Hermetic Microstrip Mixer Package

Microstrip transmission lines are widely used in subsystems, however the broadband double-balanced mixer is difficult to realize in this planar geometry, and packages to contain double-balanced and triple-balanced mixers have not been compatible with microstrip insertion. The authors describe a new hermetic package that is.

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Microstrip transmission lines are widely used in microwave subsystems because of the many advantages they provide the designer. Microstrip lines are used for both the interconnections between components and for realizing many of the components themselves. However, one component that is difficult to realize in the microstrip environment is the broadband double-balanced mixer. Orthogonal, i.e. three dimensional, double-balanced and triple-balanced, mixers offer performance that is not available in planar technology. Unfortunately, these devices customarily have been packaged in housings that do not provide well matched transitions into microstrip. Making reliable and well matched connections between the microstrip transmission lines and these packages has been one of the major challenges faced by the subsystem designer.

To solve this problem we designed a microstrip compatible mixer package that allows the full performance of orthogonal mixers to be easily and reliably integrated into microstrip based subsystems. This paper describes the development of this package and provides some applications information for the subsystem designer.

Advantages of Microstrip

Microstrip transmission lines are regularly used in microwave subsystem designs for their many advantages. Microstrip lines are easy to manufacture in both thin film and soft board environments and result in great reductions in size and weight compared with coaxial transmission lines. The microstrip medium also allows the designer to integrate many of the components of his design directly into the board that is used to make interconnections. For example, power dividers, couplers, and filters can be realized in the microstrip environment.

Furthermore, because of these advantages, microstrip transmission lines and components have received a high level of attention in the literature and from the developers of computer aided design software. This vast amount of available design data and the resultant facility and accuracy of modeling with microstrip are further advantages to the subsystem designer. When correctly designed, microstrip lines provide low radiation loss and good isolation. Not surprisingly, for all of these reasons, microstrip is often the preferred medium for realizing and interconnecting components in a microwave subsystem.

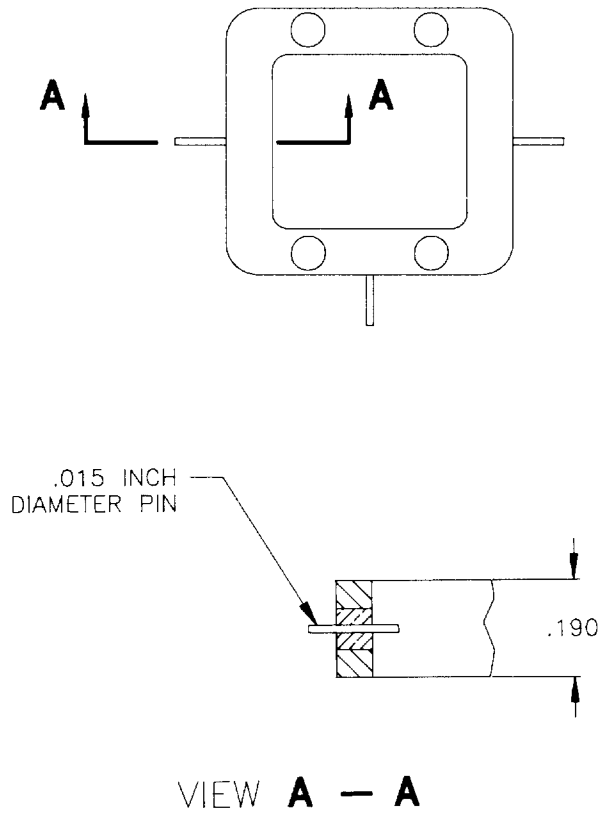

Figure 1. Typical mixer package.

Problems with Traditional Mixer Packages

A major problem with a microstrip based subsystem layout has been the integration of packaged microwave components. For example, consider a typical double-balanced mixer package as shown in Figure 1. The package uses coaxial fired-in, glass feedthrus having a 15 mil diameter pin in a housing wall that is 190 mils high. Since the feedthru is centered with respect to the height of the package, the distance between the bottom of the pin and the bottom of the package is about 90 mils. However, the typical microstrip substrate thickness is only 15 mils, which is usually mounted on a 15 mil thick carrier.

