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ASSURED COMMAND AND CONTROL FOR THE ROYAL CANADIAN NAVY IN A DENIED, DEGRADED, INTERMITTENT AND LOW-BANDWIDTH ENVIRONMENT

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Service Paper

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Lieutenant-Commander Christopher Jawornicki

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AIM

1. The aim of this service paper is to present solutions for the Royal Canadian Navy (RCN) to enable assured command and control (AC2) for its fighting units when engaged in a high-end war fight where a denied, degraded, intermittent and low-bandwidth (DDIL) environment is likely to occur and hamper the normal means of command and control (C2). To ensure AC2 in DDIL environment, a proposal will be made to upgrade and revitalize legacy high frequency (HF) communications systems, and to integrate them into an upgraded C2 apparatus.

INTRODUCTION

2. Western nations' navies have had uncontested access to the electromagnetic (EM) spectrum to support their communications and information exchange requirements (IER) over the last few decades. Access to military satellite communication (SATCOM) constellations such as the Wideband Global SATCOM (WGS) system and the Advanced Extremely High Frequency (AEHF) constellation have allowed for continued growth of networked and internet-protocol (IP) data to be passed to ships with relative ease. A steady increase in SATCOM bandwidth and throughput has put even more reliance on this communication method. Access to SATCOM allow ships at sea to use the computer networks onboard to support their enterprise, logistics and maintenance applications as if they were in homeport and physically hardwired to the internet.

3. While western navies have many different types of communication systems on board, until recently only SATCOM allowed access to IP networks with collaborative websites and portals, classified intelligence, emails, and orders and directives from higher headquarters and command at sea, in a way that no other communication system onboard could replicate. The connectivity of ships at sea has become so prevalent that it is now expected that a deployed ship will not only have continuous SATCOM access but be given a larger bandwidth pipeline (compared to ships conducting force generation (FG)) to support the myriad of IERs, including C2.

4. This dependance on SATCOM has allowed other legacy methods of passing orders and directives to fall by the wayside, that nearly all C2 is passed electronically via SATCOM. Whether emails, electronic chats, telephone voice orders by voice over IP (VOIP), or even traditional formatted military messages, all these means are primarily passed via SATCOM due to the ease in passing said traffic, but also the speed in which this data can be relayed.

5. Despite these advantages, it is important to note that SATCOM also has its limitations and vulnerabilities. SATCOM can be easily affected by a myriad of factors, and in a future high-end war fight with near peer adversaries it is very likely that

SATCOM communications will be interrupted. However, fighting units will still be required to carry out missions and tasks, and must be able to adapt and adjust based on higher command direction, and thus the means to assure C2 need to be invested in.

DISCUSSION

6. A warship can find itself in a DDIL environment through a variety of scenarios, such as weather conditions, signal latency, the finite throughput of SATCOM, self imposed emissions control (EMCOM) states, denial actions against the enemy, or denial actions by the adversary such as jamming or interference or even kinetic actions against satellites, as well as by other means. Thus, C2 in a DDIL environment can be very challenging. Operational planners must be ready to respond to a DDIL environment, regardless of the cause, and overcome deficiencies to fight through. The ability of a Commander to exercise their authority and provide direction over assigned forces is dependent on the passage of critical information, essential elements of information, and the ability to exchange vast amounts of data across a complex and varied theatre. In the maritime domain where the Commander may be thousands of miles away from their assigned forces, awareness of DDIL and mitigating strategies and technologies becomes paramount to success.

7. The concept of AC2 seeks to maintain the RCNs ability to exercise C2 in the presence of a DDIL environment. According to United States Navy (USN) doctrine, a warship in a DDIL environment has three primary warfighting functions that must be maintained: command forces in any environment (C2), coordinate fires in all domains (integrated fires), and assess fires and own force status (battlespace awareness (BSA) and maritime domain awareness (MDA)).[1] To achieve AC2 and maintain said warfighting functions in a DDIL environment, forces must rapidly adjust their C2 apparatus to support the movement of mission-essential information once a denial or degradation is detected. As the amount of degradation or denial increases, assigned forces need to prioritize their IERs and communication methods to ensure that they maintain critical IERs to support C2, BSA/MDA, and integrated fires (see Figure 1).

[1] "US Navy Information Dominance Roadmap 2013-2028."

