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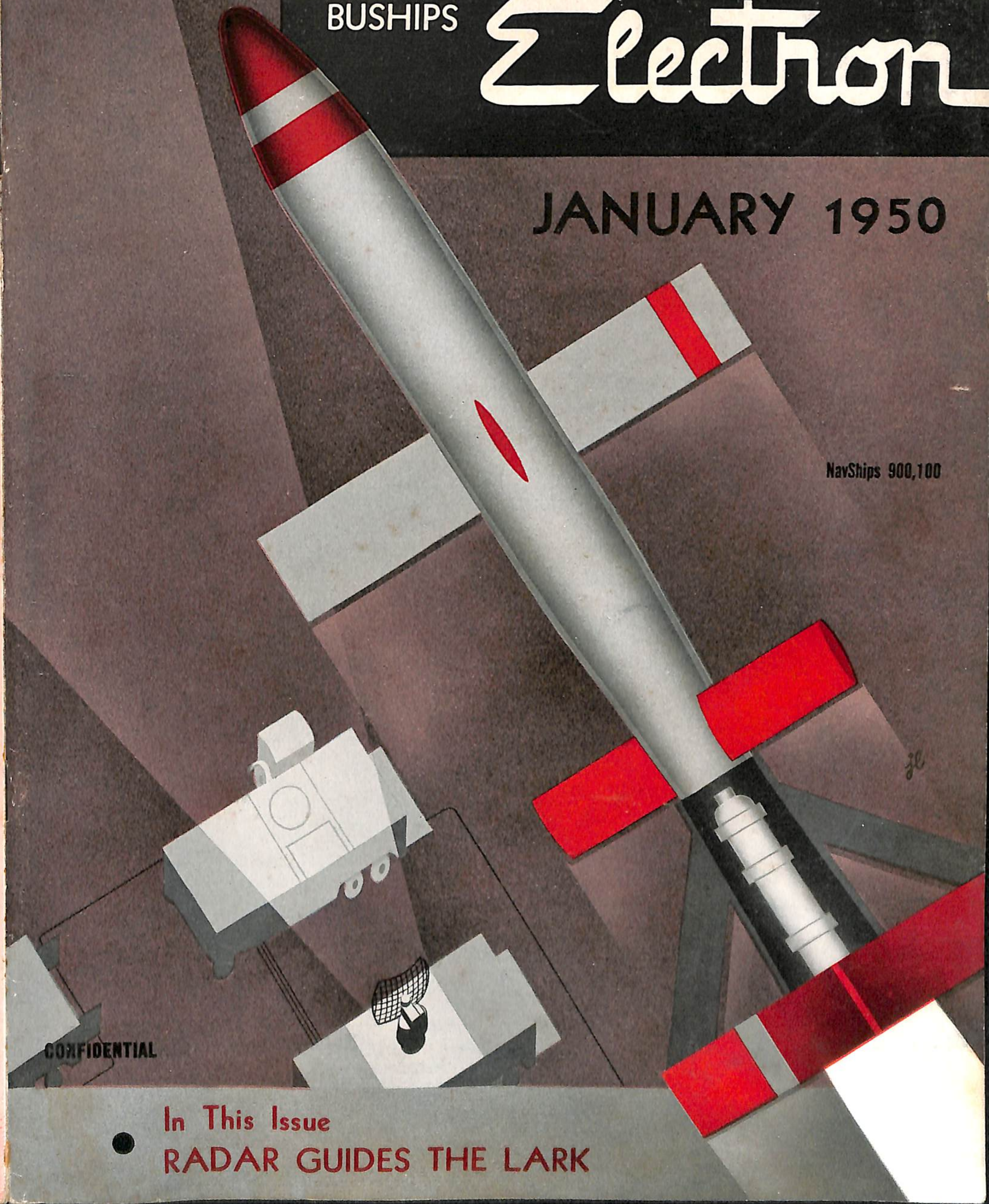

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THIS ISSUE

MISSILE GUIDANCE RADARS

AN/MPQ–5 and AN/SPQ–2

This is the first of two CONFIDENTIAL *articles prepared to acquaint electronics personnel with the progress being made in the field of guided missile control. This discussion is aimed at disseminating general information on the subject equipment. The second article will be a technical discussion of the individual components of the subject equipment. The information is from a report prepared by the Equipment Research Branch of the Naval Research Laboratory.*

Introduction

It has become increasingly evident that the guided missile will be one of the most important weapons of the future. The U.S. Navy has consequently undertaken an extensive research and development program in the guided missile field. One Navy project now in an advanced stage of development is the "Lark", a jet-propelled, subsonic-speed bird designed for radar-beam guidance. The Equipment Research Branch of the Naval Research Laboratory, headed by Mr. Peter Waterman, has been responsible for development of the mid-course guidance system for Lark. The system includes an automatic-target-tracking and missile-guiding surface radar. Two prototype versions of this radar have been under concurrent development at NRL. These are the ground Lark SP–1M (Figure 1) (designated AN/MPQ–5) and the shipborne Lark SP (designated AN/SPQ–2) radars.

The Lark SP–1M is now operating at the Naval Ordnance Test Station, Inyokern, California, while the Lark SP is in operation at the NRL Chesapeake Bay Annex. A contract has been let by the Bureau of Aeronautics for commercial construction of two duplicates of the Lark SP–1M. A second contract, sponsored by the Bureau of Ships, has been let for the duplication of the Lark SP for shipborne use on the *USS Norton Sound (AV–11)*. In addition the U.S. Air Force is currently considering the negotiation of a contract covering the construction of one unit of the Lark SP–1M system.

The guidance system for the Lark missile will consist of an automatic tracking radar, which transmits information in the radar beam suitable for interpretation by a missile flying in the beam so that the missile can fly under control to the target; a missile or missiles containing suitable control equipment to guide the missile along the tracking beam; and a homing and computing mechanism in the missile automatically functioning at a predetermined range from the target to transfer control of the missile flight from the surface radar to the homing radar. The homing radar guides the missile on a collision rather than a beam-riding course. To accomplish the objectives necessary in this project numerous investigations and tests were conducted. These principally included: Tactical considerations; Spectrum analyses of frequencies contained in the trajectories of interest; Servo bandwidth requirements; Propagation of electromagnetic waves through propellant gases; Reflection, attenuation and modulation of the control line;

Noise dispersion; Receiver design and construction; Missile flight stability; Airframe response characteristics; Auto-pilot and control response characteristics; and specifications for and studies related to alternate control systems. Procedures, techniques and instrumentation have been developed for testing and evaluation of the system.

Although specifically covering the Lark SP–1M, the material in this discussion applies in general also to the Lark SP radar. The Lark SP is the shipborne counterpart of the vehicle-mounted Lark SP–1M, built by the Naval Research Laboratory. The radars are functionally identical, the principal differences being in the inclusion of correction for own ship's course, a stable element, and a third (cross level) antenna axis in the Lark SP.

Initial Lark Guidance Specifications

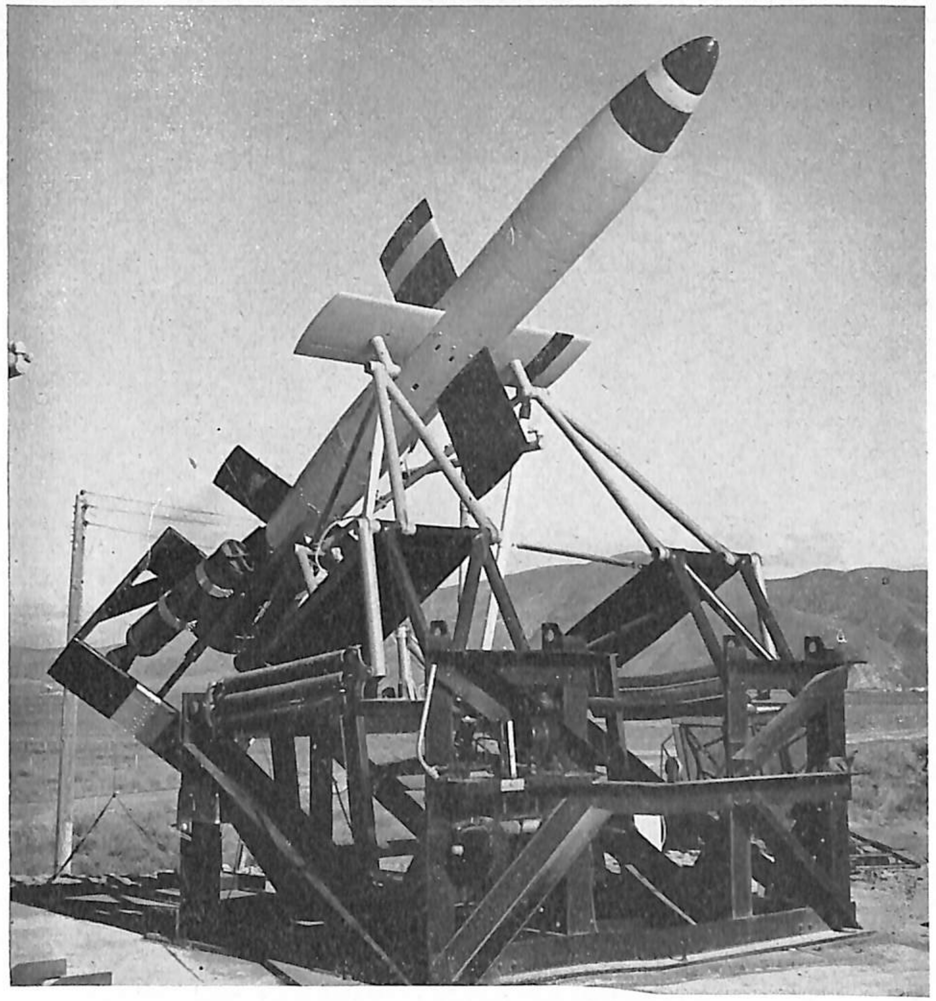
The Bureau of Aeronautics specifications required that control of the missile be effective over a range of 90,000 yards and to an altitude of at least 40,000 feet. The Lark missile is intended to attack an approaching enemy aircraft capable of making a speed of 300 knots and capable of executing 3g turns. Two versions of the missile are under development: The XSAM–N–2 Lark (KAQ–1), designed and manufactured by the Fairchild Pilotless Plane Division; and the XSAM–N–4 Lark (KAY–1), designed and manufactured by the Consolidated-Vultee Aircraft Co. The target is assumed to have a radar reflecting area approximately equivalent to that of a medium bomber.

The requirements indicated above place certain restrictions upon the performance of the surface radar to be used. Moreover the initial time limitation precluded the design and development of a new type radar and suggested the modification of an existing radar. The radar must be capable of detecting and automatically tracking a target to 45 nautical miles in range. It must be provided with stabilization against roll and pitch, and with facilities for transmitting coordinate information to the missile using the regular radar transmitter. A further restriction was that the normal functions of the radar should not be adversely affected by the new applications. A study of existing shipborne radars indicated that the SP Fighter Director and Search Radar would give the desired detection range; that the provisions for stabilization had been incorporated in the mount; that this radar was installed on Naval carrier vessels; and that it was practicable to modify the SP so as to provide the required automatic tracking and missile guidance functions without sacrifice of any of the original functions of the radar. Another factor favoring the selection of the SP was the existence of the SP–1M mobile counterpart which could be modified for field test application. For these reasons, although the required modifications were extensive, the SP and SP–1M radars were selected for use in the Lark program.

Design Considerations

The performance requirements for the ground radar, listed in the preceding paragraph, have been expanded in the actual design of the Lark SP–1M radar to permit broader application of the equipment than the problem specifications require. Because the development of missile guidance equipment by the Department of Defense is progressing rapidly, it was considered that the design of a guidance system for the Lark missile should anticipate some of the future requirements of an operational anti-aircraft missile guidance system. It was considered desirable, for example, that the SP and SP–1M equipments be modified so as to be adaptable for command as well as for beam-rider guidance. Such an extension in usefulness of the equipment would mainly require provision for automatic tracking of the missile as well as of the target. Missile tracking was further desirable so that data on missile range and position with respect to radar line of sight could be obtained and recorded. The need for measurement of target and missile positions and rates and of the time relation between data recorded at the Lark SP–1M and that recorded by other field test activities, and the need for a record of the mode of operation being applied at various times and of communication between the operators of all ground equipment, made it desirable to include a complete data taking and recording section. Optical tracking of the target or missile, with provision for control of antenna position from an optical tracking stand, was also considered desirable. A computer that would generate simulated target courses and rates, thus permitting displacement of the radar antenna as a function of theoretical target motion, was deemed useful in field test operations, as a substitute for real targets and to permit repetition of identical runs for comparison purposes. Performance of the tracking servos is predicted upon supersonic target and missile speeds. Minimum radar performance requirements for angle tracking were determined by expected tactical target maneuvers. Minimum requirements for range tracking were determined by expected tactical missile velocity capabilities, since the missile will normally be moving directly away from the tracking radar, and be capable of a greater speed than the target. Since Naval carrier vessels already are equipped with the SP radar, an important design consideration was to minimize the difficulty of modifying these equipments for automatic tracking and missile guidance with the components developed in connection with this redesign. This consideration made it desirable that the chassis of the two systems be as nearly interchangeable as possible and that cabling and other changes, to convert an SP radar into a Lark SP, be minimized.

Many of the physical components of the original SP and SP–1M equipments were unsuitable for the missile



The LARK in launching position.

guidance purposes. The original systems used a spark gap modulator for keying the transmitter. This modulator was unsuitable for pulse-time modulation for missile reference use and was replaced with a hydrogen thyratron modulator. The original SP–1M antenna mount was found to be statically unbalanced and was accordingly modified. The SP–1M equipment trailer, which was not sufficiently rigid, was further stabilized. The original nutator (scanner) was replaced with a redesigned nutator taken from an SCR–615B radar equipment. Antenna polarization was changed from horizontal to vertical to take advantage of the resulting reduced direct surface reflection (an important factor in using the radar for control) and to simplify the design of the missile antennas. The beam cross-over (two-way) was changed from its original 0.45 db down to approximately 3.0 db down with a two-degree squint angle. This cross-over point had been determined as optimum by theoretical analysis.

The Lark missile has an effective radar cross section of about 0.07 square meter area at the tail aspect. For command guidance, and for field test of beam-rider guidance, it was desirable to track the missile out to its maximum range. It was therefore necessary that the missile carry a beacon. The beacon is operated at a frequency slightly different from the S-band SP transmission frequency so that a missile beacon receiver is provided. In addition, a missile range unit and coordinate detector are required to allow simultaneous tracking of both the target echo and the missile beacon signals.

Modifications of the SP and SP–1M radars have been extensive. The operational usefulness of the radars as search and fighter director equipments has not been compromised by the inclusion in their signal transmission of the intelligence required for missile guidance. On the contrary, the original radars have been appreciably improved by the addition of automatic tracking circuits and the redesign and addition of improved radar and servo circuitry. The system, as now constituted, not only supplies missile intelligence to an airborne receiver, but also provides instrumentation for the recording of data useful to the analysis of missile flight performance and of guidance control. Table 1, which follows, summarizes the minimum design requirements for the Lark SP–1M radar. The requirements for the Lark SP are identical except for the inclusion of stabilization quantities. Certain assemblies of the

Lark SP were developed after evaluation of similar Lark SP–1M assemblies, and have therefore, improved performance and/or extended range.

TABLE 1

MINIMUM PERFORMANCE AND REQUIREMENTS FOR THE LARK SP–1M

Control of Equipment	Complete control from radar console.
Transmitter	
Peak Power	700 kw
Pulse Repetition Rate	Controllable 350–850 pps (nominal 576 pps)
Pulse Length	1 microsecond
Antenna	
Gain	35 db
Beam Width	3°
First Side Lobe (two way)	21 db down
Squint Angle	2°
Crossover (two way)	3 db down
Dish Diameter	8 feet
Search Scan	6 rpm
Nutator Scan	24 cps
Receiver (Target and Missile)	
Noise Factor	less than 15 db
Gain (I-F stages)	140 db
Bandwidth	2.2 Mc
AGC	7 stages
I-F Gating	Provided
AFC (Missile)	Provided
AFC (Target)	Provided
Range Units (Target and Missile)	
Maximum	Dials calibrated to 100,000 yards
Minimum	300 yards
Accuracy of Timing Circuit	10 yards (with calibration 5 yds.)
Automatic Range Following	Max. Error + 5 yds outgoing 750 yds/sec^2 (3000 knots steady state error + 5 yds.)
Manual Position Gear Ratio	250 yds/rev.
Automatic Position Slew	10,000 yds/sec.
Maximum Range Rate for Tracking	4500 knots
Range Synchro Transmission	1000 yds/rev. and 100,000 yds/rev. (alternate speeds require gear substitution)
Bandwidth	Selectable, 12.0 or 1.2 radians per sec.
Optical Tracking Stand (Target Acquisition and Optical Monitoring Station)	
Number of Axes	Two
Error for Bearing and Elevation Input	0.1° at 10°/sec. ($E = \frac{\ddot{\theta}}{100}$)
Field of View	3°
Position, Rate, and Slew Control of Antenna Mount	Bearing and elevation
Position Control	3° per handwheel revolution (no zero freq. stiffness)
PPI Unit	
Sweep Ranges	(4, 20, 50, 100, and 200 miles)
Sweep Markers	(1, 5, 10, 20, and 50 miles)
Handcrank Following Error	$\frac{\dot{\theta}}{24}$
Antenna Pedestal	
Mount Position Synchro Transmission	(Train—1 speed and 36 speed; Elevation—2 speed and 36 speed).
Slew Velocity—Elevation & Bearing	36°/sec.
Tracking Accuracy (Automatic in Elevation)	$E = \frac{\dot{\theta} \text{ in}}{100} + \frac{\ddot{\theta} \text{ in}}{10}$ (Approx) independent of elevation angle.
Tracking Accuracy (Automatic in Horizontal Plane)	$E = \frac{\dot{\theta} \text{ in}}{100} + \frac{\ddot{\theta} \text{ in}}{10} \times$ secant of elevation angle (Approx)
Radial rms Error (Small Targets)	1 mil.
Data Recording Unit	
Synchro Following Error	Static 0.2°
Missile and Target "R" Scope	Provided
Sound Recorder	Provided
Power Sources and Requirements	Either self-contained or external 110-volt, 3-phase, 60-cycle, 7kva.
Communications Equipment	VHF, UHF, phone intercom
Height Finding (Target)	Provision for
Ventilation, Heating and Cooling	
Blowers	Where required
Refrigerating Units	2 external 2-ton units
Heating Units	Provision for
Spare Parts	100% of essential parts
Operating Personnel	Maximum 5, minimum 2
Test Equipment	Supplied where necessary
Modes of Operation	Automatic (in 3 coordinates for target or missile) Manual (at console and at telescope) Computer (Target motion simulator)

General Description

The Lark SP–1M radar beam is conically scanned at 24 cycles per second and for beam rider guidance purposes may be pulse-time modulated at the scanning frequency. Guidance intelligence needed to maintain the missile on a course along the beam requires measurement at the missile of both the amplitude and the angle of displacement. Error amplitude (distance from beam axis) is determined by measurement of the amplitude modulation of the received radar signal. The amplitude modulation is a linear function, within limits, of displacement distance from the beam center. Pulse-repetition-frequency modulation at the scan frequency provides a reference signal for the measurement of angular displacement of the missile from a zero reference. (The Lark SP–1M radar system is shown in abbreviated block form in Figure 2, while the original, unmodified SP–1M radar is shown in Figure 3.)

