Short Paper: The Softwater Modem – A Software Modem for Underwater Acoustic Communication

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Outline

- Introduction
- Architecture
  - System
  - Modem
- Signal Processing
- Computational Performance
- Summary and Future Work

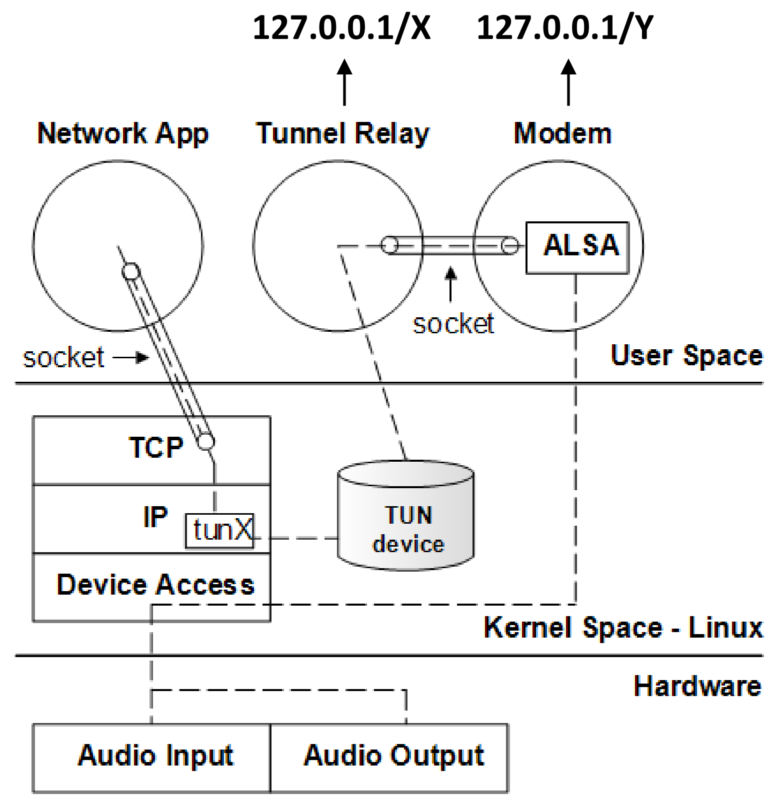
Introduction

- Goals
  - Easy deployment of applications written with sockets
  - Extensible platform for real-time channel estimation and communication
  - Low cost underwater acoustic modem fully implemented in software

- Features
  - Uses sound card of PC
  - Supports binary and 4-FSK (frequency shift keying) modulation
  - User-adjustable parameters, including
    - Bit rate
    - Carrier frequency
    - Detection threshold
  - Exploits a per-frame LFM (linear frequency modulated) chirp signal for synchronization and channel estimation
  - Can use Levinson-Durbin matrix inversion for equalization of slowly varying channels (zero forcing equalizer)
  - Can employ Reed-Solomon codes for error correction
  - Incoming frames and impulse response estimates can be saved to .wav and .csv files for offline analysis; SNR is computed and logged

System Architecture

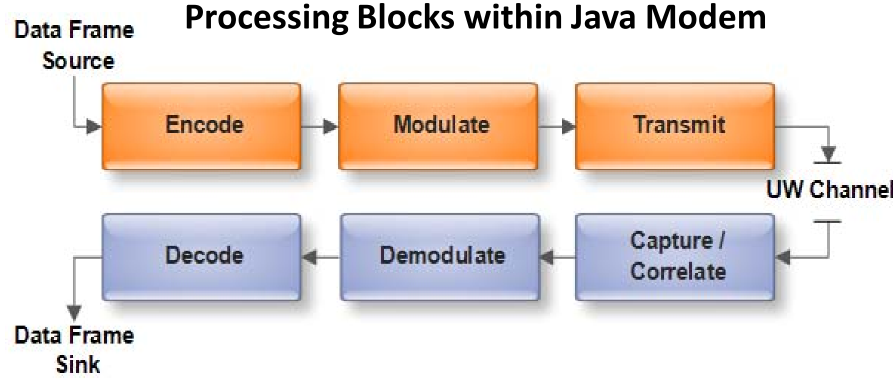
- Includes 3 levels of user space applications
  - Network app (TCP/UDP, any language)
  - Acoustic modem (Java)
  - Tunnel relay app for passing IP datagrams from the network app to and from the software modem (C)

