NAIC-ID(RS)T-0268-95

NATIONAL AIR INTELLIGENCE CENTER

INTEGRATED U.S. AND WESTERN EUROPEAN DEVELOPMENT OF ELECTRONIC WARFARE EQUIPMENT

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HUMAN TRANSLATION

NAIC-ID(RS)T-0268-95 6 November 1995

MICROFICHE NR: 95C000689

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English pages: 21

Source: Mei Guo, Xi Ou Yi Ti Hua Dian Zi Zhan She Bei De Fa Zhan; pp. 44-52

Country of origin: China
Translated by: SCITRAN
F33657-84-D-0165
Requester: NAIC/TASC/John L. Gass
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ABSTRACT A general discussion of the history of the integrated development of electronic equipment as well as the current status. There is a certain discussion with regard to the technological characteristics.

KEY TERMS Integration Electronic warfare Jammer

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1. THE CONCEPT OF ELECTRONIC WARFARE SYSTEM INTEGRATION

1.1 The Evolution of Integrated Structures

During the Second World War, due to the technological level of radar and communications being relatively low, and with jet type aircraft possessing high altitiude, high speed, high maneuverability, and relatively strong defense penetration capabilities, the requirements with regard to electronic support and cover were certainly not pressing. After the Korean War, the electronic warfare equipment that was utilized were generally single function, stand alone systems. To give an example, the reconnaissance receivers associated with reconnoitering enemy radar signal wave bands and jammers operating to jam the same enemy radars were positioned separately and independently on aircraft. The two were separately operated by technical personnel. Due to one piece of equipment only corresponding to one type of function, with regard to the reconnaissance and jamming of many enemy radars, there was then a separate need for a good number of separate pieces of equipment. This created very great difficulties in both operator working and spacial distribution and maintenance on aircraft. The Vietnam War and the Third Middle East War provided excellent opportunities to test new models of U.S. forces electronic warfare equipment. At the same time, they also stimulated enthusiasm in U.S. forces for the development of electronic warfare systems. Taking the Navy as an example, electronic warfare equipment primarily aimed at coping with antiship missiles and antiaircraft missiles began to be developed, produced, and put into service in large amounts during this period.

Since the 1970's, U.S forces electronic warfare equipment has entered into a period of high speed development, upgrade and replacement. Active jamming technology and preliminary power management technology began to be employed. Electronic warfare reconnaissance, alarm, and receiving equipment employed advanced signal processing and receiving technology. Reaction times were shortened, increasing suitability for use in complicated electromagnetic environments. One characteristic of this phase was that--besides increasing reaction speeds associated with reconnaissance receiving equipment and jamming equipment--such systems as those associated with reconnaisance receiving, noise jamming, deception jamming, and so on, began to be connected together through main lines or computers, forming the initial combined systems.

Seen from the point of view of structure, combined system forward terminals or sensing devices are mutually connected separate structures. However, data are still capable of going through high speed main lines to be entered into central processors. In processors, data reception and related processing is carried out, producing a synthesized or integrated data output. This type of output is capable of being sent to certain individual operators. It is also capable of switching on certain individual autonomous type reaction measures. Examples of this type of combined system are the integrated defense avionics program (IDAP) and the Luoleier (phonetic) Company's AN/AAR-47 passive missile alarm system.

Combined system special characteristics are:

(1) Integration of information associated with various relevent forward terminals, increasing the rate of utilization and data quality. (2) Using central computers to replace operating personnel in carrying out data processing, increasing reaction speeds.

The shortcomings of combined systems lie in the relatively few connections between their various parts, thus creating:

(1) Low system reliability, (2) Volumes which are still relatively large.

When there is no way for a single piece of equipment to operate, it will have severe effects on information synthesis and threat evaluation processes. Orders associated with the corresponding reaction measures selected may possibly have no way to form an effective output. This will lead to "nullification" of the entire system. Although, in all such areas as information and data utilization, combined systems have made relatively great progress as compared to free standing systems, in battlefield /45 electromagnetic airspace with high frequency spectrum densities and the combined existence of soft and hard kills and damage, this type of system is clearly too delicate and weak--very, very greatly lowering the actual combat efficiency.

The digital avionics information system (DAIS) developed by the Air Force in the 1970's is perhaps capable of acting as the seed of a U.S. forces integrated avionics information system. It opts for the use of a theory of mutually interchangable subsystems. Subsystems are produced by certain firms separately and used for different models. Moreover, it is changed from an analog system to a digital system to create good conditions for the integration of electronic computers and airborne electronic equipment. F-15 and F-16 fighters as well as B-1 model bomber system architectures are nothing else than designs based on the principles of digital avionics information systems.

In the 1980's, the U.S. Air Force gave rise to the "Pave Pillar" development project. Several new technologies came out one right after the other. This had great significance for the realization of the standardization and modularization of electronic equipment and its integration. Among these were included very high speed integrated circuit (VHSIC) chips used in the Navy's standard electronic module (SEM-E), ADA language error tolerant operating systems, as well as fiber optic data trunk lines with information transmission rates of 50Mb/s. These new technologies offered a technical guarantee for electronic equipment integration. In the middle of the 1980's, the U.S. Congress set up a joint integrated avonics working group (JIAWG). Its mission was to draw up common standards for Navy A-12, Air Force advanced combat fighters, and the Army's light helicopter RAH-66, setting up stable connections, and making the development of multichannel data sources into a possibility.

