F. Arndt, J. Bornemann, D. Grauerholz & R. Vahldieck
Microwave Department, University of Bremen, Germany

Material and Circuit Evaluation for Millimetre-Wave Applications: A Broadband Fin-Line Mixer for Millimetre Waves*

Abstract A low-cost broadband fin-line mixer has been designed for 28 to 40 GHz operation. RT/duroid is employed as substrate material and beam-lead PIN diodes (HP 5082-2716) are used. The said mixer is well suited for millimetre-wave applications, the measured conversion loss being about 10 dB over the whole frequency band.

Résumé Un mélangeur économique à ligne nageoire à large bande a été conçu pour fonctionner entre 28 et 40 GHz. On a utilisé un substrat en RT/duroid ainsi que des diodes PIN à connexions en poutre de type HP5082–2716. Avec une perte par conversion d'environ 10 dB sur l'ensemble de la bande de fréquence, ce mélangeur est tout indiqué pour les circuits en ondes millimétriques.

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Introduction

It has already been demonstrated that wide-band, low-loss integrated circuits can be constructed for millimetre wavelengths using fin-line techniques[1,2]. Because of its advantages in terms of wide-band single-mode bandwidth, low insertion loss and production economy, as well as its compatibility with hybrid IC devices and waveguide instrumentation, this fin-line circuit is also well suited for use in receiver front ends or in broadband measuring equipment as a mixer unit.

Unlike the more complicated mixer structures reported in References 3–7, which utilise a variety of transmission lines integrated onto the substrate, the mixer described here was developed specifically for low cost as well as ease of manufacture and procurement, whilst still meeting the need for very broad band operation. Based on a single-ended mixer structure[8], the design incorporates a number of other low-cost circuits: an exponentially tapered unilateral fin-line circuit combined with a simple series capacitance adaptation to a sort of waveguide coplanar section, an inexpensive beam-lead diode (HP 5082-2716), and a simple wire, periodic-loaded low-pass filter.

The fin-line millimetre-wave mixer has a conversion loss of about 10 dB over the whole frequency band of 28–40 GHz.

Design

Figure 1 shows the fin-line mixer in section. The principal components are the tapered fin-line on RT/duroid material within a WR-28 waveguide housing (7.112 mm × 3.556 mm), the variable short-circuit at $\lambda_{fin}/4$, the beam-lead PIN diode, the IF low-pass circuit, and the LO input (shown in Fig. 4).

Figure 2a shows the approximate equivalent circuit of the mixer (without the fin-line taper) at midband frequency. The equivalent circuit of the diode, together with its characteristic data, is shown in Figure 2b (the HP 5082-2716 diode data have been converted to the chosen frequency range of 28–40 GHz).

The first design problem is to adapt the RF source to the diode input impedance. Two circuits are used: a fin-line taper and a series capacitance C_s (Fig. 2a). The fin-line taper consists of an exponentially tapered section (cf. Fig. 1). The slot width, chosen to be about 60 μm, corresponds to a characteristic impedance of about 100 Ω for the unilaterial fin-line.

The series capacitance C_s was realised by experimental optimisation using a silver blot on a photo lac layer (Fig. 3). Apart from the problem of adaption of the RF signal, C_s has to be small because it shunts the IF signal.

The LO circuit is coupled to the mixer by a waveguide flange beside the mixer housing (cf. the photograph, Fig. 4, of the designed mixer). A waveguide resonator is formed by means of a step in the height of the waveguide flange. The measured insertion loss was about 13.5 dB at 8–11 mW LO input and 400 μA direct diode current. It has to be pointed out that no optimum separation of the RF from the LO signal was sought. For this purpose, this simple waveguide circuit must be replaced by a more complicated structure (e.g. irises).

The IF signal is extracted from the diode mount through a standard, inexpensive low-pass filter (Fig. 5), which is designed according to Reference 9. The IF insertion loss is about 10 dB (direct diode current 400 μA, alternating IF current about 2.8 mA). The IF signal and the diode bias are separated by an HP bias-tee.

The measured conversion loss, shown in Figure 6, is about 10 dB throughout the 28–40 GHz frequency range.

Conclusion

A simple low-cost, fin-line broadband mixer has been designed for millimetre-wave applications. The technique presented allows one to use standard low-cost, beam-lead diodes. The measured conversion loss is about 10 dB.

