CHAPTER 3

RADAR SYSTEM INTERFACING

In the previous chapters, we discussed a basic pulse radar system, basic types of radar sets and specific radar equipment used in the fleet. Most every radar we've mentioned can interface with other systems. In this chapter we'll look at some of the systems that use that radar information, such as Identification Friend or Foe (IFF) systems, Direct Altitude and Identity Readout (DAIR) systems, and Navy Tactical Data Systems (NTDS). We will not teach you specific equipment, but *will* help you identify and understand the interface of radar information with the various systems used in the Navy today.

Most of the equipment discussed in this chapter has specific maintenance training available. However, except for certain crypto equipment, you do not need *specific* training to work on the gear. Remember, as an ET, you can become an expert maintainer of ANY electronic equipment.

The first system we'll talk about is Identification Friend or Foe (IFF) equipment, specifically, the AIMS Mark XII IFF system, used by aircraft and surface vessels.

IDENTIFICATION FRIEND OR FOE (IFF) SYSTEMS

IFF equipment, used with search radars, permits automatic identification of targets before they are near enough to threaten the security of a friendly craft. In addition to friendly identification, modern IFF systems also provide other information such as type of craft, squadron, side number, mission, and aircraft altitude.

GENERAL THEORY OF OPERATION

IFF completes the identification process in three basic steps: (1) challenge, (2) reply, and (3) recognition.

Challenge

The IFF interrogator sends a coded *challenge* in the form of pulse pairs. The selected mode of operation determines the spacing between the pulses.

Reply

A friendly target's IFF transponder will automatically *reply* to the coded challenge with an omnidirectional transmission. It sends a different set of pulses at a slightly different frequency than the interrogator frequency. A suppression (blanking) signal keeps your ship's transponder from replying to its own interrogator.

Recognition

The IFF interrogator receives the coded reply and processes it for display on an indicator. *Recognition* of the target is based on the ppi display. The coded reply from a friendly craft normally appears as a dashed line just beyond the target blip, as shown in figure 3-1.

The identification process uses two sets of IFF equipment, the interrogator set and the transponder set. A ship may have one or more interrogator sets, but will have only one transponder set. Normally, interrogators and transponders aboard ships function independently.

Interrogator

The IFF interrogator operates like a radar transmitter and receiver. It uses a small directional antenna either attached to or rotated in synchronization with the air search radar antenna. The modulator of the search radar set provides synchronization triggers for the IFF interrogate.

When processing replies for display, the IFF interrogator uses the time lapse between the transmission of a challenge and the reception of a reply to determine range. The synchronized antenna information provides the correct bearing.

A high output power is not required for the one-way trip to the target taken by the transmitted pulses, so the IFF interrogator can operate at low peak power (1 to 2 kilowatts).

Transponder

The IFF transponder is a receiver-transmitter combination that automatically replies to a coded

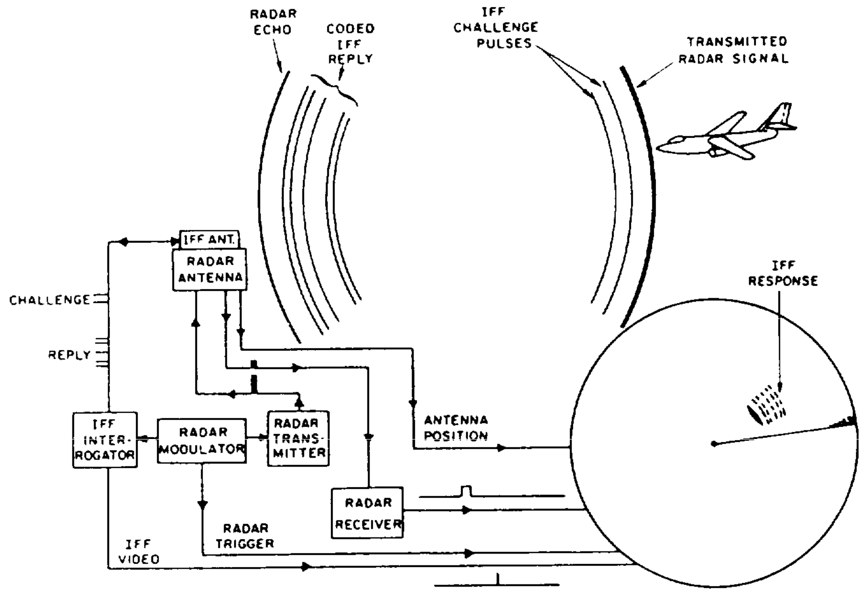

Figure 3-1.—Fundamentats of IFF operation.

challenge. The receiver section receives and amplifies signals within its bandpass and decodes the challenge signals. Reception of correctly coded challenge signals will automatically key the transmitter section to send prearranged reply signals on a different frequency.

In times of hostility, safe or unsafe transit through a particular area could depend on how well your IFF is operating. It's not very safe to approach another ship in a hostile area without being able to identify yourself as a friendly target. Also, being without an IFF that can identify the targets on your radar screen puts your Tactical Action Officer (TAO) at a disadvantage. Therefore, your understanding of IFF operation and maintenance is extremely important.

AIMS MARK XII IFF SYSTEM

AIMS is an acronym for an *air traffic control radar beacon system (ATCRBS), identification friend or foe (IFF), Mark XII system*. ATCRBS designates the civilian air traffic control system used for air control worldwide. IFF identities military systems. The AIMS system includes equipment such as interrogators, transponders, decoders, interrogator side lobe suppression (ISLS) switches and drivers, defruiters, and crypt computers.

