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DESIGN OF VERY HIGH PERFORMANCE PACKAGES FOR MICROWAVE GAAS IC's

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Abstract

In microwave applications, specific high performance packages have to be designed in order to reduce parasitic reflections, coupling effect ... In this paper, the design of a package for microwave applications up to 12 GHz is presented. From the geometry of different leads and dielectric properties, an electromagnetic simulator is used to derive propagation characteristics.
Results are discussed in terms of signal degradation, coupling and cross talk. Our analysis points out the stronger limitation of performance due to curved leads especially for high frequencies.
The influence of the connection layout in the signal degradation for a transmission through the package and the cross coupling between leads are analyzed.

Introduction

The design of specific packages is essential for microwave and high speed applications where a minimum signal degradation is required. For such applications, the characteristic impedance of leads must be constant to avoid parasitic reflections, and the layout of the chip connection has to be optimized to reduce cross talk. This fact leads to increasing demands in electrical modeling of packages, in order to predict performances of device and systems before their assembly. The use of electromagnetic simulations provides designers of microwave and high speed devices with electrical models, which include propagation characteristics, parasitic inductances and capacitances, coupling effect, etc...[1]
We present a general methodology of modeling a microwave package and the influence of different parts on the electrical performance for microwave applications. The methodology is base on the use of an electromagnetic simulator based on the Integral Equations technique associated with the Method of Moments. This technique has been applied successfully to a S08 package for Radiofrequency applications [2]. To illustrate the use of this methodology, a MS16L is analyzed. Results are presented and discussed in terms of propagation characteristics, signal degradation, coupling and cross talk.

Electrical modeling methodology

A The analyzed MS16L package

The top view of the analyzed package is presented in Fig. 1.

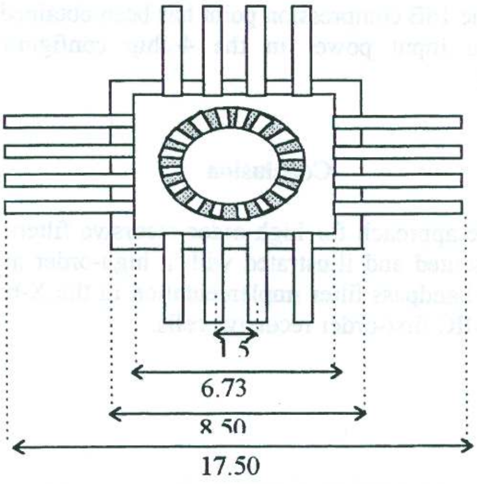


Fig. 1 a) : Top view of the MS16L package (Dimensions are in mm)

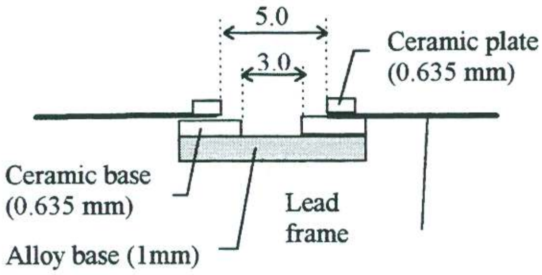
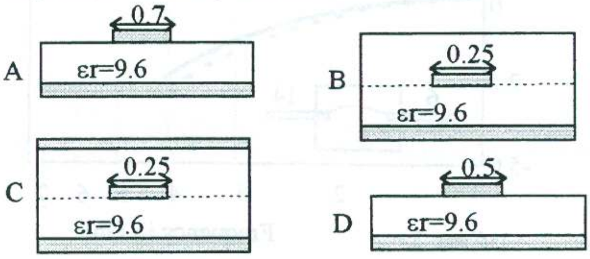


Fig. 1 b) Transversal cross section of the MS16L package

For the analysis of the propagation through the leadframe, each lead subdivided into different part

A, B, C and D corresponding to the presence of different dielectric materials. Part A is a standard uniform microstrip line, parts B and C correspond to buried microstrip lines (with a second ground plane on the top for part C), and part D is a tapered microstrip line. To avoid variations in the characteristic impedance through the lead, the strip width has to be modified accordingly.

