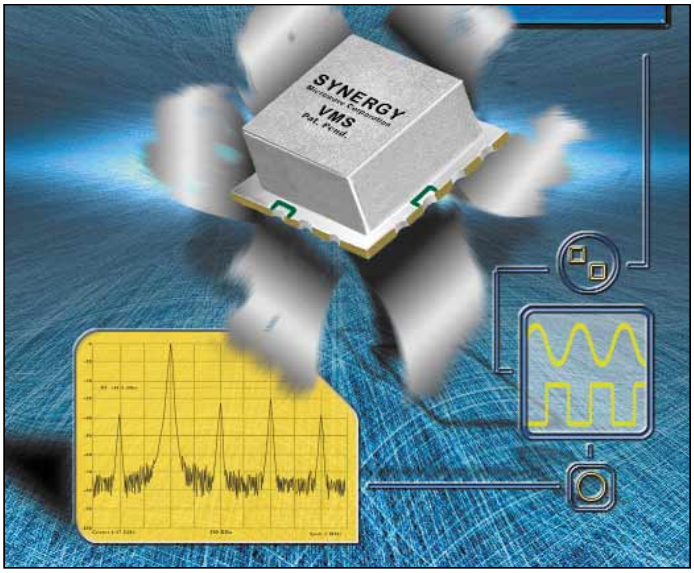
A High Dynamic Range Miniature Modulator/Demodulator

This month's cover features a new patent-pending product line with low noise figure and high isolation

Most commercially available integrated modulators/demodulators operating at cellular band frequencies and higher require many external components and lack the high dynamic range and low noise figure demanded by modern communication systems. Synergy's unique patent pending VMS series of I/Q modulator and demodulator technology allows the designer to select a low cost design with a high dynamic range in a package as small as 0.5 in × 0.5 in × 0.22 in., capable of withstanding harsh reflow environment during automated assembly. The package is EMI/RFI protected with moisture resistant capability.

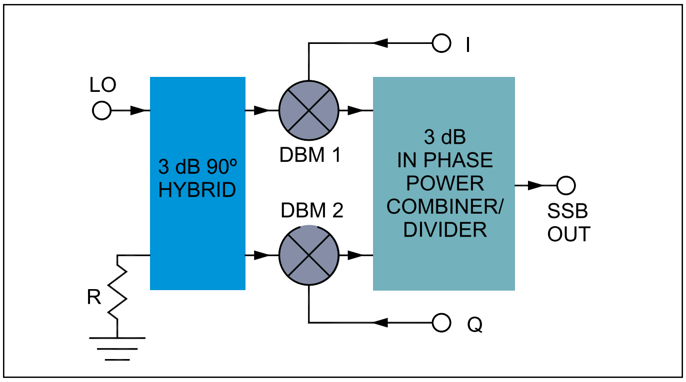


▲ Synergy Microwave announces the VMS series of I/Q modulator/demodulator products.

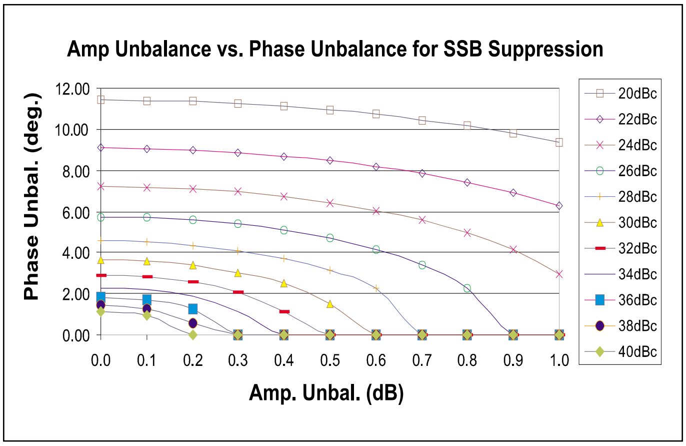
Description

Many manufacturers of active modulators claim high dynamic range when operated with low level (–20 dBm or lower) signals. Active modulators based on Gilbert Cell technology need plenty of external circuitry, including supply decoupling and tuning networks. When direct current (DC) is involved for biasing the internal devices, designers may run into unwanted spurious signals unless special care is taken in decoupling various parts of the modulator. The external circuitry also increases the required p.c. board real estate. Another suggested approach makes use of sub-harmonic modulators where the even harmonic of the local oscillator (LO) mixes with two incoming intermediate frequency (IF) signals of the same strength. The two IF signals are separated by 90 degrees in phase, resulting in either an upper sideband or a lower sideband RF signal in the case of a single sideband (SSB) modulator. In the case of a demodulator, this approach will result in two IF signals of similar strength differing in phase by 90 degrees, commonly known as a quadrature IF mixer. The carrier rejection is high due to the fact that the subharmonic mixers used in the modulator offer higher isolation at the even harmonics of the LO. However, the signal handling capability may be lower (depending on the design) than that of a fundamental type, resulting in inferior intermodulation products.

