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Straight-Through Mixer for 24 GHz

Many of those having experience in wideband communications on the 10 GHz band, have, maybe, often wished to continue these activities to the next higher amateur band. The technology used on the 24 GHz band is similar to that of 10 GHz, with exception of the dimensions. The additional path loss with fog and rain has been found not to be a problem in experiments made over 50 to 120 km. The free-space path loss at 24 GHz, is, it is true, 7.6 dB more than at 10 GHz, however, that can be compensated for by using antennas of the same size. On the other hand, this has the disadvantage of decreasing the beamwidth.

Virtually no 24 GHz components are available on the surplus market and a similar module to the 10 GHz gunnplexer manufactured by Microwave Associates does not exist, at least not at a reasonable price. Oscillators can be homemade or are available for approximately DM 300,— from various manufacturers. Circula-

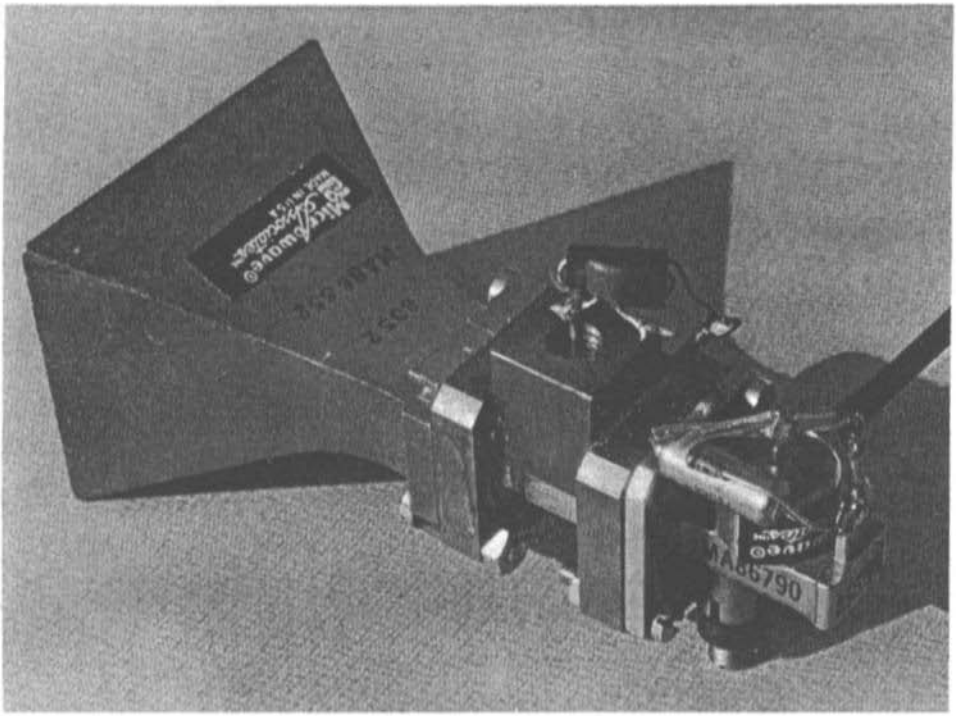

Fig. 1: The whole 24 GHz transceiver comprising Gunn oscillator, straight-through mixer, and horn antenna, is only 86 mm high.

tors for the K-band are very expensive. For this reason, a system comprising oscillator and straight-through mixer is more advisable for amateur applications.

1. PRINCIPLE OF OPERATION

The straight-through mixer is installed in a waveguide type R 220 which is terminated by two matching flanges. One side of the mixer is connected to an oscillator with iris, and the other side to an antenna (see **Figure 1**).

The mixer is designed for oscillators having approximately 10 mW output power. The power loss in the transmit branch is in the order of 3 dB. The mixer diodes should be spaced $\lambda_{wg}/4$ from the iris (λ_{wg} = waveguide wavelength). Since $\lambda_{wg}/4$ is in the vicinity of the edge of the flange, a spacing of 3 $\lambda_{wg}/4$ was selected. If an oscillator is to be used without iris, it will be necessary to change the following dimensions: In this case, the mixer diode must be spaced $\lambda_{wg}/4$ or $\lambda_{wg}/4$ plus any number of $\lambda_{wg}/2$ from the Gunn diode. The mixer can be equipped with three tuning screws (M2) spaced $\lambda_{wg}/4$ from another. The position with respect to the mixer diode is not critical (**Figure 2**). The author, however, did not use tuning screws since they only provided a sensitivity improvement of approximately 1 dB in his prototype.

The waveguide wavelength λ_{wg} can be calculated as:

$$\lambda_{wg} = \frac{\lambda}{\sqrt{1 - \left(\frac{\lambda}{2a}\right)^2}}$$

λ = Wavelength in air
or 12.42 mm for 24.150 GHz

a = internal dimension of the wide side of the waveguide; with R 220, a = 10.67 mm.

