SIMULATION OF IMPULSIVE NOISE ENVIRONMENT FOR ORTHOGONAL FREQUENCY DIVISION MULTIPLEXING WIRELESS SYSTEMS

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ABSTRACT
This paper presents an alternate method to generate impulsive noise environment in the simulation of orthogonal-frequency-division-multiplexing (OFDM) wireless systems. The incorporation of discrete Fourier transform operator in the OFDM receiver/demodulator randomizes the impulsive noise components due to the spreading of energy at different sub-carriers, and therefore the characteristics of impulse noise transforms to approximately Gaussian distribution. In latest wireless mobile multimedia technology based on the space-time block-coded orthogonal-frequency-division-multiplexing (STBC-OFDM) or on the space-frequency block-coded orthogonal-frequency-division-multiplexing (SFBC-OFDM) systems, the Alamouti's STBC demodulation scheme further randomizes the impulsive noise components at the input of final decision device at the receiver end, which enhances its Gaussian character. Therefore, the presented work emphasis on the fact that while simulating the OFDM systems in impulsive noise environment, we may generate the impulsive noise components by merely incorporating equivalent Gaussian noise with zero-mean and corresponding variance. Hence, the overall effect of the impulsive noise on the performance of high data transmission rate STBC-OFDM or SFBC-OFDM wireless systems is approximately Gaussian in nature, which facilitates the simulation procedure.
Keywords:- STBC-OFDM, SFBC-OFDM, impulsive noise, Gaussian noise, Alamouti's scheme.

I. INTRODUCTION

Space-time block-coded orthogonal-frequency-division-multiplexing (STBC-OFDM) and space-frequency block-coded orthogonal-frequency-division-multiplexing (SFBC-OFDM) schemes have boosted the data transmission rates in the latest mobile wireless communication systems [6], [7]. The merger of STBC [1], [2] and SFBC technologies with OFDM technology undoubtedly exploited the spatial-diversity, time-diversity and frequency-diversity to increase the overall diversity gain to improve the overall capacity of the underlying advanced communication systems. But, the situation becomes miserable in the presence of impulsive noise. To mitigate the adverse effects of impulsive noise, the statistical characteristics of the impulse noise must be known. This type of noise is generated due to the application of electrical devices, mechanical devices and natural sources. Therefore, it is important to understand the nature of impulse noise at the wireless receiver for the final decision in the information symbol detection.

The only significant factor required to be known at the receiver is the impulsive noise energy per OFDM symbol duration. Therefore, the long OFDM symbols combat impulsive noise better than the short OFDM symbols. For both STBC- and SFBC – OFDM systems, the receiver encompasses the discrete Fourier transform (DFT) operator [5]. In the present work, we will investigate the impulse noise as well as the additive white Gaussian noise (AWGN) samples at the output of DFT operator for both systems, and subsequently at the input of final decision device at the receiver.

II. SIMULATION MODEL AND RESULTS

At the output of DFT operator in any type of OFDM systems [5], the impulse noise component is

$$I_l[k] = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} i_l(n) \exp\left(-\frac{j2\pi kn}{N}\right) \qquad (1)$$
$$for\ k = 0,1,2,\ \ldots,N-1$$

where, N is the number of sub-carriers. The above equation may be redefined as

$$I_l[k] = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} i_l(n,k) \qquad (2)$$
$$for\ k = 0,1,2,\ \ldots,N-1$$

The zero-mean AWGN components with variance $\sigma_{\eta g}^2$ is

$$G_l[k] = \frac{1}{\sqrt{N}} \sum_{n=0}^{N-1} g_l(n) \exp\left(-\frac{j2\pi kn}{N}\right) \qquad (3)$$
$$for\ k = 0,1,2,\ \ldots,N-1$$

The central limit theorem states that the probability distribution of I_l approaches the Gaussian distribution $\sqcup\left(0,\ \sigma_{\eta i}^2\right)$ in the limit [3] as $\left(1/N\right)$ approaches zero for a large number of sub-carriers. It can be shown that the variance of zero-mean Gaussian-plus-impulse noise is

$$\sigma_{\eta gi}^2 = \frac{1}{N} \sum_{n=0}^{N-1} \frac{1}{2} E\left\{ gi_l(n) gi_l(n)^* \right\} \qquad (4)$$

$$\sigma_{\eta gi}^2 = \frac{1}{N} \sum_{n=0}^{N-1} \sigma_{\eta g}^2 + \frac{1}{N} \sum_{n=0}^{N-1} \frac{1}{2} E\left\{ i_l(n) i_l(n)^* \right\} \qquad (5)$$

where, $(.)^*$ and $E(.)$ are the complex conjugate operator and expectation operator respectively. If N_i is the number of impulse noise occurrences within an OFDM symbol interval/period, then

$$\sigma_{\eta gi}^2 = \sigma_{\eta g}^2 + \left\{ \frac{N_i}{N} \right\} \sigma_{\eta i}^2 \qquad\qquad (6)$$

It is a well-known result that if the real and imaginary parts of a complex random process are independent wide-sense stationary Gaussian processes [3], then the magnitude and phase of this complex random process follow Rayleigh and uniform distribution respectively. Therefore, we will plot the magnitude and phase of the impulsive noise components at the output of DFT operator for its statistical characterisation.

