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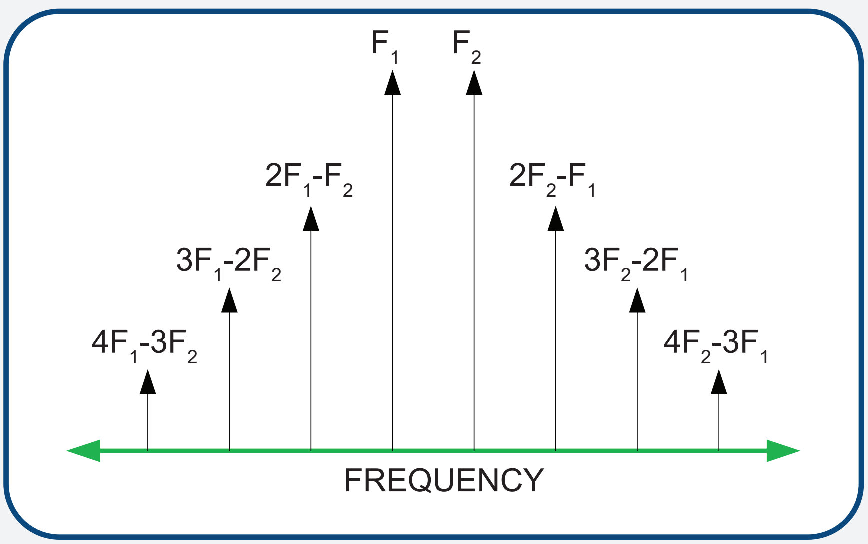
Case Study

Evaluation of Intermodulation Products Displayed by Spectrum Analyzers



By: Jim Bryant

Date: March 2010

Document Number: 1801-00189-EN

Bryant Solutions, Inc.
2603 Camino Ramon, Suite 276
San Ramon, California 94583

+1-925-968-9265
info@bryantsolutions.com
www.bryantsolutions.com

If you have ever (or will ever) look for interference at an antenna site with multiple carriers, you should take the time to read this paper. It could potentially prevent unnecessary equipment and personnel costs. Consider the scenario where you are at an antenna site due to a complaint of interference from a third party. You are at the site to verify whether your equipment is a source of the interference. You analyze the problem with your spectrum analyzer and determine that there is intermodulation and your system's control channels are creating at least a portion of this interference. You take corrective action to resolve potential sources of the interference. Several thousand dollars later you determine that in fact, there is no external interference (intermodulation) at the site in question, but in fact, the intermodulation is occurring inside your spectrum analyzer. This paper takes a look at how to ensure your spectrum analyzer is not a source of this intermodulation.

The spectrum shot in Figure 1 indicates several carriers are present at the site in question. Given the number of carriers at this site, there is a potential for intermodulation, adjacent power and co-channel interference between these carriers. For this paper, we are interested in potential interference from two or more of these signals to create intermodulation products. The signals in question for this paper are GSM (channel 134), UMTS (channel 4381) and CDMA (channels 384, 425 and 466). Looking at this analysis of signals, it does not appear the spectrum analyzer's analog-to-digital-convertor (mixer/ADC) is in saturation. The GSM signal which is above the -30 dBm reference level does not appear to be high enough of a power level to cause the mixer/ADC to go into saturation for the spectrum analyzer in question.

