INTEGRATED FIN-LINE MILLIMETER COMPONENTS

Paul J. Meier
AIL, a division of Cutler-Hammer
Melville, New York 11746

Abstract

A PIN attenuator and band-pass filter have been developed to demonstrate the advantages of integrated fin-line over microstrip at millimeter wavelengths. These advantages include lower loss, less stringent tolerances, and better compatibility with hybrid devices.

Integrated fin-line has been proposed as a superior transmission line for the construction of millimeter integrated circuits.[1,2] The advantages of integrated fin-line over microstrip at millimeter wavelengths include lower loss, less stringent tolerances, better compatibility with hybrid devices, and the ability to obtain a simple transition to standard waveguide. This paper will describe some basic millimeter components which have been developed to demonstrate the capability of integrated fin-line.

Figure 1 shows the cross-section of a fin-line structure which is suitable for mounting semiconductor devices. Metal fins are printed on a dielectric substrate which bridges the broad walls of a rectangular waveguide. Unlike slot-line,[3] fin-line is a nonplanar transmission line in which the metal walls have a strong effect upon the propagation characteristics. The substrate material can have a low dielectric constant, which eases tolerance problems at millimeter wavelengths. In the structure shown, the upper fin is insulated from the housing at dc by a dielectric gasket, but is grounded at RF by choosing the thickness of the broad walls to be a quarter wavelength in the dielectric medium. Bias may be applied to a semiconductor device mounted between the insulated fin and lower fin, which is directly grounded by a metal gasket. Nylon screws hold the halves of the housing together and align the substrate and its associated gaskets.

Figure 2 shows the test fixture which was constructed to experimentally demonstrate the capability of millimeter components constructed in integrated fin-line. The fully assembled fixture is shown adjacent to a duplicate set of components. The housing mates directly with two standard WR28 waveguides and has identical inner dimensions (0.14 × 0.28 inch). The substrate is cut from a 0.010-inch sheet of laminate (Duroid 5880) and includes six mounting holes and two stepped edges. The latter protrude into the abutting WR28 waveguides and serve as quarterwave transformers. After establishing a low-reflection transition between WR28 waveguide and a slotted waveguide loaded by a dielectric slab (d/b = 1.0), the substrate metallization is tapered until the desired gap between the fins is obtained. The illustrated transitions at the ends of the substrate are each three wavelengths long near the middle of the instrumentation band (33 GHz). The measured VSWR of each transition is 1.2 or better across the 26.5 to 40 GHz band. A more compact transition is feasible with quarterwave transformers substituted for the fin-line taper. The substrate metallization also includes an RF-blocking network connected to the upper fin.

To demonstrate the compatibility of integrated fin-line with semiconductor devices, two beam-lead PIN diodes (Alpha D5840B) were mounted across the fins near the center of the previously discussed substrate (d/b = 0.1). The diodes were spaced a quarter wavelength apart at a frequency near the lower end of the instrumentation band. The measured insertion loss of the PIN fin-line attenuator is plotted in Figure 3 as a function of bias, with frequency as a parameter. At the lower end of the band, the reversed-bias insertion loss of the attenuator is only 0.3 dB, thereby demonstrating the capability of constructing low-loss semiconductor mounts in fin-line. As the bias is varied in the forward direction, the attenuation varies smoothly over a 14-dB range throughout a 20-percent band. It is believed that the performance of this preliminary circuit could be significantly improved by substituting lower capacitance diodes (such as the D5840E) and by optimizing the diode spacing and fin-line gap. The encouraging data that has been obtained suggests that more complex circuits such as phase shifters, amplifiers, mixers, and local oscillators can be successfully constructed in fin-line by low-cost batch techniques.

In fin-line circuits where semiconductors are not required, lower loss can be obtained by printing the fins on both sides of the dielectric substrate and grounding these directly to the housing.[2] To supplement the earlier measurments of unloaded Q performed in the 3-cm band, the insertion loss of integrated fin-line has been measured in the 9-mm band.[4] By accurately measuring the insertion loss of two fin-line transmission fixtures of different length, the loss has been found to be 0.1 dB/wavelength for grounded fins with d/b = 0.1. This corresponds to an unloaded Q of 273, which is in agreement with the X-band cavity measurement of 250 (which included iris loss).

