Does the Wireless Industry Really Need All These Digital IF Standards?

Lee Pucker
Spectrum Signal Processing, Inc.

There seems to be a proliferation of digital intermediate frequency (IF) standards occurring in the wireless industry. These standards define the physical layer interface and higher-level protocols necessary for moving digitized signals between the radio frequency (RF) front-end and the signal processing subsystem in a digital radio architecture. The reason for these standards comes down to basic economics: by defining standard modules and interfaces in these systems, radio equipment designers and manufacturers (original equipment manufacturers, OEMs) enable multiple component manufacturers, as defined by the SDR Forum, to enter the market with modular product offerings [1]. As more and more vendors enter the market with these standards-based modular products, the modules will become commoditized, allowing OEMs to choose equivalent modules from a range of vendors and consequently driving down the cost per module due to competitive pressure. OEMs will thus enjoy reduced costs in their overall radio platforms while focusing entirely on their own competitive differentiation, which is often in systems integration, application development, and services.

With that in mind consider the following:

• In 2002 LG Electronics, Nokia, and Samsung Electronics founded the Open Base Station Architecture Initiative (OBSAI) to define and agree on a base station architecture at the modular level [2]. Membership in this organization is open, with over 100 member companies, allowing input on requirements for a broad range of air interface standards including wideband code-division multiple access (WCDMA), Global System for Mobile Communications/Enhanced Data Rates for GSM Evolution (GSM/EDGE), and CDMA2000