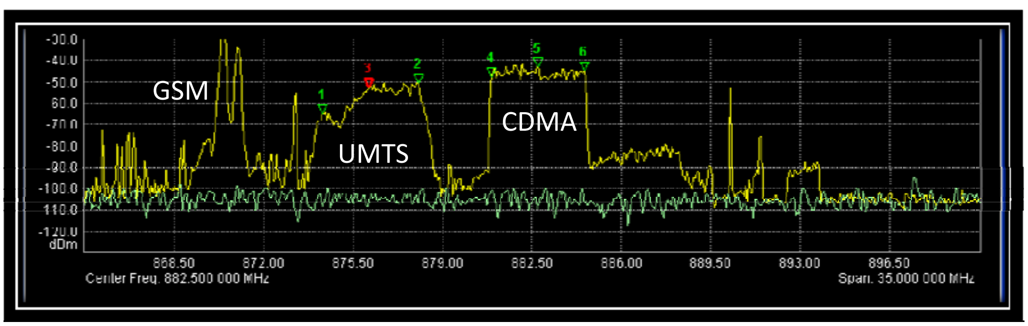


FIGURE 1: Spectrum Analyzer Screen Showing Signals Present

Figure 2 below shows a second file saved using the same spectrum analyzer. This measurement was taken while at the same antenna site. The technician set up his spectrum analyzer to view that portion of the spectrum owned by the carrier who filled the initial complaint of interference. This is a proper and crucial first step to identifying interference.

Upon further analysis for the sector in question, the technician determined the following for the two signals in Figure 2:

- When GSM 850 is shut down, both signals disappeared.
- When UMTS 850 is shut down, the signal on the right disappeared.
- When CDMA 850 is shut down, the signal on the left disappeared.

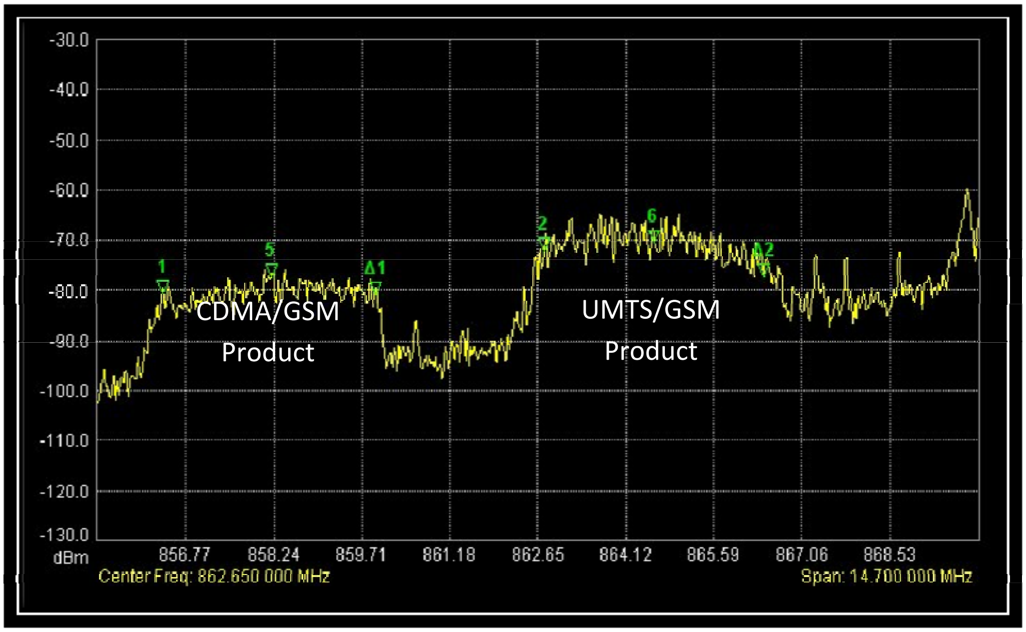


FIGURE 2: Spectrum Analyzer Screen Showing Intermodulation Products

The technician properly predicted that the signal on the left is a product of CDMA and GSM, and the signal on the right is a product of UMTS and GSM. However, as a general rule, we never recommend turning off frequencies or removing/replacing system units (products) as a means for troubleshooting. This type of troubleshooting affects network performance and eventually customers.

To properly analyze this mixing, we needed to take a look at each intermodulation product separately. Given that there are multiple GSM control channels at this site, we needed to determine which channels are mixing with UMTS and CDMA to create the products in Figure 2. For the UMTS/GSM product, we took the center frequency of this product and the center frequency of the UMTS signal in Figure 1 and calculated the GSM frequency.

