

INVESTIGATION OF PASSIVE IM LEVEL VS POWER

Overview:

The purpose of this experiment was to investigate the relationship between Passive Intermodulation (PIM) levels and the carrier powers that generated the PIM. This effort was motivated by inquiries from Summitek Instruments' customers as well as work being done by the IEC (International Electrotechnical Commission) directed at developing recommended test methods for Passive IM measurements.

Theoretical Relationship:

PIM is generated within a passive device whenever two or more carriers encounter a semi-conducting region in the device under test (DUT). Typical causes are poor contact junctions and material properties. The intermodulation products of interest in wireless telecommunications systems are generally the odd order products, which are mathematically defined as follows:

$$\text{IM3 (Third Order IM Product)} = 2 * F_1 + F_2$$

$$\text{IM5 (Fifth Order IM Product)} = 3 * F_1 + 2 * F_2$$

$$\text{IM7 (Seventh Order IM Product)} = 4 * F_1 + 3 * F_2$$

Etc.

Considering the composition of the power in the IM products, theory says that with a 1 dB change in Carrier Power 1 and Carrier Power 2 would produce a 3 dB change in IM3, a 5 dB change in IM5 and so forth. Furthermore, if the only one of the carrier powers is changed while the other remains constant, theory says that there would be a change in IM power equal to the coefficient for the carrier that is being varied. For example, if the Carrier 2 power is held constant while the Carrier 1 power is varied by 1 dB, it is expected that IM3 would change by 2 dB, IM 5 by 3 dB and so forth.

Objectives:

The experiment was designed with a goal of answering the following questions.

1. How does the magnitude of the Passive IM power vary as a function of the carrier powers that give rise to the intermodulation?
2. Is the relationship between IM3, IM5, IM7 and IM9 predictable?
3. Does PIM generated by a discontinuous junction behave the same PIM arising from material properties?

Procedure:

The Summitek Instruments Passive IM Analyzers have the capability to measure multiple IM products simultaneously. This is advantageous because it allows all of the IM products to be measured at the same time without changing any of the test conditions. Because the Summitek PIM Analyzers measure IM that lands in the receive band, it is necessary to select a pair of test frequencies that generated all four of the IM products within the receive band. The DCS1800 band is the only one of the major wireless band



that has this characteristic. The carrier frequencies and resultant IM frequencies are as follows.

Carrier 1 = 1805 MHz

Carrier 2 = 1828 MHz

IM3 Frequency = 1782 MHz

IM5 Frequency = 1759 MHz

IM7 Frequency = 1736 MHz

IM9 Frequency = 1713 MHz

The test powers recommended by the IEC are 43 dBm (20 watts) per carrier. Therefore, 43 dBm was chosen as the base power level for the test. From this starting level, the carrier power was decreased in 1 dB decrements for one or both of the carriers depending upon the test being performed.

Test 1: Both carrier powers are kept equal and decreased in 1 dB steps from 43 dBm down to 30 dBm.

Test 2: Carrier 1 is kept constant at 43 dBm and Carrier 2 is decreased in 1 dB steps from 43 dBm to 13 dBm.

Test 3 Carrier 2 is kept constant at 43 dBm and Carrier 1 is decreased in 1 dB steps from 43 dBm to 13 dBm.

Two different test samples were measured. The first, referred to as “Diode” in the test results, is a Passive IM Standard made by Spinner. This is a 7-16 DIN Male-to-Male adapter into which is placed a diode for the purpose of generating passive IM. The second test item is a nickel plated 7-16 DIN Male-to-N Female adapter.

Test Setup:

All measurements are made as a Reverse (Reflected) IM measurement. The test equipment is a Summitek Instruments Model SI-1800A Passive IM Analyzer. The Device Under Test is attached to the output port of the SI-1800A with the output port of the DUT terminated into a SI-20A Low IM Termination. The carrier frequencies are selected as specified above and the IM data is measured and logged to file automatically using the Production Mode of the analyzer. This minimizes operator intervention to improve the quality of the results.