Modes of Operation

The Mark XII system can challenge in five different modes (1, 2, 3/A, 4, and C), each with a specific function. The video decoder unit, associated with a specific indicator, provides control signals that the interrogator uses to send challenges and decode replies in the various modes. As we mentioned in chapter 2, when the operator has multi-radar inputs available, the radar distribution switchboard routes the control signals to the correct interrogator unit.

SIF MODES.— Air traffic control and code monitoring for friendly aircraft and surface craft use selective identification feature (SIF) modes (modes 1, 2, and 3/A). Challenges in these modes consist of two pulses spaced at a characteristic interval for each pulse, with a third pulse added for ISLS operation, as shown in figure 3-2.

For SIF modes, the transponder reply is a binary code contained between two bracket (framing) pulses. Framing pulses are present in every reply, regardless of code content. Each reply code corresponds to a unique 4-digit decimal code. For each mode, the user dials the desired reply code into the transponder using thumbwheel switches. Mode 1, 2, 3/A, and C replies, by themselves, cannot be separated according to mode. The interrogator, knowing in which mode it has challenged, separates and identifies the replies with the proper mode.

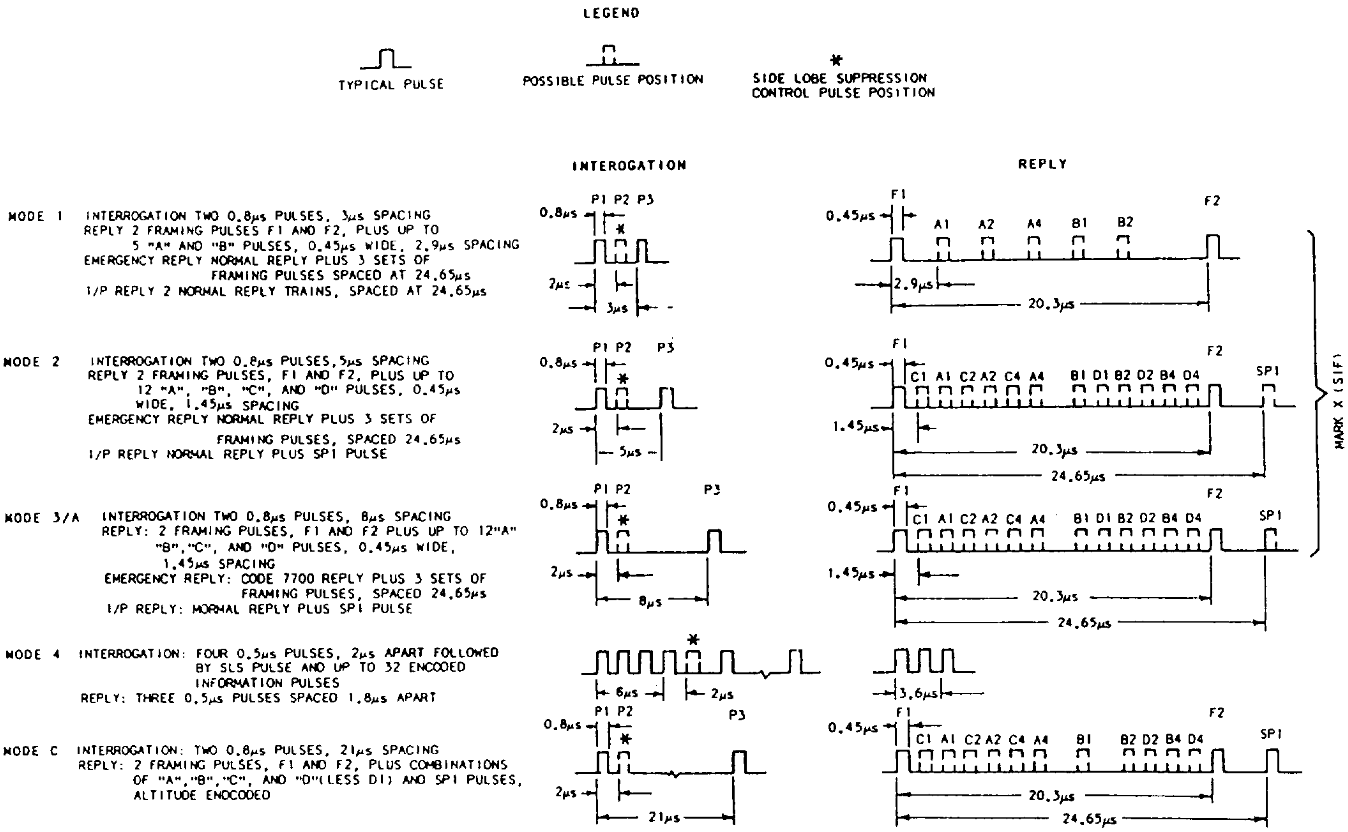

Figure 3-2.—AIMS Mark XII IFF interrogations and replies.

When desired, a transponder may send an identification of position (I/P) reply to mode 1, 2, or 3/A interrogations. This reply, when decoded, marks on the indicator a particular aircraft with which the system operator has voice communications.

A pilotless aircraft containing a transponder transmits an X-pulse reply when responding to SIF mode interrogations. This is a normal mode reply with an additional pulse occupying the center position of the reply train.

Mode 1.— Mode 1 operation, set at the control box C-6280, is for military use only. The first digit of the reply code must be a number from 0 to 7. The second digit must be a number from 0 to 3. The remaining two digits will normally be 0. Military emergency replies (called 4X or four train emergencies) include the normal reply plus 3 sets of framing pulses for both modes 1 and 2.

