

# A Preamble Structure for Fast Acquisition and Equalization of QAM Signals

fred harris, San Diego State University

Chris Dick, Xilinx Corporation

# Synchronization

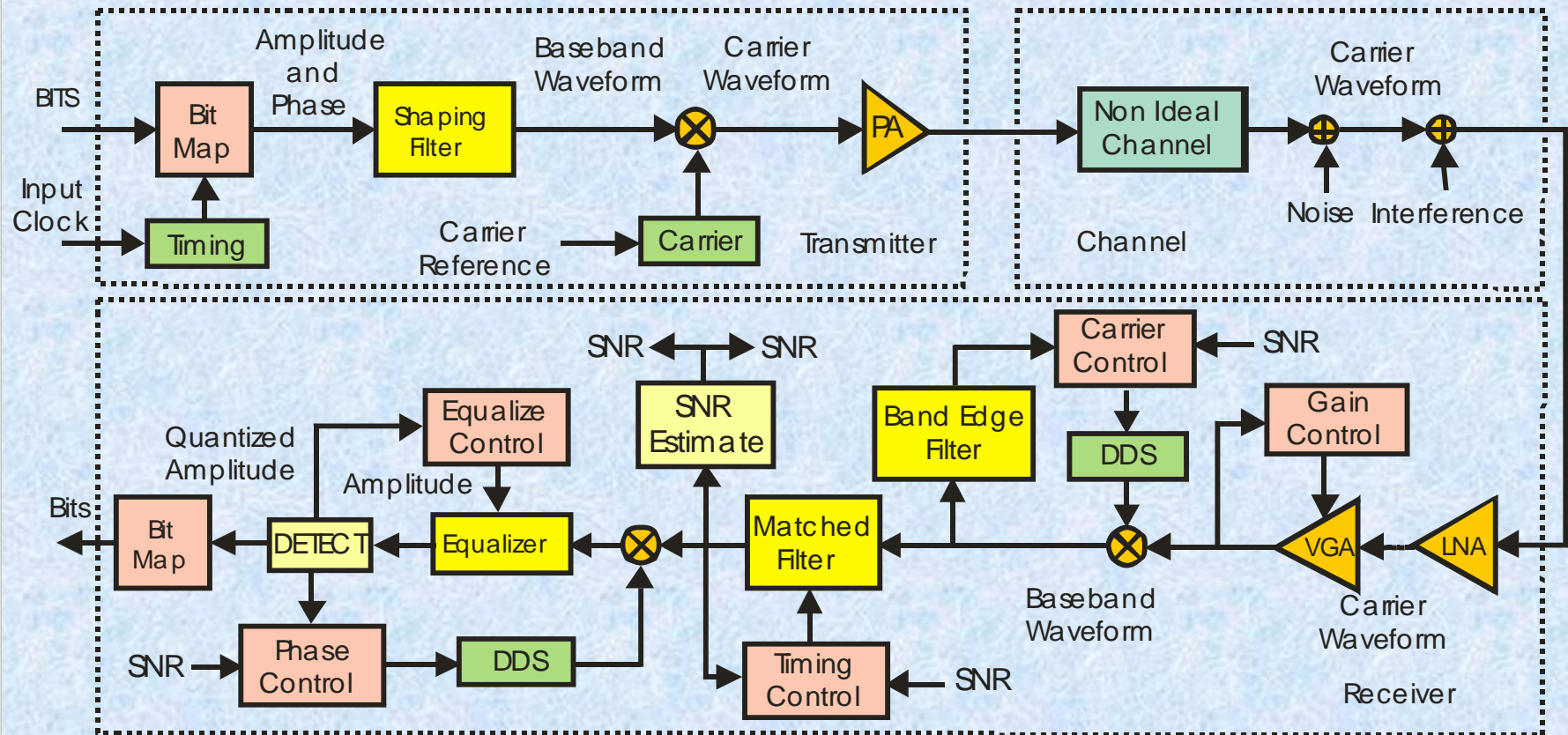
Chronos: Ancient Greek Immortal Being (Χρόνος)  
Recognized in the modern age as Father Time.

Chronometer: A term coined in the 1800's to  
describe accurate clocks.

Synchronize: from the Greek prefix “syn” meaning  
“together with”, and “chronos”  
which we interpret as time.



To Demodulate a Signal, the Receiver must  
 Estimate Unknown Parameters of the Received Signal:  
 Squelch, Signal Strength, Frequency and Phase of Carrier,  
 Frequency and Phase Of Modulation Waveform,  
 Channel Impulse or Frequency Response, and SNR



Energy for Synchronizers is  
Embedded in Excess Bandwidth of  
Modulation Signal:

If There is no Excess Bandwidth.  
Energy must be supplied by  
Modulator in  
Preambles or in Pilots.

IS-95 Uses Pilots  
IEEE 805-11a Uses  
Preamble and Pilots



Synchronization based on extracting energy from excess bandwidth is common in the Broadcast Community.

Does not require Additional Transmitted Energy!

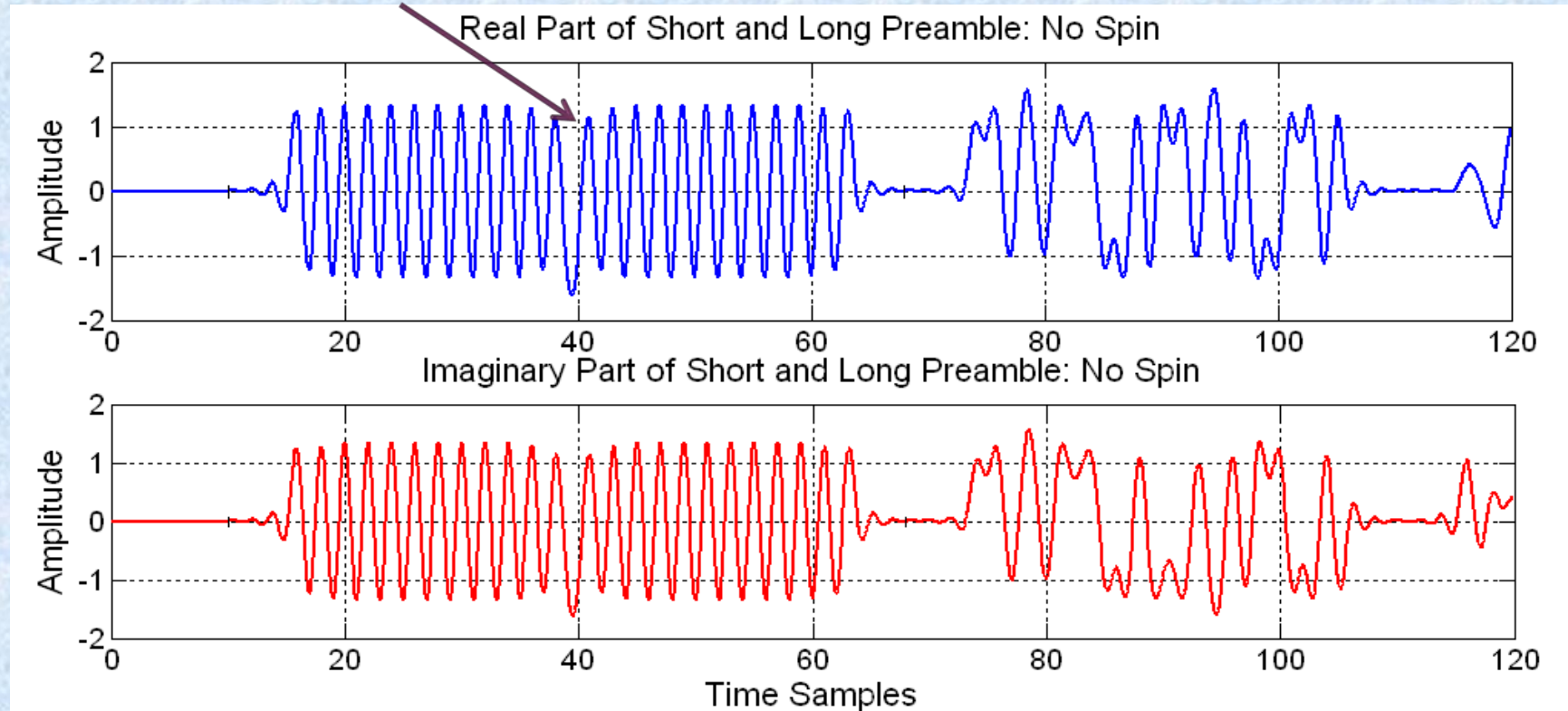
Synchronization May Require Processing of Thousand's of Symbols to extract Signal Statistics. Acceptable for Broadcast.

Not acceptable for Peer to Peer or Burst Modems.

We were asked to Design a Fast Acquisition Preamble for Burst Modem Application:  
Whole Acquisition in Less than 100 Symbols!

# Two Segment Structure of Burst Modem Preamble

## Sign Reversal



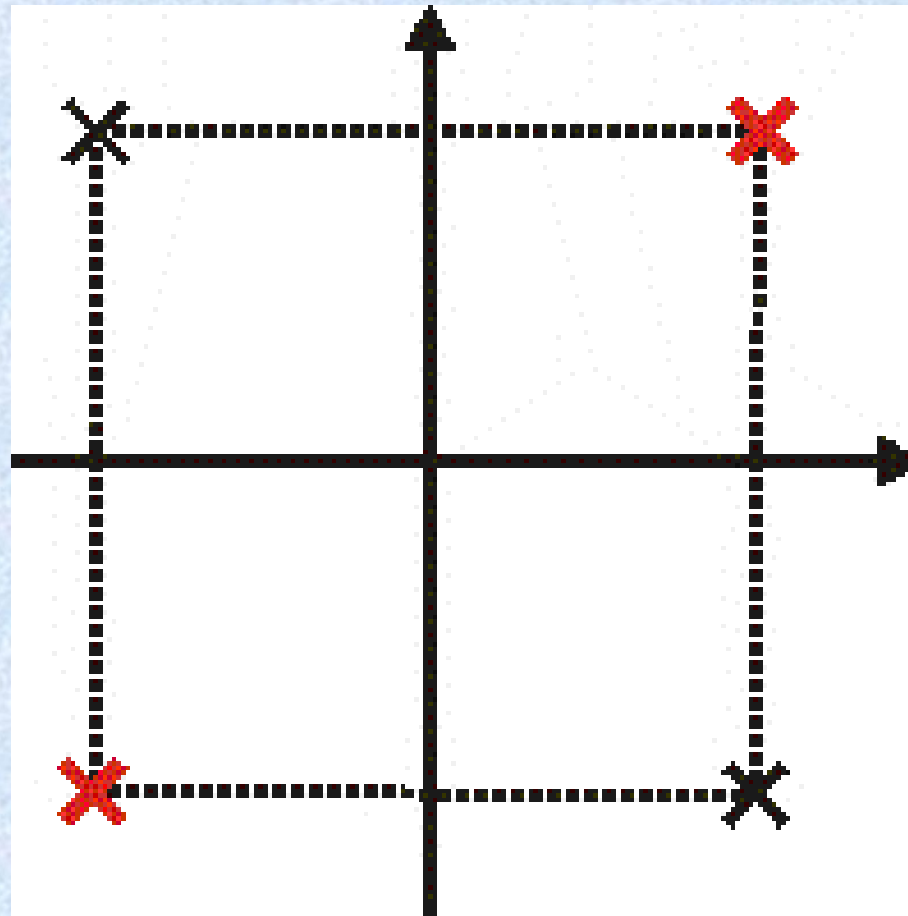
Repeated Component  
For Squelch, AGC, Timing,  
And Carrier Acquisition

