Waveguide for the 24 GHz Band

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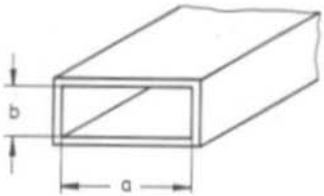
Three types of waveguides are suitable for use on the 24 GHz band (amateur band from 24.000 to 24.250 GHz):

R 220 = WR 42 = WG 20
R 260 = WR 34 = WG 21
R 320 = WR 28 = WG 22

As can be seen in the data sheets of these waveguides, or in the table given in (1), the last mentioned type can only be used with some limitations at 24 GHz; however, it possesses a number of advantages, which are to be discussed.



Designation Systems

- IEC-standard: R 220

  The number following the R (R = rectangular waveguide) indicates the central operating frequency (x 10 GHz); in our example: 22 GHz

- US-standard: WR 42

  The number following the designation WR indicates the waveguide dimension »a« in decimal inches; in our example: a = 0.42 inches

- British standard: WG 20

  The number following the designation WG (Wave Guide) is only a serial number that increases with frequency.

Dimensions

The waveguide dimension »a« (see drawing) of the three previously mentioned waveguides is:

R 220: a = 10.668 mm = 0.42"
R 260: a = 8.640 mm = 0.34"
R 320: a = 7.110 mm = 0.28"

The dimension »b« is only important for the breakdown voltage (radar-transmitters !). Of course, it does have some effect on the installation of semiconductors, and is also standardized. This will be discussed later.

Operating Frequency Range

The operating frequency range f_{op} given in the data sheets is as follows:

R 220: 17.6 – 26.7 GHz
R 260: 22.0 – 33.0 GHz
R 320: 26.4 – 40.1 GHz

f_{op} is defined as:

$$f_{op} = (1.25 \text{ to } 1.9)\, f_{co} \qquad (1)$$

and is only valid for the H_{10}-wave. This is the most important waveguide-wave type; it is usually exclusively used in the amateur radio technology.

The cut-off frequency f_{co} mentioned in equation (1) results from the limit wavelength λ_l:

$$f_{co} = \frac{c}{\lambda_l} \qquad (2)$$

where c is the propagation speed of the electromagnetic waves:

$$c = 300 \times 10^8 \text{ cm/s}$$

and $\lambda_l = 2a$

where a is the inner width of the waveguide (see drawing).

Example: Let us calculate the operating frequency range of waveguide type R 320:

$$\lambda_l = 2a = 1.422 \text{ cm}$$

$$f_{co} = \frac{300 \times 10^8 \text{ cm}}{1.422 \text{ cm} \times \text{s}} =$$

$$f_{co} = 210.911 \times 10^8 \text{ 1/s}$$
$$= 21.091 \text{ GHz}$$

According to equation (1), the operating frequency range is then:

$$f_{op} = (1.25 \text{ to } 1.9)\ 21.091 \text{ GHz}$$
$$f_{op} \approx 26.4 \text{ to } 40.1 \text{ GHz}$$

Wavelength in the Waveguide

The wavelength in the waveguide λ_H is important for the design of equipment. It differs from the free-space wavelength λ_o by the ratio of λ_o/λ_l. The relationship is as follows:

$$\lambda_H = \frac{\lambda_o}{\sqrt{1-(\lambda_o/\lambda_l)^2}} \qquad (3)$$

Where $\lambda_o = c/f_o$

c = propagation speed
f_o = operating frequency in Hz
λ_l = 2a

It will be seen in equation (3) that the wavelength in the waveguide will approach infinite values when λ_o approaches the value λ_l, in other words, when λ_o/λ_l approaches zero. This means that a waveguide can no longer be used in the vicinity of its cut-off frequency f_{co}.

Finding One's Own Waveguide »Standard« ?

You may have noted that the waveguide dimension »b« is not mentioned in the equations. Practically speaking, it only determines the breakdown voltage of the waveguide at high power levels. For this reason, radio amateurs need not necessarily be bound to the sometimes very expensive, and difficult to obtain standard waveguides. There is nothing to stop us using metal profiles available in metalwork and model-building shops. Suitable brass center profiles are available that are very suitable for installing components.

The decision not to use standard waveguide parts means that it is also necessary to construct such things as the flahges. Also, one will not be able to connect standard measuring equipment to a home-made waveguide system unless suitable, calculated transitions from one system to another were provided.

Calculated Values for the Waveguide Wavelength

According to equation (3) the following values result for the wavelength λ_H for the corner frequencies of the 24 GHz amateur band:

Frequency in GHz	R 220/WR 42 λ_H	R 320/WR 28 λ_H
24.000	15.42 mm	26.19 mm
24.250	15.18 mm	25.07 mm

Waveguide Type R 320

This type of waveguide (WR 28) is used outside of its operating frequency range in the vicinity of its cut-off frequency. As will be seen in the above table, the waveguide wavelengths are approximately twice as long as in the larger waveguide type R 220. This is a small advantage: The electromechanical system will be increased by factor 2, which means that the mechanical tolerances can be greater and thus construction less critical.

This advantage must be compared with a considerable disadvantage: All discontinuances in the waveguide will lead to an increase of the standing wave ratio (SWR) and will excite higher wave types. These have an adverse effect on the fundamental wave (H_{10}), and extract energy from it, thus increasing the power loss. For this reason, it should be noted that waveguide type R 320 (WR 28) can only just be used for the 24 GHz amateur band when bends and other complicated configurations such as waveguide switches are not used and when restricted to short waveguide lengths. Waveguide type R 220 (WR 42), on the other hand, can be used without limitation.

REFERENCES

(1) Lentz, R.: Designation of the Microwave Bands and Waveguides
VHF COMMUNICATIONS 8, Edition 4/1976, pages 232-233