A Method for Intercepting and Demodulating Slow frequency hopping DPSK signals (Presentation)

Conference Paper · April 2015

2 authors:

Scott Koziol
Baylor University

Steve F. Russell
Iowa State University

Electrical and Computer Engineering
School of Engineering and Computer Science

A Method for Intercepting and Demodulating Slow Frequency Hopping DPSK Signals

Scott Koziol, Baylor University
Electrical and Computer Engineering Department,

Steve F. Russell, Iowa State University
Department of Electrical and Computer Engineering (Emeritus),

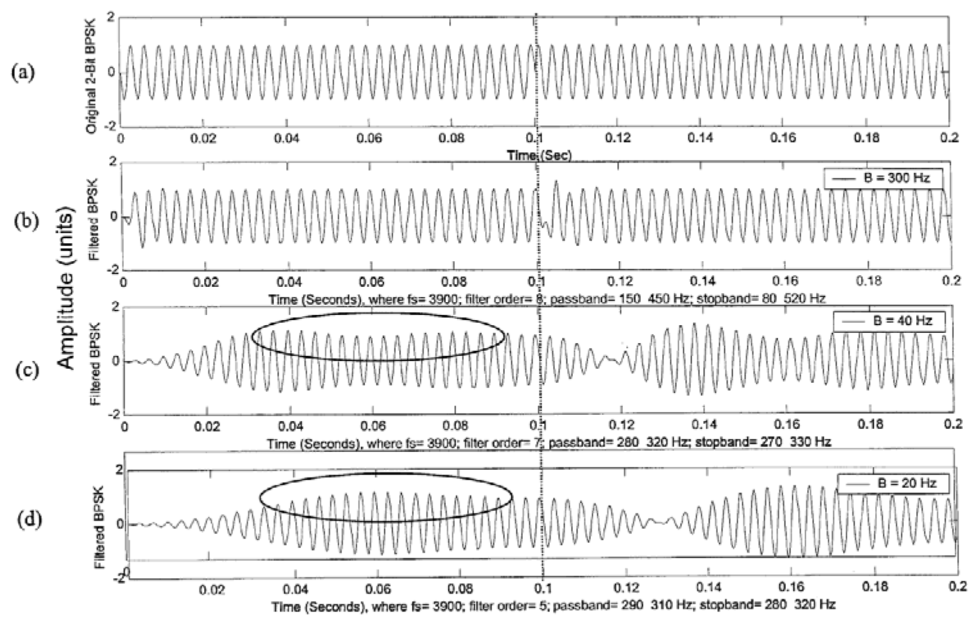
Scott_Koziol@baylor.edu, sfr@iastate.edu

Texas Symposium on Wireless and Microwave Circuits and Systems, April 23-24, 2015
Session D: Communication and Sensing Systems

IOWA STATE UNIVERSITY
College of Engineering

Problem Statement

- Design a wireless communication receiver for intercepting and demodulating frequency hopping spread spectrum (FH-SS) signals.
  - This interception receiver is based on phase modulation to amplitude modulation conversion (PM to AM)



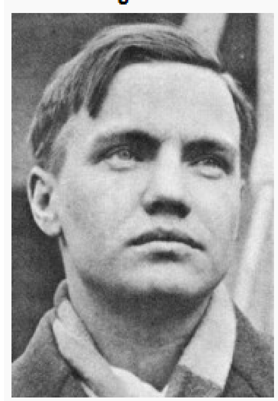
The Actress, the Musician… and the "Secret Communication System"

- Frequency Hopping Spread Spectrum
- Hedy's first husband was a munitions manufacturer
- Hedy and George thought about how radio controlled torpedoes could be foiled
  - Developed a solution using multiple frequencies
    - Using a player piano to scan through 88 frequencies

