AN/FST-2 Radar-Processing Equipment for SAGE

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Introduction

THE Coordinate Data-Transmitting Set AN/FST-2 is a real-time special-purpose digital-data processing machine which is operated at heavy radar sites as part of the SAGE air-defense system. The AN/FST-2 has a twofold mission in SAGE, conveniently identified as the Fine-Grain Data (FGD) function, and the Semiautomatic Height Finder (SAH/F) function.

The FGD functions are essentially 1) the acceptance of raw data from surveillance radars and Mark X (IFF) equipment, 2) the detection of targets, 3) the determination of the range and azimuth of the targets, 4) the labelling of Mark X targets, 5) the temporary storage of target information, and 6) the processing of the data for the digital-data telephone-service equipment which transmits it to a SAGE Direction Center (DC).

The SAH/F functions are 1) the acceptance of request messages from the direction center for height or other information about specific targets, 2) the processing of the message to provide bearing information to the height-finder radar antennas and visual information to the operators concerning specific targets, and 3) the preparation of the operator's decisions for transmittal to the direction center.

Physical Description

Because the SAGE system must be operational 24 hours a day every day, the AN/FST-2 is a duplex system, consisting of two identical simplex systems. Since no data are stored in AN/FST-2 for more than a few seconds, no necessity for cross-telling of data exists between halves of a duplex, such as is done in the AN/FSQ-7 at the direction center.

The AN/FST-2 is intended for fixed installation in a building at a heavy radar site. The electronic equipment and power supplies for a duplex are contained in 21 air-conditioned cabinets. The cabinets are arranged in three rows of 8, 5, and 8 cabinets each. For reliability, either of the two power supplies, which are located in four of the five center-row cabinets, can be switched to either of the simplex systems by means of switching circuitry located in the fifth center cabinet. A clear view of the data processing cabinets is shown in the photograph of a simplex equipment (see Fig. 1). Several cathode-ray-tube display consoles and operators' consoles also are part of the system. Approximately 43.5 kva of prime power is required to operate the duplex system, and an air-conditioning capacity of about 40 tons is needed for cooling.

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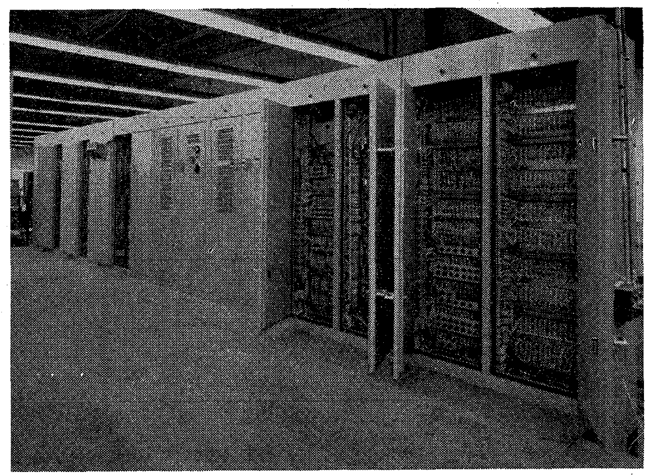

Fig. 1—Data processing cabinets for simplex equipment.

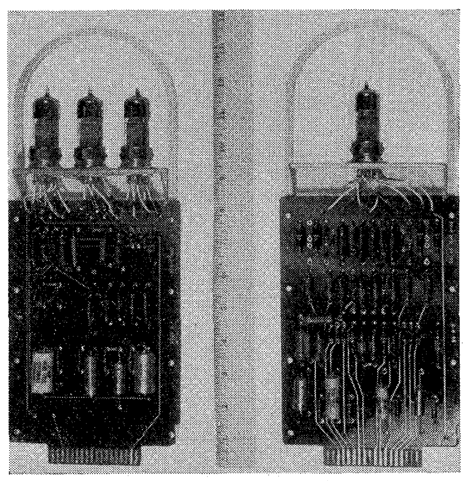

Fig. 2—AN/FST-2 plug-in package—component side.

