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Application Note 59

The Effects of Harmonic Tuning on EVM

Abstract
A customized solution allows Error Vector Magnitude (EVM) measurements as a function of input power as well as fundamental and harmonic impedances. A phase optimization at the second harmonic at Γ=0.9 can improve EVM by as much as fifty percent. Proper matching at the fundamental and the second harmonic is shown to achieve the lowest possible EVM while maintaining the desired output power.

Introduction

For the past several years, Power-Added Efficiency (PAE) has been considered the main criterion, with amplifier designers struggling to maximize efficiency while maintaining linear gain and output power. Today, high PAE has become a standard requirement and no longer retains its product differentiation.

As wireless providers shift to modulated signals (CDMA, FDMA, OFDM), error vector magnitude (EVM) has become the new benchmark. Traditionally, load pull has been performed at the fundamental frequency prior to taking EVM measurements; EVM was only measured on a matched amplifier. Two problems arise from this sequence of amplifier design and testing: the fundamental tuning does not take EVM into account, and harmonic tuning is not considered.

Hardware Setup

Figure 1 represents the hardware setup used for EVM load pull. Aside from standard instruments, a Focus Microwaves iCCMT-1220-2H-WiMAX combo tuner is used to set impedances for the fundamental and second harmonic frequencies. An Agilent E4438C modulated signal source is used in conjunction with an Agilent 89600 series vector signal analyzer to modulate, demodulate and analyze EVM of a 64QAM OFDM signal.

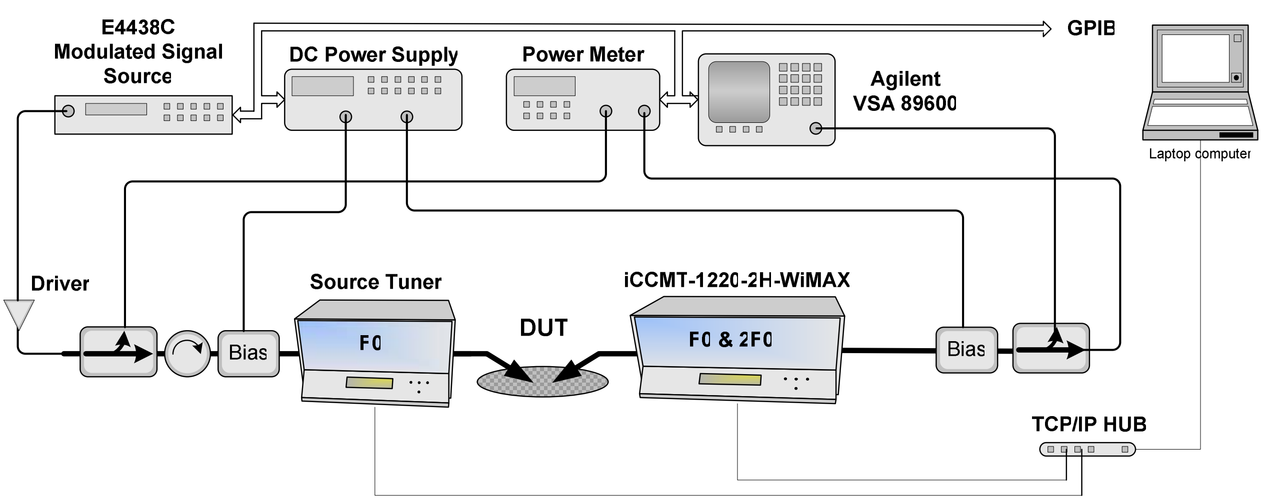

Figure 1: EVM Load Pull Hardware Setup

Effects of fundamental tuning on EVM

Accurate positioning of the fundamental frequency has a serious effect on EVM, as seen in *Figure 2*. The ramification of this is simple: EVM must be taken into account when performing the initial load pull, not at the end.

Referring to our measurements listed in *Table 1*, the lowest EVM, 3.38%, occurs at Z=2.55-j1.8Ω with a gain of 25.34dB while the highest gain, 25.99dB, occurs at Z=2.77+j1.81Ω with an EVM=5.65%. These numbers reflect the sensitivity of the fundamental impedance and how important it is to consider EVM when performing a load pull and not just gain.

