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A Straight-Through Mixer for 24 GHz

In recent years, a large number of radio amateurs have become active on the 10 GHz band. It will be seen, especially during contests, that there is a considerable trend to these higher frequencies. Of course, not all equipment is home-made. The 24 GHz band has been available to amateurs for some years now, but does not enjoy this popularity.

In the case of 10 GHz, the relatively inexpensive »Gunnplexer« has done much to increase activity on this band. In the case of home-made equipment, the so-called straight-through mixer has become popular due to the surprisingly good results obtained with it. The author described such a mixer for the 10 GHz band in VHF COMMUNICATIONS (1). This is now to be followed by a similar design for a transceiver for the 24 GHz band, which has proved itself in the field.

CONCEPT

Several different concepts for the 24 GHz band were built up and tested by the author. When making a comparison between expense and efficiency, the described straight-through mixer concept has been found to be the most favorable. **Figure 1** shows the complete, ready-to-operate module. The case is made out of PC-board material and accommodates all components necessary for operation except the battery. The waveguide module is shown in **Figure 2**.

Positioning of the Mixer Diode

Experiments with straight-through mixers for the 10 GHz band have shown that a very high sensitivity can be achieved in the receive mode, however, the transmit power remains low. This ratio is even more critical when using such a mixer for the 24 GHz band, if a special construction is not used. The reason for this relatively low transmit power is the mixer diode, mounted between oscillator and antenna.

If the diode is placed out of the E-field, which is at its strongest at the center of the waveguide, it will not absorb so much power, which means that more is available for transmit applications. One must only pay attention that the mixer diode receives sufficient oscillator injection for reception so that the receive sensitivity is not deteriorated. This means that a compromise must be found for each oscillator power level between transmit power and diode current (approx. 0.5 to 3 mA).

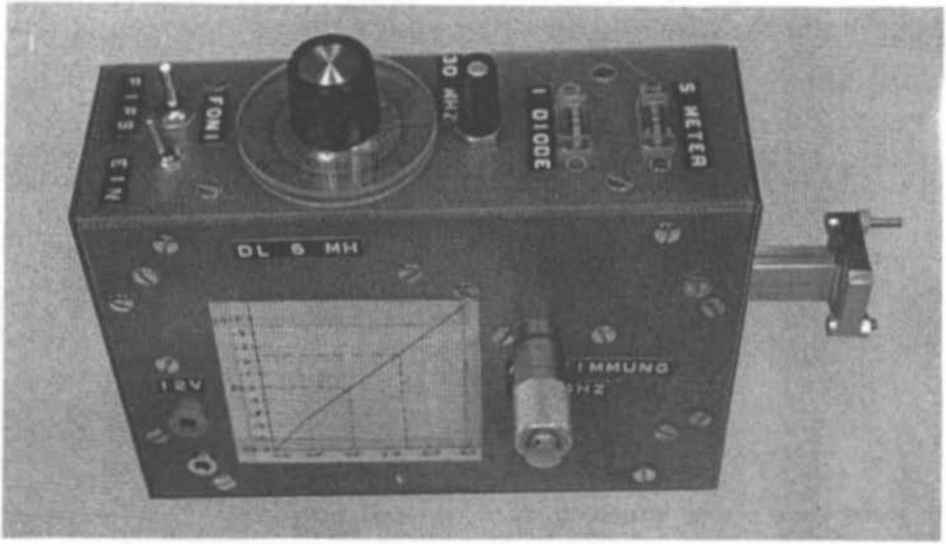


Fig. 1: The dimensions of this 24 GHz transceiver (without waveguide connection) are:
Length = 150 mm, width = 50 mm, height = 100 mm