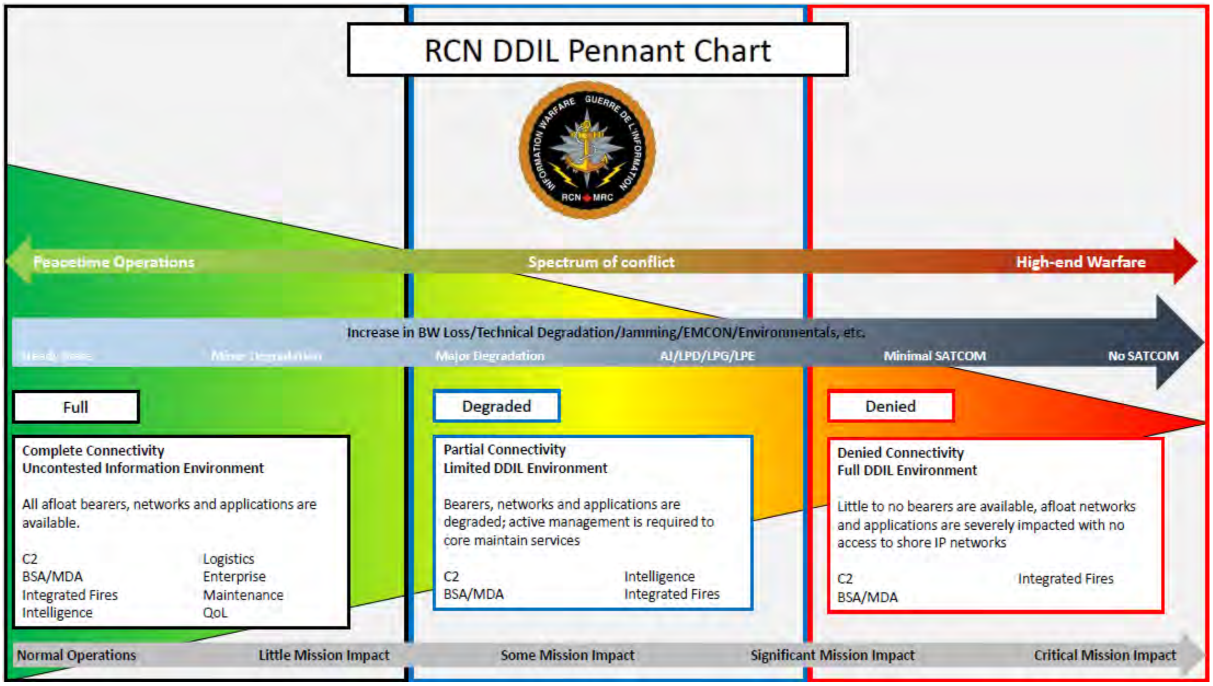

Figure 1 – RCN DDIL Pennant Chart[2]

8. At the thin end of the pennant chart when a fighting unit needs AC2 to carry out its mission, it becomes critically important to be able to shift to a communication method that cannot be easily denied or degraded yet can bridge the vast distances between a Commander and their assigned forces which may be at sea on the other side of the globe. To achieve this feat, navies rely on High Frequency (HF) communications to send information. HF communications can achieve true beyond line of sight (BLOS) communication with relative ease due to the physical nature of these radio waves. HF signals are valuable to achieve global reach as their skywave can be bounced off the ionosphere to cover vast distances. HF signals are also less susceptible to jamming and electronic interference as they propagate via multiple paths including ground waves, direct waves and skywaves (see Figure 2). This multipath propagation makes it significantly more difficult for adversaries to effectively disrupt HF communications, as successfully jamming one path may not necessarily block the signal entirely. As HF communications typically utilize a wider frequency bandwidth compared to higher frequency bands (very high frequency (VHF), ultra-high frequency (UHF), super-high frequency (SHF)), it spreads the signal energy across a broader frequency range. This wide bandwidth makes it more difficult for adversaries to selectively target and disrupt specific frequencies without affecting a broader spectrum of frequencies, including those used by their own forces. Finally, to jam any EM signal, the adversary needs to emit a signal on a given frequency with more power than the actual users. Since HF communication systems are designed to operate over long distances and under challenging environmental conditions, they often employ high-power transmitters to ensure sufficient signal strength for reliable communication. An adversary jammer would need to emit even higher-power signals to effectively overpower and disrupt HF signals

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[2] Directorate of Naval Information Warfare, "RCN DDIL Pennant Chart."

which can be technically challenging and resource-intensive.[3] Given these characteristics, HF communications are an ideal method for AC2.

