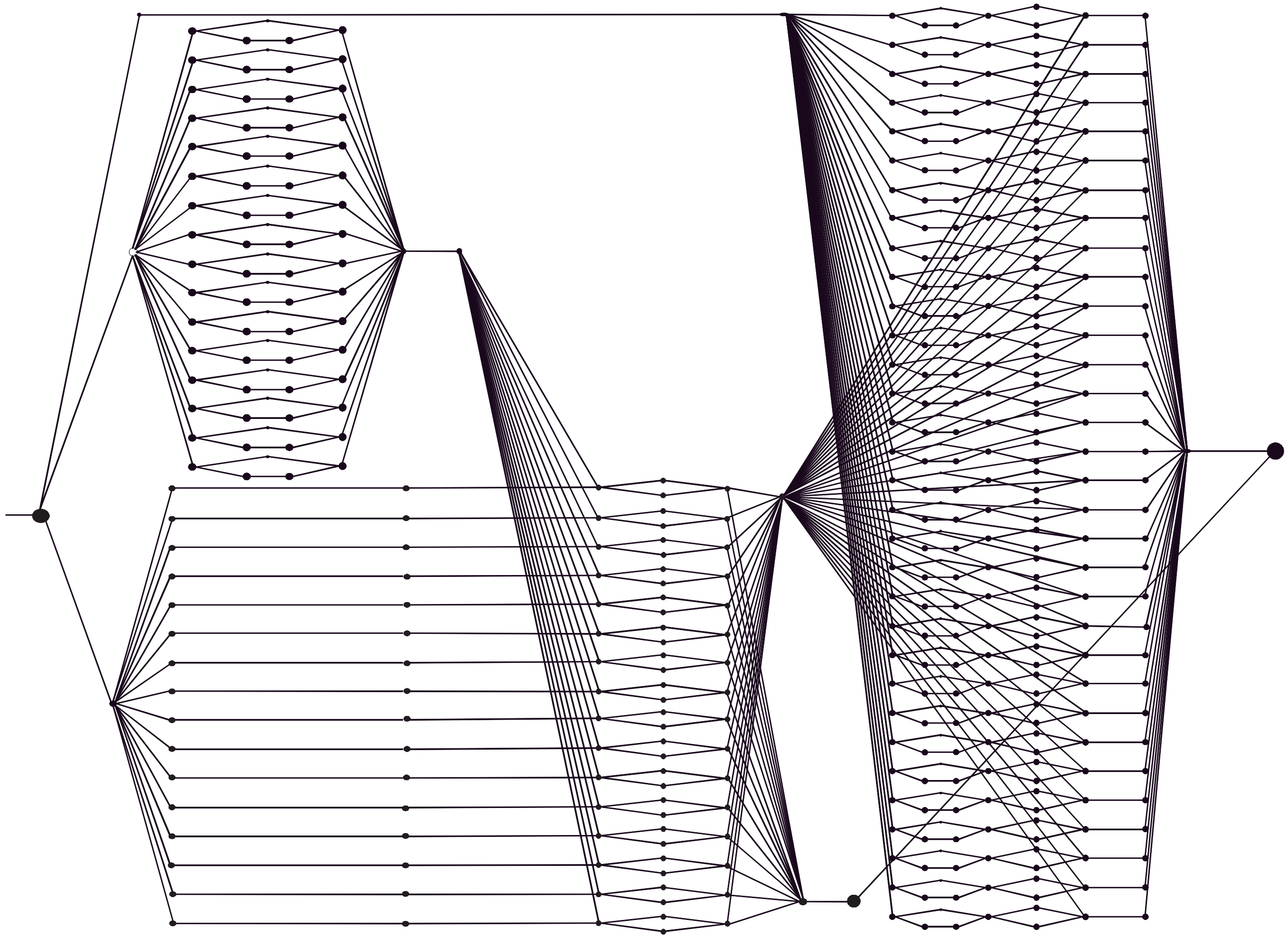
Algorithm Network: Periodogram Averaging



Approximate Processing & Incremental Refinement

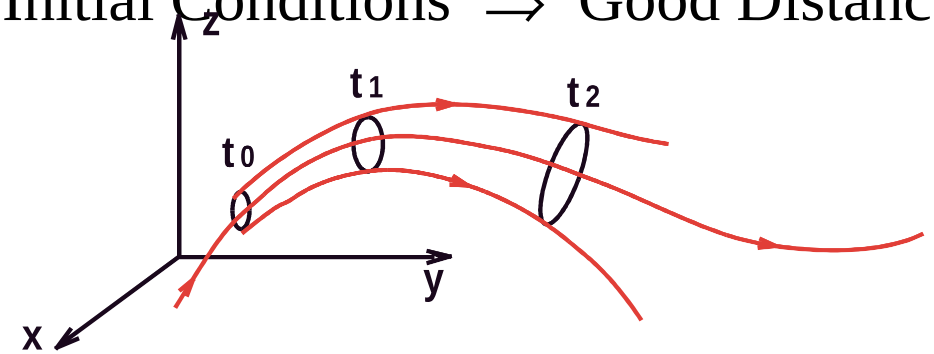
- Trading off between system performance and resource usage
- Adaptive termination of processing based on sufficient results
- Achievement of graceful degradation in task outcome as resource usage or availability is diminished
- Complete or approximate fault tolerance

Just enough – Just in time

Good enough is good enough

Analog Error Correcting Codes
(Chen and Wornell)

