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NAVAL RESEARCH PROGRAM
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MONTEREY, CALIFORNIA

GO BIG WITH HIGH FREQUENCY (HF)

EXECUTIVE SUMMARY

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Project Summary

The high frequency (HF) band in the range of 3 MHz to 30 MHz has been used for decades for long-range communications. Long ranges are made possible by unique propagation mechanisms that occur at these frequencies, primarily ground waves and ionospheric reflections. Since the advent of satellite communication (SATCOM) systems in the 1960s, HF systems have gradually decreased in importance.

Recently, concerns over the security and vulnerability of satellite systems have renewed interest in HF comms as a backup network in the event of SATCOM performance degradation or failure. HF radio capabilities do not have the capacity to meet signal demand for all combat operations. The purpose of this proposed research is to determine the amount of HF infrastructure that is needed to support combat operations adequately in a satellite degraded environment. It is necessary to assess the HF infrastructure that would be required to overcome a fully denied satellite state. Specifically, if the required warfighting capabilities are assumed to be (a) battle space awareness, (b) assured command and control (C2), and (c) integrated fires, then it is necessary to determine the HF infrastructure that is needed for combat operations across HF beyond line-of-sight (BLOS) networks.

This study looks beyond the tactical level of war to develop solutions for the operational and strategic levels. The objective of this research is to create a clearer vision into the types of BLOS HF networks that would be required to support prolonged combat operations with a peer adversary.

Keywords: *high frequency, HF, radar, voice communications*

Background

For two-way communication, the important considerations are the transmitters, receivers, antennas, and propagation channel, i.e., the physical environment between the two communicating nodes. The propagation mechanisms at HF frequencies are generally divided into three categories: the space wave (line-of-sight plus surface reflection), ground wave (a wave guided by the interface between the ground and air) and sky wave (propagation via the ionosphere). Several of these may be present simultaneously and they can change with time.

The communication links of interest in this study are those for longer distances (hundreds to thousands of km) that are achieved via skywave paths. For long-distance paths with ground-based antennas, vertical polarization is desired, and the launch angle of the antenna beam is near the horizon. For long distances, the systems require high transmitter powers and very sensitive receivers that can detect weak signals.

HF communications (3–30 MHz) use ionospheric skywave reflection for BLOS propagation over potentially thousands of miles (International Telecommunications Union, 2020). This was historically a cornerstone of naval communications, enabling ships at sea to maintain C2 links over the horizon.

HF propagation is highly dependent on atmospheric conditions, frequency, time of day, and solar activity. HF ionospheric paths are variable, and the specific frequencies that will propagate over long distances change with the time of day, season, latitude, and sunspot cycle (Hortaleza, 2021). Optimal HF frequencies drift from higher bands in daylight to lower bands after dark. Solar flares or geomagnetic storms can disrupt the ionosphere and cause HF blackouts or unpredictable behavior (Naval Network Warfare Command, 2008). These factors make HF less straightforward to use than fixed-frequency line-of-sight (very high frequency/ultra-high frequency) or satellite links, and effective HF operation often requires frequent retuning, or agile frequency management, to find a usable channel as conditions change (Hortaleza, 2021). Modern techniques, like automatic link establishment, help automate the process of finding a usable channel (Gallup, 2015).

There exist some important limitations of using HF. In particular, HF has a narrow available bandwidth and variable reliability. Traditional HF channels are only 3 kHz wide, limiting data rates to around 300–2400 baud for teleprinter and a few kilobits per second for data in most legacy systems. Even using techniques like independent sideband (i.e., pairing two 3 kHz channels for 9.6–19.2 kbps data), HF cannot approach the high throughput of modern satellite communications (Hortaleza, 2021). In terms of signal quality, HF channels are noisy and susceptible to interference. Additionally, HF communication often has notable latency due to long propagation paths and the need for automatic repeat request and error-correction in data modes. Furthermore, HF can suffer from phenomena like multi-path interference and skip zones, which are regions where no usable signal is received due to propagation geometry (Naval Network Warfare Command, 2008).