Figure 1 shows the block diagram of a typical modulator where two double balanced mixers (DBMs), whose IF ports are DC coupled, are interconnected with a 90 degree hybrid on one



▲ **Figure 1. Block diagram of a typical modulator where IF ports are DC coupled and are interconnected with a 90 degree hybrid on one side and an in-phase divider/combiner on the other side.**

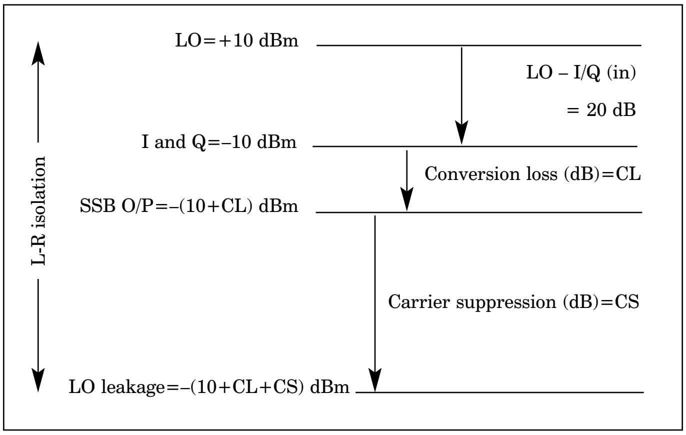


▲ **Figure 2. The plot of amplitude unbalance vs. phase unbalance for various values of SSB rejection.**

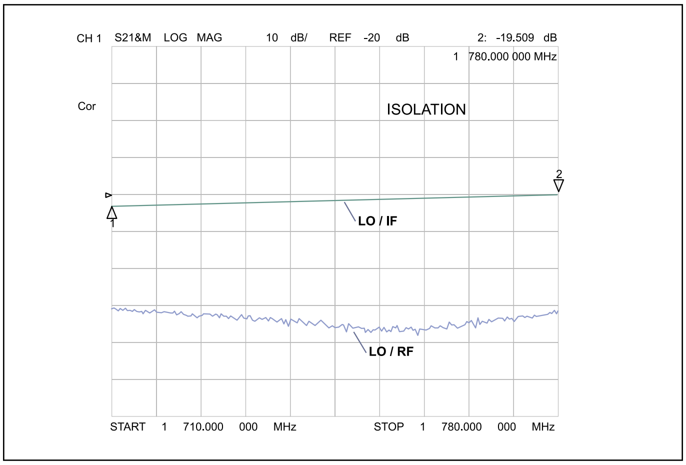
side and an in-phase divider/combiner on the other side. The carrier rejection of the modulator is directly related to the LO to RF isolation of the mixers, whereas, the single sideband (SSB) rejection is related to the combined amplitude and phase balance of the various components within the modulator. Figure 2 shows the plot of amplitude unbalance vs. phase unbalance for various values of SSB rejection. From the figure, it is evident that for 40 dB SSB rejection, one has to maintain the phase and amplitude balances as low as 1 degree and 0.1 dB respectively. The noise figure (NF) in decibels (dB) of the passive modulator is typically no more than 1 dB higher than the conversion loss of the modulator, whereas active modulators have poorer noise figure resulting in lower signal-to-noise ratio.

The modulator used in the VMS series (patent pending) reduces component count, including transformers, which are the main source of degraded phase and amplitude response at higher frequencies. The transformers used in this modulator provide higher frequency coverage with excellent phase and amplitude balance, crucial to higher sideband rejection. Also, the transformers provide improved isolation resulting in better carrier rejection. The 1 dB compression point of the modulator, coupled with carrier and sideband rejection, determines the dynamic range of the modulator. The 1 dB compression can be improved (different model) by using higher level Schottky diodes (four are used to form a ring/cross over quad), where the level is expressed by the forward voltage drop (V_f) of the diode for a given current. There is a practical limit to this. The typical values for V_f are 225 mV, 350 mV and 550 mV. One can take advantage of the fact that the effective value of V_f can be increased by connecting as many diodes as practical in series, keeping in mind the package size and the frequency response limitations. When too many diodes are housed in a single package (multiples of 4 or as required), the cost becomes prohibitive.