This results in λ_{wg} = 15.22 mm; $\lambda_{wg}/4$ = 3.82 mm, and 3 $\lambda_{wg}/4$ = 11.45 mm.

The case of the mixer diode is either 100 or 119 **(Figure 3).**

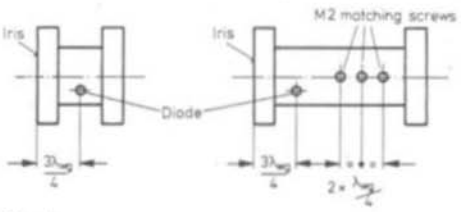

Fig. 2:
Construction of the straight-through mixer, both with and without matching screws

Special mixer diodes such as the BAT 14 are suitable, but also detector diodes will offer a sufficiently good sensitivity. The author used the K-band detector diode MA 40277 manufactured by Microwave Associates. The well-known 1N26 is not suitable for consctructing straight-through mixers, according to the author, due to its construction.

The mixer diode should be mounted on the side of the waveguide since the conversion current would otherwise be too great. The current should not be less than 400 to 500 μA, and not much more than 4 mA.

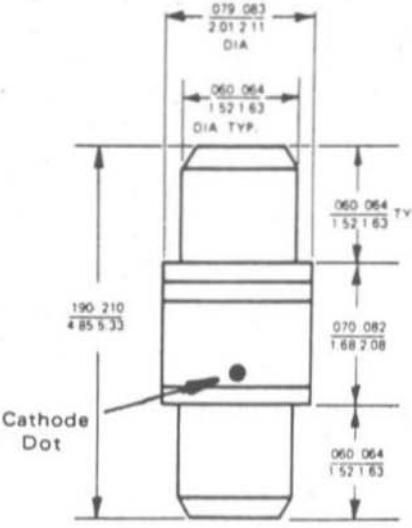

Fig. 3:
The diode case type 119 together with its dimensions in inch and mm.

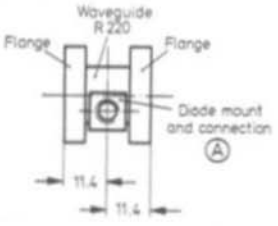

Fig. 4:
Main dimensions of the straight-through mixer

2. CONSTRUCTION

A certain amount of mechanical skill is required for construction, and it is advisable to have access to a lathe (or to know someone who has both!).

Firstly saw off a piece of waveguide that is approximately 1 to 2 mm longer than required, (see **Figure 4**). Usually, the flanges are rather loose on the waveguide, and it is therefore advisable to make several center taps around the inner hole until they fit more tightly.

After waveguide and flanges are ready, part A (**Figure 5**) should be prepared to the outer dimensions and provided with a center, 1.7 mm hole. Preferably, one should use a 10 mm rectangular brass profile for this part. The lip at the lower end is only provided to form a stop for fixing it previous to soldering, and is not absolutely necessary. It is also possible for part A to be made from round material.

Part B should be made on a lathe. The tightly fitting flanges are now placed in the correct position on the waveguide, after which part A is fixed into position using a small vice; after this, all parts are soldered to the waveguide. Any protruding pieces of waveguide are now removed with the aid of a file so that they form a flat surface with the flange. They can then be polished using emery cloth.

It is also possible to solder in steps by using normal solder for the first parts and solder with a lower melting point afterwards. With care, it is possible to avoid unsoldering the previously made joints.

Part A covers one hole in each of the two flanges. Usually, this is not important since it is sufficient to screw on the flange with the aid of three screws. For those who want to use four screws, it is possible for part A to be provided with a slot on the side that allows longer screws to be used.

The 1.7 mm hole in part A is now continued through both waveguide walls, which ensures that the mounting hole for the diode is correct. After this, the hole in part A can be extended to 4.5 mm diameter together with the soldered waveguide. The other parts are made according to the dimensions given in Figure 5 and mounted as shown in **Figure 6**. Part D can be made from an M6 screw, and does not necessarily need to be brass.

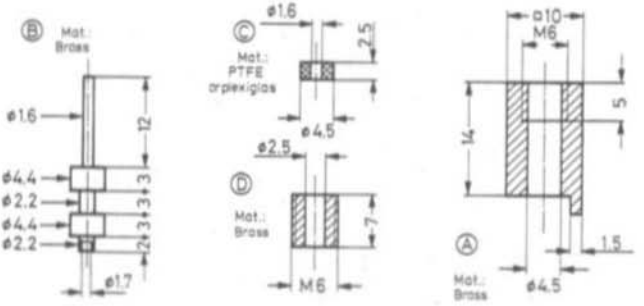

Fig. 5:
The four parts of the diode mount

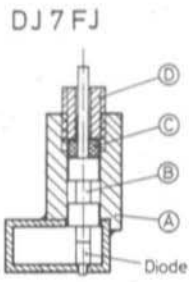

Fig. 6:
Cross section of the waveguide and diode mount

3. OPERATION

Install the diode carefully. Mount the oscillator to one flange, and connect the antenna to the other flange or leave it free. Measure the diode current to ground using an ammeter with the oscillators switched on; it should be in the order of 0.5 to 4 mA.

