Electronic Intelligence: The Interception of Radar Signals

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Preface

This book is intended as a companion volume to *Electronic Intelligence: the Analysis of Radar Signals* (Artech House, 1982). The 1982 book describes the typical analysis procedures and parameters of interest from the standpoint of technical electronic intelligence. This book is concerned with intercepting radar signals in the first place. It is concerned with receivers, but more with how to use various receivers in interception applications than with the problems of designing receivers. Other major topics are concerned with probability of intercept problems, direction finding, and location as well as the receiver characteristics needed to deal with the radar environment.

The book was made possible by the help of many others, especially Grover Boose, Probal Sanyal, Michael Szymanski, and Robert Shields. Special thanks are due to Mary Chamberlain, who expertly prepared the manuscript.

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The Role of Radar Interception in Electronic Warfare

1.1 The Importance of Intercepting Radar Signals

Electronic Intelligence (ELINT) is based on information gleaned from the analysis of the signals transmitted by radar systems or other non-communications transmitters [1]. (Here we deal with radar transmissions for the most part.) Analysis of these signals first requires that they be discovered, characterized, and preserved through recordings, photographs, or analog-to-digital conversion. This interception process is the subject of this book.

The first large scale use of radar occurred in World War II. No sooner had radar been deployed (by both sides) than the effort to counter it spawned *electronic countermeasures* (ECM), which included the interception of the radar's signals. In the early 1940s, "... the basic countermeasures principle was simple. A ship or aircraft carried a rapidly tunable receiver which could scan the wavelength bands in which enemy radars might be operating. If one was detected, its strength and characteristics gave clues as to the dangers involved and what the next tactic should be. If the operator was flying over enemy territory, he could switch on a jammer, a powerful transmitter which would overload the radar receiver rendering it ineffective, or he could dump bales of aluminum 'chaff' from the airplane, or he could dump and jam."* [2]

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*A side effect of chaff drops was that thousands of cows died in Germany from eating the foil as they grazed. In [2, Ch. 12], John Kraus mentions this and other details, including some of the activities of Harvard's Radio Research Laboratory (RRL) headed by the late Professor Frederick E. Terman. Dr. Terman was head of the Electrical Engineering Department at Stanford University, but was persuaded to join the MIT radiation laboratory in February of 1942 to work on countermeasures. Dr. Terman organized RRL, which was transferred to Harvard University a few months later [3]. Dr. Everard M. Williams, who became head of

The following illustrates the fundamental role of ELINT in preventing disastrous technological surprise [4]:

> In early 1942, the RAF Coastal Command used L-band radar as an aid for locating German U-boats recharging batteries on the surface. The overall effectiveness of the RAF in this task was quite good until the U-boats began using L-band search receivers. These receivers allowed the submarine to hear transmitted radar signals at a range greater than that over which the radar echo could effectively be returned. The U-boat therefore had time to crashdive before actually being sighted by the searching aircraft. In turn, general effectiveness of the RAF anti-submarine effort decreased. The Allies, realizing what had happened, installed new S-band search radars aboard their aircraft during early 1943. As a result of the effectiveness of new equipment the intercept rate rose sharply. German submarines sitting on the surface, listening to L-band search receivers, became vulnerable targets for S-band radar directed aircraft.
>
> As the U-boat sinkings increased, the Germans tried frantically to determine the method of detection the Allies were using. Since reports from surviving submarines stated that no radiation had been heard in their L-band search receivers prior to the attack, it was thought that perhaps an infrared detection device of some type was being employed. Considerable effort was spent in an attempt to combat a non-existing infrared threat. U-boat activity was greatly reduced by the time the German High Command realized that a new high-frequency radar (S-band) was in use.
>
> This is an interesting example of weapon (L-band radar), a countermeasure (L-band search receiver), and an improvement (S-band radar) providing a clear margin of technical supremacy.
>
> There is another point to be considered. To be sure, the use of S-band radar employing magnetrons and extending the useable frequency by a factor of ten provided a definite advantage. However, had the Germans had information as to what was being used, the time lag until they were able to develop an effective S-band search receiver would have been greatly reduced. An added advantage was gained by the Allies because of the Germans' lack of information. It is obvious then that the enemy's

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the Department of Electrical Engineering at Carnegie-Mellon University, was a Harvard graduate, and was familiar with the RRL work and with electronic intelligence. Dr. Williams was instrumental in establishing such work at Syracuse Research Corporation (SRC), beginning in 1958, and attracted a number of Carnegie-Mellon graduates to SRC, including the author.

lack of information is the basic requirement of the so-called "secret weapon."

