Electrical Characterization of Packages for Use with GaAs MMIC Amplifiers

Rev. V4

Abstract

A test methodology will be presented which combines the advantage of on-wafer RF probing with a TRL calibration to create a completely de-embeddable, novel “test fixture” capable of electrically characterizing most any style package or device. This scheme has been used to characterize many of the currently available microwave packages in order to identify appropriate packages for our MMIC amplifier products which cover frequencies up to 12 GHz. In addition, the technique has been employed to characterize injection-molded plastic packages and to evaluate non-probeable MMIC's.

Introduction

Most package vendors have very little microwave design and characterization capability. Their limited characterization efforts typically involve the use of poor fixturing, which obscures the true frequency response of the package. Companies specializing in fixturing, while investing considerable mechanical engineering effort, expend far less on electrical considerations, often producing fixtures inadequate for use at microwave frequencies. Consequently, there is very little microwave performance data available from package vendors.

Therefore, to evaluate and identify candidate packages for each of the amplifiers in our MMIC amplifier product line, specific fixturing had to be developed for each package style considered. A novel fixturing approach was designed and implemented, which not only eliminates the need for expensive, package specific fixtures, but also overcomes the frequency limitations of traditional connectorized, plunger-style fixtures. Additionally, a rigorous calibration method was developed which allows complete fixture de-embedding.

This test methodology is applicable to practically any style device. Table 1 lists the package styles investigated. Through this work, proper electrical characterization of commonly used packages has indicated useful frequency ranges broader than expected by even the package manufacturers. This finding has allowed us to use low-cost packages for frequency applications where our competitors typically resort to high-priced custom packages.

Package Description	Manufacturer
5 lead, ceramic	Kyocera
6 lead, ceramic	Kyocera
Leadless, 6 port, ceramic	StratEdge
7 lead, ceramic	Kyocera
8 lead, ceramic	Kyocera
8 lead, glass	Mini-Systems
8 lead, glass, ground straps	Mini-Systems
Leadless, 8 port, ceramic	Oxley
Leadless, 10 port, ceramic	Alcoa

Table 1. Summary of Packages

Design Approach

To eliminate the need for expensive, device specific, traditional fixtures and overcome their frequency limitations, an RF probeable ceramic substrate was designed as the interface to the device-under-test (DUT). Figure 1 illustrates this coplanar probe to microstrip transition. It is a 50 ohm line fabricated on 10-mil thick alumina, with an 8-mil pitch, ground-signal-ground (G-S-G) probe pattern at one end. The two ground pads are connected to the substrate backside with 8-mil diameter plated vias. The G-S-G pattern can be probed using commercially available microwave probes on a standard microwave probe station. The opposite end of the substrate can be bonded to a test port of the DUT.

To complete the “test fixture,” only a thin brass block is required to serve as the mounting surface for the ceramic substrates and the DUT. If necessary, the brass block could be machined to compensate for any difference in height between the substrate and DUT test port. To fixture practically any DUT, all that is needed is a brass plate and the probeable ceramic substrates. Figure 2 shows the configuration used for characterizing our MAAM71200-H1, a packaged 7-12 GHz GaAs MMIC low noise amplifier.

