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Research on System of US Army Data Link

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Abstract: *This paper summarizes the basic concept and development process of the U.S. army data link, analyzes the main data link systems such as the U.S. army situation awareness data link, weapon coordination data link and intelligence reconnaissance data link, studies the special data links such as satellite data link and UAV data link, and finally introduces the typical integrated applications of the U.S. army data link.*

Keywords: *data link, situation awareness, weapon coordination, ISR*

1. Introduction

The future war is system confrontation under joint operation. The essence of joint operation is effective sharing of battlefield resources [1]. Data link transmits and processes battlefield situation, command and guidance, tactical coordination, weapon control and other tactical information between sensors, command and control systems and weapon platforms. It is an important link for seamless links between sensors, command and control systems and main battle weapons, and an effective means to meet the needs of battlefield resource exchange and sharing. It has become the key to improve the information level of weapon system and the overall combat ability.

The tactical digital information chain is defined by the order of the chairman of the JOINT Chiefs of Staff as "a communication link suitable for the transmission of standardized digital information by linking two or more charge systems and/or weapon systems together through a single network or multiple network structures and communication media, referred to as TADIL".TADIL is short for tactical digital Information Chain by the U.S. Department of Defense, and Link is short for tactical digital information chain by NATO and the U.S. Navy. It is commonly referred to as “Data Link” in China.

U.S. data link research began in the 1950 s, according to different operational requirements, different operational purposes, and different levels of technology, and so far have been developed and equipped with 40 multiple data, data chain platform covering ships equipped, fighter planes, unmanned aerial vehicles, satellite and ground radar and soldier equipment. Typical examples are TADIL-C/link-4, TADIL-A /Link-11, TADIL-J /Link-16, TADIL-FJ /Link-22, CDL, CEC, TTNT and so on. The development history of US Army data link is shown in Figure 1.

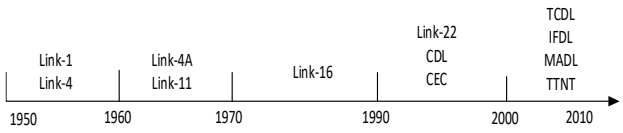

Figure 1: Development history of data link in US Army

2. Us Army's main data link system

The data Link systems developed by the US Army mainly fall into three categories. The first category is "situation awareness data link", which mainly transmits battlefield situation information and battle command information, including Link-4A, Link-11, Link-16, link-22, etc.The second type is "weapon collaborative data link", which is a data link for air defense system, anti-missile system, aerial missile (bomb) and other kinds of attack weapons. Its real-time requirements are very high, mainly including CEC, TTNT, etc. The third type is "intelligence and reconnaissance data link" (referred to by the US military as "Intelligence, surveillance and reconnaissance data link"), which is used to transmit target data (including image intelligence and signal intelligence data) acquired by various platforms to the

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information receiving system or information processing system, mainly including CDL data link and its extension.

2.1 Situational awareness data link

2.1.1 Link-4A Data Link

Link-4A is improved from link-4, which used for automatic control of aircraft unclassified data link, support the air traffic control, air intercept control, operational control, air bombing ground control system, the carrier of inertial navigation system and carrier automatic carrier landing system, and other functions, and can be used to track data exchange and transmit orders, instructions and state data.

Link-4A data link works on UHF band (225MHz~399.975MHz), the data transmission rate is 5000bit/s, the signal adopts FSK modulation, can be used as one-way link or two-way link, using "command-response" communication protocol.

When working as a one-way link, the control station (naval vessels, early warning aircraft, etc.) broadcasts the direction, speed, altitude and other commands as well as the control information such as target data to the controlled aircraft, and the controlled aircraft only receives but does not respond.

When working as a two-way link, the controlled aircraft receives the control information including the address of the aircraft and sends a reply message as a response, which mainly includes the aircraft position, fuel and weapon status, as well as its own sensor tracking data. Every 32ms is a message sending cycle, in which the first 14ms is transmitted by the control station and received by the controlled aircraft; The last 18ms is received by the control station and launched by the controlled aircraft. Controlled aircraft can respond only after receiving the control message containing its own address, so the control station can realize TDM communication in the network by controlling and allocating the transmission time of each controlled aircraft.

