# Wideband HF Channel Simulator Considerations and Validation Discussion

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# Presentation Overview

- Motivation
- Assumptions
- Basic Channel Simulator
- Harris Wideband Channel Simulator Considerations
- Validation Discussion

# 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 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

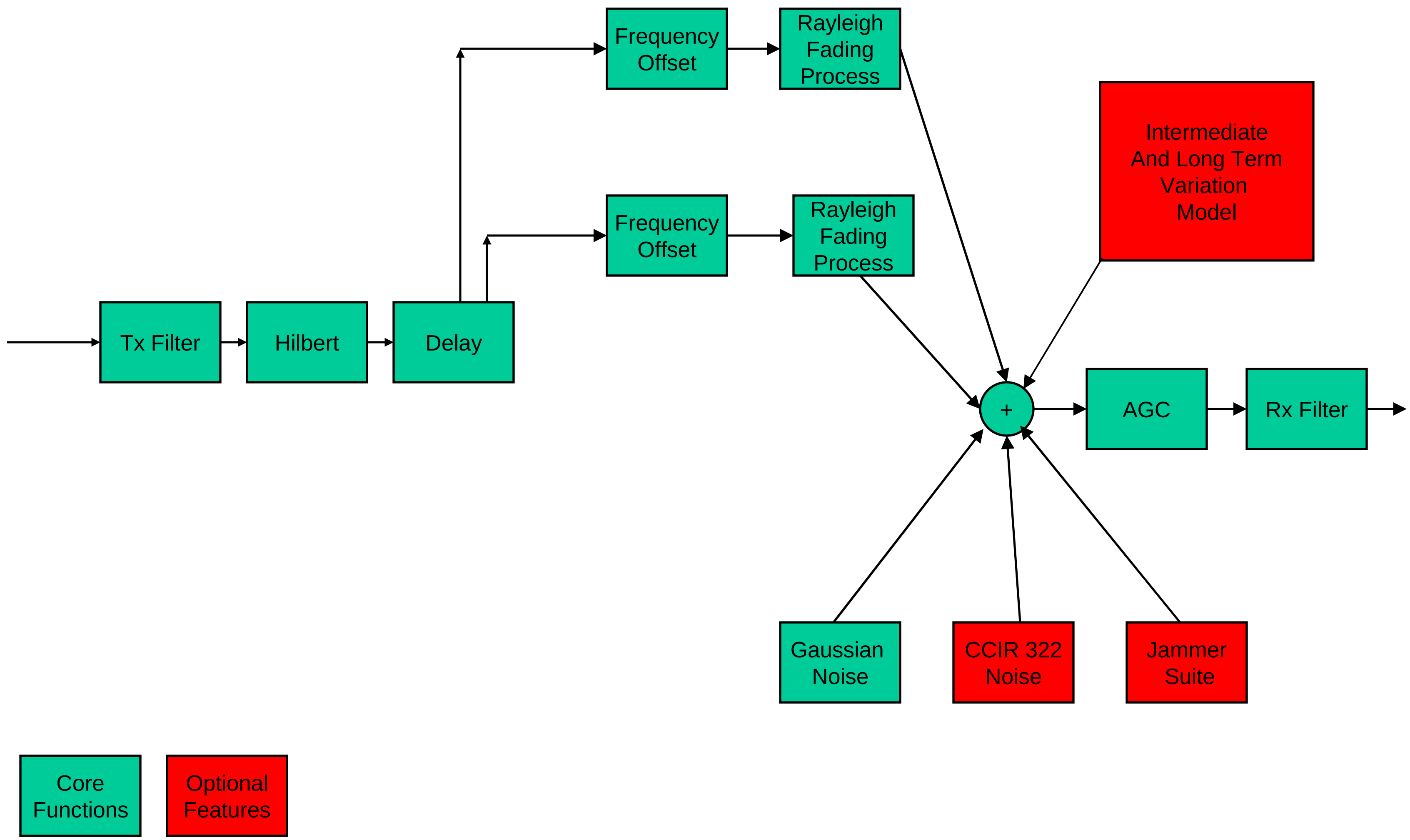
# Assumptions

- 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 10-12 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



