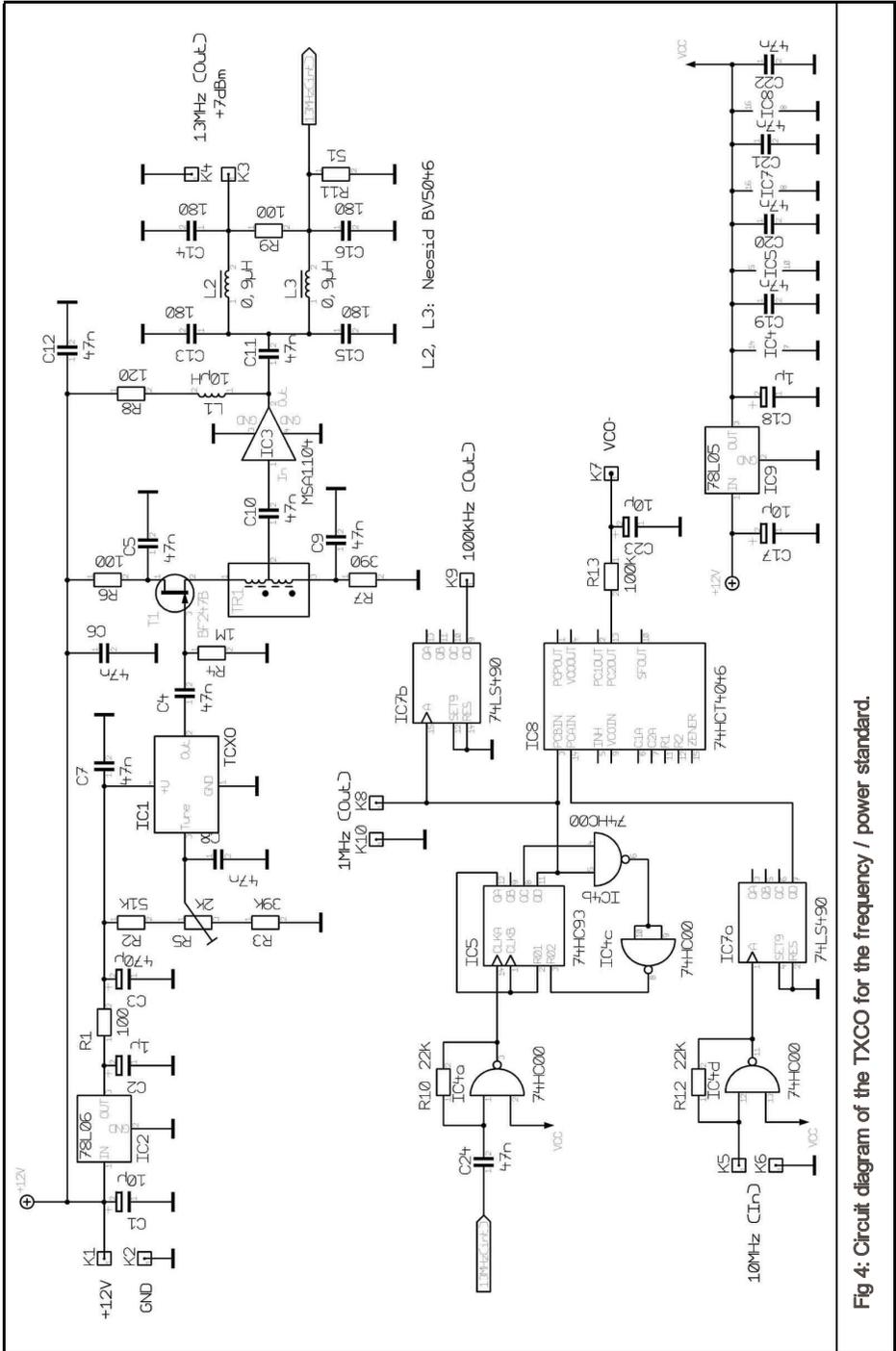


Fig 4: Circuit diagram of the TXCO for the frequency / power standard.

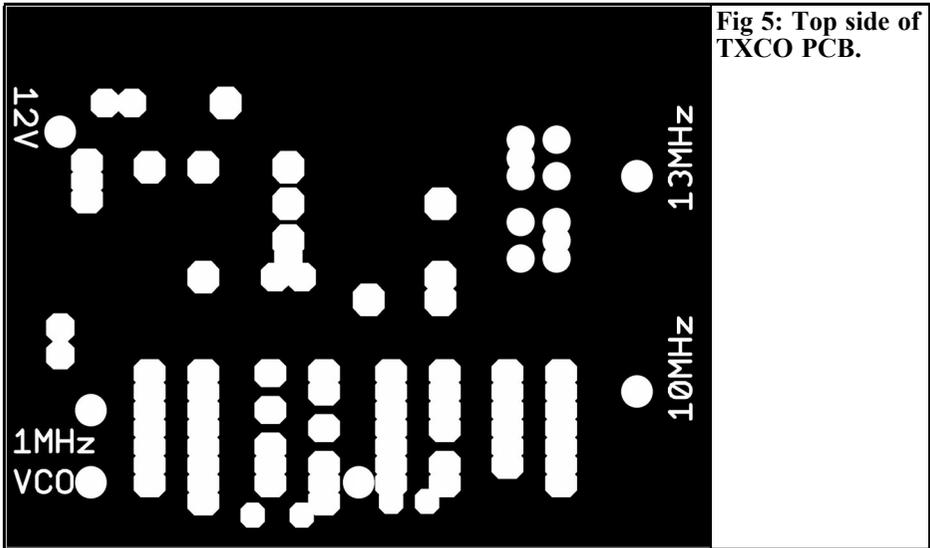


Fig 5: Top side of TXCO PCB.

stage with a type BF247B FET (T1). The latter also acts as an impedance converter to 50Ω .

The necessary amplification of approximately 13dB is provided by the MSA1104 MMIC (IC3) with an output of approximately 10mW. The latter is divided by a Wilkinson splitter (L2, L3 and C13 - C16). This gives +7dBm (5mW) at 13.0MHz available for the following stages. The power splitters second output is required internally for the PLL control circuit.

Following conversion to TTL level using IC4a (74HC00), the 13MHz is divided down to 1MHz by means of IC5 (74HC93). For any other possible uses for example as a calibration mark setter, a 100kHz signal is generated in addition through IC7b (74LS490).

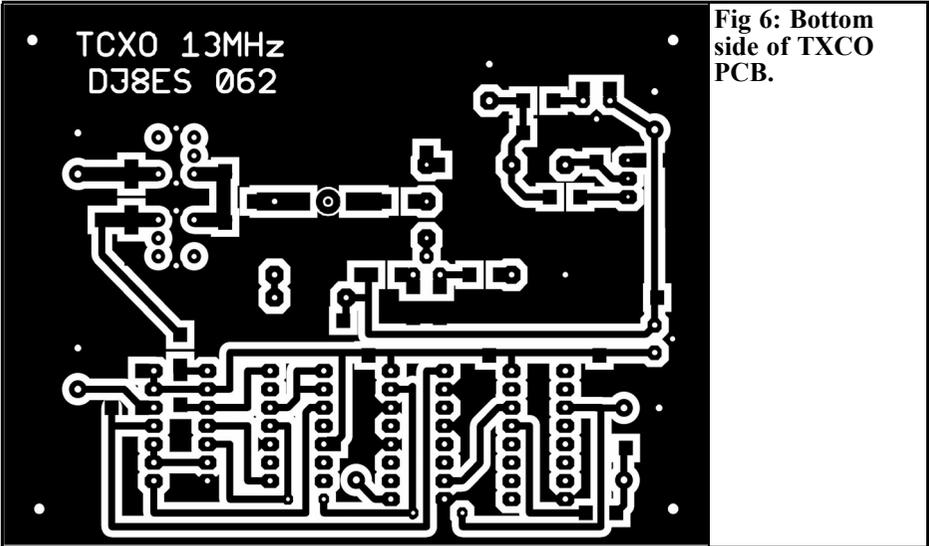
The oscillator can be synchronised with a 10MHz frequency standard, as initially required. This reference signal is divided by 10 in IC7a (74LS490). Thus two 1MHz signals are available to the IC8 phase indicator (74HCT4046). The loop filter at the PLL output is designed for a high recovery time constant due to the high value TCXO in the circuit, with $100k\Omega$ and $10\mu\text{F}$.

3.1. Assembly instructions and putting into operation of TCXO

The TCXO is assembled on a double sided copper coated circuit board - dimensions 75mm x 100mm (Figs. 5 and 6). Due to the many connections that may be necessary, it is not intended to be built into a housing.

Following the drilling of the circuit board with a 0.8mm or 1mm. drill, the components are mounted on the board in no particular order (Figs 7 and 8). As far as possible, connections to earth (resistors, terminal pins, etc.) are soldered on both sides. This provides the necessary through plating for the earth areas.

Before the assembly is put into operation, the frequency response of the TCXO is initially recorded. All that is needed to do this is a high precision frequency counter or a frequency standard. Irrespective of whether it is synchronised using a connected frequency counter or a PLL (IC8), the tuning voltage required for the nominal frequency at the tuning input of the 13MHz TXCO is important. In the specimen assembly, this voltage required was 2.490V.



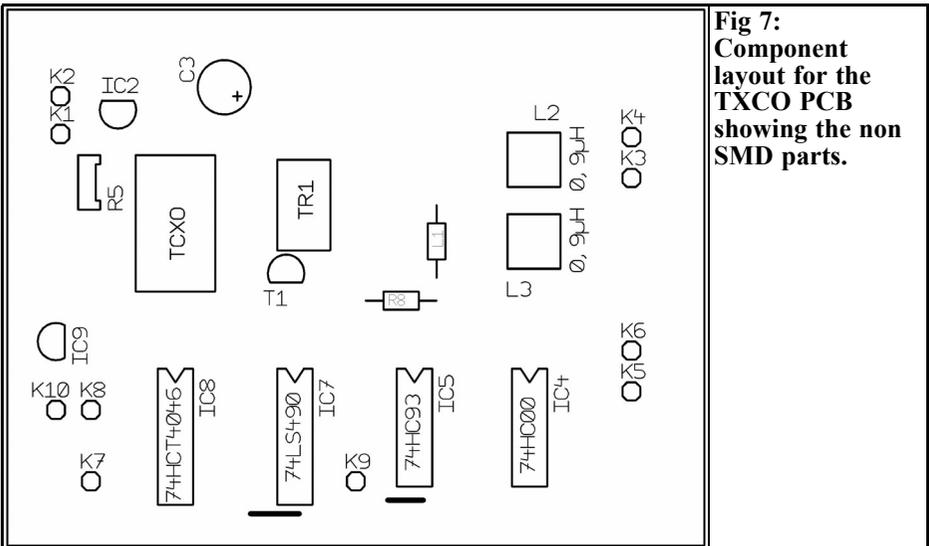
The voltage divider made from R2 and R3 must be calculated for the tuning voltage in the next stage. This is done, following the appropriate conversion, using the formula

$$V_{Tune} = V * R2 / (R2 + R3)$$

The voltage, V is measured at the +V connection of the TCXO module. As a result of the voltage drop through R1 (100Ω), this is slightly less than the

output voltage of the IC2 fixed voltage regulator (78L06). In the specimen assembly, the TCXO operating voltage was precisely 5.740V.

In the specimen assembly, the resistances are calculated at R2 = 51kΩ and R3 = 39kΩ. With a potentiometer of 2kΩ (R5), a tuning range of ±3Hz was obtained. For comparison: R5 = 1kΩ corresponds to ±1.5Hz and R5 = 5kΩ corre-



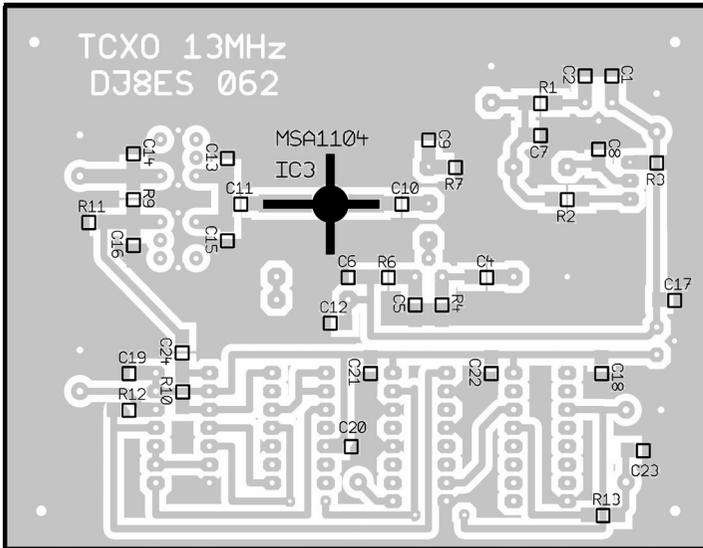


Fig 8:
Component layout for the TCXO PCB showing the SMD parts.

sponds to $\pm 7.5\text{Hz}$.

Fig. 2 graphically represents the frequency response of the TCXO, plotted against the tuning voltage applied.