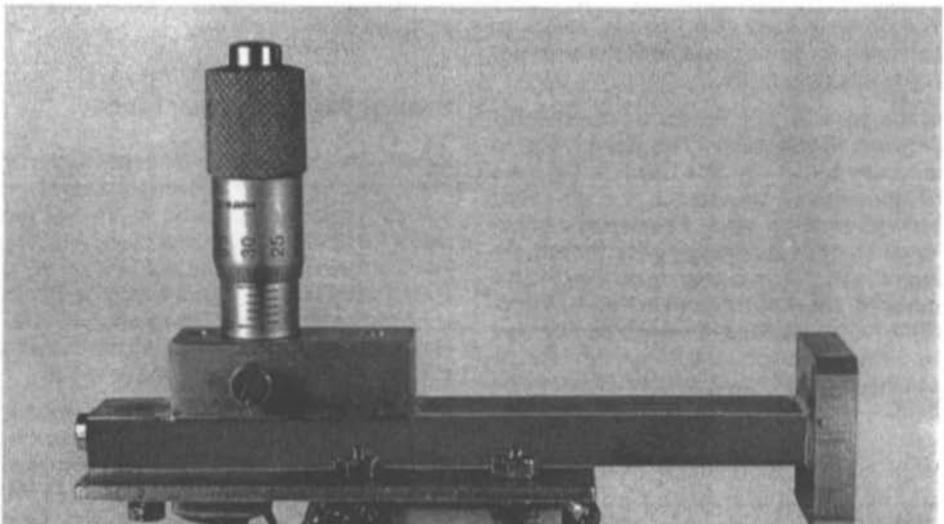


Fig. 2: The waveguide module from the side; the Gunn oscillator is tuned with the aid of a micrometer