Fig.1 (a), (b), and (c) respectively show differences in three types of system architecture.

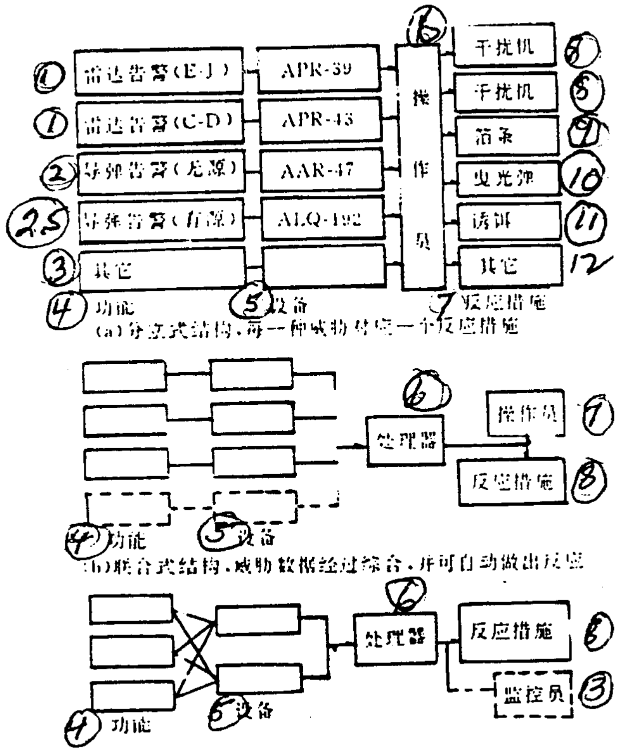

Fig.1 Three Types of Electronic Warfare System Architecture (a) Free Standing Type Architecture. One Reaction Measure Corresponding to Each Type of Threat. (1) Radar Alarm (2) Missile Alarm (Passive) (2.5) Missile Alarm (Active) (3) Other (4) Function (5) Equipment (6) Operator Personnel (7) Reaction Measure (8) Jammer (9) Foil Strips (10) Tracers (11) Decoys (12) Other (b) Combined Type Architecture. Threat Data Goes Through Integration. In Conjunction with that It Is Possible to Automatically Put Out Responses. (4) Function (5) Equipment (6) Processor (7) Operator Personnel (8) Reaction Measure (c) Integrated Type Architecture. Threat Data Goes Through Integration. In Conjunction with that It is Possible to Automatically Put Out Responses. Resources Can Be Restructured.

1.2 Integrated System Characteristics

The obvious characteristics of integrated systems are: redundant resources, dynamic restructuring capabilities, strengthened availability, and simplified capability for repair and maintenance. Another advantage which comes along with these four large characteristics is a lowering of economic life cycle costs.

At the present time, new ideas with advanced functional properties in all areas and new projects constantly emerge in large numbers. The level of costs is one of the important factors which must be considered in system development projects. Multiple integrated system functions are realized through a limited few common modules, thereby overcoming the multiple whole devices which must be employed in free standing systems or such numerous units of sensing equipment as those in combined systems, creating information resources, or the waste given rise to by power sources not capable of full utilization. Modularized designs very greatly lower development expenses and design costs. At the same time, due to reduced platform loads, it lowers requirements associated with ensuring logistic rear services. The number of common use modules is relatively small. They also provide convenience in terms of maintenance and repair. All these things lead to economic advantages. As far as modules manufactured in accordance with SEM-E standards are concerned, there are standard dimensions and shapes. These include central processors, large scale memory storage devices, array processors, main line control devices, electric power sources, sensor data connections, as well as display devices. Estimating the total number of modules on airborne platforms in the 21st century, it will probably be less than 1000. Among these, it is possible to only have less than 100 unique kinds of module types. The volumes of equipment will also be reduced due to the use of such technologies as very high speed integrated circuits (VHSIC), active microwave integrated circuits (MIMIC), and so on. This is particularly important with regard to airborne electronic warfare equipment. The signal processors used by AN/ALQ-165 jammers and AN/ALR-67's are similar to each other. However, the dimensions are only 10% of them. In reality, they are one composite microcircuit chip of 5cm x 6.35cm. Looking in concrete terms/46 below, we consider how integrated architectures realize lowering of costs relying on special characteristics possessed by systems.

(1) Resource Redundancy This refers to the safeguard which can be provided making appropriate use of resources, that is, core components of equipment or peripheral components. In the past, redundancy of key components was realized through one or two spare components or spare subsystems. This method had two drawbacks. One was that the number of spares was limited. Duing combat, the guarantee of supply is not reliable. What is more

important is that spare components take up precious space and enlarge weight quotas, thereby increasing costs. Speaking with regard to integrated systems, functions can be substituted for through the use of the same common module in another subsystem in order to realize it. For instance, a 200W general use electric power source module is just one type. It is not only capable of supplying power for radar systems. It is also able to supply power for communications systems. Resource redundancy is realized due to it being possible to share resources between various subsystems.

