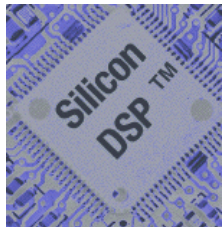


# Intersymbol Interference OFDM Modulation

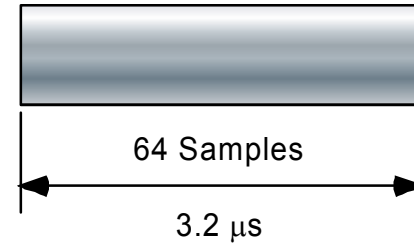
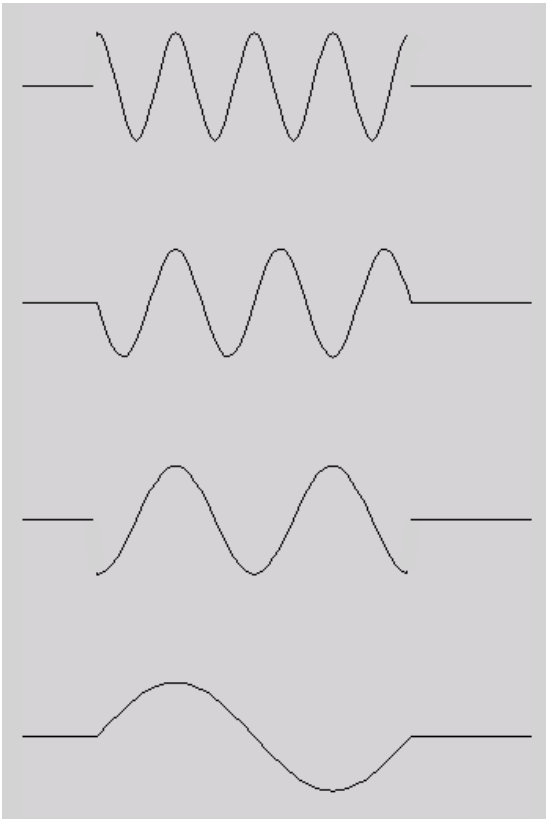
## Cyclic Prefix (Guard Interval)

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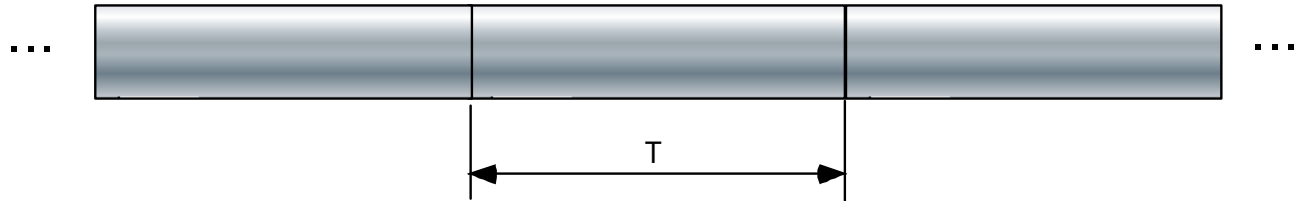


