project Report

FMCW IM

February 3, 2024

Contents

1 Introduction

Index modulation, a novel technique in wireless communication, plays a crucial role in enhancing spectral efficiency and reliability. It involves using different indices within a communication system to convey information, thereby increasing the data rate and improving system resilience. This method is gaining traction due to its ability to optimize resource utilization and mitigate interference.
Index modulation is important as it significantly enhances spectral efficiency in wireless communication systems. By utilizing different indices to convey information, index modulation enables higher data rates and improved system robustness, making it a valuable technique in modern communication protocols.
The synergy of index modulation and radar communication presents opportunities for optimized wireless systems with improved spectral efficiency, data rates, and overall performance, making them vital areas of research and development in modern wireless communication and radar technologies.

joint radar-communication systems represent an innovative approach that integrates radar and communication functionalities within a unified framework. By sharing common resources and infrastructure, these systems offer enhanced spectrum efficiency, reduced hardware complexity, and improved overall performance. The fusion of radar and communication capabilities enables a more versatile and adaptive use of the electromagnetic spectrum, paving the way for advanced applications such as cognitive radar and spectrum sharing.

2 System Model

2.1 Guard time

Question : Introduce a 0.1 microseconds guard time at the end of each chirp to enhance system performance. This additional time is beneficial for?

Adding a guard time at the end of each chirp is beneficial for enhancing the system performance in several ways:

1. **Reduced Interference**: The guard time helps in reducing the interference between consecutive chirps. Without the guard time, the end of one chirp may overlap with the beginning of the next chirp, causing interference

and making it difficult to distinguish between them.

2. **Improved Accuracy**: The guard time allows the receiver to accurately detect the end of each chirp. This is important for accurately measuring the time-of-flight of the signal, which is used for distance measurement in radar systems.

3. **Increased Range**: The guard time also enables the system to operate at longer ranges by reducing the effects of multipath interference. Multipath interference occurs when signals from the transmitter are reflected off objects in the environment and arrive at the receiver at different times, causing distortion and reducing the accuracy of the measurements. The guard time helps to mitigate this effect by allowing the reflected signals to decay before the next chirp is transmitted.

After the receiver takes the chirp sequence ,gives it to two functions, each func firstly separates each chirp and deletes the delay at the end of chirps:

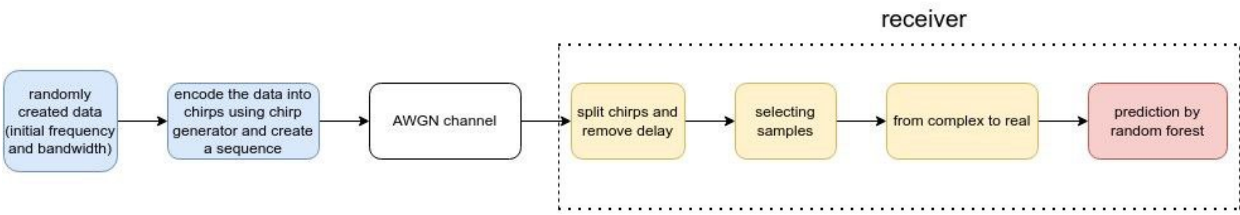

Figure 1. Flowchart of proccess

3 Receiver

3.1 random forest model

Random Forest is a suitable choice for predicting the bandwidth and frequency of the chirp in index modulation due to its ability to handle high-dimensional data, capture complex relationships between input variables, and provide robust predictions. Additionally, Random Forest is adept at managing noisy data and can effectively handle a large number of input features, making it well-suited for modeling the intricate relationships involved in predicting bandwidth and frequency in index modulation. Moreover, its capability to handle non-linear relationships and its resilience to overfitting make it a strong candidate for accurately predicting the parameters associated with chirp signals used in index modulation.

For training the model, we need a descent amount of chirps, which was generated using chirp generator. 2000 chirps with snr of 20 dB, choosing a rather high snr helps reducing the overfit upon noise and tracking the real data.

Since the number of samples for each chirp is very high (30400 samples) we used fscchi2 function to take only more relevant samples to the bw ,initial frequency. After choosing the important samples, the model was trained and eavaluated to optimize some parameters :

1. **The number of chosen samples** : the more samples we choose, the more complex the model will be and more accurate (if we do not assume overfitting)
2. **The number of trees** : too small number will lead to not classifying all of the different possible frequencies and bandwidths and too many trees will lead to high calculations and enormous runtime.