(2) Dynamic Restructuring Capability Restructuring refers to using one thing for many uses. Dynamic, by contrast, refers to their flexibility. In the same way, this characteristic has two types of significance contained in it. During combat one of them refers to situations in which hardware modules are damaged and it is not possible to obtain timely supply of new modules. It is possible to adjust airborne resource software structures, newly designating other modules to realize capability supplementation and complete the key missions, or, at least, to be able to reduce to the greatest extent possible the damage brought to the system due to module loss of efficiency. The second refers to going through software organization to change system function points of emphasis so as to coordinate different unit missions. To cite an example, a communications station operating in a friendly area, in an enemy area, could go through "restructuring" and change into a jammer. Computers which carry out processing of positions and directions of flight are also capable of use in order to divide up and select out signals intercepted by radar alarm receivers, or used to make indentifications of new models of threat means. Dynamic restructuring capabilities are reliant on integrated systems capable of using characteristics associated with software functions replacing certain hardware functions as the foundation of their acquisition.

(3) High Availability Availability is a scale to guage key combat platform component average malfunction interval periods (MTBCF). The mean time period between malfunctions for F-16's is 11.5 hours. The mean time period between malfunctions for F-15's is 30 hours. F-22's are 70 hours. Reliability and maintainability standards in the Plan 2000 drawn up by the U.S. Air Force are: in 30 days, the probability of taking off four sorties each day from bases with bad environments is 60%. Key component average malfunction interval time periods are 500 hours.

Factors directly influencing availability include hardware reliability, measurability, and maintainabiliy. Very high speed integrated circuit (VHSIC) and microwave/millimeter wave integrated circuit (MIMIC) technology development raised module first order reliability. Advanced cooling technology associated with SEM-E cards caused solder connection stress problems which are the largest proportion among circuit board malfunctions to achieve maximum improvement. On cards, 25% of resources are used in inspection and measurement. Self-inspecting equipment is capable of pinpointing malfunctioning modules, providing very great conveniences for maintenance and repair.

Availability is the decisive factor associated with system battlefield survivability. Besides technological support associated with high reliability hardware itself, software restructuring capabilities also provide added guarantees of availability. High availability will very, very greatly lower real system costs. That is, besides including initial development and production expenses, sums in which operating expenses, rear service logistical guarantee expenses, and so on, are also included.

(4) Simplified Maintainability Maintainability and producibility are factors which must be considered first in developing prototypes. In order to guarantee actual electronic warfare equipment combat efficiencies on the battlefield, the maintainability must be simplified and effective. In April 1991, the U.S. Air Force decided on the F-22 to act as the model selected as an advanced tactical fighter. The F-22 framework design was new. Each subassembly was capable of being directly loaded and unloaded. Within subassemblies, they possessed self-checking, built in equipment and malfunction diagnostic equipment. Malfunction test measurements and analysis had already realized a conversion to module functions. Limited numbers of modules reduced the burden of storage. Aided by advanced self-checking equipment built in, outside maintenance and repair is convenient and easy to carry out. In this way, it is possible to lower the life cycle expenses associated with all important equipment.

Another design requirement associated with the F-22 and the Navy A-12 is to opt for the use of integrated avionics equipment. This includes such avionics systems as integrated electronic warfare systems (INEWS) and integrated communications, navigation, and indentification electronics systems (ICNIA), and so on. These electronic systems will carry out structural designs together with the carrier aircraft to realize an integration of avionics equipment platform classes. Despite the fact that, at the present time, only prototype designs have been completed, evaluations of the level of integration associated with advanced fighter aircraft aviation systems still clearly show that INEWS core processing sections are capable of containing 10 to 15 kinds of different types of modules--approximately 90 to 100 items. Communications, navigation, and identification function sections opt for the use of 30 to 40 kinds of module types. Numbers of modules for each part are equal. In this way, all it takes is a small number of modules, and it is then possible to complete electronic warfare system functions.

1.3 System Information Flow

Integrated systems are composed of multiple item, multifunction modules. Under the control of central computers, going through commonly used main lines, data transmission and data exchange is realized, opting for the use of command/response forms. Subsystem internal processors should operate using parallel methods. The effect is to carry out preprocessing on signals. Central computers, then, take charge of comprehensive analysis of information as well as policy making processes.

Resources shared by various processors include:

-commoı. use memory storage devices

-data flows transmited by high speed data main lines

-various subsystem resources.

Multiple processor structures are as shown in Fig.2.

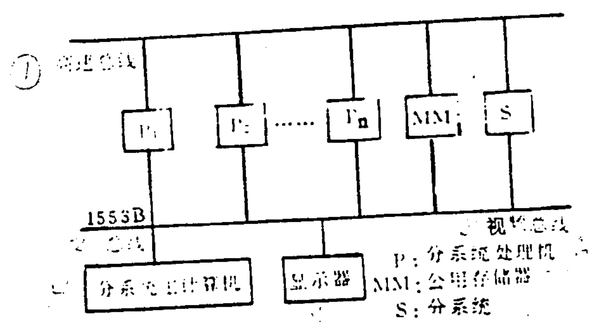

Fig.2 Integrated System Multiprocessor Architecture (1) High Speed Main Line (2) Main Line (3) Video Frequency Main Line (4) Main Subsystem Computer (5) Display Device (6) Subsystem Processor (7) Common Use Memory Storage Device (8) Subsystem

2 ELECTRONIC WARFARE SYSTEM INTEGRATION LEVELS

The U.S. Air Force believes that integrated system means two things.

