Automated HF communications

by James V. Harmon, LTC David M. Fiedler (NJARNG), and LTC John R. Lam (Ret)

The automated HF communications system is good news for the NOE pilot who already has the complex task of flying his helicopter, performing his mission, and operating other systems.

In order to fight and survive on the modern battlefield, Army rotary wing aviators are forced to fly Nap-of-the-Earth (NOE) to avoid detection and reduce the probability of being hit by enemy air defense weapons. NOE flight profiles present a difficult communications problem for Army aviators and their Signal officers trying to communicate between aircraft or air-to-ground while engaged in tactical operations.

Line-of-sight and limited ground wave propagation modes commonly used by SINCGARS (VHF-FM) and other on-board LOS communications systems operating at frequencies above 30 MHz are inadequate for low altitude NOE non-line-of-sight (NLOS) operations.

HF radios, on the other hand, can communicate using any of four different propagation modes including ground wave, LOS, Near Vertical Incident Skywave (NVIS), or long haul skywave (see FM 24-18, Appendix M). As shown in Figure 1, it is the short range NLOS HF propagation modes provided primarily by NVIS, and in some cases by ground wave, that allow an NOE helicopter pilot to communicate with other NOE pilots or designated battle management communications ground stations while flying at low altitude for cover and concealment.

Although use of HF solves the technical problem of communicating over short range NLOS paths, there are serious user training, experience, and workload problems associated with using current HF radios, especially in an NOE environment. HF communication procedures and radio operations are much more complex than those required for LOS radios due to the additional variables associated with the use of skywave propagation modes. Adding modes, such as Communications Security (COMSEC) and Electronic Counter Counter Measures (ECCM) that are needed to counter battlefield intercept and jamming threats, further complicates the pilot's task. Every new communications mode represents a new set of tasks to compete for the pilot's time and attention and detracts from his ability to fly and fight.

Automation is the solution

While operating in the NOE flight profile, a helicopter pilot must maintain visual contact outside the cockpit. The challenge is to make HF a usable and reliable means of communications in this complex environment by automating the workload intensive link establishment procedures, simplifying the user interface, and minimizing the requirements for operational attention from the pilot. This is an achievable goal through the application

for nap-of-the-earth flying

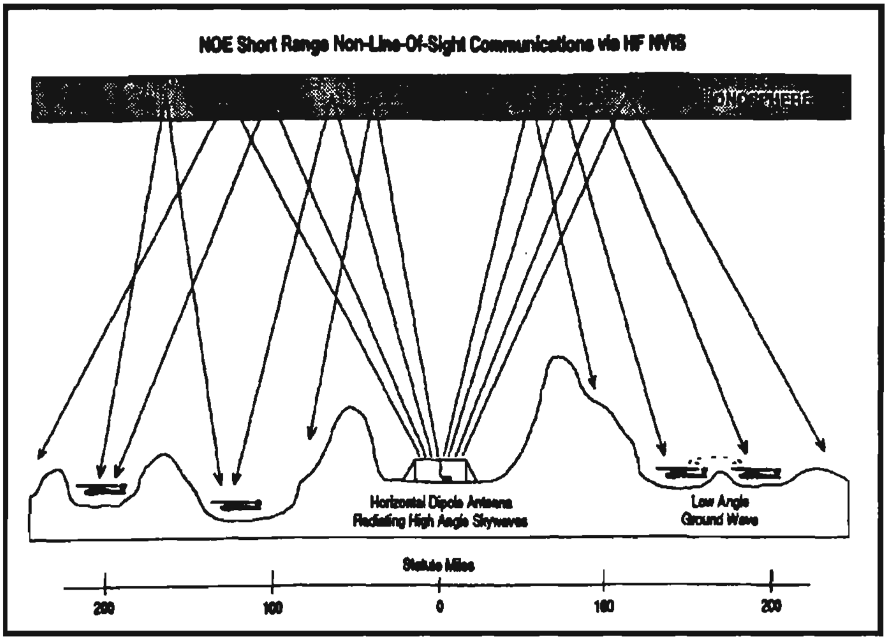

Figure 1

of existing technologies and Automatic Link Establishment (ALE) concepts that have been well proven in the field.