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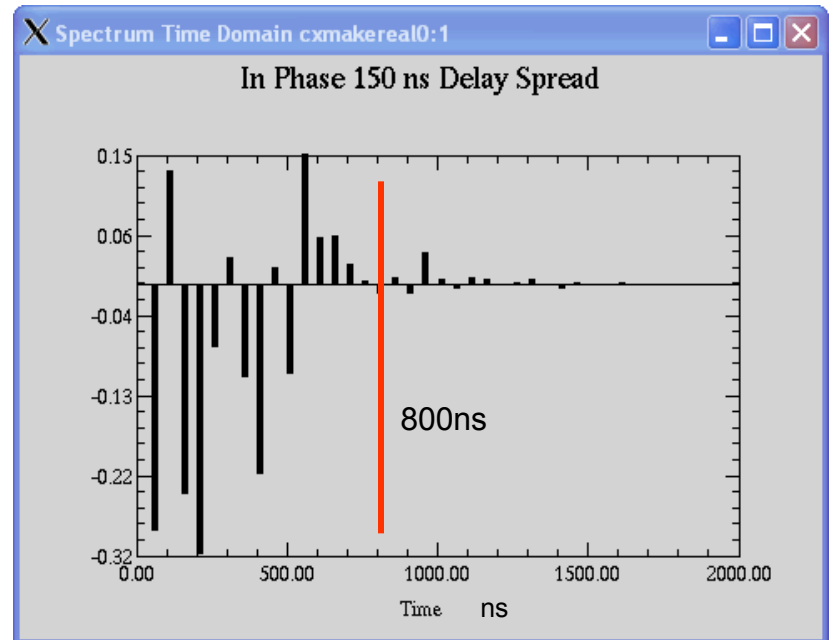
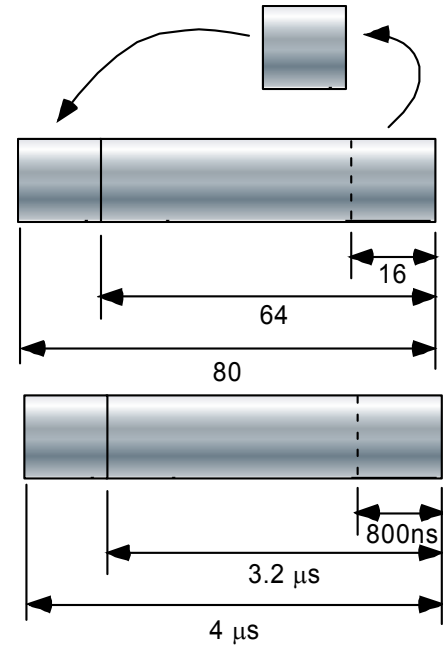