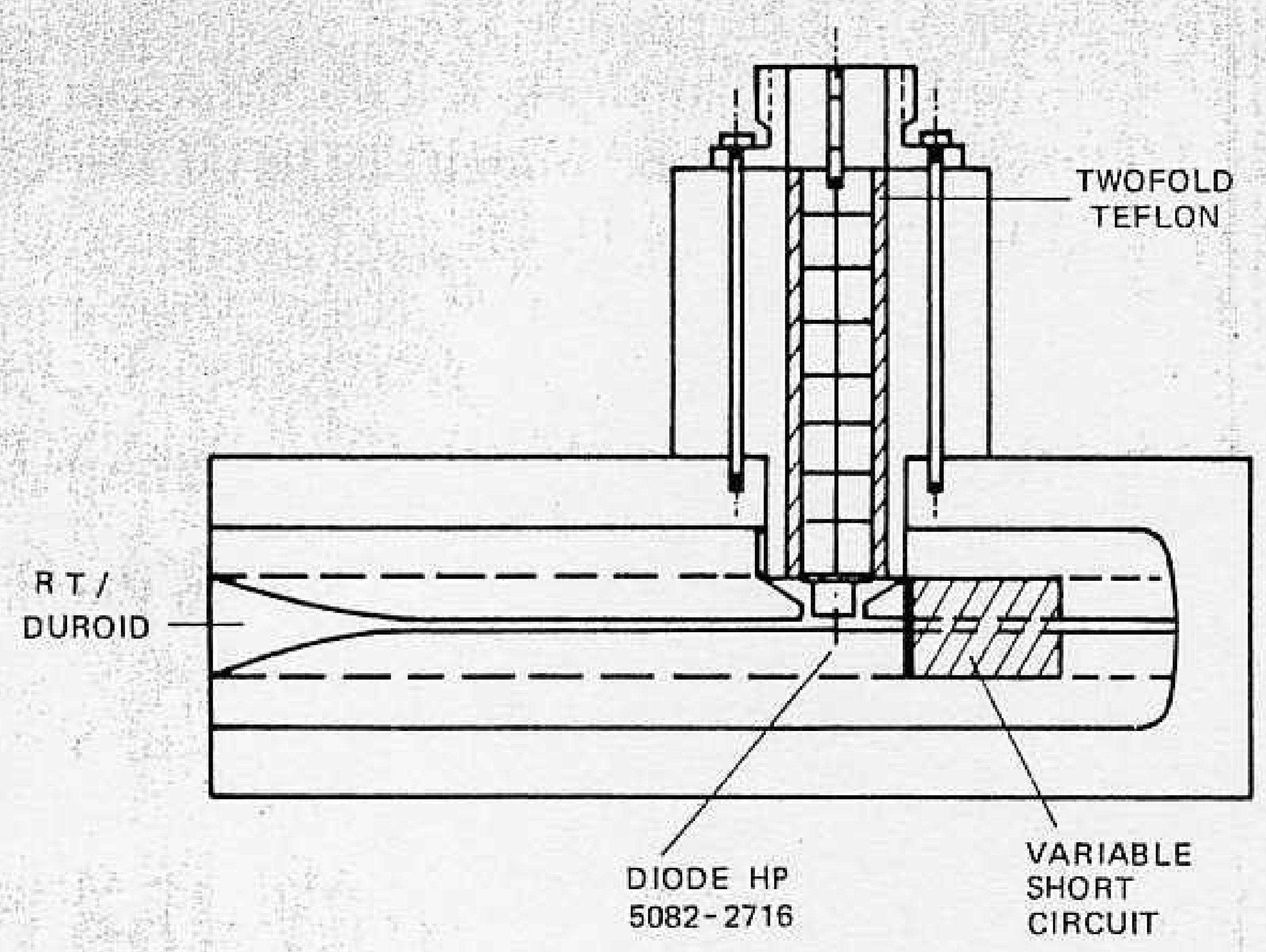

Figure 1. The new fin-line mixer for millimetre-wave (28–40 GHz) operation

