# PACKAGING AND SYSTEM INTEGRATION OF MICROWAVE AND DIGITAL MONOLITHIC IC's

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## ABSTRACT

Multilayer microwave substrates offer numerous advantages for today's high density packaging requirements. A single firing, multilayer process which uses a combination of thick and thin film metallization on hardened ceramic has been developed. This technology promotes the integration of digital, analog, and microwave circuit designs onto a single multilayer substrate. It provides an increase in interconnect density, a reduction in the number of parts and a decrease in assembly operations. This represents a novel packaging approach which provides greater design flexibility and superior electrical performance for microwave products such as couplers, filters, MMIC modules, delay lines, and millimeter-wave packages.

## INTRODUCTION

The use of hardened ceramics eliminates the need to design the artwork with a shrinkage factor, as required with standard cofired green-sheet technology. Mechanical tolerances of 0.25 mils for line widths and spaces can be achieved based on thin-film techniques. Vias of 6 to 40 mil diameter are laser drilled and chemically processed to ensure reliable adhesion of the gold paste to the ceramic. Both electrical and thermal vias can be processed according to the customer's design needs. For multilayer substrates, a straight alignment technique is used, which consistently ensures high yields in the filling and lamination process. In green-sheet cofired technology, staggered vias are needed to prevent post-firing protrusion of the metallization that results from the differential shrinkage of the via fill paste and the ceramic.

## STRATEDGE PROCESS

This packaging approach known as the **STRATEDGE™** process, has acceptable electrical performance from DC to 40 GHz. The process combines the performance of thin film, the cost advantage of thick film, and the benefits of cofired technology, into the manufacture of integrated microwave circuits. Ceramic materials, including alumina, aluminum nitride, BeO, and quartz can be processed. The substrate can range from .005 to .080 inches in thickness and can have a surface finish better than 5 microinches. Power dividers and couplers, as well as resistors and capacitors can be deposited and trimmed to within 1% tolerance. The substrates can be laser cut to complex geometries with high yields.

Traditionally, power conditioning, logic, and microwave circuitry have been fabricated on separate substrates compartmentalized within a housing. Double-sided packaging techniques are used, to distribute the DC networks on the backside, up to the microwave devices on the top side of the housing. This approach doubles the hermetic seal area and reduces module reliability and manufacturability.

Single-sided modules, designed to enhance producibility, often require multiple substrates and complex housing geometries to integrate the bias networks and RF circuitry. The bias networks are routed around and over microstrip transmission lines to the device bonding pads. This is typically accomplished using a single layer of 99.6 percent alumina with thin-film metallization for the DC bias and control lines.

Using the **STRATEDGE™** process, the bias and control lines can be routed on any of several layers of a single multilayer substrate and interconnected through vias. The bonding pads can be accurately placed relative to the device to eliminate the jumpering of RF lines and devices while minimizing bond lengths. The RF transmission line can be designed as stripline or microstrip, depending on the requirements for integration within the multilayer substrate. As many as 11 layers have been demonstrated.

## APPLICATIONS

This technology is critical for microwave modules with high circuit density. One area in particular is the MMIC Transmit/Receive module. These compact modules require dense packaging techniques to support array applications. The **STRATEDGE ™** process

provides a multilayer substrate that impacts this dense construction environment by routing both the RF transmission lines and the DC bias and control traces. Figure 1 shows an example of this type of substrate. It is a five layer board with the two bottom layers forming a stripline transmission media. The transmission line is part of the receive path, for a T/R module, connecting the LNA amplifier chain to the phase and amplitude control section (vector modulator). The top 3 layers are used to route a total of 19 DC bias and control signals to the six GaAs MMIC devices making up the vector modulator. Control is required for 5 bits of phase shifting, 4 bits of amplitude control, built-in-test, and transmit/receive switching. The substrate measures 1.11 x 0.15 inches.