Mode 2.— Mode 2 operation, set in at the transponder unit, is also for military use only. In mode 2 and 3/A reply codes, each of the four reply digits can have any value from 0 to 7.

Mode 3/A.— Mode 3/A operation, also set at the control box, is available for military or civilian use. Mode 3/A military emergency replies consist of a combination of 4X and 7700 codes. Civilian emergency replies use just the 7700 code. A 7600 reply code, for both military and civilian use, indicates a failure in radio communications. A 7777 reply code is assigned to interceptors on active air defense missions. Any transponder sending replies to mode 3/A with codes of 7500, 7600, 7700, or 7777 will trigger an alarm at nearby FAA towers.

The FAA's nationwide computer network tracks all assigned mode 3/A codes. The Department of Defense is assigned four mode 3/A code blocks (50XX, 54XX, 61XX, 64XX) for use within U.S. national air space.

A conflicting signal from your ship could cause havoc for both local and national air control functions. The mode 3/A code assigned to your unit during an operation is probably not a code authorized for military use in national airspace. It may even be the same as one assigned to a commercial flight. To avoid problems with air control, keep mode 3/A off the air when your ship is in port or coastal waters.

MODE 4.— Mode 4 operation is for military use only and allows for secure identification of friendly aircraft and surface vessels. IFF automatically generates a reply code according to a preset crypto key list. As shown in figure 3-2, mode 4 interrogations use encoded, multipulse trains with 4 (sync) pulses and an ISLS pulse, followed by up to 32 information pulses.

When the transponder receives and processes a valid mode 4 interrogation, it sends out a time-coded, three-pulse reply. The interrogator converts the valid mode 4 reply back to one pulse. The reply is then time decoded before it is presented on the indicator. There are no emergency replies for mode 4 or mode C.

MODE C.— Mode C replies used by civilian and military aircraft indicate aircraft altitude and are taken automatically from the aircraft's barometric altimeter. Mode C interrogations are the same as those for SIF modes. Replies are binary codes contained between bracket pulses similar to those for SIF modes.

The reply, derived from an encoder linked to the aircraft altimeter, may represent any altitude from -1,000 feet to +126,700 feet in 100-foot increments. Shipboard transponders are wired to reply to mode C interrogations with bracket pulses only (code 0000).

Commercial aviation has implemented the Traffic Alert and Collision Avoidance System (TCAS), which uses a low-power mode C interrogator-processor. Using mode C altitude reports, it computes the closest point of approach (CPA) to other aircraft and displays the information as an overlay on the weather radar indicator. General aviation aircraft flying below 12,500 feet reply to mode C with empty brackets (code 0000), the same code used by Navy ships.

TCAS cannot distinguish between replies sent by your ship and those sent by small aircraft. It assumes that a mode C target is at the same altitude as itself if no altitude is reported. Therefore, your ship's mode C reply can set off a projected collision alarm in the cockpit of an arriving or departing airliner, causing the pilot to make unnecessary and dangerous maneuvers. Since this situation is a great threat to air safety, your transponder's mode C should always be secured in or near port, unless you are testing the unit, with the antenna disconnected.

Equipment Components

As we mentioned earlier, the interrogator and transponder sections of the AIMS Mark XII IFF operate independently of each other. In the following paragraphs, we'll discuss each section, beginning with the interrogator section.

INTERROGATOR SECTION.—The major units of the interrogator section (except the video decoder group) are usually mounted in a rack located in the radar equipment room, as shown in figure 3-3.

A simplified block diagram of the interrogator section is shown in figure 3-4. The **Interrogator Set AN/UPX-23,** provides rf challenges for the various modes. It also receives transponder replies and processes them into proper video signals for application to the decoders and indicators.

The **pulse generator** provides IFF system pretriggers that initiate challenges for the enabled modes. In a "slaved IFF system," associated with a specific radar, the pulse generator synchronizes the interrogations with the radar. In a "black IFF system," not associated with a radar, it produces triggers internally.

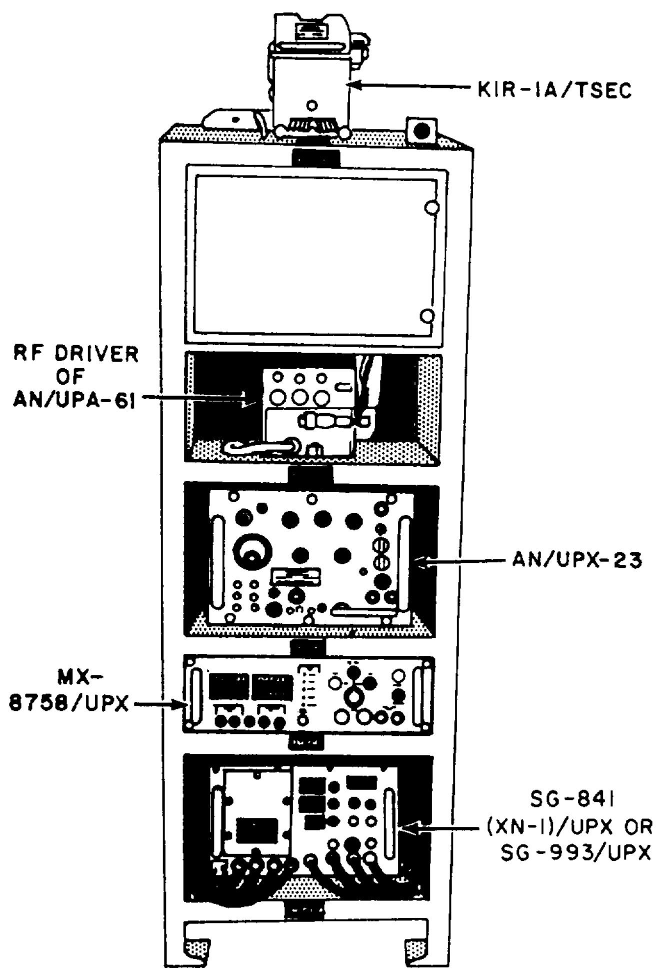

Figure 3-3.—Mark XII IFF interrogator equipment.

