cover story

Wideband Mixers Hit High Intercept Points

These new passive diode and high-intercept-point FET mixers employ patented approaches to achieve wide dynamic range without high LO power or conversion loss.

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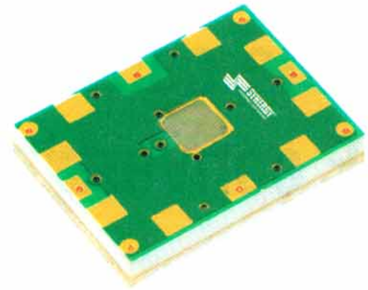
Mixers are essential to most communications systems. Traditionally, they are used to upconvert signal frequencies for transmission and downconvert received signals to lower intermediate frequencies (IFs) for signal processing. Although they are inherently nonlinear devices, communications systems designers try to extract as much linear, wide-dynamic-range performance from these components as possible. To help this cause, Synergy Microwave (Paterson, NJ) has developed two new twists on the conventional double-balanced mixer: one employing Schottky diodes with distributed-element transformers for low-cost, broadband performance and the other based on the reflection-mode commutation of FET mixers. The new Galaxy Series of mixers are fabricated with the firm's Synstrip™ technology (see *Microwaves & RF*, June 2000 Cover) and include the broadband diode model SGM-3 **(Figs. 1 and 2)**, with RF and local-oscillator (LO) ranges of 1 to 8 GHz, level conversion loss with frequency, and DC-coupled IF port. The new SFM line of passive FET mixers can operate with low noise figure and high dynamic range without the need of excessively high LO signal levels. For high isolation, signal leakage between ports is minimized through amplitude- and phase-cancellation techniques.

Frequency mixers are a critical component building block in receivers generally due to the unwanted signal components that result from the frequency-translation process. Through the act of heterodyning, a mixer beats incoming RF signals

1. The Synstrip™ Galaxy Series of mixers employ two novel techniques to achieve high output levels and good linearity with moderate LO power.

with tuned LO signals to produce desired IF outputs. As part of the process, however, the mixer also generates spurious signal products that can limit the sensitivity of a receiver. Especially when these unwanted signals are close in frequency to the desired carrier signals, they can mix and cause undesirable intermodulation distortion (IMD). Because of the congestion of applications below 3 GHz, including cellular systems, Bluetooth, and wireless local-area networks (WLANs), it is often more practical to minimize the generation of spurious products rather than trying to filter them at the mixer's output port.



2. The new mixers are based on a proven multilayer circuit-board technology that provides good unit-to-unit repeatability.

Mixers can achieve frequency conversion through linear or nonlinear means. Linear frequency conversion usually occurs due to a time-varying conductance, such as by pumping LO power to a switching device.[1] Nonlinear frequency conversion takes place according to a quasi-square-law characteristic, such as a diode's voltage-current (VI) transfer characteristic or a transistor's transconductance characteristic. Synergy's two new mixer series operate on both mixing techniques using either broadband diodes or FET switching devices where the transistors' gate capacitances are resonated and the gates driven with high-frequency sinusoidal signals. This leads to an improvement in energy transfer to the mixing cell, and increases the slope of the LO drive used for switching the FET network. The diode-based SGM series mixers operate on square-law characteristics. **Figure 3** shows typical conversion loss for a model SGM-3 mixer while **Fig. 4** shows typical isolation performance.

In conventional FET mixers, the transistor gates are connected directly to the RF source and LO. In the new patent-pending approach, the gates are connected by means of a parallel tuned resonant network for optimum slope and conduction duty cycle.[2,3] Properly selected (for gate-to-source resistance), this network allows a practical balance in the trade-off between mixer conversion loss and IMD.

FET mixers can be designed for both passive and active use. Passive mixers, usually based on diode rings or FET quads, provide good linearity but require high

LO levels and exhibit high conversion loss. Active mixers, which are often based on a Gilbert-cell architecture with biased semiconductor devices, can work with low LO levels and often provide conversion gain, but with decreased linearity compared to passive mixers.

