DIGITAL SYNCHRONIZATION AND COMMUNICATION TECHNIQUES

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RESEARCH IN DIGITAL SYNCHRONIZATION AND COMMUNICATIONS

- DIGITAL CODING/MODULATION UNDER INVESTIGATION
  - MPSK (BPSK, QPSK, OQPSK, MSK)
  - MDPSK (DBPSK, DQPSK, ODQPSK, DMASK)
    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

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![Graph 1](image1)

![Graph 2](image2)
Desired Modem Implementation

DIGITAL SYNCHRONIZATION PROBLEM SPACE

\[ \frac{T}{\tau} \]

CM: CONSTANT MODULUS
N-CM: NON-CONSTANT MODULUS
DA: DATA-AIDED
DD: DECISION DIRECTED
N-DD: NON-DECISION DIRECTED

RANDOM VARIABLE PLANE \((T \ll \tau)\)
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

\[ x(n) \rightarrow \text{MATCHED FILTER OUTPUT SAMPLE} \]
\[ \beta \rightarrow \text{REGISTER} \]
\[ r(k) \rightarrow \text{RLS ESTIMATOR OF } k = \exp(i \omega_d) \]
\[ r(n+1) \rightarrow \text{NOISY REFERENCE SAMPLE} \]

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

\( \beta = 0.875 \)

\[ \text{RMS Phase Error, degrees} \]

\[ \text{Symbol Number} \]

\( \text{SNR}=2\text{dB} \)

\( \text{SNR}=10\text{dB} \)

SYMBOL TO SYMBOL PHASE ROTATION LEARNING CURVE.

\( \omega_0 = 1.0 \text{ radians/symbol} \)

\[ \text{RMS Phase Rotation Error, degrees} \]

\[ \text{Symbol Number} \]

\( \text{SNR}=2\text{dB} \)

\( \text{SNR}=10\text{dB} \)
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=2dB)
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
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.