Japanese data link

J.P. Gillen

Time-Division Data Link (TDDL) equipments have been developed for the Japanese Air Self Defense Forces to be used in Japan's BADGE (Base Air Defense Ground Environment) system. These programs have been coordinated with, and approved by, the U.S. Department of Defense to extend and strengthen allied Far East Air Defenses. A fall-out from these design programs has been the transfer of manufacturing technology to Japan through RCA licensing agreements with Japanese manufacturers for state-of-the-art military equipment configurations.

SINCE 1964, the Government Communications and Automated Systems Division has been providing to the Japanese Air Self Defense Forces (JASDF) equipments designed for ground-to-air digital data communications in Japan's Base Air Defense Ground Environment (BADGE) system — the air defense umbrella for the Japanese homeland archipelago. The BADGE system coordinates the detection, tracking and identification of enemy air penetration and then via digital data communication directs interceptor aircraft to an optimum tactical intercept location in countering the detected threat.

RCA had been a prime participant with JASDF and the United States Air Force (USAF) in establishing the digital data communication standards for the original BADGE system implementation. To insure operational compatibility of communications equipment on-board the interceptor aircraft with the BADGE system, close coordination between JASDF, USAF, aircraft manufacturers, and RCA was required to define system and equipment configuration requirements. Detailed definition of these requirements provided a solid base for equipment design and manufacture with minimum problems encountered in achieving the desired compatibility during flight test and subsequent operational usage.

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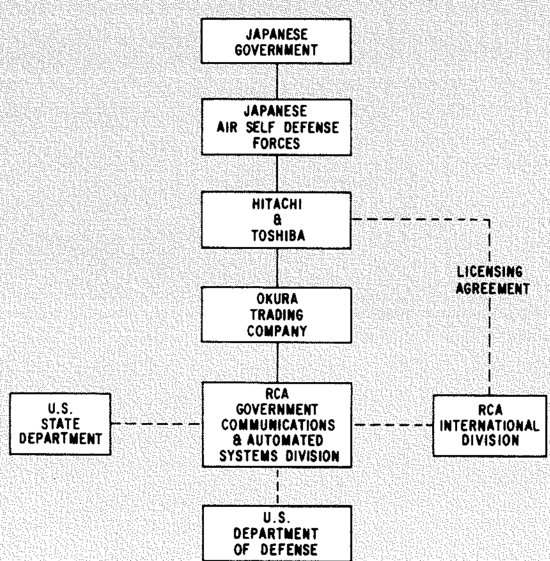

Fig. 1 — Equipment procurement channel for Time Division Data Link (TDDL).

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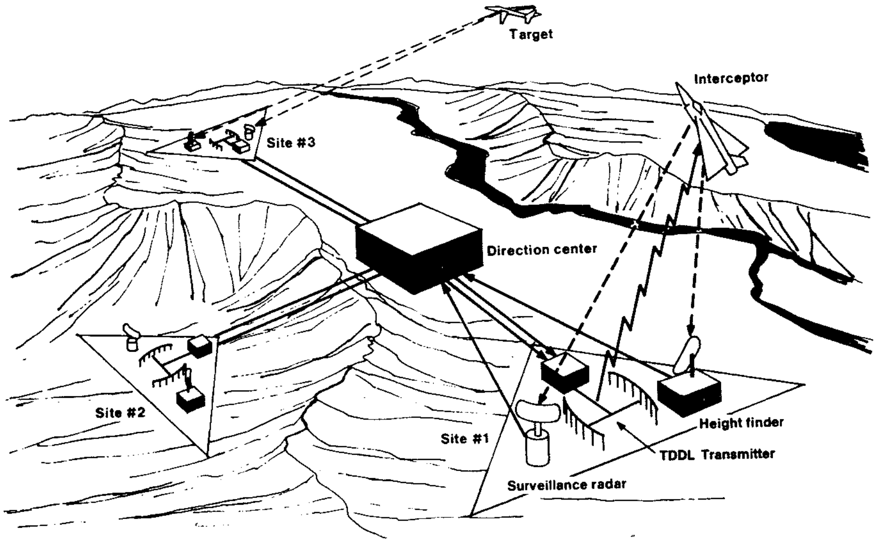

Fig. 2 — Typical BADGE direction center and communications complex.

