Navy Communications Overview

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Abstract—**The history of communications in the Navy has shown the importance of the role it plays in conducting military operations. A general overview of Navy communications is discussed, providing the framework for the new developments for the 1980's. Discussion focuses on three major areas: strategic, long-haul two-way, and tactical communications.**

INTRODUCTION

"INFORM the troops that the communications are out," is an anecdote which highlights the importance of something taken for granted even after it is lost. Preplanning helps, but coordinated actions are improbable without a real-time exchange of information.

The loss of communications in military operations reduces the effectiveness of a platform by limiting the volume within which an enemy can be detected and identified to its immediate environment. A command center is rendered ineffective if well informed but unable to coordinate the resources under command. These examples highlight the critical role which communications play in military operations.

The challenge to Naval communications is to provide command centers, sensor systems and platforms, the means of coordination for execution of the warfare tasks. This involves communications at ranges within line of sight to those which are global. In addition, there is the unique requirement to communicate with submarines concealed beneath the ocean's surface. The diverse nature of the communications need provides an opportunity for application of most of the technology existing today and serves as a driver for the technology to be developed.

The communications must be available in peacetime and survive electronic jamming and the physical threat associated with wartime situations. The global mission of the Navy requires the systems to be interoperative with those of other services and Allied Nations where combined operations are anticipated. These factors related to Naval communications must be taken into consideration in the architecture which serves as a guide to support the current and future programs.

II. OVERVIEW OF THE NAVY COMMUNICATIONS STRUCTURE

A. Systems

Two primary systems support Navy operations. These are the Defense Communications System (DCS) and the Naval Communications System (NCS).

The DCS provides the interconnection between the various land based facilities. This connection not only includes the Navy facilities which are land based and related to the NCS, but long-haul communications between Europe, the United States, and the Pacific. The DCS uses a mixture of diverse communications media ranging from satellites to leased telephone lines and represents the interface for the NCS and the land based structure, other services, and allies.

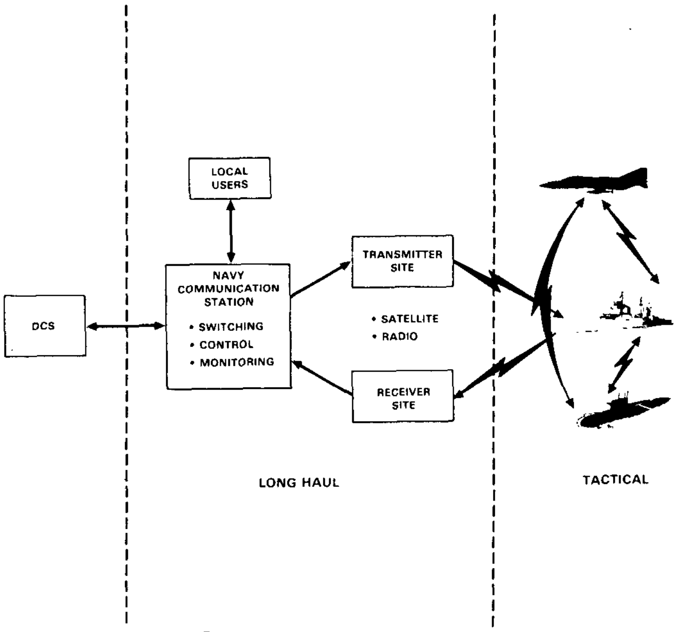

Fig. 1. Network, interfaces.

The Naval Communications System for the purpose of discussion can be divided into three functional areas. These are: 1) strategic, 2) long-haul communications to/from units at sea, and 3) tactical communications among operating units at sea.

Strategic communications have the single most important function of maintaining connectivity between the National Command Authority and the nuclear submarines operating at speed and depth. This represents a unique challenge for communications designs because of the restrictive medium of seawater and the survivability required in a nuclear exchange.

The "long-haul" communications to/from units at sea are characterized by a network of land based communications stations which interface with the DCS. Each of the Navy Communication Stations is arranged in a similar manner. Information is received from the DCS at the Navy Communication Stations which serve the local command. Once the information is processed, the traffic is transmitted via the appropriate means to the units at sea. In a like manner, traffic from the units at sea are received at the Navy Communication Station and when appropriate, routed to other land based facilities through the DCS. See Fig. 1 for the representation of this interconnection.

