The Software Modem: A Software Modem for Underwater Acoustic Communication

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PURPOSE

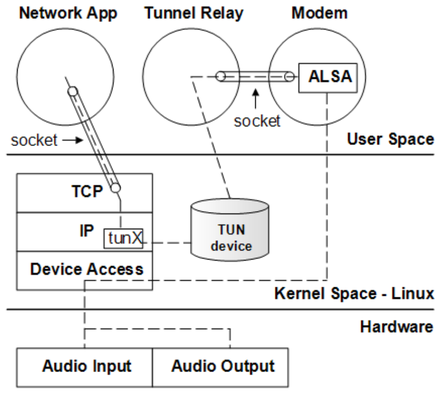
- Low cost underwater acoustic modem fully implemented in software
- Easy deployment of applications written with sockets

FEATURES

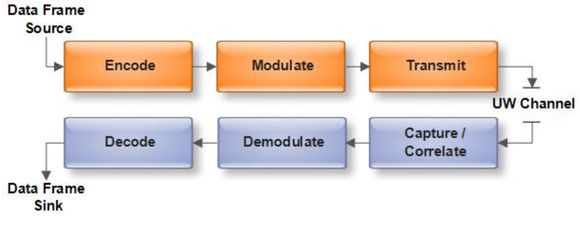
- Uses sound card of PC
- Supports binary and 4-FSK (frequency shift keying) modulation
- User-adjustable parameters, including
  - Bit rate
  - Carrier frequency
  - Detection threshold
- Exploits LFM (linear frequency modulated) chirp signal for frame synchronization and channel estimation
- Can use Levinson-Durbin matrix inversion for equalization of slowly varying channels
- Employs Reed-Solomon codes for error correction

SYSTEM ARCHITECTURE

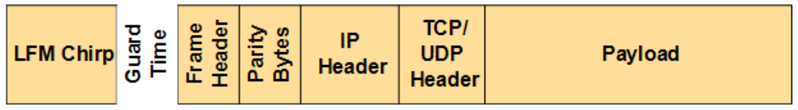
- Highest layer is user space application that utilizes TCP or UDP
- Lowest layer is Java application that implements functionality of acoustic modem
- Middle layer employs Linux TUN device for passing IP datagrams between network application and Java modem



MODEM PROCESSING BLOCKS



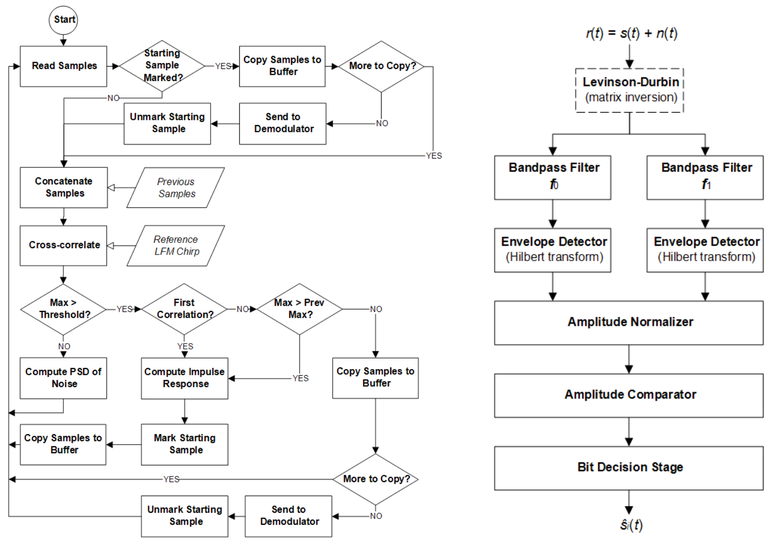
FRAME FORMAT



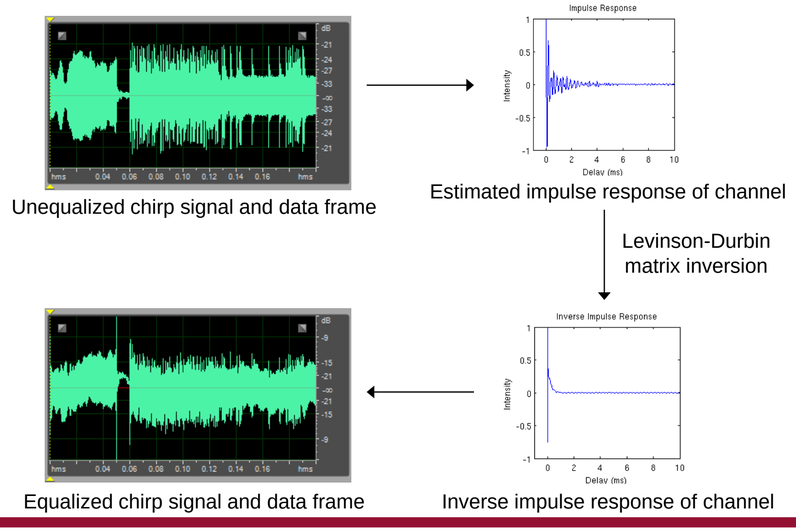
LFM Chirp – used for frame synchronization and channel estimation; spans frequency band of data modulation
Guard Time – silence to allow all multipath components to dissipate
Frame Header – includes 16-bit CRC and 16-bit length fields

SIGNAL PROCESSING

- Searching for packets and buffering samples (left)
- Demodulating packets (right)



- Example of channel equalization



Unequalized chirp signal and data frame

Estimated impulse response of channel

Equalized chirp signal and data frame

Inverse impulse response of channel

PERFORMANCE

- Measured with JRat
- Each frame consisted of a 4-byte frame header, 16 parity bytes, and 128 bytes of payload, for a 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%

- Estimated BER (bit error rate) versus various signal levels in AWGN (additive white Gaussian noise) channel