NEW INTEGRATED mm-WAVE COMPONENTS USING FIN-LINES

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ABSTRACT

New integrated fin-line components are presented: reflecting and matched PIN-attenuators, power-divider, PIN double-throw switch, and different oscillator configurations. All exhibit excellent performance and great flexibility in design and application.

Introduction

Today the demand rises for inexpensive, but quality-satisfying and highly reliable mm-wave components. Different approaches employing quasi-planar structures have been presented in the recent time /1 - 5/. Various components are described in this paper, which are either newly presented or show an improved performance. Since an exact treatment of different fin-lines and related structures has been achieved /6/, accurate calculation and CAD with a high degree of automization has been made possible. In fact all the used layouts were computer-generated and automatically plotted on film thus allowing arbitrarily complicated topologies incorporating curvilinear contours.

PIN-Attenuators

High achievable attenuation and broadband operation is not the essential problem when designing fin-line PIN-attenuators. The attenuation can be increased by use of more diodes (up to about 50 dB) without affecting the insertion loss, as has been shown in the past. More effort has to be taken to minimize the insertion loss in the turned-off case. To this end fin-line transitions employing tapers have been optimized. The optimal taper shape and length was found taking a general parabola with real exponent for the slot-width variation with length. The general configuration of a PIN-attenuator using two optimal tapers is shown in Fig. 1. The return loss of such a taper is better than 20 dB broadband. The beam-lead diodes have a spacing of a quarterwavelength on the unilateral fin-line at midband.

Fig. 2 gives a graph of typical transmission curves of a three-diode attenuator operating from 26 to 40 GHz. Attenuation can be adjusted between 0.4 dB (with reverse bias) and about 28 dB with very good flatnes over frequency.

For some applications this reflecting type attenuator is not desirable. A matched attenuator can be realized employing bilateral fin-line, soldering one diode across the slot on one side and a second one on the other side. This allows for seperate biasing of the diodes, which is adjusted in a way that one diode reflects and thus produces the attenuation and the second one provides for the match. Fig. 3 demonstrates how the return loss of this device stayes below 15 dB for any adjusted attenuation. Attenuation can be increased by use of more diodes to furnish the reflection, but not much beyond 20 dB with this type of layout, since part of the energy is bound to the back-side fins and cannot be coupled to these diodes.

Power-Divider

Very broadband and flat power-dividers for different power ratios are realized with series connections of two fin-lines, Fig. 4. Different ratios of slot-widths, corresponding to different line-impedances, have been tested and revealed that the theoretical values of line-impedances stated in /6/ have good relevancy for this type of design. A 1:1 power divider using two 150 Ω output lines and a 300 Ω input line showed a return loss of typical 20 dB and a transmission of 3.4 ± 0.2 dB per arm in the band from 26 to 40 GHz.

PIN-Switch

Using a similar layout as in Fig. 4 but with three equal-slot arms a PIN-diode double-throw switch has been designed. The two output arms contain two PIN-diodes each. Each arm can be biased seperately thus allowing for switching the energy from one arm to the other. Fig. 5 shows the transmission performance of the switch operating from 26 to 40 GHz. The on-state gives an insertion-loss of about 1 dB, whereas the off-state reveals 20 dB of isolation. For reverse operation, namely feeding one output arm, the coupling to the second output arm is less than 23 dB. The design has not yet been optimized. Lower insertion loss and higher isolation are expected by the experience with the PIN-attenuators. However, the PIN-switch has already successfully been used as a Dicke-switch in a Ka-band radiometer. In this application the fast switching time of about 10 ns is of high interest.

