Innovative Technologies Enable Higher Levels of Integration for Radar Applications

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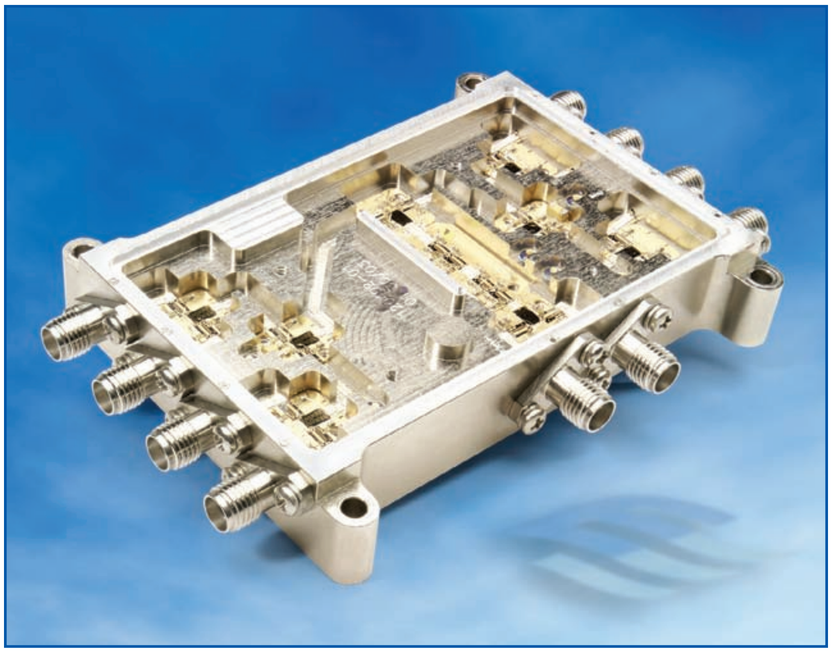
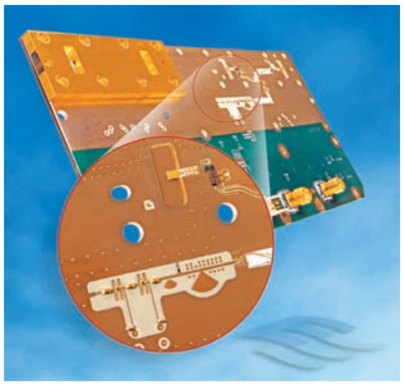


The radar systems in development today have little resemblance to the bulky legacy systems of yesterday. The newest digital processing techniques employed to reduce clutter, decrease the probability of false detection and increase the probability of accurate target detection are driving greater amounts of functionality and integration into the microwave and millimeter wave front ends. In addition to these higher levels of integration, the design requirements of these systems now include low cost and lighter weight, packing higher degrees of circuit density into smaller volumes. Two technologies currently in production at Endwave, MLMS™ and Epsilon™, are well suited to satisfy these aggressive new requirements.



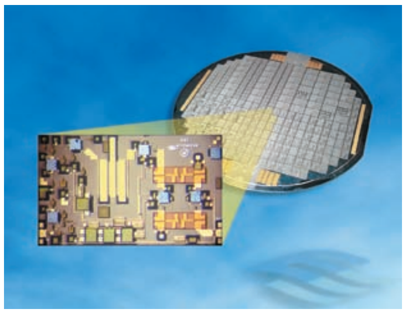
Epsilon™

Despite technological advances in MMIC devices, manufacturing techniques, and design tools, conventional millimeter-wave module housings are still fabricated utilizing costly precision machining techniques, after which they are plated with expensive materials. These housings simply serve to hold, shield and protect the high-frequency circuitry. As cost reduction due to enhancements in the circuit electronics have tended to outpace the improvements in module and system-level packaging techniques, housing costs have become an ever-increasing percentage of the total cost of the radar front-end bill of material.

