Table 1: Simulation Parameters

Parameter	Value
Carrier Frequency	2.0 GHz
Number of Subcarriers	128
Bandwidth	20MHz
Transmitter Velocity	5 Kmph
Training Length	$30-70$
Receiver Velocity	50 Kmph
Angle of Departure	$\mathbb{U}[-\pi, \pi]$
Angle of Arrival	$\mathbb{U}[-\pi, \pi)$
Sampling Interval	1 ms
Number of Paths	5 - 30
Amplitude	$\mathbb{N}(0, 1)$
Phase	$\mathbb{U}(0, 2\pi)$

3.2 Complex Amplitude Estimation

Once the effective Doppler frequencies and delays of arrival have been estimated, the complex amplitudes of the$\hat{K}$ dominant paths are computed via a solution of the set of linear equations in (11) for the first subcarrier. We solve the equations using regularized least squares as

$$\hat{\boldsymbol{\beta}} = (\mathbf{G}^{\dagger}\mathbf{G} + \nu\mathbf{I})^{-1}\mathbf{G}^{\dagger}\hat{\mathbf{h}}(0) \tag{29}$$

where ν is a regularization parameter that is introduced to minimize the effects of errors in $\mathbf{G}$ on the predictor performance. We chose ν empirically in our simulations.

4 Channel Prediction

Using the estimated channel parameters, the mobile to mobile channel impulse response can be predicted into the future by substituting the parameters into (5) for the desired time instant. The predicted channel is given by

$$\tilde{H}(\ell+\Delta, s+\delta) = \sum_{k=1}^{\hat{K}} \hat{\beta}_k \exp(j(\ell+\Delta)\omega_k\Delta_t - j2\pi(s+\delta)\Delta_f\tau_k) \tag{30}$$

where Δ denotes the number of temporal samples ahead to be predicted.

5 Numerical Simulations

In this section, we analyse the performance of the mobile to mobile parametric channel prediction algorithm proposed in this paper. The prediction error of the algorithm is evaluated using the normalized mean squared error (NMSE) criterion[2]

$$\begin{aligned}\text{NMSE}(\tau) &= \frac{\mathbb{E}[|\tilde{h}(\tau) - h(\tau)|^2]}{\mathbb{E}[|h(\tau)|^2]} \\ &\approx \frac{1}{M}\sum_{m=1}^{M} \frac{\sum_{z=1}^{Z} |\hat{h}(\tau) - h(\tau)|^2}{\sum_{z=1}^{Z} |h(\tau)|^2}\end{aligned} \tag{31}$$

where M is the number of snapshots. The wideband doubly selective time-varying channel is generated using the parameters in Table 1 (except where otherwise stated). In Figure 3, we plot the amplitude (i.e gain) of the frequency selective mobile to mobile channel. It shows that the channel exhibits both time and frequency variation. A similar observation is made in Fig. 4 where we plot the phase (in radians) of the mobile to mobile channel. Compare to previous results on fixed to mobile cellular systems, the temporal variation of the mobile to mobile channel is relatively faster. This is due to the additional Doppler spread introduced by the mobility of the transmitter. This agreed with observations in [2, 3] where it was also shown that mobile to mobile channels has significantly different statistics. In Figure 5, we present a plot of the actual and estimated delays and effective Doppler frequencies for one realization of the channel at SNR=20dB. As can be observed from the plot, the algorithm produces very accurate estimates of the channel parameters for all the paths present in the channel. Figure 6 shows a plot of the actual and predicted channel gains at SNR=20dB for prediction horizon up to 0.5s. We observe the our algorithm is able to track the amplitude of the channel accurately even for such long prediction range. This is a tremendous improvement over previously reported methods for fixed to mobile systems. Similarly, figure 7 presents the actual and predicted phase of the channel for the same prediction horizon. We observed that the phase angle prediction is also very accurate except for a single instant where the algorithm produces some errors in the phase. A typical variation of the channel across the frequency samples is shown in figure 8 where we plot the channel amplitude versus frequency values. We observe that our algorithm is also able to predict the channel accurately for all frequency instants. This is expected, since the algorithm utilizes both the temporal and frequency statistics of the channel to aid the prediction. Finally, we present the normalized mean square error versus prediction length for different SNR values in Figure 9. We observe that the prediction error increases with increasing prediction length and decreases with increasing SNR. A plausible explanation for this is that as you travel away from the prediction point, it becomes more difficult to predict the channel accurately and the parameter estimation accuracy improves

[2]The NMSE in our simulation is averaged over all the subcarriers in the wideband system.

with increasing SNR.