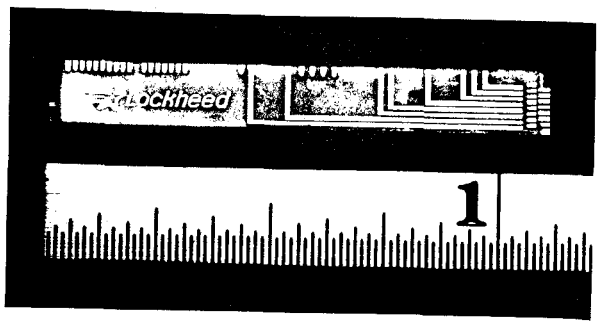



Figure 1

The substrate was fabricated with two .010 and three .005 layers of 99.6% alumina. The interconnection from layer to layer is handled by .006 via-holes. This connection scheme allows many layers of DC to be stacked up over the RF transmission line. The RF and DC lines are deposited with a thin-film process to minimize resistive losses. A ground plane shield between the RF and DC layers was designed into the board to eliminate RF coupling to the bias and control lines.

A second example further illustrates the effectiveness of this technology. Figure 2 illustrates the requirement. The substrate must pass two transmit and two receive signals, along with control lines for two SP2T switches, in a channel width not to exceed .385. This was accomplished by using three alumina layers. The two receive lines pass through the substrate as stripline via the first two .010 layers. The two transmit paths use a microstrip transmission line format, on top of the third layer (.005 thick). This isolates the transmit and receive paths while permitting the "RF crossover" to occur. A microstrip Wilkinson power splitter was designed on the first layer to combine the two receive paths. Furthermore, the top layer was designed to attach chip capacitors and resistors. These components are used to set and filter the LNA bias. The substrate is shown in figure 3.

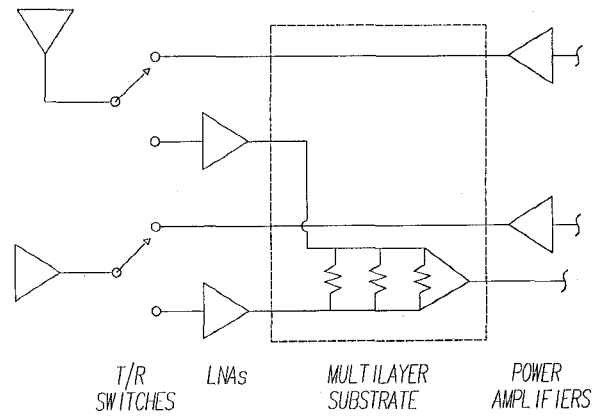



Figure 2

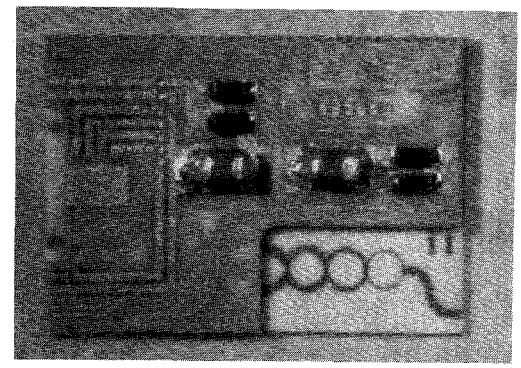


Figure 3

Figure 4 shows performance on one of the microstrip transmission lines. The Insertion loss is less than 1.0 dB up to 13 GHz and less than 2.0 dB to 20 GHz. The input and output match is better than a 2.0:1 up to 20 GHz.