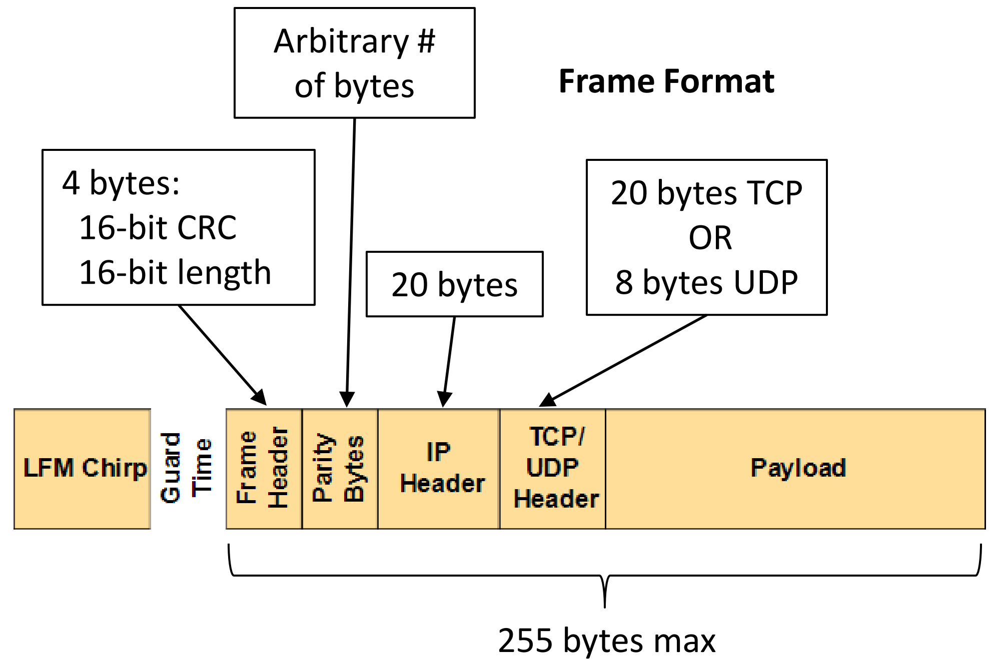


Modem Architecture

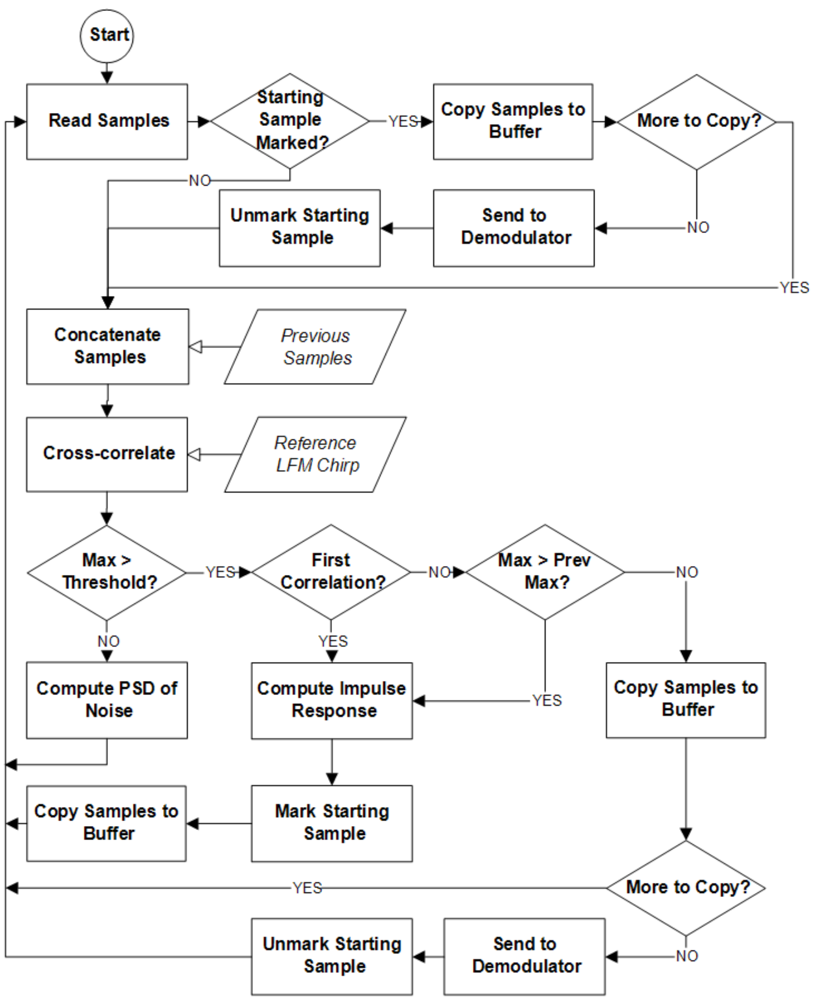
- Transmit and receive tasks are in modular, “assembly line” fashion
- Each stage is a separate thread
- Threads communicate by placing the resulting item on inter-connecting thread-safe queues

