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ELF FIELD STRENGTH MEASUREMENTS MADE IN CONNECTICUT DURING 1975--ETC(U)
AUG 77 P R BANNISTER, F J WILLIAMS

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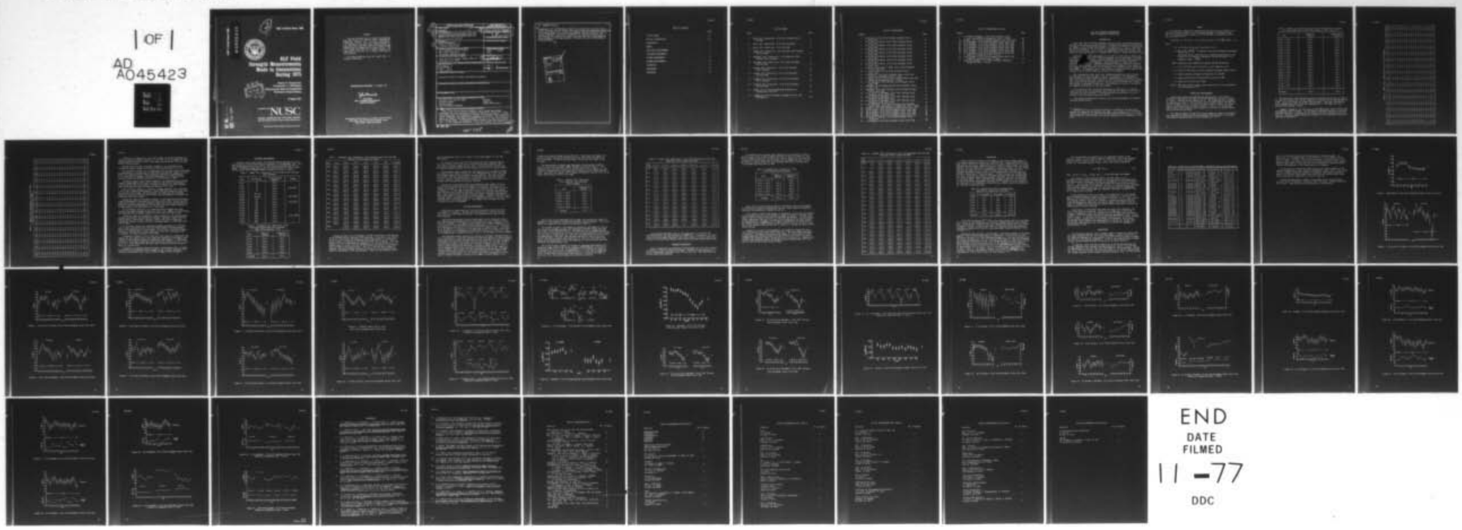

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ELF Field Strength Measurements Made in Connecticut During 1975

Peter R. Bannister
Frederick J. Williams
Submarine Electromagnetic Systems Department

15 August 1977

prepared by: NUSC
NAVAL UNDERWATER SYSTEMS CENTER
Newport, Rhode Island • New London, Connecticut

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PREFACE

The work described in this report was performed under NUSC Project No. A59007, "Project SEAFARER ELF Propagation Studies" (U), Principal Investigator, P. R. Bannister (Code 341); Navy Program Element No. 11401 and Project No.X0792, Naval Electronic Systems Command, Special Communications Project Office, CAPT C. D. Pollak (Code PME-117); Program Manager, ELF Communications Division, Dr. B. Kruger (Code PME-117 -21), Director.

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Both 42 and 76 Hz horizontal magnetic field strength measurements (amplitude and relative phase) were made in Connecticut during 1975. These measurements were for the purpose of further investigating sunrise, daytime, sunset, nighttime, and seasonal ELF propagation variations. The transmission source for these 1.6 Mm range measurements was the U. S. Navy ELF Wisconsin Test Facility (WTF). The principal results obtained from these measurements were: (1) ELF nighttime propagation is much more variable than daytime (over)

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20. ABSTRACT (Cont'd)

propagation, (2) the "Halloween effect" was observed for the sixth year in a row, (3) phase velocity changes during pure nighttime propagation conditions occasionally appear to be greater than changes associated with the sunrise-sunset terminators crossing the transmitter or receiver locations, and (4) there may be as many as 80 nights each year when the average nighttime field strength will be approximately 3 dB lower than that on preceding or following nights.

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ELF FIELD STRENGTH MEASUREMENTS MADE IN CONNECTICUT DURING 1975

INTRODUCTION

Since June 1970, the Naval Underwater Systems Center, New London Laboratory (NUSC/NL), has sporadically made farfield, extremely low frequency (ELF) horizontal magnetic field strength measurements in Connecticut.[1-5] Prior to October 1971, the local measurement site was located in the Nehantic State Forest, East Lyme, Connecticut. Presently, it is located in Hammonassett State Park, Madison, Connecticut. There are no power or telephone lines within a 1 km radius of these sites.

Continuous wave (CW) measurements at 42 and 75 Hz were made in Connecticut at various times during 1975. These measurements are for the purpose of further investigat[illegible]nrise, daytime, sunset, nighttime, and seasonal ELF propagation variation[illegible]ring the measurements, NUSC narrowband ELF field intensity receiver[illegible] utilized.[6] Effective integration times per sample of 30 minutes and 1 hour were employed. Each 30 minute effective integration time sample is an average of three 10 minute, two 15 minute or one 30 minute actual integration time samples. Furthermore, each 1 hour effective integration time sample is an average of two 30 minute effective integration time samples.

The transmission source for these 1.6 Mm measurements was the U.S. Navy ELF Wisconsin Test Facility (WTF). The WTF is located in the Chequamegon National Forest in north-central Wisconsin, approximately 8 km south of Clam Lake. The transmission source consists of two 22.5 km North-South (NS) antennas (one buried and one elevated) and one 22.5 km elevated East-West (EW) antenna. Each antenna is grounded at both ends. The transmission station is located at the midpoint intersection of the two antennas.

The electrical axis* of the WTF EW antenna is 114°E of N at 75 Hz and 118°E of N at 45 Hz; the electrical axis of the WTF NS antenna is 14°E of N at 75 Hz and 11°E of N at 45 Hz.[7-8] The WTF antenna array pattern can also be steered to any particular receiving location.

This report discusses the results of the latest measurements and compares them with previous data.

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*Electrical axis, or electrical location, is defined as the sum of the antenna axis angle and the pattern skew angle. For instance, at 75 Hz the EW antenna axis direction is 109°E of N and the measured pattern skew is 5° clockwise; therefore, the electrical axis of this antenna at this frequency is 114°E of N.

THEORY

For distances sufficiently removed from the region of the antipode, the farfield horizontal magnetic field strength component H_ϕ produced by the WTF array (normalized with respect to the EW antenna at a current of 300 A) may be expressed as[1,9]

$$20 \log H_\phi \sim K + 20 \log E - \alpha\rho - 10 \log a \sin \frac{\rho}{a} + 20 \log \frac{F(\phi)}{B} \text{ dBA/m }, \quad (1)$$

where

K = -143.7 dB at 45 Hz and -139.3 dB at 75 Hz

$E = \left(h_{KM}\sqrt{\sigma_{eEW}}\ \sqrt{c/v}\right)^{-1}$ is defined as the earth-ionosphere waveguide excitation factor; note that E is inversely proportional to the product of the effective ionospheric reflecting height h (in kilometers times $\sqrt{\sigma_{eEW}}$

σ_{eEW} = effective earth conductivity beneath the WTF EW antenna

= 2.8×10^{-4} mho/m at 45 Hz and 3.2×10^{-4} mho/m at 75 Hz

c/v = ratio of free space to earth ionosphere waveguide phase velocity

α = earth-ionosphere waveguide attenuation rate (dB/Mm)

ρ = great-circle distance between WTF and receiver (Mm)

a = radius of the earth ($\sim$6.37 Mm)

$F(\phi)/B$ = WTF array pattern factor, which equals unity in the direction of the EW antenna axis.[7,8]

MARCH-APRIL MEASUREMENTS

Sunset transitional and nighttime CW transmissions at 42 Hz were received in Connecticut from 2000 to 0400 EDT during the period of 13 March to 4 April. The WTF antenna phasing was 0°. The normalized daily averages are presented in table 1, and the actual field strength samples and SNRs are listed in tables 2 and 3. The daily averages listed in table 1 are normalized to the WTF EW antenna at 300 A and 45 Hz. That is, 1.4 dB has been added to the actual measured field strengths (0.8 dB for the pattern factor and 0.6 dB for 20 log 45/42).

