An Improved Leaded Small Outline Package and Equivalent Circuit

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***Abstract*—A leaded plastic package has been developed that significantly improves the insertion and return loss, and pin-to-pin isolation of SO-type packages based on measured data and three-dimensional electromagnetic simulations. In addition, an equivalent circuit has been developed that accurately models the circuit behavior of the improved package to above 8 GHz.**

***Index Terms*—Circuit modeling, CoPlanar Waveguide (CPW), electromagnetic modeling, small outline (SO) package.**

I. Introduction

LEADED packages have been used for RFIC applications for many years [1]. Although frequency allocations for commercial wireless communications are increasing, the basic structure of the leaded packages has remained constant—the only improvement of RF performance has been in scaling the package smaller in size from Small Out line (SOIC) to Shrink SO (SSOP) to Miniature Shrink SO (MSSOP) form factors. This paper will introduce a new lead frame structure that transforms the traditional low-pass lead frame characteristic into one useful for broadband RFIC applications, and presents an equivalent circuit that accurately describes its electrical behavior. This is an ex tension of our previous work on plastic leaded packages [2], [3].

II. Traditional and Modified Package Structures

Fig. 1 contains the outline of a traditional SSOP8 package and modified SSOP8. An embedded microstrip line Thru was inserted to gauge the relative performance of each package. The encapsulating plastic has electrical performance similar to Sumitomo 6300H $(\epsilon_r = 3.6)$. The paddle in the traditional SSOP8 is grounded by extending pins 1, 3, 6, and 8 directly to the paddle, which are then grounded to the PC board ground with vias. A package such as this is usually modeled with coupled π-type networks each representing one pin of the lead frame [2], [4].

Two changes are proposed to improve the traditional SSOP8 pin package. The first is to maintain a constant width in the lead frame spaces, which creates an Embedded CoPlanar Waveguide with Finite Ground (ECPWFG) structure from the circuit board to the end of pins 2 and 7. The second modification is extending the plastic encapsulant to cover the lead frame bends. This provides a sufficient mechanical anchor so that the hooks at the ends of the SSOP8 lead frame can be removed. With the extension of the plastic and the constant spacing of the lead pitch, a constant impedance ECPWFG structure extends from the PC board to the wire bond location [5]. Given similar lead frame geometry and form factor, the cost associated with these changes would be a one-time change for retooling. It has be shown with measured and simulated data that this type of lead frame has broadband performance with excellent isolation characteristics [3].

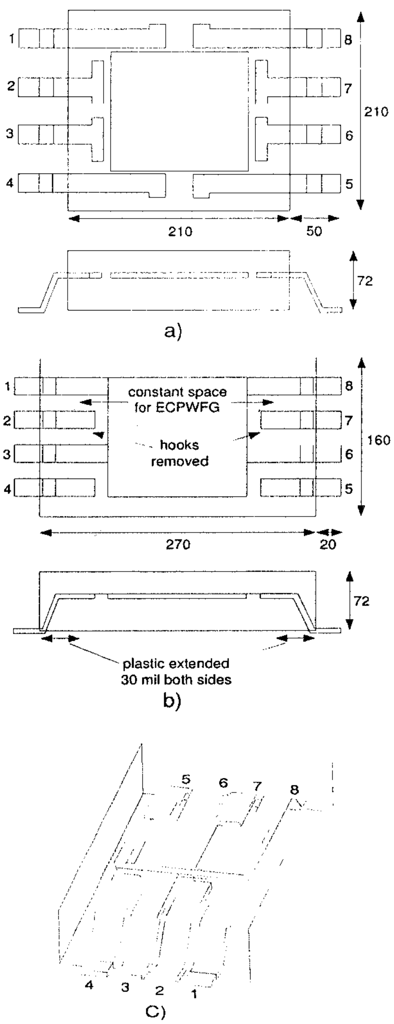

Fig. 1. Package structures: (a) traditional SSOP8; (b) proposed modified SSOP8 (ECPWFG package). Lead pitch is varied in the modified case to present 50 Ω, and packages are simulated with microstrip line Thrus as shown in the 3-D view of the modified package (c).