The basic timing frequency for range is established by a 164-kc crystal oscillator in the target range unit. The range unit provides one-microsecond transmitter-keyer pulses to the modulator at an average frequency of 576 pps. The time between transmitter-keyer pulses is modulated at 24 cps by the antenna lobing reference generator. Trigger pulses for the A and R scope indicators, and a range gate (whose time delay from the transmitter-keyer pulse is variable and accurately calibrated in range on the range dial) also originate in the range unit. The transmitter-keyer pulse triggers the hydrogen thyratron modulator which in turn keys the magnetron at approximately 576 pps. The r-f energy is transmitted through waveguide, TR circuits, ATR circuits, and the antenna which is nutated at 24 cps. Energy reflected from the target impinges on the antenna, passes to the target receiver where it is amplified and demodulated

The LARK CONTROL SYSTEM set up for operation.

to give video pulses. The pulses are separated into two channels, gated and ungated video. The ungated video serves to present all objects within the antenna beamwidth on the PPI scope and the target A and R scopes. The gated video contains only those echo pulses which occur at the same time as the range gate. The gated video pulses are supplied to the range and coordinate detectors which produce error signals for driving the range, train, and elevation servos and for operating the cross-pointer meters.

Since the frequency of the beacon reply signal from the missile differs from the radar frequency by approximately 55 to 105 megacycles, the beacon signals are not received by the target receiver. Consequently, a separate beacon local oscillator and receiver channel is provided to convert the beacon signal to the 30-megacycle i.f. The signal passes through i-f and video channels which are identical to those in the target receiver. Ungated video is displayed on the missile A and R scopes while gated video is again supplied to range and coordinate detectors. The missile range and coordinate detectors are identical to those in the target channel. The train and elevation error signals from the coordinate detectors are used to operate cross-pointer meters or, depending on the mode of operation, may be used to control the antenna for automatic tracking of the missile. The range error signal operates the range servo system of the missile range unit. The output of either the missile or the target receiver may be used to control the antenna. The target and missile ranging systems are identical, except for the inclusion of a height finding potentiometer in the target range unit. Normally the target range unit supplies the 164-kc timing signal to the missile range unit, and the transmitter-keyer pulse output from the missile range unit is not used.

Major Units

The major units of the Lark SP–1M radar equipment are listed in Table 2 which follows. The NRL unit number (Column 2) in Table 2 indicates the first digits of the numerical series of reference symbols used for component designation in that unit. This numerical identification system is applied throughout to designate schematic diagrams, parts, etc. For example, R–3301 would be a resistor in the d-c Servo Amplifier Unit, Unit 3300.

TABLE 2

MAJOR UNITS

Type Designation: Army-Navy	Type Designation: NRL	Name of Unit	Location*
	100T	Target Receiver Unit	OT
	100M	Missile Receiver Unit	OT
	300M	Missile Range Unit	OT
	300T	Target Range Unit	OT
CG–20ACQ (Navy, Modified)	500	Main Power Unit	OT
	600	Synchronizer and Missile Coordinate Detector Unit	OT
	700	Auxiliary Power Unit	OT
	800	PPI Unit	OT
CDY–20ACP (Navy, Modified)	900	High Voltage Power Unit	OT
	1000T	Target Indicator Unit	OT
	1000M	Missile Indicator Unit	OT
	1200	Target and Manual Coordinate Detector Unit	OT
	1300	Target and Missile Range Detector and Servo Amplifier Unit	OT
	1400	Power Control Unit	OT
	1500	System Control Switching Unit	OT
	1600	Handcrank Servo Amplifier Unit and Telescope Servo Preamplifier Unit	OT
	1700	Target Local Oscillator Preamplifier Unit	ET
	1800	Telescope Final Amplifier Unit and Telescope Amplifier Power Unit	OT
	2000	Transmitter	ET
	2300	Hydrogen Thyratron Modulator Unit	ET

*ET—Equipment Trailer; OT—Operations Trailer

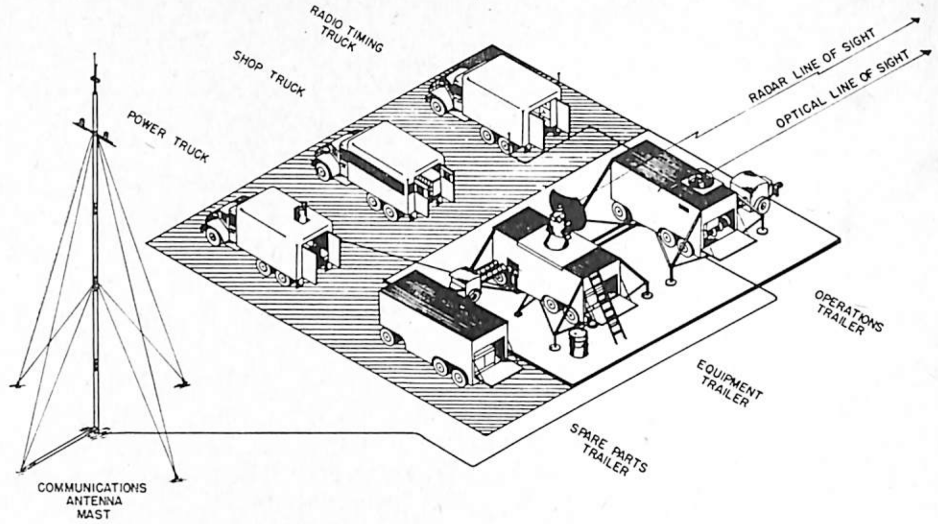


FIGURE 1 — Artists sketch showing typical arrangement of the Lark SP–1M Guided Missile Control System trucks, trailers, etc. for field operations.

Type Designation: Army-Navy	Type Designation: NRL	Name of Unit	Location*
	2400	D-C Motor Generator and Power Filter Unit	ET
	2500	Modulator Variac Control Unit	ET
	2600	Handcrank Isolation Relay Unit	OT
	2700	Reference Voltage Distribution Unit	OT
	2800	Missile Cross-Pointer Meter Unit	OT
	2900	D-C Voltage Regulator Unit	OT
	3000	Antenna Unit	ET
	3200	Antenna Control Unit	ET
	3300	D-C Servo Amplifier Unit	ET
	3400	D-C Servo Amplifier Power Unit	ET
	3500	D-C Servo Equalizer Unit	ET
	3600	Synchro Capacitor Unit	ET
	3800	Simulated Target Programmer	OT
	4200	Missile Oscillator Preamplifier Power Supply	ET
	4300	Missile Oscillator Preamplifier Unit	ET
	4400	Standing Wave Amplifier	ET
	4700	Echo Box	ET
	4900	Power Distribution Panel	ET
	5000	15-kw Gasoline Engine Alternator	ET
	5100	Cable Panel, Equipment Trailer	ET
	5150	Cable Panel, Operations Trailer	OT
	5300	Power Unit PE137	
CAJH–10306 (Navy, Modified)	5400	Dehumidifier Units	
CAHU–10305 (Navy, Modified)	5500	Spare Parts Trailer	
	6200	Keep-Alive Power Supply	ET
	6300	D-C Relay Box	ET
CAHU–10301 (Navy, Modified)	7100	Equipment Trailer	ET
CAHU–10302 (Navy, Modified)	7200	Operations Trailer	OT
	8100	Dial Box Unit	OT
	8200	Camera Control Unit	OT
	8400	Time Comparator Unit	OT
	8500	Remote Range Indicator Unit	OT
	8600	Commutator Unit	OT
	9100	Telescope Unit	OT
Model B–AVE		Sound Recorder	OT
Model TCS–12	4850	Radio Equipment (Communications) VHF	OT
Model SCR–624A (Army)	4850	Radio Equipment (Communications) VHF (4 channels)	OT
Model BD–72B (Army)	4850	Telephone Switchboard	OT
CRB–23367 (Navy)	4850	Selector Control Units (2)	OT

*ET—Equipment Trailer; OT—Operations Trailer

Equipment Trailer

The Lark SP–1M Equipment Trailer, Unit 7100, is a modified Navy Type CAHU–10301 Trailer. This trailer contains equipment primarily associated with the transmission of the radar signal and with the antenna servo drive system.

The trailer also includes a work bench, a tool cabinet, heating and cooling equipment and a type 224A Dumont Oscilloscope. The trailer is equipped with outrigger and supporting jacks for minimizing vibration during operation. Storage space for these devices is available in the trailer.

Motor-Generator Sets

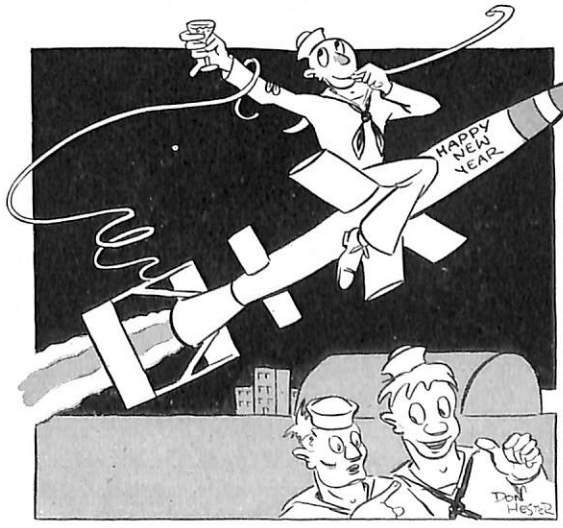
The 15-kw Gasoline Engine Alternator is a standby electrical power source, used in normal operation only to drive the cooling units. The generator has a 3-phase 60-cycle output of 15 kilowatts at 110 volts. The d-c motor-generator set has an output of +420 volts at 7.2 amperes current capacity. It is used as the d-c supply for many units of the radar system. The compound-wound motor-generator set is controlled from a relay box (Unit 6300) which contains the required relays for starting, running and stopping the unit. A power filter is provided to remove brush and other noise in the motor-generator output. This unit contains about 200 microfarads of capacitive filtering.

Transmitter Section

The Missile Oscillator Pre-Amplifier Power Supply consists of a four-tube voltage regulator which provides the following regulated d-c voltages: +300, —150 and —250 volts. The power supply derives its positive and negative d-c inputs from the d-c motor-generator and power filter (Unit 2400) and the modulator variac control (Unit 2500) respectively. The signal input to the Missile Oscillator Pre-Amplifier is a 30-Mc i-f signal from the converter in the antenna waveguide. A second input to this unit is an automatic frequency control voltage from the Missile Receiver. The pre-amplifier unit increases the i-f signal level for transmission via coaxial cable to the missile receiver located in the Operations Trailer. This unit contains the 2K–28 Klystron local oscillator for the missile channel converter. The Local Oscillator Pre-Amplifier amplifies at intermediate frequency an input signal derived from the crystal mixer in the waveguide. Three stages of i-f gain are applied. The output is fed via coaxial cable to the Target Receiver in the Operations Trailer. The 2K–28 Klystron local oscillator for the target channel converter and automatic frequency control circuits are also contained in this unit. The Standing Wave Amplifier is a vacuum tube detector and amplifier which is used for making standing wave ratio measurements. Its input is a signal picked up by a movable probe in the output waveguide. The Keep-Alive Power Supply is located in the top section of the transmitter cabinet and provides 900 volts d.c. to pre-ionize the missile and target TR tubes.

Pulse modulation of the transmitted signal is effected by the Hydrogen Thyratron Modulator. The unit receives a pulse-time modulated synchronizing pulse from the range unit. This pulse is shaped and used to trigger a pair of hydrogen thyratron tubes connected in series across the usual pulse forming delay line. The modulator supplies transmitter keyer pulses of about one microsecond duration and at about 8000 volts amplitude. These pulses are sent to the transmitter via a high voltage coaxial cable. Upon receipt of the pulses from the modulator, the transmitter unit power transformer amplifies the 8000 volts to about 22,000 volts and applies them to the magnetron.

The Lark SP and Lark SP–1M Radars are both equipped with an 8-foot antenna reflector dish. The Lark SP–1M dish is truncated at the top and bottom to facilitate trailer stowing. Additional sections to complete the circular periphery of the dish are added when the radar is in use. Antenna position intelligence is transmitted by 1-speed and 36-speed synchro generators for train and by 2-speed and 36-speed synchro generators for elevation. Additional 36-speed train and elevation synchros are provided for transmission of data to the Data Recording Unit. The antenna can be slewed in elevation and train at 36 degrees per second; the servo transmission bandwidth in train and elevation is 40 radians per second for handcrank input. The Antenna Unit is mounted on an elevator platform located in the Equipment Trailer. The unit consists of the mount proper and its drive motors, synchros, and tachometers; an 8-foot reflector, a nutating mechanism, an offset boresighting telescope, and two tracking cameras. The unit may be raised for use, or lowered for stowage and transport, by the elevator mechanism. The remaining units such as Antenna Control Unit, d-c Servo Amplifier Unit, d-c Servo Amplifier Power Unit, d-c Servo Equalizer Unit, and the Synchro Capacitor Unit act as adjuncts to the antenna control functions such as rotation, elevation and train.



Oh, that Thaddeus! Always out on a Lark somewhere.

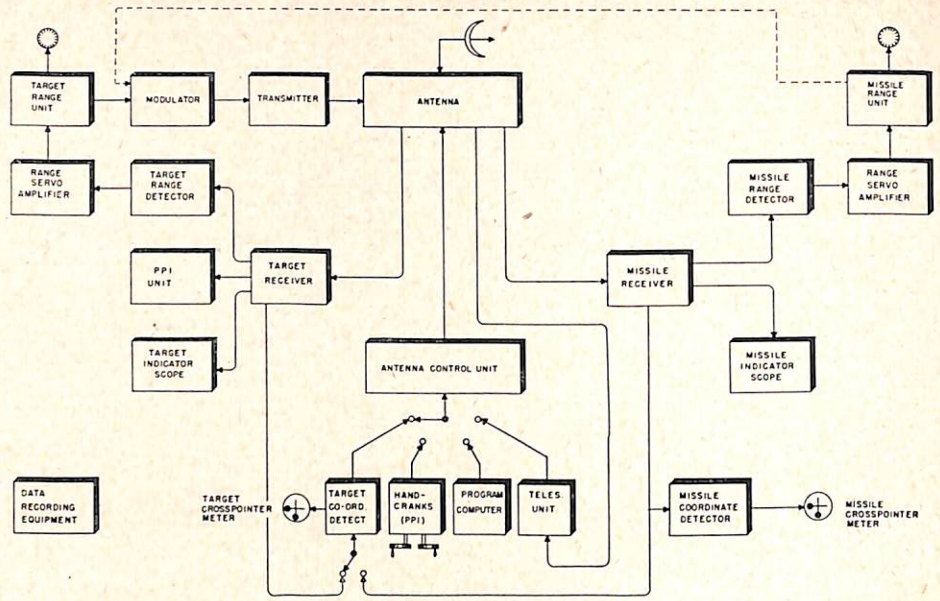


FIGURE 2—Brief functional block diagram of the Lark SP–1M Guided Missile Control System.

Operations Trailer

The Operations Trailer is a Navy Type CAHU–10302 Trailer, as modified by the Naval Research Laboratory. This trailer contains all equipment necessary for operating the Lark SP–1M Radar Equipment. This trailer has a body similar to that of the Equipment Trailer, and is designed as the control center. A telescope dome has been installed in the trailer roof to maintain a closed system for air conditioning. A heating and cooling system is also provided. The trailer has been stabilized to maintain collimation between the optical handstand and the antenna vertical axes, and to minimize vibration when the equipment is in operation.