Broadband Component  
For Channel Probe

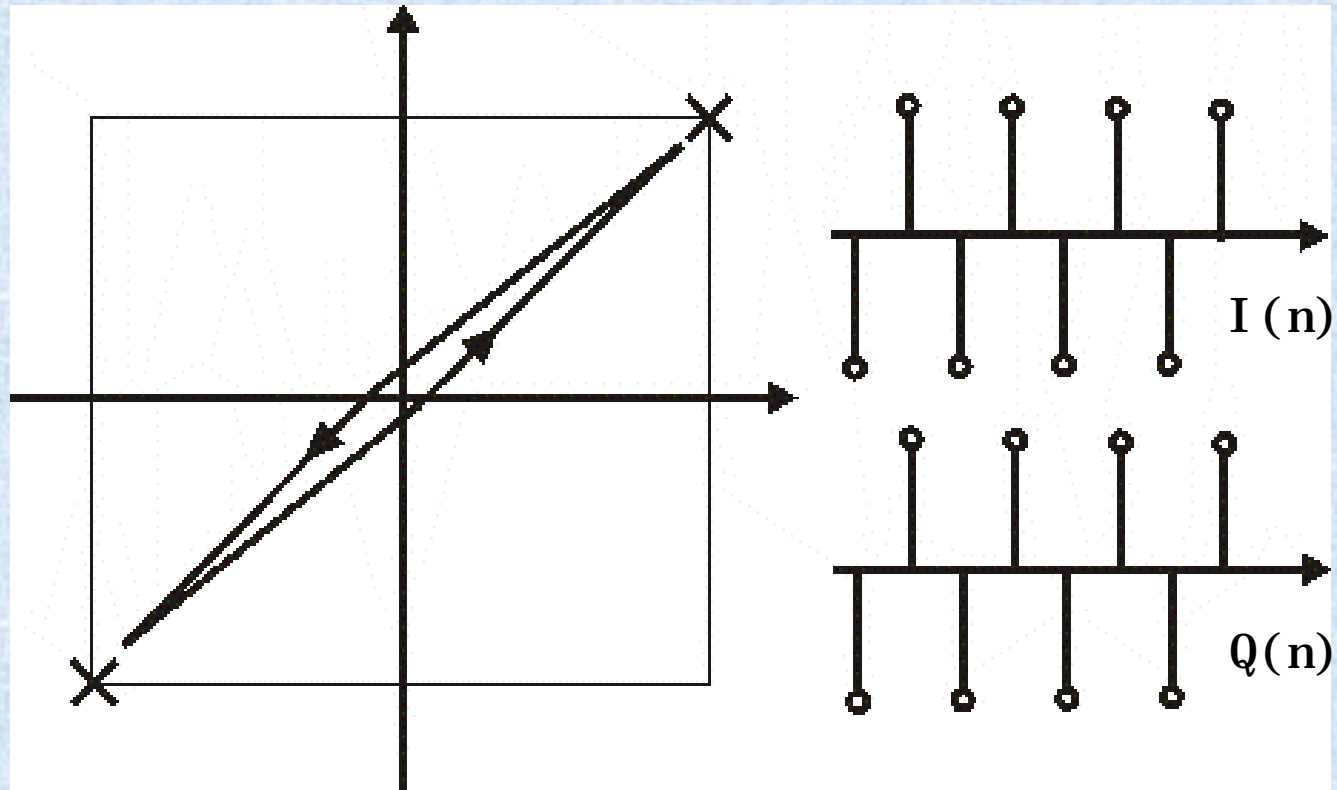
Gaps For Clarity  
of Presentation



# QPSK Constellation



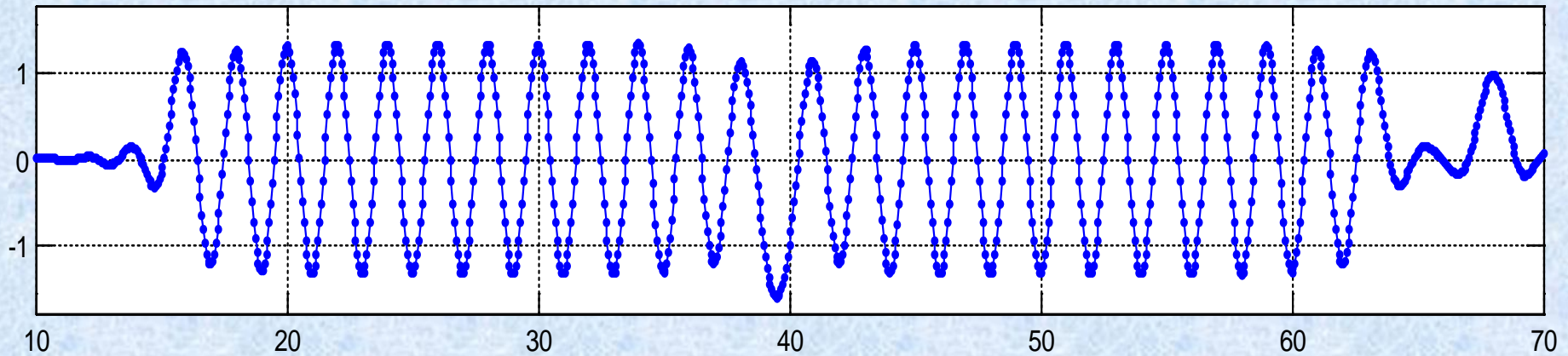
## Short Preamble: Two Corners of QPSK Constellation



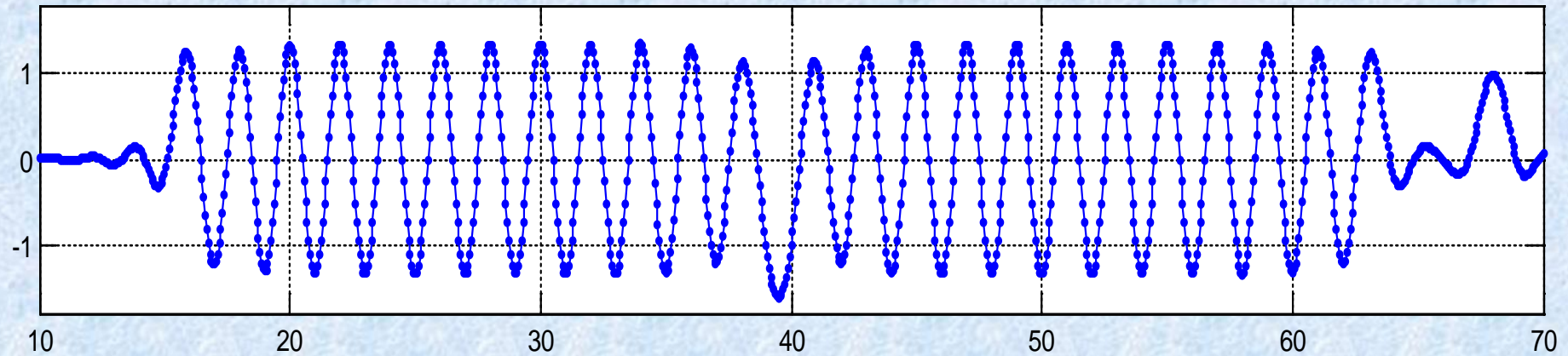


# Timing Recovery: Locate Sample at Peak of “Sinewave”

Real Part of Short Preamble: No Spin

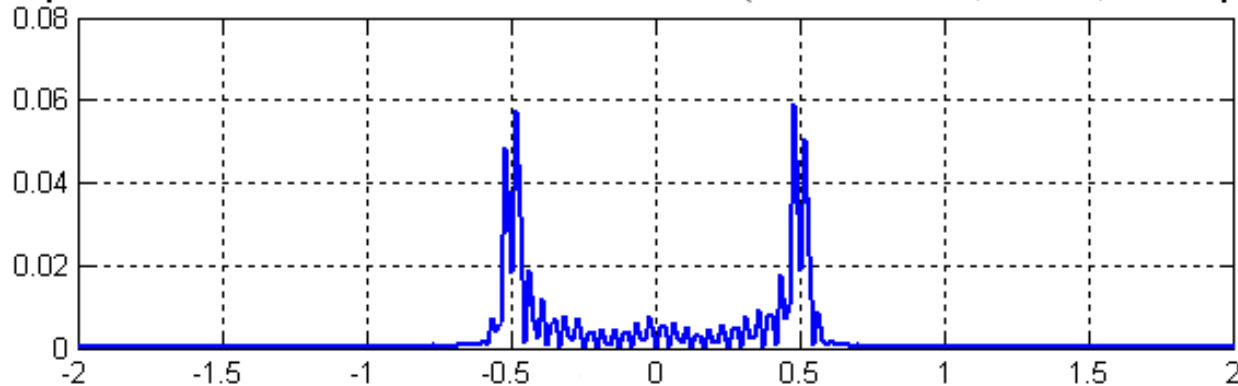


Imaginary Part of Short Preamble: No Spin

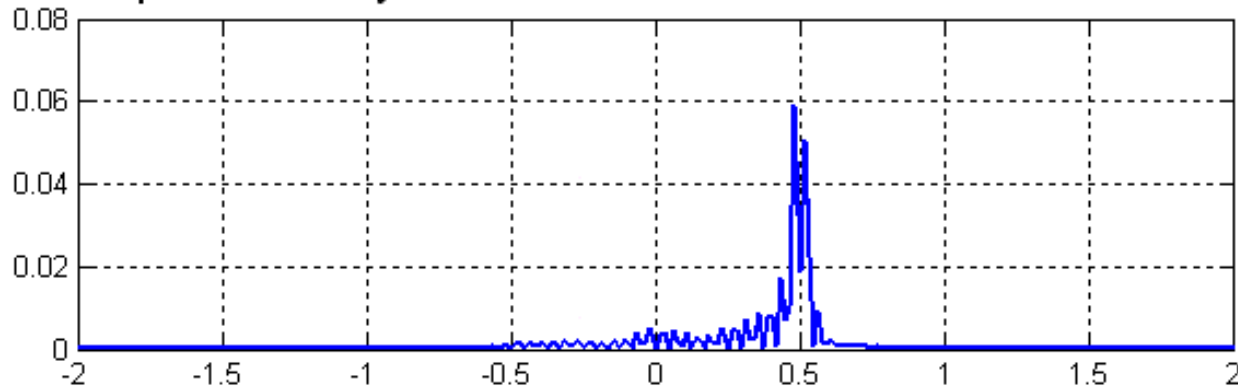


# Spectra of Short Preamble And of Synthetic Hilbert Transform of Short Preamble

Spectrum of Preamble at Demodulator (with channel, noise, and spin)

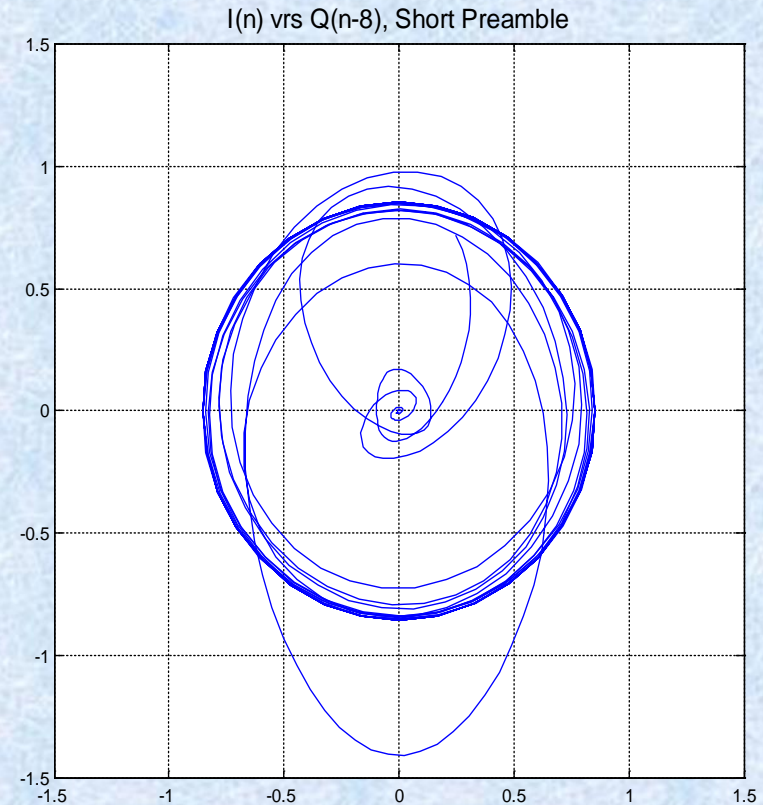
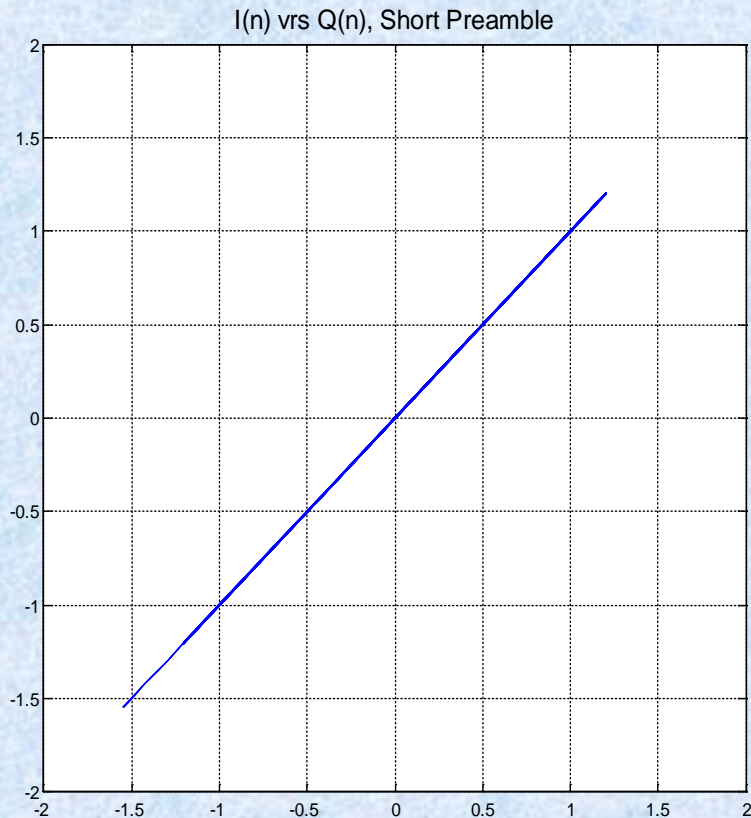


