Investigating Simple Multipath Compensation for Frequency Modulated Signals at Lower Frequencies

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***Abstract*—**Radio propagation from point-to-point is affected by the physical channel in many ways. A signal arriving at a destination travels through a number of different paths which are referred to as multi-paths. Research in this area of wireless communications has progressed well over the years with the research taking different angles of focus. By this is meant that some researchers focus on ways of reducing or eluding Multipath effects whilst others focus on ways of mitigating the effects of Multipath through compensation schemes. Baseband processing is seen as one field of signal processing that is cardinal to the advancement of software defined radio technology. This has led to wide research into the carrying out certain algorithms at baseband. This paper considers compensating for Multipath for Frequency Modulated signals. The compensation process is carried out at Radio frequency (RF) and at Quadrature baseband (QBB) and the results are compared. Simulations are carried out using MatLab so as to show the benefits of working at lower QBB frequencies than at RF.

***Keywords*—**Quadrature baseband, Radio frequency, Multipath Compensation, Frequency modulation, Signal Processing.

I. Introduction

MULTIPATH propagation occurs when RF signals take different paths or routes from a transmitter to a receiver. The cause of the different paths is due to the signal from the source (transmitter) being reflected by objects in its path and therefore resulting in multiple signals arriving at the destination (receiver). It is mainly classified into two categories namely *fast* and *slow* fading. Fast fading is associated with the structures surrounding the mobile receiver whilst slow fading is affected by terrain configurations. This paper however, looks at a simple general Multipath scenario. The received signal thus consists of the direct-path signal and the reflected versions of the direct-path signal. The reflected signals are referred to as 'Multipath signals'.

The effect of the reflection of the direct path signal by an obstacle is that the reflected signal is the same as the direct-path signal but scaled by a factor 'k' and having a time delay 'Δt'. The reflected signal is also referred to as the echo. Traditionally, Multipath compensation has been performed at RF and hence the need to investigate compensating for Multipath effects at lower Quadrature Baseband frequencies.

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II. Multipath Compensation

Multipath propagation plays a vital role in determining the nature of communication channels. This implies determination of the impulse, or frequency response of radio channels. Channel effects in cellular radio links arise from multipath propagation and these create special challenges for Space-time Processing (STP). A thorough understanding of channel characteristics is key to the development of successful STP algorithms [1]. However, this paper does not delve into other channel factors in detail but focuses on the compensation aspect of multipath. We will also ignore angular spread and constriction effects since the main purpose for the study is to justify the efficiency of compensating for multipath at QBB. It should be noted too that, we are using narrow band signals and noiseless channels are assumed. It is desired to find out the possibility of compensating at baseband frequencies as compared to the traditional RF methods and analyzing the benefits of compensating at QBB. Multipath is a form of interference and therefore it is undesired in radio propagation. Some of the effects of multipath distortion include data corruption, increased signal amplitude (constructive interference), decreased signal amplitude (destructive interference), signal nulling (when the reflected waves arrive exactly out of phase with the direct-path signal resulting in cancellation of the main signal completely)[2] . In order to mitigate the effects of multipath, a signal processing technique called 'multipath compensation' is used. This implies that the receivers should be equipped with compensators that will eliminate the multipath signals and allow for the processing of the desired direct-path signal only. For this analysis, it is assumed that the delayed multipath signal does also undergo a reduction or scaling of its amplitude by a factor 'k' and this is called the 'echo'. We therefore expect the amplitude spectrum of the direct path and multipath signal to be affected. The multipath signal thus does have changes in both the amplitude and the phase spectrum as compared to the direct path signal. The MatLab analysis results will illustrate the changes mentioned above by plotting the 'ffts' of the signal waveforms. We are considering an FM signal and analyzing the compensation process at RF and the possibility of carrying it out at QBB. The FM signals were generated in line with the equation given below.

$$y(t) = A\cos(\omega_c t + m.\sin(\omega_m t)) \quad (1)$$

III. Compensation at RF

The figure below illustrates the simulation flow for the analysis used to carry out the compensation process at RF. The parallel path shown in the diagram exists for comparison purposes. It is required so as to compare the compensated output with the direct path output that was not subjected to multipath effects.

