

**Project: IEEE P802.15 Working Group for Wireless Personal Area Networks (WPANs)**

**Submission Title:** [CSS over Multipath]

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**Re:** []

**Abstract:** []

**Purpose:** [Introduce CSS Technology for BAN Application]

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# Chirp-Spread-Spectrum over Multipath

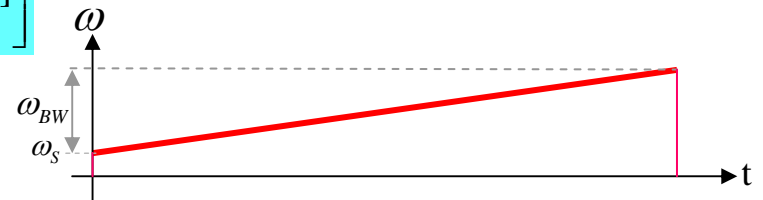
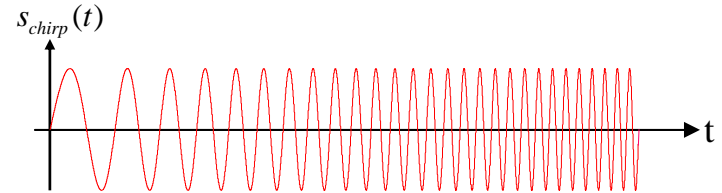
2007. 11. 15.

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kyunglee@orthotron.com

## Chirp Signal

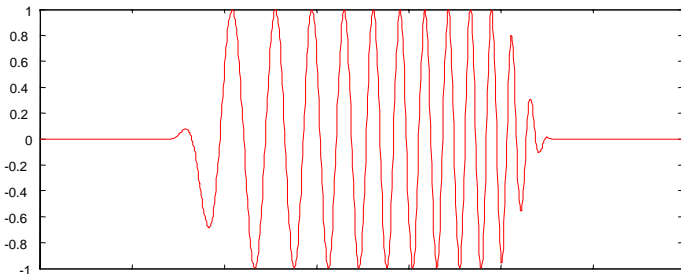
### Linear Chirp: Rectangular Window

$$s_{chirp}(t) = \text{Re} \left[ \exp \left[ j \left( \omega_s + \frac{\omega_{BW}}{2T_{chirp}} t \right) t + j\theta_0 \right] \times [u(t) - u(t - T_{chirp})] \right]$$

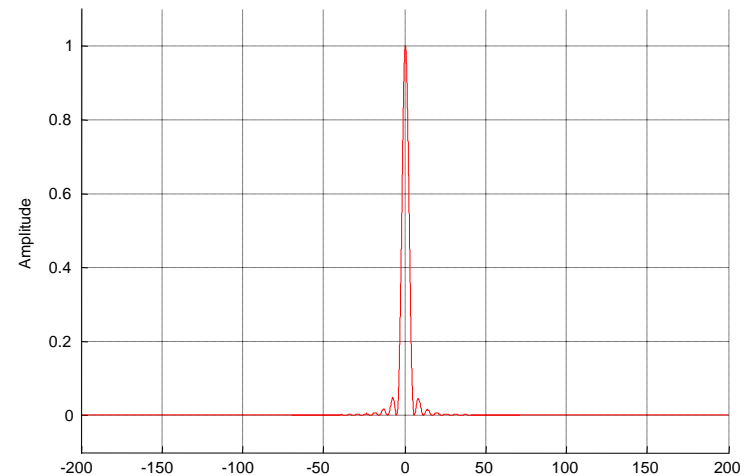


### Linear Chirp: Raised-Cosine Window

$$s_{chirp}(t) = \text{Re} \left[ \exp \left[ j \left( \omega_s + \frac{\omega_{BW}}{2T_{chirp}} t \right) t + j\theta_0 \right] \times p_{RC}(t) \right]$$

