

THE DESIGN OF PLANAR CIRCUIT MOUNTED IN WAVEGUIDE and THE APPLICATION TO LOW NOISE 12GHz CONVERTER

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Abstract

The proposed planar circuits in a waveguide and their design theory are presented together with the confirmation by experimental results. The application of this circuit to 12GHz down-converter is also shown.

1. Introduction

Recently we have developed new microwave components with a planar circuits mounted in waveguide. Metal sheet with various patterns is placed in the middle of the H plane of the waveguide in parallel to the E plane, as shown Fig. 1.

This planar circuit is very useful for low-cost mass production and high Q value. In this paper, the design theory and experimental results of this circuits and the application to SHF converter are presented.

2. Microwave Component of Planar Circuits Mounted in Waveguide

A double tuning band-pass filter can be constructed by using the patterns shown in Fig. 2(a) (b) (c). As a result of our experiment, we have succeeded in obtaining approximately 2500 for no-load Q(Q₀) at 12GHz. This design theory is described in next section. Fig. 2(d) shows pattern the band-stop filter, where the pattern used for a resonance is coupled to a ridgeguide, which is transformed from a main waveguide through a taper section of the metal sheet. Fig. 2(e) shows a coupling circuit between a semiconductor element and a waveguide. As shown in Fig. 2(e), one end of the stripline of nearly $\lambda/4$ is connected to the H plane of the waveguide, and another end is connected to the diode.

As a distribution circuit is provided between this stripline and the E plane, the impedance viewed from the diode is adjustable by changing the width of the stripline.

3. Design Theory of Band Pass Filter

3.1 Inductive Strip Type Filter

Fig. 3(a) (b) shows the geometry and equivalent T network of the perfect conductive strip inserted in a rectangular waveguide. In the case of a short circuit and an open circuit at the central plane (To) of the strip, the input normalized admittance Y_s and Y_p were found respectively. $Z_s (=jX_s)$ and $Z_p (=jX_p)$ in the equivalent T network of Fig. 3(b) were easily calculated as follows,

$$Z_s = \frac{1}{Y_s} \quad , \quad Z_p = \frac{1}{2} \left(\frac{1}{Y_p} - \frac{1}{Y_s} \right)$$

The equivalent circuit of the inductive strip is calculated using variational technique under the

assumption of the perfect conductive sheet. Results are as follows,

$$Y^{(i)} = \frac{\sum_{v=1}^N Y_{0m} \left(\sum_{v=1}^N A_{vm} m_v \right)^2 + a \sum_{v=1}^N m_v^2 Y_v Q_v^{(i)}}{Y_1 \left(\sum_{v=1}^N m_v A_{v1} \right)^2} \quad \begin{matrix} v=1, 2, \dots, N \\ m=3, 5, 7, \dots, \infty \end{matrix}$$

where $Y^{(i)} = Y_s, Y^{(2)} = Y_p$

$$A_{vm} = (-1)^v \frac{8\sqrt{a}}{\pi(m^2 - 4v^2)} \quad , \quad Y_{0m} = \frac{\Gamma_m}{jk_0\eta} \quad , \quad \Gamma_m = \sqrt{\left(\frac{m\pi}{a}\right)^2 - k_0^2}$$

$$Q_v^{(i)} = \coth \frac{T_v W}{2} \quad (i=1) \quad , \quad T_v = \sqrt{\left(\frac{2v\pi}{a-t}\right)^2 - k_0^2}$$

$$= \tanh \frac{T_v W}{2} \quad (i=2) \quad , \quad Y_v = \frac{T_v}{jk_0\eta}$$

$$k_0 = \frac{2\pi}{\lambda_0} \quad , \quad \eta = \sqrt{\frac{\mu_0}{\epsilon_0}}$$

$Y^{(i)}$ is the normalized admittance at the $Z=0$. By the Rayleigh-Ritz method the amplitude m_v are chosen so as to yield a minimum value of $|Y^{(i)}|$ for every v . The minimizing conditions should satisfy the following set of $N-1$ equations.

$$\frac{\partial Y^{(i)}}{\partial m_j} = 0 \quad , \quad j=2, 3, \dots, N \quad \text{for } m_1=1$$

Fig. 3(c) shows the calculated values for the normalized series reactance X_s and the normalized shunt reactance X_p . The construction of the band pass filter with the inductive strip and equivalent circuit are shown in Fig. 4. Then, the design method of the bandpass filter was derived by applying the equivalent net-work of the inductive strip to the usual method of the filter design.