Military equipment procurement for the BADGE system from a United States manufacturer is accomplished by the Japanese Government through a Japanese industry military equipment supplier selected by the Japanese Government with import arrangements conducted by an indigenous trading company. Equipment export arrangements are controlled by the U.S. State Department, and equipment manufacture is under the surveillance of the U.S. Department of Defense. The equipment procurement channel shown in Fig. 1 indicates the Japai se Government selection of the Hitachi and Toshiba Corporations for procurement of RCA designed communications equipments ınd subsequent manufacture of these equipments in Japan. After initial production at GCASD in Camden to establish manufacturing assembly and test processes, the transfer of RCA production know-how to Hitachi and Toshiba is arranged under separate licensing agreements between the Japanese companies and RCA International .

BADGE system

The Japanese BADGE system consists of stategically located ground control centers, which are interconnected for transf r of tactical information in provi ng for timely interception of airborne enemy threats.

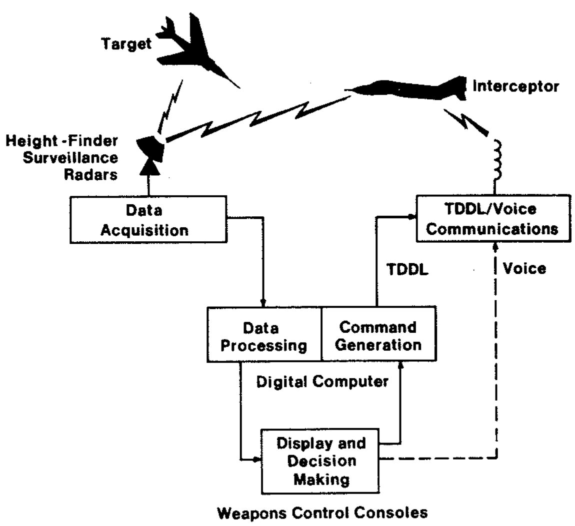

Fig. 3 — Information flow during TDDL mission.

The functional operation of a typical BADGE ground-control radar direction center and communication complex is shown in Fig. 2. Surveillance and height-finder radar data of targets and interceptors are sent to the direction center where a computer provides optimum flight path information to direct the interceptor aircraft. The interceptor command flight path information is sent from the direction center in digital format for transmission by the remote Time Division Data Link (TDDL) transmitter. The ground-to-air TDDL messages contain command tactical information for the interceptor along with range, bearing, and altitude of the target. The typical airborne TDDL equipment receives, demodulates, and processes these message which are then converted for the radar tactical display to assist the pilot in target intercept.

System description

The basic control mode of the BADGE system is Time Division Data Link (TDDL), an automatic ground-to-air communications system using digitally coded radio transmissions. When functioning in a given operational sector, TDDL uses a single uhf channel. Within the sector, time is divided into discrete intervals and a single TDDL message is transmitted to a given aircraft using any one time interval. Each message is coded for, and received by, only one aircraft; and since only one message is transmitted at a time, multi-site transmission on a single frequency provides coverage of a large sector of operation. The duration of each message is so short that messages can be transmitted to hundreds of aircraft in less time than one voice message to a single aircraft.

