AD-A183 244 SIGNAL PROCESSING AND ANALYSIS: STATISTICAL TECHNIQUES 1/1
EFFICIENT ALGORITH..(U) MOORE SCHOOL OF ELECTRICAL
ENGINEERING PHILADELPHIA PA DEPT O.. S A KASSAM

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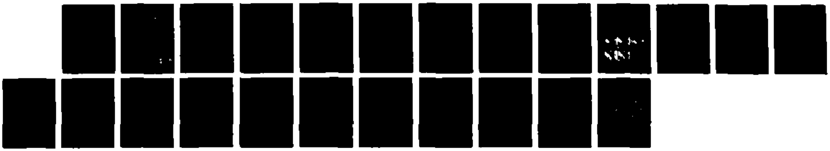

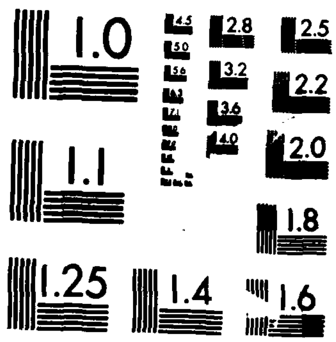

MICROCOPY RESOLUTION TEST CHART
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19. ABSTRACT (Continue on reverse if necessary and identify by block number)

A VAX 11/750 minicomputer and an image display and graphics controller and additional pieces of hardware were acquired. This equipment has enabled the signal Processing Research Laboratory to be established at the University of Pennsylvania. The laboratory supports the needs of four faculty members and ten graduate students working on AFOSR and ONR sponsored research.

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AFOSR-TR- 87-0943

FINAL TECHNICAL REPORT

AFOSR EQUIPMENT GRANT 84-0255

SIGNAL PROCESSING AND ANALYSIS: STATISTICAL TECHNIQUES, EFFICIENT ALGORITHMS, NONLINEAR PROCESSING, EM ANALYSIS

Grant Amount: $141,339

Grant Year: July 15, 1984 - July 14, 1985

Report Date: August 27, 1986

Saleem A. Kassam
Principal Investigator

This equipment grant was awarded for the purpose of upgrading our research capability in the areas of signal processing and analysis, on which we have been active for over ten years primarily under AFOSR sponsorship. At the beginning of the equipment grant period we had no laboratory associated with our research; we now possess a very useful laboratory facility, the SIGNAL PROCESSING RESEARCH LABORATORY, which has been established in two rooms made available to us in the electrical engineering department. An industrial cash grant was obtained to meet the power supply and air conditioning costs for the laboratory. The total area of the facility is approximately 800 square feet and houses the hardware which has been acquired under the equipment grant.

The two main hardware systems that have been possible through this grant are:

1) A VAX 11/750 minicomputer system with 4Mb of main memory, a floating point accelerator, communication ports, two 456 Mb disk drives, a tape drive, four terminals including two graphics terminals, two printers and two plotters;

2) An image display and graphics controller (Raster Tech) with two color monitors, which is interfaced to the VAX and to a DEC Rainbow microcomputer, and a video camera with a frame grabber resident on an IBM PC XT microcomputer for image capture.

Additional pieces of hardware acquired under this grant include a digital signal processing development system installed in an IBM PC XT microcomputer, an IBM PC AT microcomputer, communication modems and printers.

A primary need that the new laboratory has been serving very well is that of a reasonably powerful computational and simulation facility which can be coupled directly to signal processing hardware. Another major function of this laboratory is to provide image processing facilities which have turned out to greatly enhance our research activity in the applications of new signal processing ideas in this important area. The signal processing research laboratory is currently supporting the needs of four faculty members (Profs. Kassam, Ansari, Berkowitz and Kritikos) and ten graduate students, working primarily on AFOSR sponsored research and on other related research programs supported by ONR. In the area of statistical and digital signal processing this laboratory is supporting research in nonlinear and adaptive filtering techniques, nonparametric and robust detection and filtering, multidimensional digital filters, spectrum estimation, and computationally efficient algorithms in signal processing. In the area of electromagnetic analysis the equipment is supporting work in three-dimensional EM imaging, design of smart signal processing antenna arrays, and other related concepts.

The computer facility is operated entirely by the users themselves. Maintenance and software costs are being met by laboratory fees charged to grants and contracts, as well as from industrial sources of gifts and grants. In fact, one very positive result of the establishment of this laboratory is that industrial equipment and cash gifts have been easier to get.