After running the training code a few times, we found the sweet spot for the two parameters, saved the models and index sorted by fscchi2 for testing on 256 chirp sequence.
The test was executed in ML reciever code which is the final receiver, the precision result is shown in the table below:

```
function data = data(sequence)
   w = size(sequence,2);

   B = reshape(sequence,[30600,w/30600]).';

   b = B(:,1:end-200);

    for i = 1:size(b, 2)
      C{i} = b(:, i);
    end
data = table(C{:});

end
```

then the important samples (which were determined in training of each models by fscchi2 function) are selected, the selected samples will be the inputs of predict function:

```
predict function:

   idx = idx_f(1:5000);
   pre_data_f = data(:,idx);
```

since data is complex, the input of model is real and imaginary parts of the preprocessed data:

```
data_real = [real((pre_data_f{:,:})),
imag(pre_data_f{:,:})];
```

now the chirps are ready to be passed to the models for determining bw and frequency:

```
detect_init_f = predict(model,data_real);
detect_B = predict(model,data_real);
```

4 One-bit transfer

In chirp index modulation, achieving one-bit transfer using upchirp/downchirp and on-off keying involves a clever use of frequency modulation and amplitude modulation to encode information within a single bit.

1 : **Upchirp and downchirp**: Upchirp and downchirp refer to the frequency modulation of the chirp signal. In upchirp, the frequency of the signal increases over time, while in downchirp, the frequency decreases. By using this modulation, different chirp signals can represent binary values (0 or 1).

2 : **On-off keying**: On-off keying is used to modulate the amplitude of the chirp signal. When the signal is present, it represents one binary state (e.g., 1), and when the signal is absent, it represents the other binary state (e.g., 0).
By combining upchirp/downchirp for frequency modulation and on-off keying for amplitude modulation, a one-bit transfer can be achieved. For instance, the presence of an upchirp signal could represent a '1' while the absence represents a '0', and similarly, a downchirp signal or lack thereof can represent the opposite. This methodology effectively encodes binary information within the chirp signal, enabling one-bit transfer in chirp index modulation and radar communication.

