

Hardware Implementation of an Adaptive Minimum Bit-Error-Rate (MBER) Beamforming Algorithm

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Overview

Wireless Channel Effects

Adaptive Array Beamforming

MBER Algorithms

Problem Statement

Objectives of the Study

Proposed Methodology

Gantt Chart

Wireless Channel Effects

Noise

- Transmitter and receiver thermal vibrations

- Black body radiation

- Usually modeled by Additive White Gaussian Noise (AWGN)

Interference

- Multiple Access Interference (MAI)

- Co-Channel Interference (CCI)

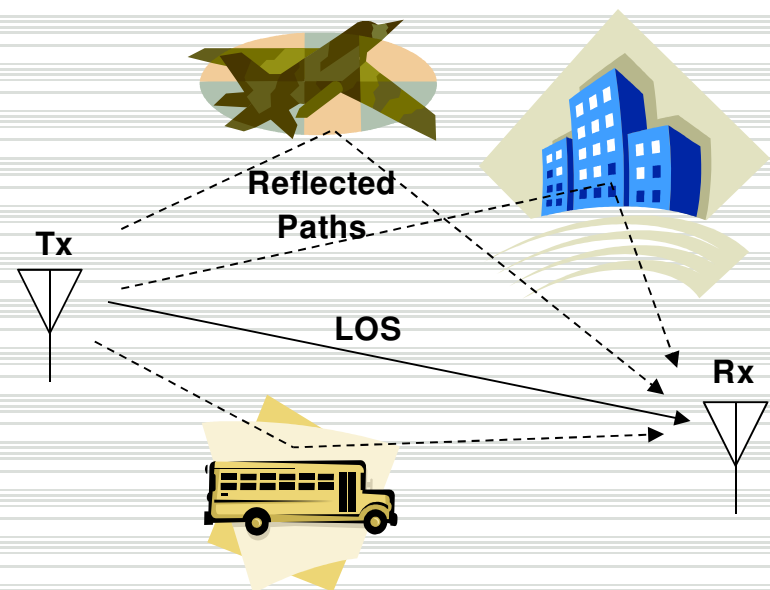
Wireless Channel Effects

Multipath

Receiver signal
vector sum of multiple
path signals

May cause fading

May cause inter-
symbol interference
(ISI)



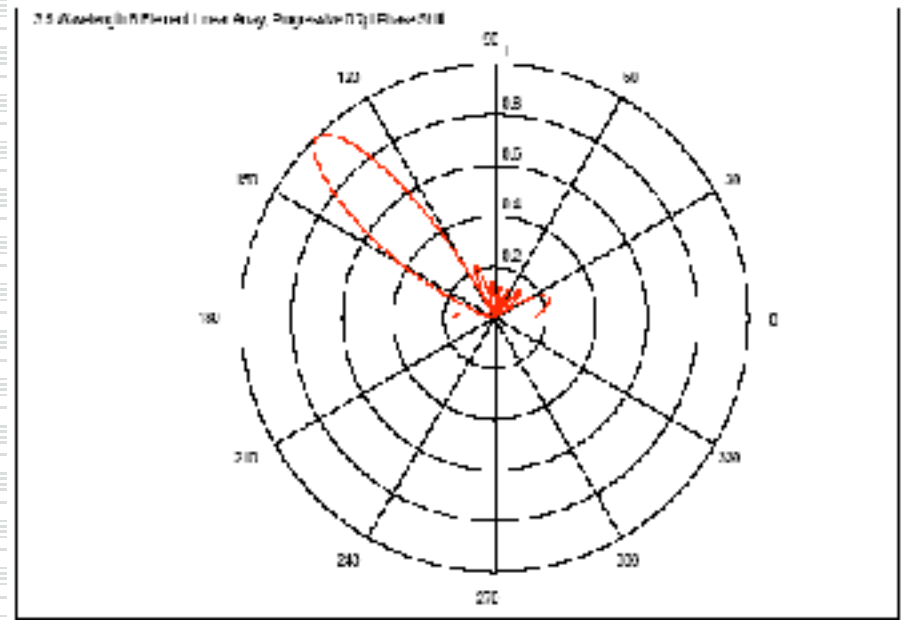
Adaptive Array Beamforming

Antenna arrays may be used to combat wireless channel effects

Signals received by antenna elements multiplied by weights to control beam pattern

Beamformer output:

$$y(k) = \mathbf{w}^H \mathbf{x}(k)$$



Adaptive Array Beamforming

Traditionally, Mean-Squared-Error (MSE) is minimized

Error:

$$\varepsilon(k) = d(k) - y(k) = d(k) - \mathbf{w}^H \mathbf{x}(k)$$

Cost function:

$$\text{MSE} = E[d^2(k)] + \mathbf{w}^H \mathbf{R} \mathbf{w} - 2\mathbf{p}^H \mathbf{w}$$