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Oscillators

Fin-line configurations give a great flexibility in building Impatt- or Gunn-oscillators. All designs do not need a choke in the bias line, have good thermal properties, and yield easy application of the active element to the lines. Out of a variety of ten tested configurations four are presented, Fig. 6.
In Fig. 6a an assymmetrical fin-line is shown, with the Gunn-element mounted in the bottom wall of the waveguide housing. A sliding short provides the resonant line-length behind the Gunn-element. A realized oscillator of this type can be mechanically tuned in the range of 27 to 38 GHz. (Above 38 GHz the short showed resonances itself).
The oscillator structures of Figs. 6b - d have characteristically mounted the active element in the back part of the housing. This allows for a great freedom of possible resonating structures extending in front of the active element. Fig. 6b depicts a unilateral fin-line, which is crossed by a microstrip on the back of the substrate to produce the resonance. Also the dual micro-strip-slot configuration yields good results, Fig. 6d. A similar effect as the microstrip in Fig. 6b has the strip in Fig. 6c contacting the two fins some length away from end. This configuration also works with bilateral fin-line.
In all cases the width of the strips or the contact allows to adjust the coupling of the resonator to the ongoing fin-line, whereas the distance to the active element determines the oscillating frequency. With the same Gunn-element but different resonators oscillations in the entire band from 26 to 40 GHz were generated. With some of the configurations twice the rated power of the Gunn-element could be extracted.
When introducing an additional quartz tuning screw the oscillators can be fine-tuned. The quartz screw has to come very close to the fin structure since the fields are bound strongly to the slot. Possibilities of electronic tuning are also seen but have at the time not yet been realized.
In conjunction with known configurations of fin-line balanced mixers /e.g. 3, 6/ these oscillatores can be used to set up a completely integrated mm-wave front-end. In this case the transitions from fin-line to hollow waveguide as shown in Fig. 6 are unnecessary.

Acknowledgement

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References

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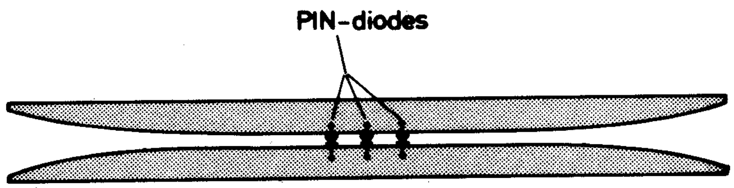

Fig. 1
General configuration of fin-line PIN-attenuator.

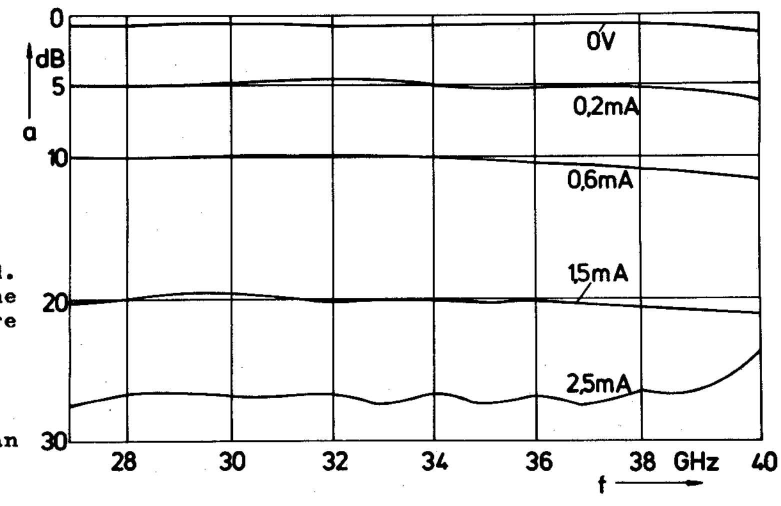

Fig. 2
Attenuation of a three-diode PIN-attenuator for K_a-band use. (diodes: ai 6-6474-30, quartz substrate)