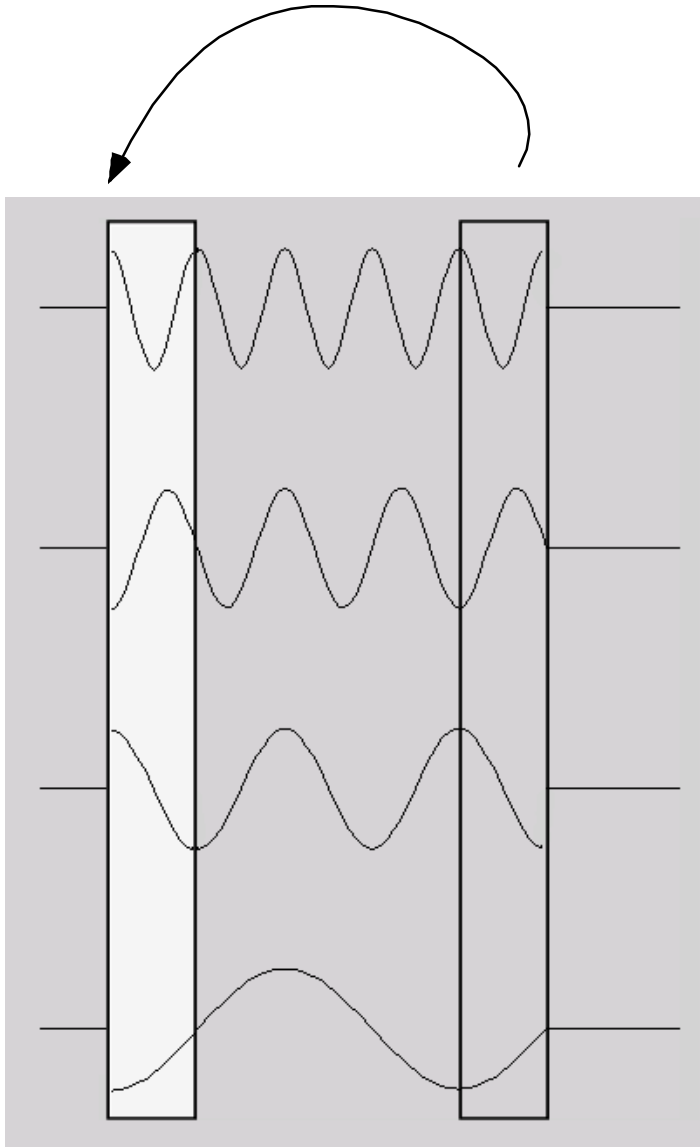
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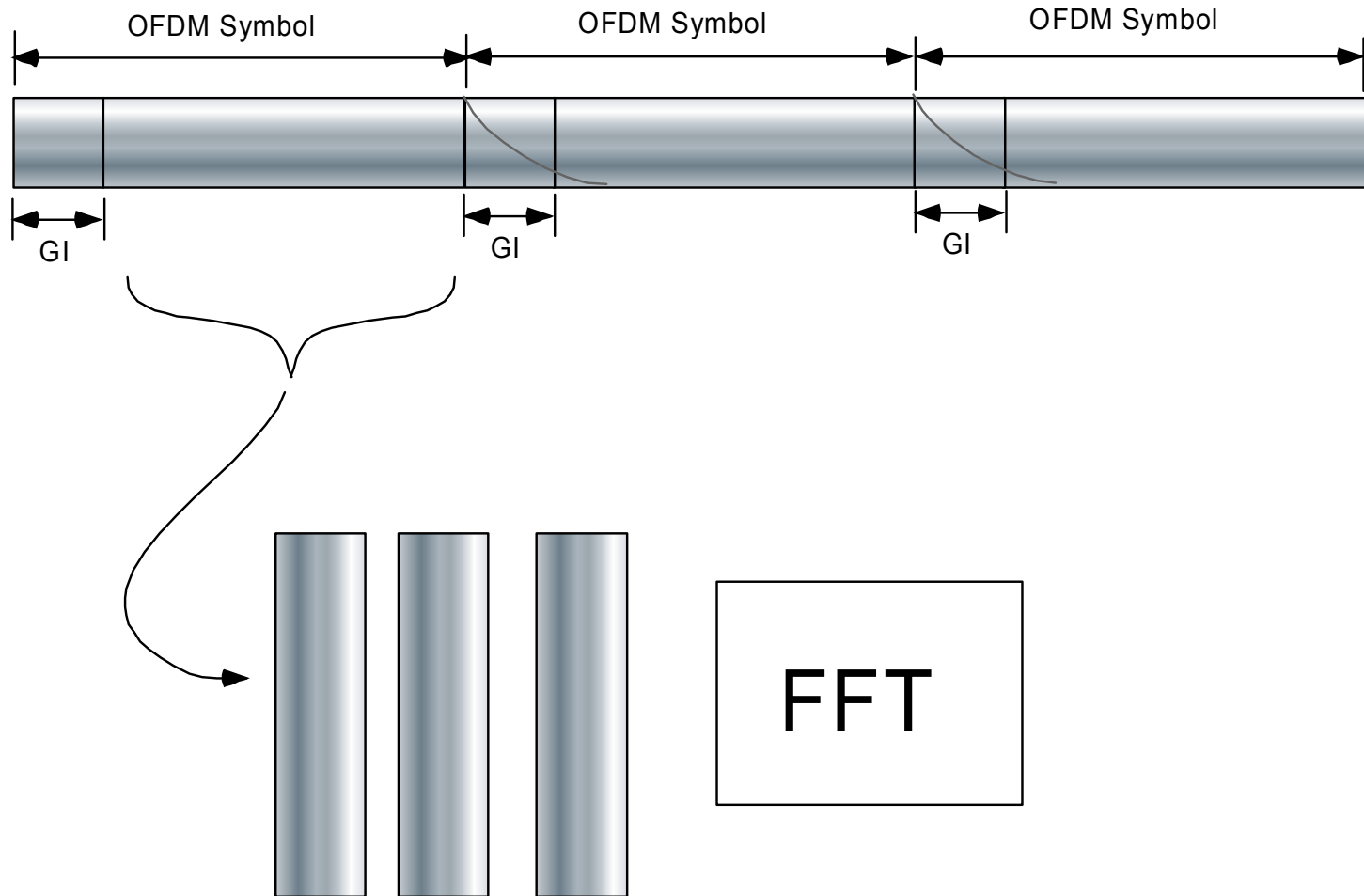
$\Delta f = 312.5 \text{ kHz}$