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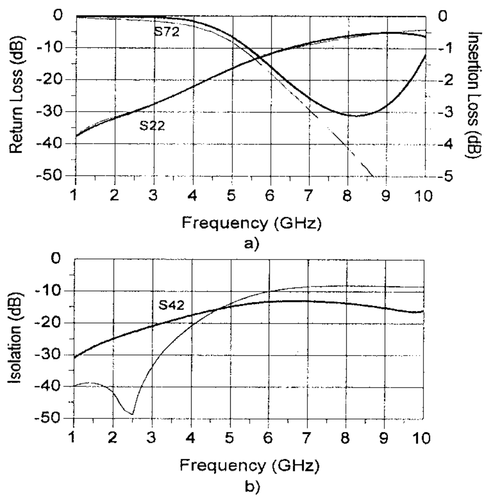

Fig. 2. Traditional SSOP8 package simulated (thin line) and modeled (thick line) responses: (a) return and insertion loss; (b) isolation.

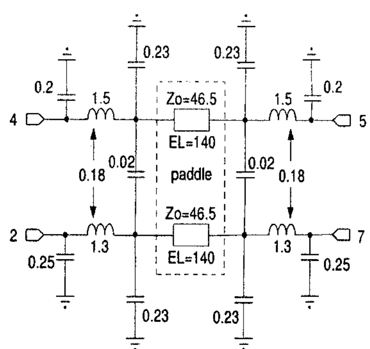

Fig. 3. SSOP8 equivalent circuit. Capacitance, and inductance is in pF and nH, respectively. Electrical length (EL) is at 10 GHz, and Z_o is characteristic impedance in Ω. Series inductances have 0.25 Ω series resistance (not shown).

III. Equivalent Circuit Model for SSOP8 Package

Three-dimensional electromagnetic simulations were per formed on both packages of Fig. 1. The simulation tool used was Ansoft *High Frequency Structure Simulator* (HFSS) [6]. The results of return loss (S22), insertion loss (S72), and isolation (S42) are illustrated in Fig. 2 for the traditional SSOP8. The useful bandwidth of the package, defined where the RL is less than 20 dB, is about 5 GHz. This confirms the value given in [7] of 4 GHz for SO-type packages.

Also included in Fig. 2 is the modeled response of the equivalent circuit in Fig. 3, using the standard π-network for SO lead frames. The lumped element values were determined from the static simulation tool Ansoft *Spicelink* [6]. Note the lead frame and wirebond inductance have been merged into one series inductance, with the coupling capacitance lumped toward the paddle. From Fig. 2(b), the model overestimates coupling below 5 GHz, and underestimates above 5 GHz. The π-network model acts as a high frequency choke due to the series inductances, and this is confirmed in Fig. 2(a), where S72 is attenuated above 5 GHz. The embedded microstrip line impedance (Z_o) and electrical length (*EL*) were obtained from analytic expressions for embedded microstrip lines [8]. Some optimization was done on the elements to improve the match, although the model provides the most accurate results below 7 GHz.

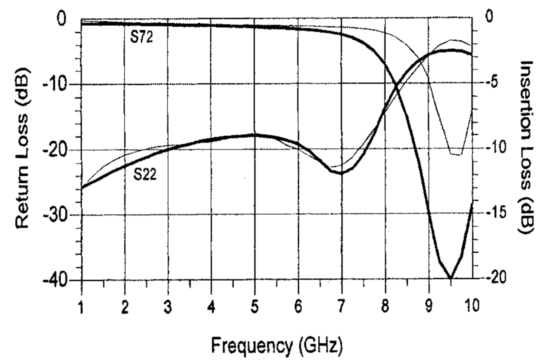

Fig. 4. Prototype ECPWFG package measured (light lines) versus circuit model (thick lines).

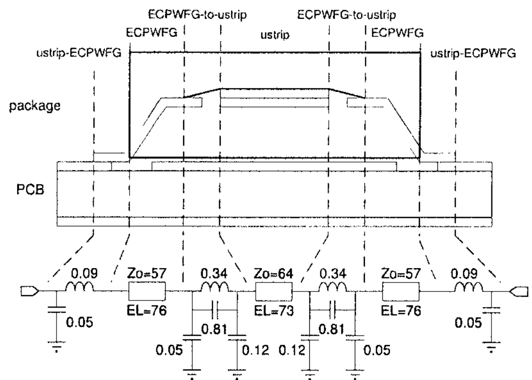

Fig. 5. Prototype ECPWFG package equivalent circuit. Capacitance is in pF, inductance in nH, Z_o in Ohms, electrical length (EL) in degrees at 10 GHz.