# Harris Wideband Channel Simulator Considerations

- 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)
  - Supports waveform “left justified”, (0Hz -> symbolRate/2) or “centered” on a 19.2KHz subcarrier
- Radio TX and RX Filters and AGC 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)

# Harris Wideband Channel Simulator Considerations

- 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 1024thsample)
    - 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

# Harris Wideband Channel Simulator Considerations

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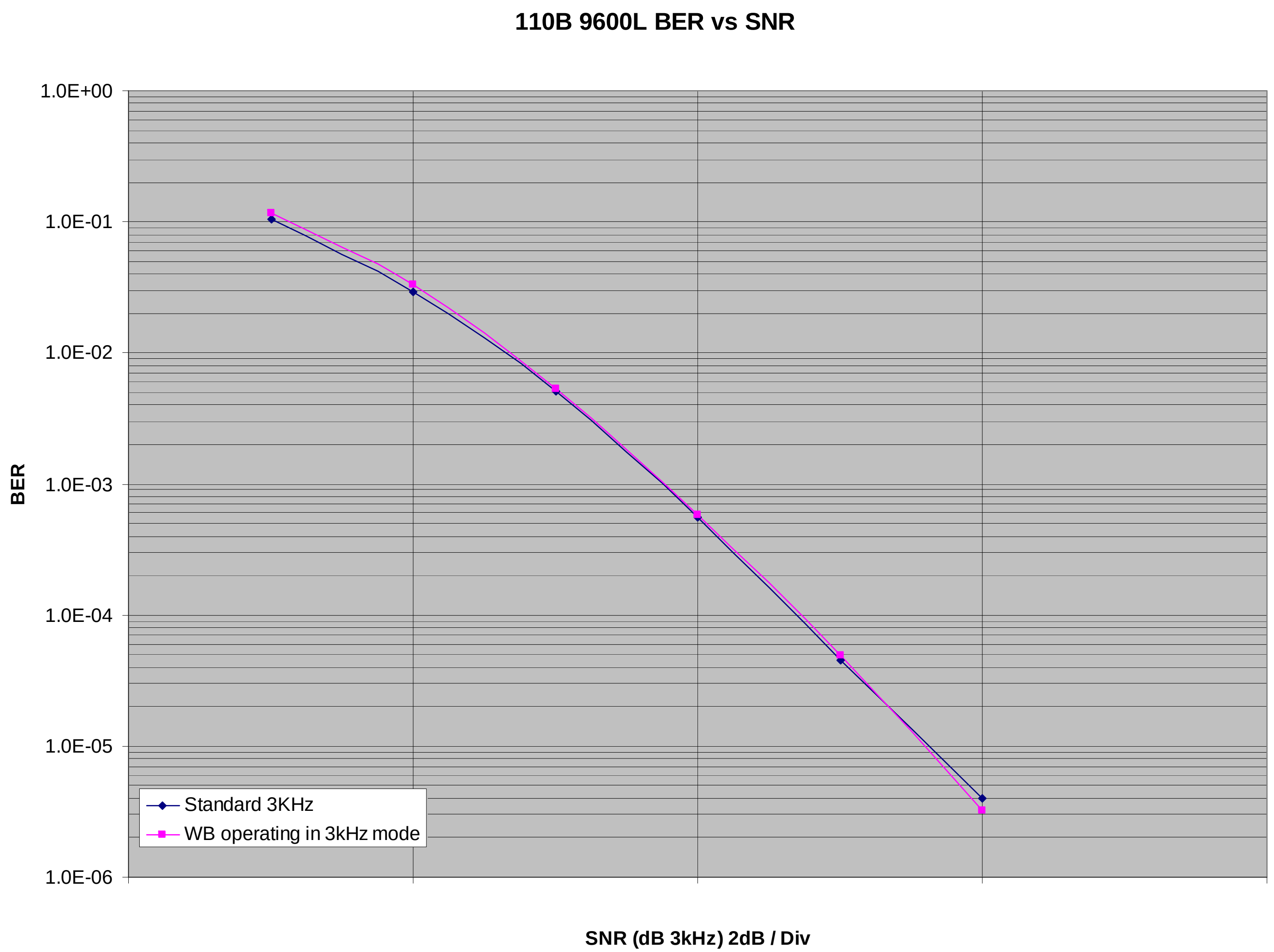
- Fading Process / ITV-LTV Process
  - Will be updated at same rate, more samples between updates because of higher sample rate
- Frequency Offset / Jammer generation
  - Done on a per sample basis
  - New sample rate needs to be taken into account to ensure correct offset and interferer frequency
- 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