Today, the Navy Communication Station network is com-

Manuscript received January 15, 1980.
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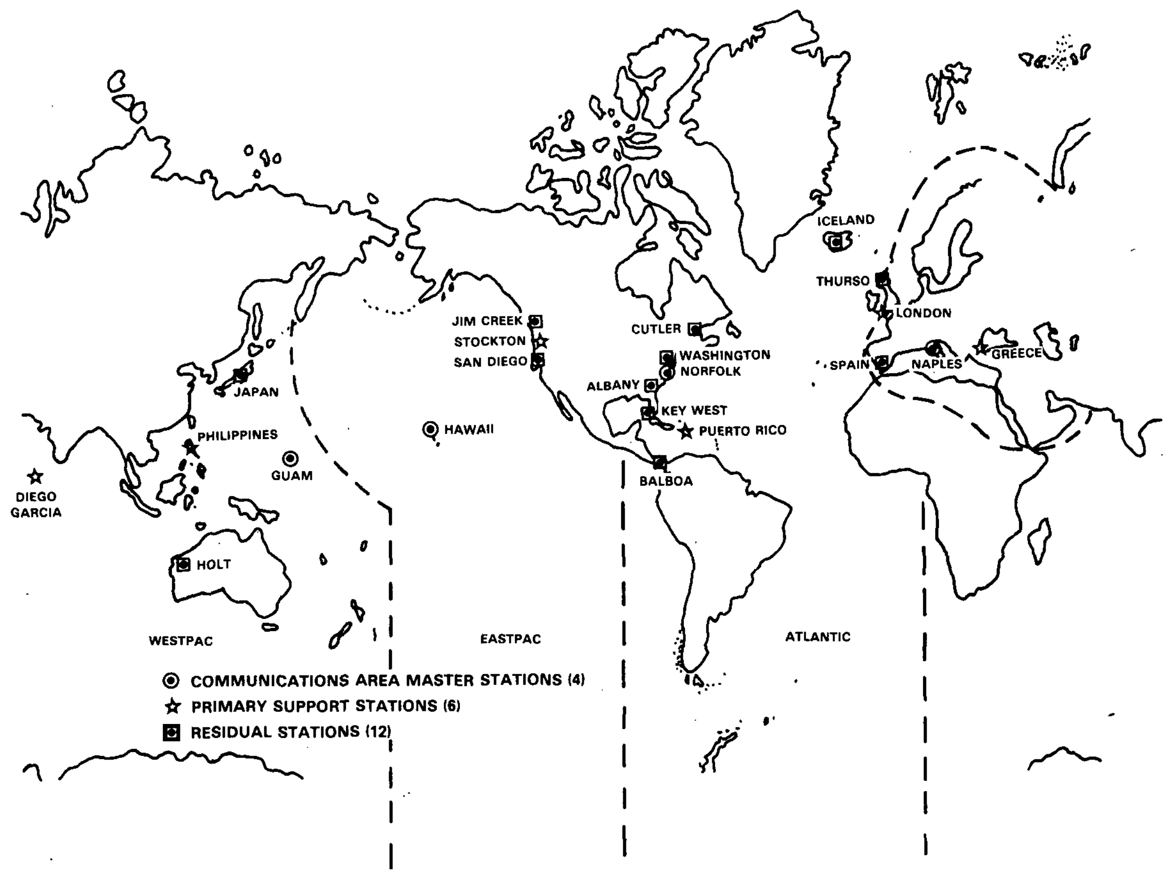

Fig. 2. Navy communications stations.

posed of four communications area master stations providing area coordination in the Western Pacific, Eastern Pacific, Atlantic, and Mediterranean regions. In addition, the Navy maintains six primary support stations and 12 residual stations; all of which are controlled by a master station in their area. Fig. 2 shows the location of the various sites.

The long-haul two-way communications are provided by satellites and a high frequency (HF, 3-30 MHz) network. These are the only means available for the two-way information exchange between shore and units afloat.

Tactical communications provide the necessary coordination among the units at sea. The communications connectivity is shown in simplified form in Fig. 3. Included in the figure is a submarine in direct support of the units shown.