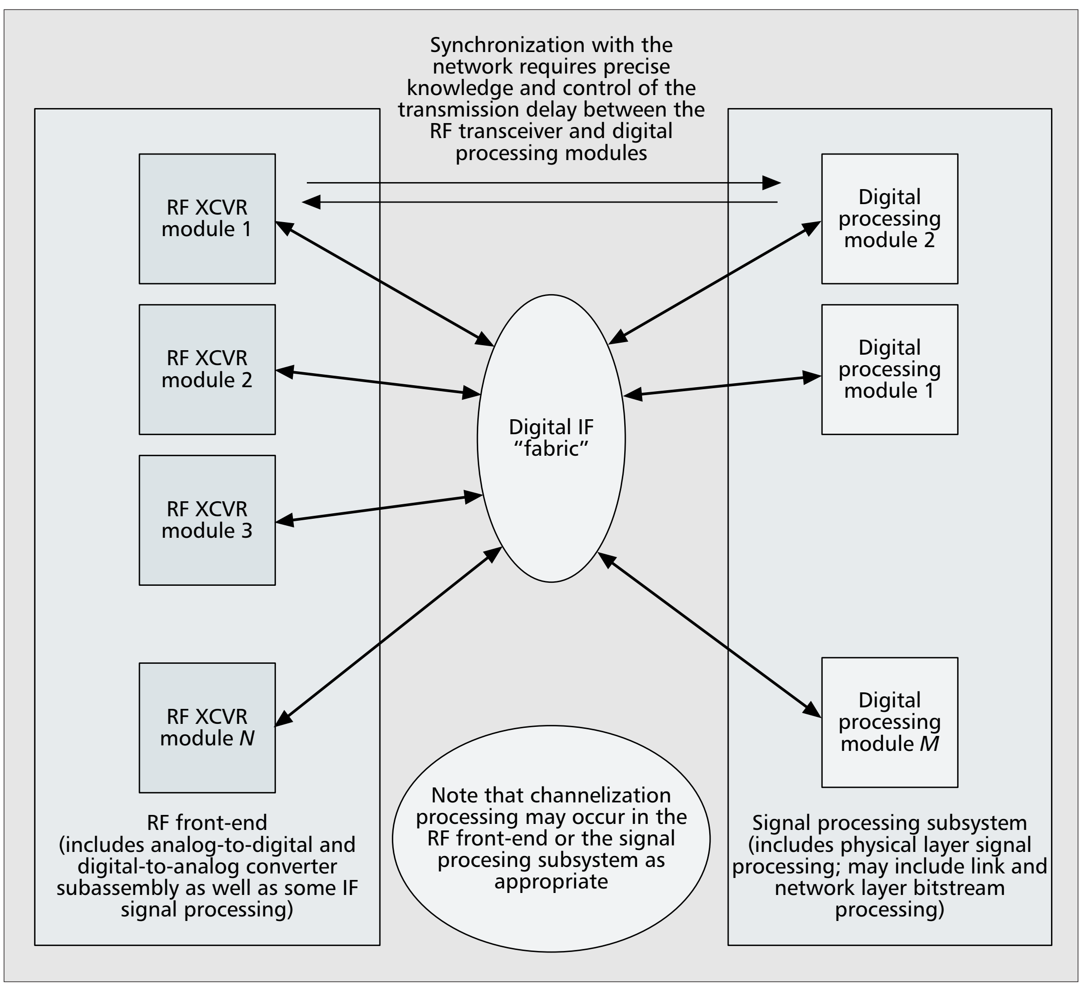

FIGURE 1. *Common digital IF architecture.*

[3]. OBSAI defines open interfaces at multiple reference points within the base station architecture, with reference point 3 (RP3) representing the RF front-end to baseband processing interface [4]. The RP3 specification is open and available for download [5].

• In apparent response to the OBSAI effort, Ericsson, Huawei, NEC, Nortel Networks, and Siemens jointly founded the Common Public Radio Interface (CPRI™) industry initiative [6]. CPRI roughly corresponds to RP3 in the OBSAI architecture [7]; however, unlike OBSAI, which supports a wide range of standards, CPRI focuses exclusively on Third Generation Partnership Program (3GPP) Universal Mobile Telecommunications System (UMTS) Terrestrial Radio Access (UTRA) release 5 [8]. The CPRI standard is also open and available for download [9].

• The End-to-End Reconfigurability Project (E^2R) is exploring these and other related technologies, with a goal of defining standardized system architectures that "provide common platforms and associated execution environments for multiple air interfaces, protocols and applications" [10]. This project is being done under the auspices of the European Union 6th Framework Program, and is structured into six technical work packages. Work package four (WP4) explores the issues associated with radio modem reconfigurability, and includes both OBSAI and CPRI as part of their review of state-of-the-art technologies with respect to the physical aspects of the RF front-end and digital baseband processing [11].

The desire for a digital IF standard is not limited to the commercial market space, and as such there are a number of initiatives underway in the defense sector as well:

• VITA-49 was formed in 2004 as a formal VITA Standards Organization working group to create a "new interconnect standard for passing IF data between system elements in a digital format" [12]. This effort is targeted at the defense commercial off-the-shelf (COTS) industry with an emphasis on the needs of the signals intelligence (SIGINT) community [13].

• The Software Based Communications (SBC) Domain Task Force (DTF) of the Object Management Group (OMG) has issued a formal RFP for platform-independent and platform-specific models (PIM and PSM) for digital IF [14]. This group began as the Software Radio Domain Special Interest Group focused on developing a commercial PIM and PSM for software radio components based on the Joint Tactical Radio System (JTRS) Software Communications Architecture [15]. As with VITA-49, this effort is lead by companies focused on the defense sector; however, the work of this group is more centered on command control communications and computers (C4) [16].

These efforts all define, or will define, a subset of the technologies that would be supported in a common digital IF standard addressing the broader needs of the wireless application space as a whole. At a high level, the requirements for this common standard are fairly well defined. The digital IF standard must do the following:

Allow 1 to *N* front-end RF transceiver modules to communicate with 1 to *M* back-end digital processing modules. *N* and *M* are defined based on application need, with support in a generic digital IF specification providing for:

- One RF module connecting to one processing module following a traditional radio model
- IF or baseband signal data to flow between a single RF front-end and multiple back-end processing modules for extremely wideband or high-channel-density architectures
- Multiple RF channels to be processed on a single processing module for MIMO, smart antenna, or beamforming applications

Allow a mix of wide and narrowband channels while maintaining quality of service requirements for each channel.

