ASYMMETRICAL STRUCTURE FIN-LINE : AN ALTERNATIVE FOR SATELLITE APPLICATIONS

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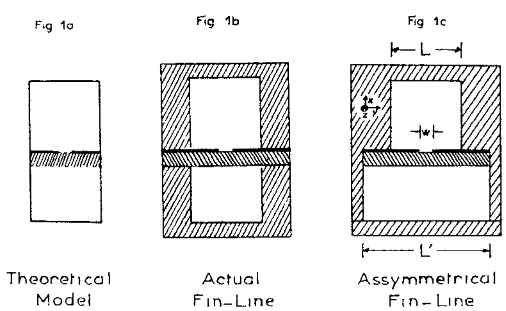
Summary

A new kind of fin-line has been developped, compatible with classical M.I.C. technology : the dielectric substrate is soldered in an asymmetrical wave-guide.
We first expose the reasons which, in space applications, lead to this structure.
Then we present a theoretical model, based on spectral domain analysis, and we compare the Electromagnetic Field distribution of the new line and of classical line.
At last a 4/20 GHz Up converter is presented, using the Asymmetrical Structure Fin-Line (ASFL).

Introduction

Since Meier has proposed the Fin-Line as an alternative for millimetric circuits (1), many active and passive devices have been presented, using this versatile transmission line: mixers (2), (3), oscillators (4), (5), filters (6), (7).
On the other hand various theories have been proposed for the line and for the analysis of discontinuities.
The conventional Fin-Line is shown in fig. (1-a) but in most applications soft substrates, with low dielectric constant, are inserted between two half-rectangular wave-guides fig. (1-b).



To transpose this technology into space domain, one must overcome three problems :
- The temperature behaviour of soft substrates related to the ageing of circuits.
- The mounting of active components : thermo - compression or soldering is often destructive for beam leads on soft substrates, and satellite quality level cannot be guaranteed.
- The electromagnetic compatibility : the isolation provided by the notches is not wide-band. So external fields can be coupled to the Fin-Line.

The solution for bonding may be to stick the components ; to improve the electromagnetic compatibility one has to isolate the Fin-Line groves.

The alternative we propose, is to use hard, space qualified substrates (fused silicate, Alumina) soldered in quasi-rectangular wave-guide boxes as in fig. (1-c) ; the mounting of components is well known and the mechanical and thermal behaviour are satisfactory.
Moreover, the Electromagnetic isolation of the line is quite better.

However a question arises : do the asymmetry of the structure and the high dielectric constant increase the discontinuity with the input wave-guide, and affect the electrical performances of the line ?

We show in the third part that good results can be performed on 20 % bandwidth with an alumina substrate of 0.254 mm thickness around 20 GHz.

A.S.F.L. analysis and electrical performances

1) The A.S.F.L. is analysed using the spectral domain technic :
The propagation constant is extracted from algebraic equations that relate Fourier transform of the currents on the fins to those of the electric fields at the dielectric-air interface.
In a first time, we get basis functions (Ez, Hz) which satisfy to the boundary conditions on the walls of the wave-guide (Et = 0, Hn = 0).
Then we obtain the transverse components (Ex, Ey and Hx, Hy) in terms of Ez, Hz.
Afterwards from the continuity conditions at the interfaces we derive :
- The complex Fourier coefficients of the fields.
- Two coupled algebraic equations :

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$$Y_{yy}.\tilde{E}_y + Y_{yz}.\tilde{E}_z = j\,\omega\mu_0\tilde{J}_y$$
$$Y_{zy}.\tilde{E}_y + Y_{zz}.\tilde{E}_z = j\,\omega\mu_0\tilde{J}_z$$

$\tilde{J}_y$ and $\tilde{J}_z$ are Fourier current densities.
Y_{ij} include the Fields amplitudes.

We verify that the equations established for this study of A.S.F.L. are compatible with some results published in the case of conventional unilateral Fin-Line. (8)

Then, applying Galerkin's method to this system, we derive an eigen value equation and obtain the dispersion characteristics .

At last we calculate the characteristic impedance by the usual definition :

$$Zc = V^2/2P$$

2) Electrical performances of A.S.F.L. are compared with those of a conventional unilateral Fin-Line.
The connecting waveguide is WR42, the substrate is 0.254 mm thickness Alumina.