- 3rd Order Intermodulation Product = 864.6 MHz = 2F1 – 876.2 MHz (4381)
- $F1 = \frac{864.6 \text{ MHz} + 876.2 \text{ MHz}}{2} = 870.4 \text{ MHz}$ = GSM Channel 134

This GSM channel was shown in Figure 1 as the signal exceeding the spectrum analyzer's reference level. We then calculated for the CDMA/GSM product and came up with the following:

- 3rd Order Intermodulation Product = 858.2 MHz = 2F1 – 882.75 MHz (384, 425, 466)
- $F1 = \frac{858.2 \text{ MHz} + 882.75 \text{ MHz}}{2} = 870.475 \text{ MHz} \approx 870.4 \text{ MHz}$ = GSM Channel 134

Figure 3 illustrates the frequencies and intermodulation equations used for our calculations. Here is a breakdown of the assignments:

> F_1 = GSM Channel 134 (Centered at 870.4 MHz)
> F_2 = UMTS Channel 4381 (Centered at 876.2 MHz)
> F_3 = CDMA Channels 384, 425 and 466 (Centered on Channel 425 at 882.75 MHz)

Using these frequency assignments for the F_1, F_2, and F_3, you can then calculate the 3rd intermodulation products seen on the spectrum analyzer seen in Figure 2.

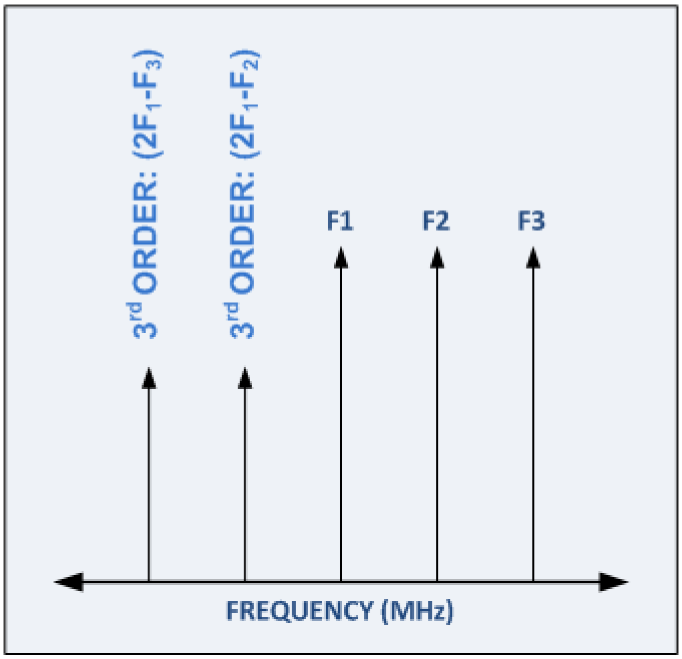


FIGURE 3: Intermodulation Fundamentals and 3rd Order Products

We were not at the site when the measurements were taken and the saved files from the spectrum analyzer did not indicate mixer/ADC saturation. Therefore, our preliminary review of the technician's measurements indicated he had set up his unit properly and had captured actual interference at the site. However, after thousands of dollars in contractor and equipment costs, he was told by the manufacturer of the spectrum analyzer, that the mixing was in fact created within their unit. In fact, the manufacturer sent the technician a bandpass filter for the frequencies covering the 3rd order intermodulation frequencies. When the technician connected the filter to the input of the spectrum analyzer, the intermodulation products could not be seen. As indicated by the manufacturer, this pointed to the spectrum analyzer as the mixing point and not the system. We concurred with the manufacturer's findings; however, given we were not seeing mixer/ADC saturation on the unit, we became concerned this false positive scenario again. Therefore, we initiated a test to determine exactly what went wrong and how it could be prevented in the future.

Figure 4 below shows the test setup used to recreate the intermodulation (mixing) problem. We used vector signal generators to recreate the UMTS and GSM signals seen in the field.