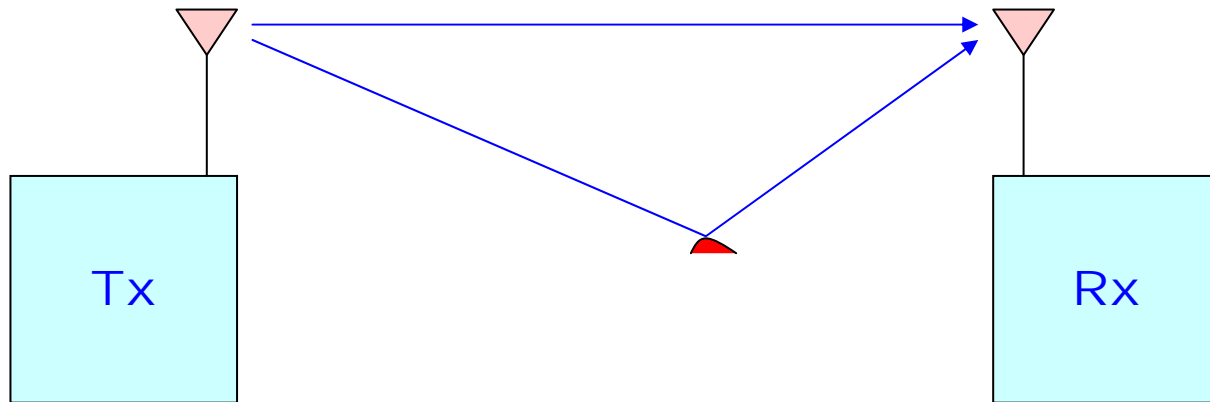


Correlation Property of Chirp Signal

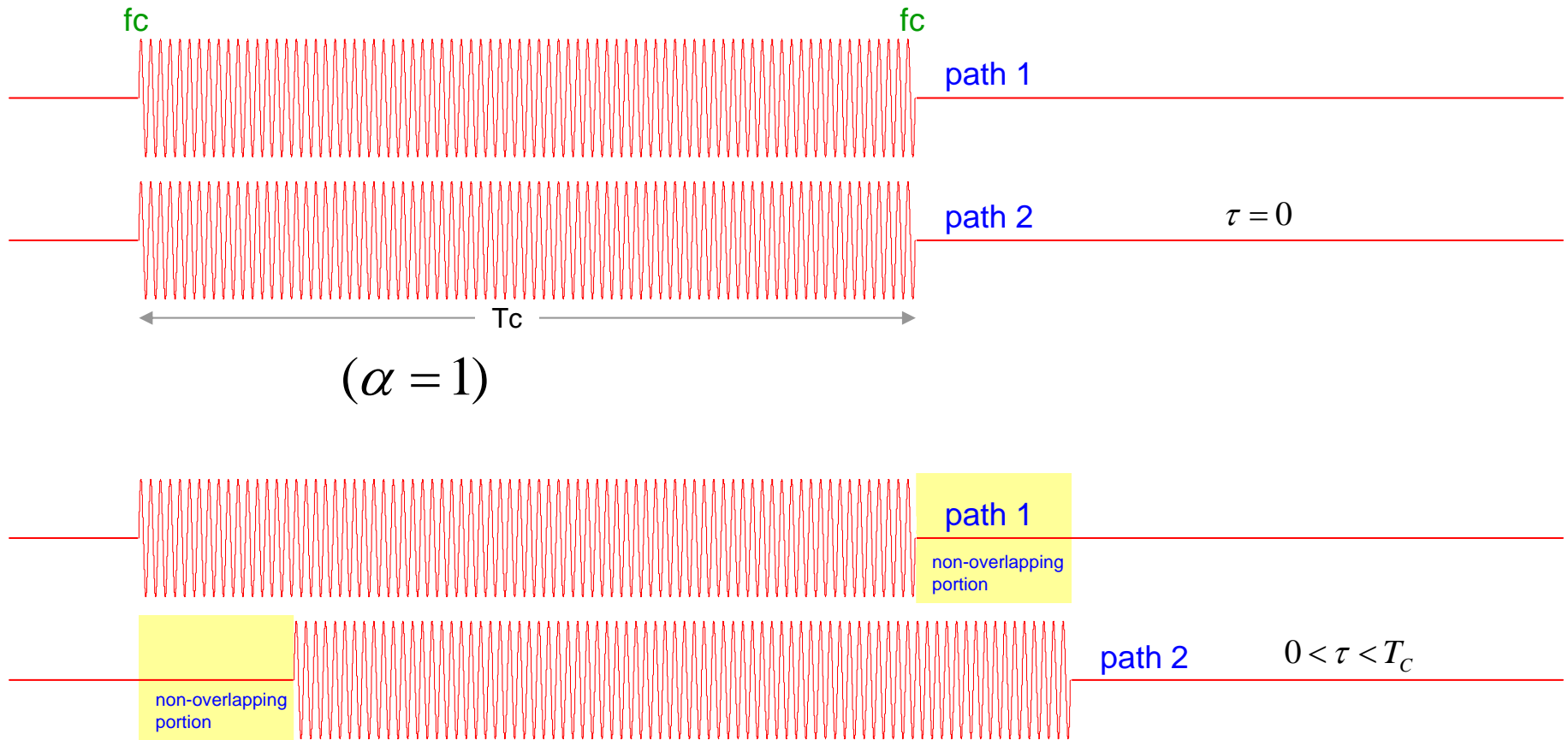


## Two-path Model

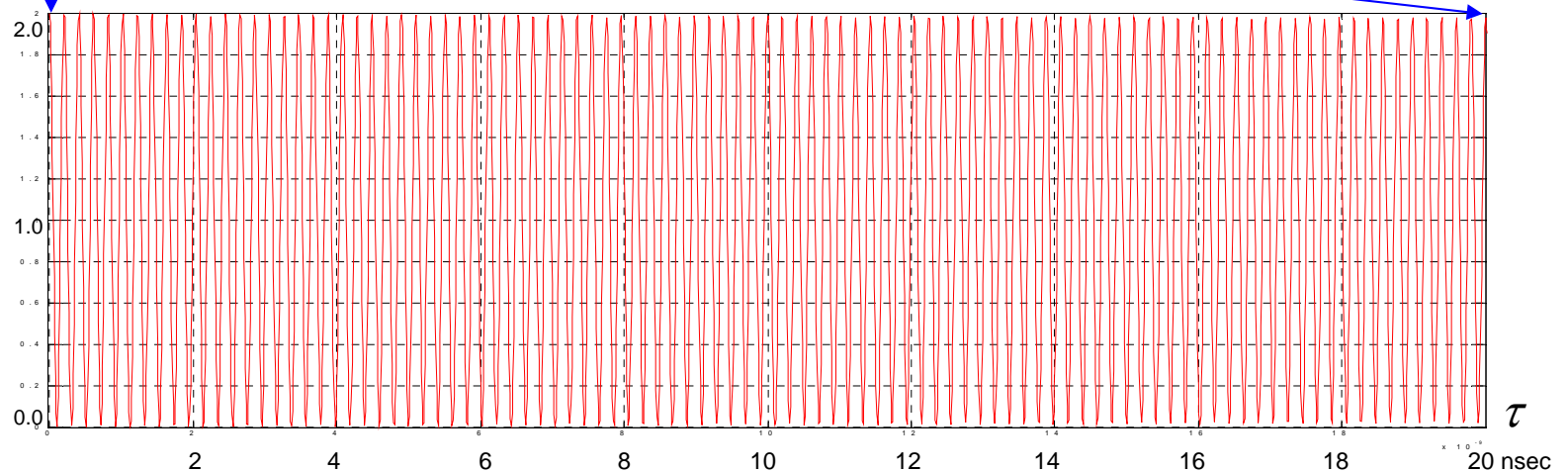
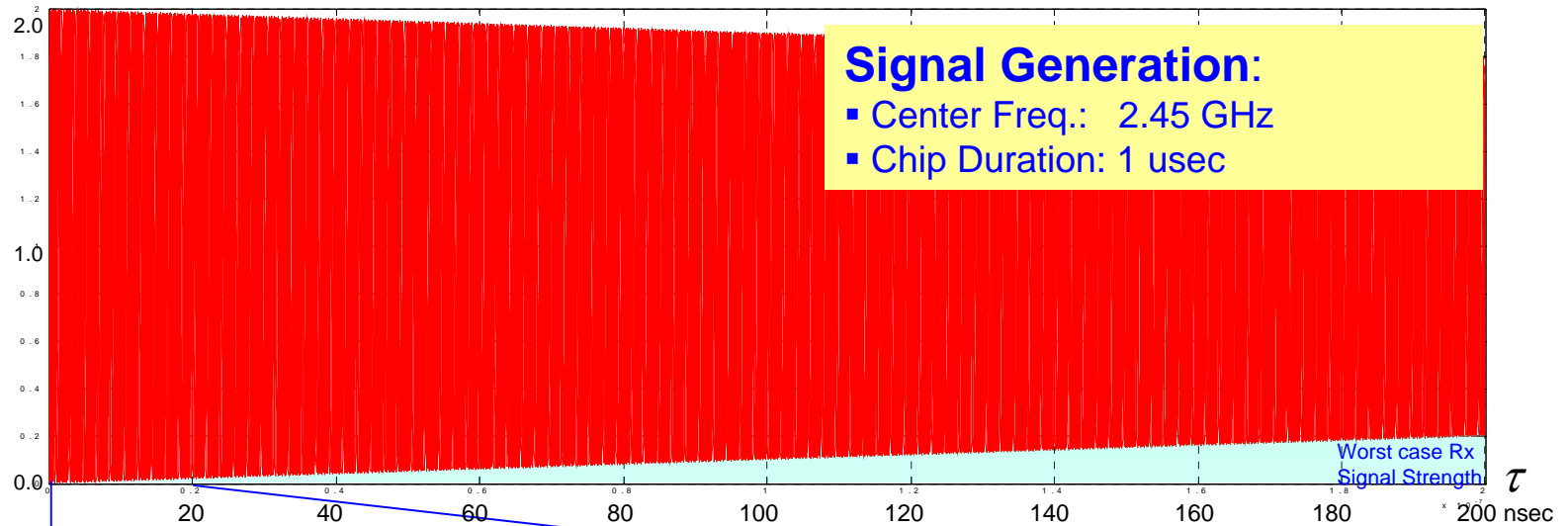
$$h(t) = \delta(t - T) + \alpha \cdot \delta(t - T - \tau)$$



