British Library Cataloguing in Publication Data

Stevens, Michael C.
Secondary surveillance radar.
1. Secondary radar
I. Title
621.3848

ISBN 0-89006-292-7

Library of Congress Cataloging-in-Publication Data

Stevens, Michael C., 1936–
Secondary surveillance radar.

Bibliography: p.
Includes index.
1. Secondary surveillance radar. I Title.
TL696.R25S84 1988 629.136′6 88–3301

ISBN 0–89006–292–7

ARTECH HOUSE, INC.
685 Canton Street
Norwood, MA 02062

International Standard Book Number: 0-89006-292-7
Library of Congress Catalog Card Number: 88-3301

10 9 8 7 6 5 4 3 2 1

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Secondary Surveillance Radar

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Artech House
Boston and London

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Acknowledgments

The assistance of the following people and organizations with the preparation of this book is gratefully acknowledged: Donald Aaron, Michel Biot, Kevin Bond, John Boyachoc, David Clifford, Nicholas Comyn, Claude Eymann, Michael Gee, Clinton MacNeil, Vincent Orlando, Philip Platt, Melvin Rees, Terence Roblett, John Shaw, David Spalding, Peter Stanley, James Thurgood, Richard Trim, Brian Watson and Brian Wyndham; Allied Bendix Aerospace, Civil Aviation Authority, Eurocontrol, Hazeltine Corporation, Lincoln Laboratory, Royal Signals and Radar Establishment, Sivers IMA, Télécommunications Radioélectroniques et Téléphoniques, and especially Cossor Electronics Ltd.

Chapter 1

Introduction

Civil aviation is concerned with the safe and expeditious movement of people and freight from one point on the globe's surface to some other desired point. The responsibility for this safe passage is that of the pilots of the aircraft involved. In this responsibility they are assisted by ground-based systems and personnel. Safety is maintained by assuring adequate separation of aircraft, and to this end appropriate procedures and recommended practices have been devised by the International Civil Aviation Organization (ICAO). Many countries provide an air traffic control (ATC) service in at least part of their airspace. Pilots are required to file flight plans before their departure so that their intentions are understood and their flight can be integrated with other air traffic.

The degree of separation required for aircraft is influenced by the quality and accuracy of the position data available. In sparsely populated areas external aids to the pilot can be few and far between and separations of as much as 30 min of travel can be set for aircraft on the same course. These procedural separations are very generous since they are dependent on the aircraft's own navigation accuracy and allowance must be made for possible errors in navigation. However, they are inappropriate in areas of dense traffic, and the use of ground radar is required in order to handle demands on airspace without prejudicing safety.

The word "radar", which is an acronym of RAdio Detection And Ranging is usually taken to mean what is more accurately called primary radar. In primary radar a high power pulse of radio frequency energy is transmitted from a rotating antenna and if this strikes the body of an aircraft then a small amount of that energy is reflected back towards the rotating antenna. The skill of the primary radar design engineer is directed to the detection of this small amount of reflected energy. When an aircraft has been detected in this way its range can be determined by measuring the elapsed time between the transmission and subsequent reception of the reflection since the speed of a radio wave is known. The aircraft's bearing is indicated by the direction of the antenna at the time that the aircraft is detected.

Like any system, primary radar has its good and bad points. The major good point is that, for its operation, it does not require anything special of the aircraft other than that it presents a reasonable radar-reflecting surface. The bad points are that primary radar also obtains returns from rain, from the ground and even from birds, and these extraneous returns make it difficult to distinguish between real aircraft and the background clutter. Many special techniques have been developed to overcome these problems with some considerable success. However, primary radar is unable to distinguish one aircraft from another similar aircraft and in most cases cannot determine height to sufficient accuracy.

Secondary radar overcomes these difficulties. Secondary radar, more precisely secondary surveillance radar (SSR), requires each aircraft to carry on board a special transmitter–receiver equipment known as a transponder. An SSR ground station transmits pulses of radio frequency energy from a rotating antenna in the same way as for primary radar except at a very much lower power level. Only sufficient power to overcome the one-way path loss to the transponder is required compared with the two-way path loss for primary radar. SSR transmits pulses of a few hundred watts in power compared with a few hundreds or thousands of kilowatts in the case of primary radar. Upon reception of the ground-station signal, the transponder transmits a reply on a different frequency. The use of a separate frequency prevents the reply from being confused with possible returns from rain, birds or terrain. The aircraft range and bearing are determined from the time delay and antenna direction in the same way as for primary radar.