The linearity performance of a FET mixer, as evaluated in terms of the third-order intercept point, is affected by variations in the load impedance. Thus, the most predictable performance occurs with a purely resistance termination as the load. This type of stable termination can be achieved by terminating the mixer with a filter, but the filter appears purely resistive only within its 3-dB passband. As the filter's impedance rises beyond its passband, the mixer's intercept performance degrades. In an active FET mixer, the devices are biased for gain, but at the expense of intercept-point performance. Passive mixers require higher LO power levels, but provide better third-order-intercept performance.

Distortion in a FET mixer can be evaluated in terms of its signal-to-distortion ratio (SDR). The SDR in a FET appears according to the switching mechanism:

$$SDR \approx 20\log(S/v_{in}f_{in}) - 4\text{ dB}$$

$$S = [v_g/t]_{t = tr, tf}$$

where:

S = the slope of the gate voltage swing,

t = the time of the gate voltage swing (from rise time to fall time),

f_{in} = the input frequency,

v_g = the gate voltage signal swing, and

v_{in} = the input signal voltage.

By increasing the slope of the gate voltage swing (S), either by increasing the slope (increasing the magnitude of the gate voltage signal) or reducing the rise/fall time of the gate voltage swing, it is possible to improve a FET mixer's SDR performance. Similarly, the distortion performance can be improved by reducing the magnitude of the input signal voltage, v_{in}. This can be done by reducing the gate-source resistance, although this also increases the conversion loss. The solution, as implemented in the SFM line of FET mixers is to add the optimum value of resistance across the FET gate and source so that the effective magnitude of the signal swing across the gate and source will be reduced and the SDR will be improved without an appreciable increase in the conversion loss. In this way, the gate is optimized in terms of impedance for maximum energy transfer, improving the third-order IMD performance with only moderate increase in conversion loss.

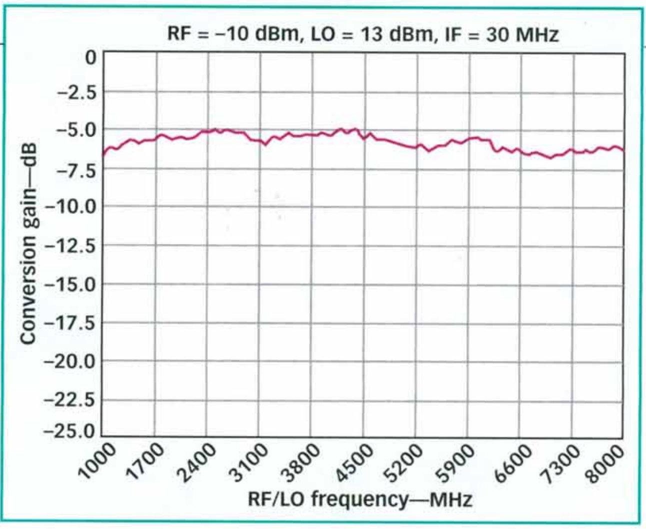
Patents applied for concerning these mixers embody techniques for improving the bandwidth of distributed-element transformers in broadband mixers, such as the SGM series. Other patents relate to the SFM mixers, enabling the development of FET mixers that can work with nominal LO levels of +17 dBm but with the capability of delivering high output levels (in terms of the 1-dB compression point) and excellent linearity (in terms of the third-order intercept point). For example, model SFM-4 covers an RF range of 700 to 1200 MHz with an LO range of 650 to 1000 MHz and IF range of 50 to 200 MHz. As with the other SFM FET mixers, it operates with +17-dBm nominal LO power and exhibits conversion loss of typically 9 dB and nor more than 9.5 dB. It achieves a third-order intercept point of typically +38 dBm with a 1-dB compression point of typically +23 dBm. The MESFET mixer draws less than 50 mA current from a single +5-VDC supply and delivers the isolation figures associated with most FET mixers: LO-to-RF isolation of at least 25 dB and typically 30 dB, LO-to-IF isolation of at least 25 dB and typically 30 dB, and RF-to-IF isolation of at least 17 dB and typically 20 dB. Isolation is measured using sinewave LO signals.