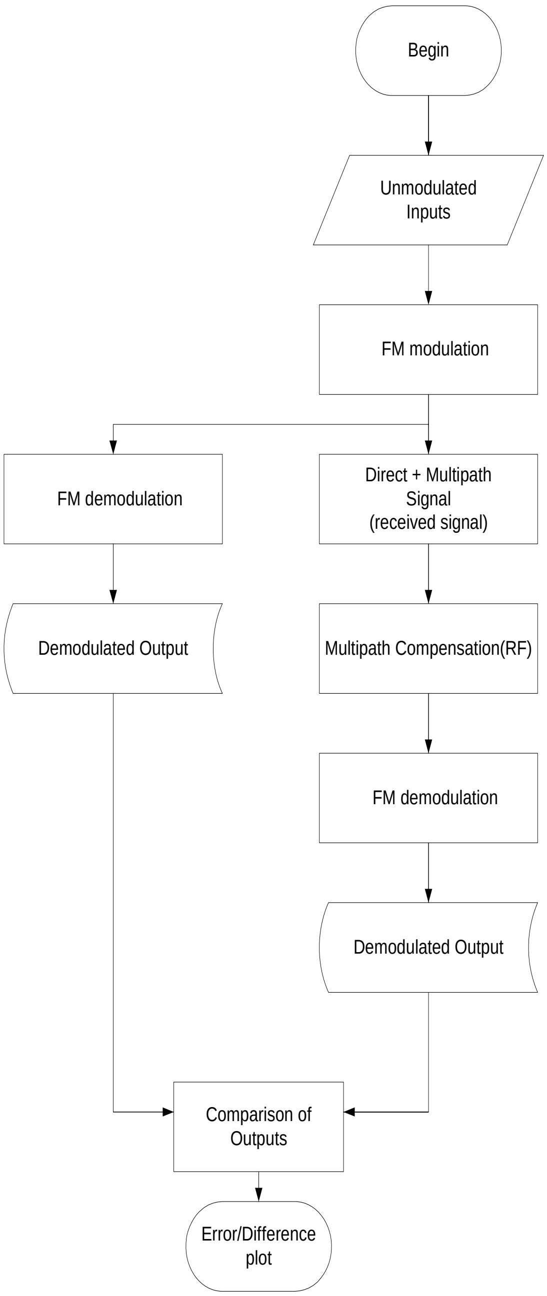

Fig. 1 Simulation structure Flow diagram

A. Theoretical Analysis

The simulation analysis uses some of the inbuilt MatLab functions to generate some of the signals. The theoretical analysis below gives us an insight as to how the signal processes from its un-modulated state down to the compensation and demodulation as was illustrated by the flow diagram.

$$y(t) \;= fm\,\mathrm{mod}(x) \quad (2)$$

The multipath is achieved by multiplying the direct path FM signal with the channel 'H' in the frequency domain and the compensated output is achieved by multiplying the multipath signal with the inverse of the channel 'H'. This is done at the receiving end. The output signal is then compared with the non-multipath version demodulated signal or simply, the demodulated output of the demodulated output from the direct path transmission only. A difference plot is then produced to show the accuracy of the compensation process.

B. Simulation Results-RF

The simulation results of the compensation analysis are now given in Fig. 2 below. From Fig. 2(c) it is seen that the signal has 2048 samples of which the last 1020 are zeros and this is due to the zero padding that was done when carrying out the circular convolution. The delay in the FM analysis was 4 samples too and so the received signal had non-zero values up to 1028 samples. The compensation process effectively compensated for the multipath effects and therefore, the compensated signal had non-zero values up to 1024 and the remaining zeros were eliminated to retain the original input signal length.

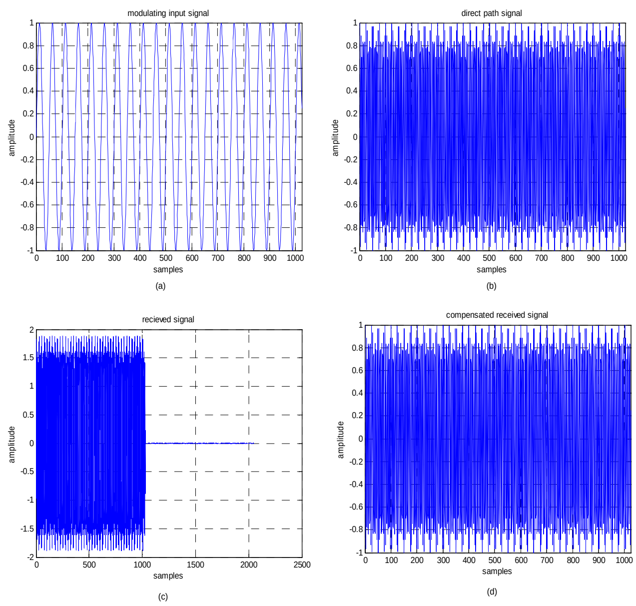

Fig. 2 (a) modulating signal (b) FM modulated input signal (c) Received signal (d) Compensated signal