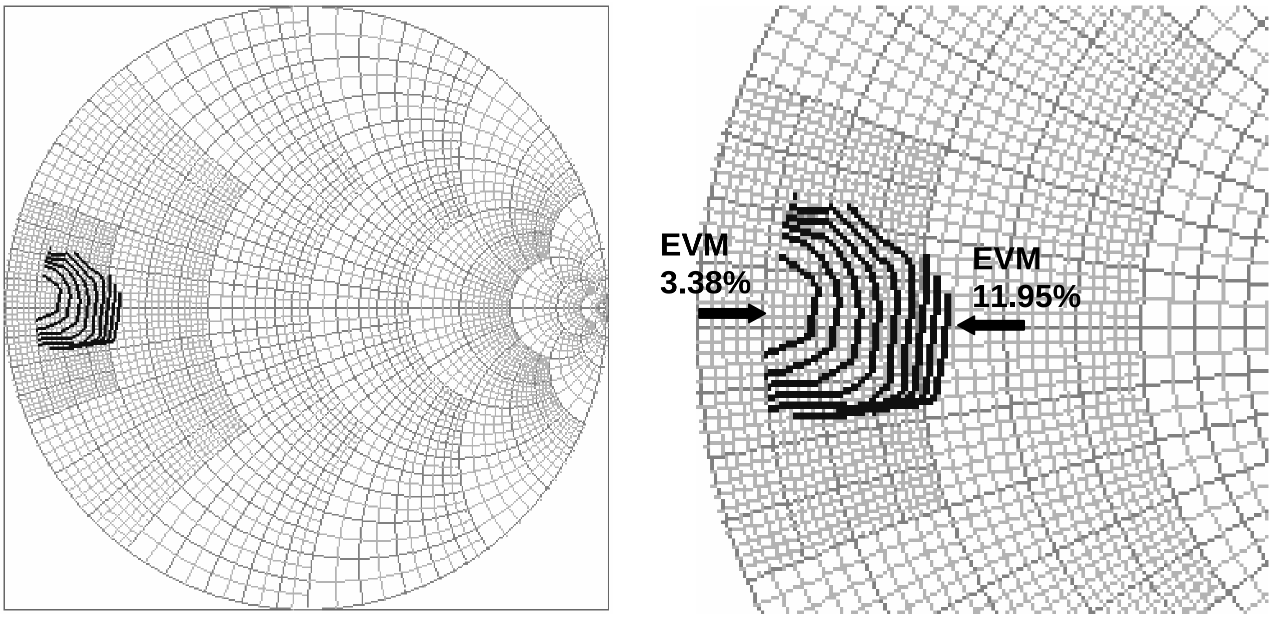

Figure 2: EVM Contours for Pout=constant=14dBm, Pin=variable, 2Fo Unmatched

R	*jX*	*Gain[dB]*	*EVM[%]*	*R*	*jX*	*Gain[dB]*	*EVM[%]*
12.04	1.23	22.85	11.95	5.07	5.93	23.94	10.48
11.48	-1.44	22.97	11.63	4.81	3.81	24.97	7.98
11.21	-4.09	22.58	11.83	4.59	1.77	25.58	5.28
9.87	4.14	23.66	10.58	4.41	-0.24	25.57	4.00
9.27	1.57	24.16	9.40	4.26	-2.20	24.88	4.52
8.88	-0.93	24.38	8.13	4.16	-4.10	23.76	7.22
8.62	-3.33	24.07	7.78	3.09	5.64	23.82	11.35
7.74	4.98	23.68	10.97	2.93	3.69	25.31	8.27
7.39	2.67	24.46	8.86	***2.77***	***1.81***	***25.99***	***5.65***
7.12	0.49	24.81	7.43	2.64	-0.04	25.97	3.52
6.88	-1.66	24.86	6.15	***2.55***	***-1.80***	***25.34***	***3.38***
6.75	-3.77	24.30	6.74	2.46	-3.53	24.14	5.73