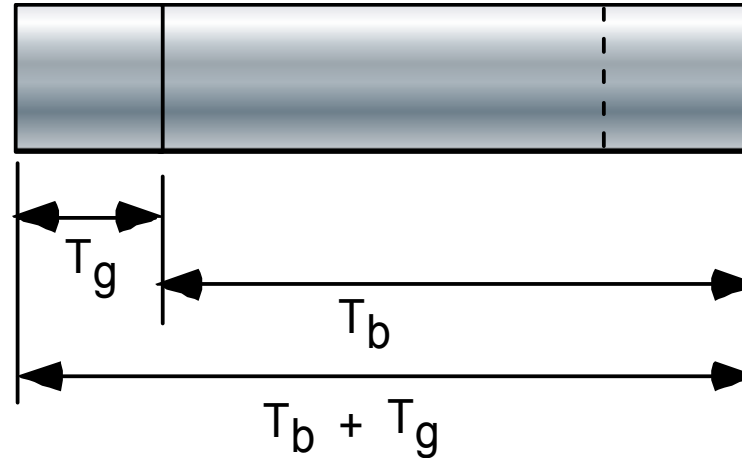
# Cyclic Prefix



# Cyclic Prefix (Guard Interval)



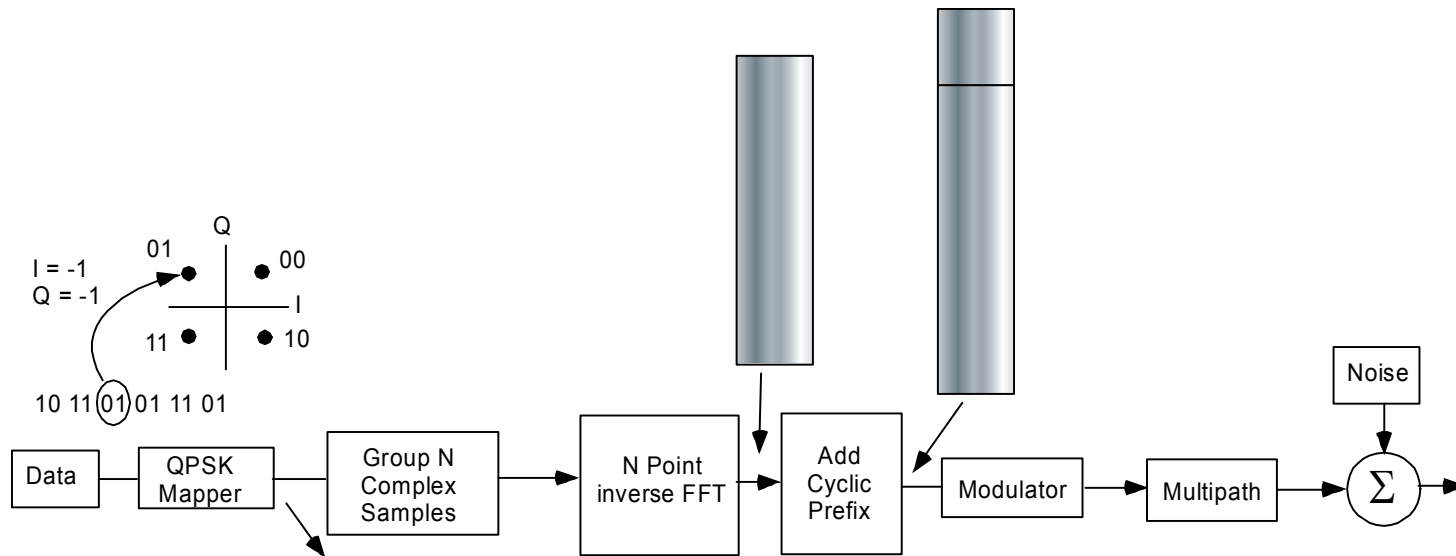
# SNR Loss Due to Cyclic Prefix



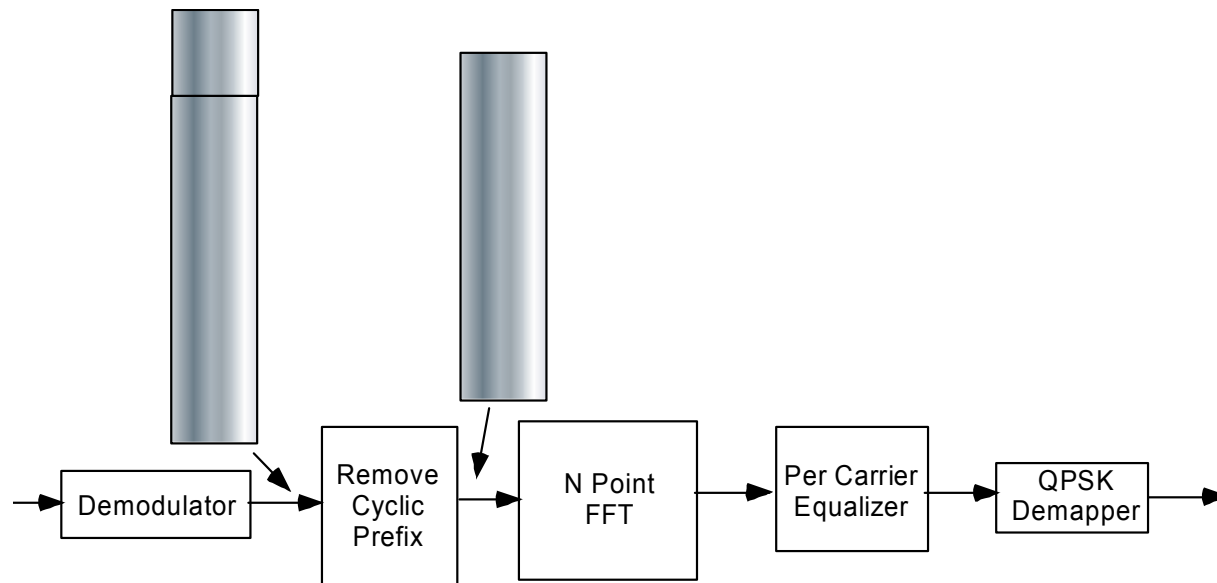
$$10 \log_{10} \left( 1 - \frac{T_g}{T_b + T_g} \right) \text{ dB}$$

