iDirect Government

WHITE PAPER

Waveform Virtualization

INTRODUCTION

We at iDirect Government™ (iDirectGov) recognize the critical need for resilience, security, and SWAP within the US DoD. Key elements to support these needs are virtualized waveforms and a platform that seamlessly interoperates with various satellite services and waveforms.
In order to facilitate these requirements, iDirectGov has introduced the first foundational element in its REVOLUTION ecosystem – the REVOLUTION 450mp. This man-portable modem is a software-defined radio that, in conjunction with iDirectGov's Waveform Development Kit, enables both iDirectGov and 3rd party waveforms to be virtualized and run on the 4-Series platform.

VIRTUALIZING WAVEFORMS

The goal of virtualizing waveforms has been pursued by the satcom industry for years, and various companies have made strides toward achieving multi-waveform modems. For the most part, this success has been limited to waveforms owned by a company operating on a modem developed by that same company.

iDirect Government reviewed these barriers and determined the best way to break down the obstacles preventing the US DoD from achieving its goals was to offer a Waveform Development Kit that would streamline the process of putting 3rd party waveforms on software-defined radios. The key attributes of this waveform development kit would include the following:

USER-FRIENDLY DESIGN
The WDK eliminates the need for in-depth hardware knowledge, requiring only a minimal level of system information.

SIMPLIFIED HARDWARE INTERACTION
All hardware interactions are abstracted through a unified set of APIs and standardized FPGA interfaces.

COMPREHENSIVE DEVELOPMENT PACKAGE
The WDK comprises a dedicated hardware platform and a robust software development environment, facilitating swift implementation and seamless porting of exiting waveform libraries.

VERSATILE OPERATION
Waveforms ported to the 450mp WDK can function as either a standalone modem or a DIFI modem.

FUTURE-READY ADAPTABILITY
Implemented waveforms can be easily recompiled for upcoming iDirectGov platforms, including the REVOLUTION line cards currently in development, enabling 3rd party waveforms in the REVOLUTION ecosystem.

INTELLECTUAL PROPERTY PROTECTION
When using the WDK, the 3rd party waveform developer can provide an encrypted core to iDirectGov. The waveform will interact with the hardware through clearly defined, secure interfaces. The encryption is provided and controlled by the 3rd party, so the intellectual property is protected.

MODEM INTEGRITY
Each of the waveforms provided by means of the WDK will be certified and signed by iDirectGov to provide customers with confidence in both the performance as well as security of the modem.

Traditional Barriers to Virtualizing Waveforms

COMPLEX HARDWARE INTERATION
Historically, waveforms were designed to work on a specific hardware platform. Porting these waveforms to a different hardware platform often required extensive engineering adjustments adding time and cost. In addition, enhancements or improvements to the waveform would result in additional engineering modifications.

EXTENSIVE KNOWLEDGE AND TRAINING
Waveform developers needed in-depth knowledge of the hardware, which meant significant training or study was required for every new hardware platform. This knowledge transfer represented additional investment for both the waveform and the hardware developers.

LIMITED ADAPTABILITY
Waveform integration on a new hardware platform was just as much effort as the first hardware platform, with little ability to reuse work.

LIMITED PROTECTION OF INTELLECTUAL PROPERTY
The willingness of various industry players to collaborate was limited by the lack of protection for intellectual property. In order to effectively implement a 3rd party waveform on a platform, key details would have to be shared by both parties.

