

Electronic Concepts for The Compleat Idiot: A Simplified Look at Passive Intermodulation Distortion

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In a previous edition of the Newsletter we talked about the subject of Signal Integrity and commented on the subject of intermodulation distortion as follows:

Signals also may be impacted by noise that is not simple background static but actual interference by other unwanted signals. These can come from any number of sources including signals reflected from bad metal connections, designs that have square corners, plated through holes, etc. Remember that electromagnetic waves add or subtract from one another, so if two signals are in the same transmission line at the same time, the resultant signal coming out the far end looks like the arithmetic sum of the two. If one is the mirror image of the other the two can even null out. More commonly the unwanted signal improperly “modulates” the other and distorts the data it is carrying. This is the basis for the term “intermodulation distortion.” If the distortion gets too severe, then the signal is not readable and some or all the data is lost. (You can read the entire article, entitled “Electronic Concepts for the Compleat Idiot: A Simplified Look at Signal Integrity” on Arlon’s website at www.arlonmed.com)



Now let’s look briefly at a little more detail about the little devil called PIM (Passive Intermodulation) -- what it is and how it results in signal distortion. In assembling this information I was especially appreciative of input from Summitek Instruments,

whose people and website (www.summitekinstruments.com) were a storehouse of information both on the subject itself and the equipment and methodology of testing. The British poet, Alexander Pope, said, “A little learning is a dangerous thing...” and with as little as I have learned about PIM, I may be very dangerous indeed, but nevertheless, and in keeping with the “Fools-rush-in-where-angels-fear-to-tread” principle, here goes...

Passive Intermodulation is present whenever RF signals at two or more frequencies are present in an RF transmission line in a nonlinear system. Such signals can be mixed as a result of nonlinearity in the system, usually attributed to junctions between dissimilar materials and similar anomalies in the transmission pathway. Since in many telecom systems the transmit and receive bands are fairly close together, when the mixed signals

overlap in frequency with the transmit or receive band of a system (for instance the third order mixing of any two frequencies, F_1 and F_2 , referred to as IM3, is equal to $2*F_1 \pm F_2$) they can appear as noise, or interference above and beyond the normal and random “noise floor” of the system.

PIM is especially problematic on the receive side of a system where signal strength is typically very low relative to the transmit side. A handheld phone for example transmits at power levels of 0.1 Watt or thereabouts which is the maximum strength of the signal that will be received, whereas the base station may transmit at 50 Watts or more. Therefore the receive antenna is a particularly vulnerable system component for PIM interference. According to Summitek, “Because PIM products typically increase significantly as the average transmit power level increases, the effect of PIM on a base station may only become significant when the base station becomes fully loaded. Just when the most capacity is needed, passive IM level can rise up and interfere with normal base station operation.” (For more details go to Summitek’s FAQ page at www.summitekinstruments.com/passive/faqcont.html)

Arlon MED’s Microwave Materials group has recently introduced a line of PTFE-based copper-clad laminate products that have been optimized to minimize the effect of the PWB substrate on signal distortion due to passive intermodulation (PIM) in etched planar antennas for cellular infrastructure. This introduction came only after two years of intensive experimental design work that looked at every aspect of the materials, construction and fabrication of copper clad laminates that are intended for frequency-sensitive applications. In the past we had seemingly contradictory feedback on the subject of our materials and PIM -- some said our material was better than competition, and some said it was worse. Setting aside issues such as the quality of mechanical and soldered connections and the like, it is possible to produce antennas from the same piece of laminate that vary by as much as 50 dBc simply due to differences in the process of PWB fabrication (i.e. the effect of different bare board fabricators), so the task before us was nontrivial. Before we were done, we took apart, then put back together, our entire product line, including the choice of all raw materials and our entire manufacturing procedure.

We found a lot of things that didn’t impact PIM, but in the end we established that there were statistically significant interactions between certain of the raw materials we used as well as the way in which they were assembled and how they were processed. All this despite the fact that when we first entered into this project we had been told by a number of design people that PIM was largely the result of poor metallic mechanical junctions, the presence of ferrous materials in the system and/or some kind of contamination in the RF pathway. The last place to look, we had been informed, was the laminate material itself.



How low a value of PIM is “good” is a question that goes to the individual design. In Arlon’s own experience our products exhibited values (before the work to enhance PIM performance) that ranged from -135 to -140 dBc in the range of 1850-1990 MHz on an etched microstrip test platform using a Summitek S1-900A Passive Intermodulation Analyzer (typical 3rd harmonic output data and test equipment pictured here courtesy of Summitek Instrument). The PIM enhanced products exhibit values from -150 to -

155 dBc in the same test setup, while the materials generally show better values by 5-10 dBc (i.e -155 to -165 dBc) in actual production antennas. For most antennas a value of the 3rd harmonic at -145 dBc has been sufficient, although for some 3G cellular applications a value of -155dBc or lower is required. (Note please that -155 dBc is approaching the limit of sensitivity of the available test equipment, so values better than that may be hard to discriminate.)

The bottom line is that as demands on laminate materials in terms of their contribution (or lack thereof) to PIM distortion become more critical, designers have a family of Arlon products available to help implement a cost-effective way to bottom out that PIM noise threshold.