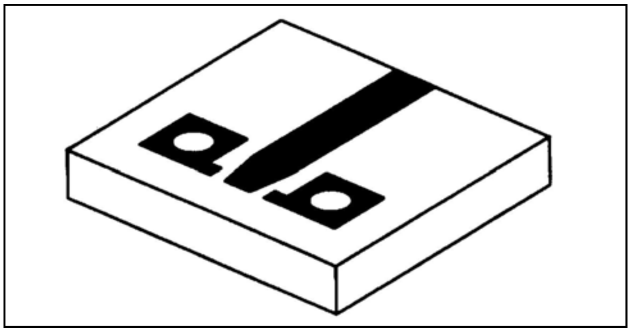

Figure 1. Probeable Ceramic Substrate

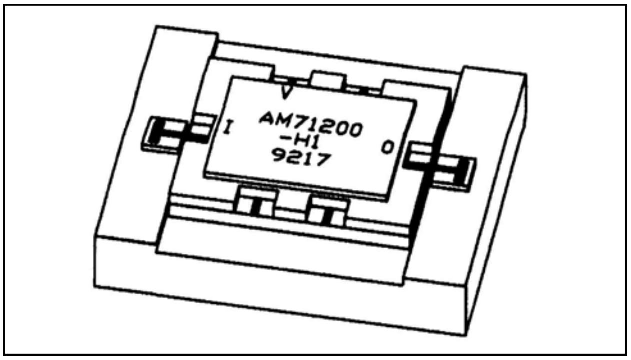

Figure 2. Fixtured MAAM71200-H1

To de-embed this "test fixture," a set of through-reflect-line (TRL) standards was employed. A "zero-length" through, a short, and two delay lines were fabricated. These standards, shown in Figure 3, are used with the common TRL de-embedding algorithm. This allows any measurement made with the probeable ceramic substrates to be de-embedded to yield data for only the DUT with connecting bonds. Bond wires can also be de-embedded by first characterizing and modeling them using this same "probeable ceramic" technique. For this work, multiple bond wire and ribbon lengths were characterized to generate fully scalable bond models.

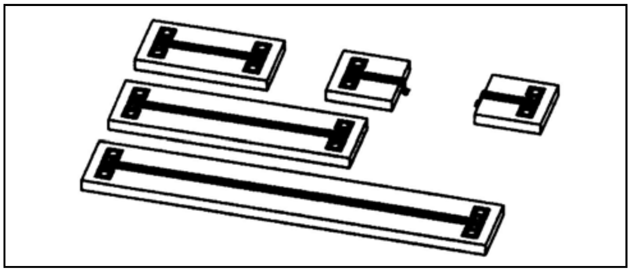

Figure 3. TRL Calibration Standards

To demonstrate the package characterization method, the evaluation of a standard Kyocera 8-lead ceramic flat pack will be examined. Figure 4 shows how one feedthrough structure in the wall of this package was tested. Package leads were cut close to the package body, and the ceramic substrates were mounted flush to the package ports. Two short 3-mil wide gold ribbons bond the substrates to the package.

Similarly, sealed packages with leads internally terminated with 50 ohm chip resistors were tested to determine the cross-coupling between opposite and adjacent leads. Through-lines within sealed packages were also measured. With this data, the true electrical performance of the package was determined and models for the feedtrhough and coupling were developed.

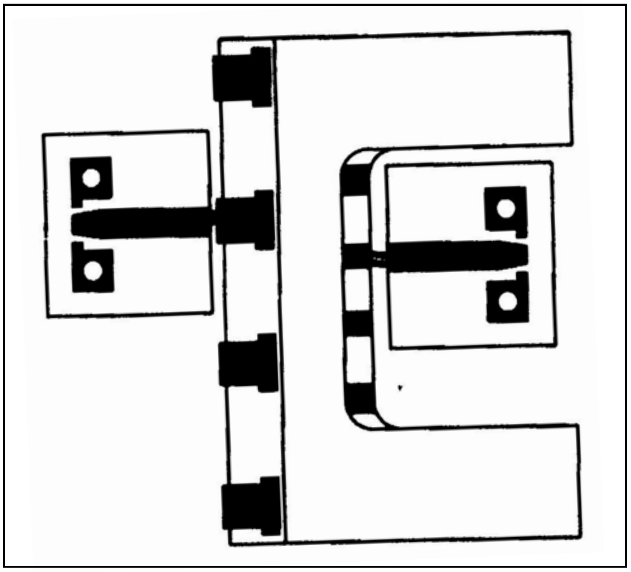

Figure 4. Fixtured Feedthrough

This information allows the identification of an appropriate package for existing MMIC products and provides an accurate model for incorporating package effects into future design work.