There are two important considerations that will impact measurement. These are the noise floor of the receiver and the residual intermodulation of the test setup.

Receiver noise floor establishes the impact that thermal noise will have on the data measured. The greater the s/n ratio, the less impact due to noise. An s/n ratio of 20 dB or greater is recommended.

Residual Intermodulation is the term used to define the amount of intermodulation being generated by the test setup. Just as a basestation cannot lock on a cellular call that has power levels below any interference sources arriving at the basestation at the same time and frequency as that of the cell phone, it is not possible to get an accurate measurement of the passive IM performance of the DUT if the residual IM of the test setup is greater



than the PIM of the DUT. Additionally, the residual IM can corrupt the accuracy of the measurement if it is not sufficiently below the level of PIM generated and being measured on the DUT. It is generally recommended that the residual IM level of the test setup be 10 dB or greater below the PIM levels being measured.

The noise floor of the SI-1800A is -140 dBm. The residual IM of the test setup, which is the SI-1800A terminated by the SI-20A, is -130 dBm with 2 x 43 dBm carriers (-173 dBc).

Measurement Results:

The measurement results are presented graphically in Figures 1 through 6 (attached). In each case, a straight-line approximation is used to determine the slope of the data. A summary of the results is given in the following table, which includes the measured and the slope predicted by theory. Note that IM9 data is not included because the power levels were too close to the receiver noise floor to be meaningful.

	Diode Equal Power F1 = F2	Nickel Equal Power F1 = F2	Diode F1 Constant	Nickel F1 Constant	Diode F2 Constant	Nickel F2 Constant
IM3	2.0 [3.0]	2.3 [3.0]	0.8 [1.0]	1.0 [1.0]	1.6 [2.0]	1.9 [2.0]
IM5	3.3 [5.0]	2.7 [5.0]	1.6 [2.0]	1.6 [2.0]	2.1 [3.0]	2.5 [3.0]
IM7	4.1 [7.0]	1.5? [7.0]	2.2 [3.0]	**	2.6 [4.0]	2.1 [4.0]

Observations:

1. When the carrier powers are varied together, the rate of decrease in IM is slower than predicted by theory. Conversely, as the power in the carriers is increased, the rate of increase in IM is less than predicted by theory.
2. The deviation from theory increases with increasingly higher order IM products. However, because the s/n ratio is decreasing at the same time, these results may be biased by the affects of noise. Despite the impact of noise, the data does suggest this is a true observation.
3. The material based PIM generator behaves more uniformly (nearly constant slope with power) than the diode standard.

Conclusions:

1. Since the increase in IM level with increasing power is less than predicted by theory, measuring at lower power levels and then extrapolating the data to the IM level that theory predicts at these higher power levels yields a very conservative estimate of the IM levels that would actually be measured at the higher power.



2. Because the slope is less than predicted, it takes smaller levels of the second carrier to produce large IM response when in the present of a second higher power carrier than would be predicted by theory. This is an important observation in view of the increasing tendency toward collocating wireless services.
3. Diode standards are not the ideal PIM standard.

Suggestions for Future Work:

1. Measure more the same kinds of PIM sources, since a sample of one is not statistically significant.
2. Test in different frequency bands.
3. Repeat the tests using different PIM sources.