# Harris Wideband Channel Simulator Considerations

- 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 utilized 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 Harris 3kHz / Wideband HF Channel Simulator



# *Validation Discussion*

- US MIL-STD 188-110C will have an appendix (H) that provides recommendations for an HF Channel simulator
- Simulator will need to support both the standard 3-kHz channel and wider bandwidth (up to 24 kHz) HF channels
- Wider Bandwidth introduces additional considerations which have been discussed in this presentation
- Do we need actual performance requirements in order to validate a channel simulator implementation?

# Validation Discussion

- All HF Channel simulator parameters can affect performance, which are the most significant?
  - Overall distortion
  - SNR
  - SNR under fading
  - Fading path spectrum

# Validation Discussion

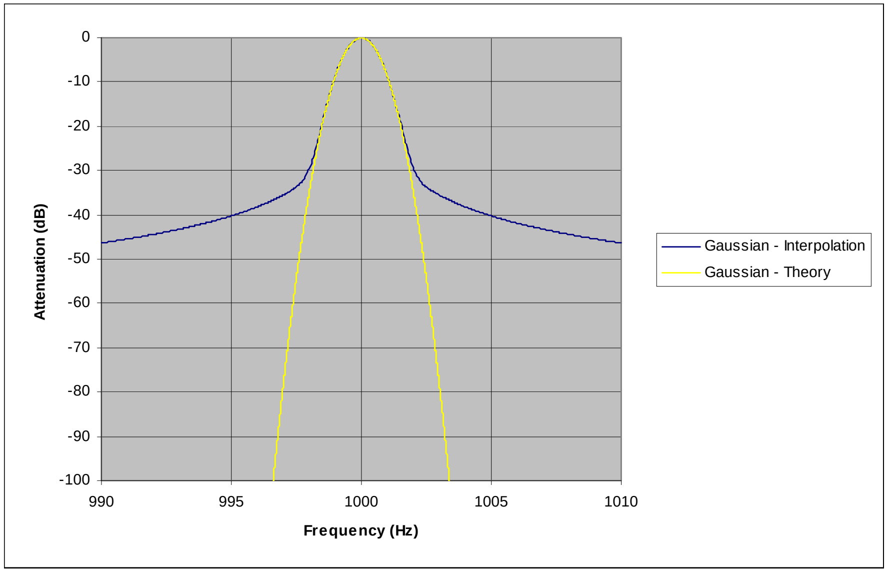
- Are there simple tests that can be used to validate the key parameters? Black Box testing paradigm.
  - Overall distortion – Measure frequency response / bandwidth.
    - Swept tone or white noise input.  Collect output samples for spectral analysis.
    - Proposed quality metric 3dB BW points, variation in dB in pass-band.

# *Validation Discussion*

- SNR: Input a sinusoid at 25% of bandwidth measure resulting signal to noise, repeat test at 50% and 75%.
  - Input tone measure output power (PA = Signal + Noise)
  - Remove tone, measure output Power (PB=Noise)
  - SNR == 10.0Log10( (PA-PB)/PB)
  - Proposed quality metric SNR error, less than 0.25 dB?
- SNR Fading: Repeat above test for single fading path and dual fading path
  - Observation time must be longer.
  - Proposed quality metric SNR error, less than 0.25 dB?

# Validation Discussion

- – Fading path spectrum – Single fading path at 1.0Hz, repeated at 0.1 and 5.0Hz
  - Tone input at center of pass-band
  - Output samples processed by windowed FFT, averaged, spectrum compared to Theoretical Gaussian
  - Proposed quality Metric, %error (Hz) at -30dB or -40dB



# Summary

- Harris's wideband HF simulator 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
- Proposal for channel simulator validation