DEFENSE INFORMATION SYSTEM HF ENTRY - A LOOK TO THE FUTURE

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ABSTRACT: The advent of state-of-the-art equipment; combined with new interoperability and performance standards such as Federal Standard 1045 (Automatic Link Establishment) and MIL STD-188-110A (high performance modems); as well as automated computer based interface and control systems, procedures, and protocols has resulted in the reemergence of HF radio as a reliable, high performance vehicle for long distance (over the-horizon) connectivity as well as remote operation from subscriber locations by people who no longer require special training in HF radio techniques. The purpose of this paper is to describe the application of these new technologies in the transition of the Defense Information System HF Entry Station Modernization Program.

THE DEFENSE INFORMATION SYSTEM HIGH FREQUENCY RADIO ENTRY STATION MODERNIZATION PROGRAM One of the missions of the Defense Information Systems Agency (DISA) is to provide world wide long haul telecommunications for contingency operations of the unified and specified commands (CinCs) by utilizing the strategically

located Defense Information System (DIS) HF entry stations (Figure 1). These stations utilize 3KHz Voice Frequency (VF) Independent Sideband (ISB) channels to provide data, voice, and secure voice connectivity for remote user access into the Defense Information Systems via the Defense Switched Network (DSN), the Automatic Digital Network (AUTODIN), and the Defense Data Network (DDN). Unfortunately, most of the equipment located in the stations is obsolescent utilizing 1960's state-of-the-art technology which barely supports reliable transmission of 3KHz analog voice or 300 bit per second (bit/s) data.

Understandably, users are reluctant to utilize these facilities as long as other more reliable, high capacity alternative transmission systems are available. Moreover, use of present HF equipment is manpower intensive requiring highly skilled personnel to operate and maintain.

However, it is now possible through the use of new technology, techniques, and procedures to significantly improve the reliability, performance, and capacity of the HF entry stations while simultaneously reducing costs of operation and personnel requirements through improved efficiency and automation. This is the objective of the DCS HF Entry Station Modernization Program.

FIGURE 1. DIS HF RADIO ENTRY STATIONS

BACKGROUND For the past thirty years, long-haul High Frequency radio communications have been relegated to an increasingly diminishing role in the Department of Defense. HF, as most of us know it, had proven to be unreliable, manpower intensive, capacity limited and dependent on an unstable and unpredictable ionosphere to sustain its transmission path. Prior to the advent of satellite communications and high capacity submarine cable systems, HF was the primary Department of Defense transmission media for transoceanic and intercontinental telecommunications. As the newer media matured, the use of HF radio for long-haul communications has steadily declined until it reached its present status – that of a tertiary back-up system to be used only when other media are unavailable or saturated. As a consequence, fixed HF facilities have suffered from benign neglect as evidenced by obsolete equipment, lack of adequately trained personnel, and a diminishing operating budget. Most attempts at upgrading HF facilities have been intermittent, uncoordinated, and largely unsupported.

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Recent developments in technology have spurred a renewed interest in HF radio as a prime telecommunications media. The advent of digital signal processing, sophisticated forward error detection and correction techniques, and microprocessor control systems have resulted in the development of a series of adaptive, automated HF radio equipment and techniques which can dramatically improve HF reliability and performance while simultaneously reducing the requirements for highly skilled specialized HF operators. These techniques/equipment include but are not limited to (1) Automatic Link Establishment (ALE) and automatic networking, (2) high performance data modems designed specifically for optimum operation in the HF media, (3) automatic tuning of HF transmitters, receivers, and antenna couplers, and (4) automated system operation from remote locations. Concurrently with the advent of these improvements, a coordinated DoD, Federal agency, and industry effort was inaugurated to develop, refine, and implement HF radio standards to assure that new equipment will be interoperable regardless of manufacturer and meet the performance levels required for reliable operation. This effort has led to the development of Federal Standard-1045/MIL-STD-188-141A "Automatic Link Establishment" and MIL-STD-188-110A "Data Modems". The DCS HF Entry Station Modernization Program proposes to provide the following capabilities utilizing currently available technology and equipment:

A. Reliable data transmission at information rates of 2400 (design objective 4800) bits/sec with access to the AUTODIN or DDN network by means of appropriate interface equipment.

B. Intelligible and recognizable voice communications (both secure and clear) from a remote HF subscriber through the DSN or other switched networks to a desired destination with minimum operator intervention at the HF Entry facility (dial-up service).

