On the Susceptibility of Coded OFDM to Interference: A Simulation Study

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***Abstract*—The susceptibility of broadband wireless communications signals (e.g., LTE, IEEE 802.11) to interference has been a topic of significant research. In this paper, we implement a simulation-based study on the impact that interference can have on the bit error rate (BER) performance of coded orthogonal frequency-division multiplexing (OFDM) transmissions. Our study covers two types of interference (a narrow-band tone signal and a pulse train signal), and two popular coding schemes (Turbo and LDPC). Simulation results show that Turbo and low-density parity check (LDPC) coding schemes provide large coding gains in the presence of white noise (without other interference), but are not effective against the narrow-band tone and pulse train interference. This observation calls for more robust coding and/or filtering design against interference for coded OFDM transmissions.**

I. Introduction

We know that error correction codes (ECC) are effective in protecting signal transmissions in noisy channels. Turbo code and Low Density Parity Check (LDPC) codes are powerful schemes that have been adopted for 4^{th} generation (4G) Long Term Evolution (LTE) systems [1] and new 5G radio systems [2], respectively. Both of these technologies make use of orthogonal frequency-division multiplexing (OFDM) and its variations. OFDM is a very efficient modulation scheme that can provide high spectral efficiency, low side lobes (i.e., adjacent-band emissions), and simplified receiver processing.

The ability to recover corrupt bits is the primary reason for the use of ECC. In some cases, bits may be corrupted by the characteristics of the propagation channel, and in other cases they may be corrupted by an interfering signal (either intentional or unintentional). ECC aids in recovering the original packets while adding some small amount of redundancy/overhead. However, despite the use of ECC, some corrupted packets may not be recoverable.

In the context of LTE applications there appears to be little open literature focused on this important topic. Traditional susceptibility measurements and discussions typically focus on the overall impact of one system on another, such as adjacent band interference, or spectrum sharing systems which may use overlapped, broad spectrum bands.

In this paper, we consider two types of interference that are narrow in either frequency or time domains, namely, a narrow-band tone signal and a pulse train signal. An interferer is introduced into the same frequency channel as the intended coded OFDM signal and the impact is measured by examining changes in bit error rate (BER).

This examination begins to answer two questions: how does the type of interfering signal (e.g., tone vs. pulse train) impact the receiver's ability to decode the signal? Is one type of ECC more robust against interfering signals than another?

II. Simulation Model and Method

We devise a model consisting of information that is coded using an ECC, and processed through quadrature phase shift keying (QPSK) modulation, and applied to OFDM subcarriers to form symbols. Then, the encoded signal is passed through an ideal channel and subjected to either white noise or an interfering signal.

We construct an OFDM signal to mimic a simplified downlink LTE signal, modeling only the modulation and coding parts of the data payload. We assume perfect synchronization and channel estimation at the receiver. The OFDM signal has a 10 MHz bandwidth with either Turbo [3] or LDPC [4] ECC. The parameters for OFDM modulation are given in Table I.

The interference signal types considered include a random single-tone continuous wave (CW) signal, and a random pulse train signal. The tone signal has a bandwidth that is equal to the OFDM subcarrier bandwidth, and its center frequency changes randomly either after an OFDM symbol duration (for the uncoded case) or after a code block length duration (for the coded cases). For simplicity, the pulse train signal uses a Gaussian pulse with frequency $0.1f_s$ and fractional bandwidth 0.5, where f_s is the sample rate of the OFDM signal. The pulse occurs once per OFDM symbol duration, but the pulse starting time varies for different OFDM symbols.

We simulate a rate-1/3 Turbo code and a rate-1/2 LDPC code. The Turbo-coded OFDM method encodes 396 infor-

TABLE I
OFDM Parameters Used for Simulation

Parameter	Value
FFT Length	1024
Number of data subcarriers	600
Number of guard subcarriers	424
Subcarrier bandwidth	15 kHz
CP Length	73 (samples)
Symbol duration	1/14 ms
Sample rate f_s	15.358 MSam/s

mation bits to 1,200 coded bits, which are converted to 600 QPSK symbols, and put on the 600 data subcarriers in an OFDM symbol. The LDPC-coded method has a block length of 32,400 information bits, which are then coded by LDPC, modulated by QPSK and carried by OFDM symbols.

When interference is considered, the power of white noise is set to zero. The interference power is averaged over each OFDM symbol duration. Thus, for single-tone or pulse train signals, the interference powers have significant peak values in either the frequency or time domain.