For IEEE802.11a the loss is 0.97 dB or close to 1 dB

# OFDM Modulation/Demodulation

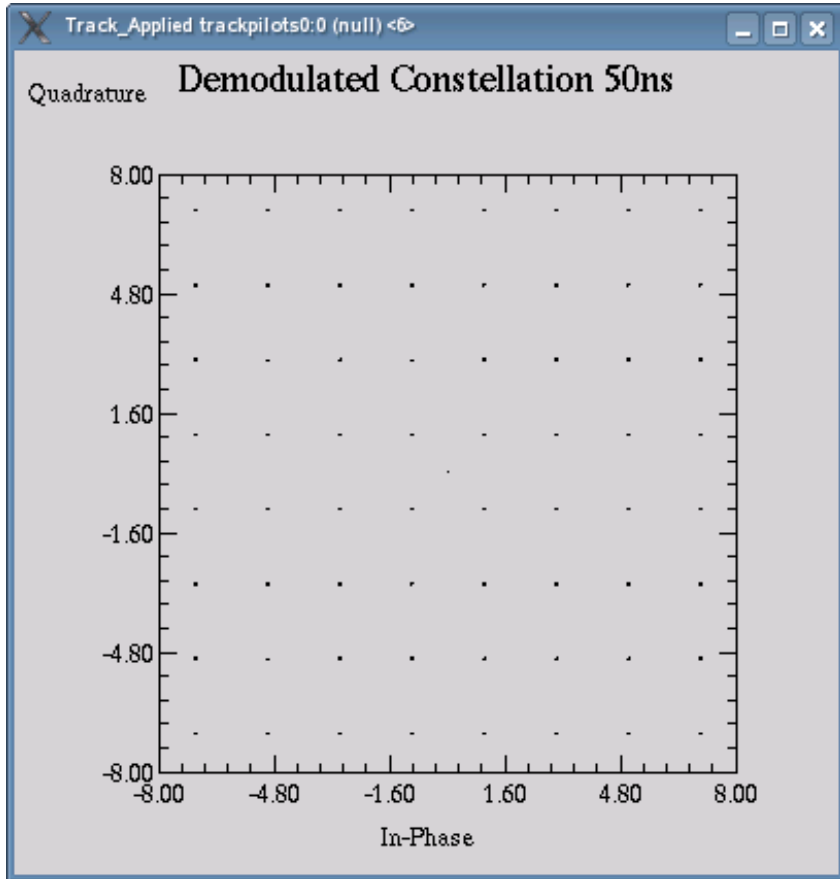


$$X_k = I_k + jQ_k$$

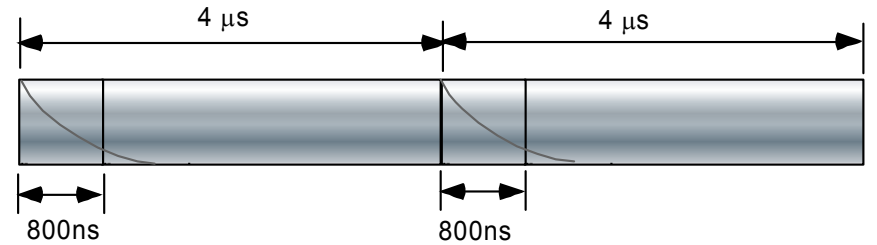
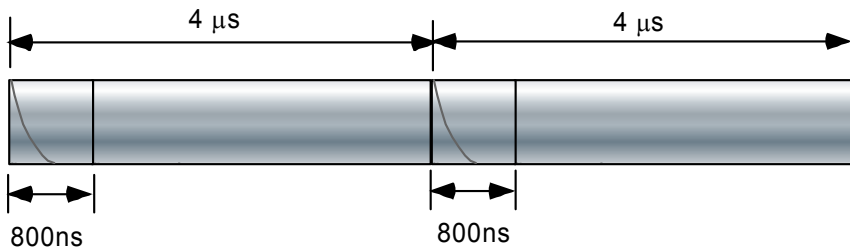
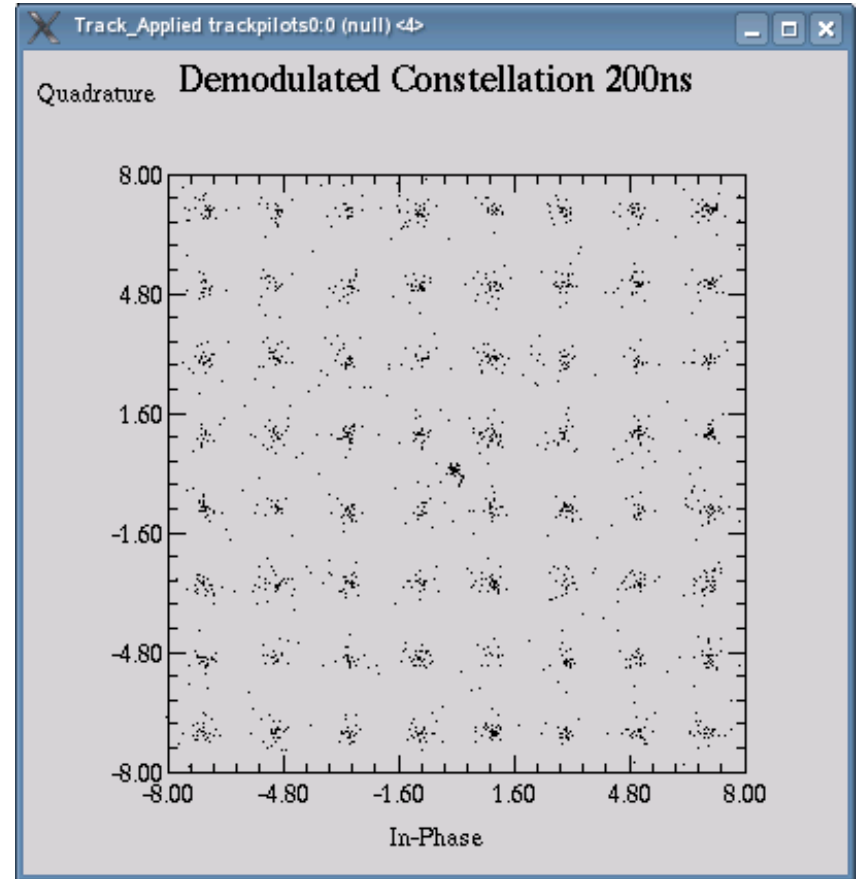