Figure 1
PIM of Diode Source vs Equal Carrier Power

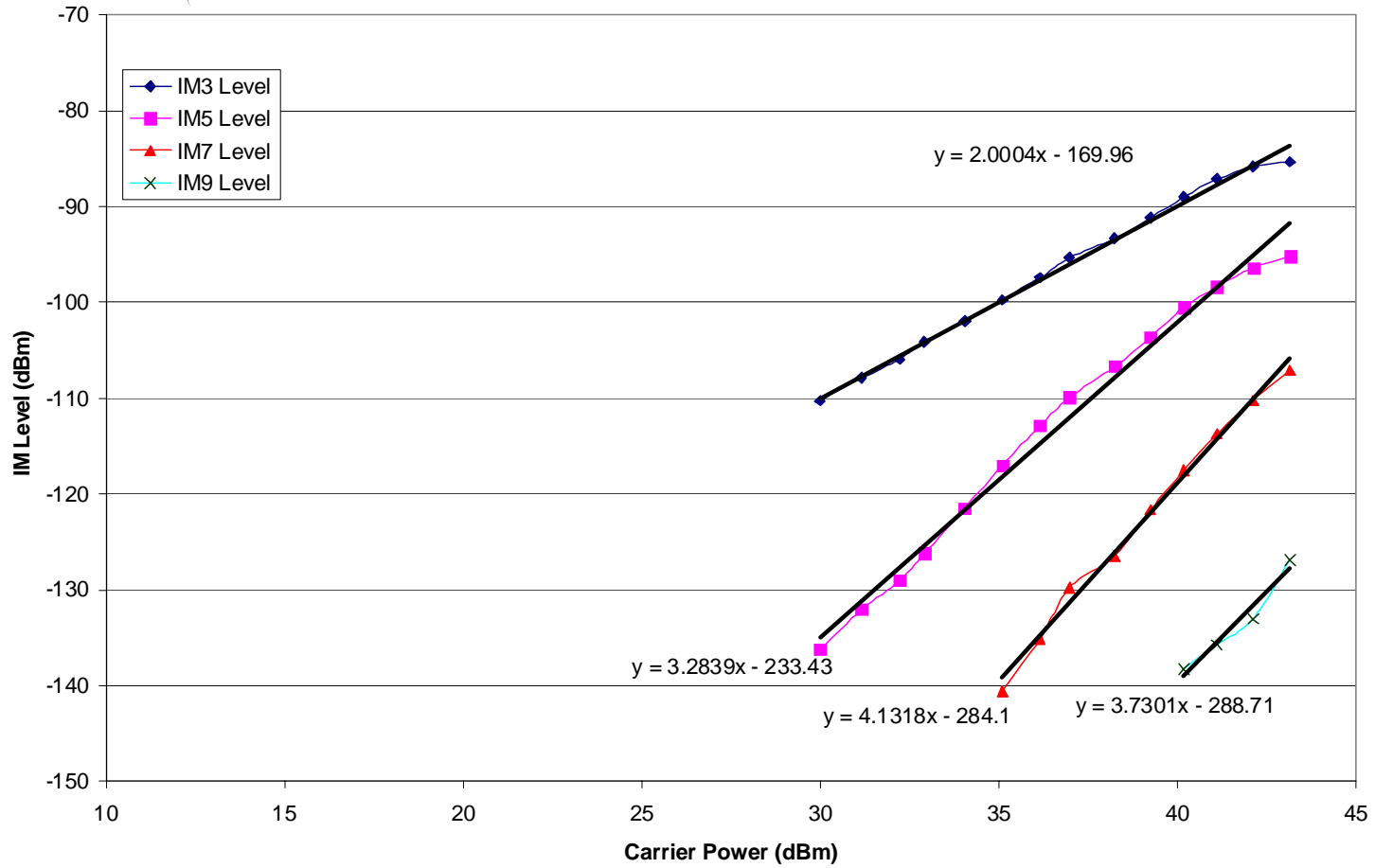




Figure 2
Nickel Connector IM vs Equal Carrier Power

