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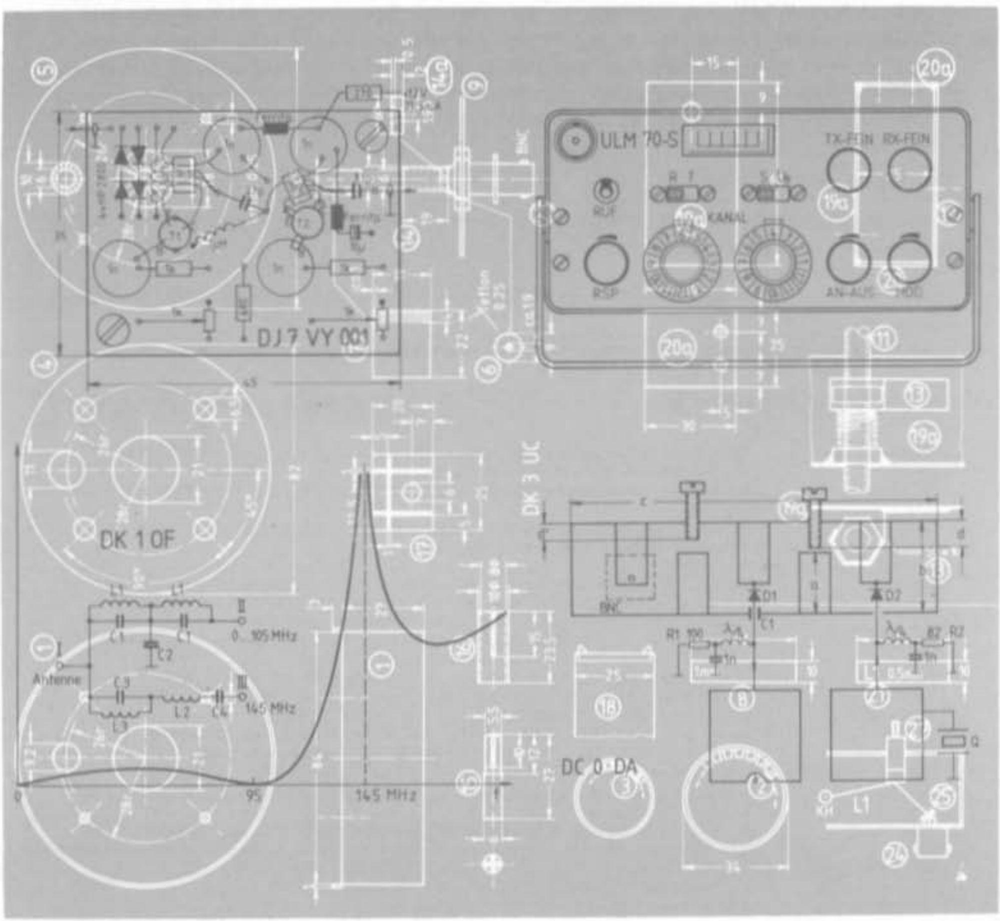

VHF COMMUNICATIONS

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A SHF TRANSMIT CONVERTER WITH A VARACTOR DIODE HAVING HIGH EFFICIENCY AND LOW INTERMODULATION

Part 2: Frequency Converter and Oscillator Module for the 23 cm Band

by H. Fleckner, DC 8 UG

The described transverter converts an input signal on the 2 m band linearly to 23 cm. The required local oscillator frequency of 1152 MHz is obtained using a 96 MHz crystal oscillator followed by numerous frequency multiplier stages (see **Figure 1**). The mixer operates as a varactor power-up converter; its efficiency with respect to the oscillator power, is mainly dependent on the cut-off frequency f_C of the diode. **Figure 2** shows this relationship in the case of an abrupt PN-varactor at maximum drive of the input signal. The power ratios given in part 1 of this article for up-converters, are valid for loss-less diodes at low signal levels, e.g. for parametric drive of the mixer. However, if the mixer is driven to maximum in order to achieve the highest possible output power, the relationship given in Figure 2 will be valid.

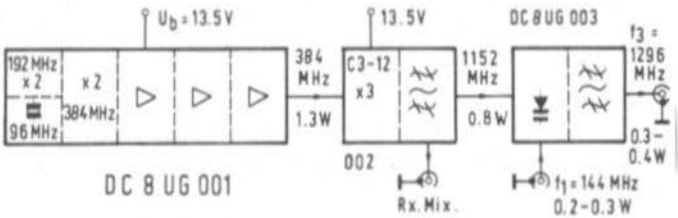


Fig. 1: A linear transmit converter for 144 MHz/1296 MHz comprising three modules

The local oscillator module supplies an output power P_2 of 0.8 W at 1152 MHz. When using the given varactor diode BXY 27 it is possible to obtain an RF efficiency of $\eta_{RF} = 0.7$ due to its cut-off frequency $f_C = 100$ GHz. The output power P_3 at 1296 MHz, would therefore be 0.56 W, without circuit losses. An output power of 0.4 W was measured which resulted due to the use of a diode having a lower cut-off frequency and due to the losses in the filter and matching circuits.

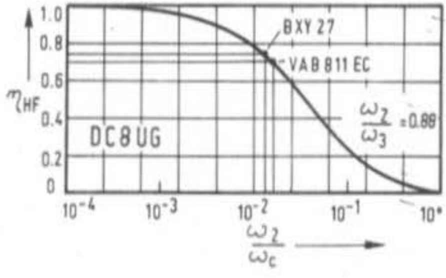


Fig. 2: RF-efficiency as a function of the ratio of operating to transient frequency

The output power was obtained at an intermodulation ratio $IM_{R1} \geq 20$ dB for the first intermodulation product in a two-tone test. In this case, the output power at 1296 MHz amounted to 0.2 to 0.3 W and the suppression of the oscillator frequency was – 28 dB.

The transmit converter can be used on its own for mobile or portable operation, or as an exciter for a subsequent linear amplifier stage. It is also possible for the transmit converter to be used as receive converter, or for a portion of the local oscillator signal to be coupled out to feed an external receive converter.

1. OPERATION

The oscillator comprises two separate modules: the 384 MHz oscillator chain DC 8 UG 001, and the power tripler equipped with transistor C 3-12 in module DC 8 UG 002.

1.1. 384 MHz Oscillator Chain

The circuit diagram of this module is shown in **Figure 3**. With the exception of the output stage, the semiconductor complements and a few design details, the circuit is very similar to that described by DC 8 NR in (4). The signal level after the first amplifier stage (T 4) amounts to 40 - 50 mW into 50 Ω. This is then amplified to approximately 150 mW in transistor T 5 and a gain of between 1.1 and 1.3 W is provided in T 6 according to the operating voltage.

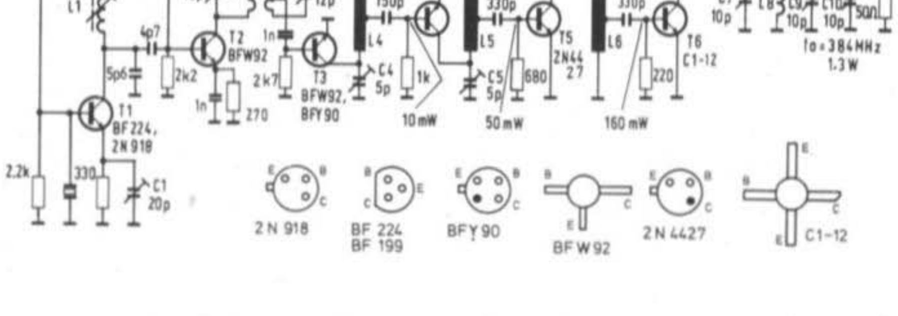


Fig. 3: The 384 MHz local oscillator module DC 8 UG 001

The output transformation with L 7, C 7 and C 8 is followed by a high-pass filter and a variable low-pass (Pi) circuit. These two filters provide additional selectivity for the 384 MHz carrier. A multi-stage, critically-coupled bandpass filter would, of course, be better in this position, however, for simplicity and ease of construction, it was not used here. **Figure 4** shows the measured output spectrum of this module at P_0 = 1.3 W into 50 Ω. The spectrum analyzer bandwidth amounted to 0 to 900 MHz with a scale of 100 MHz/cm. The harmonic suppression was better than 40 dB.

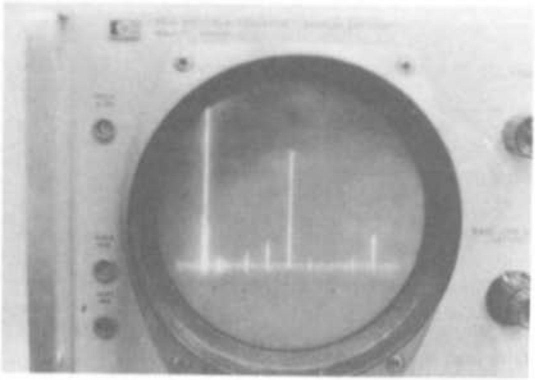


Fig. 4: The output spectrum of the 384 MHz local oscillator

1.2. Tripler 384/1152 MHz

The tripler is equipped with the CTC transistor C 3-12. This transistor is not designed specificly as a frequency multiplier, unlike the RCA transistor 2 N 4012, but only costs about a third of the price. Power multipliers operate in class C, and the current flow angle Θ determines the magnitude of the output voltage.

Figure 5 shows the characteristic of a power amplifier in class C; it is only driven by the peaks of the input signal, which means that current impulses result at the output that have a high harmonic content. The selection of the current flow angle using resistor R_{BE} allows the output signal to be adjusted for maximum. The most favorable value is determined experimentally (6).

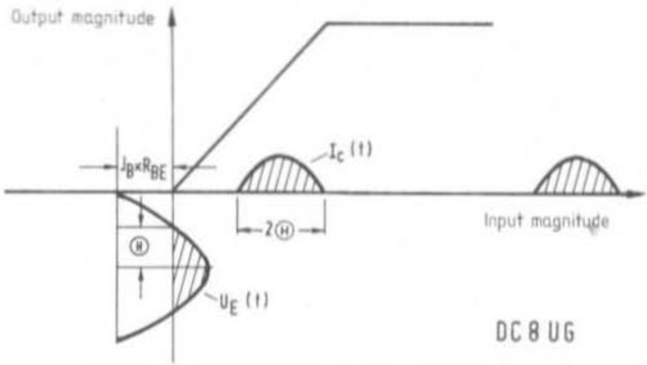


Fig. 5: Class C characteristic and drive peaks

Figure 6 shows the circuit diagram of this module. Resistor R_{BE} is in the order of 150 Ω. The idler circuit at the output increases the RF efficiency. Resistor R_D in the DC-line is used for suppression of parasitic oscillations and is very necessary. Its value should not exceed 5 Ω ! The matching of the transistor output to the 1152 MHz bandpass filter is made using a series circuit with variable coupling capacitor. Due to its high capacitive reactive impedance at low frequencies, it forms a very good high-pass filter together with the input circuit of the band-pass filter.

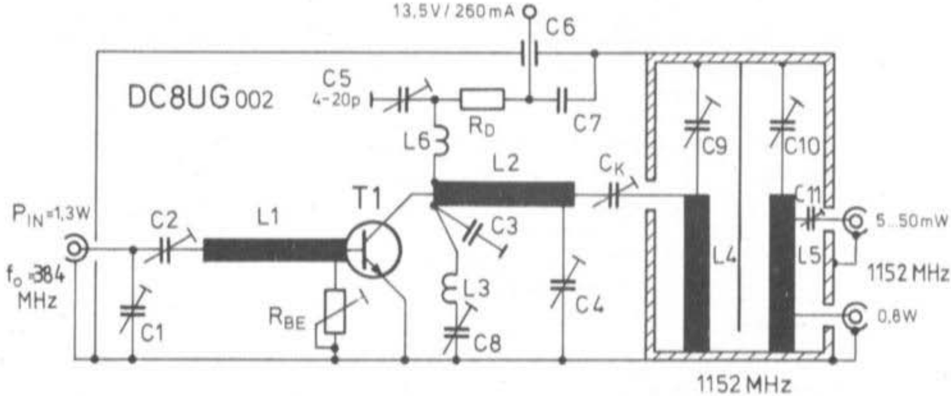


Fig. 6: The tripler module 384 MHz/1152 MHz DC 8 UG 002

1.3. Frequency Converter

The principle of frequency conversion using varactor diodes was discussed in Part 1. In the case of power-up converters, the relationship between the RF efficiency and the ratio of the upper sideband frequency to varactor cut-off frequency is taken from the large-signal technology, and is shown in Figure 2. The up-converter will, in principle, operate satisfactorily with any varactor diode whose cut-off frequency is in the order of 100 GHz. However, in order to obtain a high RF efficiency, it is better when diodes having an abrupt PN-junction (pronounced C/U dependence in the blocking range), or charge storage are used, when driven in the low area.

In the case of storage diodes, it is important that the switching time is as short as possible (~ 1 ns), and that the storage time is large with respect to the period duration of the RF signal. The author's prototype uses a storage varactor diode manufactured by Varian. The type number is VAB 811 EC; the cut-off frequency is 74 GHz, and it possesses a storage time of 200 ns and a switching time of 1.5 ns. This diode has an inferior efficiency to the varactor diode BXY 27 manufactured by Philips due to the relatively low cut-off frequency and long switching time. The varactor diode BXY 27 has a characteristic C/U curve of a storage diode **(Figure 7)**. It is specially designed for the frequency range in the order of the S-band and provides RF efficiencies in the order of 70 %.

It should also be mentioned here that GaAs-diodes possess higher cut-off frequencies, however, they are not suitable for the conversion of high power levels due to the higher heat resistance in comparison to silicon. Furthermore, it is very difficult to manufacture storage diodes in GaAs, since the life of the minority carriers is too low.

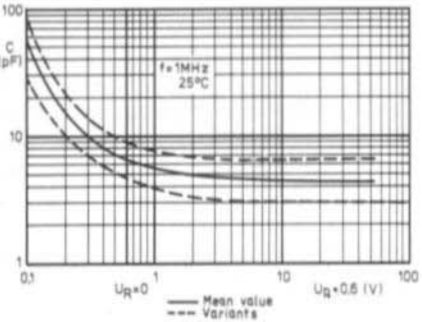


Fig. 7: C/U characteristic of the varactor diode BXY 27

The following main signals appear in the frequency spectrum of the converter:

1. $1152 + f_{IF} = f_3$	(f_{IF} = 2 m frequencies)
2. 1152	local oscillator
3. $9 \times f_{IF}$	Harmonics of f_{IF}
4. $1152 + 2 \times f_{IF}$	Conversion product
5. $2 \times f_3 - 9 \times f_{IF}$	Intermodulation product

f_3: Required signal
All frequencies given in MHz.

The circuit diagram of the converter is shown in **Figure 8**. The bandpass filter at the output ensures that the local oscillator signal is suppressed by 28 dB and that the unwanted conversion product at the second harmonic of the IF frequency by approximately 50 dB. The ninth harmonic of the IF and its intermodulation product are within the passband range of the filter. This is due to the harmonic relationship of the amateur bands. According to the drive of the mixer, these will be suppressed by 40 to 50 dB. However, these signals will not cause any difficulties during practical operation, since the products will be more than 900 kHz away from the required signal when using 1296.1 MHz.

This problem can be solved completely by using a lower crystal oscillator frequency and a correspondingly higher input signal frequency, e.g. 144.1 MHz ≙ 1296.0 MHz. Any other type of mixer for the 23 cm band having an intermediate frequency of 144 MHz will also possess this signal spectrum, usually with inferior suppression values.

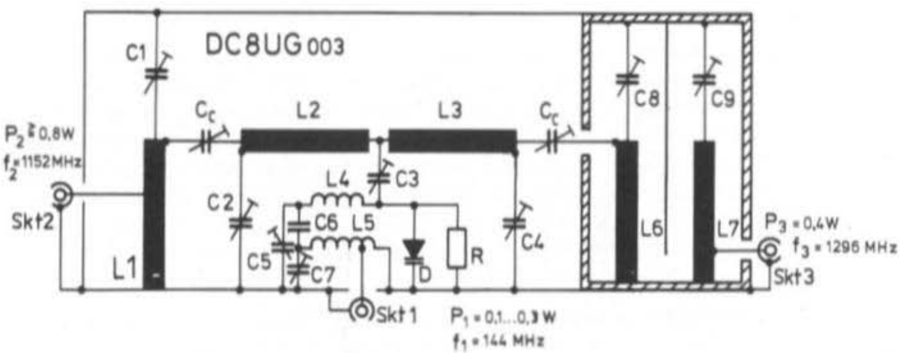


Fig. 8: The linear transmit converter DC 8 UG 003

2. CONSTRUCTION AND ALIGNMENT

Certain measuring units are absolutely necessary for the construction of the transverter, and it is necessary that they be obtained and/or constructed.

These are:

1. Multimeter, or tube voltmeter
2. Frequency meter from 200 to 1300 MHz (5), (7)
3. Dipmeter, or frequency counter up to 200 MHz
4. Power meter up to 1300 MHz, or directional coupler with low VSWR terminating resistor (several low-inductive resistors in parallel).

For amateurs that do not have any experience of construction in the GHz range, it is recommended that they carry out construction together with experienced SHF amateurs. Several measuring and alignment errors can be avoided in this manner. The cable lengths between the modules should be as short as possible for matching reasons (shorter than a tenth of the wavelength), or an even multiple of an electrical $\lambda/2$.

2.1. Local Oscillator Module

The double-coated PC-board DC 8 UG 001 (see **Figure 9**) is constructed up to the fifth stage (2 N 4427) in the same manner as module DC 8 NR 006 described in (4). The following changes have been made:

1. Dimensions: 160 mm x 70 mm for the PC-board and the case height of 46 mm with 30 mm intermediate panels.
2. Transistors T 2, T 3, and T 4 had been replaced by the transistor types: T 2 and T 3 = BFW 92, BFY 90, and T 4 = BFY 90. It is necessary for the transistor BFW 92 to be soldered to the conductor side of the board.
3. The voltage of the zener diode is increased to 10 V and the voltage dropper resistance amounts to 82 Ω.
4. The collector resistor of T 3 amounts to 27 Ω, 22 Ω for T 4, and 10 Ω for T 5. The base-emitter resistor of T 5 is reduced to 620 Ω.
5. The tap on the resonant line L 7 is now at the center.

The base and the collector of transistor T 6 (C 1-12) are placed through slots in the PC-board; attention should be paid that the ground surface is removed approximately 2 mm around the slots on the upper side of the board; this is made best using a sharp knife. For cooling, it is necessary for the transistor to be touching the board. The base and collector connections are soldered on the lower side of the board, whereas the emitter connections are soldered to the upper side. The required intermediate panel is soldered into place directly over the center of the transistor, however, enough room must be provided so that the transistor can also be removed if required (cutout 20 mm x 10 mm). Further details can be seen in the photograph given in **Figure 10**, and from the component location plan.

After studying the position and installation of all components, the mounting of the components on the board can best be started by mounting the resistors, capacitors, and transistors, as well as the inductances up to stage T 3. It is absolutely necessary to carry out a functional check of each individual stage before mounting further components. The oscillator, for instance, can be checked with the aid of a VHF-FM broadcast receiver, or absorption wavemeter. The 192 MHz signal can also be checked with a dipmeter switched to the absorption mode, after which it can be aligned to maximum with the aid of C 2 and C 3. After resonating the 192 MHz circuits, C 4 can be aligned for maximum after connecting a power meter via a coupling capacitor of 150 pF. The power output should be in the order of 10 mW into 50 Ω. This means that a 384 MHz signal is available which is amplified in transistor T 4 to 50 mW. This step-by-step method of mounting the components (and intermediate panels) and checking is now continued. A power output of 150 mW should be measured at L 6; the total current should be in the order of 140 mA at 13.5 V.

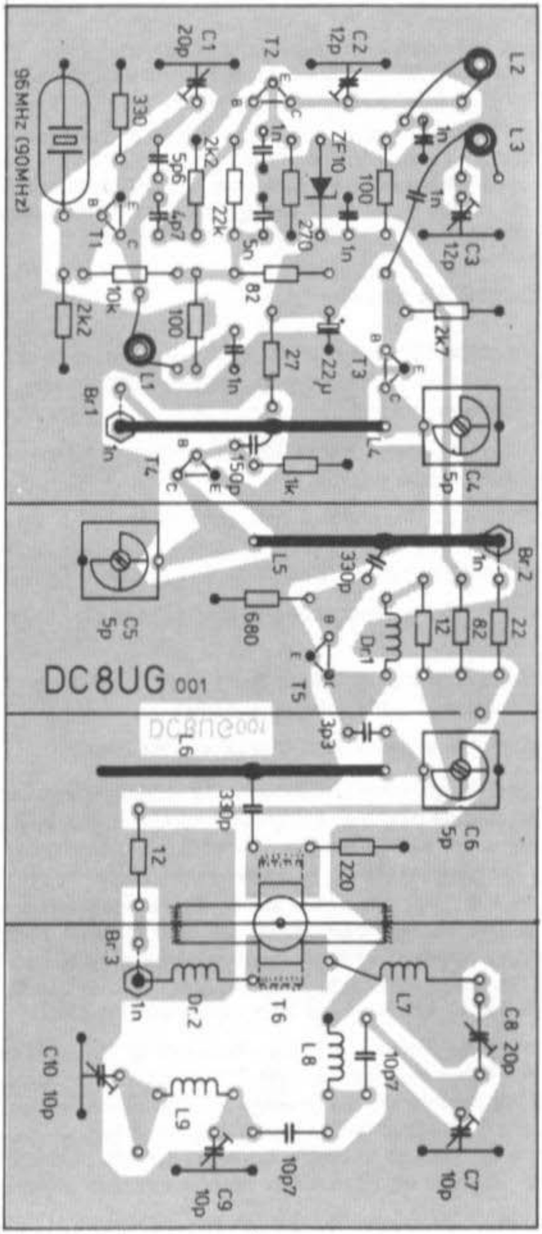


Fig. 9: Double-coated PC-board DC 8 UG 001

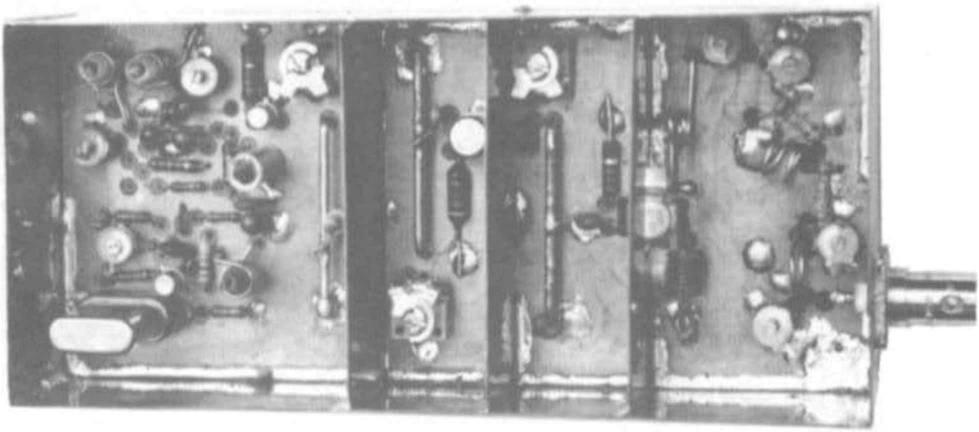


Fig. 10: Photograph of the author's prototype

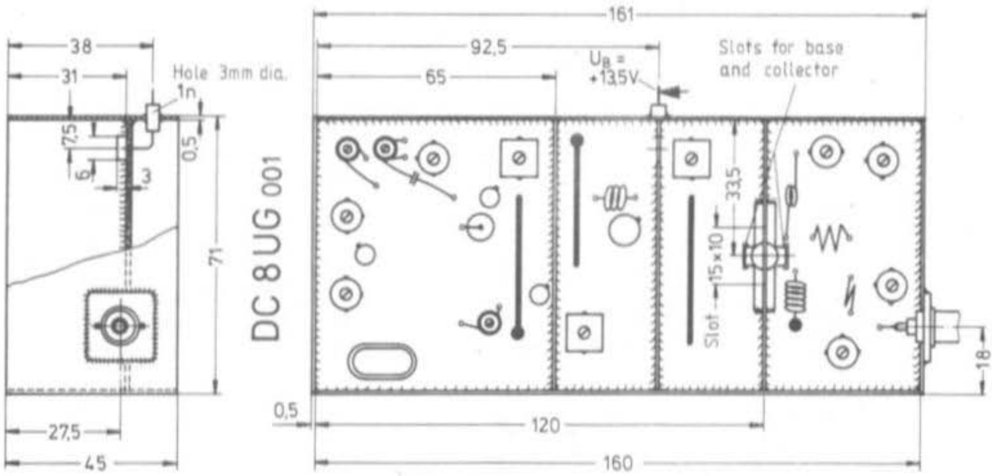


Fig. 11: Component locations in module DC 8 UG 001 with the most important dimensions

Finally, transistor C 1-12 is installed together with the associated filter circuits. Before checking the overall operation, the PC-board is soldered on both sides with the case and intermediate panels constructed from 0.5 mm thick brass plate, and a BNC connector is installed at the output. After this, the output signal is taken from trimmer C 7 and connected to the power meter, and the 10.7 pF capacitor of the high-pass filter is disconnected. An output power of 1.4 W should be present at this position after correct alignment of the input and output circuits. The overall current drain now amounts to 250 to 260 mA. The filter combination of high-pass and low-pass filter is now connected and the output power aligned to approximately 1.3 W by varying the values of capacitors C 8, C 7, C 9, and C 10, as well as slightly bending inductance L 8. The completed module can be provided with a cover which should be spring-loaded to ensure that it is well screened. The high side panels ensure that no capacitive effects are possible.