One method of integrating the package into the subsystem is to mount the package onto the surface used to mount other subsystem carriers, as shown in Figure 2. A gold ribbon is then used to connect from the microstrip interface of the subsystem to the pin of the package. Since the pin is about 90 mils above the bottom of the package, the distance between the pin and the top of the microstrip interface is 60 mils. Therefore, a relatively long ribbon is needed to make the connection between the pin and the microstrip transmission line.

The inductive reactance of this ribbon is too large at high frequencies for this approach to give an acceptable match. Also unacceptable is the path for the ground currents which must travel up the package wall to the coaxial feedthru, further deteriorating the match. To solve the problem associated with the long ribbon, engineers often machine a cavity into the subsystem to lower the feedthru pin of the

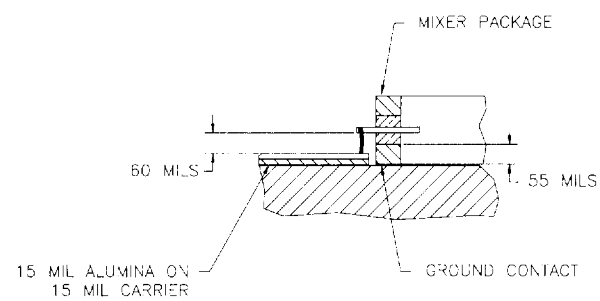

Figure 2. Typical mixer package mounted to ground plane.

package so that it is closer to the microstrip interface, as shown in Figure 3.

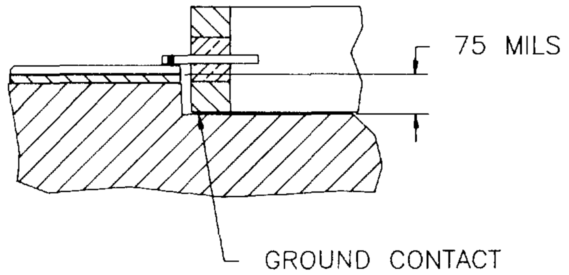

Figure 3. Typical mixer package mounted in cavity.

This solves the problem with the long ribbon but exacerbates the ground current discontinuity. The ground current then must travel down the cavity wall and back up the package wall. To shorten this ground current path one could try making a connection between the side of the package and the side of the cavity. However, making this connection is awkward and impractical to realize reliably, especially in applications with wide temperature variations. In these environments differences between the thermal expansion coefficients of the package and the subsystem base material cause the gap to vary in size. Adding to the problem is the fact that the connection must be made on two or three sides of the package simultaneously.

Package Concept and Design Objectives

There were three goals in the development of the new package. The first was to make the package as similar to a circuit on a carrier as possible, because the methods used to interface circuits on carriers into subsystems are well understood. In this method the ground connections are made at the bottom of the carrier and the microstrip traces are connected together with gold ribbons or bond wires as shown in Figure 4.

The ribbon interconnection has low loss and reflection at microwave frequencies as long as the thickness of the carriers is held to a minimum to minimize the ground current discontinuity. It also accommodates differential temperature expansions because small changes in the distance between the carriers have little effect on the current path. A slight arch in the ribbon between the two traces provides stress relief for this connection. Figure 5 shows this approach extended to the microstrip compatible package.