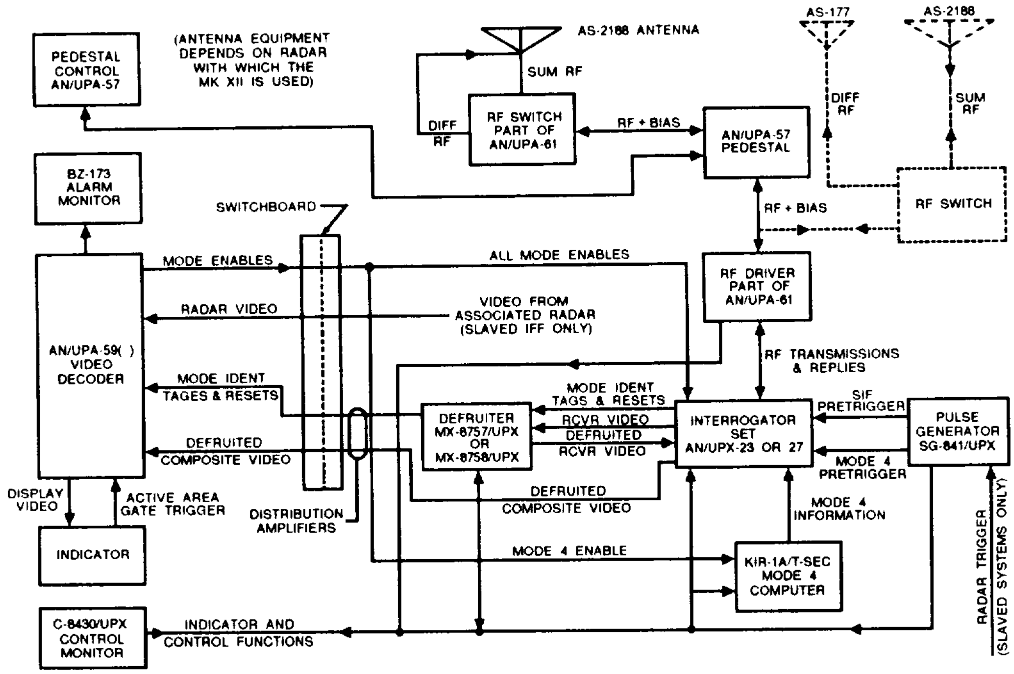

Figure 3-4.—Mark XII IFF system interrogator station.

The **Computer, KIR-1A/TSEC,** encodes mode 4 challenges for transmission by the interrogator. It also decodes the received mode 4 transponder replies. The code changer key, TSEC/KIK-18, inserts the mode 4 code into the computer.

The **Video Decoder, AN/UPA-59(),** has various configurations. The most common configuration uses a video decoder, an intra-target data indicator, and an alarm monitor.

The *video decoder* provides control signals that the interrogator uses to display challenges in the various modes. It also decodes and processes reply video (mode 4 video goes directly through without processing) and provides video output to the indicator. The video decoder will accept radar video from an associated radar and route it, with or without IFF video, to the indicator for display. An *intratarget data indicator* plugs into a receptacle in the decoder's front panel. It provides readouts of reply codes for modes 1, 2, and 3/A and direct altitude readouts for mode C. The *alarm monitor* contains a loud speaker and indicator lights to provide audible and visual alarms when IFF emergency signals are decoded.

The **defruiter** can be one of two types of interference blankers. The MX-8757/UPX is a four-channel type, using one channel per mode for modes 1, 2, 3/A, and C. The MX-8758/UPX is a one-channel type, using one channel for all modes. Both units remove nonsynchronous transponder replies (fruit) and receiver noise from IFF video.

The **control monitor** functions as a remote control and remote monitor for the interrogator section. The front panel of the control monitor is shown in figure 3-5.

The **Switch and Driver, AN/UPA-61,** provides ISLS operation for the Mark XII system. Targets at close range may reply to side and back lobes, as well as to the main antenna beam. This could cause a target to appear for nearly 360 degrees close to the origin of the display, a phenomenon known as "ring-around." ISLS prevents ring-around by inhibiting transponder replies to side lobes.

The **Antenna Pedestal Group, AN/UPA-57,** can operate in any of three modes: slaved to a radar system, self-synchronous, or manually. It consists of a manual pedestal control unit, a control power supply unit, an antenna pedestal assembly, and a pedestal disconnect mast switch.