Epsilon™ Packaging is a proprietary technology that makes clever use of existing printed circuit board fabrication techniques to replace these expensive machined metal parts. This paves the way to achieve mass production of modules having efficient heat extraction with minimal weight and size. The package has no ceramic or machined metal parts, and has been successfully demonstrated in advanced module designs to 100 GHz.

Lightweight multilayer FR4 material furnishes the structural support previously provided by the metal housings. A single integrated board stack accepts both low-cost surface-mount components and wire-bonded chip-on-board (COB) components, and thus eliminates many connectors and other interconnects for improved reliability and performance variability. In addition, a significant reduction in size results through integration of components for signal processing, control, and power conditioning, facilitating high-level integration for demanding defense applications.

Exceptional electrical shielding of the RF circuitry is achieved through the use of advanced shallow blind-via slot technology and implementation of minimum-mass conductive-epoxy-attached metal-clad FR4 lids. Selective permeability techniques prevent hydrogen poisoning while providing field-proven environmental protection. This packaging technology utilizes the same materials and techniques used in the commercial deployment of tens of thousands of Endwave T/R modules, operating worldwide in harsh terrestrial environments.



MLMS™

The number of applications for high-frequency electronics is growing rapidly in both the defense and commercial sectors. The pressure is on to achieve lower cost and improved reliability over current technologies - similar to that achieved in the lower-frequency world traditionally dominated by silicon ICs. As we enter the world above 10 GHz, we find ourselves exiting the world of precision op amps, lumped elements, and separately packaged ICs on 4-mil trace-and-space PC boards. The reasons are made clear when we analyze the quantitative effects of interconnect return losses and lengthy connections on unit-to-unit performance variability. As operating frequencies increase, bond wire interconnections between components can introduce so much variability that hand tweaking and/or expensive control circuitry is required to meet the needed performance specifications.

To overcome these problems, MLMS™ (MultiLithic MicroSystem) technology has been developed and qualified in MIL-STD environments. MLMS™ uses flip-chip and electromagnetic coupling methods to eliminate bond-wire connections and interconnect variability. With MLMS™ technology, a complex millimeter-wave subsystem (such as a complete receiver or transmitter) can be placed on a single compact substrate with no bond wires in the RF path. The technology enables mixed-technology integration, taking advantage of the best semiconductor technology available for each portion of the subsystem. These include building blocks of GaAs, InP, SiGe, Si and other semiconductor devices including HBTs, PHEMTs, optimal PIN diodes, high-cutoff Schottky diodes, Endwave patented varactors, as well as custom or catalog MMICs. With large passive elements incorporated on the inexpensive substrate, the semiconductor cost content is reduced to a minimum.

MLMS™ assemblies are proving to be extremely rugged, withstanding cycling between liquid nitrogen and a 300° C hotplate, cycling between freezing and boiling while under water, and mechanical shock testing to maximum available levels of 3000 G and calculated levels of over 100,000 G – proving a quantifiable ability to reduce cost without compromise to reliability.

Radar Example

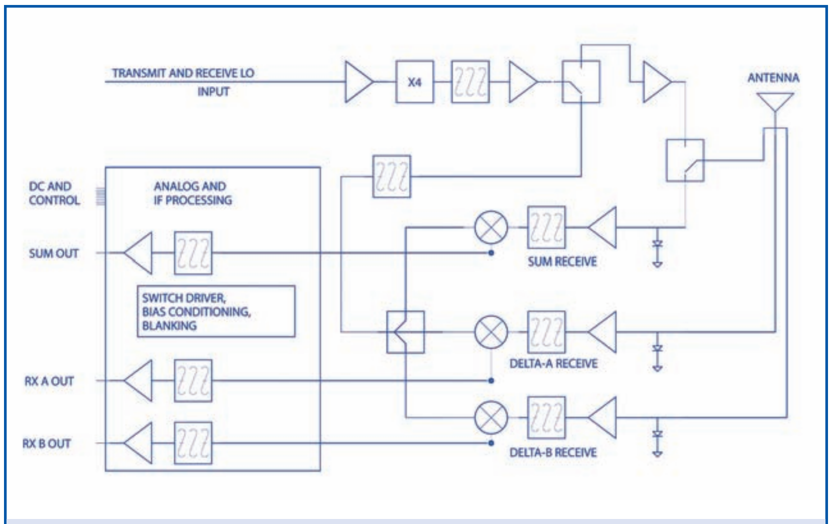
Incorporating these technologies into a classic monopulse radar achieves the design goals listed in the introduction with the added benefit of enhanced reliability and performance. This simple design has been around since the MIT Radiation Laboratory days and variants of it are still used in proposals for current and future platforms.