- Message sample specifies initial condition, time segment of state sequence specifies transmitted code
  $X_n = f[x_{n-1}]$ X_o = message $X_1 \ldots X_n$ = code
- Sensitivity to Initial Conditions $\Rightarrow$ Good Distance Properties



- Well suited to channels where SNR is (i) unknown, (ii) time varying, (iii) spatially varying
- Superior to digital codes
- Superior to linear modulation

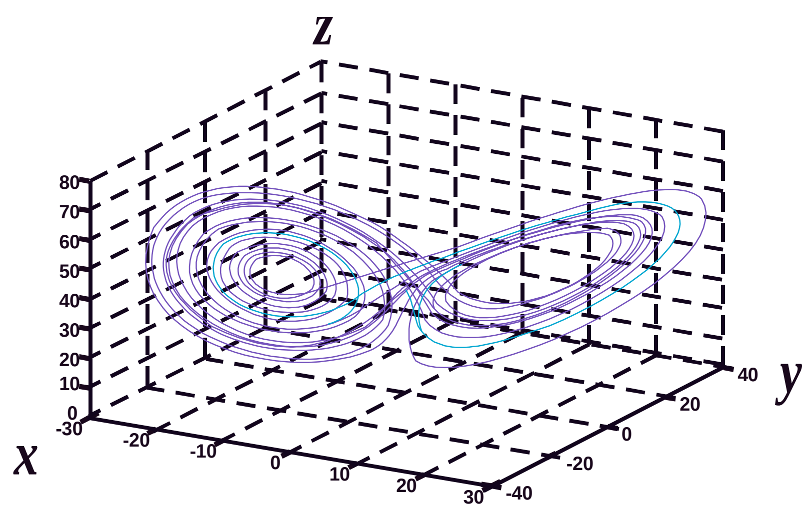
Chaotic Signals and Systems

- Nonlinear Dynamical Systems
  $$\dot{\mathbf{\bar{x}}}(t) = \mathbf{F}[\mathbf{\bar{x}}(t), \mathbf{u}(t), t]$$

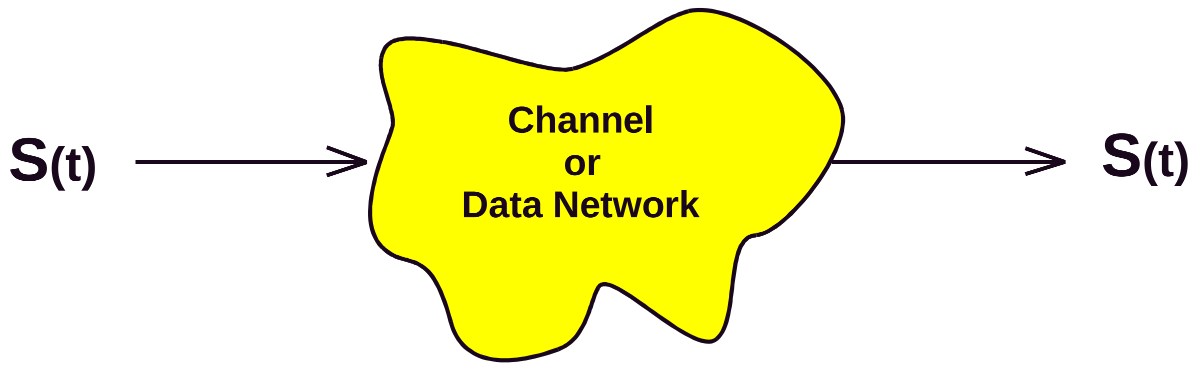
Deterministic & SDIC $\Leftrightarrow$ Chaotic Behavior