The average normalized nighttime field strength was about 0.5 dB higher than measured in January, March, and September 1974 and about 0.5 dB lower than measured during November 1972 and December 1973.[1,2,5]

Table 1. March 1975, Connecticut, 42 Hz Field Strength Daily Averages (All data normalized to the WTF EW antenna at 300 A and 45 Hz)

Date	Sunset H_ϕ (dBA/m)	Nighttime H_ϕ (dBA/m)
3/13 — 3/14	-148.8	-149.8
3/14 — 3/15	-149.8	-150.8
3/15 — 3/16	-149.9	-149.0
3/17 — 3/18	-148.6	-148.6
3/18 — 3/19	-149.2	-149.7
3/19 — 3/20	-149.4	-149.8
3/20 — 3/21	-149.9	-149.4
3/21 — 3/22	-148.4	-148.6
3/22 — 3/23	-149.3	-150.3
3/25 — 3/26	-148.4	-149.3
3/27 — 3/28	-148.1	-150.7
3/28 — 3/29	-152.8	-150.2
3/29 — 3/30	-149.6	-149.2
3/30 — 3/31	-148.9	-149.5
3/31 — 4/1	-147.6	-150.0
4/1 — 4/2	-148.8	-149.2
4/2 — 4/3	-150.8	-149.7
4/3 — 4/4	-149.5	-149.7
Average	-149.2	-149.5

The March-April field strength averages are plotted versus time in figure 1. The effective integration time per sample was 30 minutes and the average SNR was 20 dB. All plotted times are sample starting times. Note that the nighttime field strength from 2100 to 2315 was approximately 1.5 dB higher than that measured from midnight to 0400.

Figures 2 through 10 are daily plots of the March-April sunset transitional and nighttime field strengths. The 80 percent confidence interval for the pure nighttime mean data is presented to the right of the collected data points for each day. Sample-to-sample variability in excess of this confidence interval is regarded as significant.

Table 2. March 1975, Connecticut, 42 Hz Field Strengths

Date	2000	2030	2106	2136	2212	2242	2318	2348	0024	0054	0130	0200	0236	0306	0336
3/13	-150.5	-149.9	-151.2	-152.7	-150.1	-149.4	-151.3	-152.7	-150.4	-150.6	-152.9	-151.5	-150.4	-152.7	-153.2
3/14	-151.6	-150.9	-148.7	-150.6	-150.5	-149.7	-151.3	-151.8	-152.9	-152.7	-152.1	-154.3	-159.1	-157.4	-152.5
3/15	-151.7	-150.9	-149.5	-149.2	-149.7	-149.2	-149.0	-150.9	——	——	-151.6	-151.9	-150.9	-152.8	-150.7
3/17	-149.5	-150.5	-149.6	-149.3	-148.6	-148.4	-149.4	-149.7	-150.0	-150.7	-152.6	-153.1	-150.9	-149.8	-149.6
3/18	-151.3	-149.9	-148.6	-149.5	-150.1	-150.7	-150.2	-151.5	-152.4	-153.5	-151.9	-153.1	-151.5	-151.8	-152.7
3/19	-152.6	-149.3	-150.0	-151.0	-150.6	-151.0	-151.9	-152.4	-152.4	-151.0	-151.0	-152.5	-152.4	-151.5	-150.2
3/20	-152.0	-150.7	-150.4	-149.7	-149.7	-149.8	-150.2	-150.6	-151.2	-150.9	-151.3	-151.7	-151.5	-151.7	-152.4
3/21	-150.0	-149.6	-148.8	-149.2	-150.9	-151 9	-150.9	-149.1	-150.1	-151.2	-149.7	-150.2	-149.6	-149.5	-151.6
3/22	-150.2	-151.3	-151.7	-150.7	-149.2	-151.6	-153.3	-152.9	-151.5	-151.9	-152.2	-151.3	-151.4	-152.3	-151.7
3/25	-150.2	-149.4	-149.3	-150.0	-149.7	-150.7	-151.1	-151.4	-152.3	-151.8	-151.4	-151.9	-151.2	-150.4	-149.5
3/27	-149.2	-149.8	-148.9	-148.5	-149.5	-150.5	-151.3	-151.2	-152.2	-153.1	-153.5	-154.2	-153.9	-155.2	-154.9
3/28	-155.1	-153.4	-153.6	-152.6	-153.1	-150.9	-152.8	-152.1	-150.3	-149.3	-151.4	-150.9	-151.3	-151.8	-152.0
3/29	-152.0	-150.0	-150.1	-150.8	-150.2	-149.7	-150.8	-151.1	-152.0	-150.5	-149.6	-151.7	-151.0	-150.8	-150.8
3/30	-149.9	-150.8	-149.1	-149.1	-148.8	-149.6	-150.4	-151.0	-151.5	-151.4	-151.8	-152.3	-152.0	-152.7	-153.3
3/31	-148.9	-149.1	-149.6	-150.3	-151.1	-152.4	-152.2	-152.5	-151.8	-151.6	-150.3	-150.8	-151.8	-152.3	-152.7
4/1	-150.9	-149.6	-149.5	-150.9	-150.7	-150.3	-150.3	-149.5	-150.3	-150.5	-150.9	-150.4	-151.6	-152.0	-152.1
4/2	-152.7	-151.8	-150.8	-149.1	-150.1	-152.1	-153.2	-152.4	-152.1	-151.2	-152.2	-151.2	-149.6	-151.1	-150.7
4/3	-150.0	-151.8	-152.9	-151.6	-149.5	-148.1	-150.5	-152.7	-152.9	-152.7	-151.8	-152.2	-151.1	-150.6	-149.0
AVG	-150.8	-150.3	-149.9	-150.1	-149.9	-150.1	-150.9	-151.3	-151.4	-151.4	-151.5	-151.7	-151.5	-151.6	-151.5

Table 3. March 1975, Connecticut, 42 Hz Peak SNRs
(Subtract 3 dB to obtain rms SNRs)

Date	2000	2030	2106	2136	2212	2242	2318	2348	0024	0054	0130	0200	0236	0306	0336
3/13	21.7	22.0	20.7	19.2	22.4	23.6	22.5	20.4	22.2	23.1	21.0	22.2	23.7	22.2	21.0
3/14	20.3	21.0	23.5	21.5	21.5	22.0	21.3	20.8	18.8	19.0	19.5	17.5	13.5	15.0	20.0
3/15	22.5	23.5	24.0	24.0	25.0	25.0	25.5	23.0	—	—	21.5	20.5	23.0	22.5	23.0
3/17	24.5	24.0	25.3	24.8	26.0	26.5	25.5	25.5	25.0	24.0	20.3	20.7	23.7	23.5	23.0
3/18	22.5	24.0	26.3	25.5	24.8	24.2	25.0	23.5	23.0	22.2	23.0	23.0	26.0	25.0	23.8
3/19	22.0	26.0	25.0	24.0	24.3	24.0	24.5	22.5	23.6	26.5	27.0	24.5	25.2	26.0	27.5
3/20	20.2	22.0	21.8	22.2	23.0	22.7	21.7	22.1	22.3	23.2	22.5	22.1	22.2	22.0	21.5
3/21	24.0	25.3	25.0	25.3	24.0	22.2	22.2	24.0	23.7	22.5	23.5	23.0	23.2	23.7	23.5
3/22	23.5	23.5	23.5	24.5	26.0	24.0	22.0	22.8	24.2	23.8	24.3	24.2	24.0	22.5	23.2
3/25	24.5	23.5	24.0	22.8	23.5	22.0	22.5	23.0	23.1	24.1	24.3	24.2	24.3	24.3	25.5
3/27	20.0	20.2	19.8	20.1	20.5	19.7	19.0	18.5	18.7	18.2	18.0	18.5	17.9	18.1	17.9
3/28	14.0	15.5	16.0	17.0	15.8	18.8	17.8	19.5	22.5	23.5	22.5	23.2	21.5	22.5	22.3
3/29	22.5	25.5	25.5	25.8	26.0	27.0	26.5	26.5	25.5	26.0	28.0	26.5	26.0	26.5	27.0
3/30	26.2	25.0	27.0	26.2	26.5	24.5	24.0	24.3	24.1	24.0	23.2	23.1	22.9	21.8	22.2
3/31	24.5	25.8	26.0	25.0	24.5	23.5	23.0	23.0	24.8	25.0	26.3	25.8	24.5	23.0	22.5
4/1	24.0	26.0	26.5	25.5	26.5	26.5	26.5	26.0	27.0	25.5	25.5	25.8	25.0	24.2	24.5
4/2	20.8	22.0	23.0	24.4	24.0	21.7	21.7	22.5	24.1	25.0	24.0	24.9	27.0	25.5	25.9
4/3	19.7	17.9	17.7	19.0	21.1	24.1	22.1	17.8	16.5	16.5	18.8	17.0	19.5	17.7	20.7
AVG	22.1	22.9	23.4	23.2	23.6	23.4	23.0	22.5	22.9	23.1	23.0	22.6	23.0	22.6	23.1

On March 13-14 (figure 2), the field strength oscillated throughout the night with peak-to-trough variations of 2 to 3 dB. On 14-15 March, the field strength peaked from 2100 to 2300, then rapidly decreased (by 9 dB!) by 0230 before increasing again.

During both 15-16 and 17-18 March (figure 3), the nighttime field strength was again variable with peak-to-trough variations of 3 to 4 dB.

On 18-19 March (figure 4), the nighttime field strength steadily decreased by approximately 4 dB from 2100 to 0030 before leveling off, whereas on 19-20 March, the nighttime field strength gradually decreased by approximately 2.5 dB from 2100 to midnight, increased approximately 1.5 dB around 0100, decreased again and steadily increased by 2 dB from 0200 to 0400.

During the night of 20-21 March (figure 5), the nighttime field strength peaked at approximately 2200 and then gradually decreased by approximately 3 dB during the rest of the night. During 21-22 March, the field strength again oscillated with peak-to-trough variations of 2 to 3 dB.