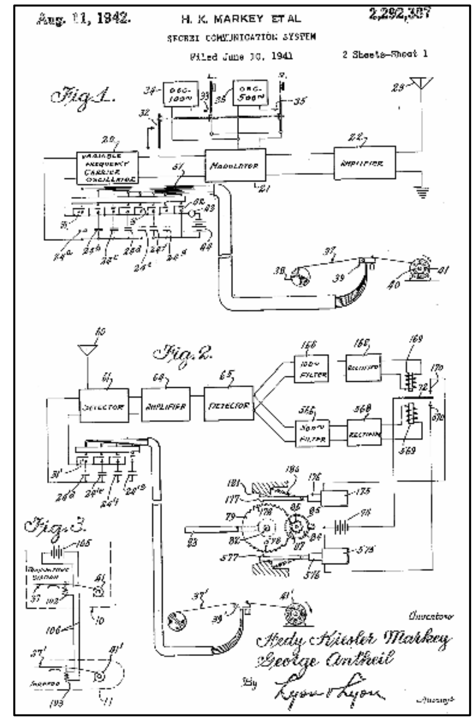
Hedy Lamarr

The Actress

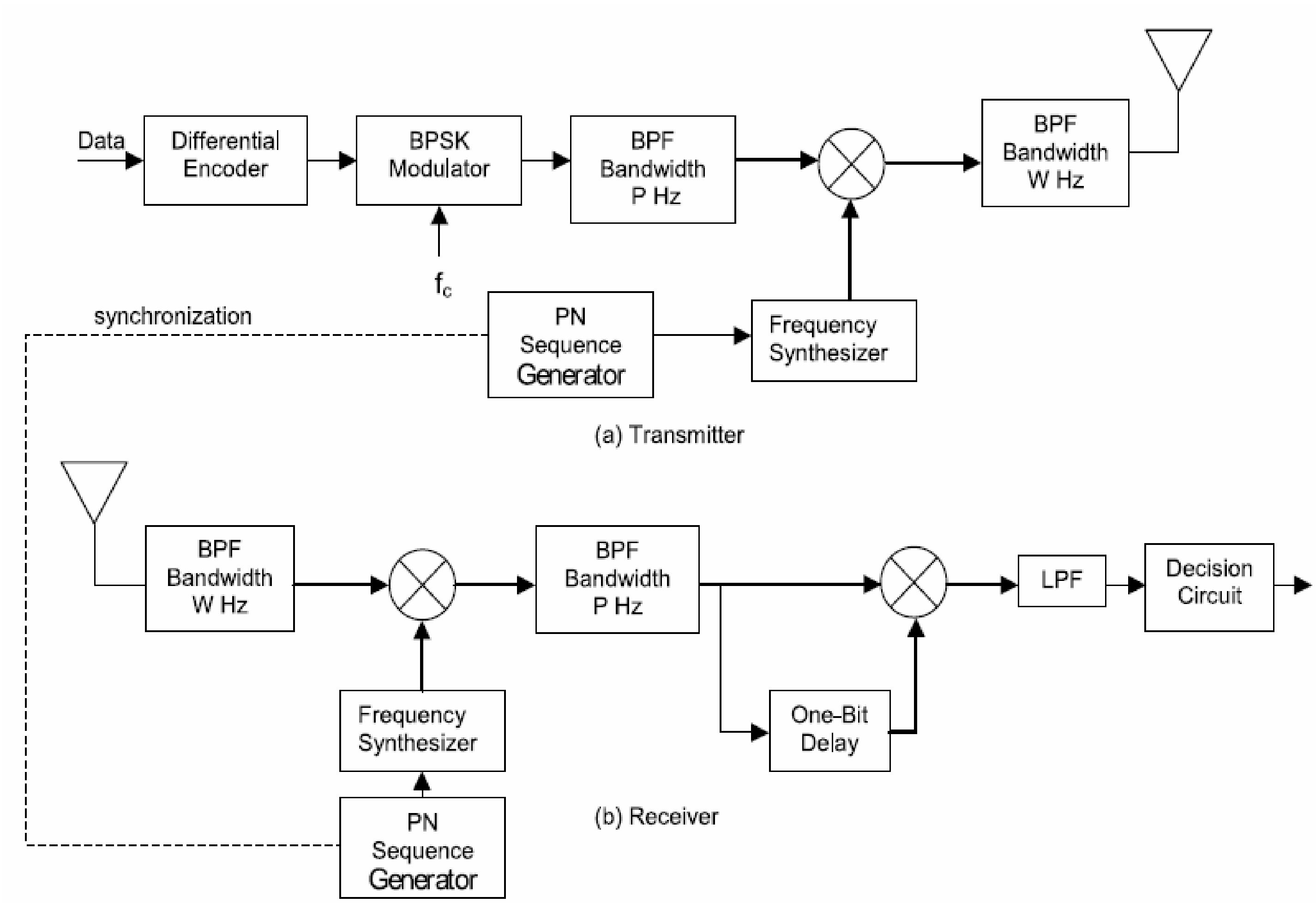
George Antheil



The Musician



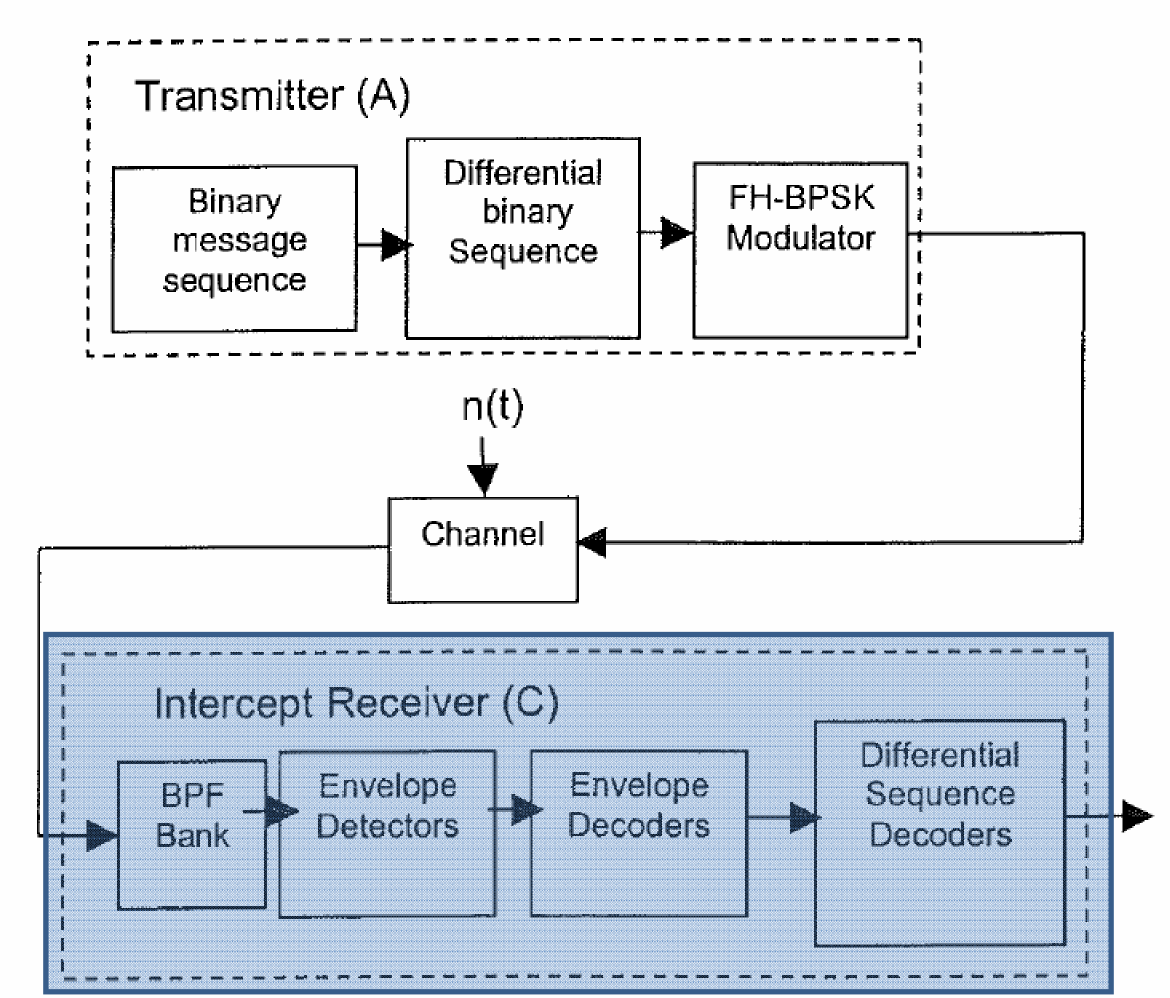
A conventional FH-DPSK transmitter and receiver system



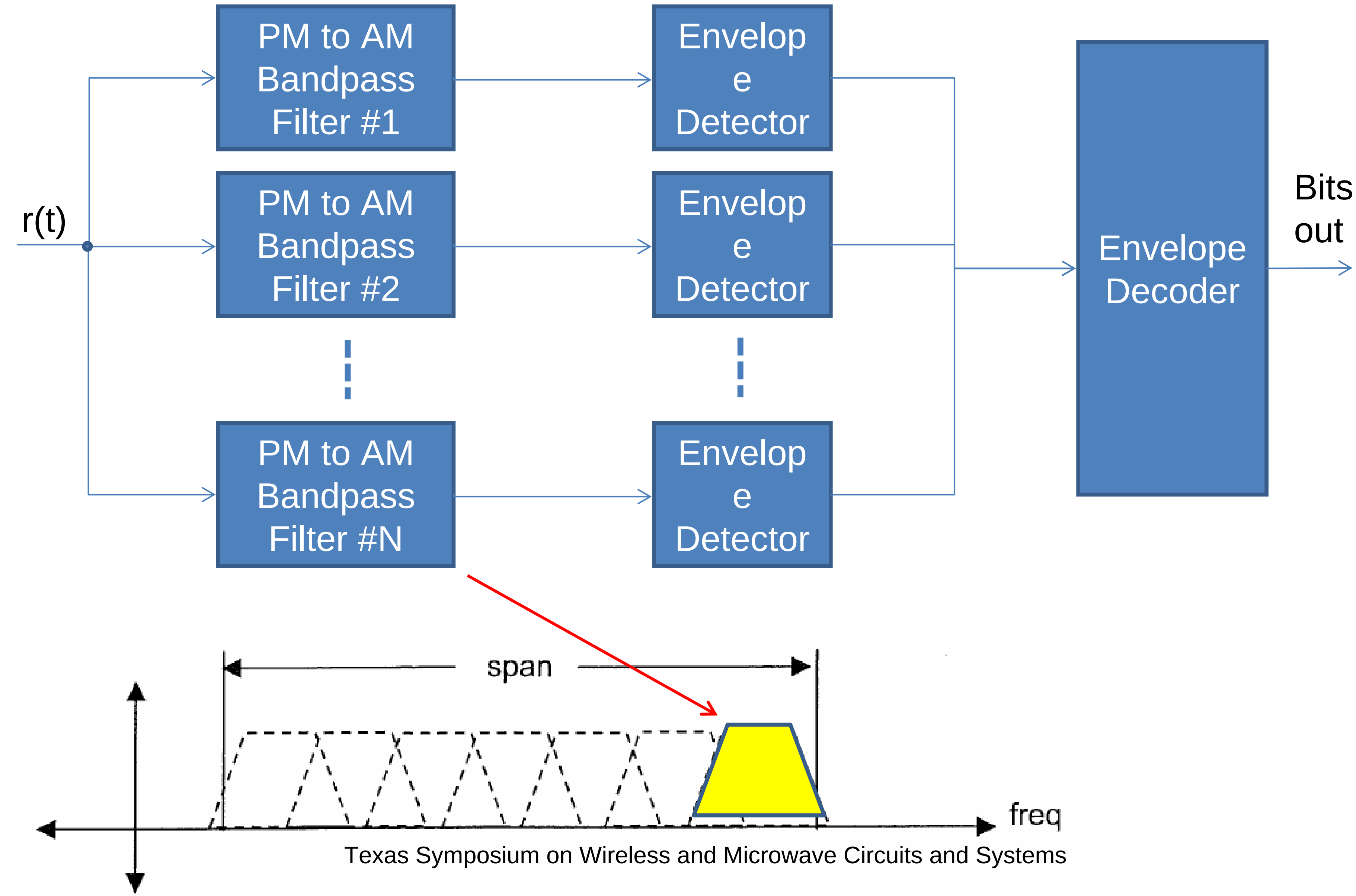
Assumptions

1. Individual hopping frequencies are unknown
2. Dwell times and bit epochs are unknown
3. There is no external synchronization available
4. The hopping span is estimated
5. Hopping is applied to the signal at bit transitions
6. Each bit is composed of an integer number of carrier waves
7. Modulation is DPSK
8. The signal is slow frequency hopped such that there are many data bits per hop
9. The first bit following a carrier frequency hop does not contain data (delay assumption)

