Microwave Journal

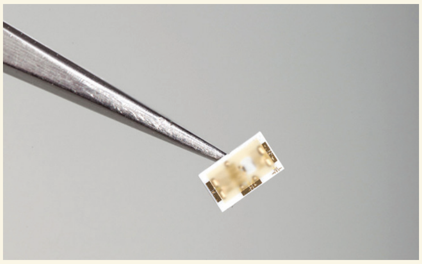
Most Valuable Process

Microlithic Mixers: A Paradigm Shift in Mixer Technology

Microlithic™ mixers are a new technology from Marki Microwave that improves previous levels of performance and packaging. Based on a patent pending technique, Microlithic technology reduces the size of state-of-the-art mixers by 14 times while still maintaining the high performance associated with Marki mixers (see ***Figure 1***). The technology achieves this combination of small size and high performance through a design methodology that combines multi-layer 3D circuitry with high-performance Schottky diode ICs in a miniaturized, integrated package. Perhaps more importantly, Microlithic mixers are optimized completely in 3D EM simulation prior to fabrication, giving Marki engineers full control over the design process, and giving customers the promise of performing full mixer simulations before they complete their bill of materials.

THE MIXER PARADOX: HYBRID VS. MMIC

The pervasive trend in electronic systems design is to improve size, weight and power (SWaP). In military applications such as satellite communications and unmanned aerial vehicles (UAV), for example, future technologies are needed that provide a reduction in SWaP while still maintaining the performance associated with existing solutions. Many companies and designers have chosen monolithic microwave integrated circuit (MMIC) technology to build RF building blocks to reduce SWaP. Indeed, components such as MMIC amplifiers and switches can achieve high performance at a fraction of the form factor of their hybrid counterparts.



▲ *Fig. 1 Microlithic mixer.*

However, not all components are ideally suited for MMIC fabrication. Hybrid mixers continue to exceed MMIC electrical performance. The hybrid/MMIC performance chasm has insulated high performance mixer vendors from the disruptive impact of MMIC technology because many applications exist that simply cannot be satisfied by existing MMIC solutions. Nevertheless, hybrid mixer vendors have had a difficult time developing smaller form factor products, and customers are often left with a paradoxical dilemma: select a hybrid mixer that is too large but offers superior performance, or select the smaller MMIC mixer that does not satisfy system requirements.

Traditional hybrid mixers are mixers that are manufactured using several different types of materials and manufacturing processes that are combined into a single package. Hybrid mixers are commonly assembled by attaching discrete semiconductor integrated circuits (IC) to pre-etched low dielectric substrates. The use of discrete ICs and low dielectric materials is both an advantage and a disadvantage when designing traditional hybrid mixers. On one hand, the de-

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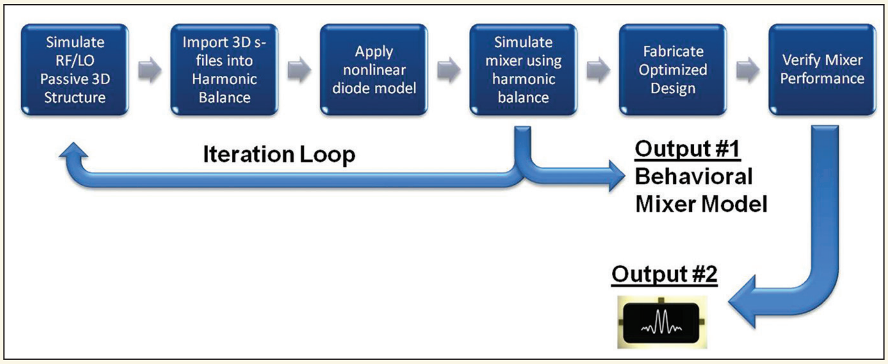


▲ *Fig. 2 Microlithic mixer design flow.*

signer can select the highest quality ICs from any number of potential vendors, and the low dielectric material will have low losses and minimal transmission line dispersion. On the other hand, attaching discrete ICs to the 3D mixer structure requires great skill and the low dielectric constant precludes circuit miniaturization. Nevertheless, traditional hybrid mixers cannot be replaced in many applications owing to their superior performance and their ability to be customized without added cost or lead time.