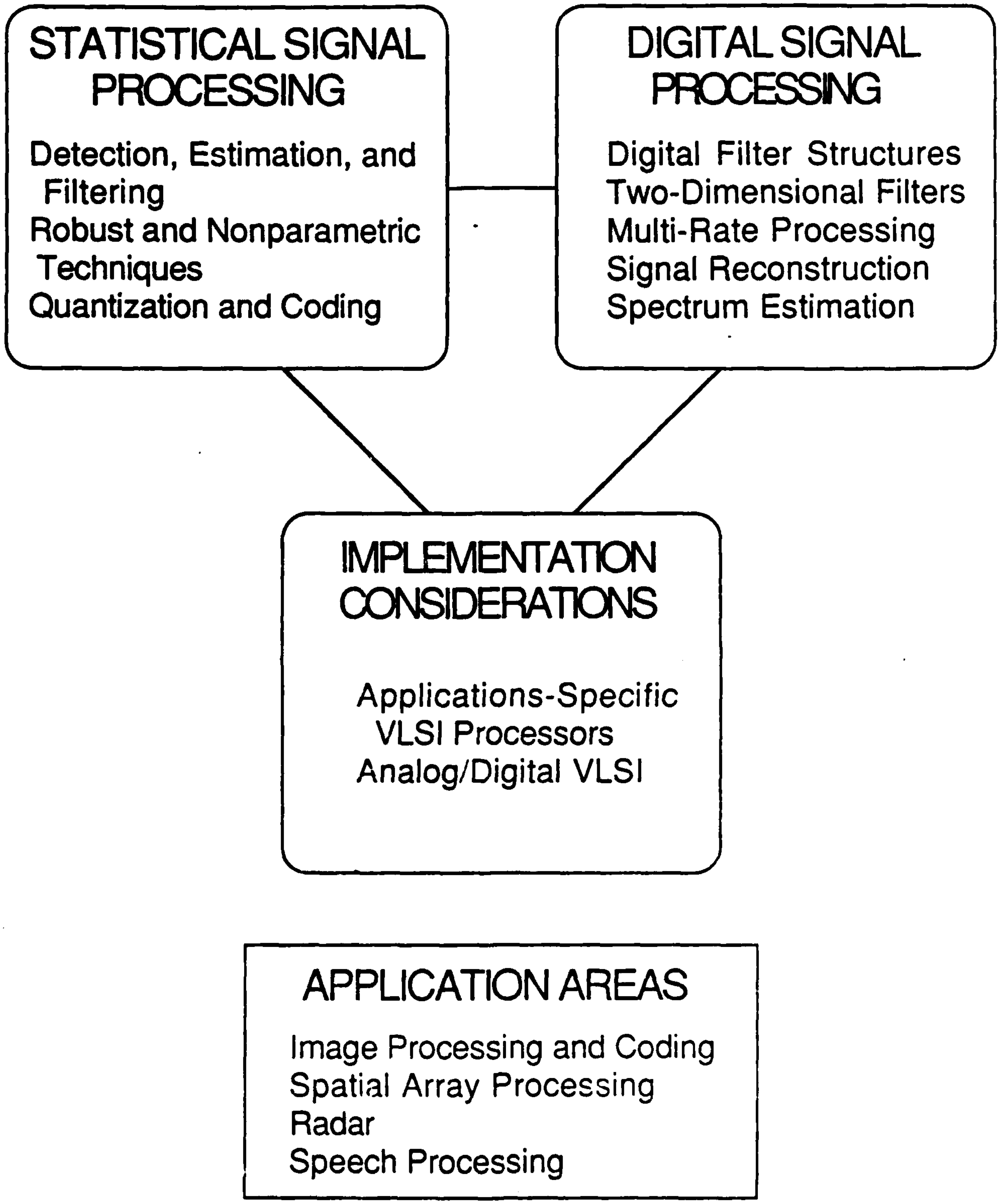
This laboratory has proved to be a tremendous resource to us. We are hoping that we will be able to continue to keep it efficient and current through the addition of new hardware and software, for which we are always seeking new funds and gifts from various sources.

The attached set of copies of viewgraphs are from a recent talk that we have prepared describing our primary research areas at the laboratory.

SIGNAL AND IMAGE PROCESSING

at the

SIGNAL PROCESSING RESEARCH LABORATORY


STATISTICAL SIGNAL PROCESSING
Detection, Estimation, and Filtering
Robust and Nonparametric Techniques
Quantization and Coding
DIGITAL SIGNAL PROCESSING
Digital Filter Structures
Two-Dimensional Filters
Multi-Rate Processing
Signal Reconstruction
Spectrum Estimation
IMPLEMENTATION CONSIDERATIONS
Applications-Specific VLSI Processors
Analog/Digital VLSI
APPLICATION AREAS
Image Processing and Coding
Spatial Array Processing
Radar
Speech Processing

SIGNAL PROCESSING RESEARCH LABORATORY

SOME SPECIFIC RESEARCH AREAS

- SIGNAL AND IMAGE RESTORATION
- SPATIAL ARRAY SIGNAL PROCESSING
- DIGITAL FILTER STRUCTURES
- VLSI IMPLEMENTATIONS

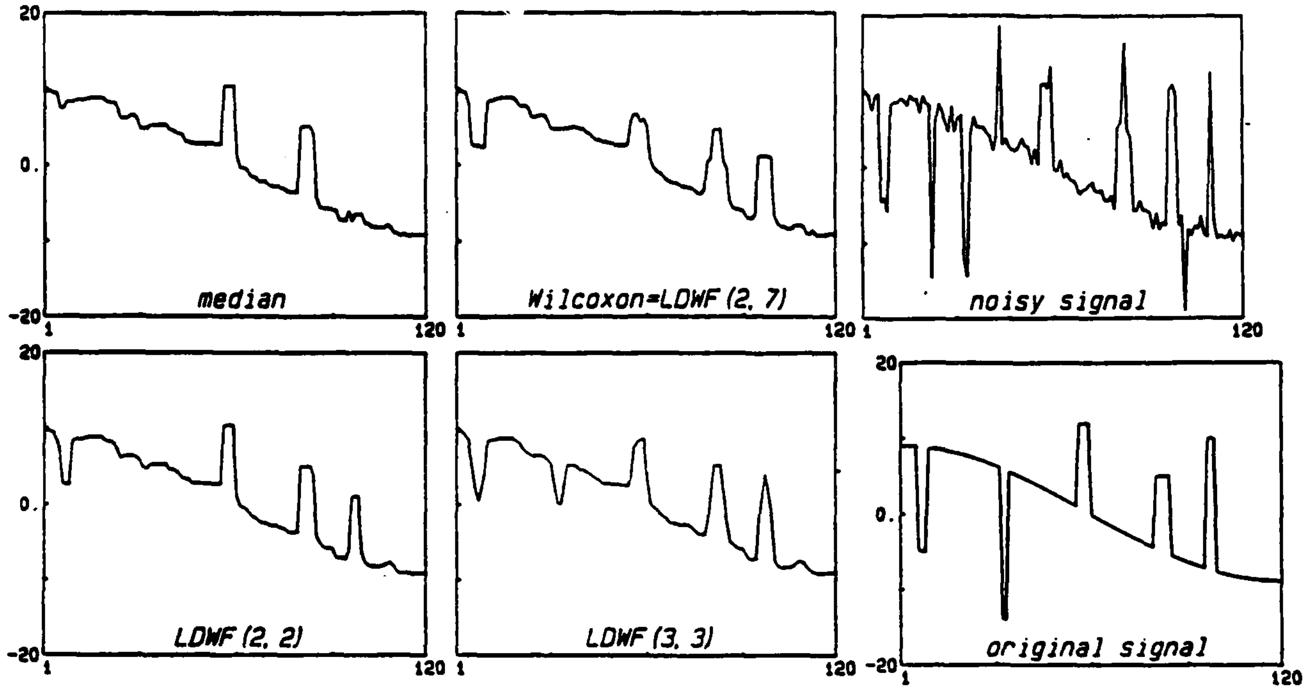
- **SIGNAL AND IMAGE RESTORATION**

1. APPLICATION OF ROBUST ESTIMATION TO SMOOTHING, FILTERING, AND ENHANCEMENT OF SIGNALS AND IMAGES

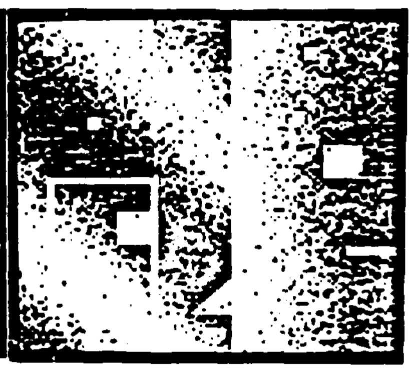
   - Non-Gaussian (Impulsive) Noise Suppression
   - Preservation of Edges in Signals
   - Frequency Selectivity

