SOME RECENT AMATEUR USE OF FEDERAL STANDARD AUTOMATIC LINK ESTABLISHMENT (ALE) SIGNALING

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INTRODUCTION

This paper describes some recent experience on the HF bands with equipment operating according to the new federal standard for automatic link establishment (ALE). Some data collected-on authorized frequencies outside the ham bands (where interference is less bothersome) are also presented to illustrate some of the analysis possibilities offered by ALE systems.

In our experiments on the amateur voice and digital sub-bands we have established links using Federal Standard 1045 ALE controllers and then used the links for voice or data exchanges. The controllers contain modems, and software that implements the ALE linking protocol and other functions connected with network operation based on ALE. Details on how these ALE controllers work have been given recently in several articles in *QEX* and *QST*.

The experiments, which began in June, have been conducted mainly to see how well ALE works in the noise and interference conditions of the amateur bands. We have interpreted ALE in our experiments as a means for establishing links that will be used for conventional ham voice or data traffic, and have tried to keep our use of the 375-bps, 8-ary FSK ALE waveform brief and at relatively low power (100 watts output).

Most of the links have been between Boston (KB 1JY and W 1IMM) and Raleigh, N. C. (NT4T), with a few between Boston and Cedar Rapids, Iowa (WAOIQM). The Boston-Raleigh link is about 500 miles long and the Boston-Cedar Rapids link about 1000 miles long. Our antennas are broad band or tuned wires (in Boston and Cedar Rapids) and a tuned whip (in Raleigh).

These experiments may have been the first use by hams of ALE in the ham bands, although hams (and many others) have been experimenting with the federal standard technique in other parts of the HF spectrum for about three years.

We have not run the ham experiments on a regularly scheduled basis, so this report gives only an indication of how well ALE works and how its performance compares with that of the conventional modes of digital signaling in the ham bands (Morse code, HF packet, AMTOR or ASCII). When permission is granted for regular use of ALE in the amateur bands, our approach should be replaced by systematic data collection.

Here’s a summary of how ALE works:

The ALE controller uses digital signal processing to automatically

- sound channels (in one- or two-way modes),
- collect and store data on channel quality,
- exchange channel quality data with other stations,

- chose the best channel (frequency) for communications,
- call a station or stations, and set up a link on the chosen frequency using the ALE protocol,
- alert operators of the established link for subsequent transmission of data or voice traffic, and
- exchange short, stored digital messages if desired.

The linking exchange is three-way: *call-response-confirmation*, and all three legs must be successful for link establishment. The short messages appear on front-panel displays of the controllers and are called automatic message display (AMD) messages.

Both ALE data frames (containing station addresses and channel quality measurements) and those of the short messages allowed by the standard are protected against bit errors by means of a powerful combination of (23,12)-Golay coding, interleaving and three-fold diversity (bit repetition) at the transmitting modem. The receiving station carries out the corresponding Golay decoding, de-interleaving and majority-vote decoding. The Golay code provides protection mainly against isolated bit errors caused by static, etc. The interleaving and repetition protect mainly against "burst errors" caused by the inter-symbol interference associated with HF multipath and by unwanted radio signals.

Data traffic can be sent over ALE links by Morse code, unprotected FSK (ASCII, BAUDOT), binary (A)FSK with some error control (HF packet, AMTOR, PACTOR), by the 8-ary FSK plus error control of the ALE waveform itself, or by some other efficient waveform with error control (for example, CLOVER, or one of the new MIL-STD-1 10A waveforms).

THE AMATEUR EXPERIMENTS

These experiments took place on an agreed-upon and stored set of 6 frequencies in the 75-, 40-, 30-, 20-, 17- and 15-meter bands.

The ham-band experiments started with either sounding or a link quality analysis (LQA) exchange. Sounding involves a set of one-way transmissions on a stored set of frequencies that allow stations scanning the set to measure channel quality. An LQA exchange is a similar two-***way*** exchange of channel quality data. In each case, a sound or LQA attempt will generally result in data collection on only a subset of the stored frequency set; namely,, those frequencies that propagated well enough to allow the corresponding stations' addresses to be read by the receiving stations.

Table 1 gives an excerpt from our ALE data log for ham-band experiments run between Boston and Raleigh on 26 August 1992 at about noon EDT. It shows that an LQA initiated by Boston got responses on 14 and 7 MHz. Channel quality in each case was high enough for communication with the ALE waveform (an AMD with no errors) and with ASCII (where errors were usually noted). Some details on the format of the log output are given below.