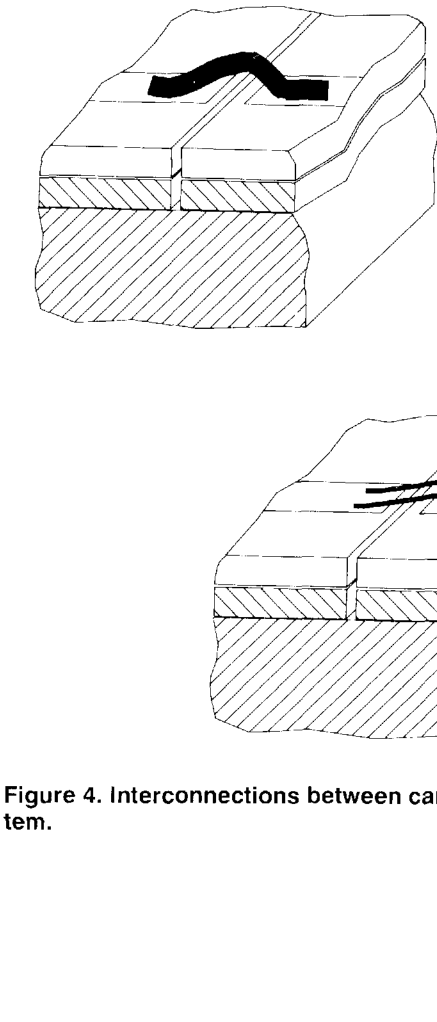

Figure 4. Interconnections between carriers in a subsystem.

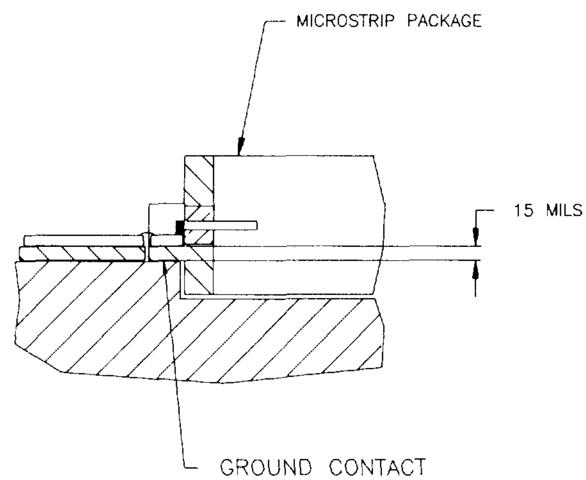

Figure 5. Side view of a microstrip package mounted in subsystem.

The second goal was to design a package that uses manufacturing processes with a proven record of reliability. This led to a hermetic package that uses a standard coaxial glass to metal seal to make the transition through the package wall. This choice is in contrast to an attempt to extend a flat strip transmission line through the glass bead seal, an approach that can be leaky and therefore unreliable. The new package was also designed to use parallel seam sealing techniques for attaching the lids.

The third goal of the new package design was to make its internal cavity the same size as existing mixer designs in order that mixers with known performance characteristics and proven reliability could be introduced in the new package without the necessity for circuit verification coincident with verification of the new package.

Finally, the goals were to be met with a package that would be usable from DC to 18 GHz and meet the reliability levels consistent with Mil standard 883. The interface chosen uses a 50 ohm microstrip line on a 15 mil alumina substrate with an effective carrier thickness of 15 mils.

Package Realization

The resulting hermetic package is shown in Figure 6, from which it is seen that the microstrip interface is a 15 mil thick alumina substrate on a metal shelf that is also 15 mils thick, a combination that provides good transmission match from DC to 18 GHz in subsystems employing 15 mil substrates on 15 mil carriers.

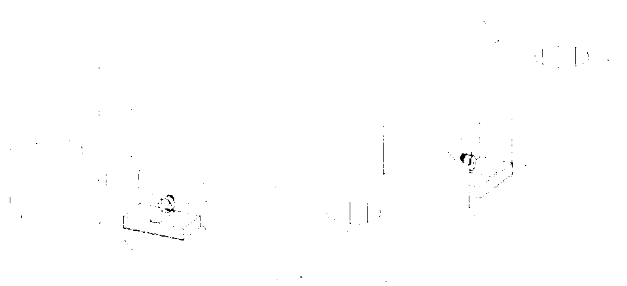

Figure 6. Three dimensional view of the microstrip compatible package.