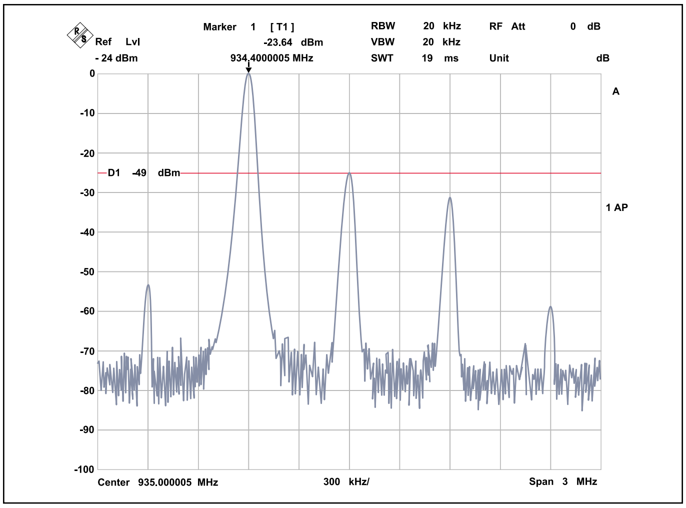
Assuming the package size and frequency response of the diode is the same irrespective of the V_f, the basic design of the modulator remains unchanged. The bandwidth limitation comes from that of the 90 degree hybrid used in the modulator. For the smallest unit, the bandwidth is typically 10 percent. The third order intermod-



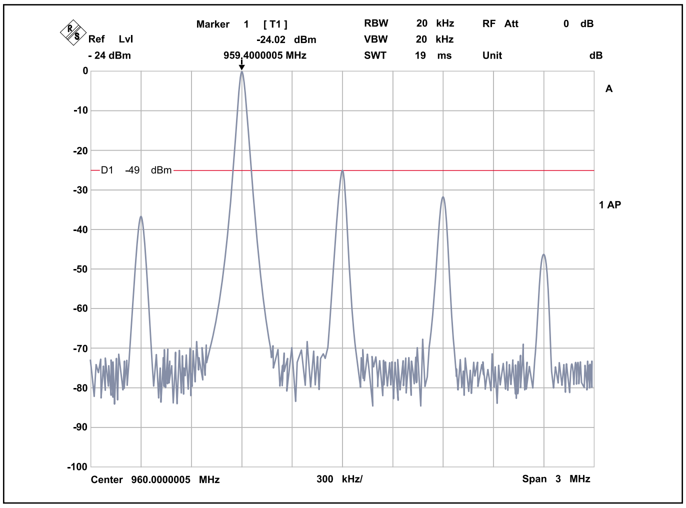
▲ **Diagram 1. Relationships to help calculate the LO/RF isolation for each of the DBMs used in the modulator.**



▲ **Figure 3. Typical isolation for a PCS band unit.**



▲ **Figure 4. Carrier and sideband performance at low cellular band for the VMS-935 model.**



▲ **Figure 5. Carrier and sideband performance at high cellular band for the VMS-935 model**

ulation product (IP3) depends on the V_f of the Schottky diode, the L/R, L/I and R/I isolations in the mixers and the impedance match at all ports.