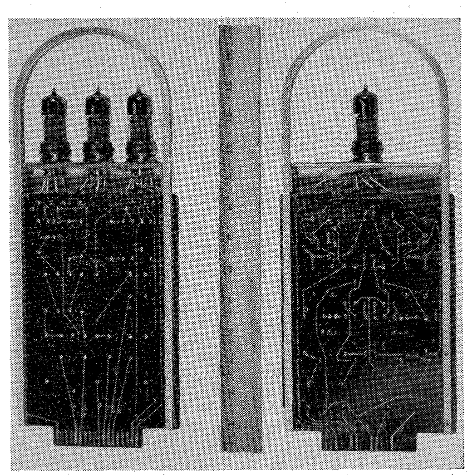

Fig. 3—AN/FST-2 plug-in package—wiring side.

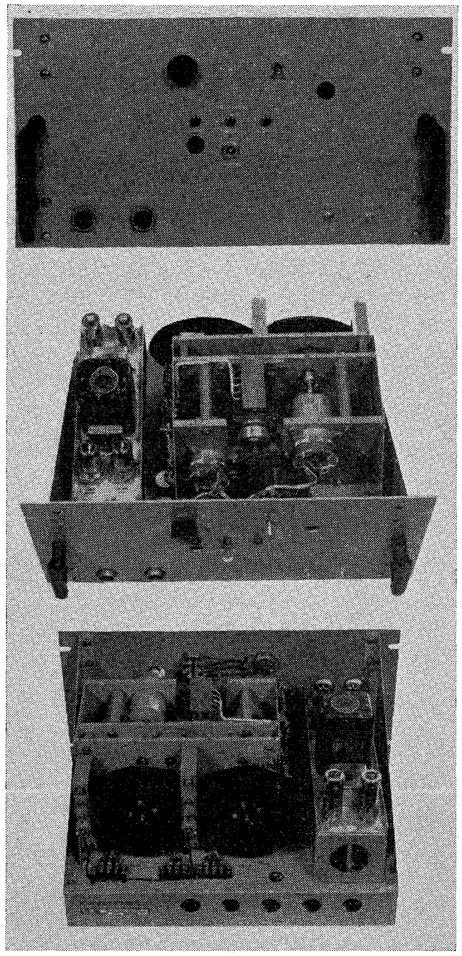

Fig. 4—AN/FST-2 chassis—azimuth mark generator.

The machine is designed with diode logic and vacuum-tube circuits. Approximately 6900 vacuum tubes and 24,000 diodes are used per duplex. The basic building module is a printed circuit plug-in package such as that shown in Figs. 2 and 3. Computer circuits, such as flip flops, buffer and inverter amplifiers, gates, pulse amplifiers, and diode matrix groups, are assembled as complete units on these packages. This approach facilitates machine assembly, simplifies trouble isolation, and permits a "replace and repair" maintenance procedure. Circuits with large components or special requirements in wiring or fabrication are assembled on standard chassis, such as that shown in Fig. 4. These chassis are mounted in the cabinets on sliding racks to permit easy access. Figs. 5 and 6 show two views of AN/FST-2 cabinets (note chassis arrangement in Fig. 6).

Functional Description

Fine Grain Data Section (FGD)

The input circuits of the FGD accept the output signals from the search radar and Mark X (IFF) equipment. These signals are processed so as to eliminate or minimize the effects of radar-receiver noise and residual ground, sea, and cloud clutter. Digital circuits within the FGD