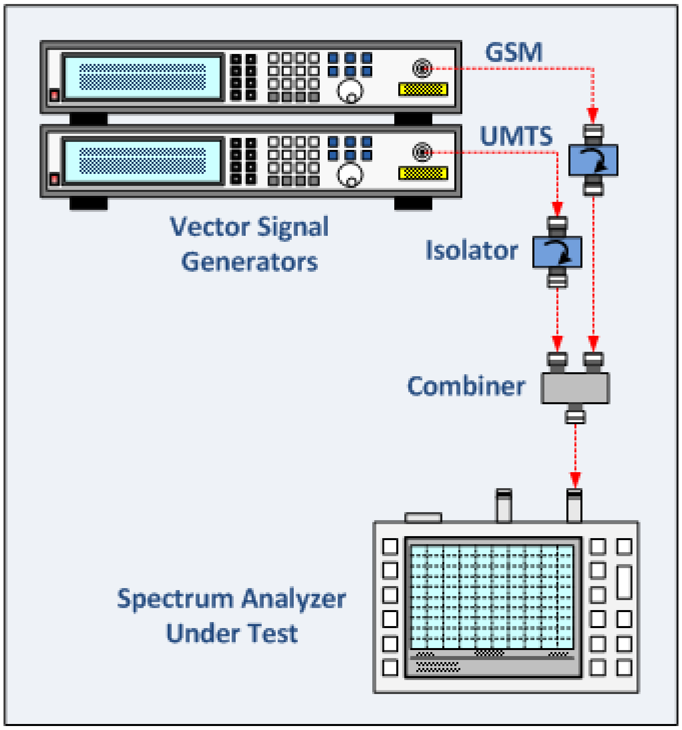


FIGURE 4: Test Setup

Figure 5 shows the GSM and UMTS signals on the same manufacturer and model of spectrum analyzer used by the technician who originally encountered this problem. Here are some of the spectrum analyzer settings and signals used for the test:

- Preamplifier: Off
- Internal Attenuation Setting: Manual
- Internal Attenuation Value: 0 dB
- F_1 = GSM = 870.4 MHz @ ~ 240 kHz OBW
- F_2 = UMTS = 876.2 MHz @ ~ 4.2 MHz OBW
- 3rd Order Intermodulation Product = $2F_1 - F_2$ = 864.6 MHz @ ~ 4.2 MHz OBW

Our goal is to slowly increase the GSM power level until the spectrum analyzer indicates mixer/ADC saturation. The power level of the UMTS signal was kept constant. As long as the spectrum analyzer is not indicating mixer/ADC saturation, we should not be seeing the 3rd order intermodulation products of the UMTS and GSM signals. Ideally, we should begin to see the 3rd order intermodulation product begin to develop at the same time the unit indicates mixer/ADC saturation.

Figure 5 and 6 indicate that the spectrum analyzer is showing the 3rd order intermodulation product, but the unit did not indicate mixer/ADC saturation.