TDDL messages are transmitted from complex ground control centers, which are needed to maintain control over large numbers of high speed interceptor aircraft in a large volume of airspace. In operation, all of the ground systems contain the data acquisition, data processing, and data transmission functions shown in Fig. 3. The data acquisition function includes radar equipment needed to detect, track, and identify all aircraft. The data processing function automatically processes, stores, and updates the acquired data and computes intercept commands. The data transmission portion transmits data-link command information to the TDDL-equipped aircraft. In a typical intercept

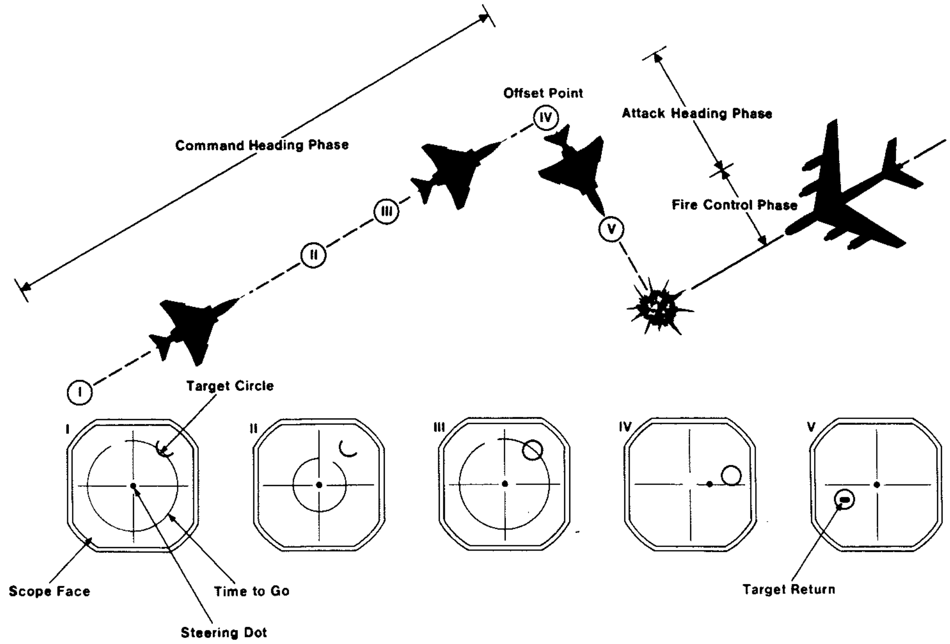

Fig. 4 — Radar display for typical TDDL mission.

mission, the following information is transmitted via data link and is processed and displayed on aircraft instruments.

Aircraft information	*Target information*
Command heading (before turn)	Target altitude
Command altitude	Target range
Command speed	Target relative bearing
Time-to-go (to turn)	
Attack heading (after turn)	

The TDDL mission directs the interceptor aircraft through a command heading phase, an offset point, and an attack heading phase to a location where the interceptor pilot can make radar and/or visual contact with the enemy threat and then execute the appropriate tactical approach. A typical TDDL mission intercept path and associated radar displays are illustrated in Fig. 4.

The ground-control centers transmit data link message to many different aircraft simultaneously on a time division basis since each message requires only 14 ms for transmission. TDDL messages are binary coded by the ground-control stations and consist of 70 bits of data. Each message contains 13 bits representing the aircraft address — 8 bits (256 combinations) define the squadron to which a particular aircraft is assigned, and 5 bits (32 combinations) designate the individual aircraft; 8192 discrete address combinations are available. If two or more TDDL-equipped aircraft are flying the same mission in formation, they may be assigned the same address, and can be controlled by a single data-link transmission. The object of the ground control system is to direct the interceptor aircraft to a point in space relative to the target where the interceptor can achieve radar or visual target acquisition and can successfully complete the mission.

An operational region, in which the aircraft receives data link messages, may comprise an entire ground environment or may be a section of larger ground environment. Time is divided into discrete intervals within the operational region. A single message is transmitted by a single transmitting site to a given aircraft during any one time interval. Depending upon the position of the aircraft at a particular instant, messages are received from the ground control equipment that is operating in the associated operational region. Two types of operation are used depending upon the size of the operational region and the range of the transmitter. Single-site operation is used when line-of-sight transmission provides sufficient range to cover the operational region and multisite operation is used when the operational region cannot be covered by line-of-sight transmission from a single transmitter.