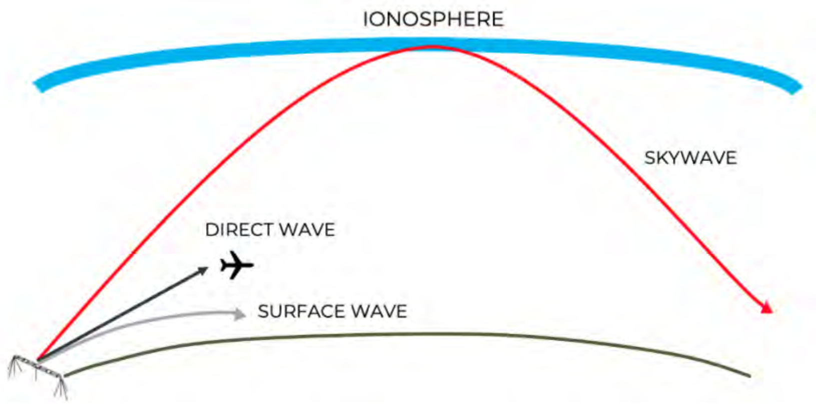

Figure 2 – HF radio wave propagation paths[4]

9. Although the RCN does have preplanned tactical responses for Naval Communicators (NAVCOMMs) to carry out onboard a ship in case of communications degradation or denial, these responses are specifically tailored to a given communication system, and not to the entire C2 apparatus onboard. To maintain C2 with Commanders ashore, the NAVCOMMs need to manually revert to legacy HF systems to send military messages as the last C2 resort. The RCN's current HF setup onboard its ships is outdated and generally not well understood by junior NAVCOMMs due to a lack of training and real-world use. In a typical RCN plan for primary, alternate, contingency, emergency (PACE) communication methods, forms of SATCOM take precedence as primary and alternate, while HF is usually relegated to emergency communications only.

10. While HF has its advantages as stated above, it also has its disadvantages which led to the decline in its usage. The time of day can have an effect on HF over-the-horizon ranges. The ionosphere is affected by solar radiation and thus acts differently during the day than it does at night, which affects the ranges that are able to be achieved on a given transmission frequency. Phenomena such as solar flares and coronal mass ejections send particles that can penetrate the ionosphere and cause atmospheric disturbances that can seriously disrupt HF. With the legacy HF equipment onboard RCN ships, a skilled NAVCOMM needs to continually adjust the transmission frequency based on the atmospheric conditions to achieve proper transmission. This is typically done by listening to the sound of the broadcast at the transmitter or receiver and "hearing" whether the radio waves sound distorted or not, and thus whether a good transmission connection link has been achieved. The "ear" that is required to properly tune HF transmission links is

[3] Withington, "HF Radio: Still Valid After 100 Years - Asian Military Review."
[4] Lespretentieux, "HF Communications Are Making a Comeback, and Here's Why You Need to Get in on It! - Base Camp Connect."

often referred to as an "art" that is learned through experience, according to NAVCOMMs.[5]

11. The other disadvantage of HF is that until recently, HF communications were physically restricted to data at rates of up to 9.6 kilobits-per-second (kbps) due to the narrow frequency band in which they transmit within. This is in distinct contrast to the megabit-per-second (Mbps) data rates which can be achieved by higher frequency communications such as UHF, SHF and SATCOM. Additionally, HF could only pass voice or data in the form of radio teletype or formatted military messages.

12. HF communications have continued to evolve and advance due to continual research and development, leading to four distinct generations of improved HF technology (see Figure 3). These advancements, plus updates in standardization protocols such as the US Department of Defense's Military Standard-188-110B (MIL-STD-188-110B) and the North Atlantic Treaty Organization's Standardization Agreement 4539 (STANAG 4539) have opened up greater frequency bandwidth within the HF spectrum to increase HF's throughput with speeds of up to 240kbps in good propagation conditions.[6] The updated protocols now allow IP traffic to be passed in real time, and with the increased throughput, file and low-resolution video transfers can even be transmitted.