To meet achieve hermeticity, the package has fired-in, coaxial glass feedthrus, which allow stress between the metal wall and the glass feedthru to be spread uniformly over its circumference, a clear advantage over the the highly stressed, sharp corner configuration of a typical cofired package (having a ribbon conductor pass through the glass bead instead of a pin).

For compatibility with existing mixer designs, the center pin of this glass feedthru extends into the package interior. This, along with the internal dimension of the package, allow existing mixer designs to be "dropped in." A gold ribbon is used to make the connection between the center pin of the coaxial feedthru and the microstrip transmission line interface of the package.

To minimize the inductance of the ribbon, the location of the pin must be close to the top of the alumina substrate so that only a short length of ribbon is needed for the hookup. Since the substrate is 15 mils thick, this brings the ground of the substrate quite close to the coaxial feedthru.

This made a small diameter feedthru necessary so that the outer diameter of the feedthru did not intersect with the flange. A 10 mil diameter pin with a 42 mil diameter glass seal was selected for this transition. The flange around the package holds the substrates and acts as the mounting surface. This flange is thin directly beneath the substrates but is 74 mils thick elsewhere, thereby affording a sturdy mount.

Interface Details and Mounting Guidelines

Figure 7 shows the details of the microstrip interface. The substrate material for this microstrip line is 99.5% pure alumina with a dielectric constant of 9.6. The top metallization is 99.999% pure, class III gold which is suitable for thermocompression wire bonding or gap welding. This gold has a minimum thickness of 100 micro inches. As seen in the drawing the microstrip line ends in a pad that is 25 mils wide by 18 mils long. This pad serves two purposes. The extra width at the end of the line provides a slight excess shunt capacitance to tune out the series inductance of the bond wire or ribbon used to connect to the package. This pad also makes the package compatible with a 25 mil wide ribbon, which could be used to connect to a 25 mil wide line.

This geometry gives a 50 ohm microstrip line on a 25 mil thick alumina ground plane spacing. Accordingly, with a slight modification to the mounting procedure, the package well accommodates subsystems with up to 25 mil ground plane spacing. This modification consists of bringing the top of the substrate to a proper height for bonding and using a wider ribbon. The trade-off between raising the package 10 mils to align the substrate surfaces, or bonding at two different levels is a choice to be made by the subsystem designer in such larger ground plane applications.

However, if desired gaskets or epoxies for mounting carriers and components this procedure can be extended to the microstrip compatible package, with the restriction that the package not be exposed to temperatures that reflow the Sn63 solder used inside.

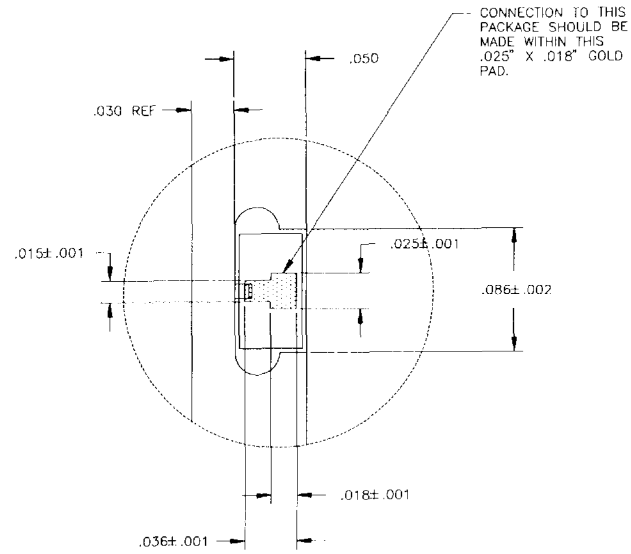

Figure 7. Details of the microstrip interface.