A typical single-site transmission (Fig. 5) shows how all messages are sent in sequence on a single uhf channel. For example, assume that four different aircraft are within an operational region and that seven messages are to be transmitted to these four aircraft. As seen in Fig. 5, the seven messages are transmitted sequentially. Each message, in addition to containing the desired information, contains a binary-coded address which corresponds to one aircraft. Thus, all

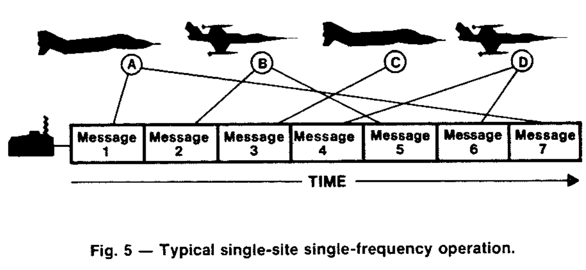

Fig. 5 — Typical single-site single-frequency operation.

messages that are transmitted are received by all four aircraft. However, only the aircraft with the address, corresponding to the message address, processes the received data. Since messages 1 through 4 are transmitted to different aircraft, each message contains a different address. Messages 5, 6, and 7 contain the same addresses as messages 2, 4, and 1, respectively. Messages 1 and 7 are transmitted to aircraft A, messages 2 and 5 to aircraft B, message 3 to aircraft C, and message 4 and 6 to aircraft D — all in a time sequence by the single transmitter.

When the operational region cannot be covered by line-of-sight transmission from a single ground TDDL transmitter site, multiple-site operation provides for complete coverage with a single uhf channel. In multi-site operation, the originator of the message is able to select the TDDL transmitter site closest to the aircraft for which the message is intended. During the next time interval, another site may be selected to transmit a message to a second aircraft. A typical example of multi-site operation (Fig. 6) shows how messages 1 and 7 are transmitted to Aircraft A by transmitter I, messages 2 and 5 are transmitted to aircraft B by transmitter II, message 3 to aircraft C by transmitter III, and message 4 and 6 to aircraft D by transmitter III.

The airborne receiver detects, decodes, checks, and stores the message data which is then processed to generate information displays for the pilot. The airborne portion consists of the antenna system, receiver, converter/coupler, power supply, and cockpit control unit. These items are coupled to the radar in the aircraft, which displays the various items of the data message to provide the pilot with the required flight-control information.

TDDL ground-to-air message structure

Each TDDL message consists of 70 message time slots, or bits indicated by a binary one or binary zero. These bits represent various types of information contained in the message. Information content includes: (a) sync recognition to enable positive data link message recognition and insure proper synchronization between ground and airborne TDDL equipments (b) aircraft address identification; (c) message type; (d) four data words; (e) control bits to provide relay control of TDDL-associated aircraft equipment. Appropriate parity check bits are included for the message type and data word.

ARR-670 data link program

During the present BADGE system expansion program to incorporate the F4E(JA) Phantom interceptor aircraft as a tactical unit, RCA proposed to JASDF an airborne ARR-670 TDDL equipment configuration (shown in Fig. 7). The F4E(JA) Phantom was designed specifically by McDonnell Douglas for manufacture in Japan. The expansion utilized existing demonstrated designs wherever possible. The RCA-designed R-662 Receiver and C-662 Control subassemblies which had been successfully integrated in previous Japanese and USAF TDDL equipped aircraft were included. Since airborne TDDL equipment interface and installation requirements vary from one aircraft type to another, certain accommodations had to be included in the ARR-670 TDDL equipment electrical and mechanical design. Interfacing this equipment set with the F4E(JA) Aircraft Weapon Systems Control, APQ-120 Radar, Central Air Data Computer and Magnetic Heading Generator necessitated a new electrical design for the Converter-Coupler and Power Supply subassemblies. A new mechanical packaging design was required for installation of the R-670 Receiver-Converter in the aircraft electronics equipment compartment. Unused space in the Converter-Coupler subassembly has been reserved for future data link system growth capability.

