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by

R. W. Burhans
Avionics Engineering Center
Department of Electrical Engineering
Ohio University
Athens, Ohio 45701

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R. W. Burhans
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Department of Electrical Engineering
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ABSTRACT

A problem with the Omega System is a lack of suitable low-cost hardware for the small user community. A collection of do-it-yourself circuit modules are under development intended for use by educational institutions, small boat owners, aviation enthusiasts, and others who have some skills in fabricating their own electronic equipment. Applications of the hardware to time-frequency standards measurements, signal propagation monitoring, and navigation experiments are presented. Detailed circuit information is in preparation for publication in another journal. A family of Mini-O systems have been constructed varying from the simplest RF preamplifiers and narrowband filters front-ends, to sophisticated microcomputer interface adapters.

INTRODUCTION

Do-it-yourself electronic systems have become increasingly popular as evidenced by the large circulation of popular-oriented electronic magazines like Popular Electronics, Radio-Electronics, Byte, The Audio Amateur, as well as a host of smaller club-type newsletters devoted to both the professional and amateur electronic circuit buff. Dozens of firms specialize in supplying hardware items at low-cost for the kitchen table and basement workshop experimenter. Low budget educational institutions have made very good use of these developments in providing themselves with sophisticated electronic equipment which they otherwise could not afford.

MICROPROCESSOR TECHNOLOGY

The explosive growth of microcomputer systems during the past year or so is well demonstrated by the circulation of new publications such as Byte (circulation > 50,000) devoted entirely to small computer systems or personal computing systems based on the recently developed 8-bit microprocessors (central processing unit of a small computer which handles data bytes in an 8-bit, 2^8 format). It has been estimated that tens of thousands of personal computing systems have been fabricated in the past year due to the wide availability of fabrication kits, partially assembled circuit boards, and single chip devices at low cost. A minimal computing system with 1000, 8-bit words of permanently stored monitoring programs (ROM) and 1000 words of temporary memory (RAM) can cost as low as $300 complete with keyboard, hexidecimal data display, and even a cassette recorder for permanent storage of large blocks of program software routines.[1] For an additional $200 or so, the user can supply himself with a sophisticated data input-output device in the form of a TV Typewriter with a full alpha-numeric keyboard which displays English text or graphical material as "pages" on an ordinary TV set. In the same price range a number of hard copy printers are now available which supply permanent copy on ordinary adding machine tape.[2]

Microprocessors can also be interfaced with a great variety of external instruments as input-output devices through the use of standard digital-to-analog or analog-to-digital conversion routines. Omega receiver systems are a prime candidate for these techniques where some minimal front-end hardware is used to supply raw Omega data in a format suitable for software manipulation with a microcomputer system. In the simplest microprocessor-oriented Omega receivers this raw data is software filtered to obtain line-of-position (LOP) information for two or more selected Omega stations which are in turn recorded on a strip chart recorder through a D/A converter for use by the marine navigator.

The Mini-O system is configured to supply the basic front-end and timing systems necessary to operate a microprocessor or to be used as an independent monitor receiver with various forms of hardware signal processors. Very complex systems may be fabricated for a hardware cost of under $1000 when the user supplies his own electronic circuit fabrication and interface wiring skills.

MINI-O BASICS

The Mini-O concept is an Omega receiver configured in circuit board modules consisting of an antenna preamplifier,[3] front-end filter-limiter, zero crossing and amplitude comparators, and a minimal Omega sequence timer with internal or external clock reference oscillator. Various other modules have been devised to hardware digital filter the raw data and to supply information at a suitable low interrupt rate for microprocessor use, Figure 1. The first Mini-O receiver supplied data in a 4-bit format for direct recording on a strip chart recorder with simply averaging each station phase over a single time slot.[4] The most recent Mini-O receiver supplies Omega data in a 6-bit format for each time slot at a low, 40 Hz, data rate using the digital equivalent of a superheterodyne receiver method. The superhet uses the internal clock as a local oscillator to provide a low intermediate frequency (IF) at a low 40 Hz frequency to match the digital IF filter characteristics to the analog narrow band input filters.

Progress in precision wristwatch technology provides low-cost means in the form of quartz tuning fork and mechanical bar resonators to analog filter the raw Omega signal. The bandwidth of the front-end is in the range of 4 Hz to 14 Hz which provides quite good rejection of noise and off-channel interfering carriers.

SIGNAL AMPLITUDE DATA

An example of the output signal amplitude envelope from a Mini-O front-end is shown in Figure 2. This type of recording made on a Heathkit recorder with a 10 second per inch chart drive speed, is useful for monitoring signal amplitude variations of the Omega carrier wave. An example of the effect of local absorption of signals while flying through fog or clouds is shown in Figure 3, where the ripple on the peaks of the signal amplitude changes as the receiver antenna moves in and out of the cloud formations. Another example is the effect on Omega signal amplitude at local sunset when the phase discontinuities are most pronounced and the background noise appears to increase, as in Figure 4. These illustrations also show the performance of two different types of front-end systems, a 30 Hz bandwidth model with two stages of ceramic filtering versus a 4 Hz model with a single stage quartz tuning fork filter.[5] This type of amplitude data is of considerable value to the experimenter in educating him on the peculiarities of Omega signal reception for a variety of receiver operating environments. In particular the use of very narrowband analog RF methods in the Mini-O receiver allows inspection of signal amplitude data which is often not possible in the raw output from a conventional 100 Hz type of Omega front-end.