2.2. Frequency Tripler

The drawing given in **Figure 12** and the photograph given in **Figure 13** give both the mechanical dimensions and the position of the components in the tripler. This module comprises a PC-board which is combined with a two-stage filter comprising discrete elements. **Figure 14** shows PC-board DC 8 UG 002 of the tripler. The output coupling to the frequency converter DC 8 UG 003 is made galvanically, whereas the signal for the receive converter is made capacitively via a screw-mounted BNC-connector. The inner conductor and the PTFE insulation have been shortened up to the metal part of the connector.

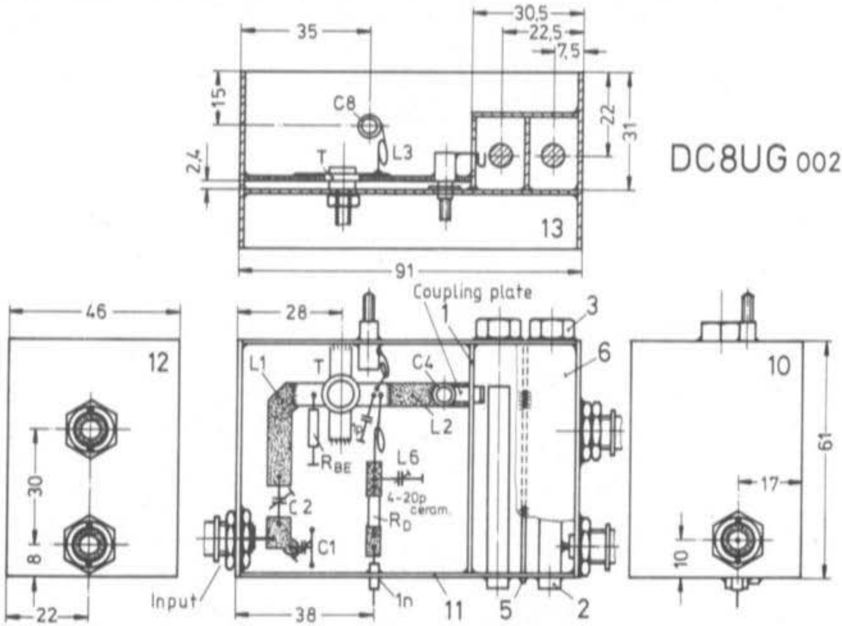


Fig. 12: Layout of module DC 8 UG 002 with the most important dimensions

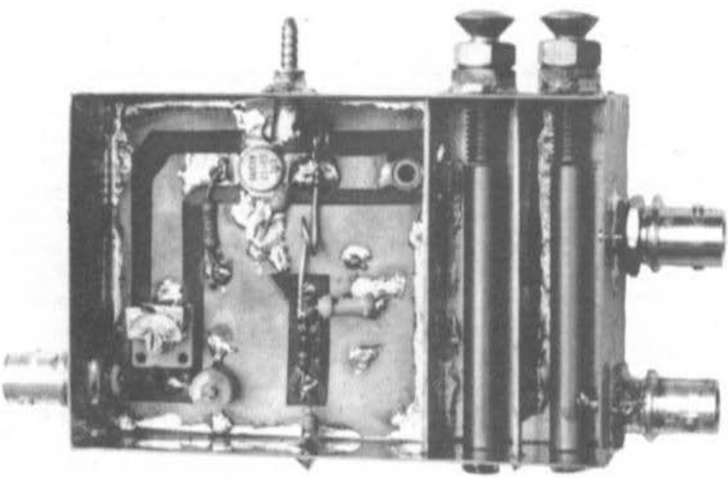


Fig. 13: Photograph of the author's prototype

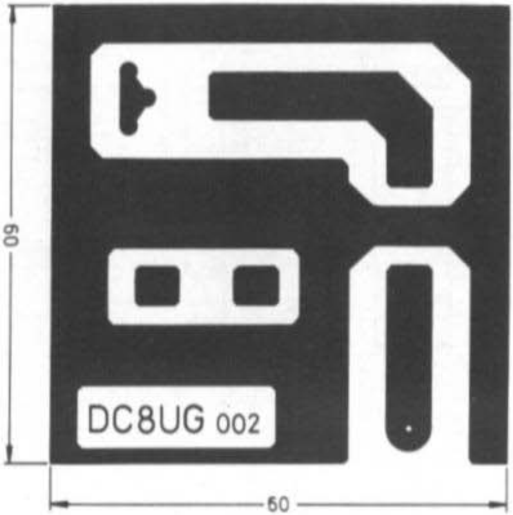
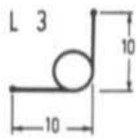
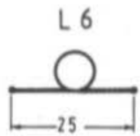


Fig. 14:
PC-board DC 8 UG 002
for the tripler

2.3.1. Components for DC 8 UG 002

C 1:	Plastic foil trimmer 2 - 22 pF (Philips)
C 2:	15 pF air-spaced trimmer (tronser)
C 3:	1 pF ceramic
C 4, C 8:	0.6 - 6 pF tubular trimmer (Philips)
C 5:	4 - 20 pF ceramic trimmer
C 6:	1 nF feedthrough capacitor
C 7:	100 nF ceramic; connected on the outside
C_C, C 9, C 10, C 11:	see illustrations
L 1, L 2:	printed inductances
L 3:	1.5 turns of 1.2 mm dia. silver-plated copper wire close wound on a 6 mm former
L 6:	1 turn, otherwise as L 3
R_D:	5 to 10 Ω
T 1:	C 3-12 CTC
R_{BE}:	Establish value experimentally, approx. 100 to 200 Ω, 1/4 W, carbon resistor





The construction commences with the cutting of all parts and drilling the holes according to **Figure 15**. The spacing between the base plate and the PC-board is maintained using 2.4 mm spacers. Trimmer C 4 is firstly mounted onto the base plate, after which the base plate and the drilled board (a 10 mm hole for the transistor and a 6 mm hole for trimmer C 4) are glued together with the aid of the two spacers. The filter panel with cutout is soldered to the base plate (100 W soldering iron), after which the side panels are soldered to the PC-board and base plate. The filter lines and alignment screws can now be mounted, as well as the intermediate panel of the filter. After soldering the front and rear panel together with their BNC connectors into position, it is possible for the trimmers, inductances, resistors and capacitors to be mounted. Trimmer C 4 is connected to the line circuit and the coupling plate soldered into place. Finally, the transistor is mounted into position.

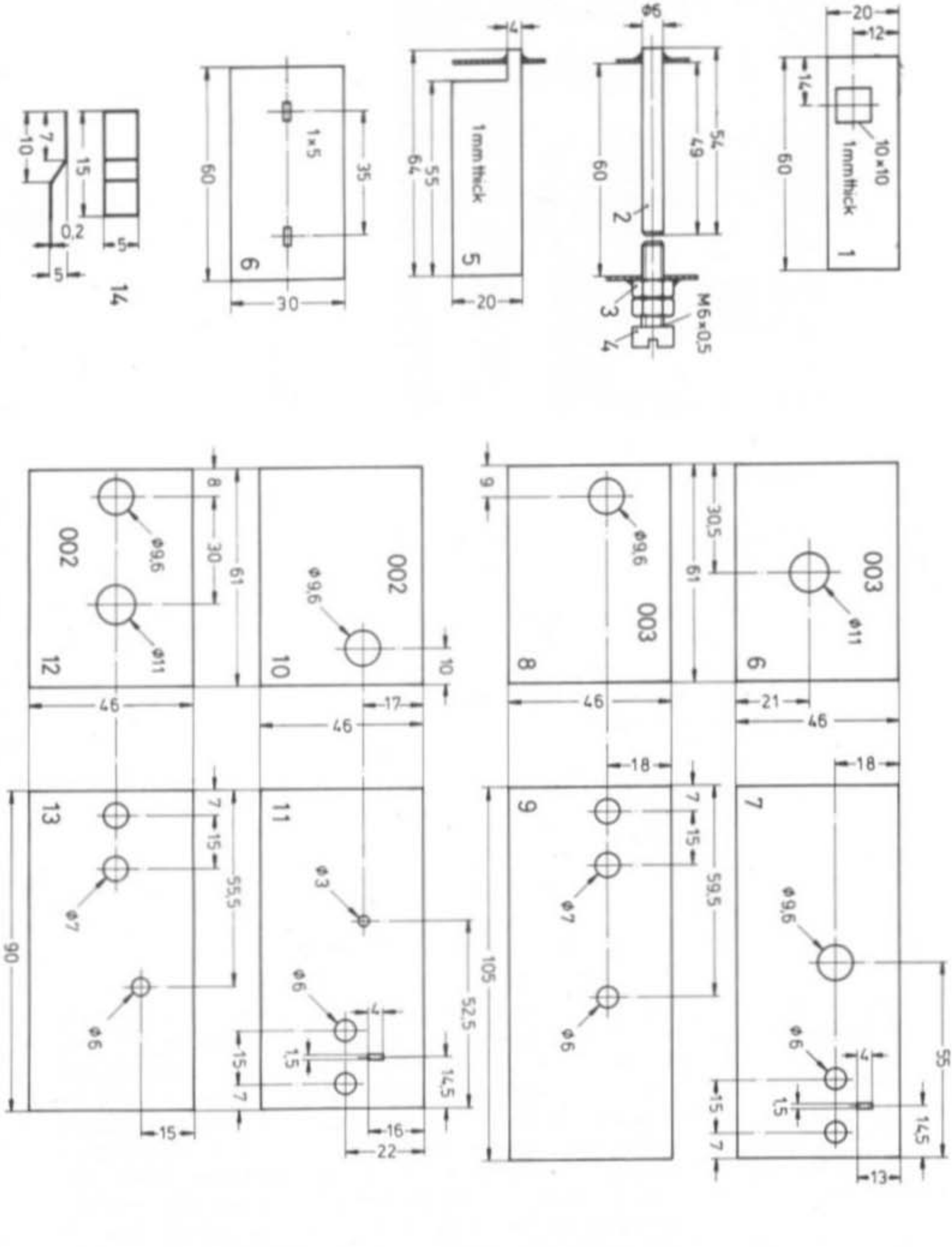


Fig. 15: Metal pieces for modules DC 8 UG 002 and 003

2.2.2. Alignment of the Tripler

A 500 mA-meter is connected in series with the power supply line, and the output is connected to a power meter. The bandpass filter is extremely selective, and it is thus necessary to firstly bring it to resonance. For this purpose, the module is driven by a 384 MHz signal and a maximum collector current of 300 mA is selected with the aid of trimmer capacitors C 1 and C 2. Finally, the bandpass filter is brought to resonance whereby the screws should be spaced approximately 0.8 mm from the lines. The power meter or directional coupler should now bring an indication in its most sensitive range. After this, the idler circuit (C 8), C 4, the coupling capacitor C_C and the input and bandpass filter circuits should be aligned alternately until the maximum output power has been obtained. If the tripler is working correctly, the current drain will be in the order of 260 mA at 13.5 V and the output power will be 0.8 W. After alignment, the cover of the filter should be soldered into place.

An output power of 5 to 50 mW should be present at the output connector for the receive mixer according to the position of the adjustable BNC-connector.

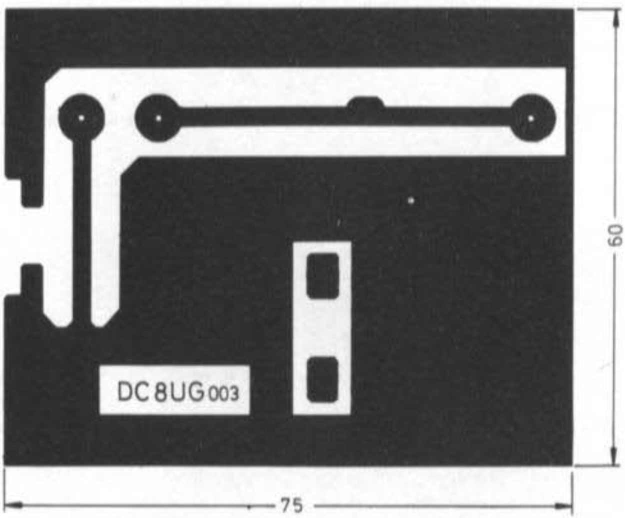


Fig. 16: Double-coated PTFE board DC 8 UG 003

2.3. Frequency Converter

The frequency converter module is built up on a double-coated PC-board manufactured from PTFE (teflon). PC-board DC 8 UG 003 has dimensions of 75 mm x 60 mm, and is shown in **Figure 16**. **Figure 17** shows the mechanical and electrical details of the module, whose dimensions are 61 mm x 106 mm. The lower side of the board is soldered to a base plate of 1 mm thick brass which is used as a heat sink for the varactor, and for increasing the mechanical stability. Holes of 3 mm diameter are drilled at the positions marked »+« on the base plate and are counter-sunk in the direction of the board. (See »A« in Figure 17). After this, both parts are soldered together by allowing the solder to flow through the non-countersunk side between the board and the base plate.

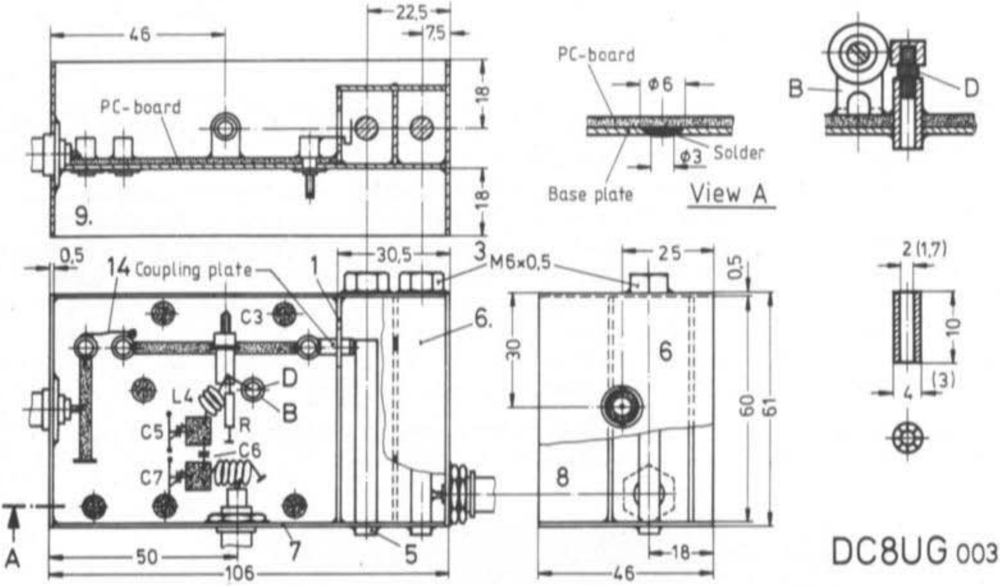


Fig. 17: Layout of module DC 8 UG 003 with the most important dimensions

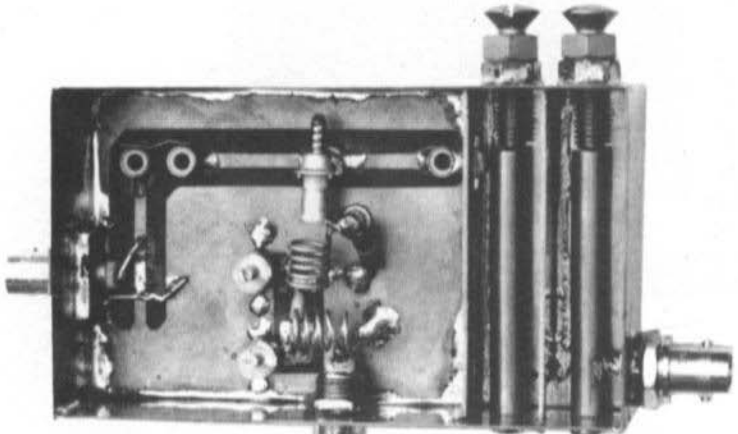


Fig. 18: Photograph of the author's prototype

After this, the holes are drilled, the intermediate panel to the filter is soldered into place, and the cutout for the BNC-connector of the 1152 MHz input is mounted into place. The panels of the case are now constructed from 0.5 mm thick brass plate (see Figure 15), and provided with the required holes. It is recommended that the tubular trimmers be fitted into the base plate and soldered into place at this point, and also the BNC connector for the local oscillator signal. The side panels and filter parts can now be soldered into place. This is made in the same manner as with the tripler. This is followed by mounting the front and rear panels; a minimum of solder should be used within the filter.

Now, the 144 MHz circuits are mounted into place, the tubular trimmers are soldered to the resonant lines, and the coupling plates are mounted into position. The varactor is mounted in a spring-loaded brass bushing which is placed through the board in the designated position and soldered to the upper and lower side, (see detail »B« in Figure 17). In the case of the BXY 27 the bushing will comprise a 3 mm dia. tube having an inner diameter of 1.7 mm; this is available in many hobby shops. After the varactor has been mounted, it is then possible for capacitor C 3 to be connected with its rotary plates to the PC-board and the stationary plates to the varactor. This is done by either soldering the stator tag to the diode quickly using a very hot soldering iron, or with the aid of a small slotted bushing (see detail »B«). Attention must be paid to keeping the connections as short as possible ! Finally, inductance L 4 is soldered to C 3, and resistor R to C 3 and ground.

2.3.1. Components for DC 8 UG 003

C 1, C 2, C 3, C 4:	Ceramic tubular trimmer 0.6 - 6 pF (Philips)
C 5, C 7:	Plastic foil trimmers 2 - 22 pF (Philips)
C 6:	1.5 pF ceramic disk capacitor
C_C, C 8, C 9:	see Figures 17 and 18
L 1, L 2, L 3:	printed striplines
L 4, L 5:	5 turns of 1.2 mm dia. silver-plated copper wire wound on a 6 mm former, length 8 mm. L 5: Coil tap 1.5 turns from the cold end
L 6, L 7:	see Figures 17 and 18
D :	Storage or junction varactor with a transit frequency in the order of 100 GHz. $P_{tot} > 2$ W; e.g. BXY 27, VAB 811 EC, 1 N 5155, 1 N 5152
R :	100 kΩ; 0,5 W, carbon
Skt 1:	BNC UG 1094/U (for single-hole mounting)
Skt 2, and Skt 3:	BNC UG 290/70 (flange mounting)

2.3.2. Alignment of the Frequency Converter Module

The completed module is now driven by the 1152 MHz local oscillator signal and a 144 MHz signal of maximum 30 mW. The output signal is then measured selectively at the output, which can be done with the aid of a receiver.

The 144 MHz input is now aligned for a minimum standing wave ratio, which is followed by optimizing the bandpass filter for the required output signal. After one has established that the required signal is present at the output, all circuits are aligned alternately for maximum. It will be necessary for the coupling plates and C 3 to be varied during this alignment. The series circuit comprising C 5 and L 4 will affect the suppression of the ninth harmonic of the input signal. C 5 is aligned for minimum output at this frequency. This should be made using a receiver tuned to the frequency. However, if such a receiver is not available, it will be sufficient when the position of C 5 coincides to that of C 7. This circuit allows the ninth harmonic of the input frequency to be suppressed by approximately 10 dB.

Finally, the transmit converter is driven at higher and higher level with the 144 MHz signal until the output power no longer increases (saturation). The input power at this point will be in the order of 0.2 to 0.3 W, and the output power at 1296 MHz will be between 0.4 and 0.5 W after carrying out the fine alignment if the varactor BXY 27 has been used. After this, it is possible for the cover of the filter to be mounted into place.