The tuning potentiometer ($2\text{k}\Omega$) should be a 10 turn helical potentiometer and it should be incorporated into the front panel with the frequency tuning change-over (internal/external). The external setting can be carried out using the PLL circuit. To this end, K7 (VCO control voltage) is connected to the tuning input of the TCXO (loop from R5).

- C1,C17 capacitor radial
- C1,C17 $10\mu\text{F} / 25\text{V}$, SMD tantalum
- C23 $10\mu\text{F} / 16\text{V}$, SMD tantalum
- C2, C18 $1\mu\text{F} / 16\text{V}$, SMD tantalum
- R5 Spindle carrier. $2\text{k}\Omega$, Model 64W
- R8 Carbon film resistor. 120Ω $\frac{1}{2}\text{W}$, RM 10mm
- TR1 Transformer (trifilar), 7 turns 0.2mm Cu enamelled wire
- 10 x Terminal pin 1 mm
- 1 x Circuit board DJ8ES 062

SMD components, model 1206:

3.2. TCXO assembly components list

- T1 Transistor BF247B
- IC1 TCXO 13,000 MHz, Philips
- IC3 MMIC MSA1104
- IC4 74HC00
- IC5 74HC93
- IC7 74LS490
- IC8 74HCT4046
- IC2 78L06, 6V voltage regulator
- IC9 78L05, 5V voltage regulator
- L1 $10\mu\text{H}$ choke
- L2, L3 BV5046 Neosid $0.9\mu\text{H}$,
- C3 $470\mu\text{F} / 16\text{V}$, electrolytic

- 14 x 47nF
- 4 x 180pF
- 1 x 5 Ohm
- 3 x 100Ohm
- 1 x 390Ohm
- 2 x 22kOhm
- 1 x 51kOhm
- 1 x 39kOhm
- 1 x 100kOhm
- 1 x $1\text{M}\Omega$

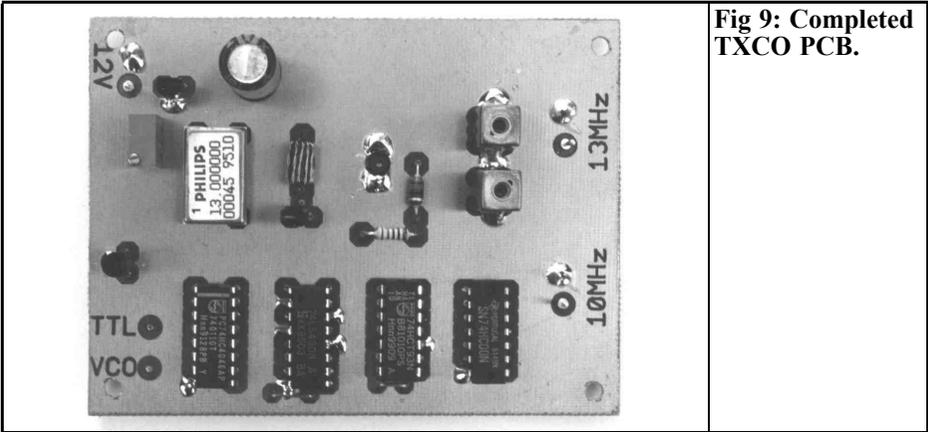


Fig 9: Completed TXCO PCB.

4. The quadrupler

One of the design considerations for the circuit was an output frequency in the area of 50MHz. To obtain this, the TCXO frequency of 13.0MHz must be quadrupled. This achieved with the transistor T1 (BFR90a). It has a high resistive input using of a 1:9 transformer (TR1). Approximately 7 turns (trifilar) are wound on a ferrite core and wired up for the transformer. The type and form of

this ferrite core are not at all critical.

A 6dB attenuator is connected in series to match the level of this quadrupler stage to the output of the TCXO assembly.

The 3 stage band filter following the transistor filters out the desired 52.0MHz. Fig. 23 shows the frequency spectrum, measured at full power at the output of the amplifier stage described below (Section 5). All harmonic and spurious signals are attenuated by more than 35dB.

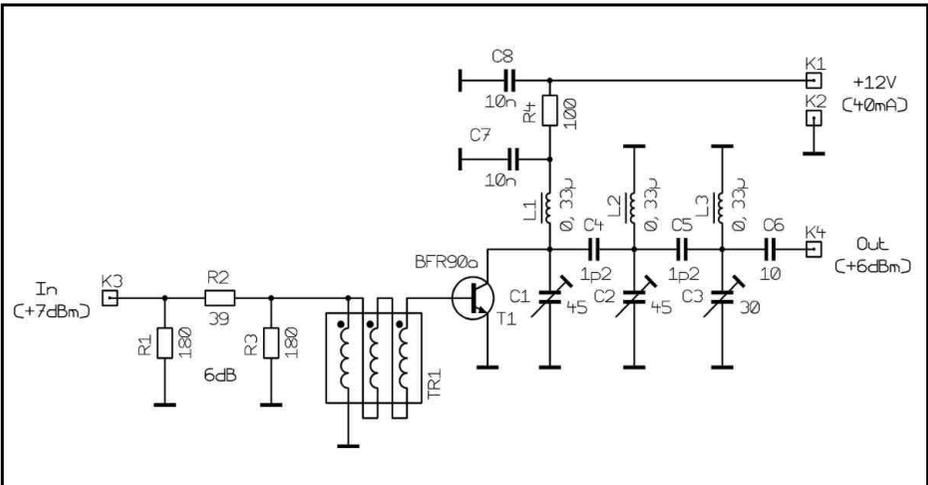


Fig 10: Circuit diagram of quadrupler with three stage band pass filter.

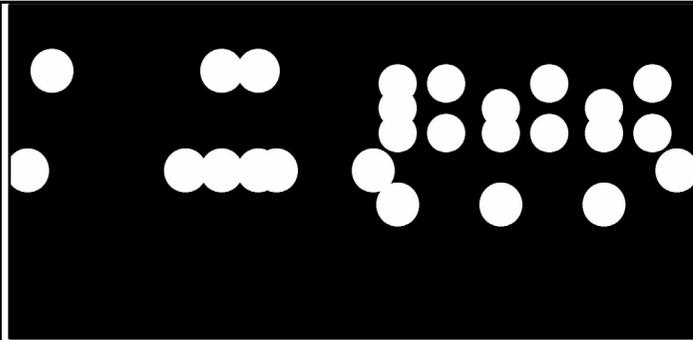


Fig 11: Top side of quadrupler PCB.

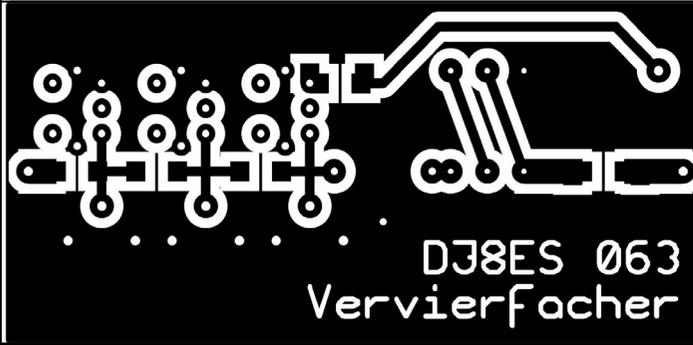


Fig 12: Bottom side of quadrupler PCB.

4.1 Assembly instructions and putting the quadrupler into operation

The quadrupler assembly is mounted on a double sided copper coated circuit board, which has the dimensions 34mm x 72mm (Figs. 11 and 12). It thus fits into a standard 37mm x 74mm x 30mm tinplate housing. In the specimen assembly, the input and output are SMA sockets. The operating voltage (+12V at 40mA) is fed in through a 1nF

feedthrough capacitor.

When the circuit board has been drilled, it is populated in accordance with Figs 13 and 14. Special attention should be paid to the 1:9 transformer, do not to mix up the two connecting wires!

It makes sense to solder the circuit board into the tinplate housing before mounting the components. The circuit board is inserted deep into the housing. The earth areas are soldered to the frame on both sides. Both the input and output and the

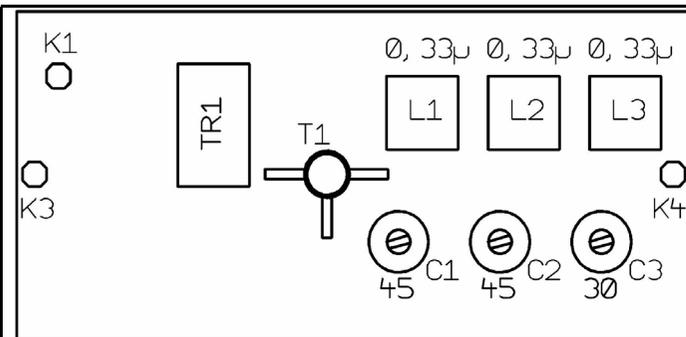


Fig 13: Component layout of quadrupler PCB showing non SMD parts.

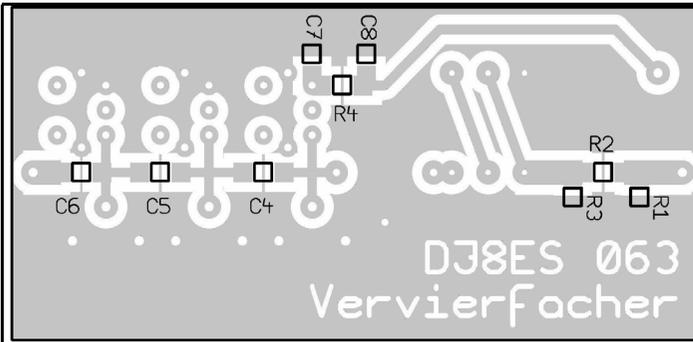


Fig 14:
Component layout of quadrupler PCB showing SMD parts.

power supply are connected to the circuit board using thin connecting wires.

The assembly can be put into operation immediately after a visual check. The foil trimmers in the 3 stage band filter are pre-adjusted to the mean setting.

With an input of +7dBm (5mW) from the TCXO assembly and a calibrated band pass filter, the quadrupler should supply a frequency of 52MHz at the output socket, with a level of approximately +6dBm (4mW)

4.2. Quadrupler components list

| | |
|-------|--------------------------------------------------------------|
| T1 | BFR90a |
| L1-L3 | BV5049 Neosid 0.33μH |
| TR1 | Transformer (trifilar), 7 turns with 0.2mm Cu enamelled wire |
| C1, C | 45pF (violet), foil trimmer RM 7.5 |
| C3 | 30pF (red), foil trimmer RM 7.5 |
| 1 | Circuit board DJ8ES 063 |

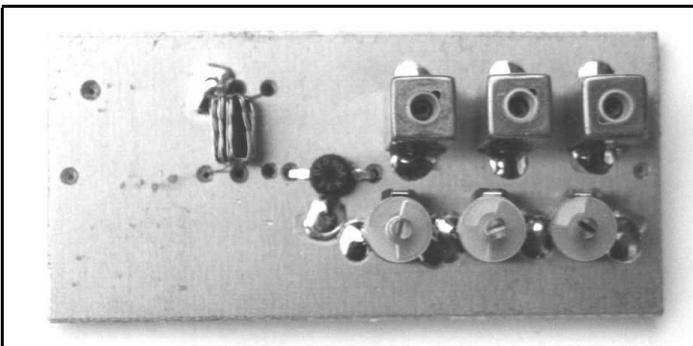


Fig 15: Top side of completed quadrupler PCB.

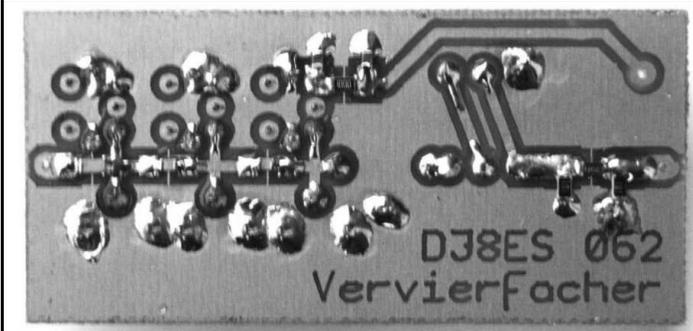


Fig 16: Bottom side of completed quadrupler PCB.