DIURNAL OMEGA DATA RECORDING

All Omega users are familiar with the diurnal changes in the Omega LOP grid. An example with the Mini-O receiver 4-bit data for the G-D pair is shown in Figure 5. This also illustrates the reverse subtraction of D-G which gave essentially the same result 24 hours earlier only opposite in phase direction. Another phenomena noted in Figure 5 is 60 Hz harmonic burst noise caused by the 170th harmonic of 60 Hz power machinery in the local monitoring environment. This type of interference often plagues Omega users who attempt reception in their urban basement workshop with a short whip antenna stuck out the attic window. Figure 5 was made on a Heathkit recorder with a 200 min/inch chart drive. Note that the discrete 4-bit steps in the total possible phase variation of 16 steps for one cycle (one lane) can be seen on these 24 hour data displays. Another example of the severity of local 60 Hz interference is illustrated in Figure 6, where the operation of heating and airconditioning equipment radiates 10.2 KHz signals in regular cycles which drift in and out of phase with respect to Omega.

It should be noted that both Figures 5 and 6 were recorded where the effective bandwidth of the digital filtering was only about 2 Hz or where the 40 Hz IF was sampled by dividing by 5 and then simply averaging only 5 samples of the resulting 8 Hz signal (i.e., $\frac{5}{40/5}$ = 5/8 Hz per time slot, with no additional tracking loop filtering). Thus this data represents very raw single time slot Omega data with a very minimum of processing, much less than used in most other Omega signal processors.

BICENTENNIAL DATA

Another type of diurnal data display is shown in Figure 7. This was made on a Rustrak recorder with a chart speed of about 1/4 inch per hour over the bicentennial weekend of July 4, 1976. The recording illustrates how reproducible the diurnal changes are in that the previous day's scatter of data points can be used to overlap the current days data at the lane crossing points from about 1200 to 2400 hours local time.

PROPAGATION PHENOMENA

Another type of observation possible with simple monitor receivers is the recording of sudden ionospheric disturbances. Figure 8 is an example where the C-D pair would normally be writing a straight line over the period 1700 to 1800 hours local time in late March. However, a significant departure was noted on March 22 which was not observed at the same time of day on March 23 or 24. This effect is typically of duration less than a half hour and with a change of a fifth of a lane or so, or about 20 centicycles. The effect is observed here even in the presence of strong periodic bursts of local ground based 60 Hz harmonic interference.

INTERNAL OR LOCAL CLOCK OFFSETS

The Mini-O receiver system can be used to determine the internal receiver clock offset error or even any external clock which happens to have a binary crystal frequency operating at 2^n Hz. The receiver has been devised to use low-cost quartz oscillators of the type used in digital clocks and watches. A Sinclair "Blackwatch" operating a 2^{15} Hz was modified to provide the oscillator output through a suitable buffer which in turn can directly operate the Omega receiver. Similarly a Westclox "GT-500" replacement clock movement operating at 2^{21} Hz has been used. A comparison of the local clock drift with respect to the Omega signals is illustrated in Figure 9.

The time a single station signal takes to make one lane change (one cycle) with respect to the clock can be a direct measure of the clock offset error during periods when the Omega station phase is not changing very rapidly. We have consistently been able to adjust Sinclair "Blackwatch" type of 2^{15} Hz crystal oscillators to offsets to within 1×10^{-7} for short periods with longer term offsets on a weekly basis of 2×10^{-6} when operated in a room temperature environment. This is more than sufficient to operate a simple type of Omega receiver. These types of observations illustrate the utility of Omega as a precision time-frequency calibration source for the low budget institutional user. All that is needed is the Mini-O system and the right clock frequency of 2^n Hz which is a very common one for present digital watch systems.

MULTIPLEXED LOP DISPLAYS

One method of reducing costs of a system for the marine user might involve the use of a single channel recorder which can record two LOPs by time-sharing or alternate-cycling of the recorded output. An example record is illustrated in Figure 10 where the Mini-O receiver first records for 90 seconds on C-D then switches for 90 seconds on C-G and repeats the sequence indefinitely. The C-G record shows a lane change half-way through, with the C-D LOP drawing a straight line in this example.

