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E-mail Over High Frequency (HF) Radio: Filling the Communications Gap During Unexpected Telephone Outages

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WHY USE HF E-MAIL?

A natural or manmade disaster can quickly overload local-area communications systems, causing widespread interruption of essential telephone and Internet services. A fire at a telephone company's central office or cellular radio site could shut down its emergency generator, and its battery backup system could be depleted within hours. During the May 2000 wildfire in Los Alamos, New Mexico, area telephone systems were overwhelmed immediately. The three cellular networks and U S West's telephone system all failed: Users encountered constant busy signals, trunk busy signals, incoming calls being turned away, uncompleted outgoing calls, and no dial-tone. At times like these, high frequency (HF) radio can provide a communications path to the Internet for sending and receiving electronic mail (E-mail) messages.

HOW DOES HF E-MAIL WORK?

Many different systems are now being developed to send E-mail messages over HF radio links connected to the Internet. These systems require at least one HF radio station to serve as an E-mail messaging ground entry point (gateway). Some of these systems use the current second-generation (2G) Automatic Link Establishment (ALE). ALE, which is available in some HF radio transceivers, provides automatic setup and operation. With a laptop computer (running an appropriate terminal program), an HF radio data modem, and an HF radio transceiver with ALE, even an operator who has no radio knowledge or experience can send and receive E-mail messages. A major drawback to the widespread use of existing HF E-mail systems is that most systems are proprietary and not interoperable with any others.

COMPARISON OF TECHNOLOGIES

For several years, the United Nations (UN) High Commissioner for Refugees and the International Red Cross have been using an HF E-mail system to provide E-mail service to remote users who have no access to telephone lines.

