DIGITAL SYNCHRONIZATION AND COMMUNICATION TECHNIQUES
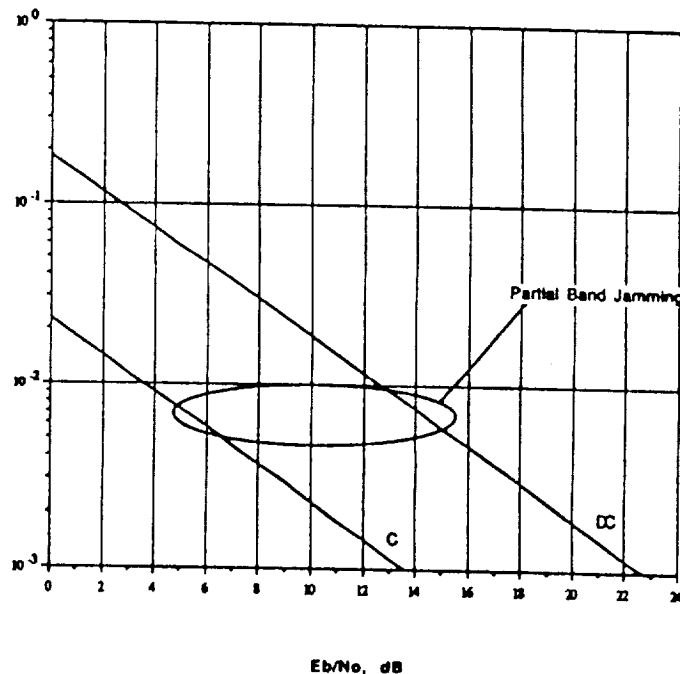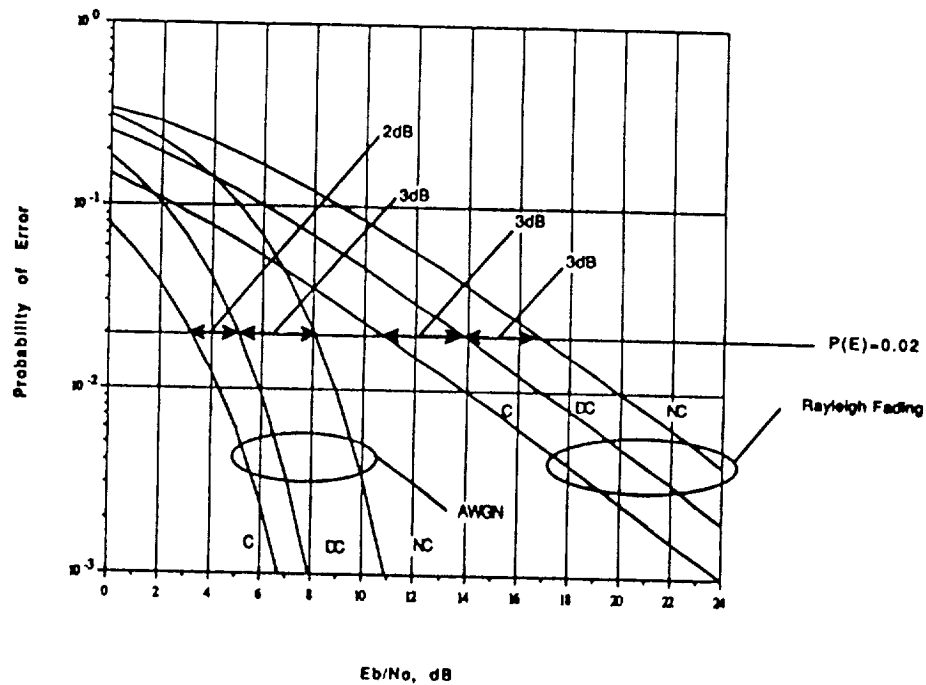
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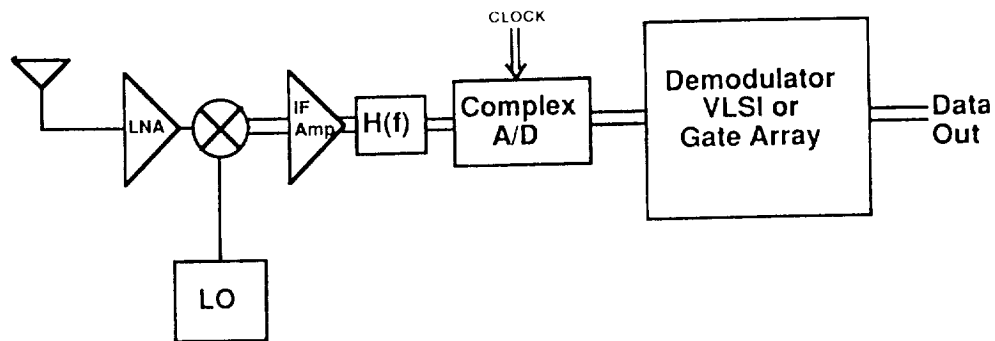## RESEARCH IN DIGITAL SYNCHRONIZATION AND COMMUNICATIONS