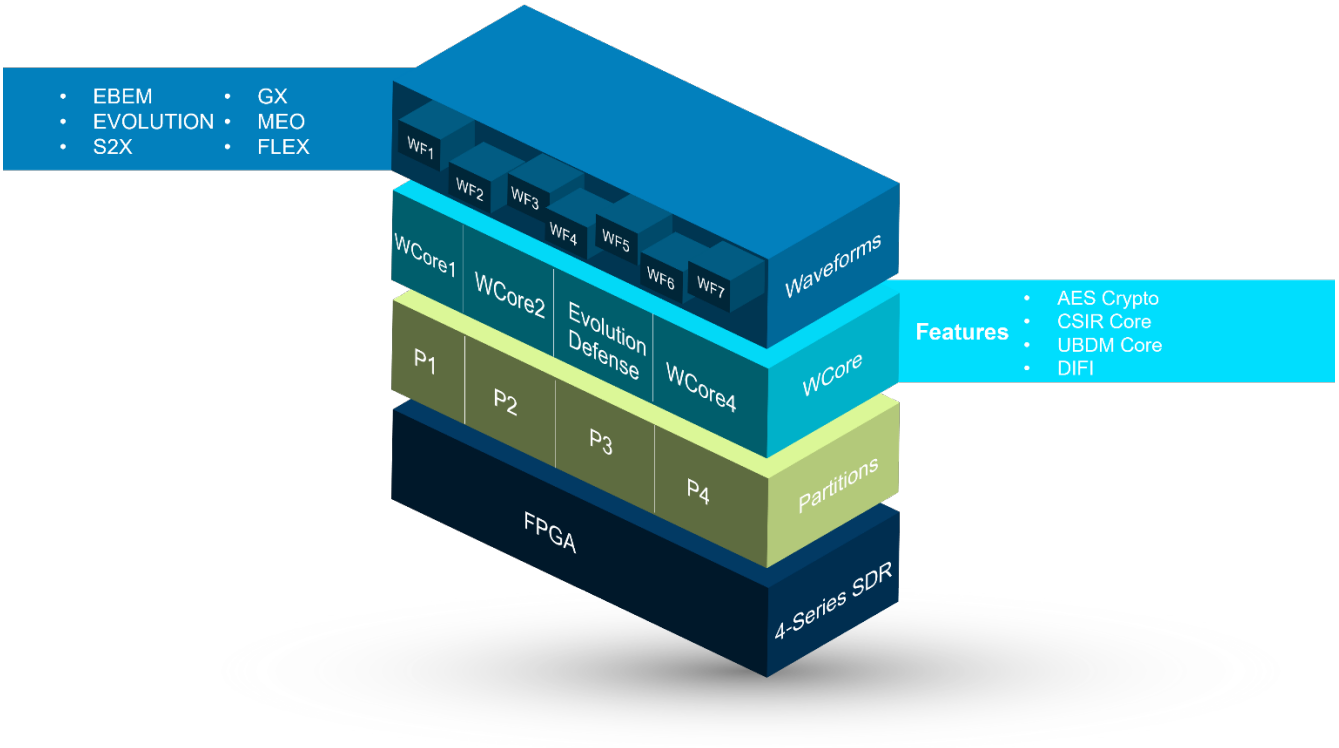
REVENUE ASSURANCE
Lastly, industry players didn't have a path to ensure they were compensated for the use of their intellectual property.

REVENUE ASSURANCE

Each waveform will be licensed before it will operate on the platform, and the 3rd party waveform owner will be compensated according to the commercial agreement in place with iDirectGov.

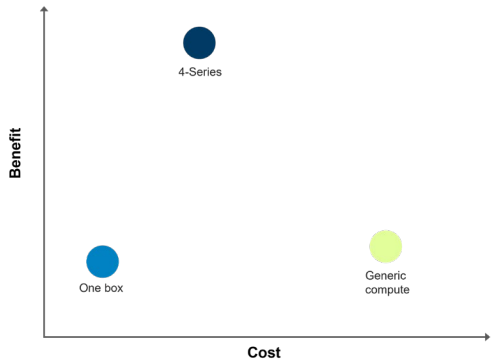
WAVEFORM VIRTUALIZATION STRUCTURE

The key elements of the Waveform Virtualization Structure include the WCore, which is the abstraction layer, and the WSlice, which holds the virtualized waveform.



Each of the partitions in the 4-Series modem can support a WCore. And each WCore can support one or more waveforms (WSlice) depending on the size of the waveform. In addition, each waveform can access core capabilities like AES encryption and CSIR.

HARDWARE SELECTION



There are alternative solutions available for Virtualized Waveforms. Options include:

ONE "BOX" WITH MANY VENDOR-SPECIFIC "CARDS" INSTALLED

While this solution is least disruptive to the current SATCOM market space, it is also least beneficial to end users. Overall complexity and SWaP have not been optimized.