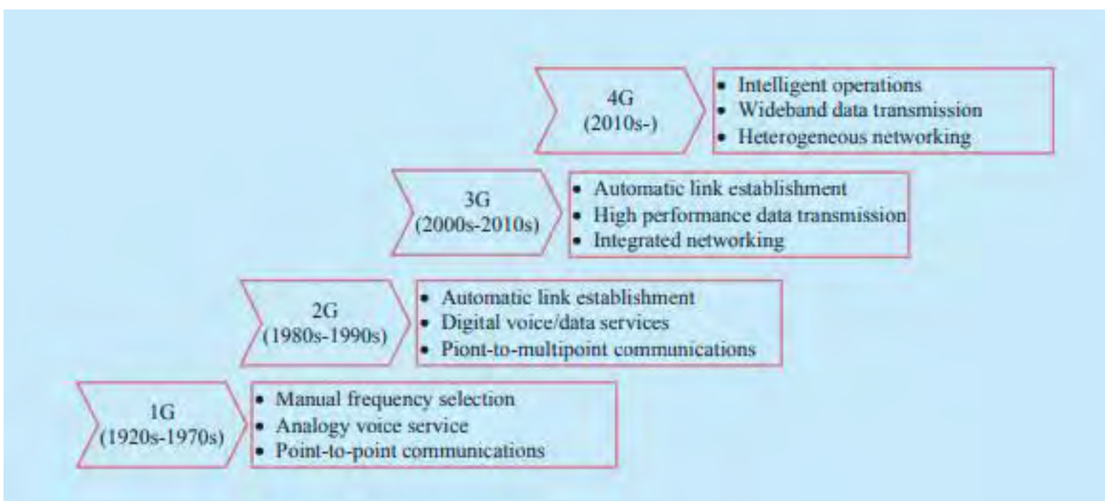

Figure 3 – The evolution of HF communications.[7]

13. Furthermore, technological advancements have been made to the actual radios that are used to transmit radio waves. The latest innovations have ushered in software defined radios (SDRs) which have revolutionized HF communication by enabling greater flexibility and adaptability. These radios use software processing to handle modulation, demodulation, filtering, and other signal processing tasks, allowing for dynamic adjustments to changing propagation conditions and interference environments. SDRs also offer advanced signal processing techniques such as adaptive modulation and error

[5] Korvela, "How HF works in the RCN", January 2021.
[6] Withington, "HF Radio: Still Valid After 100 Years - Asian Military Review."
[7] Wang, Ding, and Wang, "HF Communications: Past, Present, and Future."

correction to improve communication quality and efficiency. SDRs also feature automatic link establishment (ALE) which automates the process of establishing and maintaining communication links between HF radios based on the given atmospheric conditions, thus simplifying operation, and reducing the workload on operators. Finally, SDRs are also frequency agile, meaning that the radios can rapidly switch frequencies during transmission to avoid interference and jamming. SDRs use techniques such as frequency hopping spread spectrum (FHSS) to spread the signal energy across multiple frequencies, making it difficult for adversaries to jam or intercept the communication. Given these advances in technology, HF communication is now being integrated into networked communication systems, enabling seamless interoperability with other communication methods, including SATCOM, VHF, UHF, and data networks. Networked HF systems provide enhanced connectivity and flexibility for users operating in diverse operational environments.[8]

