Testing of FPGA Telemetry Decoders

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Background

Deep Space Network (DSN)

The DSN is an international antenna network funded by NASA. It provides support and communications for various space missions and can also perform radio astronomy.

Goldstone Deep Space Communications Complex

70-meter antenna at Goldstone, tracking MSL at the time

New Downlink Channel

Implementation of a new downlink channel is in progress for the DSN, which consists of a new 34-meter antenna and telemetry processors.

Foundation work for the new 34-meter beam waveguide antenna in Canberra, Australia

Telemetry Overview

Below is a summary of the wireless communication process standard to the DSN. Test signals were used to simulate distortion and noise introduced in the process, obtaining a close representation to signals received by the DSN.

Information → Encode → Modulate → Transmit → Receive → Demodulate → Decode → Information

- **Encoding** – data is encoded to ensure its integrity (right, green)
- **Modulation** – data represented as high frequency signal ready for transmission
- **Transmission** – signal is amplified and transmitted via an antenna
- **Receiving** – DSN antennas track and receive signals from spacecraft and landers
- **Demodulation** – signal is brought back from high frequency band, noise and degradation present
- **Decoding** – read and decode the discretized signal with noise (below, gray)

Decoder Implementation

The decoders are implemented on FPGA boards but require testing to validate functionality and evaluate performance. These decoders are meant to eventually replace legacy components at other DSN facilities as well. The functionality and performance of the decoders must be the same as those which they are replacing. The FPGA decoder can be seen below, integrated into an existing system.

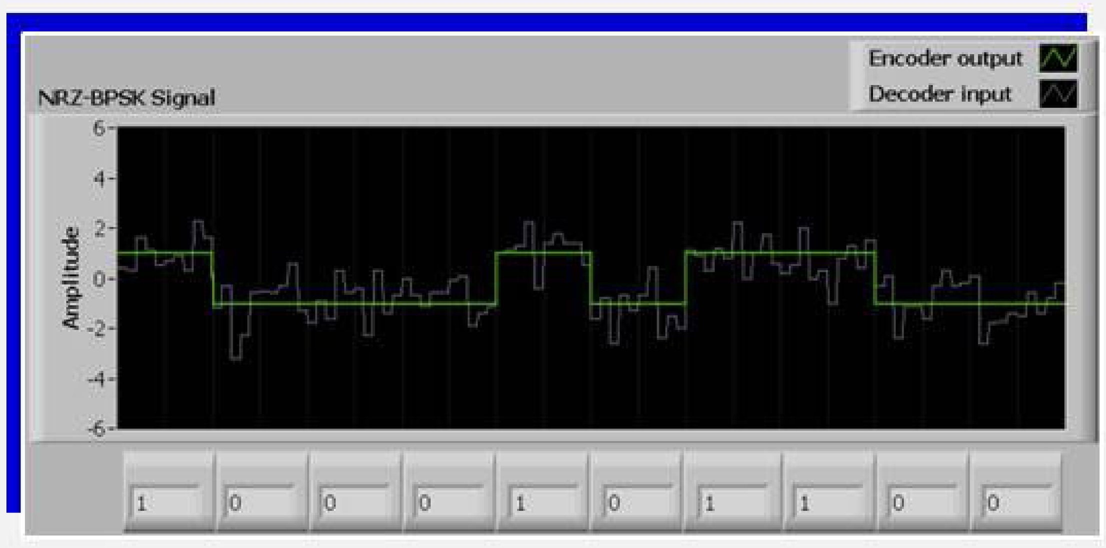
Legacy Telemetry Processor

Decoder FPGA Implementation

Project

Project Focus - Telemetry Decoders

The project focuses on testing and evaluation of telemetry decoders for the new downlink channel. These decoders are responsible for reading and decoding demodulated signals in order piece together data from spacecraft and landers such as the Mars Science Laboratory. The decoder's performance is gauged by its ability to correctly decode signals similar to those received by the DSN.



Example comparison of encoded data (green) and demodulated signal received at the decoder input (gray)

Data Processing & Analysis

Measures of performance were obtained by comparing the input data to the output of the decoder. Large sets of data were processed using Python script to obtain parameters such as Bit Error Rate (BER), Symbol Error Rate (SER) and Signal-to-Noise-Ratio (SER). These were compared to theoretical performance curves and those available from the existing decoder.

Although these measures can signify whether there is a discrepancy, they do not help identify its source. Additional output parameters were added to isolate sections of the test setup in order to determine the source of an error.

Future Work

Testing is an ongoing processes as updates are made to the firmware. At the conclusion of the internship, the Turbo Decoder was under evaluation. Once the Turbo Decoder is fully tested and implemented on FPGA, the next capability to be evaluated is the Reed-Solomon decoder. The same test setup is utilized along with a similar procedure. The end goal is full implementation of the telemetry decoder.

Test Setup

The test setup is summarized below. The DSN Signal Generator (DSG) can be set to generate signals at different symbol rates, power levels and utilize concatenated codes. The signal is attenuated using a separate box before noise is added. At the receiver, the signal is demodulated and passed to the telemetry decoder.

DSG → Attenuator → (+) → Receiver → Telemetry Decoder → FER and BER measurement

Noise Generator → (+)

DSN Signal Generator (DSG) and test setup

Test Results

The majority of testing during the internship was focused on the Turbo Code encoding scheme. Testing was conducted at different pairs of symbol rate and code rates, while varying the SNR for each case.

Several issues were encountered during the course of testing and their causes identified. Some of these include performance degradation at higher symbol rates, effects of amplitude scaling on performance, bursts of errors at the decoder output and conversion errors.

Conclusion & Acknowledgments

In the course of the internship I was able to apply knowledge from the digital communications field and learn about how these concepts are implemented on NASA's Deep Space Network.

My mentor Chau Buu and other members of the Telemetry Signal Processing group (333E) were often available to to assist me with their expertise and skill on troubleshooting the issues that we encountered. Their support and added perspective is much appreciated.

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