ALE can reduce the pilot workload associated with using HF communications systems to a level equivalent to that of current VHF or UHF systems and eliminate the need for special HF operating skills by effectively automating the procedures that the pilot would normally be expected to perform. For example, a pilot and his unit Signal officer have, in the past, been required to manually coordinate the selection of primary, alternate, or backup frequencies and continuously monitor noisy HF channels to avoid missing incoming calls. Establishing an HF communications link typically required repeated voice calls to the desired second party who must be effectively monitoring the same channels. These tasks had to be accomplished simultaneously with flying and fighting.

New HF ALE systems are capable of dealing with the HF propagation variables in real time and establishing an HF communications link for the NOE pilot without increasing pilot workload. These systems use receiver scanning techniques to monitor ten or more channels in a fraction of the time it would take a pilot to manually monitor just one alternate frequency. The ALE system does the listening on the scanned channels, relieving the pilot from this fatiguing responsibility.

While scanning, the HF ALE system mutes the receive audio to eliminate the characteristic HF background noise and other audible distractions. Calls are placed and received by automated data transmissions containing the addresses of the stations involved. The pilot simply identifies the net or individual net member station he wishes to contact by selecting its address and pressing the push-to-talk (PTT) key. The HF ALE system does the rest and even chooses the calling channel from the list of available scanned channels. A three-way data handshake is completed to verify the bi-directional integrity of the link and, the receive mute is removed upon successful completion of the link establishment process as a signal to the pilot that he may begin normal PTT communications.

A new degree of HF communications reliability is provided in that if there is a propagating HF in the assigned list of ALE scanned channels which will support communications between two particular platforms or stations, an HF ALE system can establish that link automatically within seconds and without prior coordination or operator assistance. There is no longer a need for the pilot to continually listen to noisy HF channels or risk missing incoming calls.

FED-STD 1045 and Appendix A of MIL-STD-188-141A define a common waveform, signal structure, and protocol characteristics to assure over-the-air interoperability between HF ALE systems built by different manufacturers. The following discussions are based on HF communications systems implemented in accordance with these standards.

The ALE process

An HF ALE system implies the use of an embedded ALE processor, functioning as an HF system (NET) controller, and an associated embedded HF data modem to provide the integrated HF system functions needed to establish a usable communications link for the pilot. These ALE functions include receiver scanning, addressing, sounding and link quality analysis (LQA), automatic channel selection, and calling protocols. The HF data modem, controlled by the ALE processor, enables the HF radio system to transmit and receive selective calling addresses and channel sounding signals that facilitate the automatic linking process. A simplified operator interface can be provided with the HF ALE systems using a dedicated manual Remote Control Unit (RCU) or an integrated cockpit management bus control system.

The HF receiver portion of the HF ALE system is caused to scan a list of authorized HF communications frequencies selected by the unit Signal Officer from the units authorized Signal Operating Instructions (SOI). Frequencies included in the list of scanned channels are chosen as those most likely to provide the best probability of communications success based on propagation predictions, recent history, and other available propagation data.

Typically, frequencies ranging from 2 to 4 MHz are more likely to provide the best NVIS communications during the night- time hours with the range transitioning to 4 to 8 MHz for day- time operation. Scanning consists of stepping the receiver from one preset frequency to another and dwelling on each frequency just long enough to detect an ALE call or evaluate an ALE sounding signal should such a signal be present. The receiver is always scanning, listening for ALE sounds or calls when not actively engaged in a communications link.

Each participant in the HF net is assigned an individual address which uniquely identifies that radio from all other radios in the net. Net addresses are used to group individuals together into tactical configurations. If a sounding signal is detected during the scanning process, a channel quality measurement is made on the received signal which also contains the address of the transmitting station. Measurements are made on all ALE sounding signals received and the resulting channel quality data is stored in a local Link Quality Analysis (LQA) data base referenced to the transmitting station's address and the frequency on which the signal was received. The LQA data base is then used in the automatic channel selection process when placing a scanning ALE call.

The use of sounding data in the channel selection process greatly improves the probability of successfully establishing a usable communications link on the first try, thus saving time and reducing channel loading.

