Switch Solutions for Systems with Low PIM Requirements

The effect of nonlinearities is becoming more prominent in signals with higher amplitude as it results into intermodulation levels that are more evident. These signals interfere with the desired system behavior and causes unwanted results. In order to reduce intermodulation in passive devices, low PIM designs are required.

This paper will focus on defining Passive Intermodulation (PIM) and the concerns around PIM, the cause of PIM in both general terms and in switches, and present a solution for systems with Low PIM requirements.

Definition of PIM and the Concerns

Passive Intermodulation (PIM) or **Passive Intermodulation distortion (PIMD)** is the unwanted amplitude modulation of signals containing two or more different frequencies in a system with nonlinearities. For instance, cascaded system components may generate intermodulation products such that is adds additional frequency components to the output signal. As these extra signals become larger, they may compromise the intelligibility of the system output signal

If the circuit has nonlinear characteristics, then the fundamental frequency (Fn) components will become distorted in the time domain and generate series of higher order harmonic frequency components in the frequency domain.

> The lowest frequency produced is known as the fundamental frequency, where harmonic frequency is a multiple of a fundamental frequency. The fundamental frequency is also called the first harmonic.

Normally, the components of concern are 3rd, 5th, and 7th order. These odd-order PIM products typically fall within the vicinity of the original frequency components and may therefore interfere with the desired system behavior. Since the 3rd order is of greatest signal strength, our primary concern is with the 3rd order harmonic.

PIM Equation

Intermodulation (IM) products are generated when two or more frequencies are applied to a nonlinear transmission element such the signal applied does not have a proportional ratio between current and voltage at the same time. The numeric value that follows is the sum of the integer multipliers used for each of the two parent tones to realize the given IM product.

So let's say, if the fundamental frequencies are F1 and F2 (carrier frequencies), then the possible intermodulation frequency components can be described by the equation:

$$F_{PIM} = n \bullet F1 \pm m \bullet F2$$

where the sum of *m* and *n* is the product order

For example:
(2F2-F1), where the constants are n = 2 and m = 1, the sum of m and n (2+1=3) results to a 3rd order Passive Intermodulation (PIM) product.

Specifying and Calculating PIM

PIM is specified in dBc and dBm terms, where dBm is a measure of power relative to 1 mW and dBc is a measure of dB below a specify carrier level. A typical input power level in testing passive devices is +43 dBm (20 W) and if the permitted PIM is -120 dBm, it results to the following PIM level value:

-120-43= -163 dBc

Today, a typical low PIM requirement is between -110 dBm to -120 dBm with two carrier signals at +43 dBm.

If the carrier frequencies are F1=1930 MHz and F2=1990 MHz at 3rd order product, it results into a PIM frequency of 1870 MHz.

$$2F1-F2 = 2x1930 – 1990 = 1870 \text{ MHz}$$

Causes of Passive Intermodulation

Passive intermodulation (PIM) occurs in passive devices such as in cables, antennas and RF switches (all non-linear devices), where the PIM product is the result of at least two multiple high power tones mixing induced by ferromagnetic materials, junctions of dissimilar metals, metal-oxide junctions, contaminated junctions and loose connectors. The effect of nonlinearities is becoming more prominent for signals with higher amplitude; consequently the intermodulation is more evident.

PIM can also occur in RF switches when conductors made of two galvanically unmatched metals that come in contact with each other. However, the most common source of passive intermodulation in RF switches comes from the conduction of signal current through unstable contact junctions (high contact resistance) or ferromagnetic metals, which has a nonlinear magnetization-inductance hysteresis.

Dow-Key Solutions for Systems with Low PIM Requirements

Filtering can reduce or eliminate the PIM generated by the active devices in systems such as amplifiers, but passive components inserted in the transmission line that cause PIM cannot be filtered. The only solution to reduce PIM in the transmission path is to design low PIM passive devices.

Dow-Key Microwave has invested in R&D for new RF switch products and introduced to the market a family of special RF switches, with SMA connectors, which meet very stringent low intermodulation requirements imposed by today's test and communication industries. The new Low PIM family provides a much improved PIM performance and is available as an option to users with Low PIM needs.

Since PIM characteristics depend on carrier frequencies, power level, and number of other factors, Dow-Key has certified the Low PIM product line per the criteria shown in Table 1.

3rd Order Intermodulation for two carrier @ approximately 43.0 dBm				
Product Description	First Carrier Frequency	Second Carrier Frequency	PIM Frequency	PIM Level
Standard	1930 MHz	1990 MHz	1870 MHz	110 dBc Min.
Low PIM	1930 MHz	1990 MHz	1870 MHz	160 dBc Min.