Fig. 2 a) : Geometry of a lead



dielectric thickness : 635 µm
strip thickness : 12 µm

Fig. 2 b) Transversal cross section of parts A- D

For each part, our modeling methodology consists in three following steps :

i) calculation of electromagnetic field components,

ii) calculation of the series and parallel, admittances by integration of electromagnetic fields,

iii) derivation of Rc, α, and β.

B Electromagnetic modeling with the Method of Integral Equations

The method of integral equations (MIE) was developed to solve Maxwell's Equations in a multiconductor structure. Let us consider a system of conductors in a multilayered medium as shown in Fig. 3.

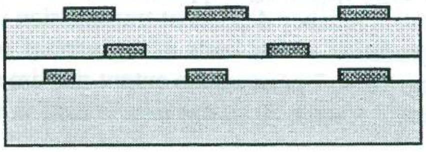


Fig.3 : General structure analyzed by the MIE

Integral equations are the solutions of the propagation equation in terms of vector and scalar potentials, expressed in function of the charge and the current densities on different conductors .
Conductors are discretized in rectangular elements, in which the charge or the current densities are assumed to be constant. Integral equations relates the scalar and vector potentials in any point of space to the current density of each conductor elements. The method of moments in used to solve the integral equations and L, C matrices are calculated from electromagnetic fields.
For a multiconductor system, L and C matrices are defined as following :

$$[V]=[L]\,[dI/dt] \qquad [Q]=[C][V]$$

where Vi, Ii, and Qi are voltage, current and charge on conductor number i, Lij and Cij are Maxwell-defined inductance and capacitance coefficients.
For use in circuits simulators, Kirchoff-defined L-C matrices are deduced. In that case Lij and Cij are related to the voltage drop between conductors i, and j. The new L- C matrices are deduced from the previous matrices by the following relations :

$$C'_{ij}=-C_{ij} \text{ for } i\neq j, \quad C'_{ii}=\sum C_{ij}$$
$$L'_{ij}=L_{ij}$$

Analysis of package performance.

The package electrical performance is analyzed in terms of propagation characteristics, signal degradation, coupling and cross talk.

A Propagation characteristics

Assuming a lossless dielectric material with a dielectric permittivity εr=9.6, propagation parameters for different parts has been calculated and reported in table 1a and 1b

Table 1a : Inductance and capacitance per unit length

	W(µm)	C(pF/cm)	L(nH/cm)
Part A	700	1.77	4.00
Part B	250	1.669	5.90
Part B	250	2.14	5.00
Part C	500	1.49	4.62

Table 1b : Characteristic impedance and propagation time

	W(µm)	Rc(Ohms)	Tc(ps/cm)
Part A	700	47.6	84.0
Part B	250	59.2	99.9
Part B	250	48.3	103.3
Part C	500	55.7	82.9

When the strip width varies from 250 µm to 700 µm, the characteristic impedance varies from 47 to 60 Ohms according to the configuration (microstrip, buried strip or stripline).
Another significant parameter for Rc sensitivity is the dielectric permittivity εr. Here, the values of εr are 9.4, 9.6, and 9.8. Variations of Rc are illustrated in Fig. 4 a and Fig. 4 b.