The LinK-4A data link system is deployed on U.S. Navy aircraft carriers, guided-missile cruisers, combat aircraft such as E-2C and F-14, Marine Corps electronic warfare aircraft EA-6B, and Air Force early warning and control aircraft E-3.

2.1.2 Link-11 Data Link

The Link-11 data link is an important tactical data link for real-time exchange of electronic warfare data between U.S. and NATO naval vessels, ship-to-shore, ship-to-air, and air-shore, as well as tracks and points in air, water, and underwater, and transmission of command, alarm, and command tactical digital information. It is equipped with encryption modules.

The Link-11 data link operates in HF band (2MHz~30MHz) and UHF band (225MHz~400MHz) and supports two transmission rates: 1364bit/s (45.45 frames per second, 22.0ms per frame) and 2250bit/s (75 frames per second, 13.33ms per frame). The waveform adopts the subcarrier parallel multi-tone system and consists of 16 single-tone waveforms, among which 15 are phase-shifted single-tone, each single-tone represents 2bit data and is modulated by DQPSK. The other one is a non-phase-shifted 605Hz single-tone whose energy is 6dB higher than other single-tone. HF carrier frequency adopts SSB modulation, UHF carrier frequency adopts FM modulation.

Link-11 data link mainly has three working modes: polling, broadcast and radio silence. In addition, there are three auxiliary working modes: network synchronization, network test and short broadcast, among which polling is the most important one. When Link11 works in polling mode, each incoming unit (including network control station and outpost station) is assigned a unique address and shares one transmission frequency by TDM. The network control station manages the whole network by establishing a polling order for the address codes of various sentinel stations. In this order, each sentinel station is allocated a signal transmission time slot, and only one station is allowed to use the network spectrum to send information at any time. In link-11 broadcast mode, the network control station repeatedly broadcasts its data, and all other access units are radio silent, unquestioned, and unable to send messages.

In addition, the U.S. military also has a dedicated point-to-point, full-duplex land-based data link, the Link-11B, for interconnecting land-based tactical air defense and aircraft control units.

The platforms equipped with link-11 data link mainly include AIRCRAFT carriers, guided-missile cruisers, guided-missile destroyers, guided-missile frigates, nuclear-powered submarines of the US Navy, E-3 early warning aircraft of the US Air Force, AIR Force Regional Air Operations Center (AOC), Control and Reporting Center, RC-135 Joint Rivet, U2 Distributed Common Ground station. U.S. Army

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Patriot Missile Battalion, Theater Missile Defense Tactical Operations Center, etc.

2.1.3 Link-16 Data Link

The Link-16 data link is a new, tri-service, tactical data link for command, control, and intelligence. Widely equipped by the US military and NATO, using the TDMA system and J series message format standards. Compared to Link-4A and Link-11, Link-16 improves the capabilities of the data link in terms of technology and usage, and adds some types of data interaction. Major improvements include improved anti-jamming, enhanced security, increased data rates, increased information interaction, reduced terminal size for use in fighter and attack aircraft, digital anti-jamming secure voice, relative navigation, accurate participant location and identification, flexible centrless networks, etc.

The functional endpoints of the Link-16 data link system include the Joint Tactical Information Distribution System (JTIDS) and the Multifunctional Information Distribution System (MIDS). MIDS is a miniatures endpoint of JTIDS and is mainly used for tactical aircraft.

JTIDS/MIDS works in the frequency band 960MHz~1215MHz, and 51 pseudo-random frequency points are selected with a minimum interval of 3MHz between frequency points. JTIDS/MIDS is a wireless data broadcast network using TDMA access mode. Each network member broadcasts the information generated by its own platform in a certain time slot in turn, and receives the information broadcast by other members when not broadcasting. A 24h day is divided into 112.5 hours, each hour 12.8min is divided into 64 frames, each frame lasts 12s including 1536 time slots, each time slot 7.8125ms, is the basic unit of access to the network. Each unit in the network is allocated a certain time slot to complete a certain function. Each in-network unit is specified to send or receive in a timeslot. Each time slot includes jitter, synchronization, time precision synchronization, headers and data, and propagation delay. Data is transmitted in a time slot as a series of pulse symbol packets carrying messages. The width of a pulse symbol packet is 13μs, that is, the frequency hopping rate is 76923 hop /s, where the carrier modulation signal width is 6.4μs, followed by 6.6μs is the no-load time. Each pulse is composed of 32 chip spread spectrum, using MSK modulation, and contains 5bit information, which is encoded by RS. The system supports three data rates: 26880 bit/s, 53760 bit/s, and 107,520 bit/s.