Table 1: 3rd Order Intermodulation for two carriers in Standard and Low PIM switches

Dow-Key Low PIM switches are specifically designed and guaranteed to meet 3rd order PIM requirements below -160 dBc at 1870 MHz and at approximately +43 dBm with carrier frequencies 1930 MHz and 1990 MHz.

PIM Performance and Test Data

Followed are typical PIM performances of Low PIM switches compared to Standard switches with SMA connectors. See figures 1 through 4.

PIM tests were conducted at Dow-Key facility using Dow-Key Low PIM and Standard switches. For more information on specific Low PIM switch products, contact Dow-Key Microwave.

Low PIM Switch - Forward (Through) IM Power

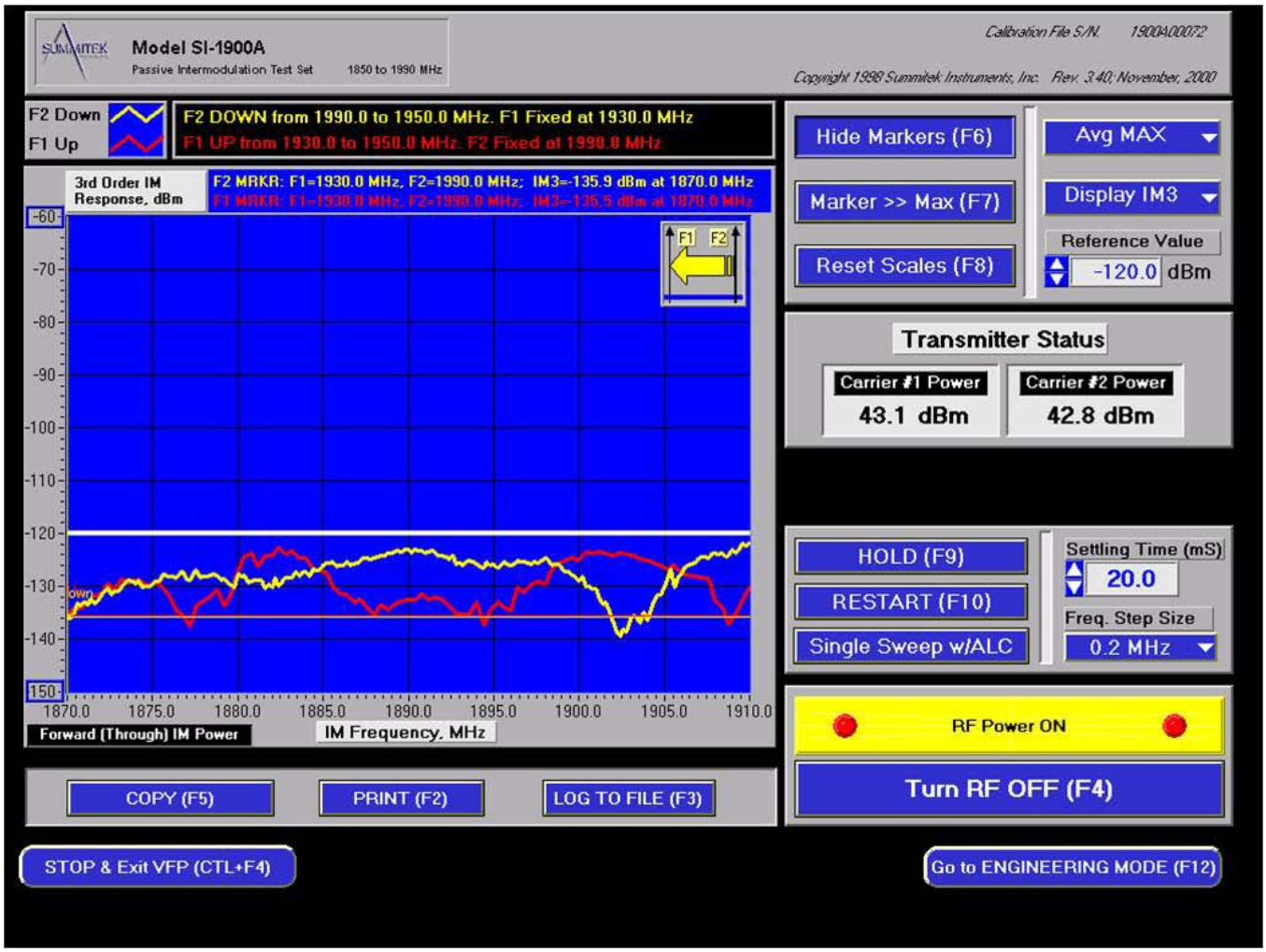

Figure 1 (Low PIM Switch): 3rd Order IM Response - Forward (Through) IM Power – Sweep Mode