The communications spectrum for the tactical communications range from high frequency (HF) to ultrahigh frequency (UHF) which is contained in the range from 3 to 3000 kHz.

B. Information Content

The Naval Communication System supports three basic types of information: voice, message traffic, and data communications. With the exception of the need to communicate with nonmilitary units and satisfy peacetime controlling regulations, the trend is toward all digital communications. This fact is based on the desire to provide security for the voice communications used for military coordination. The process of securing the voice links results in a digital information exchange similar to that associated with data and message traffic.

The trend toward all digital communications provides an opportunity to apply common design techniques regardless of the information content. With this situation, the military communication systems of the 1980's should have the capability to accommodate any type of information exchange. This has the attractive characteristic of permitting increased efficiency in using the available spectrum and readily permits electronic interference protection by bandwidth spreading.

III. STRATEGIC AND SUBMARINE COMMUNICATIONS

A. Function

The Navy's survivable leg of the strategic deterrent, the ballistic missile submarines, and the attack submarines, share a family of similar communication needs which present special challenges to Navy communications systems. Both types of submarines are built to move freely throughout the total volume of the ocean either to avoid detection and attack or to pursue enemy submarines which are seeking to avoid detection. Communications requirements to receive information from the shore and to send information back must be met without compromise or constraint.

Submarine based missile systems are a part of the nuclear deterrent because a potential enemy could not be assured that a "preemptive" or "first strike" attack would prevent the submarine forces from retaliating. To satisfy this attribute, considerable emphasis is placed on survivable or reconstitutable versions of communications.

B. Present Systems

Shore to submarine traffic is broadcast from six large very low frequency (VLF, 3-30 kHz) radio transmitter facilities

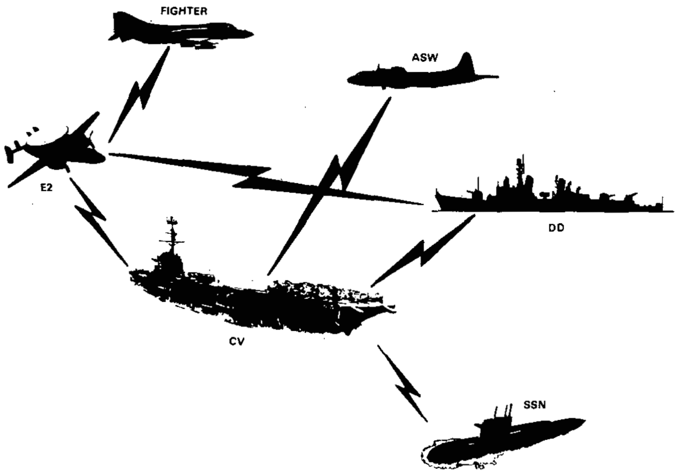

Fig. 3. Tactical communications.

located around the world. These stations, using techniques and, in some cases, hardware going back to the 1920's, radiate powerful signals (1-2 MW) from enormous "aerials" (Fig. 4).

Submarines are able to receive the VLF signals worldwide with trailing wire or buoy mounted antennas. Back-up transmitters operating at low frequencies (LF, 30-300 kHz) or high frequencies (HF, 3-30 MHz) provide shorter range communications. Ultrahigh frequency (UHF, 300-3000 MHz) satellite facilities (GAPFILLER, FLEETSATCOM, and eventually LEASAT) [1], [2] are also used but require a mast mounted antenna. The UHF satellite system allows the submarine to receive a large volume of information relatively free of ocean area constraints during a brief exposure period on the surface.

Because all of the foregoing systems depend on fixed, land based facilities which are subject to preemptive attack, the Navy operates a survivable airborne VLF communications aircraft known as "TACAMO" [3]. A large transport type aircraft (EC-130), TACAMO carries a fully equipped radio room (Fig. 5) with a number of receivers and transmitters to receive and acknowledge messages as well as a high-power VLF amplifier and long-trailing wire antenna (~5 kM). One or more of these aircraft is constantly on patrol and ready to relay messages to the submarines if the fixed land based facilities are destroyed.

