MM-WAVE GUNN OSCILLATOR WITH DISTRIBUTED FEEDBACK FIN-LINE CIRCUIT

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ABSTRACT

Periodic fin-line structures are used to create specified reflection, coupling and matching in a mm-wave Gunn oscillator. The design of the distributed reflector is described and the performance of oscillators in Ka-band is shown.

Introduction

The characteristic behavior of periodic structures is commonly used in different applications. Only recently have grating structures in dielectric waveguides been shown advantageous in the design of mm-wave oscillators /1, 2/. Though different approaches to fin-line oscillators were given in the last years /3 - 6/, none employed periodic structures.

Oscillator layout

Fig. 1 shows the essential layout of a fin-line oscillator using a grating structure as a distributed feedback circuit. The setup consists of an asymmetrical fin-line with Gunn diode at it's end, a grating structure, and a taper to hollow waveguide. The grating structure serves several purposes. The generated power is coupled to the output port via the gratings, these being designed to give an optimum match. Additionally the well-known stop-band phenomenon of periodic structures is used to create specified reflection thus serving as a distributed feedback circuit. The advantage is, that the stop-band frequency, and by that the oscillating frequency, can be adjusted by the geometric period of the perturbations independently of the reflection coefficient, which depends only on the number and amount of perturbations.

Calculation of the periodic structure

Any type of periodic structure can be employed for the above stated purposes. As is seen from Fig. 1 a periodic arrangement of series stubs was chosen as most suitable for this application. To arrive at a satisfying description of the grating it was first checked experimentally how to model the series stub discontinuity. It turned out that an effective electrical stub length of it's geometrical length plus one half of the connecting slot width is a good approximation for the end- and branching-point effects. This holds for low impedance stubs (implying narrow slots), branching in a right angle thus not having direct coupling to the connecting fin-line.

The periodic arrangement of a finite number N of perturbations is easily calculated by standard transmission line theory. Let in our case denote z the normalized stub impedance and Θ it's electrical length, then the scattering parameters of the series branch (with infinitely short connection between input and output ports) are

$$s_{11} = \sin\Theta \,/\, (2j/z \cos\Theta + \sin\Theta),$$
$$s_{21} = \cos\Theta \,/\, (jz/2 \sin\Theta + \cos\Theta). \qquad (1)$$

Name the complex reflection coefficient on the connecting fin-line r, then the finite grating is calculated by recurring

$$r_{n+1} = \frac{s_{11} + (s_{21}^2 - s_{11}^2)\, r_n}{1 - s_{11}\, r_n} \exp(-j4\pi d/\lambda), \qquad (2)$$

$$n = 0\ (1)\ N,$$

with $r_o = 0$ and d the geometric period of the structure. Fig. 2 shows one example of the resulting transmission characteristic of a grating with N = 12 series stubs of normalized impedance z = 0.5 over the normalized frequency $2d/\lambda$. The first stop-band occurs when the geometrical period is approximatively one half wavelength long. Notice that the center-band frequency changes with the number and amount of perturbations. Also the bandwidth decreases with increasing number of perturbations, which is not shown here.

Oscillator design

The design of the oscillator now is straightforward. Consider Fig. 3 as equivalent circuit of the structure of Fig. 1. The given data are typical of a 35 GHz Gunn diode; Z_L = 200 Ohm is the line impedance of the asymmetrical fin-line with a slot of 430 μm to fit the geometrical size of the diode cap. In contrast to a linear generator the specific IV-characteristic of a Gunn diode with resistance R_G demands an impedance of

$$Z_3 = 2 * (-R_G) \qquad (3)$$

to deliver maximum power to the load /7/. In the considered example of Fig. 3 equ. (3) results in a necessary load impedance of Z_2 = (0.0256 - j 0.0132) * 200 Ohm as seen from the accessable diode port. Assuming a match at the input of the distributed reflector this impedance can be achieved with a grating structure of 10 dB transmission loss and a 0.35 λ line after the last perturbation. For N = 12 stubs this leads to stub lengths of l = 0.095λ .