The characteristic impedance (fig. 2), the effective dielectric constant (fig. 3), the bandwidth of the fundamental mode (fig. 4) are plotted versus L'/L at 20 GHz.

The analysis of the curves Zc (L'/L) and εeff (L'/L) shows that Zc and εeff depend especially on W/L parameter when L'/L (asymmetry of the structure) has a limited influence.

On the other hand the bandwidth of the fundamental mode can be slightly improved by acting on L'/L.

We note that this improvement is obtained with Zc nearly constant, so without dismatching the A.S.F.L. and the feeding waveguide.

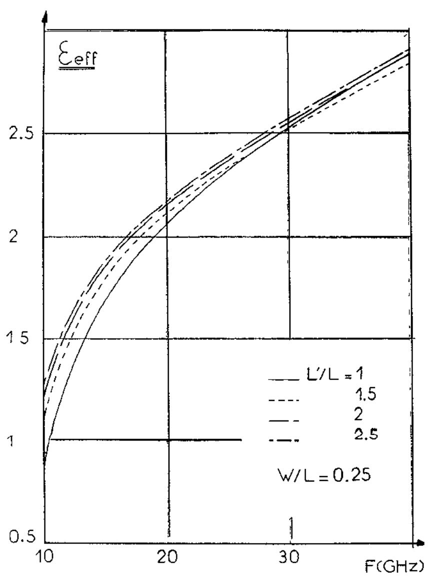

FIGURE 2 : εeff vs. L'/L

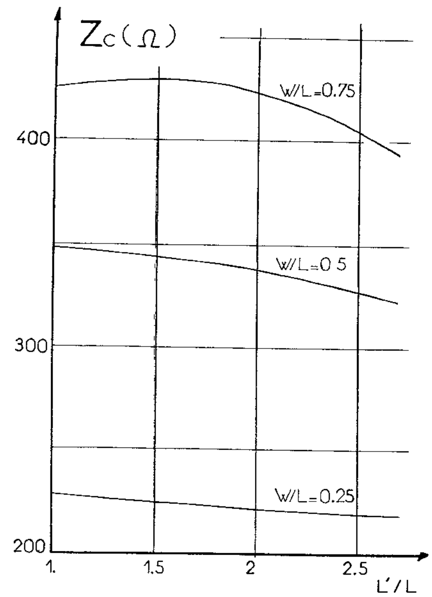

FIGURE 3 : Zc vs. L'/L

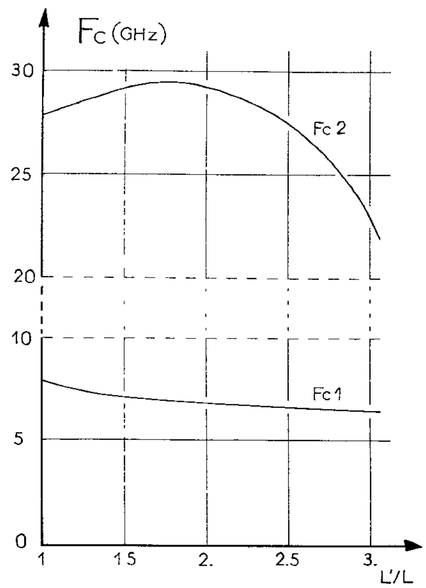

FIGURE 4 : Cutoff frequency of dominant and first higher order mode vs. L'/L ; W/L = 0.25

Furthermore, we compute the dispersion curves εeff (F) of the two types of line, between 10 and 40 GHz (fig.5).

In all cases (L'/L = 1.5, 2.0, 2.5) the asymmetrical line is better than the symmetrical one :
the dispersion rate is 0.039 εr/GHz when it is 0.047 εr/GHz for the classical Fin-Line between 20 and 30 GHz.