C. Future Systems

Future developments emphasize enhanced survivability against either electronic or physical attack on transmission facilities and/or submarines. The extremely low frequency (ELF, 30-300 Hz) subsystem [4] has been under development for nearly 20 years and is now awaiting a decision for production. Because of the extremely low attentuation rate in seawater at this frequency (~0.03 dB/m), signals can be received with an antenna trailed from the submarine at hundreds of feet below the ocean's surface. With current VLF systems on submarines operating at such depths and speeds, the Navy must depend on a special towed buoy to carry antennas and receiving equipment.

Satellite communications at extremely high frequency (EHF, 30-300 GHz) can be employed using small periscope or mast mounted antennas transmitting at EHF. The combination of wide-band signal processing available in this frequency band and small high-gain transmitting antenna provides substantial resistance to both jamming and undesired transmission interception. Downlink frequency selection and signal design will be for direct reception by the submarines and TACAMO with feasible satellite power requirements. Design should limit the demands on the spacecraft electronics and antennas in order to allow the capability to be placed on a number of leased or government owned "host" satellites. This is desired to limit design costs and delays plus enhance survivability through proliferation.

In the much longer term, laser satellites may replace fixed VLF facilities and transmit to submarines at depth either to a hull mounted receiver or to an advanced towed buoy. A blue-green wavelength is selected to penetrate the visual transmission window where clear water is as lossless as at ELF (~0.03 dB/m). Various impurities and organisms in the water increase losses, as do absorption, scattering, and pulse stretching in clouds. To obtain the desired data rates at submarine depths requires high power lasers, narrow beams, and narrow-band wide field of view optical receivers; all of which tax available technology. Efforts underway sponsored jointly by the Defense Advanced Research Projects Agency and Navy are seeking to develop the device technology and refine the channel models to a point where a practical blue-green laser system may be designed [5].

The future Strategic and Submarine Communication System will have little increased capacity but, rather, will ensure that the survivability of the communications means is consistent with the survivability of the submarines themselves.

IV. LONG HAUL COMMUNICATIONS

A. Function

"Long-haul" communications are characterized by beyond line of sight distances and two way "connectivities" between fleet elements and shore commanders or between independent fleet elements. Typical functions include support (intelligence and logistics), force direction and, in crisis, detail exchange of information pertaining to the situation by the on-scene commander.

Before Marconi, ships sailed over the horizon with only broad policy guidance (Do your duty; defeat the enemy.). Soon after the wireless became practical, HF communications became the means for both sides to command forces and to detect and track enemy forces. About a decade ago, it was widely believed that the then new satellite communication technology would make HF obsolete and unnecessary. Since that time, it has become obvious that satellites have significantly increased communications capability but have some areas of vulnerability. This fact, plus the need to interoperate with allied navies and to support tactical operations dictate the need for a modern HF capability to augment the satellite communications.

B. Present Systems

More than 15 years ago, the Defense Department developed a super high frequency (SHF 3-30 GHz) satellite communications system consisting of a large number of small satellites (Interim Defense Communication Satellite Program, IDCSP)

