Benefits of Quadrature Baseband Versus Radio Frequency Demodulation Algorithm

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***Abstract*— The continued advancement of software-defined radio (SDR) technology has been a key factor furthering research into the implementation of most signal processing algorithms at baseband. Traditionally, most algorithms have been carried out at radio frequency (RF). With the coming of SDR, the processing can be done at baseband frequencies which are more compatible with the fast developing software radio technology. This paper looks at selected demodulation algorithms and investigates the possibility and benefits of carrying them out at quadrature baseband (QBB). Simple beamforming, multipath/Doppler shift compensation cases are considered. The analysis is carried out using MatLab simulations at RF and QBB and the results do show the possibility of carrying out the selected demodulation algorithms at QBB with the expected benefits**

***Index Terms*— Quadrature baseband, demodulation, beamforming, compensation.**

I. Introduction

Modulation shifts a signal up to much higher frequencies than its original span. This often results in doubling of the bandwidth. However, baseband frequencies are much lower than radio frequencies and therefore, signal processing at baseband presents this key advantage [1]. This facilitates for more sub-sampling to be carried out at QBB than at RF. The sub-sampling in turn results a reduction in the number of samples being processed entailing a reduction in the processor load.

Software radio technology advancement has been a factor in promoting research into baseband signal processing. Baseband signal processing technology is experiencing a period of radical change [2, 3] encouraging the need to investigate more about baseband processing in order to implement most functions that were traditionally implemented at RF so as to utilize to the benefits that come with working at baseband. Selected algorithms were investigated to show the benefits in terms of processing load of QBB against RF. For the analysis, we have to simulate the baseband signals before the processing can commence. The resulting signal can then be converted to digital form and further processing can be done in a DSP [4]. Narrowband signals and noiseless channels are assumed for the analysis.

II. Beamforming

The benefits of beamforming at QBB compared to RF are best seen by carrying our the processing using the two methods and then comparing the beam patterns produced before the comparison can be made in terms of the processing load. Simple beamforming at RF involving the summing up of 4 input signals at RF was done before demodulating the summed-up signal. The beam pattern is produced from the output signal by plotting the amplitude of the output signal against theta. Let the input signals be denoted as s_0, s_1, s_2 and s_3, the beamformed signal as s_4 and the demodulated output as s_5. The beamforming was done using MatLab simulations for selected demodulation schemes. For this particular paper, only one scheme was considered. The theoretical analysis

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for the RF and QBB simulations is summarized in the figures on the next page.