FPGA + CPU-BASED SOFTWARE-DEFINED RADIO

This solution optimizes SWaP and cost while providing the desired flexibility and interoperability. It will work for current SATCOM modem architectures while future-proofing with DIFI capability.

PURE SOFTWARE-DEFINED WAVEFORMS RUNNING ON GENERIC SERVERS (CPU'S OR GPU'S) USING DIFI

While this solution may appear to be the most versatile on the surface, the reality is an expensive and power-hungry modem that only works in a full DIFI environment.

To get the same level of performance on a CPU as on a FPGA, integrators will need very powerful hardware, which also drives power requirements easily in excess of 55 watts. For that power, iDirectGov can provide two digital modules, optimizing SWaP and providing redundancy.

iDirect Government chose the FPGA + CPU-based SDR because it best meets the needs of the end user community. This new suite of SDR modems is called REVOLUTION 4-Series, and the first modem currently on the market is the REVOLUTION 450mp.

REVOLUTION 4-SERIES

The REVOLUTION 4-Series SDR expands on the open standard approach to iDirectGov's IP satellite modems, designed into both hardware and software, which is critical when developing a technology that must interoperate and be virtualized, while maintaining state-of-the art security. A logical block diagram of iDirectGov's REVOLUTION 4-Series modem is shown in Figure 1 below.

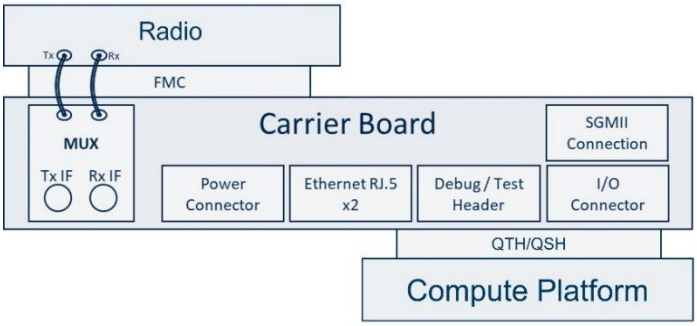


Figure 1. REVOLUTION Modem Logical Diagram

From a hardware perspective, the REVOLUTION 4-Series SDR modem architecture consists of three core components:

RADIO MODULE

The REVOLUTION modem's radio is responsible for amplifying, filtering, and converting the RF signal to and from digital form between the RF and the compute platform. The receive chain converts the L-Band RF from the BUC/LNB to digital data which is then sent to the compute platform via a JESD204B interface, while the transmit chain converts the digital data from the JESD204B interface to L-Band RF. The radio section also includes a MUX that couples DC power for the BUC/LNB together with control tones and reference clocks to create the IFL.

COMPUTE PLATFORM

The compute platform used at the tactical edge is an FGPA/SOC with an ARM Processor (SoC). This component performs digital signal processing and is responsible for security and management.

CARRIER BOARD

The carrier board brings all the modules together by routing the signals between one another and external I/O (e.g., Ethernet). It also provides a physical mounting structure for the modules.

The radio and the FPGA communicate using a standards-based JESD204B interface. This design provides the flexibility to use a different radio or FPGA module without the need to redevelop a custom interface. In addition, the interface allows this architecture to seamlessly support DIFI-compliant terminals. The elegant, all FPGA design of the modem allows it to be a true software defined radio (SDR) in a SWAP-friendly form factor.

The REVOLUTION 450mp is a multi-purpose, multi-orbit, and multi-waveform modem that can host both iDirect and third-party waveforms. This includes, but is not limited to the following:

- iDirectGov Evolution Defense ATDMA
- iDirect Velocity GA (Intelsat Flex)
- iDirect Velocity GX (Inmarsat)
- SES mPower
- Others as desired
- MIL-STD-188-165B EBEM (Future)
- DVB-S2X SCPC
- DVB-S2X SCPC Return
- LPI/LPD

The REVOLUTION 450mp modem optimizes SWAP. This SDR is approximately 16 square inches in size and requires less than 20W of power. For more complex systems that require additional transmit/receive capabilities and/or more processing power, additional radio and/or FPGA modules can be added to the system. For example, a two radio/two FPGA module (Revolution 4750 available 3Q2025) will support twice the amount of capacity as a single radio/FGPA solution. This allows the system to grow seamlessly with end user demand. A picture of the REVOLUTION 450mp is shown below in figure 2.