The link-16 data link is mainly equipped with the US Navy's aircraft carriers, guided-missile cruisers, guided-missile destroyers, amphibious common assault ships, nuclear-powered submarines, F/A-18, EA-6B, The U.S. Air Force's E-3 Airborne Warning and Control System (AWACS), Air Force Regional Air Operations Center (AOC), Control Reporting Center (CRC), RC-135 Joint Rivet, E-8 Joint Surveillance Target Attack Radar System, EC-130E Airborne Battlefield Command and Control Center, F-15A/B/C/D/E, F-16, U2 Distributed Common Ground Stations, the ARMY's Patriot Missile Battalion, Forward Territorial Air Defense Command, Control and Intelligence System, Theater Missile Defense Tactical Operations Center (TMD), Theater High Altitude Defense (THAAD), Joint Tactical Ground Station (JTAGS), U.S. Marine Corps Tactical Air Operations Center (TAOC), Air Defense Communications Platform (ADCP), NATO Hurricane, E-3 Airborne Warning and Control System (AWACS), Control Reporting Center (CRC), etc.

Because the Link-16 does not work in the band that supports over-the-horizon transmission, and many Link-11 platforms are not equipped with JTIDS, both link-16 and Link-11 will be used by combat platforms for quite some time.

2.2 Weapon collaboration data link

2.2.1 CEC

CEC (cooperative engagement capability) data link is a revolution of the navy's development data link, and shore-based platform used for sea and air combat units in the sensor and weapon system directly chains, increasing the synergy of target detection and recognition, support the fire control level of comprehensive tracking precision, realize coordinated control of target threat fire fight.

In naval area air defense operations, the key is to improve the response speed of combat platform, the accuracy of target calculation and its own concealment, break through the limitation of platform sensor performance, and discover the target in time. The CEC system (Cooperative warfare Capability) shares raw sensor data across all platforms while maintaining accuracy and time characteristics, and fuses multi-sensor data to form a unified, distributed area defense system.

The main functions of CEC include composite tracking, precise alerting, and cooperative operations. Compound tracking means that multiple radars are used to realize continuous tracking and compound

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track is formed by data fusion to improve tracking accuracy. That way, if a unit's own radar fails to receive updates for a while, it can still rely on data from other units to keep track continuous, rather than simply extrapolating[2].Accurate hint refers to the use of remote radar data to detect the target, the local radar directly accurate positioning and acquisition of the target, reducing the time from detection to tracking. The cooperative operation refers to the direct use of long-range radar data to launch the missile and guide the missile to intercept the target to achieve the beyond-visual-range attack of the missile.

Each CEC node includes a data distribution server (DDS), cooperative engagement processor (CEP), and integration with existing systems. DDS works in C-band and adopts phased array antenna, which is not easy to be intercepted or interfered by the enemy. The combination of frequency hopping and direct sequence spread spectrum is adopted on waveform, which enhances anti-interference and security ability. The data transmission rate can reach 10Mbit/s. CEP is a large-capacity processor used to track and process the target data provided by the local node and other nodes in the network.

The various combat systems integrated with CEC include Aegis cruisers and destroyers, aircraft carriers and large-deck amphibious ships, Patriot missiles, and shipborne E-2C early warning aircraft.

2.2.2 TTNT

TTNT (Tactical Targeting Network Technology) data link is a high-speed data link network between manned and unmanned aerial platforms and ground stations to meet the needs of air Force combat aircraft for precision strikes against highly mobile ground moving targets.

TTNT data link is a high-speed, broadband, self-organizing network based on IP, which can realize the dynamic networking of multiple platforms. It works in L band and can accommodate up to 200 users. The network entry/exit time is less than 5s. When the transmission distance is 185Km, the transmission speed is 2Mbit/s and the delay time is 2ms.

