TN-09: Portable Sonobuoy Receive Processing with RFvision-1 Supermini

Introduction

Sonobuoys are vital tools for security and intelligence gathering. The sonobuoys provide both a deployable acoustical signal source and reception of underwater signals of interest. These received signals are transmitted to monitoring units that process the signal for analysis, classification of any target and recording for replay and post event analysis.

The current approach involves modulating (typically FM) a RF carrier with the acoustic signal and then transmitting the modulated RF carrier to the monitoring platform. At the receiver end the RF is down-converted to baseband and demodulated using a separate radio receiver for each channel. The acoustic analog outputs are then digitized for further acoustic processing. New generation sonobuoys use digital modulating techniques to overcome RF interference in littoral waters and also use higher channel bandwidths. Seamless switching between analog and digital channels and programmability of RF carrier frequency and channel bandwidth is required for implementing a flexible sonobuoy receiver.

Figure 1: D-TA’s Sonobuoy RF receiver providing digitized acoustic data to 3rd party COTS Sonobuoy Acoustic Processor and providing simultaneous recording of sonobuoy channels.
The use of software radio technology can offer significant cost savings and potential performance improvements by digitization at the RF level and subsequent digital processing. The advantages include elimination of multiple analog receivers (one per FDM channel is required in the traditional method); better matching of digital receivers; a future-proof architecture that can allow arbitrary selection of BW, IF and modulation scheme and cost reduction by eliminating acoustic sampling products. The portable and rugged RFvision-1 Supermini provides a low-cost and a compact solution to Sonobuoy and other multi-channel receiver applications. It provides channelized RF receiver combined with integrated RF record/playback capability and can be directly connected to the 3rd party COTS acoustic processors.

The Supermini performs the required FM demodulation in the built-in FPGA processor and provides digitized demodulated data over a 1GbE to any COTS Acoustic Processor (like the Thales TMS 2000 and others). The Supermini is available in commercial and rugged versions and can be installed in a rotary or fixed wing platform for easy system deployment. The Supermini is an open-architecture platform and thus is easily reconfigurable and customizable for specific use cases. It is also available as a coherent multi-channel platform and a multi-antenna version is used for direction finding and buoy retrieval.

**Summary Specification**

<table>
<thead>
<tr>
<th>FEATURE</th>
<th>VALUE</th>
<th>COMMENTS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Receive Section</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Received Structure</td>
<td>SDR based</td>
<td>ADC precision 16-bit</td>
</tr>
<tr>
<td>Number of Antenna Inputs</td>
<td>1 or 4 (for localization or interference reduction)</td>
<td>Additional RF inputs possible</td>
</tr>
<tr>
<td>Standard sonobuoy channels</td>
<td>32</td>
<td>Can be expanded by adding additional FPGA resources</td>
</tr>
<tr>
<td>Independent tuning</td>
<td>Yes</td>
<td></td>
</tr>
<tr>
<td>Independent BW setting</td>
<td>Yes</td>
<td>The sonobuoy channels can be independently programmed for bandwidth (analog or digital buoys)</td>
</tr>
<tr>
<td>Frequency Coverage</td>
<td>136 to 173.5 MHz</td>
<td>Standard sonobuoy channels. Fully tunable option till 8 GHz is also available</td>
</tr>
<tr>
<td>Tuning resolution</td>
<td>Sub Hz</td>
<td>Meets 375 kHz channel spacing</td>
</tr>
<tr>
<td>Noise Figure</td>
<td>5 dB</td>
<td></td>
</tr>
<tr>
<td>IF BW</td>
<td>240 kHz (analog)</td>
<td>Bandwidth is programmable</td>
</tr>
<tr>
<td>Adjacent channel Rejection</td>
<td>&lt; 90 dB</td>
<td>Can be customized for additional rejection. Rejection is provided by digital filter</td>
</tr>
<tr>
<td>Out of Band rejection</td>
<td>80 dB (freq &gt; 225 MHz)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>80 dB (freq &lt; 80 MHz)</td>
<td></td>
</tr>
<tr>
<td>FM demod</td>
<td>Integrated</td>
<td>Implemented in the FPGA. Upgradeable</td>
</tr>
<tr>
<td>Output data rate</td>
<td>49777.78 Hz or custom</td>
<td>Other data rates possible via software control</td>
</tr>
<tr>
<td>Full scale output for deviation</td>
<td>128 kHz</td>
<td></td>
</tr>
<tr>
<td>Raw I/Q out</td>
<td>Yes</td>
<td>FM demod option can be bypassed and basebanded sonobuoy channel output possible. Allows users to implement customized processing</td>
</tr>
<tr>
<td>FM output interface</td>
<td>1GbE (10GbE option)</td>
<td></td>
</tr>
<tr>
<td>I/Q data output interface</td>
<td>10GbE link</td>
<td>Provided to integrated recorder. Can be provided to the user as option</td>
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### Sonobuoy System Description

