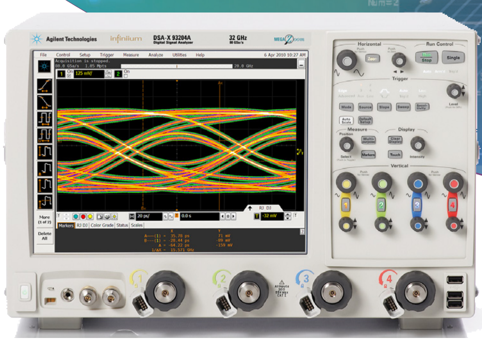
Solutions for

MIMO RF Test and Debug

Ensuring Quick and Accurate Four-Channel, Phase-Coherent MIMO Measurements

Application Note



Overview

Multiple-Input Multiple-Output (MIMO) is a signal transmission technique promising higher data rates for a single user using two or four streams of data transmitted with multiple antennas. Multiple antennas transmit the data on the same frequency and at the same time without interfering with one another. While single antenna implementations of Orthogonal Frequency Division Multiple Access (OFDMA) signal formats such as Mobile WiMAX™ and 3GPP Long Term Evolution (LTE) can enable increased data rates, even higher data rates can be realized by doubling or even quadrupling the number of antennas in the implementation, as is the case with four-channel MIMO.

Because of such benefits, MIMO has become a key technology of emerging 4G wireless standards. One such standard is 3GPP Long Term Evolution (LTE), the evolution of 3GPP UMTS. LTE will provide peak rates of 326.4 Mbps (downlink) and 86.4 Mbps (uplink) for a 64QAM 4x4 MIMO configuration (Refer to the book "LTE and the Evolution to 4G Wireless: Design and Measurement Challenges," Table 1.4-1). Currently, most work with LTE focuses on single antenna implementations of MIMO, but as LTE evolves, such designs may ultimately migrate to two- and four-channel MIMO to take advantage of the higher data rates possible.

Problem

MIMO is a very complex technology. As engineers migrate to four-channel MIMO, that complexity will increase significantly, introducing a multitude of design and testing challenges that impact peak data rates and make it difficult to troubleshoot and debug hardware performance issues. To ensure optimal performance in a four-channel MIMO implementation, engineers must perform comprehensive, four-channel phase-coherent MIMO measurements like error vector magnitude (EVM)—a key metric for transmitter performance. Because RF and baseband impairments like timing errors, LO phase noise, power amplifier gain/phase distortion, and IF/RF filter group delay can contribute to transmitter EVM degradation, gaining insight into such error mechanisms is critical to uncovering potential MIMO performance problems. Unfortunately, since four-channel MIMO is not yet widely implemented, such a capability has not emerged until now.

Solution

R&D engineers working on LTE-based systems with four-channel MIMO functionality require a quick and accurate means of performing four-channel MIMO RF test and debug. They need the ability to look at all four channels individually, as well as at the inter-relationships between the channels. Moreover, they need to be able to debug both the design and the hardware.

One way to address this challenge is through the use of a time-coherent, multi-channel wideband oscilloscope and vector signal analysis software. The oscilloscope performs the necessary four-channel phase-coherent MIMO measurements and is also useful in diagnosing potential timing errors between transmit antenna channels. When used with the oscilloscope, the software enables the measurement and analysis of LTE MIMO signals from a number of different perspectives: time, frequency and modulation domains. This helps the engineer diagnose and isolate hardware performance issues.

The Infiniium 90000 X-Series high-performance oscilloscope and 89600 Vector Signal Analysis (VSA) software from Agilent Technologies offer such a solution. Well-suited for two- or four-channel MIMO measurements, the 90000X Infiniium oscilloscope provides time-coherent multi-channel inputs, wide bandwidths to measure RF modulated carriers, and deeper memory to analyze multiple frames of data for demodulation with the VSA software. Its low noise (~2 mV at 50 mV/div, 32 GHz) and low jitter performance (~150 femto-seconds) ensure exceptional measurement accuracy and yield a low residual (baseline) EVM performance that's necessary to making four-channel LTE MIMO measurements. The VSA software also supports both two- and four- channel MIMO. It runs inside the 90000X oscilloscope to enable the characterization of complex, time-coherent LTE MIMO signals with detailed and simultaneous spectrum, modulation and time waveform analysis.