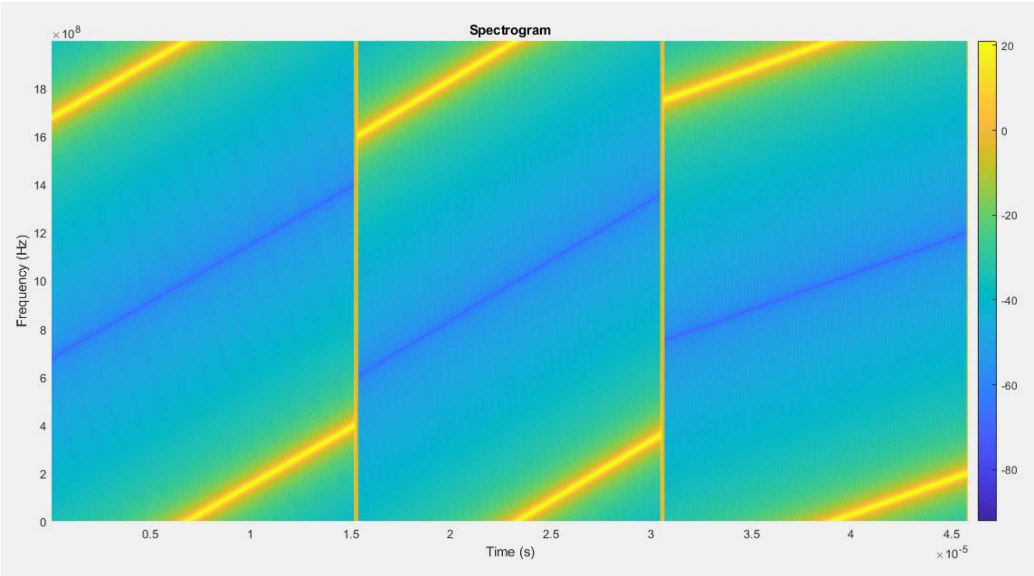

Figure 2. Signal STFT

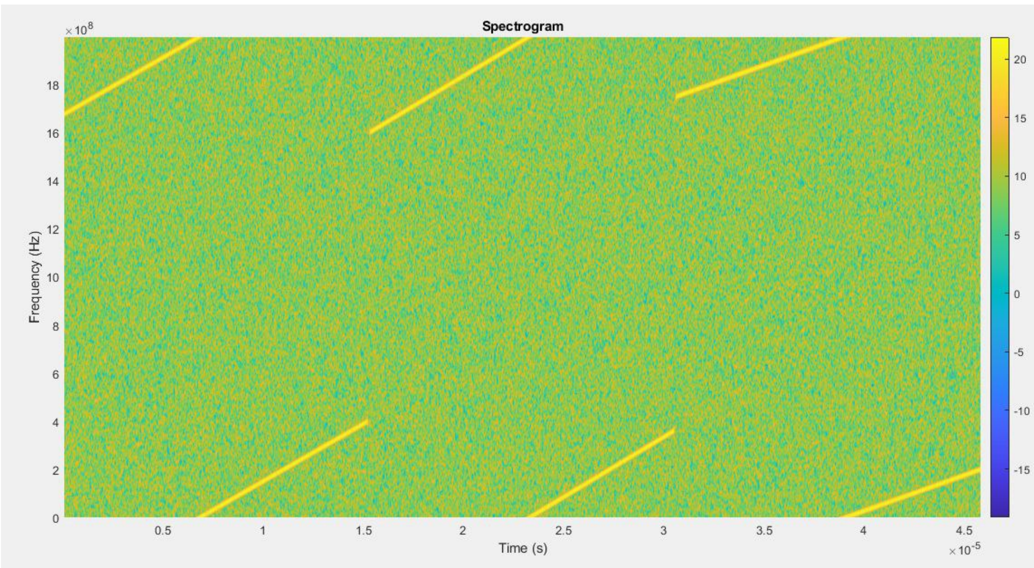

Figure 3. Signal STFT when SNR=0

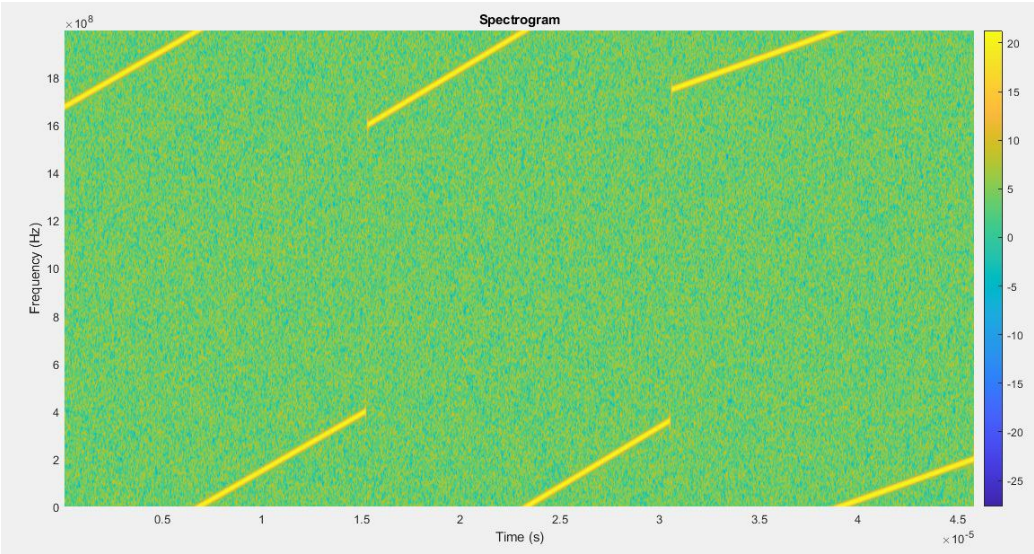

Figure 4. Signal STFT when SNR=10

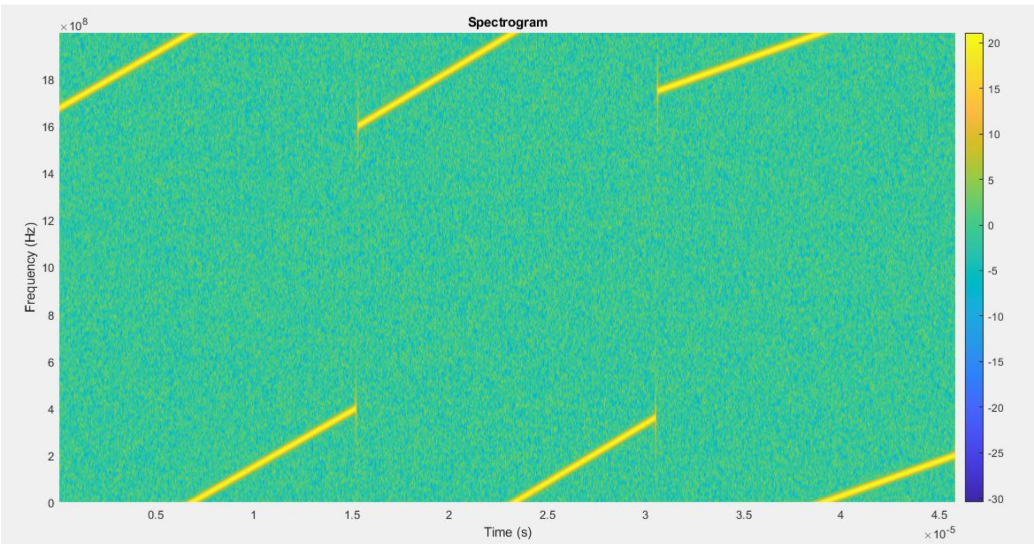

Figure 5. Signal STFT when SNR=20