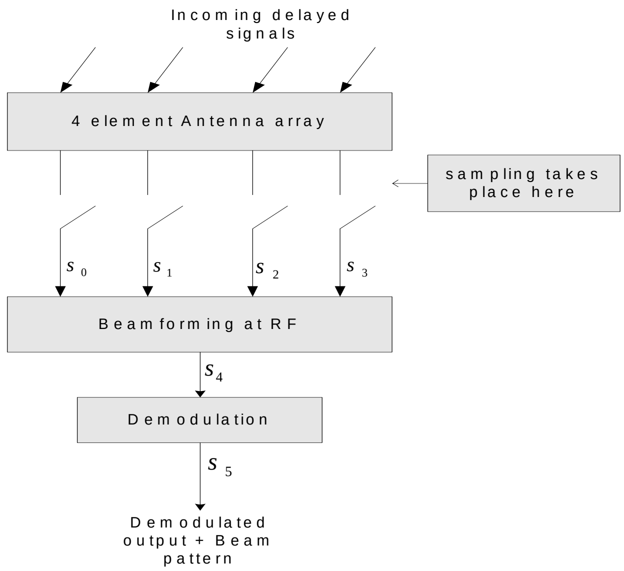

Figure 1: *Beamforming at radio frequency*

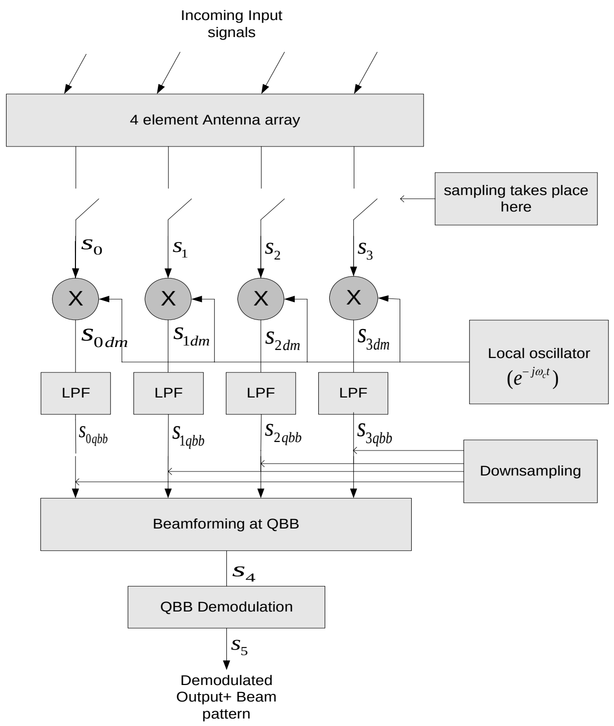

Figure 2: *Beamforming at Quadrature baseband*

Figure 1 and 2 basically show the theoretical analysis structure from which it is seen that for the QBB case, the beamforming shifts downs to baseband. It should be noted from the figure that the subscript 'dm' denotes down- mixing. This entails that the processing now takes place at a much lower frequency of operation which enables further sub-sampling to take place. The figures on the below illustrate the beam patterns produced for the AMDSB-LC beamforming simulation for the coherent detection method at RF and QBB.

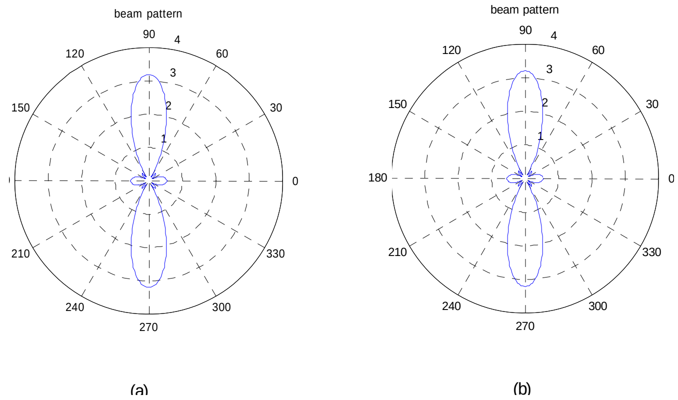

Figure 3: *Beam patterns* **(a)** *at RF* **(b)** *at QBB*

A difference/error plot between the two beam patterns produced showed a very insignificant difference between them. It thus suffices to conclude that beam forming at quadrature baseband is more advantageous since the process takes place at much lower baseband frequencies.

III. Compensation

The analysis looked at multipath and Doppler shift compensation so as to see the benefits of compensating at QBB as compared to RF. The cases were simple noiseless cases for which the signals used were subjected to multipath and Doppler shift effects. The analysis was carried out using MatLab simulation with the time delay and frequency shifting coming into play in the generation of the multipath and Doppler shifted signals. The figures on the next page show the general flow structure of the simulations for the compensation carried out at RF and QBB.