# Examples of ISI with Cyclic Prefix

## 50ns Delay Spread

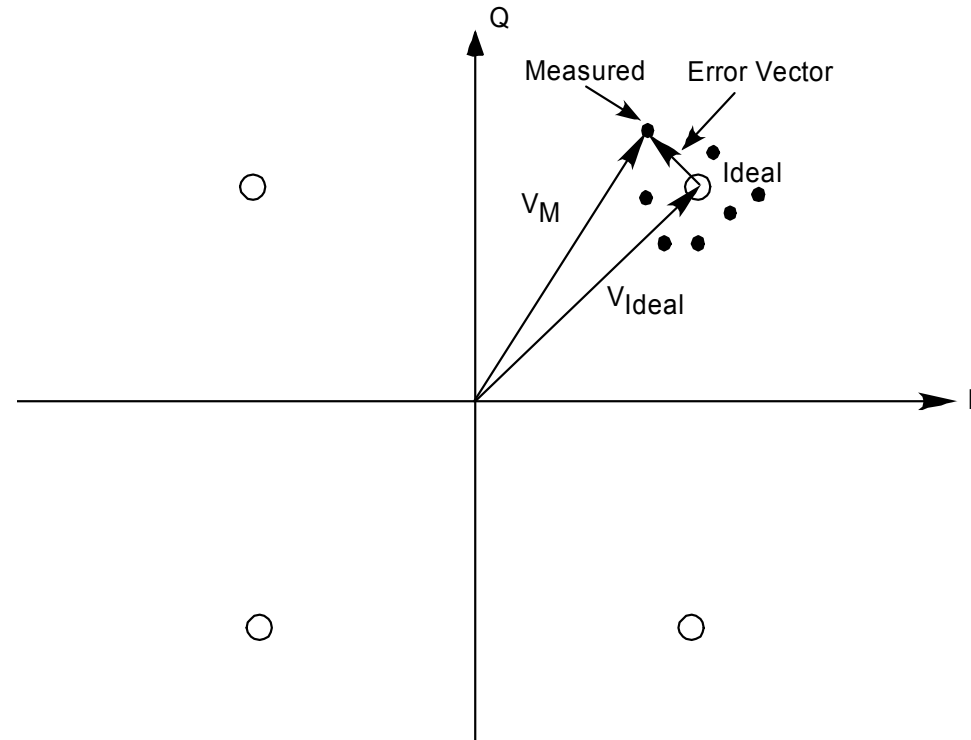
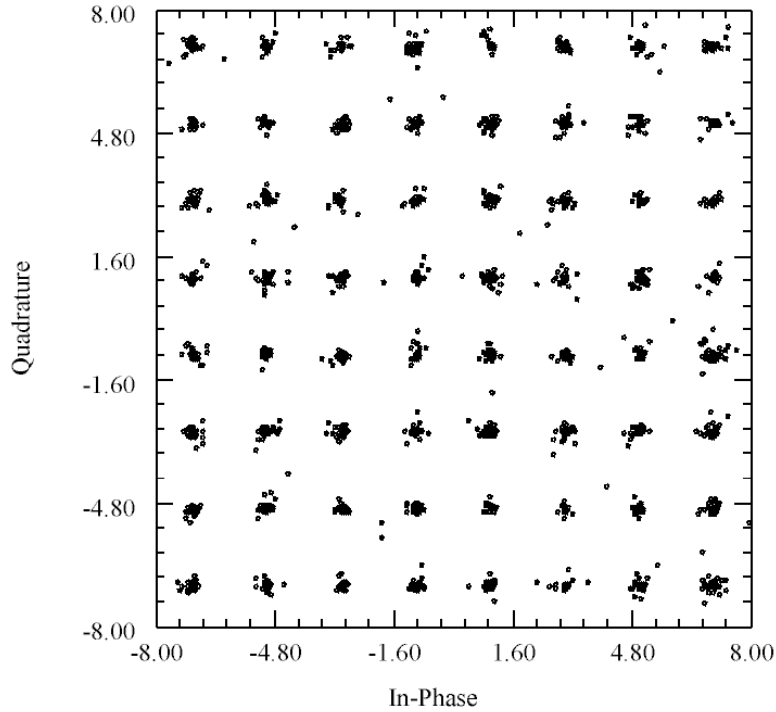


