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, DQPSK, 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 showing performance comparison between coherent, differentially coherent, and noncoherent detection methods.](image)

---

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

\[ x(n) \text{ MATCHED FILTER OUTPUT SAMPLE} \]

\[ \beta \text{ - SAMPLE WEIGHTING FACTOR} \]
EXPONENTIALLY WEIGHTED PHASE ESTIMATOR LEARNING CURVES.

\( \beta = 0.875 \)

SYMBOL TO SYMBOL PHASE ROTATION LEARNING CURVE.

\( \omega_0 = 1.0 \) 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 (\(E_b/N_0=2\text{dB}\))
SIMULATED STEADY STATE WATERFALL CURVE OF THE EW DD ESTIMATOR FOR SQPSK MODULATION. $\beta = 0.875$
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. \( R_b = 2 \text{dB}, \beta = 0.875. \)

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

---

![Diagram 1](image1.png)

- Eb/No = 20 dB
- 10 dB
- 6 dB
- 3 dB
- 0 dB

---

![Diagram 2](image2.png)

- Es/No = 20 dB
- 10 dB
- 6 dB
- 3 dB
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.