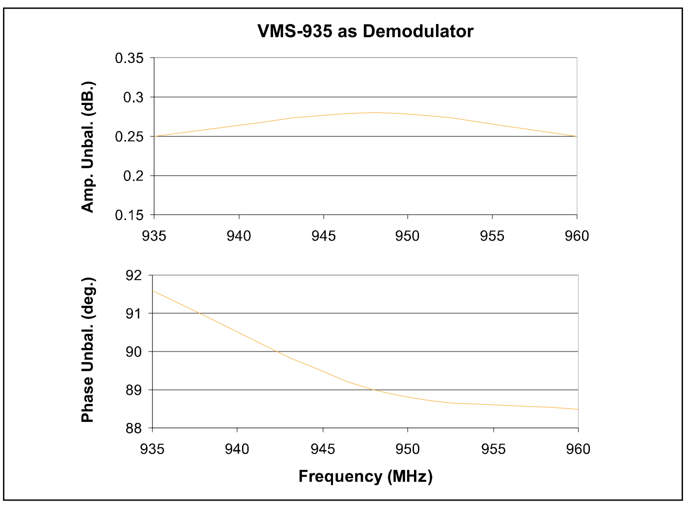
Importance of LO/RF isolation

As pointed out earlier, the LO to RF isolation determines the carrier rejection in the modulator. Diagram 1 helps the designers to calculate the LO/RF isolation for each of the DBMs used in the modulator. The isolation number for each of the DBMs will decrease by 3 dB, due to the combining effect in the in-phase combiner. In the diagram below, we will assume that the modulator is being driven by a LO drive of +10 dBm and the I and Q levels are –10 dBm each.

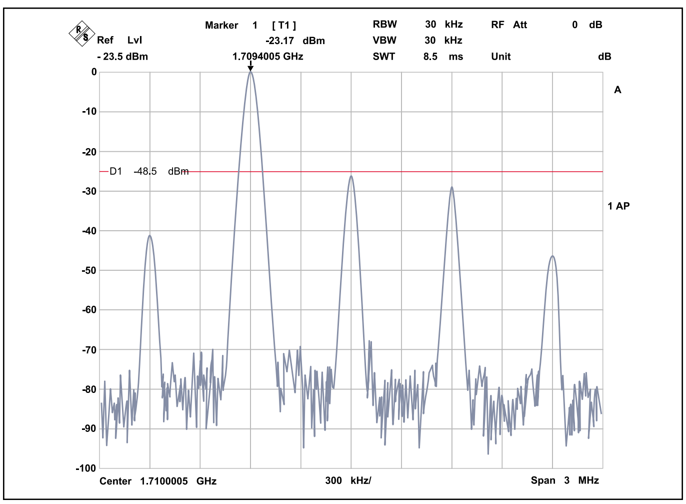
For a carrier rejection of 30 dB and a typical conversion loss of 5 dB, the LO/RF isolation of the modulator will be 55 dB and each of the DBMs will have 52 dB of isolation. At higher frequencies, it is difficult to reach this figure with a conventional approach, while the new approach can easily achieve this in smaller size. Figure 3 shows a plot of typical isolation for a PCS band unit. LO/RF isolation is better than 50 dB, while the LO/IF isolation is 20 dB.

Performance

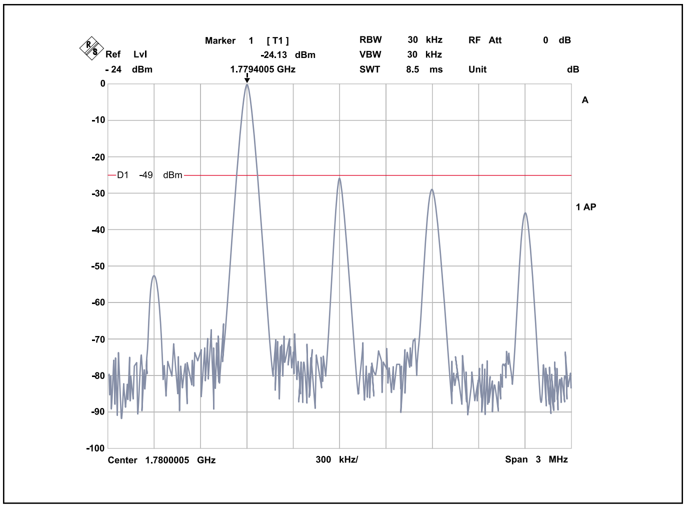
Two models, VMS-935 and VMS-1710, operating in the popular 935 to 960 MHz cellular and 1710 to 1780 MHz PCS frequency bands, are selected to highlight the performance of the new technology. For each of these applications, the I and Q levels are set at –10 dBm each with a 90 degree phase difference between them at 600 kHz, while the LO level is fixed at +10 dBm. Figures 4 and 5 display the carrier and sideband performance in the cellular band for the VMS-935 model, showing that the SSB rejection is 30 dB (min.) across the band. With minor modifications, VMS-935 can be used as a demod-