Lorenz System

$$\dot{x} = \sigma(y - x)$$
$$\dot{y} = rx - y - xz$$
$$\dot{z} = xy - bz$$



Communication Systems

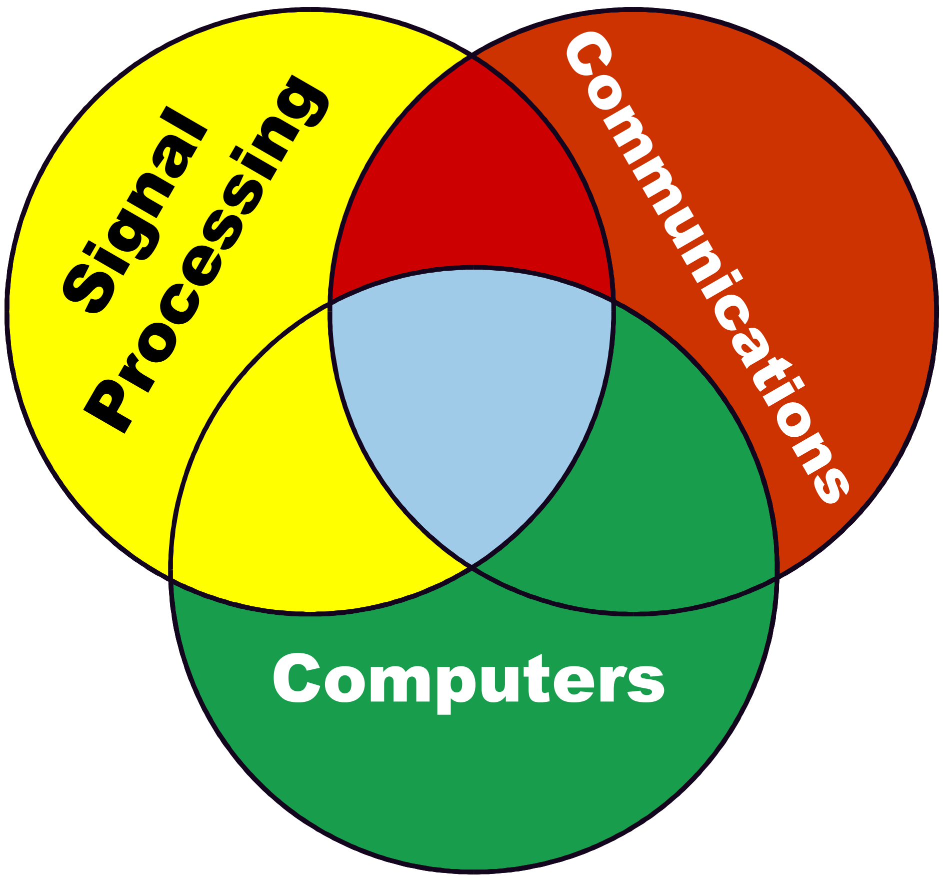


- Coding and channel conditioning for error detection and correction
- Optimum routing
- Network load balancing
- Channel capacity theorems

Communication Based on Chaos

- Self-synchronizing transmitter and receiver *(Pecora and Carroll)*
- Signal masking (*Cuomo and Oppenheim*)
- Low-power modulation (*Hayes, et al.*)
- Analog error correcting codes (*Chen and Wornell*)
- High-dimensional chaotic signals using lasers (*VanWiggeren and Roy*)

Digital Convergence



“If you look ten years out, many of the common DSP applications haven’t even been invented yet and the market demand should reach about $50 billion within the next ten years. In addition, DSP performance will be more than 200 times what it is today.”

Tom Engibous
President and CEO
Texas Instruments

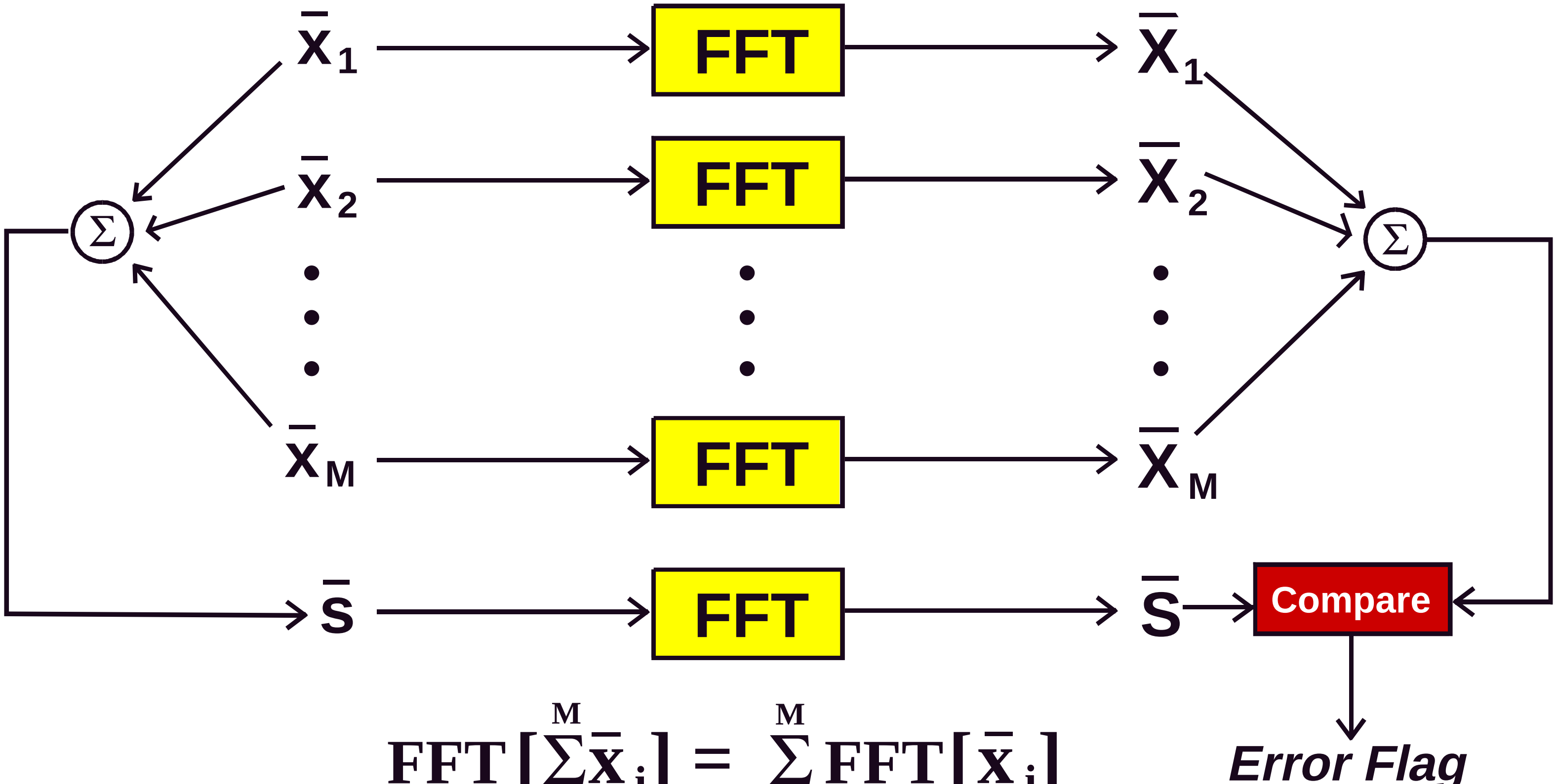
“DSP is the glue of three converging industries … computers, consumer electronics, and communications.”