NAVIGATION EXPERIMENTS

Several flight tests of the first Mini-O 4-bit system were conducted. An example recording made in November 1975 during a short flight from the Albany, Ohio Airport to the Henderson, West Virginia VOR and return is shown in Figure 11. Here the upper trace is a single station pair B-C (B was Trinidad in those days) which clearly shows one lane change. The 4-bit LOP recording was not blanked and used a simple RC filter which shows the transient behavior of a digital subtraction circuit and D/A in this example. The bottom trace is the signal level from the 4 Hz narrowband front-end. Current navigation experiments are underway using an improved version of the Mini-O with a microcomputer interface.[6]

SUMMARY

Examples of the data output from a single channel Omega receiver operating at 10.2 KHz are presented. The output can be used by the observer for various time-frequency, propagation, and navigation experiments. This Mini-O receiver concept has been devised to help low budget users become familiar with the operational details and peculiarities of Omega receivers. The present configuration of Mini-O is towards an interface for use with microcomputer systems which are becoming increasingly available to almost any potential user of Omega hardware.[7] A more detailed account of the actual circuit details of Mini-O will appear in a future paper now in preparation.

ACKNOWLEDGEMENT

The Mini-O receiver concept has been a peripheral development (spin-off) from results obtained under the Tri-University Program in Air Transportation supported by NASA Langley Research Center, Grant NGR 36-009-017. Additional help on the project has been provided by Mr. Rich Salter, Mr. Lee Wright, and Mr. Dan Moyer. The encouragement and advice of Dr. Richard H. McFarland and Dr. Robert W. Lilley is greatly appreciated on these results.

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[6] R. W. Lilley and R. J. Salter, "A Microcomputer-Based Low-Cost Omega Navigation System", paper presented at International Omega Association Symposium, Washington, D.C., July 1976.

[7] R. W. Lilley and R. J. Salter, "Simulation Analysis of a Microcomputer-Based Low-Cost Omega Navigation System", TM 26 (NASA), Avionics Engineering Center, Ohio University, Athens, Ohio 45701, May 1976; also presented as a paper at the National Aerospace Symposium of the ION, Warminster, Pennsylvania, April 1976.

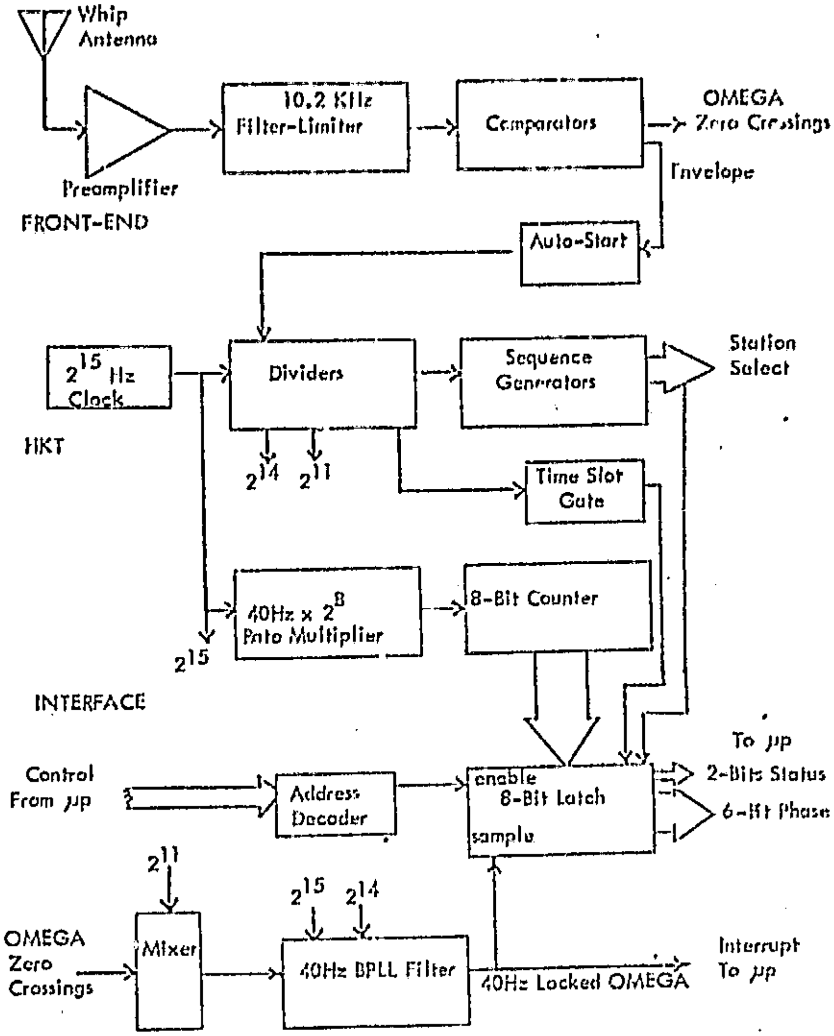


Figure 1. Mini-O System.

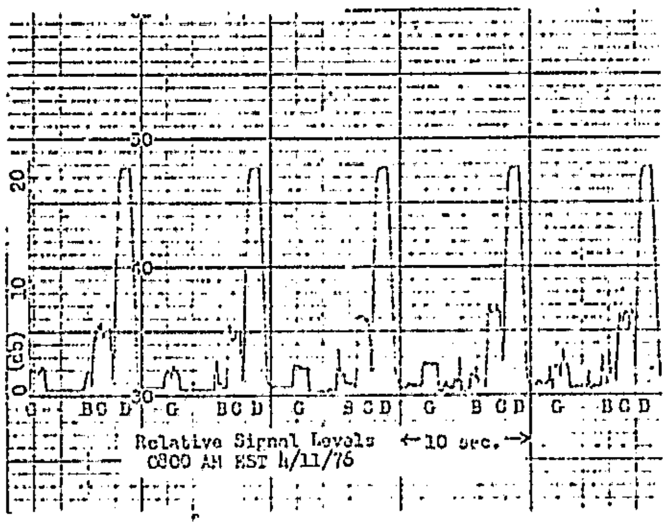


Figure 2. Signal Envelope at 10.200 KHz.

