

## **ECE 463 Lab 10: IoT –LoRa**

### **1. Introduction**

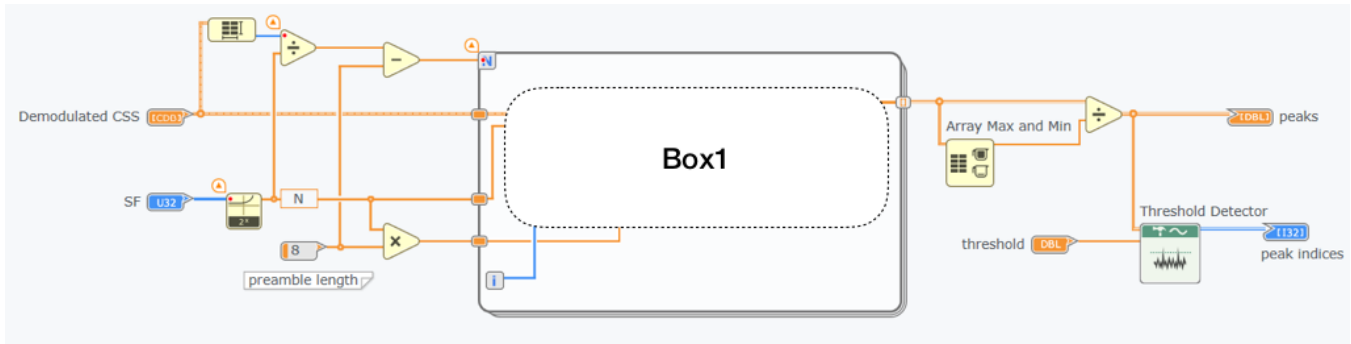
LoRa (Long Range) is a spread spectrum modulation technique derived from chirp spread spectrum (CSS). LoRa devices and wireless radio frequency technology is a long-range, low power wireless platform that enables smart IoT applications. In this lab, we will implement LoRa transmitter & receiver and demonstrate them in wireless.

#### **1.1. Contents**

1. Introduction
2. LoRa: Tx
3. LoRa: Rx
4. LoRa: USRP

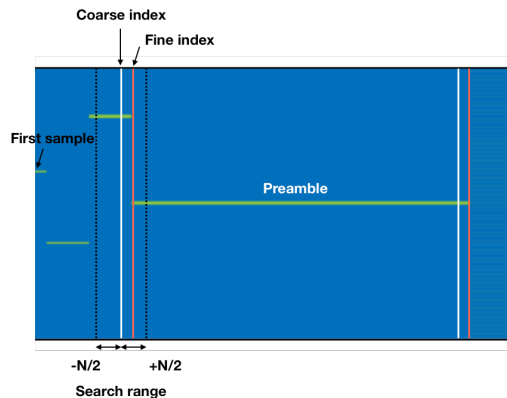
#### **1.2. Report**

Submit the answers, figures and the discussions on all the questions. The report is due at the beginning of the next lab.



