DOPPLER ESTIMATION AND MITIGATION IN OFDM

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ABSTRACT

Due to relative velocity of obstacles with respect to transmitter or receiver packet get compress or expend according to V_r relative velocity. This is Doppler disturbs orthogonality of sub carriers and must be estimated and mitigate at receiver. Since the Doppler encountered is frequency dependent, it is non-uniform for OFDM as it involves a range of frequencies [1]. A two-step approach to mitigating the frequency-dependent Doppler drifts due to fast-varying acoustic acoustic channels is adopted: Non-uniform Doppler compensation via re-sampling. This step converts a "wideband" problem into a "narrowband" problem. High-resolution uniform compensation on residual Doppler by modeling it as induced by carrier frequency offset (CFO)[2]. This step fine-tunes the CFO term corresponding to a "narrowband" model for best ICI reduction. MATLAB simulation for doppler estimation and its mitigation ushing hyperbolic chirp signal is presented in this paper.

Keyword : - *Hyperbolic chirp, Doppler estimation, preamble, postamble, autocorrelation.*

1. INTRODUCTION

The preamble has been chosen so as to have the desirable properties of very high correlation even at negative SNRs as well as low correlation sidelobes [9]. There are several optimum binary sequences which satisfy these properties. A study of different preambles has been conducted as a part of High Speed QPSK Modem. It was found that Hyperbolic chirps also known as linear period modulated (LPM) signal represented by $x(t)=\cos((2*\pi/a)*\log(1+(a*t/T)))$, where $a = (1/f1 - T)/t1$, has the desirable properties of preamble. The salient features of LPM signals are-

- High correlation peak to side-lobe value
- High correlation peak in case of Doppler. The cross-correlation properties between the LPM signal and its Doppler shifted version are shown in Chart1 for Doppler ranging from -300Hz to +300 Hz.

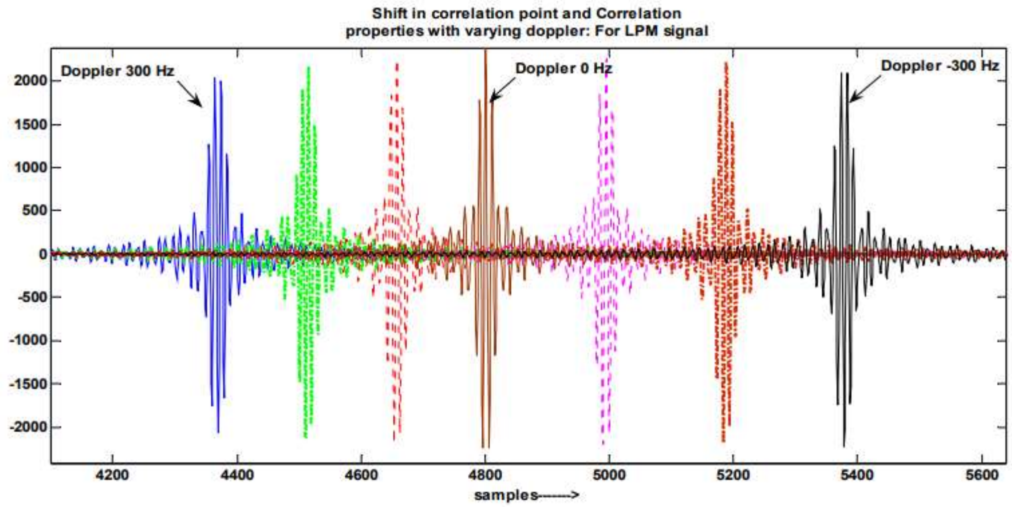

Fig-1: Correlation characteristic of LPM signal with its Doppler shifted version

As can be noted from the chart1 the correlation peak value degradation is insignificant for varying Doppler. Based on the above observations LPM signal (hyperbolic chirp), was chosen to be used as preamble waveform[3] . It was also observed that For LPM signals the correlation peak point extends along the correlation delay axis as a function of Doppler shift [2]. For proper synchronization this delay needs to be estimated and compensated so as to arrive at the correct start point of training sequence. The amount of shift in correlation point as a function of Doppler is shown in figure1.