Adaptive Array Beamforming

Minimizing MSE indirectly minimizes the BER

Optimum weight vector given by:

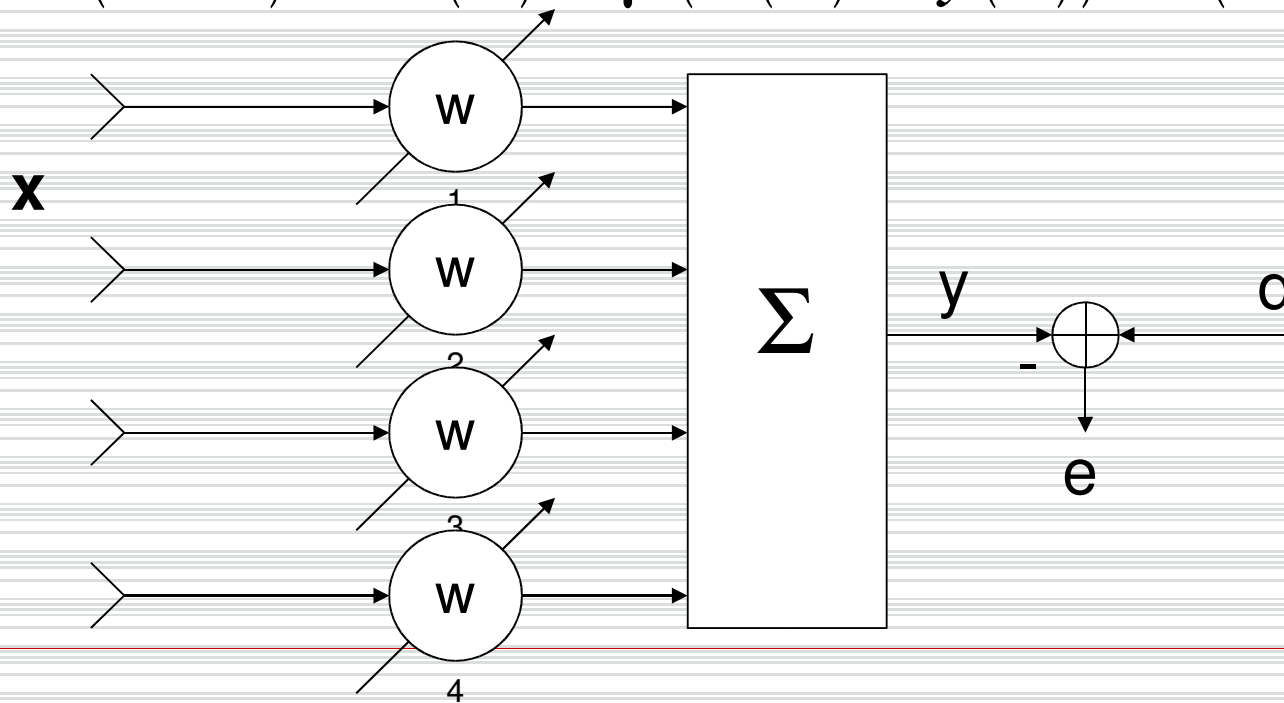
$$\mathbf{w}_{\text{MMSE}} = \mathbf{R}^{-1} \mathbf{p}$$

\mathbf{R} and \mathbf{S} usually not known, hence the need for adaptive algorithms

Adaptive Array Beamforming

Least-Mean-Square (LMS) algorithm used to iteratively update weights:

$$\mathbf{w}(k+1) = \mathbf{w}(k) + \mu(d(k) - y(k)) * \mathbf{x}(k)$$



MBER Algorithms

S. Chen et al, “Adaptive Minimum Bit Error Rate Beamforming,” *IEEE Transactions on Wireless Communications*, April 2002.

BER should be directly minimized, not the MSE

MBER Algorithms

For M sources using BPSK, there are $N_b = 2^M$ possible sequences \mathbf{b}_q

Output takes values from the set:

$$\mathbf{Y}_R = \left\{ \bar{y}_{R,q} = \Re[\mathbf{w}^H \bar{\mathbf{x}}_q], 1 \leq q \leq N_b \right\}$$

$$\mathbf{Y}_R^{(\pm)} = \left\{ \bar{y}_{R,q}^{(\pm)} \in \mathbf{Y}_R, b_1 = \pm 1 \right\}$$

Cost function:

$$P_E(\mathbf{w}) = \frac{2}{N_b} \sum_{q=1}^{N_b/2} Q(g_{q,+}(\mathbf{w})) \quad g_{q,+}(\mathbf{w}) = \frac{\text{sgn}(b_{q,1}) \Re[\mathbf{w}^H \bar{\mathbf{x}}_q^{(+)}]}{\sigma_n \sqrt{\mathbf{w}^H \mathbf{w}}}$$

