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
  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
Desired Modem Implementation

**DIGITAL SYNCHRONIZATION PROBLEM SPACE**

- **T/τ**
- **CM**: CONSTANT MODULUS
- **N-CM**: NON-CONSTANT MODULUS
- **DA**: DATA-AIDED
- **DD**: DECISION DIRECTED
- **N-DD**: NON-DECISION DIRECTED

RANDOM VARIABLE PLANE (T << τ)

ALGORITHMS
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

\[ x(n), RLS \text{ ESTIMATOR OF } k = \exp(i \omega_d), \text{ MATCHED FILTER OUTPUT SAMPLE} \]

\[ r(n+1), \text{NOISY REFERENCE SAMPLE} \]

\[ r(k), \text{REGISTER} \]

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

$$\beta = 0.875$$

SYMBOL TO SYMBOL PHASE ROTATION LEARNING CURVE.

$$\omega_0 = 1.0 \text{ radians/symbol}$$
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 (Eb/N0=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. $R_b = 2$ 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

![Graph showing the S-curve for a decision-directed BPSK and QPSK loop EW estimators. The graphs depict the average innovation phase error against estimator phase error for different SNR values (0dB, 3dB, 6dB, 10dB, Eb/No=20dB).

- **Above Graph:**
  - Y-axis: Average Innovation Phase Error (degrees)
  - X-axis: Estimator Phase Error (degrees)
  - Curves for different SNR values:
    - 0dB
    - 3dB
    - 6dB
    - 10dB
    - Eb/No=20dB

- **Below Graph:**
  - Y-axis: Average Innovation Phase Error (degrees)
  - X-axis: Estimator Phase Error (degrees)
  - Curves for different SNR values:
    - 0dB
    - 3dB
    - 6dB
    - 10dB
    - Es/No=20dB
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.