## 200ns Delay Spread



# Error Vector Magnitude EVM

Demodulated Constellation 150ns

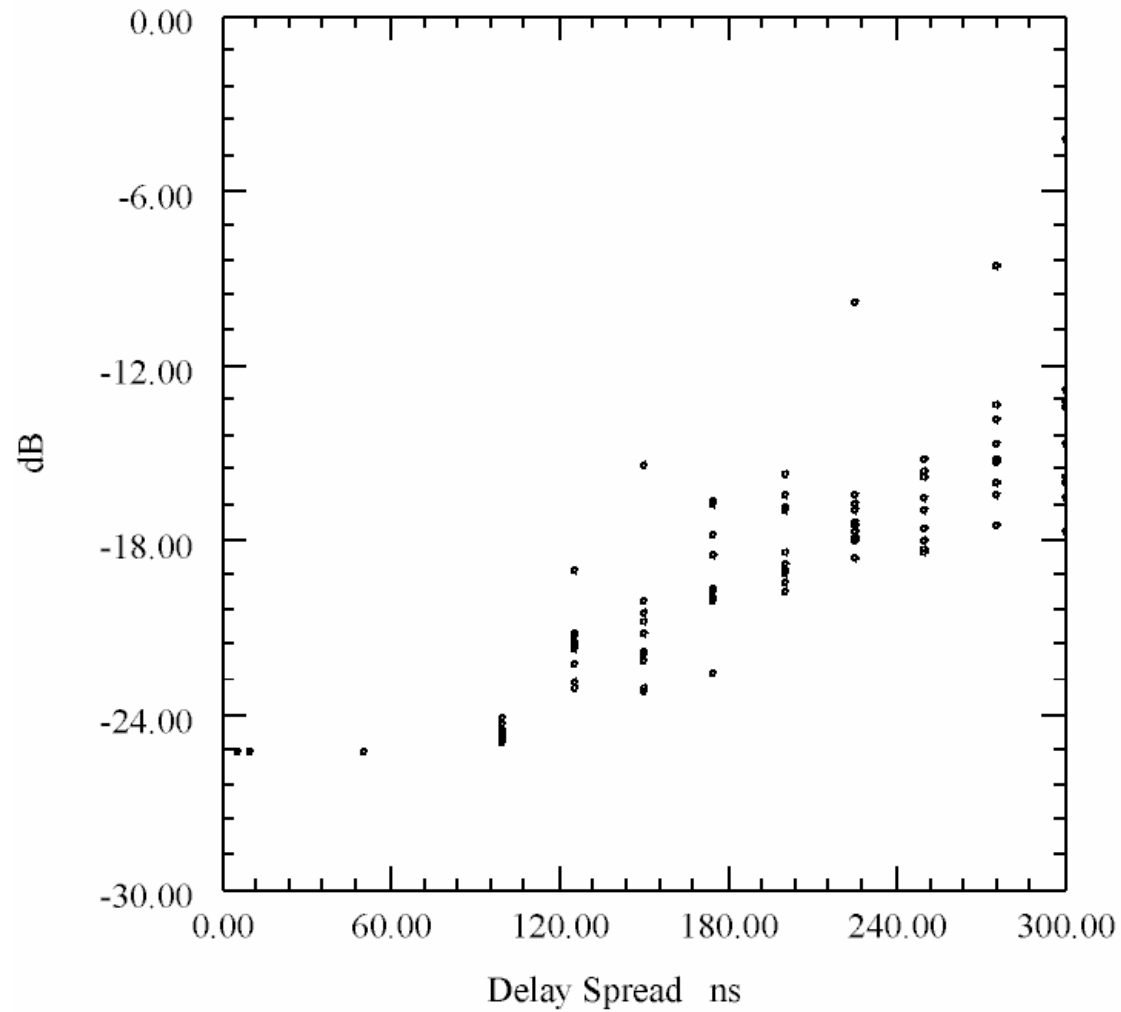


$$EVM = \frac{\frac{1}{N} \sum_{i=1}^N |V_{Measured} - V_{Ideal}|^2}{\frac{1}{M} \sum_{j=1}^M |V_{Ideal}|^2}$$

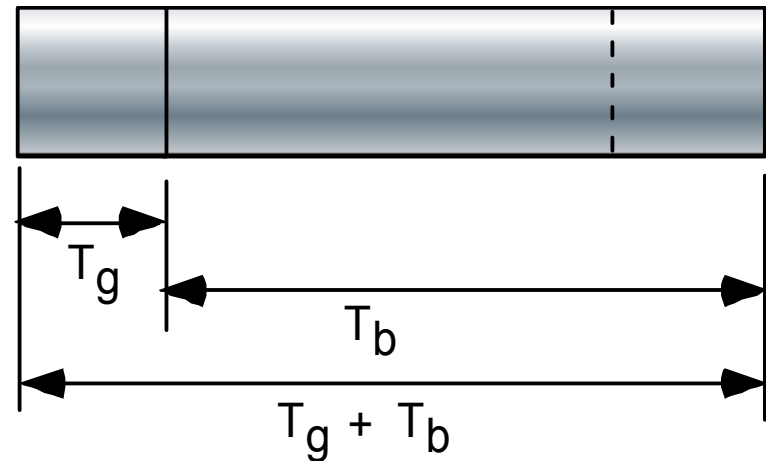
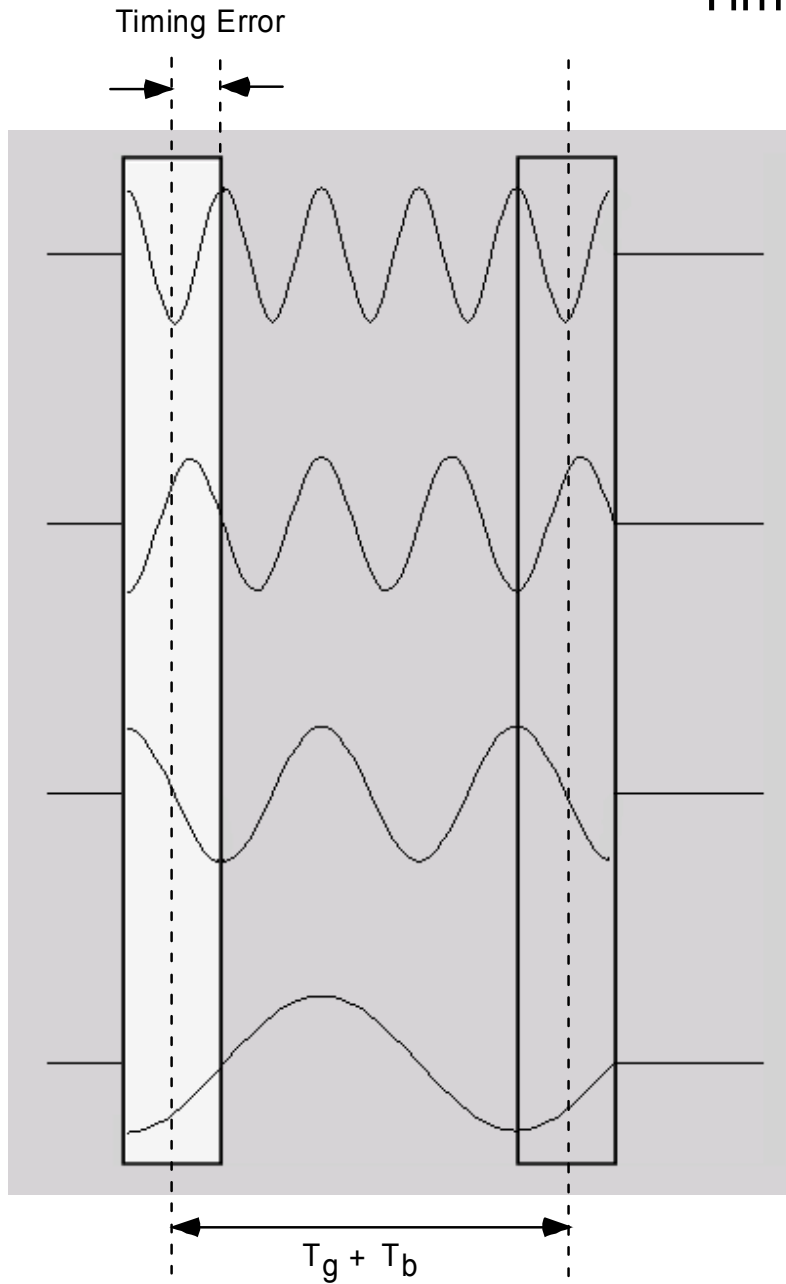