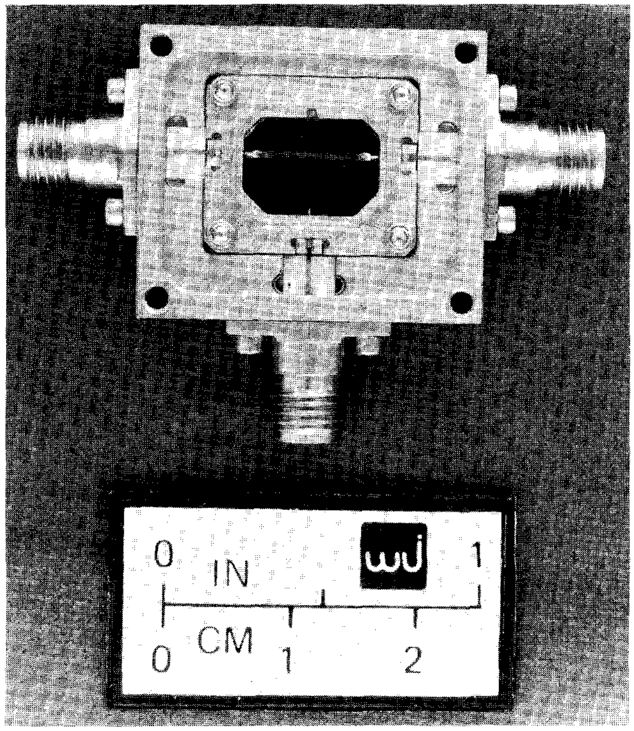

Figure 8. Photograph of the new hermetic mixer package mounted in a microstrip test fixture. Lid is removed and 50 ohm line installed for test purposes.

The cavity for mounting this package must be deep enough so that the bottom of the package does not come in contact with the bottom of the cavity. This is to insure that the grounding of the package takes place under the microstrip line. The mounting holes on the flange are spaced far enough from the cavity wall to allow for threaded inserts to be used. This is important if the package is mounted to a soft base material such as aluminum. A photograph of the package mounted in a microstrip test fixture is shown in Figure 8.

To insure good grounding to the package the flatness of the mounting surface should be better than 1 mil and the surface finish should be a maximum of 0.016 RMS. With these tolerances the package can be mounted directly to the subsystem without the need for conductive epoxies or gaskets.

Performance of the Package

To characterize the performance of the microstrip compatible package several circuits were built. The first two of these were used to verify the performance of the microstrip-to-microstrip launch and the transition to the inside of the package. The next circuits were used to verify the performance of the package in a typical microwave subsystem environment. These included circuits consisting of four packages to ascertain the performance of launching from one package to another and to investigate the isolation between two channels built with microstrip compatible packages. The performance of these circuits was also determined over temperature and compared to a similar circuit using conventional packages.

To determine the quality of the package match over frequency the package was tested in the test fixture shown in Figure 8 with a 50 ohm transmission line inside the package. Figures 9 show the

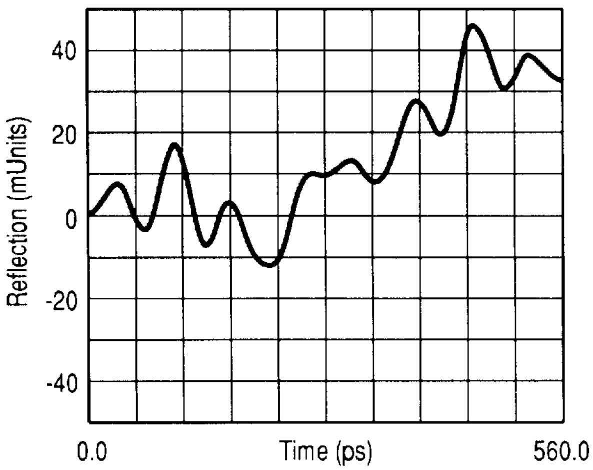

Figure 9a. Time domain reflection test of the new package.