The main advantage of SSR is that it can obtain extra information from the aircraft. The availability of the on-board SSR equipment allows a rudimentary data link to be added to the radar function. The ground SSR station codes its transmission by emitting pairs of pulses of different spacing. At the same time as determining the aircraft's range and bearing the ground station can also ask the aircraft "Who are you?" or "What is your altitude?". The response of the airborne transponder is in the form of a multiple-pulse reply carrying as data either its identity number or its flight level. The ability of SSR to obtain this additional information about the aircraft is of immense value to the air traffic controller on the ground. As a result SSR is becoming the major sensor for ATC.

Other advantages of SSR include the ability to obtain long-range cover (over 200 nautical miles if required) at lower cost, as SSR is only a fraction of the cost of an equivalent primary radar. The latter fact is producing a trend to the use of SSR only at *en route* sites away from major airports.

The SSR ground equipment comprises a rotating antenna, a tower with antenna-turning equipment, a transmitter–receiver, which is usually called an interrogator, and a reply-signal processor known as a plot extractor or digitizer. The ground station transmits to the aircraft on a frequency of 1030 MHz and receives the aircraft's response on a frequency of 1090 MHz. Figure 1.1 shows a typical SSR antenna, in this case mounted on a colocated primary radar antenna with which it shares the tower and turning gear. The SSR interrogator and a plot extractor are normally installed in an equipment room, and examples are shown in Fig. 1.2. The plot extractor converts the reply data into a target report for each aircraft and sends these reports via land lines to ATC centers. The target report data are displayed to the air traffic controller in the form of a map-like presentation. The display shows the position of each aircraft, with either its SSR identity number or its associated

Fig. 1.1 SSR antenna (Cossor type CRS512) mounted on a primary radar antenna (TI type ASR8) at Geneva airport.

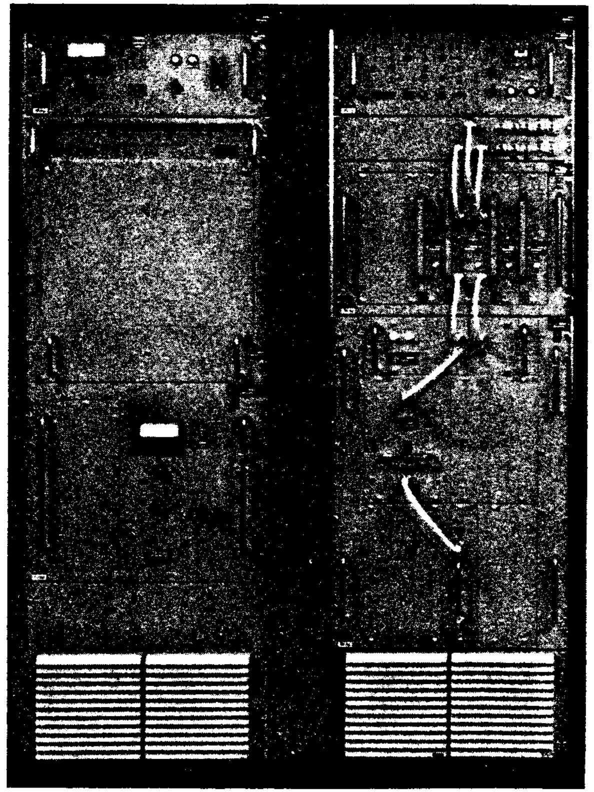


Fig. 1.2 Typical interrogator (right) and plot extractor (left) (Cossor types 9610 and 9620 respectively).

flight number, together with its height. An example of such an ATC display is shown in Fig. 1.3.