Table 1: Load Pull Data for Pout=constant=14dBm, Pin=variable, 2Fo Unmatched

Effects of harmonic tuning on EVM

Until recently, harmonic tuning has been primarily used for devices that are heavily compressed. The effect of harmonic tuning on a highly compressed device is an immediate increase in PAE. Harmonic tuning, however, can also be used on devices that are uncompressed, backed off from P1dB. It is this type of harmonic tuning which concerns manufacturers of WiMAX and WLAN platforms since these devices statistically operate in a linear state, as seen in *Figure 3*.

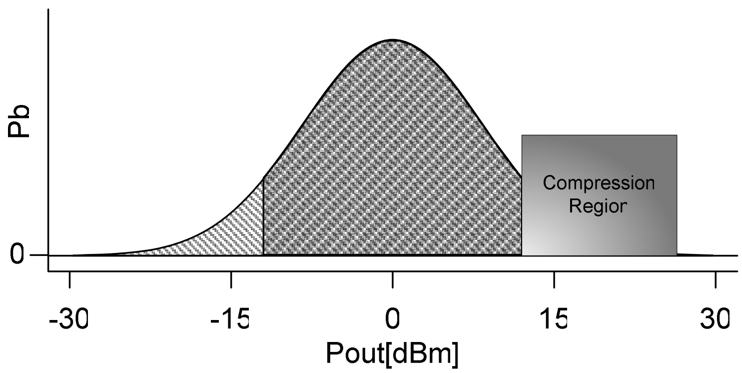

Figure 3: Statistical operating power

EVM measurements are a direct function of input power; an increase in power leads to an increasing trend in EVM. Depending on how the second harmonic is terminated, the level at which EVM begins deteriorating differs. *Figure 4* presents the varying EVM as output power is increased from 4dBm to 16dBm. The overall level of EVM is much higher when unmatched at the harmonics compared with a matched state. Referring to our measurements, EVM at 13dBm output power without matching the second harmonic is over 5%, while matching the harmonic yields an EVM of 2%. Since the acceptance level for EVM is 2-3%, it is essential for the second harmonic to be properly terminated.

