CLOVER-II: A TECHNICAL OVERVIEW

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ABSTRACT

The CLOVER-II four tone-pulse signal, methods of synchronization, control and data modes, Reed-Solomon coder, and transmission protocols are described.

INTRODUCTION

In a paper at last year's conference[1] I reported results of some on-the-air testing of a new HF data communication system I have been developing over the last few years. These tests verified my expectation that the "Cloverleaf" system would provide very worthwhile performance improvements over any mode in present amateur use. The original version has been named "CLOVER-I". It is distinguished by having data pulses at one center frequency, practical channel spacing of 100 Hz, error-corrected throughput of well over 100 bits/second in the best of conditions, and a requirement for very high frequency precision in the radios.

In August of last year I teamed up with Bill Henry (K9GWT) of HAL Communications. We decided to pursue development of a second version which we named "CLOVER-II." This version has 500 Hz channel spacing and error-corrected throughput of over 500 bits/second in the best conditions. It will work with existing synthesized radios of recent design. First production units are scheduled for delivery by early 1992. A patent application covering both versions was filed on July 8 of this year.

THE CLOVER-II "CARRIER"

The "Carrier" of the CLOVER-II signal is a sequence of four overlapping pulses having smoothly-shaped amplitude envelopes and ascending center frequencies. Each pulse has a duration of 32 ms and successive pulses are offset by 8 ms. The pulse envelopes are Dolph-Chebychev functions. The power spectrum of each pulse is at least 50 dB down outside its subchannel width of 125 Hz. The pulse at the lowest frequency begins at the frame origin. The pulse 125 Hz higher begins 8 ms after the origin, the pulse 250 Hz higher begins 16 ms after the origin, and the pulse 375 Hz higher begins 24 ms after the origin. The peak-to-average power ratio (crest factor) of this carrier is only 6 dB.

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[1] Petit, R.C. (W7GHM), "The 'Cloverleaf' Performance-oriented HF Data Communication System", ARRL-CRRL 9th Computer Networking Conference, page 191

The CLOVER-II carrier has been designed for 500 Hz channel spacings. The spectrum of the CLOVER-II signal is the same, data or no data, and regardless of the data speed. Four CLOVER-II signals can fit into the 2-kHz space now required for the same level of channel isolation with the narrow-shift FSK modes. Fig. 2 shows measured power spectrum data for CLOVER-II, HF packet, and AMTOR. As a test I set up one of the prototype CLOVER-II controllers to report the total power level of an incoming CLOVER-II signal in the lab. Then I moved the transmitter signal up exactly 500 Hz and got a second measurement of the total power in the original receive channel. There was a 52 dB difference.