The TTNT is designed to be compatible with the Link-16 data link, which is already widely used across air Force platforms. It adopts J series format and can interoperate with 16 chain at message level. In terms of hardware design, TTNT is designed as a functional module that can be plugged into a Link-16 terminal and can be started with a key to ensure compatibility.

2.3 Intelligence and reconnaissance data link

Intelligence and reconnaissance data link is a data link specially used to distribute high-bandwidth reconnaissance intelligence such as images, videos and high-speed data flow information. It is mainly used to support reconnaissance and surveillance operations, with unified message format and waveform specification, long transmission distance, fast transmission speed, large system capacity and other outstanding characteristics. In the 1990s, the United States Department of Defense decided to use the CDL (Common Data Link) data link technical specification developed by the Defense Aviation Reconnaissance Agency as the general information and reconnaissance data link standard of the United States army, and popularize and apply it to the three armed forces of the United States, making the United States army began to have the common information and reconnaissance data link standard of the three armed forces. At present, the US army is gradually forming an information and reconnaissance data link equipment system, which is based on the basic CDL data link standard and consists of space-borne, airborne, ship-borne and land-based terminal equipment[3].

American intelligence spaceborne reconnaissance data link is not the standard of CDL data link, rely on mainly by GBS (global broadcast business) and SDS (satellite data system), TDRSS (tracking and data relay satellite system) and space systems such as communication satellite to assume empty - star - earth/ship as well as star - a star - between intelligence reconnaissance data transmission.

Airborne information and reconnaissance data link is one of the earliest and most mature information and reconnaissance data links in the U.S. Army's information and reconnaissance data link equipment system, which is mainly used for airborne space-space-ground, space-space-ground, space-space-air and space-ground information data transmission. The data links used include MIDL data link, "Advanced Boot Spur" data link, SE-CDL data link, A-CDL data link, N-CDL data link, MP-CDL data link, TCDL data link, "Eagle Link", TCDL-N air-ship/ground data link and "MR-CDL" data link. It can be equipped with U-2 reconnaissance aircraft, F-16 Theater Airborne Reconnaissance System, RC-135 Joint Rivet signal intelligence reconnaissance aircraft, E-8 reconnaissance aircraft, E-10 reconnaissance aircraft, E-3 early warning aircraft, RQ-4 Global Hawk unmanned reconnaissance aircraft, Guardrail reconnaissance aircraft ground station, SH-60B Sea Hawk helicopter and its surface carrier, P-3 C anti-submarine aircraft and S-3 carrier-borne anti-submarine aircraft, ACS reconnaissance aircraft, etc.

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The U.S. Military's latest shipborne data link is the CDLS (Communications Data Link System) ship-to-air Intelligence and Reconnaissance data link system, which is mainly equipped by the U.S. Navy's aircraft carriers and amphibious landing ships.

The Ground-based TIGDL (Tactical Interoperable Ground-based Data Link) Intelligence reconnaissance data link is a ruggedified, mobile ground/surface data link used by the Army, Air Force, Navy, and Marine Corps for ground-to-ground transmission of received airborne reconnaissance data.

3. Other commonly used data links

3.1 Satellite data link

As the maneuvering capability and combat radius of the main battle weapon platform have been greatly improved, the scope of joint operations has been continuously expanded. Long-range precision strike, joint air defense and missile defense, far-sea large-scale joint operation and other operational styles require wide-area real-time situation sharing, beyond-visual-range accurate command and control, and long-range efficient tactical coordination for data link system. Satellite platform has advantages in orbit height, so it is an effective way to achieve wide coverage of data link message by transmitting data link message through satellite platform.

At present, the United States and the United Kingdom have carried out extensive application of data link satellites in command and control, intelligence and reconnaissance and other fields. Geostationary orbit communication satellites are used to enhance the capability of data link beyond visual range command and control, wide-area situation sharing and tactical intelligence distribution, and low-orbit intelligence and reconnaissance satellites are used to realize large-capacity data transmission and real-time distribution of target information. Satellite tactical data link in active service mainly includes the British naval satellite tactical data link (STDL), the U.S. navy satellite tactical data information links J (S - TDL J), the United States air force joint tactical information distribution system (JTIDS) range extension (JRE), common data link (CDL) satellite application and comprehensive broadcasting services (IBS) satellite application, etc. STDL, S-TDL J and JRE all use satellite channel to solve the problem of over-the-horizon transmission of Link-16 data link messages[4].