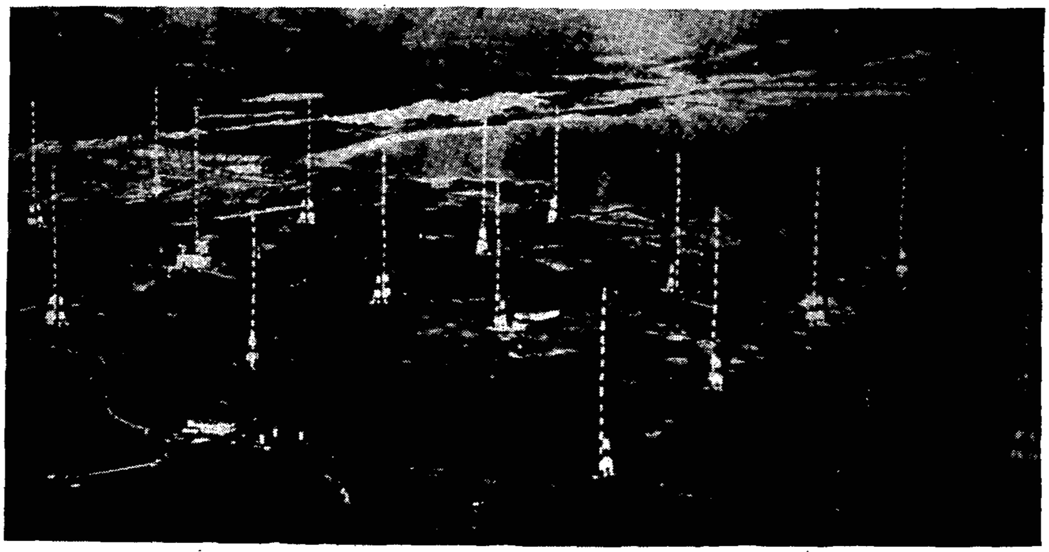

Fig. 4. Cutler, MA, VLF transmitting site.

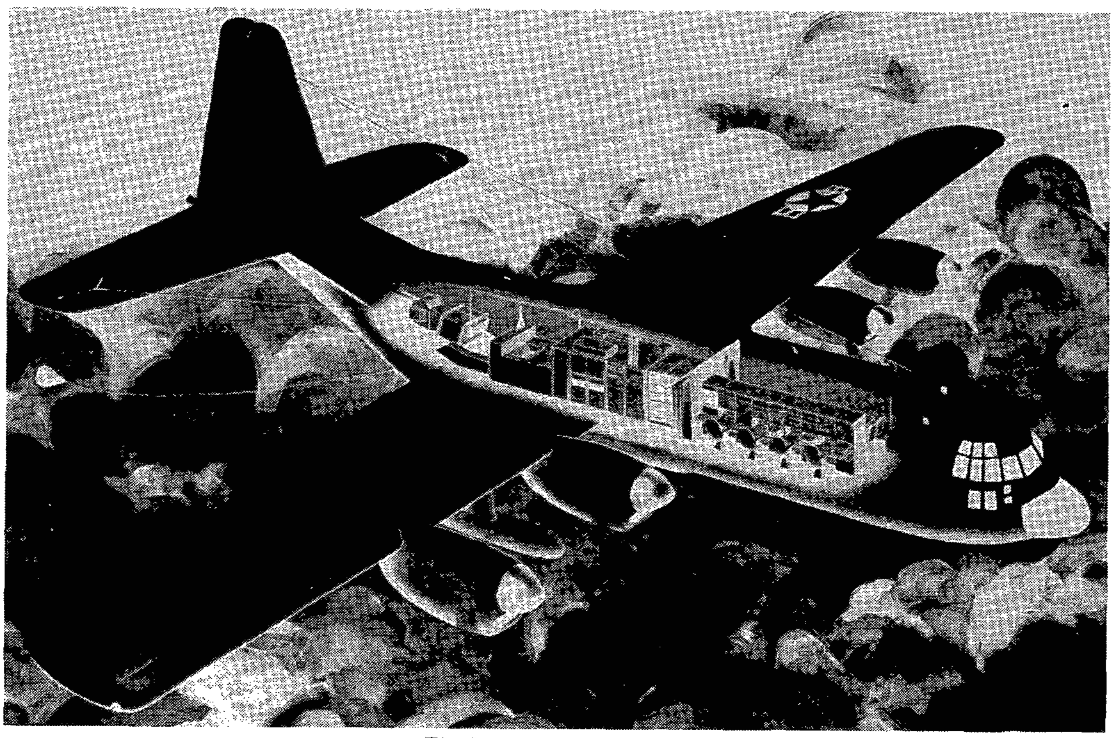

Fig. 5. TACAMO aircraft.

[6]. A few moderate sized terminals on key command ships allowed low-data rate jam resistant communications to large shore terminals (18 m antenna). Today, the SHF satellites (Defense Satellite Communications System, DSCS) [7]-[9] are larger, in geostationary orbit and are more capable, but the Navy has not increased the number of shipboard terminals. New SHF terminals with somewhat smaller antennas (1.2 m) are now being tested and evaluated. Upon successful completion of these tests, 28 terminals will be procured and installed on key command ships to allow low-data rate jam resistant communications to large shore terminals.

