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The system design of a radar track-while-scan facility utilizing modern digital techniques

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The System Design of a Radar Track-While-Scan Facility Utilizing Modern Digital Techniques

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A project report submitted to the Faculty of Engineering, University of the Witwatersrand, Johannesburg, in partial fulfilment of the requirements for the degree of Master of Science in Engineering.

Johannesburg 1985.

Declaration.

I declare that this project report is my own unaided work. It is being submitted for the Degree of Master of Science in Engineering in the University of the Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination in any other University.

.....
(Signature)

1st day of September 1985.

Abstract

The system design of a Track-While-Scan facility for a small surveillance radar is presented. The reader is introduced to Track-While-Scan concepts and a brief review of tracking filters is given. A particular system requirement is detailed and the design of a Track-While-Scan system is described using an available personal computer to implement the digital processing.

Dedication.

To my mother and late father.

Jean and William Henery.

Acknowledgements.

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Table Of Contents

1.0 INTRODUCTION 15

1.1 Present System 16

1.2 Design Aims 17

1.3 Report Structure 19

2.0 WHAT IS TRACK-WHILE-SCAN 20

2.1 Surveillance Radars 20

2.2 Tracking Radars 22

2.3 The Track-While-Scan-System 22

2.4 TWS Process Stages 25

2.4.1 Target Detection 25

2.4.2 Target Acquisition And Tracking Windows . . . 26

2.5 Track Initiation 27

2.5.1 Resolution Of Track Ambiquity 29

2.5.2 Track Filtering And Predicition 30

2.6 The Basic TWS System 31

3.0 THE TRACKING FILTERS 32

3.1 How The Target Is Tracked 32

3.2 Basic Concepts Of Tracking Filters 34

3.2.1 The Tracking Model 34

3.2.2 Linearity And Coordinate Translations 35

3.2.3 Filter Memory Types 36

3.3 Review Of Tracking Filters 37

3.3.1 The Alpha Filter 38

3.3.2 The Alpha-Beta Filter 40

3.3.2.1 The Discounted Least Squares Alpha-Beta Filter 44

3.3.2.2 The Benedict - Bordner Alpha-Beta Filter . . 46

3.3.2.3 The Expanding Memory Alpha-Beta Filter . . . 47

3.3.2.4 Adaptive Alpha-Beta Filters 49

3.3.3 The Alpha-Beta-Gamma Filter 50

3.3.4 The Kalman Filter 51

3.4 Tracking Filter Design 56

4.0 HOW THE TARGET IS TRACKED 58

4.1 The Tracking System 58

4.2 Target Designation 58

4.3 Track Initiation 59

4.3.1 Opening The Track File 60

4.3.2 Setting Up The Acquisition Window 61

4.4 Track Predicition 62

4.4.1 The Mean Of The Extremeties Algorithm 64

4.4.2 The Mean Range And Azimuth Position 65

4.4.3 Weighted Echoes Method 67

5.0 THE SYSTEM DESIGN 68

5.1 Integration Into The Present Radar System . . . 68

5.2 Man-Machine Interface 69

5.3 The Window Generator 72

5.4 Number Of Targets To Be Tracked 72

5.5 Target Parameters 73

5.6 Window Sizes 73

5.7 Choice Of Tracking Filter 75

5.8 Tracking Filter Initialisation 77

5.9 Track Ambiguity Algorithm. 78

6.0 SYSTEM IMPLEMENTATION 79

6.1 The PPI Display 79

6.1.1 The X And Y Deflection Voltage Generators . . 79

6.1.2 The Z-Modulation Generating Circuitry 82
6.2 The Joystick Interface 87
6.3 The Symbol Generating And Positioning Circuitry 89
6.4 The Track-While-Scan-Processor 99
6.4.1 The Window Generator 99
6.4.1.1 The Memory Card 102
6.4.2 The TWS Algorithm 105
6.4.2.1 The Setup Process And Main Calling Routine . 105
6.4.2.2 The Initiate Routine 108
6.4.2.3 The Cancel Routine 113
6.4.2.4 The Track Routine 114
6.5 The TWS Program 116
7.0 SYSTEM CONSTRUCTION 117
7.1 PPI Drive Circuit And Symbol Position Generator Circuit 117
7.2 TWS Window Generator And Memory Card 120
8.0 SYSTEM PERFORMANCE 123
8.1 Predicted Results 123
8.2 Method Of Obtaining Results 124
8.3 System Performance 125
9.0 DISCUSSION 129
10.0 REFERENCES 131