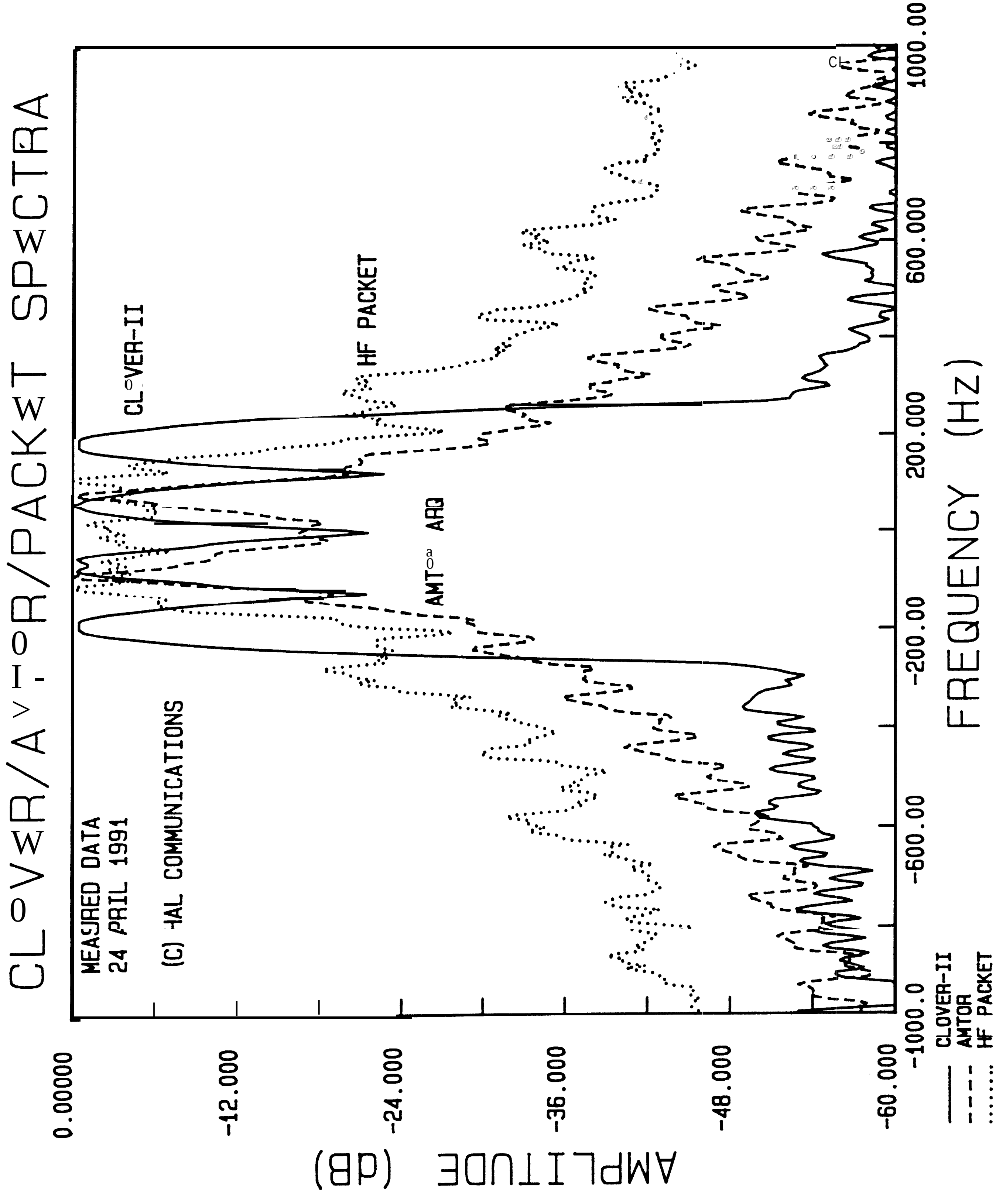
One may logically ask, "Why not just stick to one tone pulse frequency, as you did in CLOVER-I, and speed it up by a factor of 53" CLOVER takes a hint from CW. The duration of a pulse is much longer than the uncertainties in time-of-arrivals due to multipath. The energy in one CLOVER pulse is concentrated in a very narrow band. When selective fade sets in, all of the pulse more or less fades in unison. The very high subchannel isolation permits the receiver to decode each subchannel independently, recovering data even if a subchannel amplitude is many dB below that of its neighbors. Compensation for channel variability (adaptive equalization) is very easy with this arrangement.

TIME AND FREQUENCY SYNCHRONIZATION

CLOVER is a synchronous data-transmission scheme. Two levels of synchronization are required. "Frame sync" positions the receive data-sampling processor to the instant of maximum S/N of the four pulses in a frame. "Epoch sync" establishes the boundaries of Reed-Solomon codeblocks. Both forms of sync are obtained during the link-establishment process and are valid until a link reset occurs, either for station ID every 10 minutes or to recover from a long series of decode failures.

Frame sync is obtained from a 1/2-second observation of the CLOVER-II carrier with a signal averaging process applied to the pulse magnitudes. Epoch sync plus "target" station identification is obtained from a crosscorrelation between a byte pattern in which the target station callsign is embedded, and the "MYCALL" data of each receiving station.

