Athanasios Vasileiadis

Postgraduate Researcher: University of Sheffield

Supervisor: Edward A Ball

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Time and phase synchronization with two RSP2s

Motivation

Time synchronized, phased array platforms have been prohibitively expensive and have high software complexity. The purpose of this work is to show that multiple RSP2s are capable to be time and phase synchronized and operated through Matlab. Furthermore, RSP2 control through Matlab will enable researchers and hobbyist to develop their own digital signal processing algorithms at a significantly lower cost. The Matlab toolbox can be found here [1].

Test setup

The test setup consists of two RSP2, an anchor node, and a target signal. To achieve phase synchronization, the two RSP2 are initialized as a daisy-chain, where the clock of the first RSP2 acts as a clock master on the second RSP2. More information on how to initialize multiple RSP2 in daisy-chain can be found here [2]. For both anchor node and target signal SPIRIT1 low data rate, low power transceiver [3] is used. The anchor node transmits a PRBS OOK modulated signal at 869.1 MHz. A two-way splitter and two cables with equal length allows a zero-phase difference feed to the two RSP2 at Port B. Similarly, the target signal is a PRBS OOK modulated signal at 869.3 MHz. As described above, a zero-phase difference feed reaches port A of both RSP2. For detailed information regarding the setup see Table A and a picture of the setup in *Figure 1*.

Table A: Detailed information of target signal and anchor node.

	Target signal	Anchor node
Frequency (MHz)	869.3	869.1
Sample Rate (kSamp/s)	1	1
Power (dBm)	-70	-40
Port	A	B
Modulation	OOK	OOK

Port switching is not recommended as it was found to introduce a random phase offset between the two RSPs. The cable length between the RSP2 and the antenna at port A or anchor node and port B is recommended to be the same in order avoid unnecessary pre-calibration. Both RSP2s are set to port A, and port B is fed with a strong synchronization signal, which leaks to port

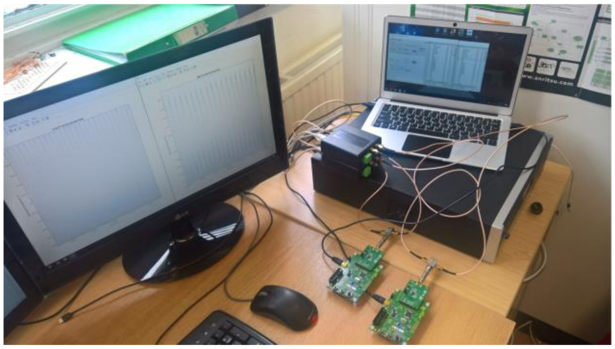

Figure 1: Picture of the setup.

