BER and FER Analysis of DVB-S2 Waveform Under Partial-Band Noise Jamming

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Abstract

The Digital Video Broadcasting - Satellite - Second Generation (DVB-S2) is a video broadcasting standard that was developed out of the need for better performing satellite communication systems. Its use in satellite communication systems range from High-Definition Television (HDTV) broadcast services to satellite news gathering in both commercial and military applications. The growth of DVB-S2 systems has led to the prospect of adversarial jamming attacks on these communication systems. The purpose of this paper is to analyze the effect of the bit error rate (BER) and frame error rate (FER) of DVB-S2 waveforms under partial-band noise jamming (PBNJ) attacks. This paper will also distinguish which component of the waveform is most vulnerable to jamming attacks. The system will be simulated in MATLAB to investigate the results.

I. Introduction

In this paper, simulation will be done using MATLAB's Satellite Communications Toolbox add citation and trademark, which comes equipped with an end-to-end DVB-S2 simulator.

II. System Description

A. Channel Model

We consider a frequency hopped system with total bandwidth W, that is assumed to be jammed by a partial band noise jammer (PBNJ) with a total power of JW in a fraction of the bandwidth ρW where $0 < \rho < 1$. This makes it such that the PBNJ has a power spectral density of J/ρ within the partial band that is jammed. Also, the center frequency of each hop is chosen randomly across the entire bandwidth. The bandwidth of each hop is assumed to be small as compared to the bandwidth of the PBNJ, hence, a hop is either jammed entirely or not at all. This, in turn, means that the probability that a hop is jammed is ρ.

Under this model, the SNR of any given hop can be modeled as

$$\text{SNR}_h = \begin{cases} \text{SNR}_h^N = \frac{E_s}{N_0} & \text{w/ prob. } 1-\rho \\ \text{SNR}_h^J = \frac{E_s}{N_0+J/\rho} & \text{w/ prob. } \rho \end{cases} \tag{1}$$

where E_s/N_0 is the average energy per symbol to noise ratio, and can be converted to the average energy per bit to noise ratio E_b/N_0 using the standard conversion, $E_s = R \cdot E_b$, where R is the spectral efficiency in bits/symbol.

Furthermore, the assumption is made that there is one symbol transmitted per hop. This can be modeled on a per symbol basis as:

$$y_i = x_i + n_i + \alpha j_i \tag{2}$$

Where y_i is the ith received symbol, x_i is the ith transmitted symbol, n_i is a white noise process with power $N_0 W$, j_i is the jammer white noise process with power $\frac{J}{\rho}W$, and α is a bernoulli random variable with probability ρ.

B. Signal Choice

In the DVB-S2 standard there are 11 code rates (1/4, 1/3, 2/5, 1/2, 3/5, 2/3, 3/4, 4/5, 5/6, 8/9, 9/10) and 4 modulation schemes (QPSK, 8PSK, 16APSK, 32APSK) [1]. In this paper, the modulation code rate (MODCOD) that will be used is QPSK 1/4. This MODCOD has the lowest spectral efficiency (~ 0.5 bits/symbol) at the benefit that it provides the most amount of redundancy. This allows it to be the most resilient to any noise, along with any jamming interference that may be present. Hence, any performance hindrance to a DVB-S2 signal using MODCOD QPSK 1/4 will be magnified using any other MODCOD.

III. Analysis

IV. Experiments

A. BER simulation under PBNJ

Given the BER curve for a specified MODCOD and JNR, a theoretical BER curve under PBNJ can be derived by noting that the jamming of each symbol occurs independently. The

