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Flexible Software-defined Test Instruments

Today’s rapidly changing development environments demand flexibility in all aspects of design. The next generation of software-defined test instruments are a key element in cost control, time to market, design flexibility and standards evolution. | By Greg Jue

There are many challenges in addressing instrumentation needs for emerging communications signal formats. Time-to-market pressure drives R&D development to begin before the wireless standards have been finalized. This, in turn, drives demand for early R&D test instrumentation solutions for the given wireless standard, while providing the flexibility to accommodate changes in the signal format as the standard evolves.

Similarly, the custom/proprietary nature of aerospace/defense applications requires instrumentation solutions to generate and analyze custom/proprietary signals. Typically, this might be provided in the form of custom test equipment designed for a particular application. While custom test equipment may provide a unique solution, it may also be limited in terms of flexibility to adapt to changes in the signal format. Additionally, it may be expensive to develop initially, and time-consuming and expensive to modify for different signal formats or applications. For these reasons, it may be desirable to use off-the-shelf test equipment and leverage the flexibility of software to create and analyze the custom/proprietary signals.

This article demonstrates a novel approach for providing flexible software-defined instrumentation solutions using the design software running inside the test equipment to address emerging communications signal formats and aerospace/defense R&D applications. Several examples are

Figure 1. Conceptual design and verification flow using design software inside of instruments.
shown with the design software running inside an ARB, to provide a flexible signal source capability, and running inside an oscilloscope, to provide a flexible signal analysis capability. Specifically, an emerging communications signal format example is shown for an UWB EVM measurement. In addition, an aerospace/defense example also is shown for a linear FM chirped radar POD measurement. While quite different, both examples will utilize the same off-the-shelf test equipment setup and leverage the flexibility of the design software running inside the instrumentation to provide the unique application solution.

Software-defined Instrumentation Applications

Using the design software or similar software inside the instruments allows designers to create software-defined instrument applications and also offers many benefits in terms of a design and verification flow.

Typically, a design and verification flow begins with an EDA solution used to put together the system and circuit designs. At this stage of the design flow, test equipment is not yet involved since it is still a design-only phase. Simulation signal sources and signal measurements are used in the software to begin designing the system and circuits. For emerging communications signal format applications (like UWB), these signal sources and measurements could be available as pre-defined simulation test benches, which are pre-configured to perform key simulation measurements such as EVM and BER. For aerospace/defense applications, native behavioral models in the software could be used as building blocks to construct custom/proprietary simulation signal sources and measurements so that the system and circuit design phase can begin.

When the design phase is complete and DUT hardware returns from fabrication, early R&D verification testing can begin. If off-the-shelf instrumentation solutions are not readily available for the given emerging communications signal format, then the software can be combined with test instrumentation to provide an early R&D test solution. Likewise, for aerospace/defense applications, custom/proprietary signals may not be offered as off-the-shelf test solutions. In these instances, it may also be useful to combine the software with test instrumentation to create custom R&D test solutions.

There have been numerous publications written on concepts like Connected Solutions to extend the instrumentation's functionality for R&D applications. Most of the work-to-date has been implemented in the form of an external PC (such as a laptop) connected to the test instrumentation to perform the signal generation and signal analysis. This has enabled measurements such as coded BER to be performed for R&D applications by extending the instruments' capability with the software.

However, once the Connected Solution has been created, the designer might take this a step further by installing the design software inside the instrument solution. This is somewhat dependent on the instrument platform, and whether it can support installing and running the design software or similar software. After the software is installed on the instrument, it might also be configured to run the measurement automatically by pressing a button on the instrument's front panel or by pressing a button in the instrument's application software. This effectively creates a software-defined instrument, using the design software to define the signal source and measurement.

Thus, a design and verification flow from a pure design phase to an R&D test phase might conceptually look like Figure 1. The signal analyzer might be used to generate the test signal in addition to analyzing the measured signal by using the instrument links available in the design software.

Note that this flow helps to bridge the design and test phases for a more seamless transition, leveraging IP developed in the design phase directly into the test phase by using design software inside the instrumentation. This IP can be in the form of signal sources and measurements for emerging communications signal formats, custom/proprietary signal sources and measurements for aerospace/defense, or even simulated system and circuit design IP modeled in the design software. Bridging the gap between the design and the test phase helps eliminate duplication in creating IP for the design phase and then later re-creating similar IP for the test phase. In addition, because design software is flexible, it can be modified to accommodate changes as an emerging signal format evolves or to model different signal scenarios for aerospace/defense applications, such as interferers or jammers.
The next section examines an emerging communications signal format example and an aerospace/defense example that both use the capability described above. While these two examples are quite different, they both use the same off-the-shelf test equipment setup, with the design software providing the unique application solution capability.

**Emerging Communications Signal Example: UWB**

This first example illustrates how this capability can be used to address the needs of an emerging communications signal format. To create the software-defined instrumentation solution to use for early R&D verification testing, the design software is combined with a wide-bandwidth ARB, a high-frequency vector signal generator with wideband I/Q inputs and a high-speed oscilloscope. The basic flow is shown in Figure 2.