4. TIPS

4.1. Using Mixer Diodes

Mixer or detector diodes are very sensitive to static charge. This means that good care should be taken and they should be handled in the same way as older MOSFETs without internal protection. After installing the diode, the connection pin should always be galvanically grounded (for example, using a 6-hole ferrite choke). If a diode has been damaged, it is not always noticed immediately since it still has a slight diode-behaviour, in other words the forward and reverse current are still somewhat different, but are not in the original relationship to another. This can be easily checked with the aid of an ohmmeter. A mixer equipped with a damaged diode is usually 10 to 20 dB less sensitive than a correct one.

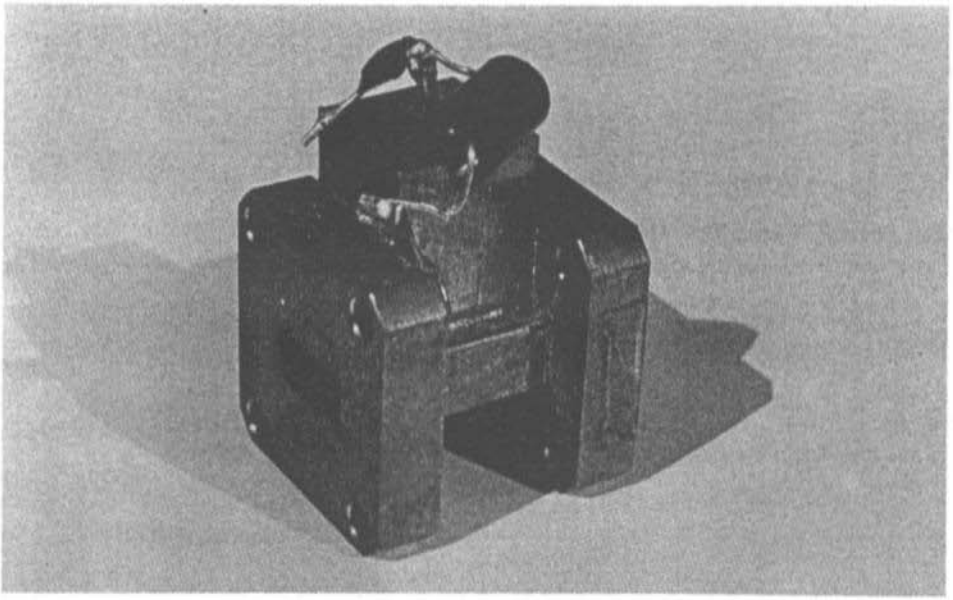

Fig. 7: The completed 24 GHz straight-through mixer

4.2. Type of Waveguide

If another waveguide is to be used to construct an efficiently operating mixer, it is only necessary to calculate the waveguide wavelength and to install the diode also at a spacing of 3 $\lambda_{wg}/4$ from the iris. However, the author recommends R 220 since this is the most common type of waveguide for the K-band. Measuring equipment, attenuators, external mixers of spectrum analysers, directional couplers, and other equipment all use this type of waveguide. If one then has access to such equipment, (and some lucky amateurs have), one will be angry to find that one cannot connect it.

4.3. Oscillators

It should be noted during construction of Gunn oscillators that it is possible for an oscillator to oscillate in the incorrect mode. The frequency will be a few GHz too high, and will hardly be affected by the tuning screws. In this case, the connected mixer will not indicate any, or a very low conversion current, although the current and voltage values are correct at the Gunn oscillator. In such cases, the Gunn diode usually has sought its $\lambda/2$ resonance from its location to the side-wall of the waveguide. This can usually be avoided by careful construction of the oscillator, and especially of the diode mount. A further measure is to use a waveguide type for the oscillator where the required frequency is at its lower limit. This means that the path from the center of the waveguide (usual location of the Gunn diode) to the side-panel is so short that the resulting $\lambda/2$ path results in a frequency at which the Gunn diode will no longer oscillate. In the case of 24 GHz, this would result in an oscillator having an iris suitable for R 320, with the rest of the module using R 220.

Attention should be paid with the iris of a Gunn oscillator that it is not too small, since it is easily possible to lose 10 dB of transmit energy. If the power can be measured in some way, even if only relatively, it is advisable to increase the size of the iris until one comes to the point where the output level hardly increases. It is then possible for the iris to be left as it is, or to make a second one with a slightly smaller size. The somewhat greater instability of the oscillator with respect to external effects can usually be compensated for using an AFC circuit.

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