The *manual pedestal control* is usually located at the ppi. The front panel controls allow the selection of free run, slave, or manual operation. The *control power supply unit,* located below decks, develops all power required for the antenna pedestal group. In the free run operation mode, the power supply unit can rotate the pedestal assembly at up to 15 rpm. When slaved to a

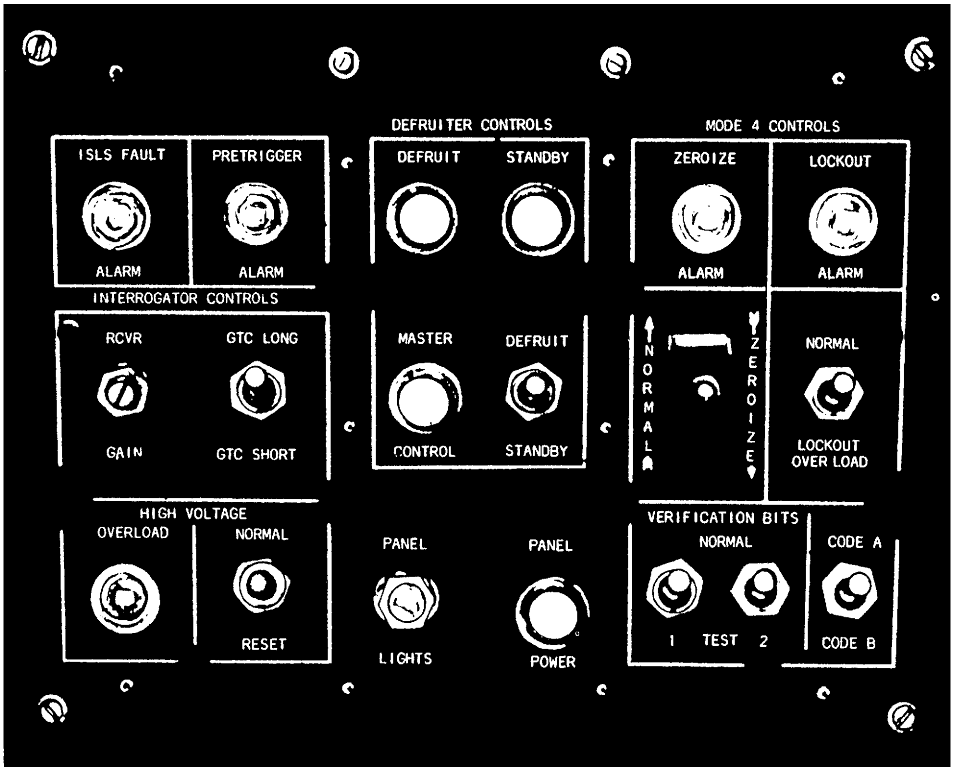

Figure 3-5.—Control monitor front panel.

radar, it can accommodate rotation rates from 2 to 30 rpm, receiving radar synchro information via the radar switchboard. In the manual mode, it can position the antenna to any azimuth directed from a remote position. The *antenna pedestal assembly* can mount the AS-2188( )/UPX or any other 10-foot antenna designed to mount on the same platform. The *pedestal disconnect mast switch*, located above decks, removes all power from the pedestal assembly.

The selection of system antenna equipment depends on which radar is using the Mark XII system. For installations where the rotary joint will not pass the switching bias, the AS-2188( )/UPX will transmit a sum pattern only, with a separate AS-177( )/UPX omnidirectional antenna transmitting the difference rf. Some installations use an integral antenna to transmit and receive both radar and IFF signals, with difference rf transmitted on a separate AS-177( )/UPX antenna.

TRANSPONDER SECTION.—The transponder receives interrogation pulses and, in turn, generates the proper reply pulses. A simplified block diagram of a typical shipboard transponder section is shown in figure 3-6. As we discussed before, desired reply codes are set by thumbwheel switches for modes 1, 2, and 3/A; ships are wired for code 0000 mode C replies. Mode 4 replies are coded automatically according to the crypto key installed in the TSEC/KIT-1A.

The organizational-level maintenance of the Mark XII IFF system is performed by ETs (NEC ET-1572). You must have formal training or written permission from your commanding officer to work on the TSEC/KIR-1, TSEC/KIT-1, or TSEC/KIK-18 crypto units.

The *AIMS Newsletter*, published by Naval Electronic Systems Engineering Activity (NESEA) St. Inigoes, Maryland, provides information to shipboard technicians and operators on AIMS systems, primarily Mk XII IFF and its related subsystems. It keeps you up to date on any equipment modifications, PMS changes, and significant interface problems. It also gives you an AIMS hotline number to use if you have any questions or problems concerning maintenance or operation of Mk XII IFF equipment. You can find more information on this publication in ET, Volume 2, *Administration*.

Agreements between the Navy, Air Force, and FAA, under the AIMS program, required the development of a system to present ATCRBS data instantly, in symbolic and numeric form, directly on the indicator, and superimposed over live radar video. The AIMS Mark XII IFF system does this for ships. Under the AIMS