Spectrum of Synthesized Hilbert Transform at Demodulator

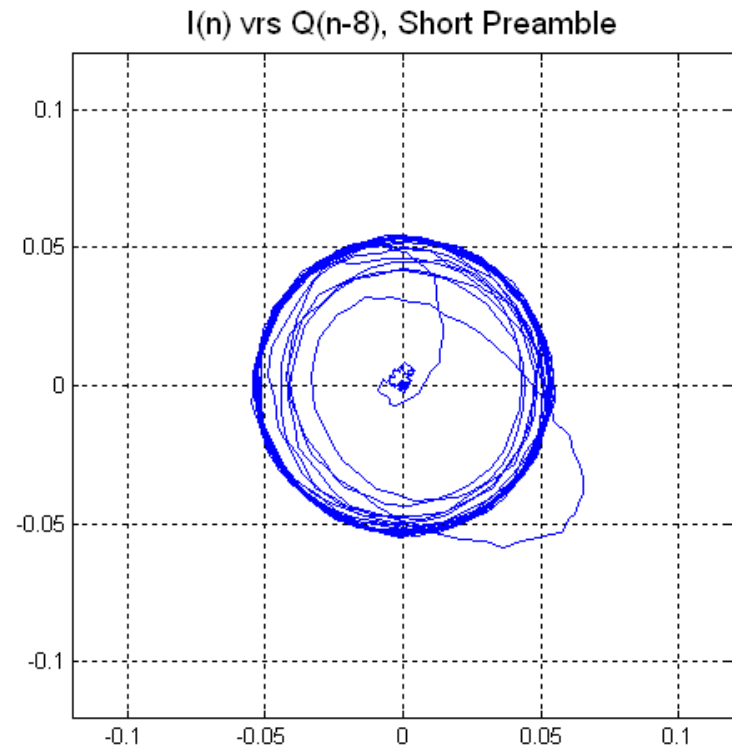
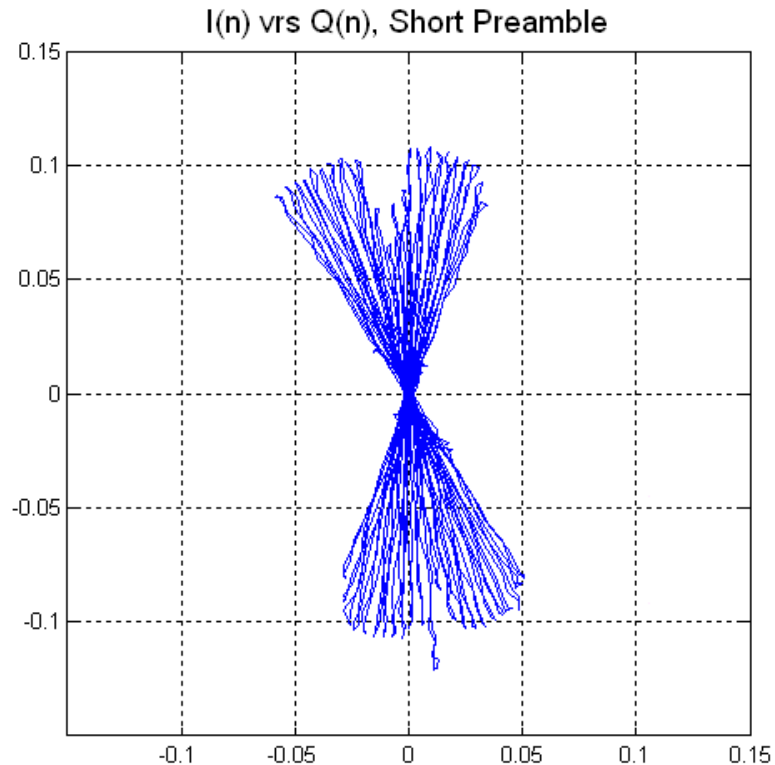




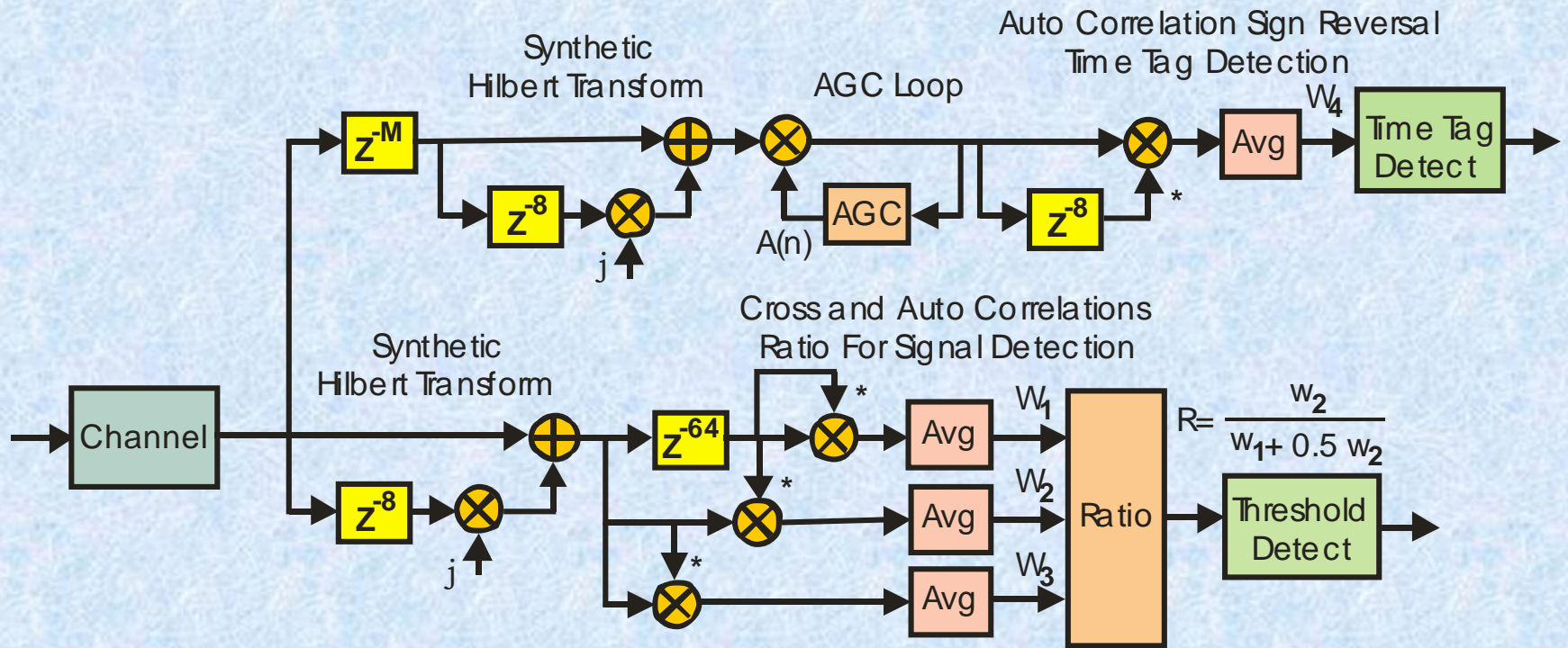
# State Transition Diagrams of Short Preamble and of Synthesized Hilbert Transform



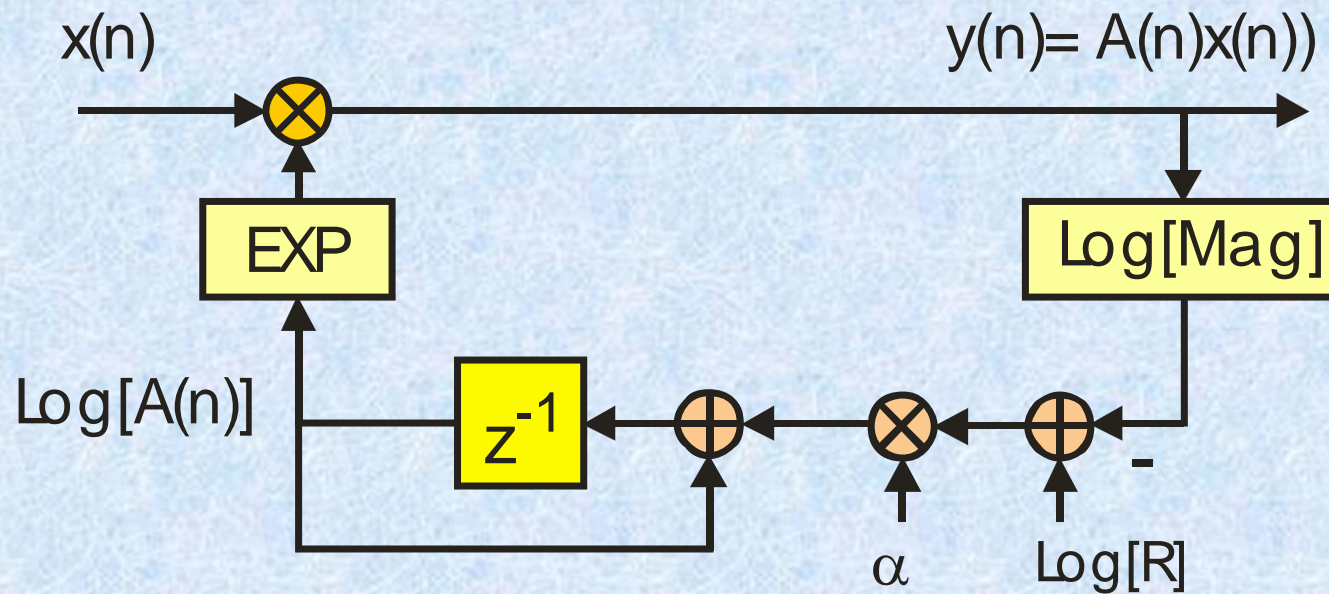
# State Transition Diagrams of Short Preamble and of Synthesized Hilbert Transform





