CHAPTER 3
AUTOMATIC LINK ESTABLISHMENT

3.1 Introduction and overview of automatic link establishment systems

The United States has developed a series of HF radio standards that characterize and specify protocols and parameters for automatic link establishment (ALE), networking, linking protection, high-speed data modems, and basic HF radio parameters.

Automatic link establishment is a robust, adaptive HF radio method for automatically establishing communications over HF single sideband (SSB) links. Using ALE, an operator or computer-initiated control signal can automatically initiate point-to-point or point-to-multipoint calls. The ALE controller can be programmed to scan one or more frequencies, pick the best frequency for operation, and switch to voice or data operation immediately upon link establishment. The ALE system initiates calls on selected channels, which are rank ordered, through an internally programmed link quality analysis (LQA) algorithm. This permits the link establishment process to have the most likely chance of success on its initial trial using previously measured LQA numerical channel scores that are stored in the system's memory. The identities of the calling and called stations are exchanged between stations, along with call sign designators to distinguish the calling from the called station.

Optional features include linking protection, which uses security methods to prevent unauthorized network entry, transmission and reception of user data, and over-the-air reprogramming (OTAR).

The ALE link-establishment and link-management functions are performed by reliably conveying the ALE link information over HF channels between station pairs. This high reliability is obtained by triple redundancy transmission of the ALE data, by interleaving, and by using Golay forward error correction.

An adaptive HF radio system block diagram is shown in Figure 3.1. The ALE controller provides the automation of the linking process. ALE networking functions and linking protection functions can also be incorporated into the ALE controller. After the link is established, data or voice communications can be initiated by switching a high speed data modem into the circuit.

ALE is designed to be modular in nature, and uses audio tones and serial data signals to interface the ALE controller with HF-SSB radios. It can be embedded as a low-cost, integral part of modern HF-SSB radios using digital signal processing (DSP), either as a standard or optional module. It can also be added to many existing HF-SSB radios as an external appliqué, either as a stand-alone component, or as a personal-computer (PC) compatible kit of hardware and software. Also available are tools such as calibration and test signals on audio compact discs (CD), which permit the development and interoperability testing of ALE products without costly channel simulators.
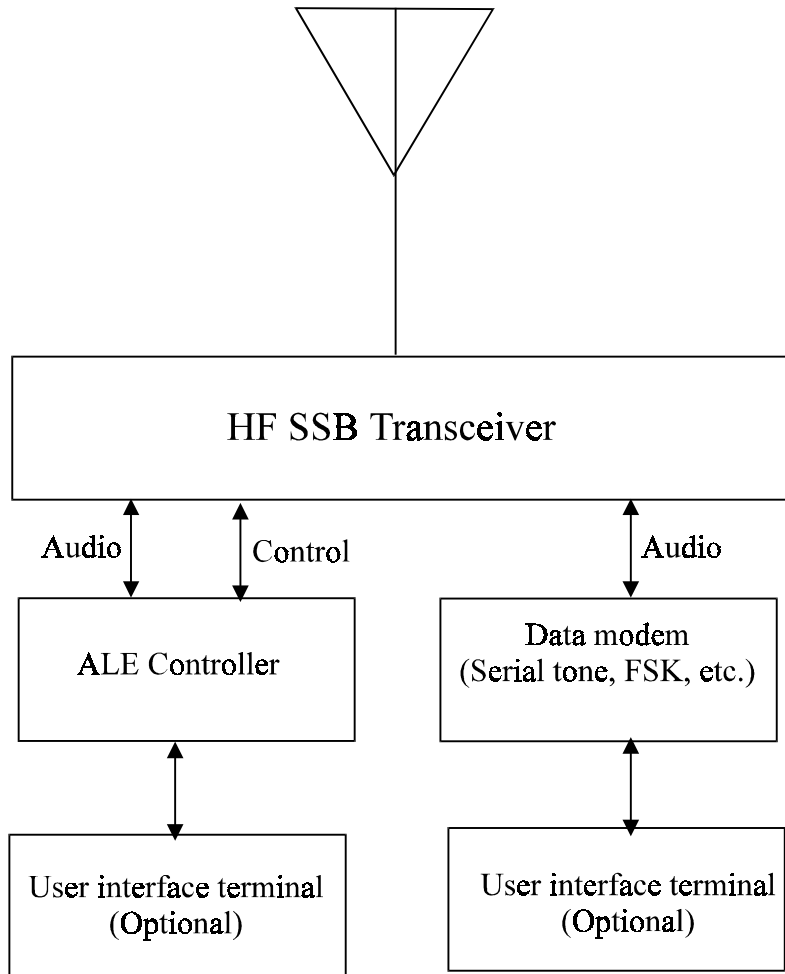
FIGURE 3.1
Adaptive HF radio system block diagram

3.2 ALE transmissions and word format

The ALE waveform is designed to pass through the audio passband of conventional SSB radio equipment. The waveform is an 8-ary frequency shift keying (FSK) modulation with eight orthogonal tones. Each tone is 8 milliseconds in duration and ranges in frequency from 750 Hz to 2500 Hz with 250 Hz separation between adjacent tones. Each tone represents three bits of data, resulting in an over-the-air data rate of 375 bits per second (b/s).