Allow some level of dedicated processing within the RF subsystem. This processing could include digital channel filtering on an IF signal, digital sample rate conversion, or even full channelization processing, extracting from or inserting into the IF spectrum specific channels of interest.

Support synchronous (coherent) processing across multiple digital IF channels. This is again required to support smart antenna or beamforming applications. Synchronization for these applications must be accurate to the sample, with a delay compensated sample clock distributed to each converter element.

Provide a delay calibration mechanism on RF-to-processing and processing-to-RF paths to define a fixed latency for each communications path. This is necessary to support, for example, synchronization on burst communications networks using time-division multiple access (TDMA) or frequency-hopped spread spectrum schemes.

Support synchronization with external "events," such as a 1 pulse/s (1PPS) signal from a Global Positioning System (GPS) receiver, which is accurate to the sample. This is again to allow for things such as synchronization on burst communications networks.

Support synchronous control channels between the RF front-end and the back-end digital processing that are tightly integrated with data channels to provide for hard real-time control in frequency-agile applications.

So why does the wireless industry not develop and adopt a common digital IF standard instead of creating and supporting subsets of this standard with features that are segment-specific? Although I am sure there are numerous answers available, in my opinion one of the more compelling answers comes down to economics. As stated earlier, in order to achieve the cost benefit the OEMs are driving toward, a certain level of commoditization is required in the RF front-end and digital processing modules that interface through these standards. This fundamentally limits the ways in which component-level vendors can differentiate any modular product supporting a digital IF standard within in a given market space [17]. Differentiation through vendor-specific features that are introduced to a market to extend a digital IF interface standard to provide additional capability will not be sustainable: if one module vendor does offer differentiated performance, and this level of performance thus becomes necessary within the market space, all companies competing on that module will be driven to support similar performance within a market-driven cost window

What this means is that in this commoditized model, there are no real market drivers for supporting features within a given market segment that are not widely utilized within that segment. Furthermore, adding on additional digital IF features to support reuse of a broader technology across multiple segments may be cost prohibitive. In general, OEMs will require modules that provide the level of performance necessary to address their segment-specific application needs within a given cost window. Depending on the cost of supporting these features, extending the supported digital IF standard in a modular product servicing one market segment to allow the technology used in that product to be reused in a separate modular product targeted at another market segment may drive the cost of the product outside the target window.

So, given the differences in both application requirements and the drivers for size, weight, power, and ruggedization between the various commercial and defense segments, what this means is that there is no real cost incentive for a vendor to develop a module with digital IF features that extend beyond the specific needs of a given market segment. So, does the wireless industry really need all of these digital IF standards? The answer may be yes: from a business perspective it makes sense that independent digital IF standards would be required with specific features selected from the ideal case to cost optimize for the application needs within a given market segment.

That said, an industry consortium rationalizing these standards to maximize reuse of their constituent technologies across the various market segments could offer significant cost benefit to the wireless community as a whole. Such rationalization would allow component-level vendors to develop a base product offering with digital IF features that can scale to meet the specific needs of individual market segments. With such rationalization, cost savings is accrued by these vendors by amortizing the development cost of digital IF technology across multiple segments, spreading their overhead across multiple products and thus improving their overall profitability.

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Biography

Lee Pucker [M] (Lee_Pucker@spectrumsignal.com) is the Chief Technology Officer for Spectrum Signal Processing Inc. He provides the integral leadership and technical direction for Spectrum's future products to meet the demanding customer requirements of tomorrow. His expertise and areas of interest include software defined radios, architectures for high performance digital signal processing, and communication system design. He received his Bachelors of Science in Electrical Engineering from the University of Illinois, and his Masters of Science at The Johns Hopkins University. He has been a member of the IEEE since 1983.