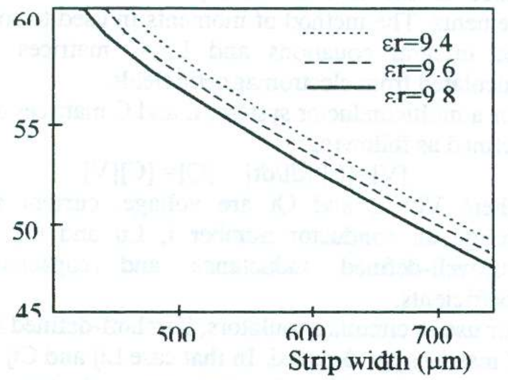


Fig. 4 a) Characteristic impedance sensitivity for microstrip model A and D

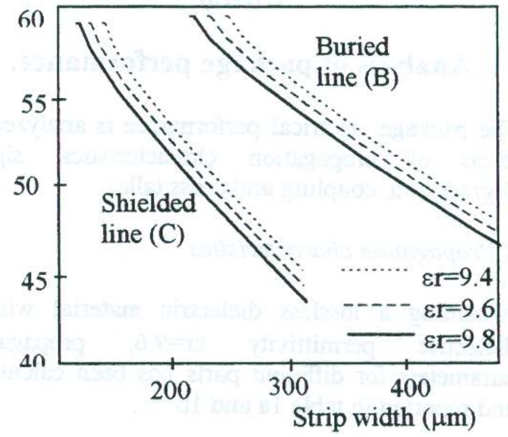


Fig. 4 b) Characteristic impedance sensitivity for stripline model B and C

Results above enable designers to control the strip width according to different dielectric layers, and according to the presence of a metallic cover or not, when a controlled impedance is required especially for microwave or high speed logic applications.

B Transmission characteristics of the package

From propagation characteristics, a simplified equivalent network consisting of lumped capacitances and inductances is elaborated, enabling the computation of S-parameters.

In order to illustrate the influence of the leadframe on the dynamic performance of the package, a 50 Ω microstrip line has been assembled with the package using wire bondings. Fig. 5 show the transmission coefficient between 2 opposite lines through the package for straight leads and for curved leads. At high frequencies, a significant contribution of the vertical part of the curved lead can be observed.

The transmission coefficient is defined as :

$$20 \log (Vt/ Vi)$$

where Vt and Vi are the transmitted and the incident voltage.

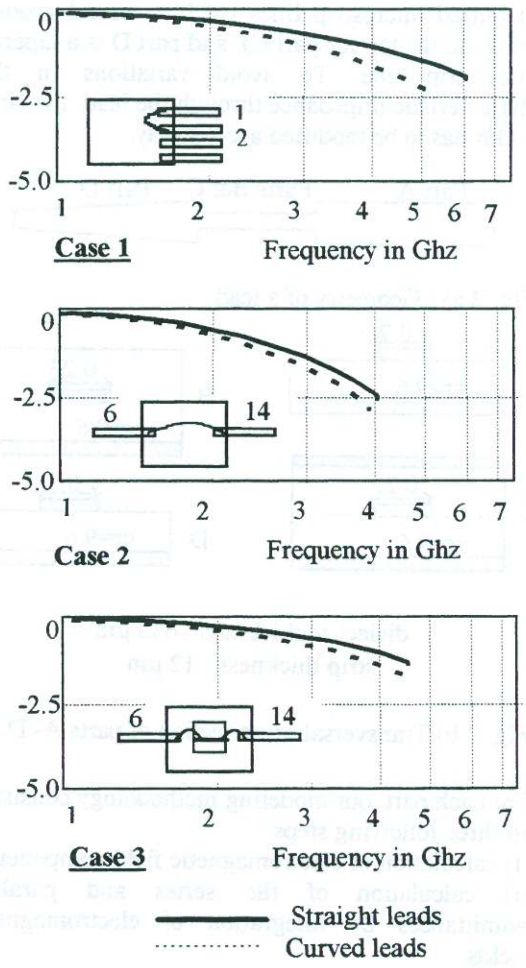


Fig. 5 : Transmission through the package - Comparison between straight and curved leads :
- case 1 : adjacent lines
- case 2 : opposite lines through a wire bonding
- case 3 : opposite lines through a 50 Ω GaAs chip

In different cases, curved leads exhibit a greater attenuation for high frequencies. This attenuation is related to an additional inductance corresponding to the vertical part of the lead.

For high speed logic applications, the consequence of the frequency dependent transmission is a signal degradation which leads to an increase of the rise time. Table 2 presents the output rise time for cases 2 and 3 when a 30 ps rise time is used as input.

Table 2 : Degradation of signal for high speed logic applications (30 ps rise time excitation)

	Straight leads	curved leads
case 2	65 ps	70 ps
case 3	50 ps	60 ps

C Coupling effect and cross talk

Let us consider the transversal section of 2 conductors in part A for example (Fig. 6).