Will Strauss
Forward Concepts Marketing

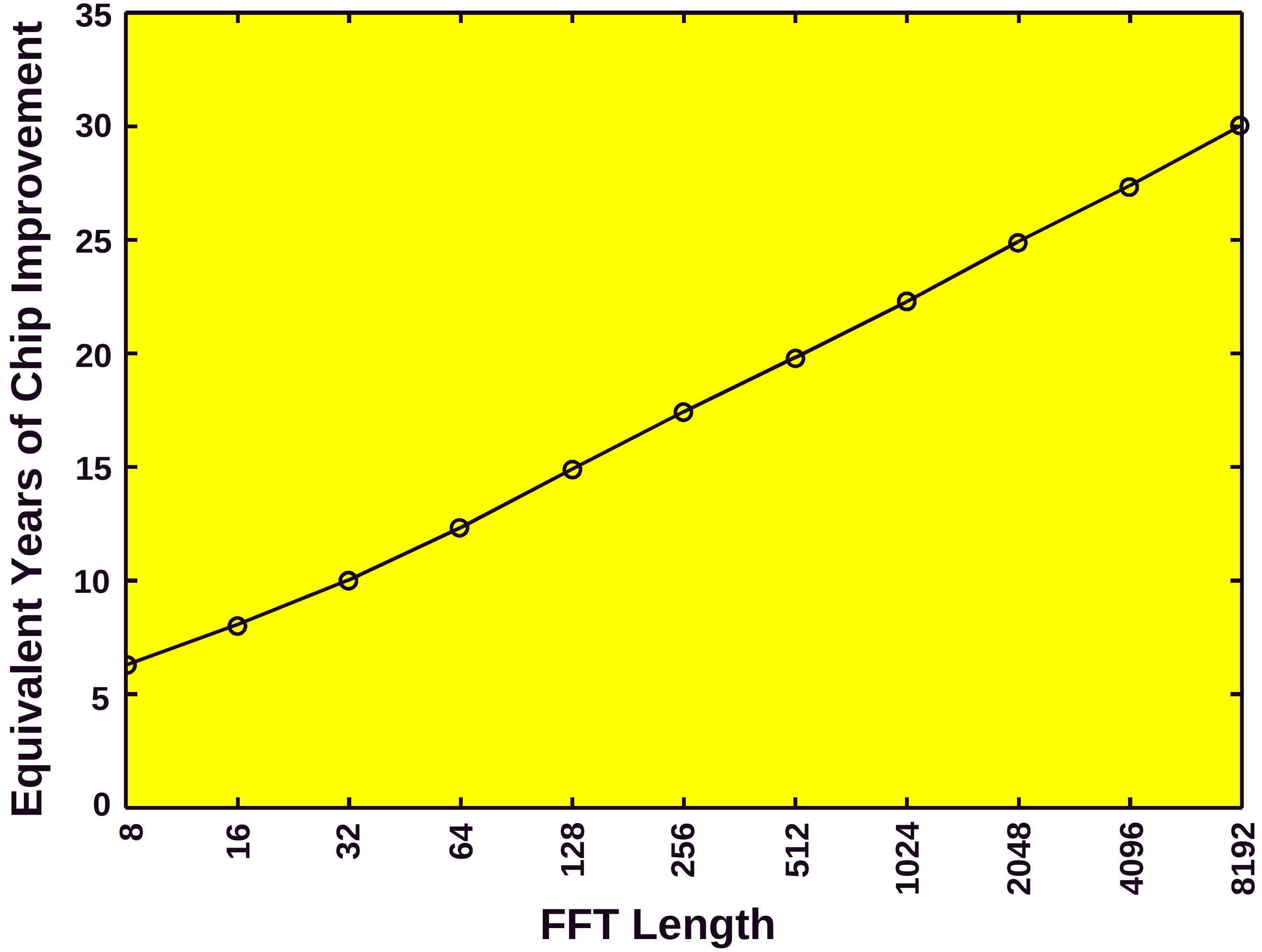
"DSP is a discipline that allows us to replace a simple resistor and capacitor with two anti-aliasing filters, an A-to-D and D-to-A converter, and a general-purpose computer or an array processor as long as the signal we are interested in doesn't vary too quickly."

