

## Low Latency, Low Power IoT Communication Systems Coexistent with LTE using CRAN

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### Introduction

We communicate using our phones because they operate in different frequencies and will not cause interference this way. However, the cost for companies to buy a certain range of frequency spectrum can be very high.

We came up with a novel way to solve this problem by using the technique of phase combining. And the following will be our simulation and the experiment result.

### Objectives

- Successfully distinguish between transmitted signals within the same frequency so that we are able to increase the number of users within some certain range of frequency spectrum. In other words, the frequency spectrum would not be as crowded as before, which leads to :
  - Low latency-fast
  - Low power –low energy
  - IoT Communication Systems- transmitters, receivers

### Testbed

- Use grid in orbit lab
- Software Defined Radio(SDR)
- N210 and X310
- GNU Radio
- C++
- Matlab



Orbit grid testbed

### Challenges

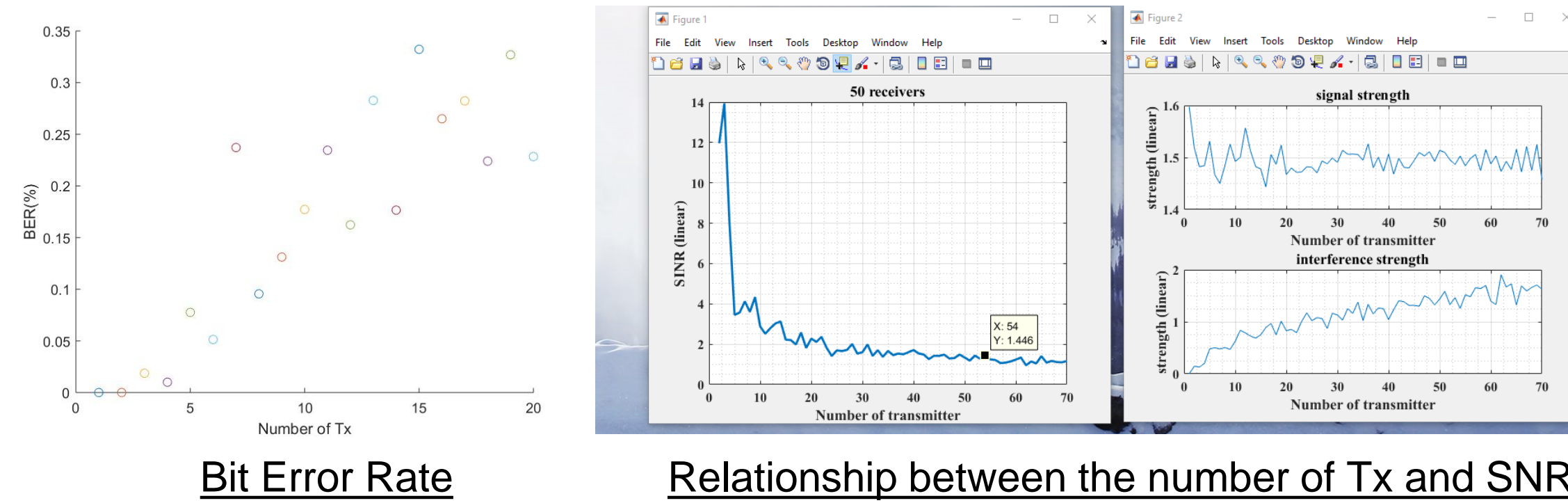
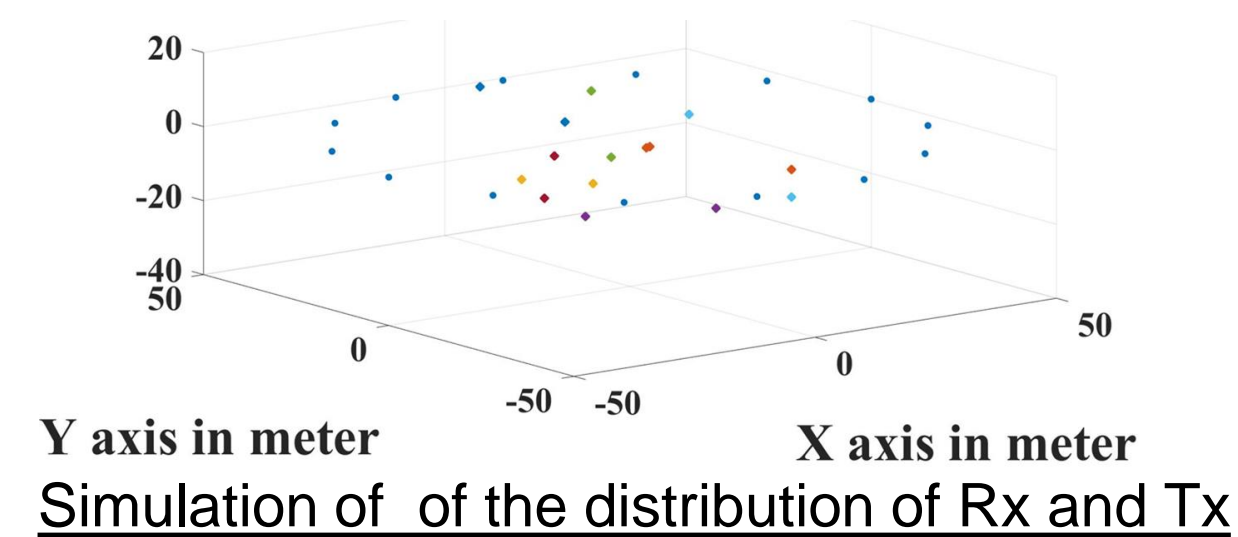
- Two users operating at the same frequency will often cause collision and interference.
- Number of USRP N210 are limited.
- Flowchart would not run properly on USRP X310. (always get underflow when we run an experiment)

