Stand-by for faint signals from rare maintenance tests on a new SAM model.

AN ELINT VIGIL, UNMANNED

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One of the more difficult electronic intelligence collection problems is that of picking up the signals associated with a missile. It is particularly difficult for the smaller missiles, such as surface-to-air types which transmit signals of relatively low power, if they are besides not often fired. A case in point is the Soviet SA-2 missile Guideline, older versions of which are used extensively against U.S. aircraft in North Viet Nam. The newer models are so far deployed only in the Soviet Union and a few Bloc countries, notably East Germany.

For the development of electronic countermeasures against surface-to-air missile systems the prime intelligence targets are, first, the type of proximity fuze they use to detonate the warhead, and second, the tracking beacon which, emanating from a transponder on the missile responsive to a ground guidance transmitter, serves to determine the missile's position in flight. If the characteristics of the fuze are known the warhead can be detonated at harmless ranges. If the tracking beacon can be jammed, the ground radar's computer can be confused as to the missile's location and so made to misdirect it. The Elint problem, then, is to determine the frequencies and modulation characteristics of these signals in the normal peacetime environment when live missile firings are rare and usually inaccessible. This problem exists for the latest version of the Soviet SA-2 system.

The Problem Signals

This latest SA-2 system consists of the Fan Song E track-while-scan radar and the Guideline III missile. At the operational launch site there are a number of mobile vans housing the radar, the associated computer, and the missile guidance transmitter. There are 6 missile launchers. The radar is in the C-band microwave range, approximately 5000 MHz[1], and the guidance transmitter in the UHF L-band (700-800 MHz). A mobile test van checks each missile's proximity fuze, guidance system including beacon transponder, and autopilot about once every six months.

These semiannual tests of the missiles' electronics are made with special equipment connected up by cable to exercise the various functions. But a certain amount of energy nevertheless leaks from the missile antennas during the tests. Although its level is extremely low—on the order of thousandths of a watt—such small amounts of power can be detected at long ranges by the use of sufficiently sensitive receiving equipment. The probability of intercept in any particular case depends upon the estimated power leakage, how close the collection site is, and the sensitivity of the receiving system.

A further problem is that of keeping on the lookout for the signal and recognizing it when it comes. If the test schedule is not known, a 24-hour surveillance is required over an extended period of time. The signal may last only a few seconds for each missile tested. For recognition purposes a "model" of the expected signal must be constructed, comprising the limits of possible fuze and beacon signals estimated on the basis of known systems and the current state of the art. Fortunately the characteristics of a proximity fuze signal are normally quite distinct from those of other radar-like signals. As for the beacon signal, it will have the same pulse repetition frequency as the ground radar, though at a different radio frequency, so that it too should be recognizable.

Designing an Automatic Monitor

The first task is to set up specifications for the target signals. The possible types of proximity fuze signals are basically three: continuous wave, pulse, and FM. These could be narrowed on the basis of U.S. practice and some intelligence on older Soviet proximity fuzes, but it is dangerous to estimate Soviet electronic development from U.S. analogies, since Soviet design practice and philosophy often departs from ours even where ours is well understood and available to

[1] By international agreement:
1 Kilohertz = 1 kilocycle per second
1 Megahertz = 1000 KHz
1 Gigahertz (GHz) = 1000 MHz

Soviet designers. Therefore all possibilities, in the absence of positive intelligence, must be considered equally likely. The postulated ranges of frequency, modulation characteristics, and propagated power of the proximity fuze signals are outlined in Figure 1. The beacon signal is simply assumed to be a one-for-one pulse reply to the L-band guidance transmitter, which is in synchronism with the Fan Song E radar pulses.

Figure 1. SA-2 Guideline Proximity Fuze Model

Parameter	Expected Value	Uncertainty
a. Carrier Radio Frequency	3.6 to 3.8 GHz or 9 GHz	3.2 to 4 GHz and 7.5 to 10.5 GHz
b. RF Carrier Modulation		
(1) Pulse Modulation		
(a) Pulse Width	0.4 μsec	0.3 to 0.6 μsec
(b) Pulse RF	200 KHz	100 to 250 KHz
(c) Duty Factor	0.08	0.03 to 0.12
(d) Pulse RF Jitter	negligible	10% noise jitter
(2) FM-CW or CW		
(a) Voltage-Controlled Modulation Frequency	1 MHz	0.5 to 2.0 MHz
Frequency Deviation (peak to peak)	10 MHz	5 to 15 MHz
(b) External Ferrite Modulation Frequency	50 KHz	20 to 150 KHz
Frequency Deviation (peak to peak)	1 MHz	250 KHz to 2 MHz
(3) Modulation	sinusoidal	sinusoidal to noise
c. RF Power		
(1) Pulse Carrier	5 w peak	3 to 10 w peak
(2) CW Carrier	5 w average	3 to 10 w average
d. Antenna Gain	12 db	10 to 15 db
(1) Antenna Pattern	hollow cone	4° to 12° 3-db BW
(2) Antenna Front Sidelobes	−10 db	−6 to −20 db
(3) Antenna Back Lobes	−7 db	−5 to −10 db
(4) Main Beam Polarization	linear	linear to circular
(5) Number of Channels	2	2