Tom Barnwell
Georgia Tech

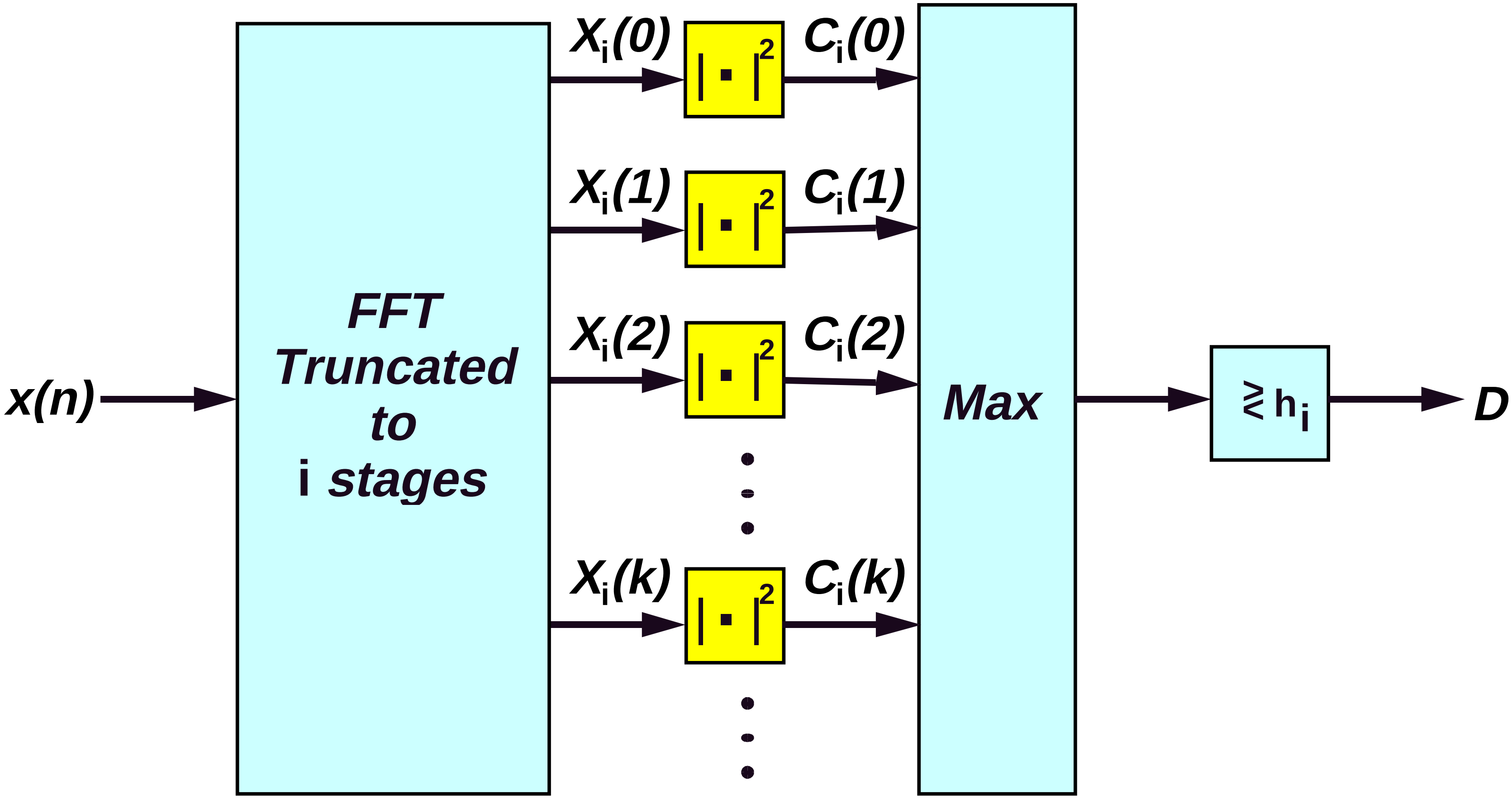
Error Detection in FFT Calculations

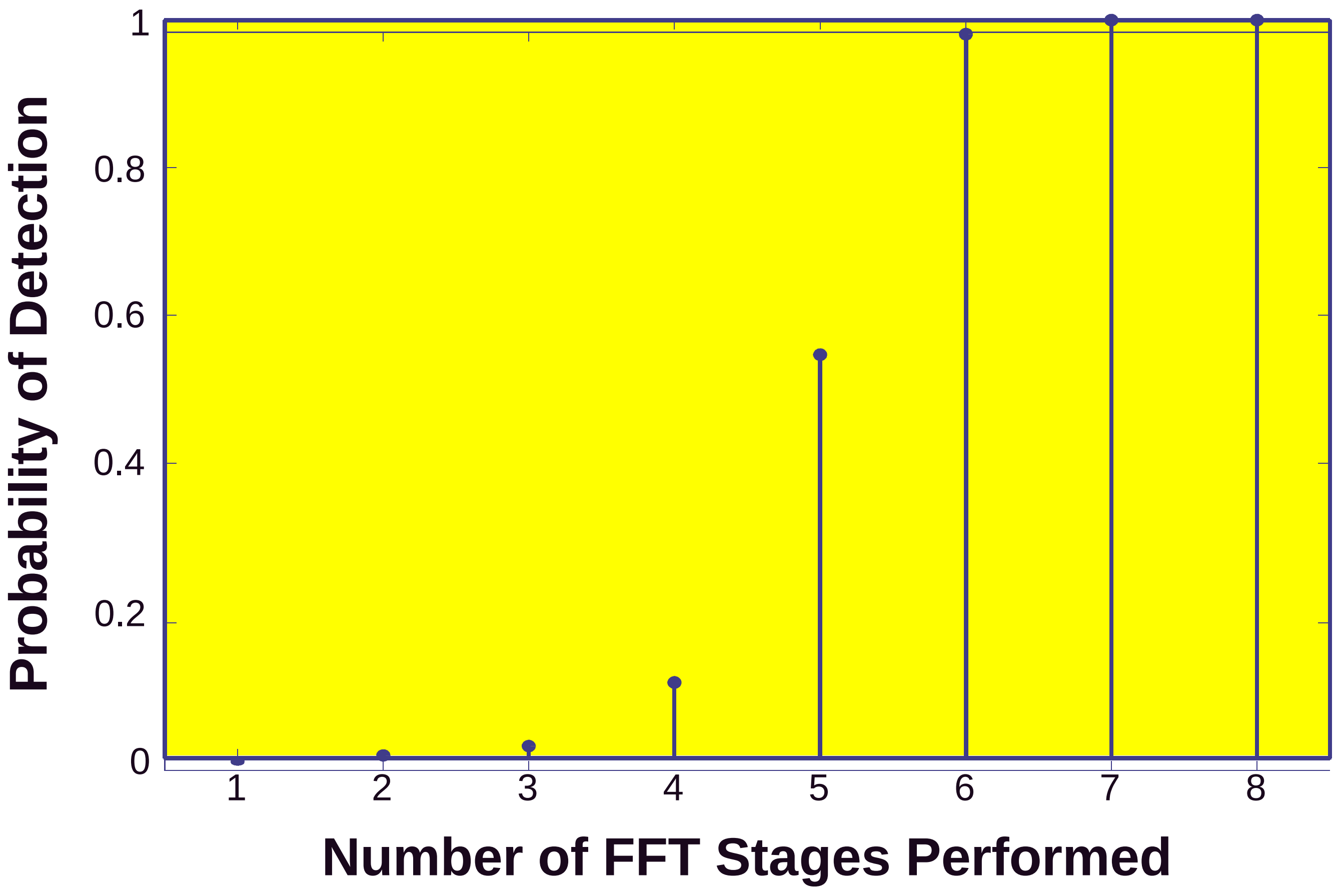


$$\mathrm{FFT}\left[\sum_{i=1}^{M}\bar{x}_i\right] = \sum_{i=1}^{M}\mathrm{FFT}\left[\bar{x}_i\right]$$


Equivalent Years of Chip Improvement
0
5
10
15
20
25
30
35
8
16
32
64
128
256
512
1024
2048
4096
8192
FFT Length

Incremental Refinement Detector of Sinusoids in Noise





Detection Probabilities at Successive FFT Stages