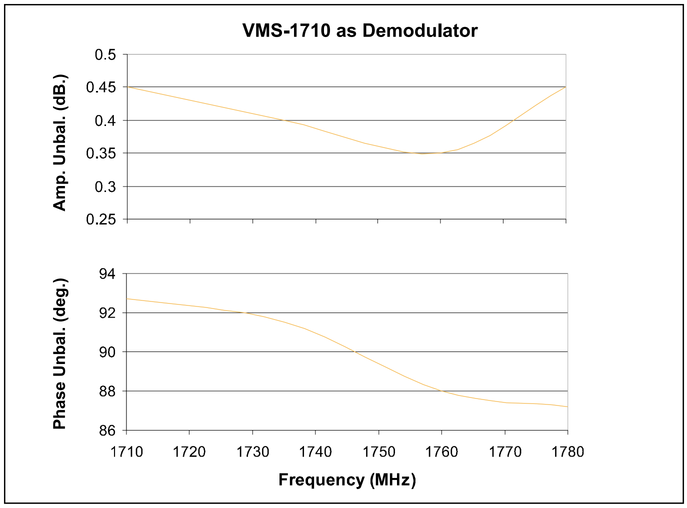
▲ **Figure 6. The amplitude and phase unbalances across the full band of 935-960 MHz.**



▲ **Figure 7. Carrier and sideband performance at low PCS band for the VMS-1710 model.**



▲ **Figure 8. Carrier and sideband performance at high PCS band for the VMS-1710 model.**

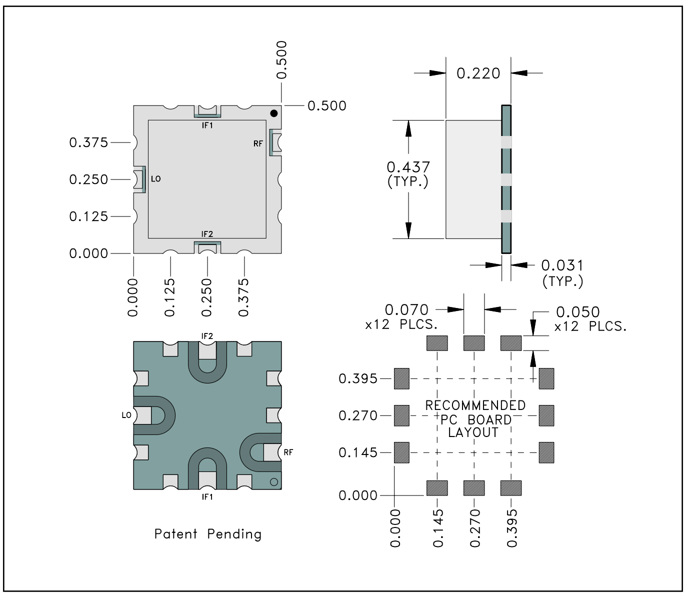


▲ **Figure 9. The amplitude and phase unbalances across the full band of 1710-1780 MHz.**

ulator, and Figure 6 shows the amplitude and phase unbalances across the full band of 935-960 MHz. The amplitude balance is within 0.3 dB and the phase balance is within ±1.7 degrees.

Figures 7 and 8 highlight the carrier and sideband performance in the PCS band for the VMS-1710 model, where the SSB rejection is 27 dB (min..) and the carrier rejection is 25 dB. VMS-1710 can be tuned to function as a demodulator, and Figure 9 shows the amplitude and phase unbalances across the full band of 1710-1780 MHz. The amplitude balance is within 0.45 dB and the phase balance is within ±3.0 degrees. The plots shown in Figures 4, 5 ,7 and 8 also display products that are related to the harmonics of the I and Q signals mixing with the LO. For higher dynamic range, it is highly recommended that the modulator be operated in the linear range. Units designed for higher compression points offer lower levels of the above products.

The outline drawing and the recommended layout of mounting pads for the VMS series modulators is shown in Figure 10.



▲ **Figure 10. The outline drawing and the recommended layout of mounting pads for the VMS series modulators.**

Conclusions

The exceptional RF performance of the new lower cost modulator is demonstrated through the above examples. This new design can be manufactured consistently in large volume and will be available in various packages as needed. The frequency of operation can be easily extended to 3 GHz and more using printed transmission lines for transformers, 90 degree hybrids and an in-phase combiner/divider. This unique approach combines a better noise figure and dynamic range with reduced cost in external circuitry, and requires much less real estate on printed circuit board. ■

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