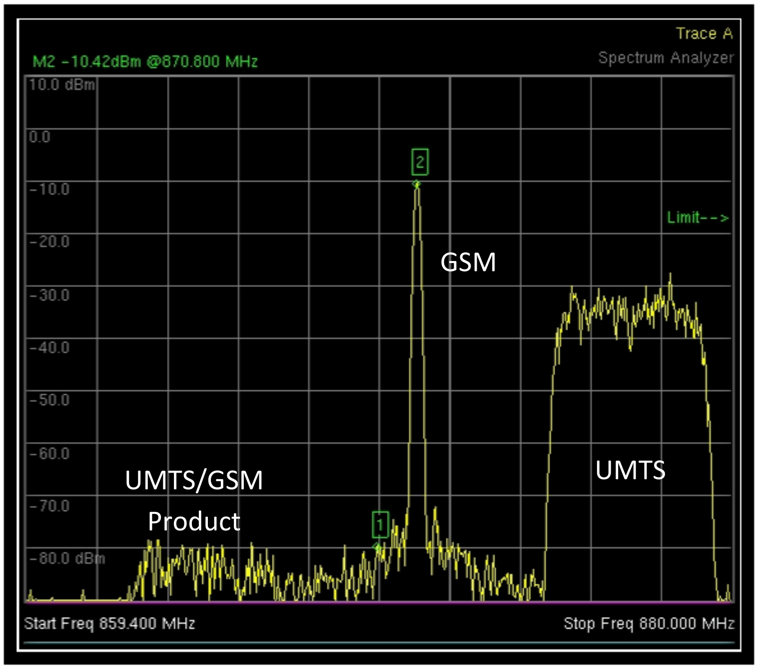


FIGURE 5: Intermodulation Products <u>without</u> Mixer/ADC Over-Range

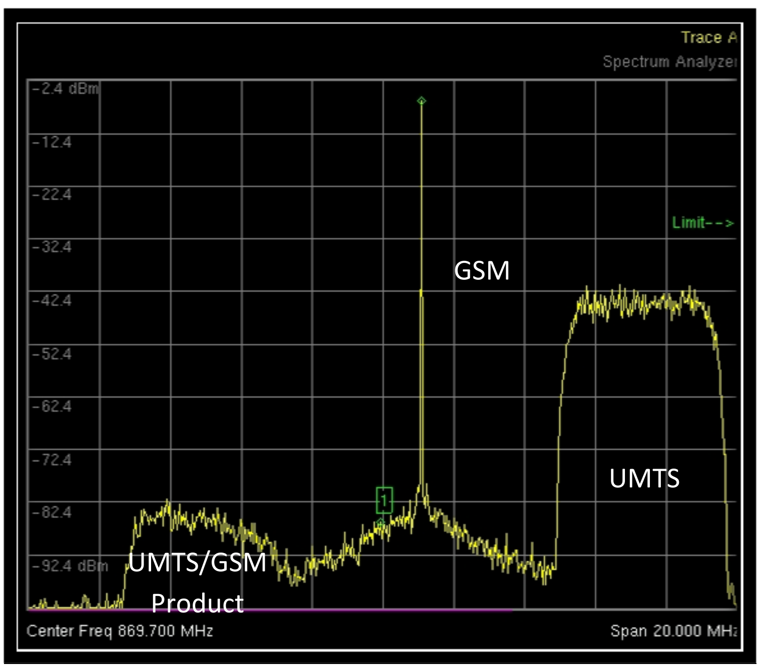


FIGURE 6: Intermodulation Products <u>without</u> Mixer/ADC Over-Range

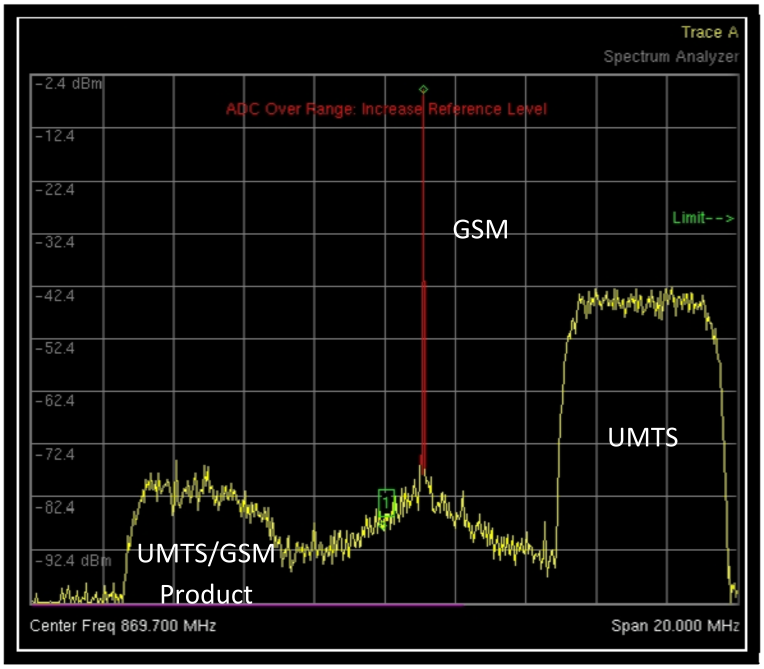


FIGURE 7: Intermodulation Products with Mixer/ADC Over-Range

Figure 7 shows that the spectrum analyzer finally indicates mixer/ADC saturation well after the unit illustrates a very strong 3rd order intermodulation product of the UMTS and GSM signals.

In conclusion, if you suspect your unit may be in mixer/ADC saturation, simply increase the internal attenuation (if it is in manual mode) or set the unit to auto attenuation. If this causes the intermodulation level(s) to change, the spectrum analyzer is contributing to some or all of the distortion. Use of internal parameters such as manual attenuation and RBW are advanced functions and should only be used if you are familiar with their impact on measurements.

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