ON MODULATION CLASSIFICATION USING FRACTAL DIMENSIONS

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Abstract

Fractals became a useful mathematical tool in various fields of pure and applied science, biomedical engineering, signal processing and finance. The use of fractal dimensions proved to be an important tool in the field of signal processing as it measures the complexity of the signal. Modulated signals can be characterized by fractal dimensions as it measures the regularity of the signal. This paper discusses the fractal dimension of randomly generated digitally modulated signals such as ASK, BPSK, QPSK, FSK and 16-QAM. The effects on fractal dimension due to moving window and signal to noise ratio are evaluated for each type of modulations. Box dimension algorithm is used to calculate the fractal dimension.

1. Introduction

1.1 Signal Generation

In telecommunications, modulation is the process of varying a periodic waveform. Modulated signals can be characterized by fractal dimensions as it measures the regularity of the signal. The modulated signals were generated using VisSim Comm, a communication signal Modeling and Simulation software. In the first step of the experiment samples of signals were generated using four blocks namely data source, modulator block , Additive White Gaussian Noise (AWGN) block and output block as represented in Figure 1.

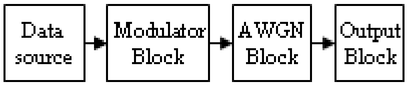

Figure 1: Blocks for signal generation

Data source: The data source usually consists of a random sequence generator that generates random symbols needed for the modulator block.

Modulator Block: This block accepts the random symbols from the data source and generates a modulated signa based on the selected modulation technique. In this experiment FSK, QPSK, BPSK, ASK and 16 QAM modulation techniques were used.

AWGN Block: This block implements an AWGN channel in which white Gaussian noise is added to the input signal. The appropriate noise variance is automatically computed based on the desired SNR. The experiment was performed using five different SNR (0, 1, 10, 30, and 100 dB) for each modulation technique.

Output Block: The output block usually consists of a window which displays the output of the AWGN block and any other signals like the data or carrier signals that are connected to it.

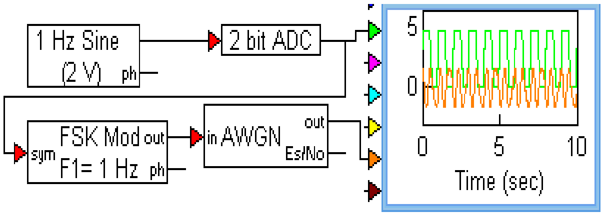

Figure 2: VisSim communication blocks for signal generation

Figure 2 displays an example of the blocks used in VisSim Comm for the generation of FSK modulated signals. The input data (green) and the modulated signal (orange) can be seen in output window of VisSim [3].

1.2 Windowing

In the second step of experiment the signal cuts were generated. A moving window was applied on the sample of modulated signals. The signals generated by each modulation technique were tested using five different window sizes. The windows were applied at 2 sec, 4sec, 6sec, 8sec and 10sec.

1.3 Fractal Calculation

In the third step, the fractal dimensions of the modulated signals were calculated using BENOIT 1.3 software. BENOIT is a computer program that measures fractal dimension of a given data using different algorithms such as ruler, box, information, perimeter-area and mass for analysis of self similar patterns.

In this experiment the box-dimension method was used due to its ease of implementation [4]. In the box-dimension analysis, the grid should be overlaid for each box size in such a way that a minimum number of boxes are occupied. This is accomplished in Benoit by rotating the grid for each box size through 90 degrees and plotting the minimum value of N as described in equation (1), where is the number of boxes of linear size ‘d’ required to cover a data set of points distributed in a two-dimensional plane and D_b is the fractal dimension.

$$N \approx \frac{1}{d^{D_b}} \qquad (1)$$

Benoit requires the data to be fed in the form of a bitmap file with a black background and the data points in white. The software converts any colored details other than black background into white [5]. Finally the mean, variance and standard deviation of fractal dimensions were calculated for all the 30 samples in each case using MATLAB coding.

2. Results And Discussion

Two different cases were considered for the analysis of the results. In the first case, complete windows of the modulated signals generated at different signal-to-noise ratios were taken into consideration and in the second case, the moving window was applied on the modulated signals generated at different SNRs. The range of fractal dimensions, mean, standard deviation and variance were determined from the data for further analysis of the synthetic signals.

