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 characteriz-
 ing most any style package or device. This scheme
 has been used to characterize many of the currently
 available microwave packages in order to identify ap-
 propriate packages for our MMIC amplifier products
 which cover frequencies up to 12 GHz. In addition,
 the technique has been employed to characterize in-
 jection-molded plastic packages and to evaluate non-
 probeable MMIC’s.

Introduction
Most package vendors have very little microwave
design and characterization capability. Their lim-
 ited 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 mechani-
 cal 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 pack-
ages for each of the amplifiers in our MMIC ampli-
 fier product line, specific fixturing had to be de-
 veloped for each package style considered. A novel
 fixtureing 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 cali-
 bration method was developed which allows com-
 plete 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 pack-
 ages for frequency applications where our competi-
tors typically resort to high-priced custom pack-
ages.

<table>
<thead>
<tr>
<th>Package Description</th>
<th>Manufacturer</th>
</tr>
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<tbody>
<tr>
<td>5 lead, ceramic</td>
<td>Kyocera</td>
</tr>
<tr>
<td>6 lead, ceramic</td>
<td>Kyocera</td>
</tr>
<tr>
<td>Leadless, 6 port, ceramic</td>
<td>StratEdge</td>
</tr>
<tr>
<td>7 lead, ceramic</td>
<td>Kyocera</td>
</tr>
<tr>
<td>8 lead, ceramic</td>
<td>Kyocera</td>
</tr>
<tr>
<td>8 lead, glass</td>
<td>Mini-Systems</td>
</tr>
<tr>
<td>8 lead, glass, ground straps</td>
<td>Mini-Systems</td>
</tr>
<tr>
<td>Leadless, 8 port, ceramic</td>
<td>Oxley</td>
</tr>
<tr>
<td>Leadless, 10 port, ceramic</td>
<td>Alcoa</td>
</tr>
</tbody>
</table>

Table 1. Summary of Packages

Design Approach
To eliminate the need for expensive, device spe-
cific, traditional fixtures and overcome their fre-
quency limitations, an RF probeable ceramic sub-
strate 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 com-
mercially available microwave probes on a stan-
dard 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 neces-
sary, the brass block could be machined to com-
pensate 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.
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 feedthrough and coupling were developed.

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 7. Feedthrough Model

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 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.
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.

### Table 2. Packaged Amplifier Products

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

Acknowledgements

Written by Stephen R. Smith and Michael T. Murphy. The authors thank Scott Mitchell and Ted Begnoche for testing these devices, Brenda Milinazzo for assembling them and Bill Fahey for helping to prepare this paper.

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