Figure 2. REVOLUTION 450mp Satellite Modem

The hardware specifications for the REVOLUTION 4-Series SDR provide for the most cost effective, scalable, and SWAP-friendly platform for modems at the tactical edge. The foundational attributes for this type of platform at the hub-centric location would be similar in technology and capabilities, but the same basic architecture can be implemented in larger shared-resource compute platforms. Data center locations have a substantial amount of processing power and storage. Processing-intensive tasks such as demodulation can also be placed onto FPGA resources within the data center's servers. This would allow the opportunity to deploy the same security architecture at the hub-centric location and simplify the NIST approval process by having common architectures at both the hub and tactical edge.

HARDWARE SECURITY IN REVOLUTION

iDirectGov and Xilinx have partnered on the architecture and design of a single chip FIPS 140-3 compliant solution using a Zynq UltraScale+ MPSoc and iDirectGov's secure execution environment (SEE). The SEE takes advantage of Xilinx's trusted execution environment (TEE) to ensure the proper operation of the execution levels of the ARM trusted firmware on the Cortex processors within the FPGA. Together, this allows the iDirectGov architecture to maintain a strict logical separation between non-secure application code and the secure FIPS 140-3 certified cryptographic module software.

RADIO SECURE BOOT

The Waveform Development Kit was designed to simplify adding 3rd party content onto the secure 4-Series SDR, but the question arises as to whether a bad actor could also easily add content. iDirectGov has ensured it will be impossible for an adversary to add malicious code by implementing Secure Boot. Secure Boot is enabled by burning e-fuses which are physical fuses that exist at the hardware level. In this environment, the secure software is responsible for more than just the standard AES encryption associated with FIPS 140-3 certification. The secure software module is responsible for configuration, control, and monitoring of hardware and programmable logic. During execution, the software initializes, verifies the software image residing in secure flash, and performs a series of self-tests. This process ensures all applications installed on the 4-Series modems must be verified and signed with iDirectGov's private key or they will not execute in the FPGA.

For more details on how the iDirectGov and Xilinx architecture works, please refer to the white paper posted on Xilinx's website. This solution ensures a complete chain of trust from the manufacturing of the wafer, through the supply chain, and into the package loaded onto the FGPA. The foundation of this security is through the 2D barcode, or the device DNA. This allows for full traceability and verification from wafer to fielded systems. And as mentioned above, these FPGAs can operate stand alone at the tactical edge or can be part of a larger data center's compute resources.

CONCLUSION

The iDirect Government 4-Series Suite of SDR modems combined with the Waveform Development Kit will provide maximum resilience, security, and SWAP for US DoD customers while supporting commercial innovation and development by protecting IP with encryption and licensing options.

ABOUT

iDirectGov, LLC, a U.S. corporation, delivers secure satellite-based voice, video and data applications with anytime and anywhere connectivity in the air, at sea and on land. iDirectGov's advanced satellite IP solutions are used for critical ISR, airborne, maritime and COTM communications to support force protection, logistics, situational awareness, disaster recovery and emergency response. Building on more than 15-years of global satellite communications experience, iDirectGov provides the most bandwidth-efficient, scalable and highly secure platform to meet specialized applications of multiple federal, state and local government agencies, including the Department of Defense, both domestically and abroad. iDirectGov has been a trusted partner of the U.S. government for more than 17 years. All its employees are U.S. citizens, with a third being U.S. military veterans.

iDirectGov's specialized technology includes transmission security (TRANSEC), Communication Signal Interference Removal (CSIR) anti-jam technology and Open Antenna Modem Interface Protocol (OpenAMIP). All Defense-grade products sold by iDirectGov are designed, developed, assembled, programmed and verified within the United States.