Console Assembly

A normal complement of three operators at the console assembly controls the operation of the radar equipment. These are Target Range, Missile Range, and PPI operators. Elements of the console are described in the following paragraphs.

The System Control Switching Unit is located above the center bay of the console assembly. Through selector switches, this unit permits the operators to select any of the several modes of operation. The principal modes of tracking operation are as follows: Manual through handcranks on the operating console, or hand controls on the telescope unit; Automatic radar tracking of either missile or target; Computer, by introduction of simulated target or missile course through a computing device. The computer, which is used for test purposes, causes automatic displacement of the radar beam at expected tactical rates, as if the beam were actually tracking a target. Switches are provided for "local," "computer," or "telescope" operation and for automatic tracking in train or elevation or both; for starting and stopping cameras in the data recording unit; for causing a marker to be placed in the recording film; and for turning on and off the pulse-time modulation. Switch positions are indicated by lights located on the switching unit and in the data recording section.

The Target Receiver amplifies and detects the i-f signals from the target oscillator preamplifier and provides video signals at its output terminals. I-f amplification is performed in two channels, one of which is gated and the other ungated. The range gate is received from the target range unit, is shaped, and supplied to the portion of the i-f channel which performs the gating. Both gated and ungated video are available from cathode follower output stages for use in such units as the Target Indicator, the Remote Range Indicating Unit, the Target and Manual Coordinate Detector, and the Target Range Servo System.

The Power Control Unit contains the switches, relay controls, and timing circuits necessary for applying power in the proper sequence to various units of the radar system. It also contains two coaxial relays, controlled from the System Control Switching Unit, which transfer antenna control between target and missile channels. One of the coaxial relays permits control of the antenna by video from either the target or missile receiver. The video which is not being used to control the antenna is used to operate a cross-pointer meter. The second coaxial relay is used to insure the proper application of automatic gain control voltages to the receivers. If this relay were not provided the AGC voltage developed by one receiver would interact and vary the gain of the other receiver.

The Missile Receiver is identical in most respects to the Target Receiver and performs similar functions, except that it contains an automatic frequency control circuit for the local oscillator of the missile receiver channel.

The Target and Missile Indicator Units are identical. Each unit contains two five-inch cathode-ray tubes on which are displayed, respectively, an "A" sweep of 100,000 yards length and an "R" sweep consisting of the 2000-yard portion of the information displayed on the "A" sweep which contains the range gate and target (if any) being tracked. Each unit contains its own sweep generators. The sweep synchronizing signals are obtained from the target or missile range unit.

The PPI, in addition to the PPI tube, provides handcranks for manual control of the antenna position in train and in elevation. Each handcrank assembly includes a servo motor and tachometer generator. In automatic operation each servo motor drives its handcrank to keep it in position with the antenna mount. Graduated dials indicate the ordered mount position. The unit also contains a search position switch, operation of which provides continuous mount rotation in train for the presentation of radar search on the PPI tube. This unit also contains a sine potentiometer connected to the elevation gear train. The voltage output from this potentiometer may be used in conjunction with a slant-range voltage from the range unit to measure target height for elevation angles less than 30 degrees.

The Target and Missile Range Units are identical physically except for a height-finding potentiometer contained in the Target Range Unit. These units perform the function of timing for the complete system. The basic timing signal is derived by frequency division from a 164-kc crystal oscillator in one of the units. The frequency division is accomplished by gated blocking oscillators which are synchronized with the output of the crystal oscillator. Pulses are provided for timing the modulator and the indicator units and phase-shifted pulses are provided for the gating circuits. The mechanical section of the range unit contains the motors, gearing, and tachometers for the range servo system. A height-finding potentiometer is installed in the Target Range Unit. This potentiometer has a voltage output directly proportional to the target range. As described in the preceding paragraph, this voltage may be used to compute the target height.

The Target and Missile Range Detector and Servo Amplifier contains a range detector which receives gated video and the range gate from the receiver. These inputs are arranged so that they feed circuits providing a d-c output voltage which is proportional to the difference between the actual target range and the indicated range, and of a polarity which indicates whether the displacement direction is positive or negative. This voltage is applied to a balanced modulator producing a modulated 60-cycle carrier which is fed into a servo amplifier, amplified, and used to drive the range servo motors located in the mechanical section of the Target and Missile Range Unit. Two identical chassis are contained in the unit, one for missile and another for target tracking.

The Target and Manual Coordinate Detector provides the error signals used to drive the antenna and the manual control handcranks for either manual or automatic tracking operation. This unit consists of four coordinate detector circuits. One input signal is derived from the gated video from either one of the radar receivers as selected at the switching unit. The selected signal contains up-down and right-left position intelligence. The other input signal is derived from the two-phase 24-cycle reference generator at the antenna. From these inputs two d-c voltages are generated for use as train and elevation control signals. The manual coordinate detectors receive their input signals from the handcrank synchros and from the synchro bus and develop d-c control signals for use by the amplidyne drive system.

The Handcrank Servo Amplifier and Telescope Servo Amplifier receives low-level error signals from the synchro control transformers located at each handcrank and amplifies these for use as a power control signal by the handcrank servo motors. The Telescope Servo Preamplifier similarly receives low-level synchro error signals from the synchro control transformers located in the telescope stand. These signals are amplified and delivered to the Telescope Final Amplifier Unit.

The Reference Voltage Distribution Unit derives its 24-cycle input signal from the reference generator in the antenna mount by a 2-phase four-wire circuit. The distribution unit changes the impedance of this 2-phase 24-cycle input for distribution to other parts of the radar system. The unit also contains a component resolver which is used to shift the phase of the reference voltage applied to the range unit for pulse-time modulation. The phase of this voltage is continuously variable through 360 degrees.

The Missile Cross-Pointer Meter Unit is located at the top of the right bay of the operations console. Its function is to indicate the elevation and train error for either the missile or the target depending on the mode of operation. This unit derives its error signals from the Synchronizer and Missile Coordinate Detector Unit. The Synchronizer and Missile Coordinator Detector Unit contains four synchronizing circuits which act as a switching unit between fine and coarse control, and prevent false zeroing of the synchros of the antenna mount, the handcrank, and the telescope manual controls. For the elevation channel, coarse and fine speeds are two and thirty-six respectively, for the train channel they are one and thirty-six. When the displacement between antenna position and handcrank position and between antenna position and telescope position is in excess of 2.5 degrees, the synchronizer unit causes these elements to realign at coarse speed; for errors less than 2.5 degrees, alignment is accomplished at fine speed. The missile coordinate detector, contained in this unit, delivers error signals to the Missile Cross-Pointer Meter.

Optical Tracking Equipment

The Optical Tracking Equipment consists of the Telescope Unit, the Telescope Servo Preamplifier, the Telescope Final Amplifier and the Telescope Amplifier Power Unit. The Telescope Unit is a modified telescope unit from the Radar Mark 7 Mod 1. It contains the servo-drive and synchro units necessary to permit the telescope optics to follow the antenna position. Slew sight and slew knobs are provided for target acquisition, for continuous optical target tracking, and for rapid slewing of the antenna mount. Handwheels are provided for position control of the antenna mount. The unit may be used for manual-optical tracking and for bore-sighting the antenna dish. The Telescope Final Amplifier is located in the Operations Trailer opposite the console assembly. Its function is to amplify the signals received from the telescope preamplifier, and to deliver control power for the train and elevation servo motors located in the telescope stand. The telescope amplifier power unit provides the necessary plate voltage for the telescope final amplifier unit.

Data Recording Section

The recording equipment for the Lark SP–1M is arranged to record the following general data: Antenna present position information in train and elevation; Range information from both target and missile range units; Target course generator outputs; Target and missile coordinate position on cross-pointer meters; Operation of various control switches; Target and missile video signals; All telephone and radio voice communications; and time comparison of cine-theodolite shutter openings with local camera shutter openings. All data except voice communications are recorded on 16mm motion picture film. Voice communication is recorded by a disc-type sound recorder.

The Dial Box Unit presents the following data: 1- and 36-speed antenna train position, 2- and 36-speed antenna elevation position, 2 and 36-speed range data from the computer, 1000- and 100,000-yard-per-revolution range data from the target and missile range units, cross-pointer meter indication in two coordinates showing target and missile deviation from radar line of sight. Also photographed with dial indications are six indicator lights which show switch positions on the System Control Switching Unit as follows: automatic elevation, automatic train, pulse-time modulation, computer time motor, computer and telescope. These data are recorded by a single 16mm motion picture camera synchronized with the tracking cameras by the Camera Control Unit.

The operation of all cameras is controlled from the Camera Control Unit. All camera shutters are rotated by self-synchronous motors supplied with power from this unit. The unit triggers all synchronizing flag lights.

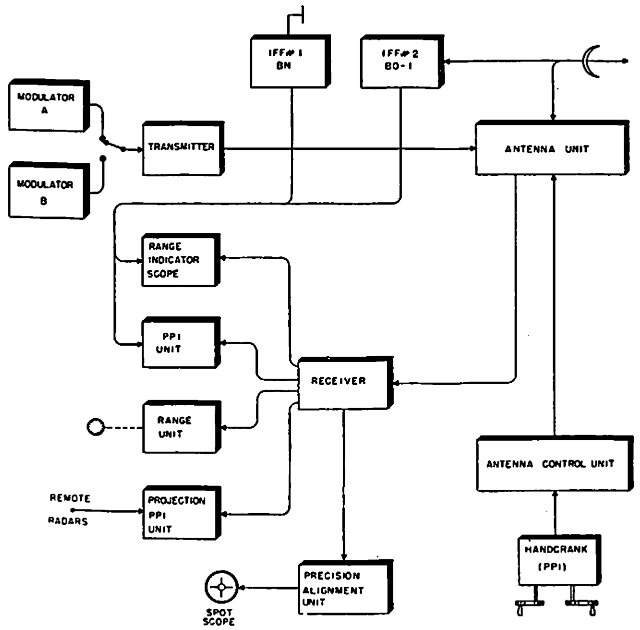


FIGURE 3—Functional block diagram of SP–1M Radar before modification to Lark SP–1M.

These lights are mounted in each camera so that, when the lights are energized at the beginning of a run, the film will be fogged for a period of five seconds. A synchronization point for all film is provided in this manner. Indicator lights in this unit will show continuity in flag light circuits by means of a bulb in series with each camera circuit. The unit includes a run-time clock which is mounted on the front panel, to indicate the length of camera runs. A synchronous motor contained in this unit drives through a gear box a 7G synchro generator which in turn supplies power to 5G synchro motors driving the camera shutters. Various shutter speeds may be selected by changing the gear box ratio. Camera operation may be started either locally or by a remote control switch located on the System Control Switching Unit.

Two input timing signals are received by the Time Comparator Unit. One of these originates at the test-range timing truck and indicates the periods during which the Askania cine-theodolite shutters are opened. (The theodolites and timing truck are not part of the Lark SP–1M equipment). The second input indicates the shutter time opening of all local cameras. Each input flashes a strobotron tube located behind slits which are on a common horizontal axis. The timing signals are photographed by a continuous strip camera and make it possible to compare the phase between the theodolite timing and the local shutter opening.

Range sweeps from both the missile and the target range units are presented on a single scope tube in the Remote Range Indicator to provide a continuous record of signal variation, interfering targets, and range tracking performance. On the right side of each sweep an indicator light will show whether manual or automatic tracking of the signal appearing in the gate is in effect. At the left edge of each sweep is a second indicator light which indicates the video channel, target or missile, which is being used for automatic operation of the antenna.

Communications Section

The Communications Section consists of a telephone switchboard, a medium-high-frequency radio equipment (TCS–12), a very-high-frequency radio equipment (SCR–624A), and associated selector control units. The telephone switchboard will connect all operators to provide individual or conference-type communication. Radio equipment TCS–12 consists of a radio receiver and transmitter, operating in the 1.5- to 12-Mc band. Radio equipment SCR–624A consists of a four-channel v-h-f transmitter and receiver, operating in the 100- to 156-Mc band. Both are used for communication with aircraft and control centers. All speech received or transmitted via radio equipment is introduced into the telephone switchboard and can be monitored by all operators and recorded on a sound recording instrument. This equipment is located so as to be under control of the operators at the console assembly.

Miscellaneous

A considerable number of additional units are required for the complete Lark SP–1M system. These include: Spare Parts Trailer; Dehumidifier Units; Power Unit PE137; Machine Shop and Timing Trucks; Test Equipment; Range Unit Bridge Adjuster; and a Nutator Phasing Unit.

The Spare Parts Trailer is similar to the Operations and Equipment Trailers. It contains a complete set of spare parts for maintenance of the entire system. The parts are stowed in metal boxes racked in shelves along the sides of the trailer.

The Dehumidifier Units are transportable air-conditioning systems which connect with flexible ducts to the Operations and Equipment Trailers. When in use, they reduce operating temperature and humidity, thus minimizing equipment failures and personnel fatigue. Each unit consists of a York refrigerating unit of two-ton capacity driven by a five-horsepower, 220-volt, 60-cycle, three-phase motor. Transformers permit operation on a 110-volt, 60-cycle three-phase supply.

The power unit is a PE137-A type unit mounted on a type CCKW353 (Army) truck. This unit supplies all current required for the operation of the Lark SP–1M system. It is a portable, self-contained, gasoline electric power plant consisting of a four-cylinder gasoline engine connected to an alternating current generator. The generator is a 3-phase, 4-wire generator of the revolving field type, rated at 120/208 volts, 60 cycles, 900 rpm, 31.3 kva at 80% power factor. A transformer bank converts the output of the generator to a 3-wire 3-phase supply.

The test equipment supplied with the Lark SP–1M is listed in Table 3. All of the equipment except the Range Unit Bridge Adjuster and the Nutator Phasing Unit is available commercially. The Range Unit Bridge Adjuster is a variable impedance device designed for coupling an oscilloscope to various terminals in the range units without loading the circuit whose waveform is being monitored. It consists of cathode followers and a probe device. The Nutator Phasing Unit receives a 24-cycle signal from the reference generator. This signal is differentiated, amplified, and then used to key a General Radio Company "Strobolux" which in turn is used to illuminate the end of the nutating antenna. By means of this equipment it is possible to adjust the phase of the 24-cycle modulation voltage relative to nutator position.

TABLE 3
TEST EQUIPMENT

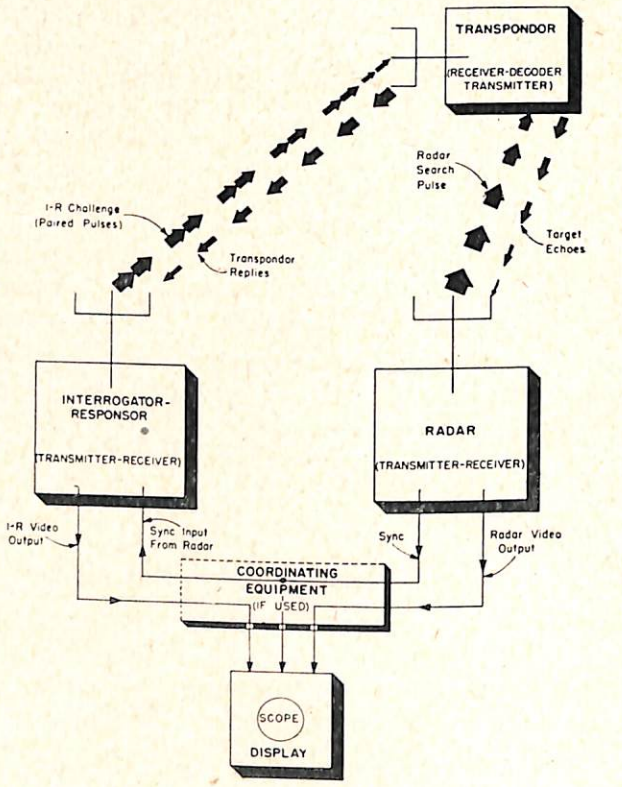
Type Designation	Name of Unit	Instruction Book	Supplier
TS–155B/UP	UHF Signal Generator Equipment	TM 11–2657B	Boonton Radio Corp.
TS–34/AP	Oscilloscope	AN 08–35TS34–3	Western Elec. Company
CPF60057	Portable Vacuum Tube Tester	....	Precision Apparatus Co.
CE–36 (Army)	Test Equipment (for SCR–624)	AN 08–401E36–2	Bendix Radio Corp.
....	Junior Voltohmyst	....	Radio Corp. of America
CTO 600–77 (Navy)	Volt-ohm-milliameter	NavAer 08–508–6 —May 1944	Triplett Elec. Inst. Co.
....	Range Unit Bridge Adjuster	....	NRL
F9G	Frequency Standard Unit		NRL
....	Nutator Phasing Unit (Strobolux and Keyer)	....	NRL
Mk 2 Mod 3	Synchro Test Unit	....	Ford Inst. Co.
224A (Dumont)	Oscilloscope	....	Dumont

Mark V

IFF/UNB SYSTEM

This is the first in a series of CONFIDENTIAL *descriptive and technical discussions on the Mark V IFF/UNB System. The information presented in this and subsequent articles on this subject is based on material contained in reports prepared by Commander Operational Development Force, U.S. Atlantic Fleet, and the Combined Research Group of the Naval Research Laboratory, Bellevue, D. C.*

In all the great military organizations and throughout the course of all major wars of history, the subject of security and its application to the immediate and planned strategic and tactical maneuvers, has been of paramount importance. In the early days of our modern civilization and on down through the pages of history, to the present time, each military organization has striven to prevent infiltration and surprise attack by utilizing some method of identifying friend from foe. In the pursuit of this phase of military superiority, great advances have been made—from the word of mouth challenge of the foot soldiers past and present to the latest in electronic devices which automatically challenge an approaching aircraft or vessel or other instrument of war bent on our destruction. With the advent of the electronic age, particularly in the field of radar and other late developments, it became imperative that an organization know the identity of any object located in the immediate vicinity, be that object in the air, on the ground, or on the sea. However, it was not enough to be aware of the intruder but also that the knowledge be obtained in sufficient time to permit the commander of the alerted organization to arrange his defenses to best repulse the imminent attack. Still another factor required consideration—the physical well-being of the personnel and conservation of energy and machine. In this regard, it was deemed mandatory that the identification devices not only detect the intruder but immediately identify same as friendly or foe. Obviously, when an intruder was identified as an enemy, elaborate preparations were required to prepare for battle. If the intruder was identified as friendly, these elaborate preparations were unnecessary and both men and machines could be spared for rest and repair.