After finding out what frequencies were good, we then choose one: of them manually for linking, or let the modem pick what it thought was the best one, and then try to set up a link automatically. In experiments carried out around noon between Boston and Raleigh, the chosen frequencies were usually 10 or 14 MHz, which agrees with IONCAP predictions of about 14 MHz for the average MUF for Boston-Raleigh in summer. In experiments run in the evening, the preferred Boston-Raleigh frequencies were 7 or 10 MHz (the IONCAP MUF was about 11 MHz). The preferred frequencies for Boston-Cedar Rapids were a few megahertz higher.

Table 1. Data Log for Ham-band Experiments on 26 August 1992

NT4T/IMM ALE/ASCII 26.8.92											
LQA de IMM with longwire											
Date						Freq.	SNR		BER		Comb.
8/26/92	GMT	Event		From	Ch		To	Fr	To	Fr	Score
8/26/92	16:57:36	Lqa_initiated_to	NTTP	IMM	35						
8/26/92	16:57:57	Lqa_initiated_to	NTTP	IMM	34						
8/26/92	16:58:14	Lqa_initiated_to	NTTP	IMM	33	14.08	*	20	0.021	0	99
8/26/92	16:58:34	Lqa_initiated_to	NTTP	IMM	32						
8/26/92	16:58:52	Lqa_initiated_to	NTTP	IMM	31	7.093	*	19	0.083	0	81
8/26/92	16:59:12	Lqa_initiated_to	NTTP	IMM	30						
* No measurement received from NTTP											

In 70 or 80 trials, automatic link establishment almost always worked on the first try[1]. On each established link we initially send an Automatic Message Display (AMD) message about 80 characters long. These messages appear on the front panel of the receiving controller and are protected by ALE error control. We send AMDs for comparison with digital signaling using various ham waveforms (HF packet, ASCII, AMTOR or Morse code).

The AMD messages always arrived -without error over the channels chosen by the modem. as has automatically sent Morse code, which we demodulate by ear.

Voice communications were usually readable, but were carried out against a background of strong summer static, caused probably by lightning discharges a long distance from our stations.

Packet messages, whose errors are controlled by a form of automatic repeat request (ARQ), suffer sometimes from the well known effects of multipath fading: packets about 80 characters long occasionally took two or three tries to arrive correctly. Our KAM or PK-232[2] *packet* modems' tuning indicators suggested that multipath (rather than noise) was the cause of this,

ASCII transmissions are of course unprotected by any error control. We sent 80-character ASCII messages over the same frequencies chosen by the controller for ALE. We judged reception quality by counting character errors. Character error rates between 5 and 20% were common for ASCII, and most errors came in bursts

Similar things happened with AMTOR FEC (Mode B), although the error rates were a bit lower than for ASCII. This is expected since AMTOR FEC uses two-fold character repetition and a CRC error-detecting code for error control. Error rates -were not reciprocal, a reflection, perhaps, of the different antennas or different noise levels. or both.

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[1] On one notable occasion, however, there was so much noise and interference on 7 MHz that an attempt to link at about 2200 GMT took 4 tries. AMTOR, on the other hand, could not be read at all.

[2] It is instructive to note that because of the fact that ALE takes place on *fixed* channels, it is not possible (or at least not easy) to communicate on an ALE channel with amateur multi-mode controllers that use different FSK mark and space frequencies. This is the case with the KAM and PK-232. Fortunately, we were able to change the KAM's default mark and space to the mark and space used by the PK-232.

The sounding and LQA mechanisms of the ALE system make it easy to collect data on short-term or long-term channel quality (useful in network analysis) and on antenna performance. The controller can be programmed to sound (a form of broadcasting to any stations scanning the frequency set) on schedule or to call and exchange channel data with a particular station. Either method allows receiving stations with data storage capabilities (a PC with a hard disk) to collect channel quality data systematically. Current equipment measures channel quality in terms of signal-to-noise ratio (SNR) and bit error rate (BER), which are measured independently.