The ALE standard word consists of 24 bits which are separated into a 3-bit preamble field followed by three 7-bit ASCII character fields. The function of each transmitted ALE word, as designated by the preamble code, is related to the basic ALE capabilities. There are eight word types: TO, THIS IS, THIS WAS, DATA, REPEAT, THRU, COMMAND, and FROM. Each 7-bit ASCII character field is used to specify an individual address character or as ASCII text, depending on the preamble.

3.3 Protocols

3.3.1 Scanning

All ALE stations, when operational and not otherwise committed, continually scan a preselected set of channels, or "scan set," listening for calls and ready to respond. The minimum dwell time on each channel is the reciprocal of the scan rate, and the channels in the scan set are repeatedly scanned in the same order. ALE receivers scan channels at either 2 or 5 channels per second resulting in a dwell time of 200 ms or 500 ms. When a transmitter wishes to "capture" a scanning receiver, it will transmit a signal that will be recognized by the scanning receiver. The duration of this "scanning call" must be sufficient to ensure that if the receiver is indeed scanning for calls, it will land on the channel carrying the scanning call before the transmitter ceases emitting.

3.3.2 Selective calling

Selective calling in an ALE system involves the exchange of ALE frames among stations. This selective calling capability supports all higher level ALE functions, including link establishment and data transfer. The general structure of an ALE frame consists of one or more destination addresses, an optional message section, and a frame conclusion which contains the address of the station sending the frame.

The fundamental ALE operation of establishing a link between two stations proceeds as follows:

1) The calling station addresses and sends a call frame to the called station.

2) If the called station "hears" the call, it sends a response frame addressed to the calling station.

3) If the calling station receives the response, it now "knows" that a bilateral link has been established with the called station. However, the called station does not yet know this, so the calling station sends an acknowledgement frame addressed to the called station. At the conclusion of this three-way handshake, a link has

been established, and the stations may commence voice or data communications, or drop the link.

3.3.3 Individual calling

Systems for HF automatic link establishment have a protocol suite for both single channel and multiple channel linking. All ALE stations, when not otherwise committed, continuously listen for calls. The protocol consists of three parts: an individual call, a response, and an acknowledgement.

3.3.4 Sounding

A sound is a unidirectional broadcast of ALE signaling by a station to assist other stations in measuring channel quality. The broadcast is not addressed to any station or collection of stations, but merely carries the identification of the station sending the sound.

3.3.5 Multiple station operations

A net call is addressed to a single address that implicitly names all members of a pre-arranged collection of stations (a "net"). All stations belonging to the net that hear the net call send their response frames in prearranged time slots. The calling station then completes the handshake by sending an acknowledgement frame as usual.

A group call works similarly, except that an arbitrary collection of stations is named in the call. Because no pre-arranged net address has been set up, each station must be individually named. Called stations respond in slots, determining their slot positions by reversing the order that stations were named in the call. The calling station sends an acknowledgement as usual.

3.4 Orderwire messages

In addition to automatically establishing links, ALE stations have the capability to transfer information within the orderwire, or message, section of the frame. Orderwire messages include automatic message display (AMD), data text message (DTM), and data block mode (DBM) modes. These functions enable stations to communicate short orderwire messages or prearranged codes to any selected station(s). This permits station operators to send and receive simple ASCII text messages by using only the ALE station equipment.

3.5 Link quality analysis (LQA)

ALE systems have the capability to support the exchange of LQA information among ALE stations. The LQA process measures the quality of a channel by placing a score on it, which incorporates three types of link analysis information: bit error ratio (BER), signal-plus-noise-plus-distortion to noise-plus-distortion ratio (SINAD), and optionally, a measure of multipath. The LQA scores are stored in memory for future use. ALE stations are capable of selecting the best channel to initiate a call to, or seek, a single

station based on the values in the LQA memory, where the channel with the highest LQA score has the highest probability of being suitable for communication.

ALE radios obtain LQA scores by receiving sounds from other stations, resulting in a score on the received path from the sounding station to the receiving station. Another method of obtaining LQA scores is by initiating a bi-directional sound, a non-linking call designed to measure and transfer LQA scores. Bi-directional sounds produce LQA scores for the forward and reverse paths (in reference to the initiating station). A third method of obtaining LQA scores is during the linking process.

3.6 Network configurations

Multiple station operations are often required in HF networks where several types of network configurations, individual links, networks, and groups are encountered. The most simplistic configuration is a link that comprises only two stations and consists of a single path between the two. Star net and star group configurations consist of more than one link within the network.

Systems for HF radio automatic link establishment have a backup manual control capability.