   NEW NONLINEAR DATA-ADAPTIVE FINITE-WINDOW FILTERS (VIEWED AS GENERALIZATIONS OF MEDIAN FILTERS) PERFORM VERY WELL

   - Extension to Image Sequence Processing
   - Applications in Edge Detection, Motion Estimation, Recognition, Tracking
   - Application in CFAR Radar
   - Fast Hardware Implementations



Original Image



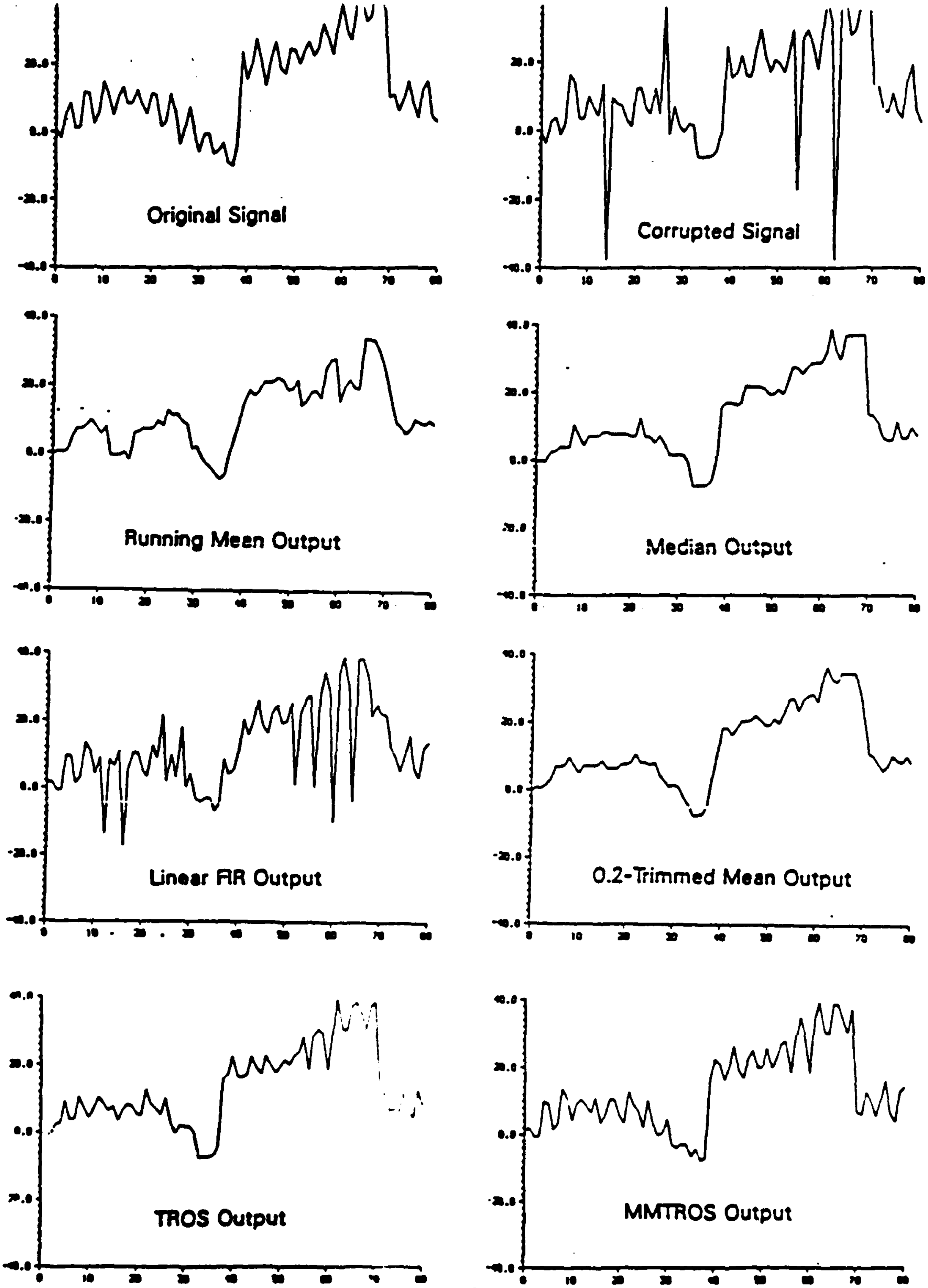
Noisy Image

Median Filter

LDWF (2,2)

LDWF (3,3)

COMPARISION OF MEDIAN AND RANK-BASED FILTERS (LDWF) FOR SIGNAL RESTORATION



Sample Filtering Results Using Windows of Size 5

• **SIGNAL AND IMAGE RESTORATION**

2. RESTORATION OF SIGNALS AND IMAGES FROM PARTIAL INFORMATION

- Restoration from Fourier Transform Magnitude Only

NEW HILBERT SPACE FRAMEWORK ALLOWS
REPRESENTATION OF CONSTRAINTS AS CONVEX SETS.
GUARANTEED CONVERGENCE TO GOOD SOLUTIONS

- *Extension to Image Sequence Processing*
- Consideration of Other Constraint Combinations
- Study of Tolerance to Noise