System Block Diagram

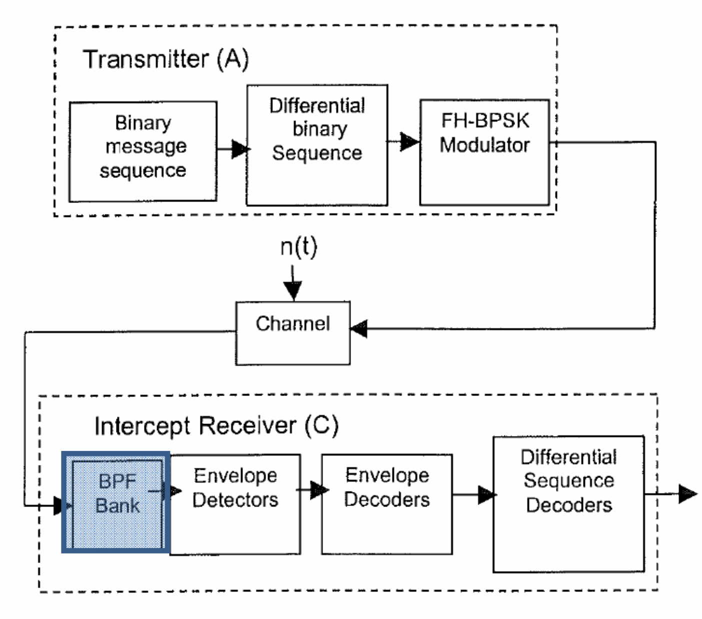


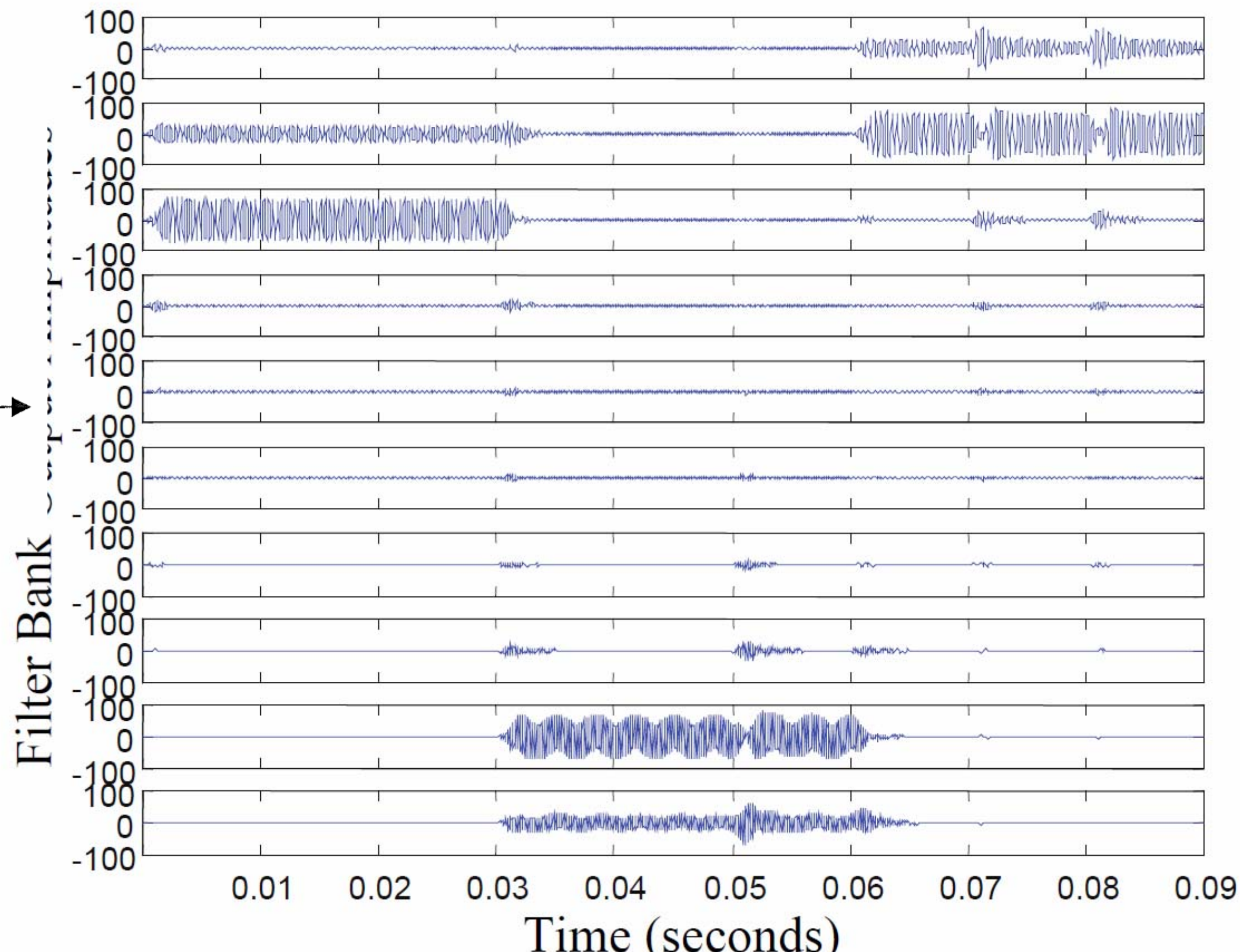
Receiver Block diagram



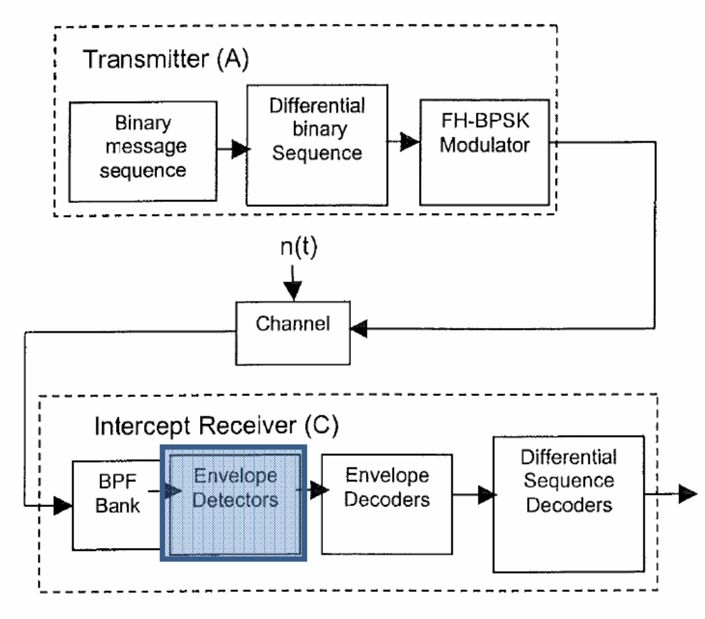
Texas Symposium on Wireless and Microwave Circuits and Systems