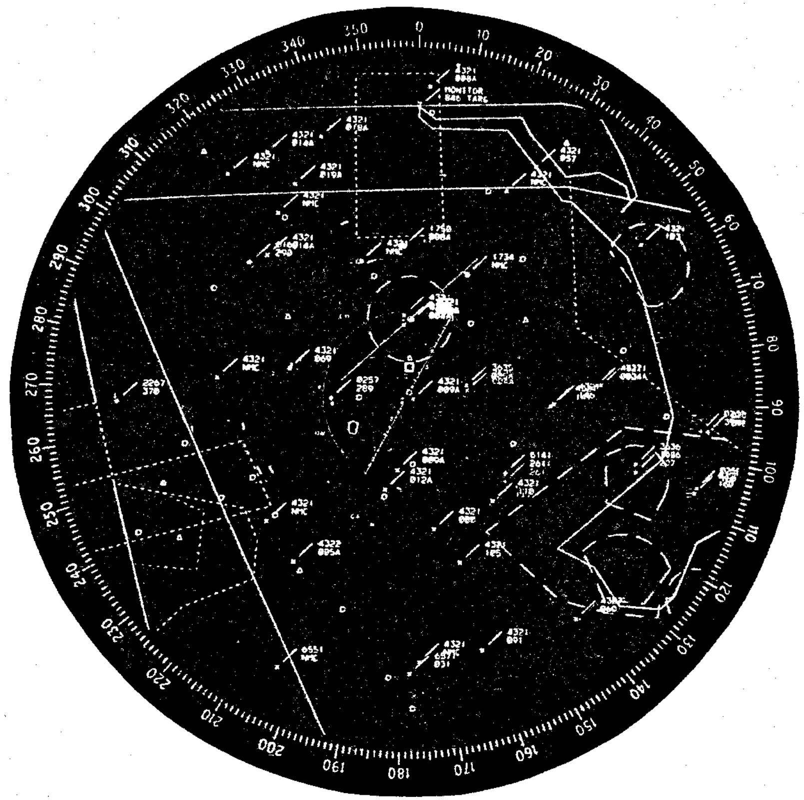


Fig. 1.3 Modern ATC raster scan display (Cossor type 9691).

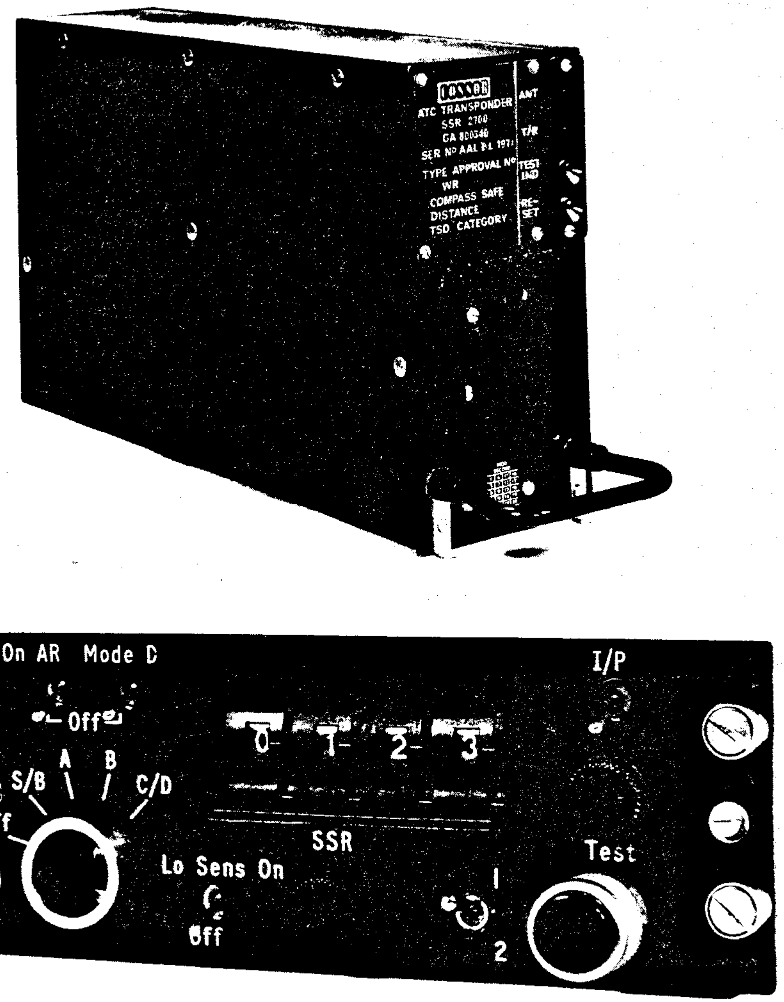
The aircraft equipment comprises an antenna, which is usually mounted on the under surface of the aircraft's fuselage, a transmitter–receiver known as a transponder which detects the signal transmitted from the ground station and transmits a reply back to it, a control unit by which the pilot can set the SSR identity number as allocated by ATC and an encoding barometer for indicating aircraft height. An example of a transponder and control unit is shown in Fig. 1.4.

A considerable advance in the performance of SSR has been obtained in recent years through the application of monopulse direction-finding techniques. Monopulse requires the use of a ground antenna with an additional beam and a second receiver channel in order to measure the direction of arrival of each aircraft reply pulse. This technique improves the bearing measurement accuracy and also increases the ability to decode the aircraft

replies accurately. In this book emphasis is placed on monopulse processing when describing ground receivers and plot extractors because of the importance of this development.

The airborne element—the transponder—is described in sufficient detail for the design and operation of the ground equipment to be understood.

SSR has attracted its share of jargon. A further complication is that the jargon differs in different parts of the world; for example, in the USA SSR is known as the Air Traffic Control Radar Beacon System (ATCRBS, pronoun-



(a)
(b)

Fig. 1.4 (a) Airborne transponder and (b) control unit (Cossor type SSR2700).