- 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
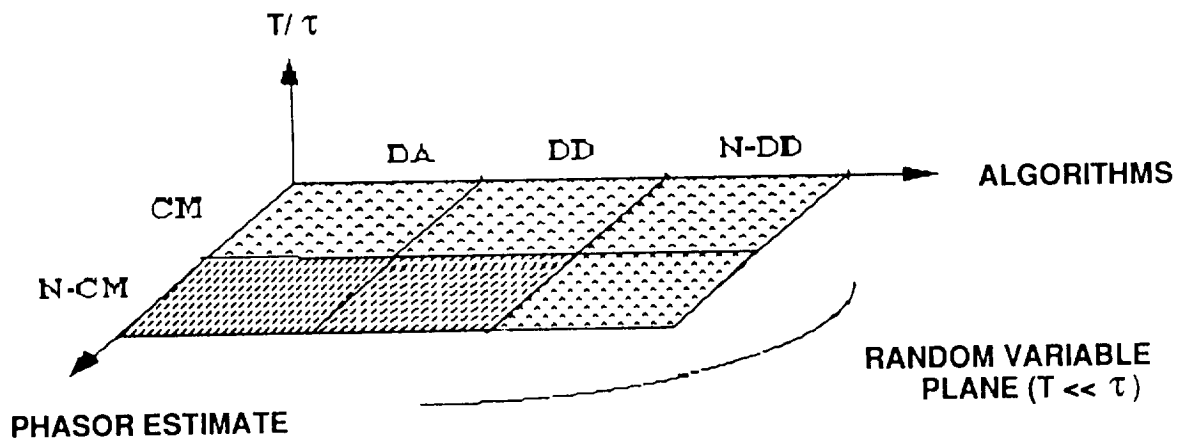
DIGITAL SYNCHRONIZATION PROJECT MOTIVATION