A little more than ten years ago, the need for jam resistant communications from shore to ship at considerably less cost than that allowed by the use of SHF terminals with repeating type satellites, led to the development of the hybrid SHF/UHF Fleet Broadcast concept operating today. A large shore terminal transmits a spread spectrum signal to the satellite providing substantial resistance to electronic jamming. The signal is "despread" or processed on the satellite and retransmitted to the earth at UHF frequency where it can be received with simple and inexpensive UHF antennas and receivers.

The satellite to carry the fleet broadcast signal processing equipment was too small to make effective use of available launch vehicles, and so it was decided that other general purpose UHF-UHF repeating channels plus channels for special applications would be added. Ten years later, the assemblage was launched as the first fleet satellite (FLTSAT). See [10] for a history of this development. FLTSAT has proven to provide excellent service and is meeting all expectations having weathered numerous design challenges.

The terminal program for the fleet broadcast and general purpose portions of FLTSAT moved along relatively quickly, producing the AN/SSR-1 (UHF broadcast receiver) and AN/WSC-3 (UHF transmitter/receiver) equipments in a few years. In order to fill the gap between the terminals and the delayed FLTSAT, the Navy contracted to lease a number of general purpose UHF repeater channels on the MARISAT satellites. This approach to space segment acquisition was perceived to be more cost-effective and satisfied the need in light of the delay of FLTSAT development.

Today, nearly all ships and many aircraft are equipped to receive the UHF Fleet Broadcast and/or to use the FLTSAT repeating channels for two-way (half-duplex) communications. Most ships have both systems and multiple AN/WSC-3 (two-way) installations are typical on major ships. The umbilical cord to the shore is firmly established and the demand has grown to meet and exceed the capacity of the dozens of channels now on orbit. In order to make more efficient use of the available channels, a demand assign multiple access (DAMA) [11], [12] concept is being developed to employ time division multiple access to increase the dataflow through each of the UHF repeater channels and to exploit the low-duty factor of most users by allowing shared channel use on demand.

In the initial years of satellite design, it was thought that HF would no longer be necessary when satellites were introduced and cost offsets from HF maintenance and upgrades were offered to balance satellite communication costs. Consequently, HF is operated today pretty much as it was in World War II. Frequency assignments are relatively fixed with little or no flexibility to account for the intended path or noise conditions at the receiver. Receivers and transmitters are manually tuned to preset frequencies and coupled to narrow-band antennas through manually tuned multicouplers. Generation of harmonic and intermodulation products between various HF signals and other shipboard emanations produce a noise background for onboard receivers which greatly exceeds natural or "atmospheric" noise. Operating disciplines and system design resulted in a vulnerability to jamming and interception from long range.

C. Future Systems

Recently, it has become increasingly apparent that the special convenience of satellite communications is accompanied by unique electronic and physical vulnerabilities. A program to modernize the Navy's HF communications capability [13] has commenced. A full suite of modern techniques will be implemented including adaptive real-time frequency selection, wideband active receive antennas, spread spectrum, adaptive interference cancelling, and automatic network management. A family of hardware modules will be fielded to meet both strategic and tactical needs and HF will once again be the dominant medium for any link not requiring the capacity or range of satellite communications. HF will also be the ultimate backup for long-haul Navy communications as it provides the only means that can function as long as there is a transmitter/receiver and a reflective media (ionosphere) to support the communications relay.

Current developments in Navy satellite communications seek to provide an alternative to UHF and SHF systems to provide substantial resistance to jamming, affordable terminals, and a system which can accommodate changing requirements and threats. Wideband uplink signals at EHF which are fully or partially demodulated on the satellite prevent "power robbing" by the jamming signal and ensure that costly spacecraft power is vested only in the desired communications (Fig. 6).

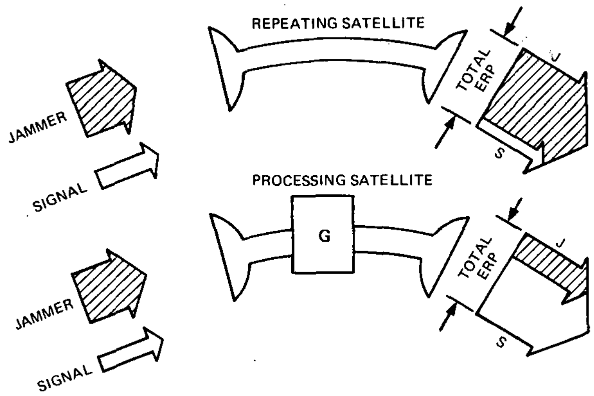

Fig. 6. Processing satellite advantage.