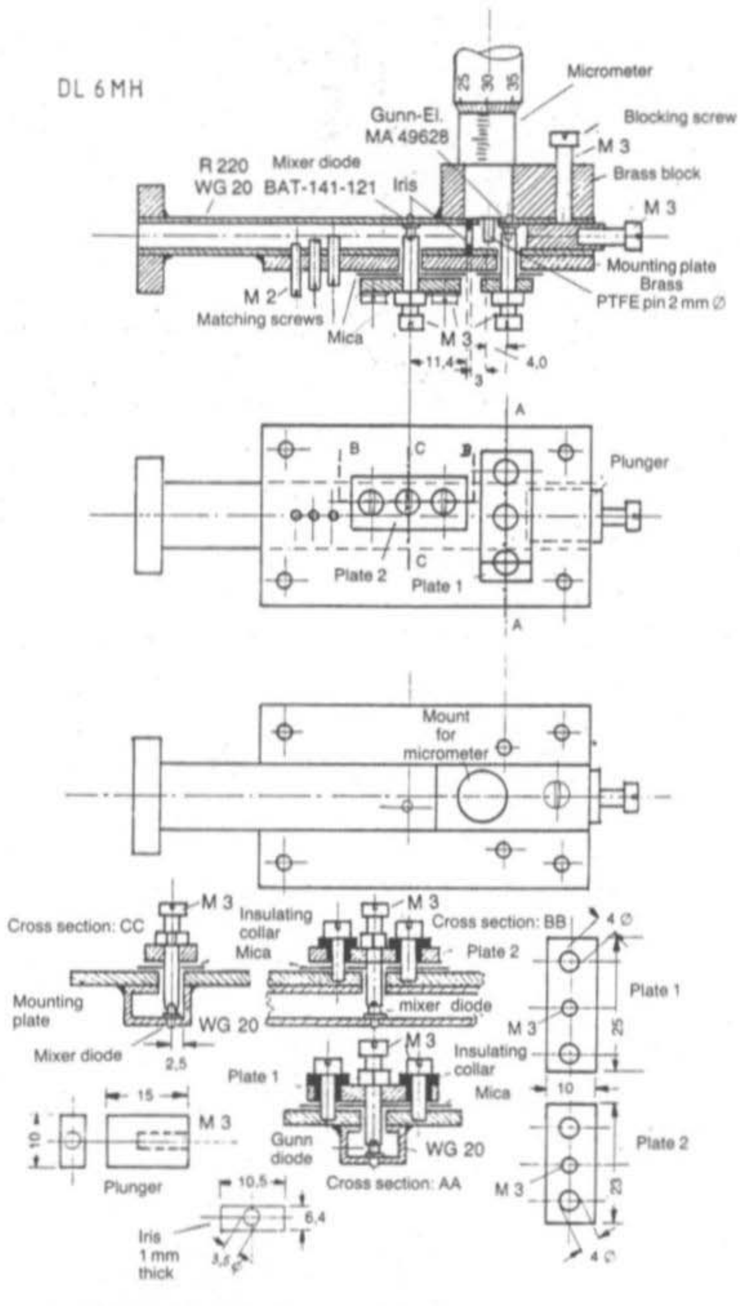


Fig. 3: Cross sectional drawing, from below and above, as well as detail drawings of the 24 GHz straight-through mixer

This seems to have been achieved in the case of the described mixer. When using a 12 mW Gunn diode, 4 to 5 mW are available in the transmit mode. During experiments made by the author on straight-through mixers where the diode was in the center of the waveguide (in other words at the position of maximum E-field), a higher conversion current was generated. However, only transmit power levels in the order of 100 to 200 μW were available. Even with these low transmit powers it was possible for communication to be made over distances of 30 km (line-of-sight), even if the signals were weak.

CONSTRUCTION

Figure 3 shows the cross section of the 24 GHz straight-through mixer; the cross-section drawing is not quite correct, but allows the construction to be described easily. The end of the waveguide is terminated with a short-circuit plunger. The plunger is provided with a layer of Sellotape in order to avoid intermittent contacts within the waveguide. The maximum RF-output of the oscillator is adjusted with this.

Tuning

A PTFE tuning pin can be inserted into the resonator chamber with the aid of a micrometer screw between the Gunn diode and the iris at the other end of the resonant chamber.

The steel pin of this micrometer is softened and drilled out in order to insert the tuning pin. A brass block is soldered onto the waveguide for mounting the micrometer screw. This block is provided with a suitable hole for this. The micrometer is clamped using 3 mm screws at the side.

Iris

The iris with an aperture of 3.5 mm diameter is mounted directly in the waveguide. In order to do this, slots are sawn into the broadsides into which the iris is placed and subsequently soldered. The slots may only be as thick as the metal plate of the iris. Normal metal sawblades provide a cut width of approximately 1 mm, which means that the iris can be just as thick. If it cannot be inserted tightly, it should be rubbed down with emery cloth. Attention should be paid during the soldering process that no solder can flow into the waveguide itself.

A rectangular slot can be used in the iris instead of the round hole. In this case, a slot is sawn into the narrow sides of the waveguide and a metal plate soldered in from both sides. The spacing between both metal plates should amount to 3 mm in the waveguide.

Length of the Resonator

The spacing between center of the Gunn diode and the iris is selected to be somewhat less than $\lambda_l/2$. Wavelength λ_l of the waveguide R 220 (WG 20) amounts to 15.25 mm at the center frequency of the band 24.1 GHz; this results in the theoretical value of 7.625 mm for 0.5 x λ_l. However, in order to provide a certain tuning range for the PTFE pin, a spacing of 7 mm has been selected. In the drawing, the spacing from Gunn diode to PTFE pin is 4 mm, and 3 mm from the PTFE pin to the iris. This is thus a total of 7 mm. This dimension is critical, since the frequency range to be achieved is dependent on this.

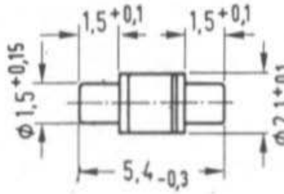
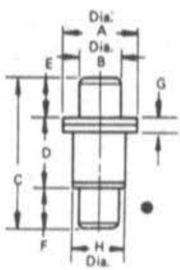


Fig. 4:
Dimensions of the mixer diode BAT 14-121, which can be used for the frequency range between 26.5 and 40 GHz. Optimum noise figure is provided at an oscillator power of 2 mW.