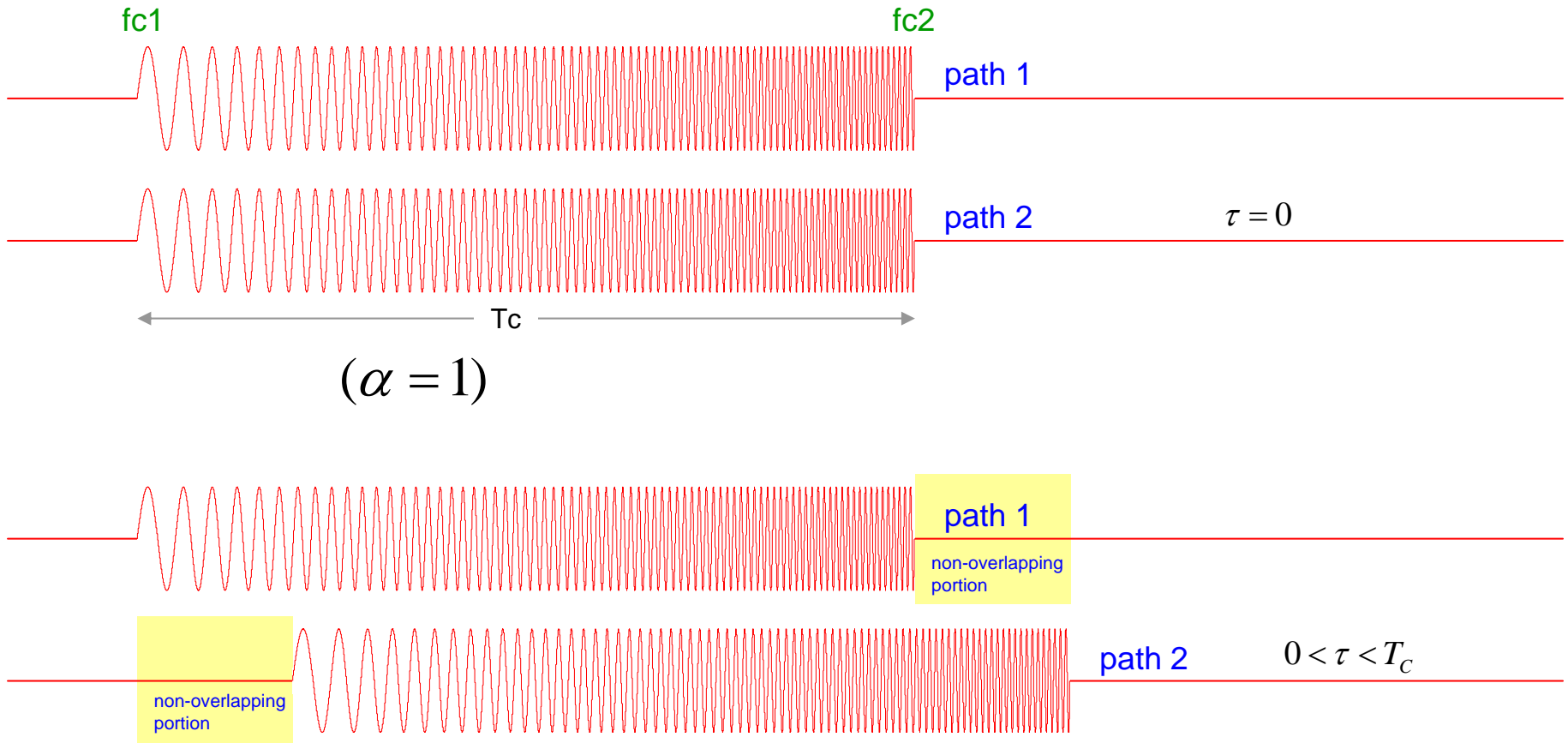
## 2-path Combining Property of Isolated DSSS