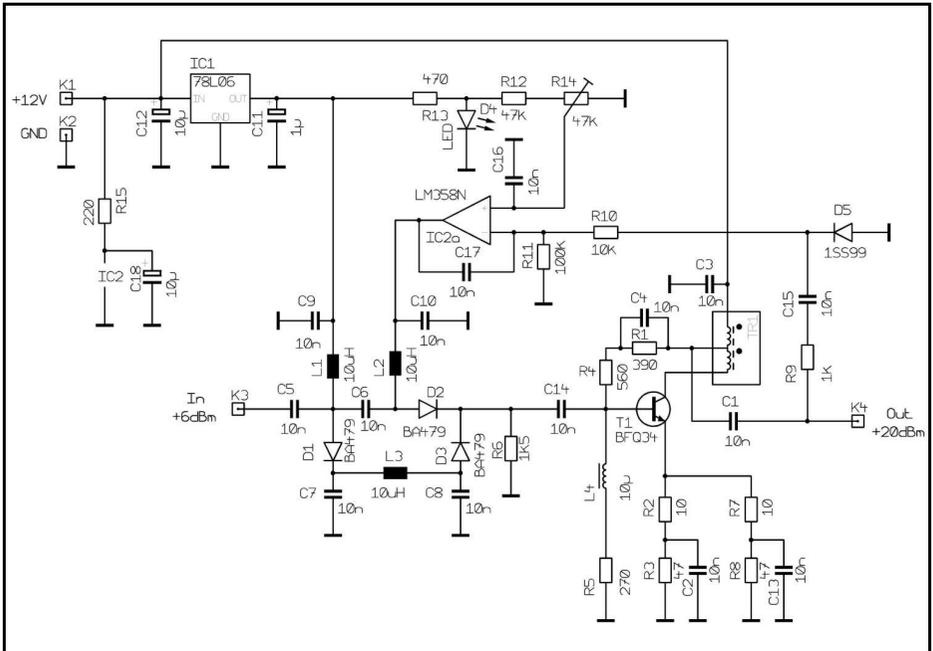


Fig 17: Circuit diagram of amplifier.

- 1 x 37 x 74 x 30 tinplate housing
- 2 x SMA flanged bush
- 1 x 1nF, feedthrough capacitor

SMD components, model 1206:

- C4,C5 1.2pF
- C6 10pF
- C7,C8 10nF
- R2 39Ohms
- R4 100Ohms
- R1,R3 180Ohm

5. The amplifier assembly

The amplifier is assembled using the tried and tested 50Ω broadband technology (Fig.17). The transistor T1 (BFQ34)

can adequately handle the output of +20dBm (100mW) plus a few dB in reserve. The stage supplies approximately 17dB of amplification.

Naturally, a cheaper type can be used in the circuit. However, it must also be able to produce the desired output!

A PIN diode attenuator is connected in front of the amplifier. The circuit, which has 3 BA479 diodes (D1 - D3) is taken from an old Siemens application. Attenuation is adjusted using the diode current.

A small part of the output is rectified, using a 1SS99 Schottky diode. The DC voltage obtained is compared in the operational amplifier, IC2a (LM358N) with the reference set using the trimmer, R14 (47kΩ). The output controls the PIN diode attenuator.

The interesting design for stabilising the reference voltage using a light emitting diode (D4) comes from Bernd Kaa (DG4RBF) [2].

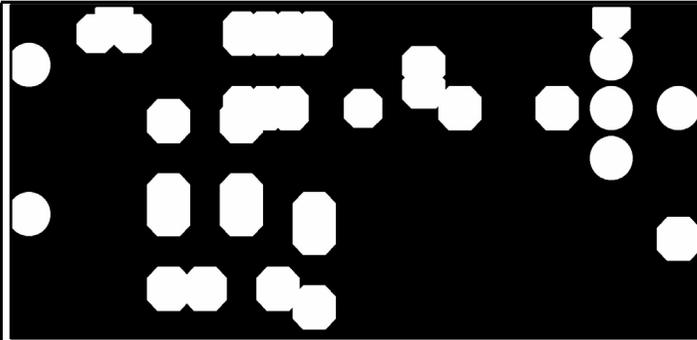


Fig 18: Top side of amplifier PCB.

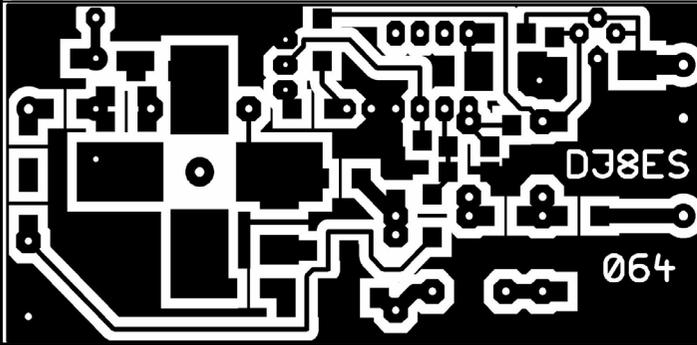


Fig 19: Bottom side of amplifier PCB.

5.1. Assembly instructions and putting the amplifier into operation

The amplifier assembly is mounted on a double sided copper coated circuit board, which has the dimensions 34mm x 72mm (Figs. 18 and 19). It fits into a standard tinplate housing with the dimensions 37mm x 74mm x 30mm. In the specimen assembly, SMA sockets have been used for the input and output. The operational voltage of +12V (approximately 90mA)

is fed in through a 1nF feedthrough capacitor.

The fully drilled circuit board is inserted deep into the housing and the earth areas are soldered to the housing frame all round on both sides. The circuit board is populated in accordance with the component plans in Figs 20 and 21 in no particular order.

The amplifier is designed to be for broadband. There is thus no need for calibration, as there normally would be.

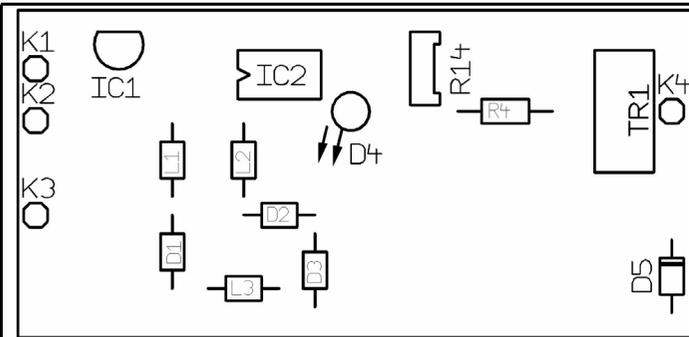


Fig 20: Component layout of amplifier showing non SMD parts.

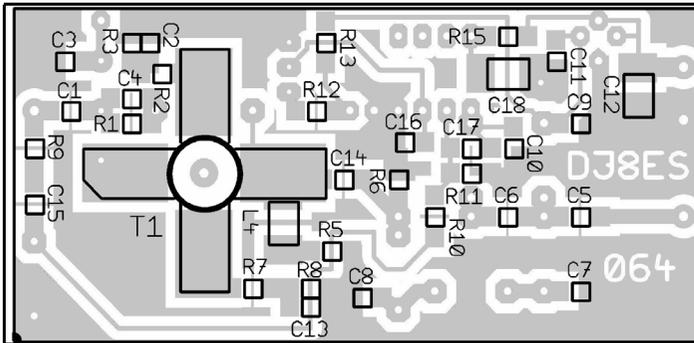


Fig 21:
Component layout of amplifier showing SMD parts.

The 47kΩ trimmer is used to set the output at 100mW. The quadrupler described above is used for input.

5.2. Amplifier assembly components list

- IC1 78L06, Voltage regulator
- IC2 LM358N, Operational amplifier
- T1 BFG34
- D1-D3 BA479, PIN diode
- D4 LED
- D5 1SS99, Detector diode
- L1-L3 10μH, Choke axial, RM 7.5 mm
- L4 10μH, SMD choke
- C11 1μF / 16V, SMD tantalum electrolytic capacitor
- C12 10μF / 16V, SMD tantalum electrolytic capacitor
- R4 560Ohm, RM 10mm

- TR1 Transformer (bifilar), 7 turns 0.2mm Cu enamelled wire
- 1 x Circuit board DJ8ES 064
- 1 x Tinlineplate housing 37 x 74 x 30 (mm)
- 2 x SMA flanged socket
- 1 x Feedthrough capacitor 1nF, solderable

SMD components, models 1206:

- 16 x 10nF
- 2 x 100Ohm
- 2 x 470Ohm
- 1 x 220Ohm
- 1 x 270Ohm
- 1 390Ohm
- 1 x 470Ohm
- 1 x 1kOhm
- 1 x 1.5kOhm
- 1 x 10kOhm
- 2 x 47kOhm
- 1 x 100kOhm

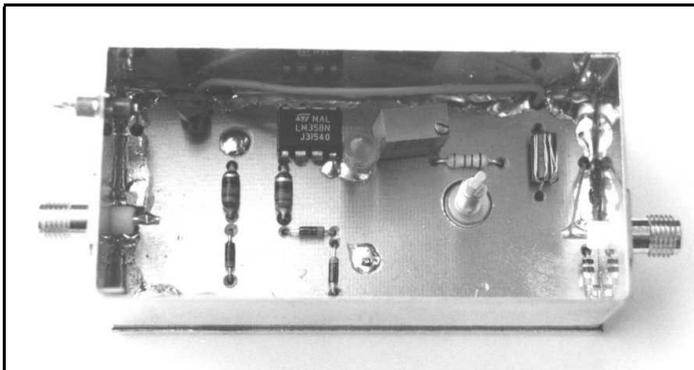


Fig 22:
Completed amplifier PCB in it's tinlineplate housing.

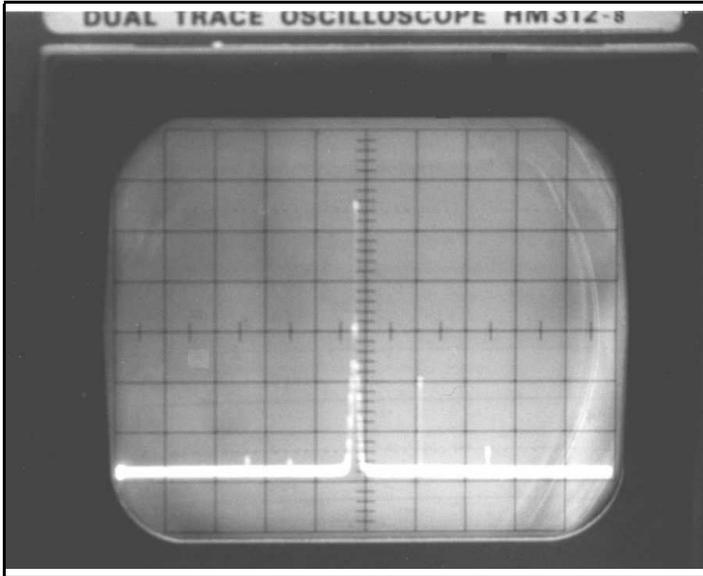


Fig 23: Picture of the output spectrum showing that any unwanted signals are at least 35dB below the wanted signal.

6. Summary

The frequency / power standard described offers a favourably priced and yet high quality aid for calibrating simple frequency counters and diode detectors or bolometer heads for power measurement.

The modular construction, broken down into oscillator, frequency multiplier and regulated power amplifier, makes individual tuning processes possible while keeping within the overall concept initially discussed. Thus a modification to another frequency range and/or another output level is possible.

As an option, a switchable attenuator, like, for example, the one mentioned in [1], can be added at the output. The output level can thus be adjusted in 1dB steps from +20dBm to 107dBm. That is more than adequate for calibration purposes.

7. Literature references

- [1] Wolfgang Schneider, DJ8ES: Control logic for a switchable attenuator; VHF Communications 1/03, Pp. 8 - 13
- [2] Bernd Kaa, DG4RBF: KW-Synthesizer from 1 - 65 MHz with DDS and wobble function; UKW Berichte 4/99, Pp. 205 - 222



Sigurd Werner, DL9MFV

76GHz amplifier

Following the publication of an article on a 76GHz transverter module [1], this article describes a mechanically compatible amplifier for this frequency. The amplifier uses two MMICs (IAF-MPA7710) connected in series, and originates from development work by the Fraunhofer Institute for Applied Solid-State Physics. The gain of the amplifier is 24dB at 76,088MHz.

The mismatches found at the transitions from microstrips to waveguides can be compensated for by careful matching (using pennants). The individual gain data for the various input power levels are shown and discussed, together with the outputs obtained. The amplifier cannot be used for reception due to the relatively high noise factor of >10dB.

1. Introduction

The weak point in microwave a connection is not, as is often wrongly assumed, the relatively low transmission power. It is frequently a poor receiver and the poor processing of the receiving signal.

Low noise preamplifiers with 20 to 26dB gain and noise factors of 0.2 to 1dB can be found in many amateur radio set-ups

on the 2m band. You are decidedly less likely to find good receivers in the GHz bands. On the other hand, there is a requirement on the transmission side as well. The typical power level at a mixer output amounts to approximately 100 μ W. This signal must be increased, with the aid of an amplifier. So its a genuine challenge to create an amplifier (or preamplifier) for 76GHz that can be used with the transverter module described recently [1].

2. Concept and selection of semiconductors

The first difficulty lies in the procurement (selection would be something of an exaggeration) of suitable MMICs for this frequency. Siemens manufacture a two-stage GaAs amplifier chip (T602B-MPA-2) for use in its car collision radar, which amplifies small signals by approximately 9.5dB [2]. The small number of semiconductors that we possessed were "consumed" on another project, and further supplies of this chip are unfortunately no longer be available.