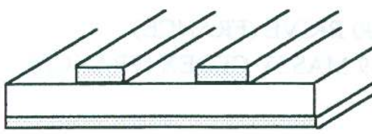


Fig. 6 : Coupled microstrip lines

Using dimensions and material properties given in Fig. 1 and 2, L and C matrices are calculated .

$$L=\begin{bmatrix} 426 & 59 \\ 59 & 426 \end{bmatrix} \text{(pH/mm)}$$

$$C=\begin{bmatrix} 152 & 8 \\ 8 & 152 \end{bmatrix} \text{(fF/mm)}$$

Corresponding electrical (Kc) and magnetic (Kl) coupling coefficients are :

Kc=0.50

Kl=0.138

Using L and C matrices calculated for the different parts of the package, and for the four leads of a transversal cross section, it is then possible to predict cross talk between leads and to perform comparison with measurements. Examples of results are given in Fig. 7a and Fig. 7b. In these plots, cross coupling is defined as :

$$20 \log (V_t/ V_i)$$

where Vt is the transmitted voltage on the quiet line, and Vi the incident voltage on the activated line.

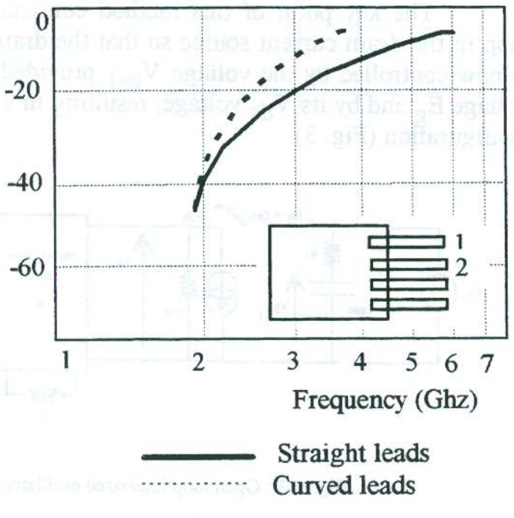


Fig. 7 a) Cross coupling for adjacent lines 1-2

Again, as for transmission, curved leads exhibit stronger limitations in performances. Here, a difference of approximately 5 dB in the parasitic signal is observed at 4 GHz.

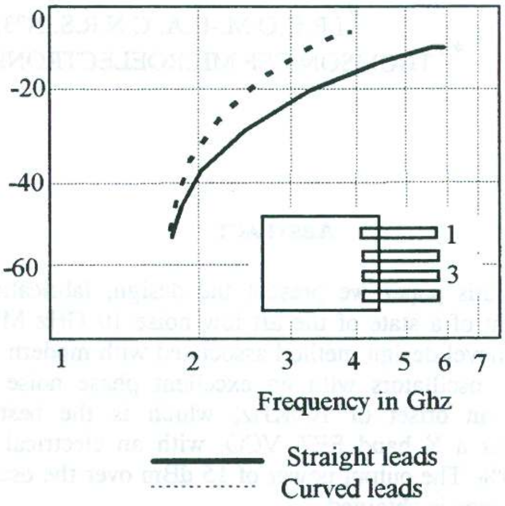


Fig. 7 b) Cross coupling for lines 1-3 with a line space

Conclusion

In this paper, the design of a MS16L package for microwave applications up to 12 GHz is presented. From the geometry of different leads and dielectric properties, an electromagnetic simulator is used to derive propagation characteristics.

Results are discussed in terms of signal degradation, coupling and cross talk. Our analysis pointed out the stronger limitation of performance due to curved leads especially for high frequencies. The influence of wire bonding in the signal degradation for a transmission through the assembly has been presented. By reducing the length of wire bondings, the transmission through a GaAs 50 Ω chip reduces the rise time degradation.

Our results enable the optimization of the package (connection layout, leads dimensions...) especially for impedance controlled and high performance applications.

References

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[2] F. Ndagijimana, J. Engdahl, A. Ahmadouche, J. Chilo, 'The inductive connection effects of a mounted SPDT in a plastic SO8 package', IEEE-MTT-S Intern. Microwave Symposium, Atlanta - USA, June 1993 , 91-94