when SNR_{in} = -6 dB, $P_{FA} = 10^{-4}$, and N = 256

Fractals

Chaos

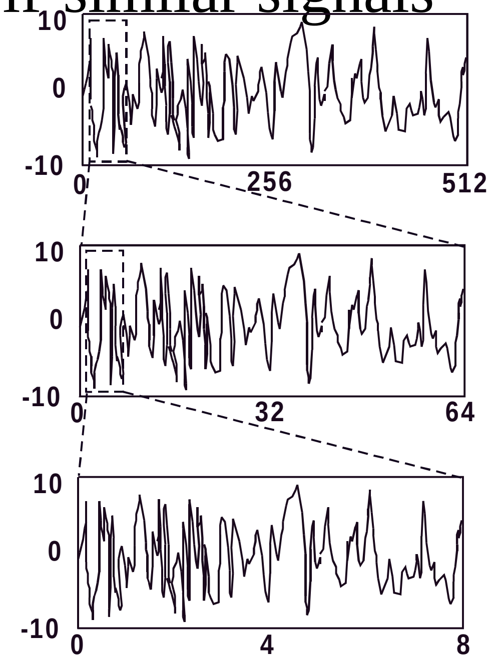
Solitons

Fractal Modulation

- Recoverable from
  - (1) Arbitrarily small duration given enough bandwidth
  - (2) Arbitrarily small bandwidth given enough duration
- Well-matched to
  - Channels of simultaneously uncertain duration, bandwidth, SNR
  - Networks with receivers having differing processing capabilities
  - Fast encoding/decoding via DWT algorithms