3.2 Slot Type Filter

Fig. 5(a) shows the construction of slot type resonator. Then, the admittance Y viewed from the slot is calculated using trial function. Results are as follows,

$$Y = j \sum_{n,m} \frac{\pi^2 P_n Q_m}{\eta \epsilon_n \epsilon_m b C \tanh \frac{\Gamma_{nm} a}{2} \left\{ \left(\frac{m\pi}{C} \right)^2 + \left(\frac{n\pi}{b} \right)^2 \right\}} \left(\frac{m^2 k_0}{\Gamma_{nm}^2} - \frac{n^2 \Gamma_{nm}}{k_0 C^2} \right)$$

where $\epsilon_n, \epsilon_m = 1 \quad n, m = 0$
 $\phantom{\text{where}} = 0.5 \quad n, m \neq 0$

$$P_n = \left\{ \frac{2C^2 l}{\pi(n^2 l^2 - C^2)} \cos \frac{n\pi l}{2C} \right\}^2$$

$$Q_m = \left\{ \frac{2b}{m\pi} \sin \frac{m\pi d}{2b} \right\}^2$$

$$\Gamma_{nm}^2 = \left(\frac{n\pi}{C} \right)^2 + \left(\frac{m\pi}{b} \right)^2 - k_0^2$$

The resonant frequency of slot resonator with planar circuit mounted in waveguide can be computed by obtaining the frequency at which Y is equal to zero.

Fig. 5(b) shows the calculated values for the dimension of resonator.

4. Application to 12GHz Down Converter

Fig. 6(a) shows the pattern of the planar circuit used for the developed 12GHz down converter, which is mounted in a waveguide. This pattern is reproducible in a accuracy less than 20μ for mass production.

Fig. 6(b) (c) shows characteristics of two 12GHz converter for 360MHz and 1.25GHz intermediate frequency.

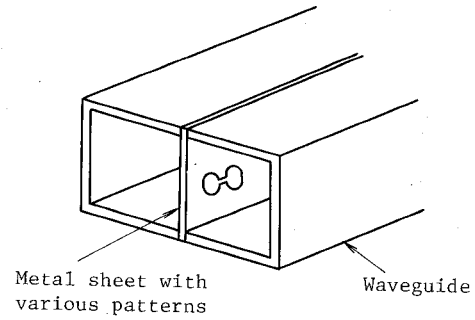


Fig. 1. Construction of planar circuit mounted in waveguide.

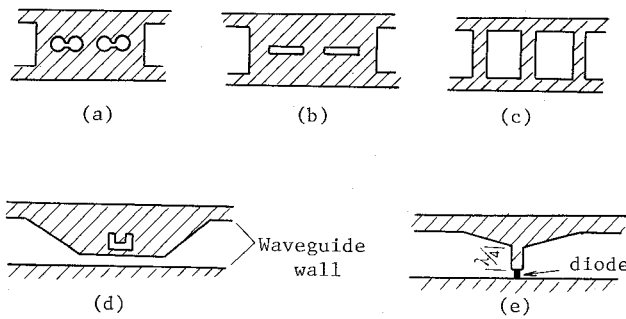


Fig. 2. Planar circuit patterns of microwave component.

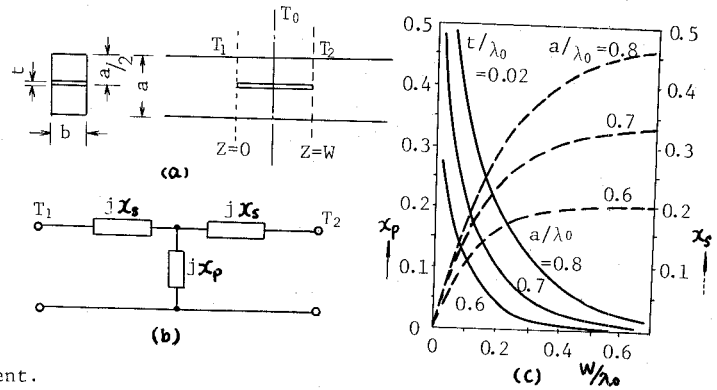


Fig. 3. Geometry, equivalent T and calculated values for an inductive strip.