2.1 Fractal Dimensions of noise and pure Sine wave

The fractal dimension of pure sine wave and white Gaussian noise were also calculated using box dimension algorithm to compare the results. The mean fractal dimension for a pure sine wave was 0.987122. The fractal dimensions for thirty different random white Gaussian noise (WGN) signals were also calculated. It was observed that the range of fractal dimension values was very small as shown by figure 3. The fractal dimension values lie between 1.5446 and 1.5963.

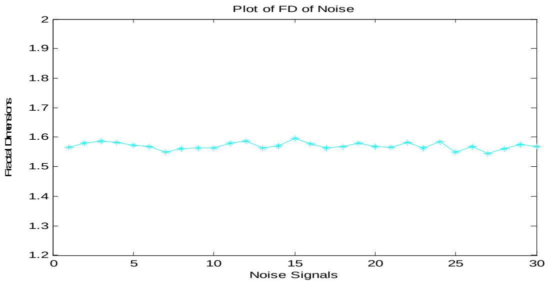

Figure 3: Fractal Dimensions of 30 random WGN signals

2.2 Complete window case

In the complete window case, the mean fractal dimensions of the modulated signals were plotted over the complete range of signal-to-noise ratios considered during the signal generation as shown in figure 4. From this plot it was observed that the modulation techniques can be differentiated based upon the fractal dimension values obtained at SNRs greater than 10dB. It can also be observed from the plot that the fractal dimension values saturate after 30dB.

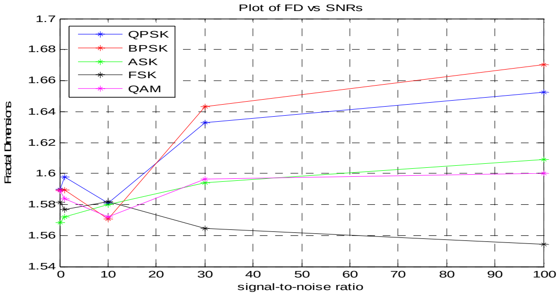

Figure 4: Mean fractal dimensions vs. signal-to-noise ratio (complete window)

The fractal dimension ranges were obtained by plotting the fractal dimensions of 30 different signal samples generated at five different SNRs in each modulation technique. Figure 5 shows the fractal dimension plot for 30 different BPSK signal samples generated at each of the SNR values of 0dB, 1dB, 10dB, 30dB and 100dB.

It can be observed that the maximum and minimum values of the fractal dimensions appear at a SNR of 100dB and the values for samples at lower SNRs lie in between these maximum and minimum values. This is due to the fact that as noise increases in the modulated signal the range of fractal dimension decreases as depicted by Figure 3. Similar results were obtained for all the considered modulated techniques. The maximum and minimum ranges obtained for each modulation technique are shown in Table 1.

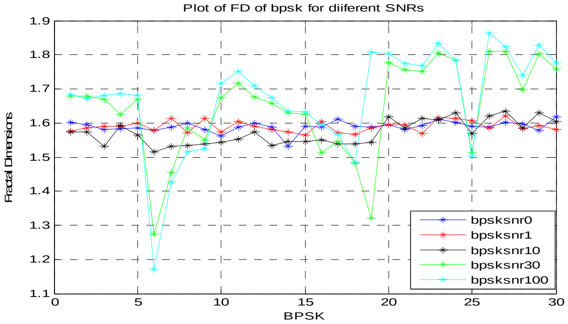

Figure 5: Ranges of fractal dimensions for BPSK modulation at five different values of SNR

Table 1: Fractal Dimension ranges obtained for all the considered modulation techniques

Modulation Type	Fractal Dimension Minimum	Fractal Dimension Maximum
FSK	1.150	1.759
QPSK	1.3175	1.8197
BPSK	1.1711	1.8639
ASK	1.1185	1.8202
16-QAM	1.2152	1.8058

2.3 Application of moving window

In this case, a moving window was applied on all the time varying modulated signals generated at different SNR values using the considered modulation techniques. The windowing was applied at 2sec, 4sec, 6sec, 8sec and 10sec and the fractal dimensions were calculated for each of the signal cuts. The mean, standard deviation and variances were also calculated separately.

It was observed from the results that as the window length increases the fractal dimension of the signal also increases and there after it gradually saturates. This is due to the fact that with the increase in frequency the signal occupies more space in the plane it belongs to. It was also observed that in all the considered modulation techniques a sample with a higher SNR value and a smaller time window had a mean fractal dimension nearly equal to that of a pure sine wave (1.1).