3.6.1 Star net

A star net is a prearranged collection of stations that operates with a single hub station in a "one-to-many" configuration. In most cases it has the function of the net control station that manages and controls the functions of the network. The star net is usually organised with significant prior knowledge of the member stations so that so that operation of the network is optimized. By using a single net address for all of the net members, efficient contact with multiple stations is achieved.

3.6.2 Star group

A star group is a non-prearranged collection of stations where typically, little or nothing is known about the stations except their individual addresses and scanned frequencies. Like the star net it operates in a "one-to-many" configuration using a net control station. A star group call is performed from a sequence of the actual individual station addresses of the called stations. The stations respond in a manner specified by the sequence of call addresses.

3.7 Addressing

The ALE system deploys a digital addressing structure based upon the standard 24-bit (three-character) word and the Basic-38 character subset. ALE stations have the capability and flexibility to link or network with single stations or with prearranged or as-needed groups of stations.

The ALE system provides and supports three hierarchical sets of characters; the Basic-38 subset, the expanded-64 subset, and the full-128 set. The Basic-38 subset includes all capital alphabetics (A-Z) and all digits (0-9), plus designated utility and

wildcard symbols "@" and "?". The expanded-64 subset consists of all ASCII characters whose two MSBs are 01 or 10, and includes all capital alphabetics, all digits (0-9), the utility symbols "@" and "?," plus 26 other commonly used symbols. The full-128 set includes all characters, symbols, and functions available within the ASCII code.

3.7.1 Individual station addresses

The fundamental address element in the ALE system is the single routing word, containing three characters, which forms the basic individual station address. This basic address word may be extended to multiple words for increased address capacity and flexibility for inter-net and general use. An address which is assigned to a single station is termed an "individual" address. If it consists of three characters or fewer, it is termed a "basic" size, while if it exceeds three characters it is termed an "extended" size. The three characters in the basic individual address provide a Basic-38-address capacity of 46,656 using only the 36 alphanumeric characters. Extended addresses provide address fields which are longer than three characters, up to a maximum system limit of 15 characters. This 15-character capacity enables Integrated Services Digital Network (ISDN) address capability.

3.7.2 Multiple station addresses

A common requirement in HF networks is to simultaneously (or nearly simultaneously) address and interoperate with multiple stations. A prearranged collection of stations with a common address is termed a "net," and the common address is a "net address." A non-prearranged collection of stations, *i.e.,* a collection of stations lacking a prearranged common address, is termed a "group."

3.7.2.1 Net addresses

As a prearranged collection of stations, a net is organized and managed with significant prior knowledge of the member stations, including their identities, capabilities, requirements, and in most cases, their locations and necessary connectivities. The purpose of a net call is to rapidly and efficiently establish contact with multiple prearranged stations by the use of a single net address, which is an address assigned to all net members in common in addition to their individual addresses. The net address structure is identical to that of individual station addresses, basic or extended, as necessary. At a net member's station, each assigned net address is associated with a response slot identifier to allow each station to respond to the net controller in a systematic manner.

3.7.2.2 Group addresses

Unlike a net, a group is not prearranged. In many cases, little or nothing is known about the stations except their individual addresses and scanned frequencies. The ALE group addressing mechanism provides a means to create a new group where none existed. This mechanism uses a standardized protocol that is compatible with virtually all automated stations, regardless of their individual, net, and other characteristics. The

purpose of a group call is to establish contact with multiple non-prearranged stations rapidly and efficiently by the use of a compact combination of their own individual addresses. A group address is formed from a sequence of the actual individual station addresses of the called stations, in the manner directed by the specific standard protocol.

3.7.3   Special addressing modes

The special addressing modes include *Allcalls*, *Anycalls*, *Wildcards*, *Self-address*, and *Null* address. The ALE basic address structure is based on single words that, in themselves, provide multiples of three characters. The quantity of available addresses within the system, and the flexibility of assigning addresses, are significantly increased by the use of address character stuffing. This allows address lengths which are not multiples of three characters to be compatibly contained in the ALE system address fields by "stuffing" the empty trailing positions with the utility symbol "@".

An "*Allcall*" is a general broadcast that does not request responses and does not designate any specific address. This mechanism is provided for emergencies, broadcast data exchanges, and propagation and connectivity tracking.

An "*Anycall*" is a general broadcast that requests responses without designating any specific addressee(s). It is required for emergencies, reconstitution of systems, and creation of new networks. An ALE station may use the "*Anycall*" to generate responses from essentially unspecified stations, and it thereby can identify new stations and connectivities. The selective *Anycall* is a selective general broadcast that is identical in structure, function, and protocol to the global anycall, except that it specifies the last single character of the addresses of the desired subset of receiving station (1/36 of all).

A caller may use the *Wildcard* character ("?") to address multiple stations with a single wildcard address. Responses to a call containing an address with wildcard characters are generated in pseudorandom slots to avoid collisions.

For self-test, maintenance, and other purposes, stations should be capable of using and responding to their own *Self-Addresses*.

For test, maintenance, buffer times, and other purposes, stations may use a Null Address which is not directed to, accepted by, or responded to by any station.

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