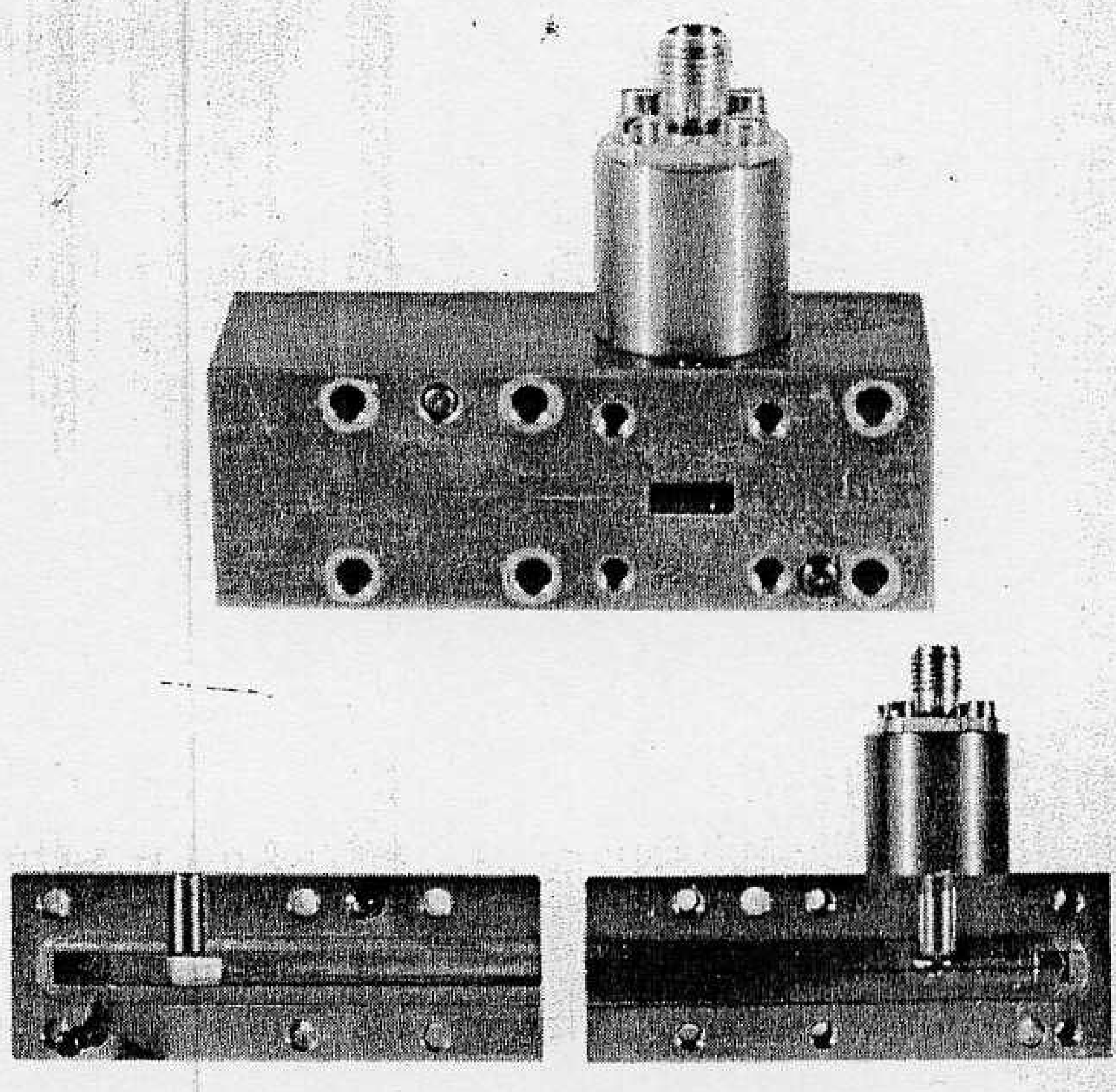

Figure 4. Photographs of the new fin-line mixer (for 28-40 GHz)