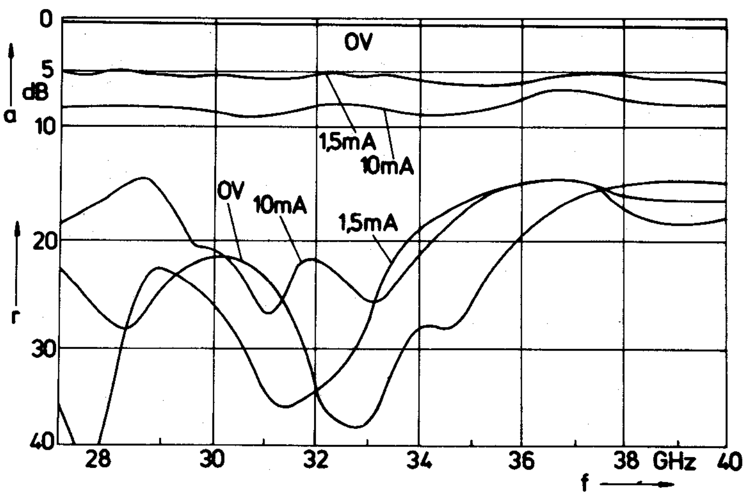

Fig. 3
Attenuation a and return loss r of a matched PIN-attenuator for K_a-band use. (diodes: Thomson CSF EH 40 301, RT-Duroid)

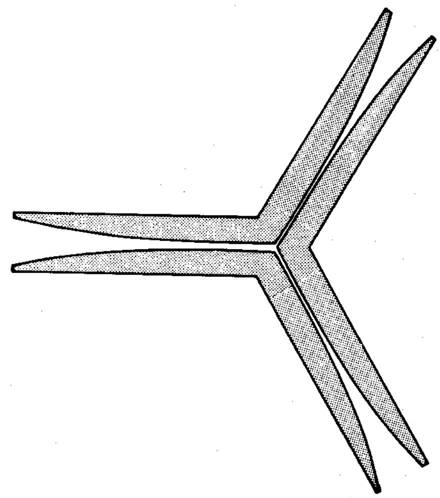

Fig. 4
General configuration of fin-line power-divider.

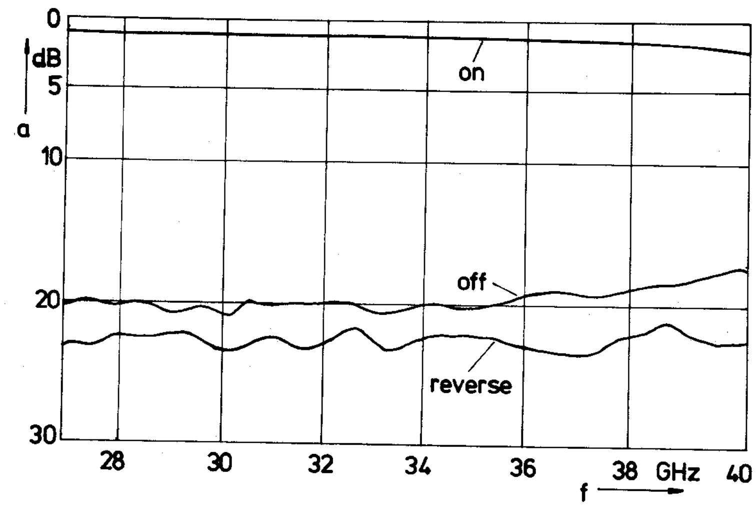

Fig. 5
Transmission of PIN-diode double-throw switch for K_a-band use. (diodes: Thomson CSF EH 40 301, RT-Duroid)

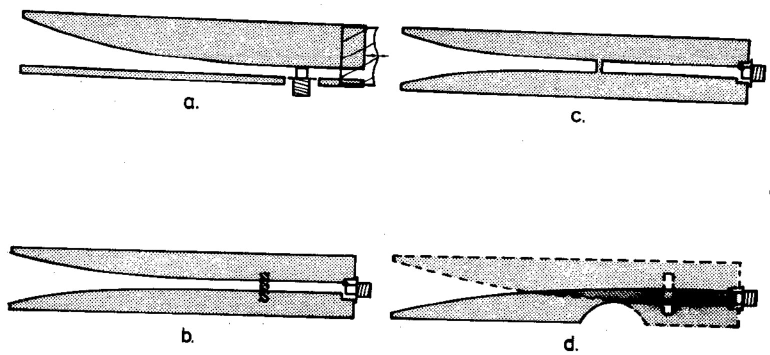

Fig. 6
General configurations of fin-line oscillators