MBER Algorithms

Optimum weight vector given by:

$$\mathbf{w}_{\text{MBER}} = \arg \min P_E(\mathbf{w})$$

Approximate Least Bit-Error-Rate (ALBER)
used to iteratively update weights:

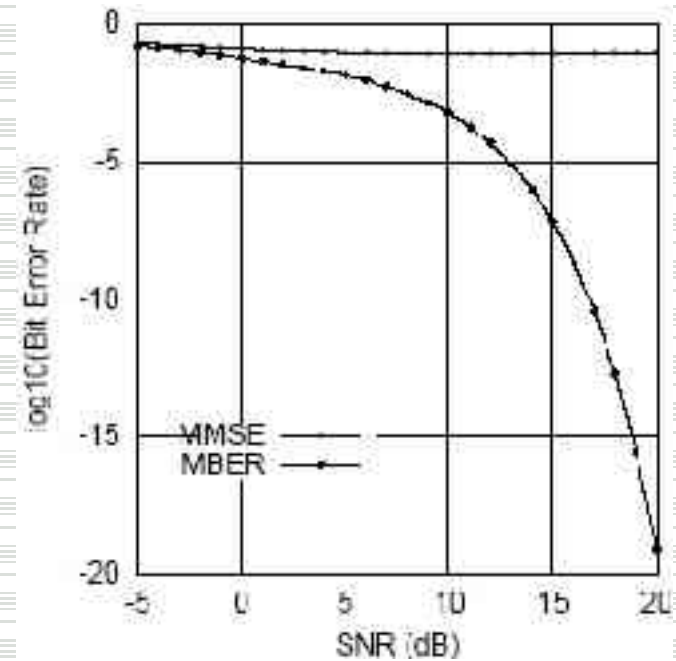
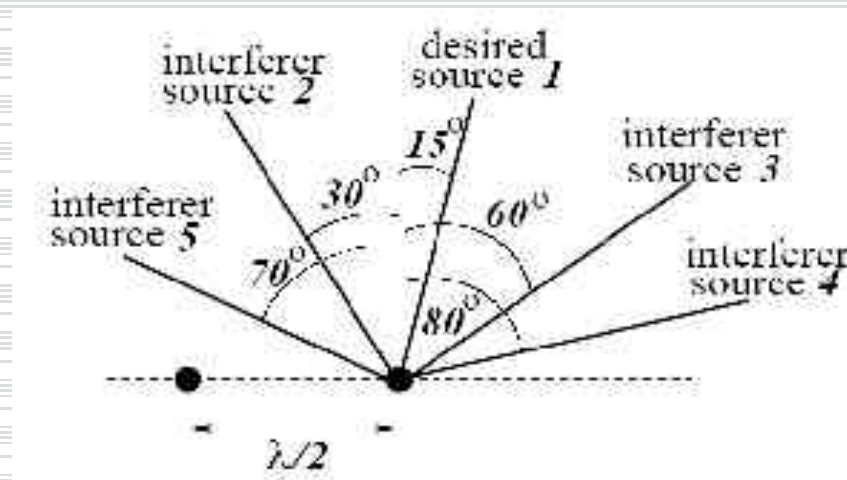
$$\mathbf{w}(k+1) = \mathbf{w}(k) + \mu \frac{\text{sgn}(b_1(k))}{2\sqrt{2\pi}\rho_n} \exp\left(-\frac{y_R^2(k)}{2\rho_n^2}\right) \mathbf{x}(k)$$

Has similar computational complexity to LMS algorithm

Converges at a reasonable rate close to optimum MBER solution

MBER Algorithms

Simulation results



Problem Statement

MBER beamformers offer potential gain over MMSE beamformers

Approximate Least Bit-Error-Rate (ALBER) algorithm was developed which has same complexity as LMS