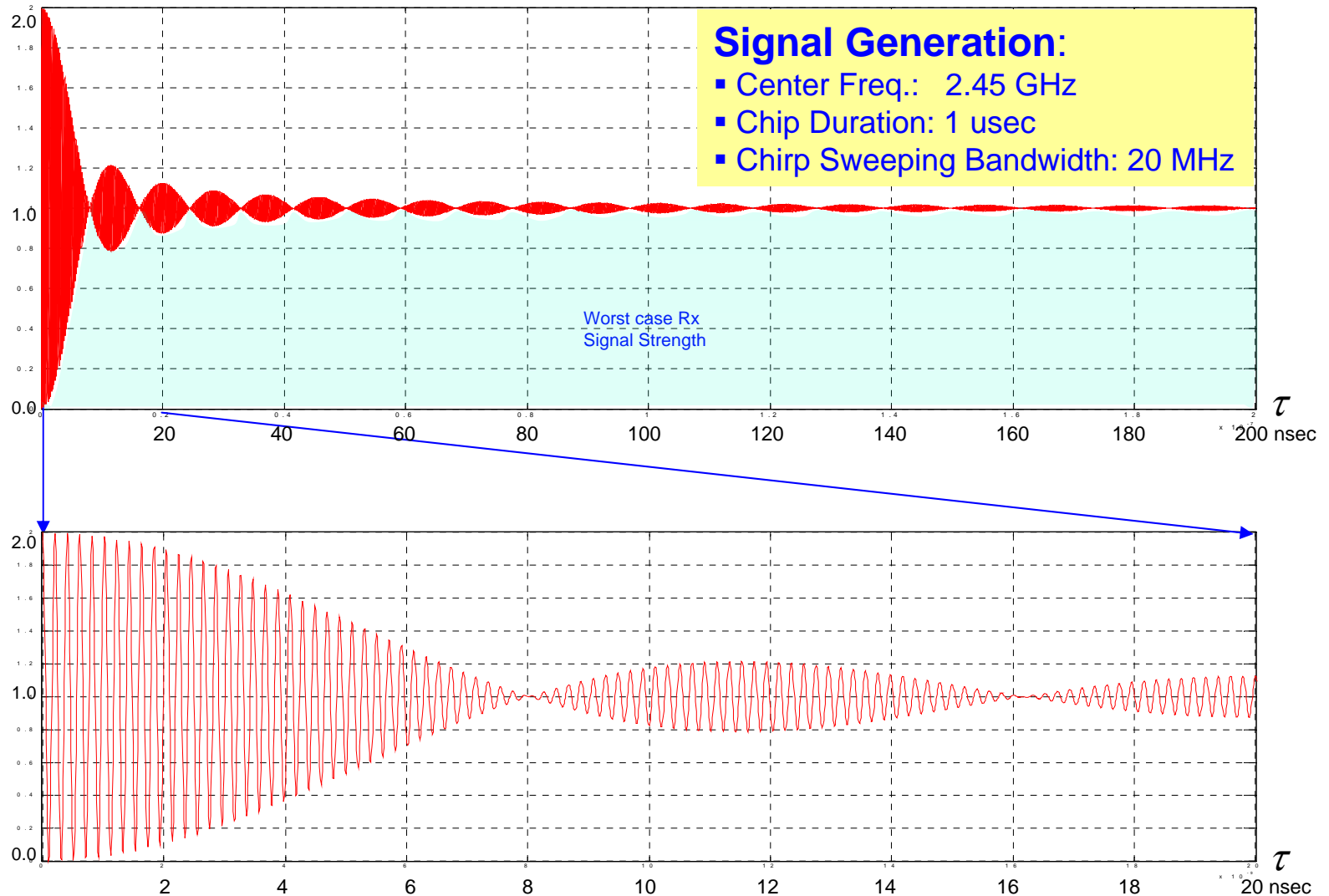
## 2-path Combining Property of Isolated DSSS



## 2-path Combining Property of Isolated CSS



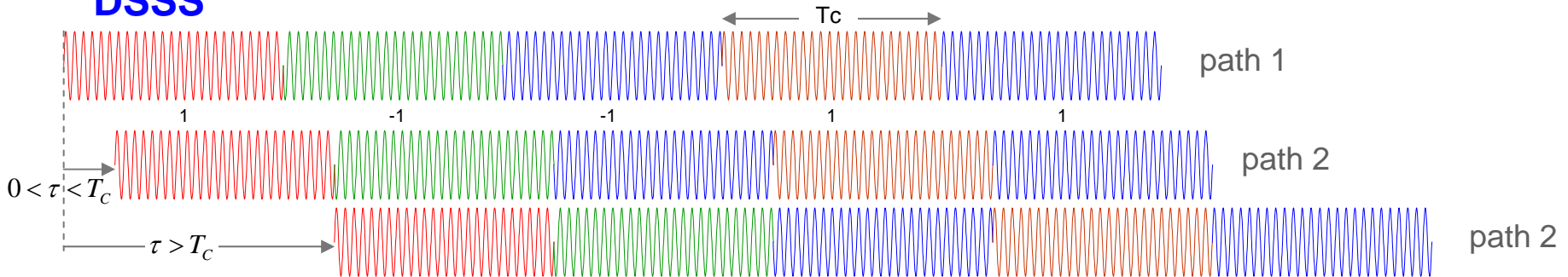
## 2-path Combining Property of Isolated CSS





