DIGITAL SYNCHRONIZATION AND COMMUNICATION TECHNIQUES

William C. Lindsey
Lincom Corporation
Los Angeles, California 90024

RESEARCH IN DIGITAL SYNCHRONIZATION AND COMMUNICATIONS

- DIGITAL CODING/MODULATION UNDER INVESTIGATION
  - MPSK (BPSK, QPSK, OQPSK, MSK)
  - MDPSK (DBPSK, OQPSK, ODQPSK, DMSK)
  - OFFSET VS NON-OFFSET
  - CONVOLUTIONAL CODES AND TRELLIS-CODED MODULATION
  - BANDWIDTH EFFICIENT

- CHANNELS UNDER INVESTIGATION
  - AWGN
  - RAYLEIGH/RICE/SCINTILLATION
  - JAMMED

- RESEARCH EMPHASIZES
  - ACQ
    - RAPID ACQUISITION WITH HIGH PROBABILITY
    - AVOIDING HANG-UP DURING ACQUISITION
  - TRACK
    - AVOIDING CYCLE SLIPPING
    - MINIMIZE TRACKING JITTER
    - ELIMINATE PHASE AMBIGUITIES
    - ACHIEVING PERFORMANCE OF CODED-COHERENT COMMUNICATIONS
DIGITAL SYNCHRONIZATION PROJECT MOTIVATION

- FUTURE COMMUNICATION MODEMS ARE LIKELY TO EMPLOY ALL DIGITAL IMPLEMENTATIONS AS THE DIGITAL SIGNAL PROCESSING SPEED BARRIER BETWEEN DIGITAL AND ANALOG HARDWARE RISES DUE TO EMERGING TECHNOLOGIES, E.G., VLSI.

- COHERENT (C) VS. DIFFERENTIALLY COHERENT (DC) VS. NONCOHERENT (NC) DETECTION IN MODEMS

![Graph of Probability of Error vs. Eb/No dB for Coherent (C), Differentiably Coherent (DC), and Noncoherent (NC) Detection]

![Graph of Probability of Error vs. Eb/No dB for Partial Band Jamming]

258
Desired Modem Implementation

DIGITAL SYNCHRONIZATION PROBLEM SPACE

CM: CONSTANT MODULUS
N-CM: NON-CONSTANT MODULUS
DA: DATA-AIDED
DD: DECISION DIRECTED
N-DD: NON-DECISION DIRECTED
SALIENT CHARACTERISTICS OF OPEN LOOP DIGITAL SYNCHRONIZERS

- Derived from adaptive filtering theory
- Do not require locally generated sync reference by means of a VCO or NCO
- Sync reference is non-constant modulus
- Does not require a phase-error measurement to update phase estimate

OPEN LOOP PHASE AND FREQUENCY ESTIMATOR

\[ x(n) \xrightarrow{\text{matched filter output sample}} \text{RLS estimator of } k = \exp(j\omega_d) \xrightarrow{\text{register}} r(n+1) \]

- \( \beta \) - Sample weighting factor
EXPONENTIALLY WEIGHTED PHASE ESTIMATOR LEARNING CURVES.
\[ \beta = 0.875 \]

 SYMBOL TO SYMBOL PHASE ROTATION LEARNING CURVE.
\[ \omega_0 = 1.0 \text{ radians/symbol} \]
A Digital Receiver Structure Utilizing an Open Loop Estimator in a Decision-Directed Architecture

\[ x(n) = d(n)e^{j\theta(n)} + \eta(n) \]

\[ r(n) = A(n) e^{j\hat{\theta}(n)} \]

The BER Learning Curve of the Exponentially Weighted Estimator for QPSK Modulation (E_b/N_o=2dB)
SIMULATED STEADY STATE WATERFALL CURVE OF THE EW DD ESTIMATOR FOR SQPSK MODULATION. $\beta = 0.875$

![Graph showing the simulated steady state waterfall curve for SQPSK modulation with $\beta = 0.875$. The graph plots the probability of bit error against $Eb/No$ in dB. There are curves for SQPSK and DESQPSK.]
SIMULATED STEADY STATE WATERFALL CURVE OF THE EW DD ESTIMATOR FOR QPSK MODULATION. $\beta = 0.875$
PROBABILITY OF REMAINING IN A HANGUP CONDITION FOR BPSK MODULATION. $R_b = 2$ dB, $\beta = 0.875$.

PROBABILITY OF REMAINING IN A HANGUP CONDITION FOR QPSK MODULATION. $R_b = 2$ dB, $\beta = 0.875$. 
'S' CURVE FOR A DECISION-DIRECTED BPSK AND QPSK LOOP EW ESTIMATORS

- Average Innovation Phase Error, degrees
- Estimator Phase Error, degrees
- Eb/No = 20dB
- 10dB
- 6dB
- 3dB
- 0dB

- Es/No = 20dB
- 10dB
- 6dB
- 3dB
Motivation For Research

• Modems used in burst mode communication systems (TDMA or FHSS) or a fading channel typically use noncoherent demodulation techniques
  - PLL structures and fast acquisition with high probability requirements are not compatible
  - Coherent demodulation improves the performance

• Technology advances favor digital receiver structures
  - VLSI or gate array implementations can significantly reduce the cost, size, and possibly power consumption while improving the reliability of modems.