One genuine alternative to this is an MMIC that has been developed at the Fraunhofer Institute for Applied Solid-State Physics in Freiburg. This is another

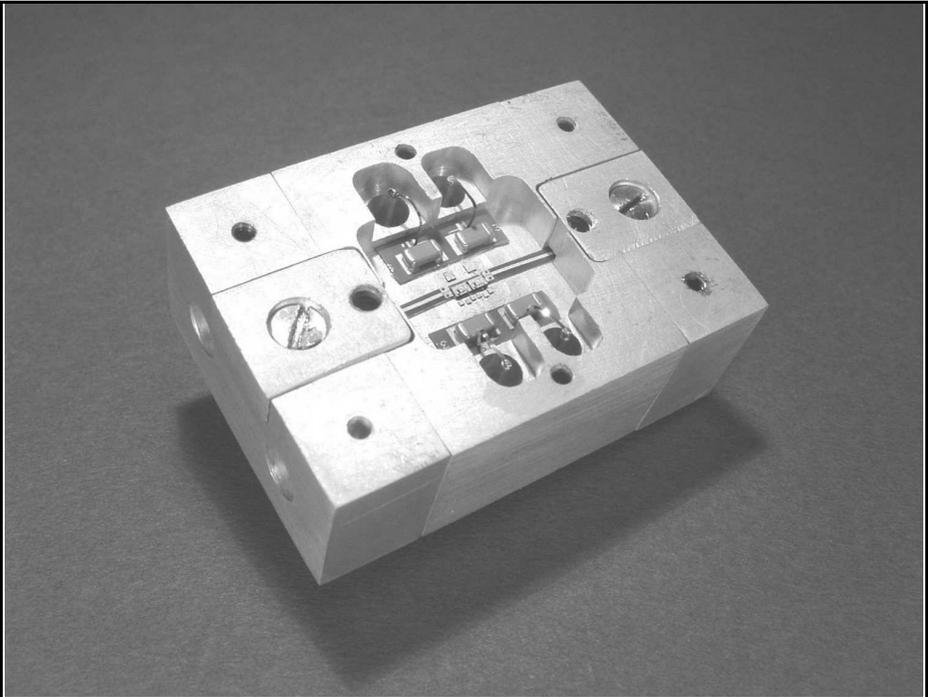


Fig 1: Picture of the completed 76GHz amplifier.

two-stage amplifier chip (1.5 mm x 1 mm x 0.635 mm), with the designation IAF-MPA7710, which has the following characteristics:

Frequency range: 73 - 80GHz
 Gain: >11dB
 Output: >14dBm at 1 dB compression, and with a power consumption of approximately 800mW [3].

Since gate 1 is earthed, only two positive voltages of approximately 1.5V (for Gate 2) and approximately 4V each for all drain connections are required.

In order to attain a usable level of amplification, two MMICs are wired in series, without any additional matching circuit between the two chips.

3. Mechanical and electrical assembly

The housing with dimensions of 27.5mm x 39.8mm x 13.5mm, was milled from brass and subsequently gold-plated (Fig. 1). The two chips were mounted in a 0.5mm hollow in the 4.1mm machined cavity. This balances out the difference in height between the MMICs (0.635 mm!) and the connection substrates (0.254 mm). Strict attention was paid to ensure that the distance between the two MMICs and their distance from the substrates were as small as possible (approximately 60 or 75 μ m) (see also Fig. 3).

The connection substrates that link the chips with the two WR-12 waveguides

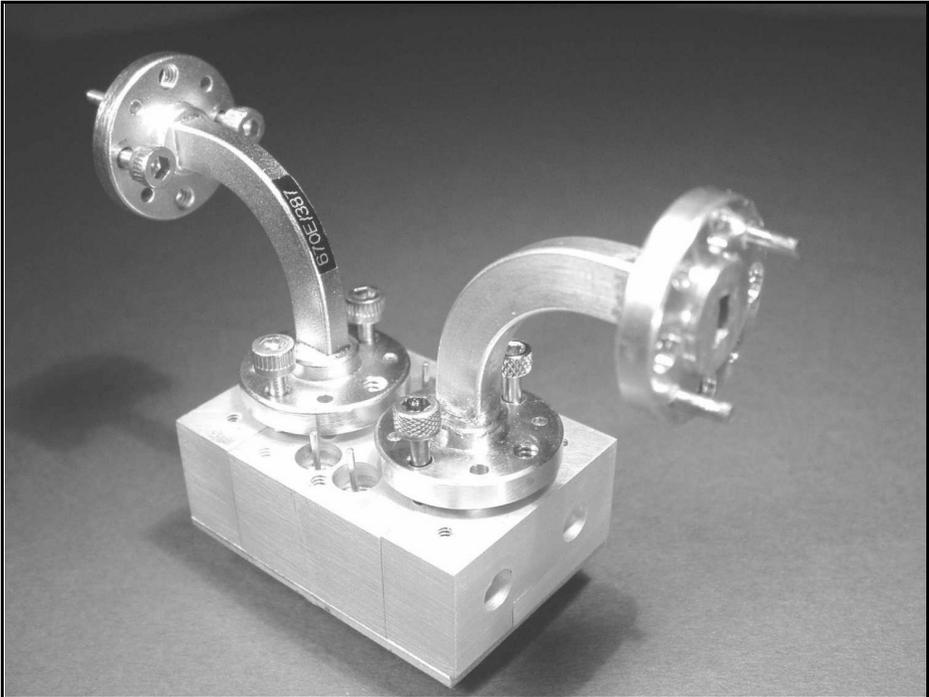


Fig 2: Picture of the 76GHz amplifier with WR-12 waveguide connections fitted.

(amplifier input and output) are made from aluminium nitride (approximately 1.1mm wide). They were sawn out of an existing ceramic, a substrate designed for other purposes by R&S. Since the chips have co-planar RF connections, the substrates likewise have a short co-planar section (0.5mm), which then goes into a 50Ohm stripline (8mm). This line projects approximately $\lambda/8$ into the waveguide, as already described in previous articles [1,5]. The ground plane of the ceramic projecting into the waveguide was milled off.

The power supplies for the chips are initially blocked with 100pF single layer capacitors, and subsequently with 100 nF ceramic capacitors, and are then fed out via feedthrough filters through the housing base (see Fig. 2). The connections between chips and substrate (or capacitors) were created using wedge-wedge bond technology [5].

The following problem arose here: The RF connection pads of the MMICs, which were actually designed for flip-chip installation, are extremely small (see Fig. 3). Directly behind these pads there are air bridges running to the chip circuit. These fragile structures are very easily caught and destroyed during the bonding by the tool that feeds the 17 μ m gold thread. The chip is then naturally unusable. This difficulty was avoided through the use of a still thinner needle and a correspondingly finer gold thread of 12 μ m. However, all other connections were created using a conventional 17 μ m thread.

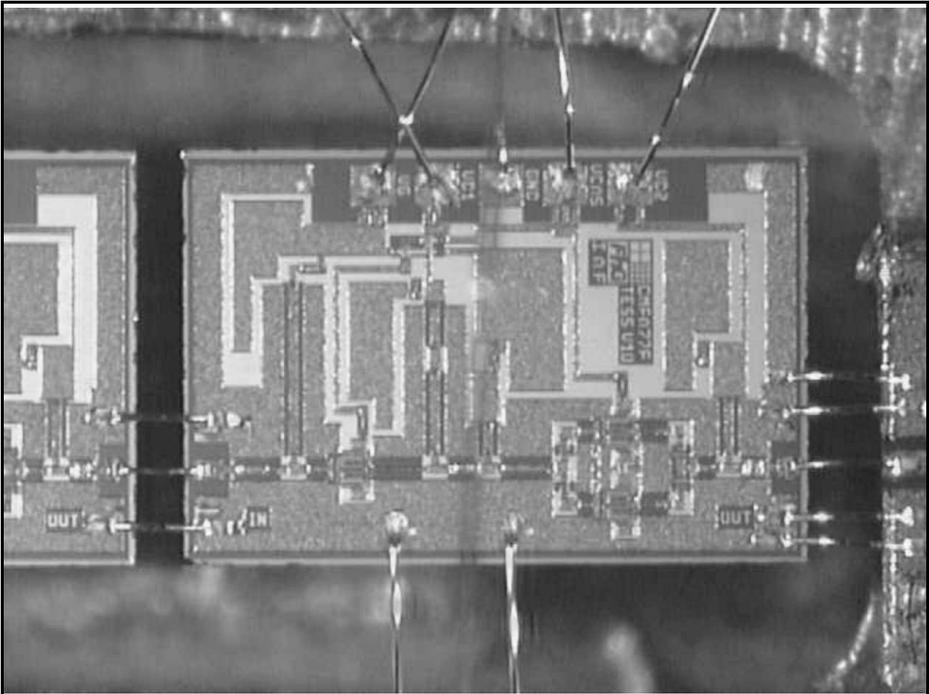


Fig 3: Picture of the 1AF-MPA7710 chip magnified about 120 times.

4. Results

4.1 Behaviour of amplifier

The amplifier was initially operated at low power levels (approximately $50\mu\text{W}$) at 76,032MHz. The gain observed was initially very disappointing (in the region of 8dB). Even after the fine adjustment of the waveguide short-circuit screws the gain reading was scarcely 10dB.

On the basis of experience of mismatching of the waveguide couplings obtained during the transverter project, another series of gold threads was attached and fastened to the striplines using a UV activated adhesive (see [1]). The input power during the matching amounted to

-13dBm. After a laborious sequence of 9 pennants, the work was rewarded by an amplification of 24dB. That means 12dB per amplifier stage, a value which tallies well with the specifications in the data sheet [3]. A value of $> 9\text{dB}$ ($\text{SWR} < 2.1$) was measured at the amplifier input, with $> 25\text{dB}$ ($\text{SWR} < 1.1$) at the output.

The gain and the output power for various input levels ($f = 76,032\text{ MHz}$) is shown in Fig 4. It can be seen that for an input power of $> -15\text{dBm}$ the amplification is already decreasing, a behaviour to be expected. At an input power of $100\mu\text{W}$, there is still 10mW measured at the output anyway (20dB gain).

Yet the saturation power of 12.6dBm remains unsatisfactory (approximately 18mW). Approximately 15dBm would have been expected! There could be several reasons for this behaviour. The large number of threads certainly in-

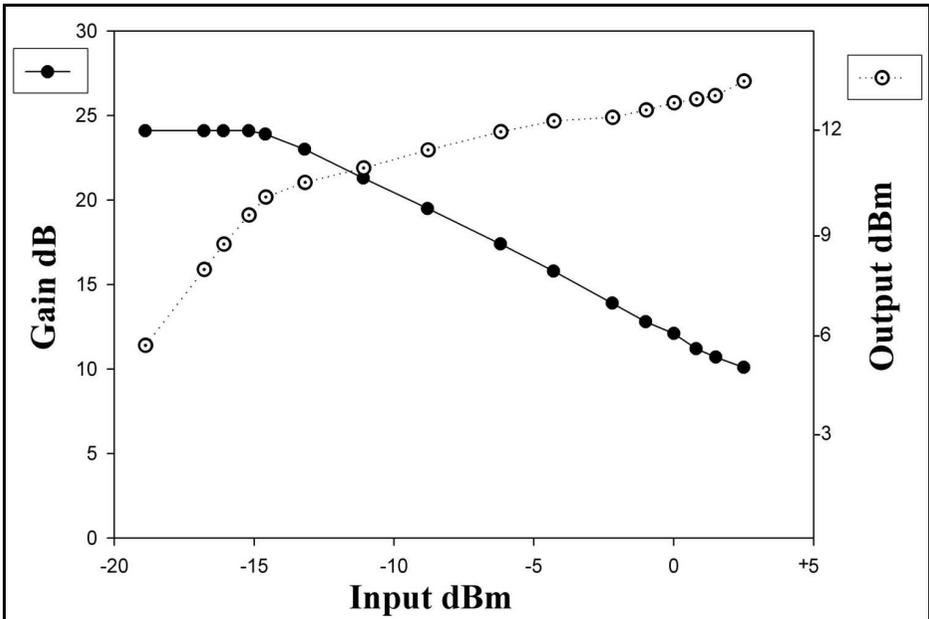


Fig 4: Transfer characteristics of the amplifier at 76,032MHz.

creased the matching and thus the amplification, but at the same time a lot of energy is lost with each stub attached. Secondly, the length of the striplines at these frequencies leads to additional losses.

The power supply voltages were varied in a further attempt to attain a higher saturation power on the individual MMICs. The optimal setting yielded the following values:

For the driver chip, gate 2 +1.4V, drains 3.0V (190mA);

for the output chip, gate 2 + 1.2V , drains 3.7V (220mA). The result was an increase in the power of only approximately 20 %.

The reduced saturation power is certainly irrelevant as regards the operation of the module, but is of particular significance in relation to the development of a power amplifier using this chip (project in preparation).

Fig 5 shows a test assembly of the amplifier in operation on a 76GHz transverter module already described [1]. Thanks to the similarity of the individual wave guide distances in the transverter and amplifier, the two modules are also mechanically compatible. The waveguide switch in the centre of the assembly acts as a transmitter/receiver switch.

The assembly's oscillation tendency is not very pronounced. A tendency to oscillate was observed at some cover positions, however, this could easily be eliminated by the introduction of a small amount of attenuation material.