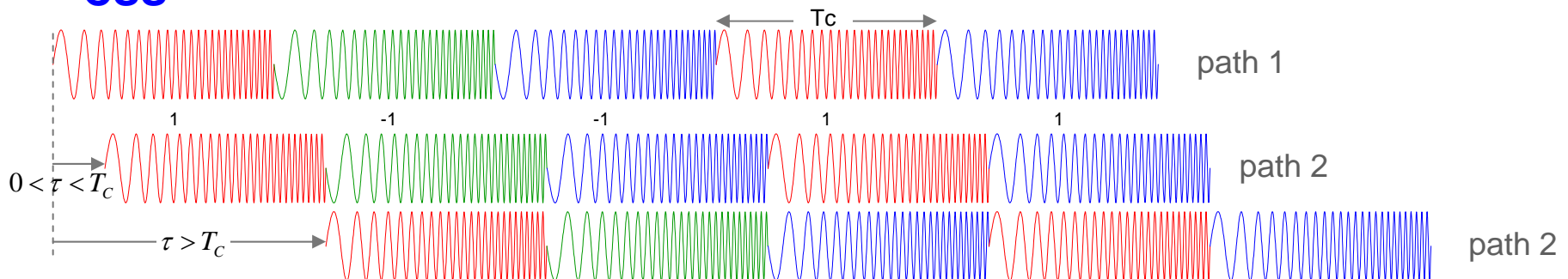
## DSSS vs CSS

### DSSS



- $0 < \tau < T_{chip}$ : Not Resolvable
- $\tau > T_{chip}$ : Resolvable

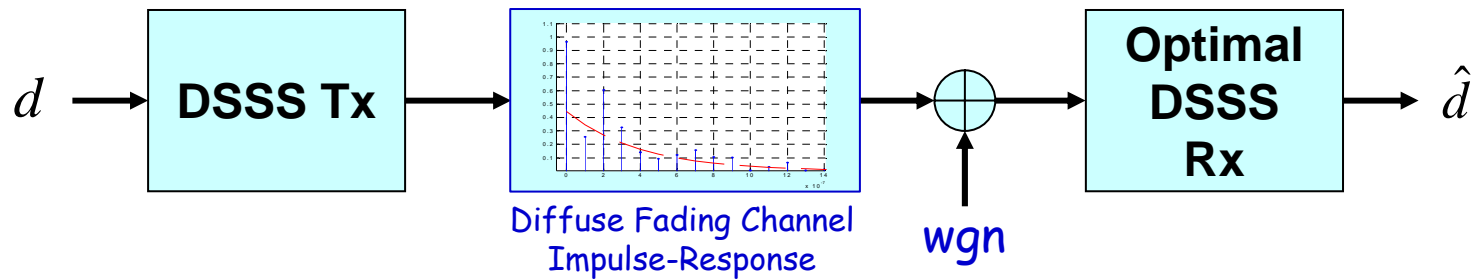
### CSS



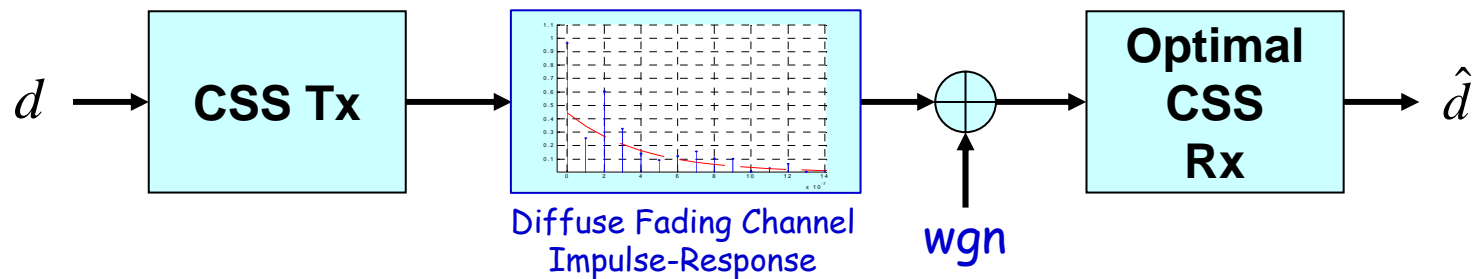
- $0 < \tau < T_c$ : Resolvable
- $\tau > T_c$ : Resolvable