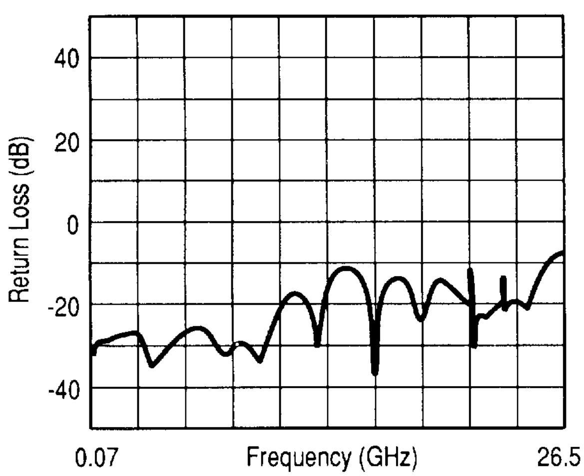

Figure 9b. Return Loss (reflection) over frequency of the package and test fixture.

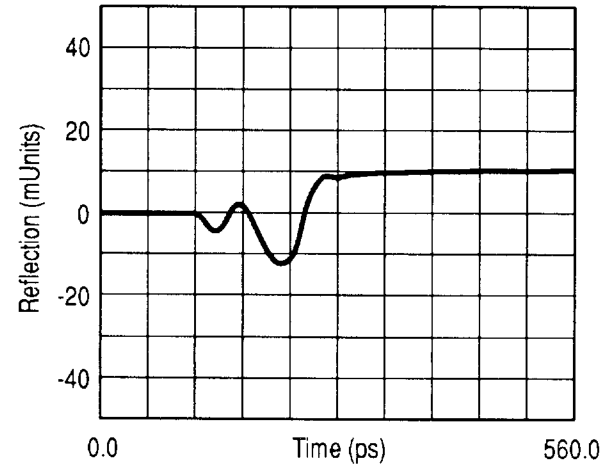

Figure 9c. Gated (calculated) time domain reflection of a single package transition.

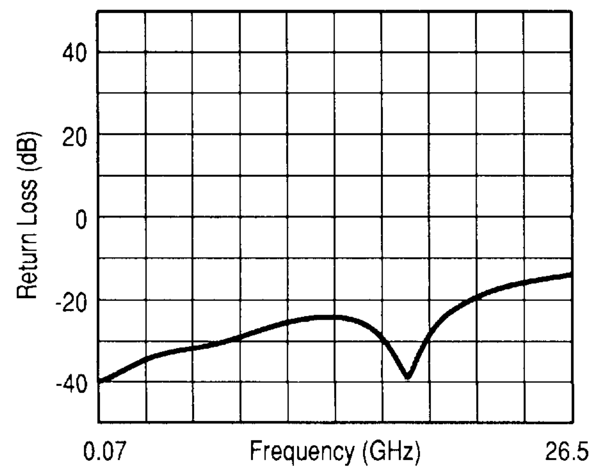

Figure 9d. Gated (calculated) return loss of a single package transition.

return loss of this circuit in both the frequency and time domains. Plots A and B include the entire circuit and plots C and D have been gated using the time delay data to estimate the return loss of a single microstrip-to-microstrip transition, found to be equal to or better than -20dB up to about 21 GHz, a 1.2 VSWR max for each connection over this frequency range.

To investigate how the new package would perform in an actual application the subsystem of Figure 10 was constructed. This subsystem, comprised of four packages, is a two channel affair with each channel having two cascaded microstrip compatible packages mounted in cavities deeper than their height and with an interconnecting 50 ohm line 120 mils long. This subsystem has two channels for isolation measurements. Each channel has two packages so that multiple launches could be investigated and to provide a more realistic test of interchannel isolation.