APPENDIX A BRIEF DESCRIPTION OF [illegible]E RADAR OPERATION

APPENDIX B CHARACTERISTICS OF THE PRESENT RADAR SYSTEM

APPENDIX C EXPECTED TARGET PARAMETERS

C.1 MILITARY AIRCRAFT C-2

C.2 CIVILIAN AIRCRAFT C-2

C.2.1 Jet Aircraft C-3

C.2.2 Propeller Aircraft C-3

APPENDIX D MATHEMATICAL DERIVATION OF THE ACQUISITION WINDOW SIZE

APPENDIX E EXPECTED NUMBER OF ECHOES RECEIVED FROM A TARGET

APPENDIX F THE SYMBOL GENERATOR CIRCUIT

APPENDIX G THE WINDOW GENERATOR CIRCUIT

APPENDIX H THE MEMORY CARD

APPENDIX I SOFTWARE LISTING OF THE TWS PROGRAM

I.1 THE SETUP PROCEDURE I-2

I.2 THE MAIN CALLING PROGRAM I-2

I.3 THE TRACKING ROUTINE I-3

I.4 THE INITIATE ROUTINE I-6

I.5 THE CANCEL ROUTINE I-7

I.6 THE SYMBOL OUTPUT SUBROUTINE I-8

I.7 THE WINDOW OUTPUT SUBROUTINE I-9

List of Figures

2.1 The output of a typical PPI display 21

2.2 The output of a typical A-Scope display 23

2.3 A PPI display with TWS symbols included 24

2.4 View of the windows 28

2.5 Block diagram of a typical TWS system 31

3.1 General schematic of a tracking filter system . . . 33

3.2 Filter memory types 37

3.3 The Alpha filter 39

3.4 The Alpha-Beta filter 42

3.5 The Alpha-Beta filter stability region 42

3.6 The Alpha-Beta filter response regions 43

3.7 Locus for the critically damped Alpha-Beta filter . 45

3.8 Locus for the Benedict-Bordner condition 46

3.9 Plot of Alpha,Beta versus N for the Expanding Memory filter 48

3.10 A general form of the Kalman filter 53

3.11 Computational stages in the Kalman filter 55

3.12 Computational steps in the Kalman filter 55

4.1 A possible set of echo returns within the window . 63

4.2 Measured target position using the Mean of the Extremeties algorithm 65

4.3 Measured target position using the Mean Range and Azimuth algorithm 66

5.1 Timing diagram of the signals output by the signal processor 68

5.2	Plot of Alpha,Beta versus N for the filter chosen .	77
6.1	Block diagram of the deflection voltage generating circuitry	80
6.2	The analog sweep voltages	83
6.3	Block diagram of the video Z-modulation generating circuitry	84
6.4	The analog sweep voltages with the Z-modulation signal	86
6.5	Block diagram of the joystick position input device	88
6.6	The PPI display and the overlay grid	90
6.7	How the signal is built up	91
6.8	Basic block diagram of the symbol positioning and generating circuitry	93
6.9	The analog symbol voltages	95
6.10	Block diagram of the symbol Z-modulation generating circuitry	97
6.11	The analog symbol voltages with the Z-modulation signal	96
6.12	The composite X,Y deflection voltages with the Z-modulation signal	98
6.13	How the window is constructed	100
6.14	Basic block diagram of the window generating circuitry	101
6.15	Basic block diagram of the memory card	104
6.16	An overview of the TWS program	106
6.17	Main calling routine	107
6.18	Initiate routine	109

6.19 Symbol positioning subroutine 110

6.20 Window positioning subroutine 111

6.21 Cancel routine 113

6.22 Track routine 115

7.1 Example of a digital wire-wrap card 119

7.2 Example of an analog printed circuit board 119

7.3 The 19" rack system 120

7.4 The window generator and memory cards 122

7.5 The IBM PC with dedicated cards installed 122

8.1 Typical PPI display showing track sequence 123

8.2 System PPI display 126

8.3 Target track on the system PPI display 127

A.1 Block diagram of the radar receiver and transmitter sections A-3

A.2 Block diagram of the typical signal processor . . . A-5

A.3 Block diagram of the basic MTI filter A-6

A.4 MTI filter response A-8

A.5 Block diagram of the m-out-of-n detector A-9

A.6 Block diagram of the cell-averaging CFAR detector . A-10

A.7 Typical antenna elevation coverage patterns A-12

D.1 Radial acceleration on a body D-3

D.2 Radial flight: possible flight paths D-5

D.3 Tangential flight: possible flight paths D-6

D.4 Window dimensions D-7

E.1 Antenna pattern and target interaction E-3

F.1 Block diagram of the symbol positioning and generating circuitry F-3

G.1 Block diagram of the window generating circuitry G-3

G.2 Timing diagram for the halting circuit G-2

H.1 Block diagram of the memory card H-3

I.1 Setup procedure I-2

1.2 Main calling routine I-3

I.3 Tracking routine I-4

I.4 Initiate routine I-6

I.5 Cancel routine I-8

I.6 Symbol positioning subroutine I-8

I.7 Window positioning subroutine I-9

1.0 INTRODUCTION

Surveillance radars are widely used both in civilian and military applications to provide airspace cover around airfields, point targets and demarcated areas.