Processing Blocks within Java Modem

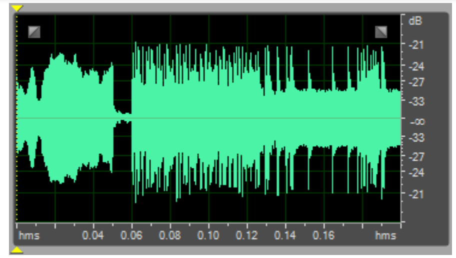




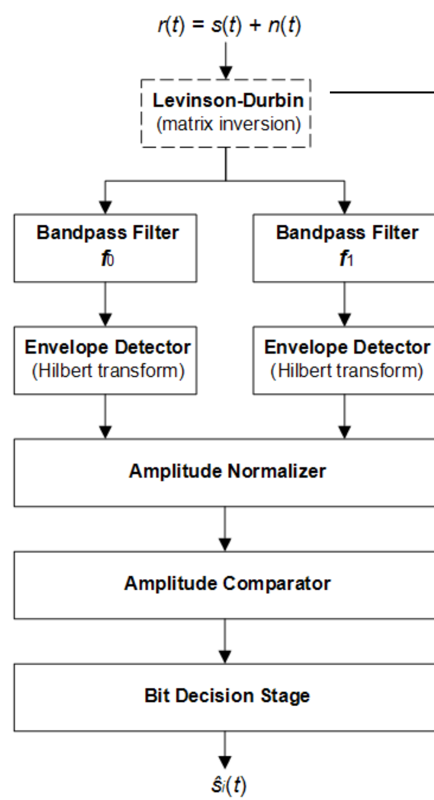
Signal Processing

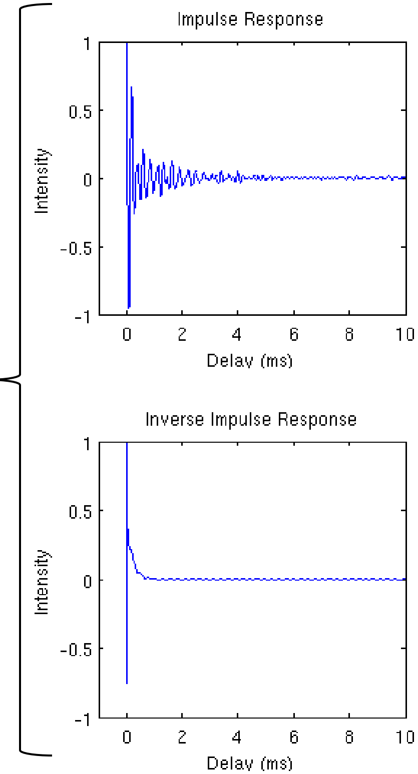


Capture/Correlate Block of Receiver

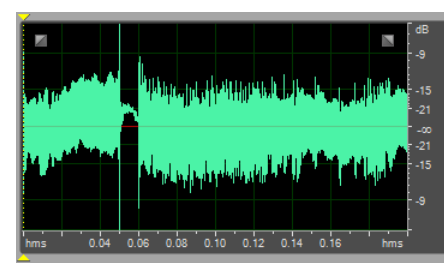


Unequalized data frame





Stages of Noncoherent FSK Receiver



Equalized data frame

Signal Processing Details

- Audio block length > length of LFM chirp preceding each frame
- Modulation index is 1, so that tones are separated by the symbol rate in Hz
- Second-order IIR filters are used
  – Best performance is obtained when the product *BT* is close to 1.0, where *B* is the -3dB bandwidth in Hz and *T* is the duration of a symbol in seconds
  [Watkins-Johnson Company, tech-notes]

Control Interface Parameters

- **CHIRP_MS** = <integer>
- **BASE_FREQUENCY_RX / TX** = <integer>
- **FULL_DUPLEX** = <TRUE/FALSE>
- **GUARD_MS** = <integer>
- **IMPULSE_RISE_MS** = <decimal>
- **INVERSE_FILTER** = <TRUE/FALSE>
- **NUMBER_OF_CARRIERS** = <2/4>
- **PARITY_BYTES** = <integer>
- **PAYLOAD_SIZE_IN_BYTES** = <integer>
- **SYMBOLS_PER_SECOND** = <integer>
- **THRESHOLD** = <integer>

Computational Performance

- Measured with JRat
- Each frame had
  - 50 ms LFM chirp
  - 10 ms guard time
  - 4-byte frame header
  - 16 parity bytes
  - 128 bytes of payload (including other headers)