• SPATIAL ARRAY SIGNAL PROCESSING

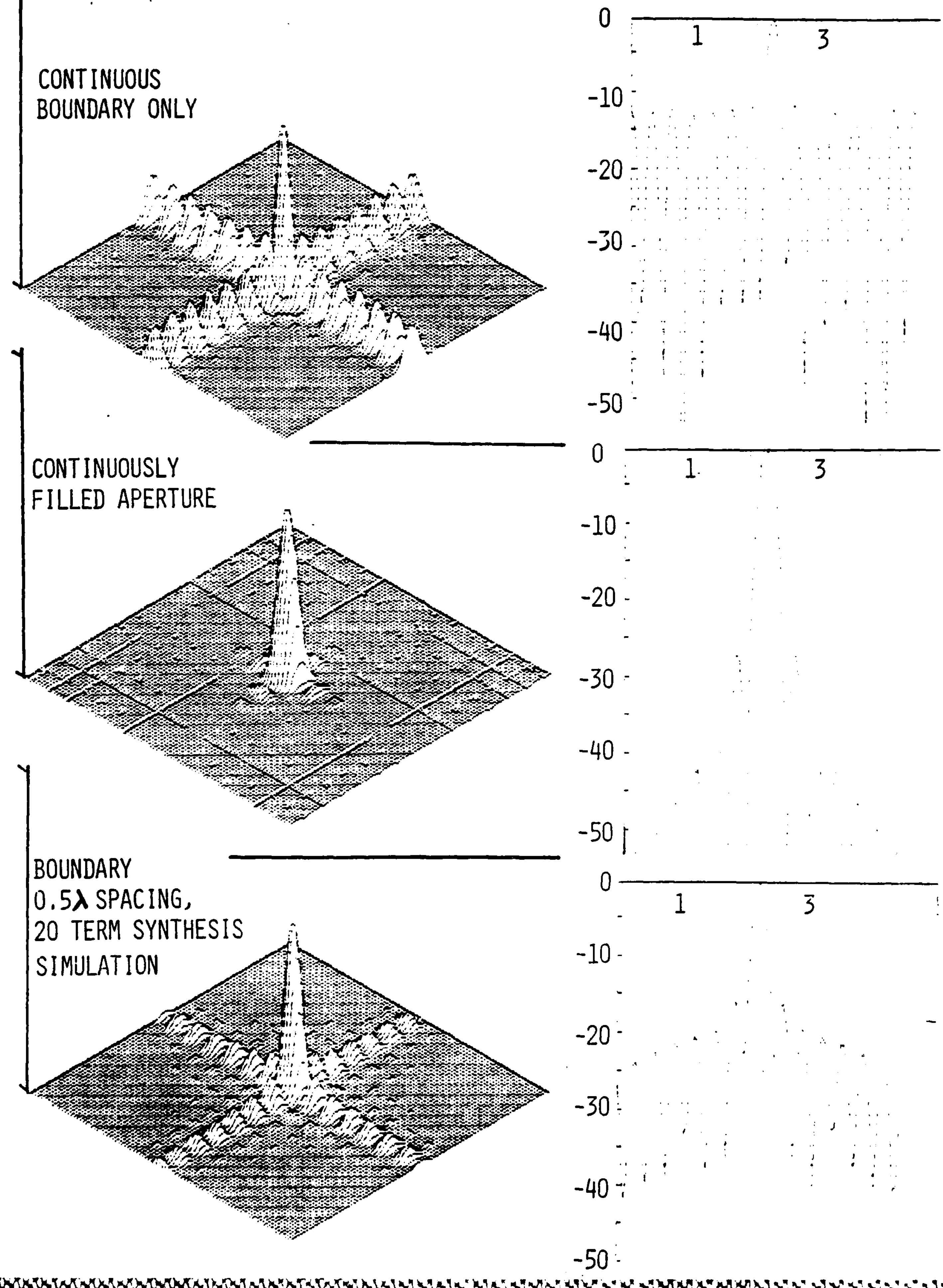
1. LOW-SIDELOBE BEAM CHARACTERISTICS FROM NARROWBAND HIGH-RESOLUTION BOUNDARY ARRAYS

- Array Elements Spaced Along Boundary of Convex Planar Aperture

NEW SYNTHESIS THEOREM ALLOWS EFFECTIVE INTERPOLATION INSIDE BOUNDARY. ACHIEVED BY PROCESSING TRANSMIT/RECEIVE DATA TO SYNTHESIZE INDIVIDUAL BEAMS, LINEAR COMBINATION OF THESE CONVERGES TO IDEAL SOLUTION

- Study Effects of Noise and Element Position Uncertainities
- Combination of Super-Resolution and Low-Sidelobe Processing
- Implementation Considerations