C. Automated operation of HF radio facilities using remote or local controllers (PC's or smart terminals) by means of a standard interface. Functions include assignment of radio transmitters and receivers to support changing missions, Automatic Link Establishment - to include automatic retuning of transmitters and receivers to accommodate variations in transmission path characteristics, and automatic over-the-air rekeying of security devices.

D. Improved interoperability through standardization, not only with DoD users, but also with other federal agencies and Allied military forces requiring access to DoD HF facilities.

STATION MODERNIZATION - A PHASED APPROACH

Modernization of DIS HF entry Stations will occur by phasing in desired improvements to meet specified requirements as the funding and technology permit. The following examples show how each of the areas - data, voice, automation, and interoperability - will be achieved.

DATA ACCESS There are two generic HF Entry Station data network access requirements: (1) transmission of message traffic in the Automatic Digital Network (AUTODIN), and (2) transmission of data packets in the Defense Data Network. In addition, specific requirements have been identified for point-to-point data services such as facsimile, telemetry, and narrow band imagery. Most of these services require end-to-end security of the mission data stream. Successful secure data communications over HF radio is dependent on three basic equipments - the HF Entry Station Modem (HFESM), the KG-84C encryption device, and the AN/FCC-100 Low Speed Time Division Multiplexer (LSTDM).

The **HFESM** uses the serial tone waveform described in MIL-STD-188-110A as its basic mode of operation. In this model, it permits high performance duplex data transmission over a 3KHz Independent Sideband (ISB) HF radio channel at rates up to 2400 bit/s. High performance (low bit error rate) is achieved by means of a cyclic redundancy coding scheme for forward error correction. It is used in combination with an adjustable bit interleaving matrix to reduce the effects of burst errors typical of HF circuits. The negative effect of these techniques is the substantial delay introduced by the interleaver, which can be as great as 12 seconds per modem (50 seconds round trip) when the full power of the interleaver is selected. This factor must be taken into account if there are time constraints on the data system operating over the HF channel. The HFESM also must be capable of operating in several other modes in order to be "backward" interoperable with the large inventory of HF data modems already deployed by HF subscribers. However, in order to achieve acceptable error performance and high throughput efficiencies at 1200 and 2400 bit/s, the basic mode of operation is the only one recommended for DIS HF Entry applications.

The **KG-84C** is the only encryption device which employs techniques specifically designed to operate over HF radio paths and tolerate the delay introduced by the HFESM. It will accept both synchronous and asynchronous serial digital data at the maximum data rates for HF operation - i.e. 2400 bit/s.

The **AN/FCC-100 LSTDM** can multiplex up to 16 synchronous and asynchronous serial data streams into a serial aggregate data stream. Although the LSTDM is capable of much higher data rates, it is limited to 2400 bit/s for HF radio applications.

Using the equipment described above, the configuration shown in Figure 2 was developed by the Center for Engineering to meet the data transmission requirements for AUTODIN HF entry. It provides for the transmission of several low speed and one 1200 bit/s AUTODIN circuit. Each terminal is configured with an LSTDM, an HFESM, a KG-84C, and an **HF AUTODIN Interface Device** (HFAID). Because the AUTODIN protocols use a block acknowledgment system (ARQ) with a maximum round trip delay tolerance of 1.2 seconds at 2400 bit/s, the Center for Engineering developed the HFAID to compensate for the excessive delay introduced by the modem. It also provides a more robust over-the-air protocol

specifically designed to overcome the effects of HF channel perturbations.

This configuration was tested extensively using prototype equipment by the Joint Interoperability Test Center at Ft. Huachuca,¹ Arizona and the Naval Command Control and Ocean Surveillance Center, San Diego, California,² and the AUTODIN Test Facility, Ft. Detrick, Maryland. As a final proof-of-concept demonstration, the system was evaluated on an operational HF trunk between Australia and Guam. The results were dramatic with significant periods of error free performance over the HF paths tested. Based on the results of the testing, DISA plans to activate the first of these high performance data circuits over a jointly operated Australian/US HF radio trunk (Project Simpson) in early 1993.