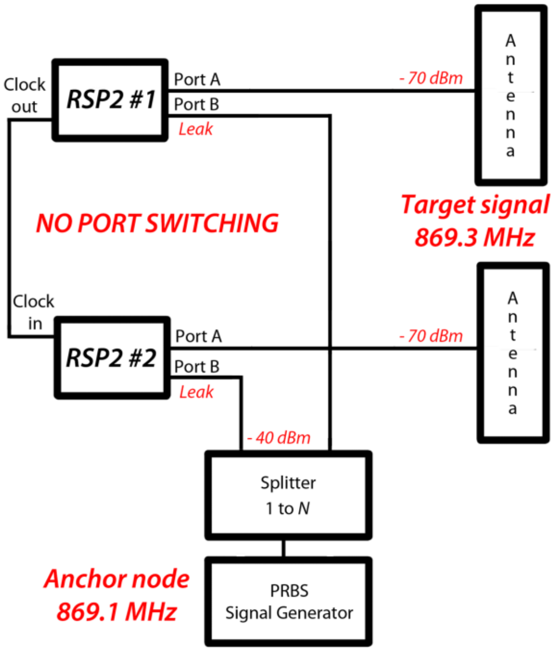

Figure 2: Conceptual block diagram of time/phase synchronized arrays

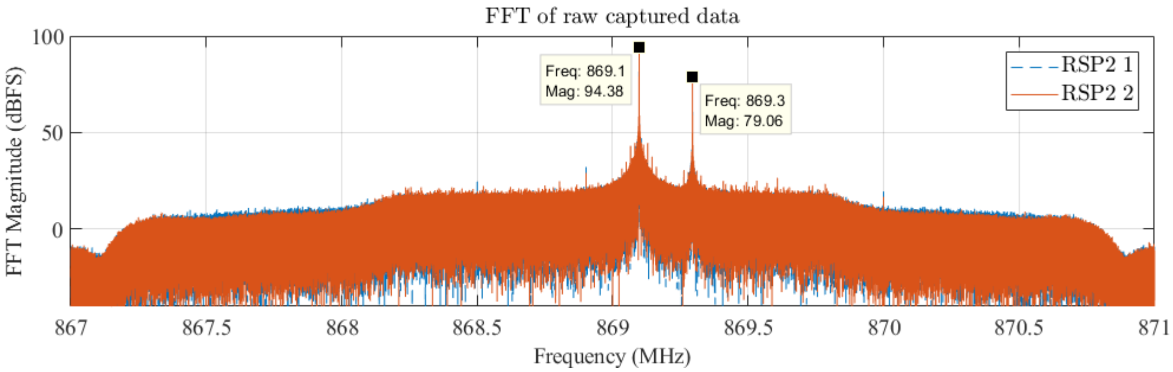

Figure 3: FFT of raw captured data for the two RSP2.

A. For time synchronized, phased array applications the target signal (conductively feed in this test) will be replaced with an antenna, *Figure 2*.

For this test, the SDRplay API is used to communicate with the device, from Matlab environment. Furthermore, a MEX file and a Class was created to allow enable communications between the two RSP2s and Matlab.

Raw captured data

In Matlab environment, the two RSP2s are initialized in a daisy-chain for phase synchronization, and both RSP2s are set to RF frequency of 869 MHz, sample rate of 4 MSamp/s, gain reduction of 50 dB, and bandwidth of 1.5 GHz. An FFT of the raw captured data can be seen in *Figure 3*. A misaligned time frame from both RSP2s can be seen in *Figure 4*. Both target signal synchronization signal (leaked from port B) falls within the RSPs IF bandwidth (100 and 300 kHz).

Synchronized data

To distinguish the anchor node and the target signal two FIR filters for each IF (100 and 300 KHz) are created in Matlab. To preserve the phase of the recorded signals a zero-phase digital filtering is used [4], since filtering might introduce an unwanted phase offset.

The phase offset of the anchor node in the two RSP2s is measured in two stages. The first stage uses a cross-correlation [5] to detect the rough time offset, which is then applied. The second

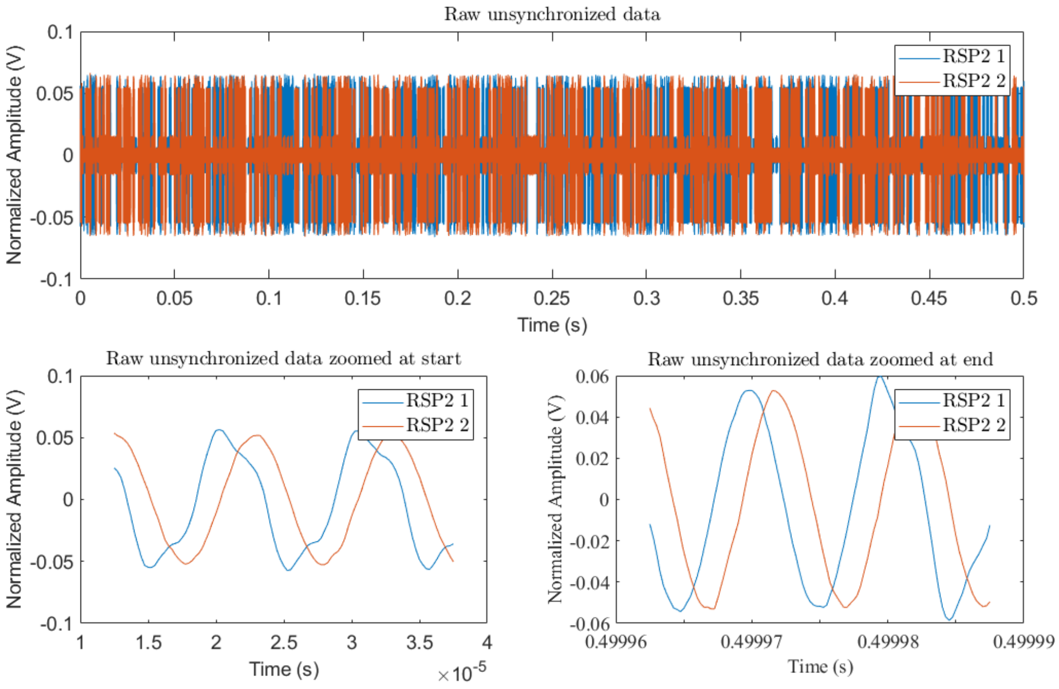

Figure 4: Raw unsynchronized data frame in time domain for the two RSP2.