# EVM vs Delay Spread 64 QAM



# Timing Error

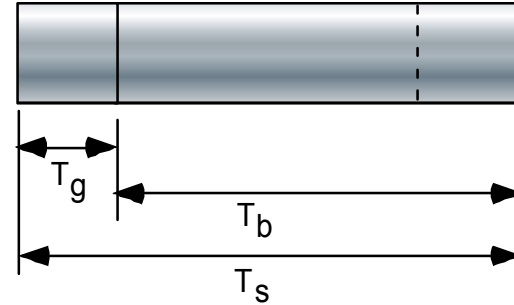


# Rate Dependence on Cyclic Prefix

$$\text{DataRate} = \frac{N_{\text{Data}} b_m c_r}{T_s}$$

$b_m$  is the number of bits per modulation symbol

$c_r$  is the coding rate



<b>T<sub>g</sub></b>		<b>Rate</b>
<i>ns</i>	<i>Samples</i>	<i>Mbps</i>
400	8	60
800	16	54
1600	32	45

$$b_m = 6$$

$$c_r = 3/4$$

$$N_{\text{Data}} = 48$$

# Original Paper Introducing Cyclic Prefix

## DIGITAL SOUND BROADCASTING TO MOBILE RECEIVERS

Bernard Le Floch, Roselyne Halbert-Lassalle, Damien Castelain  
CCETT (Centre Commun d'Etudes de Télédiffusion et Télécommunications)  
35512 Cesson Sévigné, France

IEEE Transactions on Consumer Electronics, Aug. 1989.

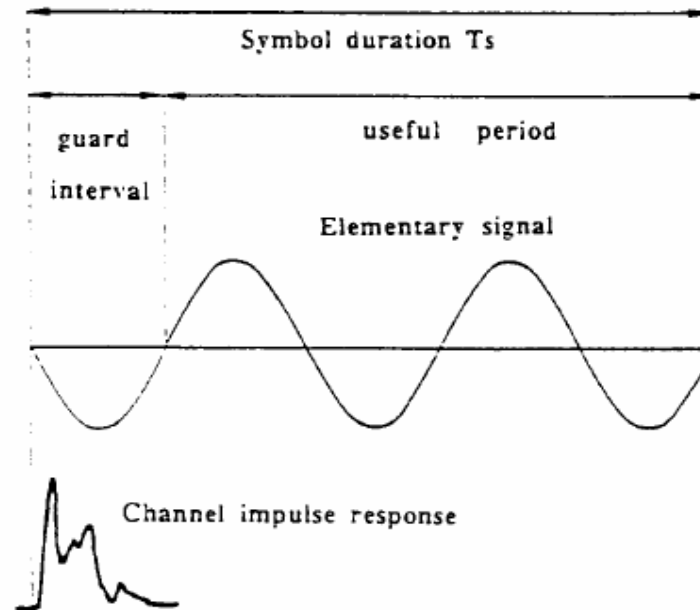


Figure 3

Use of a guard interval to suppress  
the intersymbol interference