- FUTURE COMMUNICATION MODEMS ARE LIKELY TOO 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

Eb/No, dB

Eb/No, dB

Desired Modem Implementation

CLOCK

LNA · IF Amp · H(f) · Complex A/D · Demodulator VLSI or Gate Array · Data Out

LO

DIGITAL SYNCHRONIZATION PROBLEM SPACE

T/τ

DA   DD   N-DD

CM

ALGORITHMS

N-CM

PHASOR ESTIMATE

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

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

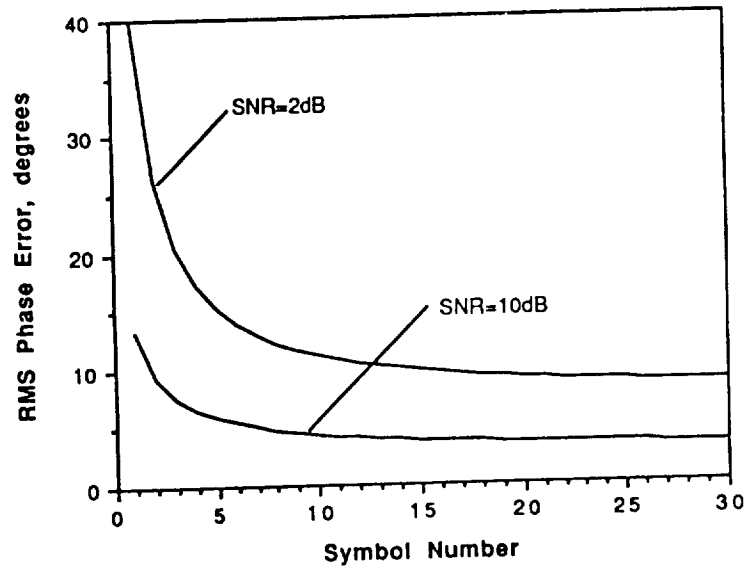- DOES NOT REQUIRE A PHASE-ERROR MEASUREMENT TO UPDATE PHASE ESTIMATE

OPEN LOOP PHASE AND FREQUENCY ESTIMATOR

RLS
ESTIMATOR
OF $k = \exp(j\,\omega_d)$

MATCHED FILTER
OUTPUT SAMPLE

NOISY REFERENCE
SAMPLE

$x(n)$

$r(n+1)$

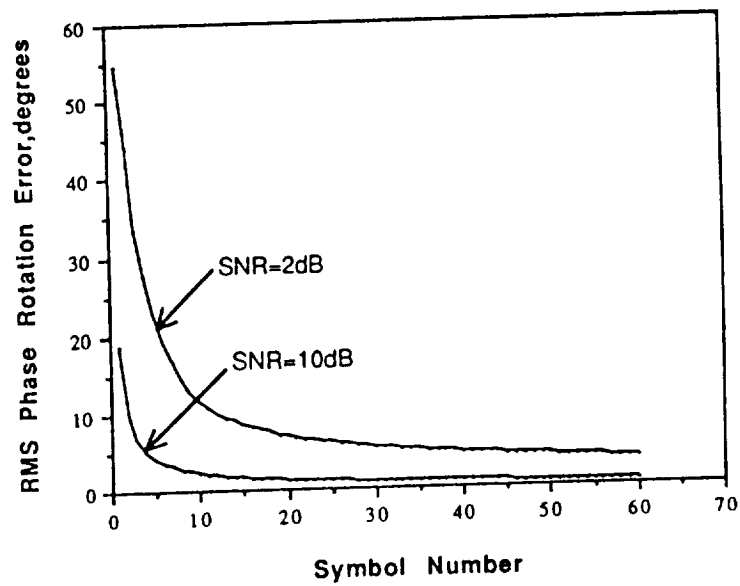$r(k)$

REGISTER

β

β - SAMPLE WEIGHTING FACTOR

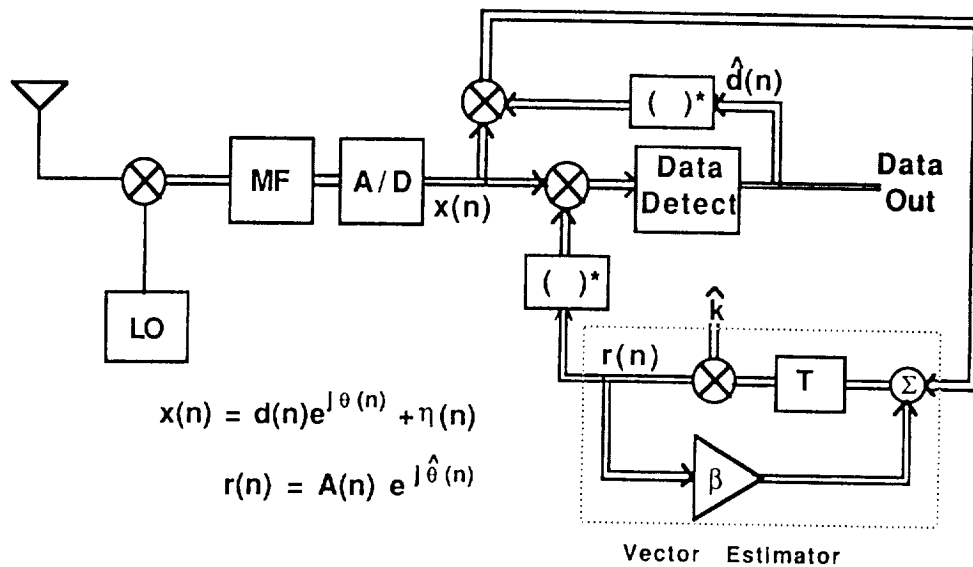# EXPONENTIALLY WEIGHTED PHASE ESTIMATOR LEARNING CURVES.