Receiving a Scanning ALE call

Figure 2 is a simplified flow diagram showing the ALE process for receiving a scanning ALE call. When an automatic call comes in, the only operator involvement in the process is "push to talk" to communicate after the link has been established.

The automated process starts with the system in the normal scanning mode, listening for ALE sounds and calls as it dwells periodically on each of the scanned preset channels. If an ALE sound is heard, an LQA measurements is made on the received signal, the data is logged into the system's LQA data base, and scanning continues. If an ALE call is heard, the receiving system will stay on the channel and attempt to link if the called address matches the receiving station's address. Otherwise, the receiving station will resume scanning.

If the called address corresponds to the local station's address, the receiving station will remain on the channel, decode the caller's address, and transmit an ALE response to the calling

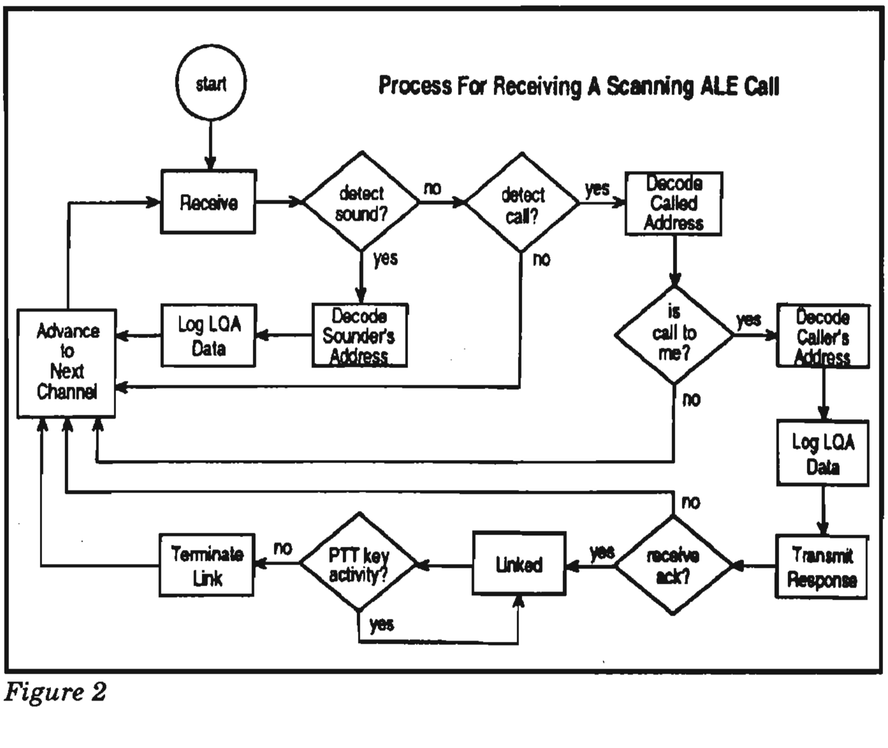

Figure 2

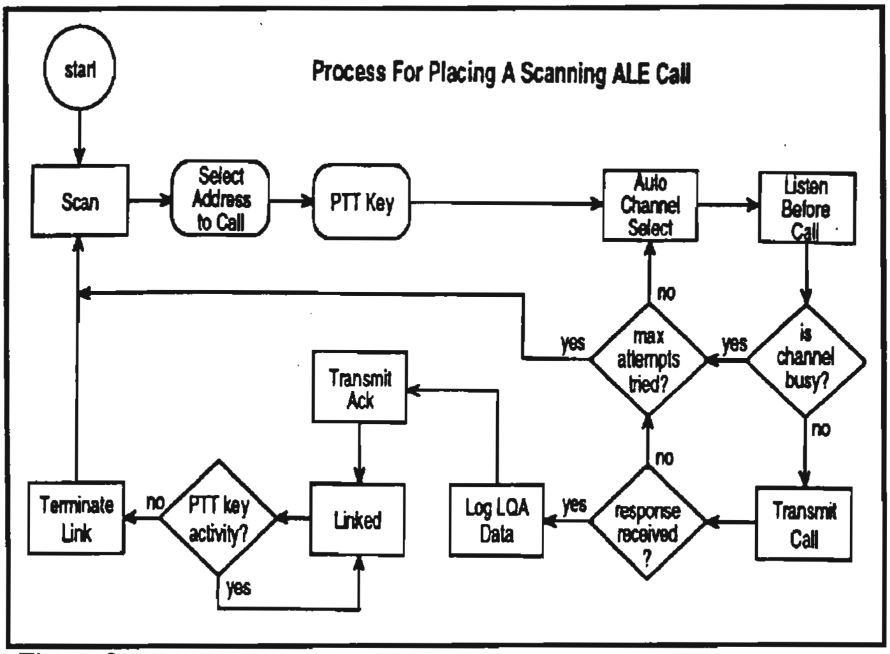

Figure 3

station. An LQA update will be made on receipt of the caller's address, since this portion of a scanning ALE call is identical to a sound except that it is transmitted for a shorter period of time and thus not available to other scanning stations who did not remain on the calling channel.

The response transmitted consists of a combination of the caller's address followed by the local station's address. The caller's system will automatically transmit an ALE acknowledgement to confirm the link if the response was received. If an acknowledgment is received, the called station will enter the "linked" mode.

Once linked, the system is available to the operator for normal PTT voice, secure voice, data, or secure data operation. The link may be manually terminated by the operator or allowed to time out and automatically return to the scanning mode based on the lack of PTT key activity for a period of time.

Placing a scanning ALE call