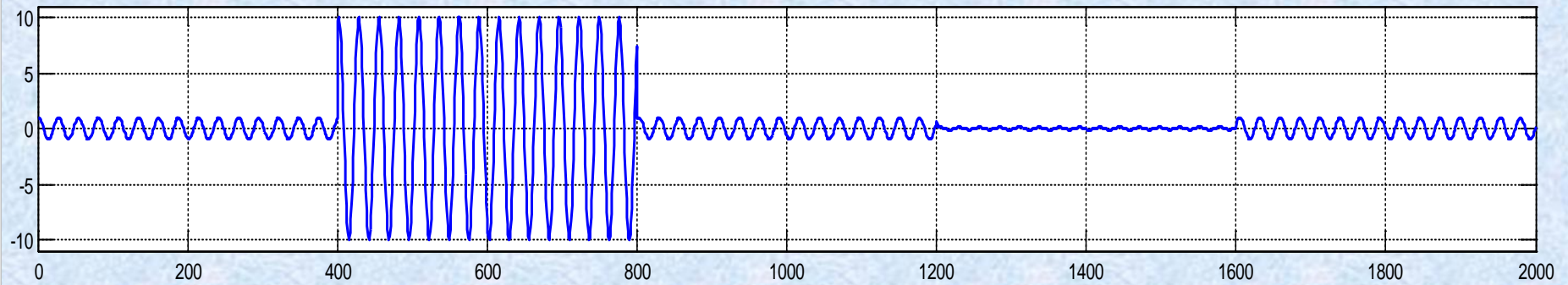


# Log Automatic Gain Control Loop

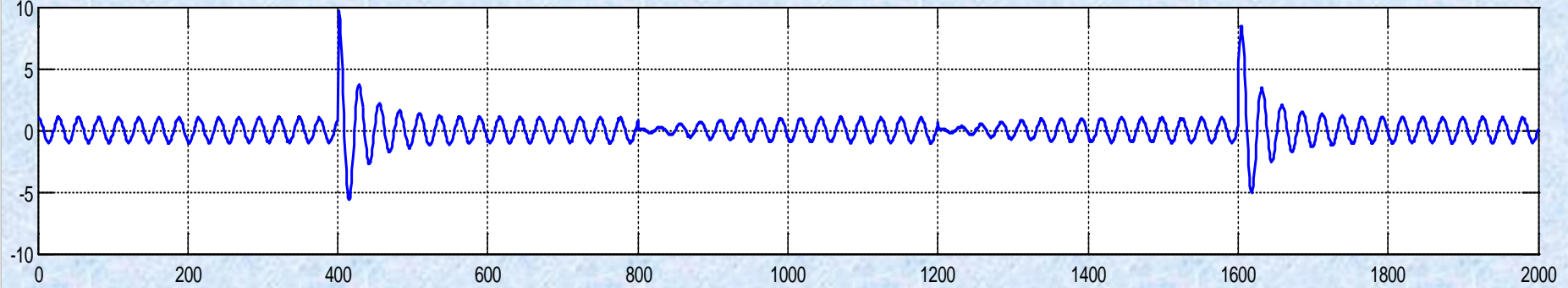




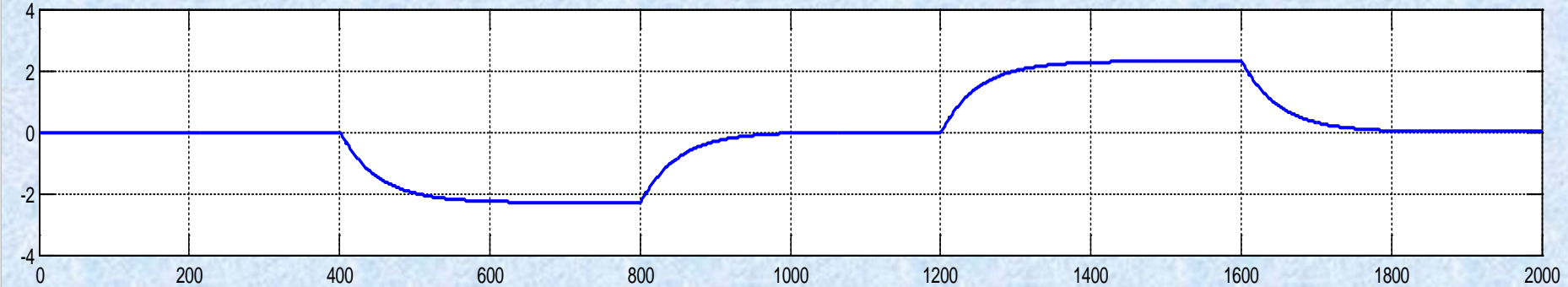
Input Signal Levels



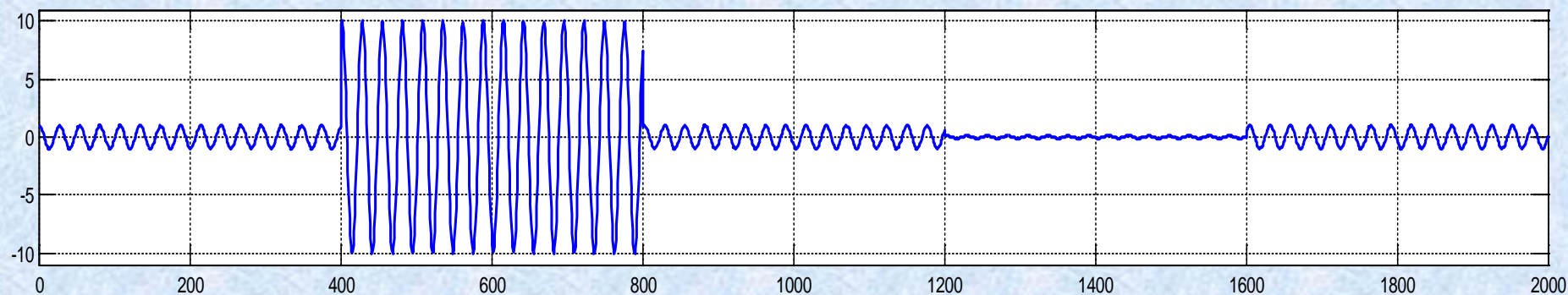
Output Signal Levels



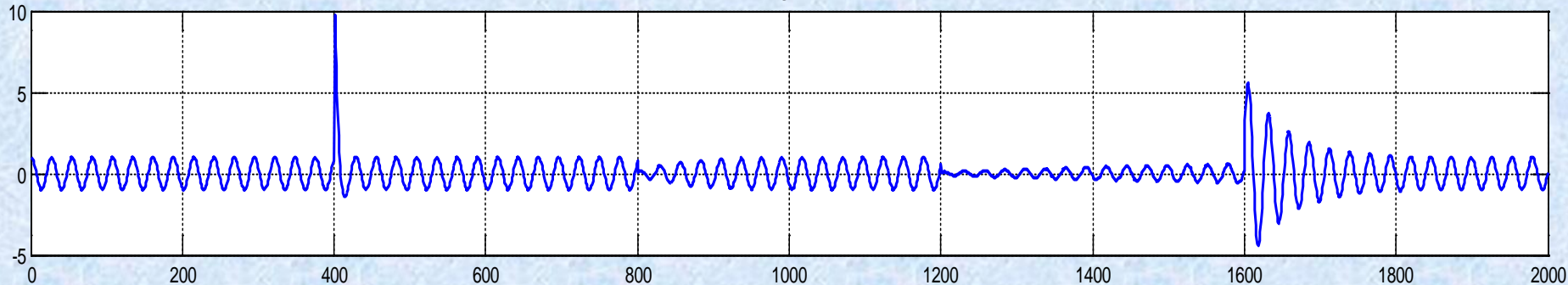
Log Loop AGC Control Levels



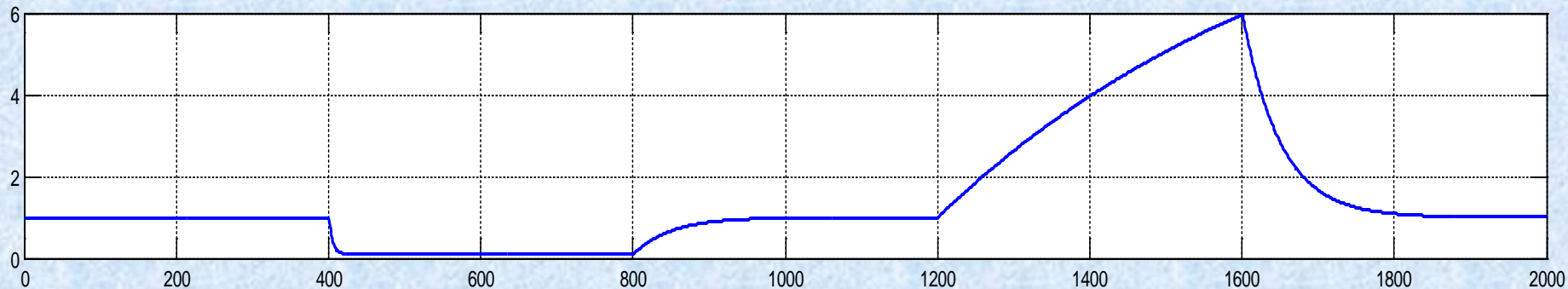
Input Signal Levels



Output Signal Levels

