The System Design of a Radar Track-While-Scan Facility

Utilizing Modern Digital Techniques

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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.

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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

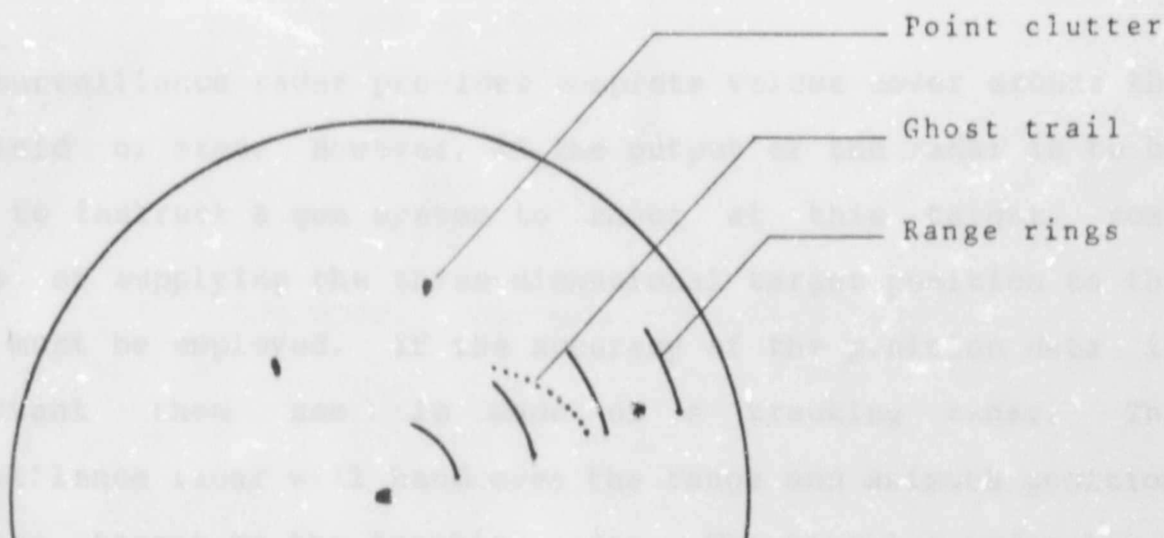

Figure 2.1 The Output of a Typical PPI Display

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.