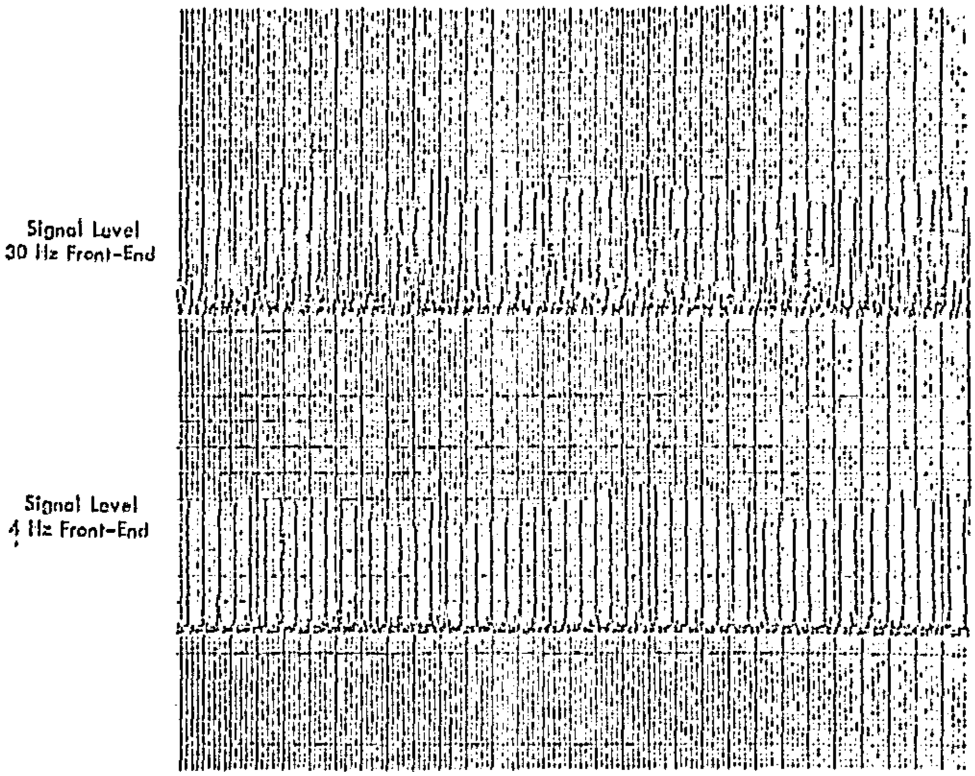


Figure 3. Amplitude Ripple in Signal Levels Caused by Flying Through Cloud.

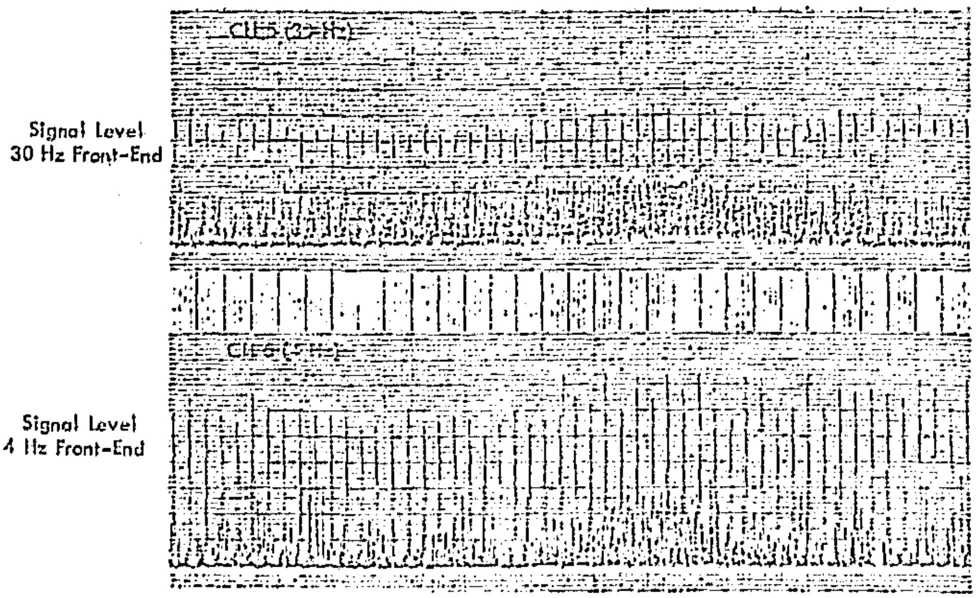


Figure 4. Sunset Disturbance on Signal Amplitude, 10.2 KHz.