3. SUMMARY OF THE MEASURED VALUES

The described transmit converter and local oscillator module were measured using a spectrum analyzer type hp 851 B and a thermal power meter type hp 435 A. The measured spectra are given in the following photos **(Figures 19 - 21)**. All measurements were made at 13.5 V, and maximum output power. The most important measuring values can be summarized as follows:

384 MHz local oscillator module DC 8 UG 001

Spectrum: Figure 4
$P = 1.3$ W
All harmonics suppressed
better than 40 dB

Tripler DC 8 UG 002

Spectrum: Figure 19
$P_2 = 0.8$ W into 50 Ω
All harmonics suppressed
better than 56 dB

Analyzer bandwidth:
350 to 2100 MHz at 200 MHz/cm

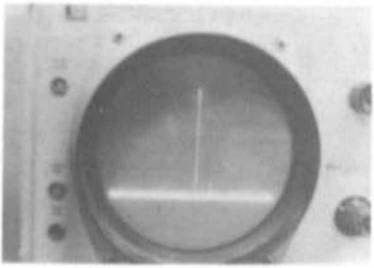


Fig. 19: Spectrum of the tripler

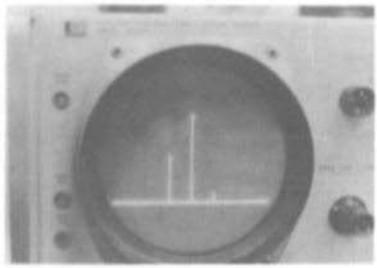


Fig. 20: Spectrum 1 of the converter

Frequency converter DC 8 UG 003

Spectrum 1: Figure 20
Analyzer bandwidth: 800 - 1800 MHz at 100 MHz/cm
$a_{1152} = -28$ dB, $a_{1152} + 2 \times f_{IF} = -50$ dB
at $P_3 = 0.4$ W into 50 Ω

Spectrum 2: Figure 21
Analyzer bandwidth: 1291.1 - 1301.1 MHz at 1 MHz/cm
$f_3 = 1296.1$ MHz with $P_3 = 0.4$ W
Upper spectral line = 9 x 144.1 MHz = 1296.9 MHz
a = – 48 dB
Lower spectral line = 2 x 1296.1 MHz – 1296.9 MHz = 1295.3 MHz
a = – 46 dB

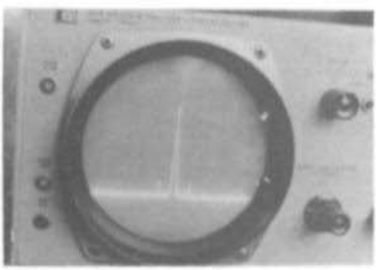


Fig. 21: Spectrum 2 of the converter

Intermodulation rejection for the first intermodulation product $2\ f_a \pm f_b$

This measurement was carried out by DK 2 DPX on another prototype of the transmit converter DC 8 UG 003 equipped with the BXY 27 varactor. With a local oscillator power of 1.7 W and an input power of 0.7 W, the intermodulation ratio was determined to be 41 dB ! Theoretical papers (1) regarding the intermodulation ratio of varactor up-converters state that the intermodulation ratio will not be worse than 19.6 dB even when they are driven up to saturation ($P_{3\ max}$), as is shown in **Figure 22**. Practical measurements usually exhibit better values.

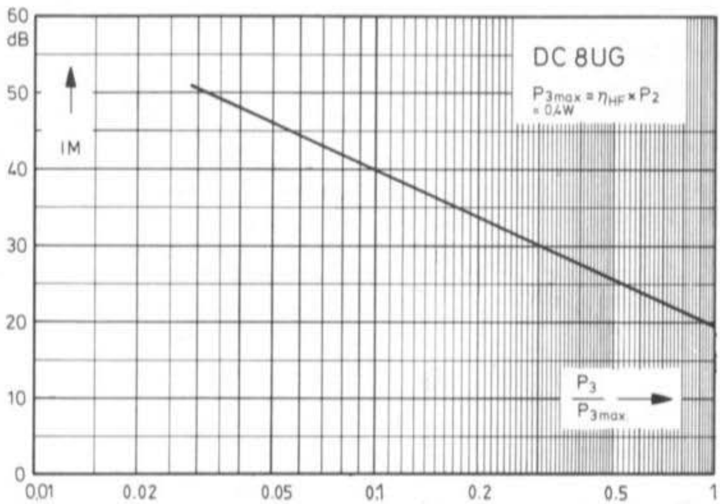


Fig. 22: Intermodulation ratio as a function of drive

The author would like to thank the Institute for High Frequency Technology of the Technical University of Braunschweig as well as DK 2 DPX and DJ 2 WW for their assistance and provision of the required measuring equipment.

4. REFERENCES

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IEEE, Transactions on Microwave Theory and Techniques, Vol. Mtt-13 No.6, Nov. 1965

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HARMONIC FILTER
for the ULM 70 and ULM 70 S TRANSCEIVERS

by I. Sangmeister, DJ 7 OH

Even a well constructed and well aligned 70 cm transmitter will produce some harmonics. It is especially important to suppress the first harmonic which falls into the UHF television band. A bandpass filter was selected so that it is also possible to attenuate harmonics of 144 MHz that are generated in the last frequency multiplier. The disadvantage of this circuit is that very high frequencies will not be suppressed due to ground and/or capacitive coupling between the input and output. However, it is not very important here since the transit frequency of the output transistor is only in the order of 800 MHz.

In order to simplify the wiring of the ULM 70 transceiver, the antenna changeover relay has been included in the harmonic filter module. There are two possibilities of connecting the filter into the circuit:

a) Antenna relay connected directly to the antenna circuit **(Figure 1a)**:
Advantages: less loss in the receive mode, and thus higher sensitivity.
Disadvantages: greater loss in the transmit mode, since the relay and antenna socket cause two points of discontinuity, which must both be compensated for using the output trimmer of the harmonic filter. This means that the aligned filter will not be balanced.

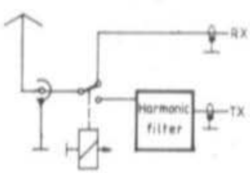


Fig. 1a

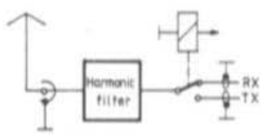


Fig. 1b

b) Harmonic filter between antenna socket and relay **(Figure 1b)**:
Advantages: additional selectivity during reception. Less power loss in the transmit mode because the input trimmer of the harmonic filter can compensate for the capacitance of the relay. The output trimmer only needs to compensate one point of discontinuity: between the short cable and the antenna socket.
Disadvantage: Attenuation of the input signal.

Both methods can be realized using the PC-board DJ 7 OH 002 shown in **Figure 2**. **Figure 3** shows the filter mounted into version b of the transceiver. This comprises the PC-board (A), mounting plate (B), side panels (C, D_1 and D_2), intermediate panel (E) and cover (F). Parts A to F are made from double-coated epoxy PC-board material, 1.5 mm thick. The metal parts can be cut from tin plated steel using shears. For drilling, the tin plate is clamped between the two layers of PC-board material so that it is held securely.

PC-board DJ 7 OH 002 is 41 mm x 33 mm and is double-coated. Construction is somewhat simplified if the holes are provided with through-contacts. The two trimmers are airspaced (Tronser) trimmers with a maximum capacitance of 7 pF; these possess 4 pins with a spacing of 7.5 mm. The two inductances are made from 1 mm dia. silver-plated wire; they are wound identically, but in opposite sense, using a 4 mm former, and are both 8 mm in length. They are soldered into place as shown in the drawings. The coil tap is to be found approximately half a turn from the cold end. The following National relais are suitable for antenna change-over switching: RSL 12, RSD 12, or RS 12. Relay type RH-12 is less suitable due to the plastic casing.

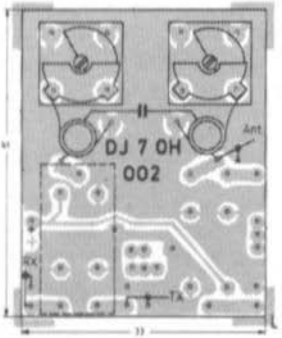
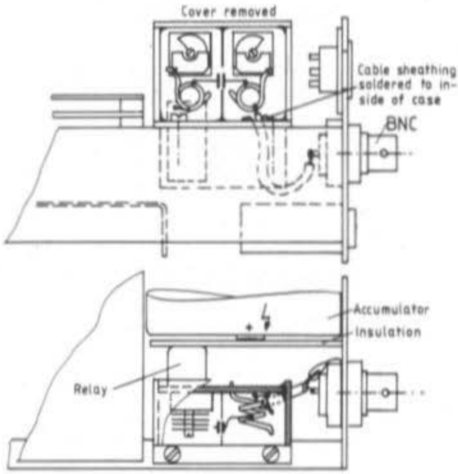


Fig. 2: PC-board of the harmonic filter and antenna relay



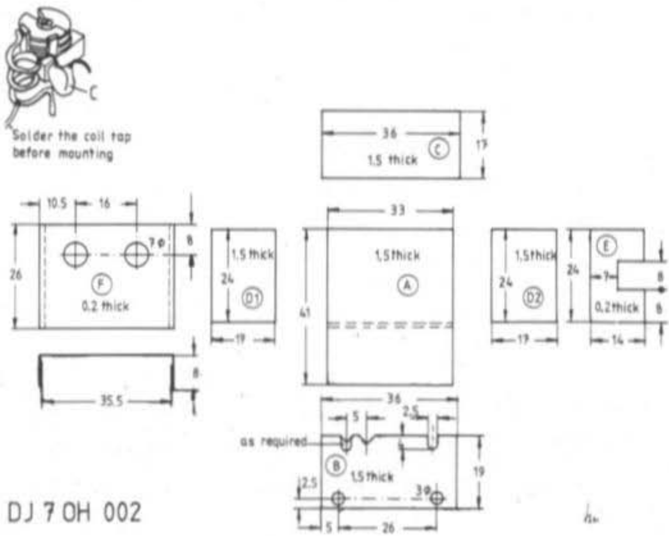


Fig. 3: Parts and construction

The components are mounted onto the PC-board from both sides. The first component to be mounted is the relay. Due to the symmetrical construction, it is possible for the components to be mounted on the opposite side when the filter is to be used for other equipment.

After mounting the relay, side panels C, D_1 and D_2 are soldered around the edge of the main board so that it protrudes by approximately 2 mm. It is necessary for part B to be provided with a small slot for the solder pins of the relay; a slot is provided on the other side for the coaxial cable. After this, it is possible for the case to be sealed and the intermediate plate soldered into place; it is not necessary at this position for the solder joints to be completely »water-tight«. The cover is bent so that it sits firmly onto the case.

If the PC-board does not possess through-contacts, the ground holes should be slightly larger so that a wire (or copper foil strip) can also be placed through the hole and soldered into place on the inside and outside. It is now possible for the trimmers and the inductances to be soldered into place. The coil tap and the coaxial cable are connected to the inductances before soldering into place. After this, it is only necessary for the coil tap to be connected to the relay and the outer conductor of the coaxial cable soldered to panel B.

In order to obtain the required passband curve, the coupling capacitor (1 pF ceramic disk type) can be soldered to various positions on the inductances.

THE ULM 70 S

A FM Transceiver for the 70 cm Band with Synthesizer

by I. Sangmeister, DJ 7 OH

Originally, the 70 cm transceiver ULM 70 was designed for local operation within the Ulm area of West Germany, as a construction project to increase activity on the 70 cm band. The compact transceiver, however, was found to be ideal for holiday use and travelling. Of course, the limitation to a few crystal-controlled channels was a disadvantage.

Complete freedom of frequency selection is offered when using a synthesizer. The construction and alignment as well as the installation into an operational ULM 70 is to be described in detail. The construction of the synthesizer is no more difficult than that of a superhet VFO; however, the latter would cause far more mechanical problems when one considers the scale and slow motion drive.

The problems encountered with the synthesizer are due more to the unfamiliar phase control technology. However, this is a low-frequency technology that one soon becomes accustomed to. In order to ease the transition, special importance has been paid in this article to providing detailed alignment information. Many points are mentioned which need not be taken into consideration normally. No great demands are placed on the required measuring equipment: A low-frequency oscilloscope without DC-coupling, a 50 MHz frequency counter, and a high-impedance multimeter are sufficient.

1. CONSTRUCTION

The block diagram of the synthesizer was given in edition 2/1977 of VHF COMMUNICATIONS. At that time, the crystal oscillator of the receiver was used in order to convert the VCO frequency to the dividable intermediate frequency. The module described here only differs from the original concept in that it possesses its own crystal oscillator. This means that the modifications to the completed transceiver are kept to a minimum and that the synthesizer module is also suitable for use in other equipment.

The synthesizer is connected to the VFO-inputs of the 70 cm transceiver, and the switch placed into the »VFO« position. This means that it is also possible to change from the local frequency to any frequency selected on the synthesizer by just changing the position of this switch.

Figure 1 shows the frequency plan, which is mainly determined by the requirement of compatibility with the original transceiver: The oscillator must provide frequencies in the order of 48 MHz which are then multiplied by nine in the transceiver. Of course, it would, no doubt, have been more elegant to generate the final frequency; however, this would cause a higher current drain for faster frequency dividers and counters. The number of selectable channels was limited to 100. It is possible using an additional switch to obtain 120 channels, however, 100 channels with a spacing of 25 kHz will normally be sufficient if the band limits have been correctly selected. If channel »00« corresponds to 431.000 MHz all European repeater input channels will be covered and the frequency range will be up to 433.475 MHz. The ATV band commences above this. In order to receive the output frequencies of the repeaters, the frequency range is shifted by 7.6 MHz upwards, and by 10.7 MHz downwards.

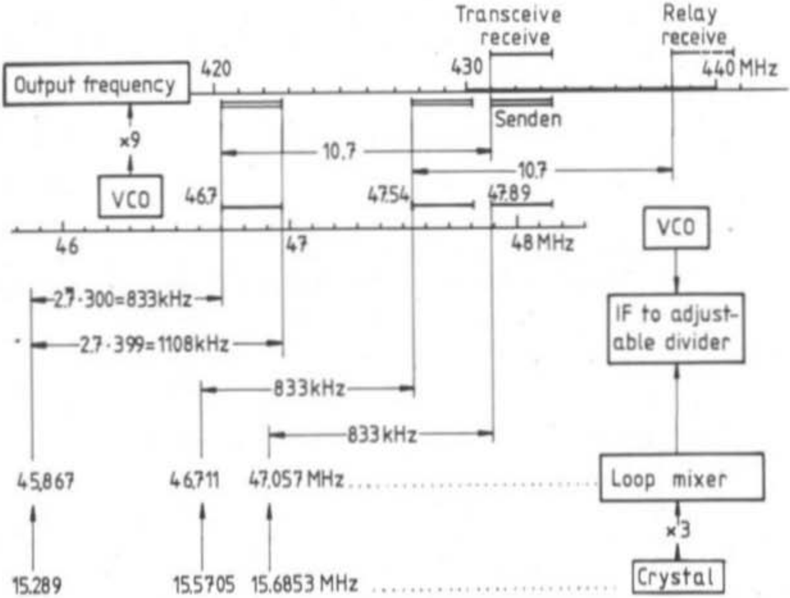


Fig. 1: Frequency plan

Since the VCO frequency is multiplied by nine, it is necessary for it to be shifted in steps of 25 kHz/9 = 2.777 kHz. No further dividers are to be found between VCO and adjustable divider, which means that 2.777 kHz is also the frequency of the phase comparator. This is a very low, and audible frequency ! The lower the frequency, the more difficult it will be to filter it out. However, it has one advantage of being in the audible frequency range in that it can be checked more easily. 25 kHz interference can be far more complicated, which has been found in the case of several older developments. In order to suppress the low frequency interference as well as possible, a sample-hold phase detector with compensation of the ramp voltage is used.

2. CIRCUIT DIAGRAM

Figure 2 shows the complete circuit diagram of the synthesizer. The control loop operates in a clockwise direction. The voltage-controlled oscillator (VCO) in the upper left-hand portion of the diagram possesses the only inductance of the module. This is an air-spaced coil constructed from enamelled copper wire which is fixed onto a ceramic former with lacquer together with the feedback winding. This means that it is firmly fixed, which is important since only low-frequency interference up to approximately 200 Hz will be controlled.

The coarse and fine adjustment of the VCO is made with the aid of two varactor diodes. Since an intermediate frequency of 10.7 MHz is relatively low for a 70 cm transceiver, the VCO is also able to provide the local oscillator signal for the receive mixer. The PC-board is provided with three potentiometers for frequency adjustment of the VCO to the center frequency of each of the bands shown in Figure 1: »Transmit«, »Repeater«, and »Transceive Reception«.

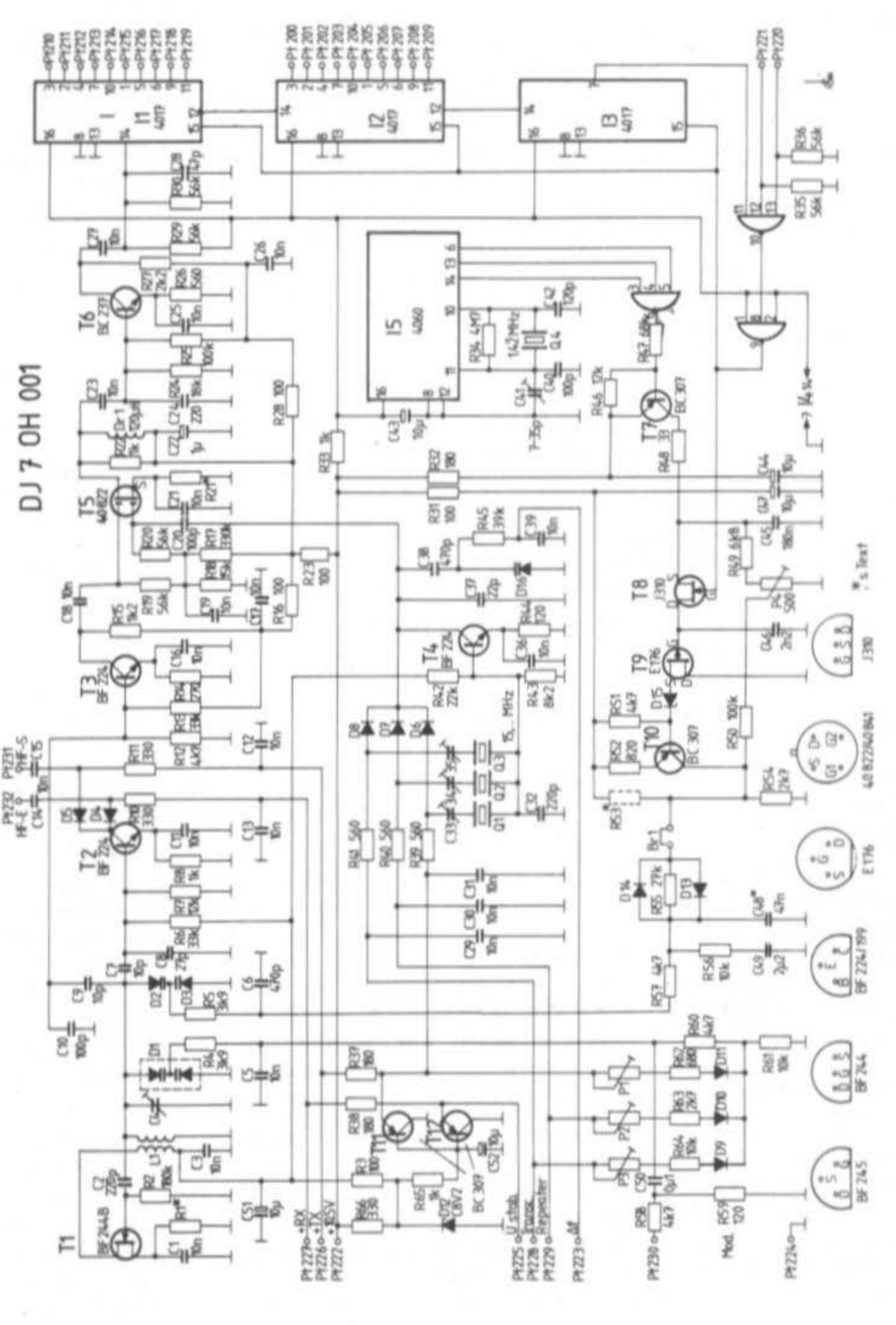


Fig. 2: Circuit diagram of the synthesizer DJ 7 OH 001

The highest frequency is required in the »transmit« mode, and for this reason the circuit switched in via diode D 11 should have the lowest resistance.

The modulation is fed in after the resistor R 60 via capacitor C 50. The required AF voltage is very small, and for this reason the characteristic of the diode is practically linear. The voltage divider comprising R 58 / R 59 should have as low a resistance as possible since R 60 forms a voltage divider together with R 59 for any interference voltages that may be present on the switching lines. In addition to this, capacitor C 5 is connected in parallel which would cause the high-modulation frequencies to be clipped if a high-impedance circuit were used.

The other pair of varactor diodes (D 2, D 3) is equipped with lower capacitance types. These varactors allow the frequency to be varied by approximately 4 MHz (on 70 cm). The control voltage is connected to this point.

Due to the large component of the varactor diodes in the resonant circuit capacitance, a large temperature dependence of the free-running oscillator is to be expected. An exact compensation will not have very much success due to the non-linearity of the characteristic. The switching diodes D 9 to D 11 provide a partial compensation. The rest of the compensation can be made using ceramic trimmer C 4 (N 750) by varying the parallel capacitors. A fine alignment is possible by aligning the potentiometers and trimmers in opposite directions. However, this is only necessary when the temperature range is doubled or tripled, as in the case of mountain field days etc. Stable operation is offered between 0 and + 35°C with sufficient reserve when using the given circuit.

The buffer stages are simple RC-amplifiers. Transistor T 2 is matched at the input and drives into a low impedance of 330 Ω. This is sufficient for cable lengths up to approximately 15 cm. If the synthesizer is to be installed in a separate cabinet, it is recommended that a wideband resonant circuit be provided at the collector for matching to 50 Ω coaxial cable, and the transmit receive switching deleted.

The buffer stage of the loop is only loosely coupled to the VCO. Since it is driving into a mixer input capacitance of approximately 10 pF, it is possible for the collector resistor to be high-impedance.

A dual gate MOSFET is used as mixer for the loop. The type is uncritical due to the low frequency. Unfortunately, it will always be necessary for the operating point to be aligned with the aid of R 21. A normal transistor will not have sufficient decoupling between the mixer inputs, and when using the applied harmonic mixing circuit, would even cause an interference signal in the vicinity of the VFO frequency. The crystal oscillates in parallel resonance at approximately 16 MHz. In this manner it is possible for only the attenuated harmonics to be passed via the buffer to the VCO. The crystal oscillator can be pulled by one channel using varactor diode D 16, which means that it is possible for frequencies to be set to an intermediate channel spacing externally.

The mixer is followed by a wideband resonant circuit comprising Ch 1 / C 24, which is aligned to approximately 1 MHz. A high-gain stage equipped with an AF transistor increases the level of the IF signal to full operating voltage deviation. Capacitor C 28 has been found to be very important. This capacitor is connected directly to the output of the divider and filters out all higher frequencies that originate from the various oscillators. The triggering point of the first divider would be undefined if this capacitor was not used and this could cause an oscillation noise on the VCO signal, which would be independent of the selected channel.

CMOS/ICs type 4017 with decoded outputs are used as divide-by-ten adjustable dividers. This simplifies the circuit considerably; however, does not allow remote control, as would be the case when using conventional BCD-controlled dividers. Connection wires of up to 10 cm are permissible between the PC-board and the front panel. The most important advantage is that it is outputs that are connected here, and not sensitive inputs that must be filtered individually. In addition to this, the inputs of CMOS-ICs are liable to be destroyed by excess voltages at the inputs; for this reason, they should be grounded at low impedance.