EXPEFUMENTS OUTSIDE THE HAM BANDS

Channel Quality Measurement

As an example of channel quality data collected with the ALE protocol consider the spreadsheet excerpt shown in Table 2, which was made using data collected automatically from an RS-232 port on the ALE controller in Boston. The excerpt refers to two sets of linking exchanges made by "MIB" (Boston) with "MTR" (in Virginia, about 400 miles) and "SUN" (in Florida, about 1000 miles) on various frequencies.

In each case, the SNR (in dB, maximum value = 30) and bit error rate (BER) on the links were measured in Boston. These are listed in the **From** columns. In the case of the SUN links, Boston also recorded the SNR and BER that *SUN* measured: these are in the To columns, and were sent to Boston as part of the LQA exchange that normally occurs during the three-way linking process. In the case of MTR in Virginia, only the BERs are two-way: equipment incompatibilities prevented a two-way SNR exchange. The **Comb Score** column contains scores (maximum value = 120) that reflect the overall quality of each link; these: were calculated by the Boston controller from the two-way SNR. and BER measurements.

Figures 1 and 2 show the variation of two-way SNRs and BERs on the links with SUN at 10.4 MHz listed at the bottom of the spreadsheet in Table 2. These links were made by repeatedly commanding the Boston controller to try 10.4 MHz, and the measurements were taken over the course of about 5 minutes. "Measured at MIB" refers to the measurements made in Boston of the quality of **the** SUN signal (in **the From** column), and "Measured at SUN" refers to the measurements made in Florida of MIB's signal and sent as ALE orderwire data back to Boston (in the **To** column). Since the controllers measure SNR and BER. by independent means, the BER can't be derived precisely from the SNR and vice versa.

It can be seen that SUN's SNR was significantly greater than MIB's during all of this period, perhaps a result of different background noise levels at each end of the link. Both signals suffered somewhat more variation during the first 2 minutes than the last 2, with the SUN signal changing significantly faster during the first 2 minutes than the MIB signal. The early variations probably reflect the presence of radio interference; the interference was probably not present during the last 2 minutes.

It is interesting to compare this measured performance with that predicted by the IONCAP program used by *QST* and many others in forecasts of DX operation. IONCAP predicts that this link has an optimal working frequency (FOT) of about 14 MHz at 2200 GMT, and a reliability (probability that the SNR required for ALE will be achieved) of 70%. The reliability at 10 MHz is about 46%. (In this prediction we assumed a sunspot number of 100, equal noise levels at each end of the link, and the use of zero-gain isotropic antennas.) Note that the use of 15 MHz between 21:55 and 21:56 resulted in a BER of zero for both ends of the link. This suggests that there was less multipath (and inter-symbol interference) at 15 MHz than at 10 MHz (the predicted MUF was 18 MHz).

The markedly different SNRs recorded at each station (assuming that the controllers are using comparable measurement techniques) suggest that the noise levels or antenna gains are in fact different. It should be kept in mind that IONCAP predicts *monthly averages* of the MUF, FOT and SNR, and says nothing about radio interference, so differences between its predictions and actual performance at a particular time are to be expected. IONCAP should be viewed in the context of ALE systems as a means for choosing the set of frequencies to be tried by the controller; we should *not* expect it to tell us the frequency that will actually be chosen.