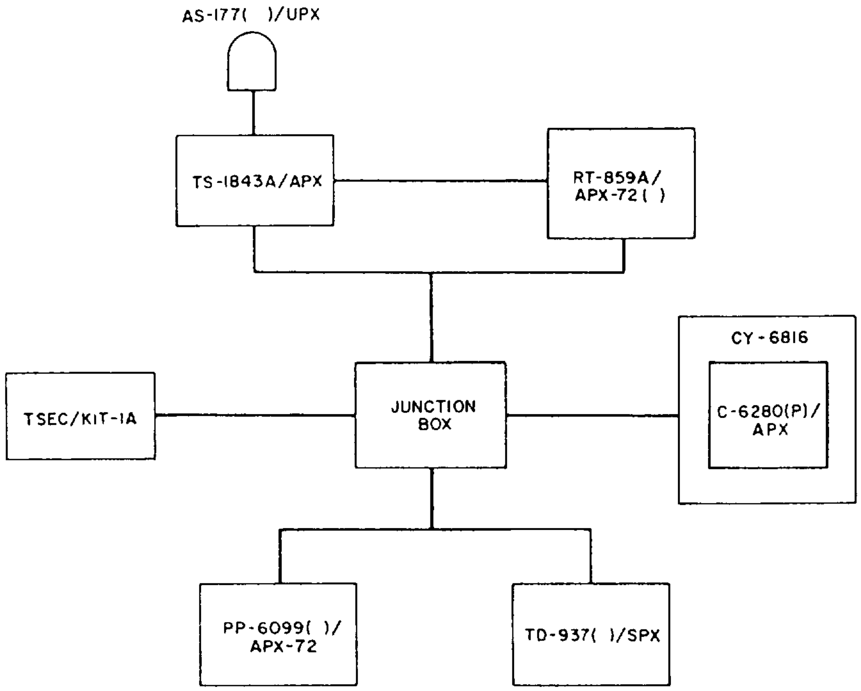

Figure 3-6.—Typical shipboard Mark XII transponder section.

program, the Navy, Air Force, and FAA further agreed on specifications for a ground/shore-based configuration called the DAIR system.

DIRECT ALTITUDE AND IDENTITY READOUT (DAIR) SYSTEM

The DAIR air traffic control system provides several different types of configurations for different user requirements. They are as follows:

- Type 5, DAIR
- Type 10, Radar Air Traffic Control Facility (RATCF) DAIR
- Type 8, Carrier Air Traffic Control Center (CATCC) DAIR
- Type 12, Amphibious Air Traffic Control (AATC) DAIR
- Type 13, Shipboard DAIR.

The Navy Training Plan (NTP) for the Type 13 system is currently being reviewed for approval. This shipboard DAIR system is scheduled to replace all Type 8 and Type 12 systems in the fleet; however, there is currently no confirmed time for the conversions. We will include the specifics of this system in the first revision of this volume after the NTP is approved and an installation schedule is set. In the meantime, if you would like to find out more about the Type 13 system, contact the instructors who teach the DAIR systems at the Naval Air Technical Training Center, NAS Memphis, Millington, TN.

All the types of DAIR systems use an operator (or a team of operators) to control air traffic via display devices. Each operator gathers and assembles information by monitoring and operating display devices. The operators use this information to control air traffic within a given area.

DAIR (AN/TPX-42A(V)5)

AN/TPX-42A(V)5 gives the air traffic controller rapid, positive identification and altitude data on transponder-equipped aircraft. It is used for ground-controlled approach at shore installations, such as Naval and Marine Corps air stations (NAS, MCAS), radar operational facilities (ROF), and radar air traftlc control facilities (RATCF). At expeditory airfields, the AN/TPX-42(V)5, in a transportable shelter with ASR, is used by Marine Air Traffic Control Squadrons (MATCS). This system operates with a primary radar. The radar supplies synchronizing triggers and azimuth data to the system. The DAIR information is superimposed on the primary radar video.

All the equipment for the DAIR system, except antennas, is installed in remote shelters, vans, control rooms, and equipment buildings. Depending on the requirements of the site, a variety of configurations could be used.

RATCF DAIR (AN/TPX-42A(V)10)

RATCF DAIR is used at major shore installations to increase the capability of the AN/TPX-42A(V)5 interrogator system. This programmable system retains all the features of the DAIR system and modifies the signal-processing chain. The use of computer-processed data increases controller efficiency and traffic handling capability. Some of the RATCF DAIR new capabilities include:

- Automatic tracking of emergency targets
- Audible and visual alarm when an aircraft descends below a preselected minimum altitude
- Altitude monitoring with an alarm when targets stray 300 feet from controller-assigned altitude
- Semi-automatic handoff and exchange of flight data between operators and facilities

RATCF DAIR offers an expanded display and aircraft tracking capability and impacts other radar systems in the same way as DAIR The RATCF DAIR interfaces with FAA enroute centers, ARTS facilities, Air Force PIDP facilities, and other RATCF DAIR facilities.

CATCC DAIR (AN/TPX-42A(V)8)

The AN/TPX-42A(V)8 is designed for air traffic control aboard aircraft carriers. Its radius of coverage can extend to 200 nautical miles, although air traffic controllers are responsible only out to 50 nautical miles. Controllers cover their area of responsibility using the alphanumeric display of flight identity, altitude, and other pertinent information provided by this system and superimposed over primary radar video.

The CATCC DAIR system accepts trigger and azimuth data from several shipboard radars. It also accepts ship's data such as speed, heading, position, clock time, and barometric pressure and displays them in a tabular list on the controller's indicator. The system automatically computes the final bearing and displays it as a vector on the indicators.

A controller can put flight information into the system, via a keyboard, up to 24 hours before aircraft take-off or recovery. The system automatically tracks aircraft (using beacon response), matching each aircraft with the proper identification data from the flight data tabular list. As each aircraft leaves the controller's area of responsibility, its track is passed to another CATCC control position, CIC, or ACLS/PALS as appropriate.

Some of the significant operating capabilities of the CATCC DAIR system include:

- Automatic tracking and alphanumeric identity of selected aircraft by aircraft side numbers
- Independent radar selection by position
- The ability to accept NTDS map or to draw anew or modified map from a keyboard
- Independent maintenance modes for displays with computer-driven maintenance patterns
- Built-in Test Equipment (BITE) with computer-assisted diagnostics

Figure 3-7 shows a typical CATCC DAIR system interface diagram. CATCC DAIR interfaces with many systems including:

- NTDS
- Keyset Central Multiplexer (KCMX)
- ACLS/PALS
- IFF
- RD-379 recorders
- Radar switchboards

CATCC DAIR equipment is installed in the CY-7567 electrical cabinet and the MT-4939 and MT-4940 electrical equipment racks located in the auxiliary radar room. The CATCC operations room has 5 indicator-control groups and 5 keyboard controllers, including the emergency IFF/radar switch.