These radars provide elevation coverage as determined by the antenna vertical radiation pattern and, in general, full azimuth coverage.

All targets within this volume of coverage are then displayed. It is up to the operator to identify the status of the targets (friendly or enemy) and to monitor the flight paths of these targets.

Tracking radars, in contrast, are used to track a particular target in three-dimensional space and to supply the target position to, say, a gun or missile system. These radars do not provide coverage over a large area and usually form part of a defensive system.

A facility that would combine the wide coverage of the surveillance radar with the ability to provide particular target tracks is called a Track-While-Scan system. This system will allow the radar to operate as a normal surveillance radar displaying all targets within the area and in addition allows the operator to designate targets to be tracked. The Track-While-Scan system would then extract the target position

from the radar system and make predictions as to where the target will be expected to lie on the following scan. Tracking algorithms are employed to implement this prediction. The predicted position is indicated on the surveillance radar display and if necessary may be output to a gun or missile system. Multiple targets may thus also be tracked.

1.1 Present System

A ground-based surveillance radar capable of detecting aircraft to a maximum range of 15km has been built, based on a commercially available marine radar. The modifications to the original radar include an improvement to the receiver, the development of new timing circuits and a digital signal processor.

The digital signal processor consists of two Analog-to-Digital converters, a digital Moving Target Indicator filter and associated Vector Adder and a Constant False Alarm Rate detector.

The signal emerging from the signal processor is one-bit video and may be termed the primary video signal. This primary video signal is passed onto the Plan Position Indicator display for the output of the radar data.

The original Plan Position Indicator display has been left

untouched.

Appendix A contains a brief description of surveillance radar operation.

Appendix B lists the characteristics of the present radar system.

1.2 Design Aims

There presently exists a short-range surveillance radar for which no Track-While-Scan facility is avaliable.

In order for the operator to designate targets and for the Track-While-Scan processor to indicate the target tracks on the display some means must be made available to allow the system to write the information to the display. This Track-While-Scan data is termed the synthetic video signal. The present Plan Position Indicator display does not allow the inclusion of any synthetic video at all.

The first design aim was to implement a new display capable of displaying the synthetic video signals as well as the primary video signal. The particular choice of display had not been finalised so the driving circuitry had to be capable of being interfaced to a wide variety of commercially available X-Y-Z vector-type displays. The requirement for displaying up to

three target tracks and a designation marker was catered for.

Most literature available on the subject of Track-While-Scan systems tends to concentrate on the simulated performances of the various tracking algorithms and few, if any, have concentrated on the implementation of a system. In order to demonstrate that a working system may be constructed a particular type of tracking algorithm, namely the Benedict-Bordner Alpha-Beta Filter with an exponentially decaying value of alpha was implemented using an IBM PC to execute the program and dedicated hardwired logic to interface the IBM PC to the radar. This allowed the system to be demonstrated for single track operation. Further work would then involve an investigation into the feasibility of tracking multiple targets using a single-board computer to implement the tracking algorithms.

An IBM PC was chosen to implement the Track-While-Scan processor for the following reasons:

1. It allowed the development and debugging of the algorithm to be implemented in a high level language.

2. A single board computer was unavaliable.

3. The aim was to investigate the viability of using a small processor to implement the Track-While-Scan system.

1.3 Report Structure

The first section of the report looks at the Track-While-Scan process in detail and describes the various stages in the tracking process. As was mentioned earlier a tremendous amount has been written on the performance analysis of the various tracking algorithms. An introduction to the method of tracking is detailed as well as a brief review of the various types of tracking algorithms. These sections deal primarily with the theory involved in Track-While-Scan processes and numerous works on the subject are referenced.

The system requirement is then detailed and typical aircraft performance figures are quoted, around which the system is to be designed. This is followed by a detailed description of the expected system operation and the exact implementation of every unit within the system is described.

Once the system was built it was tested and found to work successfully. The typical target types and flight paths were investigated and photographic evidence is presented to substantiate the conclusions.