For higher frequencies, notable for PCS applications, model SFM-62 covers an RF range of 1800 to 2200 MHz with an LO range of 60 to 200 MHz (at +17 dBm) and IF range of 1840 to 2275 MHz. The conversion loss is typically 9.5 dB and no higher than 10.5 dB. The input third-order intercept point is typically more than +38 dBm while the 1-dB compression point is typically +23 dBm. The LO-to-RF isolation is at least 40 dB and typically 50 dB, the LO-to-IF isolation is at least 40 dB and typically 50 dB, and the RF-to-IF isolation is at least 17 dB and typically 20 dB. It also draws less than 50 mA current from a single +5-VDC supply.

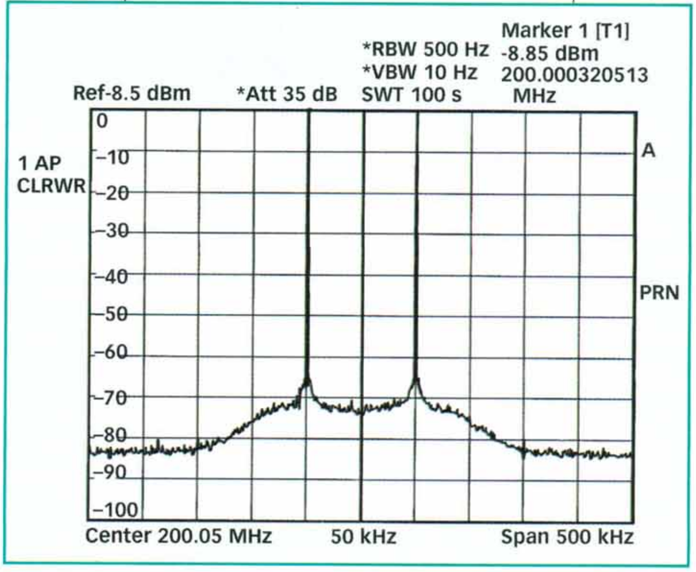
For translation of RF signals from 100 to 600 MHz, model SFM-63 provides a fixed IF of 65 MHz when running with LO signals from 165 to 665 MHz and LO power of nominally +17 dBm. The worst-case conversion loss is 9.5 dB and typically 8.5 dB while LO-to-RF and LO-to-IF isolation levels are at least 25 dB and typically 30 dB. The RF-to-IF isolation is at least 18 dB and typically 23 dB. The 1-dB compression point is typically +23 dBm while the input third-order intercept point is better than +40 dBm and typically +42 dBm or more. As with the other mixers, the SFM-63 consumes less than 50 mA current from a single +5-VDC supply.

Covering a full octave, model SFM-5 handles RF signals from 1200 to 2400 MHz and LO signals from 1100 to 2000 MHz (at +17 dBm) and delivers IF signals from 50 to 200 MHz. The conversion loss is typically 9 dB and a maximum of 10.5 dB. The LO-to-RF isolation is at least 20 dB and typically 25 dB, the LO-to-IF isolation is at least 18 dB and typically 20 dB, and the RF-to-IF isolation is at least 15 dB and typically 20 dB. The mixer achieves a 1-dB compression point of typically +23 dBm and an input third-order intercept point of typically higher than +38 dBm. It has the same power requirements as the other SFM mixers and is designed for an operating temperature range of –20 to +70°C.

The new high-intercept-point FET mixers are housed in 22-pin surface-mount packages, with three pins for LO, RF, and IF connections, one pin for the power supply, and the remaining pins for ground connections. The package measures just 0.65 × 0.65 × 0.27 in. The FET mixers are the first in a series of new mixer designs based on the patent-applied-for reflection-mode commutation of semiconductor devices to optimize the trade-off between linearity and conversion loss. The circuit topology is not limited to these frequency bands, and the company continues to further increase bandwidth and third-order-intercept performance in upcoming products. **Synergy Microwave Corp., 201 McLean Blvd., Paterson, NJ 07504; (973) 881-8800, FAX: (973) 881-8361, e-mail: sales@synergymwave.com, Internet: www.synergymwave.com.**



3. The conversion loss of a diode-based SGM-3 mixer remains relatively flat from 1000 to 8000 MHz.



4. This spectrum-analyzer plot shows the high isolation of a diode-based SGM-3 mixer.

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