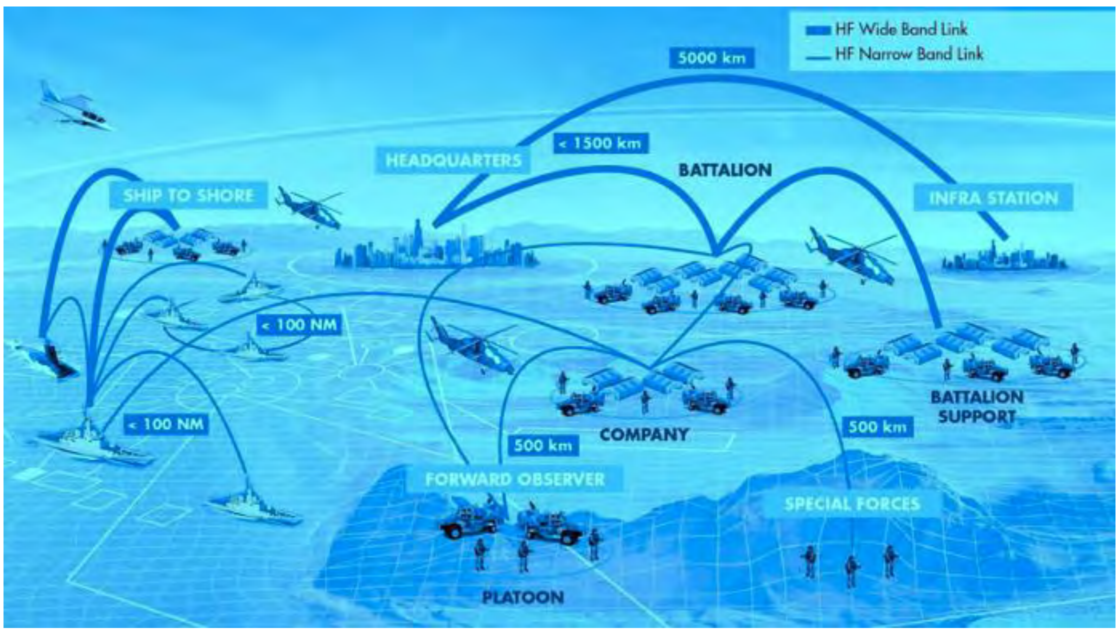

Figure 4 – Connected battlespace using HF links to cover vast distances[9]

14. To fully utilize the capabilities available in the newest HF technologies as a method to achieve AC2, there needs to be full integration into the C2 apparatus on deployed ships. While an upgrade to new HF SDRs with the associated antennae will still achieve a means of C2 in a DDIL environment, it will still be dependent on operators to recognize and assess DDIL situations, expected durations and their impact, and then for NAVCOMMs to manually switch to HF communications. A truly integrated C2 apparatus will ensure seamless transitions between PACE communication methods to ensure near continuous C2 in all DDIL scenarios.

15. Operational planners need to prioritize IERs and core services based on the mission, and assign them to the PACE information exchange bearers that are available,

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[8] Ibid.
[9] Withington, "HF Radio: Still Valid After 100 Years - Asian Military Review."

and can be maintained in face of the DDIL threats. Regardless of the level of information services, core services are deemed critical to maintaining reliable C2 and to allow the mission to continue, despite the effects of the adversary. IERs must be understood prior to any mission, with risks understood, and with mitigating strategies determined through pre-established tactics, techniques, and procedures (TTPs), as it is far too late to react to threats to the information exchange once in mission.

CONCLUSION

16. Advancements in SATCOM have been pivotal in facilitating seamless communication and information exchange aboard ships, enabling the extension of enterprise-level capabilities in remote maritime environments. However, the vulnerabilities and limitations of SATCOM, and the ease in which they can be denied in a high-end war fight by near-peer adversaries underscore the imperative for alternative communication methods to maintain C2. HF communications are a robust solution, offering global reach, resilience against jamming, and given the capabilities available in the latest generations of HF communications, they offer Commanders and their assigned forces to continue to exchange information to maintain C2, BSA/MDA and integrated fires, thus achieving true AC2 in a DDIL scenario.

RECOMMENDATION

17. The RCN should invest in new HF SDRs capable with the latest technologies for its entire fleet of surface ships. Although the Canadian Patrol Frigate (CPF) is the ship most likely to be in a high-end war fight, all ships may experience DDIL scenarios outside of their control and will still need to be able to communicate with Commanders and higher headquarters ashore. Upgraded HF SDRs will not only improve the functionality and provide AC2, but they will also decrease the workload on operators and ensure that it doesn’t take an experienced NAVCOMM to setup assured communication links. To allow the RCN to benefit the most from the aforementioned capabilities, the RCN also should invest in upgrading the entire C2 apparatus onboard, so that NAVCOMMs and operators can quickly identify DDIL situations, and thus prioritize IERs and communications methods to ensure the mission specific tasks are still able to be completed and reported on.

18. The RCN, through the Directorate of Naval Information Warfare (DNIW) and the Canadian Forces Maritime Warfare Centre (CFMWC) should work with its Five Eyes and NATO allies to test and develop TTPs to ensure NAVCOMMs and operators recognize critical IERs in DDIL situations and adjust the C2 apparatus accordingly. As it currently stands, Commanding Officers and Commanders ashore are reluctant to train operators to assess DDIL situations (such as the cause, the expected duration, and the impact on operations) as disconnecting from SATCOM means losing the ability to use enterprise systems to preserve logistics, maintenance, intelligence and even quality-of-life applications, and even the day-to-day reach-back with fleet support staff and commanders ashore.

19. Finally operational planners, as well as ships staff need continuous training in DDIL and its impacts on operations. They need to be proficient in how to pre-plan responses to DDIL scenarios, to prioritize IERs and associate them accordingly within a PACE plan. These actions need to be trained and exercised in all FG, so that once ships are deployed, they can maintain AC2 at all times.

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