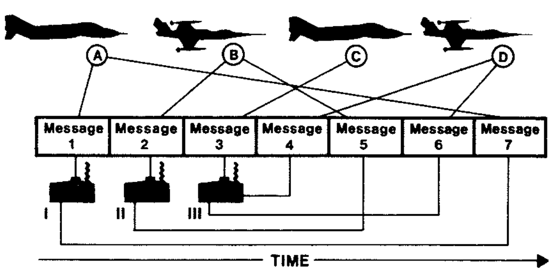

Fig. 6 — Typical multi-site single-frequency operation.

Equipment description

The ARR-670 Data Link Receiving Set consists of Receiver-Converter and Control units, as shown in Fig. 7. The Receiver-Converter contains three subassemblies, a Receiver, a Converter-Coupler, and a Power Supply.

The Receiver R-622 subassembly is a multiple channel, double conversion superheterodyne receiver tunable to any one of 1750 channels spaced at 0.1 MHz intervals from 225.0 MHz to 399.9 MHz. Any one of the 1750 channels can be selected manually and any 26 of the channels can be pre-set for automatic selection from the C-662 Control. The Receiver is designed for reception and demodulation of a.m. or FSK signals. The a.m. signal output provides voice communication to the aircraft interphone circuit and the fm signal output supplies TDDL information to the Converter-Coupler subassembly.

The Converter-Coupler subassembly processes the TDDL data for validity prior to digital computation with other aircraft information. The computed data is converted to analog form for radar display.

The Power Supply subassembly provides the necessary voltages for all units of the ARR-670 Set.

The Control, C-662, is designed for remote operational control of the Receiver and Converter-Coupler. In addition to volume, squelch, manual and automatic frequency channel control for the Receiver, the C-662 provides Address and Mode Select control of the Converter-Coupler.

Interconnections between the R-670 Receiver-Converter, C-662 Control and associated aircraft equipment are made through the airframe wiring. Since the TDDL equipment must interface with many other items of equipment aboard

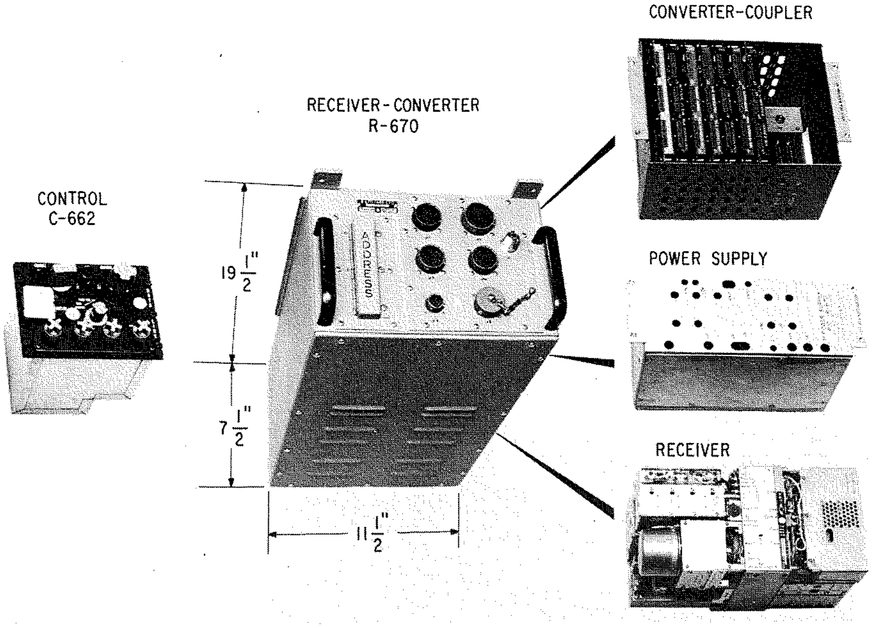

Fig. 7 — ARR-670 equipment configuration.

the aircraft (radar, air-data computer, power sources, indicators, *etc.*), interface design was a major program task.