### References

- [1][http://delivery.acm.org/10.1145/3220000/3214268/a65-Fan.pdf?ip=165.230.132.126&id=3214268&acc=ACTIVE%20SERVICE&key=7777116298C9657D%2E56792D02161BECDE%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&\\_\\_acm\\_\\_=1534367595\\_8578b2b8e12115077e92c0dc416ec61](http://delivery.acm.org/10.1145/3220000/3214268/a65-Fan.pdf?ip=165.230.132.126&id=3214268&acc=ACTIVE%20SERVICE&key=7777116298C9657D%2E56792D02161BECDE%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1534367595_8578b2b8e12115077e92c0dc416ec61)
- [2][http://delivery.acm.org/10.1145/3100000/3098845/p309-Eletreby.pdf?ip=165.230.132.126&id=3098845&acc=PUBLIC&key=7777116298C9657D%2E56792D02161BECDE%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&\\_\\_acm\\_\\_=1534367836\\_c00aebd28c01b6955118e893bc5bf7ee](http://delivery.acm.org/10.1145/3100000/3098845/p309-Eletreby.pdf?ip=165.230.132.126&id=3098845&acc=PUBLIC&key=7777116298C9657D%2E56792D02161BECDE%2E4D4702B0C3E38B35%2E4D4702B0C3E38B35&__acm__=1534367836_c00aebd28c01b6955118e893bc5bf7ee)
- [3]<http://www.winlab.rutgers.edu/~ox5bc/>