There are a wide variety of sonobuoy systems deploying different number of buoys and operating at different frequencies. Typically, most operate in the mid VHF frequency band and deploy 32 or 64 buoys. In some cases, the buoys can be programmed from the monitoring platform to transmit at a different frequency within the allocated frequency band to circumvent interference problems. Typically, a radio map of the area is done prior to setting the transmit frequencies for the buoys.

The sonobuoys operate over a frequency band of 136 to 173.5 MHz with a channel spacing of 375 kHz. Figure 2 shows a typical frequency band of operation. In this example, 32 buoys, each with a bandwidth of 375 kHz, have been assigned channel frequencies between 162.25 MHz to 173.5 MHz. Some of the new generation of sonobuoy systems may have multiple acoustic sensors/buoy and each may occupy a bandwidth up to 1 MHz.

![Figure 2: Sonobuoy frequency allocation](image-url)
RFvision-1 Supermini: Brief Description

The Supermini is a multi-channel scalable transceiver system with a complete dual mixing super-heterodyne RF up and down converter and a FPGA based high performance digital IF section. An integrated recorder is also available that records the complex I/Q data from the multiple channelized receivers. When used as a standard sonobuoy receiver, a direct sampling receive structure is used, with low noise RF gain and filter section to provide a flat pass-band response and sharp guard band thereby providing high-performance anti-aliasing filter. D-TA also offers a fully tunable RF front-end capable of frequency coverage up to 8 GHz or beyond and non-standard sonobuoy frequency plans can be accommodated.

The simplified block diagram of the sonobuoy receiver is shown in Figure 3. It comprises of two major building blocks: 〈i〉 RF Section with a single channel RF Receive and Transmit section 〈ii〉 Digital IF section with a 16-bit ADC and DAC with a large Kintex 7 FPGA and 10GbE link for high speed data transfer and 1GbE link for control.

Major Features:

- Separate RF receive and transmit path for independent receive and transmit operation
- 16-bit ADC and 16-bit DAC optimized for operation with the RF front end
- Fully functional Digital Down Converters (DDC) and Digital Up Converters (DUC) implemented in the FPGA
- Transmit capability allows transmission of CFG and CFS commands
- Large Kintex 7 FPGA for implementing optional demodulation functionalities or user code
- Programmable DDC (wideband and narrowband) for optimal bandwidth selection
- 10GbE Network for full transceive operation in the entire sonobuoy band
- FM demodulated data also available over 1GbE link for direct connect to 3rd party COTS acoustic processor
- 1GbE link for command and control

System Implementation

The RF stage of the Supermini performs gain and filtering and the sonobuoy signals are then directly digitized by the 16-bit 250 MSPS ADC. The high-speed, high performance ADC provides in excess of 85 dB of dynamic range and can handle the high dynamic range needed for sonobuoy receivers.

The RF front end has a flexible structure that allows external notch filters to be added to attenuate large interferes that may be present. This flexibility allows the same common cost-effective architecture to be used for a wide

Figure 3: System Block Diagram for the single antenna sonobuoy receiver
variety of locations by simply changing the notch filter. For even more flexibility programmable notch filters may also be used.

The narrow band channelization via Digital Down Converters (DDC) and demodulators can be implemented in the FPGA and provided directly to COTS acoustic processors. Alternatively acoustic and telemetry processing can also be implemented in the Kintex 7 FPGA (as shown in Figure 4) and the processed data is then provided to the display processor via the 1GbE interface.

Additionally D-TA's expertise in multi-core threaded real time software development allows users to implement real time sonobuoy processing to be performed in a standard off the shelf server like the DTA-1000-R as shown in Figure 7. This also allows the user to record the complex I/Q data stream for post-processing.