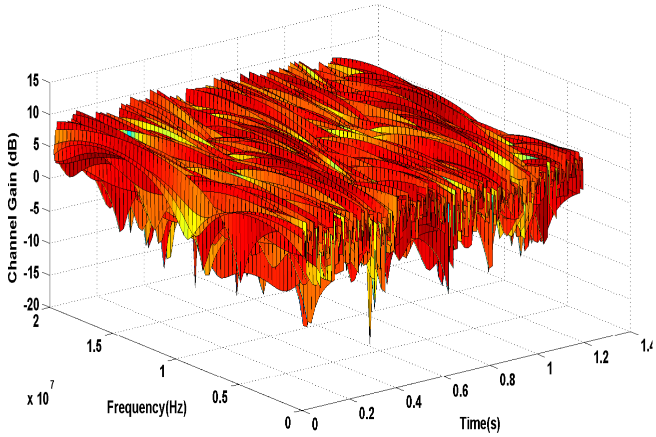

Figure 3: Amplitude of wideband mobile to mobile channel showing temporal and frequency variations of the channel.

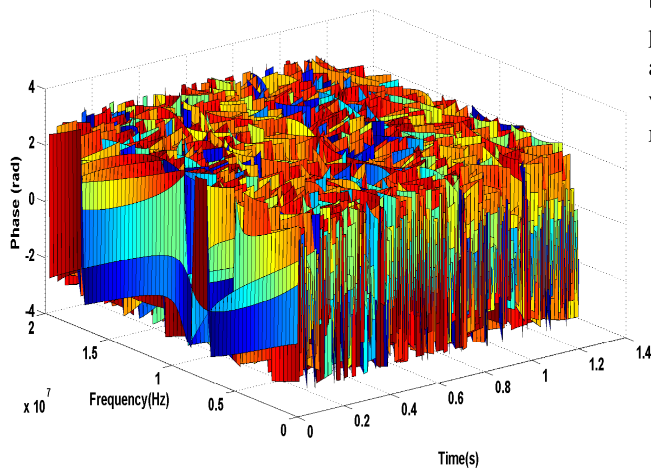

Figure 4: Phase plot of a realization of the doubly selective mobile to mobile channel.

6 Conclusion

In this paper, we have proposed a novel algorithm for the multipath parameter estimation and channel state prediction for doubly selective mobile to mobile wireless channel. Using the classical statistical model for mobile to mobile propagation, we derive a parametric model for jointly estimating the delay of arrival and effective Doppler frequencies of the multipath channel. An ESPRIT based approach is proposed for the joint parameter extraction and the estimated parameters were used to extrapolate the channel in

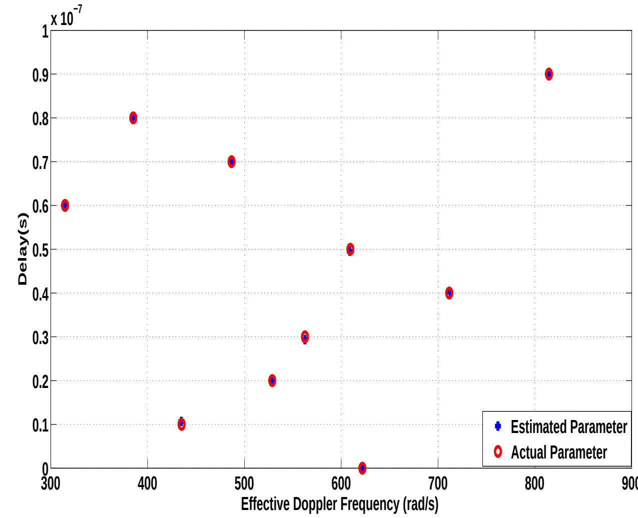

Figure 5: Actual and estimated delays and effective Doppler frequencies for a wideband mobile to mobile channel with ten propagation paths at SNR $= 10\,$dB.

both time and frequency. Simulation results show that the proposed scheme can high accurate parameter estimation and long range prediction of the fading channel. Future work will analyse the performance of the algorithm using measured channel data and system level simulations.