To demonstrate the capability of constructing low-cost passive millimeter components in integrated fin-line, various filter components were printed on 0.020-inch Duroid (Figure 4). One- and four-pole inductively coupled filters are shown at the center of the photograph, surrounded by four substrates, each printed with a single inductive element. By measuring the insertion loss of these elements across the 26.5 to 40 GHz band, families of design curves were generated to present the shunt susceptance as a function of strip width, with free-space wavelength as a parameter.

Figure 5 shows how the shunt susceptance (normalized to the characteristic admittance of the fin-line) varies with respect to the strip width (normalized with respect to the wide inner dimension of the housing) for the special case of d/b = 1.0. Larger values of B/Y_0 can be obtained for a given w/a by reducing d/b, but only at the expense of the unloaded resonator Q. Additional one-pole resonator measurements have been performed to determine the unloaded resonator Q and the reference plane at which the inductive strip can be modeled as a pure shunt susceptance.

Based upon the characterization of fin-line filter elements and published design curves[5], a four-pole, equal-element filter has been constructed and tested. Figure 6 compares the calculated response with some preliminary measurements. The calculation was performed by a computer-aided technique which solves for the overall ABCD matrix of the entire filter network including:

- Shunt susceptance of each filter element and its variation with respect to frequency
- Offset between the electrical and mechanical centerlines of the inductive elements
- Variation of guide-wavelength with respect to frequency, which is known accurately for d/b = 1.0[2, 6]
- Unloaded resonator Q of 350 (based upon one-pole measurement).

The good agreement that has been obtained between the four-pole measurements and theory indicates that integrated fin-line is a suitable medium for constructing low-cost millimeter filters, particularly for those applications where the unloaded Q is not critical or close integration is desired with hybrid circuits.

In summary, this paper has described some examples of simple millimeter components constructed in integrated fin-line. The encouraging performance obtained during this preliminary program suggests that fin-line construction techniques may be profitably employed in a wide range of millimeter components and systems. Integrated fin-line is clearly superior to microstrip at millimeter wavelengths where the former offers lower loss, less stringent tolerances, simple waveguide interfaces, and better compatibility with hybrid devices.

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References

1. P. J. Meier, Digest of IEEE 1972 G-MTT Symposium, p 221-223, May 1972.
2. P. J. Meier, Electronics Letters, Vol 9, No. 7, p 162-163, 5 April 1973.
3. S. B. Cohn, IEEE Trans, Vol MTT-17, p 768-778, October 1969.
4. D. Fleri, AIL Internal Memo, October 1973.
5. J. J. Taub, Microwave Journal, November 1963.
6. P. H. Vartanian, et al, IRE Trans, Vol MTT-6, p 215-222, April 1958.