Table 2. Data Log for MIB/MTR and MIB/SUN Links on 6 May 1992

Date	GMT	Event	To	Frm	Freq		SNR		BER		Comb
Individual calls							To	Fr	To	From	Score
5/6/92	21:39:45	Linked	MTR	MIB	9.973	USB	- -	10	0	0.029	80
5/6/92	21:40:22	Linked	MTR	MIB	7.422	LSB	- -	12	0	0.007	86
5/6/92	21:40:50	Linked	MTR	MIB	7.422	LSB	- -	18	0.014	0	97
5/6/92	21:41:20	Linked	MTR	MIB	7.422	LSB	- -	16	0.021	0.021	89
5/6/92	21:41:44	Linked	MTR	MIB	7.422	LSB	- -	13	0.014	0	86
5/6/92	21:42:18	Linked	MTR	MIB	7.422	LSB	- -	11	0.014	0.051	78
5/6/92	21:42:41	Linked	MTR	MIB	9.973	USB	- -	30	0	0	120
5/6/92	21:43:04	Linked	MTR	MIB	9.973	USB	- -	18	0	0	100
5/6/92	21:43:29	Linked	MTR	MIB	9.973	USB	- -	10	0	0.051	77
5/6/92	21:43:51	Linked	MTR	MIB	7.422	LSB	- -	18	0.014	0.029	94
5/6/92	21:44:16	Linked	MTR	MIB	7.422	LSB	- -	18	0.021	0.014	94
5/6/92	21:44:39	Linked	MTR	MIB	7.422	LSB	- -	16	0.007	0	95
5/6/92	21:45:01	Linked	MTR	MIB	7.422	LSB	- -	18	0.021	0	95
5/6/92	21:45:24	Linked	MTR	MIB	7.422	LSB	- -	10	0.029	0.044	74
5/6/92	21:45:46	Linked	MTR	MIB	9.973	USB	- -	21	0	0	104
5/6/92	21:46:12	Linked	MTR	MIB	9.973	USB	- -	30	0	0	120
5/6/92	21:46:35	Linked	MTR	MIB	9.973	USB	- -	30	0	0	120
Individual calls											
5/6/92	21:55:01	Linked	SUN	MIB	15.71	USB	7	10	0	0	55
5/6/92	21:55:25	Linked	SUN	MIB	15.71	USB	11	15	0	0	69
5/6/92	21:55:47	Linked	SUN	MIB	15.71	USB	11	30	0	0	84
5/6/92	21:56:15	Linked	SUN	MIB	15.71	USB	10	15	0	0	66
5/6/92	21:57:03	Linked	SUN	MIB	10.42	USB	6	19	0.021	0	63
5/6/92	21:57:25	Linked	SUN	MIB	10.42	USB	8	17	0.036	0	63
5/6/92	21:57:50	Linked	SUN	MIB	10.42	USB	8	30	0.007	0	77
5/6/92	21:58:11	Linked	SUN	MIB	10.42	USB	8	14	0.029	0.007	59
5/6/92	21:58:32	Linked	SUN	MIB	10.42	USB	5	21	0.051	0	59
5/6/92	21:58:54	Linked	SUN	MIB	10.42	USB	8	30	0	0	79
5/6/92	21:59:16	Linked	SUN	MIB	10.42	USB	6	13	0	0.007	58
5/6/92	21:59:38	Linked	SUN	MIB	10.42	USB	9	30	0.014	0	78
5/6/92	21:59:59	Linked	SUN	MIB	10.42	USB	8	30	0.029	0	75
5/6/92	22:00:22	Linked	SUN	MIB	10.42	USB	10	30	0	0	83
5/6/92	22:00:43	Linked	SUN	MIB	10.42	USB	11	30	0	0	84
5/6/92	22:01:05	Linked	SUN	MIB	10.42	USB	11	30	0.007	0	85
5/6/92	22:01:27	Linked	SUN	MIB	10.42	USB	11	30	0	0	84
5/6/92	22:01:47	Linked	SUN	MIB	10.42	USB	10	30	0.007	0	81