IFF MARK 5 DISTINCTIVE CHARACTERISTICS

1. *Fixed-frequency operation with transmission and reception on different channels.*
2. *Paired-pulse interrogations must be decoded before the transpondor will reply. It will not reply to single pulses or to incorrectly spaced paired pulses.*
3. *Reply pulses appear continuously on the display and may be slow coded with Morse letters to provide tactical information as well as greater security.*

FIGURE 1—Operational block diagram of the Mark V IFF System showing the basic units and signal paths.

In the early days of the late World War II, all of the major nations of the world were faced with the realization that some method was required to detect and identify as friend or foe approaching aircraft, ships, and other vehicles of war. The urgent nature of this need resulted in several crash programs to develop a system of identification which would answer the purpose. These systems were called IFF (Identification Friend or Foe) and as such they will be used throughout this and subsequent discussions on this subject. Most of us are familiar, to a certain extent, with all the IFF systems used, up to and including the Mark III which was in operation at the conclusion of the conflict. However, in the latter part of 1943 a combined research organization consisting of top-flight electronics engineers from the United States, Great Britain and Canada was assembled at the Naval Research Laboratory in Bellevue, D.C. to study and develop an IFF system vastly improved over the then-in-use Mark III IFF system. The result of research and study by this group was the development of the Mark V IFF/UNB (United Nations Beaconry) System, about which this series of articles is written. However development was not completed in time to utilize its services in the war.

As a matter of background it is believed desirable to point out the faults and shortcomings of the Mark III IFF System, which the research group was attempting to eliminate in the development of the new IFF system. In this connection there were three major reasons for embarking on a new IFF system: 1—Improved Security; 2—Improved Performance; and 3—Improved coordination with beacons. The relative importance of these factors changed according to the current estimate of the length of the war, the operational circumstances and the activity of the enemy countermeasures. The emphasis also depended on which branch of the services was stating its requirements. Boardly speaking, when the Mark V IIF/UNB project was starting, the emphasis was on improved security of IFF and better coordination with beacons. As the war progressed the emphasis shifted to improved performance, and less interest was expressed in security or in beacons.

Any identification system is liable to use or to countermeasures by the enemy. If the system comprises interrogators and transponders then the enemy may employ an interrogator to extend his range of radar detection on our units, or he may use the identification system in order to separate friends from foes in the normal way required in all air-sea defense operations. By installing transponders the enemy may seek to deceive our units. Mark III IFF employed a common transmitting and receiving frequency. This frequency was swept continuously over a frequency band which was fixed by the design of the transponder and which could be discovered easily by the inspection of captured or crashed equipment. The interrogation of Mark III IFF did not therefore present great difficulty to the enemy especially as

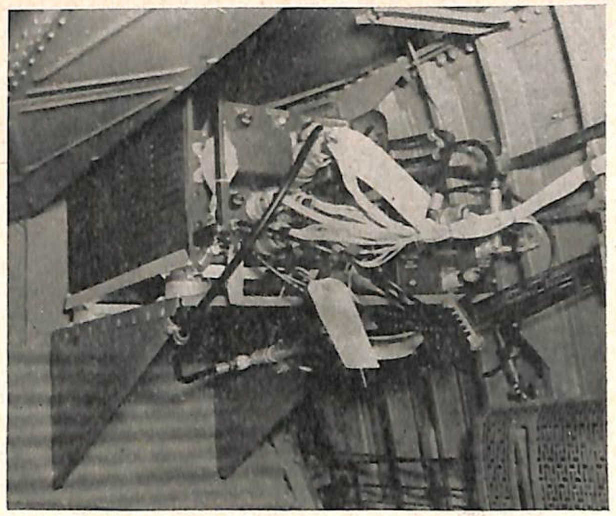


FIGURE 2 — Airborne Interrogator-Responsor AN/-APX–7 Transmitter-Receiver and Switch Units mounted in Naval aircraft.

there were several radar equipments, both enemy and friendly, operating close to the IFF frequency band.

In many respects, other than security, the performance of the Mark III IFF was considered inadequate, and it was essential that Mark V should show a substantial improvement in comparison with Mark III IFF in at least three respects insofar as performance was concerned: 1—Range and azimuth discrimination. 2—Traffic capacity. 3—Maximum range capabilities. The Mark III IFF system was designed at a time when "floodlight" radars were the most important search radars, and at a time when aircraft flew in limited numbers rather than in the hundreds and thousands which appeared in the latter days of the war. The advent of high frequency narrow beam radars with short pulse widths made it highly desirable to improve the range and azimuth discrimination of the IFF system. The traffic capacity of an IFF system can only be defined in relation to the associated radar system and the operations involved. Some items which affect traffic capacity are transpondor pulse width, interrogator-responsor beam width, display system, and the time for which an individual transpondor must be observed in order to establish an identification. Experience in the bomber raids against Europe, and later in the defense of ships against "saturation" attacks, showed that the traffic capacity of most radar systems was inadequate and that reporting systems of the M.E.W. type, using multiple PPI displays or large scale projection displays were necessary. The Mark III IFF was fundamentally unsuitable for application to these systems and in consequence pressure was applied to the Mark V IFF/UNB project to evolve a system suited to the new radars and repeaters and with a traffic capacity superior to that of the Mark III IFF. The maximum range of the Mark III

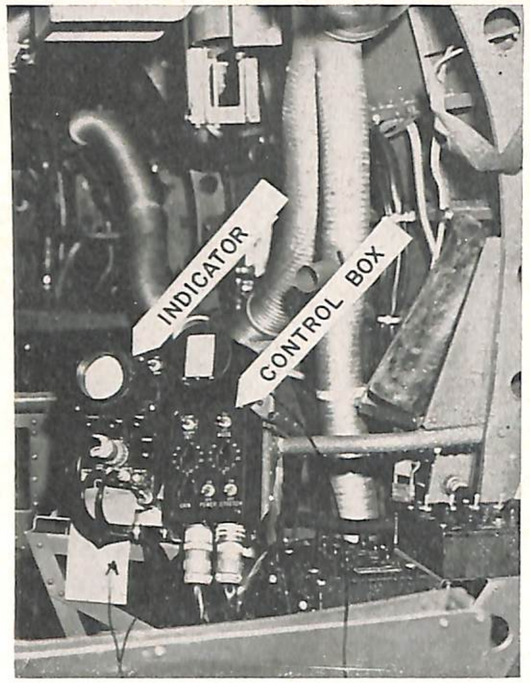


FIGURE 3 — Airborne Interrogator-Responsor AN/-APX-7 Indicator Unit and Control Box located in Naval aircraft.

IFF was found to be barely adequate for some air search radars. However, this condition could usually be remedied by improvement of the equipment or of the antenna design. The range of the system between ships was considered very unsatisfactory and the Mark V IFF/UNB system was designed to give adequate ship to ship range. In general the ground and air forces pressed for an improvement in the traffic capacity, while the navies urged an improvement in the ship to ship and ship to air ranges.

Several pre-production units of the Mark V IFF system were installed on ships and aircraft of the Operational Development Force, U.S. Atlantic Fleet in midsummer of 1947. Technical evaluation, including maintenance procedures, adjustments, detailed study and installation layout was started in September 1947 and continued throughout the overall evaluation. Tactical and operational evaluation of the entire Mark V/UNB IFF system, as installed in OpDevFor ships and planes, was undertaken in a major project embracing all possible situations requiring the use of an IFF system. This evaluation continued until approximately the first of May 1949 and included joint Army-Navy-Air Force operations in addition to the extensive trials conducted by the Navy alone. The reports on this operational evaluation were published in four volumes covering specific periods and phases of the project. A detailed analysis of the findings is impossible in this discussion due to several factors, but in general, can be summed up as follows: The system as a whole represents a definite advance in the problem of Identification Friend or Foe, with many innovations decidedly superior to those utilized in previous IFF systems. However, some ideas and practices were found to be unacceptable due to prohibitive costs, operational limitations, and complexity of operation. The system, as a whole, has not been accepted by the Navy or other branches of the National Defense Establishment up to the present time.

These discussions on the Mark V IFF System are based on the technical and tactical information contained in the OpDevFor Evaluation Reports with some historical and tabular data selected from a report by the Combined Research Group of the Naval Research Laboratory.

Before launching into a detailed discussion on the Mark V IFF/UNB system let us first briefly list the functions desired from the system. In view of the limitations and capabilities of the Mark III IFF, the Mark V IFF/UNB system was designed to provide: (a) Identification of aircraft and ships from other aircraft, ships and ground positions. (b) Azimuth, range and identity of beacon or transponder installations on ground, ships, and aircraft from both aircraft and surface vessels. (c) Miscellaneous functions such as beam approach were required from the system. These functions were to be considered in the original design but were to be provided by subsequent development.

From Figure 1 the reader can obtain a general idea of the course of events between the time the Interrogator-Responsor is triggered and the time the reply from the transponder is received at the I-R. As can be seen from this figure the interrogations from the I-R are in

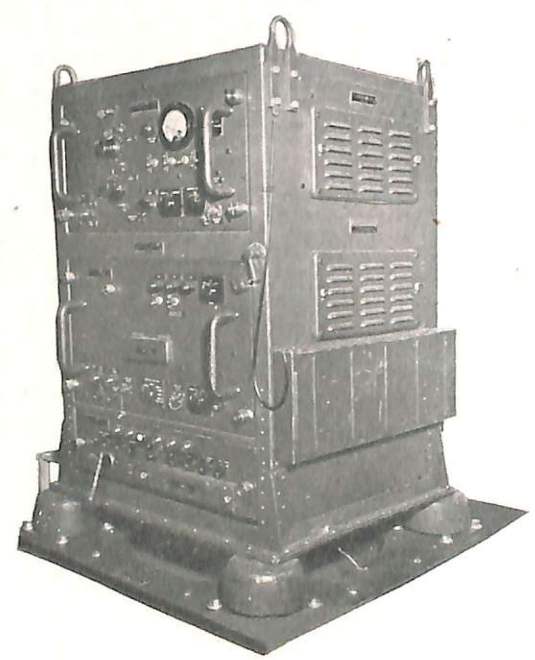


FIGURE 4—Surface high-power Interrogator-Responsor AN/CPX-3 mounted for operation aboard ship.

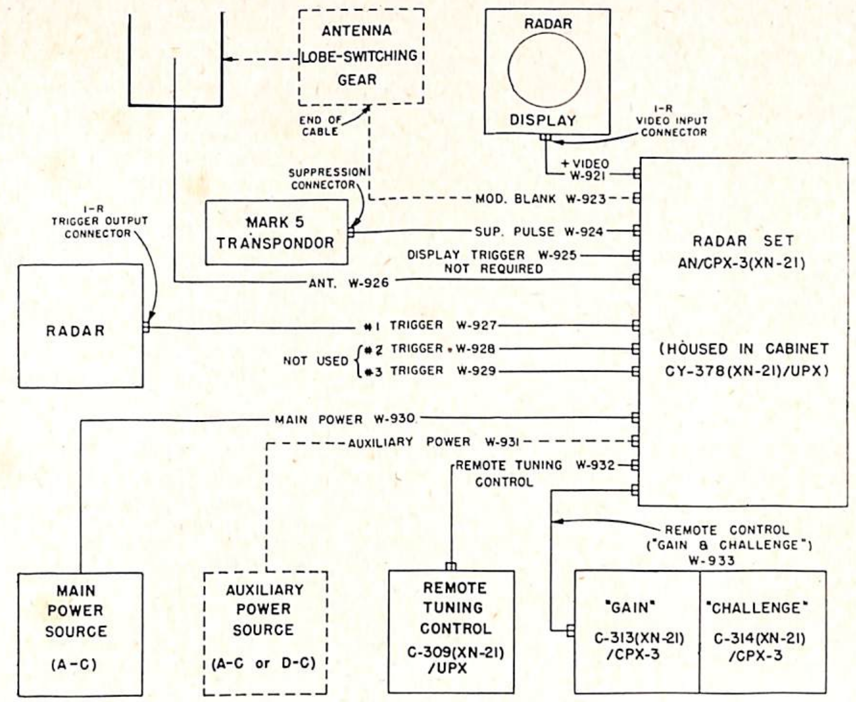


FIGURE 4a—Diagram of typical external connections for installations using the AN/CPX-3 Interrogator-Responsor with a radar display but no interconnection assembly (Coordinating Equipment).

the form of paired pulses (as compared to single pulses in the Mark III IFF system), spaced either three, five, or eight microseconds. The spacing between these pairs of pulses determines the type or mode of interrogation being transmitted by the I-R. 3-microsecond spacing is defined as IFF interrogation, 5-microsecond spacing as PI (Personal Identity), and 8-microsecond spacing as FLI (Flight Leader Identity). These three types of interrogation are called "fast coding" as opposed to "slow coding" which will be described presently. The method of generating these pulses will be discussed in detail later.

PI (Personal Identity) mode is intended for fighter direction and can be used by a controller to select a particular aircraft from among several by switching the particular aircraft (by voice transmission) to PI and simultaneously switching the I-R to PI interrogation. When transmitting PI the I-R would only trigger the aircraft transpondor set to respond to PI and hence the IFF responses from all other transpondors operating on IFF would disappear from the scope leaving the controller with the response from the particular aircraft designated to reply in PI.

FLI (Flight Leader Identity) is similar to PI in that a particular aircraft can be directed to reply in FLI and only those responses from his transpondor will appear on the scope while all other replies from normal IFF transpondors will disappear.

All interrogations are received by the transpondor in the aircraft, ship or ground station, contingent upon the transpondor being in reception range of the I-R. However, not all interrogations will cause a reply to be generated by the transpondor. The operational capabilities and limitations insofar as "fast coding" are concerned is considered of prime importance in assisting the reader to more fully understand the many ramifications of the Mark V IFF/UNB system. With this in mind, particular emphasis will be placed on a clearcut complete explanation of this phase of operation. First, bear in mind that an I-R can interrogate in either IFF, PI, or FLI and, as will be seen later, under certain conditions in all three on a time sharing basis. However, for the time being, we will assume only one interrogation mode in use at a time.

Assume a transpondor is adjusted to reply to IFF interrogations. All IFF interrogations (within reception range) will be received by the transpondor and an IFF reply will be generated in the transpondor and transmitted back to the I-R'(s). Next, assume a transpondor is adjusted to reply to PI interrogations by previous direction from a certain station which wishes to positively identify the location of that particular transpondor. The transpondor will respond to PI interrogations and at the same time continue to respond to all other IFF interrogations. However, as pointed out previously, these IFF replies will not appear on the scope of the station interrogating in the PI mode. Third, assume a transpondor is adjusted to reply to FLI interrogations, by previous direction from a certain station which wishes to identify that particular transpondor. The transpondor will respond to FLI interrogations and at the same time continue to respond to all IFF interrogations. Again, however, it is pointed out that these IFF replies will not appear on the scope of the station challenging in the FLI mode. There is a fourth type of reply which the transponder is capable of emitting, EMERGENCY. The circuits of the transponder are so arranged that, regardless of the mode of interrogration, if the set is switched to the EMERG position it will respond to any interrogation and transmit an emergency signal. The types of interrogation and associated replies are best understood by referring to Table 1.

After receipt of the interrogation, provided adjustments are correctly made to reply to that particular mode of challenge, the transponder will generate a reply and transmit same. However, the reply transmitted by the transponder will be different under different types of interrogation. A reply to an IFF mode challenge is a 1-microsecond pulse which can be keyed to 2.5 microseconds by means of a mechanical keying system to be discussed in detail later. This process of widening and narrowing the pulse provides the means for sending morse code letters which serve as additional identification of the transpondors location, be it in an aircraft,

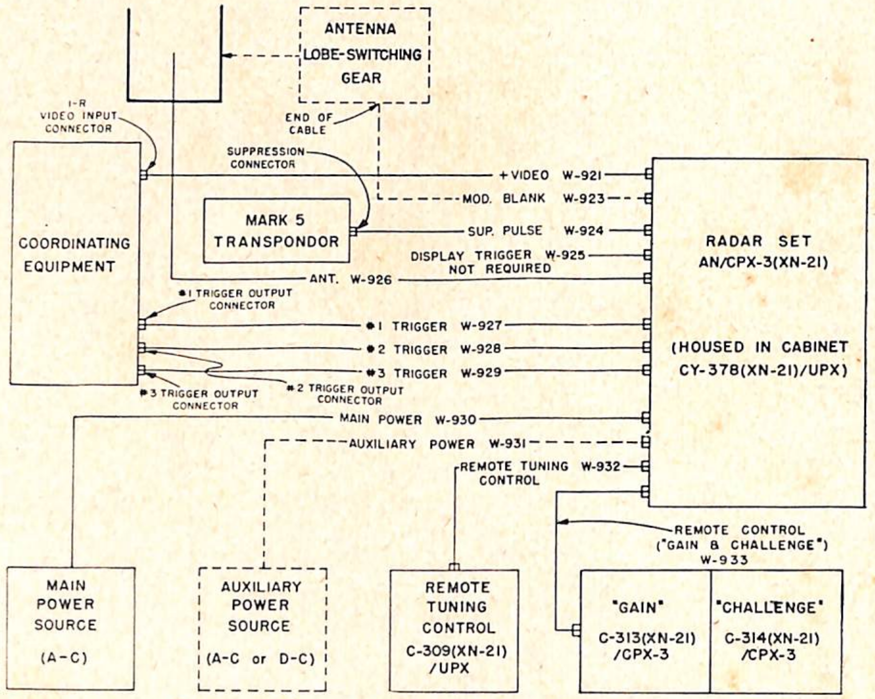


FIGURE 4b—Diagram of typical external connections for installations using the AN/CPX-3 Interrogator-Responsor with an interconnection assembly (Coordinating Equipment).

