



Solutions for

Addressing SDR Design and Measurement Challenges

Using COTS Technology and an Integrated Design-to-Test Flow to Quickly Develop Optimal SDRs

Application Note

Overview

As the communications industry continues to grow and evolve, it is becoming more critical to quickly, easily and cost effectively modify radio devices to support new and emerging technologies (e.g., Mobile WiMAX™ and 3GPP Long Term Evolution (LTE)), without requiring new hardware. Software Defined Radio (SDR)—a radio in which some or all of the physical layer functions are software defined—is one technology promising to answer this need. SDRs are typically comprised of an RF/analog section and a baseband section that utilizes programmable processing technologies like FPGAs, DSPs and general-purpose processors (GPPs).

In contrast to traditional radio devices, SDRs provide an efficient and comparatively inexpensive way to enable multi-mode, multi-band and/or multi-functional wireless devices that can be enhanced using software upgrades. Such capabilities make the SDR well suited for the communications market which serves a wide variety of radio signal formats. For example, many engineers who are currently developing SDRs are working on OFDMA physical layer waveforms like Mobile WiMAX and LTE.

Problem

Designing and testing an SDR presents a number of difficult challenges. Engineers could start the design process from scratch, but a substantial amount of time and resources are required to implement the baseband algorithms from the ground up, negatively impacting time-to-market and introducing risk. There are other factors affecting time-to-market as well, namely that the design's baseband and RF sections may be designed by several different teams, each potentially using different tools pieced together in a disconnected flow. These teams may not be collaborating and their different tools may not be well integrated, opening the door for significant system integration risks when the baseband and RF hardware are combined. Rapidly evolving standards such as LTE further add to the design challenge because the standards are subject to interpretation, which introduces risk. Developing an SDR, while maximizing resources and minimizing risk and time-to-market, now demands an alternate solution—one that incorporates commercial off-the-shelf (COTS) physical layer algorithm modeling with an integrated design-to-test flow capable of supporting both baseband and RF methodologies.



Agilent Technologies

Solution

Utilizing a COTS system design solution with built-in OFDMA physical layer algorithm models offers an ideal way for engineers developing SDRs to maximize their resources and minimize time-to-market cycles. Using commercial algorithm models as a baseline starting point, engineers can then customize algorithms to create their own proprietary SDR implementation. Design risk is mitigated through the use of an integrated simulation design environment that incorporates baseband and RF designs into a single design-to-test flow. During the design phase, baseband and RF team hand-offs are supported at each step in the flow—as the design transitions from algorithm to system to baseband (e.g., FPGA) and RF design to integration. The FPGA and RF designs are verified together in the same simulation environment, at each stage of the development process, prior to hardware implementation. During the test phase, the hardware implementation is demodulated and requires a general-purpose signal analyzer with the speed, accuracy and scalability to perform the range of measurements necessary to characterize signal quality.

Agilent's SystemVue system design solution offers an integrated design environment for SDR system design (Figure 1). Algorithm models can be modified using the existing SystemVue algorithms as a starting point, with the Baseband Exploration Library (BEL) option. This is especially useful for modifying the algorithms for a particular version of a standard, or modifying a commercial standard for a custom/proprietary SDR implementation. Additionally, SystemVue's algorithm references provide an independent check of standards interpretation relative to the baseband design and implementation—a feature which is especially useful given the complex and evolving nature of standards like Mobile WiMAX and LTE.