TWO-WAY PATTERNS, 20λ SQUARE APERTURE



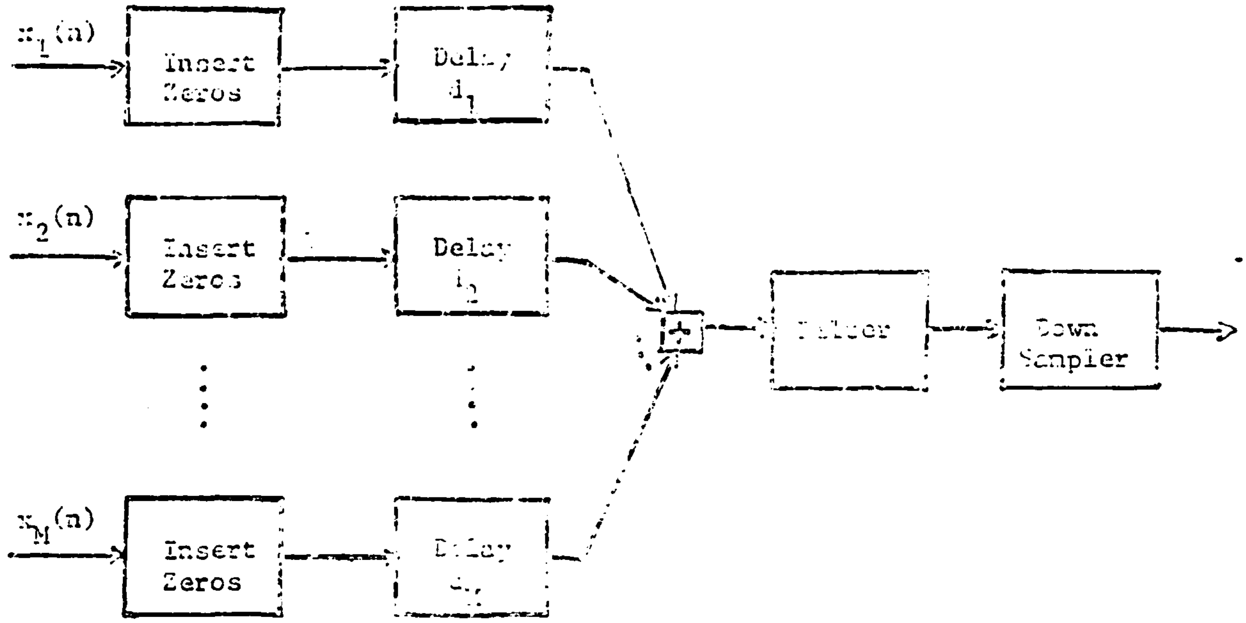
- **SPATIAL ARRAY SIGNAL PROCESSING**

2. DIGITAL INTERPOLATION BEAMFORMING

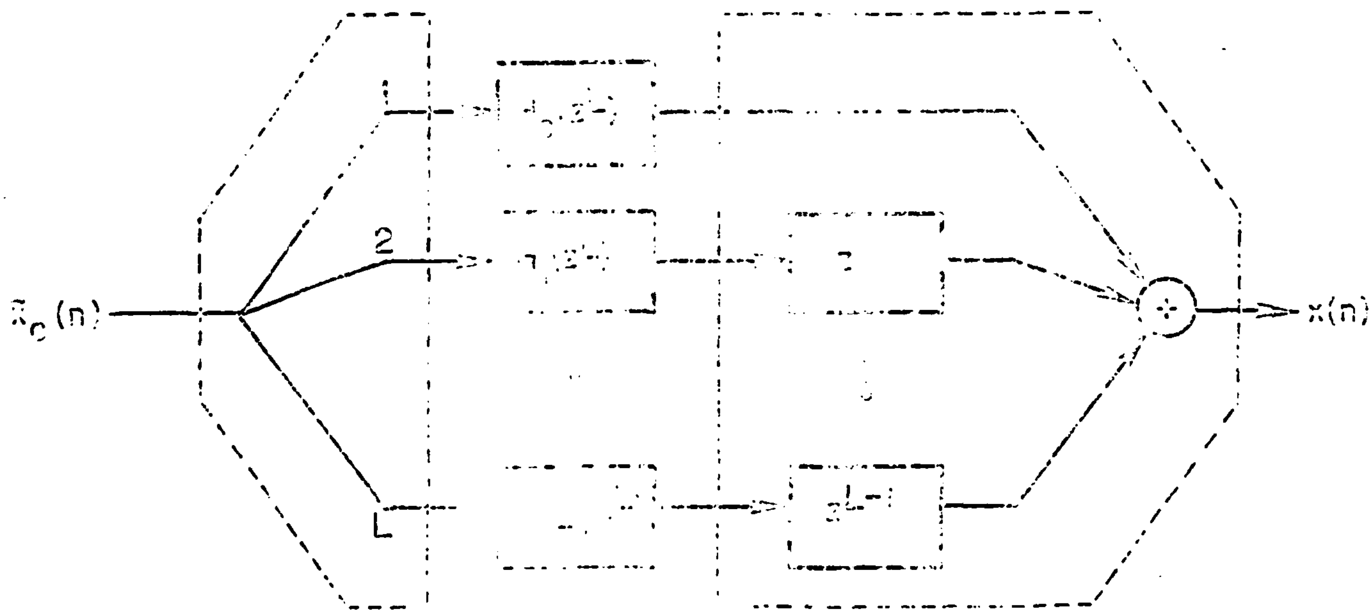
- High-Speed Beamforming for Linear Arrays

USE OF MULTI-RATE PROCESSING AND NEW RECURSIVE DIGITAL FILTER STRUCTURES FOR COMPUTATIONALLY EFFICIENT BEAMFORMING AND SCANNING

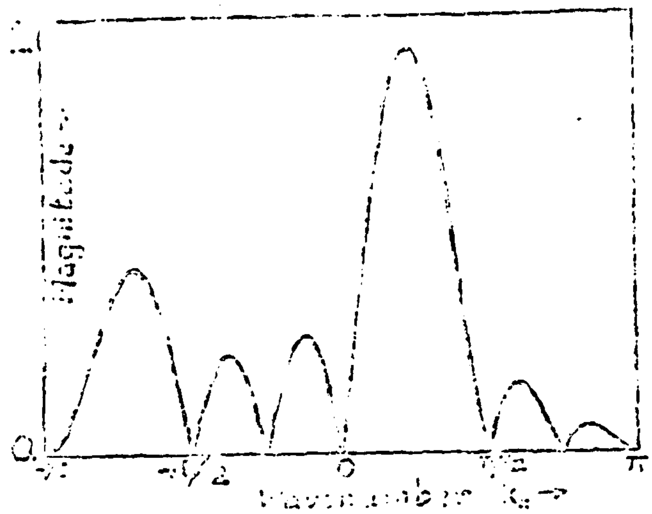
- Extensions to Non-Uniformly Spaced and Two Dimensional Arrays



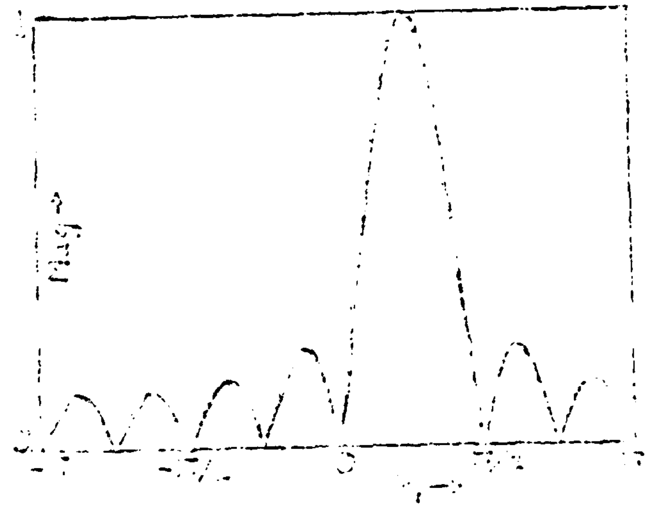
SCHEME FOR DIGITAL INTERPOLATION BEAMFORMING