Using these models for the target signals and further assuming some parameters for the collection system and its distance from the point of propagation, a calculation of the sensitivity required of the receiver system may be made. The following is a sample such calculation for the fuze signal at a single frequency to illustrate the method of determining whether the proposed system has sufficient sensitivity.

Assumptions:

Fuze power	34 dbm (2.5 watts)[2]
Fuze frequency	9000 MHz (9 GHz)
Fuze antenna gain in direction of Elint site	−7 db
Path loss for 12-mile distance to Elint site	136 db
Polarization coupling loss	3 db
Received signal power at Elint site (34 minus the three loss factors)	−112 dbm
4-foot parabolic Elint antenna gain @9000 MHz	38 db
Receiver thermal noise	−108 dbm
System noise figure (Ratio with ideal)	10 db
Signal-to-noise ratio required for receiver stop and recognition in a 4-MHz bandwidth	10 db
Over-all system sensitivity to stop and qualify a signal (Thermal noise increased by the two noise ratio figures and reduced by the antenna gain: −108 +10 +10 −38)	−126 dbm

Thus the signal-to-noise ratio at this frequency would be 126−112= 14 db, a usable figure for collection purposes.

Construction of the System

A block diagram of the monitoring system as completed is shown in Figure 2. All the signals are picked up by a single 4-foot parabolic reflector. The UHF guidance signal is taken off through its own feed (co-located with the microwave feed) and processed as indicated at the top of the diagram. The microwave signals in the range 2-11 GHz are fed to a triplexer which separates them into S (2-4 GHz), C (4-7 GHz), and X (7-11 GHz) bands. Traveling wave tube amplifiers amplify the separate bands and feed S–, C–, and X–band scanning receivers. The S–band receiver scans it continuously, covering it every two seconds, but for the sake of simplicity and economy scanner time is shared by the C– and X–band tuners under the direction of a control unit that allows two seconds of scanning in each band alternately.

The output from each of the microwave scanning receivers and the UHF receiver are fed to the analyzer, a digital computer which

[2] The decibel is a unit of comparison, a ratio of logarithms. It is related to absolute power by specifying db (here 34) above (or with a minus sign, below) 1 milliwatt (m).