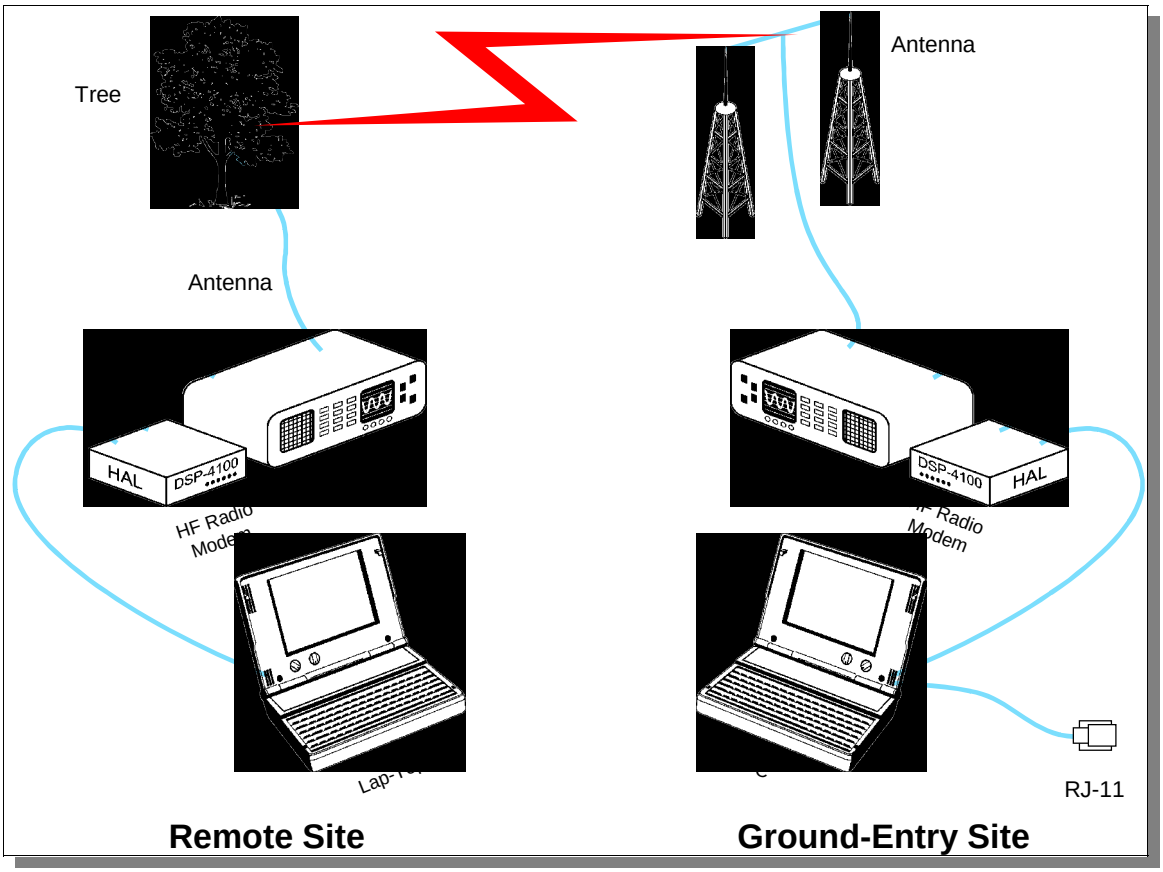

Figure 1. HF E-Mail System

The ground entry point (at the right side of the picture) provides a gateway into the Internet. Ignoring everything but the computer and the modular telephone connector, we have a standard connection over a dialup telephone line to the Internet service provider (ISP). The dialup line connection to the ISP could be replaced with a digital subscriber loop (DSL), integrated services digital network (ISDN), or even a local area network (LAN). All that would be needed to complete the gateway would be an HF radio transceiver and an HF modem (shown above the computer).

The only difference between the remote site and the gateway is that the remote site does not have the dialup phone line connection to the ISP. The HF radio link is necessary because the remote site has no cellular or wireline telephone access.

These systems use a software terminal program called Digital Transmission System (DTS) to provide a data link protocol and compression technology. The HF radio data modems used in the UN and International Red Cross systems are called CLOVER 2000. These modems are manufactured by HAL Communications in Urbana, Illinois. With these systems, data, fax, E-mail, text, and pictures can be sent worldwide over HF radio links.

Another HF E-mail system, recently developed by the North Atlantic Treaty Organization (NATO), is based on the STANAG 5066 data link protocol. Although STANAG 5066 provides the same functions as DTS, the systems are not interoperable. The NATO system specifies STANAG 4285 for its modem's over-the-air waveform. MIL-STD-188-110B data modems are being built to accommodate the waveforms specified in both MIL-STD-188-110A and

STANAG 4285. STANAG 4285 defines a NATO modem similar to MIL-STD-188-110A, but without the "auto-baud" feature (for self-identification) that is crucial for good automatic repeat request (ARQ) performance: The waveform used in both MIL-STD-188-110A and B contains embedded codes that identify data rate and interleaver. Receivers reading these codes can instantly adapt to the new settings. STANAG 4285 modems also lack MIL-STD-188-110B's more sophisticated equalizer. Therefore, the STANAG 4285 mode would be used only when NATO interoperability is required.

Reducing On-The-Air Overhead

Transmission Control Protocol (TCP) is used to send E-mail messages on the standard low bit-error-rate (BER) circuits used over the Internet. However, the error detection and correction (EDAC) capability inherent to the HF radio data modems is much more powerful and efficient than TCP. Because TCP adds extra overhead and time delays, using TCP with the EDAC in the modems would slow data throughput without providing any benefits. To avoid this problem, processing at the HF gateways must strip off the TCP from each message before it is transmitted over HF radio. Since TCP is still required by the Internet E-mail messaging system, the gateways must insert TCP into each message received from HF radio before the message can be sent as a conventional E-mail message. These functions are handled automatically by the computer software programs running at the gateways.

Code Combining

Code combining assembles several bad packets into one good packet to minimize retransmissions. This technique is very effective for increasing throughput on the relatively poor (high BER) circuits typical of HF radio. Hardware and software implementations of code combining are available from Dr. David Chase at CNR, Inc. Third-generation (3G) ALE will use code combining for EDAC.

Future Directions

Although HF radio is often used for backup communications because it is a mature technology, potential still exists for further development. Work is progressing on 3G ALE, which is in both MIL-STD-188-141B (Appendix C) and NATO STANAG 4538. Both standards specify 3G ALE with 3G ARQ and an internal supporting modem. Clear channel corrected throughput for a 3G modem should range from 4,800 to 12,800 bps. The 3G system will eventually be packaged together with an HF transceiver, eliminating the need for an external modem. Interoperability with STANAG 5066 using either a STANAG 4285 or a MIL-STD-188-110B modem waveform might require an external modem. However, according to Dr. Eric E. Johnson, a New Mexico State University professor who has been instrumental in the 3G development, these waveforms also can be included in the firmware inside the 3G ALE box. STANAG 4538 contains only the 3G ALE, 3G ARQ, and the modem. MIL-STD-188-141B includes all of those elements plus the radio specifications, 2G ALE, and several appendixes. 3G ALE will incorporate more features and functions than the current 2G ALE. It not only will use advanced modem waveforms for faster data rates and improved performance (working at lower power to provide higher throughput) but also be backwards compatible with 2G ALE.