stage is a phase offset measurement between the two RSP2s signals using FFT [6], which is rounded and converted into samples, to completely align the two RSP2s. The synchronized frame from both RSP2s can be seen in *Figure 5*.

Thereafter the time offset measured remains the same while the devices are streaming. That means that the anchor node can be turned off after the initial calibration/setup. If any setting changes on either device, a random unknown offset is added, thus requiring re-synchronization. It is theorized that this might be due to the internal switching in random indices and its affect in the phase of the received signal. Further investigation is required to determine the source of this random offset and a possible solution.

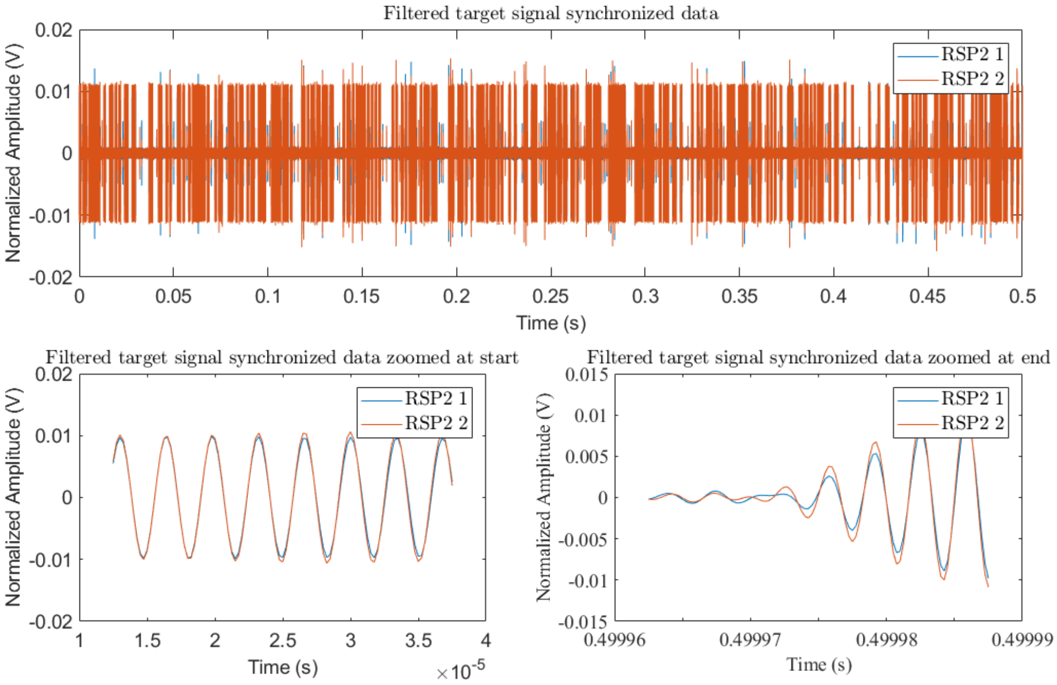

Figure 5: Filtered target signal frame in time domain for the two RSP2s.

Acknowledgments

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References

[1] https://github.com/VasAthanasios/MultiThread_SDRplayRSP2_Matlab_Toolbox

[2] https://www.sdrplay.com/docs/SDRplay_RSPII_Reference_Clock_Application_Note_R1P0.pdf

[3] https://www.st.com/en/wireless-connectivity/spirit1.html#sw-tools-scroll

[4] https://uk.mathworks.com/help/signal/ref/filtfilt.html

[5] https://uk.mathworks.com/help/signal/ref/xcorr.html

[6] https://uk.mathworks.com/help/signal/ref/angle.html

[7] https://uk.mathworks.com/matlabcentral/fileexchange/55537-hackrf-toolbox-with-spectrum-analyzer