3.2 Missile weapon data link

The missile weapon data link is composed of two parts: the data link system installed on the missile weapon and the data link system installed on the control platform. It is the physical basis of seamless information hinge and highly interoperable between the missile weapon and the whole combat system, which improves the rapid reaction ability and cooperative strike ability of the missile weapon[5].

The US military began to develop missile weapon data links in the 1980s. The typical data links developed by the US Air Force for F-15 fighter and the US Navy for F/A-18 combat airborne aviation weapons are AN/AXQ-14 and AN/AWW-13 series.

The AN/AXQ-14 data link system is a two-way L-band aviation weapon data link developed by Hughes Company in the early 1980s. It is mainly applied to combat aircraft in the form of pod and can be used to control GBU-15 laser-guided glide bomb, AGM-130 surface missile and other aviation weapons. The AN/AXQ-14 operates from 1710MHz to 1755MHz and 1755MHz to 1850MHz. It transmits video of the weapon seeker to the fighter and receives the aircraft's weapon guidance and control instructions.

The AN/AWW-13 advanced data link system is an advanced aviation weapon data link system developed by Rathion Corporation in the United States. It is mainly used in guided weapons. Missiles such as AGM-62 White Star Eye, AGM-84E, AGM-154, and SLAM-ER can be equipped with F/A-18, P-3C, S-3B and other aircraft of the Navy. The AN/AWW-13 operates in the band 1427 MHz to 1435MHz and has command, control and communication capabilities. The fighter weapon controller can establish a two-way link between the weapon and the weapon after the weapon is launched, and continue to transmit control information to the weapon after the weapon is launched, while the weapon can also send back video images obtained through the data link system.

At present, the missile weapon data link under development is developing towards networked and collaborative precision guidance and control, in the process of flight available from any network to participate in the unit and the rear command post, and other tactical unit to obtain the target data update,

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can get the target in front of the target position correction and damage assessment data, etc.

4. Integrated application of US Army data link

After years of development, the US army has developed a series of data links. However, due to technical reasons and different operational application objects, no one data link can meet all operational requirements, resulting in the coexistence of multiple data links. Therefore, how to realize the integration of multi-data link system or platform, meet the interconnection and interoperation between data links, and improve the ability of data link cooperation has become the practical needs of data link operation application.

The U.S. military has developed a variety of integrated application systems according to different operational requirements, including Air Defense System Integrator (ADSI), Command and Control ProcessorC2P), Multi-TADIL Processor (MTP), Data Link Processor/Advanced Data Link Processor, DLP/ADLP), Common Link Integration Processor (CLIP), and Common operational artifacts for data links [6], and so on. E-3 early warning aircraft is based on C2P has carried on the multi-data link integration application.

The data link system of E-3 early warning aircraft includes Link-4A, Link-11 and Link-16. C2P is a message distribution system that ensures connectivity between tactical Data System computers (ATDS) and link-4A data terminals, Link-11 data terminals, and Link-16 data terminals. It receives the output from ATDS, translates and formats the information, and sends it through three tactical data links. Similarly, C2P receives information from these three data links and provides it to ATDS after translation. Which specific link the AEW&C aircraft chooses to exchange information and command and control with other combat units depends on the configuration of battlefield communication system before the mission and the initialization conditions of different networks.

5. Conclusion

U.S. data chain has been widely applied to the command and control system, the ISR systems, weapon system, greatly improve the degree of information sharing, enhanced situational awareness on the battlefield, implements the information system and weapon system of cross-linking, improves the cooperative engagement capability, become the indispensable important part of the system of joint operations [7].

Networking, multi-service, interconnection and air-ground integration are the basic development trends of data link. The U.S. Military is developing next-generation data link systems. Overall requirements include improved data transmission rates, improved network architecture, increased system capacity, improved anti-jamming, anti-interception and data distribution capabilities, and better operational coordination.

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