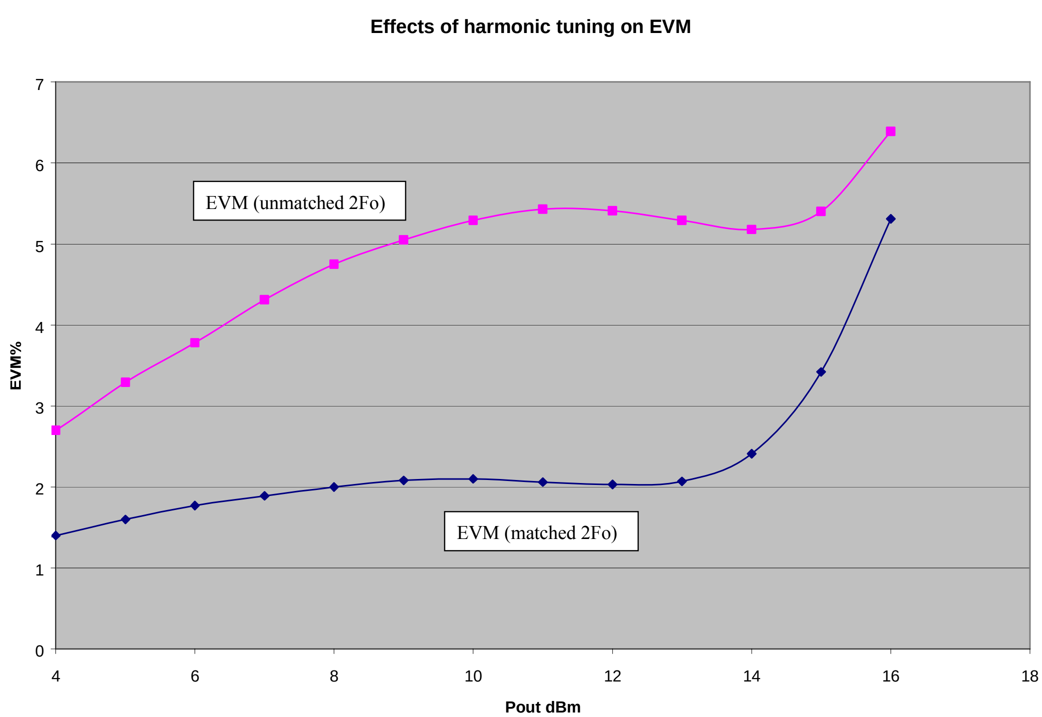

Figure 4: Effects of harmonic tuning on EVM

While EVM remains our primary concern, we cannot neglect PAE as a secondary parameter. While not highly compressed, we can still expect a PAE of 20-30%. Our measurements show that PAE improves for an EVM-matched second harmonic rather than an unmatched state.

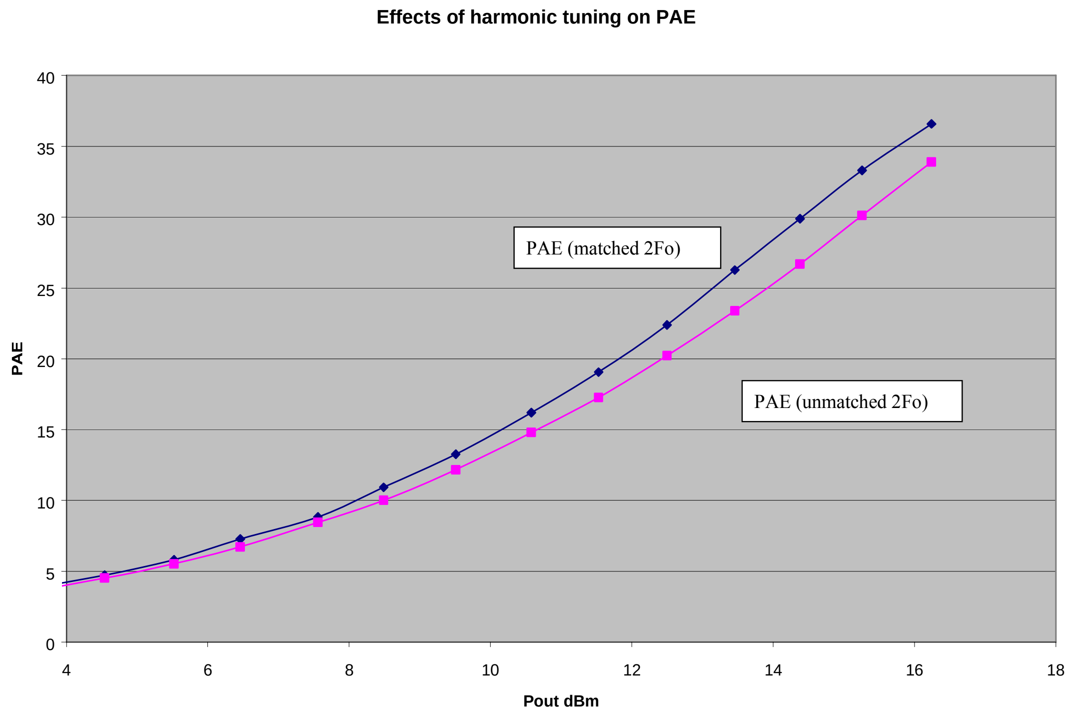

Figure 5: Effects of harmonic tuning on PAE

Conclusion

As WLAN and WiMAX become the new standard in wireless communication, it is essential for PA designers, integrators and developers to follow the guidelines set forth by customers and WiMAX Forum alike; namely strict requirements on EVM values. Focus Microwaves provides an application-specific solution for this requirement including fundamental and harmonic combo tuner model iCCMT-1220-2H-WiMAX and associated measurement and contouring software.

We would like to thank Fairchild Semiconductor's RF Group, Massachusetts, for their technical involvement with this application note.