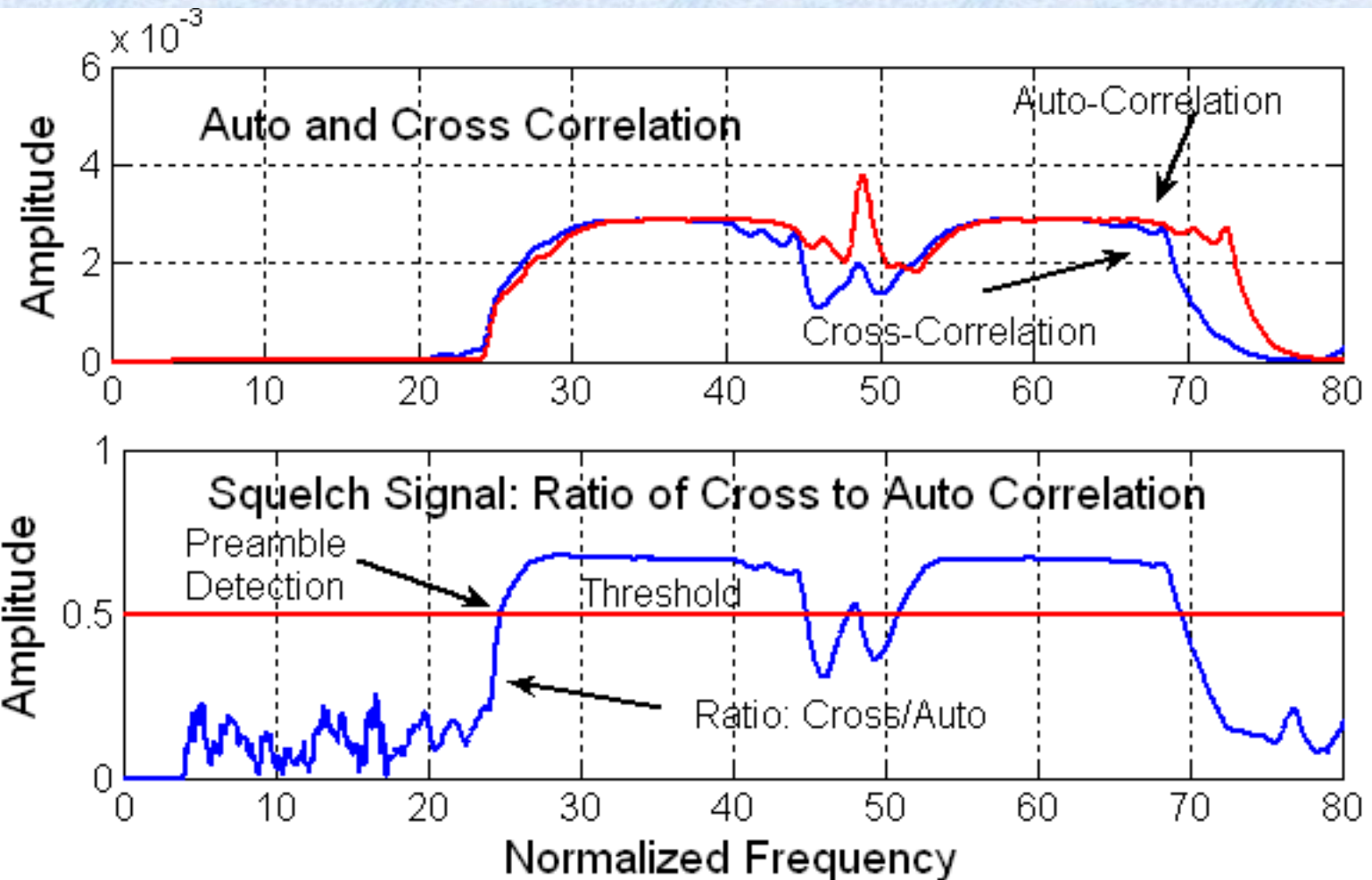


Linear AGC Control Levels

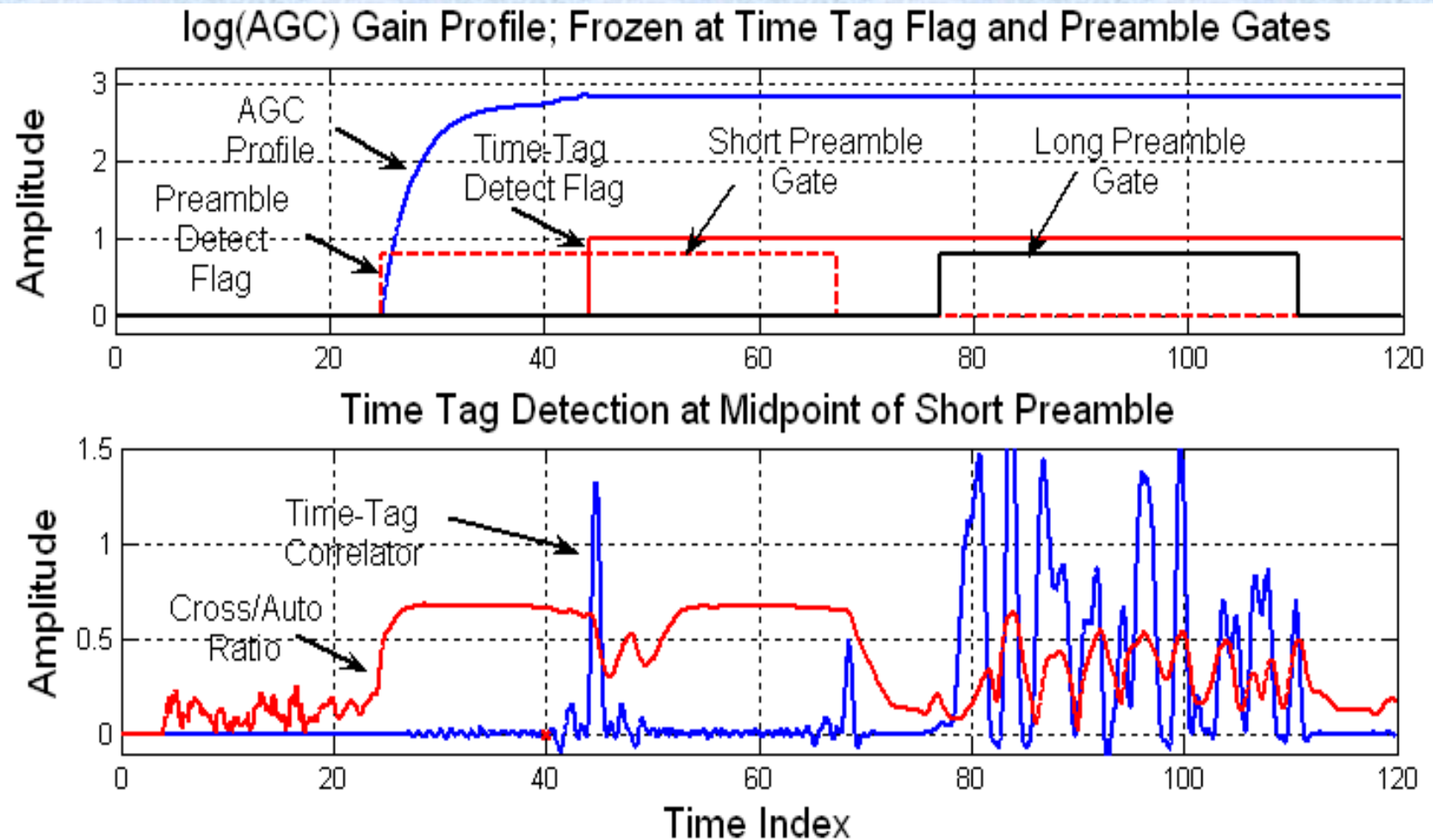




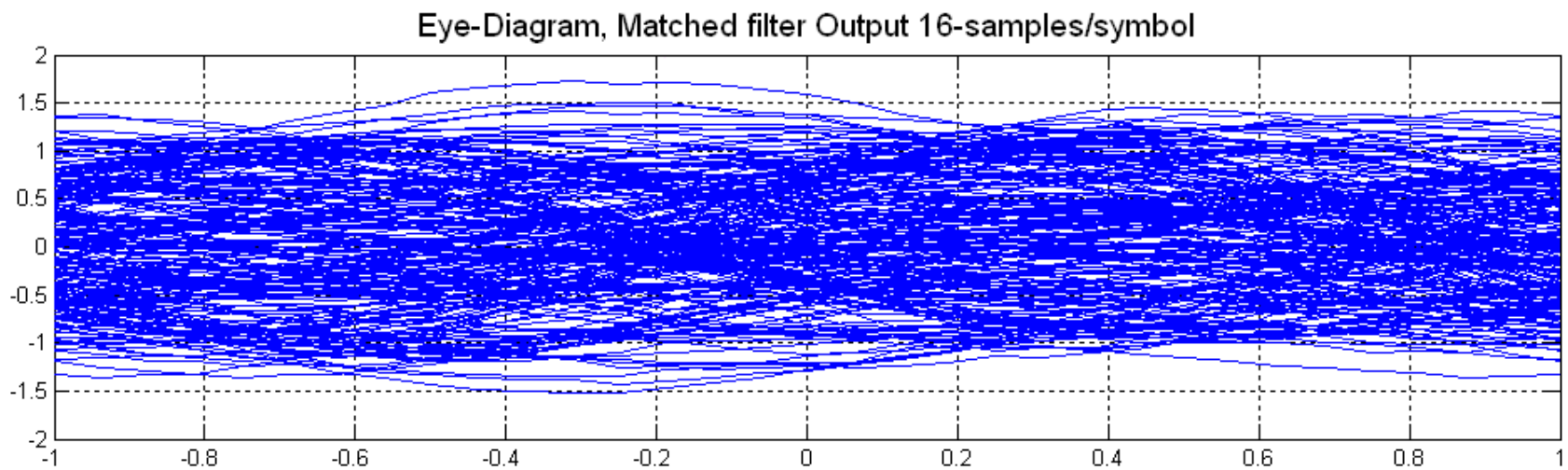
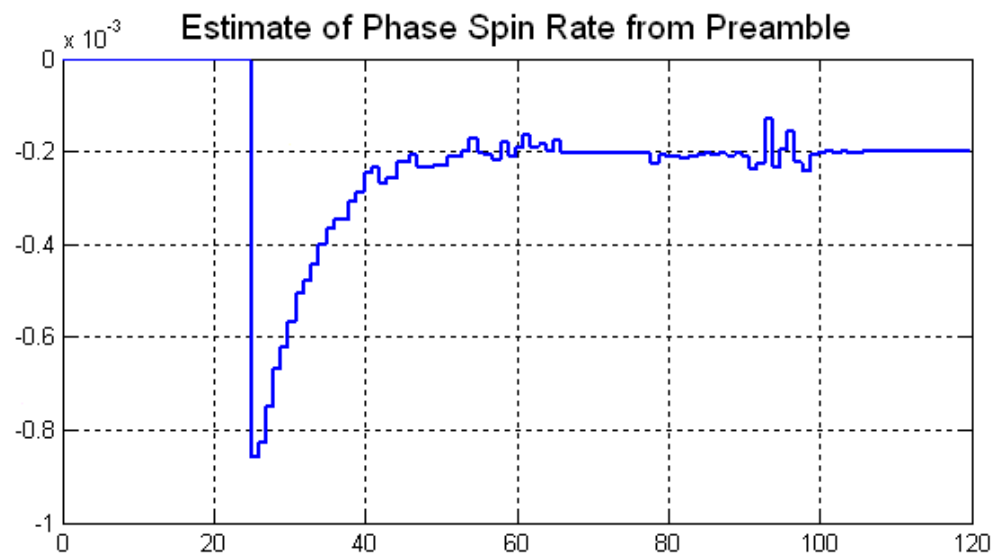
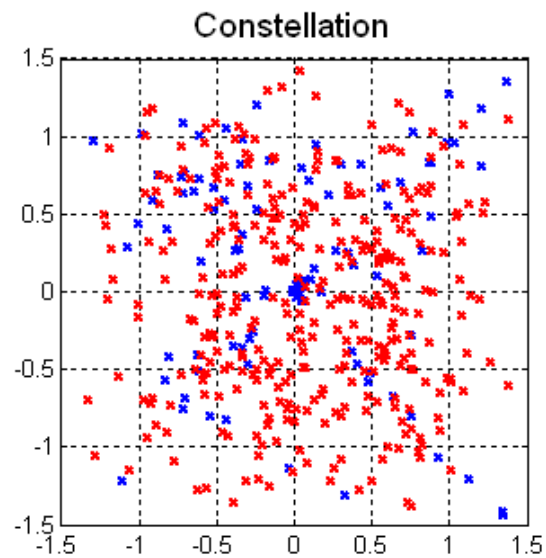
# Squelch Preamble Detection



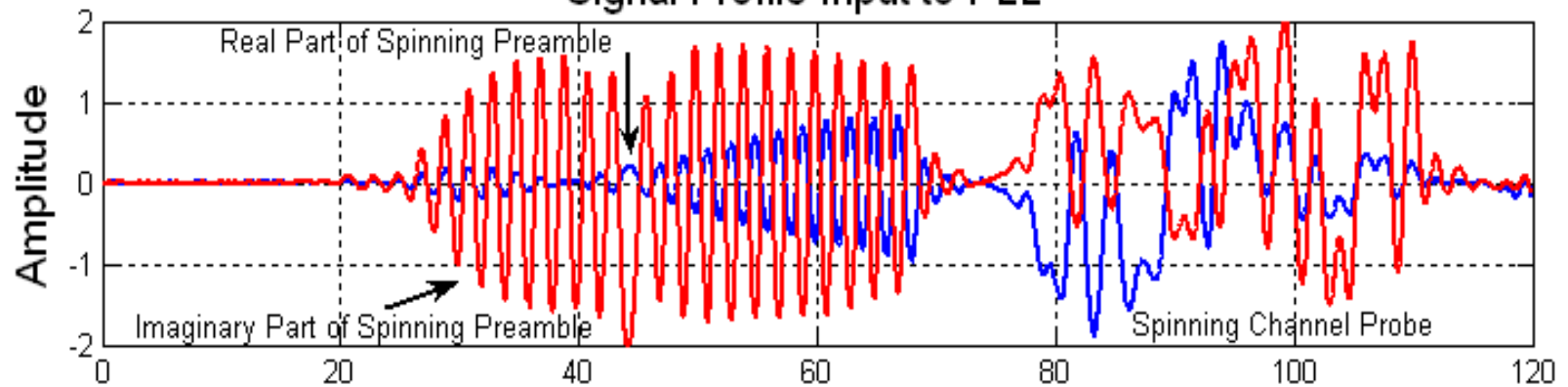
# State Machine Flags and AGC Profile, Preamble Detection and Mid Point Sign Reversal Detection