This is done at the inputs of the NAND-gate by resistors R 35 and R 36. The gate combines the selected divider outputs. After all three dividers have counted up to the selected digit, the reset-line will be activated. This will occur most certainly within half a cycle at input frequencies up to 1.5 MHz.

The reference frequency for the phase discriminator is generated in I 5 (CD 4060). This IC contains an oscillator and several binary dividers. The crystal frequency is also kept as low as possible in order to save current. The NAND-gate filters out the impulse from the divider outputs (from eight), so that the ratio at the output amounts to 7:1. The short active impulse is negative going and switches on transistor T 7. This allows capacitor C 45 to charge virtually up to the full operating voltage. The capacitor discharges itself via R 49 during the rest of the cycle. This provides the required sawtooth voltage for the discriminator.

This sawtooth voltage is fed to the source of the pass switch (T 8) during the time the reset signal drives the gate. These times are very short: 1:300 to 1:400 of 1/2777 s, which means that a good RF-FET is required. In addition to this, the through-resistance should be as low as possible so that the storage capacitance at the drain can be as large as possible.

This simple and smallest type of a phase detector has, of course, a disadvantage: it is in fact no more than a mixer, which means that harmonic conversion is possible. If the sampling frequency is half the reference frequency, the phase detector will work just as well as if these frequencies were equal, it is only the slope and the interference suppression that will be different. In order to suppress the sub-harmonic frequency, a considerable amount of selectivity would be required in the IF amplifier. One third of the frequency is suppressed sufficiently by the simple resonant circuit that no difficulties are to be expected here.

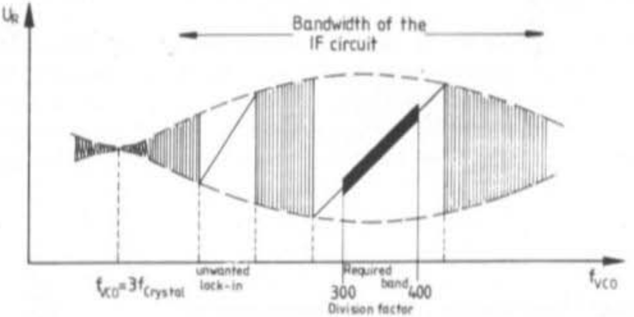


Fig. 3: Control voltage characteristic during coarse alignment

However, even half the frequency will not cause problems when the processes are taken into consideration during tuning: It is assumed that the VCO can be tuned to any frequency with the aid of the trimmer. If this is the case, the locking processes shown in **Figure 3** will be observed. The sampling frequency zero will result when the VCO and the crystal oscillator frequencies coincide. To the left of this, unwanted locking frequencies exist towards lower VCO frequencies which correspond to an image frequency, and are usually very unstable. The correct locking point is the one with the highest VCO frequency.

The sampled and stored voltage is fed via a source follower (T 9) to an inverted voltage amplifier (T 10). The source follower requires a P-type since the input voltages are in the vicinity of the operating voltage. An adjustable compensating voltage is fed to the collector of the inverter via potentiometer P 4. This neutralizes the interfering residual sawtooth voltage that is passed via the high-impedance locking resistor and the circuit capacitances to the storage capacitor when the switching FET is locked. Of course, this is not able to provide a complete suppression since the sawtooth voltage will have a different form in the main branch than in the neutralizing circuit so that a different characteristic results. However, the fundamental oscillation of 2.77 kHz can be reduced by approximately 20 dB which is the most important consideration.

A residual interference voltage of approxiamtely 1 to 2 mV (peak-to-peak) is present across resistor R 54. When this is compared with the tuning voltage variation of 2 V peak-to-peak required for tuning 2.5 MHz on the 70 cm band, this will result in an unwanted frequency deviation of 625 Hz. When using a nominal frequency deviation of 3 kHz, this would still be audible. However, no great demands are placed on the subsequent loop filter.

A part of the loop filter is already integrated into the phase detector. The pass resistor of the switching FET forms a low-pass filter together with the storage capacitor. The effective pass resistance is up to 400 times greater than given in the data sheet due to the short switching time. A limit frequency of approximately 1.2 kHz was measured. It should not be lower than this, because an oscillation of up to 600 Hz can appear during the lock-in process.

The part of the loop filter made of discrete components comprises three links: a low-pass filter (R 55, C 48) with a cut-off frequency of 100 Hz, a lag-filter (R 55, R 56, C 49) with a suppression frequency 3 Hz and a lift frequency 8 Hz, and finally a further low-pass filter comprising R 57, C 6 with a cut-off frequency of 7 kHz for filtering out needles and high-frequency interference from the digital stages.

The loop filter would dampen the oscillation appearing during the lock-in process too greatly, and for this reason a portion is bridged using antiphase diodes. They will conduct for signals that are greater than the threshold voltage. In this case, the load resistor of the inverter (R 54 in parallel with R 53) forms a low-pass filter together with C 48 whose cut-off frequency is now ten times higher in the order 1 kHz.

The PC-board possesses a voltage stabilizer for all critical stages. It is especially important for the switching voltages for the range potentiometers to be well filtered. Transistors T 11 and T 12 are used instead of zener diodes which would cause too much noise at this position. Larger filter capacitors are not possible on the switching lines, otherwise the transmit-receive switching would take too long. For the same reason, the value of capacitor C 50 should not be greater than 0.1 µF.

3. COMPONENT DETAILS

T 1:	BF 244 B or BF 245 B (pay attention to connection diagram !)
T 2 - T 4:	BF 224 or BF 199
T 5:	RCA 40822 or 40841 or similar dual-gate MOSFET
T 6:	BC 237 B or BC 413 B or similar NPN-AF transistor
T 7, T 10-T 12:	BC 307 B or BC 415 B or similar PNP-AF transistor
T 8:	J 310 (Siliconix)
T 9:	E 176 (Siliconix)

D 1: BB 104 (or BB 204 – bend up the connection leads)
D 2, D 3: BB 121 A (Intermetall) or BB 105 A (Siemens)
D 4 - D 11: 1 N 4151 (Intermetall)
D 12: 8.2 V diode (BZY 85 C 8 V 2 or similar)
D 13, D 14: HP 2800 or similar Schottky diode
D 15: Zener diode 1/3 W, value see alignment instructions
D 16: BA 138 or BB 105 A (Siemens)

I 1 - I 3: CMOS 4017 (RCA and other manufacturers)
I 4: CMOS 4023
I 5: CMOS 4060

L 1: 6.5 turns of 0.6 mm dia. enamelled copper wire and 6.5 turns of 0.2 mm dia. enamelled copper wire wound on a ceramic former of 4.5 mm dia., 10 mm long or, if not available, polystyrol coil former of 4 mm dia., close wound.

Ch 1: 120 µH, spacing 20 mm

C 4: 4.5 - 20 pF ceramic disk trimmer or plastic foil trimmer, green
C 33 - C 35: 6 - 30 pF as above, foil trimmer red
C 41: 7 - 35 pF, as above
C 45: 180 nF ceramic multi-layer capacitor
C 48: 47 nF, otherwise as C 45
C 49: 2.2 µF plastic foil capacitor 25 V

All electrolytic capacitors: Tantalum drop-type capacitors for 16 V
All 10 nF capacitors: ceramic disk types for 5 mm spacing, 8 mm dia.
All other capacitors: ceramic disk types with low TC; spacing 5 mm, 8 mm dia.

All resistors for 10 mm spacing, RC 07, 0207

P 1 - P 3: 10 kΩ trimmer potentiometers, horizontal mounting, spacing 10/5 mm
P 4: 500 Ω, otherwise as above

2 rotary switches, single wafer, 12 positions
2 knobs with numbered positions »1 - 12«

Q 1: 15.6853 MHz, HC-43/U or HC-18/U (for soldering) load capacitance: 16 pF
Q 2: 15.5705 MHz, otherwise as Q 1
Q 3: 15.2890 MHz, otherwise as Q 1
Q 4: 1.42222 MHz, HC-6/U, load capacitance: 60 pF

4. CONSTRUCTION

The PC-board DJ 7 OH 001 of the synthesizer is nearly as large as that of the transmitter DJ 0 FW 002. However, all components are mounted horizontally so that the height of the module should be less than 10 mm if smaller trimmer capacitors have been used. **Figure 4** shows the conductor lanes, and **Figure 5** the component locations. The crystals are mounted into place using three layers of double-adhesive carpet tape. The ground isolation should be especially noted: the grounding follows the signal path on the component side of the board and is in the form of an S. The ground isolation is especially important between the crystal oscillator and the VCO, and between the buffer stages and the output. It is possible for a screening plate to be soldered into place. Two holes are planned for supporting the screening can. One hole is directly adjacent to the VCO inductance, since any vibration will have the greatest effect here.

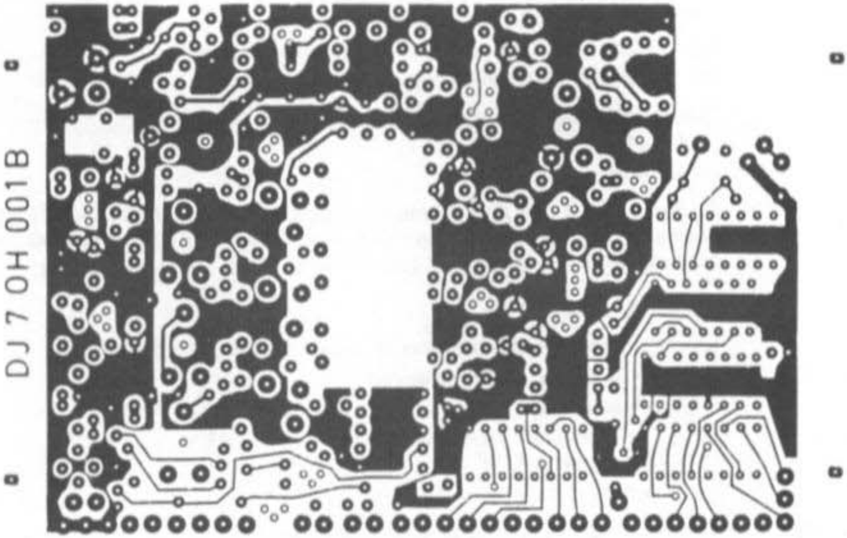


Fig. 4: Synthesizer PC-board DJ 7 OH 001, with through-contacts

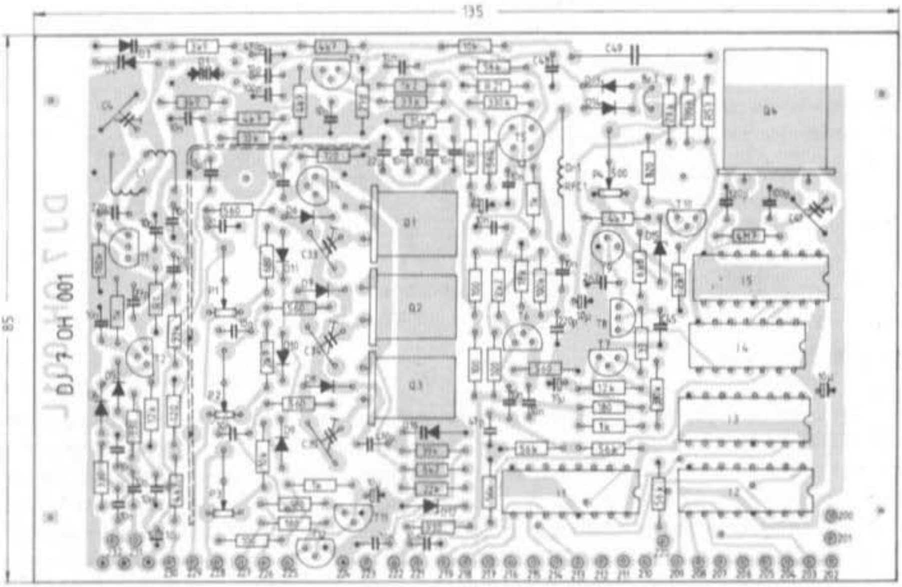


Fig. 5: Component locations

5. ALIGNMENT

The following components should still not be installed:

Mixer:	R 17 and R 21
Loop amplifier:	R 51, R 53, and D 15
VCO:	R 1

C 48 should be soldered into place temporarily and should amount to 10 nF. The bridge of the filter should also be open.

The individual stages are now brought into operation in the following order:

5.1. Connect power supply 10.5 V / 50 mA with overload protection. Connect stabilized voltage to D 12: 8.2 V ± 0.2 V. After connecting U + (10.5 V), 8.8 V ± 0.2 V should be present at Pt 225.

5.2. Check the DC-voltage conditions of the buffer stages: the current drain should be approximately 2 mA (not critical).

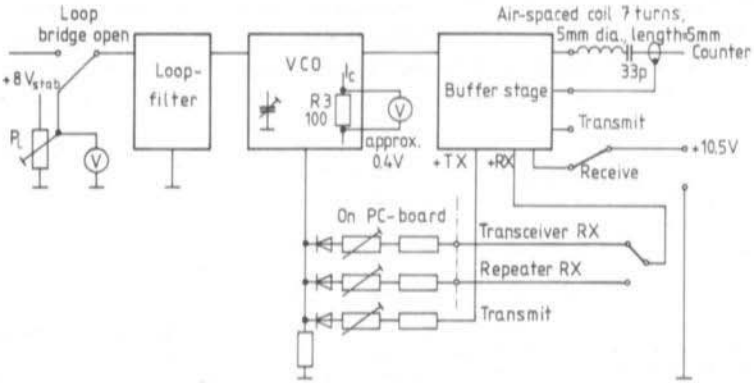


Fig. 6: Alignment circuit for the VCO

5.3. Connect the VCO according to **Figure 6**. Align potentiometer P 1 to approx. 3 kΩ. Place the switch in the »transmit« position. Select the value of R 1 so that the VCO draws approximately 4 mA. The oscillation should cease on shorting the trimmer, and the current should be reduced. Connect a counter to the RF-S output and align the VCO frequency to 48.000 kHz with the aid of C 4. The loop voltage U_L should then be aligned to 3 V. Switch to repeater receive and align R 2 without changing the position of the trimmer to 47.700 kHz. Switch to transceive receive position and align potentiometer P 3 to 46.800 kHz.

5.4. Check operation of the crystal oscillator. It should draw a maximum of 7 mA current. If a frequency counter with a high-impedance input is available (loosely coupled to the base), it is possible for the crystal frequencies to be aligned at this time. If not, they are aligned after operation of the loop is commenced by counting the VCO frequency.

5.5. Align the drain current of the mixer by selecting a suitable value for R 21 until 1 to 2 mA results. The current variation on switching off and switching on the crystal oscillators is more important than the actual current. If the source voltage is less than 1 V, it will be necessary for R 17 to be reduced to 150 kΩ and a suitable value for R 21 to be selected again. This allows a stable operating point to be selected even when sub performance transistors are used.

An oscilloscope should be connected to the drain to check operation. The intermediate frequency of approximately 800 kHz should be visible with an amplitude of approximately 200 mV on varying the tuning voltage with the aid of P_L. This should be increased to a level of approximately 7 V peak-to-peak at the output of the divider.

5.6. Check the input divider and reset logic: Check the divider outputs with the aid of the oscilloscope. If the reset logic is operating, only outputs »0« to »2« on the divide-by-100 dividers (I 3) will indicate impulses. The impulse at output »3« and the reset impulse are too short to be visible on older or cheaper oscilloscopes.

5.7. Check the reference crystal oscillator and align to 1.4222 MHz.

5.8. Check the operation of the sawtooth generator:
The voltage across the charge capacitor should have a characteristic similar to that shown in **Figure 7**, e.g. an amplitude of approximately 1.5 V peak-to-peak, and not below 8.5 V. The needles of the gate voltage of T 8 should not be greater than 9 V, in order to ensure that the gate-source path does not conduct. This is avoided by operating the CMOS-IC from a voltage of approximately 9.2 V. It may be necessary for the value of R 33 to be increased somewhat. However, the adjustment is not critical since the short reset impulses are usually not fully affected due to circuit capacitances.

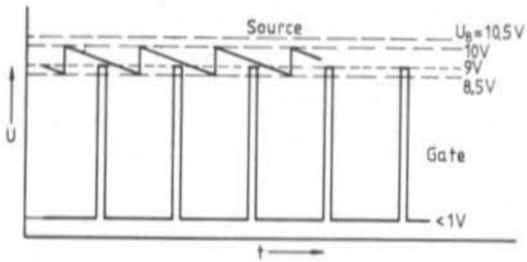


Fig. 7: Voltage characteristic across C 45

5.9. Alignment of the loop amplifier:
Select the voltage value of the zener diode D 15 so that a sawtooth voltage as shown in **Figure 8** is present at the collector resistor (R 54) of the inverter, when the VCO is aligned to the end of the band. With sub-performance FETs it will be necessary for one to three universal diodes to be connected in series in the forward direction, whereas with FETs with offset voltages in excess of 3 V, a suitable zener diode should be selected.

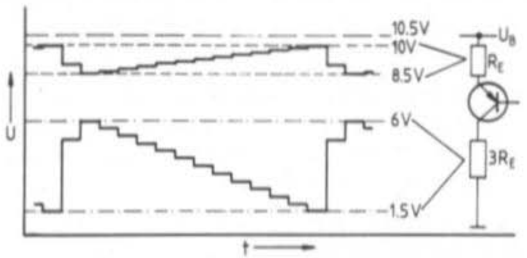


Fig. 8: Voltage characteristic at T 10

5.10. Adjustment of the loop gain and VCO center frequency:

Remove potentiometer P_L and close the loop bridge. An oscilloscope and a voltmeter (R = 100 kΩ) are connected instead to the potentiometer position. A lock-in process is seen on varying the VCO frequency instead of the previous oscillation. Typical oscilloscope traces when the frequency is too high or too low are shown in **Figure 9**.

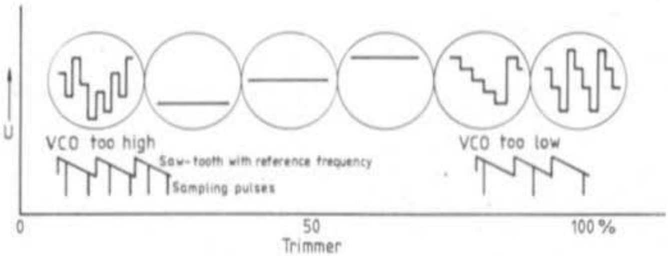


Fig. 9: Typical oscilloscope traces at the input of the loop filter

Figure 10 shows a diagram of the processes when rotating the trimmer. Due to the diodes in the loop filter, the lock-in range is nearly as large as the holding range.

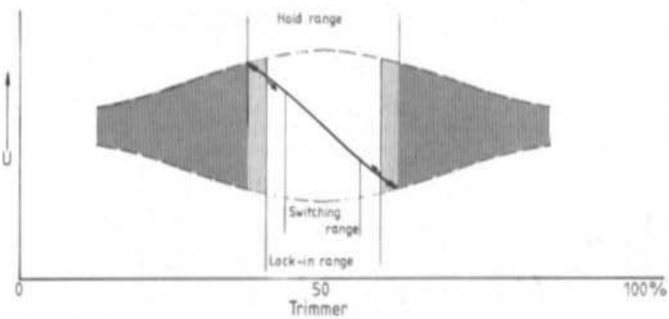


Fig. 10: Voltage characteristic at the input of the loop filter

Channel »50« should now be selected in the transmit mode. Trimmer C 4 is now adjusted so that the operating point is in the center between the two lock-in points. Normally, this does not coincide to the mean value of the sawtooth voltage. The loop voltage should deviate approximately halfway to the lock-in points on switching to channel »00« and »99«.

The switching range will only amount to about 1/4 to 1/3 of the lock-in range, except when all of the component tolerances are unfavorable at the same time. This means that the loop gain is too high. The load resistor of the inverter is reduced by providing a suitable resistor R 53. At the same time, the voltage level will be increased so that one is able to operate in a more linear portion of the varactor diode characteristic. If the residual collector-emitter voltage of T 10 is reduced to below 0.5 V, it will be necessary for R 54 to be decreased in value.

The same is now carried out in the receive modes. However, the trimmer should not be aligned further, and any alignment carried out only with the potentiometers.

5.11. Optimizing the interference suppression:

The transmit signal is monitored on a 2 m or 70 cm receiver, most favorably in the AM mode on the slope of the crystal filter. The audible oscillation is reduced to a minimum with the aid of potentiometer P 4. The oscillation should be virtually inaudible on increasing the value of C 48 to the value given in the circuit diagram. This is usually able to reduce it to the level of modulator noise.

5.12. Test for stable operation:

The value of capacitor C 48 firstly remains at a low value. This is because control oscillations could occur in the case of too high a gain (see 5.10.) and make trimming somewhat difficult. The value of C 48 should be temporarily increased further and further in order to establish the behaviour of the circuit and its tendency to oscillation. This is noted typically on switching between »transmit« and »receive«. After fitting the nominal value of C 48, it should be checked whether the control voltage varies greatly, or in jumps on varying the operating voltage between 10 V to 11 V. The control voltage must jump back to the original value within a quarter of a second after connecting the operating voltage, touching the VCO lines, and any switching process. A slow control shows that it is too near to the limits of the lock-in range.

The board should be checked for poor contacts and cold soldered joints. It is permissible for a gong-type tone to be heard on hitting the PC-board, but no crackling sounds.

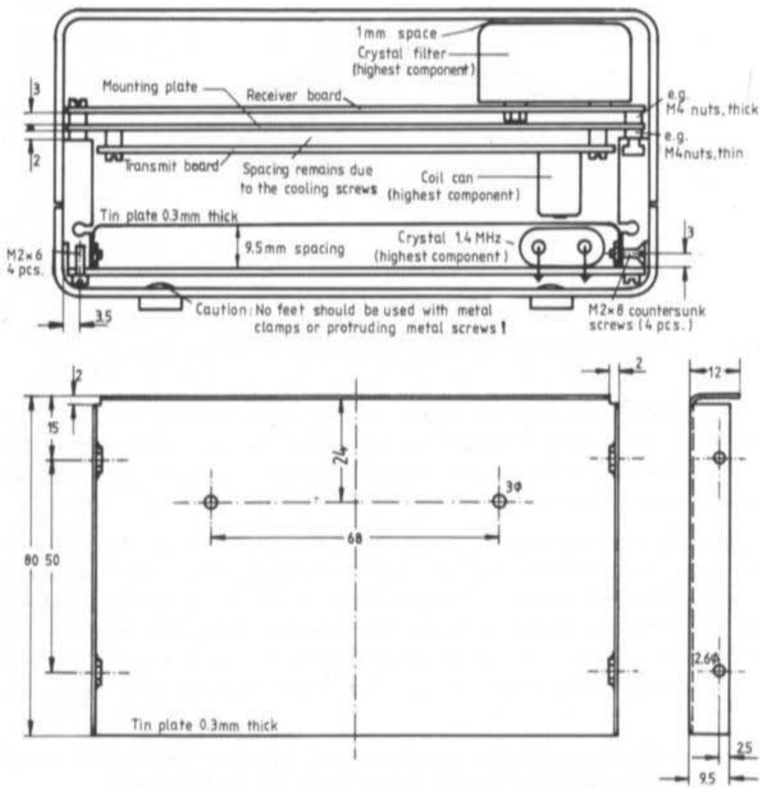


Fig. 11: Screening panel and mounting in the ULM 70 transceiver

6. INSTALLATION AND FINAL ALIGNMENT

If the synthesizer is to be installed in its own case, no further problems are to be expected. However, room is somewhat limited in the original cabinet of the ULM 70. The screening plate will detune the VCO, as will the lower cover of the cabinet to a lesser a degree. **Figure 11** shows how the synthesizer is installed into the original cabinet of the ULM 70. The mounting plate of the transmitter and receiver is raised by 2 mm.