The requirement to access the Defense Data Network via H/F radio poses a similar but more complicated problem. DDN is a packet switched network using CCITT X.25 for its data link layer protocol and TCP/IP for higher level protocols. The receive terminal will accept only error free packets; all other must be retransmitted until they are received error free. In the HF media, transmission of packets using X.25 format is extremely inefficient because of the high error density caused by fading and multipath on a typical skywave path. Early recognition of this difficulty led the amateur radio community to develop a packet radio protocol more suitable to HF applications, AX.25; however, even this protocol is not sufficiently robust to provide more than nominal protection from the effects of multipath fading. Packet throughput remains inefficient. Thus far, no satisfactory HF packet control system has been developed although there are several projects in the private and federal sectors engaged in developing a more efficient protocol which will retain compatibility with the X.25 TCP/IP protocol used in the DDN.

AUTOMATIC VOICE ACCESS Voice transmission is extremely sensitive to atmospheric and manmade noise as well as fading commonly experienced in a typical 3KHz HF radio channel and can become difficult to understand when even moderate levels of

noise/interference are encountered. In addition, special applique equipment must be provided to permit signalling and supervision information to traverse the HF transmission path in order for the subscriber to access either the Defense Switched Network or the Public Switched Network. To compensate for the special characteristics of the HF media, an extensively tested configuration has been adopted for DIS HF Entry voice access. As shown in Figure 3., a typical voice access configuration includes two additional equipments unique to the HF Radio environment and essential for near toll quality voice transmission over the radio path and transparent access to the switched networks.

The principal purpose of the **Standard Termination Unit #5 (STU-5)** is to render the HF media transparent to the supervision, signalling, and interface characteristics of a telephone subscriber access line. It performs this function by adapting/converting the signalling and supervision information from the subscriber PBX or switchboard for transmission over the HF trunk as well as providing a duplex interface between a 2-wire or 4-wire switchboard and a 4-wire VF path. At the DIS HF Entry Station it converts the signalling and supervision information to the appropriate multitone frequencies for DSN or Public Network access as well as level compensation at the network interface. This capability eliminates the requirement for human intervention at the HF Entry Station for voice access to the switched networks.

The Linked Compressor Expander, or **LINCOMPLEX**, is a device designed to substantially improve quality and intelligibility over analog HF radio links utilizing AM or Single Sideband (SSB) modulation. Its characteristics are described in CCIR Recommendation 455-1.³ Lincomplex significantly reduces the effects of noise and interference on the HF radio path by means of a robust control channel which links the speech compressor at the transmitter with the expander at the receiver to reduce the effects of noise, interference, fading, and weak signal strength – a capability beyond that of conventional compressors. The most recent Lincomplex designs use digital signal processing techniques to perform the compression, expansion and control functions. Testing has demonstrated that an improvement

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in signal-to-noise ratio of 10 - 15 dB which achieves the same effect as increasing the transmitter output power by 10 - 15 dB.⁴ The net effect is the achievement of voice quality and intelligibility approaching toll quality without increasing transmitter power.

With this system in place, calls can be placed automatically from either direction without the user ever knowing that his call is traversing an HF trunk. As far as he's concerned, he's on a toll quality circuit. The reduced manning requirements coupled with reduced transmit power requirements will result in greater efficiency and cost savings at the HF Entry Stations.

SECURE VOICE ACCESS The most logical approach for providing a seamless HF interface for secure voice is to take advantage of the universality of the **Secure Telephone Unit-III (STU-III)**. Until the introduction of the STU-IIIIR, this family of secure telephones was unsuited for HF operation because the internal modem was designed to operate over wire-line VF channels and could tolerate the HF radio channel impairments. However, the STU-IIIIR provides a digital output at 2400 bit/s which can be connected to the HFESM which can operate in the HF environment. Figure 4. provides a possible configuration for STU-III operation with

FIGURE 4. SECURE VOICE VIA HF ENTRY

HF entry access. The Center for Engineering and the Joint Interoperability Test Center are currently evaluating the performance of the STU-III/HFESM over HF. Based on the results of this evaluation, the Center for Engineering will recommend a system configuration for secure voice access in the near future.