Together, the 90000X oscilloscope and VSA software can be used to perform four-channel spatial-multiplexed EVM measurements. The oscilloscope provides the four time-coherent channels that serve as inputs into the VSA software with its MIMO measurement algorithms. Once this time-coherent input is captured from the oscilloscope, the VSA software performs all the necessary post processing (e.g., MIMO demodulation, displaying MIMO EVM measurements, etc.). By utilizing these solutions, the engineer is able to effectively locate and troubleshoot problems at any stage in the design process, regardless of whether it is an error mechanism impacting the hardware's EVM performance or other issues affecting system-level RF transmitter performance budgets.

The 90000X oscilloscope and VSA software do more then just allow the engineer to look at four-channel MIMO EVM, they also provide insight into things like antenna crosstalk—the cross coupling of signals from one antenna channel to the next. In an actual hardware implementation of four-channel MIMO, for example, the four transmitters introduce impairments like phase noise and gain compression, while the up conversion introduces intermodulation products. The power amplifier adds distortion (both amplitude and phase) on the signal as it is compressed. While each of these error mechanisms plays into the overall EVM measured at the four-channel output, antenna crosstalk from the four antennas may also impact EVM and thus, overall MIMO performance. In this case, the VSA software and 90000X oscilloscope provide a useful means of being able to measure both the EVM of each channel, as well as the antenna crosstalk from one antenna to the next.

4-Channel MIMO Measurement Example

Using the 90000X oscilloscope and VSA software, it is a straightforward process to perform four-channel MIMO measurements. Consider the example of a four-channel RF transmitter shown in Figure 1. Rather than using an actual four-channel IF-RF transmitter/upconverter hardware DUT, Agilent's SystemVue simulator provides a model of the four-channel RF transmitter with simulated design impairments.

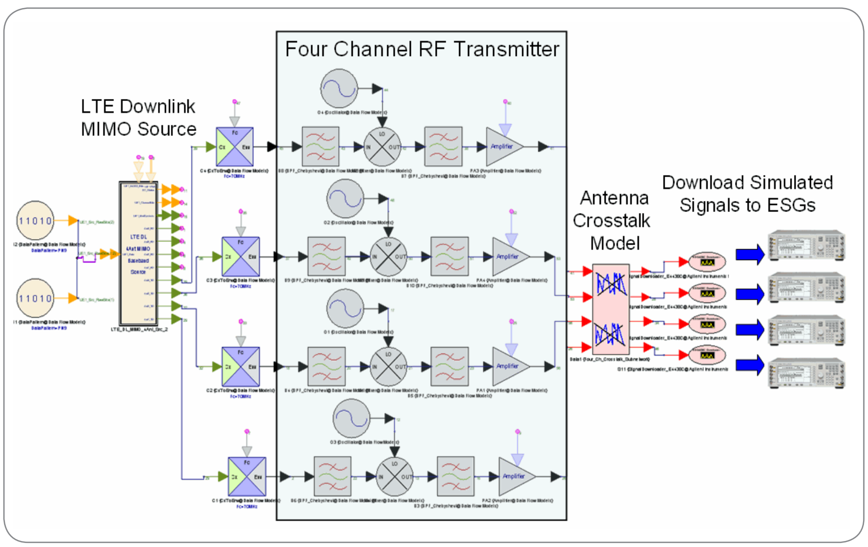


FIGURE 1: *Shown here is a simulated RF transmitter design with phase noise, PA gain compression and antenna crosstalk impairments.*

The test setup for measurement of the four-channel RF transmitter is shown in Figure 2. The four Agilent ESG signal generators represent four base station transmitter antennas. The ESGs output four test signals that are captured into four individual channels on the 90000X oscilloscope. The test signals are then demodulated by the VSA software. The four-channel MIMO measurement result is shown in Figure 3.