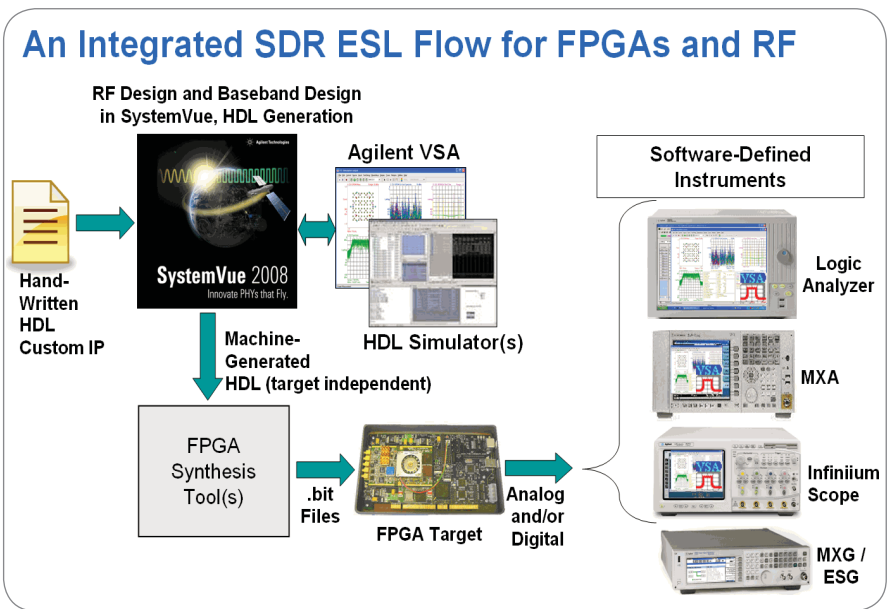


FIGURE 1: Agilent's SystemVue, VSA Software and MXA signal analyzer work together to provide an integrated, SDR flow for FPGAs and RF.



FIGURE 2: Agilent's MXA signal analyzer delivers the fast speed, accuracy and scalability necessary to demodulate today's SDR designs.

During the design process, SystemVue's algorithm references are used to generate reference vectors to facilitate baseband development when hand writing HDL code. Alternatively, fixed-point simulation models are used to model algorithms, with the baseband HDL being generated from the fixed-point models. RF behavioral models are used to construct RF transmitter/receiver designs.

The baseband HDL can be co-simulated in SystemVue, together with the RF design. Integrated instrumentation links with Agilent test equipment and with Agilent's Vector Signal Analysis (VSA) software enable SDR RF/baseband testing (demodulation) at every step of the design phase.

When the design progresses to the test phase, during hardware implementation, it is demodulated using Agilent's fast, scalable, midrange MXA signal analyzer (Figure 2). The MXA features power suite—a standard, complete set of powerful one-button measurements for characterizing signal quality that include ACPR, channel power, occupied bandwidth, spectrum emissions mask, CCDF, burst power, and spurious emission. It also supports more than 50 modulation types. Running the VSA software in the MXA enables advanced signal modulation analysis and troubleshooting of 30 additional modulation types.

Using the VSA software with SystemVue during the design phase, and with the MXA signal analyzer for measurements during the test phase, provides the engineer with a true design-to-test capability. Agilent's connected solutions makes the integration of these instruments possible, enabling signals to be downloaded and captured to and from signal sources and analyzers (Figure 3).

WiMAX IQ Modulator Design Example

If not designed properly, impairments from an IQ modulator can significantly degrade the performance of OFDMA systems. A Mobile WiMAX OFDMA IQ modulator can be designed using the integrated SDR flow in Figure 1. Here, SystemVue is used for both the fixed-point baseband and RF design (Figure 4). First the WiMAX IQ modulator design, consisting of IQ pairs generated with Agilent's WiMAX design library stored in lookup tables, is implemented in SystemVue and a fixed-point design is created. Next, the functionality of the fixed-point design is verified with the VSA software and HDL code for the FPGA is generated. The HDL and RF design are then co-simulated together to verify functionality before moving into the FPGA synthesis process and VSA WiMAX demodulation analysis of the mixed-signal design (HDL and RF) is performed. Note that instead of using machine-generated HDL for co-simulation, custom/proprietary HDL could have alternatively been brought into SystemVue and co-simulated.

Early R&D SDR Hardware Testing

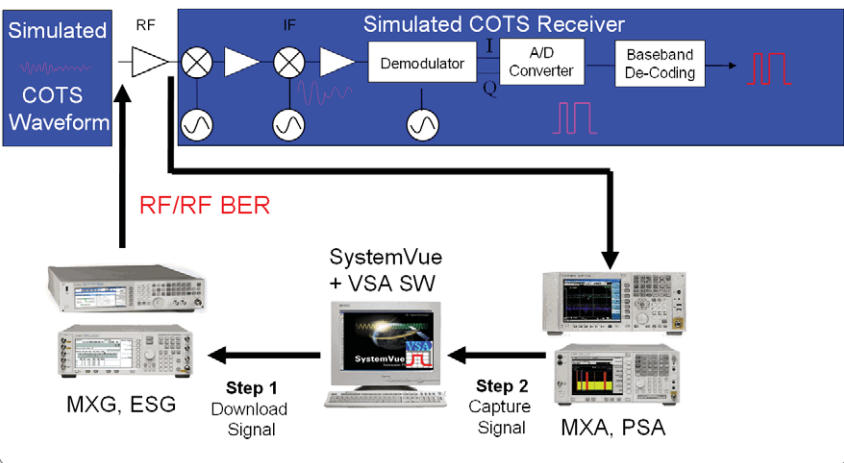


FIGURE 3: With Agilent's connected solutions, signals can be picked off along different stages of a receiver chain to measure BER with an MXA using RF/IF inputs or baseband IQ inputs.