  - Total of 1184 bits
- Frames transmitted at 1 kbps

Processing Time of Subroutines (ms)

	Desktop Intel Q6600	Laptop T60p Intel T7200	Laptop T500 Intel P8400
Transmit			
a. Modulate	8.00	12.00	13.40
b. Encode Reed-Solomon	9.33	74.40	82.60
Sum (a:b)	17.33	86.40	96.00
Frame duration	1244.00	1244.00	1244.00
Comp Time/Signal Length	1.39 %	6.95 %	7.72 %
Receive			
c. Cross-correlation	2.36	5.03	4.46
Block length	85.33	85.33	85.33
Comp Time/Signal Length	2.77%	5.89%	5.23%
Demodulate			
d. Levinson-Durbin	3.40	3.80	5.33
e. FFT convolution	29.80	65.00	43.83
f. Bandpass filtering	2.60	3.60	4.16
g. Envelope detection	61.60	117.60	84.50
h. Normalizer	1.60	3.70	1.50
i. Comparator	0.40	2.00	0.33
j. Bit Decision	0.40	1.60	0.50
k. Decode Reed-Solomon	1.33	21.40	17.40
l. Write 2 wav files	2.00	3.40	2.60
m. Write IR data to csv file	16.33	55.40	36.00
Sum (d:m)	119.46	277.50	196.15
Frame duration	1244.00	1244.00	1244.00
Comp Time/Signal Length	9.60 %	22.31%	15.77%

Summary and Future Work

- Summary
  - Implemented open source acoustic modem
  - Modem offers numerous configuration parameters
  - Performs channel characterization and records data
- Future Work
  - Add other modulation techniques
  - Convert to LMS-based adaptive DFE
  - Deploy a pair of modems for long-term channel characterization and communication experiments