## Performance over Exponential Diffused Channel

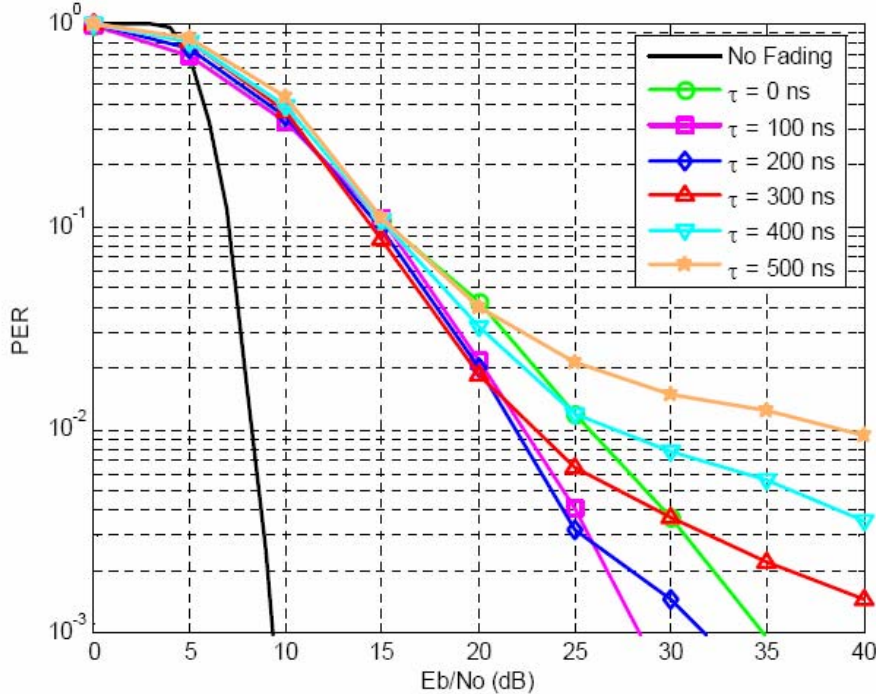
### DSSS Transceiver



### CSS Transceiver

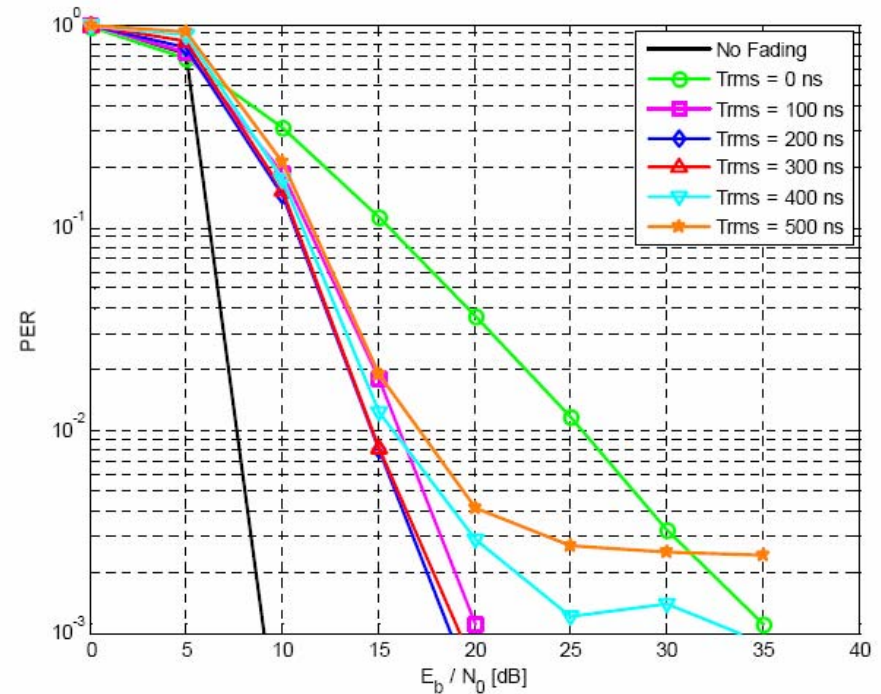


## PER over Exponential Diffused Channel



**IEEE 802.15.4 Performance  
(250Kbps)**

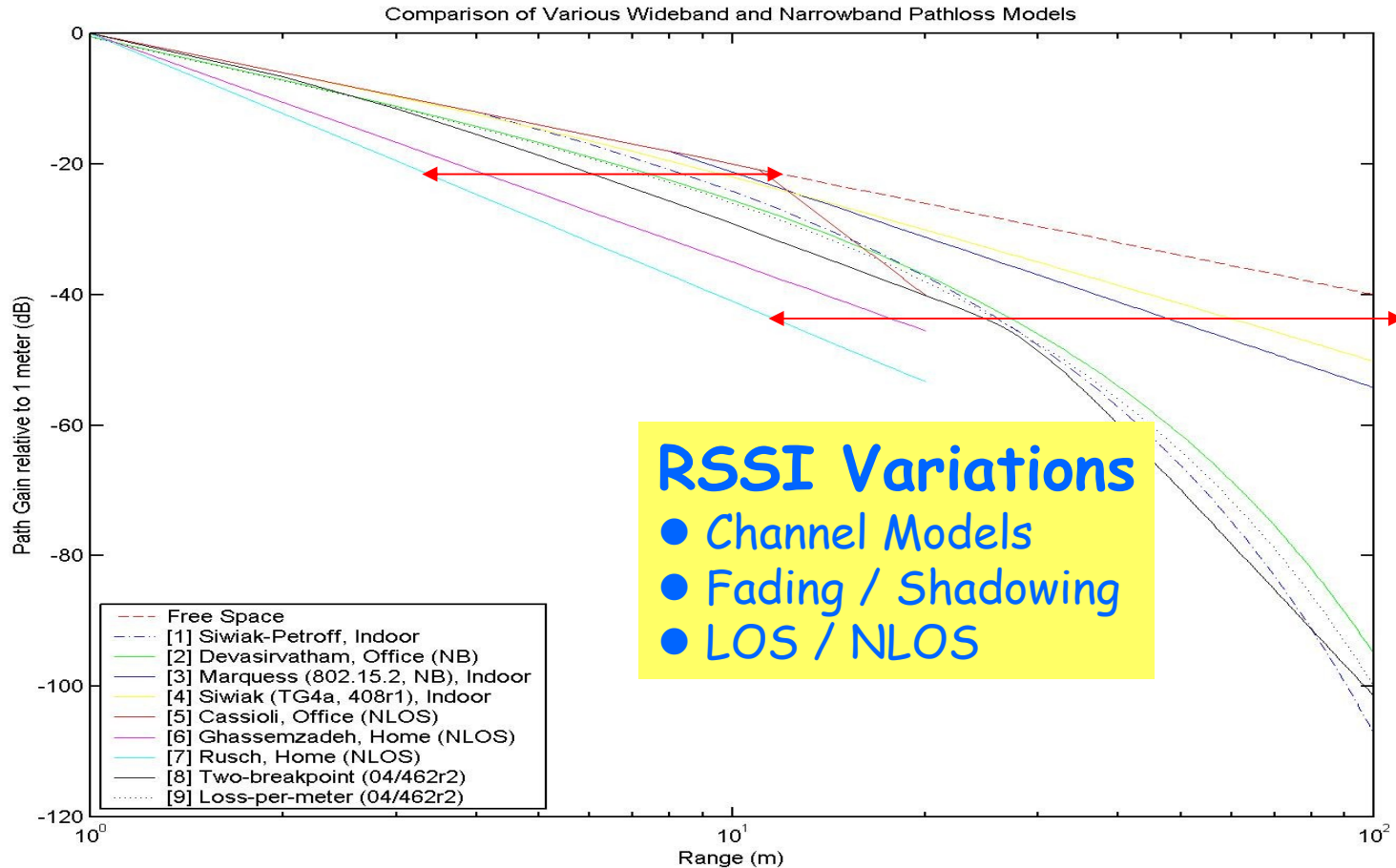
Reference: IEEE15-04-0337-00-004b



**IEEE 802.15.4a Performance  
(1 Mbps)**

Reference: IEEE 15-06-0116-01-004a