Fig. 3 below show the demodulated output resulting from the compensated signal and the direct path signal only and the difference plot between the demodulated compensated output and the direct path demodulated output**.**

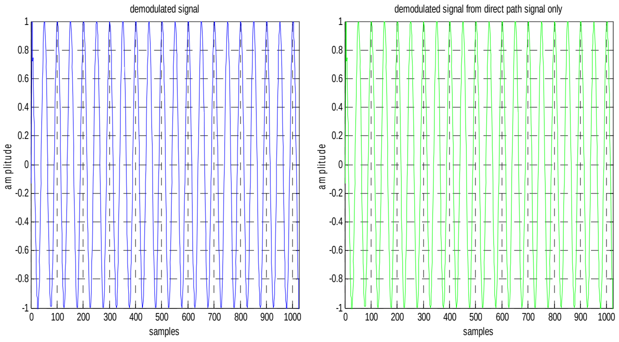

Fig. 3 (a) Compensated signal demodulated output (b) Direct path signal demodulated output

C. Spectral Analysis

The figures below show the spectral changes that took place during the compensation process. It is seen that the original signal spectrum was restored and thus the compensation was successful.

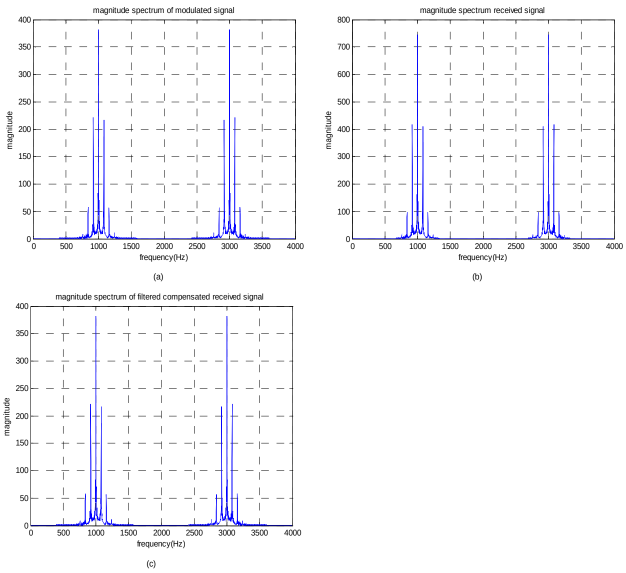

Fig. 4 Magnitude spectrum of (a) direct path signal (b) Received multipath signal (c) Compensated signal

IV. Compensation at QBB

The analysis now moves down to QBB. Here, we are again carrying out multipath compensation process but at QBB frequencies. The multipath compensation is also done at much lower sampling rates after carrying downsampling of the QBB received signal at baseband. The spectral changes taking place are also given and discussed. We are considering compensating at Quadrature baseband and therefore, a QBB baseband version of the received multipath signal had to be generated. Therefore, the received signal was mixed down by multiplying it with a local oscillator ($e^{-j\omega ct}$). The local oscillator frequency is again *coherent* with the carrier frequency. As, mentioned earlier, the multipath local oscillator length is matched to the signal length so as to have the correct down-mixing carried out. This represents an ideal case scenario. The mixed down signal is converted to Quadrature baseband by subjecting the signal to a lowpass filter resulting in the QBB signal. Therefore, compensation process can now proceed since we are at QBB. It is at this stage too that downsampling takes place so as to reduce our sampling frequency and hence enabling compensation at much lower sampling rates. Similarly, the compensator is brought down to QBB so as to have a perfect compensation process. This results in a reduction in the complexity of our compensation and processing equipment.

The flow diagram is shown in Fig. 5. Under FM Quadrature baseband demodulation, we have to *un-wrap* the phase angle and differentiate so as to get our demodulated output signal.