CLOVER uses differences in phase between successive pulses in each subchannel as its primary data-transfer mechanism. At the higher speeds, one of 16 phase levels must be distinguished every 32 ms. A frequency offset causing a phase drift of more than plus or minus 1/32 of a cycle in 32 ms will produce errors. This is only 1 Hz offset! By observing the phase changes near the maximums of each of the four pulses in a frame, the CLOVER-II receiving processor determines the frequency offset between the two stations and corrects for it. A tuning indicator will show this offset, and an alarm will be sent to the application program if this offset exceeds 10 Hz. Later versions of the CLOVER-II software may make provision for automatic fine tuning of the receiver. (However, a


CLOVER/AMTOR/PACKET SPECTRA
MEASURED DATA
24 APRIL 1991
(C) HAL COMMUNICATIONS
CLOVER-II
HF PACKET
AMTOR ARQ
AMPLITUDE (dB)
0.00000
-12.000
-24.000
-36.000
-48.000
-60.000
FREQUENCY (Hz)
-1000.0
-600.00
-200.00
200.000
600.000
1000.00
CLOVER-II
AMTOR
HF PACKET

far better alternative, in my opinion, is to make a stable synthesized radio which can be phaselocked to an accurate standard. I provided diagrams for a simple single-frequency stabilized radio last year.[2] Links using stabilized radios at both ends will deliver better performance.)

DATA AND CONTROL MODES

CLOVER-II has a suite of 7 modulation modes. These range from slow and very robust modes for the very poor propagation conditions up through the fast and fragile modes for the very best band conditions.

The first mode is actually a set of three. In these modes, phase information is not used: only the subchannel amplitudes are used. Data or control information is sent by omitting two of the four pulses in a frame. In the data-sending variant, it is a dual-diversity format, 1 bit/frame, 31.25 bits per second. This mode is useful when conditions are so poor that phase-encoded information fails altogether. The other two variants are used for link maintenance control signals.

The slowest phase mode is "Quad Inband Diversity Binary Phase." Each of the four pulses in a frame carries the same data bit. A smart diversity combiner in the receiver chooses the channel having the combination of highest amplitudes and most nearly ideal phase differences and reports its data as the best estimate. The raw data speed (not error-corrected) is one bit per frame, 31.25 bits per second. This mode has the ability to estimate the channel BER.

The next four modes encode data in phase differences only, using all four pulses. They use 2, 4, 8, and 16 phase levels, respectively, for raw data rates of 125, 250, 375, and 500 bits per second.

The fastest mode adds 4 amplitude levels to the 16 phase-level mode to get raw speeds of 750 bits per second. The incoming signal will have to be very strong and the path very stable. The receiver AGC will have to be off. I don't expect this mode to be usable very often.

REED-SOLOMON CODING AND BLOCK FORMAT

CLOVER uses large block-size Reed-Solomon coding without interleaving. All processing is done on GF(2E8) using fast transform methods. The block sizes are 17, 85, and 255 bytes, with symbol-error correcting capacities of 1 to as many as 1/4 the total number of symbols in the block. The number of data bytes in a block is (approximately) the block length minus twice the maximum number of errors it can correct. Two bytes of every block are reserved

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'Petit, R.C. (W7GHM), "Frequency-Stable Narrowband Transceiver", ARRL-CRRL 9th Computer Networking Conference, page 195 for link maintenance data. Depending on the modulation mode and block size chosen, transmission of a single block will take from about one second to about one minute.

LINK-LEVEL PROTOCOLS

Three link-level protocols are in development. The first is a point-to-multipoint somewhat like AMTOR FEC. The second is the 'dialog' protocol resembling AMTOR ARQ. The file-transfer protocol is similar to the dialog protocol except for two features. User data is sent in only one direction, and single transmissions may contain many codeblocks.

MONITORING

If a CLOVER-II controller receives a call not directed to it, or hears a CLOVER-II signal already on the channel, the controller automatically goes into monitor mode, although if the user or application program does not want to receive monitored text, the text output can be suppressed. The controller will not transmit while it is in monitor mode, thus keeping the channel clear for the session already in progress. When a session ends, both controllers on the closing session transmit a distinctive 1-second control signal announcing their relinquishment of the channel. The receipt of this signal, or a sustained “no carrier detect” condition,, enables transmit states.

IMPLEMENTATION

The production version of the CLOVER-II controller will be an IBM-AT compatible expansion card. Supplied with it will be a terminal program similar to HAL's "PC-AMTOR" for keyboarding users. A "TNC EMULATOR" port on the rear panel will permit packet BBS sysops to convert their HF ports to CLOVER-II by simply moving one RS-232 cable.