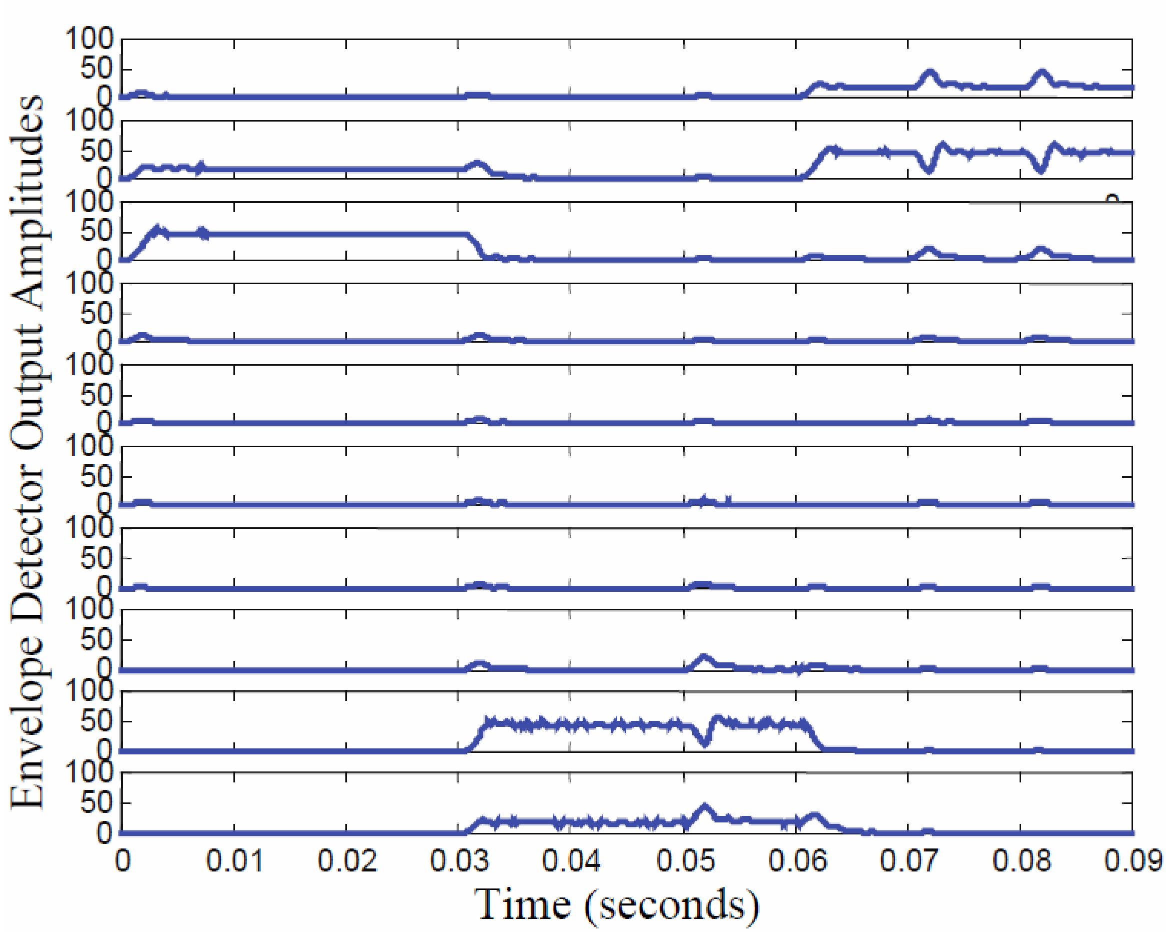
Bank of Bandpass Filters



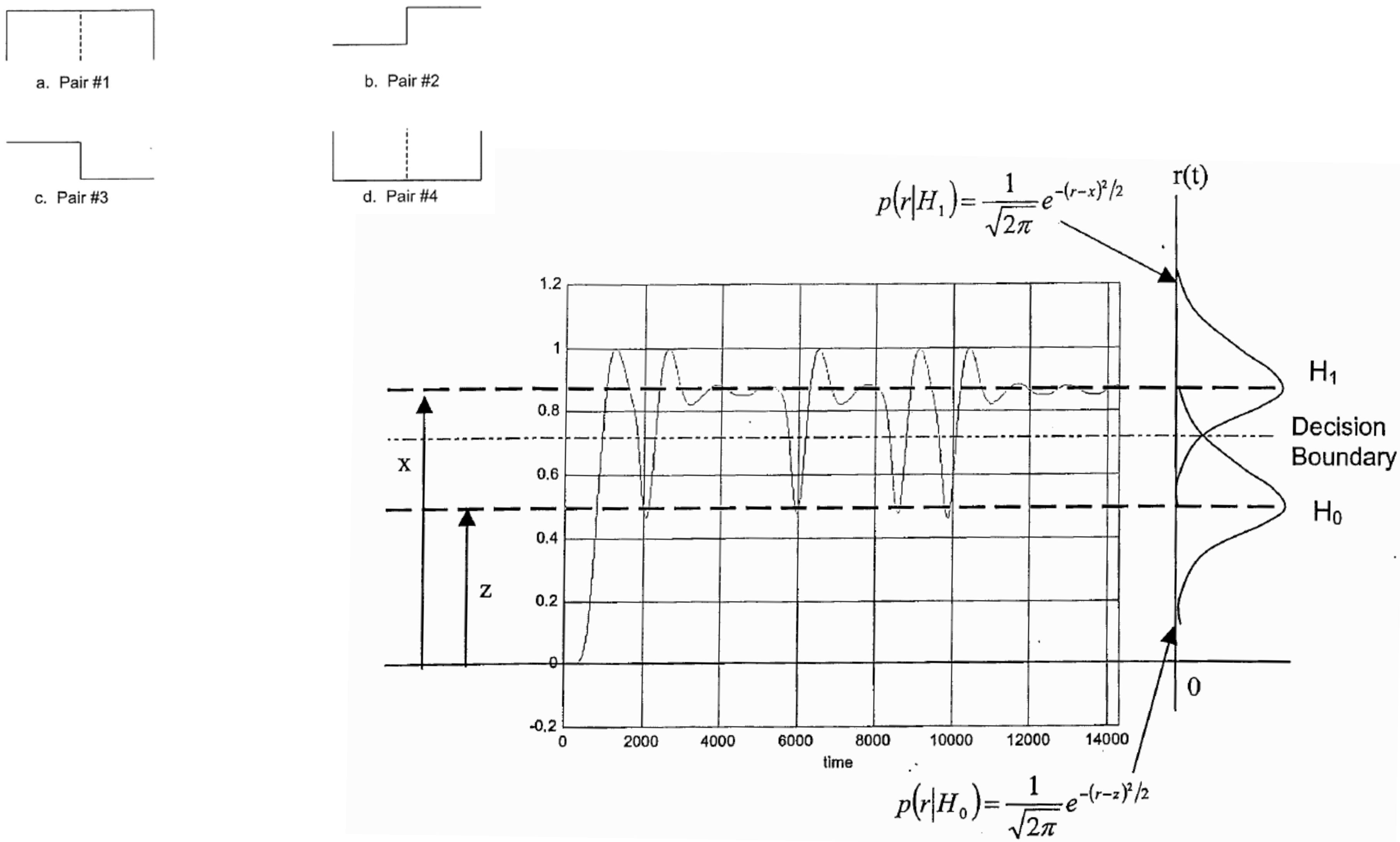


Envelope Detectors



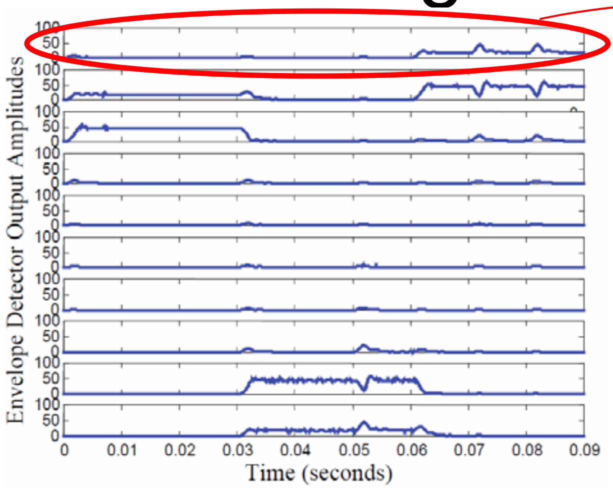


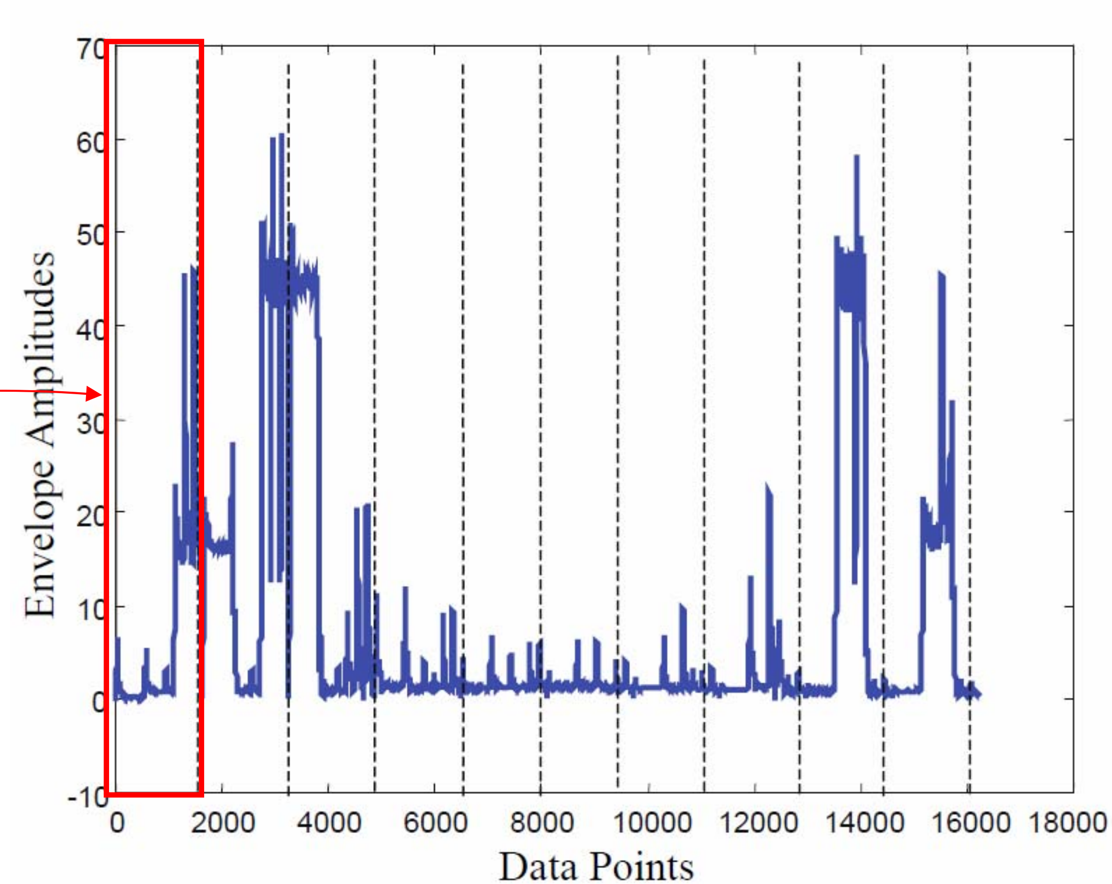
Finding a Phase Transition ?



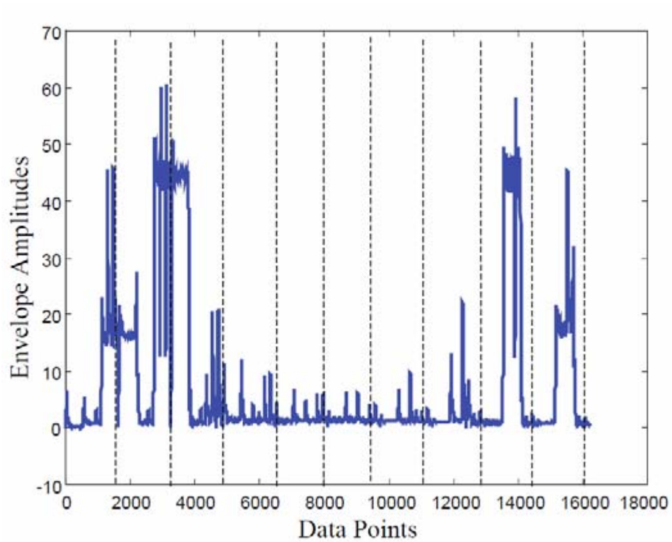
Finding a Phase Transition: Our method

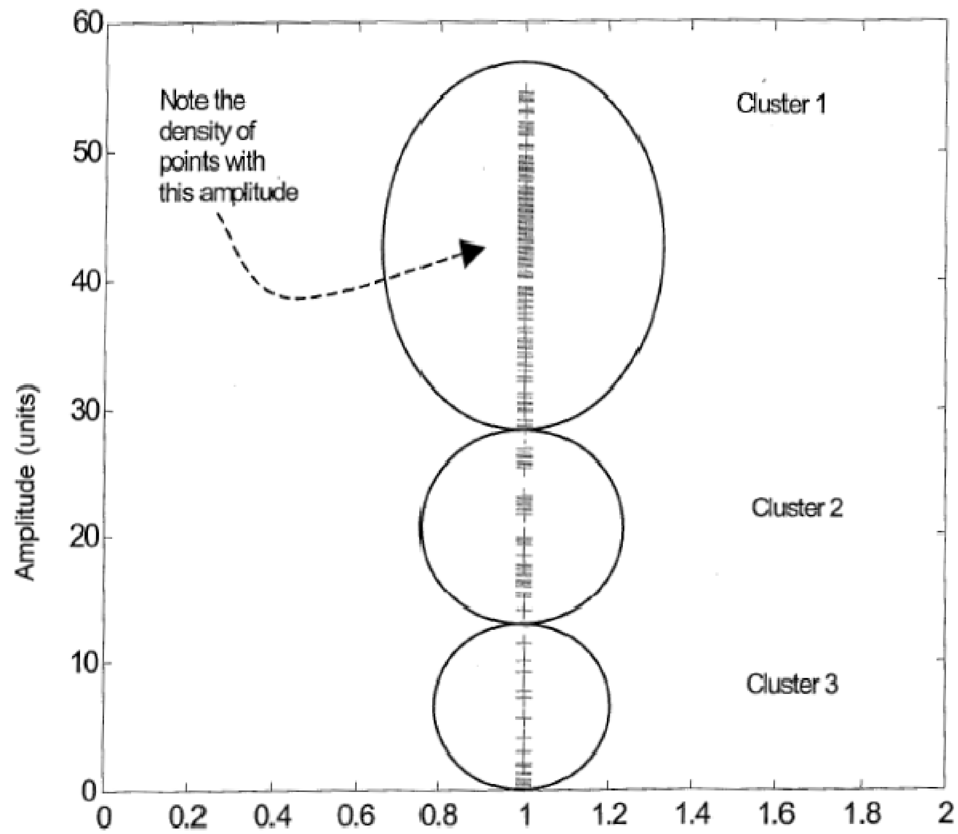
- First: Concatenate the filters outputs into one long vector



