

Attenuator for rectangular waveguide (X-band)[©]

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1 - Introduction

Many attenuators are based on the cutoff principle [1] and can be divided into two groups.

1 - attenuators realized by means of coaxial cables placed between two portions of waveguide, thus requiring a double passage between the waveguide and the cable. Due to the connection between waveguide and cable, this kind of attenuator presents some drawbacks in the realization of microwave circuits.

2 - attenuators realized by using waveguides of different dimensions. In this way it is possible to have a direct connection in the microwave circuit. However, also this latter type of attenuator has some drawbacks, due to the abrupt transition between waveguides of different sections.

Thus, a new kind of attenuator working directly in the waveguide, and in perfect matching conditions, can represent an instrument that can be extremely useful in experimental set-ups.

We describe here a cutoff attenuator for rectangular waveguides in X-band that eliminates the drawbacks mentioned above.

2 - Theory

Let us consider a rectangular. For frequency values less than the cutoff one, the attenuation α for the mode TE_{10} is [2]

$$\alpha = \frac{54.6}{\lambda_c} \sqrt{1 - \left(\frac{\nu}{\nu_c}\right)^2} \text{ dB/cm} \quad (1)$$

where ν_c is the cutoff frequency expressed in GHz and $\lambda_c (= 30/\nu_c)$ is the cutoff wavelength expressed in cm. For frequencies very close to the cutoff, a rapid transition takes place, and the cutoff attenuation α_c is

$$\alpha_c = \frac{\pi}{\alpha\sqrt{2}} \sqrt{\sqrt{\left[1 - \left(\frac{\nu}{\nu_c}\right)^2 - \eta\right]^2 + \eta^2} + 1 - \left(\frac{\nu}{\nu_c}\right)^2 - \eta}, \quad (2)$$

where η depends on the frequency and on the physical characteristics of the waveguide, that is:

$$\eta = \frac{1}{\sqrt{\pi\nu\mu\sigma}} \left(\frac{\nu^2}{b\nu_c^2} + \frac{2}{a} \right). \quad (3)$$

In Eq. (3) σ is the electric conductivity, μ the magnetic permeability of the waveguide walls, a and b are the dimensions of the waveguide ($= 1.58$ and 0.79 cm, respectively).

The attenuation is related to the transmission coefficient T by the relations

$$T = \frac{1}{1 + e^\alpha} \quad \text{for} \quad \alpha \leq \nu_c \quad (4)$$

$$T = \frac{1}{1 + e^{-|\alpha|}} \quad \text{for} \quad \alpha > \nu_c \quad (5)$$

Near the cutoff (when the attenuation tends to zero), the transmission coefficient tends to 0.5, and the cutoff attenuation α_0 is

$$\alpha_0 = 10 \log_{10}(T^{-1}) = 3 \text{ dB}$$

3 - The attenuator

The features of this particular attenuator are that

- it supplies a variation of the attenuation in a continuous way;
- it can be directly connected between two portions of waveguide (thus avoiding the waveguide-cable-waveguide passage).

The variable attenuator consists of (Fig. 1)

- a first adapter with a first variable-section component for the passage, *in conditions of perfect matching*, from a first waveguide in a first X-band ($\sim 8-12$ GHz) to a second waveguide in a second band K_U ($\sim 12-18$ GHz).
- a second adapter with a second variable-section component for the passage, again in conditions of perfect matching, from the second waveguide in K_U band to a third waveguide in the first X-band.

The first and second variable-section components were positioned so that they could slide within a second waveguide. The first and second variable-section components were mobile with respect to each other to define between them, within a second waveguide, an empty zone with a variable longitudinal dimension controlled by a knob. For frequencies in the X-band, evanescent waves originate in K_U band, thus producing an attenuation.

The variation in the longitudinal dimension (gap width) of the empty space gave rise to a variable attenuation of the pulse transmitted along the waveguides.

The experimental results of the attenuation measured with the variable attenuator are shown in Fig. 2, together with theoretical behavior of the attenuation vs. frequency.

Each experimental result is obtained from a set of the attenuation measurements as a function of the gap width (see Fig. 3).

