The near vertical incident skywave loop antennae installed on the battalion fire direction center. (Courtesy photo)

ON COMMS

One battalion's pursuit of secure long-range digital communications

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The Army is looking for ways to achieve secure communications over greater distances in cannon artillery and we may have found a solution. With trust, support, and funding from the senior commander at Fort Riley, Brig. Gen. Patrick Frank, and operational leeway from the Dagger Brigade, 2nd Brigade, 1st Infantry Division, the members of the 1st Battalion, 7th Field Artillery Regiment began a year-long journey in pursuit of secure long-range digital communication. The platform of choice maybe the most underutilized communication system in the artillery— high frequency radios.

In preparation for our National Training Center rotation and deployment to U.S. European Command, 1st Battalion 7th Field Artillery, *Lightning*, through the Fires Forward Concept, began looking at options to improve fire mission processing via secure, long-range digital communications. We needed to mass Fires using all six firing platoons beyond standard frequency modulation (FM) range. Reports from previous NTC rotations stated that field artillery units had difficulty maintaining FM communication (both voice and digital) from

Parallel construct of three high-frequency radios (right) and standard frequency modulation voice and digital (left). (Courtesy photo)

the battalion to the batteries due to range and/or jamming. Continued use of common FM communication would likely result in a common after action review (AAR), such as, "poor retransmitting station (retrans) positioning" or "failed tactical operating center jump triggers to maintain communications." We needed a communication medium that had greater range, was less reliant on retrans, and less susceptible to jamming. Given current personnel readiness and budget, we looked within the division for solutions. A conversation with Wolf 07, the senior fire support trainer at NTC, who mentioned the success Multiple Launch Rocket Systems had using High Frequency Radios (HF), got us thinking, "Why can't we? Why don't we?" And so began a pursuit for high frequency (HF) radios for secure, long-range digital communications at the National Training Center. Throughout our NTC rotation, the radios were never jammed and the battalion maintained digital communications for the duration of the fight, regardless of range.

The problem

FM is a line of sight (LOS) platform with a maximum effective range of approximately 15km. In order to extend the range of FM platforms, it is necessary to establish retrans stations. Optimally positioned, a retrans station can double the range of two frequencies. However, retrans is a directional tool. If a battalion needs to communicate with a battery 20 km to the west, a single retrans station halfway between the two echelons will likely suffice. But if a second battery is 30 km to the east, north or south, additional retrans assets are required to extend the range in those directions. Additionally, we considered the following: 1) Due to manning and/or equipment shortfalls, the average direct support field artillery battalion is likely capable of deploying one retrans station at a given moment. 2) Retrans teams are often positioned by brigade to support priority FM networks, making their availability MET-TC (mission, enemy, terrain, troops available, time, and civilian considerations) dependent. 3) Enemy forces often target retrans stations because they are soft targets with a high value. 4) FM digital's back-up communication is FM voice, a redundancy that depends on the same medium, thus not independent. Therefore, if digital gets jammed, so does voice. 5) Using FM voice as back-up to HF is also not an option because the independent back-up is susceptible to all the challenges listed above. Therefore, we also needed another communication medium for back-up that could match pace and range with the HF. We decided that JCR would become the independent back-up to HF.

Based on modification table of organization and equipment (MTOE), most units have three radio platforms available. The first and most familiar is the Advanced System Improvement Program of FM, or ASIP radio. A second, and somewhat familiar option that units have for long-range communications, is Tactical Satellite (TACSAT). However, with limited channels and lower priority for satellite when stateside, most brigade combat teams only receive one TACSAT channel. Additionally, TACSAT is generally used for voice and is reserved for contingency communication, not the primary or the alternate. The third option is an organic communication radio platform that is available to many FA units: HF. If most units are like ours, we did not have the resident expertise for these radios and most were locked away in a communication cage, only pulled out for supply inspections, then put back in. Some forward observers use HF radios for voice communication to address range shortfalls with FM, but HF is seldom the primary means of communication in cannon artillery.

Despite these challenges, we decided to use HF because it was the only available option that had a favorable cost benefit outcome.