Such "onboard signal processing" will allow the use of small, mobile terminals on both up and downlink for the first time. Full processing gain will be effective against jamming, thereby reducing the need for large effective radiated power on the uplink to contest jamming by brute force [14].

Modulation techniques will use wideband frequency hopping with a low-rate psuedonoise submodulation on each hop to allow high-efficiency, high-order alphabets and fine synchronization with minimum hardware requirements. Exact modulation parameters will be determined by tradeoffs to maximize efficiency, tolerance to timing and Doppler errors introduced by the motion of the "mobile" platforms and satellites and to minimize susceptability to optimized jamming or intercept threats [15].

Care must be taken to confine the space segment hardware, including antennas, and power demands within modest bounds so that the capability can be placed on a number of leased or government-owned satellites. Access control schemes will be "distributed" so that each terminal may enter or leave the network without a central control station. Thus, combined features of onboard signal processing, proliferated processors and noncentralized control will ensure that the system can be disabled only by physically attacking every satellite.

Long-haul communications of the future will be carefully preplanned so that the most essential command and control links are operated on the most robust satellite communications and/or HF links in the most jam resistant mode while routine or nonessential traffic will be assigned to the peacetime UHF satellite communication circuits. In this way, the current long-haul liability will become a robust asset able to support fleet elements through all levels of conflict extending into the 21st Century.

V. TACTICAL COMMUNICATIONS

A. Function

Tactical communications provide the means by which units at sea coordinate their actions, support distribution of local surveillance data and exercise control over the combat and weapon systems. The range of these coordination and control activities is varied, but is usually contained in an area bounded by a circle whose radius is 250 nmi.

B. Present Systems

Most tactical communications are provided by HF or UHF radio links capable of supporting both analog and digital communications, although the equipments to communicate by manual Morse and AM voice still exist in a form similar to that of World War II. While most of the record traffic is encrypted, there is limited secure voice and secure data communications equipment. None of the existing communications are designed to survive a dedicated attempt at electronic jamming. Voice coordination networks are developed by having a (transmitter/receiver) for each network in which a platform (ship or aircraft) may be engaged.

Digital radio systems were introduced in the 1960's. These are Link 4A and Link 11 of the Navy Tactical Data System (NTDS). Link 4A was introduced to support an automatic landing system and later grew into a means to coordinate an airborne early warning aircraft E-2C and fighter aircraft F-14A by exchanging status and target data. All carrier based aircraft are equipped with Link 14A.

Link 11 is a datalink which supports the exchange of tactical data used to coordinate the platforms in the area of operatons. Primarily operating on HF, the link is also supported at UHF where the platforms are within line of sight. The number of platforms equipped with Link-11 are limited to those which have the capability to handle and display status and target information.

Link 14 is the remaining data system operating at both HF and UHF which provides a computer controlled broadcast of the tactical data by designated ships equipped with Link-11 and necessary supporting equipment. The output of Link 14 is a standard 100 words/min teletype to minimize terminal equipment costs of those force elements not directly involved in area role of defense or offense supported by the tactical data exchange.

Link 4A and 11 use a time division multiple access technique to access the various units and exchange target information [16].

The predominant type of tactical communication is supported at UHF. Without any relay aircraft, ships separated by 30 mi or more rely on HF. The only other communications available for widely dispersed ships is UHF satellite. This form of communications for tactical exchange is available, but since it is vulnerable to a modest jamming threat, its wartime utility limits application.

A summary of the tactical communications today is best described as "suitable" for peacetime operations. The coordination function provided by these communications, however, are operationally maturing and when the links are provided electronic protection offered by present technology, the overall tactical capability will be enhanced markedly.

C. Future Systems

The development of new tactical communications equipments are faced with several constraints. First, is the number of equipments, which for the Navy can range between five and ten thousand. The new and sophisticated equipments plus installation may cost upwards of a quarter of a million per unit. Total costs are then in the range of 1.25-2.5 billion with installation over ten years and a need to operate in a mix mode (old and new equipments) while in transition.