Design constraints

Primary design thrust for the ARR-670 Data Link Receiving Set was to incorporate the required data link functions in the minimal space allocated in the F4E(-JA) aircraft. The Converter/Coupler complex logic performance requirements dictated the use of medium-scale integrated (MSI) microelectronic devices and printed-wiring multilayer boards to minimize volume. In addition, the multilayer board assembly electrical design included provisions to test board assemblies automatically under computer control during manufacturing test. MIL-E-5400 Class 2 and unique F4E(JA) environmental specification requirements necessitated emphasis in mechanical design to provide satisfactory operation in temperature, altitude, vibration and EMI.

Multilayer board design

Although multilayer board design and manufacture employs proven techniques and methods, the converter/coupler logic and analog circuit density required the use of printed wiring multilayer board interconnection methods with a higher order accuracy and precision requirements than normally encountered in printed wiring board fabrication. The technique of accurately stacking and laminating printed wiring layers to form multilayer boards with plated-through holes played a predominant role in this equipment design. The number of printed wiring layers in each multilayer board varied from a minimum of 8 layers to a maximum of 13 layers.

The density of printed interconnections with controlled characteristics was obtained by generating precision artwork compatible with production processes employed. Artwork generation was accomplished by first digitizing X and Y coordinate wiring layout data supplied by the design engineer on dimensioned gridded paper. This dimensional information was converted, via a digitizer unit, to punched-card format and then transferred to magentic tape by computer. This magnetic tape information drives an artwork generator plotter table to automatically generate the two-dimensional lines and/or points over the required plotting area. Master artwork was produced on glass to minimize variations due to temperature and humidity. Metallized mask-on-glass copies were produced from the glass master artwork for the internal layer fabrication process. These fabrication process steps are similar to producing single-sided printed wiring boards except that extremely accurate layer-to-layer registration must be maintained for the subsequent lamination, drilling, through-hole plating and finishing operations.

Automatic test

Automatic testing of printed-wiring board assemblies prior to installation in the respective subassemblies minimized testing time and identified manufacturing errors at the lowest level of assembly.

The Digital-to-Digital Converter, Azimuth Difference and Altitude Difference digital logic board assemblies were automatically tested on the RCA-designed Digital Logic Test System controlled by an RCA 1600 Computer and a "Special Equipment Controller".

The Time-To-Go, Target Range and Altitude Adcon board assembly analog input/output test requirements dictated automatic testing on the RCA Automatic Communication Equipment Tester (ACET).[1] The ACET is a programmable test system with its own control system, switching system, stimuli and measuring devices. All programming control and logic operations are performed by an RCA 1600 computer with a high-order programming language to perform complete tests.

The Power Supply Rectifier and Regulator board assemblies were automatically tested on the RCA Fixit tester, a punched tape programmmed component inspection test systm.

Program status

The ARR-670 Time Division Data Link is the most recent RCA contribution to Japan's Air Defense System as part of a program that started in 1964. This latest equipment, upon completion of design and development engineering tests, was subjected to exhaustive environmental flight testing, both at the McDonnell Douglas F4E Flight Test Center in St. Louis Missouri and at the JASDF Air Proving Ground located in Komaki, Japan. Production ARR-670 units manufactured both by GCASD-Camden and Hitachi/Toshiba in Japan are now being phased into the BADGE equipment inventory.

Reference

1. Pfifferling, F. and Williamson, D.H.: "Automatic Communicaitons Equipment Tester" RCA reprint RE-17-5-19; *RCA Engineer*, Vol. 17, No. 5 (FebNar 1972).