AATC DAIR (AN/TPX-42A(V)12)

The AATC DAIR system is designed for air traffic control aboard LHA, LPH, and LHD amphibious ships. Display capabilities are similar to those of CATCC DAIR, but new equipment and software programs provide capabilities needed for amphibious operations. The controller is provided the identity, altitude, and status of IFF-equipped aircraft within the amphibious objective area (AOA). Information such as Air Plan Lists and ship's data are also available for display on the controller's console. AATC DAIR uses the IFF beacon as a primary means of target detection and tracking, but

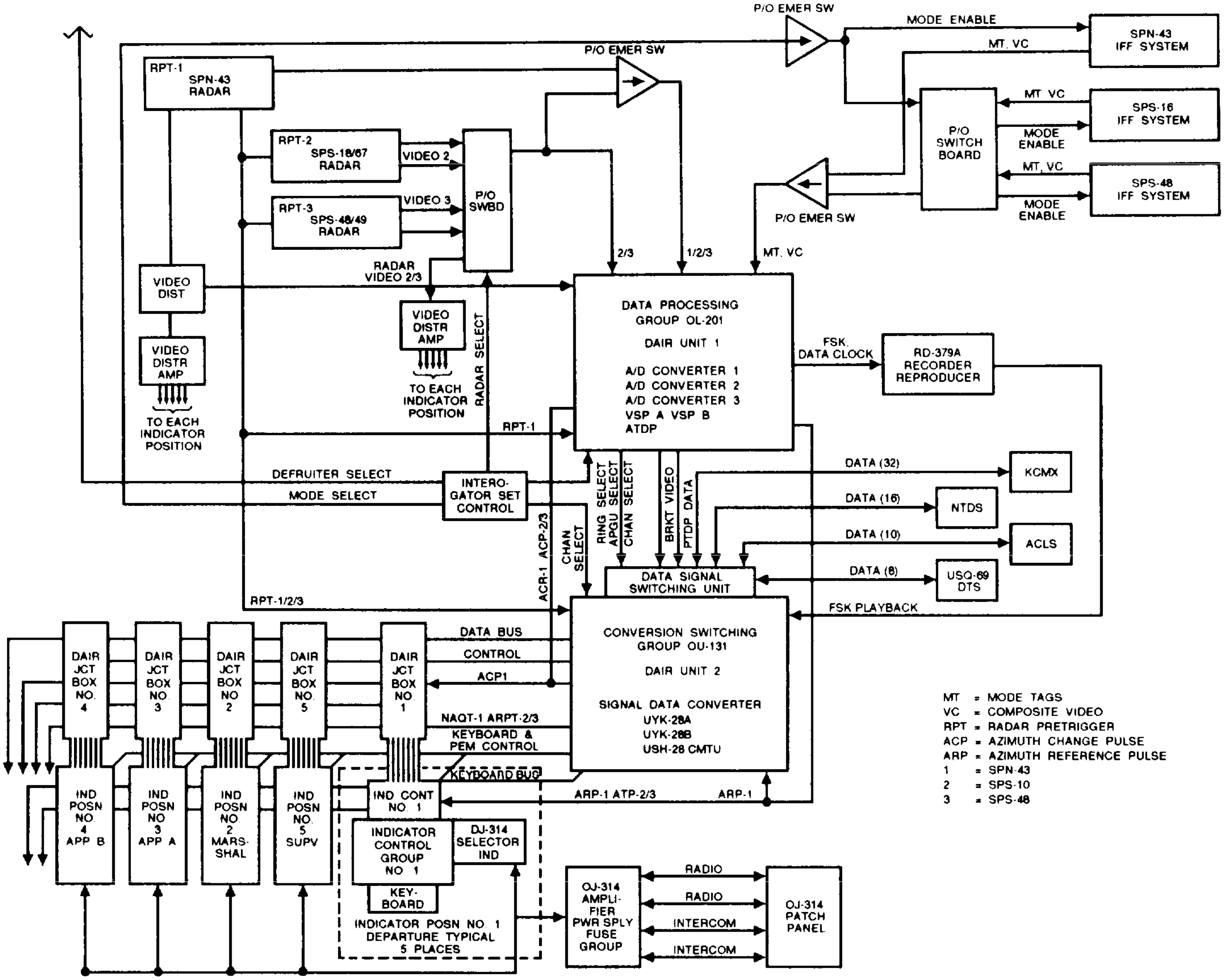

Figure 3-7.—CATCC DAIR system interlace block diagram.

also incorporates primary radar track processing as a backup.

The AN/TPX-42A(V) 12 does not replace any existing system. On amphibious-type ships, 4 indicator control groups (consoles) are located in the Helicopter Direction Center (HDC). Additional consoles are located in the Tactical Air Control Center (TACC) on LHA- and LHD-type ships. To accommodate the installation, some existing consoles may be removed from these locations, but no system is replaced. Field change kits will update currently installed CATCC DAIR systems on CV- and CVN-type ships to the (V)12 configuration.