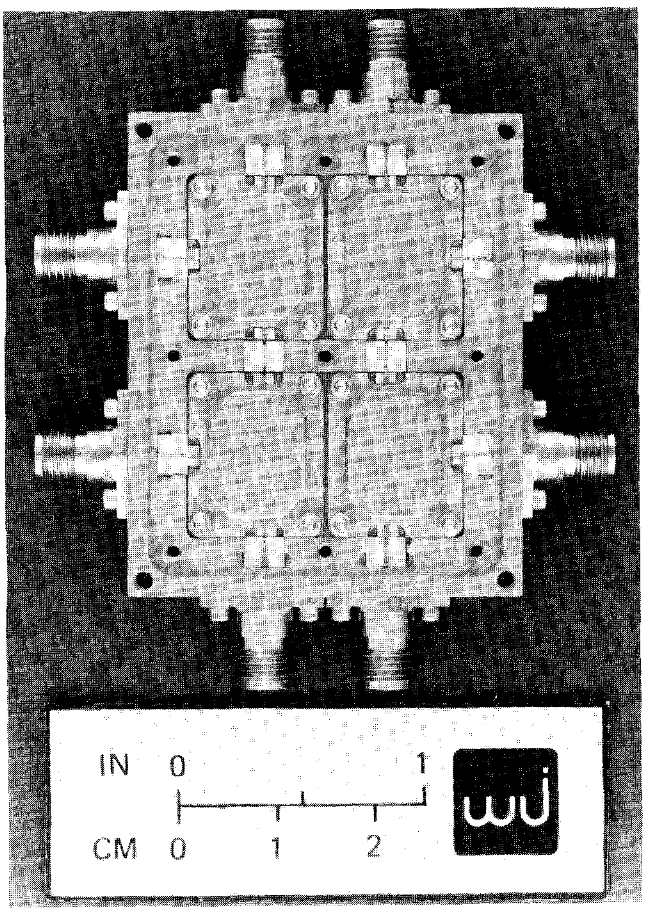

Figure 10. Photograph of multiple package test circuit. Two channels are provided so that isolation measurements can be performed.

The insertion loss and return loss of one channel is shown in Figure 11. This data includes the loss and reflections of the coaxial connectors of the test fixture as well as the transition from coax to microstrip, the two packages and the launches into these packages. As seen, the insertion loss remained below about 2 dB and the return loss below about 13 dB up to 20 GHz, even for the numerous interconnections of the channel.

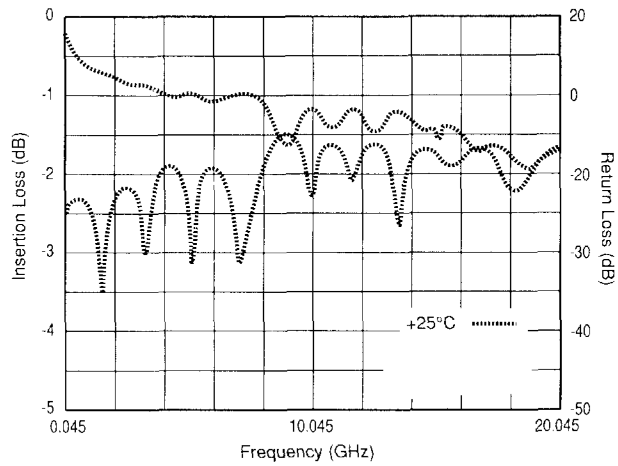

Figure 11. Insertion and return loss for one channel of the test fixture shown in Figure 10.

The isolation between the two channels of the system with and without an RF lid is shown in Figure 11. Comparing the two traces it is seen that an improvement of 10 to 40 dB is obtained by adding the lid. This consisted of 20 mil thick soft copper, having the same outline as the package and held in place with the same mounting screws which secured the package.

To verify that the connections would remain reliable over a wide temperature range the performance of the subsystem was monitored as the ambient temperature was varied from -55 degrees C to 105 degrees C. Return and insertion loss performance over the full frequency range were unchanged within the accuracy of the measurement.

The performance of the new package was compared with that of a conventional package using similar test fixturing. This subsystem uses packages with the dimensions shown in Figure 1. The mounting technique used a cavity as depicted in Figure 3. These packages contained thrulines identical to those used in the microstrip compatible packages.