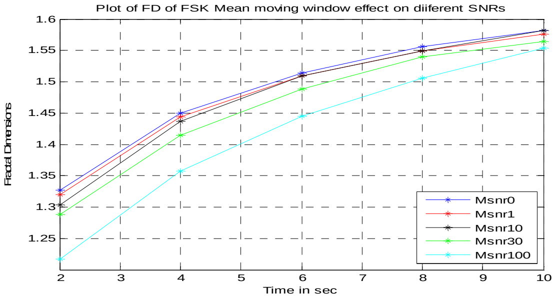

Figure 6: Mean fractal dimension values for FSK modulation at different SNR values (windowing applied)

It was also observed that for FSK modulation the mean of the fractal dimensions with higher signal-to-noise ratios was low as shown in figure 6. For QPSK, BPSK, ASK and 16-QAM the means of the fractal dimensions at higher signal-to-noise ratios were lower in case of smaller window, and were higher for windows greater than 6 seconds. Figure 7 shows the results obtained in the case of QPSK modulation. In order to obtain a precise result 30 signal samples of each modulation techniques at five different signal-to-noise ratios (0 dB, 1 dB, 10 dB, 30 dB and 100 dB) were experimented.

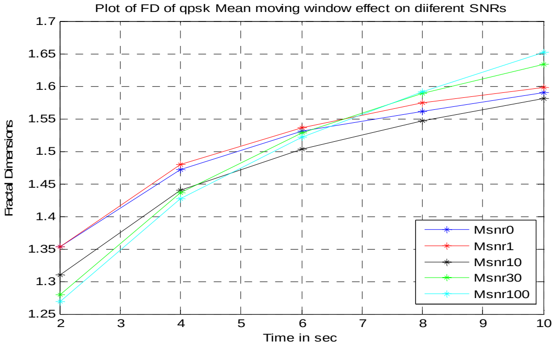

Figure 7: Mean fractal dimension values for QPSK modulation at different SNR values (windowing applied)

For FSK, PSK (QPSK and BPSK), ASK and 16-QAM modulation techniques, the variance and standard deviation of fractal dimensions showed consistent results i.e. for higher SNRs variance and standard deviation are higher. Figure 8 and figure 9 respectively show the comparison of moving window effect on the variance and standard deviation of fractal dimensions for the ASK modulated signals generated at different SNRs.

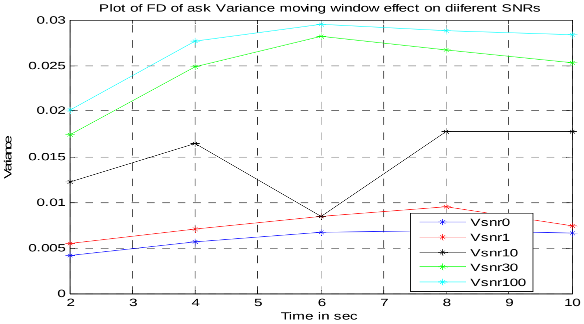

Figure 8: Effect of moving window on the variance of fractal dimensions of ASK signals at different SNRs

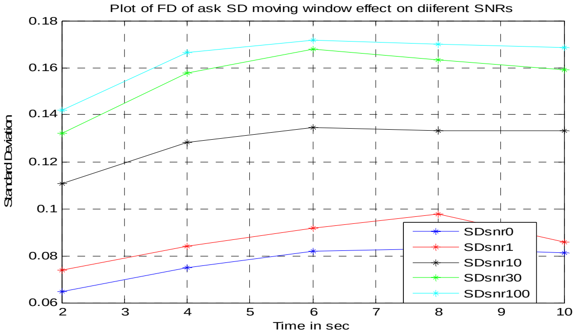

Figure 9: Effect of moving window on the standard deviation of fractal dimensions of ASK signals at different SNRs

3. Conclusion

This experiment calculated the fractal dimension ranges of different modulation techniques. The modulation techniques can be differentiated based upon the fractal dimension values obtained at SNRs greater than 10dB. It was observed that the fractal dimension increases as the window size increases and saturates after a period of time. The variance and standard deviation for the modulated signals are higher for the higher signal to noise ratio. It was also observed that when a moving window was applied on the FSK modulated signal samples low mean values of the fractal dimensions were obtained at higher signal-to-noise ratios. Whereas in the cases of QPSK, BPSK, ASK and 16-QAM modulation techniques, the means of the fractal dimensions at higher signal-to-noise ratios were lower in case of smaller window and for a window size greater than 6 seconds they were higher. Also the consideration of five different signal-to-noise ratios (0 dB, 1 dB, 10 dB, 30 dB and 100 dB) with thirty cases for each modulation technique resulted in more precise and accurate results.

References

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