When measurement results indicate an area of concern, such as a timing error, the 90000X oscilloscope and VSA software can be used to debug the problem. The VSA software provides a MIMO Information table that is extremely helpful for this task, allowing the engineer to examine the effects of antenna crosstalk more closely.

The MIMO Information table in Figure 4 reports the timing errors found in the previous downlink RF transmitter MIMO measurement. The 90000X oscilloscope measures the timing error between the antenna channels and a fix is applied. A new MIMO Information table is then displayed, assuring the engineer that the timing error has been successfully resolved.

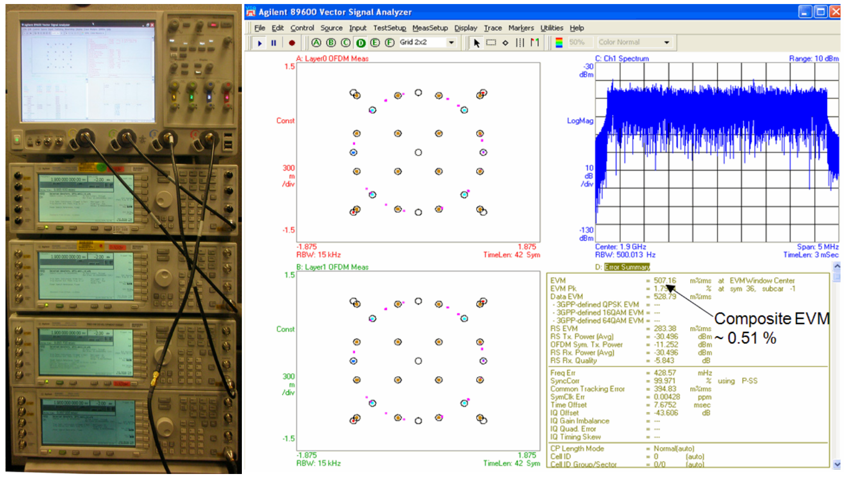


FIGURE 2: *The four-channel MIMO test setup shown on the left consists of four Agilent signal generators with arbitrary waveform generators and a four-channel 90000X oscilloscope, while a baseline measurement result using the oscilloscope is shown on the right.*

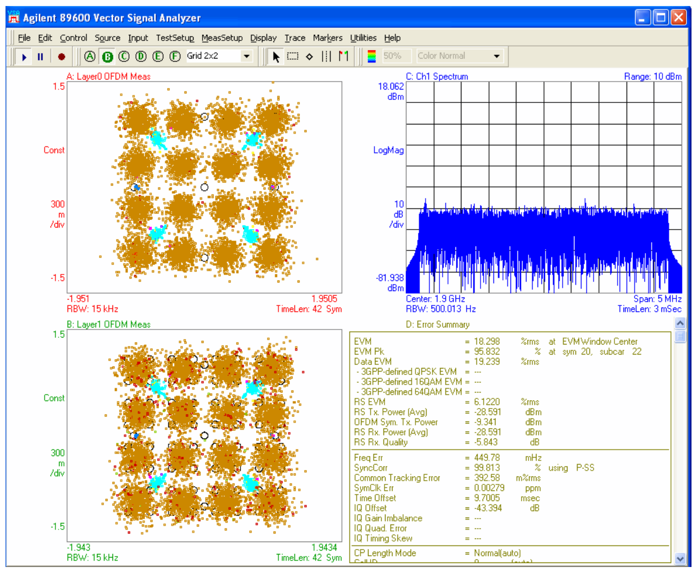


FIGURE 3: *The four-channel MIMO measurement results from a downlink RF transmitter.*