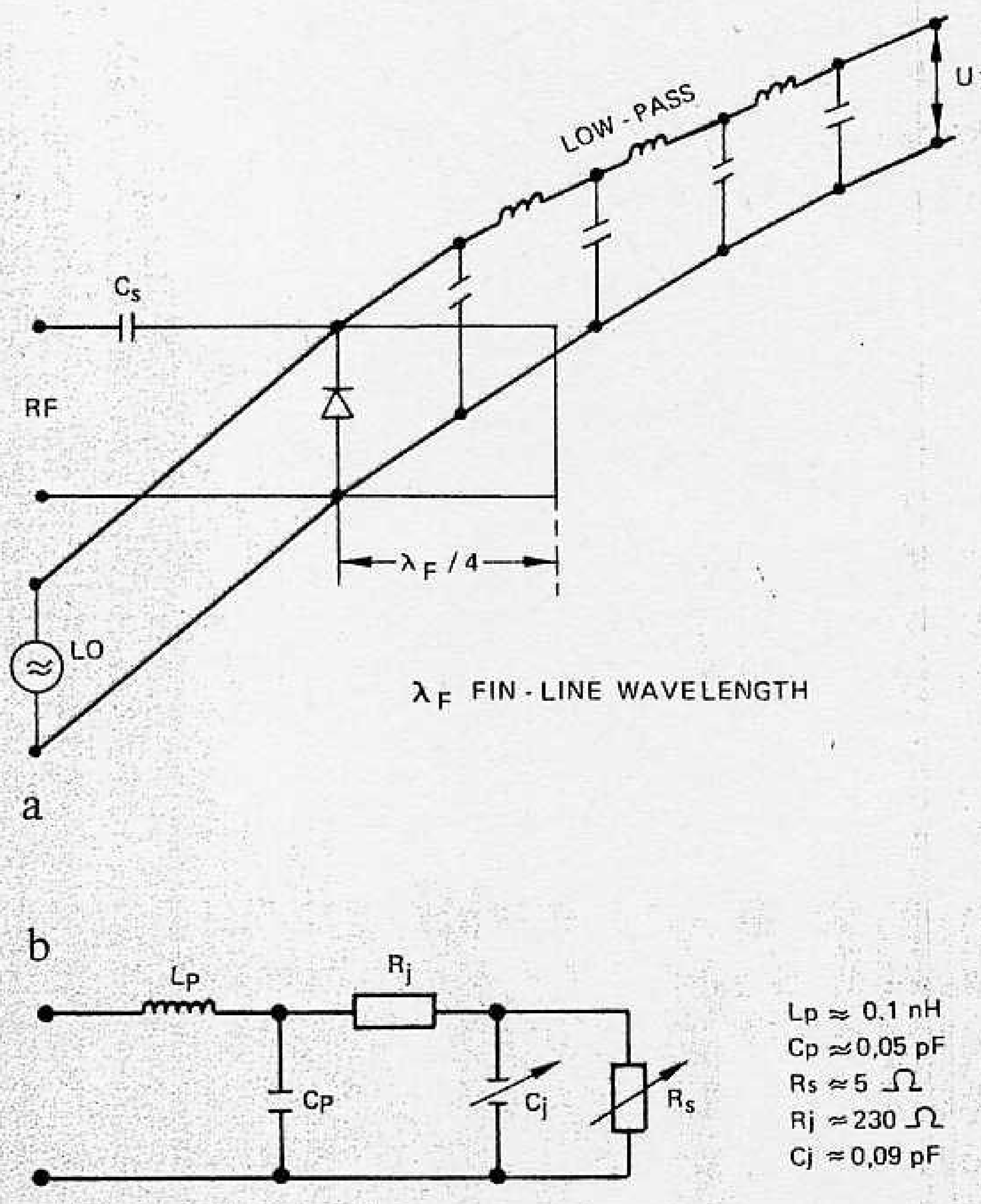

Figure 2. Approximate equivalent circuit
(a) Mixer circuit
(b) Diode (HP 5082-2716)