To generate the OFDM UWB test signal, the design software is used to create simulated UWB I/Q data. The resulting I/Q data is then downloaded to the wide bandwidth ARB. The I/Q waveforms are then input into the wideband I/Q inputs of the high frequency vector signal generator and modulated onto the carrier. Note that frequency-hopping is disabled for this example.

The design software, combined with the wide-bandwidth ARB and signal generator, represents the software-defined OFDM UWB signal source that could be used for DUT testing.

For the OFDM UWB EVM measurement, the vector signal generator’s output is captured by the high-speed oscilloscope and transferred into the design software for the EVM measurement post-processing. The oscilloscope with the design software represents the software-defined OFDM UWB signal analyzer that could be used for DUT testing. Note that for the examples shown in this article, a cable connects the vector signal generator’s output to the oscilloscope’s input (no DUT).

The actual test setup is shown in Figure 3, with the wide bandwidth ARB in the upper right-hand corner, the high frequency vector signal generator with wideband I/Q inputs in the lower left-hand corner, and the high-speed oscilloscope in the upper left-hand corner. A high-frequency spectrum analyzer is also shown in the lower right-hand corner, which was used to measure the spectral flatness of the OFDM UWB spectrum.

The wide-bandwidth ARB utilizes an embedded controller, which was used to install the design software for I/Q signal generation directly in the ARB.

The high-speed oscilloscope also has the design software installed on it to provide the software-defined UWB EVM measurement. The EVM measurement can be initiated by either pressing a button on the front panel of the oscilloscope or by pressing a button on a vector signal analyzer software application running in the oscilloscope as shown in Figure 4.

The test setup and measurement can be configured for either an RF EVM or for a baseband I/Q EVM measurement. Note: It is important to realize that this capability is not a real-time measurement, since it relies on the measured data to be captured and transferred into the design software, and the simulation measurement to be completed in the instrument.

**Aerospace/Defense Example: LFM Chirped Radar**

To illustrate the flexibility of using software for the signal generation and signal analysis, the same instrumentation test setup is used to create and analyze a custom linear FM chirped radar signal. The conceptual signal flow is the same as that shown in Figure 2 and the test setup is the same as Figure 3.

To create the software-defined radar signal source, the simulation schematic in Figure 5 is simulated on the wide-bandwidth ARB’s embedded controller.

The custom baseband linear FM chirped radar source is shown at the far left of the simulation signal source schematic. It is constructed with native behavioral models in the design software. The models are then used as building blocks to define and create the signal.

To perform the custom software-defined radar signal analysis, the radar system, including the transmit/receive switch, path models, target model, receiver and chirp post-processor, is simulated inside the high-speed oscilloscope.

The measured signal from the vector signal generator’s output is captured with the oscilloscope and then read into the design software for simulation post-processing. It is passed through a simulated transmit/receive switch and propagation path model. A target model simulates the effective radar cross-section, and the reflected signal is passed through a return propagation path model and input into a simulated receiver for down-conversion and post-processing. A custom POD simulation measurement is then performed to calculate the POD, which is dependent on both the target distance and the effective radar cross-section of the target. The simulated target distance and target’s effective radar cross-section can be varied while the simulation is running on the oscilloscope.
Again, it is important to note that this is not a real-time measurement.

The custom software-defined radar measurement on the high-speed oscilloscope is shown in Figure 7. Note that the measurement being displayed is from a prerecorded measured signal.

Summary

The early prototype work shown in this article illustrates a novel approach for providing flexible software-defined instrumentation solutions using the design software running inside the test equipment to address emerging communications signal formats and aerospace/defense R&D applications. An OFDM UWB EVM measurement was shown as an emerging communications signal format example. Using the same equipment setup, the software-defined signal source and signal analyzer was reconfigured for a linear FM chirped radar example to illustrate an aerospace/defense application.

Using the design software inside the test instrumentation to create software-defined instruments offers the benefit of leveraging IP from the design phase directly into instruments to help bridge the gap between design and test, while providing flexibility to address emerging communications signal formats and aerospace/defense R&D applications.

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Greg Jue is a communications system application specialist with Agilent EESof EDA. He is the product manager for the design software 3GPP W-CDMA design library, and has helped to pioneer combining design and test solutions at Agilent Technologies as an applications technical lead. He has authored numerous articles, presentations and application notes, including the popular Application Note 1394 on Connected Solutions, and most recently co-authored the new Logic Analyzer Connected Solutions Application Note 1471. Greg created the design software 3GPP W-CDMA course and the design software Communications System Design course, and has taught numerous RF circuit design, design courses using the design software. Before joining Agilent in 1995, he worked on system design for the Deep Space Network at the Jet Propulsion Laboratory/Caltech University.

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References and Additional Reading