2.0 WHAT IS TRACK-WHILE-SCAN

2.1 Surveillance Radars

If the volume of airspace surrounding an airfield or a particular area is to be scanned continuously for aircraft then use is made of a surveillance radar. The antenna beamshape provides the elevation pattern coverage as well as the narrowbeam azimuth pattern coverage and the antenna is made to scan in a full three hundred and sixty degree azimuth circle. The range at which aircraft are detected is limited in part by the transmitted power of the radar and the rate at which the radar pulses are transmitted. Some of the newer and certainly more expensive radars may make use of a Chirp waveform to provide a limited estimate of aircraft altitude, but in general surveillance radars are two dimensional sensors, the two dimensions being range and azimuth.

The position of the target relative to the radar may be displayed on a Plan Position Indicator (PPI) display. A typical view of a PPI display output is illustrated in figure 2.1.

Point clutter sources or clutter breakthrough from the Moving Target Indicator (MTI) filter appear as small illuminated areas on the display. The actual antenna position is indicated by the radial line formed by the range ring indicators. The range rings provide the operator with a rough indication of the distance to the target. The target movement is normally easy to

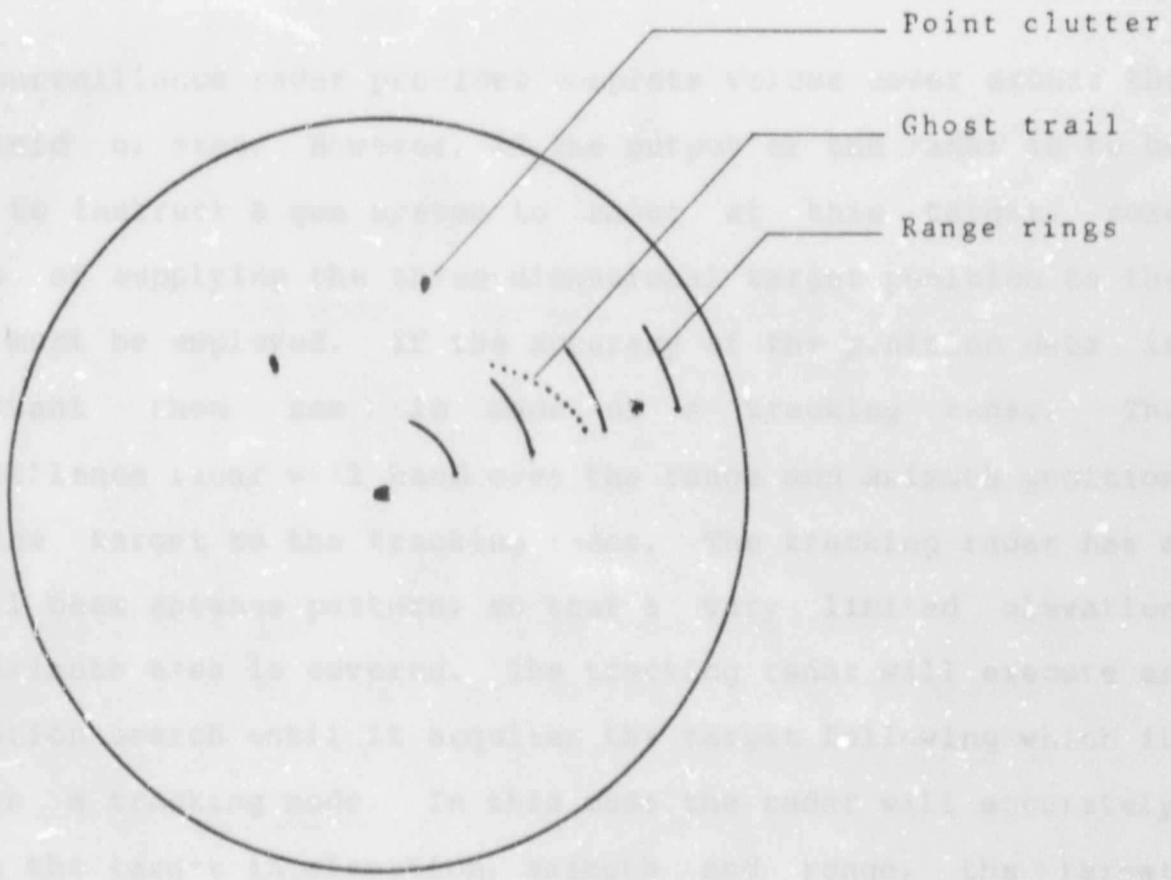


Figure 2.1 The Output of a Typical PPI Display

spot: as the target moves through the air, the sweep will illuminate successive positions on the PPI display. The previous positions are not illuminated but because of the persistence of the display one can see the older target positions. This "track" is referred to as a ghost trail, the length of this trial being dependent on the particular persistence of the PPI display phosphor.

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