The AATC DAIR interfaces with the same systems as CATCC DAIR, with the following additional interface capabilities:

- Integrated Tactical Amphibious Warfare Data System (ITAWDS)
- Shipboard Data Multiplex System (SDMS)

MAINTENANCE

The organizational maintenance for the DAIR systems is done by ETs (NEC ET-1574 for DAIR, ET-1576 for CATCC DAIR, ET-1576 with 2 weeks of difference training for AATC DAIR, and ET-1578 for RATCF DAIR). You will perform both on-line and off-line tests and alignment, system operational checks and adjustments for CATCC and AATC DAIR, and periodic inspection, verification and cleaning of certain equipments in RATCF DAIR. By using BITE for on-line fault isolation, you will be able to isolate faults to discrete components and, in some cases, to a set of several digital cards. You'll complete most repairs by removing and replacing discrete chassis components, modules, or digital circuit cards.

The Air Force performs depot-level maintenance on DAIR equipment under a joint maintenance task agreement; however, the contractor will repair all CATCC- and AATC DAIR-unique items at the depot level. Return the items that you can't repair to supply. They'll know where to send them.

All the systems we've discussed so far are the maintenance responsibility of the ET rating. The next system, NTDS, is maintained by several ratings. As we explained in ET, Volume 3, *Communications Systems*, the only way to ensure optimum operation of the NTDS system is to work closely with the other ratings involved.

NAVAL TACTICAL DATA SYSTEM (NTDS)

ET, Volume 3, addresses the NTDS tactical communications data system. In this volume, we will address the tactical radar section. The NTDS computer-centered control system coordinates the collection of data from various sources. It accepts data from ship's sensors, such as radar, sonar, and navigation inputs, and from external (off-ship) sources via communications links. It also processes and correlates this data for tactical use.

GENERAL THEORY OF OPERATION

NTDS accomplishes its objectives in real time; the system receives data from various sensing devices that are in continuous contact with the outside environment. It uses this data to evaluate an event as it happens. How often the system requires an update will determine the rate of sampling for each sensing device. The concept of standard computers operating in conjunction with each other to increase capacity and functional capability is known as the "unit computer concept." It is basic to the design philosophy of NTDS. A diagram of a typical NTDS equipment grouping is shown in figure 3-8.

NTDS integrates all systems and subsystems for performing the basic combat system functions including:

- Detection and entry
- Tracking and identification
- Threat evaluation and weapon assignment
- Engagement and engagement assessment

The NTDS system accomplishes its varied tasks by receiving, storing, and processing the data inputs from the other systems and subsystems. The operational program then distributes the processed data as usable inputs for other systems and subsystems. The data display also allows the operator to interact with the system.

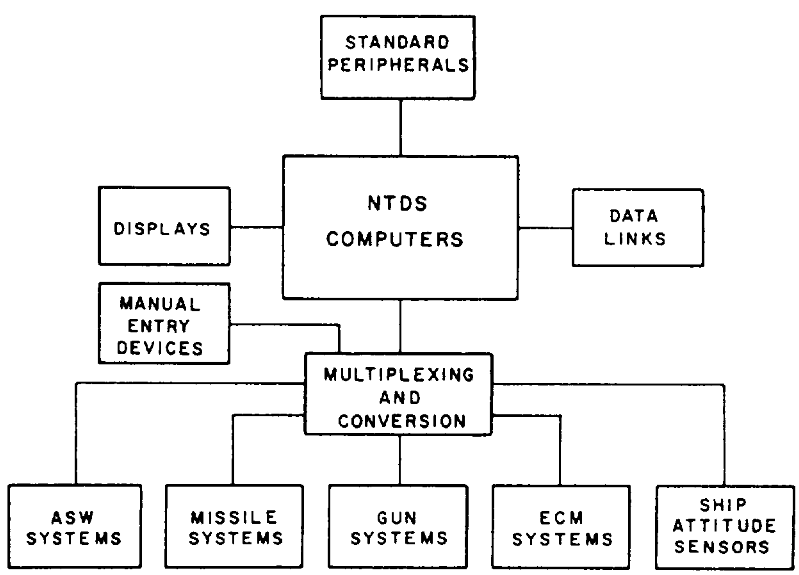

Figure 3-8.—NTDS equipment grouping.

MAINTENANCE

As an ET, you are responsible for maintaining the radar, antenna, video and sync amps, and radar switchboard, plus any associated equipment directly connected to this group.

All ships with NTDS have a *Combat Systems Technical Operations Manual* (CSTOM). The CSTOM documents the total integrated combat systems concept; you will find it a useful guide regarding communications, radar, and NTDS as a whole integrated system.

The CSTOM organizes the technical data associated with the integrated combat system, providing information required to both operate and maintain the system. It defines significant capabilities and limitations of the system, and even outlines requirements for maintaining material and personnel readiness for the system. The publication is structured as follows:

VOLUME 1—COMBAT SYSTEMS DESCRIPTION

VOLUME 2—OPERATIONAL SEQUENCES

VOLUME 3—COMBAT SYSTEM READINESS

VOLUME 4—CAPABILITIES AND LIMITATIONS

As you may imagine, with such an all-encompassing system, troubleshooting may take you beyond ET lines of maintenance responsibility. If the system has a problem, you should be aware of what the FCs, or DSs, or ICs are doing. Your expertise on the radar or the radar distribution switchboard may help prevent them from wasting their time. Being aware of what other ratings are doing also will allow you to become more familiar with other equipment and more knowledgeable about what could affect your equipment.

Regardless of your technical knowledge on a piece of gear, you must know the safety requirements associated with that gear before you work on it. In the next chapter, we will discuss safety aspects that are specific to radar maintenance.