We consider 16-QAM complex symbol constellation for STBC- and SFBC – OFDM systems. Both constant amplitude positive and negative impulses are introduced in the underlying wireless system in addition to the AWGN. Simulation results are obtained by taking the ensembled average of 250 independent experiments. The results presented in Fig. 1 depict that the magnitude distribution of impulsive samples (1) follows approximately similar pattern as followed by the Gaussian noise samples (3), which is approximately Rayleigh in statistical sense. However, the simulation results presented in Fig. 2 manifest that the phase/angle distribution of impulsive samples (1) follows similar pattern as followed by the Gaussian noise sample (3), which is approximately uniform in the statistical sense. When these are exposed to the Alamouti's STBC [1], [2] symbol detection scheme, the Gaussianness of the impulsive noise components increases due to the phase rotation. Therefore at the input of final decision, the impulse noise components follow approximately Gaussian distribution.
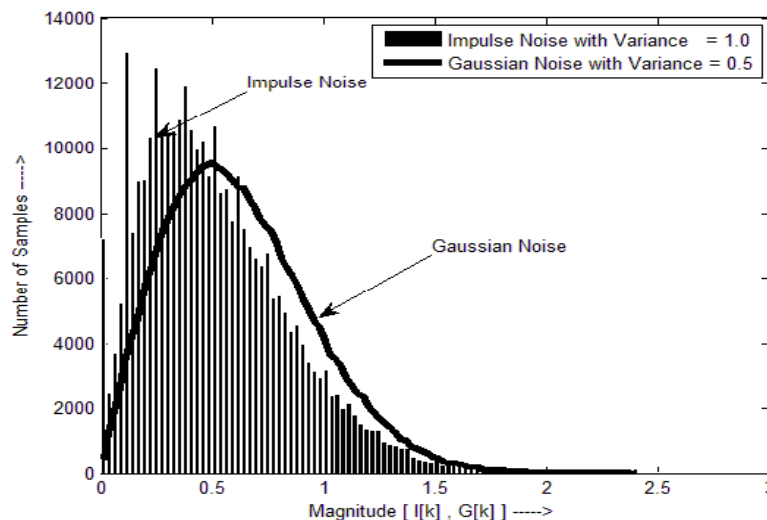

Fig. 1: Number of samples vs magnitude of samples for the determination of distribution function.
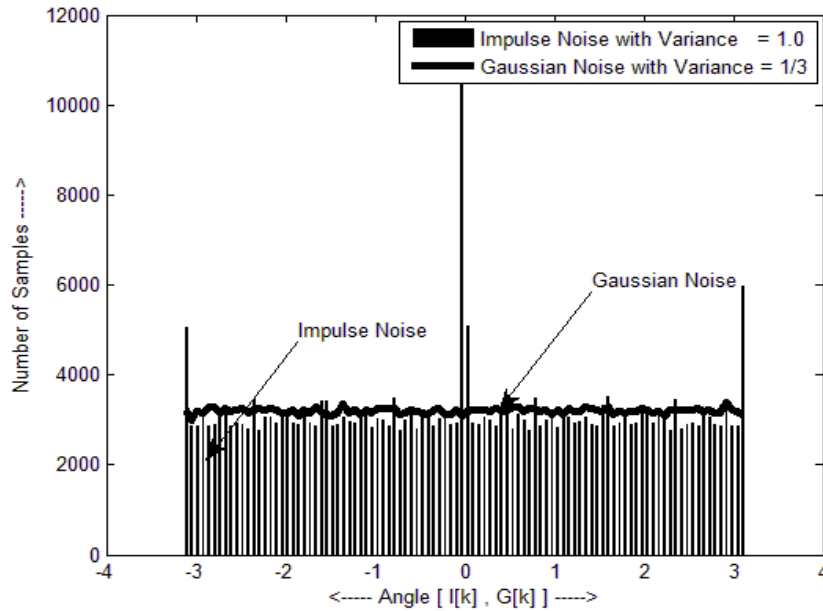
Fig. 2: Number of samples vs. phase of samples for the determination of distribution function.

III CONCLUDING REMARKS

In this paper, we have investigated the behaviour of impulsive noise at the STBC- and SFBC-OFDM receivers. The simulation results manifest that the characteristics of zero-mean AWGN with typical variance is quite similar to the zero-mean impulse noise when they are processed at the OFDM receiver due to the spreading effect of DFT operator i.e., approximately Gaussian. The DFT operator spreads the total impulse noise energy on different sub-carriers; therefore the impulse noise energy per carrier reduces. Hence the DFT operator randomizes the impulse noise components for the first time. Subsequently the Alamouti's symbol detection procedure randomizes the impulse noise components once again, which increases the Gaussianness of impulsive noise and reduces its adverse effects on the underlying OFDM systems. The exclusive benefit of the abovementioned analysis is that the impulsive noise environment can be generated while simulating any OFDM system in MATLAB by just adding the equivalent zero-mean Gaussian white noise at the appropriate stage of the receiver side. Moreover, the results obtained for the STBC- and SFBC – OFDM systems are in good agreement with the results presented in [4] for the noise bucket effect in conventional OFDM wireless systems.

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