**FM Demodulation and FPGA Processing**

The Supermini is equipped with multiple Kintex 7 FPGAs. The FPGA implements the DDC and DUC for digital down and up conversion respectively. The DDC filters the desired channel and provides the adjacent channel rejection. FM demodulators can also be implemented in the FPGA and the digitized demodulated data can be sent to COTS acoustic processors over 10GbE or 1GbE link. Alternatively, users can implement their own acoustic processing in a standard server using D-TA's multi-core optimized Software Development Kit. The FM demodulation can also be performed in software.
Radio Mapping for Programming Buoy Frequencies via CFG/CFS commands

The Software Radio based Sonobuoy Receiver system presented here has the added advantage that a radio map of the environment can be easily performed prior to deployment. This allows the operator to determine clear channels and program the buoys to operate on those channels. Operators can also periodically update the radio map and change channel allocation if required. The transmit section of the Supermini enables users to transmit the CFG and CFS commands.

Multi-Antenna Solution for Direction Finding, Localization and Interference Cancellation

The phase-coherent multi-antenna version allows users to implement sonobuoy localization. For the phase coherent operation, all 4 (or more) channels are sampled synchronously and direction finding algorithms implemented to enable buoy retrieval. The system block diagram for a 4-channel system is shown in Figure 6.
Another application for the phase coherent multi-antenna solution is interference cancellation in littoral water. D-TA’s phase coherent multi-channel RF expertise allows users to implement interference cancellation for standard and non-standard sonobuoy frequencies.

**Real Time Multi-Core Processing**

D-TA’s multi-core multi-threaded optimized Software Development Kit (SDK) allows users to easily implement sonobuoy processing in standard multi-core servers. The SDK allows users to handle the packetized data from the server (over 10GbE or 1GbE link) and allocate threads and processing cores. The SDK includes precompiled API calls and full-source example codes to enable users quickly develop their custom applications. D-TA provides hands-on training and can also develop customized software applications.
Sonobuoy Simulator

D-TA’s concept of streaming waveform I/Q data from hard drives to RF transmitters has revolutionized arbitrary waveform generation. Virtually, any waveform of any frequency and any duration can be readily generated using any popular 3rd party software (e.g., Matlab™, Octave, etc.). The simulator can be available as a portable solution (shown below in Figure 8) or rackmount configuration. This allows users to create long duration multiple sonobuoy signals and can be used to easily test sonobuoy deployment. The alternative of using multiple RF signal generators is cumbersome, expensive and does not provide long-term signal creation capability.

Figure 7: Real Time Processing using D-TA’s Multi-core multi-threaded Software Development Kit

Figure 8: Portable Sonobuoy Simulator – the system can also be used as a simulator
Figure 9: 32 sonobuoy channels simulated with D-TA Arbitrary RF Waveform Generator

Customization

The Supermini can be easily customized to meet specific user requirements. Please contact factory to discuss your specific requirement. Typical customization can include:

- Limited band of operation
- Change of RF coverage
- Additional front end filtering options
- FPGA based fast scanning with downloaded scan table
- Multi-core software application development

Training

We also offer hand-on interactive training either in our fully equipped Training Center or in your facility. The Training Center boasts a fully equipped conference room and a dedicated Training Laboratory with access to D-TA products as well as test equipment like Oscilloscopes, Spectrum Analyzers, Network Analyzers, Signal Generators, etc. The hand-on training cover a full discussion of the SDK structure, detailed product discussions and actual demo application development with actual equipment. The user would be able to create processing applications and determine optimal speed and performance. The specific applications are tailored to meet the user's exact requirement.

We also offer custom application development to meet the users' exact requirement. Please contact us for more information.
Conclusion

Taking Sonobuoy processing as an example, this brief technical note has demonstrated how a multi-channel transceiver receiver can be readily implemented using the Supermini. The Supermini is a versatile tunable SDR platform with RF up and down converter integrated with ADC and DAC and is the ideal platform to address a wide variety of applications: radar, communications, SIGINT, etc.

The Supermini is ideally suited to implement an extremely cost-effective sonobuoy platform. The demodulated and digital acoustic data can be directly connected to 3rd party COTS Acoustic processors. By providing integrated recording capability it offers additional functionality not available in the market.

Contact Information

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