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Compressive Sensing Detection method for Frequency Hopping Signals

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ABSTRACT: *In military and commercial applications FH (Frequency Hopping) signal plays important role. Since the Frequency hopping signals has the special properties like robustness to jamming and near-far resistance, we find the application of FH signals in every communication process. Even though the Frequency Hopping signals exhibits the near-far resistance problem, the signals are suffered from noise. In this paper we propose a novel approach named as compressive sensing technique to recover the FH signals, which are highly suffered from white Gaussian noise. This paper also provides the efficient sampling and also reconstruction technique which requires less number of samples for reconstruction.*

Keywords – *Compressive Sensing, Frequency Hopping Signal; Blind Detection; Numerical Characteristics; frequency.*

I. INTRODUCTION

In the process of communication frequency hopping signals plays very important role where as these signals has the adverse properties like high resistivity to adopt noise, lowest probability of detection and interception, high degree of robustness and agility to jamming [3, 4]. Since due to adverse properties of the FH signals, these signals have been presented in every application of communication process. The FH signals are also suffered from Gaussian noise components like common signal components. Therefore in modern wireless communications detection of FH signals is very important task. In this article we presents a systematic algorithm for detection of FH signals which heavily suffered from white Gaussian Noise.

II. RELATED WORK

There are several methods are available still to date for detecting the FH signals like using a wide band receiver or channel estimated receiver , cyclostationary processing and frequency-time distributions etc. all these methods involves extremely high complex measurements which includes complex Bessel's functions etc which is caused not suitable for FFH (Fast Frequency Hopping) signals and FH signals with wideband. And all the above specified methods are effectively works if there is a severe interference.

Therefore in this paper we propose a new approach for detecting the FH signals with the advantage of CS for the sparse or compressive signals [1-4]. Including the FH signal detection it provides a systematic method to develop a Compressive Sensing in Frequency Hopping Signal processing.

Remaining of this article is arranged as section III consists of the literature survey regarding to the back ground of Compressive sensing. Section IV clearly explains about the concept of Compressive Sensing based FH signal detection. Finally the analysis of results is present in section V.

III. BACKGROUND OF COMPRESSIVE SENSING

Compressive Sensing is a technique used to effectively reconstructing the signal in the case of undetermined linear systems. Compressive sensing is also termed as Compressive Sampling, Compressive Sampling and Compressive Processing. The greatest advantage with CS is that the entire system will be reconstructed by relatively measuring the few samples. In this specific type of sampling and reconstruction, it uses the sparseness or compressibility of signals. In CS the sample rate is much smaller than Nyquist sampling for effectively reconstruct the original signal through reconstruction algorithm.

In the process of CS, It consists of two parts such as performing the process by projecting the signal onto the randomly chosen vector and the signal reconstruction is performed by using reconstruction algorithm.

Assume a signal $x\left(x \in R^N\right)$ with K sparse such that (K<N). And the signal x is represented in terms ok K in some other transform domain ψ.

The process of compressive sensing:

$$y_i = <\varphi_i, x_i>, i = 1,2,\Lambda\ M, M < N \quad (1)$$

y_i : Output M samples after Compressive sensing.

φ_i : Observation vectors from 1 to M and these are in coherent with ψ.

Therefore the signal will be reconstructed using the projection of sparses of signal X. the solution of the sparses of the signal is defined by using the optimization norm l_0 as

$$\min\left\|\psi^T x\right\|_0 \text{s.t.} y = \varphi_x \tag{2}$$

Above equation 2 is a high degree polynomial function with non deterministic terms. And we can reconstruct the signal X with the help of norm as l_1 as

$$\min\left\|\psi^T x\right\|_1 \text{s.t.} y = \varphi_x \tag{3}$$

From the above equations 2 and 3, the compressive samples of the X preserve the structure of the original signal. Therefore the reconstruction is possible by just evaluating the information of compressive samples using detection algorithm.

IV. COMPRESSIVE SENSING BASED FH SIGNAL DETECTION

Blind detection algorithm of FH signal based on CS:

In this section we discuss about the detection of the frequency hopping signals based on the compressive sensing. Here the detection is processed by distinguishing the hypothesis values of compressive samples as:

$$\begin{aligned} H_0 &: y = \phi_n \\ H_1 &: y = \phi(s+n) \end{aligned} \tag{4}$$

S: sparse of the considered signal in domain ψ

n: AWGN.

ϕ : Compressive sensing processing.