β = 0.875

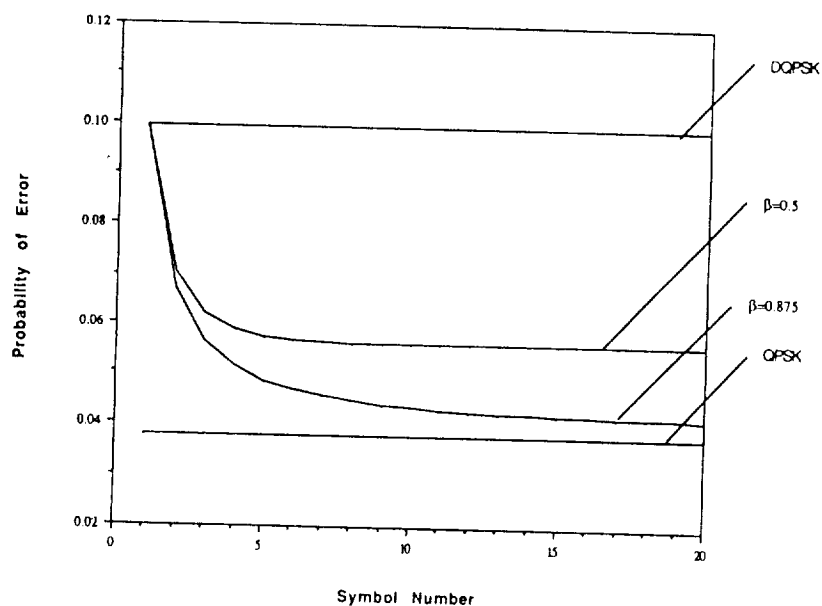

SYMBOL TO SYMBOL PHASE ROTATION LEARNING CURVE.

ω_0 = 1.0 radians/symbol

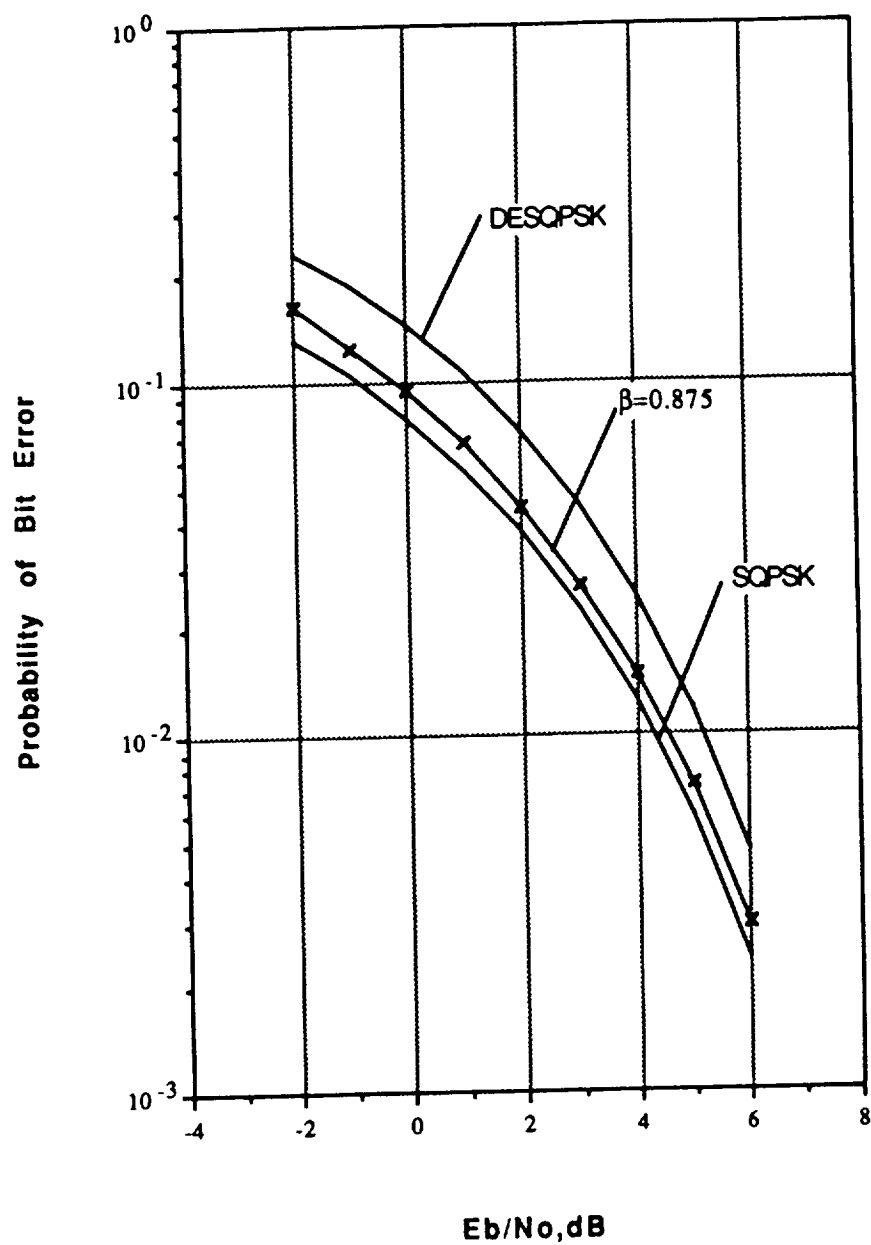# A Digital Receiver Structure Utilizing an Open Loop Estimator in a Decision-Directed Architecture