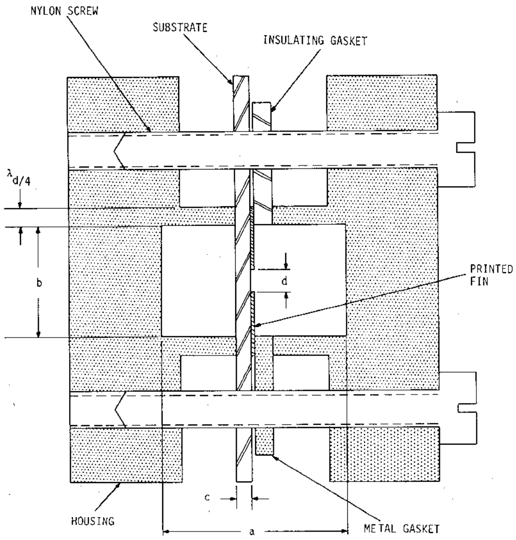

Fig. 1. Integrated fin-line with insulated fins

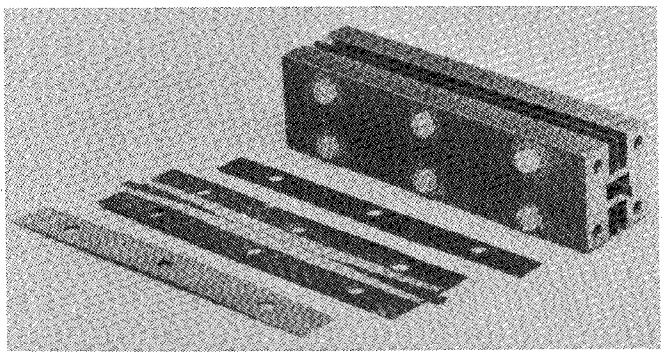

Fig. 2. Fin-line test fixture

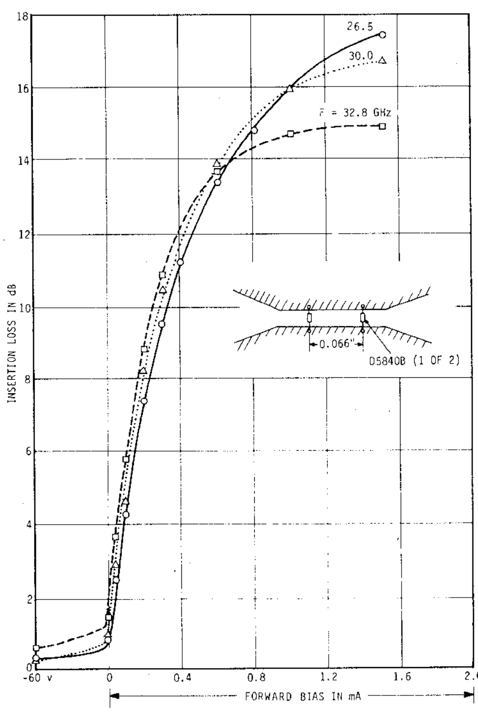

Fig. 3. Insertion loss of fin-line attenuator

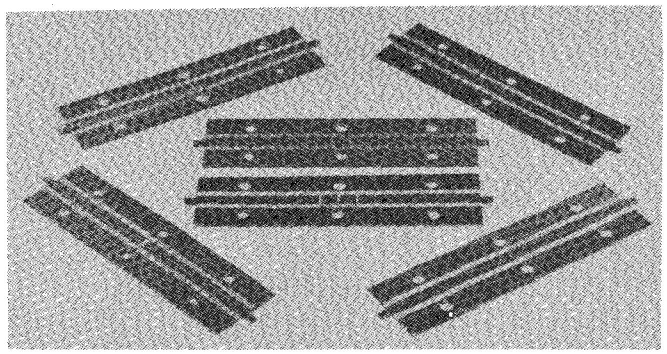

Fig. 4. Filter components

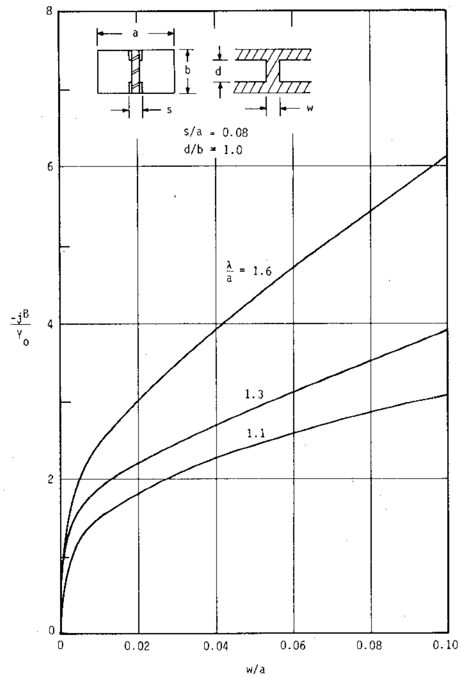

Fig. 5. Susceptance of inductive elements

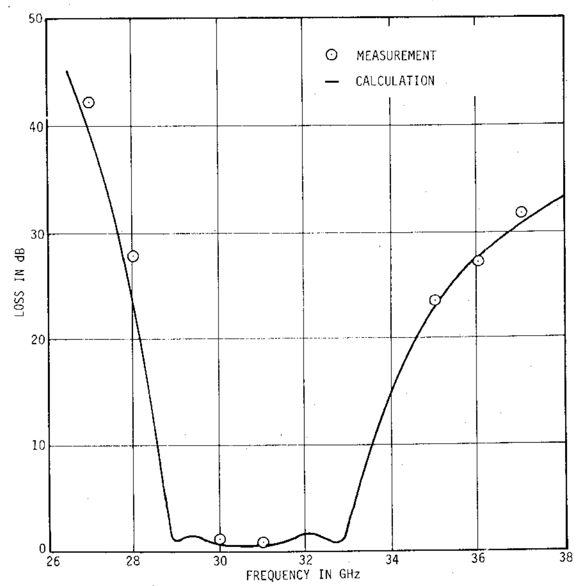

Fig. 6. Response of four-pole filter