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, DMSK) OFFSET VS NON-OFFSET
  - CONVOLUTIONAL CODES AND TRELLIS-CODED MODULATION
  - BANDWIDTH EFFICIENT

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

- RESEARCH EMPHASIZES
  \[ \begin{align*}
  \text{ACQ} & \{ \quad \text{RAPID ACQUISITION WITH HIGH PROBABILITY} \\
  & \quad \text{AVOIDING HANG-UP DURING ACQUISITION} \\
  & \quad \text{AVOIDING CYCLE SLIPPING} \\
  \text{TRACK} & \{ \quad \text{MINIMIZE TRACKING JITTER} \\
  & \quad \text{ELIMINATE PHASE AMBIGUITIES} \\
  & \quad \text{ACHIEVING PERFORMANCE OF CODED-COHERENT COMMUNICATIONS}
\end{align*} \]
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
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

β - 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_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

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

Estimator Phase Error, degrees

Average Innovation Phase Error, degrees

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

Estimator Phase Error, degrees
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.