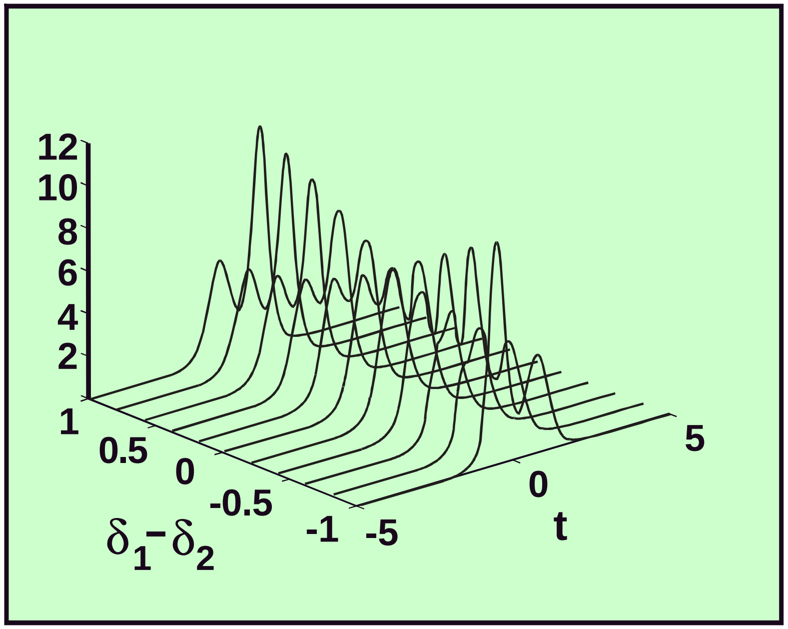
Fractal Signals

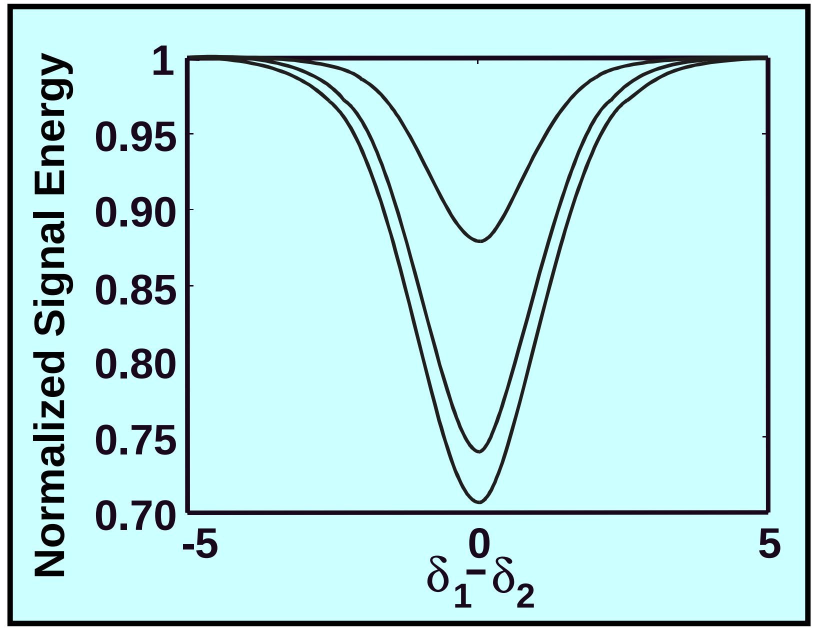
- Deterministic: **x(at)** and **x(t)** are proportional
- Stochastic: **x(at)** and **x(t)** have proportional second-order statistics
- Wavelet representation well matched to analysis and synthesis of self-similar signals



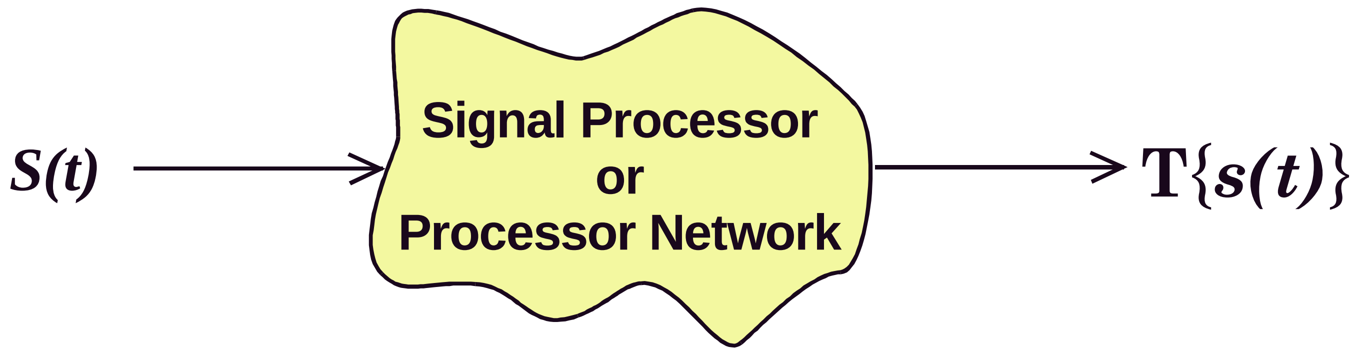
Low-Energy Signaling

Signal Energy Minimized by Multiplexing





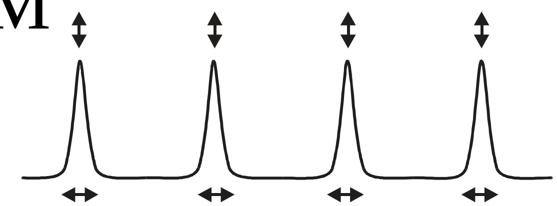
Signal Processing Systems



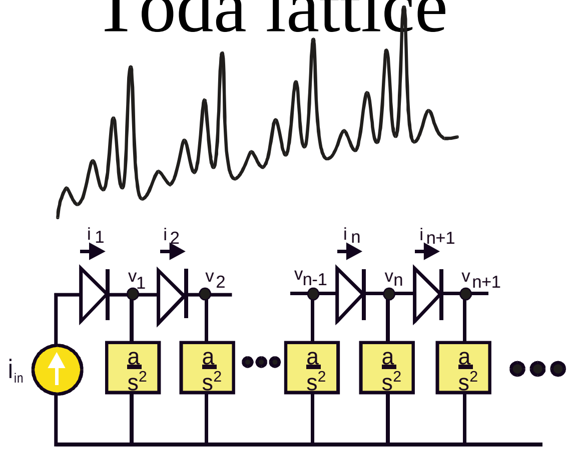
- Coding and algorithm conditioning for error detection and correction (fault-tolerant signal processing)
- Optimum routing
- Network load balancing
- "Algorithm-capacity" theorems??