Experimental Results

The feedthrough walls of each package listed in Table 1 have been tested and modeled. This feedthrough data alone largely indicates the useful frequency range of each package. Figure 5 shows the frequency response for the feedthrough of the 8-lead ceramic flatpack. This package, previously thought to be useful only at lower frequencies, demonstrates excellent performance well into X-band before resonating. Based on this result, we assembled our 2-8 GHz GaAs MMIC amplifier into this package. The performance of this packaged amplifier, part number MAAM28000-A1, is shown in Figure 6.

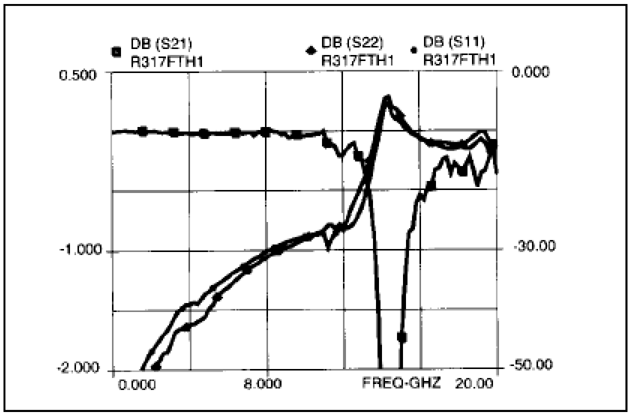

Figure 5. Feedthrough Frequency Response

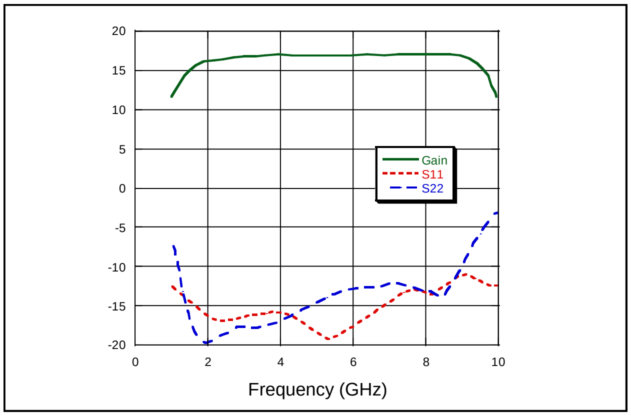

Figure 6. MAAM28000-A1 Performance

Using the de-embedded feedthrough data, Y-parameter extraction followed by a constrained optimization was performed to derive the feedthrough model shown in Figure 7.

Figure 8 shows the measured versus modeled insertion loss and input return loss for this package feedthrough. The model simulates the feedthrough performance closely over the useful frequency range of the package.

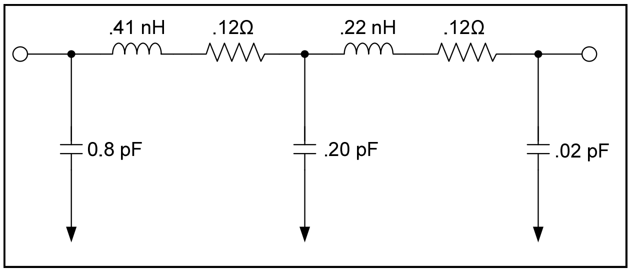

Figure 7. Feedthrough Model

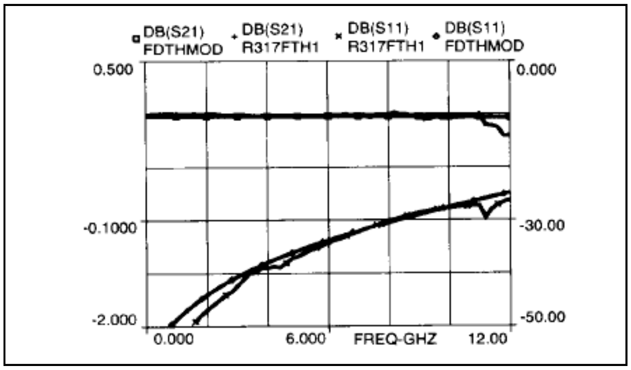

Figure 8. Measured vs. Modeled Performance

Coupling effects between package ports were also measured and modeled. A Y-parameter extraction showed that the coupling could be attributed to equivalent capacitance values. In the case of the 8-lead ceramic flatpack, coupling between adjacent ports along one side of the flatpack can be represented by a 0.03 pF capacitance. Between alternate ports along the same side, the coupling capacitance is nominally 0.003 pF. Coupling between internally terminated ports on opposite sides of the flatpack was modeled with a 0.0007 pF capacitor. This coupling model accurately predicts the measured input to output isolation, as illustrated in Figure 9, over the package's useful frequency range.