One is comprehensive integration of electronic countermeasure equipment itself. Under computer control, this is capable of automatically carrying out test measurements and analyses on threat signals and the fixing of threat source positions. In conjunction with this, multiple types of electronic countermeasure methods such as active, passive, infrared, laser, and so on are adopted in order to cope with threat radiation and hard kill and damage weapons operating in any frequency band of the electromagnetic spectrum. Beginning with the AN/ALQ-161 system installed on B-1B strategic bombers, this idea is reflected. AN/ALQ-165 airborne self-defense jammers also belong to this class. In conjunction with this, an even higher technological level is realized.

The second is electronic warfare systems themselves becoming organic parts of integrated avionics systems on platforms. Under avionics main line control, information sharing, integrated control, and integrated display are realized together with such systems as on board communications, navigation, weapons control, and so on. As far as such aircraft as the F-22 "advanced combat fighter" which is just under development, and so on, are concerned, they are nothing else than ones designed in accordance with this concept. This is a platform level one integrated electronic warfare system and will complete platform integrated combat missions. For example, with regard to reconnaissance, early warning, as well as participation in combat, and so on, platform functions are brought into play, raising carrying aircraft combat efficiency and battlefield survivability.

Expanding this, between platforms, it is also possible to go through data channels and realize even higher level one information resource sharing to complete real time battlefield data transmission and realize command and real time control of battlefield situations in the combat zone. In the future, there will be possibilities of providing needed electronic warfare support for combat units and coordinating the completion of combat missions. Moreover, the survivability of units will be very, very greatly increased. Core components which act as local C3I systems bear the responsibility for such operations as data transmission associated with other zonal C3I systems. What Fig.3 shows is typical C3I make up. The operational processes are capable of being summed up in two items:

One is optimized operation plans, that is, combat command functions.

The second is controling weapons implementing the attack and defense. In the third constituent part, electronic warfare integrated systems will be the key sections of detection systems. In conjunction with this, they bear the burden of communications between the other two parts.

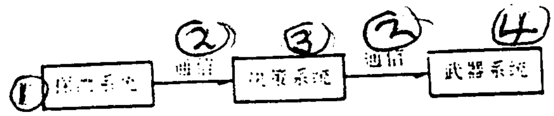

Fig.3 Basic C3I System Composition (1) Detection System (2) Communications (3) Policy Making System (4) Weapons System

Integrated systems with even broader significance are capable of actualizing key systems relating to the connecting of various combat zones with each other. Through equipment networks such as various types of sensor satellites, and so on, multiple combat zones and platforms are connected. Under orders of the command section, unified combat missions are completed. In the entire electromagnetic environment, electronic support is carried out, executing multilevel jamming and antijamming. At the present time, the U.S. already possesses a strategic reconnaissance and early warning system capable of completely covering the U.S. mainland. A strategic defense electronic early warning network is composed of large model mutually controled radar arrays, ultra line of sight radars, electronic reconnaissance satellites, and early warning satellites. Before SDI deployment, they are the strategic defense penetration electromagnetic threat which is most important and most real. After SDI deployment, they will still be the most important structural component of SDI detection, tracking, and interception systems.

3 CURRENT STATUS AND OUTLOOK FOR U.S. AND WESTERN EUROPEAN ELECTRONIC WARFARE SYSTEM INTEGRATION RESEARCH

Future battlefield environments present severe threats /48 to the survivability and operational capabilities of single function electronic equipment. Although combined systems possess relatively high technological levels and even stronger capabilities for battlefield applications, there is still no way, however, for them to satisfy the requirements of future battlefields. The idea of integrated systems designs--from a certian number of aspects--compensate for the deficiencies of combined systems. Moreover, in structural system terms, they provide extremely large improvements.

In view of the superior properties of this type of structure, various nations of the world are all competing with each other in research on developing this area.

3.1 Several Types of Advanced Electronic Warfare Systems of Western European Countries

The Makeni (phonetic) Defensive Systems Company puts out "ZEUS" to provide a combined radio frequency threat management system (alarm and jamming). It is capable of coping with pulse and continuous wave transmitters. Operations are in the C-J wave bands. "ZEUS" is already installed on British Royal Air Force "Harrier" type GR-5 aircraft.

The system is one of software driven operations. It displays and classifies data for pilots and indicates responses put out by jamming systems (including aimed type noise, speed gate towing deception, and so on). The "ZEUS" system must be connected to navigation/attack avionics systems on board the aircraft and must also connect to other airborne electronic warfare systems. Up to the present time, "Harrier" type GR-5/GR -7's already have a complete set of connected system equipment. In conjunction with this, they possess a number of integrated characteristics, including the "ZEUS" system, the GEC Pulaisai (phonetic) Company's missile alarm device, the Bofusi (phonetic) Company's BOL foil strip discharging device installed on missile launch tracks, as well as the Telake (phonetic) Company's automatic threat adaptive system TACDS tracer round launcher. "Harrier" type fighters have already become aircraft relatively well equiped with electronic warfare systems among the NATO air forces.

(2) The Ailikesen (phonetic) Company, Bofusi (phonetic) and Saite (phonetic) Stock Company cooperated to develop one type of electronic warfare system used in Sweden's JAS39 aircraft. According to the Ailikesen (phonetic) Company, the equipment in question is highly automated. Moreover, it is capable of communicating to quite a high degree with other avionics equipment on aircraft. With regard to specially designated missions, the aircraft are also capable of being fitted with radio frequency jamming pods which are able to supply multiple modes of operating capability.