TABLE I: BER Simulation Parameters

Parameter	Value
Number of Frames	10
ρ	0.2
JNR (dB)	-40

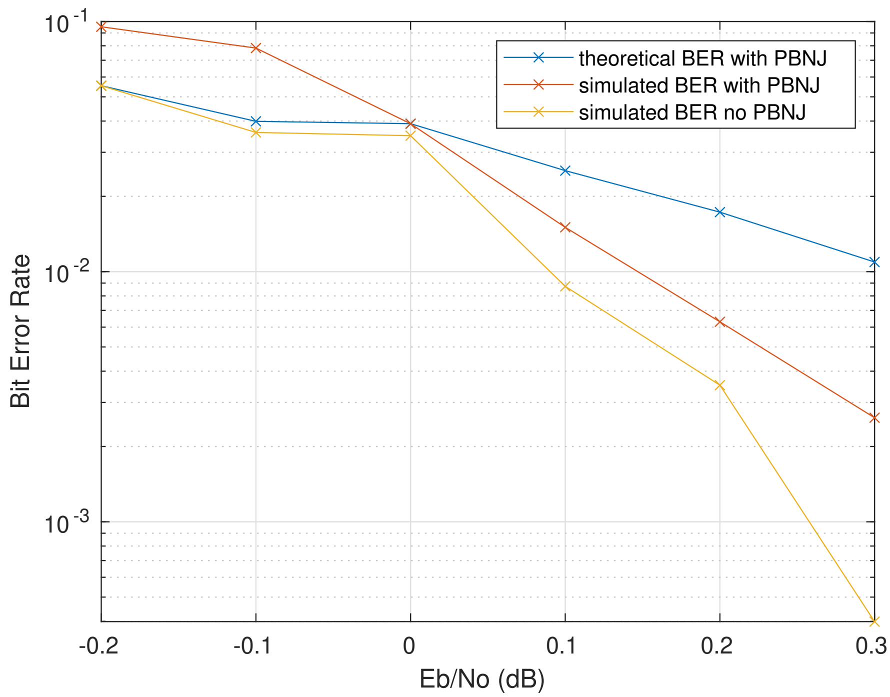

Fig. 1: BER Curves of QPSK 1/4 Signal

total probability of bit error P_b^T becomes

$$P_b^T = \rho P_b^J + (1-\rho)P_b^N \tag{3}$$

$$= \rho P_b^N(SNR_h^J) + (1-\rho)P_b^N(SNR_h^N) \tag{4}$$

where P_b^J is the probability of bit error under PBNJ, and P_b^N is the probability of bit error under noise alone.

The efficacy of this approximation can be simulated by first computing the BER curve of the signal without any jammer present, then extrapolating the curve to determine the probability of bit error at different levels of E_b/N_0 to generate the BER curve with the jammer present. The simulation parameters are shown in Table I.

TABLE II: average FER Simulation Parameters

Parameter	**Value**
Number of Frames	10
Number of Trials	15
JNR (dB)	5

The curve generated compares the simulated BER curve under PBNJ to the theoretical BER based on a no-jammer BER curve as shown in Fig. 1. The effect of PBNJ in the channel causes the BER curve to flatten. This result is consistent with the theory, as the lower the E_b/N_0 becomes, the flatter the BER curve is.

Two notable phenomena occurred when attempting to generate the BER curve under PBNJ that. The first was that the curve generated differed from trial to trial. This shows that the location of the jammed symbols did indeed have an effect on the BER that was not represented in the theoretical model. The second was that at low E_b/N_0, none of the frames were decoded and a BER value could not be obtained.

This second phenomena, the loss of frames, will be explored in the second experiment.

B. Average FER under PBNJ

To mitigate the effect of jammed symbol location on the FER curves, an empirical average was taken to see the average FER plotted against various fractions jammed. The simulation parameters for this experiment are shown in Table II. The FER curves are generated using 3 distinct values of E_b/N_0 and are shown in Fig. 2.

These curves showcase, as expected, the improvement of average FER as E_b/N_0 increases. Also showcased in this experiment is the relative stability of the average FER about a single value for each E_b/N_0 (excluding ρ = 0). This stability indicates that any amount of PBNJ present will produce the same effect on the ability of the receiver to decode frames.

C. Average FER under PBNJ of Header and Body

In this experiment, PBNJ will only be applied to both components of the transmit signal waveform. The first part of the waveform is the PLHEADER, which contains only a start of