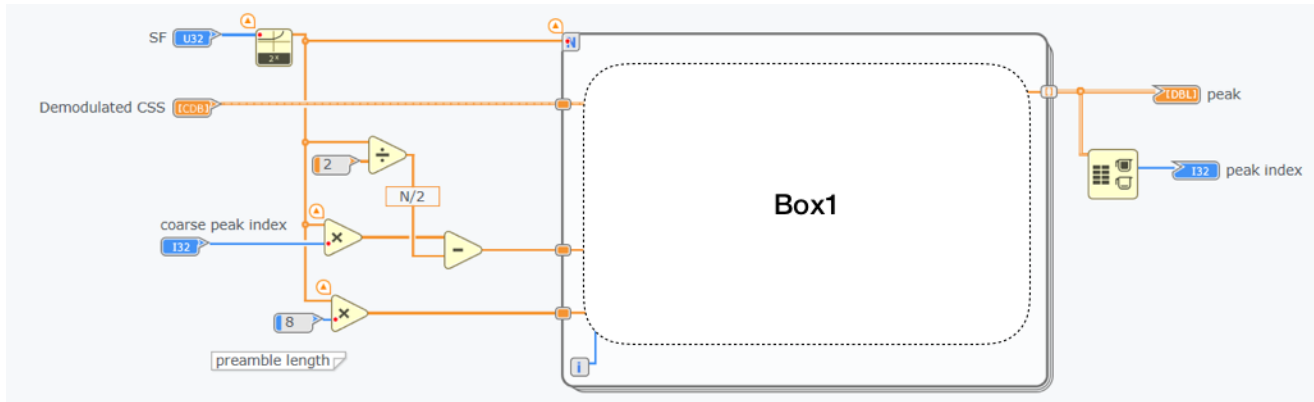
### 3.3. Fine Alignment

In the coarse alignment, it assumes the first sample of the received signal is the beginning of a chirp. However, the receiver can start sampling at any time, so the first sample can be any portion of a chirp. In fine alignment, we search the index from  $-N/2$  to  $N/2$  centered at the coarse-aligned index. The block aligns the packet in *sample-wise*. The following figure shows the first sample is not the beginning of a chirp which leads the coarse index off by a few samples. The fine alignment block finds the exact start of the preamble.



<b>fine_alignment.gvi</b>	Terminal name	Type	Description
Input	<i>Demodulated CSS</i>	Complex double array (1D)	
	<i>SF</i>	Unsigned integer	Spreading factor
	<i>Coarse peak index</i>	Signed integer	Index of the first coarse peak
Output	<i>peak</i>	Double	
	<i>Peak index</i>	Signed integer	

Complete Box1 in the following figure. Box1 performs FFT by sliding window and returns the maximum magnitude of the FFT.



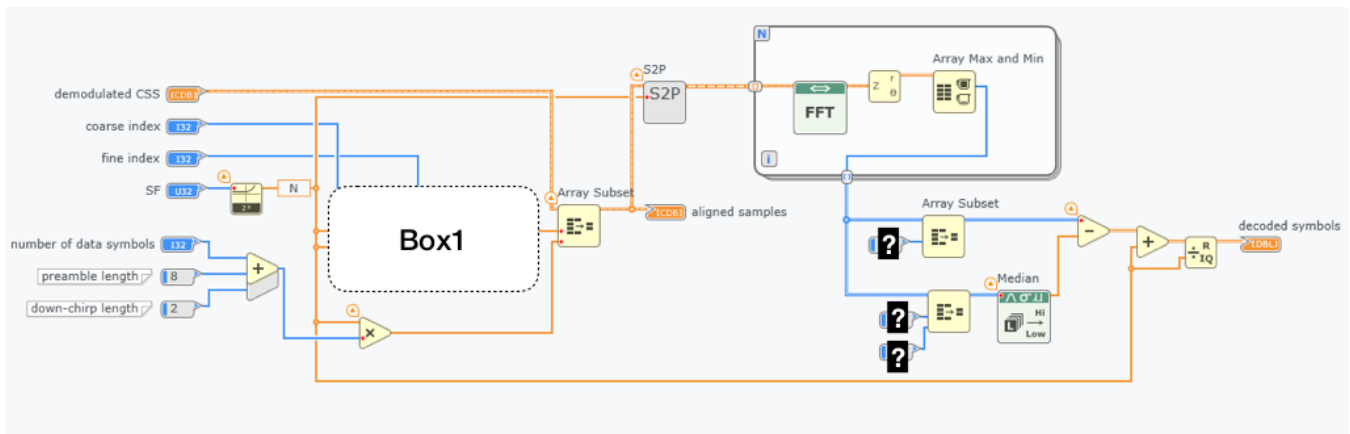
### 3.4. Decoding

The decoder block completes the following process:

1. Align the packet by using the coarse and fine index. The aligned packet starts from the preamble.
2. Divide (or parallelize) the aligned packet by chirps (N samples), then performs FFT.
3. Find the index that has the maximum magnitude of the FFT.
4. Calculate the frequency shift caused by CFO or STO on the preamble whose frequency bin should be 0.
5. Correct the frequency shift on the data symbols.