Here the AWGN is considered as $N\left(0, \sigma^2 I_N\right)$

Therefore

$$\begin{aligned} H_0 &: y = \phi_n \sim N(0, \phi_\sigma^2 \phi^T) \\ H_1 &: y = \phi(s+n) \sim N(0, \phi_\sigma^2 \phi^T) \end{aligned} \tag{5}$$

Equation 5 can be re-written as

$$\begin{aligned} H_0 &: E(y_i) = 0, D(y_i) = \sigma^2 \phi_i \phi^T) \\ H_1 &: E(y_i) = \phi_i s, D(y_i) = \sigma^2 \phi_i \phi^T) \end{aligned} \tag{6}$$

Therefore the solution for detection problem is expected difference value between the H_0 and H_1. Therefore the detection process is proposed as

- After completion of Compressive sensing process choose any 'l' samples and find the expected values between the l samples under H_1 and then find the sum of their squares.

$$H_{1\Delta} = \sum_{i=1}^{l} (y_i - E(y_i)\big|_{H_1})^2 = \sum_{i=1}^{l} (y_i - \phi_i s)^2 \tag{7}$$

- Then similarly find the deviation between the same 'l' samples and then calculate the expected values between them under H_0 and sum of their squares.

$$H_{0\Delta} = \sum_{i=1}^{l} (y_i - E(y_i)\big|_{H_0})^2 = \sum_{i=1}^{l} (y_i - \phi_i s)^2 \tag{8}$$

- If $H_{1\Delta} < H_{0\Delta}$ then choose H_1 otherwise H_0

Therefore this algorithm consists of numerical differences between the some samples of the sampling values. Therefore the compressive sensing process can reconstruct the FH signals with small number of measurements of some sampling values instead of using all samples.

BOMP based frequency Estimation Algorithm:

1. Input: inputs of the BOMP frequency estimation algorithm are sample measurements 'y', stopping iteration index 'L' and measurement matrix ϕ
2. Initialize: the process is initialized by adjusting the residual error $r_0 = y$, signal $x_0 = 0$. And keep the L=1 and $\Lambda^0 = \phi$

$$\begin{aligned} &a) h^l = \phi^T r^l \\ &b) \Lambda^{l+1} = \Lambda^l \cup \left\{\arg\max\left\|h^l[j]_2\right\|\right\} \\ &c) x^{l+1} = \arg\min\left\|y - \phi_Z\right\|_2 \end{aligned}$$

3. If l<L move step 'a;'; otherwise move step 4.
4. By projecting the maximum number of sparse coefficients into support set location as per step 2 the hopping frequencies are estimates.

$$\hat{f}^{\,1} = \arg\max(\left\|h^l[j]_2\right\|)$$

V. SIMULATION RESULTS AND ANALYSIS

This section consist the analysis of results of proposed algorithm. For simulation purpose we considered a FH signal with AWGN. The considered signal is hopped at an interval of 1ms.

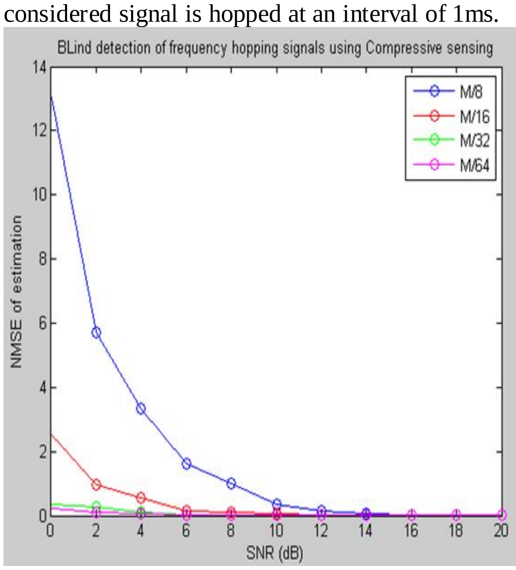

Figure1: The comparison of NMSE of with SNR

Figure 1 represents the effective and efficient comparison for our proposed CS algorithm with different hopping. The Normalized Mean Square Error value of any signal is exponentially decreases as SNR increases. For large hopping signals the NMSE value is greatly decreased as compared to low hopped signals. In figure 1 the signals with M/64 has the lowest NMSE value which represents the best detection.

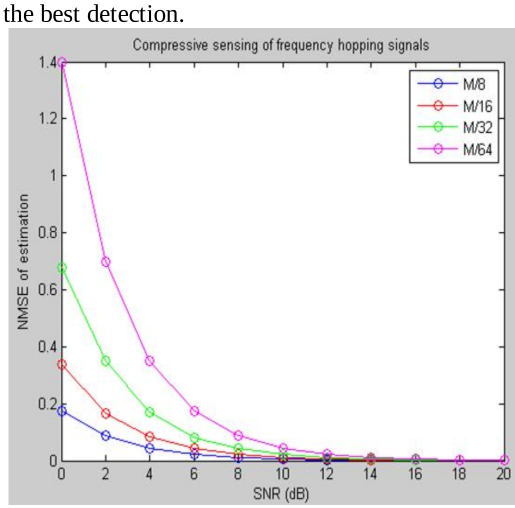

Figure 2: Compressive sensing frequency hopping

Figure 2 represents the compressive sensing frequency hopping of the signals. As discussed in above section, the simulation results shows that the NMSE of the same signal will experiences different values with respect to different hopping as shown in above figure, as already discussed the highest hopping signals experiences the poorer NMSE values which represents the our proposed method is effectively suitable for detection of FH signals.

CONCLUSION

Our proposed method is very efficient and effective one for detection of FH signals by using Compressive Sampling. Here some of the samples are enough to reconstruct the signal as discussed in previous sections which is the greatest advantage our proposed method. This method is also greatly helpful in for detection of wide band signals in non cooperative communications also.

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