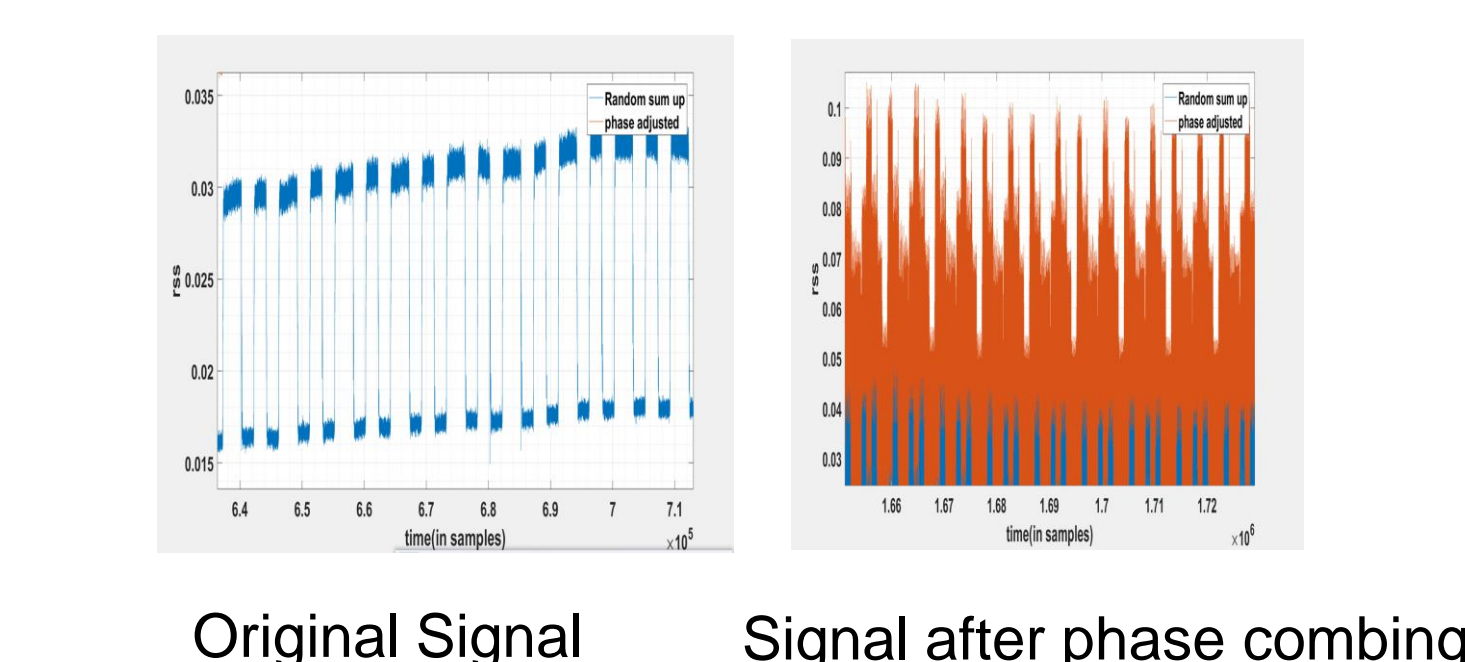