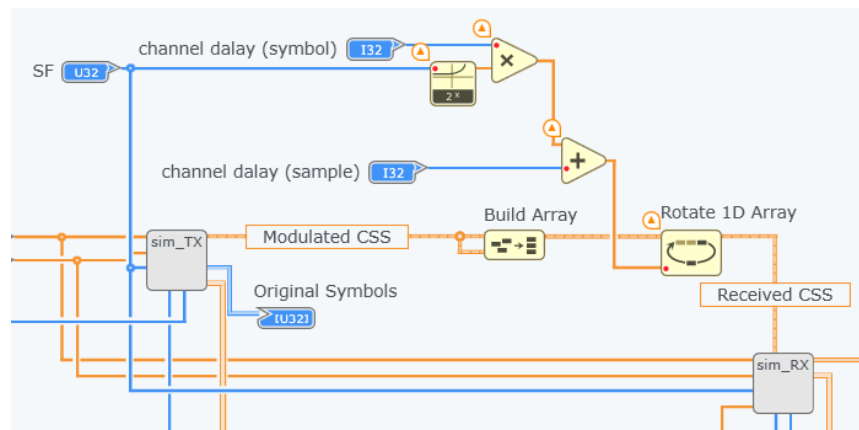
<b>CSS_decoder.gvi</b>	Terminal name	Type	Description
Input	<i>Demodulated CSS</i>	Complex double array (1D)	
	<i>Coarse index</i>	Signed integer	
	<i>Fine index</i>	Signed integer	
	<i>SF</i>	Unsigned integer	Spreading factor
	<i>Number of data symbols</i>	Unsigned integer	
Output	<i>Decoded symbols</i>	Signed integer array (1D)	
	<i>Aligned samples</i>	Complex double array (1D)	

Complete Box1 in the following figure. Box1 calculate the right index to align the packet. Find the right indices hidden by the question marks to obtain the data symbols and the preamble.



## Assignment 2 [50 points]

- (50 pints) Verify the transmitter and receiver blocks by simulation. Build sim\_RX block similar to sim\_TX block (Connect all four blocks of Rx together). Simulate the channel delay as the following figure. The detail connections with sim\_TX and sim\_RX can be different.



Try the following configuration for the simulation:

- SF = 7
- Number of data symbols = 32
- Channel delay (symbol) = 10
- Channel delay (sample) = 24

Report the followings:

- Spectrogram of the aligned demodulated CSS (use 128 for the window size)
- First 8 symbols each for the original symbols (Tx) and the decoded symbols (Rx)

#### 4. LoRa: USRP

Once the blocks are verified by the simulation, implement them in USRP. You can reuse `sim_Tx` and `sim_Rx` blocks to simplify the connections. **Note that there is no need for up/down-sampling and pulse-shaping/match-filtering.** In the receiver, calculate the number of samples to capture two LoRa packets (preamble + data).

### Assignment 3 [20 points]

1. (20 pints) Run your LoRa transceiver in wireless. Use two USRPs: one for Tx and the other for Rx. Use the following configuration:
  - Carrier frequency = 915MHz
  - BW = 500kHz
  - IQ rate = 500kHz
  - Number of data symbols = 64
  - SF = 7

**Report the followings:**

- Spectrogram of the modulated CSS at Tx (use 8 for the window size)
- Spectrogram of the aligned demodulated CSS at Rx (use 128 for the window size)
- First 8 symbols each for the original symbols (Tx) and the decoded symbols (Rx)
- Total number of symbol errors