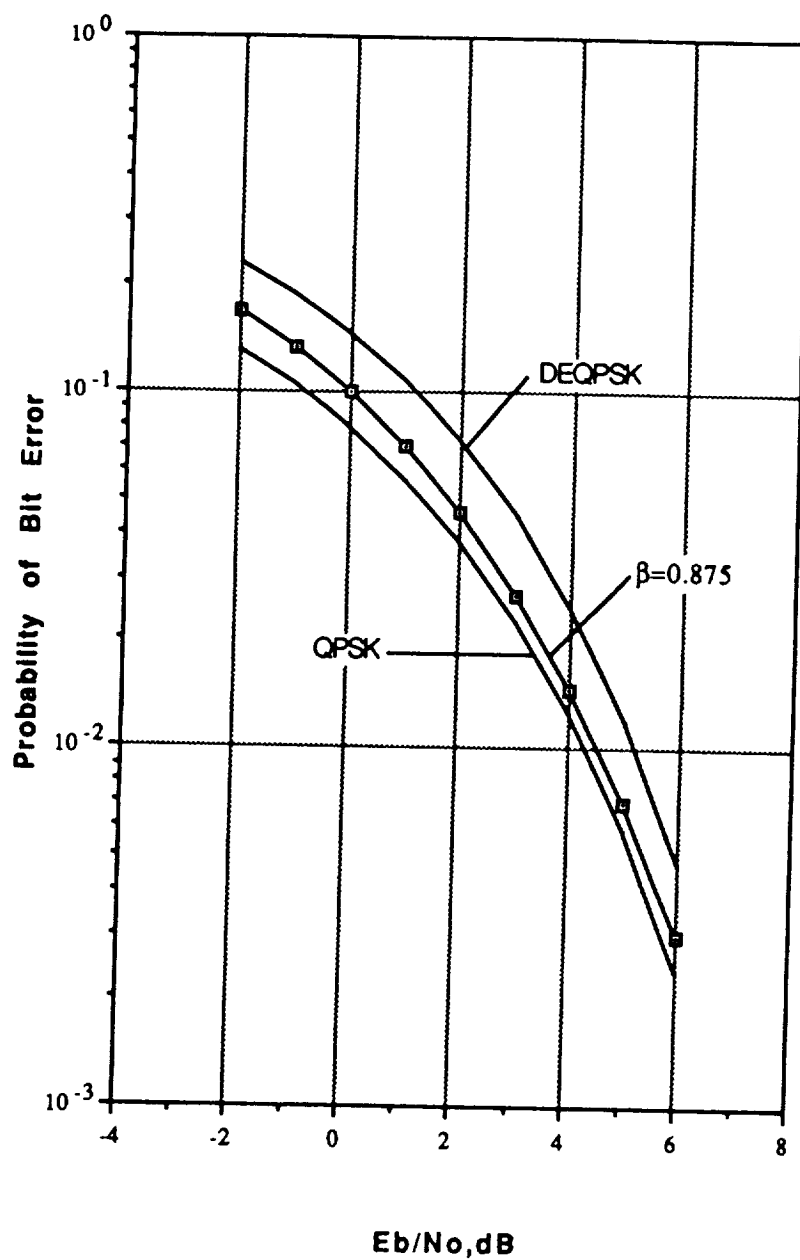$$x(n) = d(n)e^{j\theta(n)} + \eta(n)$$

$$r(n) = A(n)\, e^{j\hat{\theta}(n)}$$

Vector Estimator

The BER Learning Curve of the Exponentially Weighted Estimator for QPSK Modulation ($E_b/N_o=2$dB)
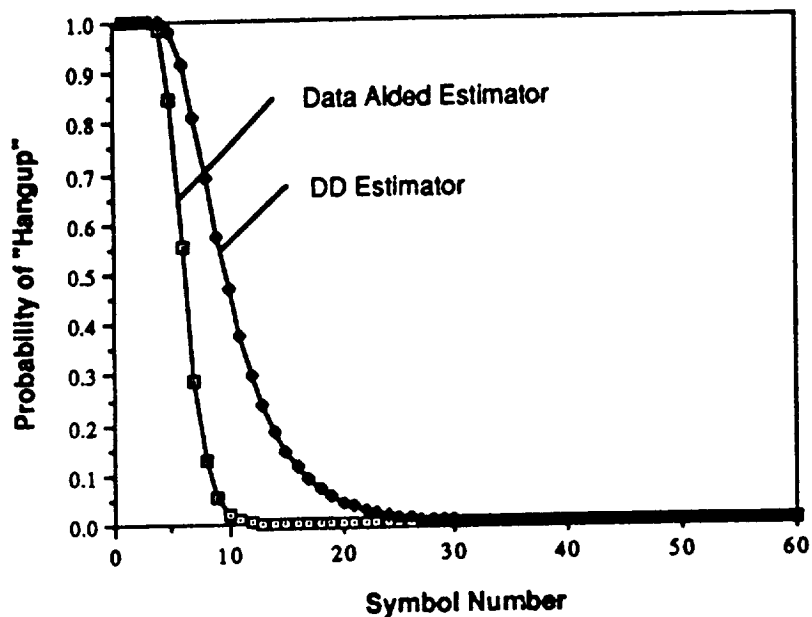
Probability of Error