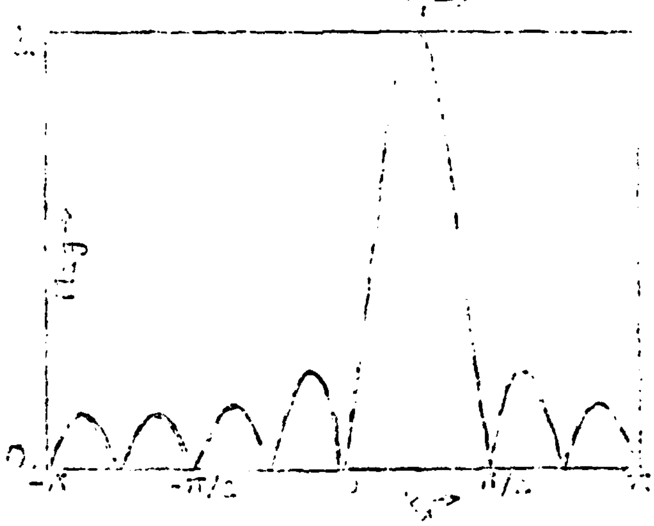
INTERPOLATOR USI[illegible] SECTIONS IN PARALLEL



OUTPUT AT LOW SAMPLING RATE



OUTPUT AT HIGH SAMPLING RATE



OUTPUT AFTER INTERPOLATION

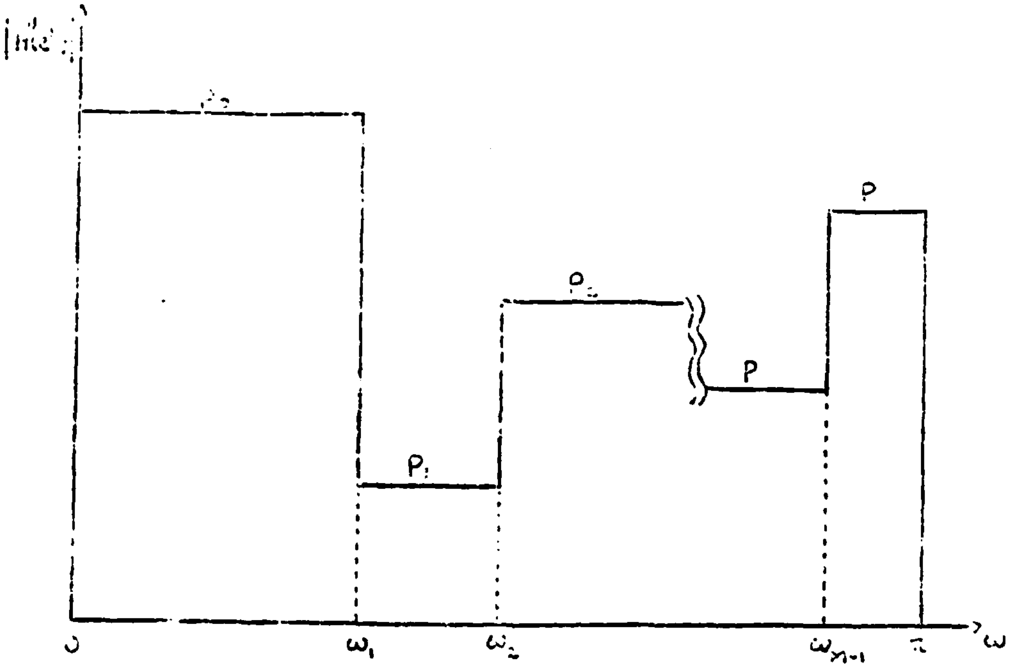
• DIGITAL FILTER STRUCTURES

INFINITE IMPULSE RESPONSE STRUCTURES FOR FILTERING AND SAMPLING-RATE CONVERSION

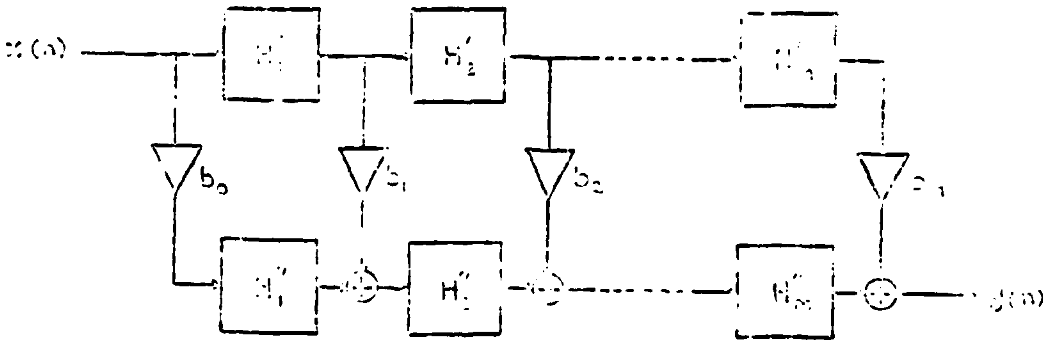
- Multi-band, Multi-level Infinite Impulse Response(IIR) Filters
- Linear-Phase IIR Filters
- Interpolators and Decimators

CONFIGURATIONS OF ALLPASS BUILDING BLOCKS RESULT IN SCHEMES WITH ATTRIBUTES OF LOW COMPLEXITY, LOW QUANTIZATION EFFECTS, AND MODULARITY

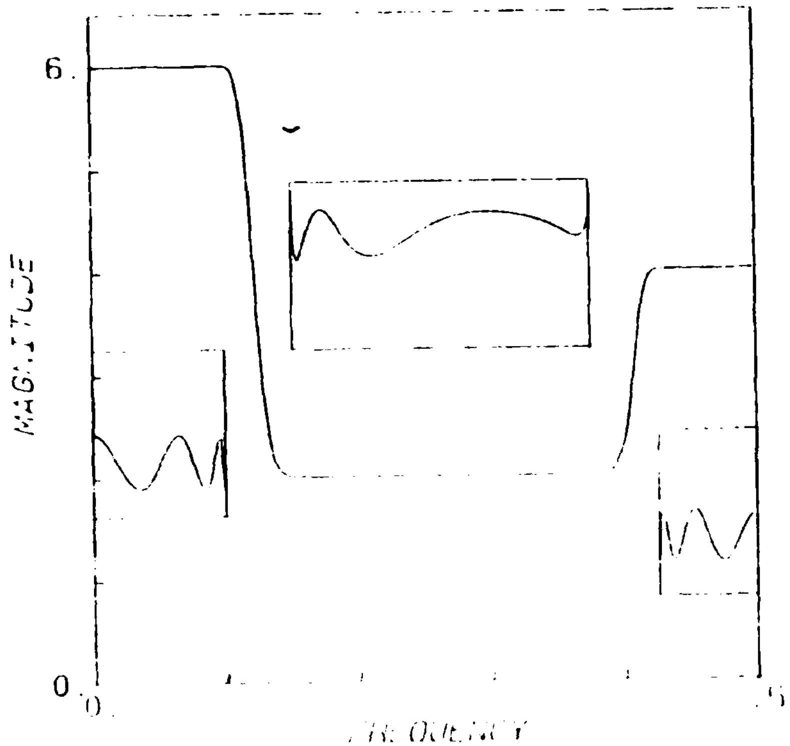
- Incorporation of coefficient constraints in allpass building blocks
- Allpass and generalized separable two-dimensional filters
- Applications in image processing and coding and adaptive filtering