On 22-23 March (figure 6), the field strength peaked at 2212, decreased 4 dB by 2318, increased approximately 2 dB by 0030 and remained at that level for the rest of the night. On 25-26 March, the nighttime field strength gradually decreased 3 dB from 2100 to 0030, and then gradually increased 3 dB during the rest of the night.

During the night of 27-28 March (figure 7), the nighttime field strength steadily decreased by approximately 6 dB from 2130 to 0400. During the next night (28-29 March), the field strength started out at the same low level and gradually increased approximately 5 dB by 0045, and then steadily decreased by approximately 2 dB during the rest of the night.

On 29-30 March (figure 8), the nighttime field strengths were less variable with peak-to-trough variations of only 2 dB. However, on 30-31 March, the nighttime field strength steadily declined 4 dB from 2200 to 0400.

During the night of 31 March and 1 April (figure 9), the field strength steadily declined 3.5 dB from 2000 to midnight, increased 2 dB by 0130 and then decreased 2 dB by 0400. During 1-2 April, the field strength was essentially constant from 2130 to 0200, and approximately 1.5 dB lower from 0230 to 0400.

On 2-3 April (figure 10), the field strength increased by 3.5 dB from 2000 to 2130, decreased 4 dB by 2318 and then steadily increased approximately 3 dB during the rest of the night. On 3-4 April, the field strength decreased 3 dB from 2000 to 2100, increased 5 dB by 2230, decreased 5 dB by midnight, and then increased 4 dB by 0400.

Presented in figures 11 and 12 are the 1 hour effective integration time samples for this period (each 1 hour effective integration time sample is an average of two 30 minute effective integration time samples). As mentioned previously, the largest nighttime signal variations occurred on 3-14 — 3-15 and 3-27 — 3-28, whereas the smallest signal variation occurred during the night of 3-29 and 3-30.

Altogether, we measured during 18 nights in March-April 1975. It should be noted that the nighttime field strength was <u>not</u> constant throughout the nighttime measurement period (2100 to 0400) on <u>any</u> of these 18 nights.

SEPTEMBER MEASUREMENTS

Daytime, sunset transitional, and nighttime CW transmissions at 76 Hz were received in Connecticut during the period of 15-26 September 1975. The WTF antenna phasing was either 60° or 300° during the daytime and 300° at night. The daily averages (not normalized) are presented in tables 4 and 5, and the actual field strength samples and SNRs are listed in table 6.

Table 4. Summer 1975, Connecticut, 76 Hz Daytime Field Strength Daily Averages

Date	WTF Phasing	Field Strength (dBA/m)	Average
6/5	0^o	-144,1	
6/6	0^o	-143.9	
7/17	0^o	-143.9	$-144.0(0^o)$
7/19	0^o	-144.1	
8/26	EW only	-144.3	
8/28	EW only	-144.1	-144.2 (EW)
9/15	60^o	-143.9	
9/16	60^o	-144.0	$-144.2(60^o)$
9/17	60^o	-144.8	
9/18	60^o	-144.3	
9/15	300^o	-142.7	
9/16	300^o	-141.9	
9/17	300^o	-143.5	$-142.5(300^o)$
9/18	300^o	-142.3	
9/19	300^o	-142.4	

Table 5. September 1975, Connecticut, 76 Hz Nighttime Field Strength Daily Averages (WTF antenna phasing = 300^o)

Date	Sunset H_ϕ (dBA/m)	Nighttime H_ϕ (dBA/m)
9/21	-144.2	-144.9
9/22	-143.7	-145.6
9/23	-143.3	-145.5
9/24	-143.5	-146.9
9/25	-143.5	-145.8
9/26	-143.4	-145.8
Average	-143.6	-145.7

Table 6. September 1975, Connecticut, 76 Hz Field Strengths and Peak SNRs (Subtract 3 dB to obtain rms SNRs)

Time	9/21	9/22	9/23	9/24	9/25	9/26	Average
1900	-144.1 (24.6)	-144.1 (26.0)	-143.1 (26.3)	-142.9 (26.8)	-143.3 (26.9)	-143.2 (26.9)	-143.4 (26.2)
1933	-144.1 (25.1)	-143.4 (27.1)	-143.9 (25.8)	-143.9 (26.2)	-143.5 (25.9)	-143.6 (26.8)	-143.7 (26.1)
2006	-144.2 (25.6)	-144.2 (26.1)	-143.2 (26.8)	-142.9 (27.4)	-143.9 (26.6	-143.8 (26.8)	-143.7 (26.5)
2039	-144.6 (24.8)	-143.2 (27.5)	-142.9 (27.0)	-144.4 (26.4)	-143.4 (27.4)	-143.2 (27.5)	-143.6 (26.7)
2112	-143.6 (26.6)	-144.1 (26.7)	-143.9 (26.7)	-144.9 (25.6)	-144.1 (26.5)	-143.3 (27.5)	-143.9 (26.6)
2145	-143.5 (26.5)	-144.6 (26.4)	-144.1 (26.3)	-145.3 (25.3)	-144.3 (26.2)	-144.3 (26.2)	-144.3 (26.1)
2218	-143.9 (26.3)	-144.1 (27.6)	-144.7 (26.0)	-146.6 (24.4)	-145.2 (25.3)	-142.5 (27.0)	-144.5 (26.1)
2251	-144.4 (24.8)	-144.0 (27.5)	-144.4 (25.9)	-146.1 (24.7)	-146.2 (24.5)	-143.8 (25.5)	-144.9 (25.5)
2324	-145.0 (24.2)	-145.2 (26.3)	-145.7 (24.8)	-147.0 (23.3)	-146.8 (23.6)	-146.0 (22.5)	-145.8 (24.1)
2357	-145.3 (24.2)	-145.7 (25.8)	-146.8 (24.0)	-147.6 (22.8)	-147.1 (23.5)	-146.5 (22.0)	-146.5 (23.7)
0030	-146.3 (23.1)	-146.8 (24.4)	-146.9 (23.8)	-149.1 (20.7)	-147.8 (22.6)	-147.7 (20.8)	-147.2 (22.6)
0103	-147.1 (21.8)	-147.6 (23.3)	-147.0 (22.8)	-149.5 (20.5)	-146.8 (23.2)	-149.0 (19.5)	-147.6 (21.9)
0136	-146.7 (23.5)	-147.5 (23.3)	-145.8 (24.4)	-147.3 (22.5)	-145.6 (24.6)	-149.5 (19.0)	-146.8 (22.9)
0209		-146.8 (24.2)	-146.4 (23.6)	-146.5 (23.7)	-144.8 (25.4)	-147.3 (21.0)	-146.3 (23.6)

During the week of 15-19 September, the WTF transmitted at 300° phasing in the mornings and 60° phasing in the afternoons. From table 4 and figures 13 and 14, we see that 300° phasing produces approximately 1.6 dB greater field strength in Connecticut than does either 60° or 0° phasing. Since the Connecticut site is approximately broadside to the WTF NS antenna (i.e., the azimuth angle is 89.5°), only the WTF EW antenna contributes to the magnetic field strength in the $\overline{H}_\phi$ direction. That is, if the WTF dipole moment is constant, the field strength received in Connecticut (in the H_ϕ direction) should be independent of WTF phasing angle. Thus, the 300° phasing results can be interpreted only as an increase in the dipole moment of the WTF EW antenna.

It should be noted that other WTF phasing and dipole moment anomalies have been observed by us and also by the Naval Research Laboratory (NRL, J. R. Davis, personal communication, 1975). We have recently resolved the WTF phasing anomaly problem, and will present the results in a future report.

The September sunset transitional and nighttime field strength averages are plotted versus time in figure 15. The average SNR was 22 dB. Note that the average nighttime field strength was not constant. The field strength from 2100 to 2315 was approximately 2.5 dB higher than that from midnight to 0230. However, during the sunset transitional period (1900 to 2100), the average field strength was essentially constant.

Daily plots of 30 minute effective integration time samples of sunset transitional and nighttime field strengths for September are presented in figures 16 through 18. The 1 hour effective integration time plots are given in figure 19. To the right of each day's data is a bracketed line segment that indicates the 80 percent confidence interval for the pure nighttime mean data. The nighttime field strength was not constant throughout the measurement period (2100 to 0230) on any of these 6 nights. The daily nighttime field strength steadily decreased from 2100 to approximately 0130 by 3 to 6 dB, before leveling off or increasing slightly. The largest field strength decreases occurred on 24 and 26 September.

OCTOBER MEASUREMENTS

Nighttime CW transmissions at 76 Hz were received in Connecticut from 27 October to 1 November. The WTF antenna phasing was 0° and the measurements took place from 1900 to 0230 EST. Both amplitude and relative phase were measured.

The October measurement period is highlighted by the "Halloween effect." This effect has been observed for the past 6 years in a row, between 27 October and 1 November. It is marked by an average drop in field strength of 2 to 6 dB, relative to the preceding and following nights.[1-5,10,11] The effect has been observed in both the 40 to 50 and 70 to 80 Hz frequency bands. It appears to be due mainly to a decrease in the nighttime excitation factor, rather than to an increase in the nighttime attenuation rate (since, at a range of 1.6 Mm, a 0.4 dB/Mm change in attenuation rate is only a 0.6 dB change in field strength).

