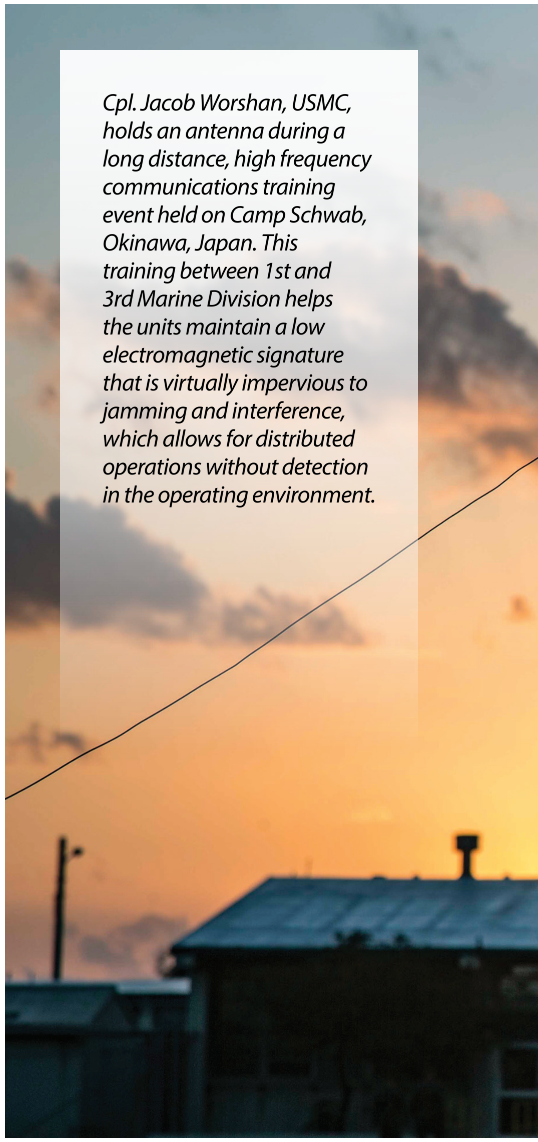
Wideband Steps Up to Fill the Gap

4G high frequency radios supplement satellite communications.

BY ERIC E. JOHNSON, PH.D., PE



Cpl. Jacob Worshan, USMC, holds an antenna during a long distance, high frequency communications training event held on Camp Schwab, Okinawa, Japan. This training between 1st and 3rd Marine Division helps the units maintain a low electromagnetic signature that is virtually impervious to jamming and interference, which allows for distributed operations without detection in the operating environment.

Concerns are growing about warfighters' ability to communicate mission-critical information beyond line-of-sight in conflicts with peer and near-peer adversaries. Just in time, a new generation of highly capable high frequency radios is emerging as a viable solution when satellite communications are denied or unavailable. Fourth-generation wideband high frequency radios can satisfy military needs with the century-old wireless technology that is experiencing a resurgence of interest from warfighters worldwide.

Commercial enterprises quickly capitalized on the technology developed in the early 20th century to provide wireless telegraph messaging to and from ships at sea. The military was quick to realize the value of long-range wireless communications to warfighters, whether to and among naval vessels and land forces or for strategic communications that bypass the wired communications infrastructure. By World War II, military wireless communications technologies were highly developed, though with varying degrees of security.

High frequency (HF) radio is attractive for its long range, but it's not as easy to use as other wireless bands. The channel can be noisy, and finding a usable frequency can be challenging. In addition, the frequencies that will propagate via an ionospheric path between widely separated locations vary throughout the day, as well as with the season and the level of solar activity.

World War II radio operators became skilled at finding and following the usable frequency band. However, once satellite communications became available for beyond line-of-sight wireless communications, military communicators largely abandoned HF radio in favor of easier-to-use satellite communications (SATCOM), and HF radio expertise faded away.

In the 1980s, the ability to locate a working frequency using microprocessor-controlled radios enabled a resurgence of interest in HF radio. Using automatic link establishment (ALE) technology, HF radio networks automatically probe the spectrum to find and track the usable frequencies among the network radios. Second-generation (2G) ALE technology, standardized in MIL-STD-188-141A, met a global need and was widely adopted, providing international interoperability.

Third-generation (3G) HF technology, developed in the late 1990s, added an integrated data transfer capability and better low-power performance compared to 2G systems. The U.S. Army's 10th Mountain Division radio operators were delighted with their 3G HF radios when they deployed to Afghanistan in 2001, and this robust technology continues to be a favorite for U.S. and allied land forces.