6.1. The 103-Channel ULM 70 Transceiver

It is possible to continue to use the original front panel of the ULM 70. The two channel selector switches are mounted besides the volume control on the lower row. In the upper row, one of the 2 x 5 pole rotary switches remains as mode switch adjacent to the 10 kΩ potentiometer of the fine tuning.

Figure 12 shows the recommended interconnection of the modules. Since sufficient room is not available, it is only possible for the crystals to be all switched and pulled together. Now two modification instructions, if the ULM 70 is to be extended using the synthesizer to a 103 channel transceiver:

The modulating voltage is taken from the frequency deviation potentiometer on the transmit board. An audio-voltage is also present here in the receive mode, which must be shorted out using a switching transistor.

The base voltage divider of the transmit crystal oscillator must be disconnected from the + 10.5 V line and connected to connection 101. This is because the switching inputs are supplied from this point with 10.5 V instead of from + S. Otherwise, the transmit oscillator would interfere in the receive mode.

The built-in loudspeaker should only be used at home. When out of doors, usually a higher volume level is required and there is some danger of microfonic feedback, since the PC-board of the synthesizer is fixed rigidly to the frame.

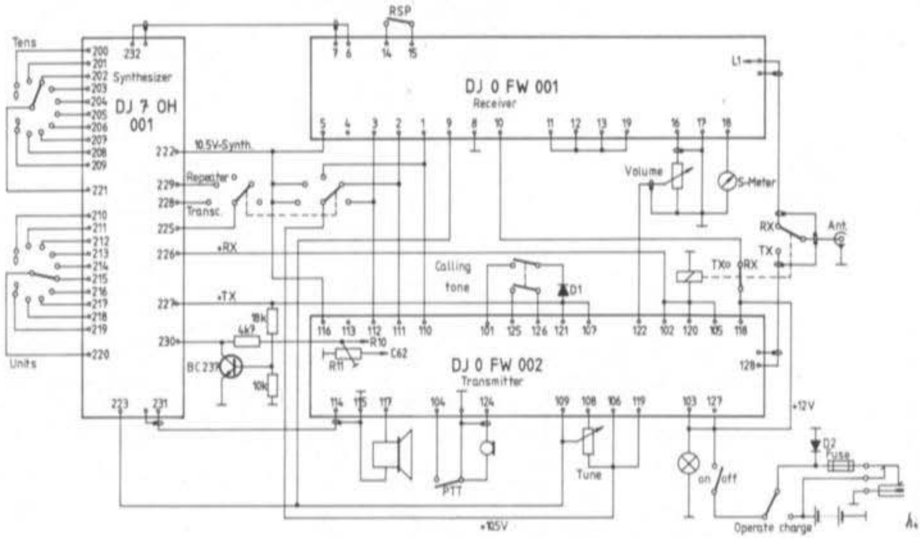


Fig. 12: Interconnection diagram of the 103 channel transceiver ULM 70

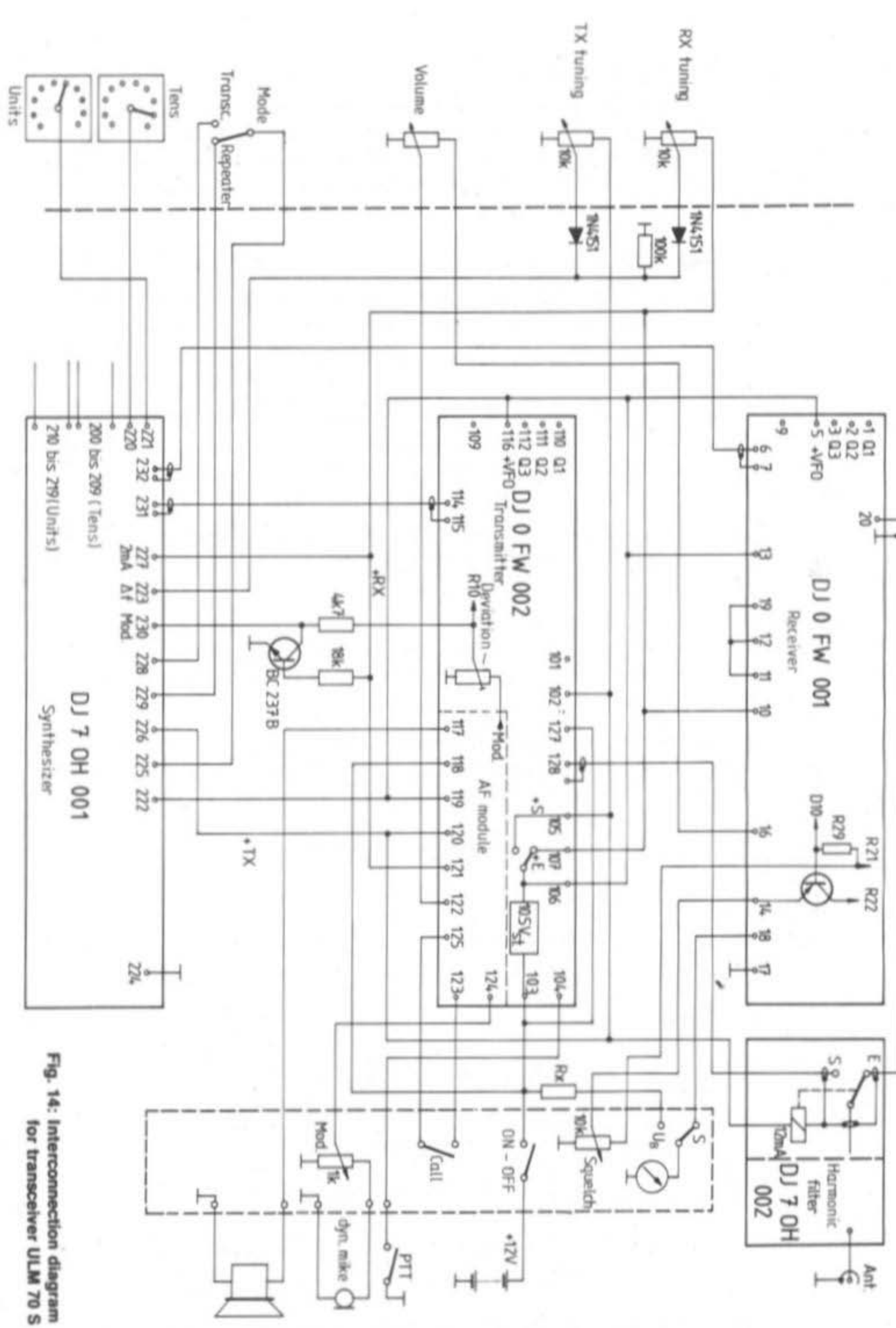
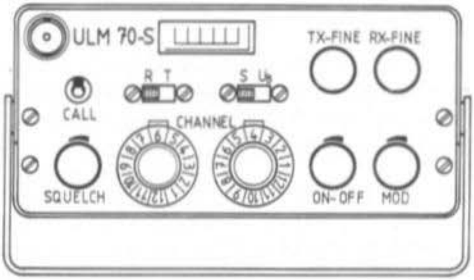


Fig. 14: Interconnection diagram for transceiver ULM 70 S

6.2. Portable Transceiver ULM 70-S

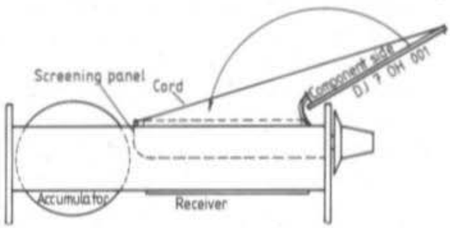
A combined microphone-loudspeaker is recommended for portable operation. In addition to this, the removal of the loudspeaker from the front panel allows more room for the components to be mounted more freely. **Figure 13** gives a recommended layout which is especially suitable for use with a carrying handle.

Fig. 13: Front panel of the transceiver ULM 70 S



No crystal-controlled channels were provided in addition to the synthesizer so that the two rotary switches could be removed and their place taken by separate fine tuning potentiometers for transmit and receive. **Figure 14** shows how these should be connected. A sliding switch is provided for switching the meter from S-meter to battery check. This type of switching is more favorable than the automatic switching in conjunction with the transmit receive relay, since it is possible to observe the reduction of the voltage in the transmit mode. This indicates far more clearly the charge conditions of the accumulator, than the absolute voltage value which is very difficult to read off.

Fig. 15: Position of the PC-board DJ 7 OH 001 during alignment



6.3. Final Alignment

The following method of alignment has proved itself in practice: A screened cable is soldered to the loop bridge and a test socket connected on the rear panel. It is now possible for the control voltage, and thus the position of the switching range within the pulling range, to be checked with the aid of a high-impedance multimeter.

The module is aligned as follows with the PC-board folded out as shown in **Figure 15**. The control voltage is then measured at channel »85«. After switching to channel »00«, trimmer C 4 is now adjusted until the same voltage is present as was present at channel »85«. After folding back the board into the unit, the control voltage should return to the original value for channel »00«.

Small corrections, for instance to compensate for the influence of the cabinet, can be carried out by adjusting the potentiometers through holes on the conductor side of the board. It may also be necessary for the interference suppression to be corrected with the aid of potentiometer P 4.

7. REFERENCES

I. Sangmeister, H. Bentivoglio, H.J. Franke: The 70 cm FM Transceiver ULM 70, Part 1 - 4
VHF COMMUNICATIONS, Editions 1/1977 - 1/1978

A 400 W POWER AMPLIFIER FOR 145 MHz EQUIPPED WITH THE 4 CX 250

by J. Kestler, DK 1 OF

Inspite of the great advances made in semiconductor technology, the vacuum tube still has its applications at high power levels. The most important advantages with respect to transistor power amplifiers are the more favorable price-relationship and a certain tolerance with respect to overload and mismatch.

The described power amplifier can be constructed without having an extensive mechanical workshop; only metal cutters, hand saw, drill and a higher-power soldering iron are required. No bending or lathing processes are required.

1. ELECTRICAL CONSTRUCTION

1.1. Grid Circuit

Virtually all exciters or transceivers used today possess output power levels in the order of 10 W, which is more than enough to drive a tetrode tube in a grounded cathode circuit. For this reason, it is not necessary for the grid circuit of the PA tube to be constructed in a low-loss, and thus narrow-band manner. In fact, this would be a disadvantage, since it would increase the tendency to oscillation unnecessarily. In addition to this, it would be necessary to retune the grid circuit any time the frequency was changed. Attention should be paid that the input VSWR of the power amplifier is virtually 1, and is independent of the drive power, which varies continuously in the SSB mode. This is especially important when the last stage of the exciter is equipped with a transistor amplifier. This because the transistor could easily be overloaded with respect to its collector voltage if the input matching of the power amplifier was poor, and then operate as a clipper. This would lead to strong distortion and splatter. This, of course, would have nothing to do with the subsequent tube amplifier, which would, however, most certainly be blamed for it.

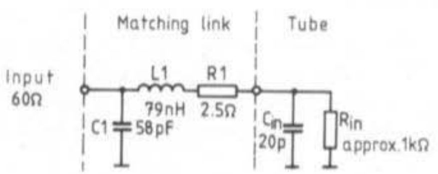


Fig. 1: Input circuit with equivalent diagram of the tube input

The input circuit used is shown in **Figure 1**. The capacitance C_{in} represents the input capacitance of the tube which possesses an ohmic component R_{in} due to the finite electron delay between cathode and grid. This effective resistance is very dependent on the grid voltage and anode current, and thus fluctuates with the drive. If one were to match this resistance to the input using a loss-less transformation link, this would mean that the input impedance of the power amplifier would also be drive-dependent. For this reason, a matching link is used that is dampened using a series resistance (R 1). The largest part of the drive power is converted into heat in this resistor. The inductance L 1 and capacitance C 1 extend the grid circuit to form a Pi-link with an impedance of 50 Ω; the Q amounts to approximately 14, which results in a bandwidth of approxamitaley 10 MHz. Measurements have shown that the input VSWR is less than 1.2 when varying R_{in} between 500 Ω and ∞. A Pi-filter is also very favorable at this position, since it will suppress any harmonics from the exciter far better than when using a simple parallel-resonant circuit.

1.2. Anode Circuit

The task of the anode circuit is to transform the output impedance of the tube to the impedance of the antenna feeder. In addition to this, it should provide a certain amount of selectivity so that any harmonics generated in the tube are sufficiently suppressed. In the shortwave range, transformation links comprising concentrated components are virtually always used. In principle, this is also possible at 145 MHz, but such low Qs will result that the efficiency of the circuit will not be greater than 60 to 70 %. For this reason, the heat loading of the components would be too high, especially at high power levels. In the past, power amplifiers were often constructed using »Lecher« lines and similar systems which were often not screened and radiated a considerable amount of energy, and not only the fundamental.

High efficiency levels in the order of 90 % can be achieved using coaxial circuits. In this case, all electrical and magnetical field lines are contained within a closed metal cage so that no unwanted radiation is to be expected. Of course, only a λ/4 stage can be used for the 2 m band, since a λ/2 resonator would be too long.

This means one has the old problem of how to ground the inner conductor in a low-loss manner, and still be able to feed the plate voltage to the tube. **Figure 2a** shows the conventional circuit; in the case, the isolating capacitor C_I is connected to the ground end of the inner conductor. In this case of a plate alternating current of 0.3 A and a resonator Q of 50, a RF current of approximately 15 A will flow at this position. This means that a loss resistance of 1 Ω at this position would already convert 225 W RF energy into heat. It is far more favorable for the isolating capacitor to be placed in the vicinity of the tube, as is shown in **Fig. 2b**. In this case, only the plate alternating current of the tube will flow via C_I and the relatively low reactive current of the tuning capacitor C 2. For this reason, the capacitance of C_I can be far less than in the case of the circuit shown in Figure 2a. The disadvantage is, however, that the anode choke is in the vicinity of maximum RF voltage and its inductivity must therefore be greater than in the first version.

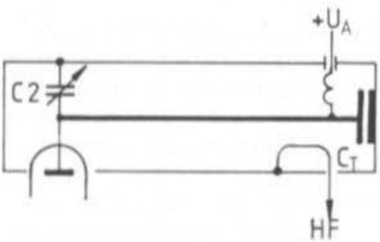


Fig. 2a:
Conventional by-pass of the inner conductor

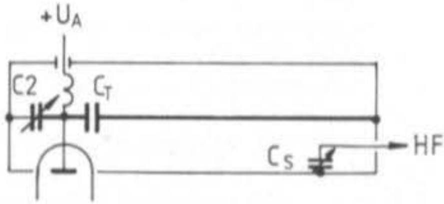


Fig. 2b:
Galvanically grounded inner conductor

Now to the output coupling of the RF-power from the coaxial circuit: There are various methods of doing this, however, the inductive coupling using a coupling loop is most extensively used due to its simplicity of construction. This is usually achieved using a link in series with a variable capacitor (C_S in Figure 2b). The task of this capacitor is to form a series resonant circuit in conjunction with the inductivity of the output coupling link, thus compensating for its reactive impedance. In addition to this, it is possible using this link to vary the transformation ratio (R_{plate} / $R_{antenna}$) of the anode circuit within certain limits; the remaining reactive components can then be easily compensated for with the aid of C 2. This possibility can be important in practice because it allows the same power amplifier to be aligned for optimum efficiency, e.g. highest output power, for the various operating modes. For example class AB_1 without grid current in the SSB mode for maximum linearity; class AB_2 for CW and FM where linearity is not important but a higher output power can be achieved. Both modes of operation result in different output impedances for the tube.

The complete circuit diagram of the VHF portion of the power amplifier is given in **Figure 3**. It will be seen that the input is followed by a VSWR bridge (HF-unit available on the market), which is mounted into the author's prototype. This allows the alignment of C 1 for minimum VSWR. In addition to this, it is also possible to check the VSWR of the antenna in the »barefoot« mode. The drive power is fed via coaxial relay A to the grid circuit. The inductance L 1 (see Figure 1) is not in the form of a component but is formed by the grid connection, resistors R 1, and the connection wires of the coupling capacitor C 10. The grid bias voltage is fed via inductance L 5; the screen grid is by-passed with the aid of capacitors C 4 and C 5, in addition to the by-pass capacitor provided on the tube socket. All supply voltages are fed in via feedthrough capacitors, in order to ensure that no VHF energy is fed to the power supply. The output power from L 3 is fed via relay B and a directional coupler to the output of the power amplifier. This directional coupler is a simplified version of that used in the measuring unit described by OE 5 THL in (1). This is used to align the power amplifier for maximum forward power into the antenna feeder.

1.3. Power Supply

The voltages required for operating the power supply are:

Plate voltage U_{Pl}:	approx. 2000 V, max. approx. 400 mA
Screen grid voltage U_{G2}:	+ 360 V, max. 25 mA
Grid bias voltage U_{G1}:	– 55 V, for blocking – 130 V
Heater voltage U_H:	6.0 V ~, 2.6 A

Since the gain factor of a tetrode is very dependent on the screen grid voltage, it is necessary for it to be stabilized in the linear mode. If the power amplifier is also to be used in class AB_2, it will be necessary for it to be driven into grid current; in this case, it will be necessary to pay attention to a low impedance of the U_{G1} source so that the grid current generated by the drive does not shift the operating point of the tube into class C. As can be seen in **Figure 4**, these voltages are stabilized with zener diodes. Neon stabilizers are now a thing of the past; it is even dangerous to use them in the voltage source for the screen grid. Firstly, if they were to become defective, this could cause flashovers within the tube due to excessive G_2 voltage and secondly neon tubes with parallel capacitors tend to oscillate and cause an unwanted modulation of the power amplifier. Lots of amateurs have wondered why their signal was several hundred kHz wide even though they were driving the power amplifier tube at low level ! Anyway, the use of zener diodes is probably even cheaper than using neon tubes.

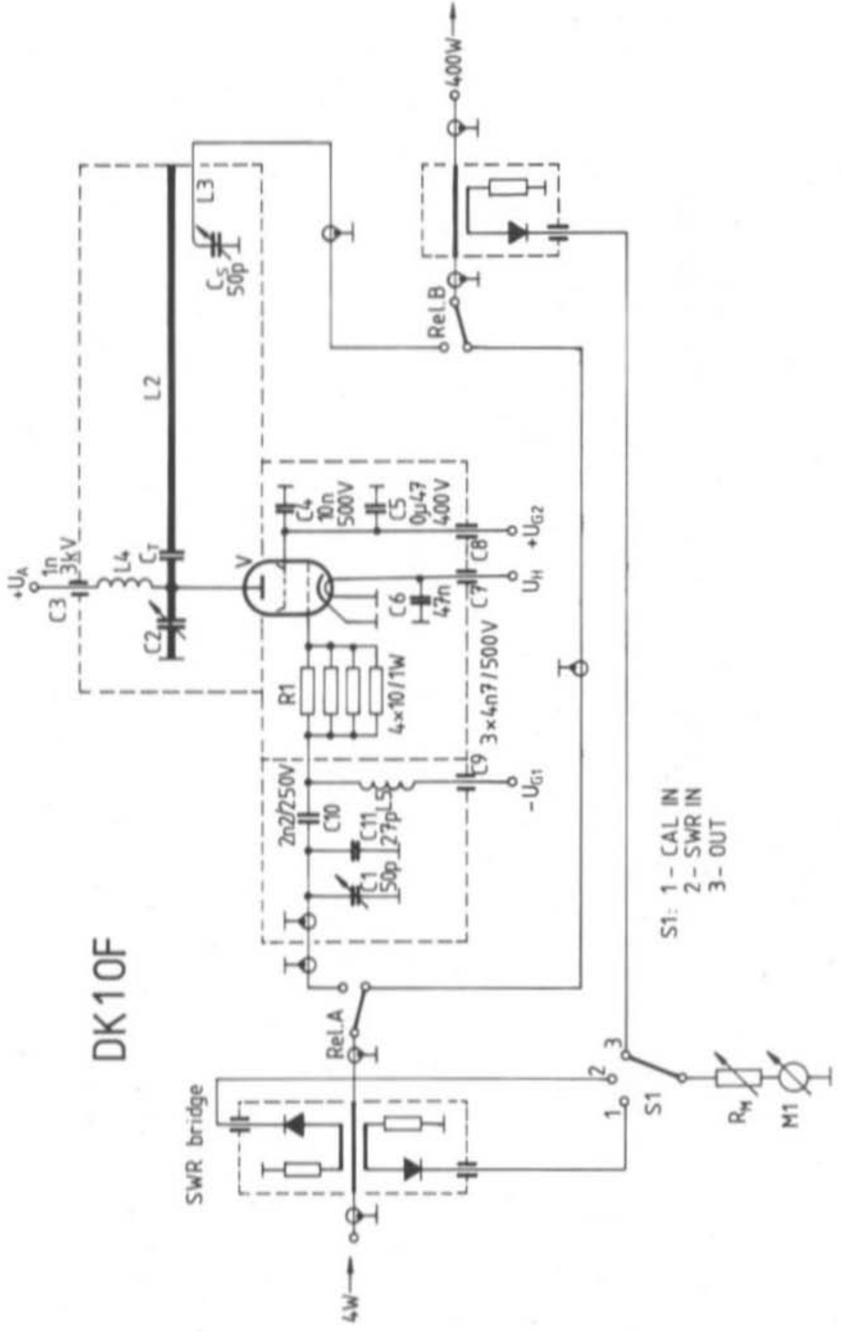


Fig. 3: Circuit diagram of a 400 W power amplifier equipped with the 4 CX 250 B tube