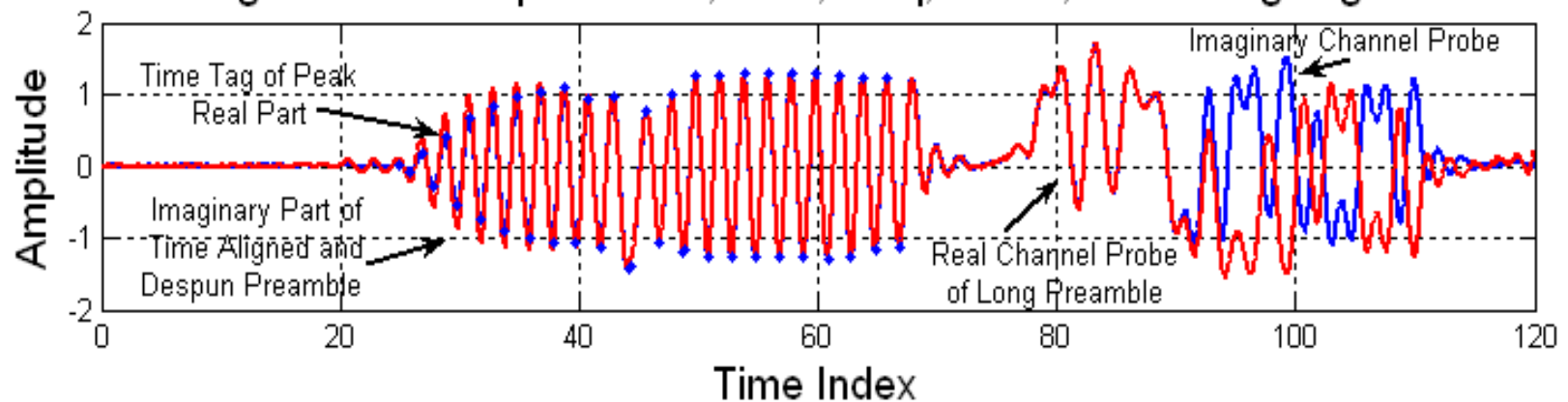




### Signal Profile Input to PLL

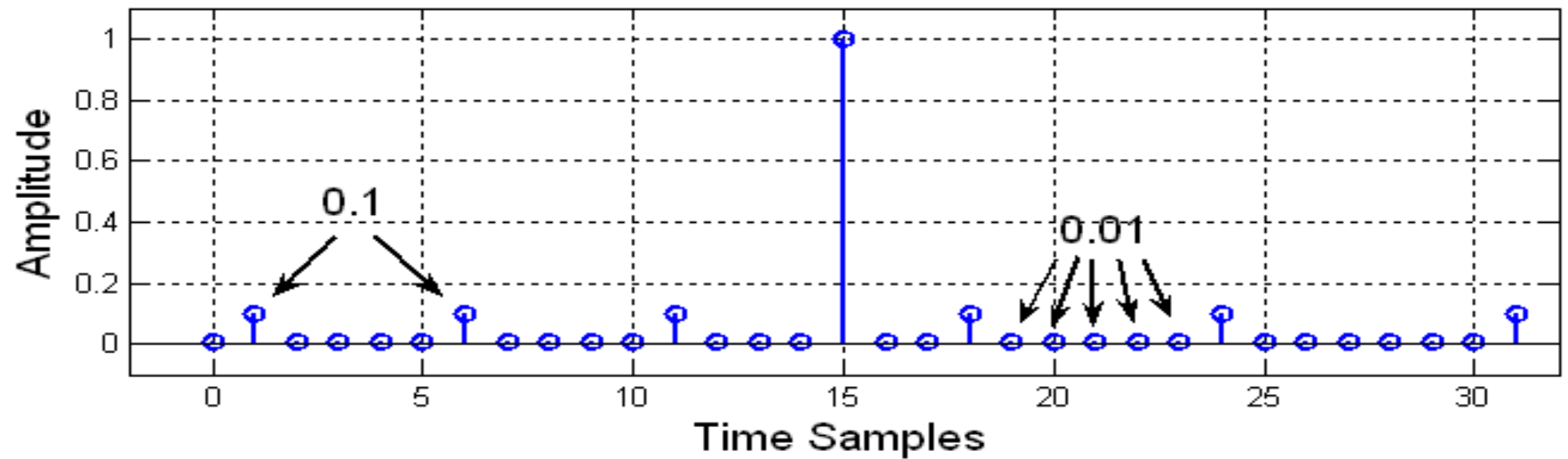


### Signal Profile Output of PLL; AGC, Freq, Phase, and Timing Aligned



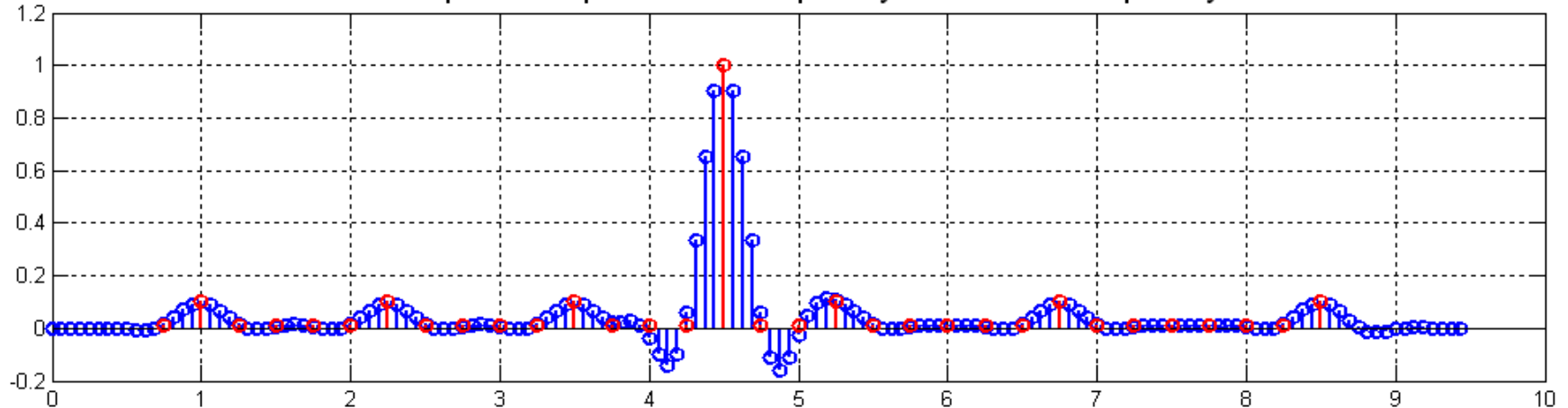


Channel Impulse Response

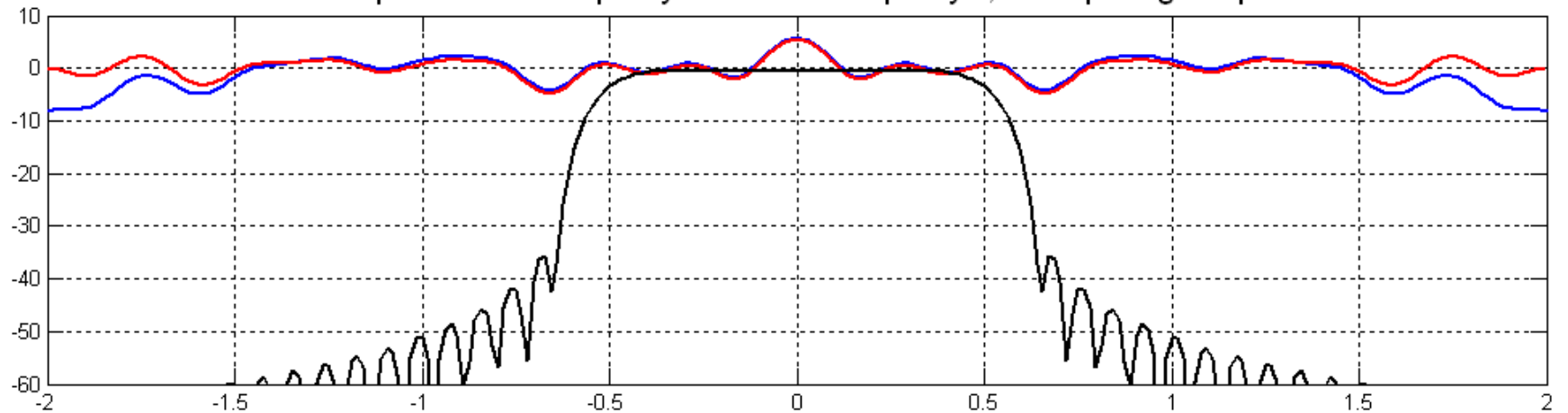


# Channel Effect in Time and Frequency

Channel Impulse Response at 4 Samples/sym and at 16 Samples/sym



Channel spectrum at 4-smpls/sym and at 16 smpls/sym, and input signal spectrum

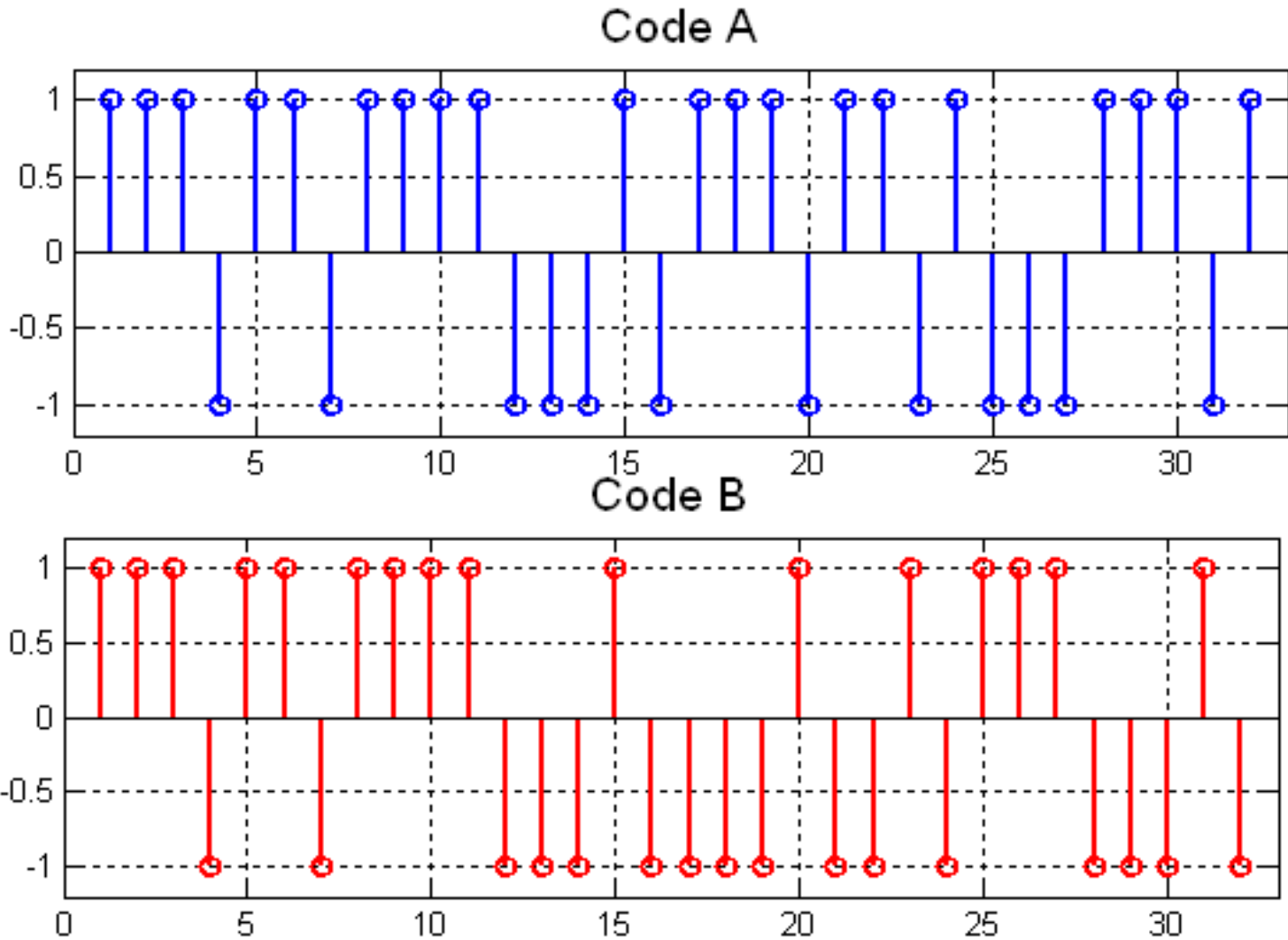




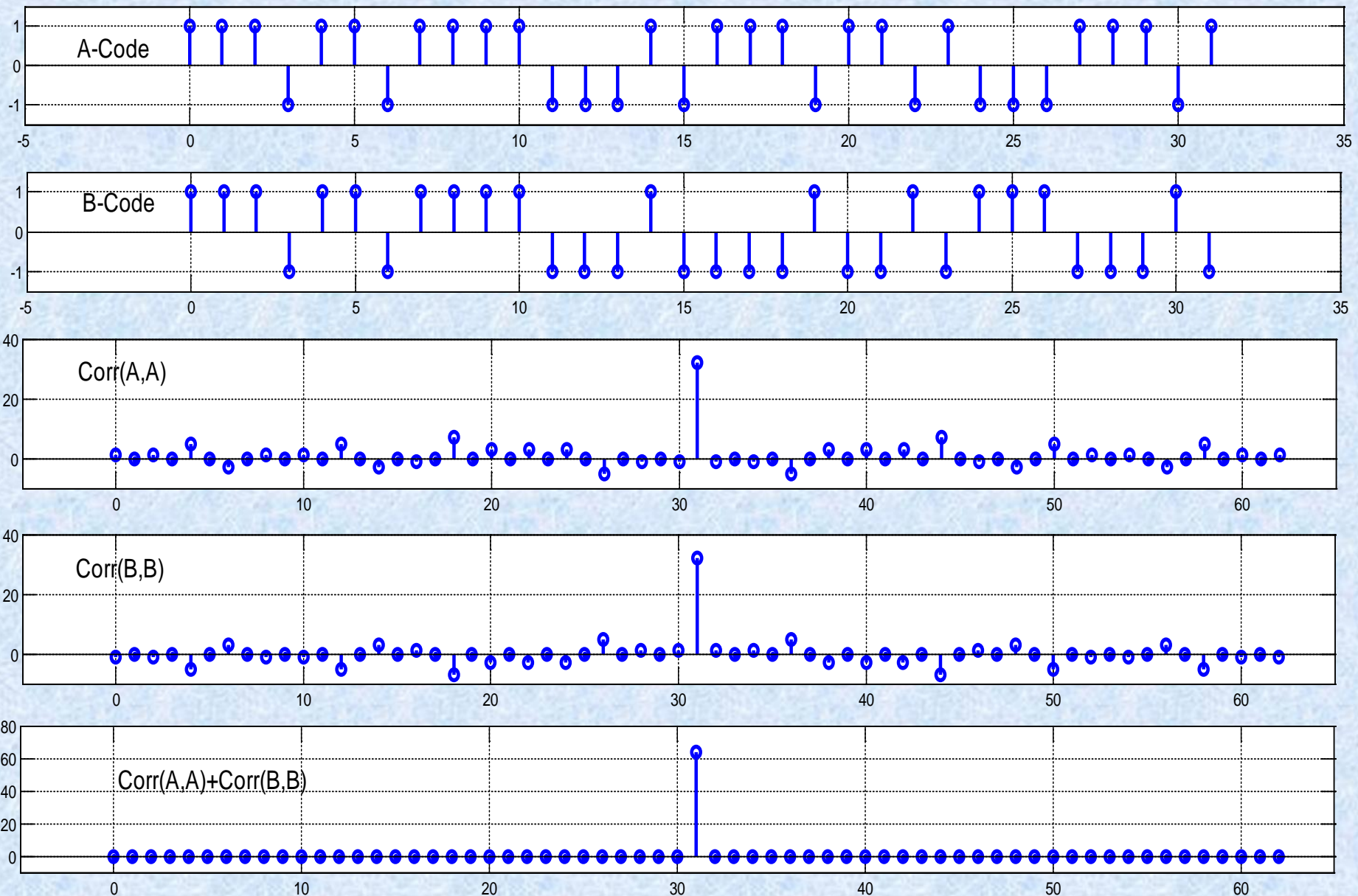