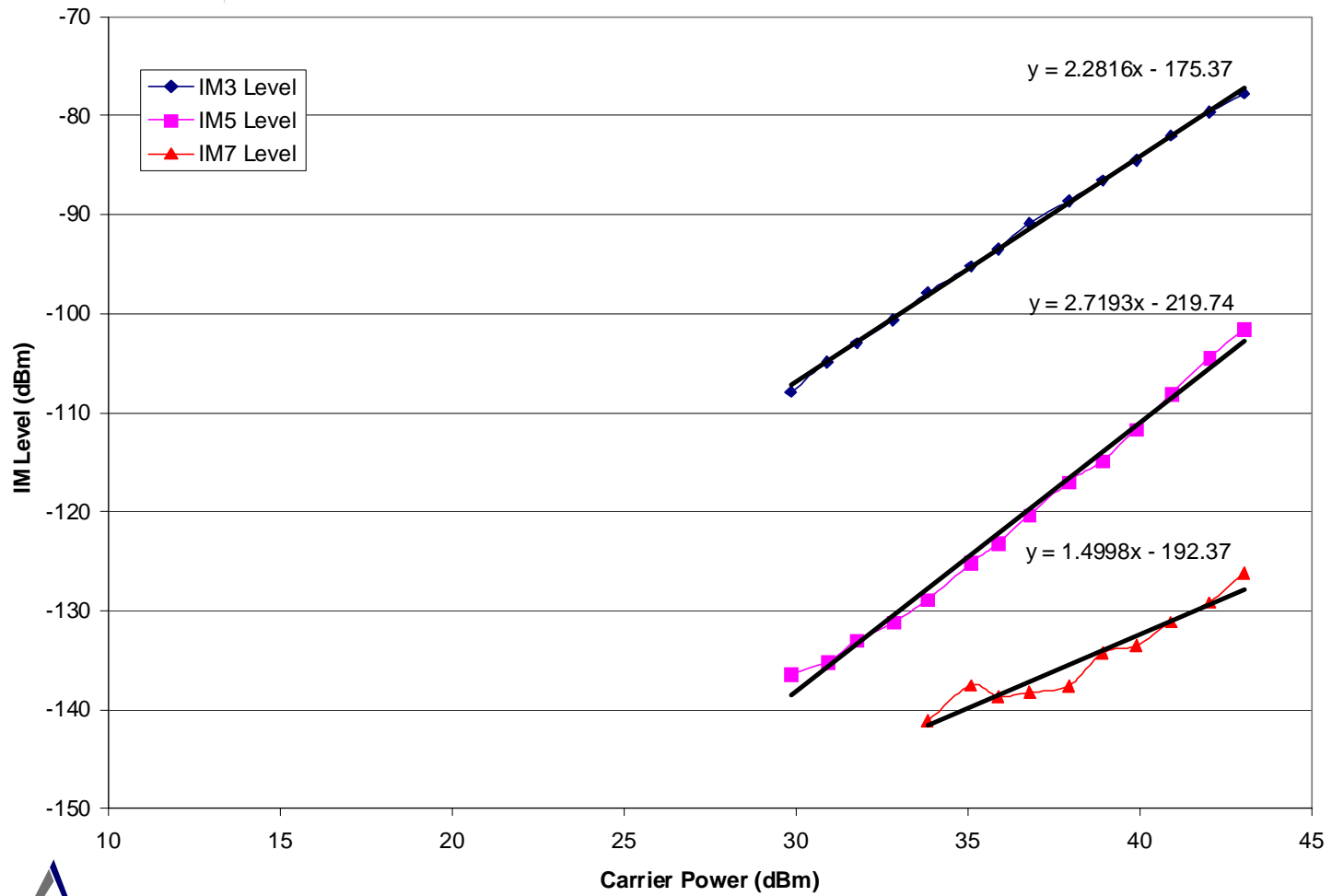




Figure 3
PIM of Diode Source vs Unequal Carrier Power
Carrier 2 Power Constant at 43 dBm