Low PIM Switch - Reflected (Reverse) IM Power

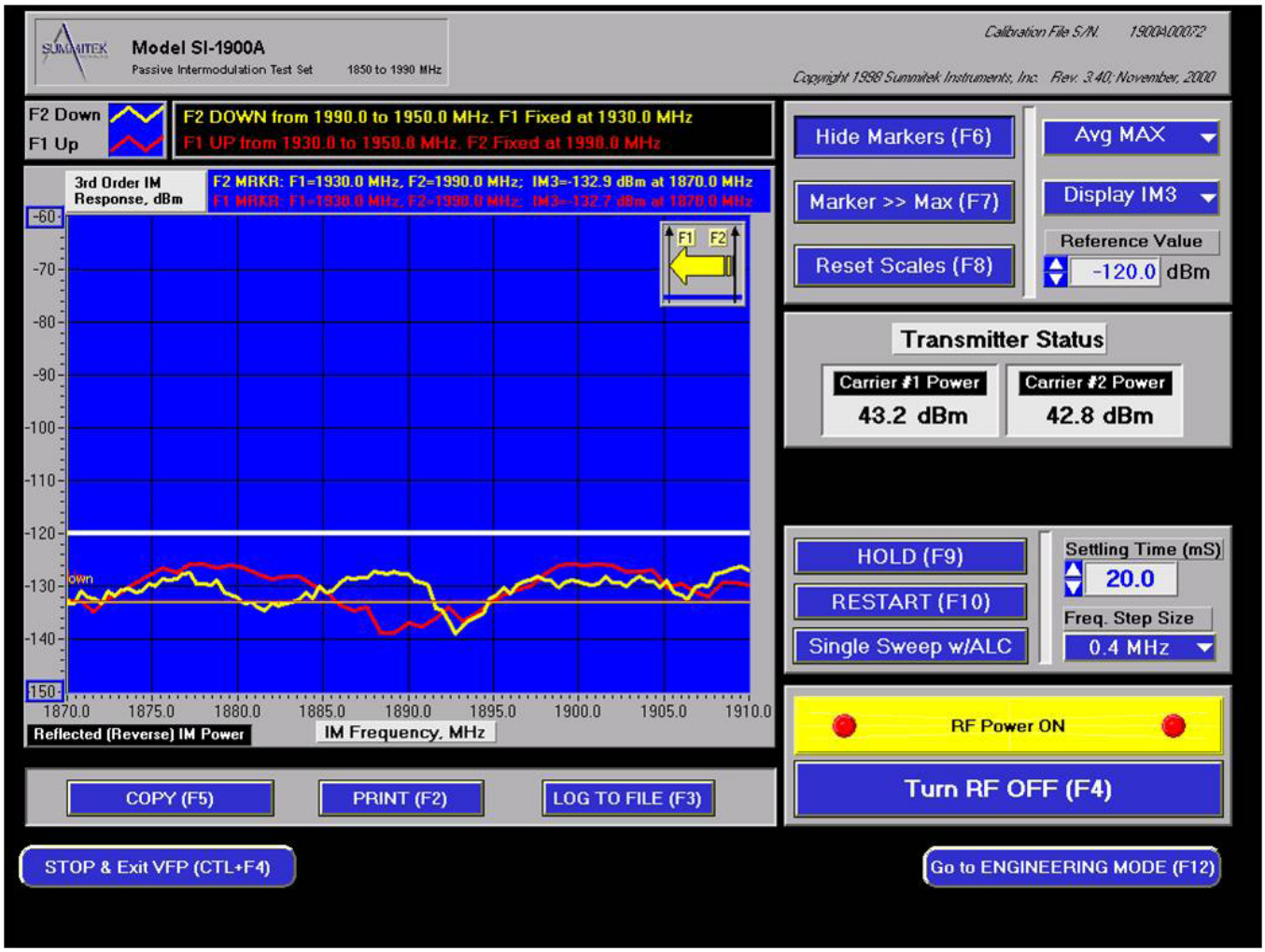

Figure 2 (Low PIM Switch): 3rd Order IM Response - Reflected (Reversed) IM Power – Sweep Mode