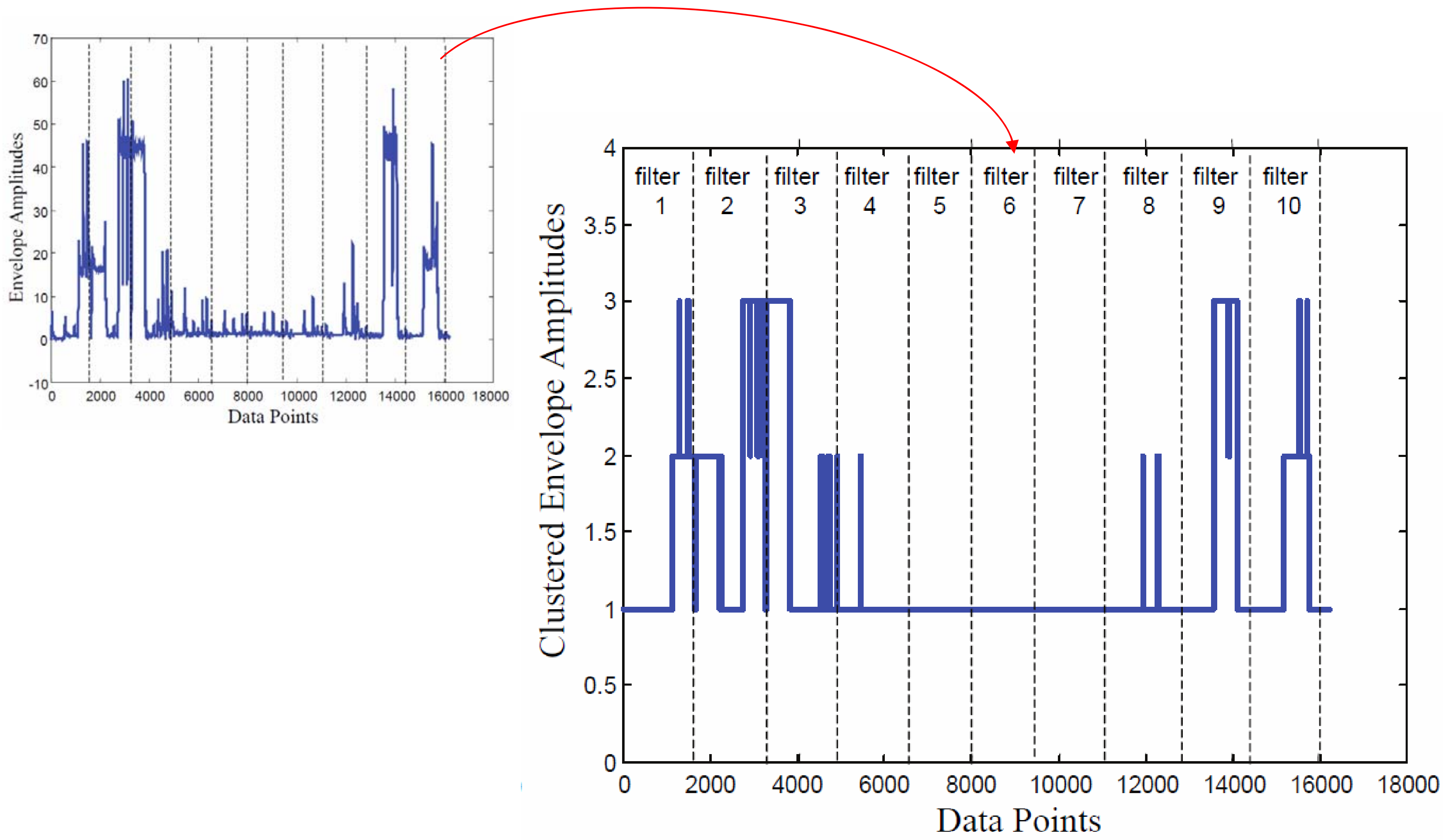


No thresholds, instead use K means clustering

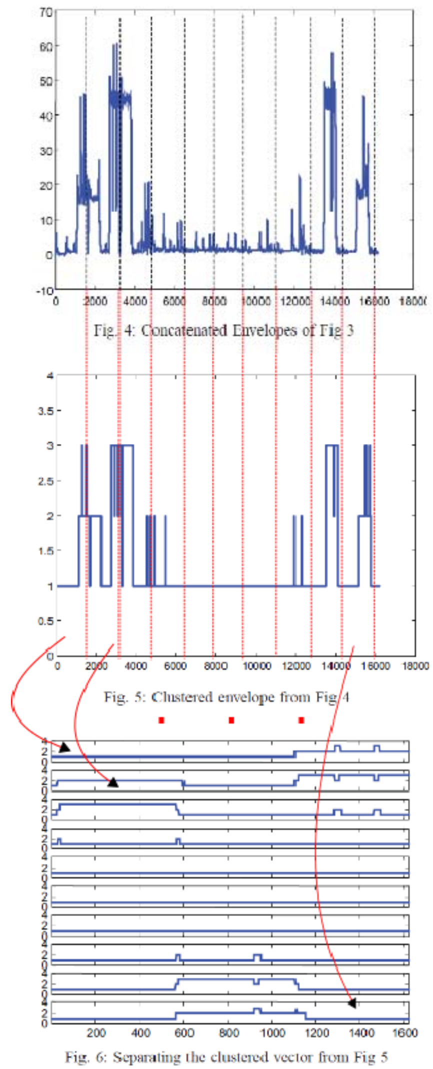




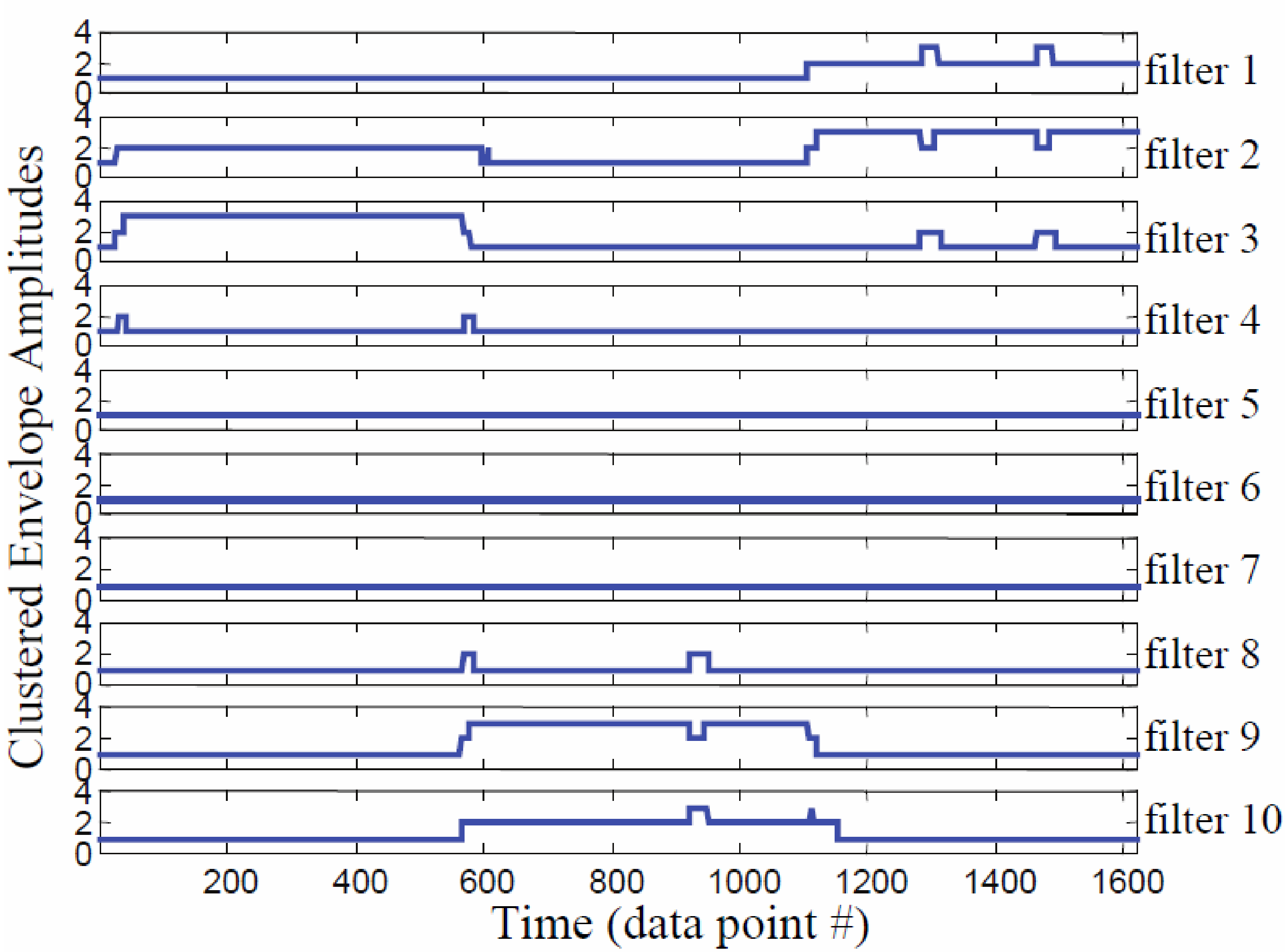