Placing an ALE call also requires very little effort from the pilot. As shown in the simplified flow diagram of Figure 3, the process for placing a scanning ALE call starts with the system in the normal receive scanning mode. The pilot designates the address of the individual or NET to be called and momentarily presses the PTT key. No other action is required from the pilot until after the link has been established and the system is ready for NVIS is the primary propagation mode for NOE. However, ground wave propagation is also important, especially for nighttime communications when the maximum usable frequency (MUF) is generally less than 4 MHz. normal PTT communications.

Once the call process is started, the ALE system automatically selects the calling channel based on LQA data stored and listens for activity on the selected channel prior to transmitting the call.

If a busy channel is detected, the system will automatically select an alternate channel that is not in use before transmitting the call. When a response is received from the called station, an update to the LQA data base is made and an acknowledgment is transmitted to complete the linking process.

If no response is received, the call will be repeated on an automatically chosen alternate channel. If no response is received after a preset number of repeated attempts, the system will automatically abort the calling process and return to the receive scanning mode. A message will be displayed to the pilot indicating the failed call attempt.

Antennas

NVIS is the primary propagation mode for NOE. However, ground wave propagation is also important, especially for nighttime communications when the maximum usable frequency (MUF) is generally less than 4 MHz.

The selection of an antenna to optimize performance in these two modes is desired. Good NVIS performance requires an antenna with a high take-off angle to maximize radiated efficiency in the vertical direction. Good ground wave performance, on the other hand, requires an antenna with an omni-directional low take-off angle to maximize radiated efficiency in all directions parallel with the earth's surface.

The present Army Standard Grounded Loop HF antenna couples high circulating currents onto the airframe making the horizontal airframe structure the primary radiating element. This provides a high take-off angle which is good for NVIS propagation but does not provide an omni-directional low take-off component to support good ground wave propagation. Due to the small size of the loop, coupling to the airframe becomes very low at the lowest HF and a small loop radiation pattern predominates. A better antenna for the NOE environment would have both high and low take-off angle