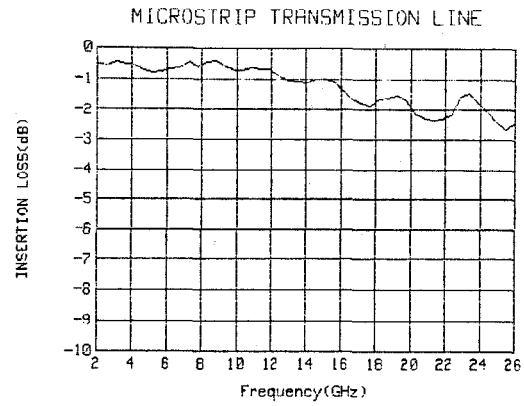
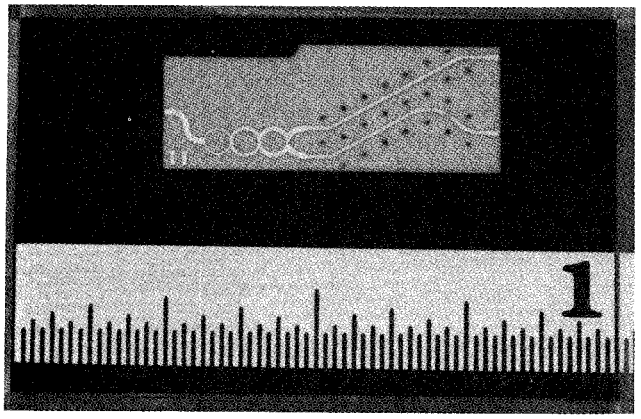
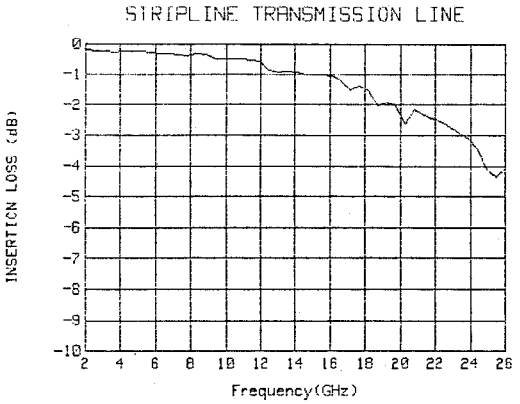



Figure 4

Figure 5 shows the performance for one of the striplines. For this evaluation, the power divider was diced from the substrate leaving just the striplines. The insertion loss is less than 1.5 dB up to 18 GHz with an associated input and output match better than a 2.0:1.





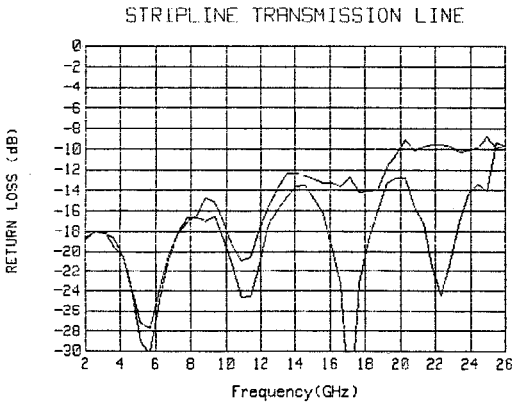
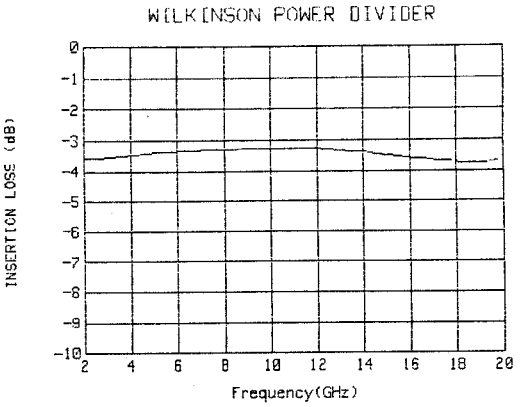




Figure 5

The results of the Wilkinson power divider are as shown in figure 6. The splitter was designed to work over the 6-18 GHz band, have less than 0.5 dB of loss, and greater than 15 dB of isolation. Figure 7 shows the insertion loss of both the stripline and the power divider combined.