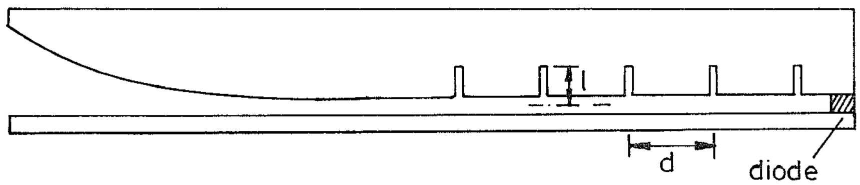

Figure 1

Basic layout of fin-line oscillator with distributed reflector

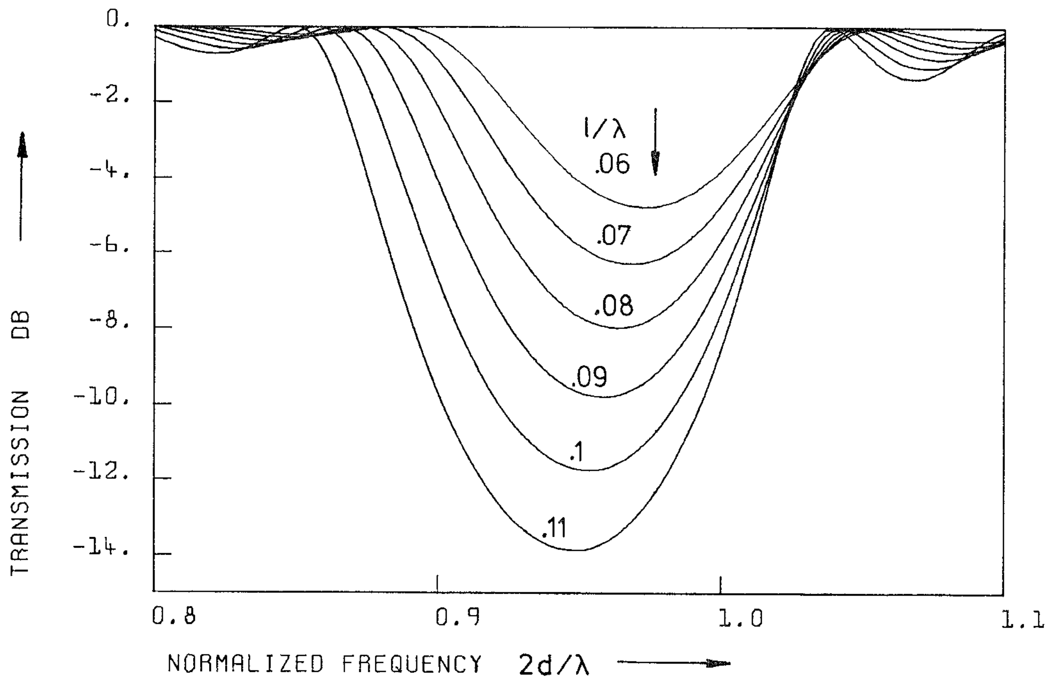

Figure 2

Transmission characteristics of periodic structure over normalized frequency consisting of N = 12 series stubs of normalized impedance z = 0.5 and varying lengths

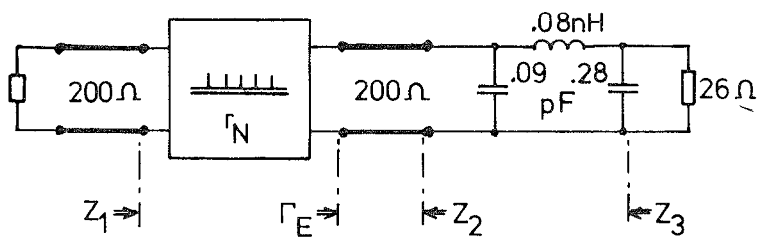

Figure 3

Equivalent circuit of structure according to Fig. 1 with typical 35 GHz Gunn diode parameters and 200 Ohm fin-line

At this point of the design everything from the distributed reflector back to the diode is fixed. In some cases the input impedance Z_1 of the grating reflector is of interest. In order to find the corresponding input reflection coefficient Γ_1, use standard transmission line and network theory. Assuming the periodic structure to be lossless allowes to compute Γ_1 from the knowledge of the (eigen-) reflection coefficient r_N only, which is given by equ. (1):

$$\Gamma_1 = \frac{r_N - \Gamma_E \exp(2j \operatorname{arc} r_N)}{1 - r_N \Gamma_E} . \qquad (4)$$

In equ. (4) Γ_E is the load reflection coefficient as seen from the output port of the grating reflector, Fig. 3.

The geometrical data of the layout were calculated from the above stated electrical data by the fin-line theory given in /8/.

Performance of the oscillators

Several oscillators were built and measured in K_a-band, using 250 μm RT-Duroid as a fin-line substrate and a μMA type 49172-138 Gunn diode. Checking different numbers and line lengths of the series stubs proved that the maximum (and rated) power was indeed achieved exactly with the calculated line lengths. A deviation of about 10 % in stub lengths results in about 10 % less power. The predicted oscillator frequency was met to an accuracy of about 2 %, which is considered to be quite good for the simple theory involved. In practice the oscillators have a short waveguide section following the diode, which can be adjusted in length with a sliding short. By this means the resonant frequency can be pulled about $\pm$ 200 MHz. The Q of the oscillators was measured by pulling technique to be in the order of 60, which is typical of these planar structures.

Summarizing, the presented oscillator design combines the easy and inexpensive fabrication of planar structures with a straightforward design and a very good performance. The inherent advantage of the employed distributed periodic feedback circuit is the possibility of adjusting frequency, coupling and matching rather independent of each other.

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