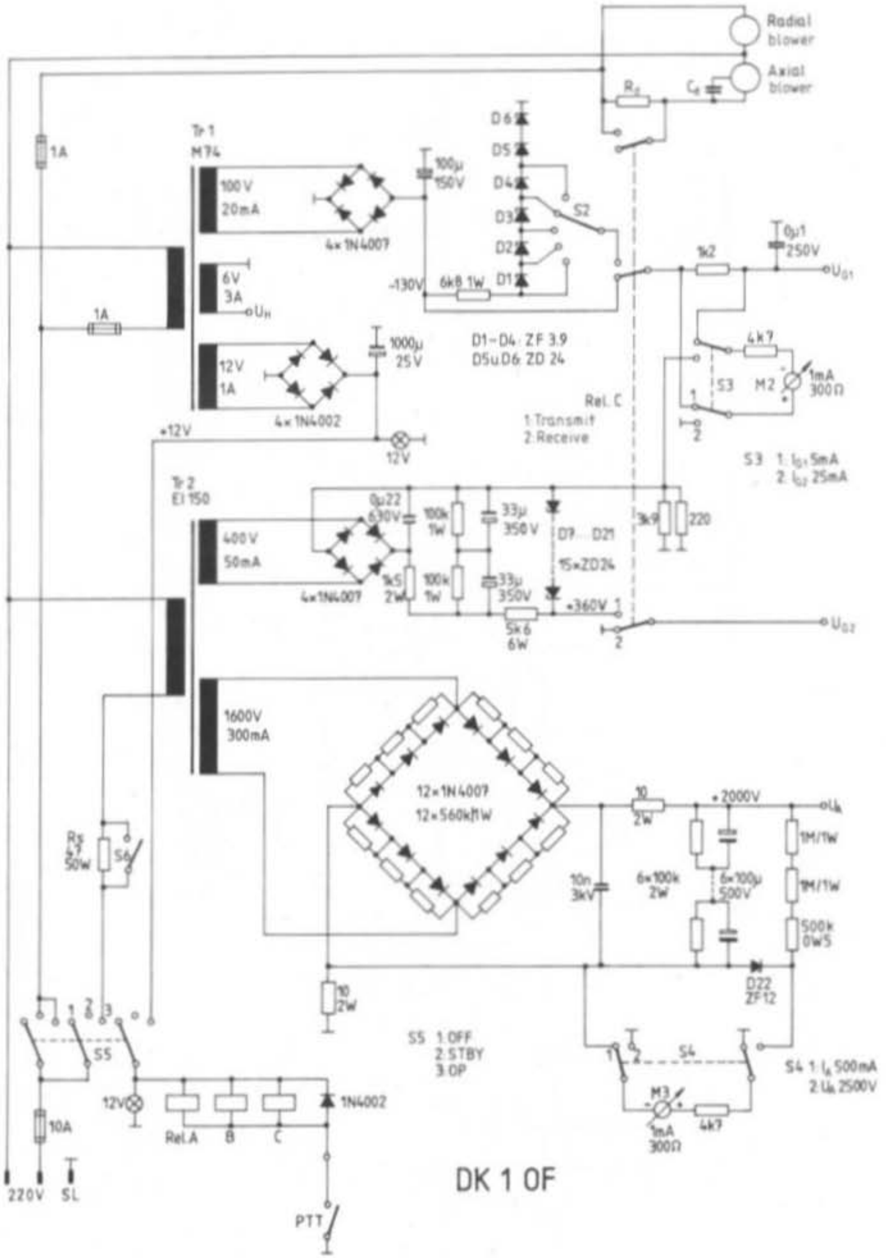


Fig. 4: Power supply for the power amplifier shown in Figure 3

It will be seen that two power transformers are used. Transformer Tr 1 is used for providing the required voltages for the heater, control grid and relay. The quiescent plate current is adjusted using switch S 2; in the stand-by mode, the full negative voltage of approx. – 130 V is fed to the grid via a contact on relay C. It was found that diode noise of PA tube was still audible in the receiver inspite of this blocking circuit, and therefore the screen grid was grounded additionally using a further contact. A third contact switches the axial blower to the full AC-voltage during transmit, whereas the speed and thus noise level is reduced during reception with the aid of the dropper resistor R_D. The radial blower works at full power at all times. The meter M 2 can be switched with the aid of S 3 to measure the control and screen grid current. According to the meter, it may be necessary to change the value of the resistors.

As can be seen in the data sheet of the 4 CX 250, the plate and screen grid voltages should not be connected until 30 seconds after switching on the heater. For this reason, a three-position switch was selected for the main on-off switch S 5. Transformer Tr 2 is not connected to the power line until position 3 has been selected, and will connect the operating voltage for the relays to the required voltage. If the power amplifier is to be connected to a power line whose fusing does not like transient surges, it will be necessary to provide the surge suppressor comprising R_s / S 6. This is also to be recommended to provide a slow charge of the plate electrolytics.

In the author's prototype, a bridge rectifier was used for the high tension supply. This has the advantage of a low-load dependence of the plate voltage and a reduction of the hum level by factor 3. If a transformer with an output voltage of approx. 1600 V is not available, it will be necessary to use voltage doubling or tripling.

Meter M 3 can be switched with the aid of S 4 for measurement of the plate voltage or current. Zener diode D 22 ensures that the full anode voltage cannot be fed to the switch and cause leakage currents; this would be audible in the receiver as a voltage discharge.

1.4. Special Components

V:	Coaxial tetrode 4 CX 250 B or R Socket: Eimac SK-600 or Philips B 8 700 70 with chimney
C 1, C_S:	Air-spaced variable capacitor, max. capacitance 50 pF
C 2, C_l:	see text
C 3:	Feedthrough capacitor 1 nF/3 kV
C 4:	Ceramic disk capacitor 10 nF/500 V
C 5:	Plastic foil capacitor 0.47 µF/400 V
C 6:	Ceramic disk capacitor 47 nF/30 V
C 7 , C 8, C 9:	Feedthrough capacitors with screw mount 4.7 nF/500 V
C 10:	Ceramic disk capacitor 2.2 nF/500 V
C 11:	Ceramic disk or tubular capacitor 27 pF
R 1:	4 pieces carbon resistors 10 Ω/1 W in parallel
R_S:	Wire-wound resistor 47 Ω, 50 W
R_D, C_D:	dependent on the blower used
R_M, M 1:	of standing-wave meter
M 2, M 3:	1 mA meter/300 Ω
L 2, L 3:	see text

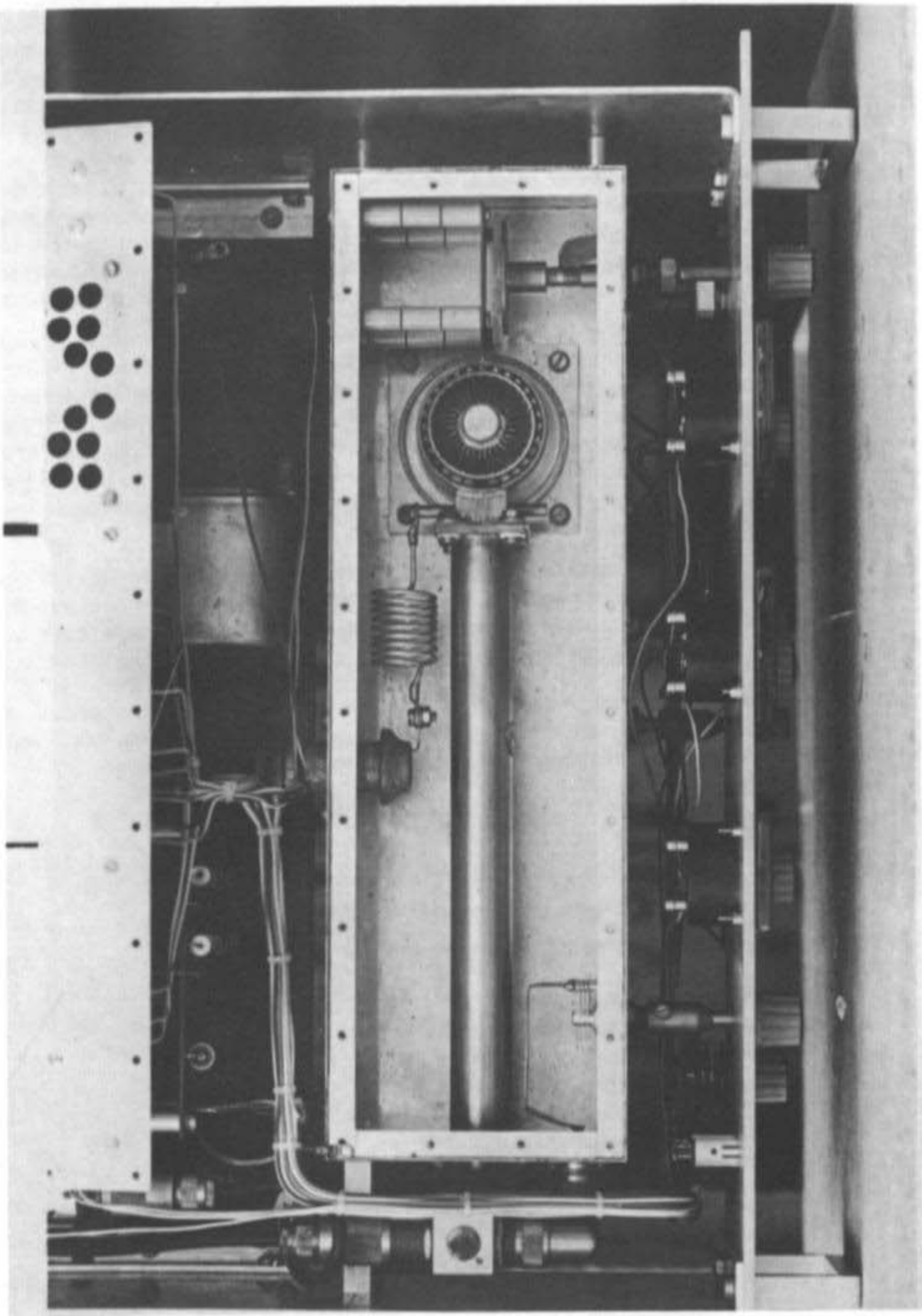


Fig. 5: Photograph of the anode side of the power amplifier

L 4:	9 turns of 1.5 mm dia. silver-plated copper wire, 25 mm inner diameter, 35 mm long
L 5:	15 turns of 1.5 mm dia. enamelled copper wire, 15 mm inner diameter, 40 mm long
Relay A:	MD coaxial relay 951, 12 V
Relay B:	Dow-Key DK 60-G 2 C, 12 V
Relay C:	Siemens relay with four changeover contacts, 12 V +
Radial blower:	e.g. Airflow 26 BTM
Axial blower:	e.g. Papst No. 3050, C_V = 1 μF / 300 V ~

2. MECHANICAL CONSTRUCTION

The following mechanical construction information does not go into the finest detail, but is more to describe the construction of a well-proved prototype. The power amplifier can be just as easily constructed in a different manner according to the individual ideas and requirements of the user. It is only important that the given dimensions are maintained within approximately 10 %, otherwise the power amplifier is very uncritical.

Figure 5 shows a photograph of the power amplifier stage from the anode side. The screening case has the following outside dimensions: length 372 mm, width 112 mm, height 120 mm. It is soldered together from 1 mm brass plate. The following individual pieces are required:

2 pieces	372 x 120 mm front and rear panel
2 pieces	120 x 110 mm side panels
1 piece	370 x 110 mm chassis
1 piece	110 x 45 mm intermediate panel
1 piece	370 x 110 mm upper cover
1 piece	135 x 110 mm lower panel
1 piece	234 x 110 mm lower panel

Figure 6 shows a drawing of the power amplifier in more detail. A brass tube of 25 mm outer diameter and 1 mm wall thickness is used for the inner conductor of the anode circuit. The grounding disk (50 mm dia.) is soldered to the ground end of the inner conductor, and one plate of the isolating capacitor C_I to the hot end. PTFE (Teflon) foil of 0.25 mm thickness can be used as dielectric; the four mounting screws of the capacitor are insulated using bushings constructed from PTFE, which are available as accessories for power transistors.

A surplus component with contact springs was used in the author's prototype as anode connection. No doubt, such a part will not be available, however, it can be replaced using a bracket with tension screw similar to that used for connecting rubber pipes. Attention should be paid, however, that the tube is not mechanically loaded. The stationary plate of the tuning capacitor C 2 is also made from 1 mm thick brass plate and is mounted using a number of interconnected ceramic supports. The variable plate uses a 2 mm thick brass disk of 45 mm dia. This is provided with a threaded hole in the center and fixed to the shaft (6 mm metric thread) with the aid of a counter nut. It is recommended that a stop be used to ensure that the master plates cannot touch and cause a short-circuit of the high tension voltage. A modified BNC connector for single-hole mounting has been modified for use as bearing. The inside of the connector was removed and a brass tube of 8 mm outer, a 5 mm inner diameter was soldered into place, and subsequently a 6 mm thread was cut into it. The author provided a fine thread with a pitch of 0.5 mm. However, this has been found to be too fine and requires several turns of the knob to find maximum. A normal 6 mm thread will therefore be better.

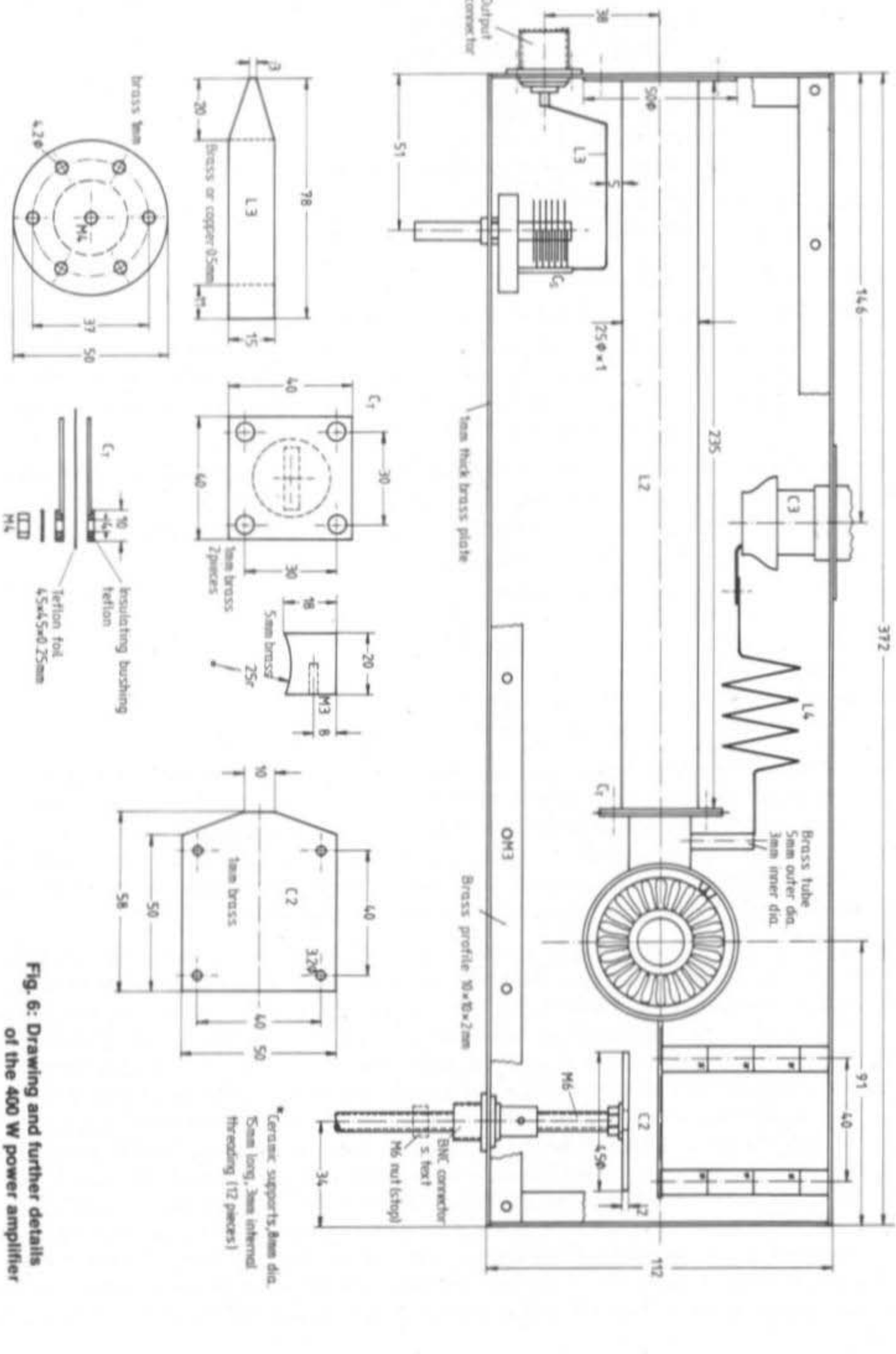


Fig. 6: Drawing and further details of the 400 W power amplifier

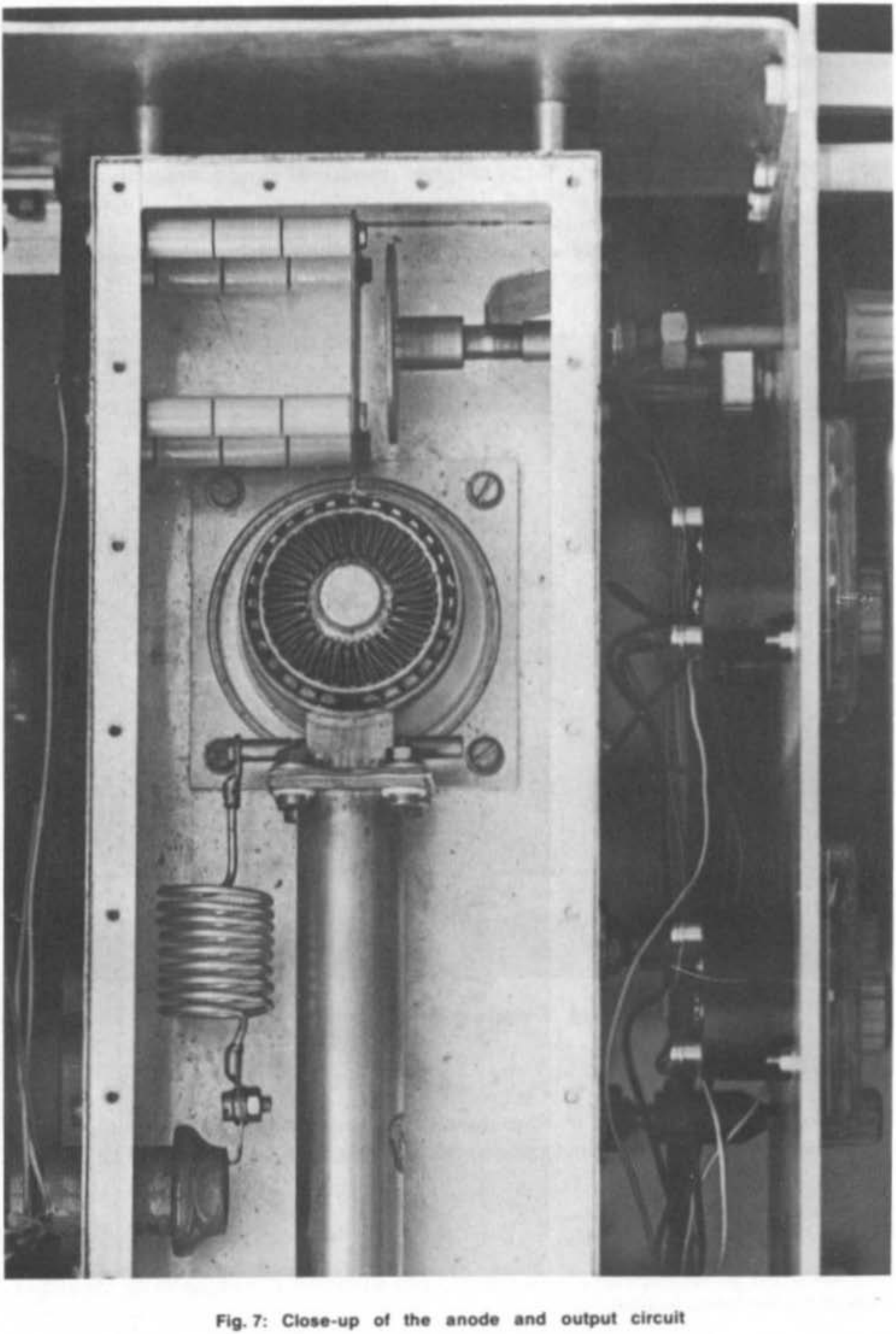


Fig. 7: Close-up of the anode and output circuit

Brass screws and nuts should be used for all mechanical connections since steel screws would heat up considerably due to the strong magnetic fields present in the resonator. **Fig. 7** shows a close-up photograph of the most important parts of the anode connection to the tube, and **Figure 8** shows a side view of the power amplifier stage in the form of a drawing. Brass profile is used for mounting the cover (10 mm wide and 2 mm thick). The spacing between the mounting holes should not be too large (approx. 40 mm), in order to ensure that the case is VHF-tight. There is sufficient room available under the chassis for mounting the VSWR-bridge and the input coaxial relay. **Figure 9** shows the grid circuit of the tube. All four cathode connections are directly soldered to the tube socket. The four parallel-connected resistors R 1 are mounted on a metal bracket.

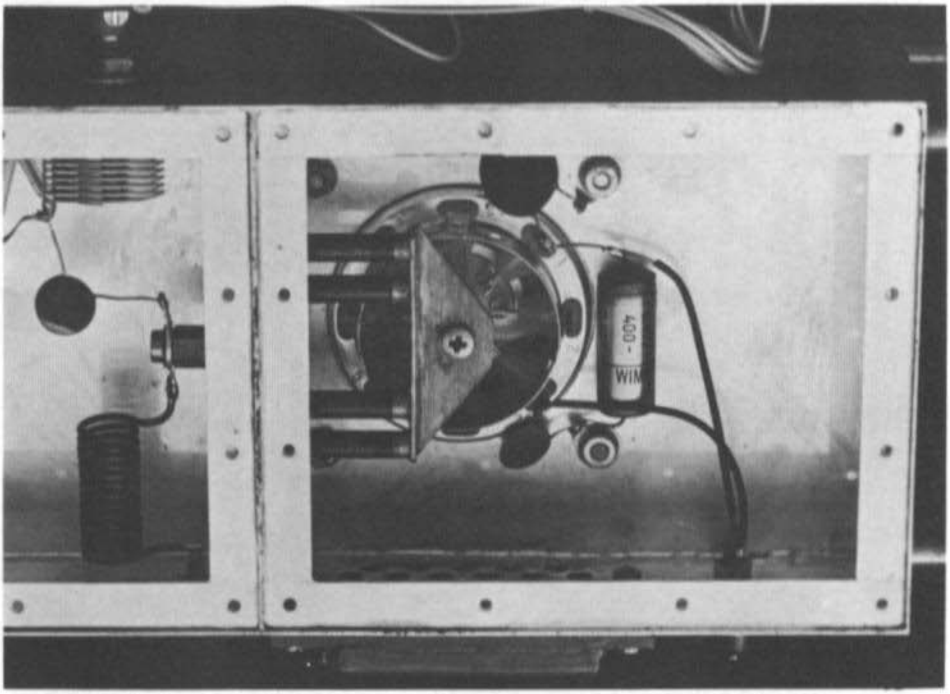


Fig. 9: Photograph of the grid circuit

3. ALIGNMENT

Firstly a very important warning: It will probably be lethal to touch the anode voltage of this power amplifier at any time. Before touching any part of the circuit remember to

1) switch off the power supply
2) discharge the high-voltage circuit
3) short-circuit the high-voltage line

The input of the power amplifier is now connected to an exciter. It is advisable for the output power of the exciter to be variable.