Figure 1. Measured SNRs @ 10.4 MHz

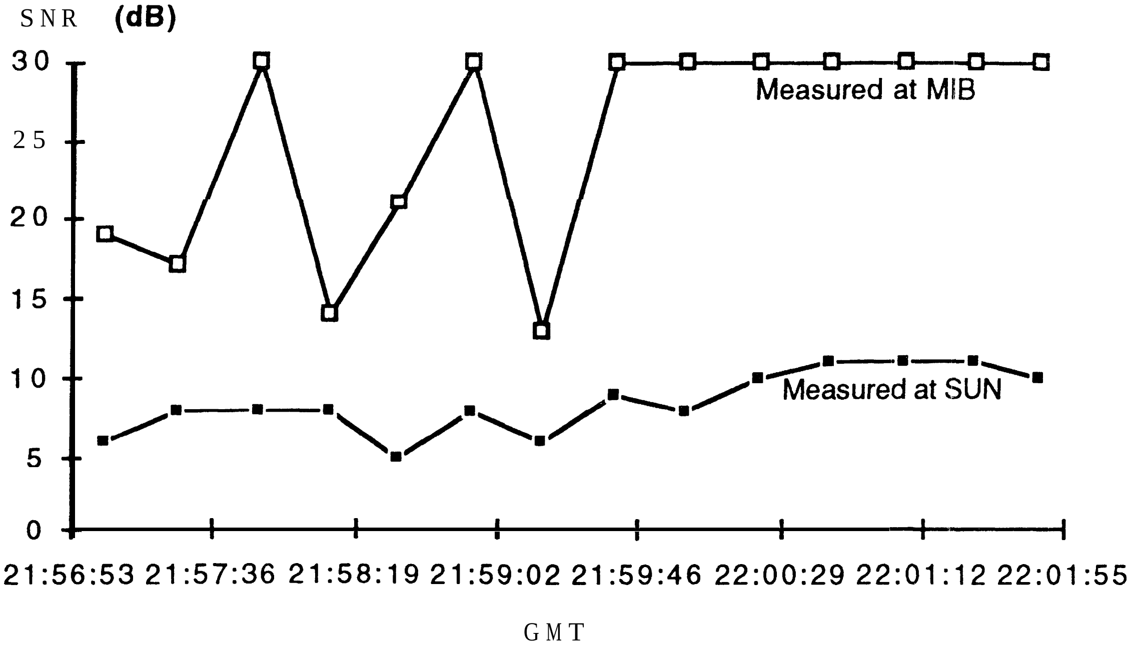
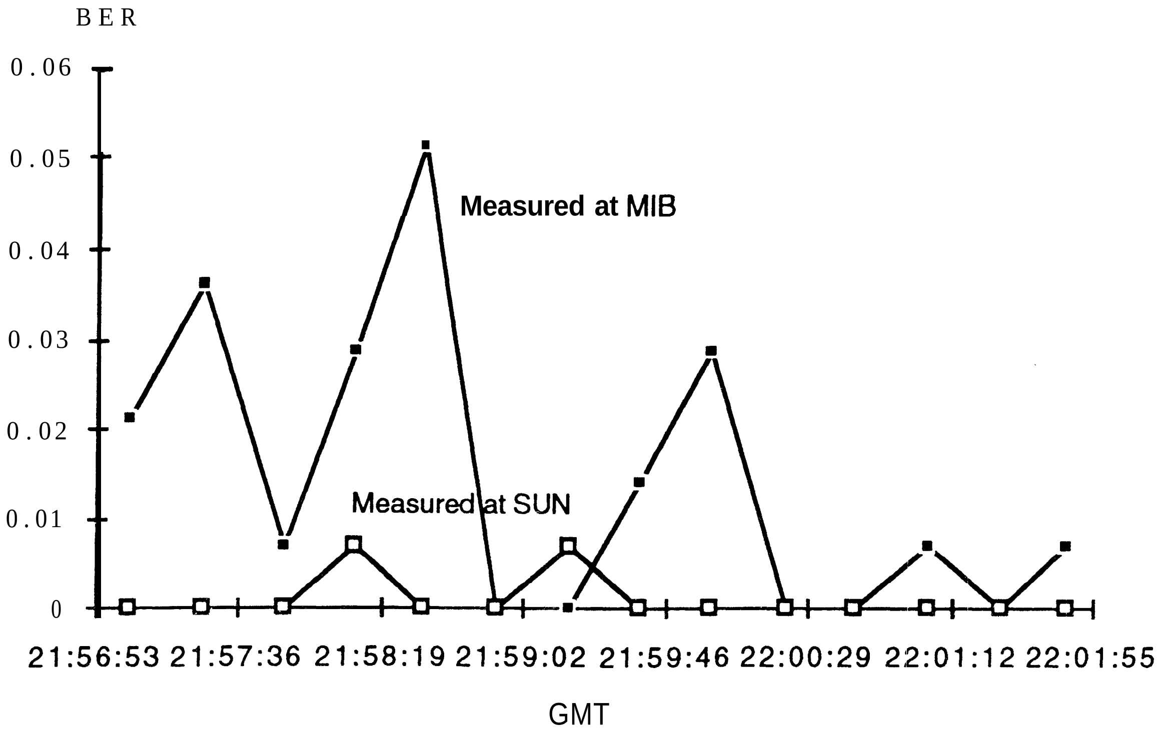


Figure 2. Measured BERs @ 10.4 MHz



This example is typical of what Is often observed on such a link, and it points to the importance for effective: HF digital signaling of an automatic means for measuring channel quality and establishing links. In this case, SUN's controller (using the Combined Scores) may well have chosen 10.4 MHz for a link attempt with MIB, but the MIB controller would probably have looked for a channel with higher Combined Score.