The National Telecommunications and Information Administration (NTIA), Institute for Telecommunication Sciences (ITS), in Boulder, Colorado, has developed a software program that runs on a Windows computer with a soundcard. This program provides an initial subset of 2G ALE capabilities for inexpensive HF radio transceivers. Mr. Charles Brain in England has independently written a similar but much more encompassing program that supports the mandatory parts of FED-STD-1045A. Neither program is perfect, and their use of soundcards is a compromise between cost and performance; nevertheless, both are promising. Mr. Brain is working on a software version of a STANAG 4285 modem.

Wave Science, Inc., has developed a modem on a Personal Computer Memory Card Industries Association (PCMCIA) card that provides many MIL-STD-188-110B functions. The company is also writing 2G ALE software for the modem.

System Price/Performance

Although the operating cost of HF radio is relatively low, especially when compared with the high usage rate costs of satellite communications systems, HF radio modems are expensive. The MIL-STD-188-110B modems now available from Harris and Collins cost almost $5,000. Clear channel corrected throughput for a MIL-STD-188-110B modem ranges from 3,200 to 9,600 bps. The Wave Science PCMCIA card is targeted at $2,000, but it does not provide all the required MIL-STD-188-110B features and functions. CLOVER 2000 modems providing a 2,000-bps throughput cost around $1,300, and CLOVER II modems (with a 560 bps throughput) cost under $300. CLOVER modems are especially useful where spectral bandwidth is limited. CLOVER II modems occupy only a 500-Hertz (Hz) bandwidth, CLOVER 2000 modems require 2,000 Hz, but a MIL-STD-188-110B modem needs 3,000 Hz.

As mentioned earlier, a data link protocol software terminal program is required in addition to the HF modem. DTS is sold through radio transceiver manufacturers as part of a complete system but not to individual users. DTS provides many useful features, including ALE, but it costs $950 per gateway in large quantities. Collins Radio has implemented the STANAG 5066 protocol set as an application (in its Rockwell HF Messenger product), but it is more expensive than DTS.

Why Not Use Both Systems?

The MIL-STD-188-110B data modems used in the NATO system are significantly more expensive than the CLOVER 2000 data modems used in the UN and International Red Cross systems. The NATO system's $5,000 modems are too expensive for some government agencies, the NCS' HF Radio Shared Resources (SHARES) program, and the amateur radio community that supports them. HF radio is particularly valuable because of all the amateur radio operators available to provide emergency terminals and gateways during disasters. Therefore, any E-mail system for emergency use must be kept affordable.

Most systems using MIL-STD-188-110B modems will use encryption, whereas most of those using CLOVER modems will not. Systems using encryption cannot have any direct over-the-air connectivity with those not using encryption, even if they all use compatible modems and terminal programs. Although the CLOVER systems could accept encryption, they would rarely need to because their function is to connect to unclassified gateways (especially amateur radio operators).

Ideally, both systems should be used. Because they would be serving two different groups, it would be necessary to use two different strings of equipment, but only at the few gateways needing connectivity to both systems. Gateways operating with both systems would need a MIL-STD-188-110B modem and a CLOVER 2000 modem.

Conclusions

HF radio can provide essential emergency voice communications and E-mail messaging at a reasonable cost. CLOVER modems provide the most practical cost-effective way to send E-mail over HF radio. CLOVER 2000 is ideal for all federal government agencies that are not required to use the MIL-STD-188-110B modem. CLOVER II is best for those agencies (and SHARES members) that cannot afford the more expensive CLOVER 2000. Work is still needed to determine which software terminal program is the most cost effective.

Additional HF E-mail Information

Due to the heightened interest in sending E-mail messages over HF radio, Dr. John S. Davies at

the Defense Information Systems Agency (DISA) is writing a Technical Information Bulletin (TIB) and a Federal Telecommunications Recommendation (FTR) addressing HF E-mail systems. The NCS Operations Division (N3) sponsors monthly SHARES meetings that attract a large group of potential HF E-mail users. Additional information about E-mail systems for HF radio is available from the High Frequency Industries Association (HFIA) and from a Web site article by Ben Parker (see Reference 16).

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