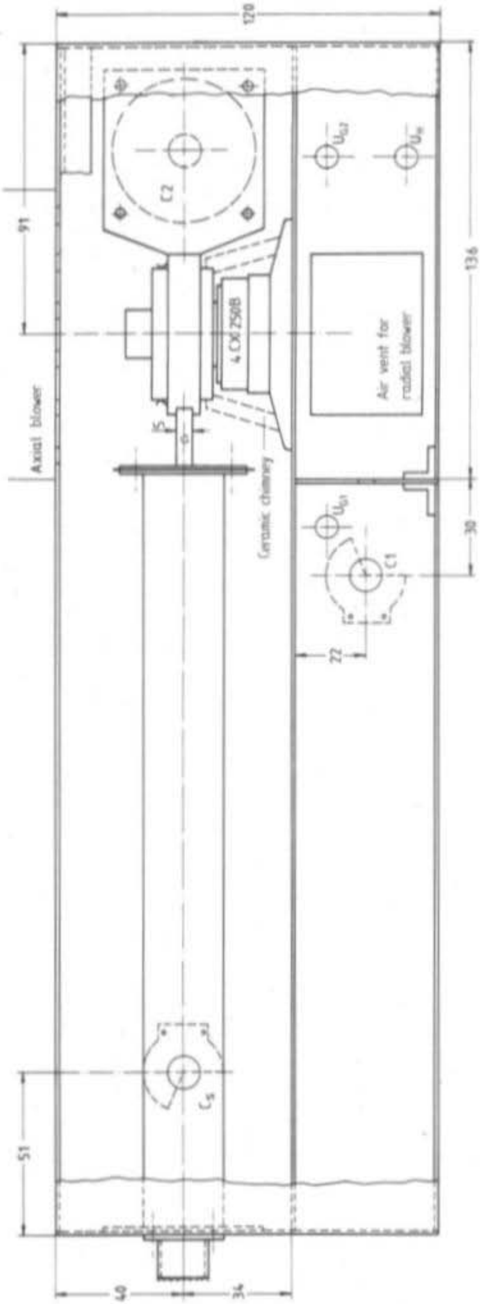


Fig. 8: Side view of the power amplifier

A dummy-load VHF wattmeter should be connected to the output. If not available, the power amplifier should be connected to an antenna. Allow the tube to warm up for a period of approximately 1 minute (Tr 1), after which the plate voltage transformer (Tr 2) can be also switched on. The plate current meter should not indicate any current flow. Switch contact (»PTT« in Figure 4) should be grounded and the quiescent current of the plate adjusted with the aid of S 2 to read 80 to 100 mA.

The exciter is now switched on and its power increased until the plate current just starts to rise. Capacitors C 2 and C_S are now aligned alternately for maximum output power. It is then possible for the drive power to be increased until a plate current of approximately 300 mA is indicated. After correcting C 2 and C_S, an output power of approximately 350 to 400 W should be indicated. Finally, the depth of the anode current dip should be checked: with the aid of C 2 take the power amplifier out of resonance temporarily and measure the anode current. It should be approximately 10 % higher than at resonance. If it is considerably higher, this will mean that the output coupling is too loose; in this case, inductance L 3 should be placed somewhat nearer to the inner conductor, or a new, larger output coupling link mounted into position. If the dip is, on the other hand, too shallow, it will be necessary to do the opposite. With the most favorable output coupling, the plate current dip and the point of maximum output power should be achieved at the same position of C 2.

The grid circuit is now aligned: The VSWR bridge at the input is switched to »return power« and C 1 adjusted for minimum VSWR. If the indicated VSWR is worse than approximately 1.2:1, the connection wires of C 10 (Figure 3) should be shortened. When aligned correctly, the point of minimum VSWR and maximum plate current will be present at the same position of capacitor C 1. It is not necessary for the grid circuit to be tuned on changing frequency within the 2 m band. If the plate circuit is aligned for maximum at 145 MHz, one will still obtain more than 80 % of the maximum output power at 144 or 146 MHz.

4. MEASURED VALUES AND EXPERIENCE DURING OPERATION

The following values were measured on the author's prototype and are given in the following table:

-	Without drive	Class AB 1	Class AB 2
Plate voltage	2200 V	2000 V	1900 V
Plate current	100 mA	300 mA	420 mA
Drive power	0	4 W	8 W
Screen grid current	0	5 mA	20 mA
Control grid current	0	0	5 mA
Output power	0	395 W	520 W
Overall efficiency	0	66 %	65 %
Input VSWR	-	< 1.2	< 1.2

The given values were measured with single-tone drive. The output power was measured using a water dummy-load wattmeter, type 334 A.

Unfortunately, no intermodulation ratios could be measured since the author did not have access to such measuring systems. However, local stations always reported the signal to be narrow-band and clean. For example, it is possible in a spacing of 60 kHz or more to work duplex, even at full output power in class AB 1. The decoupling between the two antennas is approximately 60 dB (one antenna horizontal, and the other vertical with a spacing of approximately 10 m).

The described power amplifier has been used by the author for more than three years, and is still using the original tube. It has been found to be very robust and reliable even during continuous operation in the FM mode. By the way, the neutralization of the power amplifier is so good that it will not oscillate even when the input and output are open.

5. REFERENCES

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VHF COMMUNICATIONS 6, Edition 1/1974, pages 2 - 17

ELECTRONIC CONTROL OF ANTENNA ROTATORS

Part 1: Programming using Preset Trimmer Potentiometers

by J. Kestler, DK 1 OF

This series of articles is to describe a number of accessory control units for antenna rotators that will increase in complicity and sophistication. They all allow a programmed, and automatic control of an antenna array and allow it to be brought into the required or elevation position. Such programmed antenna rotation systems are not only required by radio amateurs, but also for stereo VHF-FM listeners, for TV-reception where a large number of programmes are available and for many more applications. It is not very pleasant to press a button for several minutes and wait until the meter shows the correct direction.

Part 1 of this series is to describe a relatively simple accessory for the control unit. The series will be completed by describing a system using BCD-inputs that allows the simultaneous control of an azimuth and elevation rotator with the aid of a computer. This will allow automatic tracking of a satellite (OSCAR), or the Moon (EME).

1. PROGRAMMING AN AZIMUTH (HORIZONTAL) ROTATOR

If the direction to the station is known, which is the case when operating via a distant repeater, having a sked with a known partner, or when receiving a VHF-FM stereo transmitter, it is very advisable for the rotator to be programmed in some manner and for the required direction to be selected by pressing a button.

This article is to describe a module which is designed as an accessory for an available control unit; it allows up to 11 different antenna directions to be stored. It was especially developed for the UKW-TECHNIK rotators (KR 400, KR 500, KR 600, KR 2000), but is just as suitable for use with other types which provide an electric signal to show the momentary position of the rotator. The following requirements were placed on the unit:

- Simple circuit, without extra power supply
- Simple construction, even for newcomers
- Simple programming
- Incorrect operation should not damage the unit
- As few modifications to the original control unit as possible

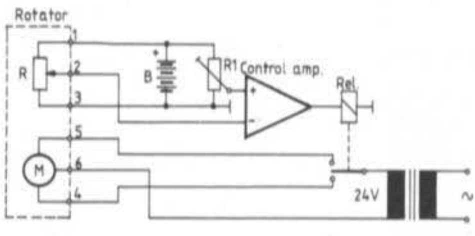

Fig. 1: Basic circuit diagram of the control circuit

2. OPERATION AND CIRCUIT DIAGRAM

The operation of the described control unit is shown in **Figure 1**. Motor M of the rotator drives both the antenna and the position potentiometer R via a gear train. This potentiometer forms a bridge circuit together with the nominal-value potentiometer R 1. The bridge is fed from the DC-voltage source B. The voltage at the diagonal position is fed to the input of a control amplifier. This actuates a relay which switches either the clockwise or anticlockwise winding of the motor to the transformer, according to the polarity at the output of the bridge. The motor will now run until the value of R is sufficient to balance the bridge. The relay will then be released and the motor will stop. If several rotator directions are to be programmed, it is possible for several resistors R 1 to be connected in parallel and to connect them individually using a switch to the input of the control amplifier.

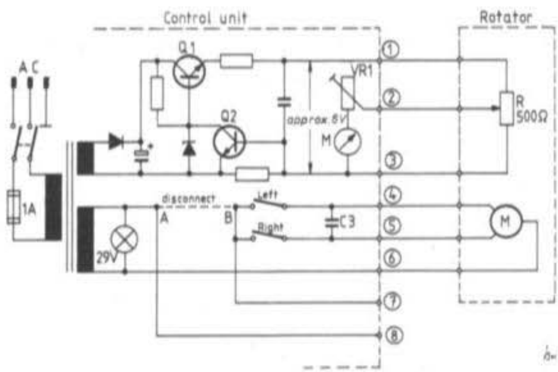

Fig. 2: Circuit diagram of the rotator KR-400

Figure 2 shows the circuit diagram of the rotator KR 400. The voltage of the upper transformer winding is rectified and stabilized to a voltage of approx. 6 V in transistor Q 1. Transistor Q 2 serves as current limiter. This voltage is available at clamps 1 - 3 where it feeds the position potentiometer R. This position is, in turn, indicated on the meter. The trimmer potentiometer VR 1 allows the meter to be aligned for full-scale deflection.

The lower winding drives the motor. If the described accessory unit is to be connected, the dashed line should be disconnected and connections A and B connected to the previously unused clamps 8 and 7 on the rear panel of the control unit.

The circuit diagram of the programming unit is shown in **Figure 3**. The connection numbers are identical to those given in Figure 2. It will be seen that there are 11 parallel-connected nominal-value potentiometers (R 1 to R 11), whose outputs are connected via a 12-position pushbutton assembly (S 1 to S 12). If position S 12 is depressed, connection 7-8 (see Fig. 2) will be switched through, and the rotator will be controlled by the original »left« and »right« buttons on the control unit. In all other positions, these buttons are out of circuit. This is very important since the motor should never be provided with voltage to both windings (4 and 5). If this were the case, the winding would very soon burn out due to the extremely high power consumption.

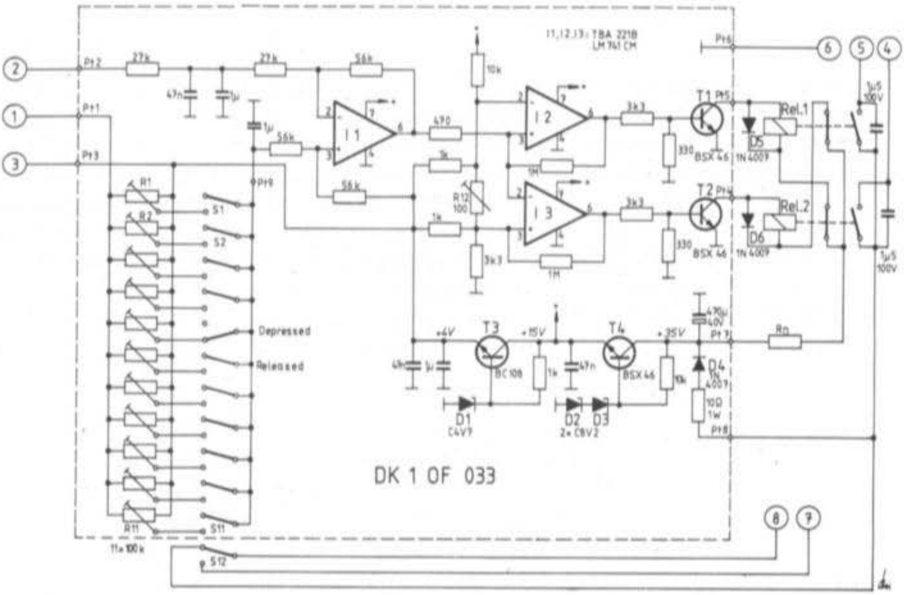

Fig. 3: Circuit diagram of the programming unit

The difference between the nominal value from R 1 to R 11 and the actual value (from Pt 2 and a filter link from the rotator potentiometer) is formed in the integrated amplifier I 1. In order to ensure that the circuit will operate with only one (positive) operating voltage, the »ground« potential (Pt 3) of the bridge is biased to + 4 V (see Figure 1). The subsequent circuit comprising amplifiers I 2 and I 3 represents a double-comparator which switches on transistors T 1 or T 2 according to whether the deviation is positive or negative. The width of the quiescent range within which both transistors are blocked can be selected with the aid of R 12. This ensures that the rotator will not oscillate continuously around a mean value.

The switching transistors T 1 and T 2 actuate a relay for switching in the clockwise or anti-clockwise winding of the motor. Both relays are blocked with the aid of break contacts, to ensure that the relay cannot be energized until the other one is released.

Since the motor represents an inductive load, flashover will be present on switching off the relay contacts. This is avoided using 1.5 μF capacitors in parallel to the contacts.

The alternating voltage from the lower transformer winding (see Figure 2) is fed in via Pt 8. After rectification with the aid of D 4, and stabilization using T 4, a DC-voltage of approx. + 15 V will be available. This is used for driving the amplifiers. The previously mentioned bias voltage of + 4 V is generated in T 3. The quiescent current of the total circuit is very low (approx. 30 mA), and the power transformer of the control unit will not heat up even during continuous operation. The value of the dropper resistor R_D is dependent on the relays used. It can easily be calculated as follows:

$$R_D = \frac{35 \times R_R}{U_R} - R_R$$

whereby R_R = DC-resistance of the relay winding
U_R = Nominal voltage of the relays in V

3. CONSTRUCTION

In order to simplify construction, a PC-board was developed for the programming unit. Its designation is DK 1 OF 033 and is single-coated. In order to save room, it is possible for the 135 mm x 75 mm large PC-board to be cut at the dashed line and to use a »sandwich« construction. The two relays are not mounted on the PC-board, so that various types can be used. The component locations on the PC-board are shown in **Figure 4**.

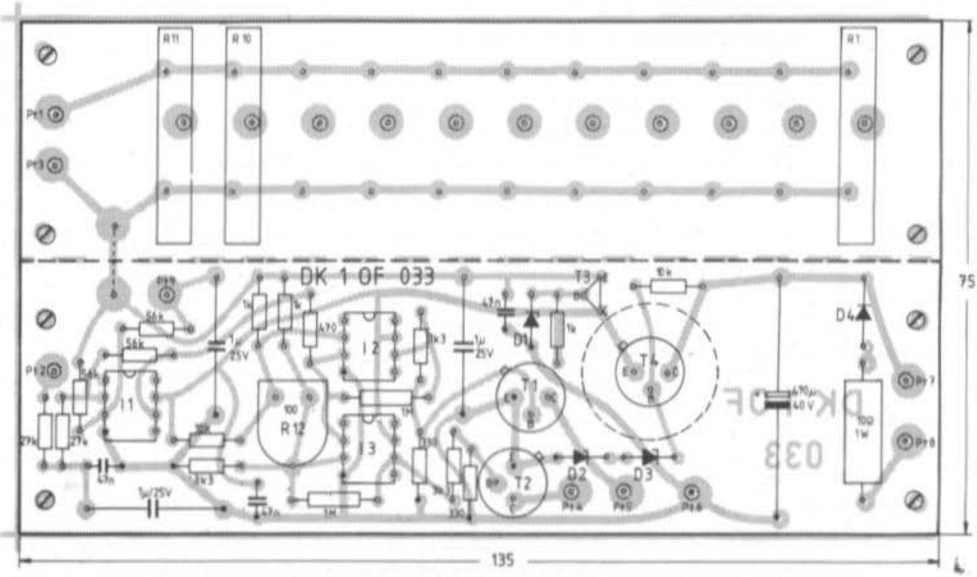

Fig. 4: PC-board DK 1 OF 033 of the programming unit

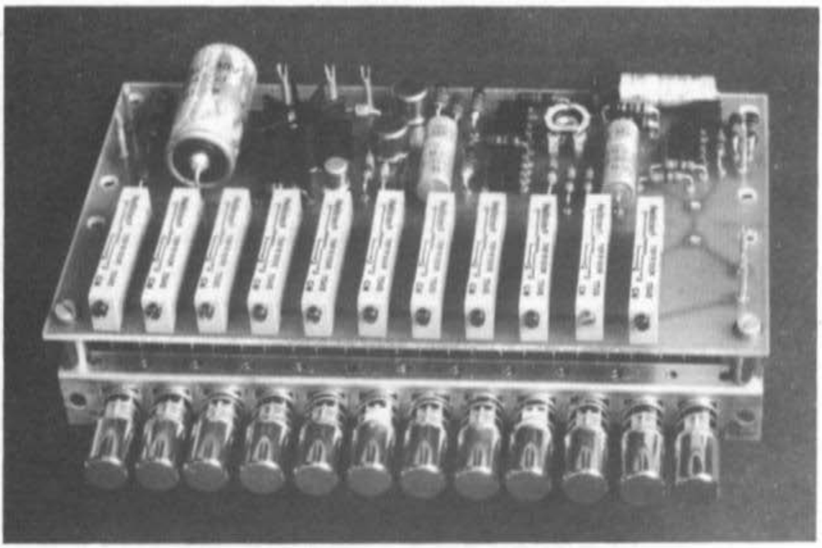

Fig. 5: An author's prototype; the pushbutton switches are directly soldered to the PC-board

3.1. Special Components

I 1, I 2, I 3:	Operational amplifier TBA 221 B (Siemens) or 741 CM
T 1, T 2:	BSX 46, 2 N 2219 A, or similar (Silicon NPN, TO-5)
T 3:	BC 108, BC 109, BC 413 or similar (Silicon NPN, TO-18)
T 4:	as T 1 with cooling fins
D 1:	ZPY 4.7 or similar 4.7 V zener diode
D 2, D 3:	ZPY 8.2 or similar 8.2 V zener diode
D 4:	1 N 4007 or similar (30 V ~, 1 A)
D 5, D 6:	1 N 4148 or similar silicon diode
R 1 to R 11:	Carbon spindle trimmers (10 turns), 100 kΩ, Beckman type 78 P (spacing 7.5/10 mm)
R 12:	Trimmer potentiometer 100 Ω, spacing 10/5 mm for horizontal mounting
S 1 to S 12:	12-position pushbutton assembly (one changeover contact each)
Rel 1, Rel 2:	24 V DC-relay, contact current min. 3 A+30 V ~, 1 break and 1 make contact e.g. Siemens V 23100 - V 7213 - F 104 (R_D = 270 Ω)

All 47 nF capacitors:	ceramic disk types
All 1 µF capacitors:	25 V DC plastic foil types
Suppression capacitors 1.5 µF:	100 V DC plastic foil types

4. OPERATION

After modifying the control unit of the rotator as described in section 2., clamps 1 to 6 are connected both to the rotator and the programming unit; clamp 7 and 8 are connected to the corresponding contacts of switch S 12. Press button 12 and switch on the control unit. The rotator should operate in this position using the two switches on the control unit.

This is followed by bringing, for instance, potentiometer R 1 to its center position (counting the number of turns) and depressing S 1. The rotator should now run until the meter approximately indicates half scale. R 12 is adjusted so that any oscillation around this point just stops. In this case, one can expect a resolution of approximately 2.5 degrees, which is considerably less than the beamwidth of even high-gain VHF and UHF antenna arrays, and should therefore be satisfactory for most applications. This can be followed by programming the 11 trimmer potentiometers on the required directions.

If the described programming unit is to be used with other types of rotators, it is possible that greater modifications will be required. Attention should be paid to what transformer voltage is used in the control unit. If this is higher than 30 V, it will be necessary for the filter capacitor at Pt 7 to be replaced by another type with a higher voltage rating.

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ATOM FREQUENCY STANDARDS and STANDARD FREQUENCY TRANSMITTERS

by Michael Klein, DK 7 UF

A large number of articles have been written about standard-frequency generators. Many of these excellent articles have already appeared in VHF COMMUNICATIONS (1), (2), (3), which were based on crystal oscillators.

1. INTRODUCTION

It is possible today to construct crystal oscillators with an accuracy of 10^{-10} Ω, however, not with amateur means. For this reason, the author does not intend to describe a new standard frequency generator, but more to explain the operation and application of an atom frequency standard. The long-term stability of such a system is in the order of 10^{-11}. Finally, the construction of a standard frequency/time system is to be described that has been in operation successfully over a considerable period of time. Last but not least, the author is to consider the construction of a controlable standard frequency/time beacon transmitter.

2. HOW DOES AN ATOMIC FREQUENCY STANDARD OPERATE ?

A rubidium (Rb 87) standard is to be considered that is representative for the various types of atomic frequency standards. Several of the major manufacturers offer small, lightweight, and inexpensive rubidium standard cells. We are sure that the first models will soon be operating in amateur radio circles.

The principle of such a standard is shown in **Figure 1**:

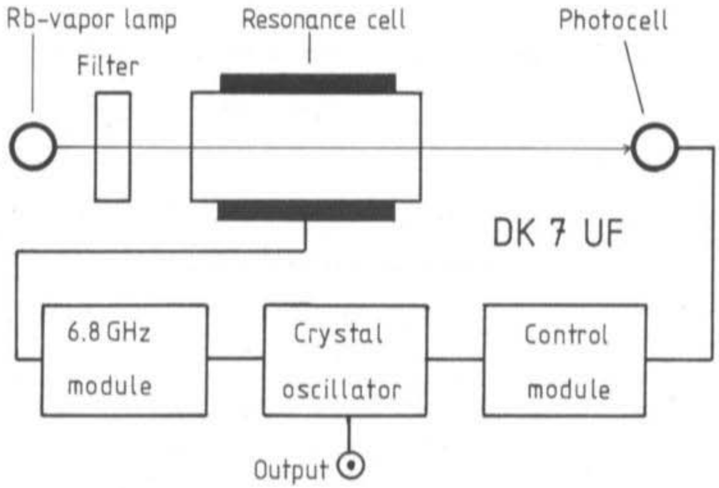

Fig. 1: Principle of a rubidium atom frequency standard

The operation of the Rb-87 gas cell standard is relatively complicated and all details are still not completely known.

The resonance cell is filled both with Rb-87 gas and a buffer gas. When in a balanced condition, these are just as many atoms with energy state E_1 as E_2. Condition E_2 is the state of higher energy. The gas cell is now illuminated with a rubidium-vapor lamp, in other words is provided with the energy $E = h \times f$. This light energizes the Rb-atoms and they are brought to the higher energy state E_3. This is called »pumping process«. The excited atoms then fall from the higher energy level to the lower levels E_1 and E_2; however, they tend to prefer the lowest level E_1.