(3) Tangpusen (phonetic)-CSF Company and the Dasuo (phonetic) Company cooperated to develop the "frequency spectrum" system ICMS2000 used on French "Kuangfeng (phonetic): literally 'storm'" aircraft. The Tangpusen (phonetic) Company assumed responsibility for the development of laser alarm devices and electromagnetic alarm devices. The Dasuo (phonetic) Company assumed responsibility for jamming systems. "Frequency Spectrum" made use of the newest technology and industrial processes. These included coherence direction finding, electrically controled antennas, microwave/millimeter wave single chip integrated circuits, and very high speed integrated circuits

VHSIC, as well as artificial intelligence methods. "Frequency spectrum" also is integrated with other avionics equipment on aircraft in order to supply complete composite sensor/data capabilities.

(4) The EWS-16 produced by the Dasuo Company possesses an electronic warfare system with integrated characteristics which can also be used on F-16's. In conjunction with this, they act as one part of "Frequency Spectrum" systems on "Kwangfeng (phonetic): literally 'storm'" aircraft. Besides improved single defensive efficiencies, they are also capable of detection, location, and identification of threats within adequately large ranges covering C-K wave bands and possessing passive identification capabilities.

(5) The EMPAR European multifunction phase control array radar developed by a combination of three European countries is a typical example of modularized design. The three contracting companies are Italy's Selenia Company, France's Thomson-CSF Company, and the U.K's Makeni (phonetic) Radar Company.

EMPAR working modalities are all around azimuth, close range detection, early warning detection at low angles of attack, priority level arranged tracking, and so on. The design principles are opting for the use of basic modular structure, carrying out modular combination on the basis of different requirements in order to achieve good system performance.

In order to complete early warning and tracking missions, radars opt for the use of G wave band operations. At the same time, they are capable of satisfying good low frequency band early warning charcteristics and good high frequency band tracking characterisitcs. Systems are controled by common use computers. In conjunction with this, power management is carried out. Basic modules are composed of antenna elements, transmission/receiving elements, signal processing elements, power management elements, and display connection sections. Among these, the function of power management computers (RMC) is the distribution of missions in accordance with priority level order. Their basic composition is a common use multiple microprocessor real time system. The function of each microprocessor is the same. Therefore, it is possible to average and divide the labor of power management missions. In conjunction with this, their numbers can be increased in accordance with needs. Software is written in the ADA language.

EMPAR composition is as shown in Fig.4.

Modularized design brings with it three advantages for EMPAR radar systems:

1) Basic module systems have the potential for combination and expansion. It is possible, based on the type of platform (mostly used on warships) and differences in unit missions, to

make combinations with other modules, achieving expanded /49 functions. Universality is good, and, seen in the long term, they cut expenses.

2) Maintenance and repair is easy. The burden of ensuring rear services logistics is reduced. At the same time, it is easy to realize computer control of repair and maintenance.

3) Availability is very strong. Even if, in the future, modules with even more advanced properties are produced, it is only necessary to make appropriate alterations to software or hardware connection sections to guarantee system compatibility. It is then possible to replace modules currently in service.

The advantages discussed above also pose a few requirements for modularized designs:

1) Designs must be convenient for flexible assembly, and radar acquisition and tracking functions are organically unified.

2) Basic module systems themselves must be organically matched. For instance, electrically controled beam antennas must be coordinated so that it is possible to handle signal processors associated with multiple wave forms.

3) Hardware and software must be for signal processors associated with multiple wave forms.

4) Prices must be low.

(6) Electronic Warfare Control Systems (EWCS)

The U.K. Makeni (phonetic) Underwater Systems Co. Ltd. recently developed a type of electronic warfare control system

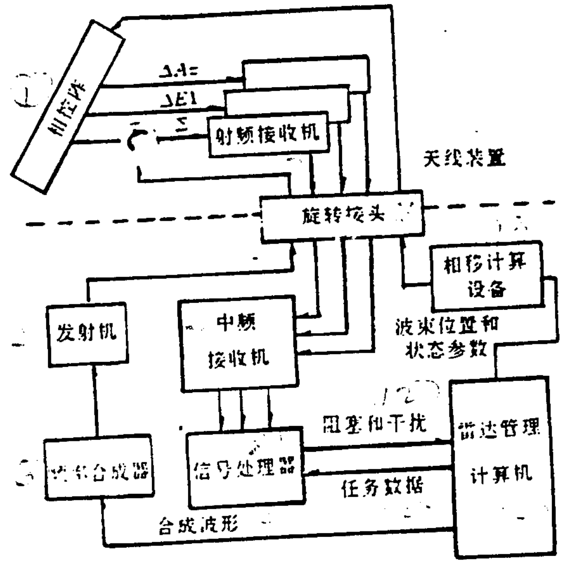

Fig.4 EMPAR System Structural Function Line and Block Chart (1) Phase Control Array (2) Radio Frequency Receiver (3) Rotating Heads (4) Antenna System (5) Transmiter (6) Frequency Synthesizer (7) Intermediate Frequency Receiver (8) Signal Processor (9) Synthesized Wave Form (10) Phase Shift Computer Equipment (11) Beam Position and Status Parameters (12) Blocking and Jamming (13) Mission Data (14) Radar Management Computer

EWCS. This set of equipment goes through its organic connections with various pieces of outside receiving equipment and jamming operation systems and is capable, during early warning simulation phases, of carrying out evaluations of soft and hard kill and damage results under specially designated threat levels. The relevent data acquired is capable of forming tactical electronic warfare data bases. Electronic warfare control systems EWCS are capable, on the basis of these data bases, of carrying out various types of integration, realizing human or automatic control of integrated electronic warfare tactics. Real combat results can rely on simulated accuracies. EWCS are software driven. They are capable of being reprogramed. They possess very high adaptability to various types of surface and underwater platforms as well as various tactical missions. In conjunction with this, it is possible to guarantee quick reactions. The functions are as shown in Fig.5.