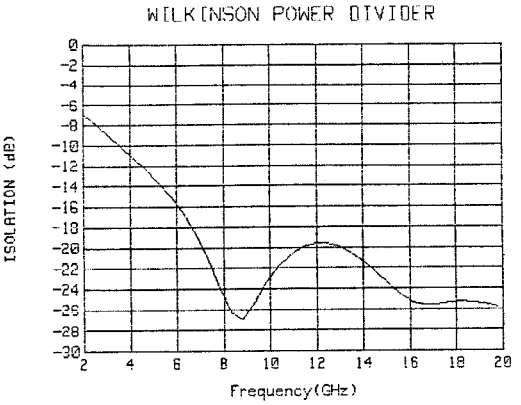
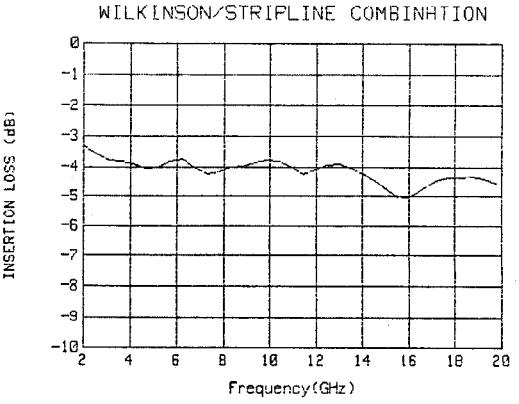




Figure 6



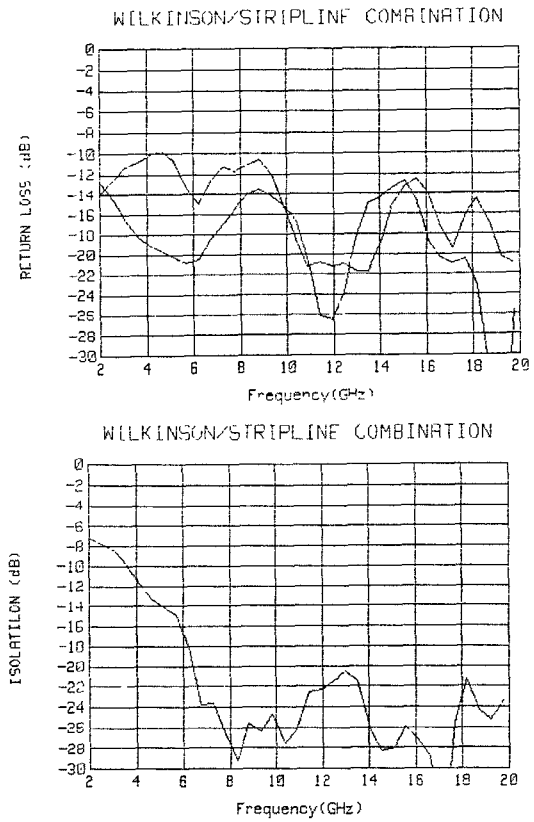



Figure 7

Delay lines are typically fabricated using coaxial cables designed to produce a desired time shift for a specific frequency. Mechanical integration can be cumbersome as these lines must be packaged (typically potted which requires fixturing) to achieve the volume constraints.

Using the **STRATEDGE ™** technology, electrically equivalent delay lines are miniaturized and packaged to result in a minimum 50% reduction in volume. Figure 8 compares the electrical data of a typical delay line assembly, to a **STRATEDGE ™** delay line.

**ELECTRICAL CHARACTERISTICS**

| PARAMETER | SPECIFICATION | PERFORMANCE |
|---|---|---|
| DELAY | 25 N.S. ± 1 N.S. | * 24.5 N.S. |
| FREQUENCY RANGE | 650 MHz to 1.30 GHz | |
| INPUT/OUTPUT V.S.W.R. | 2:1 MAXIMUM | * 1.4:1 |
| DELAY VARIATION | ± 10 N.S. | * +1 N.S. |
| DELAY IMBALANCE | ± 2 N.S. | |
| INSERTION LOSS | 2 db MAXIMUM | * 1.5 db |
| TEMPERATURE RANGE | -25°C TO +150°C | |

* OVER TEMPERATURE

Figure 8

## CONCLUSION

Multilayer microwave circuits offer numerous benefits for high density packaging necessary for higher system performance. Holz Industries, has developed the **STRATEDGE ™** process which uses already hardened ceramics in combination with thick and thin film processing. This represents a novel packaging approach which provides greater design flexibility and superior electrical performance for microwave products. The design, manufacture, and testing capabilities promotes custom designs that can be fabricated in an R&D or production environment.