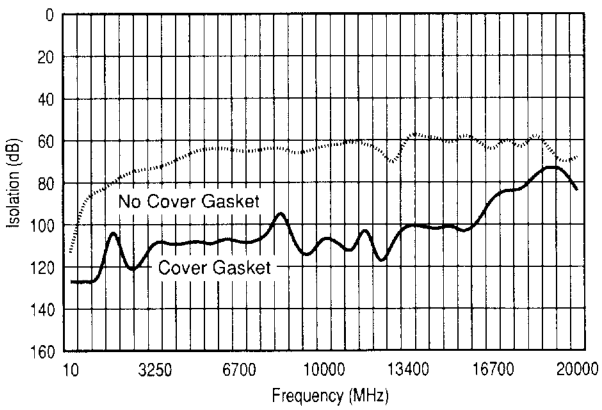

Figure 12. Measured isolation between channels, with and without package lids, using the test fixture of Figure 10.

The insertion loss measured is shown in Figure 13, from which it can be seen that this yields acceptable performance only to about 12 GHz (Note the change in the loss scale necessary for this plot).

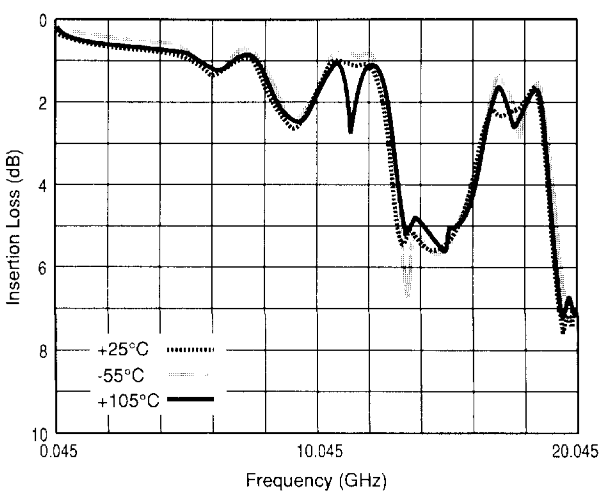

Figure 13. Insertion loss obtained with a conventional package, showing a practical limit of about 12 GHz.

Moreover, the isolation between channels for this conventional subsystem, shown in Figure 14, demonstrates that far less isolation over the band and at any given frequency is obtained with the conventional approach.

To verify that actual mixer circuits would perform well in this package, four designs were built and tested. Two of these are double-balanced mixers and two are triple-balanced. These mixers were tested in the test housings of Figure 9 and all performed as well as their conventional equivalents. The performance of the microstrip compatible mixers included the launch from microstrip-to-microstrip as well as the coax-to-microstrip transition. The performance of the conventional mixers was taken with SMA connectors mounted directly to the housings.

Steven E. Avery *received a BSEL degree from the California Polytechnic State University at San Luis Obispo in 1982 and an MSEE degree from Stanford University in 1987. He joined Watkins-Johnson Company in 1982 and has been responsible for the design of RF and microwave mixers. He has developed double-balanced and triple-balanced mixers in the 0.5 to 40 GHz frequency range.*

Currently, Mr. Avery is the head of the Mixer and Switch Development Section in the Semiconductor and Component Technology Department. In the position he is responsible for new product development for the mixer and switch product lines.

Jeffrey C. Liew received his BSEE degree from the University of California at Davis in 1989. He joined Watkins-Johnson Company as a Design Engineer, and developed a 6-40 GHz diode mixer for a spectrum analyzer front end. Mr. Liew has also developed a thin film mixer for use in radar receiver applications. This mixer utilizes thin film technologies for superb conversion loss and VSWR performance. He was also responsible for completing the development of the microstrip compatible package discussed in this article. In conjunction with the development of the new package, Mr. Liew was responsible for the development work associated with integrating four existing orthogonal mixers designs into the new package.

Mr. Liew is currently a Member of the Technical Staff assigned to the Product Design Engineering Section of the Modular Components Department. He is responsible for the design and development of cascadable amplifiers and microwave mixers for both non-catalog/Hi-Rel and catalog products. His current project responsibilities include developing various .1-1 GHz TO-8 amplifiers and supporting the microstrip compatible mixers and thin film mixer product line.

Mr. Liew is a member of IEEE.