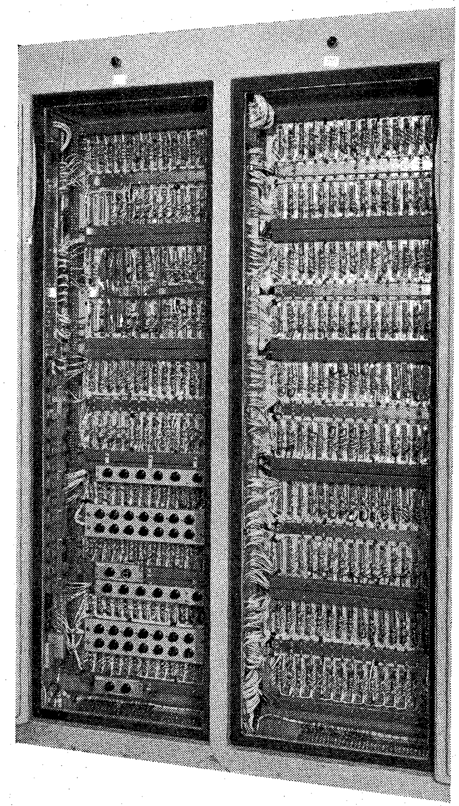

Fig. 5—AN/FST-2 cabinet—wiring side.

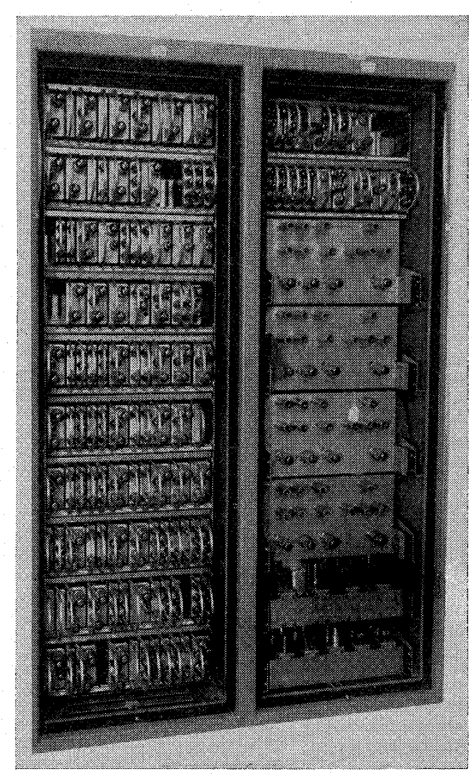

Fig. 6—AN/FST-2 cabinet—tube side.

provide a feedback signal to the input circuits to assist in the input filtering process. Radar signals which are accepted by the FGD input circuits are quantized in range, and initiate a standard pulse for further processing in the magnetic-drum portion of the machine.

The quantized video signals which pass the input section of the FGD are stored on a high-speed magnetic drum. The drum serves as a set of delay lines to store data associated with each range while the computer circuitry is processing other ranges. Each track on the drum utilizes a write head and a read head. The rotation speed of the drum is accurately synchronized with the PRF of the radar transmitter by a sensitive servosystem, so that the delay time on the drum between the write and read heads corresponds to the radar PRF. The target range stored on the drum is thus represented by the amount of time its appearance lags behind the radar trigger pulse. Digital range information is provided by a radar-synchronized precision range mark generator and an appropriate flip-flop counter.

The detection of targets is achieved by a technique which is conveniently referred to as "sliding window" detection. The quantized video returns from a number, N, of consecutive radar pulse transmissions are stored on recirculating "detector" tracks on the magnetic drum. As the returns from the latest "main bang" are written onto the drum, the signals from the oldest are eliminated. At any given instant, the drum read heads on the N detector tracks of the drum are examining the quantized video returns at a given range R_1. An accumulator and comparator circuit determines whether the number of stored video returns, n, $(0 \leq n \leq N)$ is equal to a preset threshold value, n_1. The number n_1 can be selected by the choice of a plug-in package to establish the statistical criterion for the leading edge of a target.