Another constraint is the size weight and power which usually is dictated by the old equipment which is being upgraded or replaced. Hence, the new design must live within constraints set by previous designs unless incorporated in the design of a platform under construction.

The new developments are a general modernization of the HF equipments as discussed in the "long-haul" communications section, a Joint Tactical Information Distribution System (JTIDS), and a combination VHF/UHF radio with an appliqué for antijam communications.

JTIDS is a joint service program to develop an integrated communications, navigation, and an indications friend or foe capability. Included in this system is a compatible mode with the existing tactical air navigation system (TACAN). The JTIDS waveform consists of a series of 6.4 μs pulses spread in bandwidth by a pseudorandom code whose center frequency is hopped over the frequency band of 960-1215 MHz [16], [17].

At the present time, this development has two variants, one being a structured time division multiple access (TDMA) scheme and the other a distributed time division multiple access (DTDMA). The TDMA structures the information into equally divided slots of approximately 450 unencoded information bits with each slot separated by a guard band to prevent multiple interference of users over the range of operation. The DTDMA design using the same pulse waveform which contains 5 bits of unencoded information does not restrict the user to a fixed-slot arrangement and can accommodate a user on the basis of a multiple of the basic pulse. This feature of the DTDMA which can be made backward compatible with TDMA allows the operational flexibility for complex net structures common to at sea tactical operations.

The JTIDS development will provide an enhanced electronic protection of the digital exchange between platforms. The enhancement will extend the effective range of communications to allow coordinated actions up until the final phases of engagement. In addition, the nature of this design facilitates the relay of information which provides another means to extend the horizon for communications between surface units with an aircraft as the relay platform.

The capacity of the JTIDS design is such as to accommodate both the digital information associated with links 14, 4A, and 11 plus secure voice. This attribute will ease transition of the equipments into operation since voice has been found essential to coordinate the data on targets when uncertainty in the data transfer occurs. The ability to accommodate both forms of information transfer with equal jamming protection in one equipment will provide a prudent means to transition. Since voice also plays a major role in other operations, it is necessary to develop an alternate means supporting the jamming protection for this transfer.

The combination VHF/UHF radio (COMBO Radio) is a good complement to the JTIDS development. The size of the radio will allow installation aboard fighter aircraft by replacing the space occupied by an existing UHF radio. The radio will be capable of operating in any mode of VHF/UHF, AM-FM which provides air-to-air compatibility (UHF-AM) and with the ground mobile force (VHF-FM). An appliqué to be constructed for the COMBO radio will provide jamming protection for secure and nonsecure voice. The appliqué will provide interoperability with the Army's SINCGARS-V system and will also be adaptable to interoperate with other UHF and VHF systems through software control. The ECCM capabilities achieved at VHF will also be available at UHF since the basic COMBO radio (AN/ARC-182(V)) can be operated at either band under external processor control. In the near term, the appliqué will be used to provide non-ECCM, two-way Link 4A in the F-18 as well as non-ECCM voice communications in this and other aircraft.

The future systems can best be viewed in the context of their incorporation in a given platform. The fighter aircraft represents perhaps the most stringent in size, weight, and power. The future communications complement in this case would be JTIDS, COMBO radio, plus conventional UHF radio. This provides for air-to-air connectivity of two separate electronically protected means for voice and data plus a third means of voice coordinating by the conventional radio. Thus reliability is provided redundancy and communications is protected by the diverse nature of the frequency of operation. Simultaneous data and voice would be the normal mode of operation.

For ships separated beyond line of sight, the connectivity would be provided by the improved HF equipments, EHF satellite and, when necessary, JTIDS aboard a relay aircraft.

The future systems have been constructed to provide the necessary electronic protection with the additional feature of being complemented by their incorporating in a balanced mix of communications equipments for the operational platforms needs.

VI. GOALS AND OBJECTIVES

The communications goals of the 1980's is to provide the electronic protection of the critical information exchange, modernize the existing equipments, and improve the ability to network forces for combined air, surface, and subsurface operations. This goal must be accomplished in the context of other services and Allied Nations developments providing the necessary information exchange in areas where combined operations are anticipated. With the development expected and outlined in this review, the posture of the Navy communications will be greatly strengthened and provided for the effective coordination necessary for modern warfare.

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