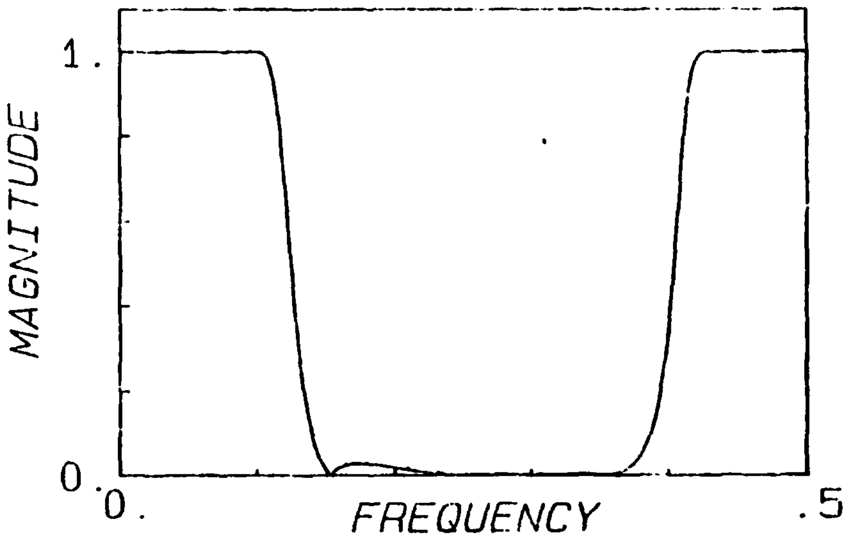
Ideal response of M-level filter (levels $p_0, p_1 \cdots p_M$)



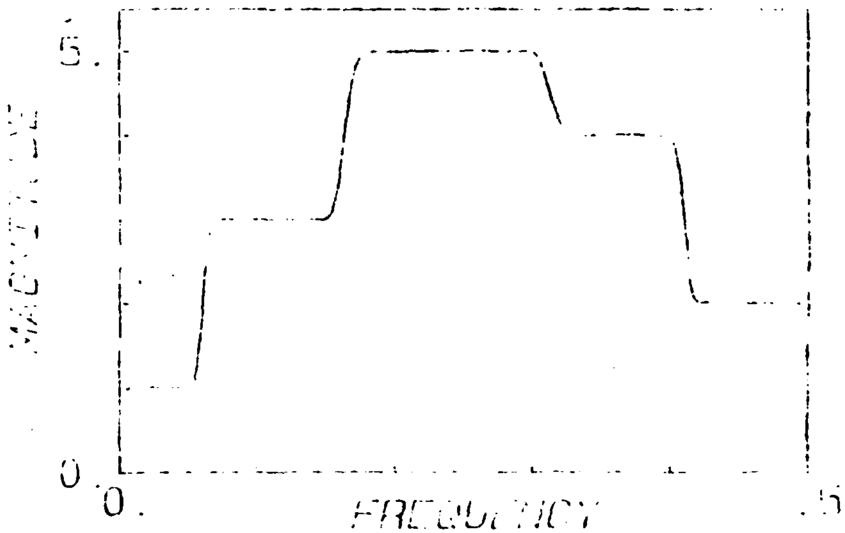
M-level filter configuration using allpass sections



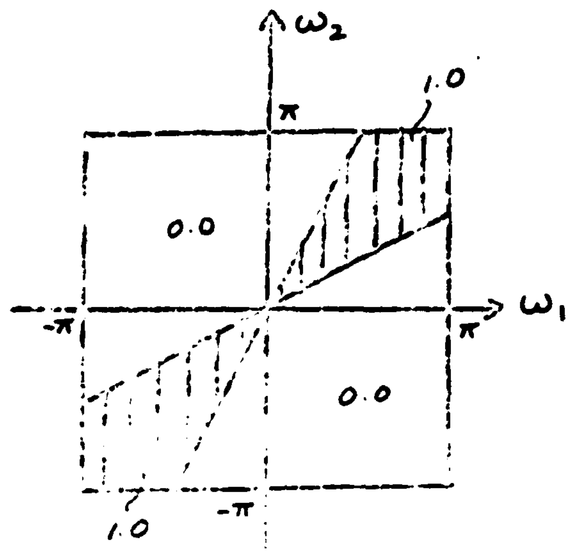
Magnitude response of 3-level filter



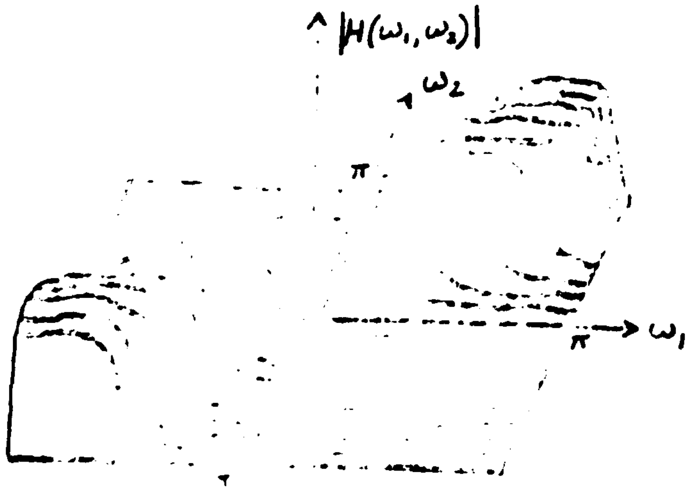
Magnitude response of 3-level filter with different path gains



Magnitude response of a 5-level filter.