The military use cases for HF radio have evolved with the technology, starting with wireless telegraphy, then analog voice. Data capability improved through the 20th century from low-speed teletype to 9600 bits per second data service at the dawn of the 21st century. This was the practical limit for the 3 kHz channel allocations that have been used historically in the HF band. Military uses of HF at the end of the last century included analog and secure voice, chat and email, but more data-intensive applications have, until

Photo by Lance Cpl. Christian Ayers, USMC

recently, required SATCOM or line-of-sight radio channels.

To send higher-speed data over HF channels, more of the HF spectrum must be allocated to each data channel. The first step in this direction was to use two adjacent 3 kHz channels in parallel, termed independent sideband (ISB) mode. The U.S. Navy quickly adopted this technique to provide 19.2 kbps HF data channels in the Battle Force Tactical Network (BFTN).

For higher data rates, new wideband HF radios are needed. MIL-STD-188-110D, which was approved in 2017, standardized modem waveforms that offer up to 240 kilobits per second in contiguous channels of up to 48 kHz, which is a practical limit imposed by current aircraft antenna tuners. Starting in 2010, wideband HF (WBHF) technology was demonstrated in military exercises and is now being fielded by U.S. and allied forces worldwide.

Current constraints on fully utilizing the capabilities of WBHF, both regulatory and practical, limit usage, however. For example, International Telecommunications Union (ITU) radio regulations specify limits on both power and spectrum allocations that vary by type of service, for example fixed, land mobile, aeronautical mobile and maritime mobile.

ITU and national spectrum allocation rules were traditionally based on 3 kHz channels, which were sufficient for voice and teleprinter use. Wider channels are currently permitted in some services, and in the maritime mobile service it is permitted to bond multiple adjacent 3 kHz channels to form a single wideband channel.

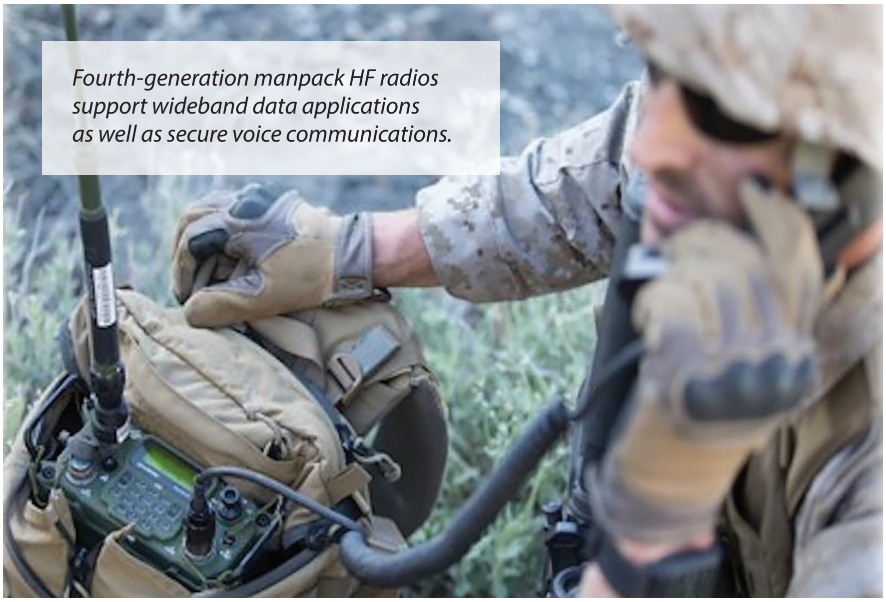
However, the aeronautical mobile service for military aircraft is still limited to single 3 kHz channels. This means that aircraft can receive WBHF transmissions from a fixed, land mobile or maritime mobile station, but they are currently limited to transmitting in 3 kHz channels. Efforts to lift this restriction are underway, but the process takes several years.

Furthermore, in some parts of the world such as Western Europe, the HF spectrum is so crowded it can be difficult to find unoccupied 24 kHz or 48 kHz channels even when radio regulations permit. The practical solution to such congestion is to adapt dynamically to whatever spectrum is available.

One approach is to examine a large segment of spectrum, for example 200 kHz, to find unoccupied 3 kHz channels. Several would then be selected for use, with no requirement that they be contiguous. A single stream of data would be sent on parallel carriers. Such "multicarrier" operation fits the current ITU regulations because it uses only 3 kHz channels, and it would adapt to congested environments by occupying only unused spectrum, avoiding the channels others are using.