Luckily, I had the chance to have the noise factor of the 76GHz amplifier determined in a professional RF laboratory (IAF, Freiburg). Initially, as a reference, the noise of the transverter module recently described [1] was measured. The value obtained of approximately 10 dB confirms our earlier estimate, carried out using amateur resources [1]. The results of the determinations for the amplifier

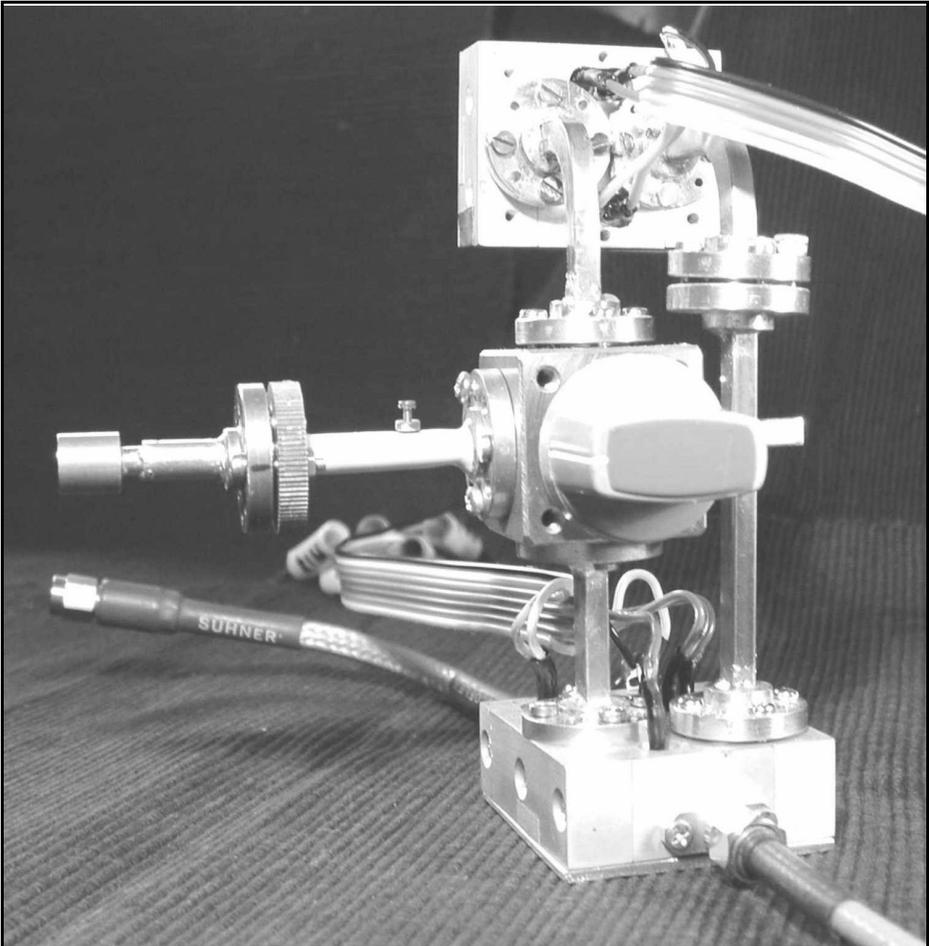


Fig 5: Test setup for the 76GHz amplifier with the transverter [1]. WR-12 waveguide connects the amplifier to the transverter with the 9.5GHz input at the back and the RF output at the front. In the centre is a 4 position waveguide switch (from Karl Ochs, DJ6BU).

(two laboratory specimens) were both unfortunately markedly over this value. For it to make sense to use the assembly as a receive amplifier, its factor had to be at least 3 dB lower than that of the receive mixer in the transverter module (i.e. at approximately 7 dB). Thus the search for a suitable low-noise semiconductor for 76GHz goes on.

4.2 Outlook and acknowledgements

As already indicated, this MMIC (IAF-MPA7710) can provide good service in the manufacture of a power amplifier. For this, however, at least two chips must be operated in parallel. Possible solutions for the addition of the outputs are “magic tee” or a $3/4 \lambda$ Wilkinson coupler on a quartz substrate (0.127mm!). A project



of this nature is being worked on at this moment.

Once again, I must express my heartfelt gratitude to many kind helpers. First of all, to the employees of Rohde & Schwarz in Munich: Dr. R. Jünemann (DK7AH), Ch. Evers and, in particular, W. Hohenester; as well as their colleagues in Memmingen: B. Mutzel, P. Feneberg and the skilful hands of Mrs. Andrea Frasch on the 13µm bonder. Special thanks are due to Dr. H. Massler (IAF Freiburg) for preparing and characterising the amplifier chips and for the noise measurements. Jochen Ehrlich (DF3CK) gave me sterling support as always and put me on the right track in many discussions.

5.

Literature references

- [1] Sigurd Werner, DL9MFV, A simple concept for a 76GHz transverter, VHF Communications 2/2003, pp. 77 - 83
- [2] Infineon Technologies Data Sheet, T 602B_MPA_2; 05.05.99
- [3] Data Sheet IAF-MAP7710, Medium Power Amplifier @ 77 GHz, Fraunhofer Institut for Applied Solid-State Physics, Freiburg
- [4] Sigurd Werner, DL9MFV, Frequency multiplier for 76GHz with an integrated amplifier, VHF Communications 1/2002, pp. 35 - 41
- [5] Sigurd Werner, DL9MFV, Amplifier for 47GHz using chip technology, VHF Communications 3/2002, pp. 160 - 164



The UK Six Metre Group

www.uksmg.org

With over 1000 members world-wide, the UK Six Metre Group is the world's largest organisation devoted to 50MHz. The ambition of the group, through the medium of its 60-page quarterly newsletter 'Six News' and through its web site www.uksmg.org, is to provide the best information available on all aspects of the band: including DX news and reports, beacon news, propagation & technical articles, six-metre equipment reviews, DXpedition news and technical articles.

Why not join the UKSMG and give us a try? For more information, contact the secretary Iain Philipps GORDI, 24 Acres End, Amer-sham, Buckinghamshire HP7 9DZ, UK or visit the web site.



Gunthard Kraus, DG8GB

Lets try again with PUFF!

Though many modern Windows programs exist, many experienced radio frequency and microwave developers still keep reaching for the tried and tested CAD program PUFF (and will hopefully do this even more after reading this article!)

1.

Examining PUFF

Lets examine once more why this is, and lets take an inventory of the points in its favour:

- In view of the efficiency, precision of the simulation and the maximum size of the circuits that can be examined, this program can be obtained for a song. Particularly if we take account of the costs of modern radio frequency simulation software packages, once the free test versions are no longer sufficient, or when we need important components that are not included in them. There is also a basic principle at work here, which is often forgotten, a simulation can be only as precise as the initial data made available. It is no problem for PUFF to keep the discrepancies in a prototype to below 1%, provided that every secondary effect involved is estimated and incorporated into the circuit as an undesirable, but necessary element (the Americans have a splendid word for describing this, “parasitics”).
- PUFF still remains an S parameter program, and can therefore not investigate any kind of three dimensional structure or antennas except in the form of model components and their S parameters. Its true that precisely the same can be said of expensive program packages, but these usually have an additional EM simulator for such tasks.
- After a number of years in which one would have to say the program was neglected rather than promoted, the world wide marketing (including the re-printed original manual) has been placed in the hands of “UKW Berichte”. So that's where we can find the latest de-bugged version 2.1, which can even be run with Windows XP on 2GHz computers. A previous issue [1] explained in detail how to do this, and what you should look out for. It also contains all the necessary details for the correct preliminary settings on the computer (e.g. the necessary changes to the config.sys file). So you should read through this article carefully, after which you should be able to use the program without a care in the world.



- Since this remains a product from the DOS era, there are no highly complicated operator interfaces which give you a lot of trouble when you try and get used to them again after not using them for a few months. After 10 minutes, you're back into it, and you can practically find the right keys blindfold. And in case you have forgotten anything, at the end of this article you'll find an updated list of all the operating commands for version 2.1. Copy it out, or download it as a PDF file from the VHF Communications homepage, and keep it near the PC, because this list isn't in the PUFF manual. It originated in a stack of notes which was built up during developing and fiddling around, and rooting around in or reading the English manual. It is arranged under a series of key words. You just search for what you want and find out the correct procedure required.
- By the standards of modern programs, the structure of the Puff screen is really simple (many people would say "primitive"). On the other hand what you can see is extremely effective:
 - A Smith diagram
 - A rectangular plot
 - A parts list (F3)
 - A simple circuit editor (F1)
 - Control information for the most important data from the printed circuit board, and basic settings for the circuit currently under examination (F4)
 - Two dialogue fields for communication with the program and/or the plot control (F2)
- Enough for successful development work.
- The program is operated exclusively by means of the keyboard, using the appropriate keys or combinations of keys, there are no buttons available at all. This naturally means that familiarisation times are short, and at the same time and extremely important, you can soon experience some success.
- When the necessary S parameter files are entered, PUFF accepts, not only its special format (*dev files), but also "official *S2P Files" in EESOF or Touchstone format from various companies, which can easily be obtained from the Internet. So if necessary (e.g. for transfer to people with other programs) you shouldn't be afraid of converting the associated Puff results file into a correct S2P file after a successful development. A simple text editor is all you need, just to delete a few items and/or add a new line, probably nothing complicated, and the sort of thing already frequently described in articles from VHF Communications. Its a pity that this wasn't integrated in the program right from the start.
- There's no particular need to emphasise the protected mode version supplied on the diskette (identifiable on the puffp.exe file). It simulates a maximum of 1,000 points, instead of the 499 which are all that's permissible otherwise. It allows for circuits of almost any size (the standard version in fact displays its error message: "Circuit too big for PUFF" at the wrong moment from time to time) and also functions just unbelievably reliably on the most modern computers, using the most recent versions of Windows.
- I had completely overlooked one PUFF tool which was available from the start, and only recently rediscovered when I came into contact with it professionally. The option of changing from "time



domain” to “frequency domain” and vice versa by means of a fast Fourier transformation (FFT) which can be called up by pressing the appropriate keys. I am currently experimenting with this, e.g. to see if I can investigate the transient response of a previously simulated oscillator PLL. Does anyone have more experience with this sort of thing?

- For newcomers who find this appealing, heres another tip for rapid familiarisation. The English language PUFF manual is well put together, but the number of examples it contains is still extremely limited. On the other hand, between 1995 and 2000 practically every issue, or every second issue, of VHF Communications contained an article on some project or application involving PUFF simulation. Just try a few things out and work them through on your computer. Moreover, most of these projects are well described and explained.

It is well-known fact that theres no rose without a thorn, we also want to mention the things people miss, or which cause problems, or which need improving but likewise with some practical tips on how you can help yourself.

The first item on this list would be the integrated microstrip line, coupled line, stripline calculator. It works very well and is easy to call up (using the parts list, F3, you just need to position the cursor on the corresponding line and enter the equals sign) and it provides precise results. But there is no way to include the cover height in the calculation, and so the results sometimes deviate from the actual circuit in practice. Its pretty cold comfort that many other programs dont do any better.

The remedy for this is very simple. Just go to the free student version of Ansoft Serenade and extract the TRL85 stripline calculator and load it onto your compu-

ter, since in relation to simple operation and attainable precision it is certainly the best on the market, see also [2]. Thus you can always make a direct comparison with the PUFF results, and in many cases youll find only slight differences. However, in critical cases (one experience of my own: coupled lines with an interaction gap over 2mm wide), you should put more faith in TRL85. Its very easy to prove this. If in such a case you enter a cover height of 200mm or more using TRL85, just for fun, then you get precisely the same result as with PUFF.

In addition, with active circuits we often miss the modern options for stability monitoring and for the representation of noise factors (in the form of circuits in the Smith diagram or as curves in a rectangular plot).

A first step towards a solution is the “kfactor.zip” program, obtainable from the Internet and written for PUFF files. But a few weeks ago a surprising solution emerged, the familiar radio frequency package “AppCad” from Hewlett Packard Agilent has suddenly acquired a new tool “Everything S Parameters” in the most recent Windows 3.0 version. You can call up any S parameter file and you can also carry out sweeps for such things as noise and stability circuits over an adjustable frequency range. A Smith diagram then shows the results with regard to noise and stability. For other data there is an option for producing tables, rectangular plots and polar plots.

So weve solved this problem too (using a somewhat complicated procedure, it is true). Im continuing to investigate the new AppCad options, and Ill be presenting the results soon in our section headed “The Interesting Program”.

The limited options for printing the screen out have likewise already been discussed in [1]. The wise man will not waste a lot of time getting worked up over this, but will use the options listed there for processing the “screenshots”.



Something that really can arouse your anger from time to time is the very primitive dialogue field for loading or saving PUFF files. There is no modern browser, and you are often forced to call up the Windows file explorer separately if you're looking for a specific file. The only way to make it easy on your nerves is not to lay out any large-scale sub directory structure for the various operations in PUFF. In the course of some comprehensive and relatively long term projects, I've got used to simply copying PUFF into a separate directory (with an appropriate name) just for this one circuit development. If everything subsequently ends well, only the result is saved, and the entire folder is deleted again.

Those are the most essential points, since you'll already be able to cope with the rest, or make do.