The approach

With the decision to use the HF (PRC-150) made, our team worked on the construction of a network that allows the battalion fire direction center (FDC) to conduct digital fire mission processing with six platoon FDCs simultaneously. Initial trials during weekly digital sustainment training revealed that in order to send and receive digital data, two radios must be linked. Unlike FM, HF requires a call to the station that you want to send data. After calling, the two radios link and digital data can be sent and received. This means that radios must link one at a time in order to transmit digital data. In other words, if you wished to send a fire mission to six platoon FDCs, you would need to link and send the mission to each platoon one at a time. Once a platoon received the mission, you would need to break the link and repeat the process with the five remaining platoons. That simply takes too much time, resulting in less responsive Fires.

Our team went back to the drawing board and sketched out a communication diagram on a whiteboard, leveraged the intrinsic routing capability of the Advanced Field Artillery Tactical Data System (AFATDS), and developed what we later called: "parallel construct." The battalion FDC would need three HF radios and three HF networks in AFATDS. The three HF radios allow them to establish a "direct" route in AFATDS with one FDC per battery. The second FDC establishes digital with battalion FDC via an "indirect" route using the first FDC as their gateway. This technique allowed the battalion FDC to communicate with all six platoon FDCs simultaneously and maintained the unit's ability to mass Fires or process six individual missions at a given time. For example, if the battalion FDC wished to send a mission to 2nd Platoon, B Battery, the mission is sent HF to 1st Platoon, B Battery, who's AFATDS transparently routes it to 2nd Platoon. The same is done in reverse when 2nd Platoon wishes to send a mission/message to the battalion FDC. There is no requirement for 1st Platoon other than to maintain FM digital communications with their sister platoon.

In order to outfit the battalion FDC with three HF radios, the *Lightning Battalion* restructured the interior of the battalion FDC vehicle. Typically, the M1068 is outfitted with three FM radio mounts with six FM radios, and one Harris HF radio mount (VRC-104) with one PRC-150 radio. We removed two of the FM mounts and replaced them with two HF mounts. This also required the replacement of FM antennas with Harris 30 foot whip antennas. These antennas are capable of ground waveform as well as near vertical incident skywave (NVIS) waveform depending on how they are positioned.

Once the battalion FDC vehicle was outfitted, we tested the viability of our designs first by conducting long-range digital communications checks on Fort Riley. We were able to send fire missions at ranges of approximately 20km using ground wave line of site with the 30-foot whip antennas. In order to truly test the range of HF, the battalion FDC then travelled approximately 90km from Fort Riley to Smokey Hill and attempted to send fire missions. While still only using ground wave LOS, the FDC was able to send digital fire missions to all six firing platoons at distance. However, ground wave LOS was inconsistent at these ranges.

Based on the inconsistency experienced at longer ranges, the unit decided to purchase Harris Loop antennas which are capable of ground wave LOS and near vertical ionosphere waveform (NVIS) simultaneously (See Figures 1 and 2). This NVIS waveform essentially sends radio waves into the ionosphere where the waves "bounce" back down. When using this waveform, the radios are capable of communicating across hundreds of kilometers, or a few meters. This configuration gave us the increased range we desired, however, it also had undesired second order effects. Having three HF antennas mounted so closely to each other, resulted in constant interference. The interference was not substantial enough to inhibit communications but it was enough to make the connection inconsistent. Not all transmissions made it from the sender to the recipient. Some missions were received within seconds while others took minutes. AFATDS may state "successful" with the station that you are communicating with, but it does not mean all transmissions were received.

Soon after installing the NVIS loop antennas, we began our NTC rotation where the new communication network faced its most challenging test. We leveraged the mandatory calibration of assigned propellant lots to test the Harris Loop antenna construct at ranges from 100 meters to 12,000 km in the desert environment. While still in the reception, staging and onward integration (RSOI) phase of training, we pushed the batteries out into the training box while the battalion FDC remained in the Rotation Unit Basing Area (RUBA) and pushed the missions forward. It was successful. We calibrated from the RUBA. For the next 14 days of training during force-on-force and live-fire, range from battalion to batteries became less of an issue.