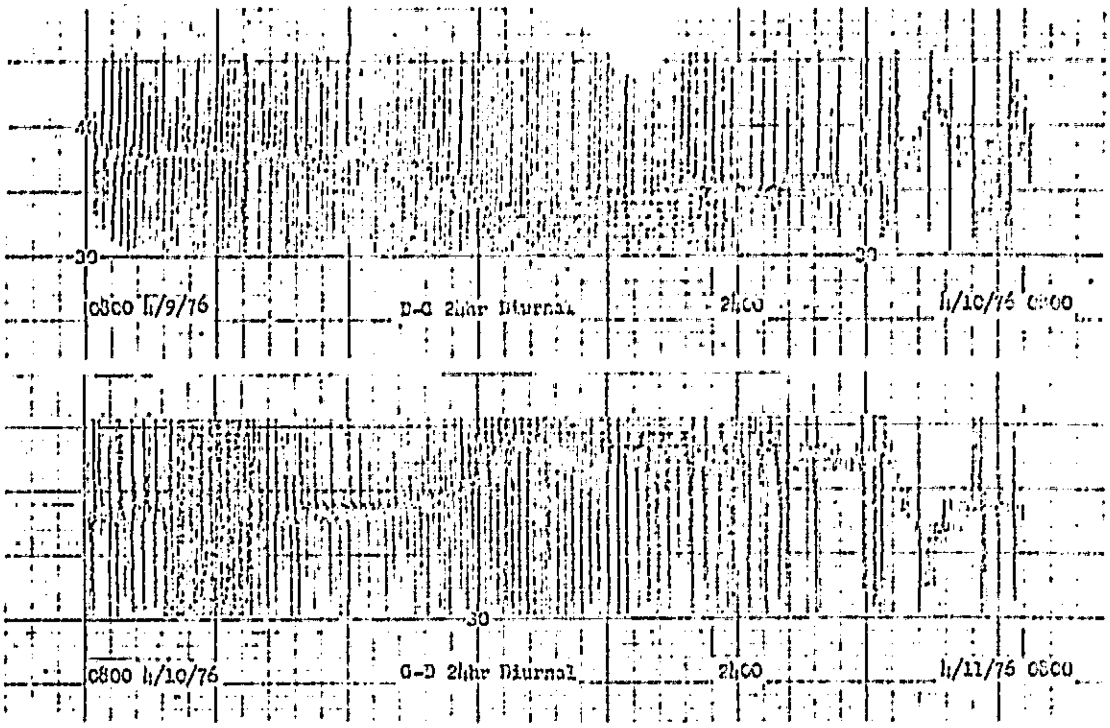


Figure 5. Mirror Image Pair Subtractions. Trinidad was temporarily moved from B to G channel for 1976. The usual subtraction for phase difference would be G-D in using older Omega charts and tables. However, the reverse subtraction D-G gives the same result reversed in phase direction. Note particularly the sunrise transition from 0600 to 0700 hours between Trinidad (G) and North Dakota (D).

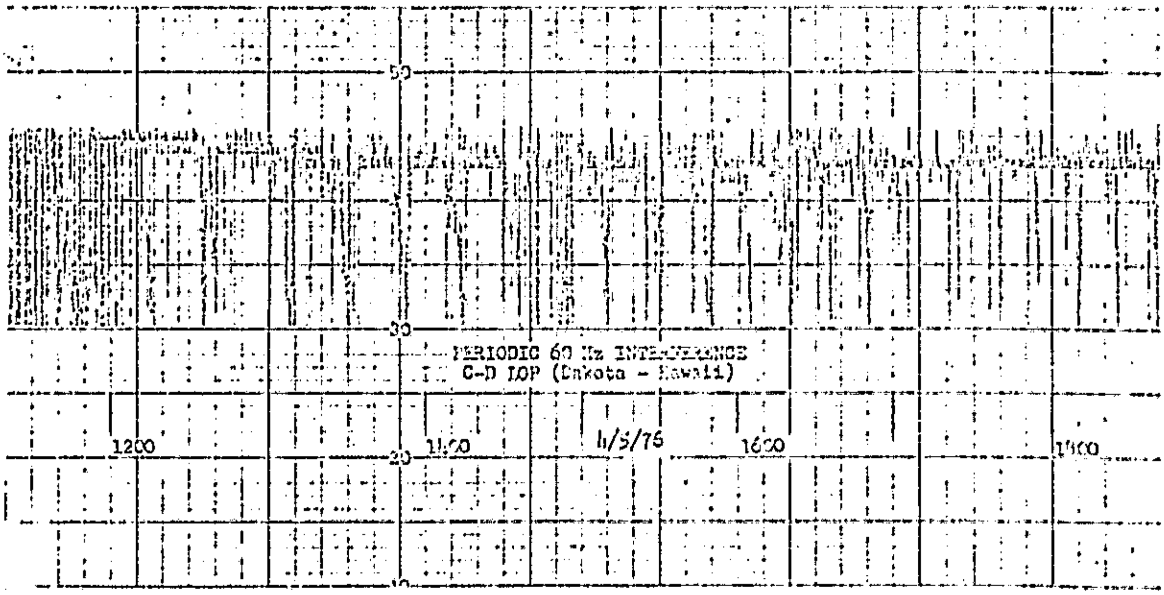


Figure 6. Periodic bursts of 60 Hz harmonics radiating from high power SCR-TRIAC controls on building heating and air conditioning systems often contribute to the noise observed in ground-based OMEGA monitoring systems. The recording from the 4-bit MINI-O system at 10.2 KHz illustrates this effect where the noisy motor controls are operating at 15 to 20 minute intervals.