The "Halloween effect" may well be related to the famous "November effect." Early observations of VLF waves transmitted from North America to England showed marked decreases in signal strength near the end of October and early November.[12] Furthermore, VLF and LF radio waves received over paths of less than 1.2 Mm in western Europe showed large departures in signal strengths, near the end of October (both increases and decreases), from their summer values.[13] This so-called "November effect" has since been identified as part of the summer-to-winter change in the D-region and has been observed as an increase in signal strength of VLF and LF waves over short (<600 km) paths.[14-16] Thomas[17] has recently used recordings of VLF, LF, and MF radio waves propagated over short paths to examine the times of onset of the summer-to-winter change in the

D-region over central Europe during 1970-1972. These times are found to be delayed by about a month on the reversal in the mean zonal circulation in the stratosphere, the delay becoming longer, the greater the height in the D-region.

The October daily averages (not normalized) are presented in table 7, and the actual field strength samples and SNRs are given in table 8. The nighttime field strength averages are plotted versus time in figure 20. The effective integration time per sample was 30 minutes and the average SNR was 20 dB. Note that the average field strength from 1900 to 2130 was only 0.5 dB higher than during the rest of the night.

Table 7. October 1975, Connecticut,
76 Hz Nighttime Field Strength
Daily Averages

Date	Nighttime H_ϕ (dBA/m)
10/27 — 10/28	-151.5
10/28 — 10/29	-146.0
10/29 — 10/30	-144.7
10/30 — 10/31	-147.9
10/31 — 11/01	-147.4
11/01 — 11/02	-146.3
Average	-147.1

Daily plots of the nighttime field strength are presented in figures 21 through 26. The effective integration time was, again, 30 minutes. The 1 hour effective integration time plots are presented in figure 27.

If we refer to table 7 and figures 21 through 24, and figure 27, we see that the field strength averages were remarkably different during the first four nights of the Halloween period. The nighttime field strength measured on 10-27 and 10-28 (which was the lowest 76 Hz average nighttime field strength ever measured in Connecticut) was 7 dB lower than measured on 10-29 and 10-30, and approximately 6 dB lower than measured from 1900 to 2300 on 10-28 and 10-29. The field strengths were relatively constant (±1.0 dB) during each nighttime measurement period with the exception of 10-28 and 10-29, when the variation was approximately 5 dB.

The relative phase (figures 21 through 27) decreased approximately 30° during the night of 10-27 and 10-28, remained fairly constant on 10-28 and 10-29 and on 10-29 and 10-30, and increased 10° to 20° during the nights of 10-30 and 10-31, 10-31 and 11-1, and 11-1 and 11-2. Note that although the field strength amplitude decreased approximately 5 dB during the night of 10-28 and 10-29, the relative phase was essentially constant.

Table 8. October 1975, Connecticut, 76 Hz Field Strengths and Peak SNRs (Subtract 3 dB to obtain rms SNRs)

Time (EST)	10/27-28	10/28-29	10/29-30	10/30-31	10/31-11/1	11/1-11/2	Average
1900	-149.7 (18.8)	-144.8 (24.9)	-144.9 (24.8)	-147.2 (24.5)	-147.7 (23.2)	-146.7 (24.8)	-146.6 (23.5)
1933	-150.8 (17.5)	-144.6 (25.5)	-145.4 (24.7)	-148.3 (23.6)	-148.5 (22.0)	-145.8 (24.9)	-147.0 (23.0)
2006	-151.2 (17.3)	-144.6 (26.1)	-144.3 (25.6)	-149.0 (22.5)	-147.4 (23.3)	-146.6 (24.1)	-147.0 (23.2)
2039	-151.6 (15.2)	-144.5 (26.2)	-145.2 (24.9)	-147.8 (24.4)	-146.4 (24.3)	-146.0 (24.5)	-146.7 (23.3)
2112	-150.4 (16.4)	-144.7 (25.6)	-144.7 (25.2)	-148.1 (24.1)	-146.8 (23.7)	-146.9 (23.4)	-146.7 (23.1)
2145	-152.2 (14.3)	-144.8 (25.9)	-143.6 (26.7)	-149.3 (22.4)	-148.3 (22.0)	-146.9 (23.4)	-147.3 (22.5)
2218	-151.6 (15.2)	-145.1 (25.6)	-144.5 (26.4)	-149.1 (23.4)	-147.8 (22.5)	-147.0 (23.6)	-147.3 (22.8)
2251	-152.8 (14.0)	-145.4 (25.3)	-144.8 (26.1)	-148.4 (23.5)	-147.5 (23.0)	-146.2 (24.5)	-147.3 (22.7)
2324	-151.7 (15.1)	-145.8 (24.3)	-145.0 (26.3)	-147.5 (24.9)	-147.5 (22.8)	-146.5 (23.8)	-147.1 (22.9)
2357	-154.3 (12.9)	-147.2 (23.3)	-145.1 (26.2)	-146.9 (24.8)	-147.3 (23.4)	-146.7 (23.8)	-147.5 (22.4)
0030	-150.6 (16.6)	-148.6 (21.3)	-144.7 (26.3)	-147.0 (25.4)	-146.9 (23.2)	-146.2 (24.1)	-147.1 (22.8)
0100	-151.7 (15.5)	-147.6 (21.7)	-144.4 (25.7)	-147.5 (24.9)	-147.5 (22.6)	-145.6 (23.8)	-147.2 (22.4)
0130	-152.1 (15.1)	-149.2 (20.5)	-144.5 (25.5)	-147.8 (24.6)	-146.6 (23.0)	-145.4 (24.5)	-147.4 (22.2)
0200	-151.9 (15.7)	-149.3 (20.8)	-144.6 (25.6)	——	-147.7 (22.3)	-146.3 (24.8)	-147.6 (21.8)

As previously mentioned, this is the sixth year in a row that the "Halloween effect" has been observed in Connecticut. Furthermore, the variations in field strength (during the first four nights) were the largest ever recorded (in Connecticut) during a four-consecutive-night measurement period.

NOVEMBER MEASUREMENTS

Sunset transitional and nighttime CW measurements at 76 Hz were received in Connecticut from 18 through 25 November. The WTF antenna phasing was 0° and the measurements took place from 1700 and 0500 EST. Both amplitude and relative phase were measured.

The November daily averages (not normalized) are presented in table 9, and the actual field strength samples and SNRs are given in table 10. The field strength averages are plotted versus time in figure 28. The effective integration time per sample was 30 minutes and the average SNR was 19.5 dB. Note that the average nighttime field strength from 1830 to 2130 was only 0.5 dB higher than from 2130 to 0500.

Table 9. November 1975, Connecticut, 76 Hz
Field Strength Daily Averages

Date	Sunset H_ϕ (dBA/m)	Nighttime H_ϕ (dBA/m)
11/18 — 11/19	——	-146.9
11/19 — 11/20	-144.4	-144.5
11/20 — 11/21	-145.6	-147.7
11/21 — 11/22	-145.5	-146.8
11/24 — 11/25	-145.4	-146.3
11/25 — 11/26	-147.1	-147.1
Average	-145.6	-146.5

Daily plots of the 30 minute effective integration time field strength are presented in figures 29 through 34, and the 1 hour effective integration time plots are presented in figures 35 and 36.

If we refer to table 9 and figures 29 through 36, we see that the November field strength fluctuations (from night to night and within each night) were nowhere near as severe as they were in September and October. The main exceptional (amplitude) night was 11-19 and 11-20, during which the field strength was approximately 3 dB higher than during the preceding or following nights. The maximum relative phase variation (~25°) occurred on 11-20 and 11-21, with most of the change occurring from 1700 to 1900 (i.e., during the sunset transitional period).

Figure 37 is a plot of the November 1 hour effective integration time field strengths measured from 1900 to 0230 (i.e., the same times as measured in October). By comparing these data with figure 27, we see that the field strength amplitude variation from 10-29 and 10-30 to 10-31 and 11-1 closely resembled the variation from 11-19 and 11-20 to 11-21 and 11-22. However, the relative phase measured during the November period exhibited much less variability than did the October relative phase.