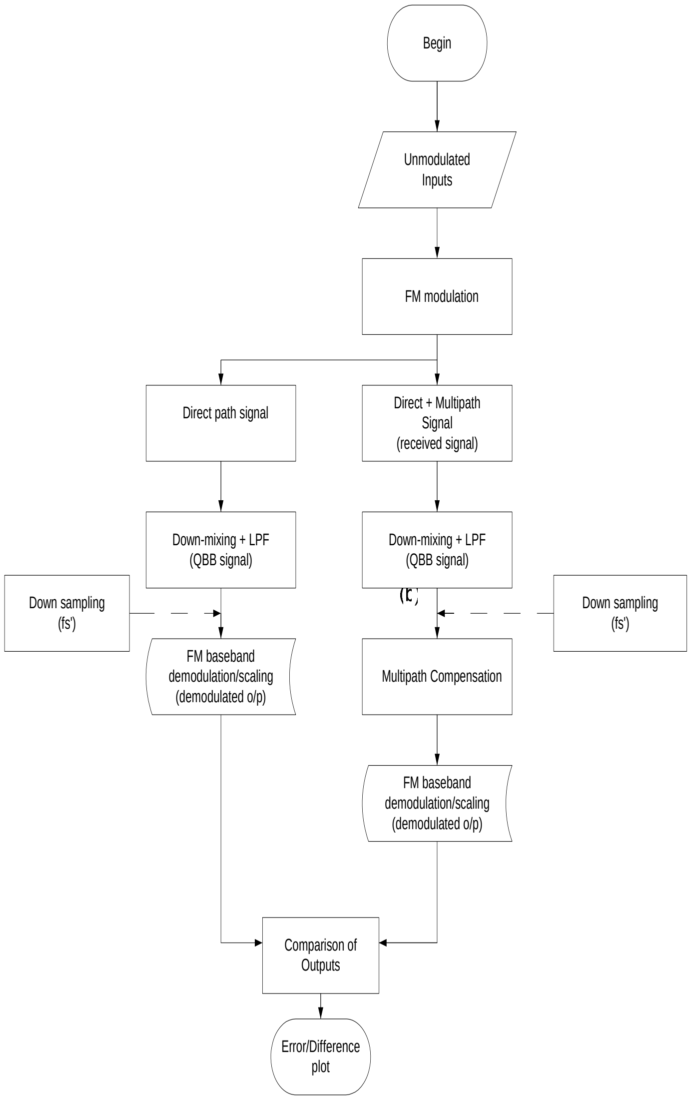

Fig. 5 FM QBB multipath compensation flow diagram

Fig. 5 illustrates Multipath compensation for FM Quadrature baseband. The procedure is basically the same as its QAM QBB counterpart. Therefore, the description of the QAM QBB flow diagram adequately describes the above flowchart except for the fact that we are dealing with FM signals.

A. Simulation Results – QBB

The MatLab simulation results are shown and discussed below. The first four figures below represent the received signal, down-mixed signal QBB signal before compensation and after compensation. The FM modulated signal remains as given in Fig. 3 (a) and is therefore not shown.

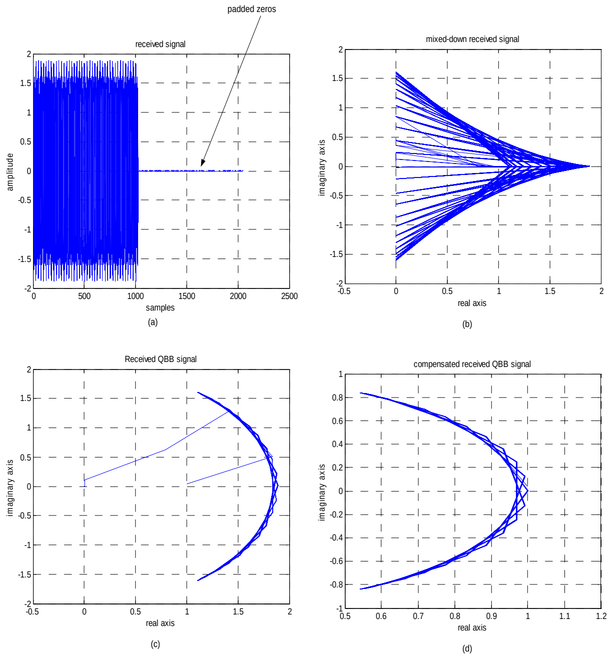

Fig. 6 (a) Received signal (b) Received down-mixed signal (c) QBB signal before compensation (d) QBB signal after compensation

The study aims to investigate the possibility and benefits of compensating for multipath in FM signals at lower Quadrature baseband and so we now proceed to look at the results of compensating at baseband. To test the effectiveness of our compensation, the demodulated output from the compensated signal is compared with the demodulated output from the direct path signal only and an error plot made. The plots in the figure below show the angle theta and its variation, the compensated demodulated output, the direct path demodulated output and the error plot.