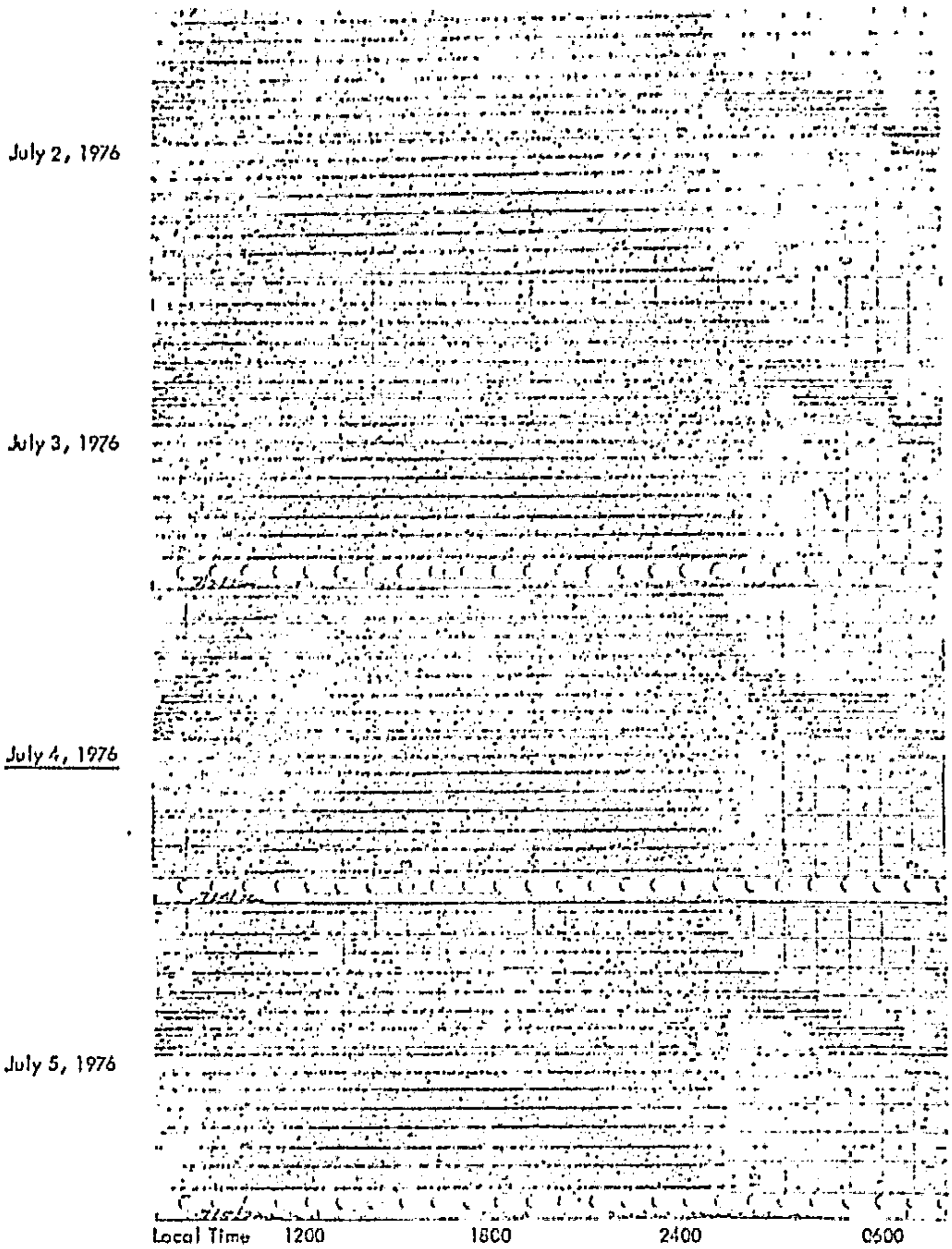


Figure 7. 4-Bit C-D Diurnal Change, 10.2 KHz.