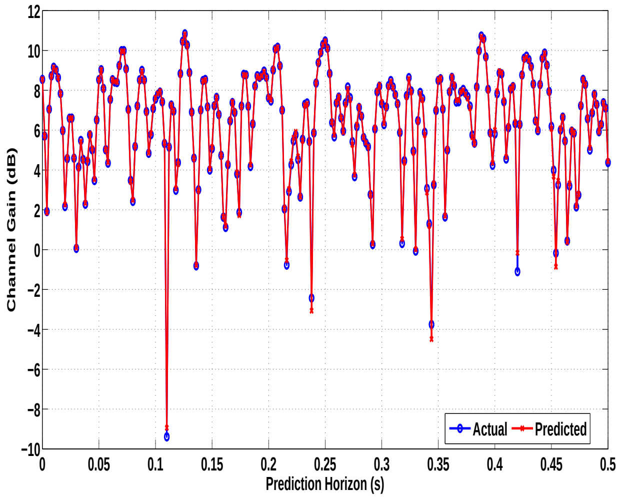

Figure 6: Actual and predicted channel gain for the 10th subcarrier of a wideband mobile to mobile channel at $\mathrm{SNR} = 20\,\mathrm{dB}$ using 100 known samples of the channel for predictor initialization.

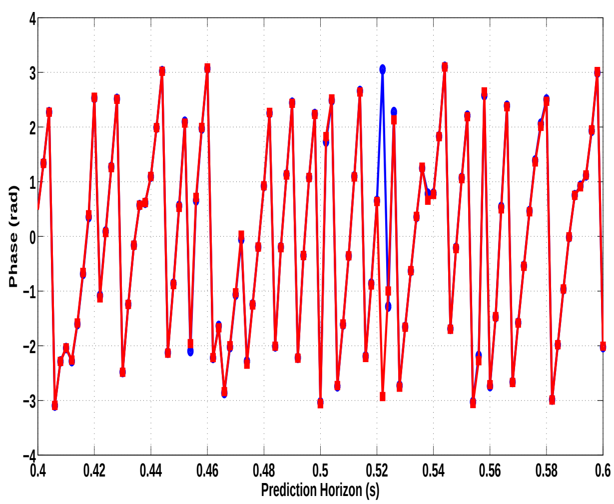

Figure 7: Actual and predicted phase for the 10th subcarrier of a wideband mobile to mobile channel at $\mathrm{SNR} = 20\,\mathrm{dB}$ using 100 known samples of the channel for predictor initialization.

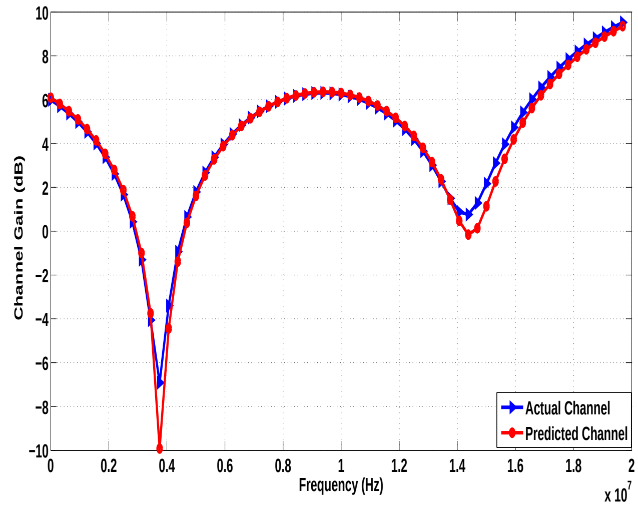

Figure 8: Actual and predicted frequency variation of a wideband mobile to mobile channel at the 580th symbol duration at $\mathrm{SNR} = 20\,dB$.

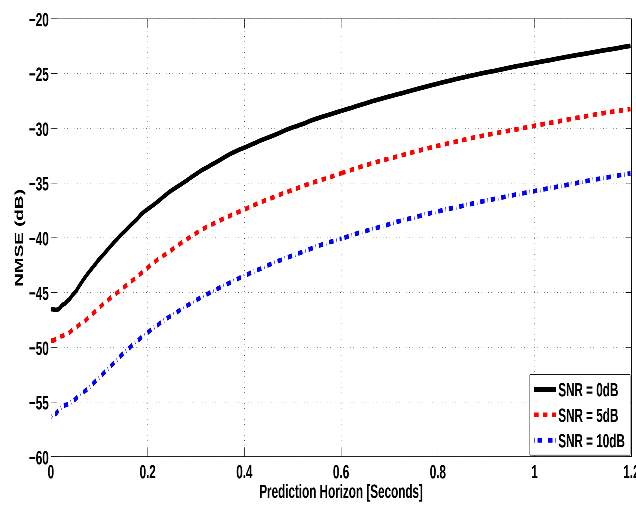

Figure 9: Normalized mean square error versus prediction horizon (s) for wideband mobile to mobile channel prediction using the proposed algorithm at SNR= $[0, 5, 10]$dB.

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