## RSSI Ranging: Poor Accuracy



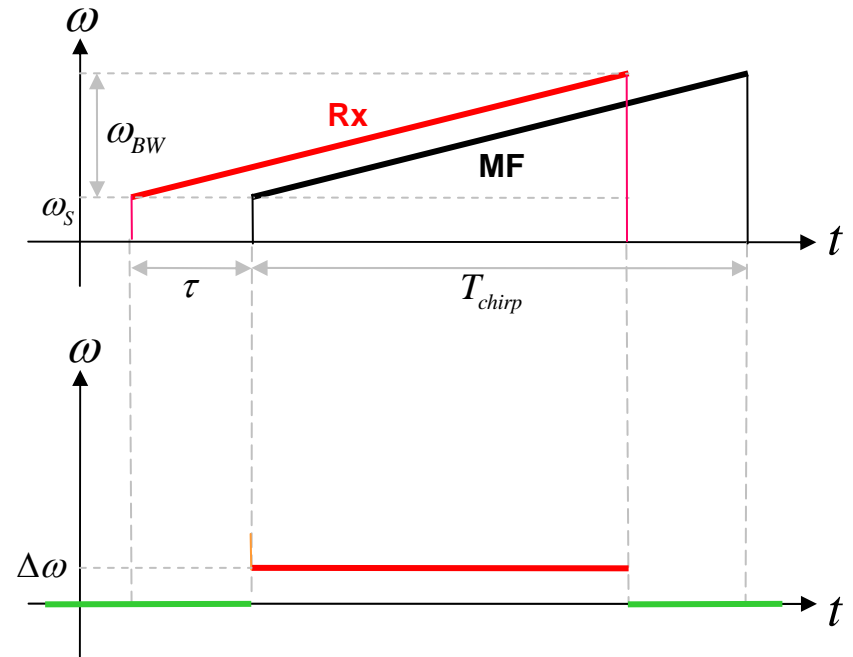
## Ranging with CSS: ToA/TDoA

### Property of Chirp-Signal

$$\tilde{s}_{chirp}(t) = \exp \left[ j \left( \omega_s + \frac{\omega_{BW}}{2T_{chirp}} t \right) t \right] \times p(t)$$

Freq-offset ( $\Delta\omega$ ) caused by Time-offset ( $\tau$ ):

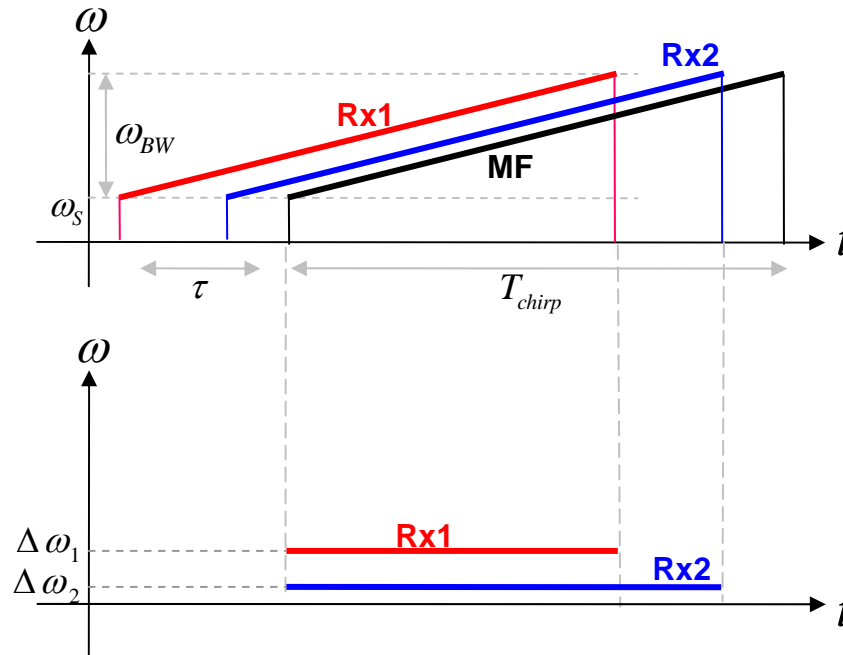
$$\Delta\omega = \frac{\omega_{BW}}{T_{chirp}} \times \tau \quad (\text{Single Frequency})$$