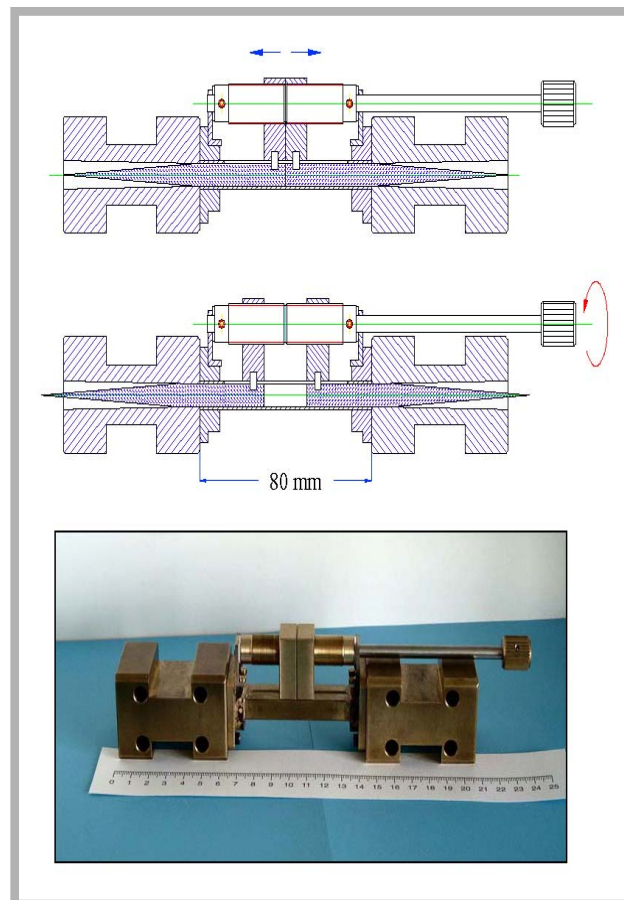


Fig. 1 - Mechanical drawings and photo of the attenuator, including the adapters for direct connection to waveguide circuits

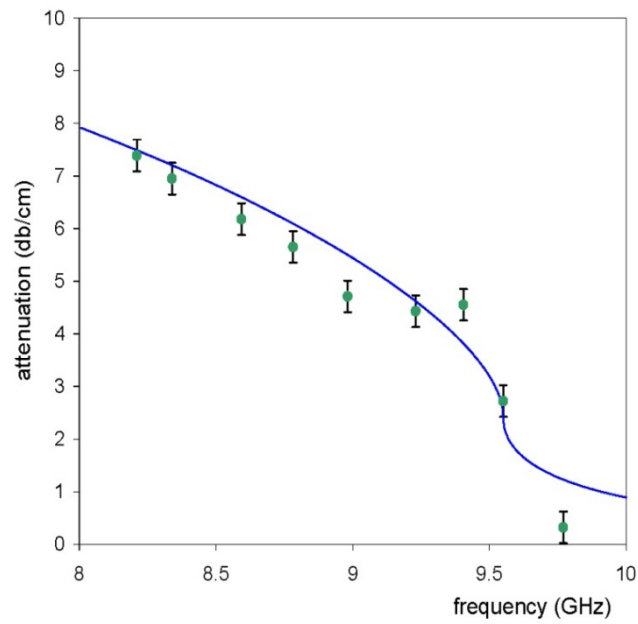


Fig. 2 - Theoretical curves of the attenuation per unit length vs. frequency, and experimental results.

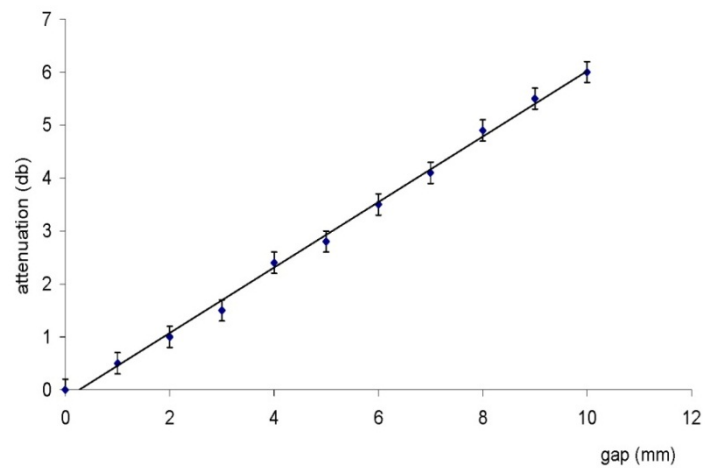


Fig. 3 - Measurements of the attenuation vs gap width, at a frequency of $\nu = 8.59$ GHz.

References

1. For a review on the matter see: David H. Russel, IEEE Trans. on Microwave Theory and Techniques **45**, 2408 (1997).
2. F.E. Terman, *Electronic and radio engineering*, McGraw-Hill, New York, 1955, Sec. 5.8.