Feasibility of real-time implementation is yet to be tested

Objectives of the Study

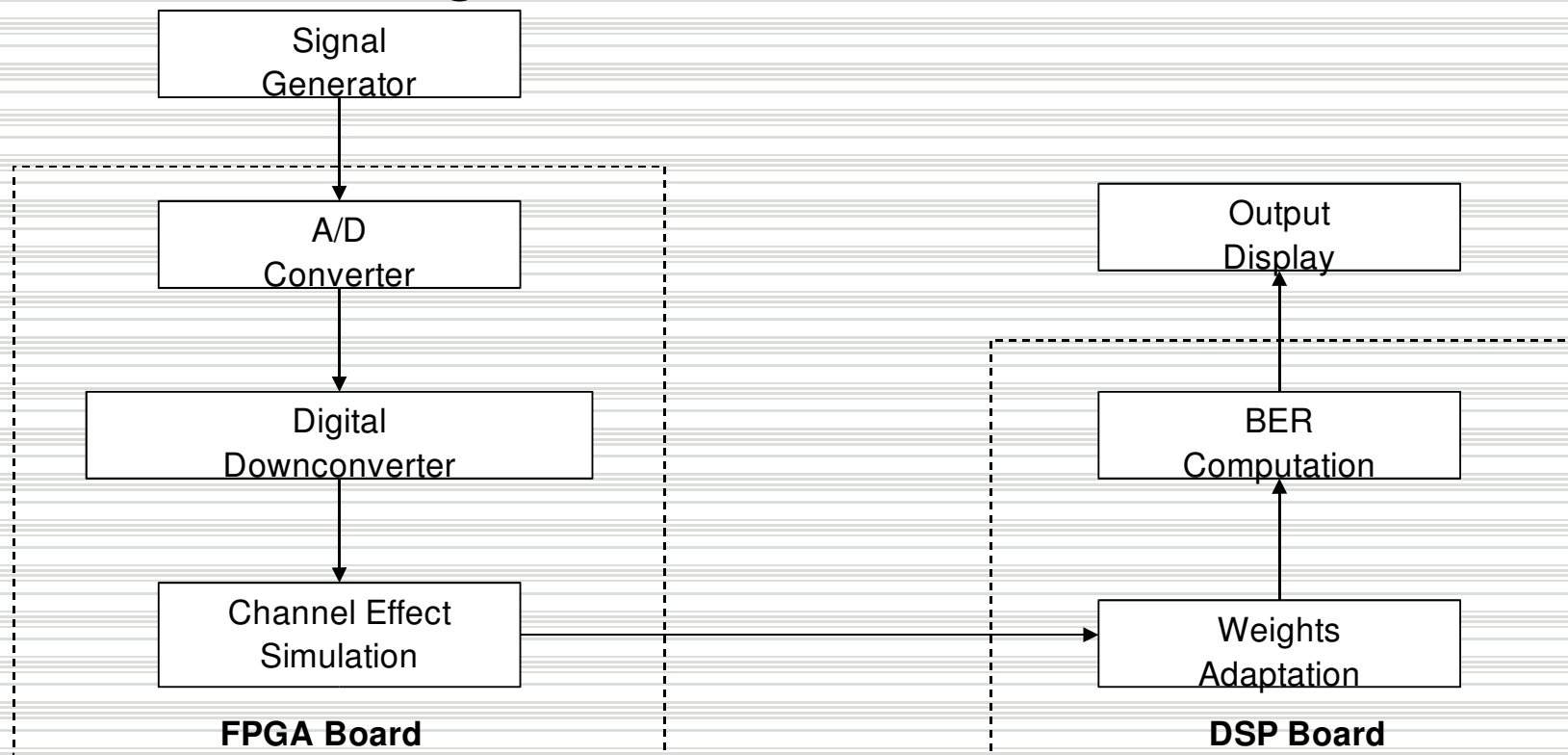
Implement ALBER algorithm in real-time on existing hardware

Compare BER performance of ALBER versus LMS

Compare memory and processing power requirements of ALBER versus LMS

Proposed Methodology - Implementation

Block Diagram



Proposed Methodology - Implementation

Signal Generator

- BPSK signals

- IF frequency of 100 MHz

A/D Converter

- Signals sampled at 80 MSPS

- 12 bits per sample

Digital Downconversion

- Performed in FPGA, Altera's Stratix EP1S25
DSP Development Board

Proposed Methodology - Implementation

Channel Effect Simulation

- Noise

- Co-Channel Interference

- Multipath

- Performed in FPGA

Weights Adaptation

- Performed in DSP board, TI's TMS320C6701

- Both LMS and ALBER algorithm will be implemented

Proposed Methodology - Implementation

BER Computation

Performed in DSP board

Output Display

DSP board interfaced to a host computer
through JTAG emulation

Simulation results displayed in host computer

Proposed Methodology -Testing

Four test cases

- AWGN

- AWGN + CCI

- AWGN + Multipath

- AWGN + CCI + Multipath

BER plots will be used as main basis of comparison for algorithm performance

Other comparisons to be made

- FPGA logic elements used

- Memory space in the DSP board needed for program and lookup tables

- Number of cycles used in DSP board

Country	Year	Value
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Gantt Chart

- (1) Design of Digital Downconverter
 - (2) Coding of Channel Effects
 - (3) Coding of MMSE and MBER algorithms
 - (4) Integration
 - (5) Testing
 - (6) Documentation
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Thank You!