1.1 Hyperbolic chirp

Hyperbolic chirp is sinusoidal signal whose frequency is continuously changing with time hyperbolically. Hyperbolic chirp is highly immune to Doppler as even after getting a Doppler its spectrum is just shifted but it is still correlate with original signal to much extent[7,8]. That is the reason hyperbolic chirp is used as preamble and postamble of OFDM packet as below

Fig-2: Hyperbolic chirp signal

Here up chirp and down chirp is used as preamble and postamble, so to find the Start and End of the packet. After reception of packet, it is first pass through a matched filter first with up chirp to find the start of Packet then with down chirp to detect end of the packet [5]. Peak in up chirp matched filter signifies the start of packet as up chirp only correlate with up chirp chart 2 shows matched filter output.

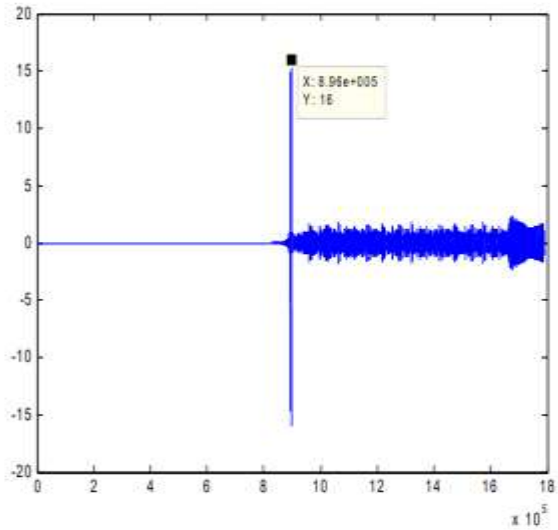

Fig -3: Hyperbolic chirp signal

As shown in chart-3 peak in matched filter is around six time larger than average peaks which is quite significant similarly with down chirp.

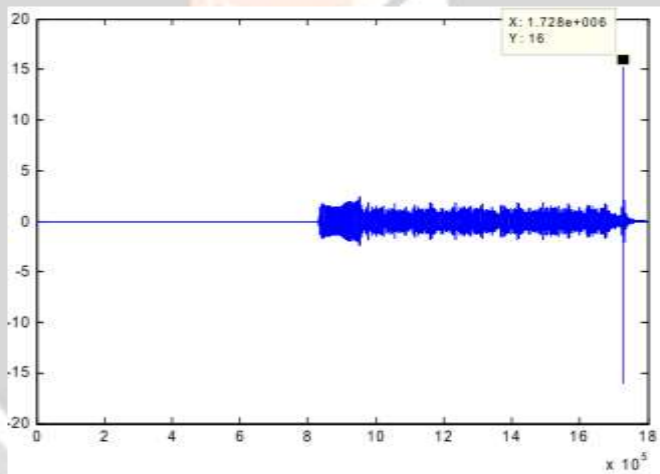

Fig-4: showing Down chirp matched filer output

1.2 Doppler insertion

Due to relative velocity of obstacles with respect to transmitter or receiver packet get compress or expend according to Vr relative velocity. This is Doppler disturbs orthogonality of sub carriers and must be estimated and mitigate at receiver. The received signal is directly sampled and all processing is performed on discrete-time entries.

2. DOPPLER SCALING FACTOR ESTIMATION

Doppler scale coarse estimation is based on the preamble and post-amble of a data packet. This idea has been used in [9] for single carrier transmissions. Via synchronization with the preamble and post-amble, the receiver estimates the time duration of a packet as T_{rx}. The time duration of this packet at the transmitter side is T_{tr}. By comparing T_{rx} with T_{tx}, the receiver infers how the received signal has been compressed or dilated by the channel[6].