Clustered Envelope



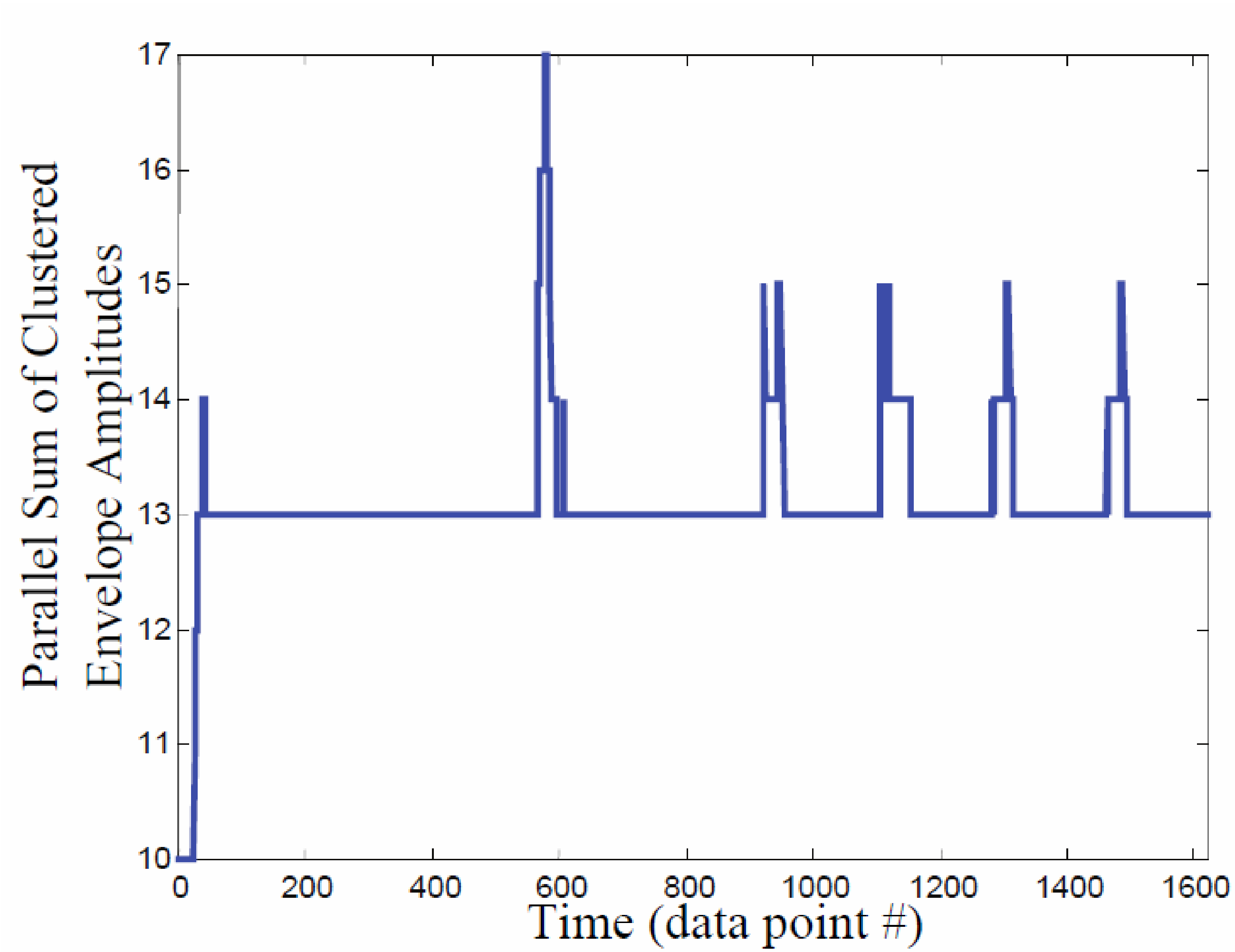
Separating the clustered vector (1 of 2)



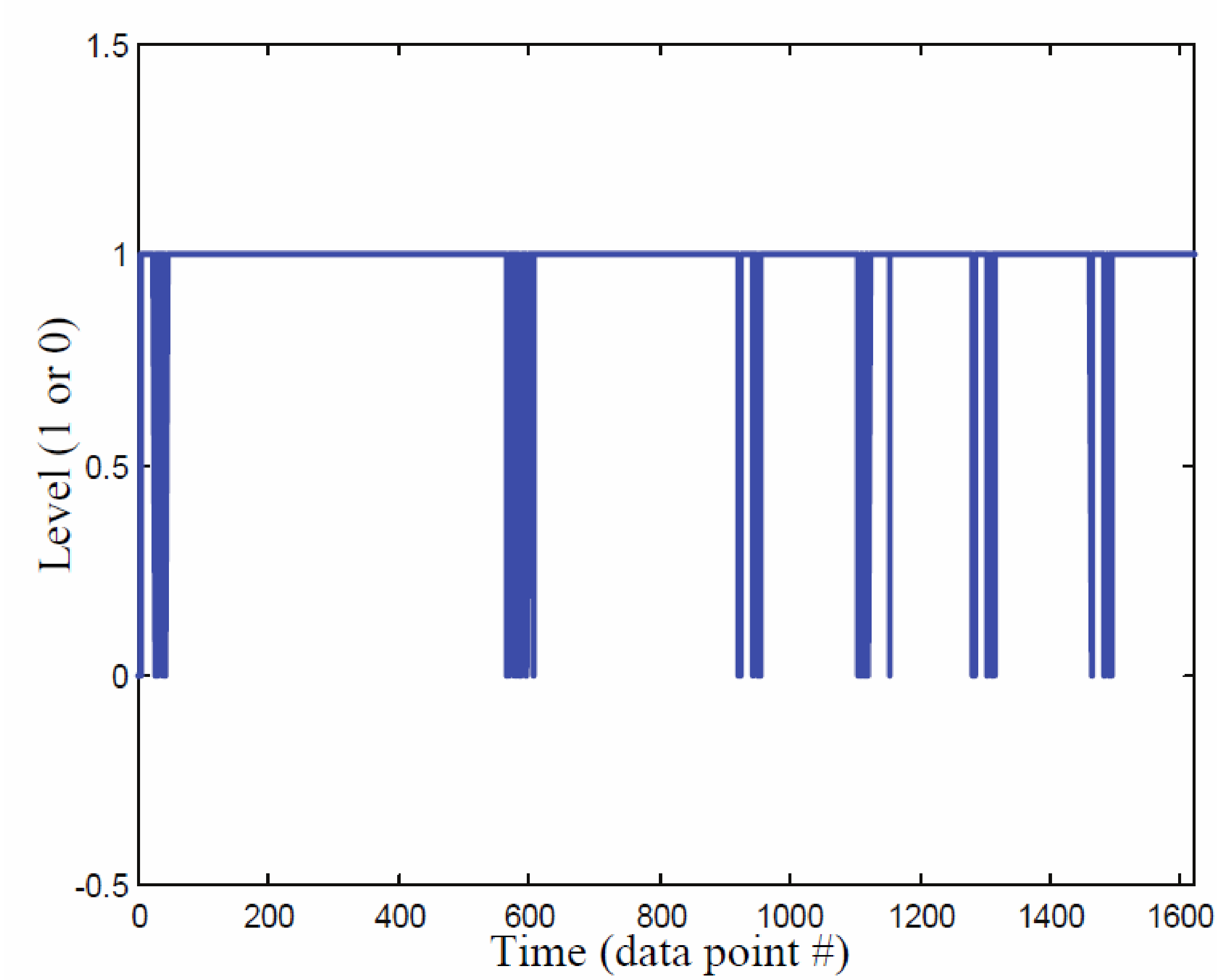
Separating the clustered vector (2 of 2)