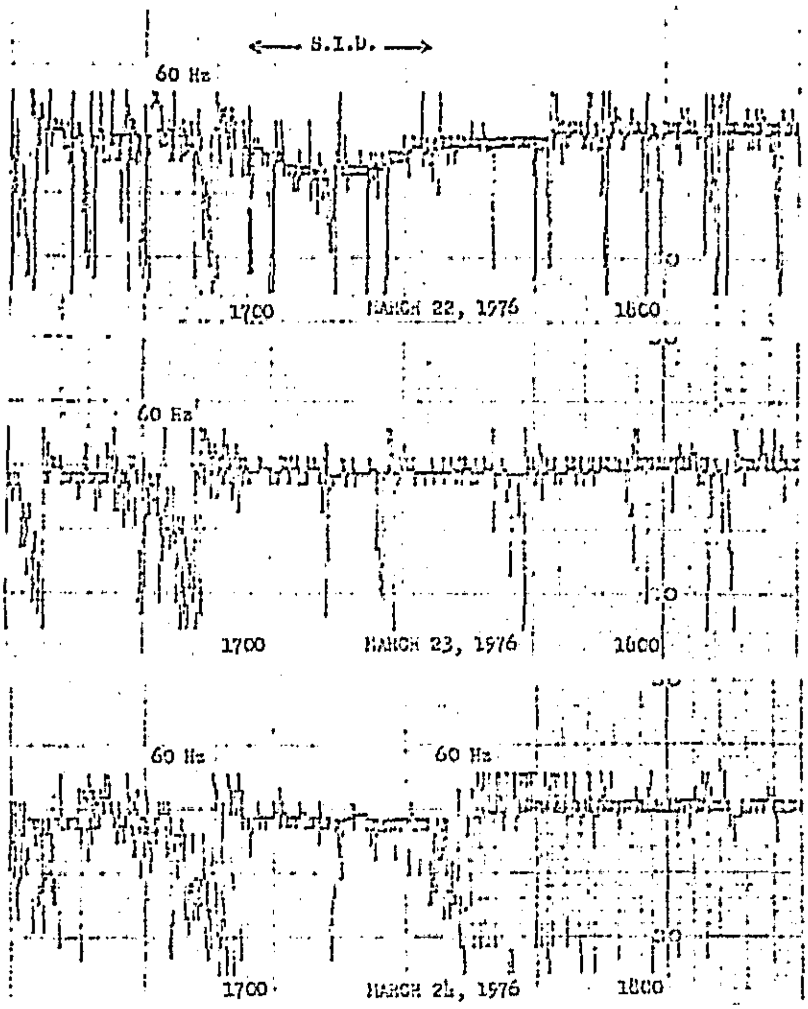


Figure 8. Sudden Ionospheric Disturbance (C-D pair contaminated with 60 Hz). The S.I.D. observed at 1700-1720 hours EST on March 22 was followed on the late evening of March 24 by a strong aurora borealis display. Note that the C-D diurnal trend for March 23 and 24 was not disturbed around 1700 hours except for periodic local 60 Hz noise interference.