Table 10. November 1975, Connecticut, 76 Hz Field Strengths and Peak SNRs (Subtract 3 dB to obtain rms SNRS)

Time (EST)	11/18-19	11/19-20	11/20-21	11/21-22	11/24-25	11/25-26	Average
1700	—	-143.5	-145.3	-145.1	-144.3	-146.9	-145.0
	—	(25.9)	(23.7)	(23.4)	(24.1)	(23.7)	(24.2)
1733	—	-144.9	-145.7	-145.2	-145.7	-147.2	-145.7
	—	(23.4)	(23.0)	(23.1)	(21.8)	(22.6)	(22.8)
1806	-146.6	-144.8	-145.9	-146.2	-146.4	-147.3	-146.2
	(22.4)	(23.6)	(22.8)	(21.3)	(22.0)	(21.9)	(22.3)
1839	-146.8	-143.8	-145.9	-147.3	-146.9	-146.4	-146.1
	(21.6)	(24.7)	(22.7)	(18.2)	(20.9)	(22.5)	(21.8)
1912	-146.7	-144.2	-146.3	-147.3	-145.1	-147.6	-146.2
	(22.0)	(24.3)	(22.4)	(20.3)	(23.3)	(21.1)	(22.2)
1945	-146.3	-144.7	-147.6	-147.1	-145.8	-147.2	-146.4
	(22.4)	(24.2)	(21.3)	(21.2)	(21.8)	(22.0)	(22.2)
2018	-146.0	-144.6	-147.7	-146.7	-145.2	-147.4	-146.2
	(22.7)	(24.4)	(21.0)	(22.3)	(23.0)	(21.8)	(22.5)
2051	-146.0	-144.2	-148.1	-145.8	-146.5	-147.7	-146.3
	(22.7)	(25.0	(20.9)	(23.8)	(21.8)	(21.7)	(22.7)
2124	-146.4	-144.1	-147.0	-146.4	-146.6	-148.1	-146.4
	(22.8)	(25.7)	(22.2)	(23.0)	(22.4)	(20.6)	(22.8)
2157	-147.6	-144.1	-147.8	-146.5	-146.1	-147.7	-146.6
	(21.5)	(25.6)	(21.4)	(22.4)	(21.6)	(20.6)	(22.2)
2230	-147.3	-144.3	-147.6	-146.5	-146.3	-147.7	-146.6
	(21.4)	(24.9)	(21.5)	(22.6)	(22.2)	(22.1)	(22.5)
2303	-147.1	-144.6	-148.3	-147.3	-146.5	-146.6	-146.7
	(21.6)	(24.8)	(20.7)	(20.8)	(22.2)	(22.8)	(22.2)
2336	-147.6	-145.0	-147.9	-146.4	-146.8	-145.9	-146.6
	(21.1)	(25.5)	(21.3)	(22.1)	(21.3)	(23.3)	(22.4)
0009	-147.6	-144.1	-149.0	-146.7	-146.8	-146.3	-146.6
	(21.6)	(25.4)	(20.2)	(22.1)	(21.0)	(23.3)	(22.3)
0042	-147.6	-144.6	-148.0	-147.0	-146.2	-146.9	-146.7
	(21.1)	(24.6)	(21.1)	(21.3)	(21.9)	(22.9)	(22.2)
0115	-147.9	-144.4	-147.9	-146.5	-146.3	-147.5	-146.7
	(21.3)	(25.0)	(21.3)	(22.2)	(21.8)	(22.6)	(22.4)
0148	-147.2	-145.0	-147.2	-147.2	-146.6	—	-146.6
	(22.2)	(24.6)	(22.0)	(21.6)	(21.7)	—	(22.4)
0221	-146.3	-144.8	-147.7	-146.8	-146.2	—	-146.3
	(23.1)	(24.8)	(21.5)	(21.7)	(21.9)	—	(22.6)
0254	-146.7	-144.5	-148.6	-148.0	-145.5	—	-146.6
	(22.5)	(24.9)	(20.6)	(20.4)	(22.2)	—	(22.1)
0327	-146.4	-145.5	-149.1	-147.3	-145.9	—	-146.7
	(22.5)	(24.1)	(19.9)	(20.8)	(22.6)	—	(22.0)
0400	-147.2	-145.4	-148.0	-146.6	-147.4	—	-146.9
	(22.2)	(24.4)	(20.9)	(22.2)	(21.6)	—	(22.3)
0433	-147.5	-145.0	-147.4	-147.0	-148.3	—	-147.0
	(22.7)	(25.0)	(21.6)	(22.0)	(20.7)	—	(22.4)

DISCUSSION

Table 11 shows the ratios of the number of low field strength nights to total nights measured in Connecticut from 1970-1975. During the 1975 measurement period, there were 9 nights out of the 36 nights measured when the average nighttime field strength (measured during at least a 4 hour period) was approximately 3 dB lower than that on preceding or following nights. In total, there have been 39 nights of the 176 measured when the average nighttime field strength (measured during at least a 4 hour period) was 2 to 6 dB lower than during the preceding or following nights. If these results are extrapolated to a year, there may be as many as 80 nights each year when the average nighttime field strength would be approximately 3 dB lower than that on preceding or following nights. This nighttime field strength reduction, also observed at other midlatitude measurement locations,[18-20] appears to be due primarily to a decrease in the nighttime excitation factor rather than to an increase in the nighttime attenuation rate.

Table 11. Number of Low-Field-Strength Nights Measured in Connecticut, 1970-1975

Year	45 Hz Band	75 Hz Band	Overall
1970	4/17	1/2	5/19
1971	2/12	0/13	2/25
1972	0/5	1/5	1/10
1973	2/8	7/41	9/49
1974	9/27	4/10	13/37
1975	4/18	5/18	9/36
Totals	21/87	18/89	39/176

It has been hypothesized[20-23] that these lower midlatitude field strengths are a result of the charged particles that are dumped from the outer radiation belt, following their insertion into the trapping zone during the early stages of magnetic storms. In many cases, there is a definite correlation between ionospheric irregularities and the lower-than-normal measured nighttime field strengths.[19-22]

During the last few years, we have made a considerable number of horizontal magnetic field strength measurements in Connecticut. One fact that we have definitely noticed is that ELF nighttime propagation is much more variable than ELF daytime propagation – both in variations from night to night and throughout each nighttime measurement period. The average normalized (with respect to the WTF EW antenna at 300 A and either 45 or 75 Hz) daytime horizontal magnetic field strengths (measured during at least a 4 hour measurement period) varied by approximately 2 dB at 75 Hz (-145 to -143 dBA/m) and by approximately 2.5 dB at 45 Hz (-148.5 to -146 dBA/m). However, the normalized nighttime field strengths varied by approximately 8 dB at 45 Hz (-154 to -146 dBA/m) and by approximately 7 dB at 75 Hz (-151.5 to -144.5 dBA/m).[1,2,5]

The received phase was measured (at the quadrature outputs of the receiver) relative to the stable reference, which had a short term frequency stability greater than one part in 10^9. For a day (D) to night (N) path change, the corresponding phase change shift at the receiver would be

$$\Delta\Phi = \frac{2\pi\rho}{\lambda}\,\Delta(c/v) \quad , \tag{2}$$

where $\Delta(c/v) = (c/v)_D - (c/v)_N$ and λ is the free-space wavelength.

The accuracy of most phase estimates is of the order of ± 5° . Therefore, we can discern the magnitude of the phase shifts associated with the sunrise-sunset terminators crossing the transmitter or receiver locations $[\Delta(c/v)]$. We can also discern the phase shifts that occur when the path is either in total daylight or in darkness $[\delta(c/v)]$. Previous results indicated that the phase changed slowly when the path was under daytime propagation conditions, and most rapidly when the terminator intercepts the path[10,24,25] (i.e., $\Delta(c/v) \sim 0.1$ to 0.16).

At the Connecticut site ($\rho \sim 1.6$ Mm), a 15° phase shift at 76 Hz during pure nighttime propagation conditions would correspond to a $\delta(c/v)$ of 0.1, whereas a 30° phase shift would correspond to a $\delta(c/v)$ of 0.2. Thus, we see that changes in phase velocity for the WTF — Connecticut path during pure nighttime propagation conditions occasionally appear to be greater than or equal to changes associated with the sunrise-sunset terminators crossing the transmitter or receiver locations.

Intuitively, we would think that when the signal level decreases, the noise level would also decrease. Table 12 is a comparison of the field strength, atmospheric noise, and SNR behavior for 33 nights when the field strength varied considerably during the nighttime measurement period, or from night to night. As can easily be observed, large decreases in signal strength are not usually accompanied by large changes in atmospheric noise levels. The average signal decrease was approximately 4.5 dB and the average noise decrease was approximately 0 dB, resulting in an average SNR decrease of approximately 4.5 dB.

CONCLUSIONS

The horizontal magnetic field strengths taken in Connecticut during 1975 have again demonstrated that the short-term sample-to-sample variability of ELF nighttime propagation is much greater than the short-term sample-to-sample variability of ELF daytime propagation. In fact, the nighttime field strength was not constant during at least 27 out of the 35 nights measured.