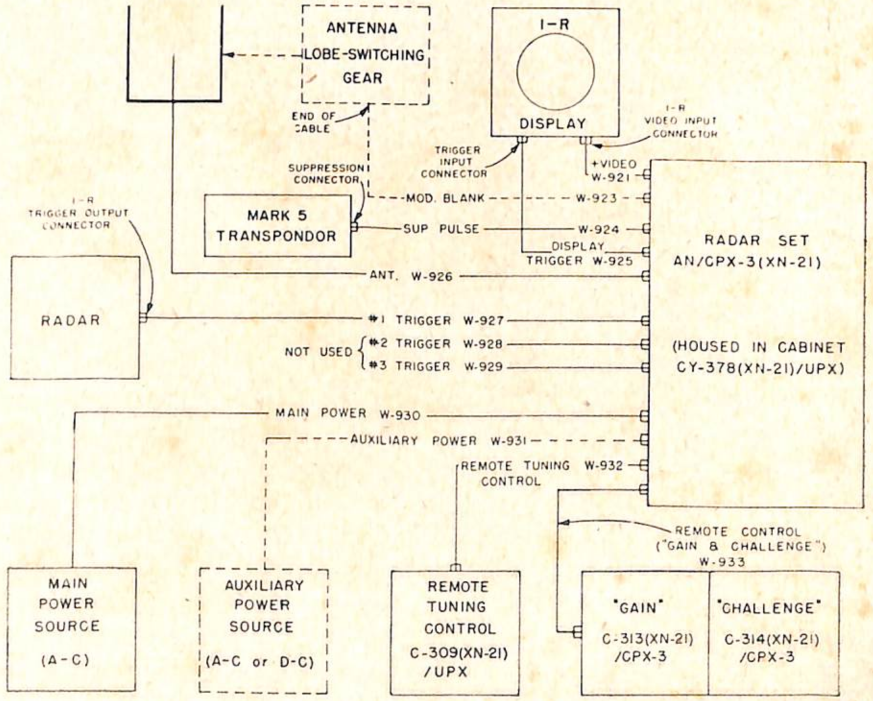


FIGURE 4c—Diagram of typical external connections for installations using the AN/CPX-3 Interrogator-Responsor with a radar and separate I-R display.

TABLE 1

INTERROGATION MODE	SETTING ON APX-6 AIRBORNE TRANSPONDER				
	IFF	IFF & PI	IFF & FLI	IFF & PI & FLI	EMERGENCY
	REPLY EXPECTED				
IFF	IFF reply	IFF reply	IFF reply	IFF reply	Emergency reply
PI	No reply	PI reply	No reply	PI reply	Emergency reply
FLI	No reply	No reply	FLI reply	FLI reply	Emergency reply

a ship, or at a ground station. The coding cycle permits transmitting a series of three letters, which of course will be subject to change from hour-to-hour, day-to-day, or other periods as set up by the tactical doctrine. A reply to a PI challenge is a pair of 1-microsecond pulses spaced eight microseconds apart. These two pulses can be keyed to 2.5 microseconds in width to facilitate morse code reply. As pointed out previously only the I-R'(s) challenging in the PI mode will receive the replies from the transpondor in the PI mode. A reply to an FLI challenge is a pulse 1-microsecond in width which can be keyed to 2.5 microseconds for code purposes. This reply is identical in characteristics to that of the IFF reply, however, the I-R challenging in the FLI mode will see only the reply from the FLI challenge. The Emergency reply, which can be generated in response to any challenge mode, consists of four 1-microsecond pulses continuously present on the "A" scope but with a fifth 1-microsecond pulse keyed on and off to transmit morse code characteristics. The spacing between the pulses in the Emergency reply is the same as for PI—8 microseconds. This pulse keying in the form of Morse code is referred to as "slow coding."

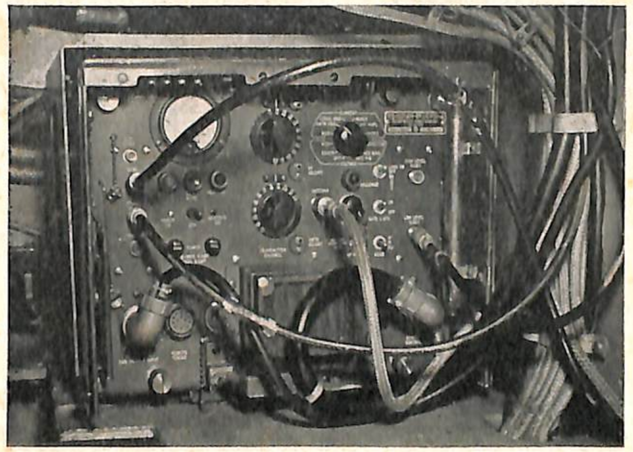


FIGURE 5—Surface medium-power Interrogator-Responsor AN/CPX-4 mounted in 5-inch gun director for operation with the fire control radar system.

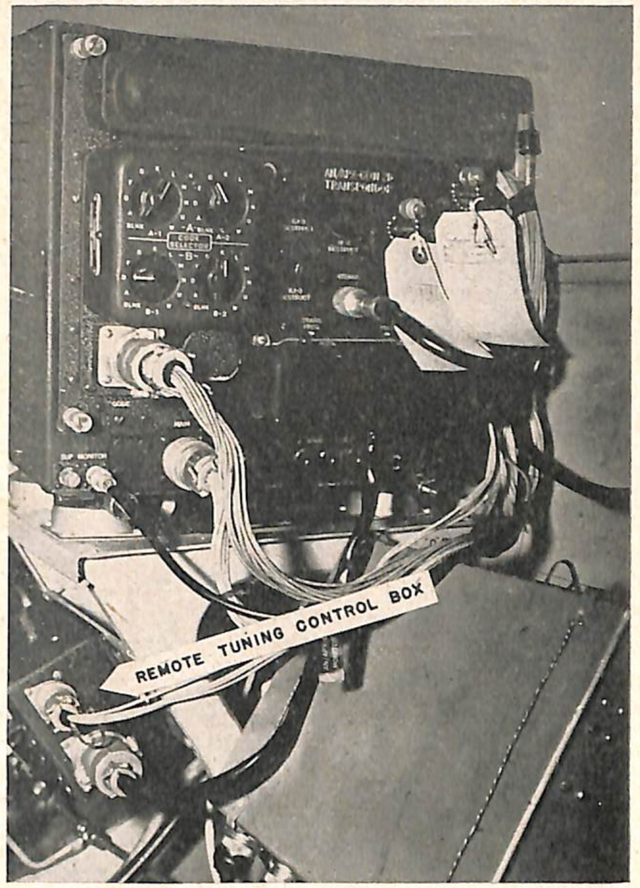


FIGURE 6—The Airborne Transpondor AN/APX-6 located in Naval aircraft.

The above "slow code" dissertation concerns the airborne transponder, the APX-6. The surface transpondor, SPX-2, is slightly different in the type of replies it emits to the various challenges. All replies from the SPX-2 are single pulses which can be keyed from narrow to wide (1 to 2.5 microseconds) to transmit Morse Code. There are no facilities for transmitting an Emergency reply from the SPX-2. Also all coded replies consist of four letters rather than three as in the APX-6.

As compared to the Mark III IFF system which utilized a common frequency in a very limited band for both reception and transmission, the Mark V IFF/UNB is vastly improved. Both the I-R and transpondor have twelve preset, automatically or manually tuned, frequency channels covering a total of approximately 200 Mc in an entirely different portion of the frequency spectrum than was the Mark III IFF. This twelve channel feature permits the use of different channels for transmission and reception, viz—the I-R will transmit and the transponder will receive on one channel while the transpondor will transmit and the I-R will re-

FIGURE 7—Surface Transpondor AN/SPX-2 (lower) mounted in rack with AN/CPX-4 on board ship.

ceive on an entirely different frequency. This frequency selectivity plus the number of channels available greatly increases the flexibility of the system.

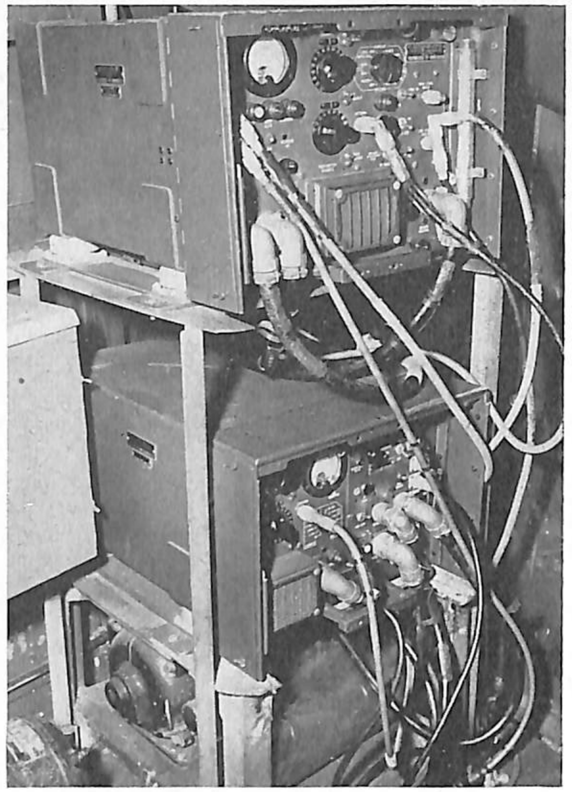
The complete Mark V IFF/UNB system is comprised of a large number of units, some conventional, others of a radically different nature. By virtue of the original design planning and projected application of the system, many units were required which had not previously been utilized in any IFF system or, for that matter, in any Naval electronic installation. A complete listing of the components of the system will be found in Table 2 which follows:

TABLE 2

Type of Equipment	Function
AN/APX-6	Airborne Transpondor
AN/APX-7	Airborne Interrogator-Responsor
AN/CPX-3	Surface High-Power Interrogator-Responsor
AN/CPX-4	Surface Medium-Power Interrogator-Responsor
AN/SPX-1	Surface Transpondor
AN/SPX-2	Surface Transpondor
AN/UPA-3	Surface Antenna
AN/UPA-4	Surface Antenna
AN/UPA-5	Surface Interconnection Assembly
AN/UPA-9	Surface Interconnection Assembly
AN/UPA-11 (AS-294 & AS-295 reflectors)	Surface Antenna
AN/UPA-15	Surface Interconnection Assembly
AN/UPA-16	Surface Interconnection Assembly
AN/UPM-4	Transportable Test Equipment
AN/UPM-6	Portable Test Equipment
AS-133	Airborne Transpondor Antenna
AS-176	Surface Transpondor Antenna
AS-177	Surface Transpondor Antenna
AS-220	Airborne Interrogator-Responsor Antenna
AS-250	Surface Transpondor and Beacon Antenna
AS-280	Airborne Interrogator-Responsor Antenna
CAY-66AME	IFF Antenna Adapted For Use With SR-3 Radar.
Mark 19 Mod 0	IFF Antenna Adapted For Use With Fire Control Radar
PPN-8	Paratrooper Beacon
TS-370	Power Meter
TS-371	Frequency Standard
TS-372	Marker Frequency Standard
TS-373	SWR Meter
TS-374	Power Standard

Interrogator-Responsors

The AN/APX-7 (Figures 2 and 3) is the airborne interrogator-responsor and provides a means of interro-



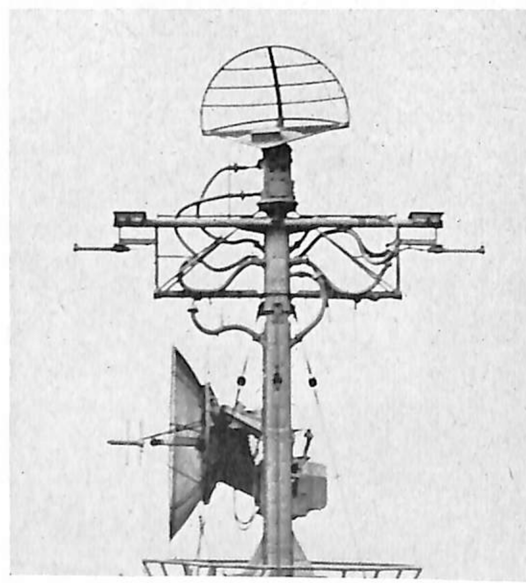


FIGURE 8 — IFF Directional Antenna AN/UPA-3 mounted atop mainmast of a heavy cruiser.

gating surface and airborne transpondors of the Mark V IFF system, and displaying the responses. The basic units of the equipment consist of a transmitter-receiver unit, an indicator, a control box, any one of three antenna systems and such additional accessories as are required by the antenna selected. The transmitter-receiver unit houses the transmitter and receiver sections of the equipment,

FIGURE 10—Airborne omni-directional antenna AS-133 mounted on underside of fuselage of Naval aircraft.

together with their power supply and control circuits. The indicator contains a three-inch cathode ray display tube, its sweep and power supply circuits, strobe generating ranging circuits, and certain control devices. The control box contains switches for challenge, mode selection, receive and transmit frequency channels, receiver gain, OFF-ON and STRETCH. Signals are displayed on a modified "L" type trace on the indicator. Five ranges are provided, 5-, 15-, and 150-miles and a

FIGURE 9 — IFF Directional Antenna AN/UPA-11 mounted on upper left platform on a light aircraft carrier.

special "strobe sweep" which is started at the range of the strobe. (For purposes of clarity, "strobe" as used in this discussion is similar to the more conventional term "range step"). Two circuits are provided to assist in slow code reading. The first, "strobe sweep" gives sufficient expansion of the sweep to distinguish between wide and narrow pulses. The second "stretch" operates through an r-c circuit so that the wide pulses give greater amplitude deflection thus providing the second method of reading slow code. Three antenna systems have been designed, but only two have been used to any extent in the system, the AS-133 and the AS-280.

The AN/CPX-3 (Figure 4) is a high-powered interrogator-responsor for surface or ground use, providing a nominal pulse power of from 5 to 9 kw (depending on the frequency) into a 50-ohm load. The input circuits are so designed that the system can accept input triggers in all three modes for interlaced challenging and simultaneous display, or it can be utilized as a single mode I-R by a local/remote controlled switching arrangement. Provisions are made for self-triggering in the event that the incoming synchronizing pulses are not available. The transmitter oscillator consists of a pulsed coaxial-line oscillator employing a type 3C37 triode in a circuit similar to a Colpitts in which the paired interrogation pulses from the modulator furnish the plate voltage. The receiver is a superheterodyne, similar in design to current radar receiver types, consisting of two preselctor cavities, local oscillator, crystal mixer, 60-Mc i-f amplifier strip and video amplifier strip. Anti-jamming features comparable to those in modern radar receivers are incorporated in the design of the receiver. A monitor jack is provided on the front panel which, in conjunction with a 12-position switch, permits monitoring waveforms throughout the modulator and driver with the UPM-4 test equipment. In addition to this monitor jack, a video output jack is provided on the front panel of the receiver for sampling the receiver output and displaying it on the oscilloscope of the test equipment. A well designed and carefully calibrated r-f probe is available on the front panel for sampling r-f energy from the CPX-3 transmitter or for injecting r-f into the receiver for measuring sensitivity and other features of overall operation. A detent tuning mechanism permits rapid selection of any one of the 12 operating channels. The transmitter and receiver sections can be so tuned to any channel, independently of one another. The CPX-3 operates from a 50-, 60- or 400-cycle, 115- or 230-volt source with link connections available to correct for a high or low voltage source. Three typical installations of the AN/CPX–3 with radar only, with interconnecting assembly, and with a separate I-R display are shown in Figures 4a, 4b, and 4c.