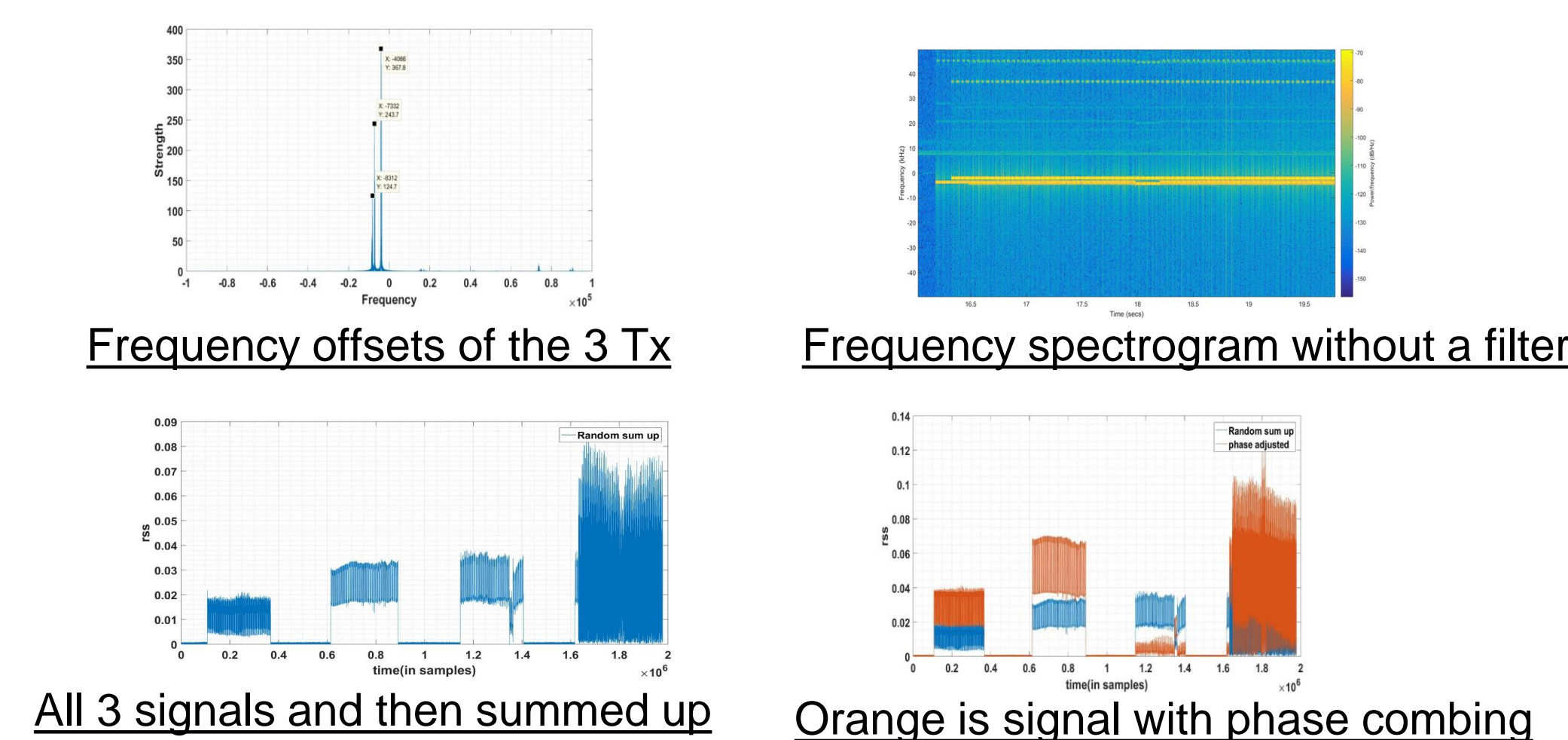
### Simulations