Symbol Number

SIMULATED STEADY STATE WATERFALL CURVE OF THE EW DD ESTIMATOR FOR SQPSK MODULATION. $\beta = 0.875$
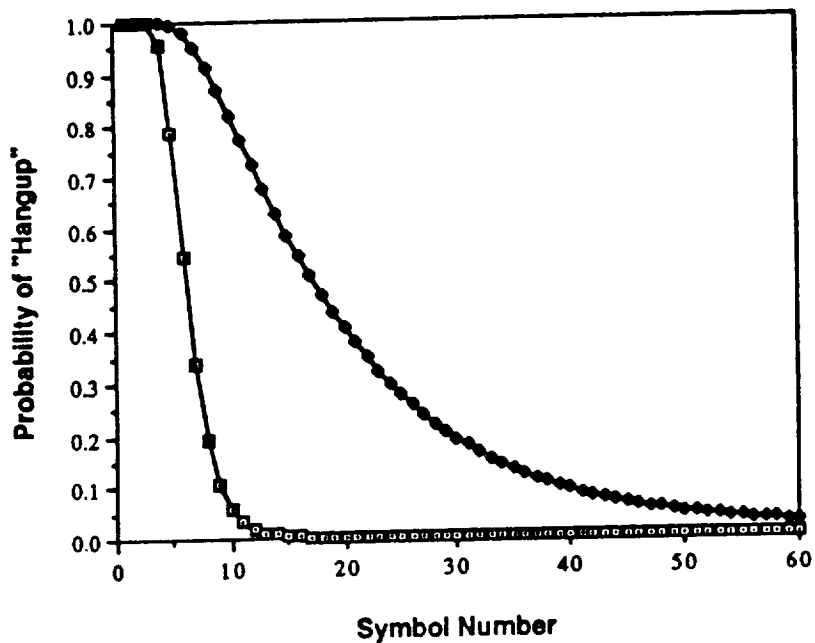
SIMULATED STEADY STATE WATERFALL CURVE OF THE EW DD ESTIMATOR FOR QPSK MODULATION. β = 0.875
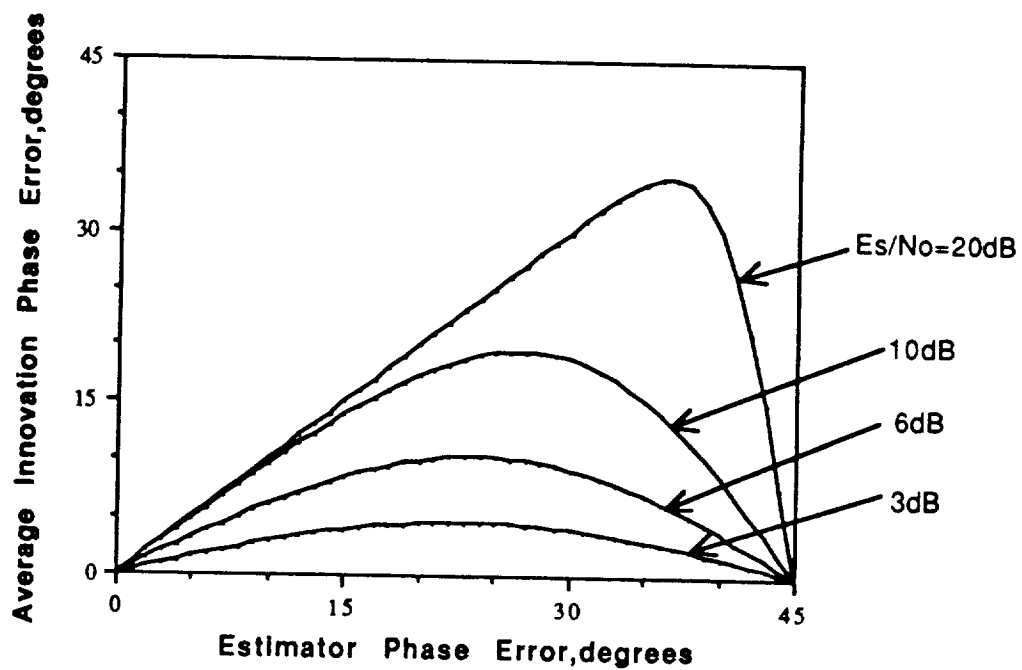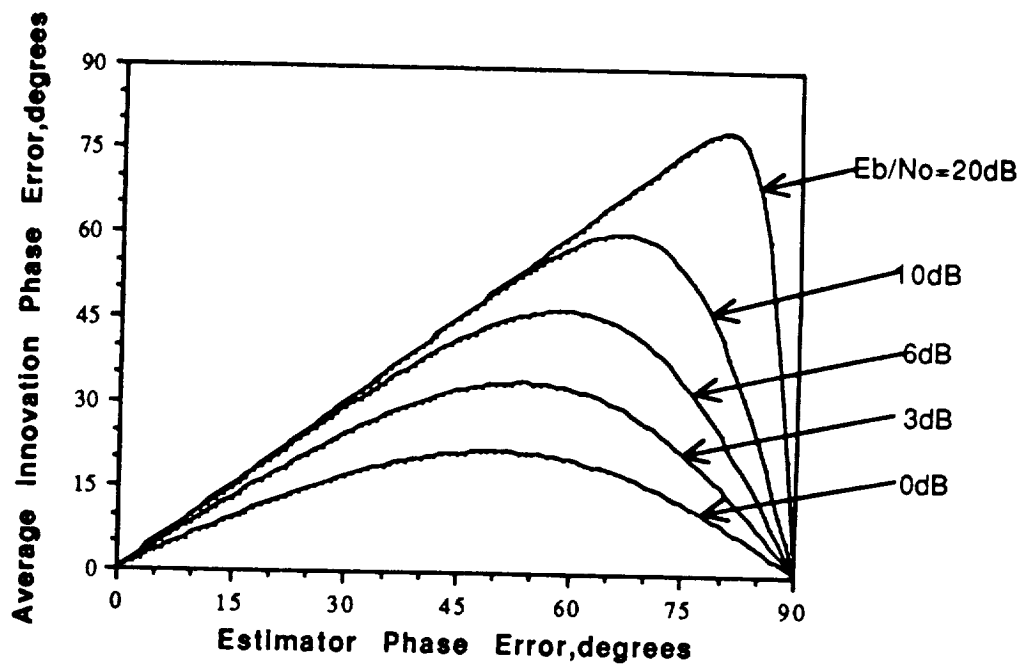
PROBABILITY OF REMAINING IN A HANGUP CONDITION FOR BPSK MODULATION. R_b = 2dB, β = 0.875.

PROBABILITY OF REMAINING IN A HANGUP CONDITION FOR QPSK MODULATION. R_b = 2dB, β = 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.

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