Standard Switch - Forward (Through) IM Power

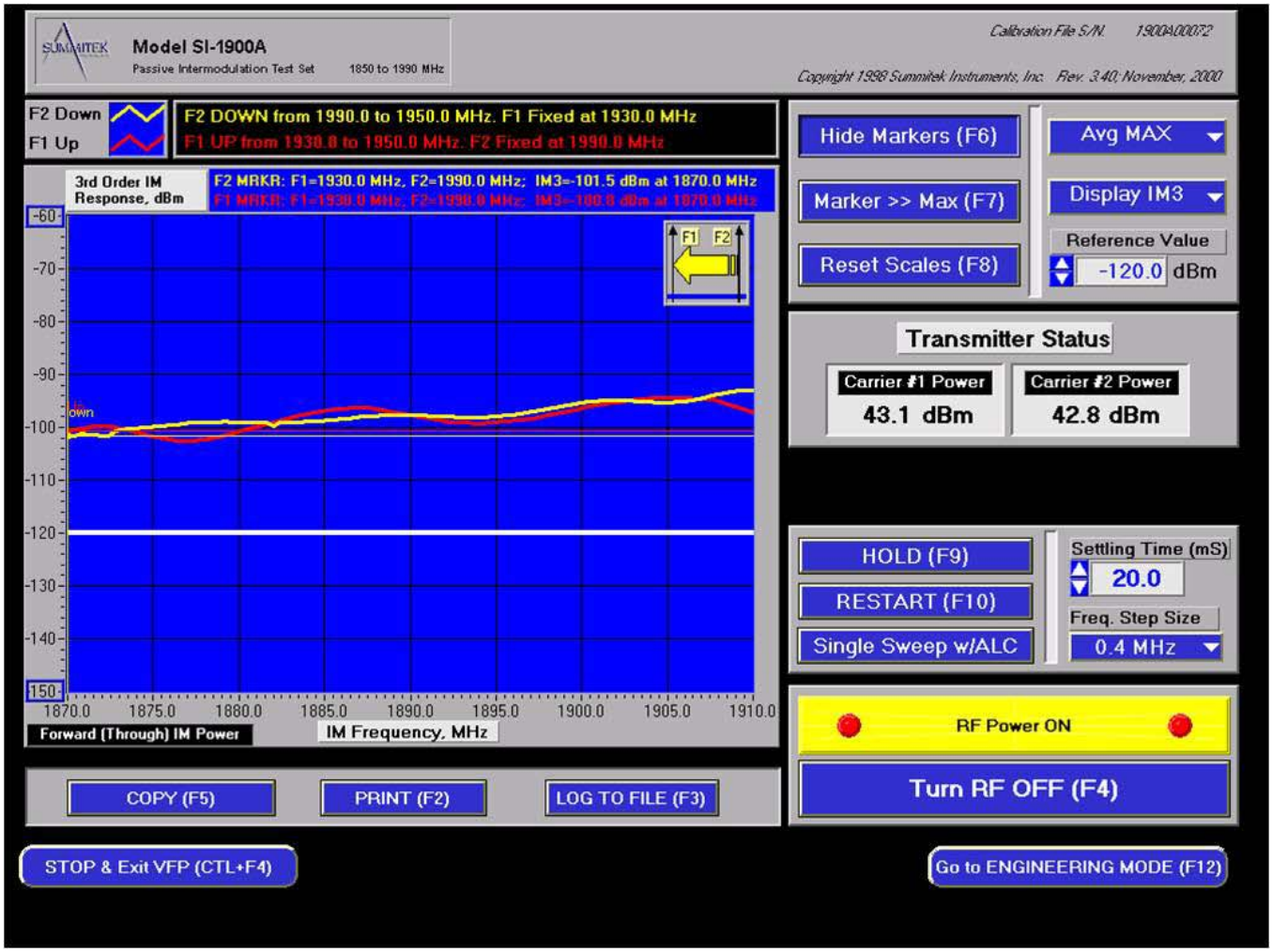

Figure 3 (Standard Switch): 3rd Order IM Response - Forward (Through) IM Power – Sweep Mode