Soliton Multiplexing

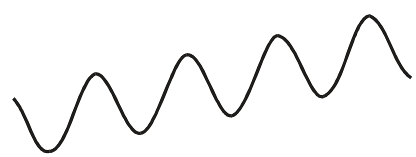
- Modulate time-separated solitons with OOK, PAM or PPM

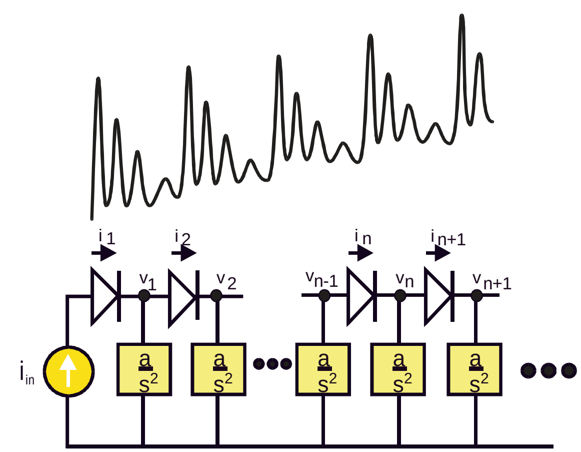


- Multiplex individual solitons together using Toda lattice



Multiplexing





Demultiplexing

Solitons

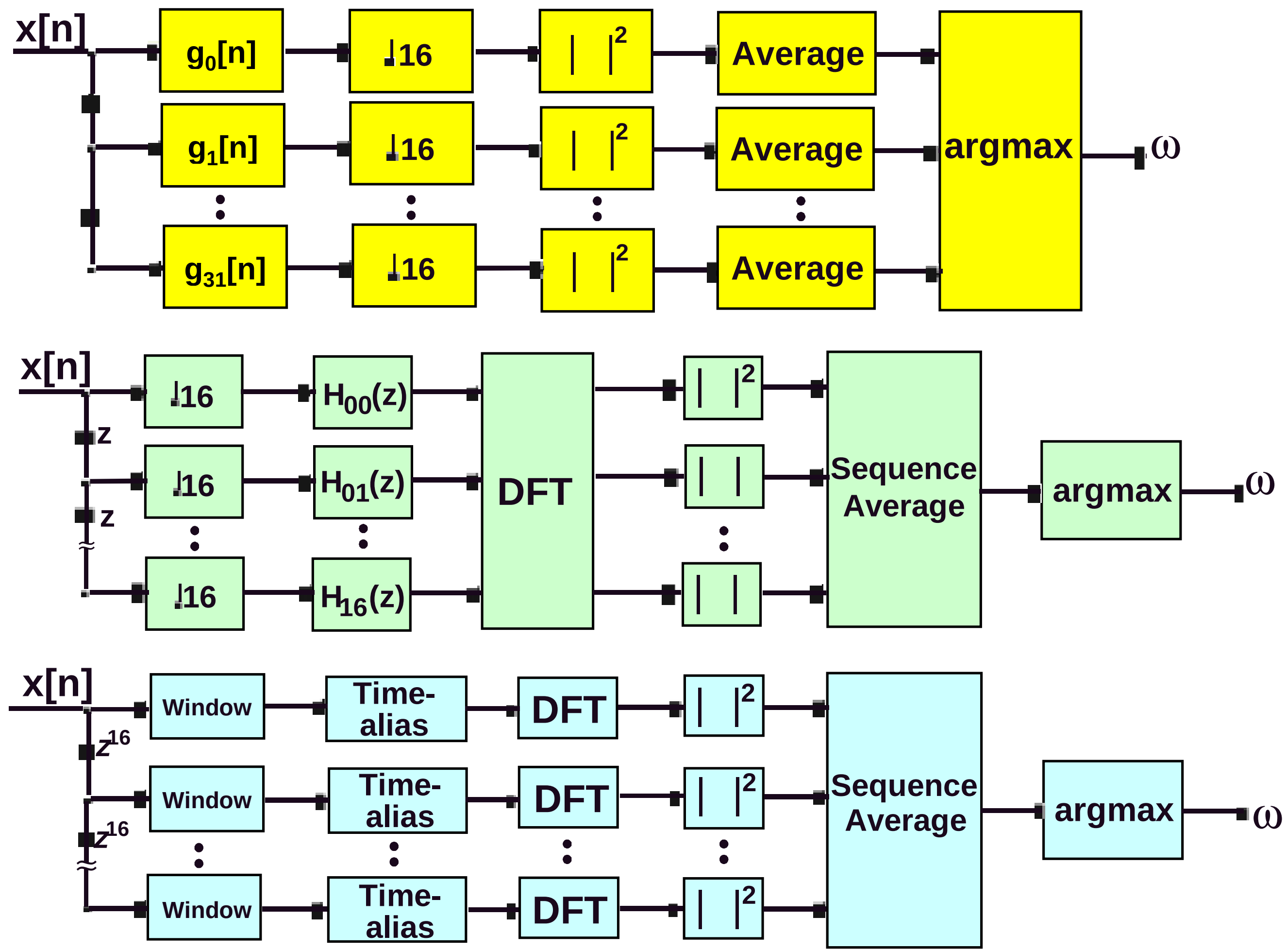
- A *solitary wave* solution to a nonlinear partial differential equation is a traveling-wave solution of the form,

$$y(n,t) = f(n - ct) = f(z),$$

where c is a fixed constant, and the energy of f(z) is localized.

- Some nonlinear partial differential equations can support multiple solitary waves with different shapes and speeds.
- A *soliton* solution to a nonlinear partial differential equation is a solitary wave which asymptotically retains its shape and velocity upon collision with another soliton.

Periodogram Averaging for Spectral Analysis



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- 600 MFLOPS–1 GFLOPS
- Power:
  - 1.5–1.9 Watts
- Physical size:
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- Price (25 KU):
  - US $20–$179