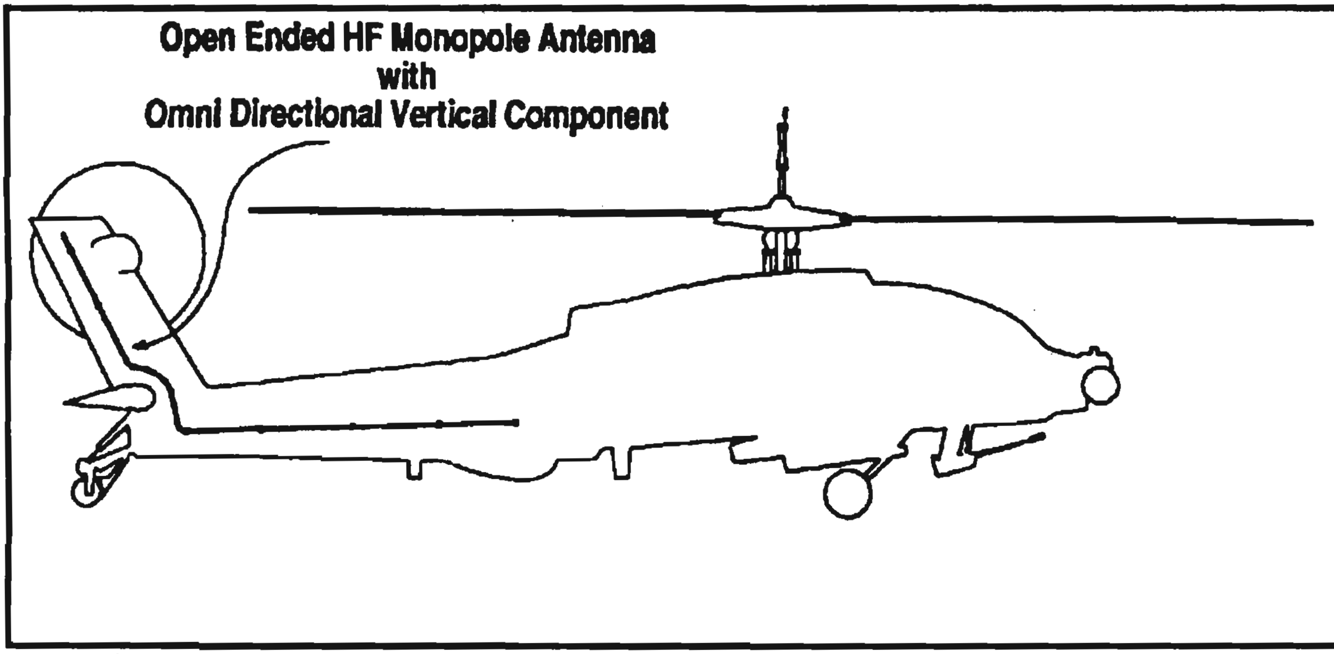

Figure 4

characteristics and would provide improved efficiency and an omnidirectional radiation pattern at the very low HF involved.

A longer open-ended monopole antenna with a vertical component offers this improvement. It is possible to install such an antenna within the limited space by continuing the antenna upward along the vertical portion of the tail, opposite the tail rotor, as shown in Figure 4. Two important objectives can thus be achieved. First, a longer antenna can be physically accommodated in the space available, increasing efficiency and coupling to the airframe. Second, the antenna system takes advantage of the vertical dimension of the monopole antenna for improved omnidirectional ground wave performance. The improved efficiency and dual mode (NVIS and Ground Wave) diversity allows the HF ALE system to take full advantage of both propagation modes to improve overall NOE communications.

Summary

The automated HF communications system is good news for the NOE pilot who already has the complex task of flying his helicopter, performing his mission, and operating other systems. ALE capability, coupled with the proper selection of antennas and frequencies, will allow the system to completely set up the required HF communications link for the pilot.

Mission essential communications can then be transmitted via the HF medium by simply pulling the transmit trigger and talking. The workload and skill levels traditionally required to communicate reliably on HF have been significantly reduced through the use of ALE and are now aligned with those required to operate other onboard radios.

The automated approach to HF communications and an improved aircraft antenna will make HF work for NOE.

Mr. (LTC) Fiedler's bio is printed on page 6 at the end of his article, "A real challenge for the user."

Mr. Harmon is a staff engineer in Communications Engineering, Collins Avionics and communications Division of Rockwell International. he is the holder of three U.S. patents, two of which are HF-ALE related. application has been submitted for a fourth patent involving multimode automatic HF communications. He has a BSEE from the University of Missouri.

Mr. Lam is a Senior Systems Engineer, Advanced Systems, CACD, Rockwell International. A retired LTC, he is a former master Army aviator with over 21 years experience in tactical Army aviation, NOE operations and night vision goggles. He has served widely in conventional, joint and special,operations arenas. He has an MAS in aeronautical science.