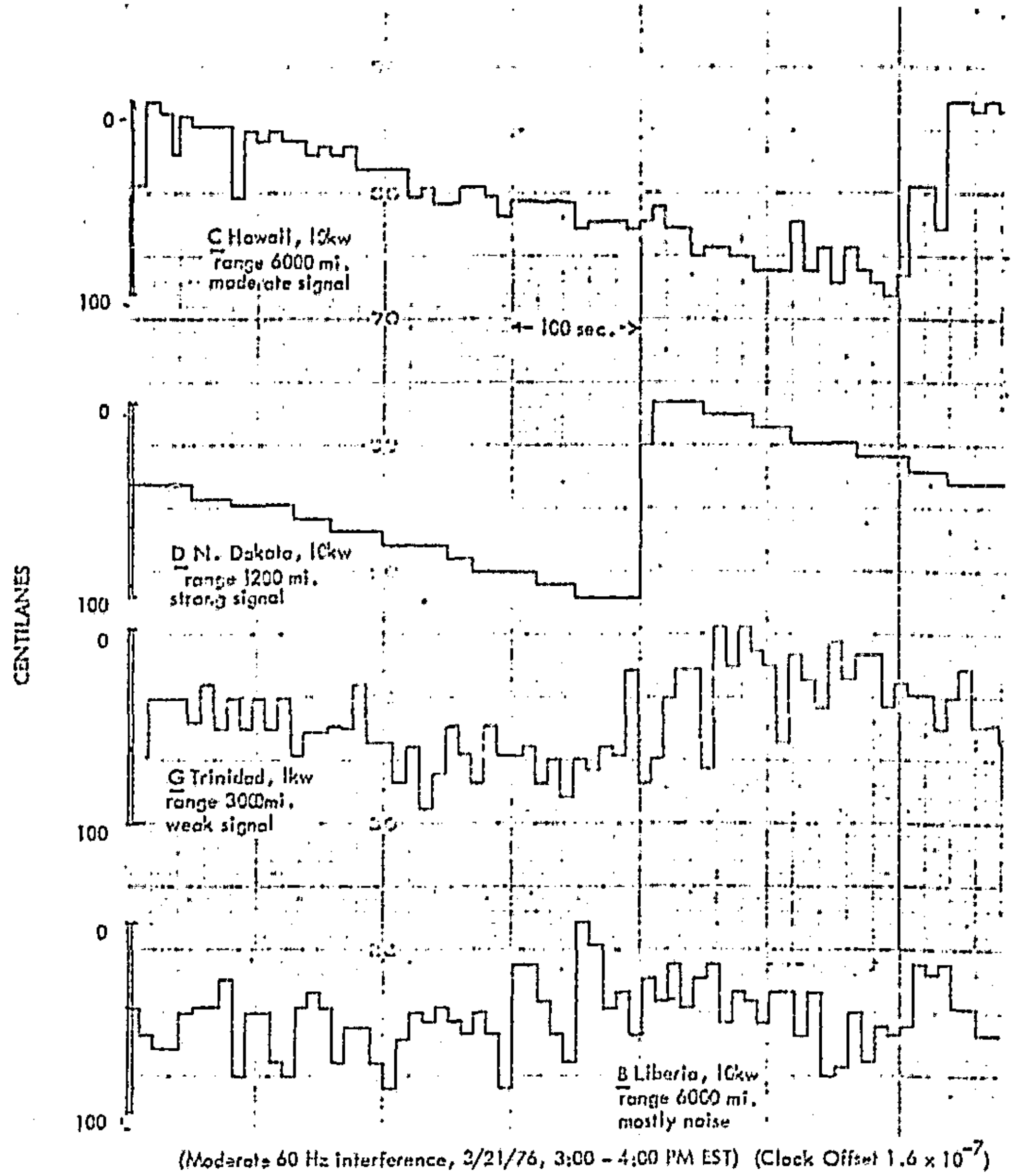
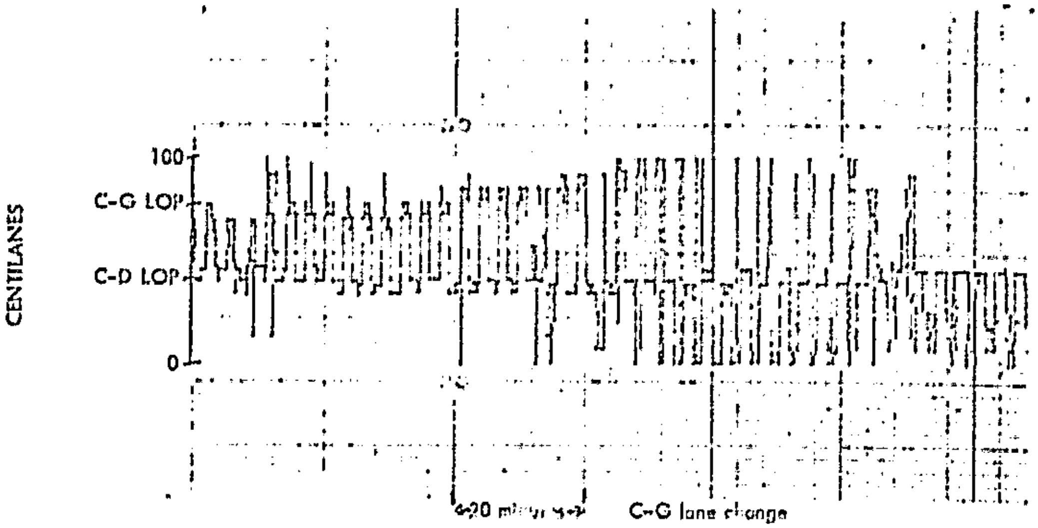


Figure 9. 4-Bit Single Station Tracking Vs. Internal 2^{15} Hz Clock.



(20 min/in. chart speed, 90 sec. MUX time, 5-7 AM EST, 3/20/76)

Figure 10. Multiplexed 4-Bit LOP Recording.

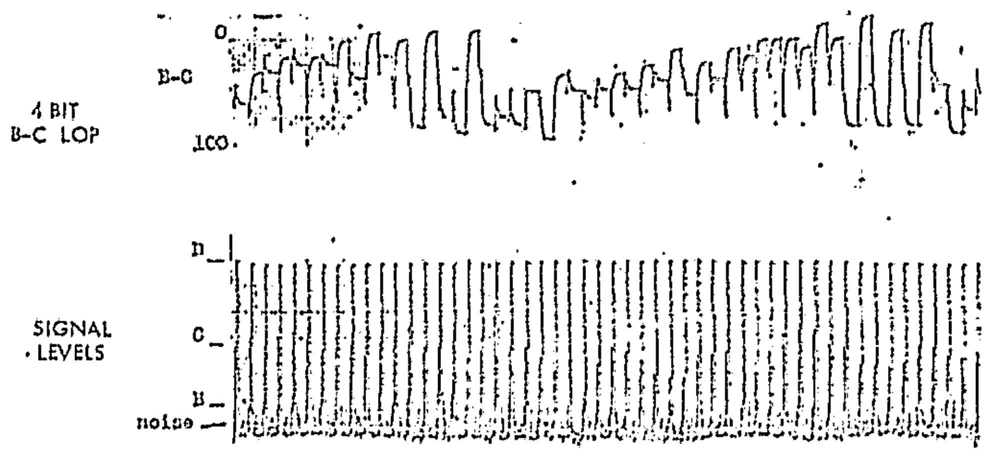


Figure 11. Lane Change and Signal Amplitude with 4-Bit Mini-O During Test Flight.