This point is mentioned here because illustrated in this example is one of the important roles of electronic reconnaissance. Had the Germans been conducting an extensive reconnaissance program at the time, it is probable that they would have intercepted S-band signals from magnetron oscillators in the development and testing stages during flights over England. The development of the magnetron was, of course, the crux of the problem of generating high power for 10 cm radar, and simple crystal receivers for reconnaissance purposes were indeed available, if the Germans had cared to use them in this application. Sensitivity is, of course, not necessary for intercepting high-power sources. Therefore, the special requirements of a reconnaissance system include being general enough to intercept the unexpected and provide intelligence inputs for an advanced ECCM program.

Of course, one can find more recent examples of the value of radar interception than World War II. In the Vietnam war, there were heavy losses of aircraft because of the large scale use of surface-to-air missiles. New tactics and the use of radar warning receivers designed with the aid of ELINT data helped reduce US aircraft losses and allowed the North Vietnamese air defense to be destroyed with much lower losses on the US side [5]. Similarly, the SA-6 missiles supplied by the Soviet Union to the Arab side in the October 1973 conflict with Israel proved a major factor in destroying low flying Israeli aircraft. New tactics and jammers eventually overcame the advantage achieved by the Arab combatants through technological surprise [5].

Radar uses have proliferated, particularly for military applications, but also for civilian air traffic control, harbor surveillance, weather monitoring, and so on. Prudence requires knowledge of the military capabilities of potential adversaries, and this means continued use of receivers to listen for radar transmissions and all of the other aspects of ELINT. For this reason, the accumulation of knowledge of radar signals has a peacetime role which grows in proportion to the development of modern weapons, many of which incorporate radar target detection and tracking.

Consider the following remarks of Soviet authors, Rear Admiral Peroumov and Captain First Rank-Engineer A. Partala, from their essay "A Look at Development of Means of Electronic Warfare" [6]:

> The military effectiveness of electronic countermeasures, even with emphasis on real life experimentation, must be regarded as confirmed only under the condition that basic characteristics of the electronic weapons of the opponent have been revealed with sufficient accuracy. But the possibility of dependably uncovering and obtaining this information is an extremely difficult task, according to American specialists; "... Experience in battle with application of means of 'electronic warfare' in Southeast Asia," writes the American press, gave evidence that even the most modern reconnaissance [intelligence] is not able to secure timely disclosure of all nomenclatured radio-electronic means, their tactical-technical characteristics, and special military employment.. And, therefore, from the beginning of military operations various surprises are probably inevitable. For prevention of large material losses and tactical operational failures, questions about preparation for 'electronic warfare' cannot really be left without attention.

In [6], these remarks are interpreted to mean: "If you don't know the exact details of the electronic threat and fail to prepare effective countermeasures in advance, you will be shot down or sunk."

In an era in which peace is maintained through deterrence, ELINT has an important role in maintaining defensive capabilities and preventing surprises — in this very real sense, knowledge is power, and where hostile radar is concerned, ELINT provides a great deal of knowledge. The path to that knowledge begins with antennas, receivers, and strategies for search, which are major topics of this book, and continues through the measurement of signal parameters and the recording and reporting of the interceptions for more detailed analysis.

1.2 The Impact of Low Probability of Intercept (LPI) Radar on ELINT

Since ELINT has such value, a natural direction for radar design would be to reduce the ability of a would-be listener to receive the radar signal. Such radar systems are said to have *low probability of intercept* (LPI) features. These may include low sidelobe antennas, infrequent scanning, reducing the radar power when tracking a closing target (as range is reduced, the radar power is also reduced), making use of waveform coding to provide transmitting duty cycles approaching one (to reduce peak power while maintaining the required average power) and using frequency hopping to force the interceptor to consider more of the spectrum in attempting to characterize the radar.