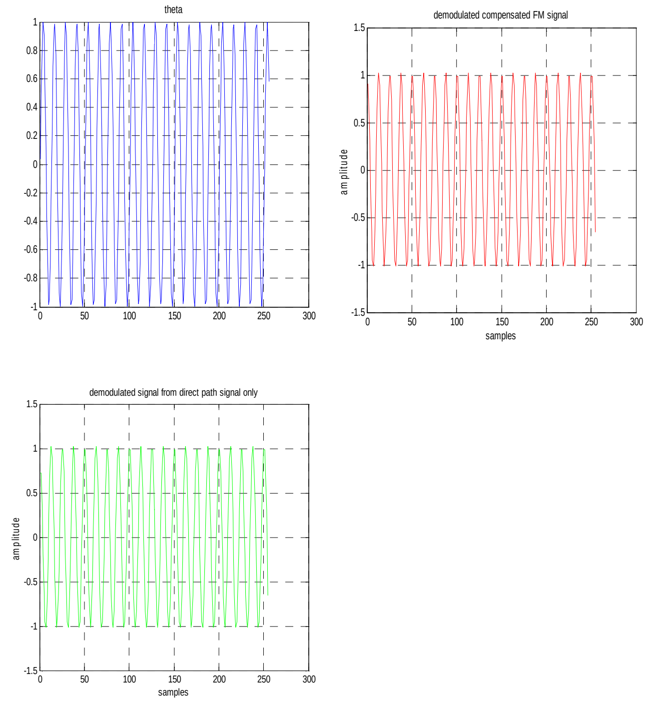

Fig. 7 (a) Theta (b) Compensated demodulated output (c) Direct path demodulated output

B. Spectral Analysis

The spectral changes taking place in the simulation are shown and discussed below.

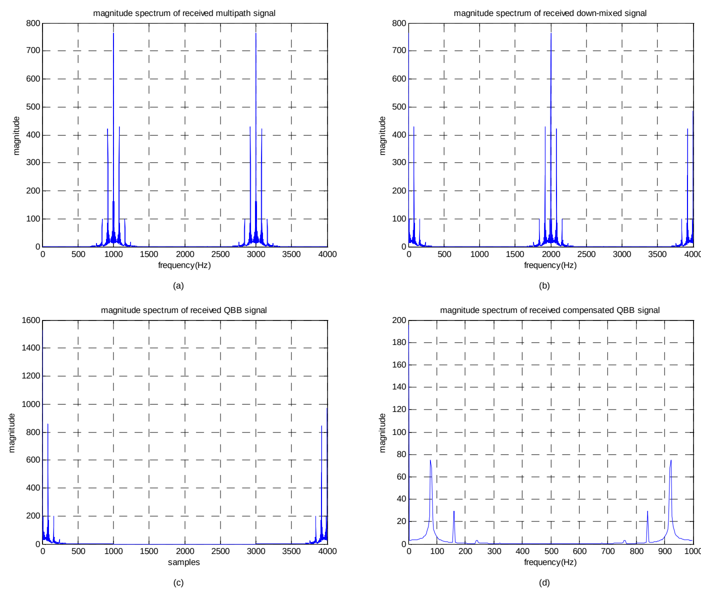

Fig. 8 Magnitude spectra of (a) received multipath signal (b) down-mixed received signal (c) QBB signal (d) Compensated and down-mixed QBB signal

The spectral changes given above start from the receiving end where a real multipath received signal is down-mixed and then lowpass filtered so as to generate a QBB signal. The downsampling was then done and the compensator is moved down to baseband and the compensation implemented at baseband. It is seen in Fig. 8(d) that the sampling rate as reduced by a factor of 4 and hence presenting a major benefit. As mentioned and explained earlier, this presents an advantage of compensating at baseband in that we are now dealing with low sampling rates and hence the compensation complexity is reduced.

V. Conclusion

The FM multipath compensation analysis was analyzed in the chapter and the spectral changes that took place were seen. It therefore suffices to conclude that FM QBB multipath compensation is effective and it comes along with its advantages which make it more preferable than RF QBB multipath compensation. Therefore, latest baseband technologies will be *gaining* on costs and reduced operation complexity by implementing Quadrature baseband multipath compensation. It was observed that the analysis started with a much higher sampling rate and at baseband, the sampling rate was reduced by half and it should be noted that further reduction is possible and the furthest point the downsampling can go is at the point where aliasing begins to occur. Nonetheless, it does suffice to say that QBB compensation surpasses RF compensation in terms of operational advantages. The core advantage of working at QBB is still that of working at Quadrature baseband frequencies which are much lower entailing less complexity of the compensating equipment.

Acknowledgment

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References

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[2] J. H. Reed, “Software Radio-A modern approach to Radio Engineering,” pp 55- 90, Prentice Hall PTR, 2002.