III. Simulation Results

We provide the BER results of uncoded, Turbo-coded, and LDPC-coded OFDM signals vs. signal-to-noise ratio (SNR) or signal-to-interference ratio (SIR), in Figs. 1-3. For uncoded transmission (Fig. 1), the SNR (SIR) is defined as bit SNR (SIR) per source bit. For coded transmission (Figs. 2 & 3), the SNR (SIR) is defined as the bit SNR (SIR) observed at each channel sample.

In the presence of white noise, Turbo code and LDPC code both provide good data protection in terms of BER, and when the $SNR = -1$ dB, have coding gains of more than 10 dB compared to the uncoded case. LDPC provides a BER result that drops more sharply than the Turbo code, and presents a lower error floor. However, the ECC schemes were not as effective when presented with interference. At a BER of 10^{-5}, the pulse train interference caused a loss of about 7.5 dB in coding gain for both Turbo code and LDPC schemes compared to the case of white noise. The loss in coding gain caused by the single tone interference is even larger. Yet, the tone interference may be mitigated by filtering or spreading the interference energy to many subcarriers instead of one. This may be achieved by use of linear pre-coding and single-carrier frequency division multiple access (SC-FDMA). This result may be provided in future work.

IV. Conclusion

We have implemented a simulation to examine the impact of interference on some example Turbo- and LDPC-coded OFDM transmissions. Simulation results show that Turbo and LDPC coding schemes are effective in reducing the BER for white noise type interference, and Turbo code may be more effective than LDPC for pulsed interference types. However, neither type is substantially effective in mitigating the detrimental effects of narrow tone or pulsed type interference. This observation requires more analysis of the signal's susceptibility, and calls for the design of more robust signals that are less susceptible to a variety of interference types. Future work will include a study of methods to suppress the effect of non-white-noise interference on coded-OFDM and LTE signal detection. Experiments with radiated signals can also be implemented to verify the computer simulation results shown here.

References

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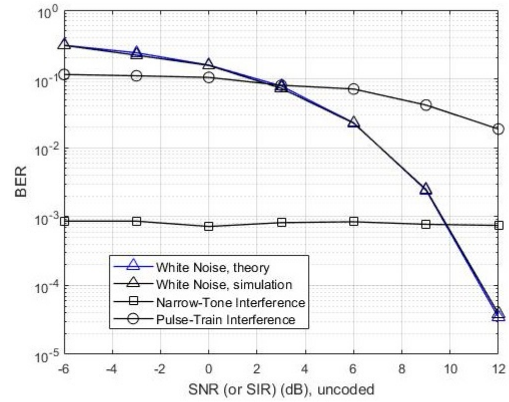

Fig. 1. BER of uncoded OFDM, affected by white noise or interference.

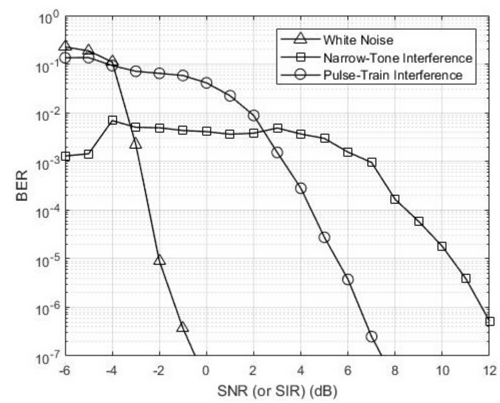

Fig. 2. BER of Turbo-coded OFDM, affected by white noise or interference.

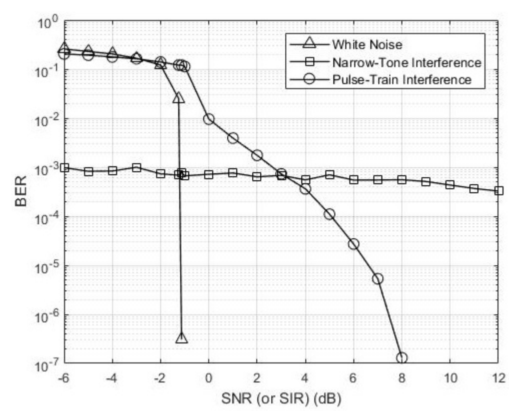

Fig. 3. BER of LDPC-coded OFDM, affected by white noise or interference.