TYPICAL
L_p = .42 nH
C_p = .20 pF

DIM.	INCHES MIN.	INCHES MAX.	MM MIN.	MM MAX.
A	.119	.127	3,02	3,23
B	.060	.064	1,52	1,63
C	.205	.225	5,21	5,72
D	.085	.097	2,16	2,46
E	.060	.064	1,52	1,63
F	.060	.064	1,52	1,63
G	.016	.024	0,41	0,61
H	.079	.083	2,01	2,11

Fig. 5: Dimensions of the Gunn diode MA-49628. The dot marks the heat-sink side (+ U_B)

Mixer Diode

The mixer diode is spaced 3/4 λ_l from the iris, which amounts to 11.4 mm. As previously mentioned, it is not mounted in the center of the waveguide. The spacing from the inside of the waveguide to the center of the diode amounts to 2.5 mm.

Three matching screws are provided in front of the mixer diode with which the diode current of the mixer can be adjusted. The author used a mixer diode type BAT 14-121, which is manufactured by Siemens (**Figure 4**). A good receive sensitivity was provided at a mixer current of approximately 200 µA. Under laboratory conditions, it was found that an input power of − 100 dBm provided a good indication on the S-meter.

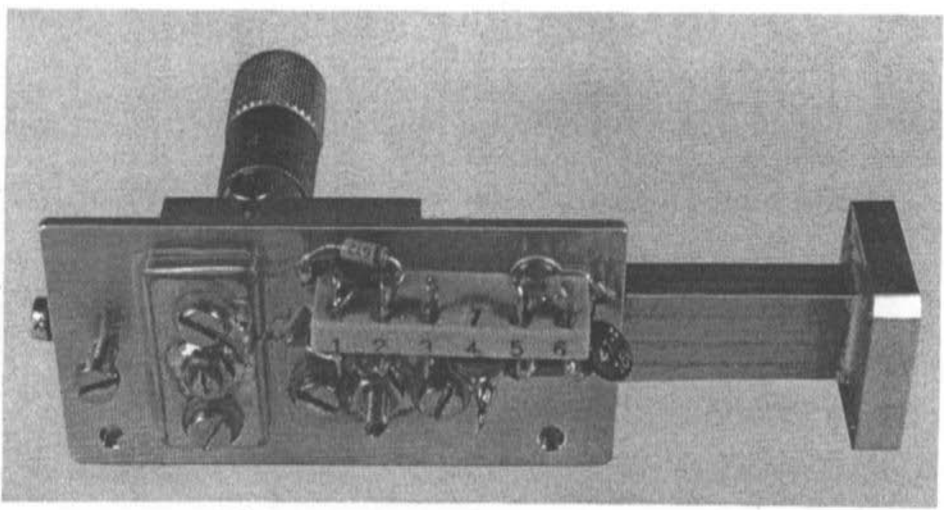


Fig. 6: The bypass capacitors for the Gunn oscillator (left) and the mixer diode (below center), as well as the solder tag strip can be seen clearly.

Bypass Capacitors

The RF-bypass of the Gunn voltage, and the intermediate frequency of 30 MHz taken from the mixer diode is made with brass plates which are insulated from the waveguide with the aid of mica layers.

A mounting plate is provided on the lower side of the waveguide. Threaded holes of 3 mm in diameter are drilled in this plate for mounting the bypass capacitors. The insulating collars are usually used for mounting power transistors.

FURTHER DETAILS

As can be seen in Figure 3, the screws for mounting the Gunn diode and the mixer diode have been drilled at their ends.

A Microwave Associates – Gunn diode type MA 49628 was available to the author.
Its main specifications at 22 GHz are:
P_{min} = 10 mW/U_{op} = 5.0 V (typ), or
8.0 V (max)/I_{op} = 200 mA (max);
case: see **Figure 5**.

As can be seen in **Figure 6**, a solder tag strip is provided on the lower side of the mounting plate for all connections. The wiring of the transceiver for 24 GHz is given in the block diagram given in **Figure 7**. **Figure 8** shows finally the internal construction.