Only the atoms at level E_2 should be energized by the pumping process. In order to achieve this it is necessary for a certain exciting energy to be selected. This is achieved by filtering out the unwanted parts of the spectrum using filter F.

The energy balance in the resonance cell is non-existent after the pumping process: There are not an equal number of atoms in state E_1 and E_2. If on the other hand one allows the Rb atoms to be irradiated in an electromagnetic field with a frequency of f_0 = 6834.682641 MHz, the balance will return. This will be observed since nearly all the energy from the rubidium vapor lamp will be absorbed within the cell under balanced conditions. The intensity of the light from the gas cell possesses a minimum and is thus a reliable indicator of the resonance conditions and can be used in the control circuit. A more detailed block diagram is given in **Figure 2**:

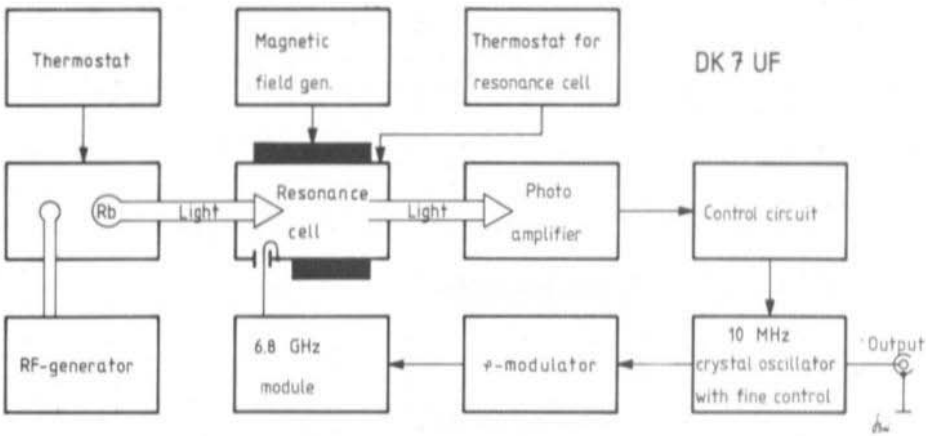

Fig. 2: Modules of the rubidium 87 standard

The principle is that the control circuit passes the frequency of the crystal oscillator, to which the 6.8 GHz oscillator is locked, until minimum photo-current is obtained.

The long-term stability of such a frequency standard can be in the order of 5×10^{-11} per month. Other frequency standards can achieve stabilities in the order of several 10^{-14}, however are usually considerably more extensive.

In order to roughly estimate the stability of such a system, two such standards were connected to a phase measuring unit. The plotted diagram given in **Figure 3** shows the deviation of the standards to another. The mean values of the relative phase deviation are given:

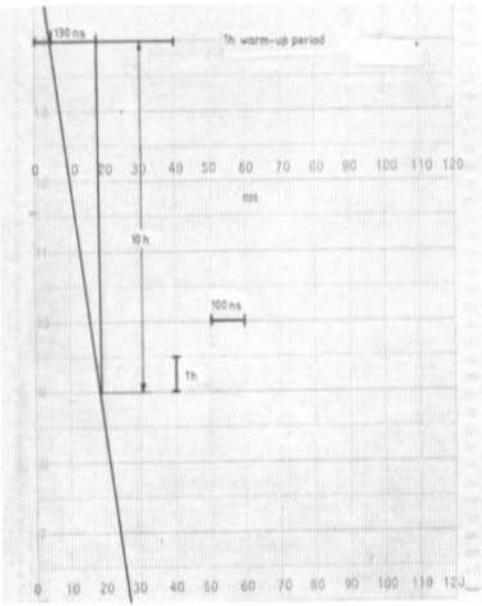

Fig. 3: Long-term drift of the Rb 87-Standard

The following values can be taken from the diagram:

Evaluation period: 10 h
Relative time deviation during this period: 130 ns

Relative error: $\frac{\Delta f}{f} = \frac{130 \times 10^{-9}}{10 \times 3600} = 3.61 \times 10^{-12}$

3. A STANDARD FREQUENCY SYSTEM

In order to utilize an atomic frequency standard to the full, the standard was included in a complete system that does not only supply standard frequencies but also measures frequencies, time and other derived magnitudes. The heart of the system is a control processor. This is necessary since the system is designed to allow automatic evaluation of the experiments. Other important elements are the three busbar systems: Data bus, Order bus, and Clock bus, which run through the whole system. There are also a number of periphery units.

The system was part of a practical research project, however, the control processor was not quite completed.

Further details are given in **Figure 4**:

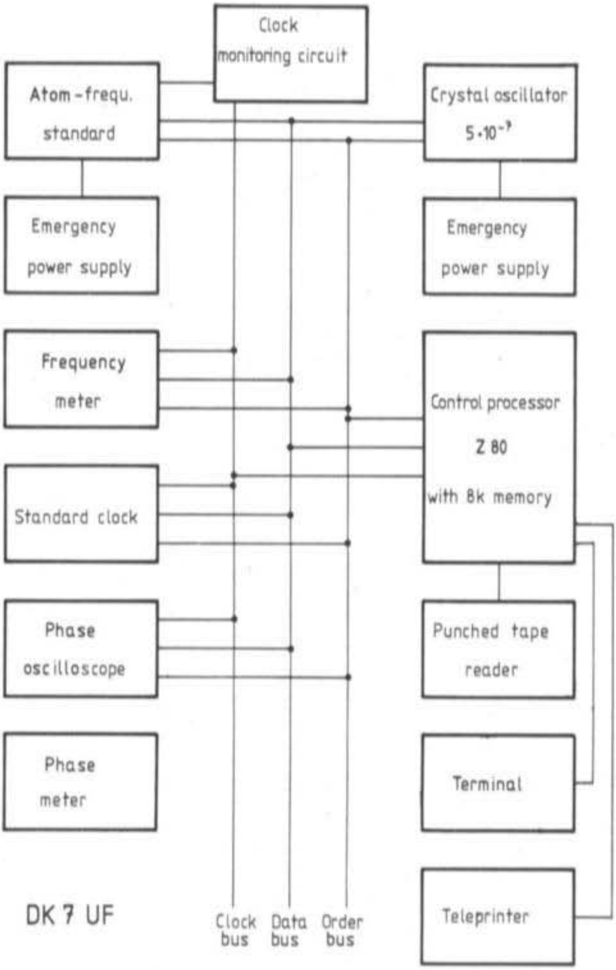

Fig. 4: Construction of a frequency/time beacon

4. A STANDARD FREQUENCY BEACON TRANSMITTER

Since a system as described in Section 3. would be too extensive for an individual radio amateur, the author suggests that it should be made accessible in the form of a controllable beacon transmitter. The most important part is an »intelligent« control computer that is able to recognize orders and to process them, even when their format is not identical to its order program. It should, for instance, be able to recognize +++ yis ++ as +++ yes +++ since the latter is one of its programmed orders. We do not intend to discuss the redundancy of the computer here. However, we would like to give an example of such communication with a computer:

dl0vg dl0vg dl0vg de dl1aa pse k

dl1aa dl1aa dl1aa de dl0vg
good morning om. this is the frequency measuring beacon dl0vg. your report is 589 589 589. when i ask you questions, please answer only with +++ yes +++ or +++ no +++. even when giving control orders please do not forget the +++ at the commencement and end of the order.
do you require an information sheet

dl1aa de dl0vg pse k

dl0vg de dl1aa +++ yes +++ pse k

dl1aa de dl0vg r. this is the information sheet:

following measurements are possible:

001 measurement of your transmission frequency
002 measurement of your frequency deviation
003 measurement of the speed of your rtty signal
004 transmission of a calibration tone of 1000 Hz,
accuracy +/- 10 exp -12 (carrier: 15 s with/without mod).
005 transmission of a 45.45 bd text
006 transmission of a 50.00 bd text
007 transmission of a 75.00 bd text
008 transmission of a 100.0 bd text
009 transmission of an ascii text, you can select the speed required. if 1000 bd is required give the order +++ 009/1000 +++
010 measurement of the speed of your ascii signal

please give the control orders directly after you call the beacon. wait until the required function is actuated when you expect a signal from the beacon. Always switch to receive after «pse k». you cannot make an error here since the beacon will not switch to transmit until your carrier is switched off. in the case of frequency deviation and speed measurements, where your carrier is required, the carrier should be transmitted for approximately 30 s, or you should speak into the microphone in a normal voice for the frequency deviation measurement. if you have difficulties, or when the beacon reports a fault, you can request further information regarding the fault by giving the order +++ help +++. please select the required control function.
dl1aa de dl0vg pse k

dl0vg de dl1aa +++ 001 +++ pse k

dl1aa de dl0vg. the required function was the frequency measurement 001.
the measurement result was 144 800 050 hz +/- 50 hz. do you require another measurement ?
dl1aa de dl0vg pse k

dl0vg de dl1aa ++ ne +++

dl1aa de dl0vg incorrect order, please repeat pse k

dl0vg de dl1aa +++ no +++ pse k

dl1aa de dl0vg sk

This may seem like something from science fiction but it is nearer to reality than you may think. It is only necessary to decide which functions are required since the ones mentioned above are just an example. If such an efficient computer is available, then the beacon could be realized immediately. There may be financial or licencing problems to be solved but no technical ones !

The author would like to hear your comments and ideas on this subject.

5. REFERENCES

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LOCAL OSCILLATOR FOR 1268 MHz
Matching the Linear Transmit Converter DF 8 QK 001

by Udo Beckmann, DF 8 QK

The module is not to be described in detail, since a similar module has already been described by J. Dahms DC 0 DA in the last edition of VHF COMMUNICATIONS. The circuit diagram is given in **Figure 1**, and the following table contains the most important details regarding the components. PC-board DF 8 QK 002 has the dimensions 170 mm by 50 mm.

Silver-plated copper wire of 1 mm diameter is used for inductances L 1 to L 8.

L 1:	4.75 turns on a 6 mm coil former with (red) core
L 2 - L 3:	1.75 turns wound on a 5 mm former, self-supporting, spaced 2 to 3 mm from the PC-board
L 4 - L 5:	1.75 turns wound on a 4 mm former, self-supporting, spaced 1 to 2 mm from the PC-board
L 6:	as L 2
L 7:	as L 4
L 8:	straight line 35 mm in length, spaced 2 to 3 mm from the board
L 9:	2 mm dia. wire, 35 mm long
L 10 - L 11:	2 mm dia. wire, 30 mm long, spaced 4 mm from ground surface

Coupling link between L 10 and L 11: 1 mm dia., length 35 mm, bend as shown.

Ch 1 - Ch 4:	4.5 turns of enamelled copper wire wound through a ferrite bead
Ch 5:	6-hole ferrite core
Ch 6:	3 turns of 0.5 mm dia. enamelled copper wire wound on 3 mm former, self-supporting
Ch 7:	3 turns of 1 mm dia. silver-plated copper wire wound on a 3 mm former, self-supporting

Components marked with a star in the circuit diagram are mounted on the lower, conductor side of the PC-board. Choke Ch 7 is bypassed with a lead-less (chip) capacitor. Further details can be seen in the photograph of the authors prototype shown in **Figure 2**.

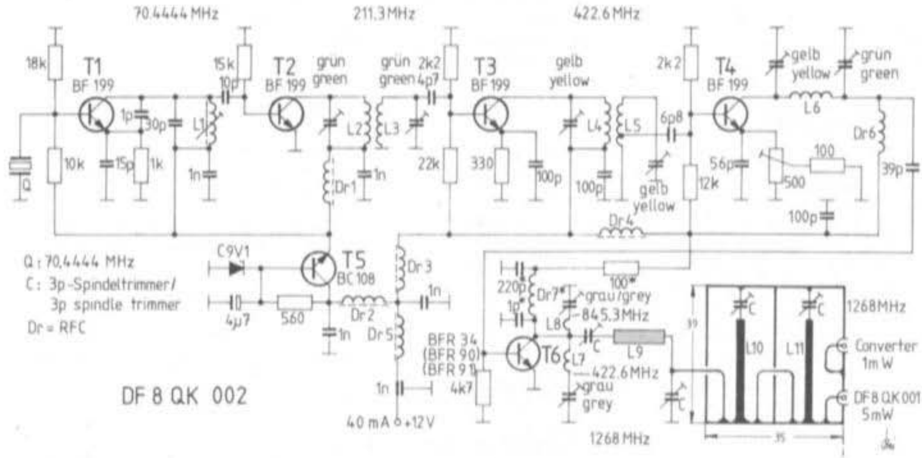

Fig. 1: Circuit diagram

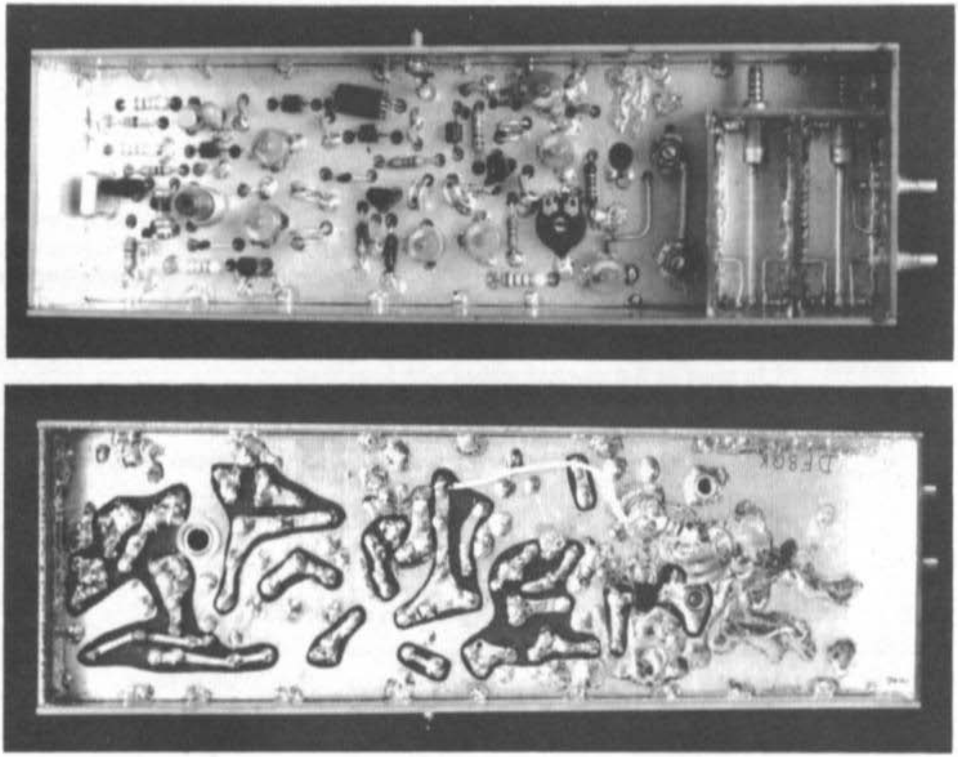

Fig. 2: Upper and lower view of the prototype DF 8 QK 002

NOTES and MODIFICATIONS

1. 400 W POWER AMPLIFIER EQUIPPED WITH 4 CX 250. Edition 2/1978

A high-tension feedthrough capacitor is required for this power amplifier (1 nF / 3 kV). Since such feedthrough capacitors are not readily available, we have received a large number of requests for them: Such a feedthrough can best be made by using a low-capacitance feed-through with PTFE insulation, and to connect a 1 nF / 3 kV ceramic disc capacitor to the inside and outside of the amplifier.

DK 1 OF

2. VARACTOR UP-CONVERTER DC 8 UG 001 - 003. Edition 2/1978

The tripler module DC 8 UG 002 possesses two outputs: one for a receiver mixer and one for the transmit mixer DC 8 UG 003. It is necessary for the transmit mixer output to be terminated with 50 Ω in the receive mode, in order to ensure that additional noise is not coupled to the receiver.

Furthermore, it should be noted that the tubular capacitor visible in the photograph (Fig. 13) of the author's prototype is **not** C 7 but C 5. Capacitor C 7 should be mounted outside the case.

DB 1 PM / DC 8 UG

3. ULM 70 Transmitter DJ 0 FW 002

After alignment of 20 transceivers, it is possible to give the following information on the transmitter:

3.1. The oscillator transistor should be replaced by a better type such as BFY 90 or 2 N 918. The following voltage drop across R 15 should be achieved:

with crystal:	0.8 ± 0.1 V)	Voltage difference must be 0.2 V
without crystal:	0.6 ± 0.1 V)	

3.2. The currents of the three multiplier transistors should result in the following voltage drops across the associated emitter resistor:

R 18:	min. 0.25 V (Dip should be min. 20 mV)
R 20:	min. 0.50 V (Dip should be min. 10 mV)
R 23:	min. 0.50 V ± 0.1 V (Dip should be min. 20 mV)

If these values cannot be achieved, T 2 and maybe T 3 should be replaced by better types such as BFY 90. Also C 22 should be reduced from 15 pF to 12 pF.

3.3. The current drain is 240 mA to 310 mA at an output power of 0.9 ± 0.15 W.

3.4. If the calling-tone generator oscillates wildly it can be neutralized by connecting a 150 pF capacitor between pin 5 and 6.

DK 1 PN

MATERIAL PRICE LIST OF EQUIPMENT
described in Edition 2/1978 of VHF COMMUNICATIONS

DC 8 UG	**LINEAR VARACTOR UP-CONVERTER**		
DC 8 UG 001	**LOCAL OSCILLATOR MODULE**		**Ed. 2/1978**
PC-board	DC 8 UG 001	(double-coated, no thru-contacts)	DM 21.—
Semiconductors	DC 8 UG 001	(6 transistors, 1 diode)	DM 62.—
Minikit	DC 8 UG 001	(10 trimmers, 4 feedthru caps., 3 coilformers with core, 1 BNC-connector)	DM 25.—
Crystal	96.000 MHz	(HC-25/U)	DM 26.—
Kit	**DC 8 UG 001**	**with above parts**	**DM 128.—**
DC 8 UG 002	**TRIPLER MODULE 384 MHz / 1152 MHz**		**Ed. 2/1978**
PC-board	DC 8 UG 002	(single-coated, without plan)	DM 10.—
Semiconductors	DC 8 UG 002	(1 transistor)	DM 28.—
Minikit	DC 8 UG 002	(4 trimmers, 1 feed-thru, 1 ceramic capacitor, 3 BNC connectors)	DM 23.—
Kit	**DC 8 UG 002**	**with above parts**	**DM 59.—**
DC 8 UG 003	**MIXER MODULE 144 MHz / 1296 MHz**		**Ed. 2/1978**
PC-board	DC 8 UG 003	(PTFE, double-coated, no thru-contacts)	DM 32.—
Semiconductors	DC 8 UG 003	(1 varactor BXY 27)	DM 68.—
Minikit	DC 8 UG 003	(6 trimmers, 3 BNC-connectors)	DM 22.—
Kit	**DC 8 UG 003**	**with above parts**	**DM 120.—**
DJ 7 OH 001	**SYNTHESIZER for 70 cm FM Transceiver ULM 70 S**		**Ed. 2/1978**
PC-board	DJ 7 OH 001	(double-coated, thru-contacts, without plan)	DM 28.—
Semiconductors	DJ 7 OH 001	(12 transistors, 15 diodes, 5 CMOS-ICs)	DM 89.—
Minikit 1	DJ 7 OH 001	(1 choke, 1 coilformer, 5 trimmers, 2 multi-layers, 1 plastic foil, 6 tantalum, and 27 ceramic capacitors	DM 45.—
Minikit 2	DJ 7 OH 001	(14 ceramic disc capacitors, 4 trimmer-pots., 62 resistors)	DM 25.—
2 switches and knobs with scale, 1 layer, 12 positions			DM 39.—
Crystal	15.6853 MHz		DM 16.—
Crystal	15.5705 MHz		DM 16.—
Crystal	15.2890 MHz		DM 16.—
Crystal	1.4222 MHz		DM 33.—
Set of above crystals			DM 78.—
Kit	**DJ 7 OH 001**	**complete with above parts**	**DM 298.—**
DJ 7 OH 002	**HARMONIC FILTER AND ANTENNA RELAY FOR THE 70 cm ULM 70 TRANSCEIVER**		**Ed. 2/1978**
PC-board	DJ 7 OH 002	(double-coated, thru-contacts)	DM 10.—
Minikit	DJ 7 OH 002	(2 trimmer caps., 1 relay RS-12, 1 m RG-174 coaxial cable, 1 m silver-plated copper wire 1 mm dia., 1 ceramic capacitor)	DM 28.—
Kit	**DJ 7 OH 002**	**complete with above parts**	**DM 37.—**
DK 1 OF 033	**PROGRAMMED POSITION CONTROL FOR KR 400 AND SIMILAR ROTATORS**		**Ed. 2/1978**
PC-board	DK 1 OF 033	(single-coated with plan)	DM 15.—
Semiconductors	DK 1 OF 033	(3 ICs, 4 transistors, 1 heatsink, 6 diodes)	DM 34.—
Minikit 1	DK 1 OF 033	(1 trimmer pot., 1 pushbutton assy., 2 relays)	DM 57.—
Minikit 2	DK 1 OF 033	(1 electrolytic, 5 plastic-foil, 3 ceramic capacitors, 20 resistors)	DM 36.—
Kit	**DK 1 OF 033**	**with above parts**	**DM 140.—**
	Spindle 10-turn potentiometers, each		DM 6.—
Kit	**DK 1 OF 033**	**complete with 11 spindle potentiometers**	**DM 199.—**

ANTENNA ROTATING SYSTEMS

KR 400

NEW!
KR 600

MXX 1000

ART 8000

SPECIFICATIONS

Type of Rotator	KR 400	KR 600	MXX 1000	ART 8000	
Load	250	400	1000	2500	kg
Pending torque	800	1000	1650	2450	Nm *)
Brake torque	200	400	1200	1400	Nm *)
Rotation torque	40	60	180	250	Nm *)
Mast diameter	38 - 63	38 - 63	38 - 62	48 - 78	mm
Speed (1 rev.)	60	60	60	60	s
Rotation angle	370°	370°	370°	370°	
Control cable	6	6	7	8	wires
Dimensions	270 x 180 ∅	270 x 180 ∅	425 x 205 ∅	460 x 300 ∅	mm
Weight	4.5	4.6	12.7	26.0	kg
Motor voltage	24	24	42	42	V
Line voltage	220 V / 50 Hz	220 V / 50 Hz	220 V / 50 Hz	220 V / 50 Hz	
	50	55	150	200	VA

*) 1 kpm ≙ 9.81 Nm

Vertical Rotor KR 500
Especially designed for vertical tilting of antennas for EME, OSCAR etc.

Type	**KR 500**
Load	ca. 250 kg
Brake torque	197 Nm *)
Rotation torque	40 Nm *)
Horiz. tube diam.	32 - 43 mm
Mast diameter	38 - 63 mm
Speed (1 rev.)	74 s
Rotation angle	180° (+ 5°)
Control cable	6 wires
Line voltage	220 V/50 Hz 30 VA
Weight	4.5 kg