AUTOMATED HF RADIO OPERATION AND INTEROPERABILITY One of the major disadvantages of HF radio systems as presently used in the DoD, is the requirement for highly trained operators to manually establish and maintain the HF transmission path. The users will not tolerate the delays resulting from these activities nor do the operating agencies any longer have the resources to operate these manpower intensive, inefficient systems. Through a coordinated effort by the Defense Information

Systems Agency, the Federal Emergency Management Agency, and the National Telecommunications and Information Administration have developed and are further developing and refining a family of standards for automated operation. The first of these standards, Federal Standard-1045/MIL STD-188-141A - Automatic Link Establishment (ALE), has been published⁵ and equipment built to these standards extensively tested. ALE provides the HF radio station with the capability to establish a circuit (link) between itself and another radio station or network without operator assistance. The prominent features of ALE include automatic signalling and response, selective calling, automatic handshaking, channel scanning and selection, and link quality analysis. Now we can field equipment which automatically determines the best operating channel, tunes to the proper frequency, and establishes the transmission path to the distant HF radio facility. Because of the ability of the ALE to select the best operating frequency, we have also determined that we can significantly reduce transmitter power and still maintain substantially higher performance levels than the manually operated systems. Tests have demonstrated that the probability of linking increases from about 60% with conventional systems to better than 95% with ALE and that equipment built to this standard by several manufacturers have successfully interoperated.⁶ Automatic Link establishment is merely the first step; A cooperative effort by Federal and DoD agencies is underway to develop increased automatic/adaptive HF standards for automatic networking, message relay/store and forward, multimedia connectivity, and linking protection.

The Center for Engineering has proposed that the DIS HF entry Stations be equipped with an ALE and Linking Protection capability. However, this capability in itself does not satisfy the fundamental requirement for total unattended operation where the user can establish a connection to another subscriber over a communications link containing an HF path in much the same manner that he calls someone on telephone. A family of control terminals is needed which can interoperate with both HF radios and subscriber terminals of various manufacture which will automatically sense when a user requires service and perform the functions described above.

Equipment interoperability is merely a subset of Systems/network interoperability. Until recently, HF radio has been primarily a point to point system with a human interface to pass traffic onto other systems/networks. Under the new concept of operation, the HF radio trunk must appear as a seamless interface to the user. This requires that the HF system not only interoperate with other equipment, but also be capable of transferring the protocols, signalling and supervision, and monitoring information through the network. This capability applies not only to the fixed strategic networks but also the tactical networks such which have unique waveform, signalling and control requirements.

The principal mission of the DIS HF Entry Stations is to support the various Unified and Specified Commands in contingency operations and deployments where by and large the depend on tactical equipment to establish and maintain communications. Based on the lessons learned in Desert Storm/Desert Shield, DISA is undertaking a major effort to assure that the tactical equipment

will interoperate with the commercial/fixed plant equipment used in the Defense Information Systems Network. The Center for Engineering and the Joint Interoperability Test Center has been evaluating the capability of the HF Entry Stations to interoperate with the tactical terminals such as the AN/TSC-122 Radio, the AN/TYC-39 Message Switch, and the AN/TTC-39 Voice Switch. Recent testing has demonstrated that the techniques and configurations discussed above will enhance interoperability and performance when traffic is routed via the HF Entry Stations

THE FULLY INTEGRATED HF ENTRY STATION

Currently efforts are underway within DoD to reduce the number of fixed HF facilities while maintaining the capability to satisfy mission requirements. Simultaneously, the remaining stations would be modernized to achieve higher levels of performance with reduced manning through the use of automated techniques and advanced technology. Thus far, this paper discusses configurations and techniques which may be applied individually to enhance a single aspect of HF radio operation. In order for HF to fulfill its appropriate role in the Defense Information System, it must be capable of providing a reliable media to support the variety of services previously described. Therefore, it would be inappropriate and inefficient to provide these services piecemeal. What is required is a complete upgrade of HF facilities with state-of-the-art automated radios and antennas which can be rapidly tuned and remotely operated. Equipment must be provided to integrate the HF facilities into the Defense Information System Network (DISN) so that subscriber can use the HF media in much the same way he uses the terrestrial and satellite transmission systems. That is, he doesn't know or care what kind of transmission facilities he uses, he merely knows that he can communicate through the network. HF radio will never be capable of providing the capacity of the more exotic transmission media. However, HF radio systems can be rapidly deployed and links established quickly once the equipment is on the ground, and the technology is available to provide the high reliability and performance for the services it can support. In order to offer the full range of services, the HF Entry Station modernization must be implemented as an integrated package, with all the stations similarly and simultaneously upgraded, they must offer a full range of services for the user, and be interoperable with their tactical counterparts. When the complete system is fielded, the DIS HF Entry Stations will be able to fulfill the mission for which they were intended.

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