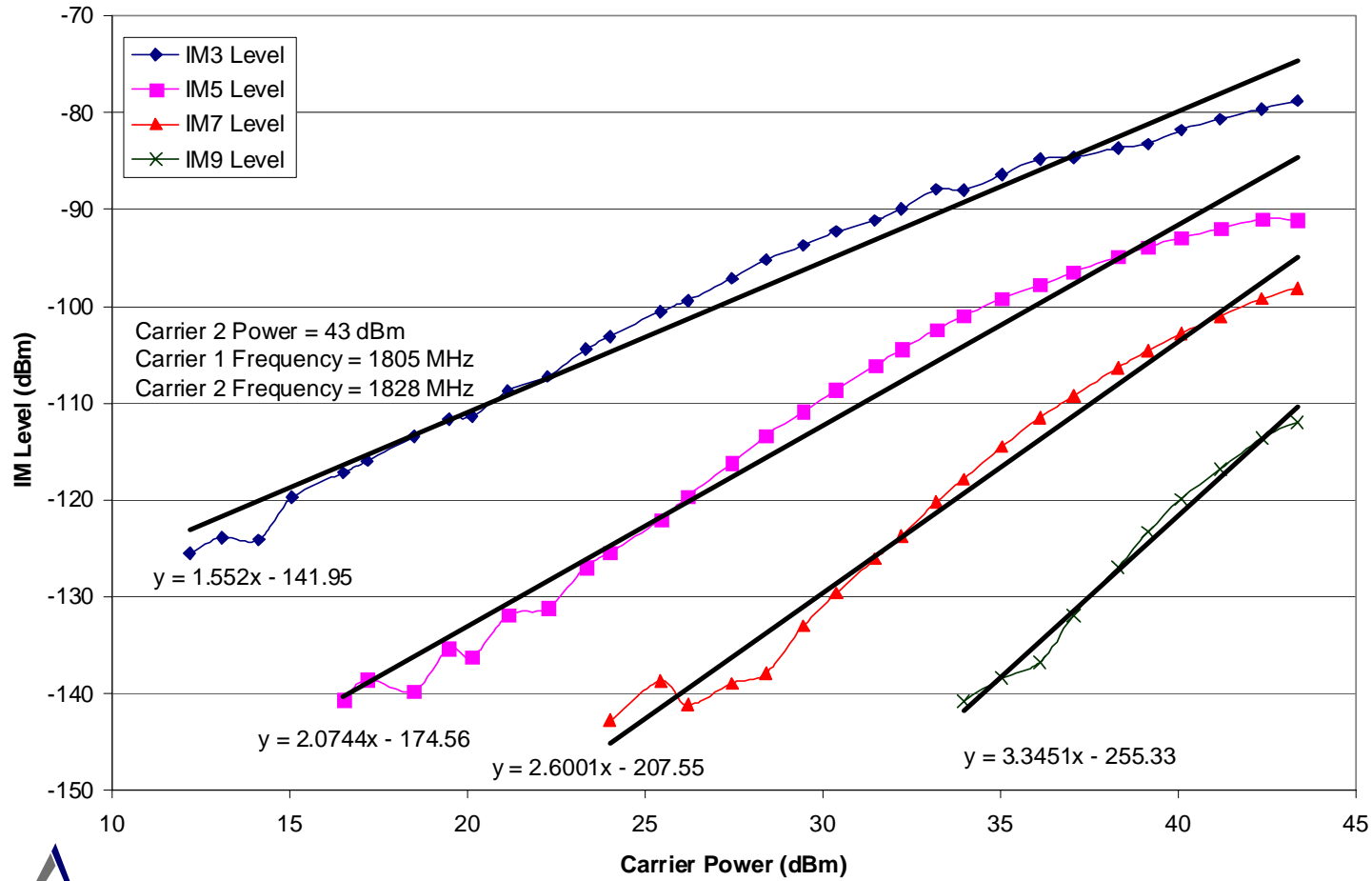




Figure 4
Nickel Plated Connector IM vs Unequal Carrier Power
Carrier 2 Power Constant at 43 dBm