- In our experiment we only have 14 Rx to use. Number of Tx simulated here are usually bigger than the number of Rx. We chose 15 Tx to simulate the experiment and 20 Tx to find the BER(Bit Error Rate). That is what is shown in our simulation below.



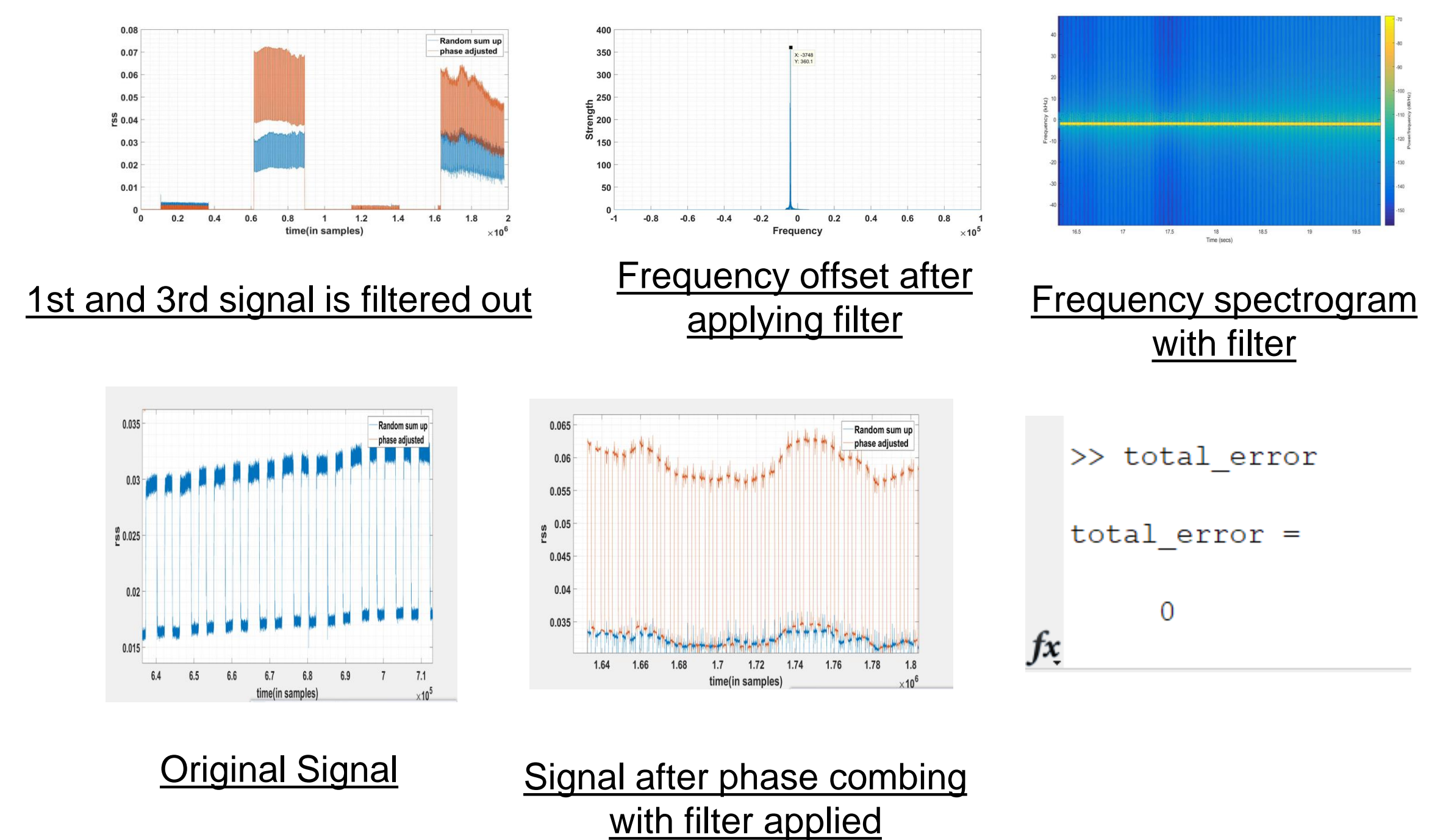
### Experiments

- Frequency offsets usually complicate signals and become a hassle, however, we found that we can actually use this initial property of each device to distinguish the signals between each Tx.
- Basic set up are as following:
  - 14 Rx: synchronized
  - 3 Tx: unsynchronized (which means they will have different frequency offsets) sending different signals
  - 1 Cloud: downloads all the experimental data



### Experiments

- As we can see from the previous section, there are two Tx which their frequency offsets are close to each other.
- We could use a filter to filter them out so that there will only be 1 Tx to be analyzed.
- The following experiment below has the same set up as the previous experiment, except we added a filter in our MATLAB analysis in order to filter out the unwanted signals to reduce interference.



### Results

- We see clearly that even though using the phase combination has some limitations, we can use devices' initial frequency offset to separate the desired signals.
- Through this set of experiments we observed good performance and that the experiments support our theory. We could not perform more general experiments using as many Rx's as we want.

### Future Direction

- Make our flowchart work with USRP X310 without underflow.
- Use X310 MIMO rack to increase the number of Rx to perform the experiment. The more Tx and Rx, the more realistic our experiments will be.
- Find alternative ways to reduce the interference other than using the Frequency offset.
- Improve the behavior of phase combining signals.