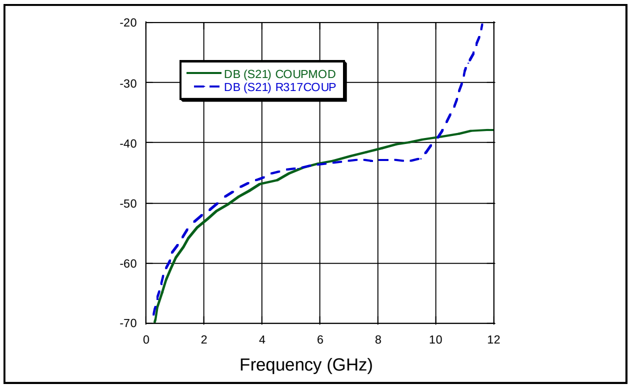

Figure 9. Package Isolation

Characterizing the packages in Table 1 produced interesting results. The five relatively inexpensive packages (the 5-, 7-, and 8-lead flatpacks) are commonly used for fairly low frequency applications. However, as detailed above, the 8-lead ceramic flatpack, supplied by Kyocera, exhibits excellent performance into X-band. Mini-Systems' 8-lead glass flatpack also exhibits excellent performance into X-band, and their version with ground straps has similar performance through C-band. The Kyocera 5- and 7-lead ceramic flatpacks, often used in switching applications, have higher insertion loss and lower return loss, but demonstrate reasonably good performance into X-band and C-band, respectively. The Oxley manufactured leadless 8-port ceramic package has excellent performance through C-band.

The remaining three packages shown in Table 1 are all advertised for high frequency applications. Of these, StratEdge's leadless 6-port ceramic flatpack exhibits the best performance through 20 GHz. The Alcoa 10-port ceramic package also works reasonably well up to 20 GHZ. Kyocera's leaded version of the 6-port ceramic package demonstrates reasonably good performance to 16 GHz.

At least one suitable package was chosen for each of the small signal amplifiers, and one of the power amplifiers, in our GaAs MMIC amplifier product line. Table 2 lists all the packaged amplifiers now offered as standard products. This test method was also used to characterize the lead parasitics of the SOP and SSOP plastic packages. That data has been incorporated into the design of several new products specifically targeted for high-volume, low-cost, commercial applications.

Bond wires, bond wire pairs and ribbons have also been characterized with this test method, resulting in scalable, empirically-derived models. In addition, this test methodology is widely employed in our engineering test lab to RF probe MMICs which are otherwise not RF probeable.

P/N (MAAM-)	Function		Package Style
02350-A2	0.2-3.5 GHz	IFA	8 lead, ceramic
12000-A1	1-2 GHz	LNA	8 lead, ceramic
23000-A1	2-3 GHz	LNA	8 lead, ceramic
37000-A1	3-7 GHz	LNA	8 lead, ceramic
71200-H1	7-12 GHz	LNA	Leadless, 6 port ceramic
28000-A1	2-8 GHz	WBA	8 lead, ceramic
26100-B1	2-6 GHz	PA	7 lead, ceramic

Table 2. Packaged Amplifier Products

A novel fixturing and test methodology has been designed and implemented which allows accurate microwave frequency characterization of virtually any device. This approach has been used to evaluate many of the currently available microwave packages. Appropriate packages have been identified for our GaAs MMIC amplifiers, resulting in many new standard products. Models for package feedthrough structures, plastic packages, and bond wires and ribbons have all been developed using this method.

Acknowledgements

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