Wideband HF Channel Simulator Considerations

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Presentation Overview

- Motivation
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- Wideband Considerations

Motivation

- Wider bandwidth HF communications waveforms (up to 24 kHz) are being investigated in the U.S. MIL-STD and NATO STANAG communities
- Wider bandwidth waveforms have the potential to provide higher capacity and improved performance
- A valid wideband HF Channel simulator design is needed to provide a capability for performance measurement and comparison of wider-bandwidth waveform designs

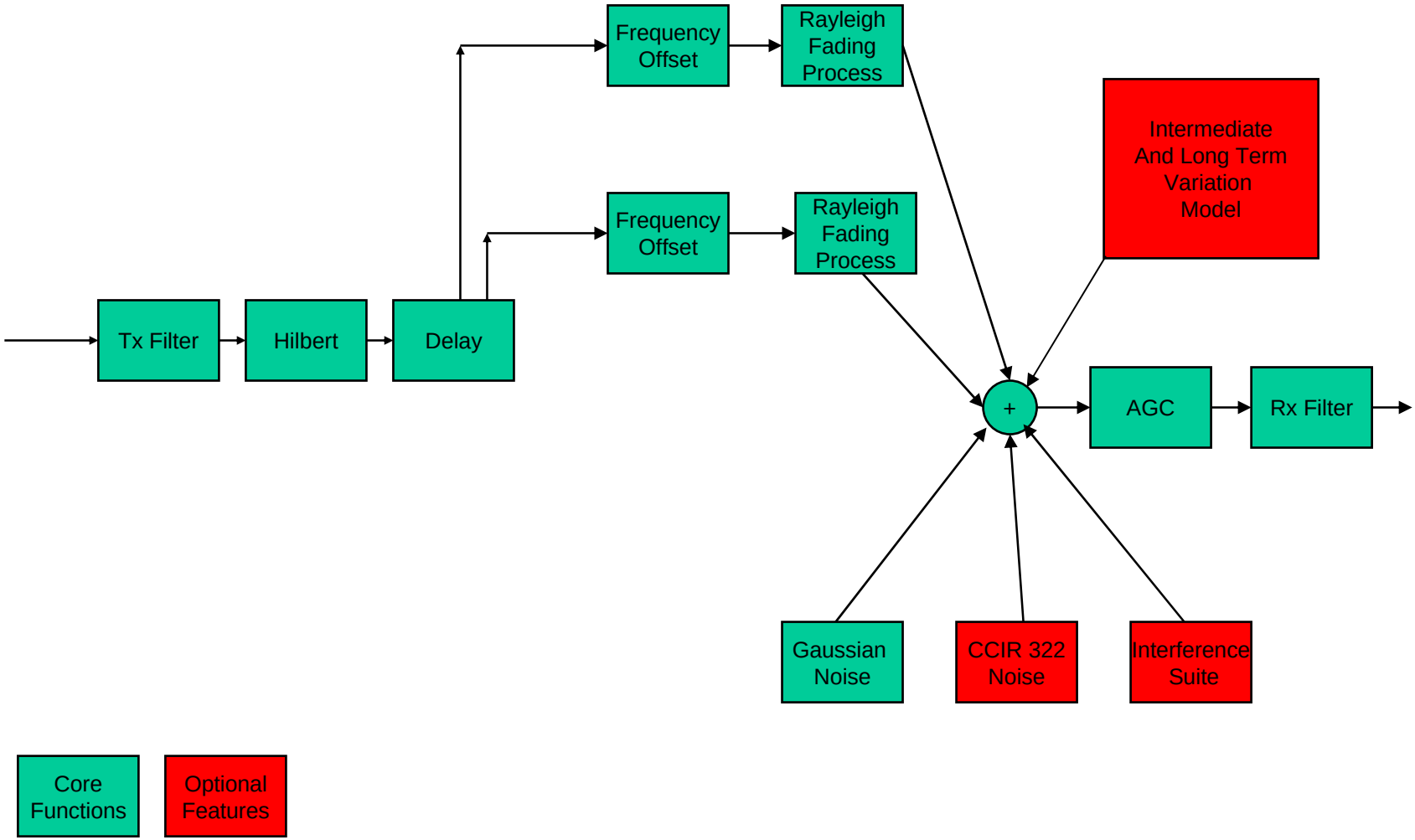
Assumptions

- Support waveform bandwidths up to 24 kHz
  - Candidate sample rate 96ks/s
- Maintain Watterson tapped delay line, Rayleigh fading channel model
  - Watterson claimed model validity at approximately 10 kHz. Assume model holds to 24kHz
  - Even if this does not precisely match real-world propagation characteristics, it will probably still provide a useful tool for evaluating HF waveforms, modems, and systems
  - Obviously will not model partial propagation bandwidths such as MUF transitions – nor does 3kHz model

Basic Channel Simulator Model

- Watterson model
  - Channel model based on tapped delay line
  - Complex fading taps based on a Gaussian filtered sequence of complex Gaussian white noise (Rayleigh-distributed amplitude)
  - Fading taps updated at rate of approximately 30x specified Doppler spread
- Frequency offset
- Additive White Gaussian Noise, CCIR 322 Impulse Noise
- Rich interference model includes tones, M-FSK, swept tones and CW-Morse
- Harris intermediate and long term variation channel model (ITV/LTV)

Basic Simulator Block Diagram



Wideband Considerations: Sample Rate, Radio Filters and AGC

- Sample rate
  - 96kS/s selected
  - Provides total simulator bandwidth of 48 kHz
  - Supports a range of subcarrier placements (recall 110B has a subcarrier of 1800Hz)
  - Implementation supports waveform ‘left justified’ (0Hz → symbolRate/2), or centered on a 19.2kHz subcarrier
- Radio Tx and Rx filters and AGC are disabled for wideband simulation
  - These vary significantly from one radio to another
  - May want to specify representative filters at some point (as in MIL-STD-188-110B and STANAG 4539)