As long as the target remains within the beam of the transmitted radar pulse, it is expected that the number of video returns in the R_1 range block on the drum will remain greater than n_1. As the beam rotates, however, and the target gets into the trailing edge of the beam, the number of returns will decrease. A second comparator, switched into operation when the leading azimuthal edge of a target is observed, is used to determine when n becomes equal to n_2, the statistical criterion for the trailing edge. The number n_2 is normally lower than the number n_1. Thus the leading azimuthal edge of a target is determined when the number of video returns at range R_1 is n_1 out of a possible N, and the trailing edge is determined when the number of video returns decreases to n_2 out of a possible N.

Upon determination of the leading edge of a target, the FGD initiates the "beam-splitting" process which calculates the azimuth (bearing) of the target to great accuracy (see Fig. 7). The rotation of the search radar antenna is converted into azimuth pulses which are counted in the FGD azimuth counter. The azimuth counter stores, at any given instant, the azimuth of the antenna in digital form. A "north-marking pulse" synchronizes the counter once each revolution. It should be noted, however, that rotation is asynchronous with the radar trigger PRF, and also that the rotation velocity is not necessarily uniform.

The azimuth of the target is considered to be the average of the leading-edge azimuth and the trailing-edge azimuth. A set of channels on the magnetic drum is used to aid in this calculation. At the leading edge of the target a zero is written in these channels in the appropriate range block (determined by drum position). As long as the radar beam is on target, as determined by the detector, every azimuth change pulse is added into the number stored in these drum channels at half rate. This is achieved by providing a digital counter which counts the azimuth change pulses between radar main bangs and then adding one half of this number into the stored accumulation each time the R_1 range block passes under the drum read heads. If at the trailing edge of the target this number were subtracted from the number in the azimuth counter, the result would be the azimuthal center of the target. However, since the output telephone equipment may not be immediately available, the accumulated count remains on the drum and continues to accumulate azimuth change pulses, but at full rate. When the target is transferred to the output registers, this final accumulation is subtracted from the number in the azimuth counter at that time to give the true azimuth of the target (see Fig. 7).

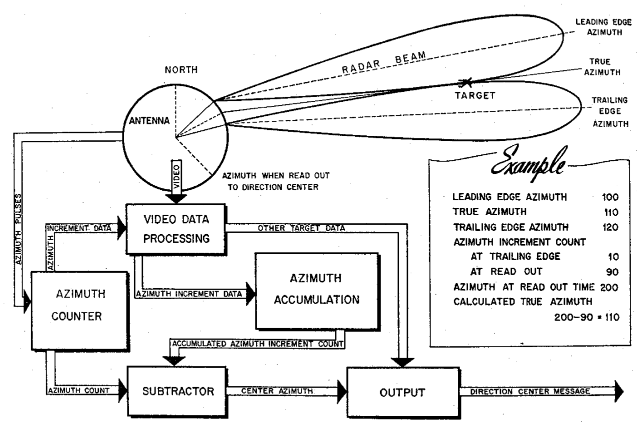

Fig. 7—AN/FST-2 beam splitting.

The target information is transmitted from the AN/FST-2 to the SAGE Direction Center. The target message, which is made up in the output section, includes range data, azimuth data, "run-length" (representing the number of azimuth change pulses between the leading and trailing edge of the target), "time-in-storage" (see below), the message label, and a sync pulse; azimuth information is taken from the drum, and digital range information from the range register. The data are transferred at high speed into a magnetic shift register whenever the telephone equipment is ready to transmit a new message. The data are then transferred (at a 1300-bit-per-second rate) from the shift register into the converter, which changes the pulse train into a sinusoidal signal. The present communication link to the SAGE Direction Center can transmit up to 50 target messages per second.

When the air traffic is heavy, it may be necessary for the AN/FST-2 to store target information for up to several seconds before the digital-data transmitter can accept it for transmission to the direction center. A "clock" circuit in the AN/FST-2 is used to measure the time between the trailing edge of the target and its transfer to the output section. This storage time is significant information, and is transmitted to the direction center. If the target coordinates are stored in the AN/FST-2 for longer than a predetermined time, the information is erased. The assumption is made that the target will be detected again on the next antenna scan, and the "old" information is useless at the direction center. Erasure of valid target data would occur only in an unusually heavy air-traffic situation.