In addition, there have been 9 nights out of the 36 measured when the average nighttime field strength (measured during at least a 4 hour period) was approximately 3 dB lower than on a preceding or a following night. During the entire 1970-1975 period, there were 39 nights out of the 176 measured when the average nighttime field strength (measured during at least a 4 hour period)

Table 12. Comparison of Field Strength, Atmospheric Noise, and SNR Behavior

Date	Frequency	Local Time	Signal Behavior	Noise Behavior	SNR Behavior
4/19/73	76 Hz	1800-2400	Decreased ∿ 7 dB	Decreased ∿ 4 dB	Decreased ∿ 3 dB
5/14/73	76	2000-2300	Decreased ∿ 6 dB	Decreased ∿ 2 dB	Decreased ∿ 4 dB
5/17-5/18/73	76	2200-0100	Decreased ∿ 4 dB	Increased ∿ 1 dB	Decreased ∿ 5 dB
9/27/73	76	1900-2130	Decreased ∿ 4 dB	Decreased ∿ 1 dB	Decreased ∿ 3 dB
10/30-10/31/73	76	1900-0300	Level ∿ 3 dB below monthly mean	Level ∿ equal to monthly mean	Level ∿ 3 dB below monthly mean
11/21-11/22/73	76	2200-0100	Decreased ∿ 4 dB	Decreased ∿ 1 dB	Decreased ∿ 3 dB
11/24-11/25/73	76	2000-0300	Level ∿ 3 dB below monthly mean	Level ∿ 1 dB above monthly mean	Level ∿ 4 dB below monthly mean
1/25-1/26/74	42	1800-0200	Decreased ∿ 8 dB	∿ Constant	Decreased ∿ 8 dB
3/19-3/20/74	42	1800-0100	Decreased ∿ 6 dB	∿ Constant	Decreased ∿ 6 dB
9/11-9/12/74	76	2200-0200	Decreased ∿ 4 dB	Decreased ∿ 1 dB	Decreased ∿ 3 dB
9/19-9/20/74	42	2100-0400	Decreased ∿ 5 dB	∿ Constant	Decreased ∿ 5 dB
9/21-9/22/74	42	2100-0400	Level ∿ 2.5 dB below monthly mean	Level ∿ equal to monthly mean	Level ∿ 2.5 dB below monthly mean
9/26-9/27/74	42	2000-0100	Decreased ∿ 5 dB	∿ Constant	Decreased ∿ 5 dB
9/28-9/29/74	42	2100-0400	Level ∿ 2 dB below monthly mean	Level ∿ 2 dB above monthly mean	Level ∿ 4 dB below monthly mean
10/30/74	76	2100-2300	Decreased ∿ 4 dB	∿ Constant	Decreased ∿ 4 dB
3/14-3/15/75	42	2100-0300	Decreased ∿ 9 dB	∿ Constant	Decreased ∿ 9 dB
3/15-3/16/75	42	2100-0300	Decreased ∿ 3 dB	Increased ∿ 1 dB	Decreased ∿ 4 dB
3/17-3/18/75	42	2200-0200	Decreased ∿ 4 dB	∿ Constant	Decreased ∿ 4 dB
3/18-3/19/75	42	2100-0100	Decreased ∿ 4 dB	∿ Constant	Decreased ∿ 4 dB
3/20-3/21/75	42	2200-0400	Decreased ∿ 3 dB	Decreased ∿ 1 dB	Decreased ∿ 2 dB
3/27-3/28/75	42	2100-0400	Decreased ∿ 6 dB	Decreased ∿ 3 dB	Decreased ∿ 3 dB
3/30-3/31/75	42	2200-0400	Decreased ∿ 4 dB	∿ Constant	Decreased ∿ 4 dB
3/31-4/1/75	42	2000-0000	Decreased ∿ 3.5 dB	Decreased ∿ 1 dB	Decreased ∿ 2.5 dB
4/3-4/4-75	42	2200-0100	Decreased ∿ 4 dB	Increased ∿ 2 dB	Decreased ∿ 6 dB
9/21-9/22/75	76	2100-0100	Decreased ∿ 3 dB	Increased ∿ 1 dB	Decreased ∿ 4 dB
9/22-9/23/75	76	2100-0100	Decreased ∿ 3 dB	∿ Constant	Decreased ∿ 3 dB
9/23-9/24/75	76	2100-0100	Decreased ∿ 3 dB	∿ Constant	Decreased ∿ 3 dB
9/24-9/25/75	76	2100-0100	Decreased ∿ 4 dB	Increased ∿ 1 dB	Decreased ∿ 5 dB
9/25-9/26/75	76	2100-0100	Decreased ∿ 3 dB	∿ Constant	Decreased ∿ 3 dB
9/26-9/27/75	76	2100-0100	Decreased ∿ 6 dB	Increased ∿ 2 dB	Decreased ∿ 8 dB
10/27-10/28/75	76	1900-0230	Level ∿ 4.5 dB below monthly mean	Level ∿ 3 dB above monthly mean	Level ∿ 7.5 dB below monthly mean
10/28-10/28/75	76	2000-0230	Decreased ∿ 5 dB	∿ Constant	Decreased ∿ 5 dB
10/29-10/30/75	76	1900-0230	Level ∿ 2.5 dB above monthly mean	Level ∿ equal to monthly mean	Level ∿ 2.5 dB above monthly mean
11/19-11/20/75	76	1700-0400	Level ∿ 2.5 dB above monthly mean	Level ∿ equal to monthly mean	Level ∿ 2.5 dB above monthly mean
			Average Decrease ∿ 4.5 dB	Average Decrease ∿ 0 dB	Average Decrease ∿ 4.5 dB

was 2 to 6 dB lower than during the preceding or following nights. In particular, this phenomenon has occurred between 27 and 31 October for the past six years. If these results are extrapolated to an entire year, there may be as many as 80 nights a year when the average nighttime field strengths would be approximately 3 dB lower than on the preceding or following nights. Further investigations of this phenomenon are in progress.

It has also been shown that large decreases in signal strength are not usually accompanied by large changes in atmospheric noise levels. Also, phase velocity changes during pure nighttime propagation conditions occasionally appear to be greater than changes associated with the sunrise-sunset terminators crossing the transmitter or receiver locations.

During the March-April, October, and November tests, NRL maintained receiver sites at Stump Neck, Maryland, Thule, Greenland, Tromsø, Norway, and Pisa, Italy. These results will be presented in an NRL report.