Sum the clustered filter banks

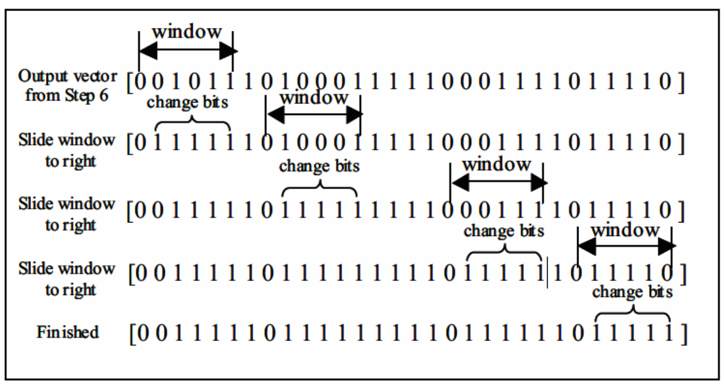


Mapped the summed vector into two values

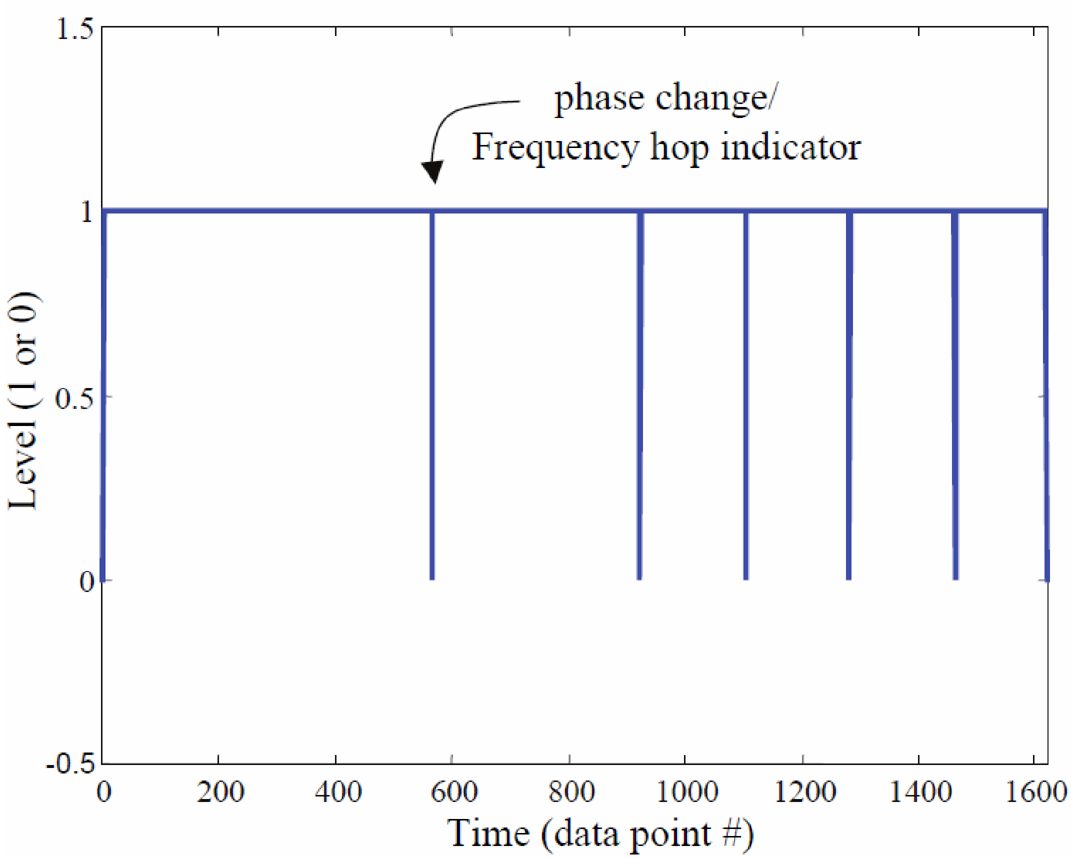


Feature Classification

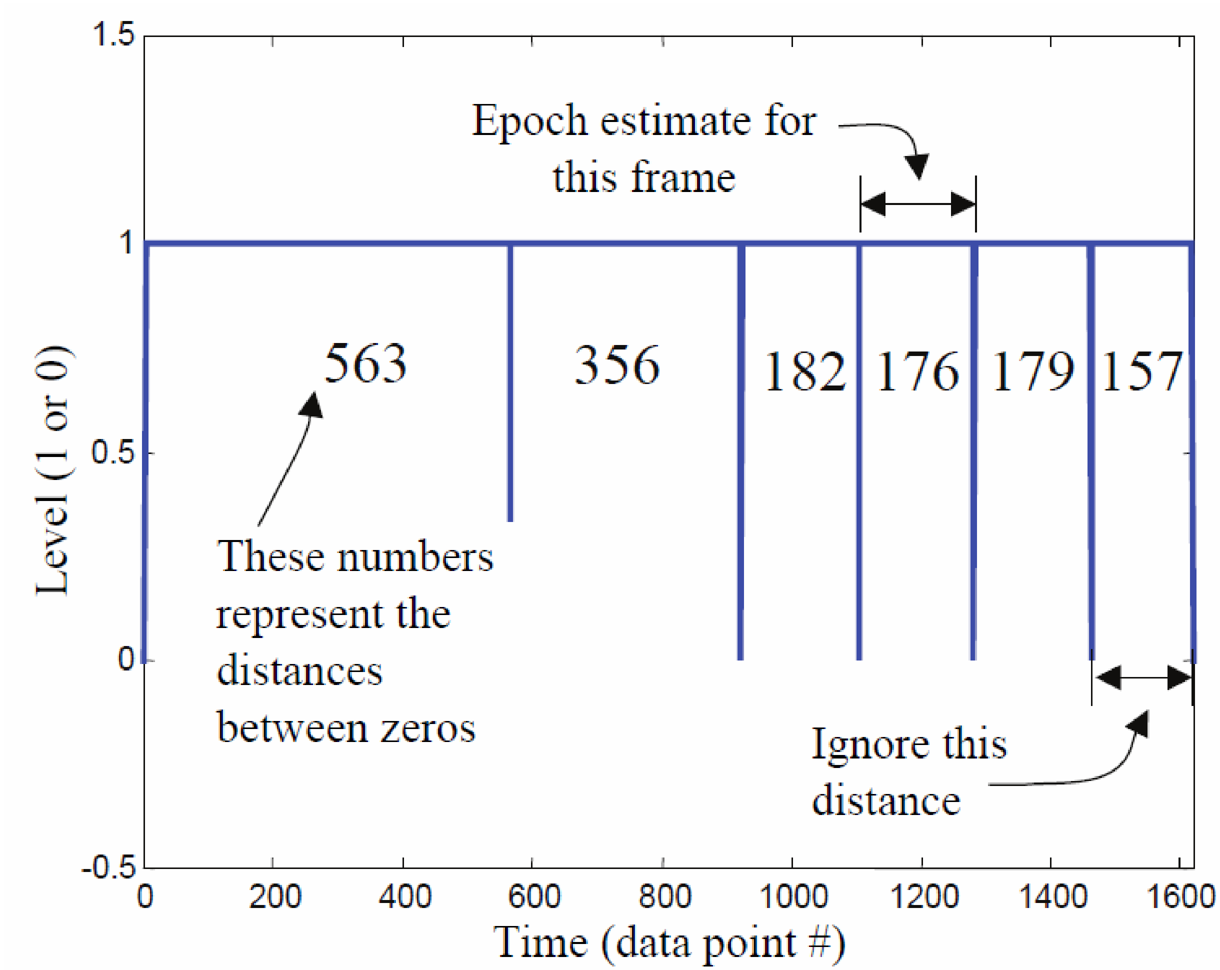
- Identify clusters of zeros with an adaptive sliding window and represent each cluster with a single zero
- The window is slid across the data to the right and stops
  - – when the left edge of the window is on a zero:
    - Then all bits within the window except for the left most zero bit are converted to ones.
  - – The window continues sliding until its left edge finds another zero and the process repeats.