2.2 U.S. Forces Integrated Electronic Warfare System Development

2.2.1 General Status of Army Electronic Warfare Systems

Beginning in 1978, there were large numbers of purchases and fitting out with new types of electronic warfare equipment. In conjunction with this, large amounts of manpower and materiel were thrown into the development of new models of advanced electronic warfare systems. At the present time, seen from the view point of technological level, their reliability is high, maintenance and utilization are simple and convenient, and they have relatively high mobility. At the same time, delivery means

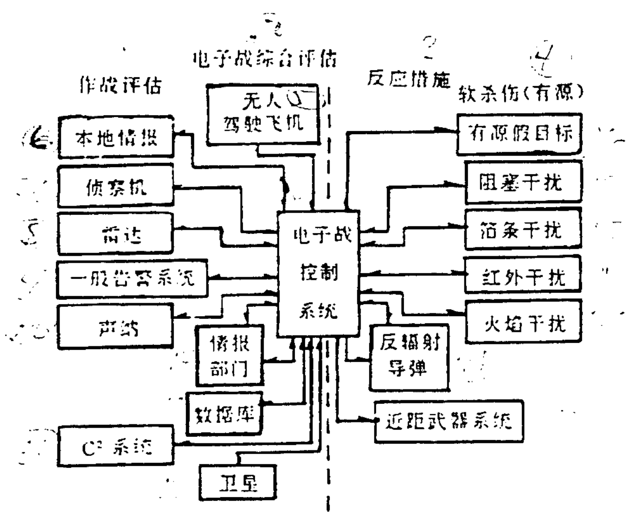

Fig.5 EWCS System Functional Line and Block Chart (1) Operational Evaluation (2) Electronic Warfare Integration Evaluation (3) Reaction Measures (4) Soft Kill and Damage (Active) (5) Pilotless Aircarft (6) Intelligence on the Places Concerned (7) Reconnaissance Aircraft (8) Radars (9) General Alarm Systems (10) Sonar (11) C2 Systems (12) Satellites (13) Electronic Warfare Control Systems (14) Intelligence Departments (15) Data Bases (16) Active False Targets (17) Obstruction Jamming (18) Foil Strip Jamming (19) Infrared Jamming (20) Flame Jamming (21) Antiradiation Missiles (22) Close Range Weapons Systems

were formed into models, standardized, and universal option was made for the use of electronic computers. As far as new models of electronic warfare computers possessing certain integration characteristics are concerned, the combining of electronics and jamming is one form, even going as far as the tank self-defense jamming system (CVSPS) with its integrated design considering together such things as the armored carrier vehicles, and so on, as well as the air defense electronic warfare system (ADEWS) which was refitted from the AN/SLQ32(V)3 warship borne electronic countermeasures system, and they had already been handed over for use in 1986. Loaded in S280 compartments, they can be transported on Army M8035 vehicles. Air defense electronic warfare systems are used primarily in order to deal with attacking aerial targets--for example, fighter bomber MIG-27's as well as MIG-24's, and so on. With regard to a series of management and development measures in technology, they are explained by one of the ideas that Army electronic warfare equipment systems led to, which was to cause the Army electronic warfare system to be brought into the electronic warfare systems of the three services.

2.2.2 Navy Integrated Electronic Warfare Systems and Development Trends

Quick reaction is one of the principles of U.S. Navy electronic warfare. On the battlefield, it lays great stress on "gaining the initiative by striking first". It advocates integrated utilization of electronic reconnaissance means, bringing to bear the advantages of electronic systems, grasping in real time the electromagnetic environment as well as friendly and enemy situations, and adopting in a timely manner directed electronic warfare measures. Another combat principle is active defense. At key moments and within adequate continuous periods of time, it opts for the use of active offensive methods--carrying out intense jamming and concentrating advantages in electronic warfare strength to destroy the normal operation of electronic systems used by enemy forces, destroying his electronic defense systems locally or even completely.

During countering of ships with aircraft carriers as their core or carrier aircraft combat processes, the primary mission of electronic warfare is to use soft kill and damage means to directly participate in such combat operations as surface strikes, air defense, antiship, antisubmarine, and so on, ensuring the operational effectiveness of combat ships as well as increasing their survivability. In particular, the carrying out of C3 countering through electronic equipment is not only to actualize important means to tactical objectives. It is also one of the naval warfare strategies integrating the use of various types of technology and weapons.

Modern warfare clearly shows that the trend in warfare is all direction, all frequency band, multilevel defense and attack on land, under water, on the surface of the sea, in the air, and in space. The Navy often relies on carrier borne aircraft to achieve air superiority as an important guarantee of naval superiority. Therefore, a good number of naval electronic equipment designs as well as improvements in which there is more and more stress on compatibility between them and the other military services--in particular, the Air Force--opt for the use of modularized design, realizing multifunction, integrated electronic warfare equipment with high battlefield survivability, such as, the ALQ-165 airborne self-defense jammer as well as the INEWS integrated electronic warfare system and fourth generation antiradiation missile "Mohong (phonetic): literally 'silent rainbow'), and so on.