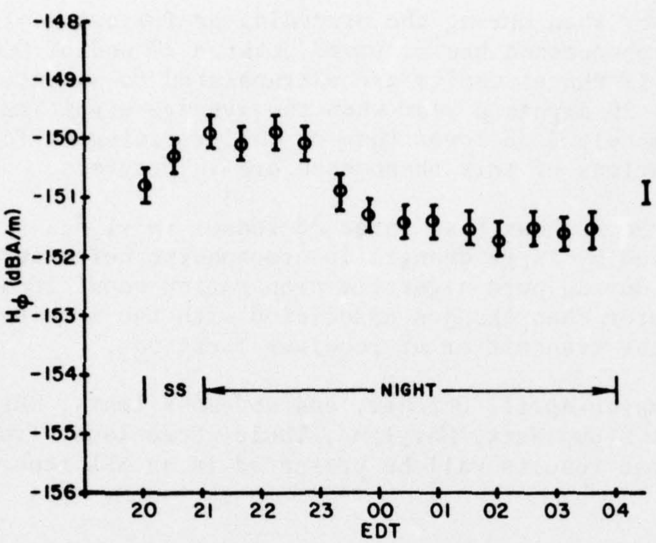

Figure 1. March-April, 42 Hz Field Strength Averages Versus Local Time

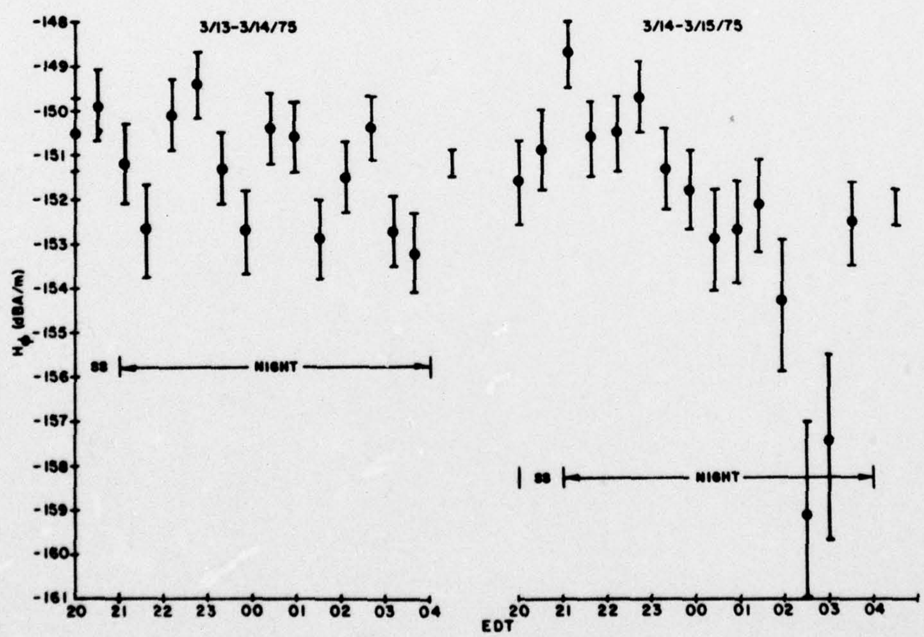

Figure 2. 13-14 and 14-15 March, 42 Hz Field Strengths Versus Local Time

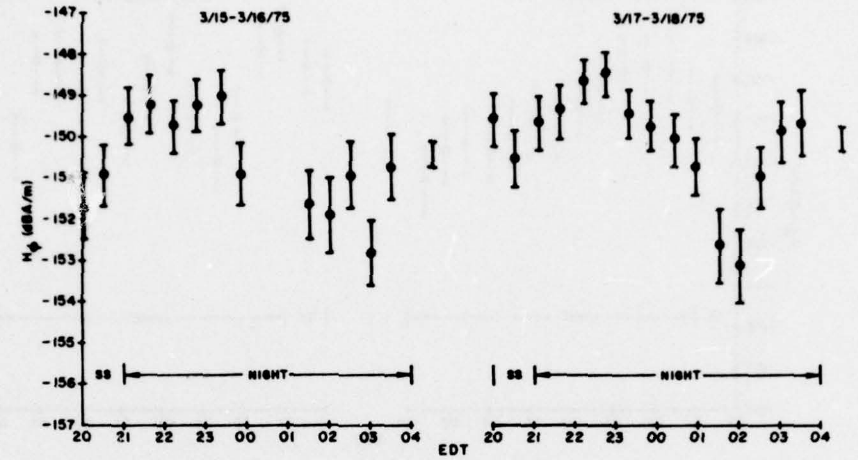

Figure 3. 15-16 and 17-18 March, 42 Hz Field Strengths Versus Local Time

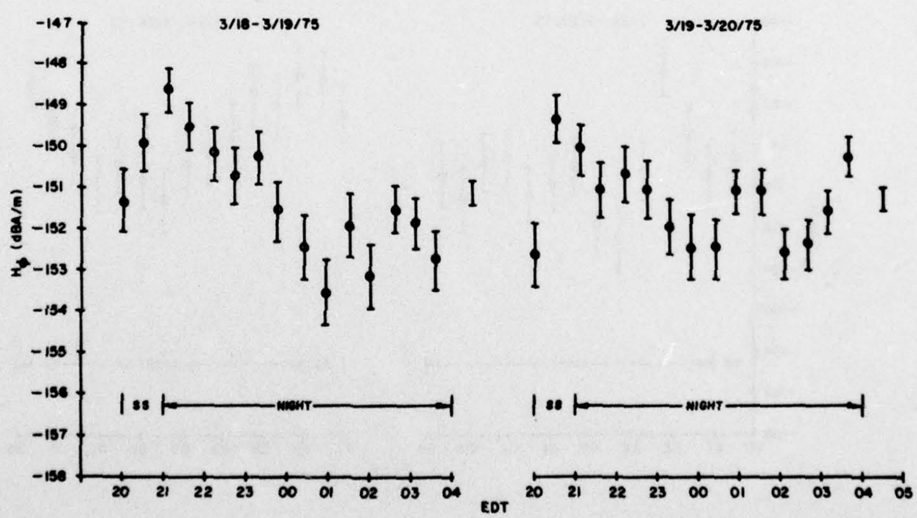

Figure 4. 18-19 and 19-20 March, 42 Hz Field Strengths Versus Local Time

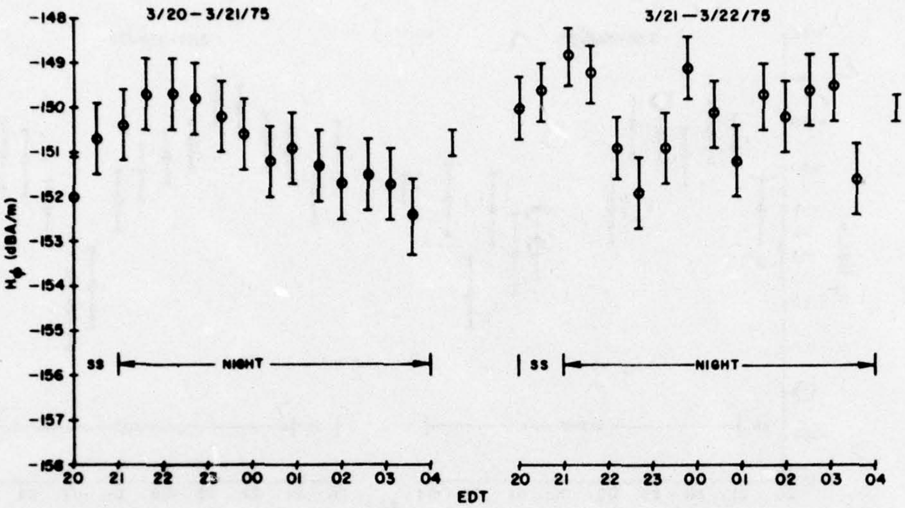

Figure 5. 20-21 and 21-22 March, 42 Hz Field Strengths Versus Local Time

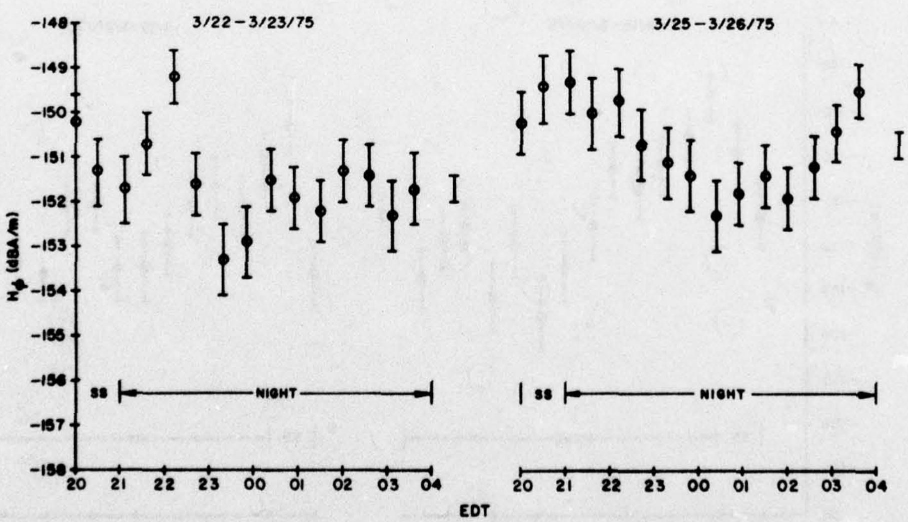

Figure 6. 22-23 and 25-26 March, 42 Hz Field Strengths Versus Local Time

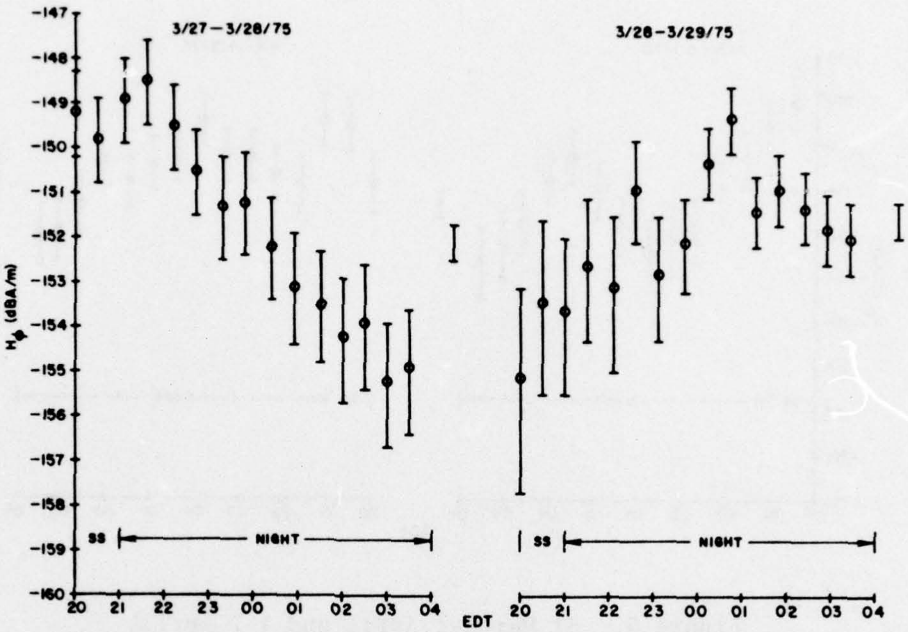

Figure 7. 27-28 and 28-29 March, 42 Hz Field Strengths Versus Local Time