IV. Equivalent Circuit Models for ECPWFG Package

In order to quantify the circuit response of an ECPWFG package, a prototype was constructed and measured. The measured and modeled response is illustrated in Fig. 4, and the equivalent circuit is given in Fig. 5. All package capacitors have 2 $k\Omega$ resistors in parallel. No coupling between ports 2 and 4 were measured.

The characteristic impedance of the lead frame in the prototype was slightly off the ideal 50 Ω at 57 Ω, and the embedded line characteristic impedance of 64 Ω. These discrepancies were corrected in the HFSS simulation results of Fig. 6, where the modified package (ECPWFG) simulation performance is plotted in conjunction with an equivalent circuit response, which includes isolation. The performance is far superior than the traditional SSOP8 case and has a useful application bandwidth of over 10 GHz. The equivalent circuit is given in Fig. 7. More elements were need to capture the fine structure of the S-parameters of the improved design, such as the zero in isolation (S42) at 4.5 GHz.

The transmission line parameters of the ECPWFG lead frame in Fig. 7 is given in [5]. The *EL* was obtained from the effective dielectric constant and physical length of the lead frame. Note that the transmission line Z_o of pin 4 and 5 are $\sqrt{2}$ times ECPWFG impedance (since one lead frame ground of the ECPWFG structure is not present). Had a 10-pin package been simulated, then each side of the package could have two ECPWFG transmission lines.

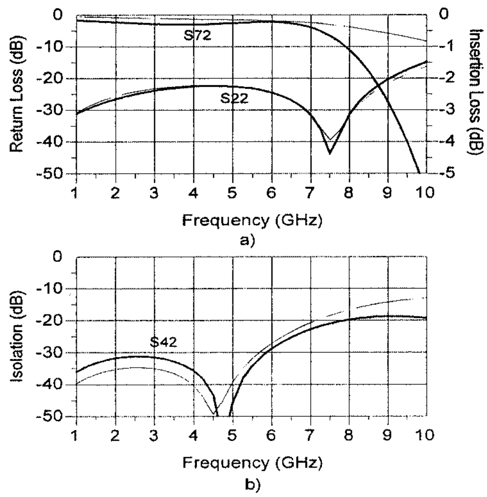

Fig. 6. Prototype ECPWFG package simulated (thin line) and modeled (thick line): (a) return and insertion loss; (b) isolation.

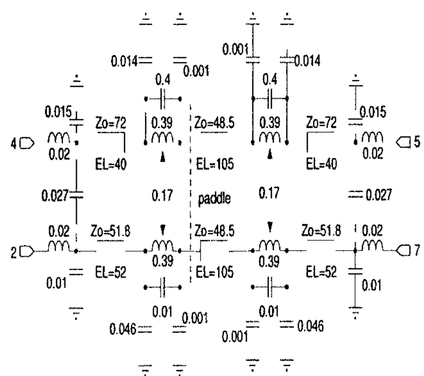

Fig. 7. Prototype ECPWFG package equivalent circuit. Capacitance, and inductance is in pF and nH, respectively. Electrical length (EL) is at 10 GHz, and Z_o is characteristic impedance in Ω. Wirebonds have 0.2 Ω series resistance (not shown).

Capacitors have been added in parallel with the wirebonds, to capture the transition from ECPWFG to embedded microstrip lines. Also, the coupling capacitors have in creased in value from the SSOP8 case, primarily due to the leads being closer (20 mil space between leads compared to 8.5 mil). However, the coupling mechanisms are dominated by the magnetic field coupling between the leads, which has been reduced due to the replacement of some series inductance with the ECPWFG transmission line. The embedded microstrip characteristic impedance and electrical length also changed from the SSOP case, because of a slight reduction in ϵ_r and the paddle being slightly smaller (120 mil compared to 90 mil). Because of the smaller paddle, the ECPWFG transmission line lead frame thus increased in length to keep the total length of the package equivalent.

Further improvements in performance can be obtained by reducing the package size to that close to the MSSOP8 dimensions. It is estimated this would improve the useful bandwidth to 15 GHz.

V. Conclusions

A new plastic leaded package design with the form factor of an SSOP8 has been developed. The package has demonstrated an increase of useful bandwidth from 5 GHz with the traditional package to over 10 GHz in the modified case. This package can be used in C-band RFIC applications where low cost and high performance are in demand.

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