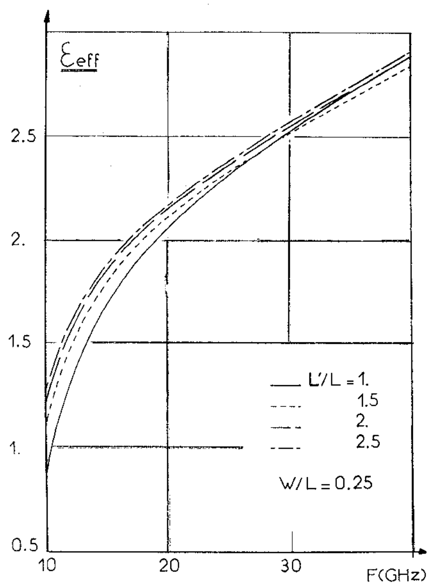

FIGURE 5 : Dispersion characteristics of effective dielectric constant

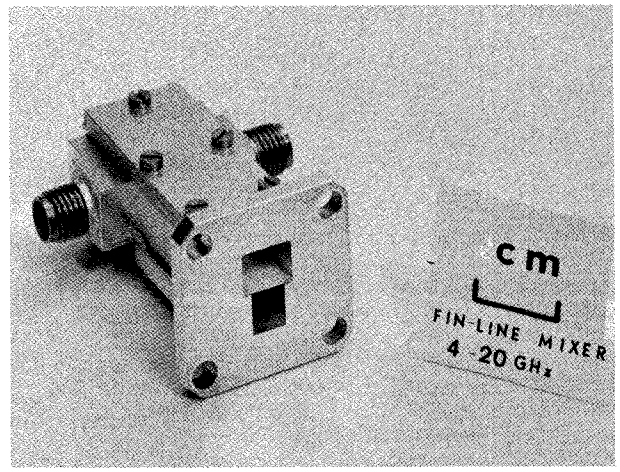

FIGURE 6 : 4/20 GHz Mixer

Application to a 4/20 GHz Mixer

We have applied the A.S.F.L. to the design of a 4/20 GHz mixer using the well known Coplanar Fin-Line junction. The dielectric is 0.254 mm thick Alumina. The L'/L ratio is 1.5 in WR 42 waveguide See fig 6.

a : Fin-Line excitation :

To calculate the transition from the rectangular waveguide to A.S.F.L. we use the pseudo-impedance $V^2/2P$ model for the two media : a quarter wave pure dielectric transformer compensates for the dielectric and structural discontinuities (a small correction is necessary to take into account a capacitive effect). Then a continuous taper lowers the impedance. See fig 7.

A double transition exhibits a return loss better than 17 dB between 17 and 21 GHz with a 10 mm total matching circuit.

b : Mixer

This **Up** converter translates the signal from 4 GHz to 20 GHz.

A Coplanar directional filter couples the input signal (at 4 GHz) with the L.O. (16 GHz).

The mixer uses Thomson GaAs Schottky diodes.

It exhibits 4.5 dB losses in 1 GHz bandwidth and less than 7 dB in the total 2.5 GHz bandwidth ; see fig 8.

The intercept point is 16 dBm with at least 14 dBm local oscillator power.

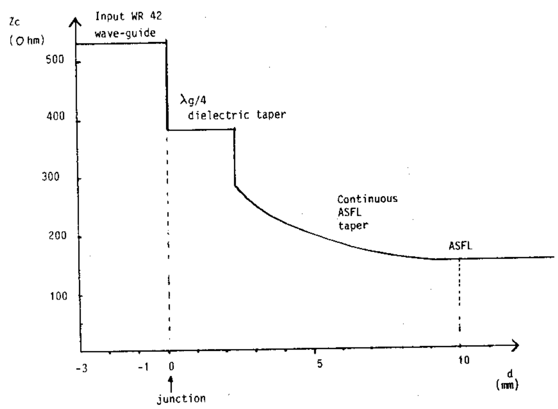

FIGURE 7 : Impedance profile of transition vs. the distance from junction

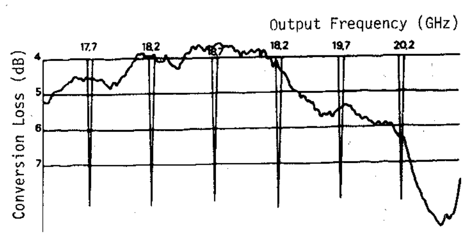

FIGURE 8 : Conversion loss of 4/20 GHz mixer

Conclusion

Let us recall the advantages of the A.S.F.L.
- Better mechanical behaviour and reliability for space applications.
- Better adaptability for mounting of active components.
- Improvement of the electrical performances.
- Better Electromagnetic Compatibility.

Furthermore we have shown an application of A.S.F.L. to the design of a mixer at 20 GHz.

Other applications are possible in the active domain (oscillators, mixers) as well as in the passive one(filters) and so for millimetric wavelength (up to 100 GHz).

Acknowledgements.

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