Finally, another practical tip, here is a list of free Internet programs which are frequently used for microwave circuit development, and I use together with PUFF, in a group on the Windows screen:

- Filter programs: fds/faisyn/filtray
- Stripline and microstrip calculator: TRL85
- Microwave structures and antennas: PCAAD, mstrip40
- CAD circuit board programs: GEDDY, Target
- Simulation of rod antennas, yagis, etc.: EZNEC
- Evaluation and printing out of screenshots, etc.: IRFAN-View
- First or last aid with radio frequency "problems": AppCad
- Additional simulation programs for monitoring or supplementing PUFF simulations, Student versions of ANSOFT and APLAC

- For simulations in the time domain: Microsim PSPICE V8 and/or ORCAD-PSPICE V9

To sum up, we can say that the recipe for operating successfully with PUFF is the same as for a good marriage, we love the strengths and the pleasant side, and we bear the weaknesses and the other side of the partner with love. And neither of us is getting any younger...

P.S.: Anyone looking for information on the current updated situation or on any new discoveries in Puff research can make an occasional visit to my homepage. (This site is in German - Ed. <http://www.elektronikschule.de>, then select "Uber uns" and "die Lehrkrafte der Schule" and select my name. There's a comprehensive range of information and items for downloading there. Just select "Microwave CAD with Puff" and check whether there's anything new).

2.

Literature

[1] Problems with Puff using Windows 98, Windows ME and Windows XP, and their elimination by Gunthard Kraus, VHF Communications 4/2002, Page 229 - 231

[2] The Interesting Program: TRL85.EXE by Gunthard Kraus, VHF Communications 4/2001, Page 199 - 205

3.

Appendix: List of operating commands for Puff 2.1



Alphabetic Key Word Catalogue for PUFF 2.1

| Key Word | Commands / key combinations |
|------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Break port connection to circuit | Press F1. Position the cursor on appropriate connection point of a port in circuit and then enter key combination <Shift + port number>. |
| Change dielectric constants of material in printed circuit board | Press F4, then enter new value under menu item "er". |
| Change external dimensions of printed circuit board | Press F4, then enter new value under menu item "s". |
| Rectangular plot diagram: Change horizontal frequency axis or vertical dB axis | Press F2, then press the "Cursor up" or "Cursor down" key until you reach the desired value or the desired diagram axis. Now the new minimum or maximum value can be entered on the frequency axis or on the dB results axis. |
| Change intervals of printed circuit board | Press F4, then enter new value under menu item Ports "c". |
| Change loss tangent of printed circuit board material | Open the setup.puf file or the special file of the project with a text editor. Then search for the appropriate line starting with "lt" and enter the new value. Note: Please use "scientific notation", in the form of a figure and a power of ten when entering data! Example: lt 2.0E-0004 {dielectric loss tangent} |
| Change metal thickness on a printed circuit board | Open setup.puf file or *.puf file of a special project using a text editor and enter new value in "mt" line. Example: mt 0.035mm. (metal thickness, use Um for micrometers) |
| Change microstrip with dispersion and attenuation | Enter tline! (or simply just "t!") instead of tline. Note: Before Puff is loaded, the appropriate file must first be called up with a text editor (or the SETUP.puf file for a new start). Then the printed circuit board thickness, the thickness of the Copper layer, the surface roughness and the loss tangent for the intended design frequency must be entered and saved there. Example: |



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| | <p>Values for FR4, material for frequency 1,700MHz $\epsilon_r = 4.33$ loss tangent = 1.5 E-2 Printed circuit board thickness $s = 1.5\text{mm}$. Conductor thickness = 0.035mm. Surface roughness = 0.002mm.</p> |
| Change number of plot points | Press F2, position cursor on "points" and enter number of calculation steps by hand (max. 499 in normal version, 1,000 in protected mode). |
| Change Smith diagram radius | Press F2 then, position cursor on "Smith radius", then enter desired radius (values between zero and infinity are permissible). Values under 1 give "Section magnification". |
| Change start frequency for plot procedure and calculation | Press F2 and then the cursor key (up or down) until the cursor is on start frequency for lower right hand of the diagram (Rectangular Plot for frequency response). Enter the new frequency, then start plot procedure using <p> or <q>. |
| Change stop frequency for plot procedure and calculation | Press F2 and then the cursor (up or down) until cursor is on stop frequency for lower right hand of the diagram (Rectangular Plot for frequency response). Enter new stop frequency, then start plot procedure using <p>. |
| Change surface roughness of copper layer on a printed circuit board | <p>Open the setup.puf file or the *.puf file of the special project with a text editor and enter the new value in the line "s".</p> <p>Example: sr: 2,000 Um (metal surface roughness, use Um for micrometers)</p> |
| Change thickness of printed circuit board material | Press F4, then enter new value under menu item "h". |
| Changing port connection intervals on printed circuit board in field F1 | Press F4, then enter the new value under menu item "s" |
| Connect port to layout | Press F1. Position the cursor on appropriate end point of circuit, enter number of port, followed by <Return>. |
| Inserting coupled lines | Enter these in F3 component list, using "Clines" or just "cl" followed by the values of "Even" and "Odd" impedance, if the impedance level of the coupled lines is different from the system imped- |



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| | <p>ance. Then the electrical length must also be specified.</p> <p>NOTE: If all spurious effects and losses are to be taken into account, enter an exclamation mark after "cl". If the impedance levels of the system and the coupled line correspond, then only one of the two impedance values must be entered (irrespective of whether it is "Even" or "Odd"). Puff then calculates the second missing value, using the formula</p> <p>"$Z_2 - Z_{\text{even}} \times Z_{\text{odd}}$" and copies it into the *.puf file.</p> <p>(Incidentally, scarcely any competitors products can do this.)</p> |
| Degree sign (°) for entering the angle for components e.g. for electrical lengths of line sections | <Alt d> (if in the F3 list) |
| Delete component on printed circuit board | Press F1, position cursor at start of component and delete it with key combination <shift + cursor direction key>. |
| Delete component (in F1 layout) | Press F1, move the cursor to start of the component and delete it using key combination <shift+cursor direction key> |
| Delete entire circuit on printed circuit board | Press F1, then <CTRL E> |
| Delete jump response in time domain | <s> (in the F2 list) |
| Delete pulse response | <i> (in the F2 list) |
| Displaying dimensions of components and lines | <p>Press F3, position cursor on component line in question and press <=>. The data then appear in the dialogue window.</p> <p>Note: If "real" simulation has been selected by adding an exclamation mark, then the first time you press this key you will just obtain the actual values for the impedances and the electrical length at low frequencies. Only when you have deleted the exclamation mark will the equals sign cause the mechanical line data to be displayed!</p> |
| Bring earth connection to a circuit point in printed circuit board | < = > (in the F1 area) |
| Enter component value (in F3 list) | <p>Press F3, move cursor to a free line of list and enter: "lumped..." (the letter "l" is sufficient).</p> <p>The components can be entered individually or as series or as a parallel circuit. Permissible units for</p> |



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| | resistances are either " Ω , $k\Omega$, etc." or values standardised to the system impedance ("1z", "0.3z", etc.). Dummy elements can be specified using the correct unit (e.g. pF, mH) or as an imaginary impedances ("+j10") or as imaginary impedances standardised to the system impedance ("-j5z"). Example for series circuit: "2 + j4-j3z" |
| Exit Puff | Press <ESC> twice. |
| Expand F3 component list (because items a...h are not sufficient) | Press F3, then press the tab key. |
| Help | Press key <F10>. |
| Jump to next node in layout | <CTRLn> (in the F1 area) |
| Load American character set (to get Ohms sign, etc.) | Before loading PUFF.EXE: <cd c:\puff>, then <chcp 437> (Note: Change AUTOEXEC.BAT and CONFIG.SYS first!) |
| Load a design file | Press F3, enter <CTRLr> then the file name and press <Return>. (Note: The file must have extension *.puf. But this need not be indicated.) |
| Load printer driver | <cd c:\puff> before loading PUFF.EXE: then, e.g. <vga2pro.com> for IBM Proprinter. Then <puff.exe> |
| Manhattan setting in field F4 | Press key F4, then you can switch between microstrip, stripline and Manhattan entries in circuit diagram field F1, using the tab key. "Manhattan" signifies that the lines listed in the F3 list and then entered using F1 are represented as being the same size as discrete components, irrespective of their actual length. This saves space and avoids the message: "the part lies outside the board". Everything eventually looks rectangular and uniform like a street plan of New York. |
| Micro-sign " μ " (e.g. for micro-Henry) | <Alt m> (if in the F3 list) |
| Microstrip setting in F4 list | Press key F4, then you can switch between microstrip, stripline and Manhattan entries in the design area F1, using the tab key. "Microstrip" signifies that a line or coupled line entered in the F3 list is being treated and calculated as a microstrip version by the stripline calculator. Pressing the equals sign then shows the associated mechanical data for the line. |



| | |
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| Enter Ohms sign "Ω" | <Alt o> (if in the F3 list) |
| Output alternate parallel circuit for S11 or S22 | Press F2, set the desired frequency and check whether the Smith chart is set to "Conductance" ("admittance"). (It's easy to recognise here that the "little circles around the infinity point" are on the left in the diagram.) If not, then switch over using the tab key. Now you can position the cursor on S11 or S22 in the F2 list. If the equals sign is now entered, then the dialogue window shows the parallel effective resistance, the parallel reactive impedance and the parallel inductance or capacity associated with the reactive impedance. |
| Output alternate series circuit for S11 or S22 | Press F2, select desired frequency and check whether Smith chart is set to "Impedance". (Easy to recognise that the "little circles round the infinity point" are on the right in the diagram.) If not, switch over using the tab key before positioning cursor on S11 or S22. If the equals sign is entered now, the dialogue window displays series effective resistance, series reactive impedance and the series inductance and/or series capacity associated with the reactive impedance. |
| Enter parallel sign for discrete component combinations | <Alt p> (in the F3 list) |
| Position component (in F1 layout) | Press F1, select the connection point for the component using the cursor and enter correct letter (see component list in F3 list). Then position component by pressing appropriate cursor direction key |
| Print design layout | Press F2, then <CTRLA>. (If required the magnification factor p must be entered directly in circuit file *.puf (new if desired), using a text processor) |
| Print out screen | For DOS: Press <PRINTSCREEN> key. (Note: Only works if printer driver, e.g. VGA2PRO.COM, is loaded before starting PUFF). For WINDOWS, this only copies screen to the Clipboard. It can then be further processed using an appropriate graphics program: e.g. CAPTURE, PAINT, PAINTSHOP PRO, IRFAN-VIEW, etc. and/or printed out |
| Print out Smith diagram | Press <PRINT SCREEN> key (Note: Will not work in DOS unless print driver loaded before start, e.g. VGA2PRO.COM). In Windows, this copies screen to the Clipboard and it can then be further process- |



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| | ed using a suitable graphics program (CAPTURE, PAINT, PAINTSHOP PRO, IRFAN-VIEW, etc.) and/or printed out. |
| Smith diagram: Re-position frequency mark | Activate using "Page up" or "Page down" key. |
| Save a design file | Press F2, then <CTRLs>, enter a new file name if applicable and press <Return>. |
| Select S parameter for calculation and plot procedure | Press F2, move the cursor down and enter the desired parameter after the letter "S" (e.g. S11). |
| Set Puff up for first start | DOS: Put a "PUFF.BAT" batch file into basic directory c: content: <chcp 437>, <cd c:\puff>, <vga2pro.com>, <puff> under Windows: use an icon with a link to start screen, but don't forget to set the main memory ranges under "Properties, memory". The conventional memory and the initial environment memory must be set to "Auto". The other hand, EMS, XMS and DPMI must each be set to "4096 kilobytes". Otherwise nothing at all will work! |
| Smith diagram: Switch from resistance display to conductance display | Press F2, then press the tab key. |
| Start plot procedure (including calculation) | <p> (in the F2 list) |
| Start plot procedure after change and also represent old plot | <CTRL p> (in the F2 list) |
| Start plot procedure as quick display (goes much faster, but result not shown until after all calculations in diagram completed) | <q> (in the F2 list) |
| Start plot procedure as quick display after a change and also display old plot | <CTRL q> (in the F2 list) |
| Set stripline in F4 list | Press key F4, you can then use the tab key to switch between microstrip, stripline and Manhattan entries in the circuit diagram F1. "Stripline" means that a line or coupled line is treated and calculated as a "coplanar" version by the stripline calculator. Press-ing the equals sign then shows the associated mechanical data for the line. |



Component Sweep

A component from the parts list can have its value changed by the program while the other components and the frequency are kept constant. In this way, a circuit can be optimised. But to do this we must first go to the F3 list and put a question mark in front of the component value.

Example: lumped ?10pF

or tline 50 ?900

Now press F2, the "Sweep limits" for the component are first set on the horizontal axis of the rectangular plot diagram, e.g.

5pF to 15pF for capacitors or

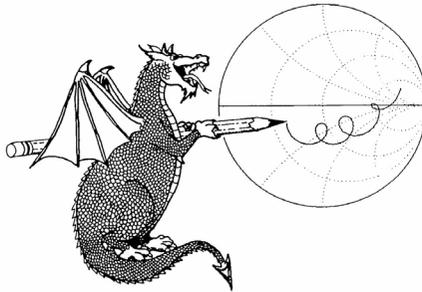
70° to 110° for microstrip line

Switch Smith diagram to "Full Screen"

Press F2, then <Alt s>.