# Complementary Codes

$$[A_{n+1}] = [A_n \ B_n], \ [A_0] = 1$$

$$[B_{n+1}] = [A_n \ \bar{B}_n], \ [B_0] = 1$$

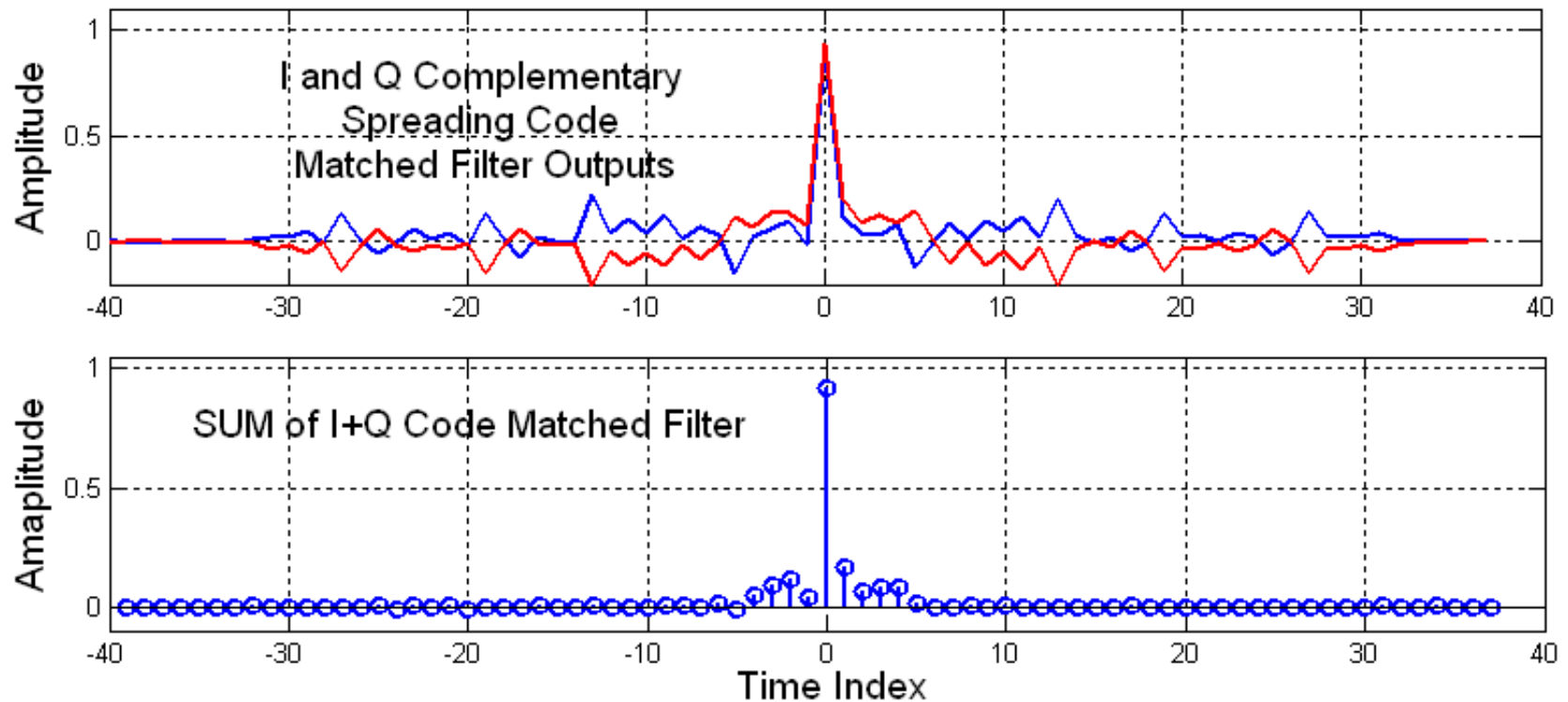


# Correlation Property of Complementary Codes

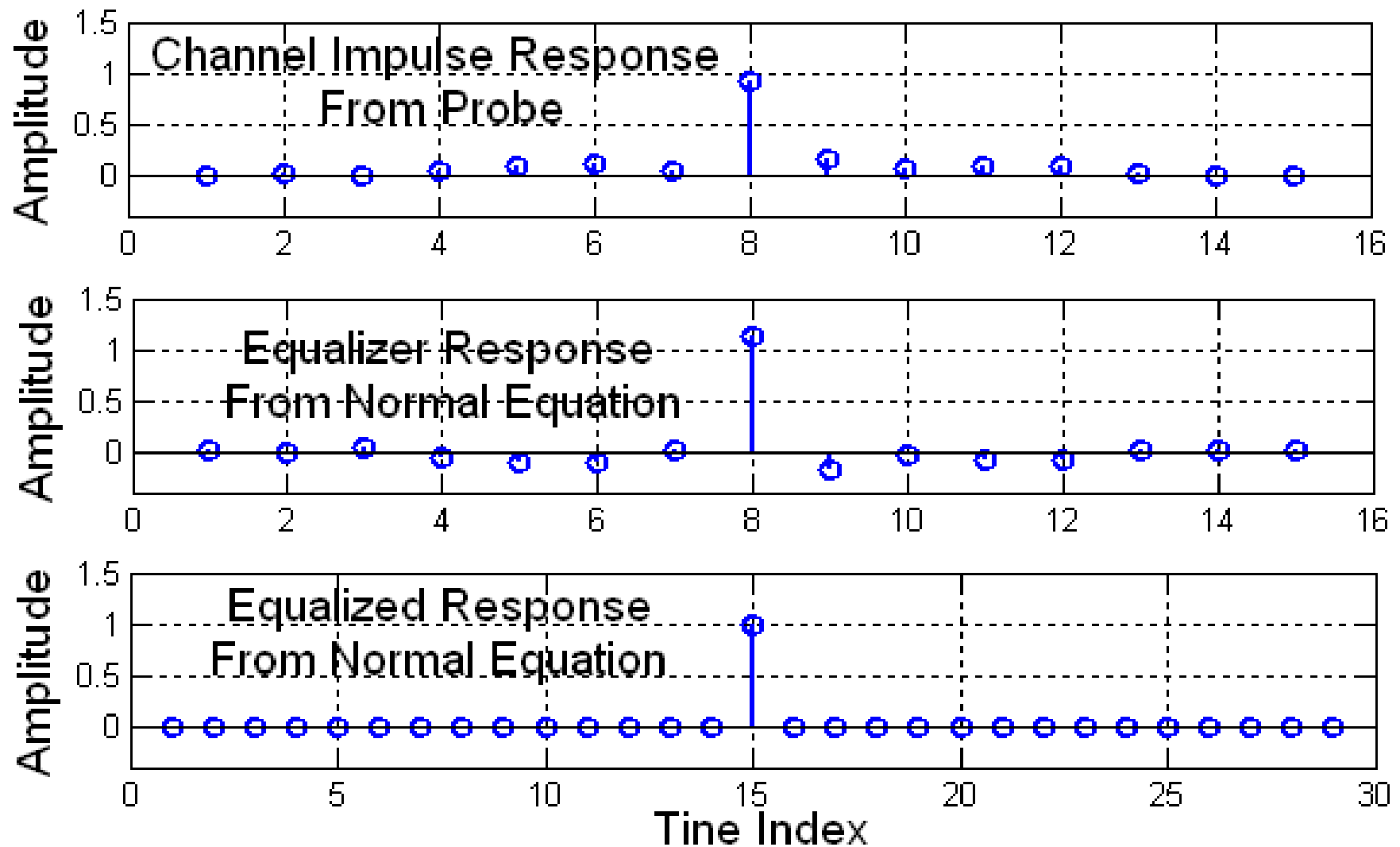




# Channel probe by I and Q Complementary Spreading Codes

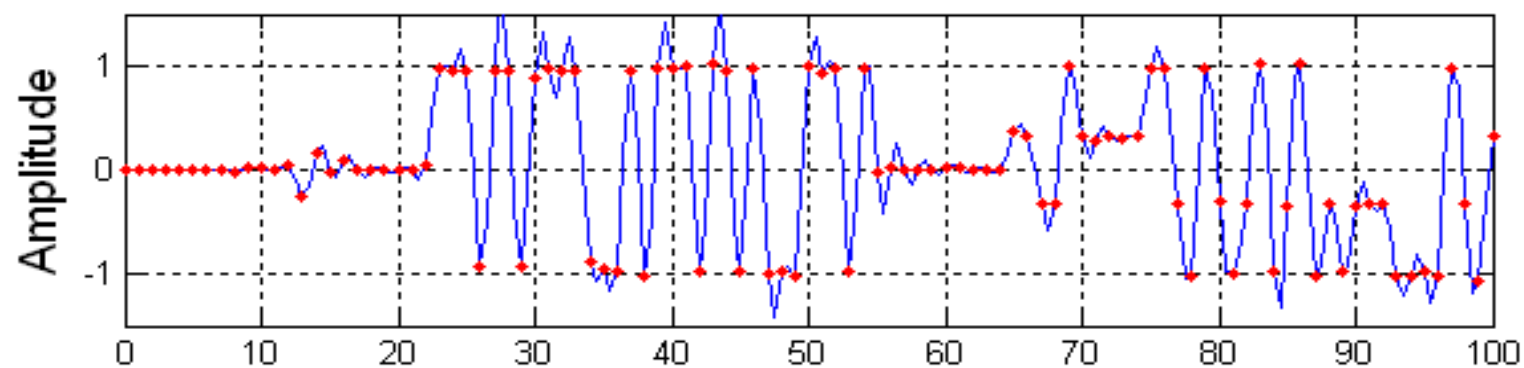


# Equalizer and Equalized Response from Channel Probe

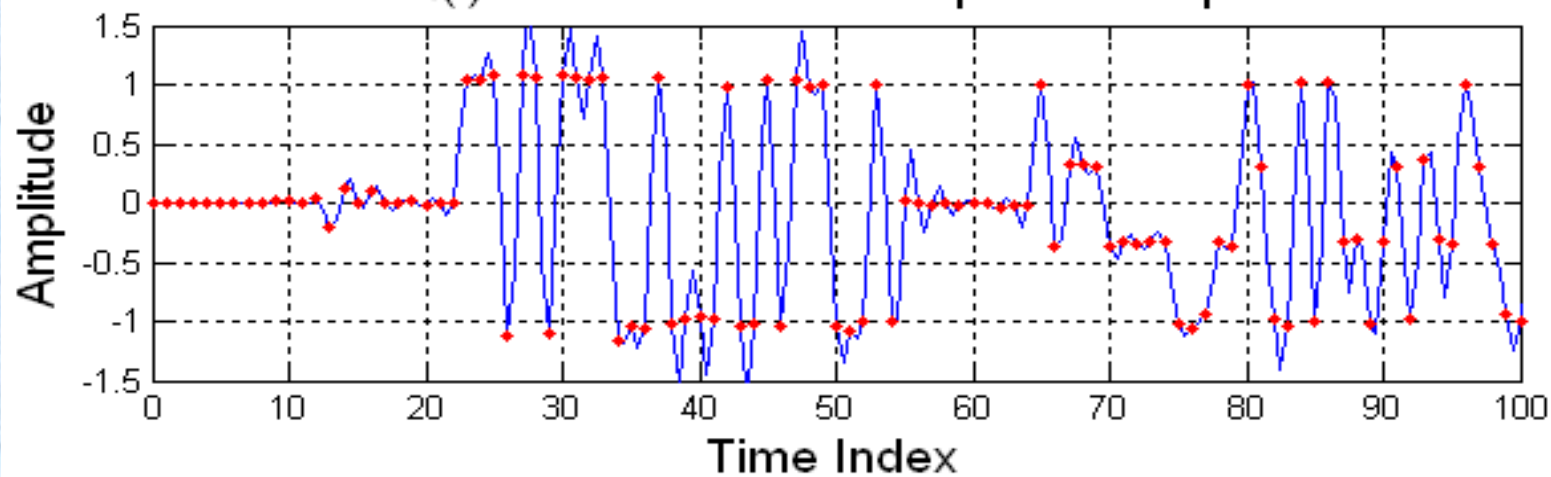




**I(t) Time Series from Equalizer Output**

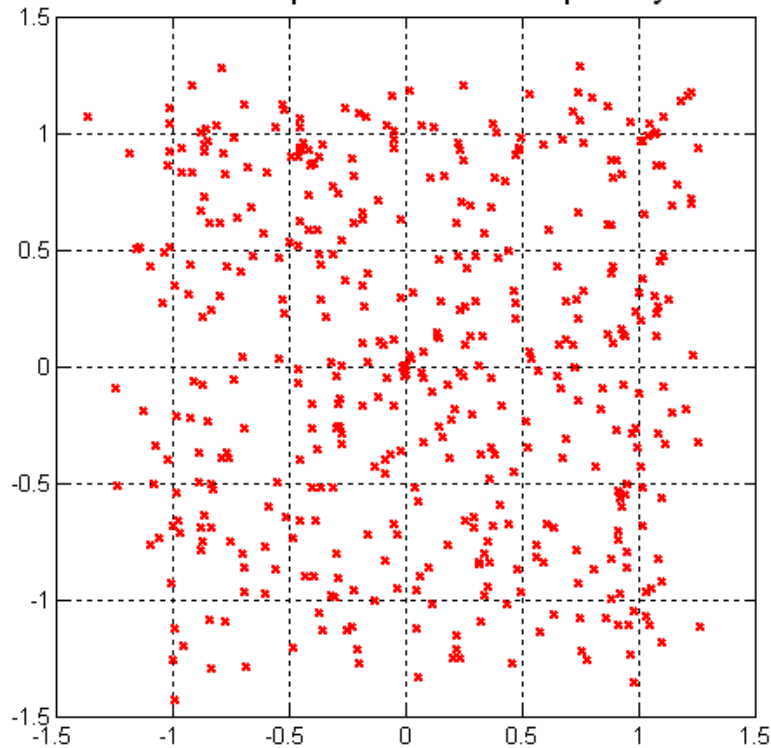


**Q(t) Time Series from Equalizer Output**

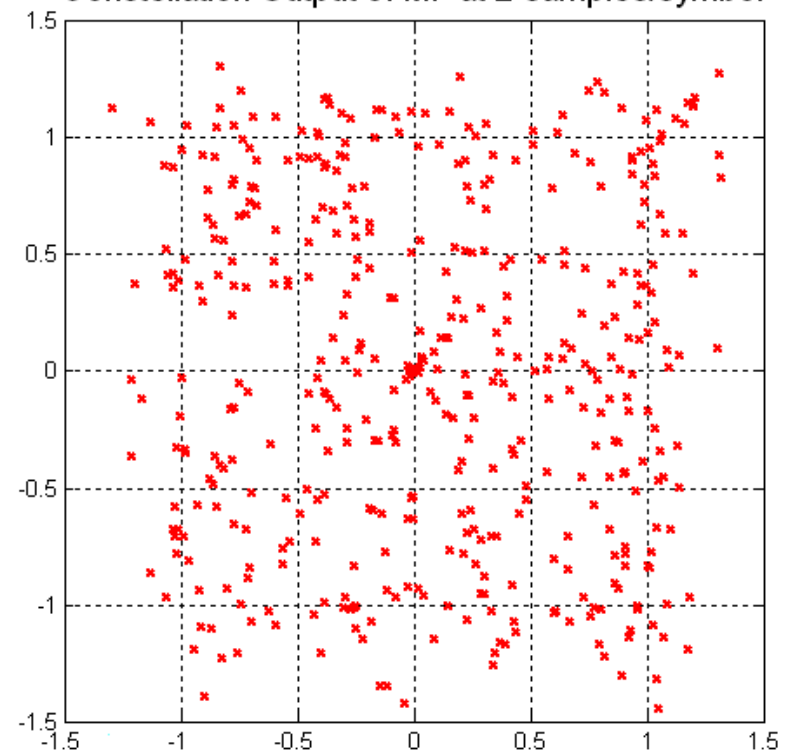