The HF does have a number of downsides. Due to the interference caused by the close proximity of antennas, as well as atmospherics during battle periods, the battalion FDC could not guarantee that a mission sent would be received 100 percent of the time. Approximately half of missions sent were received complete within seconds. The other half took minutes to reach and some never confirmed receipt. JCR was used concurrently to inform platoons of missions sent and platoons then confirmed over JCR if they received it digital on AFATDS or not. If not, fire missions were sent over JCR.

FM versus HF (National Training Center observations)

Wolf 07 (Lt. Col. Jonathan Shine) Observations: When we learned that 1-7th FA was planning to use HF Digital as their primary means of communications during their training rotation, the Wolf Team reacted with a mix of excitement and skepticism. From our perspective, the experiment was a qualified success. We have not collected specific data on how often units are able to maintain communications and over what distances, so what follows are subjective estimations based on observations of the last 12 rotations. During all of those rotations, challenges associated with maintaining digital communications was a major topic of discussion during one or both of the battalion's instrumented After Action Reviews. Since the re-introduction of the decisive action training environment, every field artillery battalion has struggled. *First Lightning* struggled less. We estimate that the battalion maintained digital connectivity via HF from the battalion FDC to all six platoons over 95 percent of the time that they were "in the box." This includes while FDCs were moving, and with no requirement to maintain FM retransmission stations. However, without JCR, the battalion would likely have failed in at least 50 percent of their fire missions. About half of the time, the transmission was either not received at all, or was received with a delay of as much as four minutes after being sent

The near vertical incident skywave loop antennae installed on M1068 Battalion Fire Direction Center. (Courtesy photo)

from battalion. As a result, the battalion's tactics, techniques and procedures were to simultaneously send all fire mission data over JCR as well as HF. Subsequent adjustments were sent entirely over JCR. During periods when the opposing force was jamming JCR, the battalion relied on FM Voice and had to significantly reduce the dispersion of their firing elements, with the added risk to the guns from enemy counter-fire that this entails.

Again, without having collected connectivity as a metric, it is difficult to state precisely how a rate of 95 percent connectivity with 50 percent loss of data compares with the average FM-based unit. Every other FA battalion has failed to maintain consistent digital communications, especially on the move and over extended distances and with the dispersion necessary to survive against the current OPFOR (who identify FA units primarily with small UAVs and possess at least a 3.5-to-1 advantage in delivery systems). Our current ASIPs FM radios are not keeping up with the pace of change in our other digital systems and the evolving capabilities of our adversaries. Overall, HF alone was clearly not sufficiently reliable to be the primary means of fire direction for 1-7th FA. However, for a relatively low cost (compared, for example, to WINT inc2), *First Lightning* demonstrated that HF has extraordinary potential to substantially increase the range, survivability and dependability of a field artillery battalion, as it does for nearly all Multiple Launch Rocket System/High Mobility Artillery Rocket System-equipped units.

Recommendations

We have not broken the code on the employment and use of HF systems for digital fire direction. Through months of trial and error, we discovered "a way" that conceivably works. Though proven more reliable at NTC than FM, there are inconsistent gaps and delays that our team was unable to solve. Additional equipment, non-MTOE, is available that increases the reliability of HF digital communications. For units using the PRC-150, we recommend purchase of the IP6600 router ($600 ea.). This router is designed to translate the data between AFATDS and the PRC-150 more efficiently and allows for a more reliable link and faster transmission.

However, if funding is available, the optimal solution is the fielding/purchase of the RF-300H- MP wideband HF tactical radio. It provides continuous coverage from 1.5 to 60 MHz with data rates up to 120 kilobytes per second, compared to the current system's 15kbps. The 300H addresses most of the inconsistencies experienced by our team with the current radios. We did not stress the 300H radios in a field environment, thus unable to attest to their durability, only power and data rate. The pursuit for reliable-secure-long-range-digital-communications in the *Lightning* Battalion continues with expansion of HF to the Bradley Fire Support platform for digital communication.

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