MMIC mixers, especially those based on GaAs processes, have demonstrated several-octave bandwidth at a fraction of the size of comparable hybrid mixers. The primary advantage of MMIC mixers is that the entire circuit (i.e., the IC devices and the passive circuitry) are integrated onto a single semiconductor wafer, thereby obviating the need for hand assembly. Monolithic mixers are well suited for high volume applications where size and cost are key drivers. Despite the obvious benefits of fully automated assembly, MMIC fabrication has certain drawbacks. Specifically, MMIC designs are inherently restricted by the finite device options and geometry design rules imposed by the foundry. Among other technical issues, GaAs foundries generally fabricate 0.004" thick wafers. This relatively thin substrate is not conducive to achieving a high even mode to odd mode impedance ratio in the mixer baluns, and therefore restricts the achievable bandwidth of the mixer. Hybrid mixers, by comparison, are often built using suspended substrates to create significantly higher even/odd mode ratios. Moreover, GaAs has a relatively high dielectric constant, which results in significant amounts of dispersion, and hence inferior mixer balance and bandwidth. Finally, the price per area in MMIC fabrication is significantly higher than in hybrid mixers, so the designer will often be forced to trade performance for chip size in order to reduce cost.

RESOLVING THE MIXER PARADOX

Microlithic mixers from Marki Microwave offer a combination of advantages that have not been achieved by either traditional hybrid mixers or MMIC mixers. The performance of hybrid mixers has been combined with the size and manufacturing advantages of MMICs to produce a mixer that can achieve decade bandwidth, low conversion loss and small form factor. This performance is achieved through a combination of 3D multilayer fabrication and IC integration that is amenable to both low volume prototyping and customization and high volume manufacturing. ***Table 1*** highlights the key attributes of the Microlithic mixers compared to traditional hybrids and MMICs.

MICROLITHIC PERFORMANCE

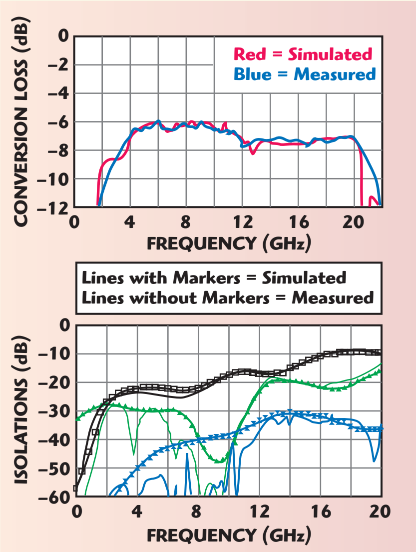
Microlithic mixers are designed using CAD tools, giving engineers full control over the optimization and customization of the designs. While traditional Marki mixers have been designed using decades of experience and painstaking trial and error, Microlithic mixers are designed completely in the virtual space and sent to fabrication only after countless optimization routines are performed to hone the design and study the inherent tradeoffs (see ***Figure 2***). Owing to the precision of the fabrication process, and the accuracy of harmonic balance modeling of the diodes, Marki engineers have demonstrated very good agreement between the mixer simulations and the bench top measurements. As shown in ***Figure 3***, simulations exhibit good agreement with measurement data.

In terms of overall bandwidth coverage, Microlithic designs have already been demonstrated through 40 GHz. These designs are all based on double balanced topologies — such as those available in Marki Microwave's M1 and M9 mixer lines — and compare either favorably and/or better than their legacy counterparts. For example, typical conversion loss for Microlithic mixers ranges from 6 to 8 dB with L-R isolation on the order of 40 dB. Furthermore, Microlithic designs are not specific to any particular semiconductor device meaning that ICs can be selected to optimize for any particular application. For example, by selecting silicon Schottky diode quads, mixers can be driven with LO drive as low as +7 dBm. This represents significant power savings compared to GaAs MMIC mixers, which require at least +13 dBm