Unfortunately, this only works in theory. Whenever multiple carriers are amplified in a single transmitter, the nonlinearities present in any realizable amplifier produce intermodulation products on numerous nearby frequencies. These unintended emissions interfere with reception by other radios in the vicinity. Even after advanced techniques are applied to linearize a transmitter, the remaining interference level is significantly higher than for single-carrier wideband transmitters.

A related phenomenon naval communicators are familiar with is the "rusty bolt" effect. Shipboard topside intermodulation interference is produced by nonlinear effects in many



Fourth-generation manpack HF radios support wideband data applications as well as secure voice communications.

metallic items found on deck, such as ladders, expansion joints, rails and guy wires. This problem is not limited to maritime environments; it can occur whenever transmitting antennas are near conductive elements such as vehicles, metal roofs, or fences. These internal and external intermodulation effects mean that any HF receivers operating near an active multicarrier HF transmitter are likely to experience severe interference on many of their assigned frequencies.

Because of this unacceptable interference, the U.S. military standards for wideband HF specify a highly adaptive single-carrier technology instead. Before sending data, a wideband ALE (WALE) system senses the occupancy of narrow subchannels within its assigned wideband channel at both ends of the link. A quick two-way handshake over the air selects the largest contiguous range of unoccupied subchannels in each direction independently, and the radios exchange their traffic using that available spectrum.

For example, a ground-to-air link for updating an air tasking order might find and use 21 kHz of unoccupied mobile service spectrum for the channel to the aircraft, while the aircraft automatically restricts itself to 3 kHz for returning acknowledgements.

The WALE link setup process is so fast that the link can be released after a message exchange and reestablished later for additional messages with little loss of efficiency.

Spectrum managers emphasize that frequency agility and efficient spectrum sharing will be key for effective use of the increasingly congested HF spectrum. Consequently, a WALE-enabled use-and-release operation is preferred over continuously occupying a channel with a nailed-up circuit for many missions.

The reliability and agility of automatically managed HF links are further enhanced by a new technology that is just now becoming technically feasible. Since the 1980s, ALE radios have scanned their assigned frequency pools, listening for calls and channel probes and sampling channel occupancy. Today, improved technology permits continuous processing of multiple channels instead of scanning them. With this staring mode, channel occupancy is known more reliably, leading to fewer collisions, and WALE link setup times are reduced to approximately one second, making staring a desirable feature in next-generation military HF radios.

The new generation of HF radios is emerging just as the services are calling for alternatives to SATCOM for wireless long-range communications. Current doctrine requires long-haul and tactical communications to continue in anti-access, area-denied confrontations and in the absence of space assets. WBHF

Photo courtesy General Dynamics

Naval HF radio serves many missions, including tactical networking within the strike group and to units ashore, as well as strategic reach-back.

cannot match the high data rates of super high frequency SATCOM but can provide continuity of communicating vital strategic and tactical messages at data rates better than UHF SATCOM. This supports secure voice, tactical chat, email and file transfer. Other key use cases are supported as well, including using WBHF as a surrogate satellite link to convey JREAP (LINK 16) messages

Modernization of military HF radio technology includes far more than just higher data rates. WBHF also offers very robust waveforms at reduced data rates for operating in hostile electronic warfare environments. Spreading signal energy over bandwidths wider than 3 kHz reduces the power density visible to adversaries, while improving resilience in the presence of jammers. Relaying capabilities also are under development that will permit the use of lower power over shorter links and will support routing around denied areas or localized ionospheric disturbances.

HF modernization efforts are now underway throughout the services, including WBHF combat net radios such as the PRC-160 in the ground forces; the ARC-190 replacement program for a wide range of aircraft; the Navy's BFTN Resilient Command and Control System Enhancement; and an upgrade to the high-power HF Global Communication System.

The U.S. WBHF standards—MIL-STD-188-110D and MIL-STD-188-141D—provide a basis for interoperability among these modernized HF radio capabilities, but program managers must coordinate their efforts to ensure that this vital interoperability is achieved. The Joint Interoperability Test Command has a key role to play in testing for interoperability during this generational change in HF radio deployments, just as they did so successfully during the emergence of 2G technology.

As concerns are growing about warfighters' ability to communicate beyond line-of-sight in conflicts with peer and near-peer adversaries, a new generation of highly capable HF radios is emerging to meet the challenges.

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