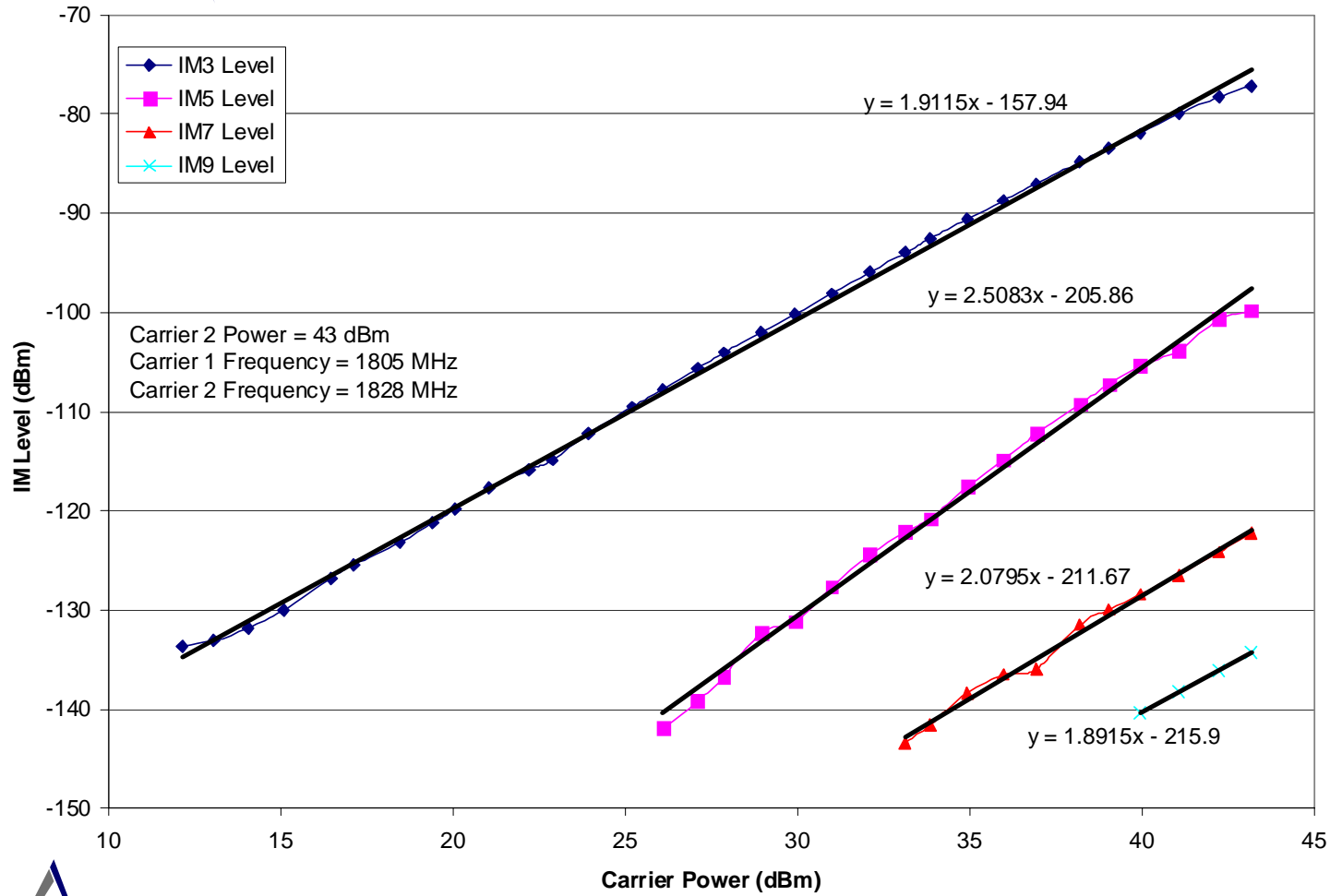




Figure 5
PIM of Diode Source vs Unequal Carrier Power
Carrier 1 Power Constant at 43 dBm