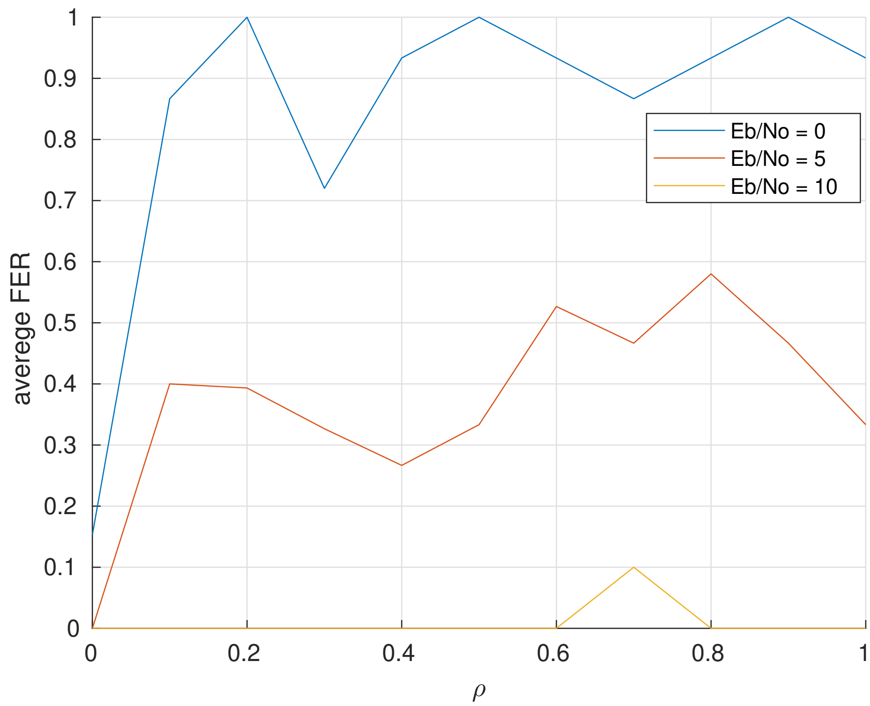

Fig. 2: Average FER Curves of QPSK 1/4 Signal

TABLE III: average FER on Waveform Components Parameters

Parameter	Value
Number of Frames	10
Number of Trials	15
JNR (dB)	5
E_b/N_0 (dB)	0

frame (SOF) sequence and a PLS (physical layer signalling) code that indicates the signal's MODCOD and FECFRAME length [1]. The second part contains the XFECFRAME, which is the encoded data that passes through a number of scrambling steps and a pilot insertion step [1].

The simulation parameters used in this experiment are shown in Table III. As seen in Fig. 3, the difference between jamming the entire signal or jamming just the information component is small. Although the PLHEADER jammer performs worse than the other 2 jamming techniques, it requires less power to implement. It should also be noted that the stability behavior is also seen when solely jamming each component of the signal.

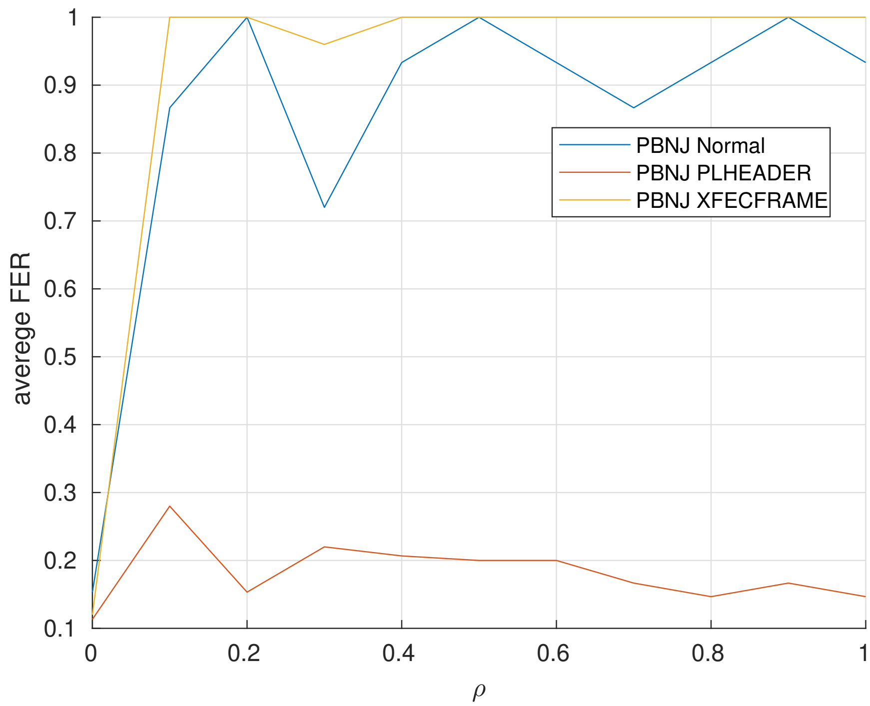

Fig. 3: Average FER Curves on Signal Components of QPSK 1/4 Signal

Thus, assuming that the JNR is fixed when choosing to target each signal component individually, the signal data component (XFECFRAME) is the most vulnerable to a PBNJ attack.

V. Conclusion

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