A medium powered interrogator-responsor, the AN/-CPX–4 (Figure 5) is included in the system to provide a suitable single mode system for smaller installations where greater power and interlaced challenging are not required. This equipment is contained in a single cabinet except for three remote control boxes. The transmitter section consists of pulse generating circuits which accept triggers from the radar or interconnection equipment, and generate the paired pulse interrogations characteristic of the Mark V IFF/UNB. Spacing between the pulses, corresponding to the three modes, is controllable from either the local or remote positions. The r-f pulse power output available from the transmitter is normally between 0.5 and 1.5 kw depending on the frequency in use. A lighthouse type triode operating in a resonant cavity is used for the generation of the r-f power. The receiver is of superheterodyne type, consisting of two r-f preselector cavities, a T-R switch tube, lighthouse triode local oscillator and crystal mixer, 60-Mc i-f strip, diode detector and video amplifier stages. Circuits are incorporated to reduce the effects of jamming or other interference, and are similar to those used in modern radar receivers. The power supply section furnishes heater, bias and plate voltages for all of the tubes used, and a 24-volt d-c supply for relays, motors and control circuits. A detent tuning assembly allows rapid selection of any one of 12 receiver or transmitter channels from either remote or local positions. Three detent mechanisms control positioning of tuning pistons in the transmitter, preselector and receiver local oscillator cavities. Two tuning motors drive the detent mechanisms of receiver and transmitter independently. The AN/CPX–4 transmitter-receiver is built on a single drawer and is housed in a small steel cabinet. All power, control and coaxial cables enter the unit from the front panel. The drawer slides out of the cabinet on slides similar to those used in filing cabinets, and makes the interior of the unit accessible for servicing. From the remote control boxes, the following functions can be controlled: challenge on-off, mode selection, receiver gain; frequency channel selection, gate, and gain time control (GTC). These remote control functions are also provided with the AN/CPX–3 high powered interrogator-responsor discussed in the preceding paragraphs.

Transpondors

The AN/APX–6 (Figure 6) is the airborne transpondor which furnishes automatically the responses to Mark V IFF interrogations. The equipment consists of a transmitter-receiver unit, and two control boxes. On

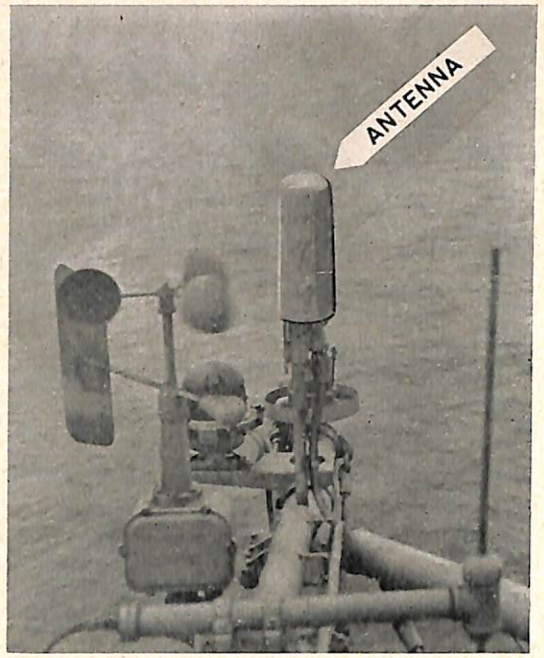


FIGURE 11—Surface transpondor omni-directional antenna AS–177 located on forward port yardarm of a heavy cruiser.

the main control unit is the selector switch for turning equipment to OFF, STANDBY, LOW SENSITIVITY, NORMAL and EMERGENCY operation. Separate toggle switches permit control of PI and FLI modes. A switch for energizing a destructor circuit is included. A monitor jack and a pair of headphones makes it possible to determine if the equipment is replying to challenges. On the code control unit is a selector switch for setting the third slow code letter to be transmitted. On this unit also is a channel selector switch, which permits changing the first and second slow code letters transmitted from one preset combination to another. With optional additional equipment the same control units can be used to remotely change the transmitter and receiver frequencies. This equipment consists of a motor-driven selector mechanism and a frequency control unit. The first two letters of the slow code can be remotely changed between two preset combinations, but for complete selection, the transmitter-receiver unit must be accessible. Power for the equipment is supplied from the 28-volt d-c aircraft source and a 117-volt, 400- to 2400-cycle source. The former is used for relay and motor operation and the latter for filament and plate supplies.

The AN/SPX–2 (Figure 7) is a medium powered transpondor designed for shipboard or shore-based operation. It delivers approximately 500 watts of r-f pulse power over the frequency range for which designed. The unit will trigger on the proper interrogation signals whose strength is 79-db below one volt or stronger. The SPX–2 can be operated from a single-phase 117- or 234-volt source at 47 to 63 cycles, or from a 380- to 550-

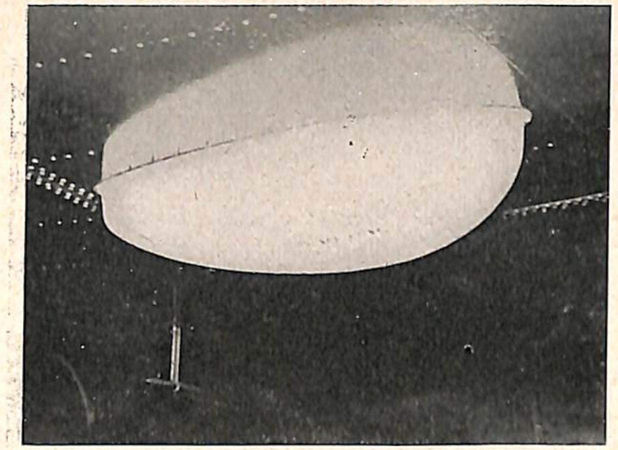


FIGURE 12—Airborne Interrogator-Responsor AN/-APX–7 Antenna Type AS–280 housing mounted on underside of wing of Naval aircraft. (Antenna proper is enclosed in the Lucite housing).

cycle source at 117 or 180 volts. The entire SPX–2 consists of a main unit, a cable junction box, a keyer unit, a remote control unit, and a remote tuning control. The equipment can be operated either by means of front panel controls in the main unit in conjunction with the keyer unit, or from a remote position by means of the remote tuning control, remote control box, and the keyer unit. In either the local or remote type of operation, the settings of the four rotary switches on the front panel of the keyer unit determine the code identification letters transmitted. A terminal strip is provided on the inside of the main unit for monitoring various voltages and waveforms.

Antennas

The AN/UPA–3 (Figure 8) is a directional antenna consisting of radiators, parabolic section reflector, a servo driving system, and a train control unit. The reflector used is 2.5′ by 5′ and provides a horizontal beam width of 14 degrees and a vertical beam width of 19.3 degrees. The servo system utilizes synchro information to control a servo amplifier capable of rotating the antenna at speeds up to 20 rpm. The train control unit provides a means of selecting the source of servo information to control the antenna, and in the manual position, the operator may control rotation by hand.

The AN/UPA–11 (Figure 9) is a directional antenna primarily designed for field use, and is provided with a mast and guy wires. It consists of the following major units: 1—AS–294 or AS–295 Antenna Array. 2—AB–124 Antenna Pedestal. 3—AM–190 Servo Amplifier. 4—C–399 Train Control Unit. The array uses slot type radiators mounted in a corner reflector, and has a horizontal beam width of 7 degrees. The antenna array may be mounted on and rotated with a radar antenna. It may also be mounted as a free swinging antenna since a complete antenna control system is provided. The servo system is unique, in that the driving power is obtained from the a-c line through synchronous relays. Relay operation is controlled by vacuum tubes from a phasing network.

The AS–133 (Figure 10) is an omni-directional antenna designed for use with the airborne transpondor (AN/APX–6) and consists of a flat, diamond-shaped plate (broad band dipole) enclosed in a streamlined Lucite housing. The housing is secured to an elliptical bezel which supports a matching section and probe assemblies.

The AS–177 (Figure 11) is an omni-directional array consisting of broadband dipoles stacked two high and mounted in a Lucite cover housing which is secured to a metal base. This antenna is designed for use with the shipboard transpondor (AN/SPX–2). The antenna housing is cylindrical in shape and presents very little wind resistance.

The AS–280 (Figure 12) is a fixed airborne antenna system for use with airborne interrogator-responsors. Its principal components are a type AS–260 fixed port antenna, a type AS–261 fixed starboard antenna, an SA–70 switch unit, and a PU–152 inverter. The two fixed antennas contain a pair of radiators backed up with two reflectors housed in a streamlined radome. The horizontal radiation lobe from the starboard antenna is displaced approximately 40 degrees to starboard of the aircraft's course. The port lobe is displaced a similar amount to port. The two are fed alternately by action of the switch unit, and the amplitude of the responses obtained are compared on the "L" trace of the indicator. By changing the course of the aircraft until the responses are equal in amplitude, the direction of the responding signal may be determined. The PU–152 inverter supplies alternating current for the operation of the motor in the switch unit.

Another airborne antenna the AS–220 was also designed for use with airborne interrogator-responsors. The AS–220 employed two directional radiating elements coupled to a capacity switch to form a lobe switching system. This antenna could be rotated by remote control to give direction finding facilities off the line of flight. It was primarily intended for installation on large aircraft which could afford to carry the weight and which could provide a suitable mounting site. The AS–280 was intended for use on aircraft which could not afford the weight or perhaps the drag of the AS–220, and on aircraft on which a suitable mounting position could not be found, or wherever the facility of taking bearings off the line of flight did not justify the AS–220.

Two special antennas were designed to operate with Mark V IFF/UNB equipment in conjunction with current radars. One was a type CAY–66AME which was adapted for mounting on an SR–3 radar antenna. It

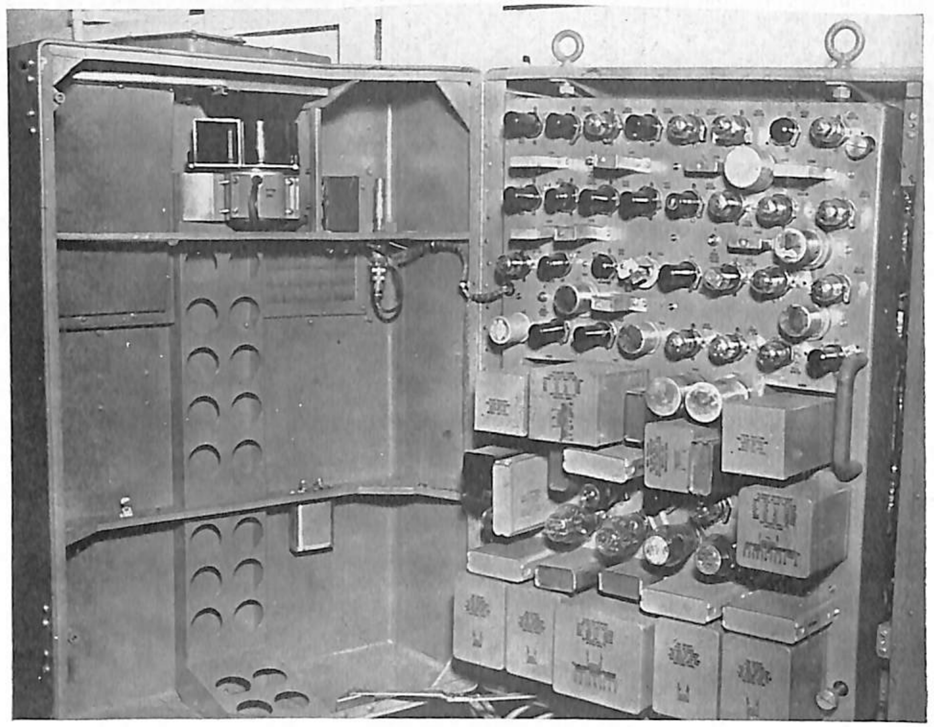


FIGURE 13—Interconnection Assembly UPA-9 Synchronizer with front panel open to show the mounting arrangement of components on inner panel.

consists of 16 half-wave dipoles arranged in a vertically polarized array that is eight dipoles wide and two dipoles high. The beam is 12 degrees wide in the horizontal and 20 degrees in the vertical and has a gain of approximately 15 db. The other is a Mark 19 Mod 0 antenna which was designed to be used with fire control radars. The antenna consists of an array of half-wave dipoles set in a reflector approximately five feet long, and is mounted atop the Mark 12 (or its counterpart) Fire Control Radar. For purposes of bearing determination lobe-switching is incorporated in this antenna system.

Interconnection Assemblies

The AN/UPA–9 (Figures 13 and 14) is one of the interconnection assemblies provided in the Mark V IFF/UNB system. This unit is used to coordinate the operation of an interrogator-responsor, a selected radar, an associated PPI (which makes it an AN/UPA–10), and a directional free-swinging antenna. The purpose of the UPA–9 is to provide a suitable display of the responsor video, so that transpondor replies may be observed, located with respect to range and bearing, and identified by their slow coding. Two individual units comprise this interconnection assembly: 1—the Synchronizer (Driver) which contains the audio decoding and azimuth gating circuits as well as video channels; 2—the Indicator Unit, which contains the trigger channels, sweep and ranging circuits, and all the operating controls.

Two different presentations of the video replies are available in this installation, the associated PPI display,

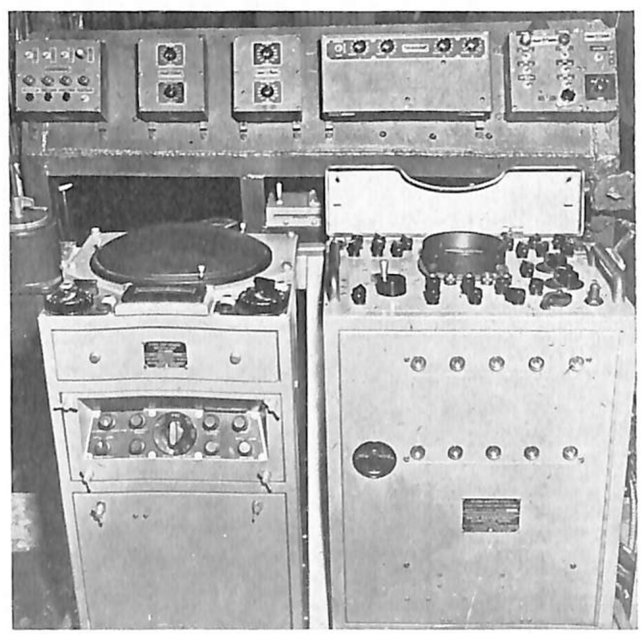


FIGURE 14—Interconnection Assembly UPA–9 Indicator with associated VJ repeater located in CIC of a light aircraft carrier. UPA–9 indicator is on right. Control boxes above are units of the Mark V IFF System.

and the "A" scope display on the UPA–9 Indicator itself. The display on the PPI can be either radar video, I-R video, or both. Selection of display is controlled by a switch on the Indicator Unit of the UPA–9. The "A" scope display consists of two sweeps, one above the other. The upper sweep displays the radar video and

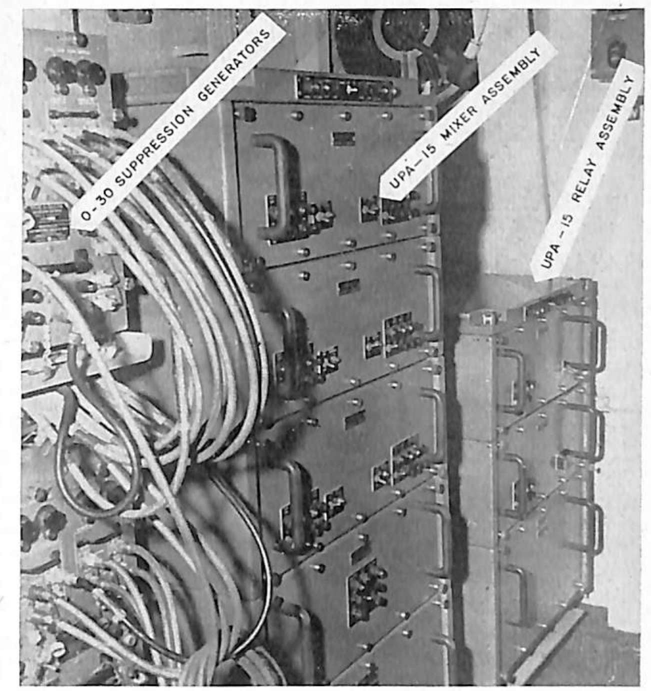


FIGURE 15—Mixer Assembly and Relay Assembly (middle and right respectively) of the Interconnection Assembly AN/UPA–15 located aboard a heavy cruiser. Units at extreme left with cables protruding are additional units used with this particular Mark V IFF installation.

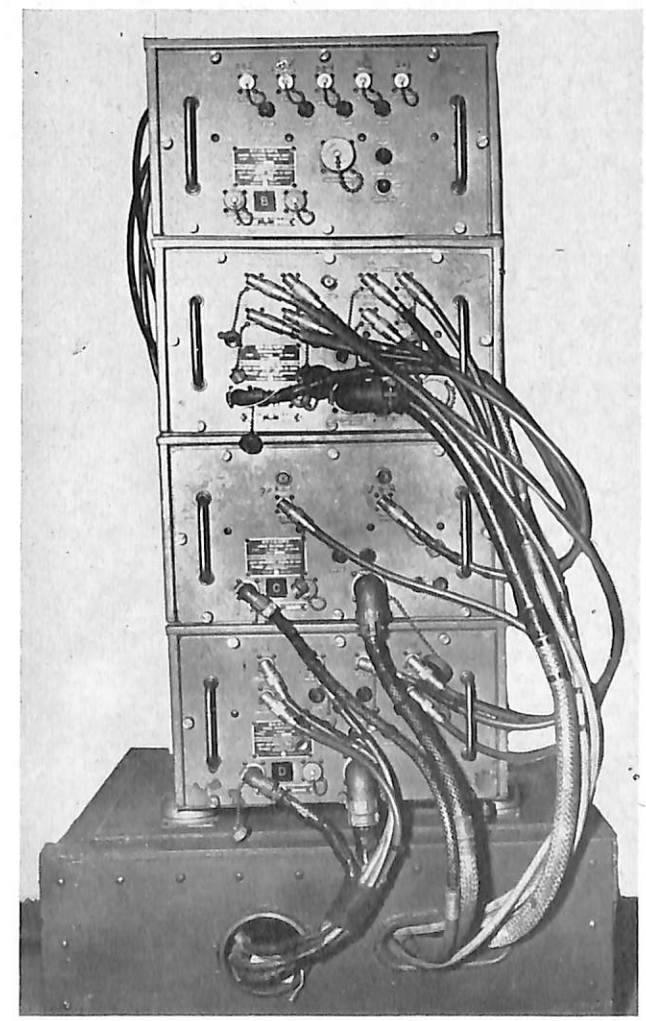


FIGURE 16—Interconnection Assembly UPA–16 mounted against bulkhead in a destroyer installation.

the strobe (range step) generated in the UPA–9, while the lower sweep displays the I-R video and the strobe. The strobe is variable in range over the entire sweep by a strobe range crank. There are five different sweep ranges available on the "A" scope, 20-, 40-, 80-, and 200-mile plus an expanded sweep. The expanded sweep is approximately 5 miles in range and is started with the leading edge of the strobe.