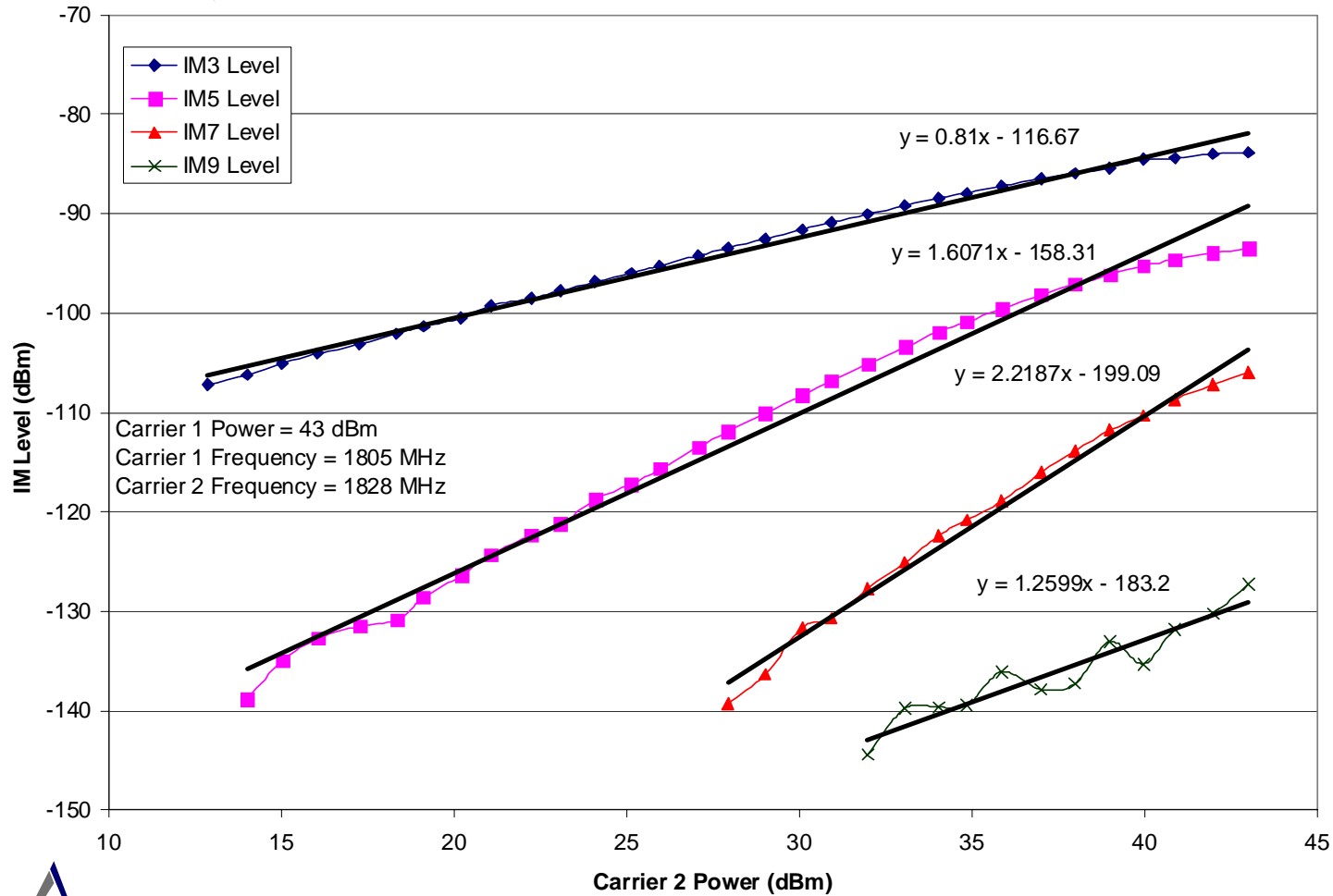




Figure 6
Nickel Plated Adapter IM vs Unequal Carrier Power
Carrier 1 Power Constant at 43 dBm