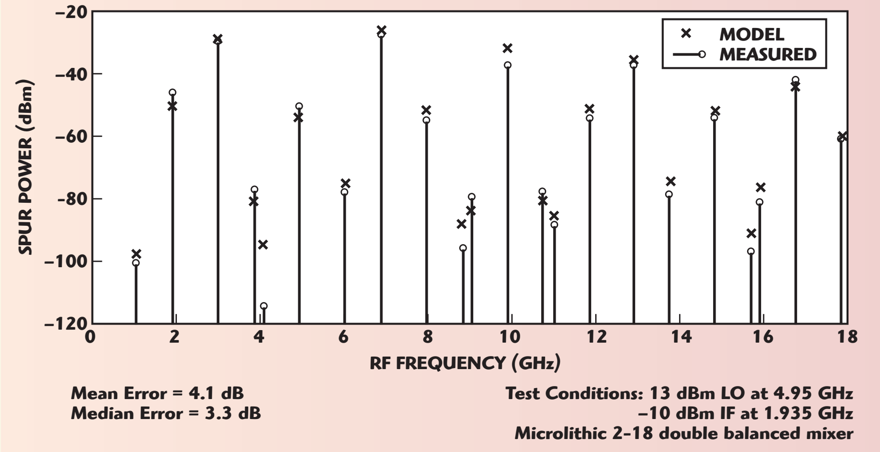
TABLE I

KEY ATTRIBUTES OF THE MICROLITHIC MIXERS COMPARED TO TRADITIONAL HYBRIDS AND MMICs

	Traditional Hybrid Mixer	Monolithic Mixer	Microlithic Mixer
Package Area	0.600" × 0.320"	0.120" × 0.120"	0.152" × 0.090"
Minimum LO Drive	+7 dBm	>+13 dBm	+7 dBm
Typical Bandwidth	Multi-decade	Multi-octave	Decade
Development Lead Time	Days to weeks	Months to years	Weeks to months
Target Volume	Low to medium	Medium to high	Low to high
Circuit Complexity	High	Low	High
Repeatability	Good	Excellent	Excellent
Customizability	High	Low	High
Nonlinear Devices	Any vendor, many choices	Limited by foundry process	Any vendor, many choices
RoHS Compliance	Sometimes	Yes	Yes
Simulation Support	Spur tables, s-files	Spur tables, s-files	Harmonic balance behavioral model



▲ *Fig. 3 Microlithic mixer simulated and measured performance.*



▲ *Fig. 4 Measured spur level vs. microlithic model (MWO).*

or more. Microlithic mixers have also been subjected to key environmental stress tests such as acceleration, shock, vibration and temperature shock with 100 percent passing yield. The performance, size and reliability of these mixers make them ideal for both military and commercial applications.

THE FUTURE OF MIXER MODELING

A significant and useful byproduct of the Microlithic design flow is the creation of an accurate and usable mixer model. These behavioral mixer models are dynamic within the context of the harmonic balance engine. In other words, no assumptions are made about the boundary conditions of the mixer ports (I/O frequencies, power levels, etc). In the Microlithic models, the nonlinear performance is predicted by the interaction of the 3D simulated passive structures, the Schottky diodes and the loading conditions of the ports — as opposed to ad hoc programming using a spur look up table and s-files. The Microlithic user will therefore have more flexibility in studying the mixer's behavior within a system and be able to optimize the design more quickly and accurately, thus saving time, money, and enhancing the scientific understanding of the mixer interaction. The plot in ***Figure 4*** demonstrates the accuracy of the Microlithic models for predicting spurious performance. Marki plans to initially develop downloadable Microlithic models for its customers who use AWR Microwave Office and eventually expand the simulation support to programs such as ADS.

THE FUTURE OF MICROLITHIC TECHNOLOGY

Microlithic mixers covering up to 20 GHz are currently available as demo units and will be available for volume purchase as both RoHS compliant wire-bondable chips and surface mount units by late Q2 2013. High frequency units are expected to demo in early Q3, with special function mixers (IQ, IR, SSB) later this year.

Ultimately, the Microlithic technology platform promises to offer smaller size, higher performance, lower power and faster time to market for a wide variety of applications. This technology represents a giant step forward in our quest to enable our customers to design faster, simplify production, eliminate complexity and shatter performance barriers.

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