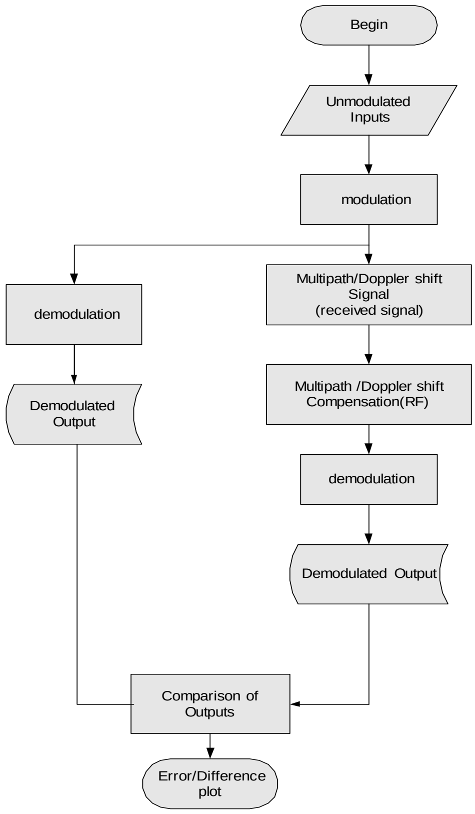

Figure 4: *Multipath/Doppler shift compensation at RF*

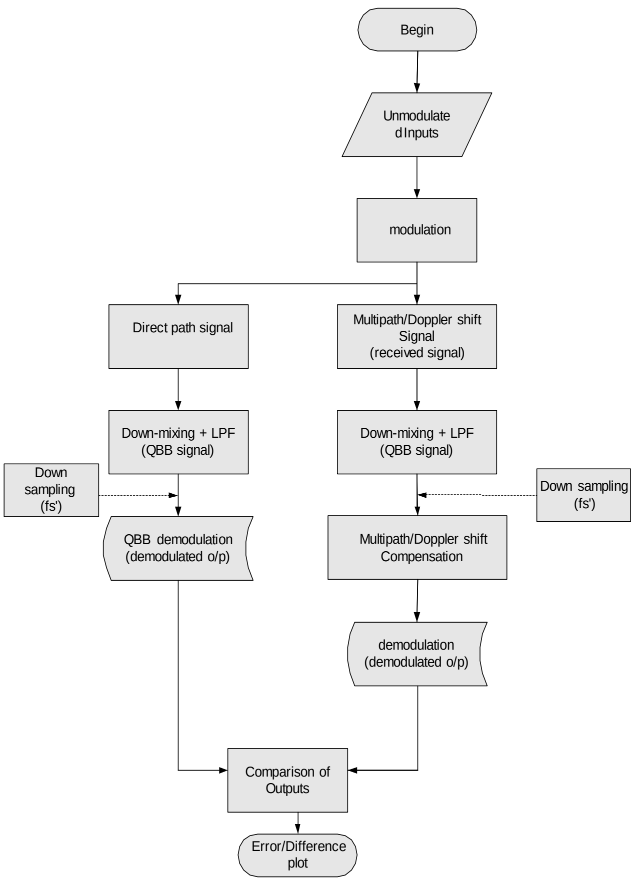

Figure 5: *Multipath/Doppler shift compensation at QBB*

From the flow diagrams above, it is seen that a parallel path exists in the simulations and this was basically for comparison purposes so as to test the accuracy of the compensation process by comparing the compensated demodulated output to the demodulated out resulting from the direct paths case. The resulting error/difference plots illustrate the numerical results of the comparisons carried out. In this case, the compensation process now takes place at QBB in preference to the traditional RF methods. The simulation results showed that compensating for multipath/Doppler shift is possible at QBB. The figures on the below show the results obtained for the QBB compensation for the analogue QAM case. It is seen that the compensation was a success and the error plot does consolidate the results obtained.

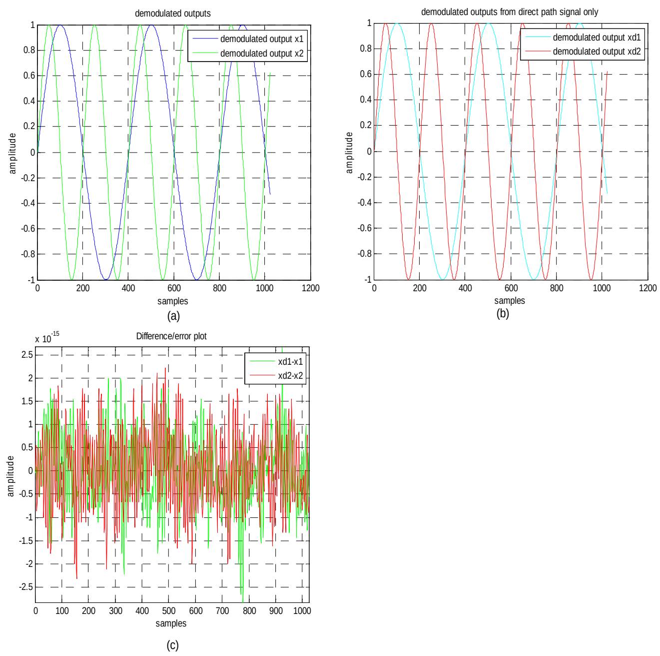

Figure 6: (a) *Compensated signal demodulated output*: *the compensated modulated output was demodulated and gives this signal output.* **(b)** *Direct path signal demodulated output: this signal output facilitates for measuring of the accuracy of the compensation process by plotting its difference from the compensated demodulated out put.* **(c)** *Difference/error plot: has a very small value of about 2.5e-14 shows a very insignificant difference which entails a successful compensation was done.*

IV. Conclusion

It has been verified that beamforming, multipath compensation, Doppler shift compensation could take place at quadrature baseband with the core advantage being the lower operating frequencies and hence reducing the complexity of the processing equipment. Therefore, the analysis was worthwhile and relevant so as to verify the possibility and effectiveness of working at quadrature baseband, whose benefits are expected to pour down to SDR technologies which currently make use of baseband processing.

References

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