Three methods of antenna rotation are provided with the UPA–9; RADAR, MANUAL and EMERGENCY. In "Radar", the IFF antenna (usually the UPA–3) is synchronized from the selected radar, and the IFF system becomes a slave to the radar. In "Manual" the IFF antenna rotation is controlled by the cursor of the associated PPI. In "Emergency" the IFF antenna is rotated by a slewing motor whose speed is controllable from the UPA–9 console. The "Radar" position is used in most general search purposes, and provides easy correlation between radar and IFF responses on the associated PPI. The "Manual" position is used when it is desired to searchlight a target to obtain slow code information. This can be further understood when the reader realizes that the IFF antenna must be stopped on the target for a sufficient length of time for the transpondor to run through its keying sequence. This usually takes about 10 to 15 seconds, depending on the operators ability to read the code. When in "Manual" the IFF antenna is positioned on the desired target with the cursor on the associated VJ. An azimuth gating circuit is used with the "A" scope in this position, and the radar signals appear on the "A" scope only when the radar antenna sweeps through the same bearing as that on which the IFF antenna is positioned. In this condition, IFF information is not presented on the PPI, since the IFF response is being continuously received and identified on the "A" scope. The "Emergency" position allows the IFF operator to operate the IFF system without an associated radar, and radar information is not displayed on the indicators in this method of operation.

Control of the interrogator-responsor is provided by a challenge switch and mode selector switch on the UPA–9 console. The mode selector switch has five positions, IFF, AIR, PI, SURF PI, FLI, and EMER. In the IFF, SURF PI, and FLI positions, the only changes made are in the actual mode of interrogation, since the same type of replies are expected in all three cases—a single, 1-microsecond pulse. In the AIR PI position the expected reply is a pair of 1-microsecond pulses spaced eight microseconds apart, and a distinctive PPI presentation is desired for this particu-

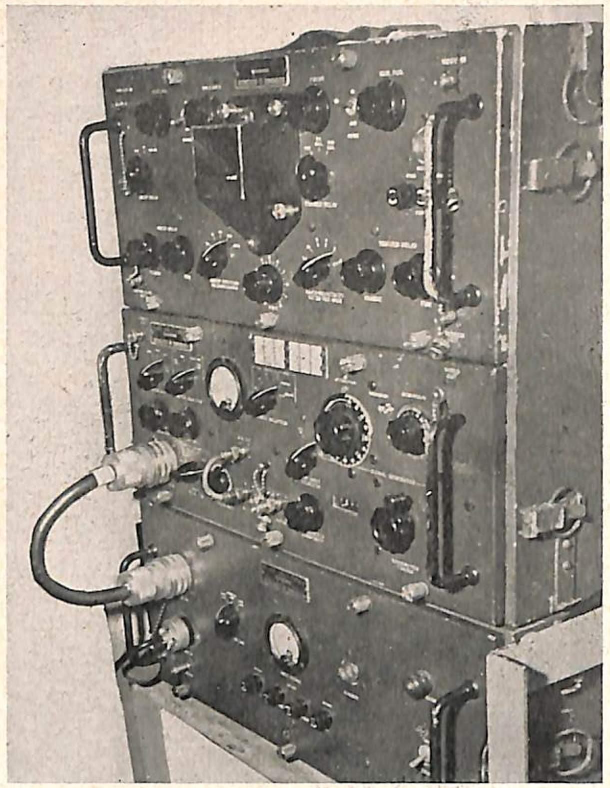


FIGURE 17—Transportable test equipment AN/UPM–4 mounted in special test rack on board a heavy cruiser.

lar reply. To facilitate this distinctive reply a decoding circuit is introduced in the video channel, whch is actuated only by the correct reply, and which produces a long output pulse (approx. 17 microseconds) when this reply is present. In the EMER position of the mode switch, another decoding circuit is inserted which is actuated only by a proper emergency reply and which produces an even longer output pulse (40-50 microseconds) than the PI decoder. This emergency decoder circuit can also be inserted in parallel with the regular video channel in the other positions of the mode switch by turning the EMER-VIDEO switch to ON. An audio decoding circuit is provided for the purpose of making slow code available for aural presentation. This audio decoding occurs, however, only when the strobe is placed directly over the replying target, so that range discrimination may be realized. A tone control and a volume control are provided to perform their respective functions on the aural signal being presented.

The AN/UPA–15 Interconnection Assembly (Figure 15) was designed to provide simultaneous availability of all three modes of interrogation used in the Mark V IFF system. The assembly is used in conjunction with the high-powered interrogator-responsor (AN/CPX–3) to furnish a flexible, multi-control presentation, IFF arrangement. The system utilizes the principle of triple time-sharing of interrogations synchronized with gating of the video stages to allow the desired replies to be presented on any one of six separate indicators. In some installations this number may be increased to twelve by the use of an additional mixer assembly. In operation the AN/UPA–15 receives the radar synchronizing pulses, divides them into an equal number of IFF, PI and FLI triggers, and passes these triggers to the interrogator-responsor. The I-R then radiates a burst of IFF interrogations, a burst of PI interrogations and a burst of FLI interrogations in sequence. The number of interrogations in each burst is the same while the spacing of these bursts gives a distinctive chopped display on the PPI for a given antenna rotation rate.

The AN/UPA–15 consists of two major units, the Relay Assembly and the Mixer Assembly. The Relay Assembly includes a Synchronizer and a Video Separator Decoder. The Mixer Assembly includes six identical mixing units and a power supply. In addition to these major units there is a control box located at each PPI where the IFF information is to be presented. The functions of the individual units in the overall system are described briefly in the following paragraphs.

The Synchronizer coordinates and times the sequence of events in the entire interlaced interrogation system. It receives synchronizing pulses from the associated radar (either direct or through a distribution switchboard) at the same rate at which the radar pulses are transmitted. For each synchronizing pulse received, delayed triggers are generated in three channels for triggering the interrogator-responsor. Simultaneously triple gates are generated which allow the triggers to pass to the I-R on one channel at a time. The total number of triggers supplied to the I-R equals the number of synchronizing pulses received by the Synchronizer, but the average rate on any one channel is only one third of this input pulse rate. Thus the I-R receives a group of triggers, at the input synchronizing pulse rate, on the IFF channel, followed by an equal number on the PI channel, and then the same number on the FLI channel. The number of consecutive triggers on each channel is controlled by the countdown ratio of the Synchronizer, which can be adjusted to allow five countdown ratios, from 1:2 to 1:32, the actual number of pulses being determined by the input pulse rate of the radar. In addition to triple gates controlling the I-R triggers, the Synchronizer supplies negative triple gates of equal length to the Video Separator Decoder.

The Video Separator Decoder receives the video replies to the interrogation challenges from the I-R and separates them into four output channels (IFF, PI, FLI and EMER) so that they may be displayed separately. As the replies are received from the I-R they are impressed on the grids of all video input stages but only one of these stages will be activated at any instant by

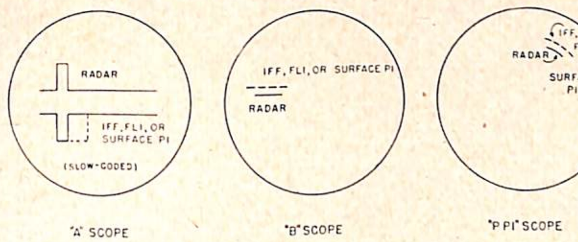


FIGURE 18—Idealized waveforms showing IFF, FLI, or Surface PI reply displays on various types of scope presentations.

virtue of a negative gate from the Synchronizer. These negative gates are synchronized with the triggers to the I-R and the replies from the I-R. For example, when IFF replies are being received, the IFF video input stage will be allowed to pass signals and the PI and FLI channels will be cut off. If EMER video is received the circuits are so arranged that these signals are allowed to pass through the emergency video circuit regardless of the mode of interrogation and the corresponding negative gate. In addition to the normal gating and video functions, the Video Separator Decoder has facilities for decoding PI and EMER video replies with the result that they are displayed along video blocks on the PPI. The length of this block for PI replies is approximately 17 microseconds and for EMER replies approximately 40 microseconds.

The Mixer Assembly consists of six identical mixing units, referred to as DIU (Display Interconnection Unit) Mixers. One of these mixers is used for each PPI presentation. The separated videos from the Video Separator Decoder are fed to individual switching tubes in the mixers and replies to the desired modes are allowed to pass through to the output where they are combined in a common output circuit and carried by coaxial cable to the associated PPI.

The Master Control Box is located at the console of the associated radar. This box provides for selection of mode, common video gain control of all modes except EMER, individual video gain control of EMER, delay between radar pulse and I-R challenge pulses, chop rate, decoded or mixed PI, radar video OFF-ON, and EMER video OFF-ON. A challenge monitor feature is available so the operator may observe what modes of interrogation are being used by other operators at remote stations which are a part of the interlaced system. Each Remote Control Box provides all the above-listed functions with the exception of the delay control, chop rate control, and the decoded or mixed PI control.

The AN/UPA–16 (Figure 16) is a small interconnection assembly designed for use in the Mark V IFF System. The equipment acts as an intermediary between the parent radar and the I-R, and between the I-R and the display devices. It interprets the replies from the transpondor(s) and presents this information in a form suitable for visual or aural readability. Switching devices are incorporated, so that operators may select the type of information desired for display at remote positions. The interconnection assembly consists of four major units and three types of control boxes. The major units are the SN–28 Coordinator, KY–12 Audio Decoder, KY–13 Video Decoder, and the SA–67 Video Switching Unit. Control boxes are C–249 Challenge Control Box, C–248 Audio Decoder Control Box and the ID–143 Remote Indicator Control Box. The first two are operated by the operator at the parent radar, and the latter at the remote indicators.

The Coordinator receives synchronizing pulses from the associated radar and generates delayed triggers for the interrogater-responsor. These triggers may be periodically interrupted in the unit to present a chopped display on the associated indicators. The Coordinator also contains the video circuits for mixing signals, furnishing IFF video, radar video, and mixed IFF and radar video outputs to other units of the system.

The Audio Decoder Unit provides a means of decoding the slow code information contained in the IFF responses and presenting it as a morse code audio signal. It contains a range circuit generating a strobe (range step), which when positioned in range on an IFF reply, gates the audio circuits so that only the selected response operates the audio oscillator. The strobe signal is sent to other units of the interconnection assembly where, mixed with the incoming reply, it may be displayed to assist in selection of the desired response for audio decoding. A "Fruit Killer" circuit is incorporated to prevent unsynchronized responses and noise from keying the audio oscillator. "Fruit" as used herein embraces unwanted signals, noise, and other interference which would distort the presentation.

The Video Decoder decodes PI and EMER multiple responses and from them generates a wide synthetic pulse output for distinctive displays of these signals. The decoded and undecoded outputs may be mixed before delivery to other units of the system.

The Video Switching Unit is used for controlling the display at as many as three remote PPI's. This unit permits operators at the remote points to select radar only, IFF only, or mixed radar and IFF signals for display on their unit, without interference to other display units in the system. However, mode selection and challenge control are provided for only one operator, normally the operator at the radar console. Indicator lamps on the Remote Indicator Control boxes show when the system is challenging and the mode selected for that challenge.

Test Equipment

The AN/UPM–4 (Figure 17) is a transportable test equipment designed for use in checking power output, receiver sensitivity, pulse width, pulse spacing and repetition, frequency measurements and many other checks on units of the Mark V IFF/UNB System. It is an invaluable aid in servicing all components of the system, including transpondors, I-R's, interconnection assemblies and display devices. The UPM–4 is normally bench-mounted and is primarily considered a shop instrument although it has been used as a portable equipment under conditions where other test equipment would not suffice. The equipment includes an Oscilloscope Unit, R-F Test Unit, Power Supply Unit and an Accessories Case. The latter is a metal case containing necessary cables, connectors, probes, clips and other paraphenalia used in operation of the unit. The Oscilloscope Unit and R-F Test Unit are contained in one cabinet. The Power Supply Unit is in a separate cabinet but is usually fastened to the bottom of the R-F Test Unit to form a single unit.

The Oscilloscope Unit contains a 3-inch cathode-ray tube, a high voltage power supply, and those electronic circuits necessary for generation of synchronizing, sweep and deflection voltages. Five sweep ranges of 3-, 12-, 50-, 500-, and 2600-microsecond duration are available. A range mark circuit provides an accurate method of calibrating sweeps or measuring pulse duration or spacing. The unit can be operated from an external synchronizing source, or may be internally synchronized, generating either delayed or undelayed triggers, for use within the unit, or for synchronizing external components of the Mark V IFF System.

The R-F Test Unit contains all necessary circuits for producing simulated pulses which will correspond in duration and separation to those which occur in all modes used in the Mark V IFF/UNB System. Also included in this unit is a wavemeter, signal generator, video calibration circuit, and calibrated attenuation network. These components are utilized when the UPM–4 is being used to measure frequencies, power output, receiver sensitivity, GTC (gain time control), and numerous other applications. Pulse repetition frequencies up to 5000-pps are indicated on a meter operated from a pulse counting circuit.

The Power Supply Unit contains control and power supply circuits, furnishing all power necessary for operation of the equipment, except voltages for the cathode-ray tube of the Oscilloscope Unit. The power supply operates from single-phase, 117-volt, 50-60 cycle ac, and a tapped transformer allows compensation for low or high line voltage.

The AN/UPM–6 is a portable test equipment designed principally to perform "Go" and "No Go" field tests and rough accuracy checks on the operating equipments of the Mark V IFF System, particularly the airborne components. The equipment does not include an oscilloscope, therefore most indications are displayed on

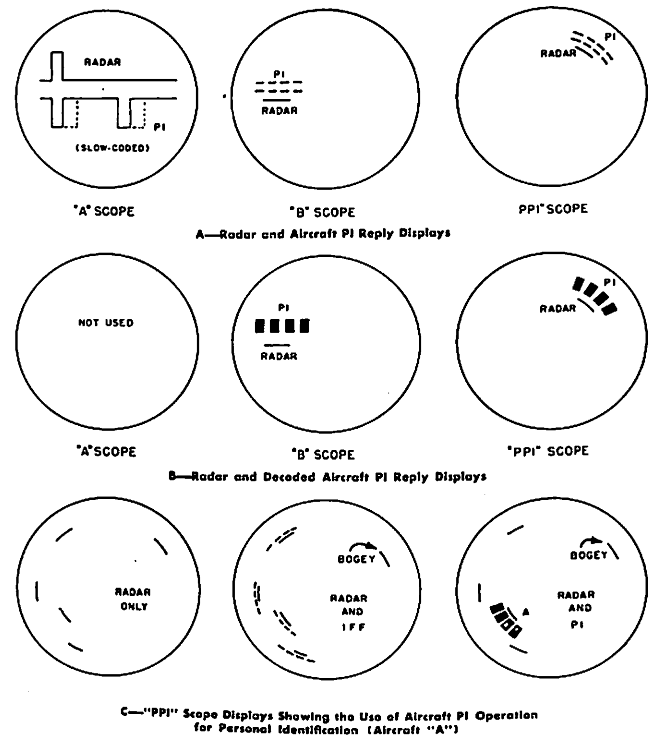


FIGURE 19—Airborne Transpondor (AN/APX–6) PI replies under varying conditions and on different types of scopes.

a peak-reading voltmeter. Slow code is read on a flashing neon lamp. The unit can be used to perform all tests that can be performed by the larger AN/UPM–4 with the exception of time base measurements, which require an oscilloscope for accurate presentation. This test equipment is self-contained except for accessories, which are included in a separate accessories case. It will operate from an a-c source of 115 volts, 47 to 2400 cycles, or from a d-c source of 20 to 30 volts. When operating from the d-c source an Inverter, Type PU–1120/U is provided.

