What is a vector signal transceiver?

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Software-defined RF test system architectures have become increasingly popular over the past several decades. Almost every commercial off-the-shelf (COTS) automated RF test system today uses application software to communicate through a bus interface to the instrument. As RF applications become more complex, engineers are continuously challenged with the dilemma of increasing functionality without increasing test times, and ultimately test cost. While improvements in test measurement algorithms, bus speeds, and CPU speeds have reduced test times, further improvements are necessary to address the continued increase in the complexity of RF test applications.

To address the need for speed and flexibility, COTS RF test instruments have increased their usage of field-programmable gate arrays (FPGAs). At a high level, FPGAs are reprogrammable silicon chips that you can configure to implement custom hardware functionality through software development environments. While FPGAs in RF instrumentation is a good first step forward, typically these FPGAs are closed with fixed personalities designed for specific purposes and allow little customisation. This is where user-programmable FPGAs have a significant advantage over closed, fixed-personality FPGAs. With user-programmable FPGAs, you can customise your RF instrument to the pin so that it is specifically targeted toward your application needs.

A vector signal transceiver is a new class of instrumentation that combines a vector signal generator (VSG) and vector signal analyser (VSA) with FPGA-based real-time signal processing and control. The world’s first vector signal transceiver from National Instruments also features a user-programmable FPGA, which allows custom algorithms to be implemented directly into the hardware design of the instrument. This software-designed approach allows a vector signal transceiver to have the flexibility of a software-defined radio (SDR) architecture with RF instrument class performance. Fig. 1 illustrates the difference between traditional approaches to RF instrumentation and a software-designed approach with a vector signal transceiver.

Vector signal transceiver architecture

The NI LabVIEW FPGA module extends the LabVIEW system design software to target FPGAs on NI reconfigurable I/O (RIO) hardware, such as the NI vector signal transceiver. This system design software is well suited for FPGA programming because it clearly represents parallelism and data flow, so users who are both experienced and inexperienced in traditional FPGA design can productively apply the power of reconfigurable hardware. As a system design software, LabVIEW is uniquely capable of blending processing done on an FPGA and a microprocessor (in your PC environment) in a way that does not require extensive knowledge of computing architectures and data manipulation. This is crucial for assembling modern communications test systems.

This vector signal transceiver software is built on this reconfigurable I/O (RIO) architecture, and features a multitude of starting points for your application including application IP, reference designs, examples, and LabVIEW sample projects. These starting points all feature default LabVIEW FPGA personalities and prebuilt FPGA bitfiles to help you get started quickly. Without these out-of-the-box capabilities, the productivity of LabVIEW, and the well-crafted application/firmware architecture, the software-designed nature of the vector signal transceiver would be challenging for many classes of users. With these traits, however, it brings unprecedented levels of customisability to high-end instrumentation.

Enhancing traditional RF test

The vector signal transceivers feature both the fast measurement speed and small form factor of a production test box combined with the flexibility and high-performance expectation of instrument-
grade box instruments. This gives the vector signal transceiver the ability to test standards such as 802.11 AC with an error vector magnitude (EVM) of up to -46 dB at 5.8 GHz. In addition, the transmit, receive, baseband I/Q, and digital inputs and outputs all share a common user-programmable FPGA, making the vector signal transceiver much more powerful than traditional box instruments.

Data reduction is a prime example, where decimation, channelisation, averaging, and other custom algorithms allow the FPGA to perform the computationally intensive tasks. This decreases test time by reducing necessary data throughput and processing burden on the host, and it allows for increased averaging, which gives users a higher confidence in their measurement. Other examples of FPGA-based, user-defined algorithms include custom triggering, FFT engines, noise correction, inline filtering, variable delays, power-level servoing, and much more.

Software-designed instruments such as the vector signal transceiver can also help to bridge the gap between design and test, allowing test engineers to incorporate or validate aspects of the design before it is complete, while allowing design engineers to use instrument-class hardware to prototype their algorithms and evaluate their designs earlier in the design flow.

Example: Power-level servoing for power amplifier test

It is important for power amplifiers (PAs) to have an expected output power, even outside their linear operating modes. To accurately calibrate a PA, a power-level servo feedback loop is used to determine the final gain. Power-level servoing captures the current output power with an analyser and controls the generator power level until desired power is achieved, which can be a time-consuming process. In simplest terms, it uses a proportional control loop to swing back and forth in power levels until the output power-level converges with the desired power. A vector signal transceiver is ideal for power-level servoing because the process can be implemented directly on the user-programmable FPGA, resulting in a much faster convergence on the desired output power value (see Fig. 3).

Other RF applications

A vector signal transceiver is more than just an incredibly fast and flexible vector signal analyser and vector signal generator. The RF receiver, RF transmitter, and user-programmable FPGA also allow a vector signal transceiver to go beyond the traditional VSA/VSG paradigm. For example, the vector signal transceiver can be completely redesigned by the user to perform complex processing for other RF applications such as prototyping new RF protocols, implementing a software defined radio, and channel emulation among others.

Example: radio channel emulator for MIMO RF signals

In recent years, multiple input, multiple output (MIMO) RF technology has grown significantly, especially in cellular and wireless standards. In addition to this, RF modulation schemes are growing in complexity, RF bandwidth is increasing, and radio spectrums are becoming more crowded. With these advances in technology, it is important to not only test wireless devices in a static environment, but to understand how these devices behave in a dynamic real-world environment as well.

A radio channel emulator is a tool for testing wireless communication in a real-world environment. Fading models are used to simulate air interference, reflections, moving users, and other naturally occurring phenomenon that can hamper an RF signal in a physical radio environment. By programming these mathematical fading models onto the FPGA, a vector signal transceiver implements a real-time radio channel emulator. Fig. 4 shows a...
2x2 MIMO radio channel emulator implemented using two vector signal transceivers in LabVIEW. Settings for the fading models are shown on the left and in the centre of the screen. The resulting RF output signals from the fading models were acquired with spectrum analysers and are displayed on the right. These spectral graphs clearly show the spectral nulls that have resulted from the fading models.

Multiple possibilities for software-designed instrumentation

The vector signal transceiver represents a new class of instrument that is software designed, with capabilities limited only by the user’s application requirements – not the vendor’s definition of what an instrument should be. As RF DUTs become more complex and time-to-market requirements become more challenging, this level of instrument functionality shifts control back to the RF designer and test engineer. The examples shown in this document barely scratch the surface of what a vector signal transceiver is capable of. To answer the “What is a vector signal transceiver?” question, you have to first answer the question of “What RF measurement and control problem do you need to solve?” With the flexibility of an accurate RF transmitter, RF receiver, and digital I/O connected to a user-programmable FPGA, the vector signal transceiver is more than likely up to the challenge. You can learn more about the NI vector signal transceiver at ni.com/vst.

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