# Di dn' t Have Much Hope

Constellation Input to MF at 2-samples/symbol

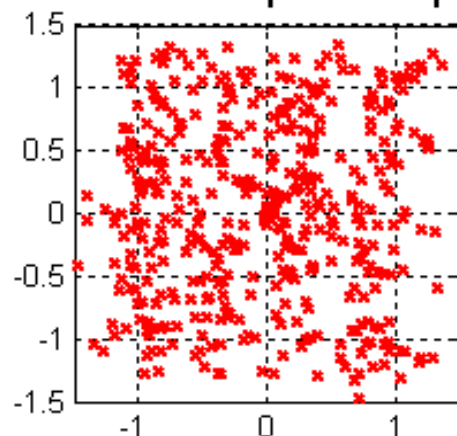


Constellation Output of MF at 2-samples/symbol

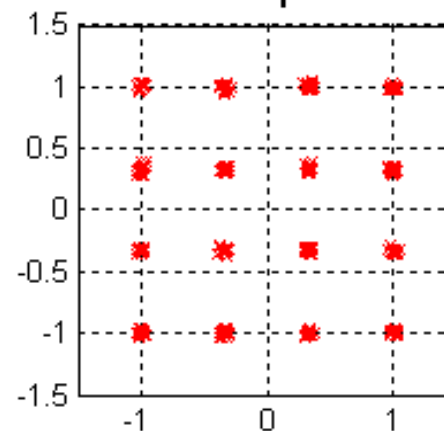


# Ye of Little Faith!

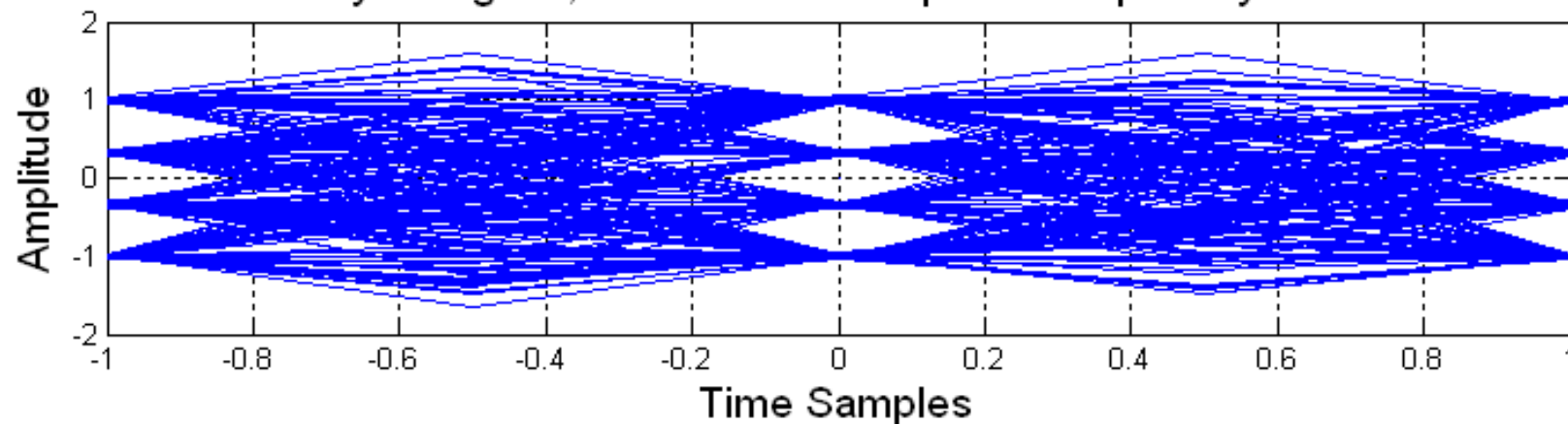
Constellation Input to Equalizer



Constellation Output of Equalizer

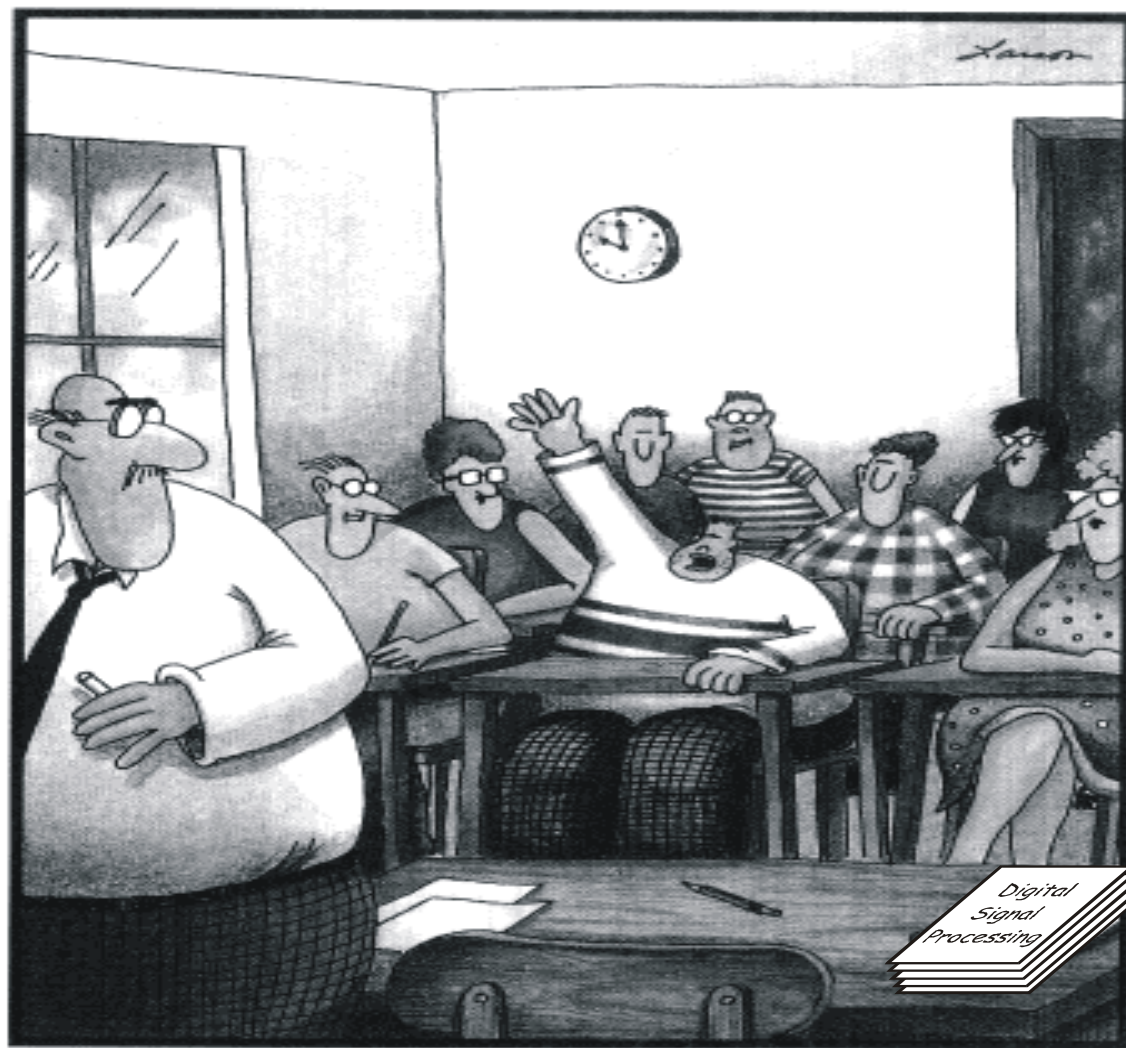


Eye-Diagram, Matched filter Output 2-Samples/Symbol





**Not Bad for Amateurs Eh?**



Professor harris, may I be excused?  
My brain is full.



# We are now Open For Questions