The AN/FST-2 processes Mark X (IFF) targets in a separate channel of the equipment. Because the airborne transponder returns are usually stronger than the "skin" returns received by a search radar, the detection criterion for Mark X targets is different. A Mark X target is denoted by a special bit in the message-label portion of the AN/FST-2 output word.

Other messages which are transmitted to the direction center and marked by special codes in the message label are 1) the "test target," which is sent once per scan and provides a limited means for checking the AN/FST-2 operation, and 2) the SAH/F reply word, which is multiplexed into the same telephone equipment and takes precedence over other messages for transmission.

Semiautomatic Height Finder (SAH/F)

The SAH/F section of the AN/FST-2 identifies and automatically accepts digital request messages received via telephone lines from the direction center. These messages normally contain the x and y coordinates of a target for which the direction center needs up-to-date height data; the request includes the estimated or last known height of that target and such essentials as the address of the radar site and the identification number assigned to the target.

By means of digital-to-analog conversion and a servosystem which includes a resolver, the digital x-y coordinates of the target are simultaneously transformed into polar coordinates and converted to analog form. The angle becomes a shaft position which, in turn, is transmitted to the height-finder radar antenna. The range becomes a voltage which is utilized to generate a range-strobe pulse. Thus the SAH/F causes the height-finder antenna to be aimed at the target, and to generate a range pulse which marks the known range of the target on a Range-Height Indicator (RHI). The SAH/F also converts the digital data contained in its height register into a dc voltage.

Upon receipt of a request message by the SAH/F, and while the antenna is being oriented, the operator at the RHI associated with the height-finder radar is alerted by a visual signal on his console. Range and height lines appear on the CRT face of the RHI along with the video (see Fig. 8).

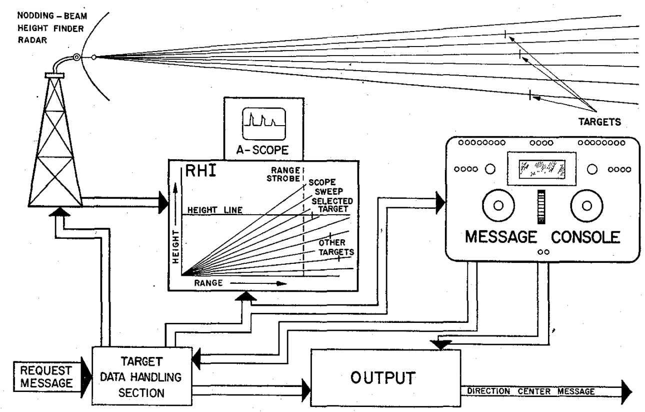

Fig. 8—Semiautomatic height-finder operation.

The elevation of the antenna and the video target returns are presented by the radar. The range-strobe from the AN/FST-2 brightens the scope sweep each time it passes the proper range point, and the height voltage from the SAH/F is interlaced with the sweeps to present a height line. The selected target will appear near the "intersection" of the horizontal height line and the vertical line made by the range-strobe points.

The operator's console contains a height wheel whose motion is converted into pulses which are counted into the height register in the SAH/F. The direction of rotation of the wheel determines whether the pulses are added or subtracted in the height register. The operator's assignment is to observe the relative positions of the target and the height line, and to rotate the height wheel until the height line is centered on the target. At that time he presses a release button which freezes the information in the height register until it is automatically transmitted back to the direction center.

Facility is provided in the SAH/F to permit the console operator to perform additional data-gathering functions. Special requests (for example, formation, number of aircraft) may be received from the direction center. These are communicated to the operator by means of visual displays on the console. An A Scope with a 5-mile range expansion provides the operator with a close-up view of the area around the selected target. Switches on the console permit the operator to select predetermined digitally coded messages for inclusion in the reply word to the direction center. Each simplex section of the AN/FST-2 is designed to operate with two height-finder radars and two console operators.