Monopulse Radar Block Diagram

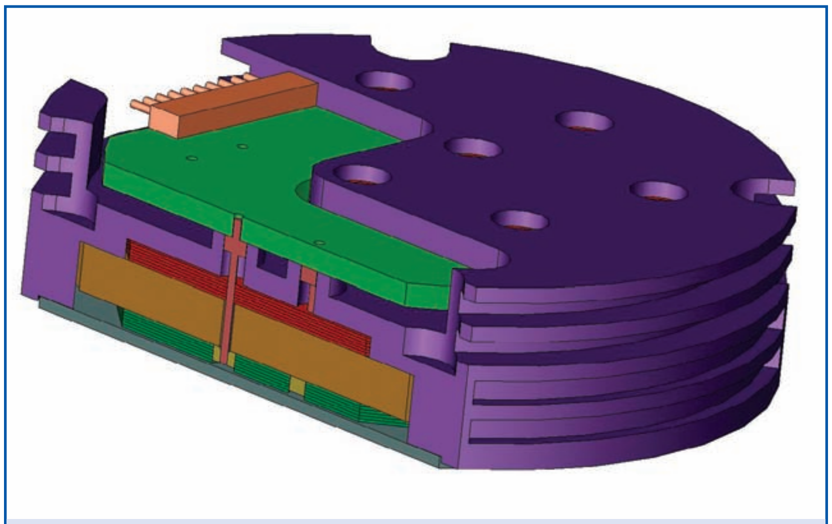
The top channel provides the transmit pulse in addition to the LO for the three receive chains. MLMS™ provides the solution for the high-powered switch located on the output of this transmit chain. The switch is capable of handling several watts at millimeter wave frequencies. The passive circuit elements for the MLMS™ switch are modeled on Ansoft's HFSS, characterized as breakouts and logged into a standard building block library. The transmit chain also contains conventional MMICs for multiplication and gain with filtering implemented in printed edge-coupled metallization on the top Teflon laminate layer.

The antenna and orthomode transducer separate the target return signal into multiple receive channels to discriminate elevation, azimuth and range values. The high isolation required between these channels is enabled by the Epsilon™ grounding and cavity techniques. The target return signal in these channels is then down converted to IF and further processed in surface mount technology. The active component bias is routed through the inner layers of the FR-4.

The circuit density and relatively high power levels present on this board require sophisticated thermal design analysis which was developed using Cosmosworks™ finite element analysis software. Stringent phase and amplitude matching, both channel-to-channel and unit-to-unit, is facilitated by an auto pick-and-place operation on Palomar 3500's and an auto bonding operation on Hughes auto-bonders. The Epsilon™ plating accommodates both wire bonding and surface-mount soldering on the same surface.



Monopulse Radar Block Diagram



Cut Away View of the Monopulse Radar

Summary

This example illustrates the combination of Epsilon and MLMS technologies used to develop a compact, reliable and highly integrated radar subsystem. These MFAs provide frequency conversion, filtering, signal amplification, digitally controlled attenuation and temperature compensated power distribution. Limiters and equalizers have been incorporated to provide front-end protection and a flat output power response vs. frequency, and particular care has been taken in the design to provide stringent phase matching and tracking performance. Many other multifunction assemblies (MFA) have been developed at Endwave, qualified to stringent screening requirements and high performance levels that advanced radar systems demand. Many of the MFA products have been designed to accommodate multi-octave bandwidths within the 0.5-85 GHz range. More information about the custom MFAs at Endwave can be found at www.endwave.com