Horn radiators or parabolic dishes can be used as antennas. The author described suitable parabolic antennas for 10 GHz and 24 GHz in (2).

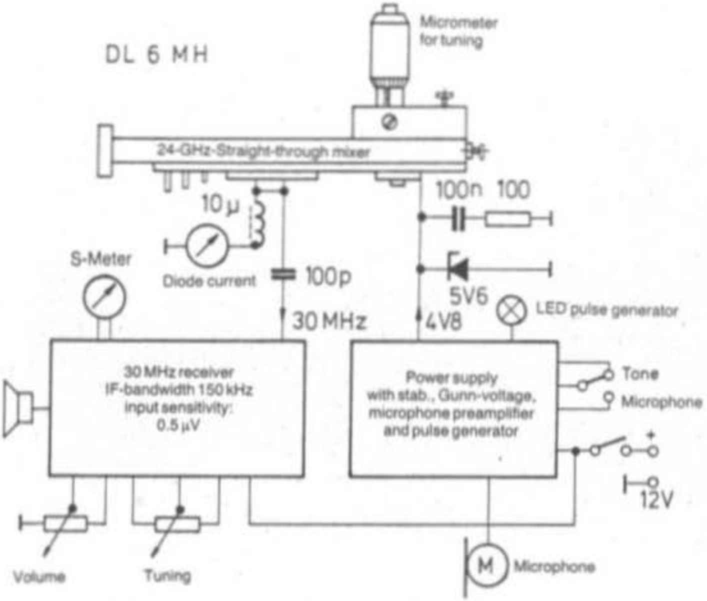


Fig. 7: Block diagram of the 24 GHz transceiver

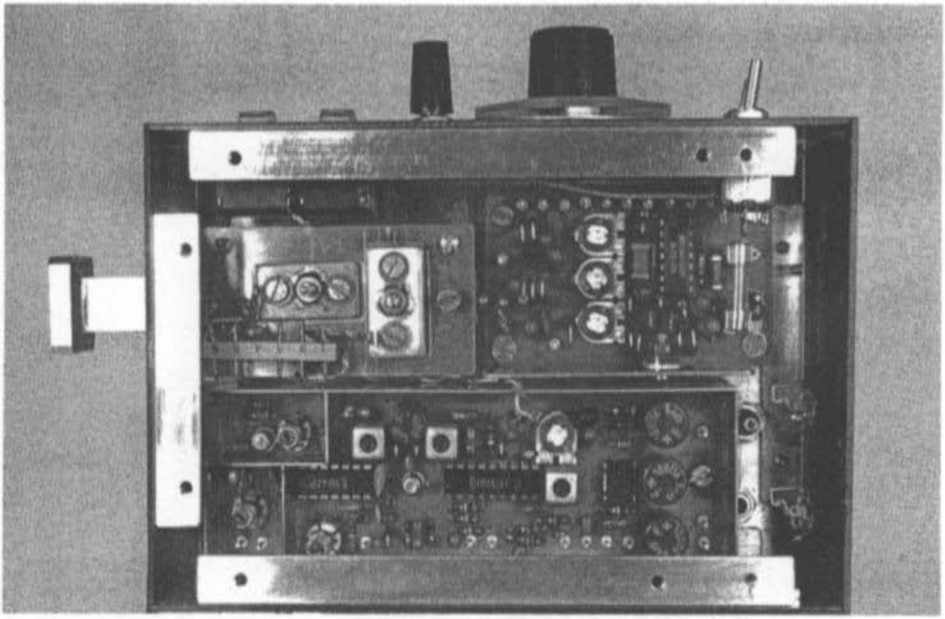


Fig. 8: **Internal view of the transceiver showing the straight-through mixer (upper left), board for voltage stabilizer, modulator, and tone generator (upper right), as well as the IF-board (below). The loudspeaker is mounted on the side panel that has been removed.**

REFERENCES

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