Important equipment and dev elopment trends:

1) Multisystem integrated receivers, raising the integrated capabilities of reconnaissance alarm systems.

AN/ALR-67(V) opts for the use of a combination of wide frequency band crystal video frequency reception and superheterodyne receivers as well as low fequency band receivers. AN/ALR-74 radar alarm receivers are one part of ASPJ projects. They opt for the use of instantaneously measured fequencies and a mutual combining of crystal frequencies and superheterodyne receiver technologies in order to facilitate dealing even more effectively with high pulse Doppler radar and continuous wave radar signals. AN/APR-43 is a combination of crystal video frequency and heterodyne tuning, etc.

2) Multiple Spectrum Integrated Alarm Systems

AN/APR-39A, which began servive in 1984, was the first time Doppler alarm integration was realized with such things as microwave, millimeter waves, lasers, and so on. It acted as a part of electronic warfare systems deployed on ship borne helicopters.

3) Electronic Jamming Systems Use Double Module Jamming Forms of Operation

AN/ALQ-100 and AN/ALQ-126B are only capable of carrying out pulse type deception jamming. AN/ALQ-99 and AN/ALQ-162 are only capable of carrying out suppresive type jamming. However, the electromagnetic environment of modern naval warfare is unusually rigorous. Electronic equipment systems such as new models of radar are many and various. Capabilities are advanced. In order to make jamming operations effective, the Navy made use of the results of Air Force research and fitted out double module jamming systems. For instance, AN/ALQ -164 used on AV-8A/C as well as the newest generation jamming system AN/ALQ-165, are capable of possessing the two types of pulse and continuous wave jamming capabilities.

4) Modularized Design Adds System Flexibility and Reduces Rear Services Logistic Pressures to Guarantee Operation

Realization of electronic warfare equipment standardization and universalization is the key to increasing result to cost ratios. Under the guidance of the concept of designing systems to carry out electronic warfare on the basis of price, the U.S. Navy did large amounts of development on electronic warfare systems associated with universalization, standardization, and building block forms. Besides ALQ-165 and INEWS--for instance, the AN/APR-39A universally used by the Navy and Army--systems acting as photoelectric countermeasures can supply to pilots full frequency spectrum warning. CMR-500B is capable of application to fixed wing aircraft. It is also capable of application to rotary wing aircraft. The Navy's own integrated warship electronic countermeasure system AN/SLQ-32(V) opts for the use of modularized design and takes reconnaissance alarms and jamming and orgainically unites them together. Besides this, the Guanian Star, Protector, and Sea Sentry also all opt for the use of building block type structures in order to adapt to the requirements of different carriers.

As far as the development of very high speed integrated circuits is concerned, it is possible to effectively increase processor processing speeds and take information handling capacities and raise them two orders of magnitude. Moreover, the volume and weight of equipment are greatly reduced. As a result, miniaturization of the entire system can be realized.

Summarizing what was discussed above, the requirements of future naval warfare on warship electronic countermeasure systems are:

(1) Numerous functions, quick reactions, and possession of integrated alarm and integrated jamming means used to handle threat targets associated with multiple areas and multiple systems.

(2) Standardization, modularization, and integrated system structure, the formation of integrated reconnaissance, alarm, and jamming systems, the carrying out of integrated designs on entire ship borne electronic countermeasure systems, making them form an integral whole.

(3) Making use of multiple sensor data transmission as well as relevent processing techniques to realize electronic countermeasure resource sharing, that is, dynamic restructuring capabilities associated with the use of information integration.

2.2.3 U.S. Air Force Airborne Electronic Equipment and Its Development Trends

In order to destroy multilevel whole air space coverage air defense fire power networks, air force airborne electronic warfare equipment is in the midst of developing from single function to multifunction equipment having computers participate in power management. With regard to integrated systems with parts such as reconnaissance, warning, guidance, and jamming transmission, etc., they will in future make further developments in the direction of the several areas below.

1) Doppler Integrated Detection and Alarm Systems

At the present time, airborne electronic warfare equipment frequency domains are generally from a few tens of megahertz to 18 thousand megahertz. Following along with the development of millimeter wave technology, numerous types of millimrter wave radar have already been introduced into use. At the same time, airborne electronic equipment--in terms of wave bands--also needs to develop in the direction of millimeter waves. Airborne radar alarm equipment AN/ALQ-69 and AN/ALQ-74 have already been fitted with millimeter wave alarm wave bands. The difficulties with technology in this area are millimeter wave reception, high power production, narrow pulse modulation, as well as wide band noise formation, and so on. With regard to jamming devices, besides expanding frequency bands, there are also problems with increasing frequency band jamming power densities. Multiple beam jamming technology is one type of advanced jammer transmission power technology. Its requirements with regard to single traveling wave tube power transmission are not high. However, multiple beams are relied on to realize 360° all around coverage. In conjunction with this, it is suitable to the actualization of jamming direction and beam power management. AN/ALQ-161's carried by B-1B bombers employ this type of technology.

2) Development in the Direction of Integration and Modularization

System structure modularization and integration in terms of function so as to ensure the simplification of rear services logistics and the reduction of loads brings very great advantages, thereby increasing system suvivability on the battlefield and maneuver flexibility. At the same time, system response times are increased, combat efficiency is increased, and it is also possible to lower development and equipment costs and save on expenditures.