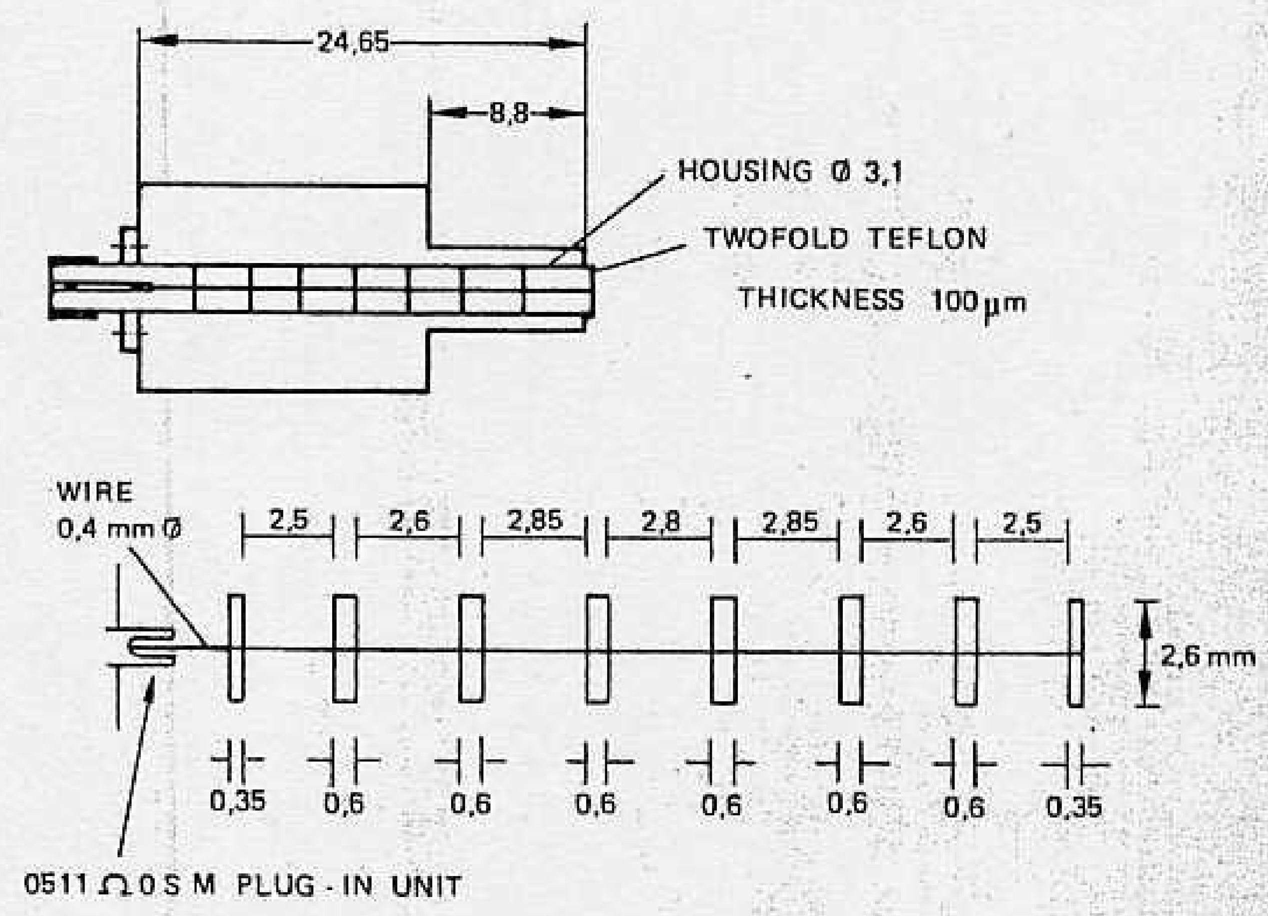

Figure 5. Low-pass design ($f = 13$ GHz) for the mixer

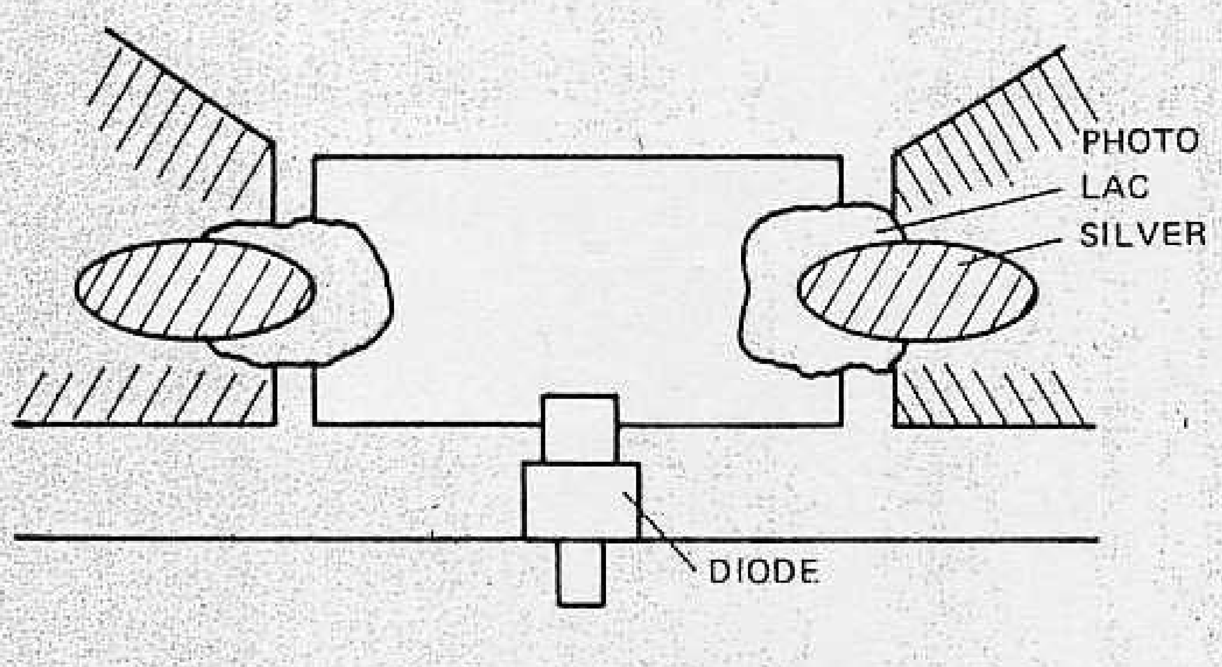

Figure 3. Realisation of the series capacitance C_s at the waveguide coplanar section in the rear of the diode (cf. Fig. 1)