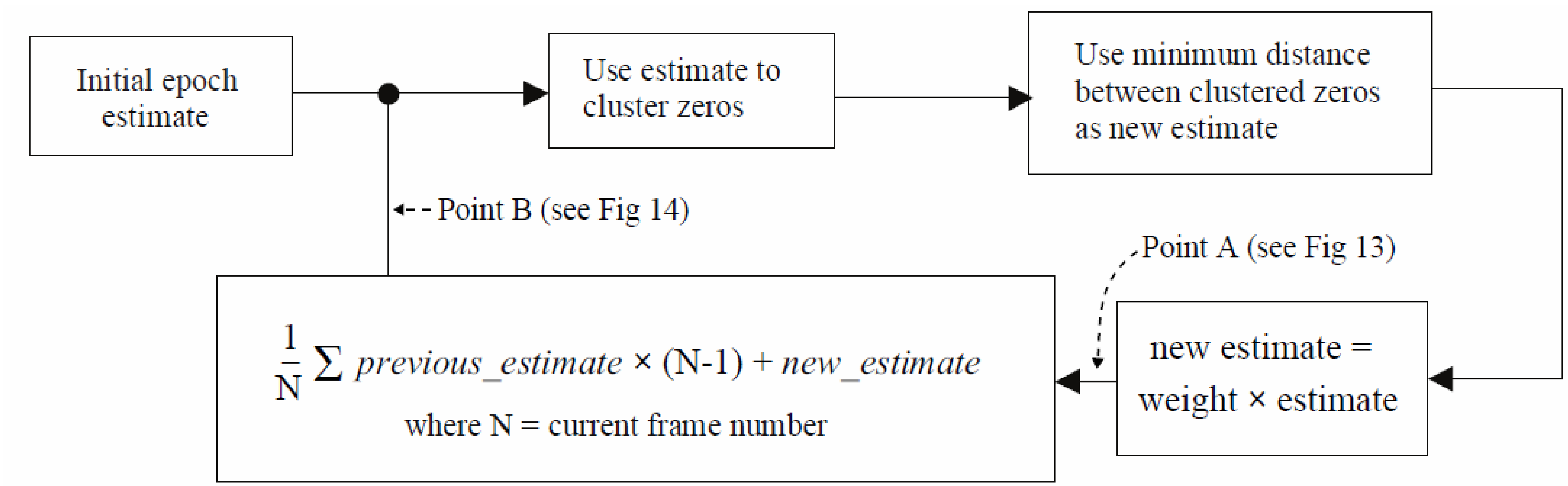
Cluster the Zeros



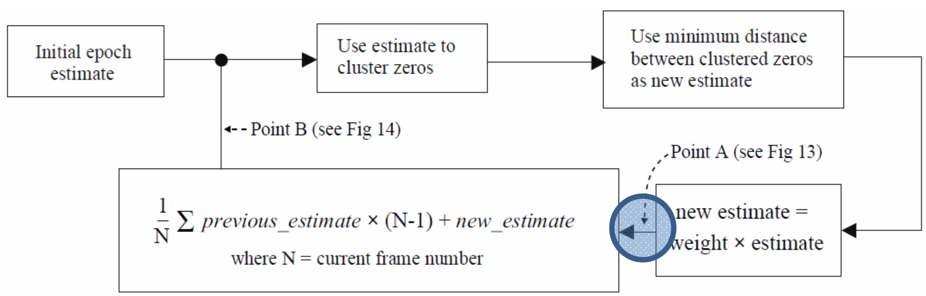
Making a new estimate of the epoch

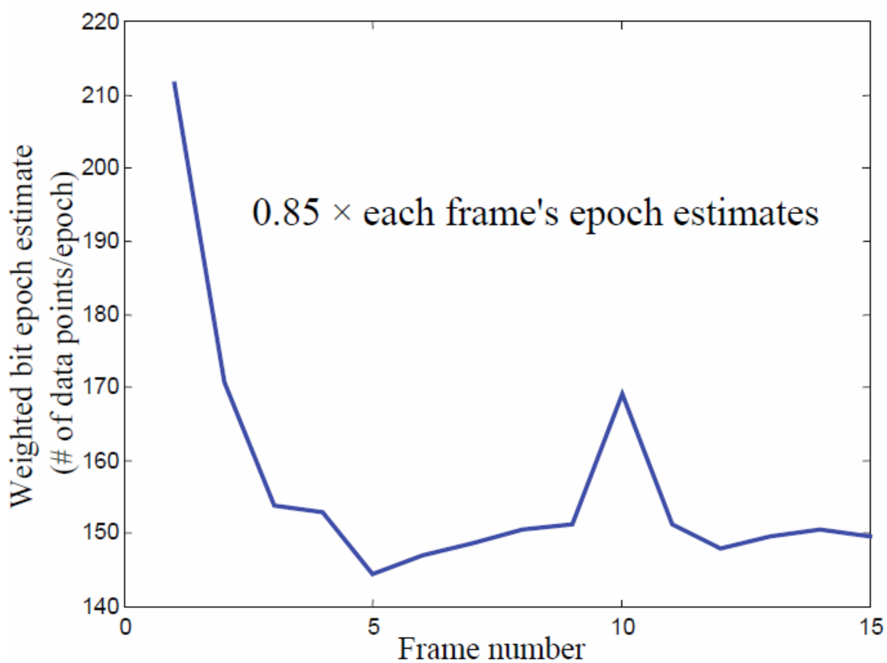


Feedback system to converge on the true epoch

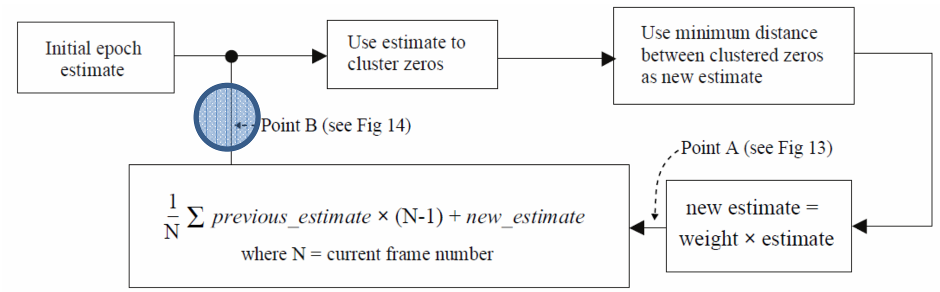


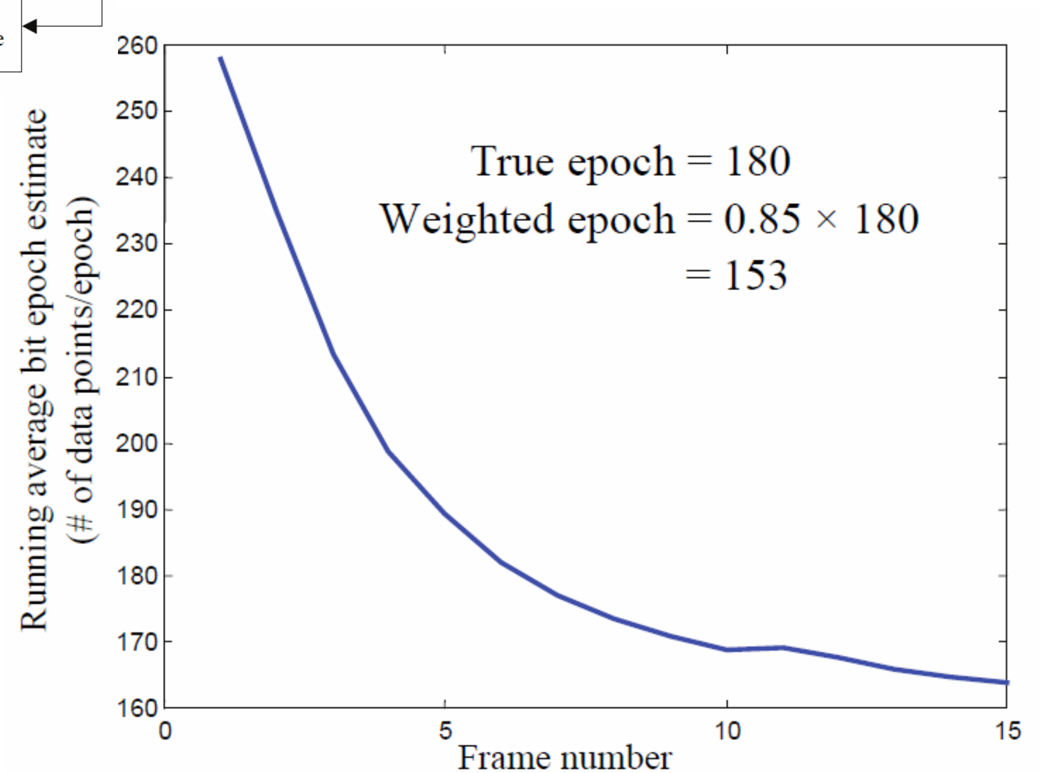
Example epoch estimates from the frames (Point A)



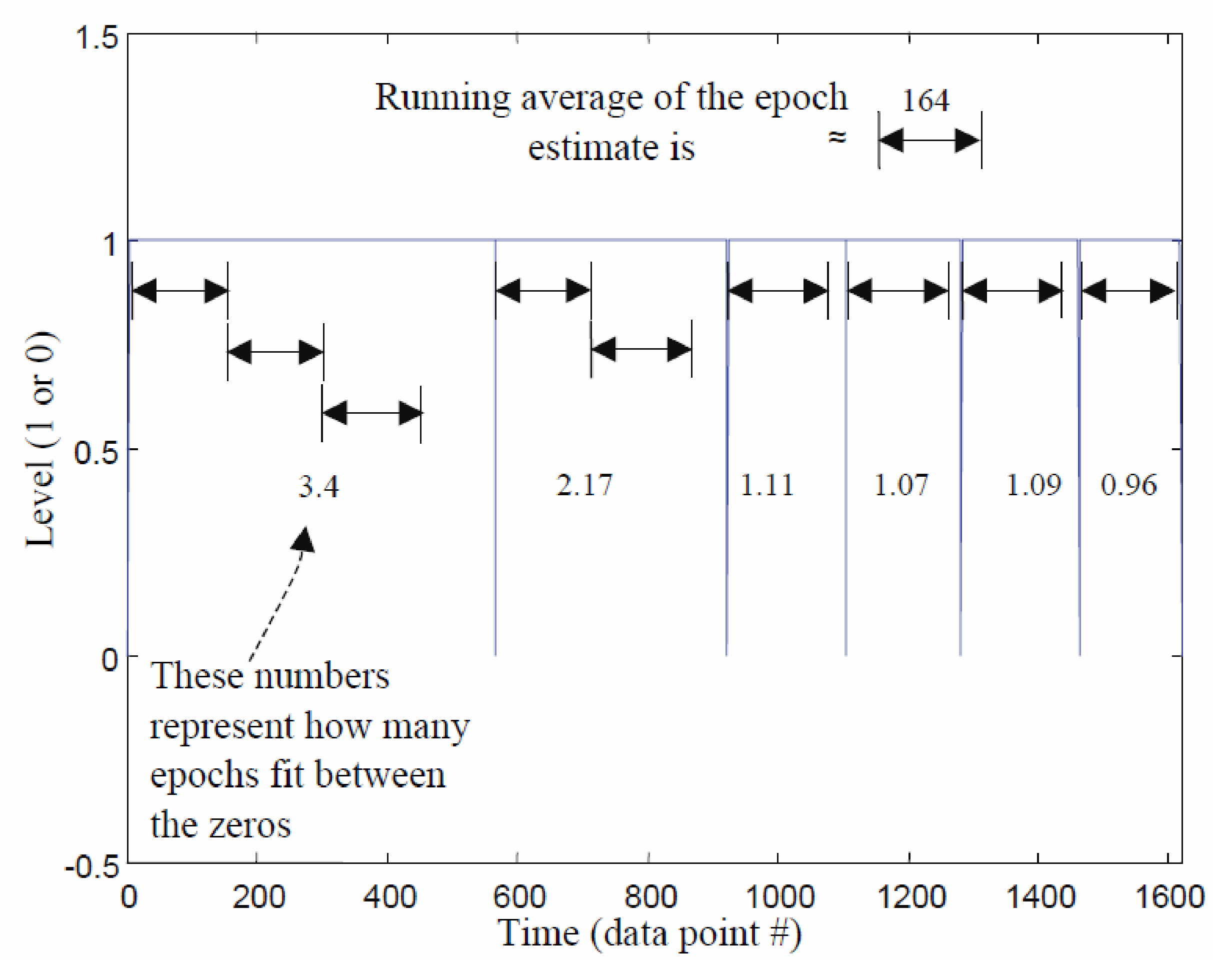


Convergence upon the weighted true epoch (Point B)





Estimating the number of bits between each zero



Decode the differential sequence

Assigning differential bits

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6
Bits/Bin	3	2	1	1	1	1
Differential Bits	1 1 1	0 0	1	0	1	0

Decoding the differential bits from table above

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6
Differential Bits	1 1 1	0 0	1	0	1	0
Decoded Bits	x 1 1	0 1	0	0	0	0

Decoded bits compared to the original message bits

	Bin 1	Bin 2	Bin 3	Bin 4	Bin 5	Bin 6
Decoded Bits	0 1 1	0 1	0	0	0	0
Original Message Bits	0 1 1	1 1	0	0	0	0

Performance Summary

SNR (db)	P_e (%)	N_{total}	N_{wrong}	$N_{training}$	$N_{freqhops}$	$N_{\frac{bits}{hop}}$	$P_{calculated}$ (%)	Unpredicable error $\frac{100(P_{calculated}-P_e)}{P_{calculated}}$ (%)
20	60	984	593	18	328	3	17	260
30	17	906	151	96	302	3	17	1.8
35	18	948	174	54	316	3	17	10
40	17	918	155	84	306	3	17	1.3
45	18	966	171	36	322	3	17	6.2
45	2	900	22	120	45	20	2.5	2.2

Predicted probability of bit error when sending 1000 bits

$$\frac{N_{freq\_hops}}{N_{Total}} \times \frac{1}{2}$$