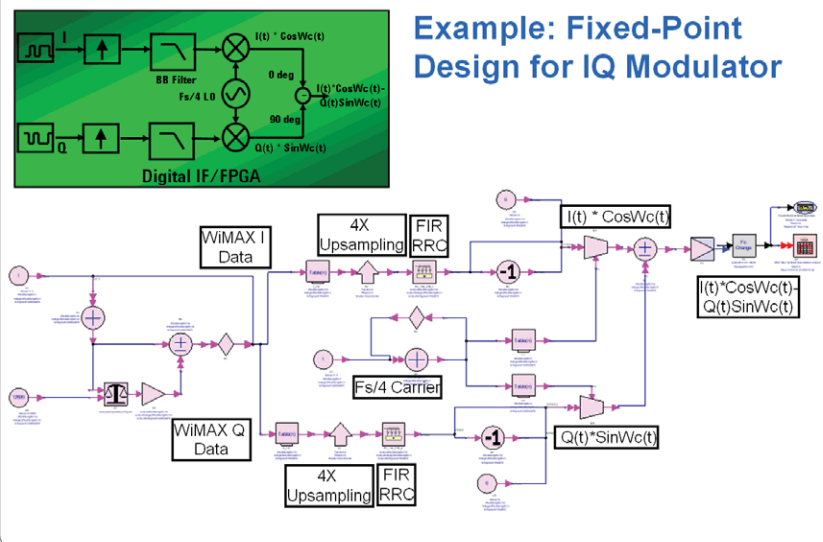


FIGURE 4: The upper left graphic is a block diagram of the WiMAX OFDMA IQ modulator design implemented in SystemVue. The bottom graphic is the SystemVue fixed-point design with various sections of the design annotated to show which part of the block diagram they correspond to.

Finally, FPGA synthesis is performed to generate a .bit file that will be used to configure/program the FPGA target. Because the FPGA board has on-board D/A converters, the FPGA output is converted to an analog IF and measured/demodulated with the Agilent MXA signal analyzer. The resulting FPGA implementation of the WiMAX IQ modulator is shown in Figure 5.

Improving FPGA and RF Team Communication/Collaboration

The WiMAX OFDMA IQ modulator design offers a prime example of how SystemVue can be used as a catalyst for improving communication and collaboration between FPGA and RF teams and as a result, minimizing design risk. In this case, the HDL co-simulation was combined with an RF transmitter that was designed in SystemVue. The transmitter design consisted of an IF-to-RF upconverter, IF/RF filtering, pre-amplifier, and a power amplifier (PA). A VSA simulation measurement element was then connected at the pre-amplifier output and the PA output. The FPGA HDL code was used as the simulation signal source.

The waveform distortions analyzed include both baseband impairments (fixed point impairments and FIR) from the HDL being co-simulated, as well as the RF non-linear impairments introduced to the waveform by the pre-amplifier and PA. Significant distortion was observed at the PA output (e.g., constellation dispersion and spectral re-growth), but only moderate distortion was observed at the pre-amplifier output. The output of the PA was heavily compressed and therefore, it introduced significant distortion to the SDR waveform. In addition, significant spectral re-growth was observed on the RF spectrum which, if measured, would impact a range of metrics like ACLR or ACPR.