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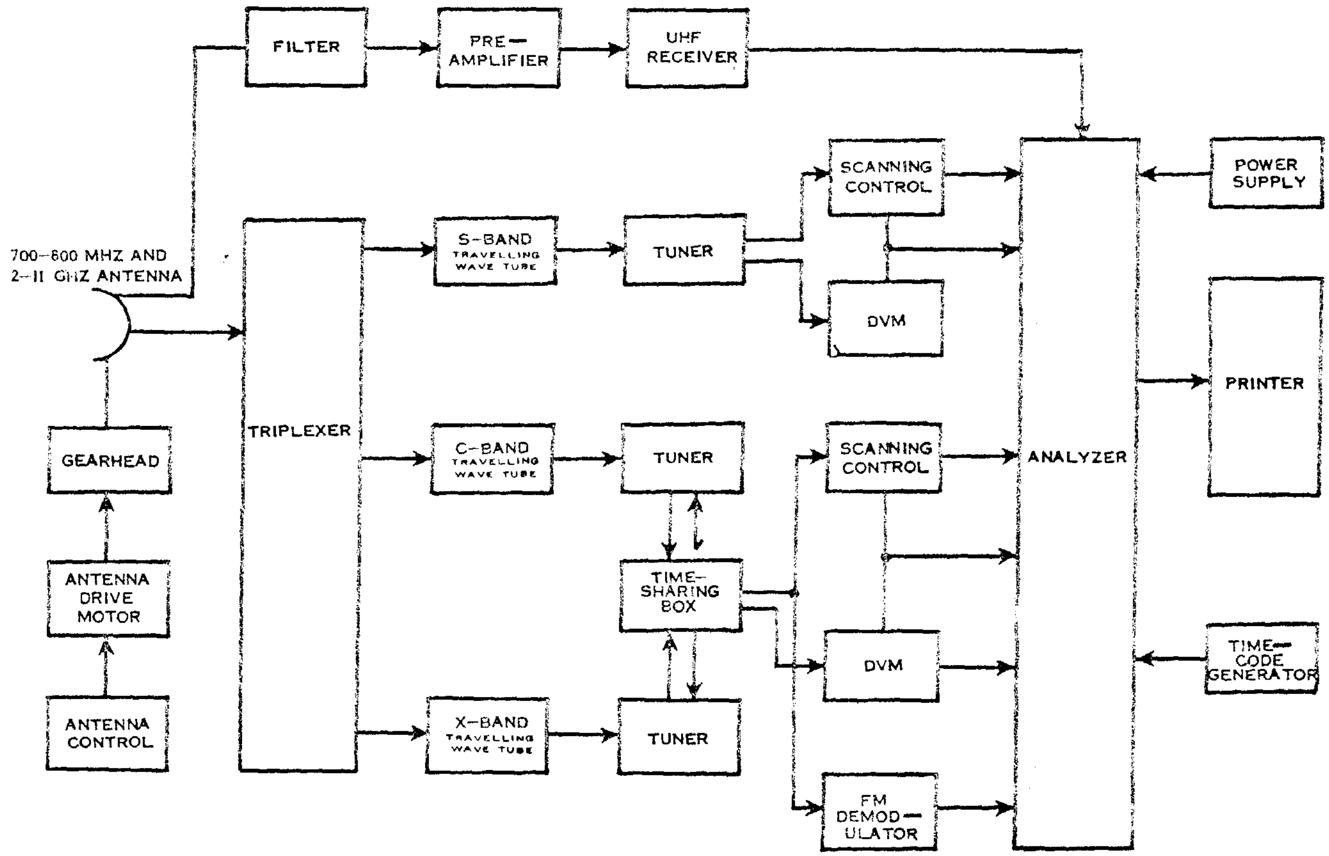

FIGURE 2. SIMPLIFIED BLOCK DIAGRAM OF COLLECTING SYSTEM

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measures and qualifies the signals and prints out data on their characteristics on a 12-column paper tape. The chief elements of data here are frequency band, amplitude, whether pulse, CW, or FM, and synchronization of radar and tracking beacon pulses. At the same time the digital voltmeters shown as DVM give a digital indication of frequency by reading the sweep voltage analog of the scanning receivers and feed it to the analyzer for print-out as a direct frequency reading on each intercept.

The FM demodulator shown processes the intermediate frequency signals from the C- and X-band tuners, producing two DC voltage outputs proportional to the FM deviation and modulating frequencies. These too are qualified and formatted by the analyzer and printed out by the digital printer.

The time code generator is a digital device which gives the time in hours, minutes, and seconds for recording with each qualified intercept.

The antenna gearbox, drive motor, and control unit are used to peak the received signal. They operate on the radar signal, since this is transmitted for somewhat longer periods than the fuze or beacon signal, giving time to orient the antenna precisely on target.

Properties and Prospects of Automation

The advantages of such an automated system are many. It can operate 24 hours a day without constant attendance by an operator. It can intercept signals that occur for only a few seconds at intervals of months which would probably be missed by an operator manually searching the spectrum. The digital computer analyzes the data concurrently, permitting decisions to be made without waiting for time-consuming manual analysis. The cost of storing the output on paper tape is much less than it would be on the magnetic tape used for raw data, particularly when surveillance extends over a long period of time.

There are also disadvantages, however, in such a system. Automatic systems are expensive. They are sufficiently complex at present to require skilled maintenance and frequent testing to assure proper performance. They are subject to false alarms: noise occasionally passes the signal qualification tests and causes a print-out of data, or some genuine radar signal may fit within the boundaries of the signal model, necessarily rather broad in searching for unknown targets. Only further analysis can eliminate this type of error.

The foregoing is only one of the possible applications for automatic Elint. Another would be statistical summary of the activity of one or more target radars to establish a pattern of operation or the doctrine which underlies it. By improving the precision with which the signal parameters are measured it may be possible to "fingerprint" each individual radar, something of great value to order-of-battle collectors in separating simultaneous signals of the same type.

By using the general-purpose digital computer with large amounts of storage, a program can be devised to recognize, sort, classify, and periodically report on all signal activity available to a collection system. There is already some activity in this area, but the sophistication possible with advanced programming techniques has only barely been explored. The potential here is the capability of doing almost everything a human operator would do. Striking advances in this direction are still around the corner. The classical Elint processes of collection and analysis will be greatly compressed in time, and the scope of things that are possible will be widened enormously.