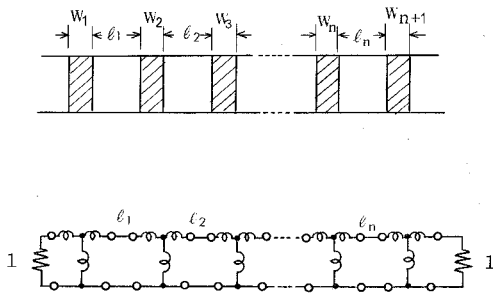


Fig. 4. Construction and equivalent network of the bandpass filter with the inductive strip.

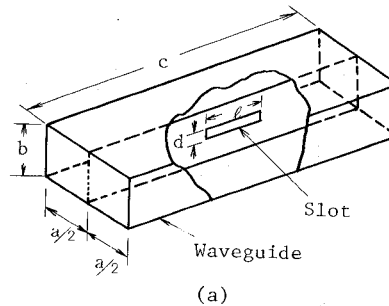


Fig. 5. Construction and dimension of slot type resonator.

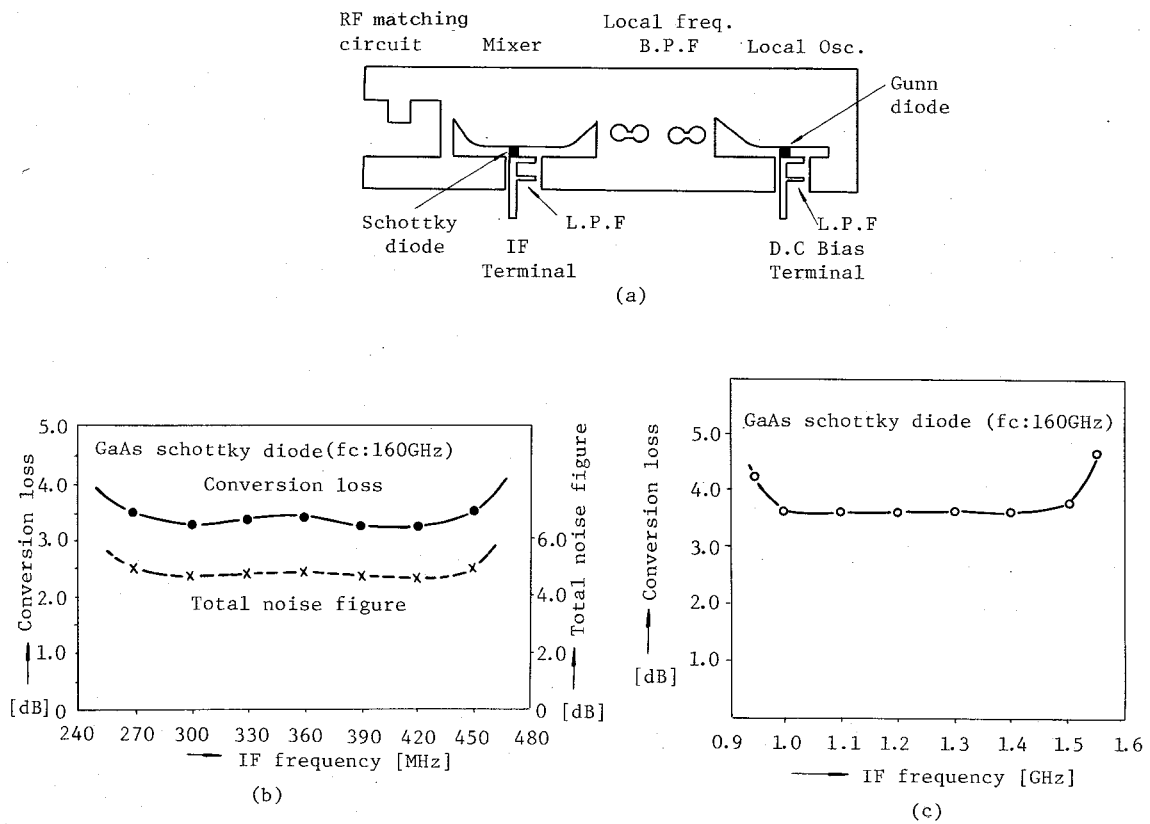


Fig. 6. Construction and characteristics of 12GHz down converter with planar circuit mounted in waveguide.