Comparison of Antenna Performance

One way to compare antenna performance is to carry out an LQA exchange on a set of frequencies with each antenna at nearly the same time. As an example of this, consider the data log excerpt shown in Table 3. It applies to a pair of LQA exchanges initiated by MIB (near Boston) with MOT (near Chicago, Ill). For the first exchange, MIB used a 100-ft, broad band, omni-directional dipole, and in the second (about 2 minutes later) a 250-ft, resistively terminated, sloping long wire pointing south. (The dashes in the **To** columns at 7.4 MHZ indicate missing measurements.)

Table 3. Dipole vs Long Wire on 20 February 1992

100-ft Omni-directional Dipole								SNR		BER		Comb
Date	GMT	Event	To	Frm	Ch	Freq		To	Fr	To	Fr	Score
2/20/92	22:51:52	Lqa_initiated_	MOT	MIB	10							
2/20/92	22:52:27	Lqa_initiated_	MOT	MIB	9							
2/20/92	22:53:03	Lqa_initiated_	MOT	MIB	8							
2/20/92	22:53:39	Lqa_initiated_	MOT	MIB	7							
2/20/92	22:54:14	Lqa_initiated_	MOT	MIB	6							
2/20/92	22:54:30	Lqa_initiated_	MOT	MIB	5	10.42	USB	24	30	0	0	111
2/20/92	22:54:46	Lqa_initiated_	MOT	MIB	4	9.973	USB	20	30	0	0	104
2/20/92	22:55:21	Lqa_initiated_	MOT	MIB	3							
2/20/92	22:55:57	Lqa_initiated_	MOT	MIB	2							
2/20/92	22:56:33	Lqa_initiated_	MOT	MIB	1							
250-ft Long Wire with resistive termination												
2/20/92	22:58:02	Lqa_initiated_	MOT	MIB	10							
2/20/92	22:58:37	Lqa_initiated_	MOT	MIB	9							
2/20/92	22:59:13	Lqa_initiated_	MOT	MIB	8							
2/20/92	22:59:49	Lqa_initiated_	MOT	MIB	7							
2/20/92	23:00:24	Lqa_initiated_	MOT	MIB	6							
2/20/92	23:00:40	Lqa_initiated_	MOT	MIB	5	10.42	USB	16	19	0	0	82
2/20/92	23:00:56	Lqa_initiated_	MOT	MIB	4	9.973	USB	18	30	0	0	98
2/20/92	23:01:11	Lqa_initiated_	MOT	MIB	3	7.422	LSB	- -	13	- .	0	23
2/20/92	23:01:46	Lqa_initiated_	MOT	MIB	2							
2/20/92	23:02:22	Lqa_initiated_	MOT	MIB	1							

The LQA scores confirm what we might expect: the omni-directional antenna does better on 9.97 and 10.42 MHz than the long wire, whose main lobes are probably not pointed toward Chicago. At 7.4 MHz, however, the long wire is apparently the winner. Of course, **there** are a number of possible explanations for this (for example, a 7.4 MHz lobe that *is* favorable for the east-west path, Of a sudden burst of noise on 7.4 MHz when LQA was tried with the dipole), so no firm conclusion can be reached on the basis of a single observation. Nevertheless, the LQA logging feature of some ALE systems is a very useful aid to the choice of antennas and antenna siting when coupled with a systematic measurement plan.

SOME ISSUES ARISING IN ALE USE ON THE HAM BANDS

Among the ALE issues that will have to be discussed and resolved by amateurs in the near future are:

- deciding what frequencies (or bands of frequencies) should be allocated for use by amateur ALE stations,

- working out effective protocols, waveforms and interfaces for sending data over links established and maintained with ALE (AX.25 packets encapsulated in ALE frames and protected by ALE error control, packets sent with the CLOVER waveform, or with other waveforms, such as those of MIL-STD-1 10A or an international standard‘! Data interface via the radio’s audio port or an IRS-232 data port?),

- coordinating the frequencies and callsigns used in **network** operation, and

- setting up an orderly and *standard* system for gathering, displaying and analyzing data on ALE performance in the ham bands.

More than 2000 federal standard ALE controllers are now used worldwide in **commercial** and military short-wave communications, and it is only a **matter** of time before a version becomes available for legitimate (if restricted) use in the ham bands. We hope that our experiments will increase interest among hams in this new and exciting technology.

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