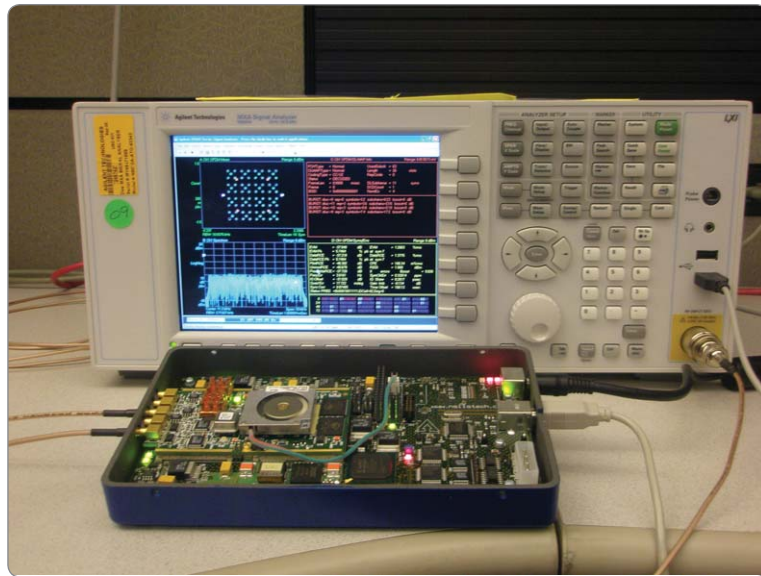


FIGURE 5: The analog IF output on the SDR FPGA board (after the DAC) is demodulated by an MXA analyzer and VSA software.

Summary of Results

While SDRs present a host of benefits for engineers developing multi-mode, multi-band, multi-functional wireless devices, these benefits come at the cost of challenges which need to be addressed to meet time-to-market demands. The time and resources required to design OFDMA SDR physical layer waveforms from scratch, and the risk associated with employing different baseband and RF flows and disconnected tools are some of the key challenges. Agilent SystemVue's algorithm development capability and integrated mixed-signal design environment can help accelerate SDR design activities while minimizing baseband/RF system integration risks. Agilent's MXA signal analyzer and VSA software provide the test capability necessary to test the hardware implementation, minimizing risk and completing the integrated SDR design-to-test flow.



The Power of X

The MXA signal analyzer, working with SystemVue and the VSA software, is a key product 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.

Offering the best combination of speed and scalability, and created and supported by renowned worldwide measurement experts, Agilent's X products are helping engineers bring innovative, higher-performing products to emerging markets around the globe. To learn more about Agilent's suite of X products please visit: www.agilent.com/find/powerofx.

Related Applications

- Communications (e.g., WiMAX and LTE) PHY layer system-level design
- Validate PHY layer baseband coding and decoding algorithms

Related Agilent Products

- SystemVue Electronic System-Level (ESL) Design Software
- N9020A MXA Spectrum Analyzer
- 89600 Vector Signal Analysis Software

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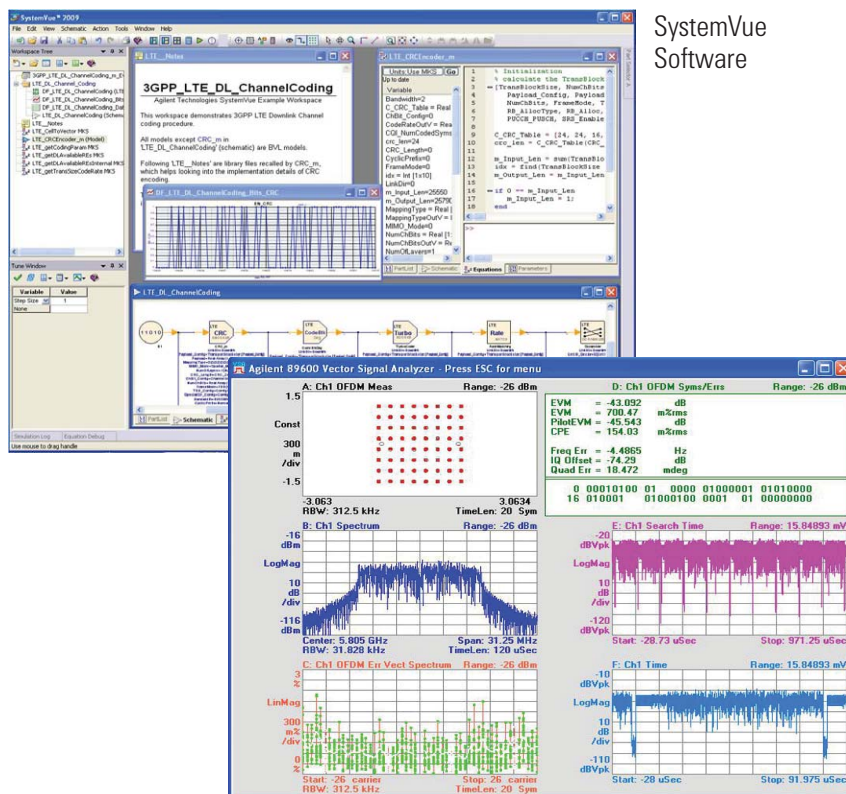
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SystemVue Software

VSA Software

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