Standard Switch - Reflected (Reverse) IM Power

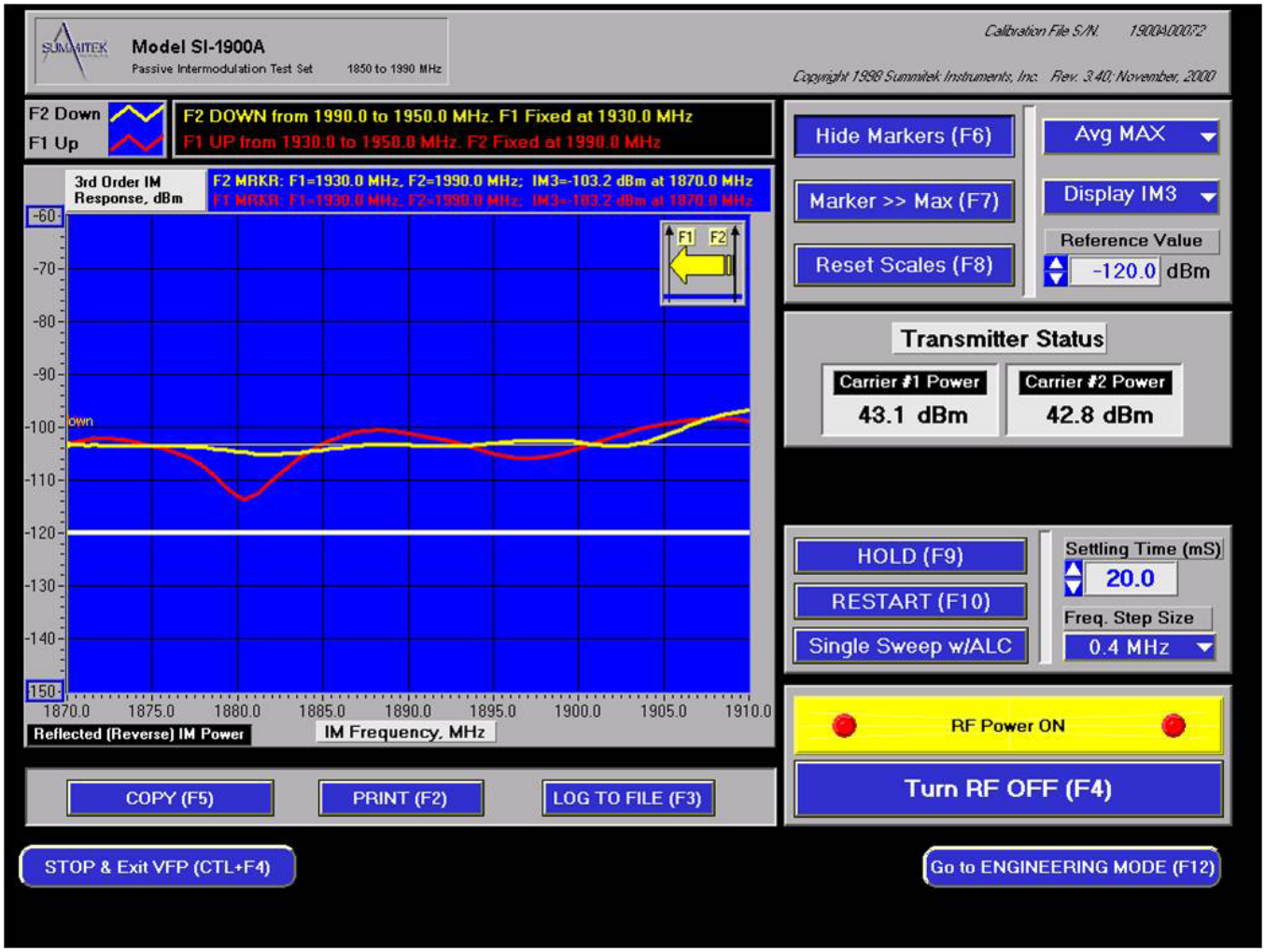

Figure 4 (Standard Switch): 3rd Order IM Response - Reflected (Reverse) IM Power – Sweep Mode

Author:
Sara Nazemzadeh has been with Dow-Key Microwave since 2007 and she holds a B.Sc. in Computer Engineering and M.Sc. in Electrical Engineering from California State University of Northridge.

Company:
Dow-Key Microwave Corporation, part of Ceramic & Microwave Products and a subsidiary of Dover Corporation, is a leader in electromechanical switches since 1945. They manufacture, as well as custom design, switches and switching systems for the Commercial, Military, and Space industries. Dow-Key Microwave specializes in broadband RF coaxial and waveguide switches operating from DC to 70 GHz, electromechanical and solid state switch matrices, fiber optic switch systems, programmable attenuators and delay lines, in addition to, PXI switch modules.