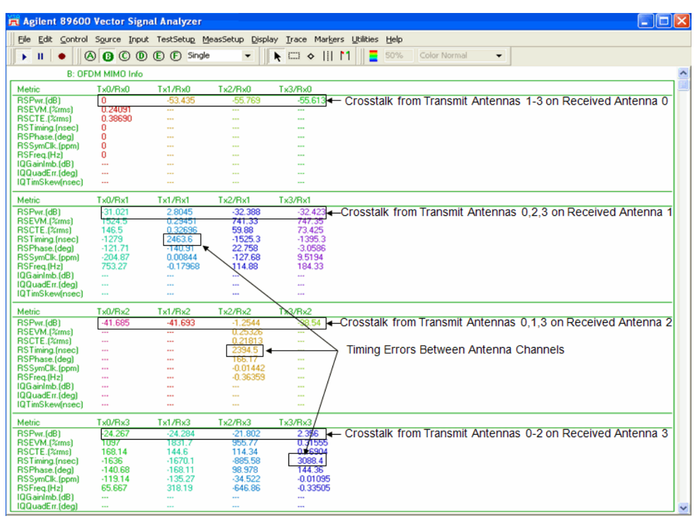


FIGURE 4: *According to this VSA MIMO Information table, timing errors exist between the antenna channels. This is problematic since timing errors which approach or exceed the LTE cyclic prefix duration (4.69 μs) can ultimately impact measurement accuracy.*

Summary of Results

Four-channel MIMO measurements introduce a multitude of testing challenges, and make troubleshooting and debugging more difficult. Fortunately, the 90000 X-Series multi-channel wideband oscilloscopes are well-suited for two- or four-channel MIMO measurements and can even help diagnose potential timing errors between transmit antenna channels. Utilizing the VSA software with the 90000X oscilloscope enables the engineer to measure and analyze MIMO signals from a number of different perspectives: time domain, frequency domain, and modulation domain. As a result, engineers can quickly and accurately diagnose and isolate hardware performance issues.

For additional information on this topic, refer to:

- Website: www.agilent.com/find/lte
- Book: LTE and the Evolution to 4G Wireless: Design and Measurement Challenges (www.wiley.com/WileyCDA WileyTitle/productCd-0470682612.html)
- Webcast: LTE MIMO System-Level Design and Test (http://seminar2.techonline.com /s/agilent_may2709)

The Power of X

The Agilent Infiniium 90000 X-Series high-performance oscilloscopes are key products in Agilent's comprehensive Power of X suite of test products. These products grant engineers the power to gain greater design insight, speed manufacturing processes, solve tough measurement problems, and get to market ahead of the competition.

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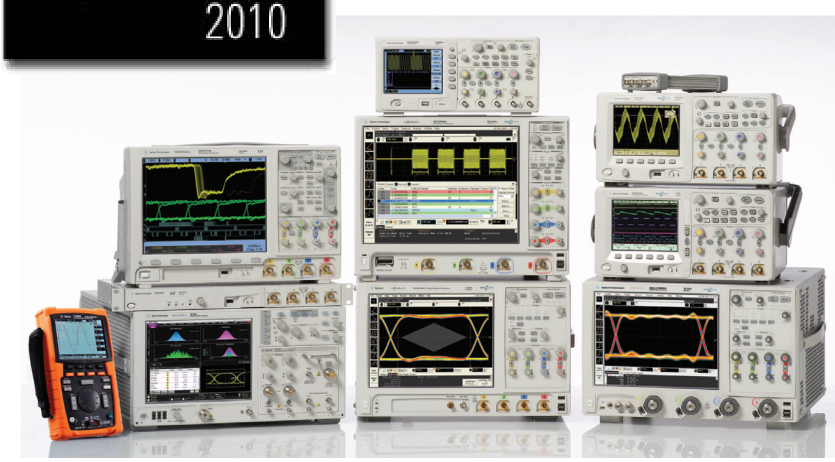
Related Applications

- Mobile WiMAX MIMO Measurements
- Physical Layer Modulation Analysis and Test
- Radar Measurements
- Satcom Measurements

Related Agilent Products

- Agilent Infiniium Oscilloscopes
- Agilent 89600 VSA
- Agilent SystemVue Design Software



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