The problem of LPI radar design is fundamentally quite difficult. Consider a search radar. It is analogous to using a searchlight to spot an airplane at night. Energy is sent out, reflected by the target and that energy is used by the observer to spot the airplane. An LPI-type searchlight design still would require that the airplane be spotted, but the searchlight itself would not be seen by an observer. Because of the fundamental nature of this question, the potential problem of LPI radar to the whole concept of ELINT is considered in Ch. 2.

The problems inherent in LPI radar design are such that electronically intercepted signal information will continue to be available; however, new approaches for interception of LPI-type radars will be needed.

The design and use of intercept receivers is heavily influenced by the design of radar systems: today's intercept receivers reflect the radar signals in use today, tomorrow's intercept receivers will reflect tomorrow's radar signals. From the earliest days of radar until the present, radar designers have not been directly concerned with the activities of would-be interceptors. Their aim has been to produce well-designed radars capable of performing specified functions without regard to the activities of ELINT station operators. Of course, radar designers and operators have always been concerned with chaff and jamming (countermeasures), and have taken steps to reduce their effects through *electronic counter-countermeasures* (ECCM) [7].

If the LPI philosophy of radar design influences the signal emissions of tomorrow's radar systems, the designers of intercept receivers must respond (as best they can) to be successful, where possible, in spite of the LPI design approaches which may be adopted. (The LPI radar designer makes a strategic mistake if he assumes that intercept receiver designs will not change in response to his actions.) From the ELINT viewpoint, it is fortunate that the fundamental physical laws are favorable to the interceptor.

Another influence on radar design will be efforts to reduce the radar cross section of targets. This makes LPI design more difficult because the lower the target cross section, the more average power is required by the radar to detect the target. Radar systems are evolving in the direction of multiple functions and multiple modes. Future radars may well have both LPI and low target cross section modes among many others in their repertoire.

1.3 Parameter Measurements and ELINT Products

The ELINT process begins with reception of the signal. However, the final results are embodied in analytical reports, which consider that which is known about the radar from many sources of information, including photographs and technical publications when available. Furthermore, the radar signal received at a single ELINT station at any one time provides only a glimpse into the radar's full capabilities and applications. It may require thousands of these isolated encounters with the signal from a particular type of radar in order to assemble a reasonably accurate portrait of the radar set. From this portrait, one can then begin the process of devising equipment and strategies to reduce the radar's effectiveness should that be necessary.

For the most part, this book is concerned with the isolated, somewhat problematical reception of a radar signal by an ELINT receiver. The situation is not one of active hostility and there is little pressure to provide information about the radar signal quickly as might be the case in tactical situations. The radar interception considered here has strategic value in developing and maintaining a well prepared defensive force which has sound electronic warfare capabilities. Seen in this light, the ELINT station's task is to thoroughly measure the intercepted signals' parameters, make recordings of those of special interest, and to report the information.

Analysis of these isolated intercepts and preparation of technical reports describing each radar or weapon system is the final step in the process of developing intelligence products. These products are useful only insofar as the individual intercept reports are of high quality and can be trusted to accurately describe the signal's parameters and behavior.* It is for this reason that the measured parameter values must be qualified by giving accuracy estimates, reporting of the available signal-to-noise ratio (SNR), using substitution methods to define input-to-output receiver transfer characteristics, and providing numerous calibration signal recordings and accurate time and frequency references, backed up with a professional attitude towards providing complete written or verbal reports.

Automation of the interception and measurement process serves to emphasize the importance of the operator: The automatic measurement and reporting systems can relieve the operator of much routine work (some of which may become impossible as the density of the radar environment increases). Automation cannot eliminate the crucial role of operator judgement and intuition in controlling the process and in responding intelligently to new or

*The problem can be succinctly stated as "garbage in, garbage out."