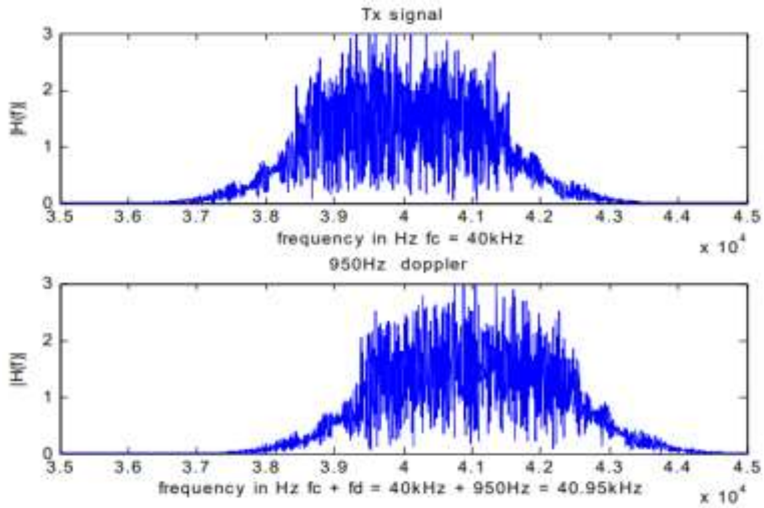

Fig -5 Spectrum displacement due to 950Hz at 40kHz

2.1 Effect of Doppler Compensation

Since the Doppler encountered is frequency dependent, it is non-uniform for OFDM as it involves a range of frequencies [4]. A two-step approach to mitigating the frequency-dependent Doppler drifts due to fast-varying acoustic acoustic channels is adopted. 1) Non-uniform Doppler compensation via re-sampling. 2) High-resolution uniform compensation on residual Doppler by modeling it as induced by carrier frequency offset (CFO).

3. MATLAB SIMULATION FOR DOPPLER ESTIMATION

In simulation a hyperbolic up chirp is added as both preamble as well as postamble to identify the Start and End of packet. Six OFDM symbols are inserted in between out of which two are block training data as shown in the Fig-6.

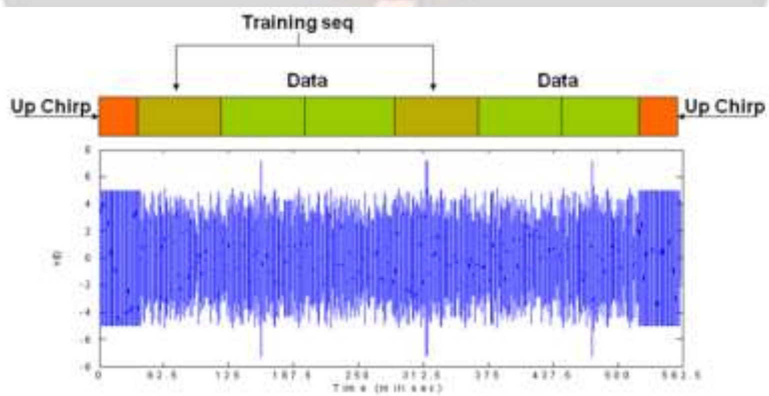

Fig -5 Spectrum displacement due to 950Hz at 40kHz

Block	Samples	Time (ms)
Up chirp	64000	40
Training	128000	80
Data	128000	80
Dn chirp	64000	40

Fd=0Hz

Total duration of packet is 560ms

- Packet duration=518.6ms
- SNR=40dB
- F_s = 1.6MHz
- F_c = 40kHz
- ΔF = 15.625Hz

Match filter wit Up Chirp

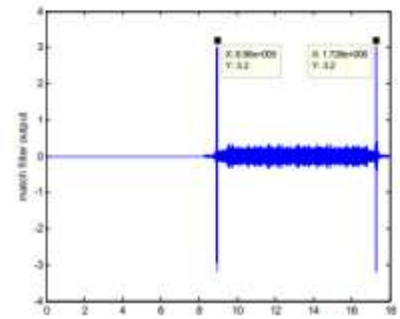

Fig -6 Matched Filter output

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T_{Tx}=5320ms
T_{RX}=520ms

f_{de}= 0Hz;

f_d =100Hz

- Packet duration =518.6ms
- SNR=40dB
- F_s = 1.6MHz
- F_c = 40kHz
- ΔF = 15.625Hz
- v_R = 7.289 knots (Towards)
- Fc Doppler = 100Hz
- F_1 = 95.39Hz
- F_{256} =104.61Hz
- Bw =3.687kHz

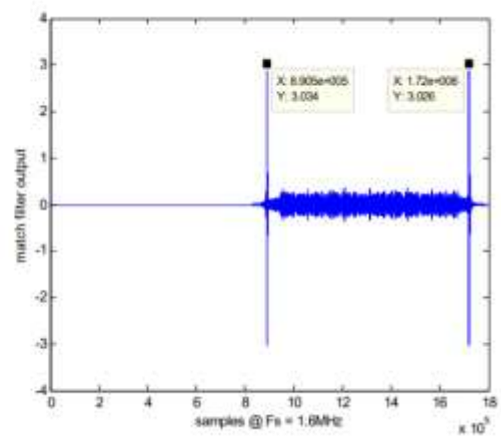

Fig -7 Matched Filter output with up chirp

3.1 Shifting of autocorrelation peak in hyperbolic chirp

Due to Doppler matched filter is not able to find original peak or position of hyperbolic chirp for positive Doppler peak get shifted toward high frequency and vice versa as shown in the Figure 8