Findings and Conclusions

The Navy's effort to revitalize HF communications comes at a time when a "high-frequency renaissance" is being acknowledged across defense circles. Where HF was once nearly written off, now it is a hot topic in ensuring resilient communications (Johnson, 2020). Senior leaders have publicly stressed the need for multi-path communications. For example, U.S. Fleet Forces Command and U.S. Pacific Fleet have directed units to incorporate alternate comms, including HF, into their training and operations plans. Large exercises include SATCOM-denial injects: in Large Scale Exercise 2023, for example, one of the objectives was to test the fleets' ability of C2 across 22 time zones without full satellite availability. Such exercises highlight any gaps that exist in HF proficiency and system performance (U.S. Fleet Forces Command Public Affairs, 2023).

Using HF in the fleet today still faces challenges beyond training. One is integration with modern networks. HF circuits are slower and often require protocol adaptations to carry modern data. While Battle Force Tactical Network provides an IP interface, applications running over it may need tuning to work well (Maldonadodelrio, 2021). There have been reports from exercises that when forced to use HF, certain data links simply time out or overwhelm the link. Doctrinally, this means units must grasp what can and cannot be pushed over HF. For example, streaming video or large imagery may be off the table; but compressed text and small situational reports are feasible.

Developing tactics, techniques, and procedures (TTPs) for a "thin C2" environment is therefore an ongoing operational task. The Navy is drafting comms plans that specify what the minimum essential data to exchange is if utilizing HF only—for example, a daily brief via formatted message, position location info via an HF Link-11/Link-22 data link in very condensed form, and reliance on pre-planned responses. The training community must incorporate these TTPs so that crews can execute them. Part of Paulaitis' (2020) recommendation was to update or create TTPs for use of assets like the HF Global Communications System (HFGCS) by surface ships. HFGCS is a worldwide network of HF stations (primarily Air Force-run) that provides coverage for aircraft and can support ships. Many Navy surface communicators were not familiar with how to utilize HFGCS (which frequencies, how to request a broadcast, etc.), representing a missed opportunity for a reliable long-range path. Addressing this by adding to doctrine and training ensures the fleet can tap into that resource.

One trend to overcome these challenges is increased HF automation and planning tools, such as fielding automated HF network planning software that can recommend frequencies and schedules (considering ionospheric forecasts) (Naval Information Warfare Systems Command, 2021). Another trend is multi-path integration—using HF in parallel with other means in an automated way. This integration would hide some complexity from the end-user and ensure that HF remains in the forefront (Hortaleza, 2021).

Recommendations for Further Research

Collectively, this analysis paints a picture of a Navy that is actively learning and adapting its high frequency (HF) communications practice. The research highlights that success in HF employment is a multi-faceted challenge: it requires modern equipment, robust training, and doctrinal emphasis. A common thread is the need for better training and awareness—every study calls for improved education on HF, from basic operator skills to high-level planning.

Encouragingly, we see these insights being applied. The Navy is updating school curricula and Personnel Qualification Standards, increasing HF training events, investing in new HF technologies, and revising doctrine (for example, drafting comms annexes that detail actions in comms-denied scenarios, including HF use). There is also more cross-pollination with allies and other services: the Air Force's expertise in HF—through extensive experience with HF Global Communications System and nuclear command and control via HF—is being shared with Navy, and vice versa.

In summary, the deep research and case studies reinforce the narrative that HF communications, once a fading art, is now recognized as a critical enabler in the U.S. Navy's operational toolkit. The fleet is re-learning and innovating in this domain, yet challenges remain in fully institutionalizing HF proficiency.

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Acronyms

BLOS	Beyond Line-of-Sight
C2	Command and Control
HF	High Frequency
HFGCS	High Frequency Global Communications System
NPS	Naval Postgraduate School
NRP	Naval Research Program
SATCOM	Satellite Communication
TTP	Tactics, Techniques, and Procedures