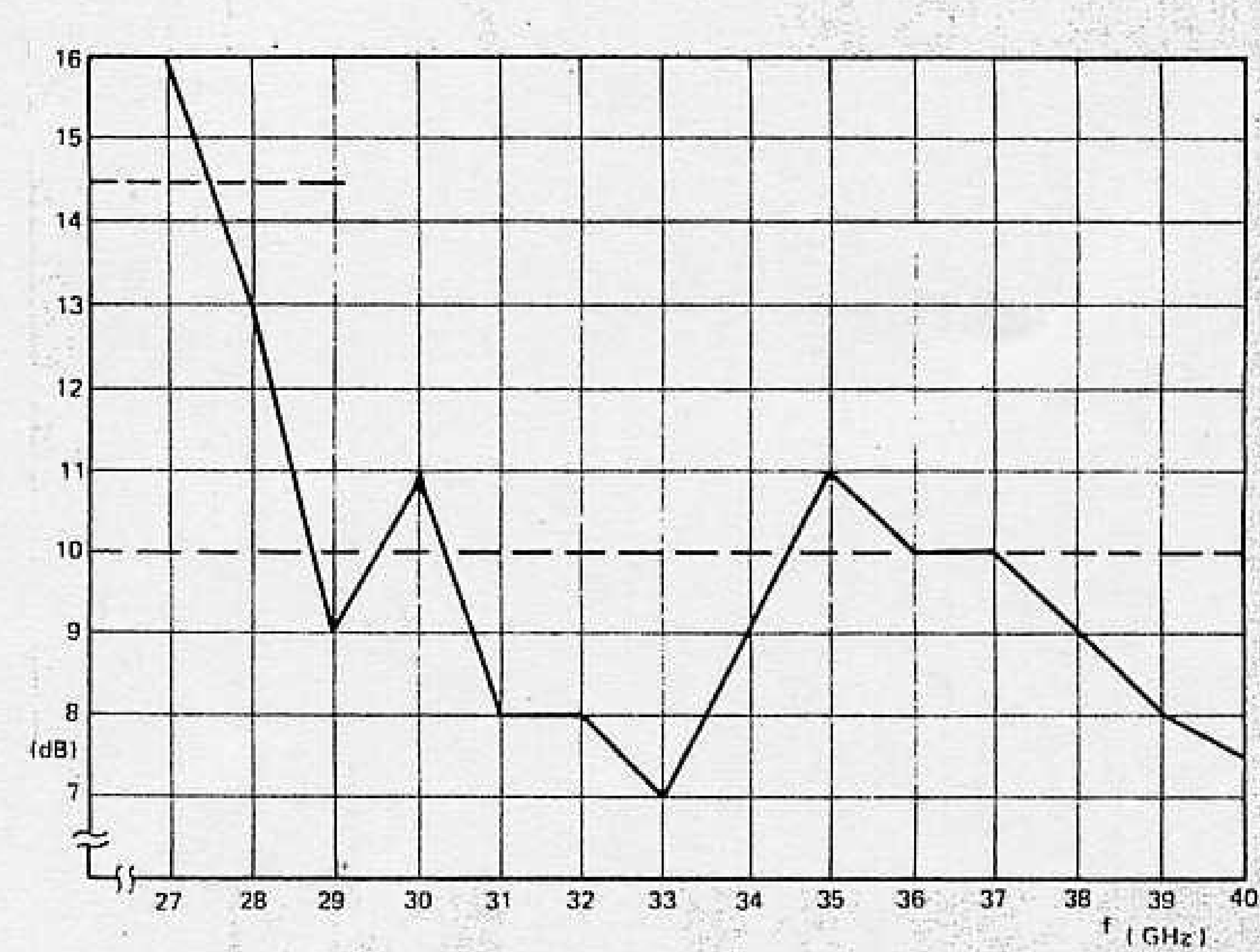

Figure 6. Measured conversion loss for the fin-line mixer as a function of operating frequency

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