



VERIFICATION OF RF HARDWARE DESIGN PERFORMANCE EARLY IN THE DESIGN PHASE

Practice:

Analyses are performed early in the design of radio frequency (RF) hardware to determine hardware imposed limitations which affect radio performance. These limitations include distortion, bandwidth constraints, transfer function non-linearity, non-zero rise and fall transition time, and signal-to-noise ratio (SNR) degradation. The effects of these hardware performance impediments are measured and recorded. Performance evaluation is a reliability concern because RF hardware performance is sensitive to thermal and other environmental conditions, and reliability testing is constrained by RF temperature limitations.

Benefits:

Identification of hardware-imposed limitations on RF subsystem performance permits designers to evaluate a selected radio technology or architecture against system requirements. In the test phase of the reliability assurance program, it also helps engineers to understand performance characteristics they encounter during testing. RF modeling and verification provides for designed-in reliability in accordance with NASA's project streamlining policy.

Programs That Certified Usage:

Voyager, Galileo, Cassini

Center to Contact for Information:

Jet Propulsion Laboratory (JPL)

Implementation Method:

For each major telecommunication function (channel) such as carrier tracking, command demodulation, two-way ranging, differential one-way ranging, and downlink telemetry, generate a model which includes each of the major sources of performance-limiting characteristics. This simulation of major hardware limitations should accurately represent their effect on RF performance. These effects may include band-limiting, non-linearities, non-zero rise and fall times, and SNR degradations. Quantify the potential impact of these limitations on ability to meet mission uplink and downlink requirements.

For example, the downlink telemetry function was analyzed for the Cassini radio frequency subsystem (RFS). The analysis was performed in eight steps, including development of:

1. Distortion definitions for trapezoidal telemetry data waveforms.

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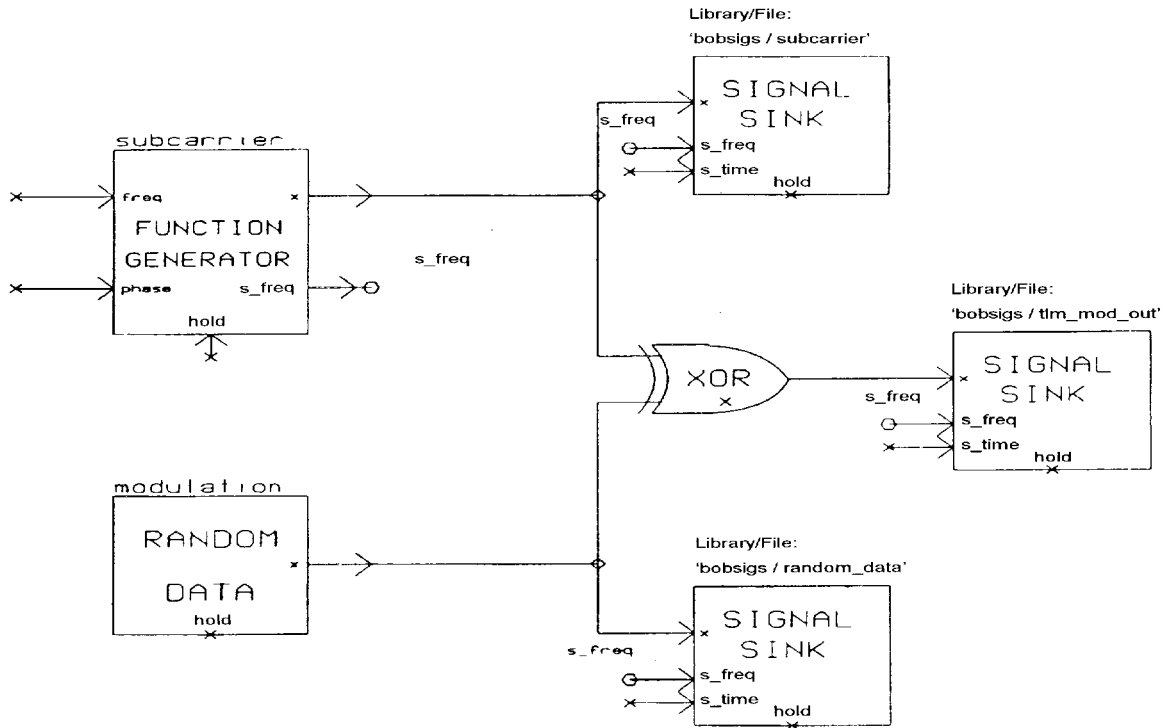


Figure 1. Block diagram of the TCU subcarrier modulator

2. Block diagram for simulating an ideal telemetry control unit (TCU) telemetry subcarrier modulator, as shown in Figure 1.
3. Block diagram for converting ideal random data waveforms into trapezoidal random data waveforms.
4. Block diagram for simulating an ideal linear phase modulator.
5. Block diagram for simulating a non-ideal linear carrier phase modulator.
6. Block diagram of a phase demodulator.
7. Signal to distortion ratio (SDR) estimator block.
8. Complete telemetry channel model.

Strong signals were analyzed; no noise of any type was included. The specific products of this Cassini RFS analysis were:

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1. Development of a model of the telemetry channel which includes the nonzero rise and fall times of the telemetry waveforms, the non-linearities in the X-band downlink carrier phase modulator, and the non-linearities in the ground receiver demodulation process.
2. Characterization of the distortion introduced in the telemetry signal by the nonzero rise and fall times.
3. Characterization of the distortion of the demodulated actual telemetry waveform at the ground receiver output due to the combined effect of the nonzero transition times and the non-linearities in the carrier phase modulator and phase modulator.

The modeled parameters were tabulated to verify compliance with Cassini downlink mission requirements.

Technical Rationale:

Early in the design phase, when the radio architecture and design concept are selected, it is necessary to understand assembly-level hardware limitations and their effect on radio performance. Given the subsystem complexity, it is often difficult to pinpoint the exact cause of unexpected test results once the subsystem has been integrated.

Impact of Non-Practice:

The performance of the delivered product may be compromised if the hardware imposed limitations are not evaluated early in the design phase. Once the hardware is delivered, it is too late to select an alternative radio architecture, and there are few opportunities to mitigate the impact of any constraints on radio performance. Lacking insight into RF hardware characteristics, test engineers may waste valuable engineering hours determining the basis for the variance between expected and observed performance. For flight projects, costly problem/failure reports and project waivers will likely be processed due to the lack of an early understanding of hardware limitations.

Related Practices:

1. *Spurious Radiated Interference Awareness*, Practice No. PD-AP-1310

References:

1. "RFS Downlink Telemetry Analysis Report," Robert Mueller (Jet Propulsion Laboratory) IOM 3367-93-392 of 8/24/93, Cassini Project.