Systems

The preceding pages have been devoted to an outline of the reasons for the development of the Mark V IFF System and provided a general description of the components involved in the system. However, there are other points of interest in connection with the use of these units. It is believed the reader will have, by this time, become aware of the possibilities of multiple combinations of I-R's, interconnection assemblies, antennas, and radar equipments which are available for different types of installations. In general, it can be said that any of the I-R's (shipboard) can be connected with any of the interconnection assemblies and an associated radar to form an IFF system. There is one exception to this rule, only the AN/CPX–3 I-R can be used with the AN/UPA–15 Interconnection Assembly when inter-

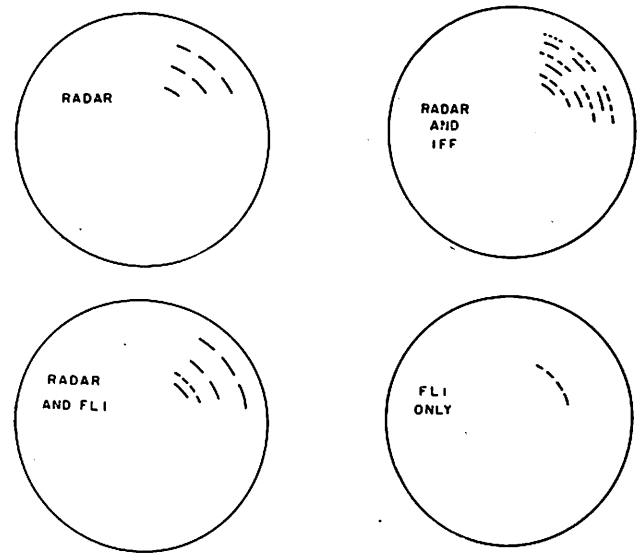


FIGURE 20—PPI display showing the use of FLI mode operation for Flight Leader Identification.

laced challenging facilities are desired, since the AN/CPX–4 does not have facilities for three-channel trigger input.

To offer additional clarification it is believed desirable to outline to the reader just what types of presentation he may expect to see on the various types of scopes utilized with the Mark V IFF System. First, the presentation on the conventional range sweep is a single pulse, a pair of pulses spaced eight microseconds apart, or four pulses spaced eight microseconds with a fifth keyed on and off in Morse code combinations. The single pulse represents an IFF or FLI response with the width varied from 1 to 2.5 microseconds for Morse code combinations. The pair of pulses represents PI responses with the widths varied from 1 to 2.5 microseconds for Morse code combinations.

The presentation on a PPI type of scope is radically different from that on a conventional range sweep. It must be remembered that the response from the transpondor will always be delayed in respect to the radar echo. This delay is variable (with operator control) from approximately 500 yards to 4000 yards. The amount of delay depends on the sweep length in use and the amount of correlation desired between the radar echo and the IFF response.

A response to an IFF or FLI interrogation will appear as an arc (periodically broken) immediately behind the radar echo of the object carrying the transpondor. This arc will be greater in azimuth than the radar echo and is usually roughly equal to the prescribed horizontal beam width of the antenna in use. Other factors enter into the picture which affect the width of the arc, but they will be explained in detail later. The spacing between the broken segments of the arc can be adjusted to suit the individual operator or condition.

A response to a PI interrogation will normally be a double arc (periodically broken) with approximately 1300 yards spacing between the two, immediately behind the radar echo of the object carrying the transpondor. The arc width is determined by the same factors as discussed in the preceding paragraph. However, there are additional presentations which can be obtained by operator controls. The first is a presentation of straight (undecoded) and decoded PI mixed on the scope. This presentation is the same as the normal PI response except that the second arc will no longer be a series of 1-microsecond pulses but will be a series of pulses approximately 17 microseconds in duration. The second is similar to the mixed version mentioned immediately above except that the arc of 1-microsecond pulses is eliminated and only the arc of 17-microsecond pulses is visible.

An EMER response will appear on the PPI in one of two forms, undecoded or decoded. Undecoded EMER replies will be in the form of four 1-microsecond pulse arcs, spaced 1300 yards apart and with the first of the series immediately behind the radar echo of the object in which the transpondor is located. Again the arc width is determined as described previously. Decoded EMER replies are in the form of two (sometimes three) 1-microsecond pulse arcs followed by an arc of approximately 40-microsecond pulses.

As an aid in identifying the various responses and combinations of responses possible in the Mark V IFF system, the readers attention is invited to the sketches shown in Figures 18, 19, 20, and 21. These are idealized presentations and the actual presentations on the various scopes will obviously not be as clear cut as shown in the sketches.

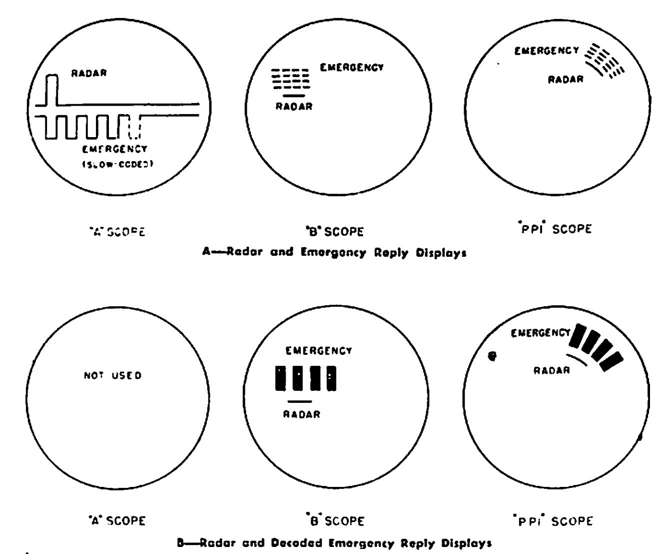


FIGURE 21—Airborne Transpondor (AN/APX–6) EMER replies as viewed on different types of scopes.

RADAR PROPAGATION THROUGH MUZZLE GASES

With the advent of gun fire control systems such as Gun Fire Control System Mark 63 and the forthcoming Gunar system in which the radar reflector is mounted on the gun or gun platform, an important problem was brought to light which necessitated investigation by the Bureau of Ordnance. During gun fire, attenuation of the radar signal was experienced when the radar reflector was pointed in such a direction with respect to the gun that the electromagnetic energy passed through the envelope of muzzle gases in front of the gun barrels.

The effect was first noted during Operational Development Force tests on the experimental Gunar controlling a 5″/38 mount when it was found that the radar echo was highly attenuated for a short period after each round. The attenuation was indicated by reduction of the pip on the A-scope, although no loss of target or deterioration of automatic tracking was experienced. It was believed that the attenuation effect might be present also in smaller weapons and might be expected to be maximum in the Gunar system where an almost continuous gas medium would exist in front of the radar reflector due to the rapid rate of fire of the 3″/50 twin.

To resolve these problems and to ascertain whether or not the attenuation is of such an order and duration as to affect an automatic tracking system, tests were conducted at the Naval Proving Ground, Dahlgren, utilizing a 3″/50 Twin Mount Mark 27 and Radar Equipment Mark 34 Mod 6. With a marginal signal, radar energy was propagated through the envelope of muzzle gases at different angles to the line of fire. While particular attention was directed to the measurement of the attenuation of the radar signal, the possibility of bending of the radar beam as it passed through the muzzle gases was not overlooked.

The results of these tests at Dahlgren should be of interest to everyone connected with ordnance and fire control. Using SPDN (non-flashless) ammunition, a 26-db one-way attenuation of the radar signal was experienced which lasted for 0.1 second. In other words, the radar was completely blanked for that length of time, indicated by a transient disappearance of the target pip from the A-scope. With SPCG (flashless) ammunition, the one-way attenuation was only 3-db and there was no evidence of blanking on the radar indicator. Bending of the radar beam was not discerned in either case. These results indicate rather obviously that the flame in the gun blast is the attenuating agent and that the muzzle gases provide only moderate diminution of the signal.

The net results further indicate that operation of the on-mount fire control systems will not be seriously affected by this condition. In the Gun Fire Control System Mark 63, the momentary disappearance of the tracking spot caused by these effects is not expected to affect manual tracking; and in automatic tracking systems such as Gunar, there is believed to be sufficient integration in the tracking circuits to overcome transient blanking of signal at each round of gun fire. However, in Operational Development Force evaluation tests on the 3″/50 Gunar system, both SPDN and SPCG types of ammunition will be used to check further the ability of the system to track automatically with transient attenuation of the radar signal while firing.—*Bulletin of Ordnance Information.*

Type of Approach	Through October	To Date
Practice Landings	10,935	283,118
Landings Under Instrument Conditions	323	11,136

MARINE CORPS NOTES

Marine Ground Control Intercept Squadron Seven at the Marine Corps Air Station, Edenton, North Carolina reports an unusual trouble with an indicator unit of a Model AN/TPS-1B Radio Set.

While the unit was being moved, the bracket supporting T-502 shifted and broke the base of high-voltage rectifier V-521. The trouble was unusual in that voltage was supplied to the PPI scope during the time the transformer was loose and the base of V-521 was broken; no voltage was supplied to the A-scope during this time. However a rather heavy 400-cycle modulation was noted on the PPI high-voltage input. It was also noted that the worm drive for deflection coil L-503 in this unit was not operating properly. Investigation revealed that the worm gear was meshing too tightly against the deflection coil gear. The trouble was remedied by filing out the bolt holes on the worm drive bracket and moving the worm so that it meshed properly with the deflection coil gear.

MARK 25 MOD 2 INDICATOR PLUG DIFFICULTIES

Several reports have been received of difficulty with indicator cables used in the Mark 25 Mod 2 equipment. It has been noted in several installations that the cable entrance packing nuts in a number of indicator plugs were not properly secured. In some cases the packing nuts were tight, but lack of sufficient rubber prevented secure tightening on the cables. As a result, several unfortunate things occurred. Water seeped into the plug causing leakage currents to flow. The strain on the cables caused damage to the conductors inside the plug. A third trouble developed because castings were rough on the inside and had sharp edges around which the cable conductors pass. Strain on a cable which was not securely tightened resulted in breakdown of insulation on the conductors at the point of contact with the sharp edges and corners. Since an ounce of prevention is worth a pound of cure, at some time during the installation of a Mark 25 Mod 2, these cables and plugs should be thoroughly checked for tightness and security by pulling on them to determine if the clamping is adequate—*W. E. Newsletter.*

CORROSION OF MODEL VK REPEATER PARTS

In October of 1948 two Model VK Radar Repeater Equipments were installed on the *USS Des Moines* at Air Defense Forward and Aft. On 1 July 1949 these installations were examined by General Electric Company Field Engineers and it was found that salt spray, rain and condensation had caused considerable corrosion of several parts. At the time of this examination, the range selector wafer switches, S-211, and the servo follow-up synchro, B-204 had already been replaced by ship's force since the original installation, and the replacements had corroded. In addition, metal surfaces surrounding the PPI scope tube and many metal surfaces inside and outside of the repeaters showed evidence of corrosion.

The amount of corrosion was sufficient to materially reduce the leakage resistance, which caused arcing and consequent failure of the equipment. Considerable time was required to repair the repeaters and the corrosion condition is liable to recur.

Investigation revealed that the greater percentage of moisture was entering the equipment through a number of screw holes located on the top surface of the repeaters surrounding the PPI scope tube. Approximately twenty-four screws are used to fasten a metal ring with a rubber gasket to the top of the VK repeaters surrounding the PPI scope tube, to prevent moisture from getting into and around the tube. In designing this equipment, however, no precautions were taken to prevent moisture from seeping in through these screw holes, or through the larger screw holes used to mount the range computer and cursor drive unit assemblies.

It is suggested that the corrosion on these units may be decreased by placing rubber grommets and flat washers under each screw head inspected, and through the application of a heavy coat of Glyptal, as a finish to aid in sealing the holes.

ELECTRONIC FIELD CHANGE INDEX

Field Change Number	Field Change Title	Date of Field Change	Serial Numbers of Equipment Affected	Modifying Activity	Man-Hours Req'd	Source of Material	Stock Number of Kit	Instruction Bulletin	Contract Number
TCS-15 Radio Transmitting-Receiving Equipment									
1	Modification of Model TCS Relay Circuit		Not applicable						
2	Modification of Tap Switches	Jan. '46	All	SF	2	Stock	None	CEMB	None
3	Modification of the Loading Coil	Jan. '46	All	SF	1	Stock	None	CEMB	None
4	Replacement of Motors and Generators		Not applicable						
5	Installation of Power Supply Filter CTD-53173 and CTD-53174		Cancelled—Superseded by Field Change No. 9						
6	Type -50159 Noise Limiter Adapter Units	Jan. '46	All	YF	2	Kit		NavShips 900,005—IB & CEMB	NXsr-42133 NXsr-48301 NXsr-65286
7	Installation of TCS Noise Limiter		Cancelled						
8	Replacement of Resistors R-303 and R-304	Jan. '46	All	SF	1	Stock	None	CEMB	None
9	Installation of Radio Interference Elimination Kit	Jan. '46	All	SF	3	Kit			N5ar-799
TCS-16 Radio Transmitting-Receiving Equipment									
1	Modification of Model TCS Relay Circuit		Not applicable						
2	Modification of Tap Switches	Jan. '46	All	SF	2	Stock		CEMB	None
3	Modification of the Loading Coil	Jan. '46	All	SF	1	Stock		CEMB	None
4	Replacement of Motors and Generators		Not applicable						
5	Installation of Power Supply Filter CTD-53173 and CTD-53174		Cancelled—Superseded by Field Change No. 9						
6	Type -50159 Noise Limiter Adapter Units	Jan. '46	All		2	Kit		NavShips 900,005—IB & CEMB	NXsr-42133 NXsr-48301 NXsr-65286
7	Installation of TCS Noise Limiter		Cancelled						
8	Replacement of Resistors R-303 and R-304	Jan. '46	All	SF	1	Stock	None	CEMB	None
9	Installation of Radio Interference Elimination Kit	Jan. '46	All		3	Kit			N5ar-799
TCZ Radio Transmitting Equipment									
1	Replacement of 28-volt Generator Brushes	Jan. '46	All with type 211101 AC Power Units	SF	½	Kits & Stock		CEMB	NXs-491 NXsr-59134 NXsr-59134
2	Removing of Audio Input Ground of Type COL-23410 Remote Control Unit	Jan. '46	All used with standard Navy receivers, such as RBA, RBB & RBC	SF	½	Stock	None	CEMB	None
TCU-1 Radio Transmitting Equipment									
1	Replacement of 28-volt Generator Brushes	Jan. '46	All	SF	½	Kits & Stock		CEMB	NXs-491 NXsr-59134 NXsr-65387
2	Removing of Audio Input Ground of Type COL-23410 Remote Control Unit	Jan. '46	All used with standard Navy receivers, such as RBA, RBB & RBC	SF	½	Stock	None	CEMB	None
TCU-2 Radio Transmitting Equipment									
1	Replacement of 28-volt Generator Brushes		Not applicable						
2	Removing of Audio Input Ground of Type COL-23410 Remote Control Unit		All used with standard Navy receivers, such as RBA, RBB & RBC	SF	½	Stock	None	CEMB	None
TDE Radio Transmitting Equipment									
1	Microphone Modification Kit	Jan. '46	1 thru 256 393 thru 441 448 thru 611 613 thru 880 993 thru 1124 1183 thru 1248 1250 1293 thru 1471 1475	YF	2	Kit	None	Kit & CEMB	NXs-3179
2	Installation of Filament Warm-Up Circuit	Jan. '46	All	YF	3	Stock	None	CEMB	None

Field Change Number	Field Change Title	Date of Field Change	Serial Numbers of Equipment Affected	Modifying Activity	Man-Hours Req'd	Source of Material	Stock Number of Kit	Instruction Bulletin	Contract Number
3	Installation of Improved Range Switch S-307B	Jan. '46	All	SF	2	Kit			NXss-3179 NXss-20802 NXsr-33634 NXsr-38682
	TDE-1 Radio Transmitting Equipment								
1	Microphone Modification Kit		Not applicable						
2	Installation of Filament Warm-Up Circuit	Jan. '46	All	YF	3	Stock	None	CEMB	None
3	Installation of Improved Range Switch S-307B	Jan. '46	All	SF	2	Kit			NXss-3179 NXss-20802 NXsr-33634 NXsr-38682
	TDE-2 Radio Transmitting Equipment								
1	Microphone Modification Kit		Not applicable						
2	Installation of Filament Warm-Up Circuit	Jan. '46	All	YF	3	Stock	None	CEMB	None
3	Installation of Improved Range Switch S-307B	Jan. '46	1 thru 340 372 thru 340 1046 thru 1351	SF	2	Kit			NXss-3179 NXss-20802 NXss-33634 NXsr-38682
	TDE-3 Radio Transmitting Equipment								
1	Microphone Modification Kit		Not applicable						
2	Installation of Filament Warm-Up Circuit	Jan. '46	All	YF	3	Stock		CEMB	None
3	Installation of Improved Range Switch S-307B		Not applicable						
	TDQ Radio Transmitting Equipment								
1	Overload Relay K-303 Change	Jan. '46	All	SF	1	Stock		CEMB	None
2	Model TDQ Transmission Line Filter Type CRV-53232	Jan. '46	1 thru 2881	YF	2	Kit	N16-K-2997	CEMB	NXsr29644
3	Caution Nameplate For TDQ	Jan. '46	All	SF	½	Kit		CEMB	N5sr-14265P
4	Provide Extended Audio Range for Communication Control Link Service	Jan. '46	TDQ transmitters when used in CCL service, provided increased audio bandwidth is required	SF	1	Stock	None	CEMB	None

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CONFIDENTIAL

Diathermy

Television

the SERVANT of MANKIND

Radar

Radio

X-Ray

THOSE of us in the military service of our country have come to look upon ELECTRONICS primarily as a weapon, either offensive or defensive, to be used against any aggressor. However, we should not overlook the tremendous achievements made in other fields such as medicine, astronomy, nuclear physics, manufacturing, etc., directly attributable to the application of electronic principles and equipment. In the field of medicine such apparatus as the X-ray, Diathermy machines, etc. have been used to ease the suffering of mankind and forward the cause of medical research. Likewise in other fields, electronic equipments have been employed to replace manual labor and lessen mental strain, solving intricate problems in only a fraction of the time previously required when accomplished by outmoded methods. TO ELECTRONICS WE OWE THE GREATEST ADVANCEMENTS IN THE HISTORY OF THE WORLD.

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