IDEAL MAGNITUDE RESPONSE OF NARROWBAND FAN FILTER



APPROXIMATI[illegible] GENERALIZED SEPARABLE FILTER

- **VLSI IMPLEMENTATIONS**

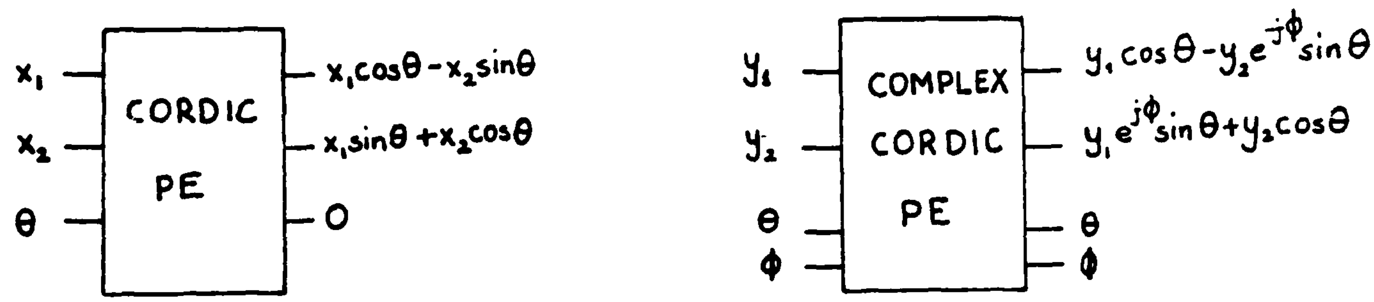
EFFICIENT IMPLEMENTATION OF HIGH-RESOLUTION SPECTRUM ESTIMATION ALGORITHM

- Multiple Signal Classification (MUSIC) Algorithm Implementation

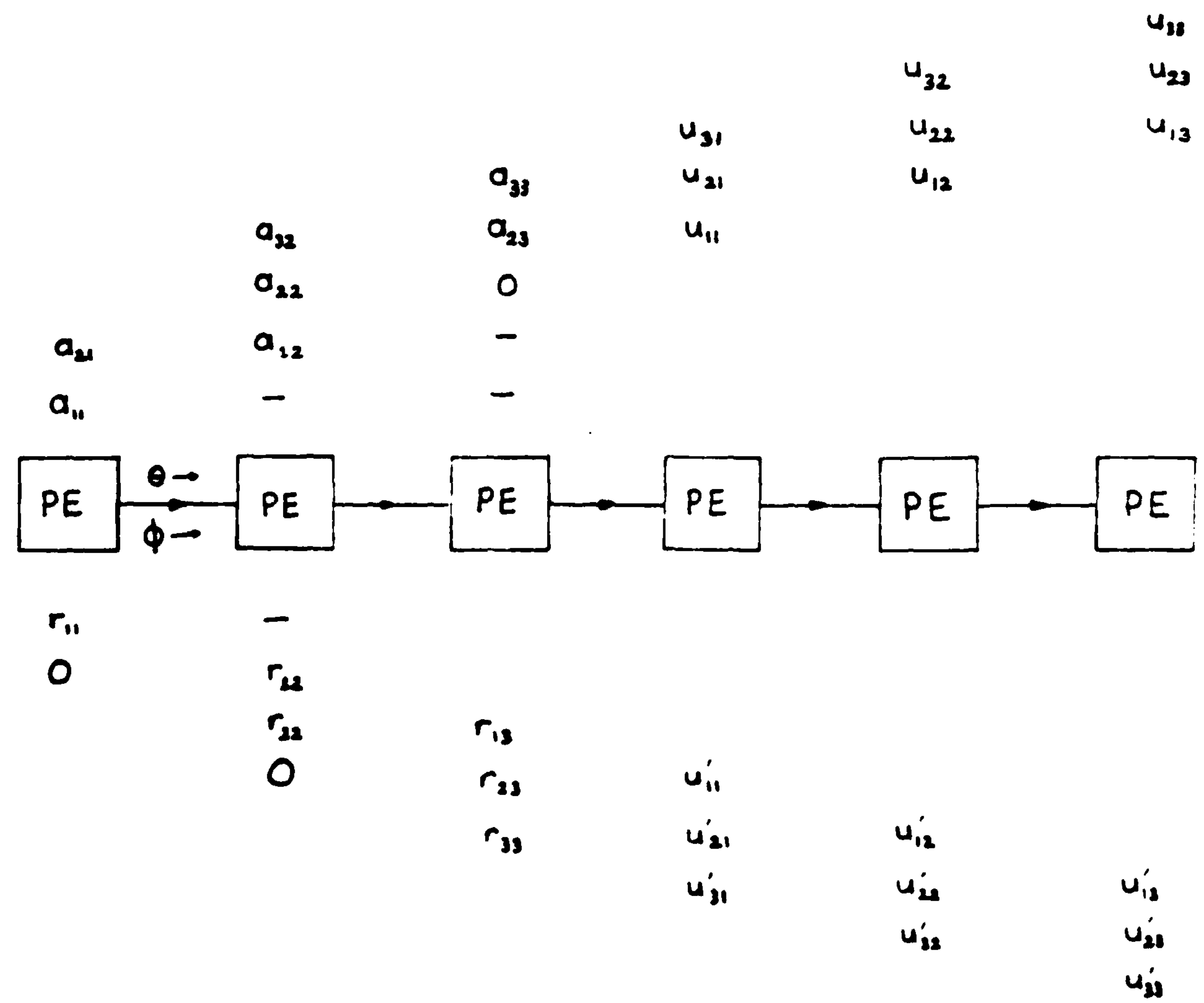
SYSTOLIC ARRAY SCHEME BASED ON THE USE OF CORDIC BUILDING BLOCKS

- Use of CORDIC blocks for filter implementations (e.g. allpass blocks)
- Interpolation beamforming using CORDIC blocks
- New general-purpose signal processor for filter implementations with structural constraints

PROCESSING ELEMENTS (PE's):



SYSTOLIC ARRAY FOR EIGENVALUE-VECTOR COMPUTATION



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