MF: Matched Filter

## Ranging with CSS: ToA/TDoA

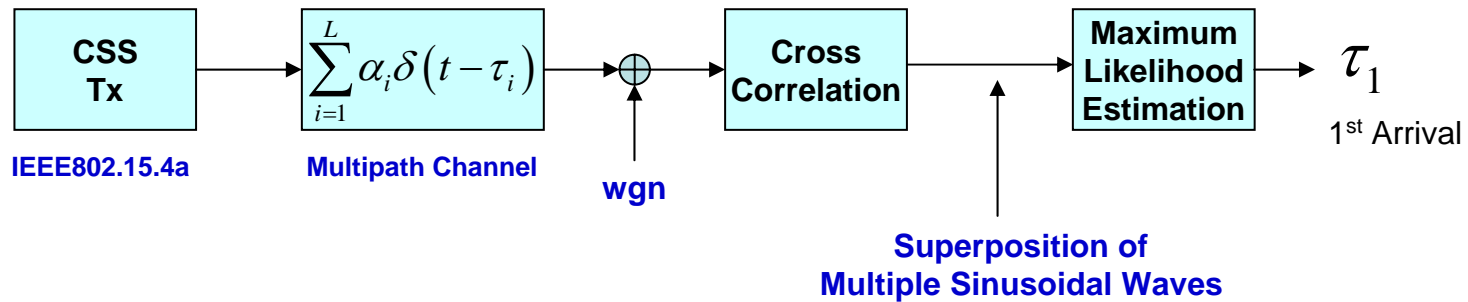
### Property of Chirp-Signal



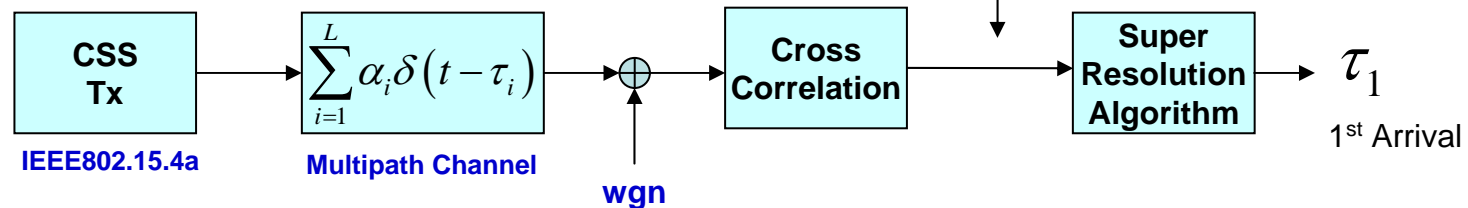
MF: Matched Filter

## High Precision Ranging with CSS

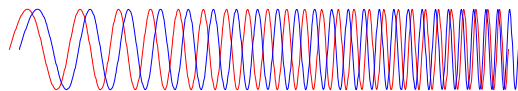
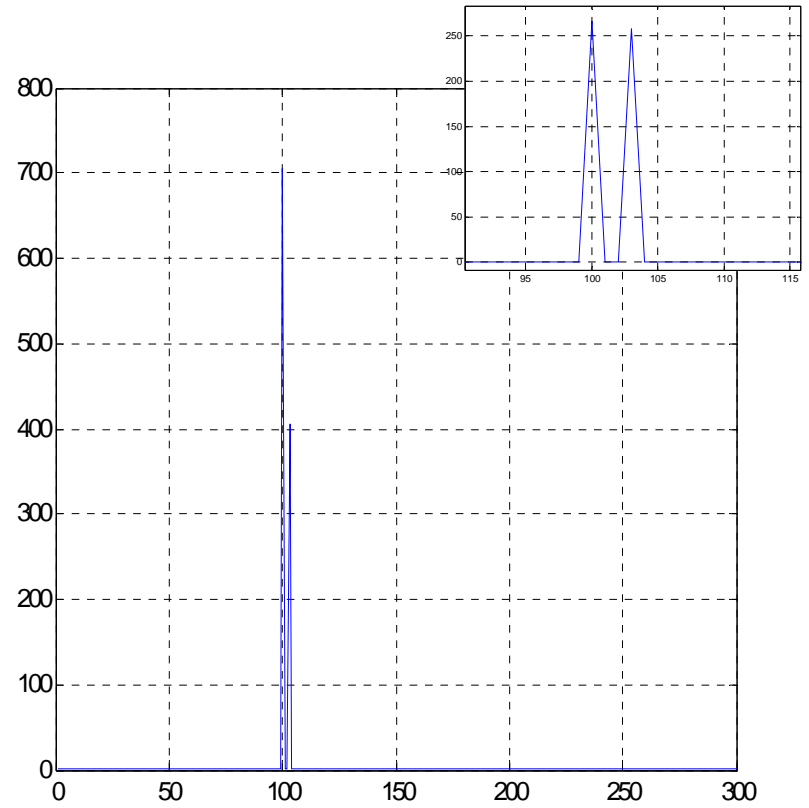
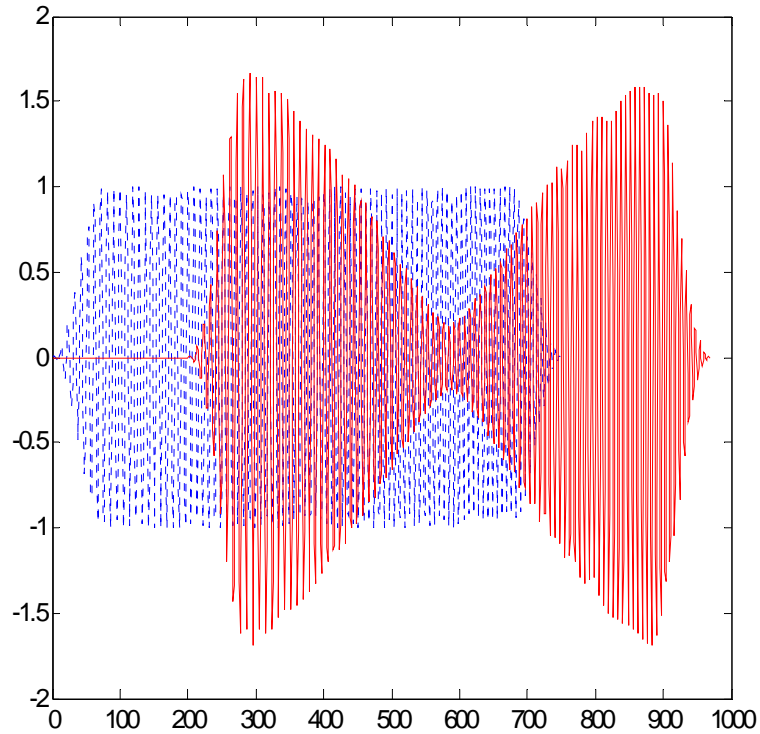
### Maximum Likelihood Estimation



### Subspace-based Method



## High Precision Ranging with CSS





## Conclusion

- CSS Signal is Robust over Harsh Multipath Environment
- CSS Signal has Very Good Indoor Multipath Resolvability
- Advantage for both Data Communication and Ranging
- Good Solution for Narrowband High-Precision Ranging
- Less Demand of Heavy FEC Coding for Reliability