Switch Smith diagram back from "Full Screen" to "Small Diagram" with separately displayed frequency response curve

<ALT s> (in the F2 list)



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Grant Hodgson, G8UBN

GH *Quad* linear amplifier for 23cm

1.

Introduction

The GH *Quad* is a high performance solid-state amplifier using 4 Mitsubishi [1] M57762 Power Amplifier modules to deliver up to 72W in the frequency range 1.24 - 1.3GHz. The amplifier is available as a full kit or mini-kit from GH Engineering [2]. The PA modules require no tuning, being internally matched at the input and output to 50Ω. The modules are biased from a regulated 9V supply. These features make the modules very easy to use, but the downside is that they are very inefficient, typically achieving around 30% efficiency. Therefore, for an output power of 72W, a total DC input power of around 240W is required, of which 168W is dissipated as heat.

It is imperative that the PA modules are not allowed to overheat, and for this reason a large heatsink is used with a thermal resistance of approximately 0.33° C/W. This measures 300 x 250 x 48mm, and weighs 3kg. The heatsink is a comb section aluminium extrusion that has been black anodised for extra thermal performance. The PCB and PA modules are mounted to the flat surface of the heatsink.

The mechanical construction of the *Quad* is critical for good results and reliability. The *Quad* mini-kit is not supplied with a case, as many constructors are able to supply their own. The first job therefore is to plan the overall mechanical layout.

Whilst it would be possible to use the *Quad* without a case, using studs or screws to support the heatsink, this is not recommended for a number of reasons.

2.

Specification

- Frequency Range 1240 to 1300MHz (may be operated above 1300MHz with some loss of output power)
- Output Power 72W typical (4W input at 1260MHz, 13.8V DC supply voltage)
- Input Power 4W maximum
- Input VSWR <2:1
- Output VSWR <2:1
- Power requirements 12.5 - 13.8V DC at 23A
- RF Connectors N-type sockets
- Size 305mm x 280mm x 185mm
- Weight 3.5kg

3.

Circuit Description

The RF input signal is applied to a



Wilkinson splitter that divides the signal into two in-phase components, each 3dB lower than the input signal. The splitter consists of two quarter wavelength transmission lines of 71Ω impedance. The outputs of the splitter are connected by two resistors in parallel which give a value of approximately 100Ω . Under normal operation, the voltages at the ends of the resistors are equal and in phase, and therefore no current flows through the resistors. In the event of an imbalance, for example due to a module failure, some of the input power will be dissipated in the resistors, and so these resistors have to have sufficient power handling capability in order to be able to cope with a fault condition.

Considering one of the two signal paths: the signal then passes through a 90° hybrid coupler, which splits the signal into two equal amplitude components, with a relative offset of 90° . Each of the two outputs from the coupler is 3dB lower than the output signals from the Wilkinson splitter. Under normal operation, there is no power dissipated across the 47Ω resistor. In the case of an imbalance, some of the power applied to the input of the coupler will be dissipated in the termination resistor. The impedance mismatch between the 47Ω resistor and the 50Ω impedance of the coupler is very small and is of no importance.

Both the Wilkinson splitter and the quadrature couplers exhibit a high degree of isolation, such that the output impedances are very close to 50Ω even if the other port has a severe mismatch.

The signals are now 6dB lower than the input signal, and the outer pair have a 90° lag relative to the inner pair. The signals are fed to the inputs of the Power Amplifier modules that have a small signal gain of around 17-18dB. The outputs of the modules are phase corrected, such that the inner signals have an extra 90° phase shift added to bring them all back in phase. This is achieved with the correct length of microstrip transmis-

sion line. The signals are then fed to a 4-way Gysel combiner [3]. This combiner is actually a derivative of the N-way Wilkinson combiner, and is a single, 4-way combiner. The insertion loss for this combiner is less than for the more usual arrangement of cascading 2-way combiners. Note that losses at the amplifier input are not considered to be a problem, as there is sufficient gain to overcome these losses. However, any losses at the output cannot be recovered and therefore a lower-loss, albeit slightly more complex combining network has been designed, along with the use of low-loss PTFE-based PCB material.

The Gysel combiner consists of 4 quarter-wave transmission lines, each of 100Ω impedance. Therefore the 50Ω impedance of the output signals is transformed to 200Ω , which give an output of 50Ω when all four are connected together in parallel. The isolating network is somewhat more complex than for the input splitters. 50Ω transmission lines, $3/4\lambda$ long are connected to each of the junctions of the 50Ω and 100Ω lines. The end of these lines are terminated with a 50Ω high-power termination resistor. This resistor is also connected to another transmission line of 25Ω impedance and $1/4\lambda$ long. These four 25Ω lines are connected together at a star point. At this point, there is a 'virtual ground', in that no current flows across the junction, but the impedance is actually very high, and approaches an open circuit. Therefore the impedance at the termination resistor is very low (approaching a short circuit) and no power flows into the resistor. Therefore, the impedance looking into the end of the $3/4\lambda$ line is very high. Consequently, the $3/4\lambda$ line places no load on the output, and no current flows into the isolating network.

In the event of an imbalance, such as that due to a module failure, the situation changes. Some of the output power from the remaining three modules will be dissipated in the terminating resistors, although most will still flow to the output

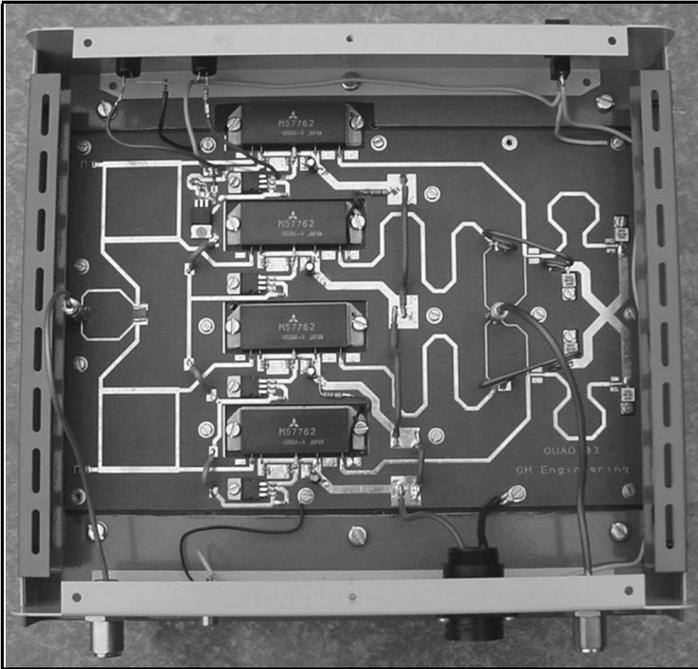


Fig 1: A picture of the GH *Quad* 23cm amplifier.

connection. However, each module will still have an impedance of very close to 50Ω presented to it, and so the effect of failure or instability of one module will not be seen by the other modules. Note that the load resistors do not dissipate this power evenly. If for example module 1 failed, then approximately 18% of the power from the three remaining modules would be dissipated in the termination resistor associated with module 1, and approximately 5% of the power would be dissipated in each of the other 3 resistors. This power split is irrespective of the nature of the failure; i.e. regardless of whether the module fails with an open circuit, a short circuit or something in between. The Gysel coupler has a bandwidth and isolation similar to that of a Wilkinson splitter, and can cope with any number of module failures.

Note that the input and output combiners have been designed to cope with a worst-case scenario; i.e. the failure of one or more PA modules. However, in practice, the M57762 modules are very

reliable, and as long as the input power to each module does not exceed 1W, the DC supply voltage is kept at 13.8V maximum and the modules are not allowed to overheat, they will give many years of trouble-free service.

This feature can be used for diagnostic purposes - if the output power is somewhat lower than it should be, then the voltage across each of the terminating resistors can be measured with a high impedance probe or an RF millivoltmeter. One resistor will have significantly more voltage across it than the other 3, and the fault will lie in the corresponding module. As an alternative to an RF millivoltmeter, each of the terminations can be removed in turn, and replaced with a length of thin coax cable, which is connected to a power meter.

Note that the 'classic' Gysel coupler uses $1/4\lambda$ line lengths throughout, but this is difficult to implement on the PCB, and so $3/4\lambda$ sections were chosen. The outer two $3/4\lambda$ lines are printed on the PCB as microstrip transmission lines. The topol-

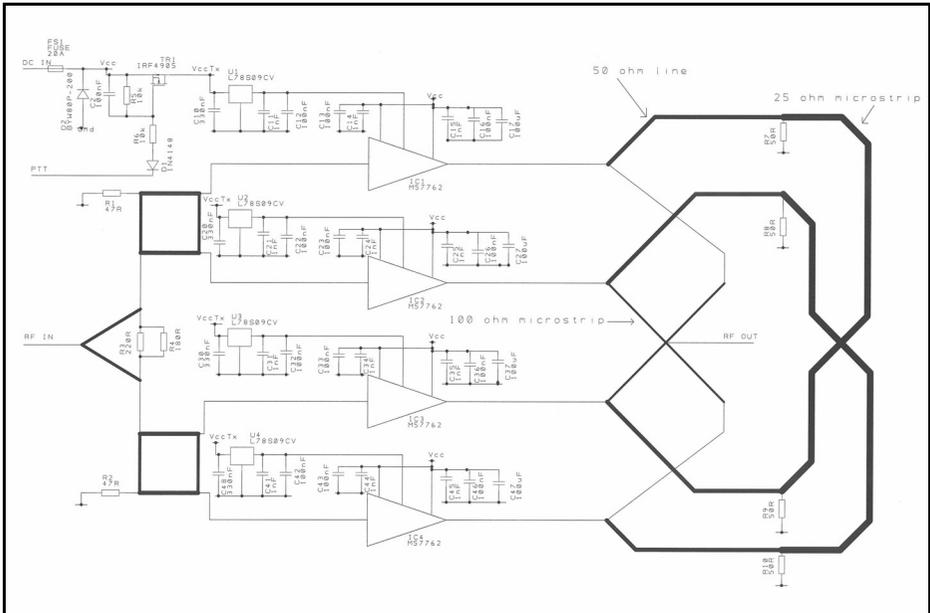


Fig 2: Circuit diagram of the GH *Quad* 23cm amplifier.

ogy of a Gysel coupler is such that it is effectively a 3-dimensional structure, and cannot be fully implemented on a 2-layer PCB. The $3/4\lambda$ line for the inner modules have to cross the outer lines, and for this reason are constructed from 0.086 semi-rigid cable.

DC and switching

The DC supply (V_{cc}) to the PCB is connected via a fuse. This is then applied to the V_{cc1} and V_{cc2} pins of the modules. Note that in the Rx/standby mode, the modules will conduct only a very small amount of leakage current.

TR1 is a P-channel MOSFET switch. In the Rx/standby mode, the PTT signal is floating, and R5 ensures that there is no voltage between the drain and source, which keeps the FET switched off. When the PTT line is taken low, the combination of R5 and R6 form a potential divider that takes the gate voltage to approximately half of the supply voltage. This causes the FET to turn on, and the

supply voltage appears at the input of the voltage regulators. The regulators provide a stable 9V that is required to bias the modules. C2 de-couples the gate of the FET to prevent accidental switching due to stray RF fields or glitches.

De-coupling is provided on each of the module pins. Note that only relatively low-frequency de-coupling is provided - no attempt is made to de-couple the pins at the RF frequency, as this is done internally within the modules.

DC blocking of the input and output signals is performed internally within the M57762 modules.

Reverse Polarity Protection

A 20A quick-blow fuse and a fuseholder are supplied with the mini-kit. This fuse should be connected in series with the positive supply to the amplifier inside the case. D2 acts as a reverse-polarity protection diode, such that if the supply is accidentally reversed, the diode will conduct and blow the fuse. Under these



conditions, the reverse voltage will not exceed approximately $-0.8V$ which should be a safe condition.

4.

Construction

Full construction details for this project are supplied with the kit which is available from the author at GH Engineering, and a copy is available for free download on the GH Engineering web site. The construction notes run to 20 pages + drawings etc, and so cannot be published in full here. However, for those that are interested in the construction of this project, some notes are given here :-

- The heatsink is very important, and a size of 300 x 200 x 46mm has been chosen as a minimum size. This will keep the modules cool for all SSB/CW operations. However, for extended ATV operations it is advisable to add a couple of cheap computer fans to aid the cooling.
- A suitable case should be obtained before building the project, as this will allow the heatsink mounting holes to be drilled and tapped at the same time as the other holes, and also allows for the position of the critical components such as RF input/output connectors to be decided at the outset.
- Most of the resistors and capacitors are surface mounted devices (SMDs). These are 1206 size components (3 x 1.5mm), and soldering them should not present any real problems to constructors who have experience of building microwave circuits.
- The PCB has SMA connectors for both input and output. SMA connectors are rated for 250W

operation at 1.3GHz, and providing good cable is used for the output lead (0.141" semi-rigid is recommended) then there will be no problems with the connectors being able to handle the power.