Wideband Considerations: Hilbert Transform

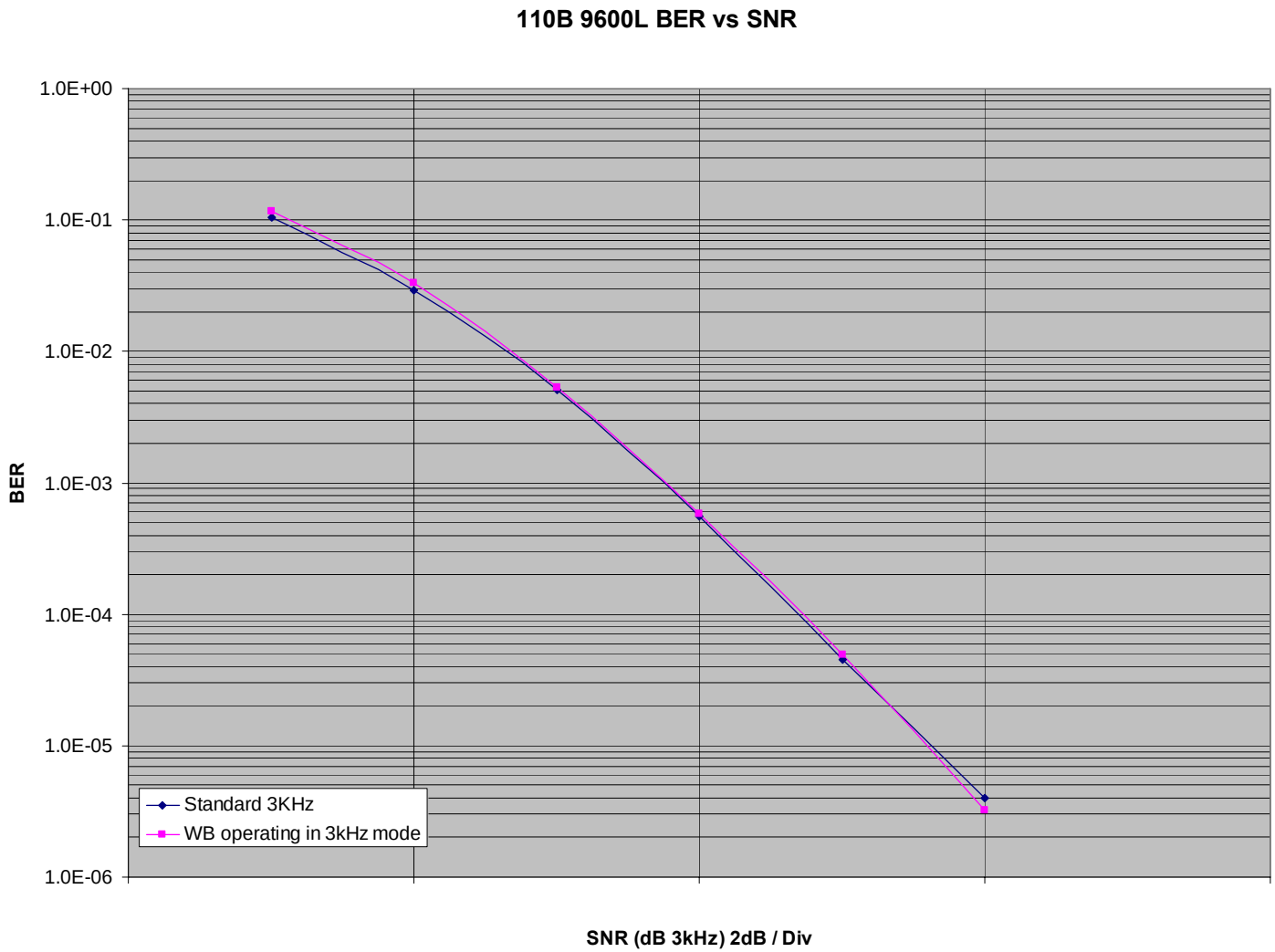
- Hilbert Transform used to generate the complex baseband signal
  - One common approach is to approximate with an FIR filter
    - Does not provide unity gain down to DC
    - As this filter is run at the higher sample rate, the low frequency 3dB point increases in frequency – presenting a problem for testing of standard 3 kHz waveforms
    - Could be solved by a large % increase in number of taps – increased computational workload
  - Instead, used an overlap FFT approach
    - Compute 2048 pt FFTs with overlap of 50% (starting every 1024th sample)
    - Zero negative frequency bins to accomplish Hilbert transform
    - IFFT to recover transformed time-domain sample stream
    - Use center (1024 samples) of each IFFT output to minimize edge effects

- Fading and ITV/LTV processes
  - Will be updated at same rate, more samples between updates because of higher sample rate
- Frequency offset and interference
  - Done on a per sample basis
  - New sample rate must be taken into account to ensure correct offset and interferer frequency
- Noise
  - Will be generated at higher sample rate, noise bandwidth is now fs/2 (48kHz), must be considered when specifying SNR to generate so that noise power is scaled appropriately

Wideband Considerations: Final Filter

- Rx Filter replaced by Final Filter
  - Noise will now be fs/2 (48kHz) in bandwidth
  - In order to band-limit channel simulator output, an overlap FFT approach is used to limit output bandwidth by zeroing out-of-band bins (analogous to Hilbert Transform approach)
  - Bandwidth (3,6,9,12,15,18,21,24 kHz) is specified
  - Subcarrier (None, 19.2kHz) is specified

Comparison of 3kHz / Wideband HF Channel Simulator



Summary

- Harris's wideband HF simulator has been used in the design and development of a Harris wideband waveform approach for HF
- Supports the testing of a family of adaptive bandwidth waveforms from 3kHz to 24kHz
- Modifications to the original 3 kHz simulator have been made to support wider bandwidths while minimizing computational impact. Model can be run real-time on PC and DSP based processors