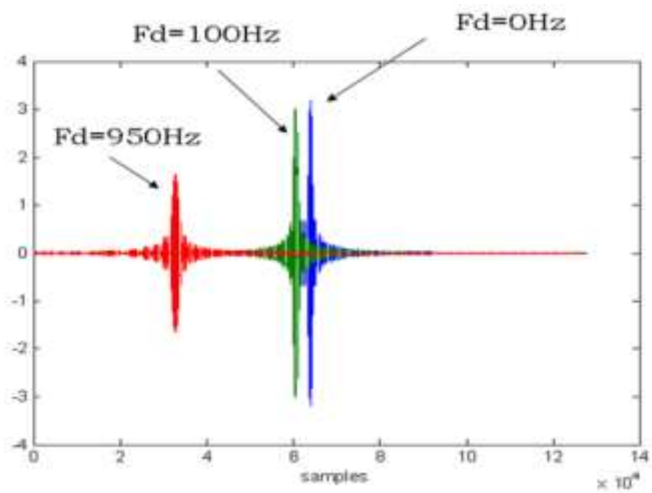

Fig -8 Matched Filter output with up chirp

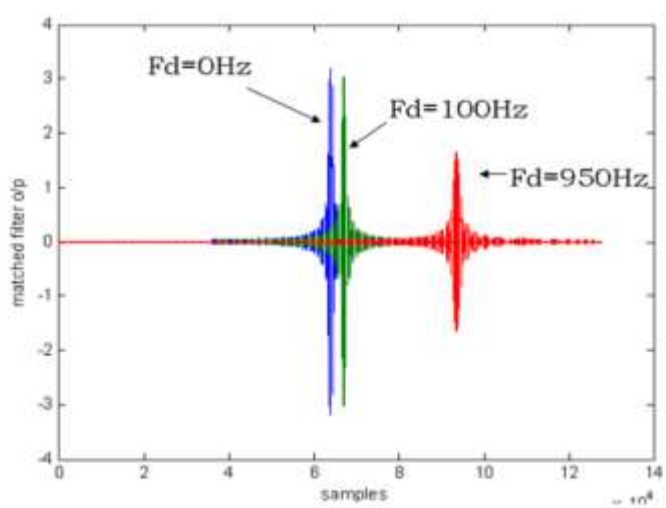

Fig -9 Matched Filter output with up chirp

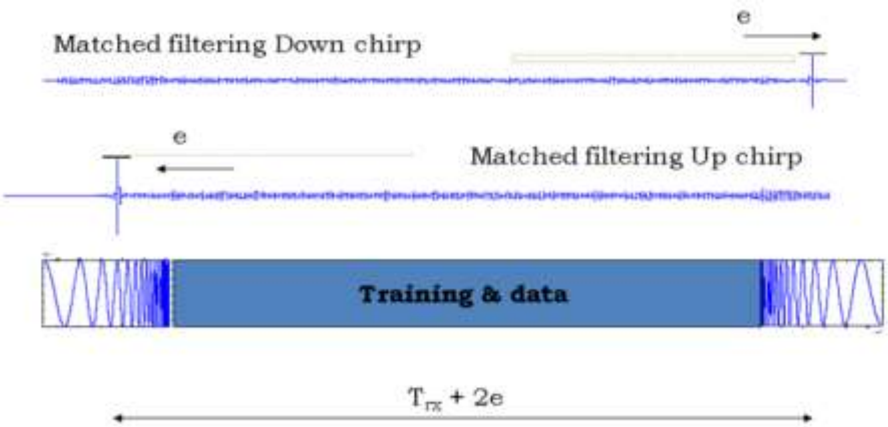

Fig -10 Increase in Trx due to shifting of chirp

Figure 10 showing direction of shifting of matched filter peak in +ve and –ve doppler respectively .As for up chirp and down chirp are taken as preamble and post amble both the matched filter peak get shifted in opposite direction to increase TRx.

4. RESULTS OF DOPPLER MITIGATION

Preamble =Up chirp
Postamble =Up chirp

Doppler (Hz)	BER
20	2.5000e-4
100	3.7500e-4
950	6.2500e-4

Preamble =Up chirp
Postamble =down chirp

Doppler (Hz)	BER
20	2.5000e-4
100	2.500e-4
950	3.7500e-4

Chart 1 Results of doppler mitigation

5. CONCLUSION

Resampling process is able to mitigate Doppler but accuracy in Trx is to be quite high. Up chirp and Down chirp as preamble and postamble respectively performs better after shift compensation. Different preamble and postamble also better in the sense as Start and End of Packet can be separately detected at receiver.

6. REFERENCES

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