Various numerous types of U.S. airborne electronic warfare equipment models reach more than 200 kinds. There are over 70 kinds of active jamming equipment. There are more than 30 types of passive jamming equipment. As a result, creating guarantees of rear services logistics is difficult. Military expenditures are enormous. The air force has altered this type of situation, increasing modularized design principles. Systems opt for the use of standard module structures. It is possible--on the basis of different operational missions and platform requirements--to carry out functional combinations, very, very greatly lowering the costs of electronic countermeasures equipment--for instance, AN/ALQ-135 and ALQ-165 equipment on F-15's as well as electronic warfare equipment on F-16's and the "advanced tactical figher" ATF currently under development.

In August, 1989, the Hughes Co. and the Air Force concluded a cooperative project to develop multifunction electronic warfare radar. The contract costs reached 6 million 200 thousand U.S. dollars. According to the Hughes Co. plan, the antenna section was developed first. In a 4x4 phase control array, each of 16 transciever modules all covered 4 frequency bands. They were capable of covering the entire frequency segment. This is one type of active phase control array system. At the same time, it is multiple function, multiple frequency, and set for test flights in the middle 1990's.

3) Develop Power Managed "Self-Adapting Electronic Warfare Systems" with Computer Participation

The next generation of electronic warfare equipment will integrate the utilization of phase control arrays, self-adapting receiver/transmiters, parallel port signal processing, as well as other real time digital control technologies, forming with central processors a power synthesis system under unified control. High speed processing is completed in a dense signal environment. Tasks are analyzed real time, and the system is a fully self-adapting one with multiple functions, full coverage in all directions and structured in frequency domains, spacial domains, and time domains. Fully power managed, self-adaptive radar countermeasure systems have the functional characteristics below:

(1) In high density threat environments, quick acquisition, separation, selection, and identification of threat signals, and, in conjunction with that, automatic determination of the level of threat.

(2) Precision measurements of threat radar operating frequencies, tuning speeds, and formation of jamming beams.

(3) Precision positioning, directed jamming, and the realization of optimal disposition with regard to beam width and power distribution.

The ALQ-131 is the standard air force jamming pod. The complete set is 8 modules. They possess fully automatic power management systems. They are capable of jamming radar signals in 5 individual wave bands. Through fitting out with multiple types of modules--including missile alarm systems, counter jamming distribution systems, as well as jamming pattern generators, and so on--it is possible to obtain very high combat performance. The system core function components include programable digital computers and connection modules. It is already current equipment on A-10, F-4, F-16, and F-4G "Wild Weasel" aircraft. It is projected that the total production amount will reach 1500 units by the end of the century.

(4) Carrying out of "open window" type coverage pulse jamming, and, in conjunction with that, the realization of simultaneous jamming against multiple radar units.

(5) On the basis of jamming results, carry out jamming parameter adjustments, determing optimal jamming modes.

AN/ALQ-165 airborne self-defense type jamming systems, AN/ALQ-131 modular structure jamming pods, as well as AN/ALQ-161 self-defense jamming devices, and so on, all opt for the use of power management technology. They possess multiple types of jamming capabilities, computer control, external reprograming, and possess very high self-adaptability. Moreover, the INEWS, which the Air Force and the Navy combined together to develop, will opt for the use of artificial intelligence technology to realize full self-adaptability.

4) Integrated Software and Hardware Kill and Damage

Electronic warfare hard kill and damage makes use of electronic counter reconnaissance systems to do precise identification and positioning with regard to enemy air defense system radars as well as communications equipment, and so on. Following that, it guides the friendly side in using antiradiation missiles as representative of various types of precision guided weapons which go and destroy them as well as related weapons systems or air defense command systems.

The U.S. Air Force has already developed three antiradiation missiles such as the "Baisheniao (phonetic): literally 'hundred tongued bird'", the "Standard", and the "Hamu (phonetic)". In the future, guidance head frequency bands will be expanded, making further developments in such areas as increasing defense penetration speeds and defense penetration ranges as well as strengthening jamming capabilities, and so on. In 1988, the engineering development phase work on fourth generation antiradiation missiles was completed. New antiradiation missiles possess even more advanced memory functions and automatic acquisition capabilities, constituting an extremely great threat to radars.

5) Photoelectric Integrated Electronic Warfare Systems

Extensions of electronic warfare equipment wave frequency ranges, increases in sensitivity and dynamic ranges, and further developments in such means as weapons system detection, fire control and guidance, and so on, cause large numbers of conventional microwave radars, infrared and laser control systems, guidance systems, fire control systems, and so on to be introduced into battlefield utilizations. In particular, in the last few years, the proportion of photoelectric equipment in military systems has gotten larger and larger. Among air to air missiles, infrared guided missiles account for approximately 60% or more. As a result, photoelectric integrated electronic warfare development also gives rise to serious attention by the military. Various types of infrared alarms, infrared decoys, infrared jamming devices, as well as laser alarms and jamming equipment have already been fitted and put into use one after the other. The Air Force already has 8 models of infrared alarm equipment selected for fitting on such combat aircraft as F-111's as well as F-15's, etc. There are also infrared pods for hanging on A-10 tactical aircraft, and so on. The direction of development in airborne photoelectric electronic warfare equipment is toward such areas as expanding optical spectra, reducing false alarms, as well as increasing discovery rates, raising jammer efficiency, along with infrared stealth, and so on.

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