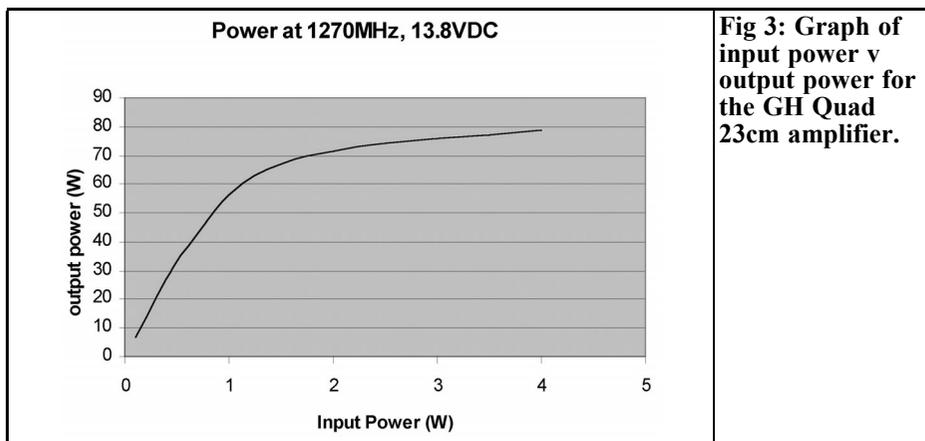
- There is no tuning, and very little to go wrong. This is an established design, and several dozen of these amplifiers are in use around the world for SSB, ATV, satellite and contest communications, and have proved to be very reliable.
- The M57762 PA modules are very reliable, providing that the input power does not exceed 1W maximum (per module) and the supply voltage

5.

Operating the amplifier

An input power of 1.5W will give an output power of approximately 65W with a DC power supply of 13.8V. The DC current drawn will be approximately 15-18A. Increasing the drive level above 1.5W will increase both the output power and the DC current, but the amplifier will no longer be linear i.e. a 1dB increase in input will give less than 1dB increase in output. The DC current drawn is approximately proportional to the input power, so even when the amplifier is close to saturation, the DC current will still increase as the input power is increased. The consequence of this is that the efficiency decreases, and the amount of heat generated increases. Therefore, it is necessary to ensure that the modules do not overheat, and the use of one or two small axial fans on the heatsink is recommended if the amplifier is being driven at power levels of greater than 2W, especially for continuous (FM) use.

Note that the input power should never exceed 5W under any conditions. If the



amplifier is being driven from a source that is capable of delivering more power than this, for example a multi-mode Transceiver such as the FT736 or the TS790, then it is recommended that an attenuator is used at the input to the amplifier. Although these transceivers have adjustable power controls, there is a possibility that the drive control could accidentally be set too high. The M57762 modules are very susceptible to excess drive levels, and could be damaged or destroyed if too much input power is applied. A suitable attenuator can easily be made from a length of thin coaxial cable; for example 3.5m of RG178 cable has a loss of 5dB at 1.3GHz, which allows the driving transceiver to be used at full power (10W) without damaging the amplifier.

Heat Dissipation

The heatsink has been designed to allow the amplifier to be used continuously for SSB or CW operation. Under these conditions, the heatsink will reach a steady-state temperature of around 60°C after approximately 45 minutes of operation with an ambient temperature of 20°C. This is a safe condition for the PA modules. Note that at 60°C, the heatsink will be very hot to the touch - care must be exercised to ensure that the operator does not suffer a mild burn from the heatsink.

For FM/ATV use, it is recommended that two axial fans are used to assist cooling of the PA modules

Fault finding

There is very little to go wrong with this amplifier, and no tuning is required. With an input power of 3W and a supply voltage of 13.8V DC, the output power will be approximately 60 - 80W depending on which part of the band is being used. For SSB use, the input power should not exceed 3W PEP, as this will drive the amplifier into its non-linear region. It is recommended that the input power does not exceed 4W.

If the output power is lower than expected, then the following procedure should be followed:

- Ensure that the output power is being measured on a meter that has sufficient accuracy at 1.3GHz - dont blame the amplifier if the power meter is at fault!
- Visually check all the soldered joints.
- Check that the DC levels are correct on pins 2, 3 and 4 of the PA modules.
- Check that the input attenuator has been fitted correctly.
- Measure the DC supply current - if



this is low, then the problem lies with the input. If the current is as expected, the problem is probably in the output section.

6.

Sequencing

Sequencing only applies to half-duplex systems. Sequencing refers to a system whereby certain delays are introduced into the control lines for the transmitter, power amplifier and masthead pre-amplifier. The purpose of the delays is to ensure protection for the antenna change-over relay and the pre-amp (if used) and transmit power amplifier.

Systems with relatively low levels of transmit power do not generally require sequencing. However, as power levels increase, the risk of damage to the system components also increases.

If sequencing is not employed, then the system changes over from Tx to Rx and vice versa at the same time. The problems associated with this are due to the fact that any antenna changeover relay needs a finite time for the contacts to move from one position to the other. This occurs on both states - Transmit to Receive and Receive to Transmit. There are thus two separate cases:

Transmit to Receive. As well as the relay needing time to change over, the Tx carrier needs a finite amount of time to decay. This decay time will depend on the type of transmitter, amplifier and power supply being used. If the antenna changeover relay starts to change over at the same time as the Tx PTT line is removed, then there will still be a certain amount of RF power flowing through the relay contacts as the contacts start to open. This will cause arcing of the contacts and could quickly lead to a deterioration in performance of the change-over relay. A sequencer will keep

the relay in the Tx position until the RF power has been removed. There is a second problem involving the use of a masthead preamplifier. If no sequencing is employed, then the DC power to the preamplifier will be applied before the change-over relay has completed the switch to receive. Thus the preamplifier may be presented with a very high input SWR, which may cause it to become unstable.

Receive to Transmit. If the transmitter is activated at the same time as the change-over relay starts to switch to transmit, then the relay contacts could arc. This is the same reason as given above, as the transmitter power could be present at the transmit port of the change-over relay, before the contacts have had time to complete the switch to the transmit position. Furthermore, due to the fact that it may take some time for the de-coupling capacitors in the preamplifier to decay, the preamplifier may still be on as the relay changes over and the transmitter is brought up to full power. Under these conditions, the isolation of the change-over relay will be a lot less than in the steady-state. There is then the possibility that a much larger amount of Tx power is presented to the pre-amplifier, whilst it is still on, which could cause the preamplifier to be damaged or even destroyed.

7.

References

- [1] www.mitsubishichips.com
- [2] GH Engineering, The Forge, West End, Sherborne St. John, Hants RG24 9LE, UK Tel +44 (0)1256 889295 www.ghengineering.co.uk
- [3] Ulrich Gysel - A new N-way power divider/combiner suitable for high power applications, IEEE MTT-S Symposium Digest 1975



Gunthard Kraus, DG8GB

Internet Treasure Trove

Antenna tools

This is really a little treasure chest, in addition to the assembly instructions for a 137kHz receiver and many other things, there is also a special page for antenna freaks with "Antenna tools". These are Java scripts to calculate everything conceivable on line. Would you care for a little taste? "Conversion between Field strength and received power / Field regions / Isotropic losses of free space radiation / field strength, field area and received power.....etc."

Address:

<http://www.giangrandi.ch/jack/main.shtml>

TCS Online conversion page

More of the same, with the Java scripts for rapid calculation of every possible aspect of telecommunications, but this time provided by a big company and on offer to customers or to anyone interested. Considerably more extensive than the previous link, but just as interesting.

Address:

http://www.tcstx.com/conversions/online_conversions.htm

Radio Mobile

The simplest thing is just to quote, word for word, the heading and description for the freeware which can be obtained here:

"This software is a tool used to predict the performance of a radio system".

Very neatly done, and free of charge into the bargain. You can see precisely how the landscape influences wave propagation because it is superimposed for this purpose once you have entered the coordinates. This is accompanied by some very good instructions and a "first example" demonstrates the freewares use.

Address:

<http://www.cplus.org/rmw/english1.html>

World Wide Web Links

Any number of interesting downloads await the radio amateur . The site covers both databases and online tools for calculating many things (not only relating to antenna technology or to circuit engineering). Just take a peep!

Address:

<http://www.w4rrc.org/RARCClubWebLink/WebLinkReferenc.html>



Pearl Scripts of Interactive Design Software

Somehow this is slowly becoming the fashion, interactive online calculators for telecommunications and antenna engineering, but the ambition (or the competition!) is obviously gradually becoming so intense that each wants to outdo the other. Just take a look at this page....

Address:

<http://www.qsl.net/n9zia/wireless/page-09.html>

AVX

Something different for a change. Anyone who wants to get well informed on the smallest details of RF and microwave capacitors might well want to click on this link. In addition to data sheets, spice models and software, there are well compiled and informative articles to study.

Address:

<http://www.avxcorp.com/SpiApps/default.asp>

Spread Spectrum

Do you just want to become a bit more familiar with this area via a good tutorial or simply to find out about the basic principles? These links can give you some confidential help.

Addresses:

<http://www.sss-mag.com/ss.html>

<http://www.mepcis.org/sprdspec.htm>

<http://www.tapr.org/ss/index.html>

And just as interesting is this page, in

which you can finally discover, in a fascinating format, something about the history of this new technology (...or perhaps you already knew that the Hollywood actress Hedy Lamarr had something to do with it?)

Address:

<http://www.ncafe.com/chris/pat2/index.html>

RF Avenue

That sounds like a pleasant stroll, and that's what this is. Mind you, it takes rather a long time and it's a stroll around the computer, for by the time you've thoroughly explored this page and tried everything out, it's long past midnight.

Such a large amount of literature, application notes, information and online calculators does make for a lot of work. Especially since the site is not confined to antenna engineering. The various fields are alphabetically listed.

Address:

http://www.newwaveinstruments.com/resources/rf_microwave_resources/

YDI

Please take a look yourself, as here too there is information on offer relating to what you can learn and calculate.

Address:

<http://www.ydi.com/calculation/>

Ingecom

Here you can obtain a very well-written article entitled "VHF and UHF Antenna Design". It is really rewarding, either as a



stimulus to further research or as a refresher of what you may already know.

Address:

http://www.ingecom.ch/Pics/an_antenna.pdf

Address:

<http://www.emctest.com/Holaday/app-notes.htm>

Holiday

This is something for people who are interested in EMF (electromagnetic field measurements), whether for professional or private reasons, in order, for example, to get to grips with the problems of risks associated with EM fields. Very good application notes and articles make it worth clicking on.

Antennex

And finally, another big jar to rummage around in, as here too the concept of antenna engineering is stretched a long way and includes many associated areas.

Address:

<http://www.antennex.com/preview/>

Amateur Television Quarterly

Great articles on :

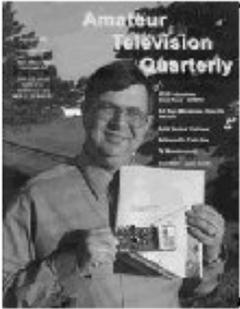
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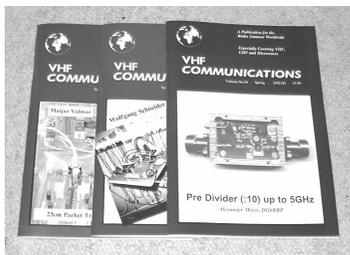
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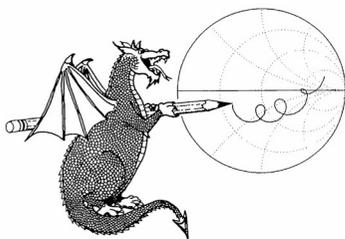
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PUFF Version 2.1 Microwave CAD Software

This software is used by many authors of articles in VHF Communications. It is supplied on 3.5 inch floppy disc with a full English handbook. PUFF is £20.00 + postage. (UK £1.00, Surface mail £1.30, Air mail to Europe £1.50, Air mail outside Europe £2.50)



VHF Communications Web Site www.vhfcomm.co.uk

Visit the web site for more information on previous articles. There is a full index from 1969 to the present issue, it can be searched on line or downloaded to your own PC to search at your leisure. If you want to purchase back issues, kits or PUFF there is a secure order form or full details of how to contact us. The web site also contains a very useful list of site links, and downloads of some previous articles and supporting information.



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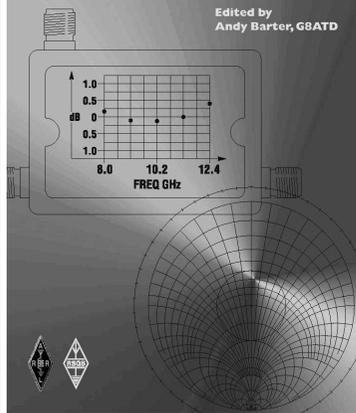
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The International Microwave Handbook

INTERNATIONAL MICROWAVE HANDBOOK

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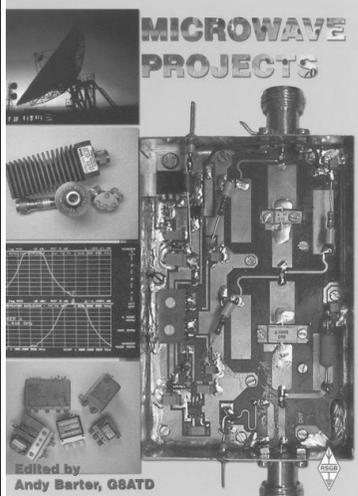
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