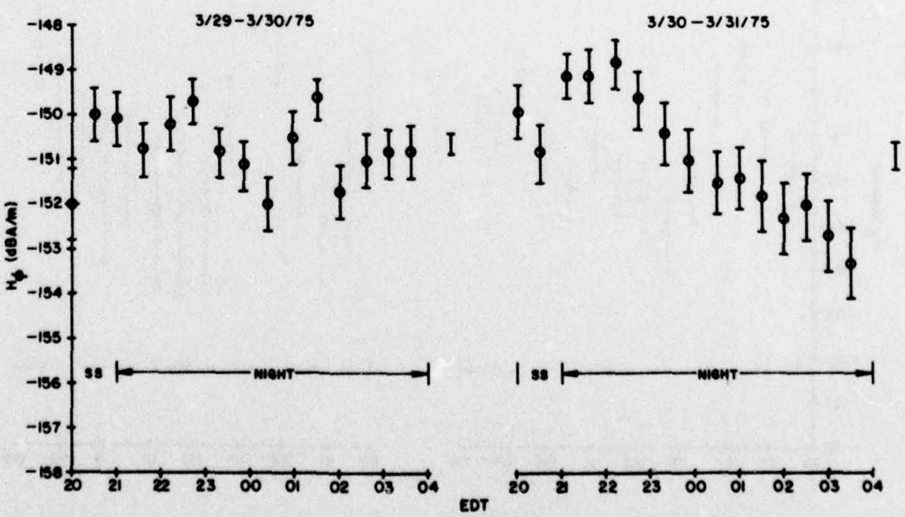

Figure 8. 29-30 and 30-31 March, 42 Hz Field Strengths Versus Local Time

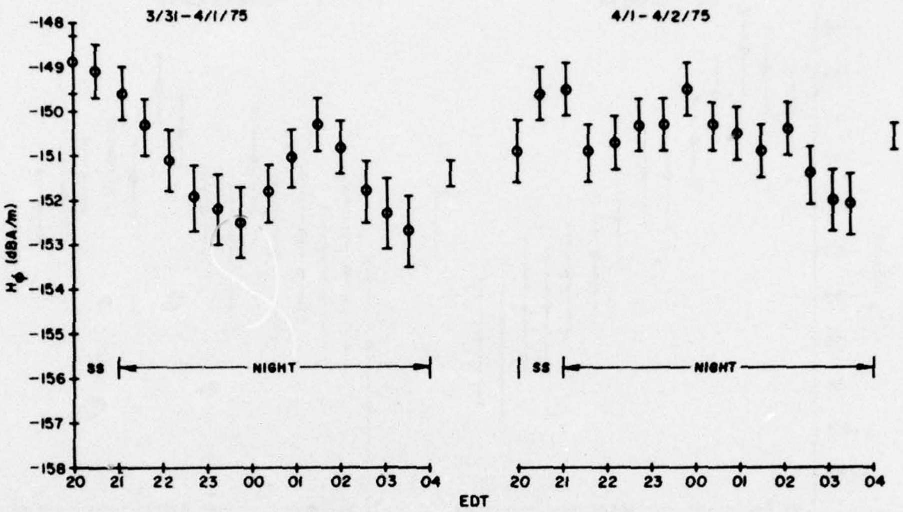

Figure 9. 31 March-1 April and 1-2 April,
42 Hz Field Strengths Versus Local Time

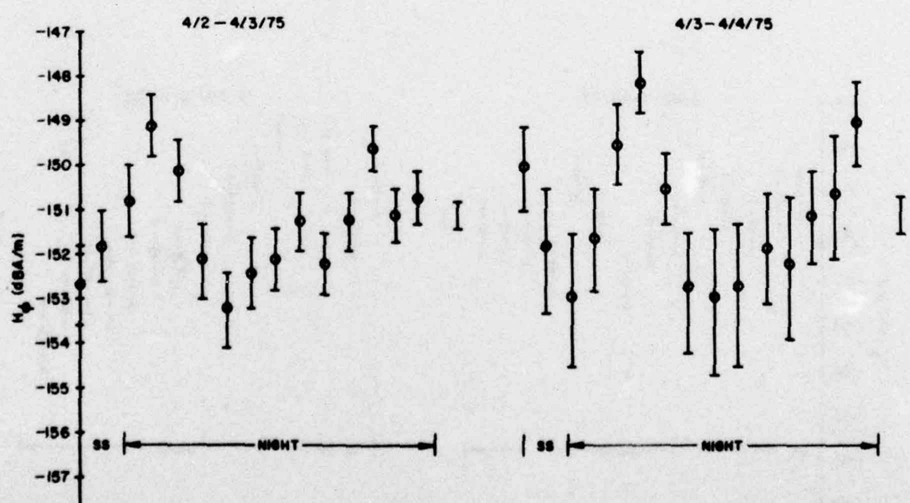

Figure 10. 2-3 and 3-4 April, 42 Hz Field Strengths Versus Local Time

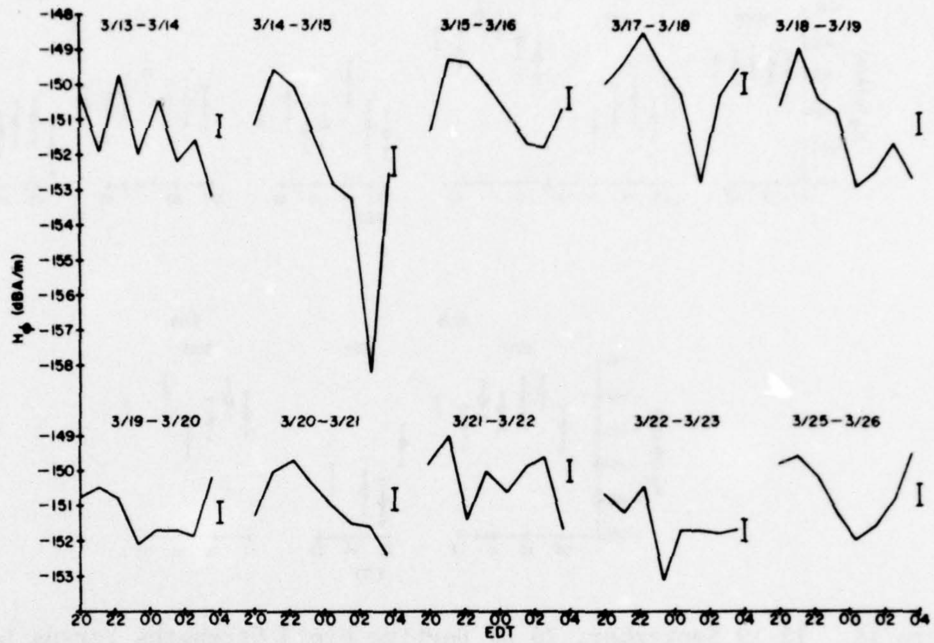

Figure 11. 13-26 March, 42 Hz Field Strengths Versus Local Time (Effective Integration Time = 1 hour)

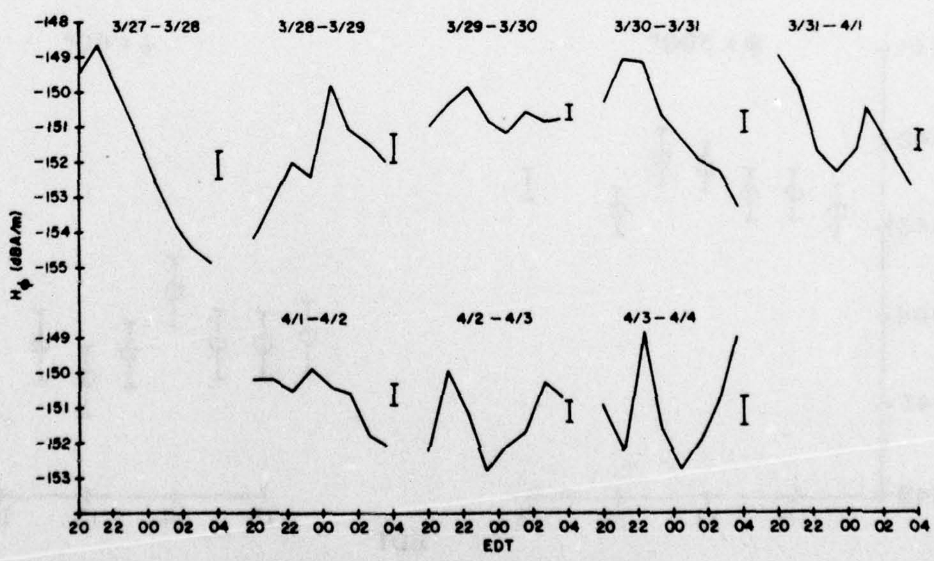

Figure 12. 27 March-4 April, 42 Hz Field Strengths Versus Local Time (Effective Integration Time = 1 hour)

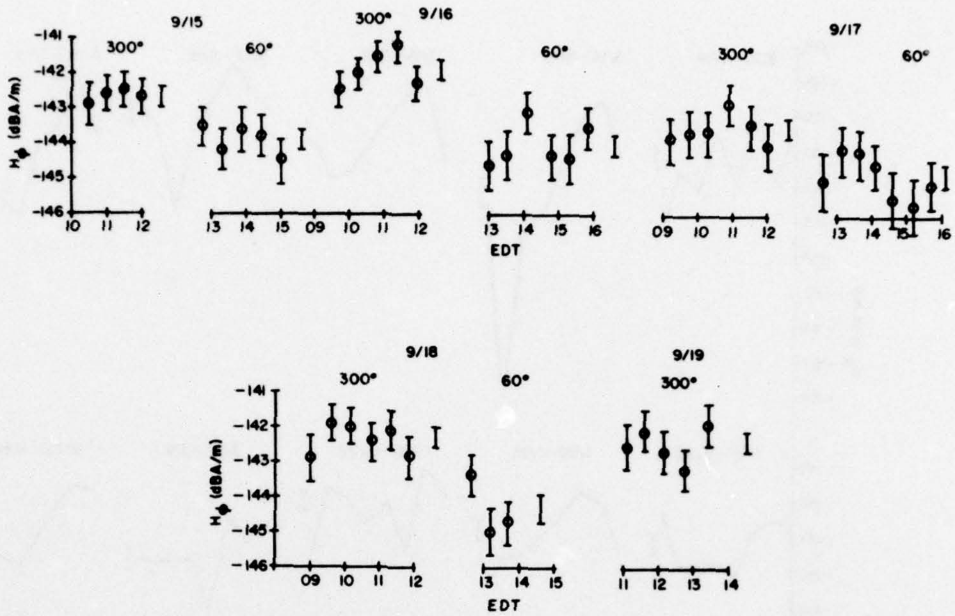

Figure 13. 15-19 September, 76 Hz Daytime Field Strengths Versus Local Time

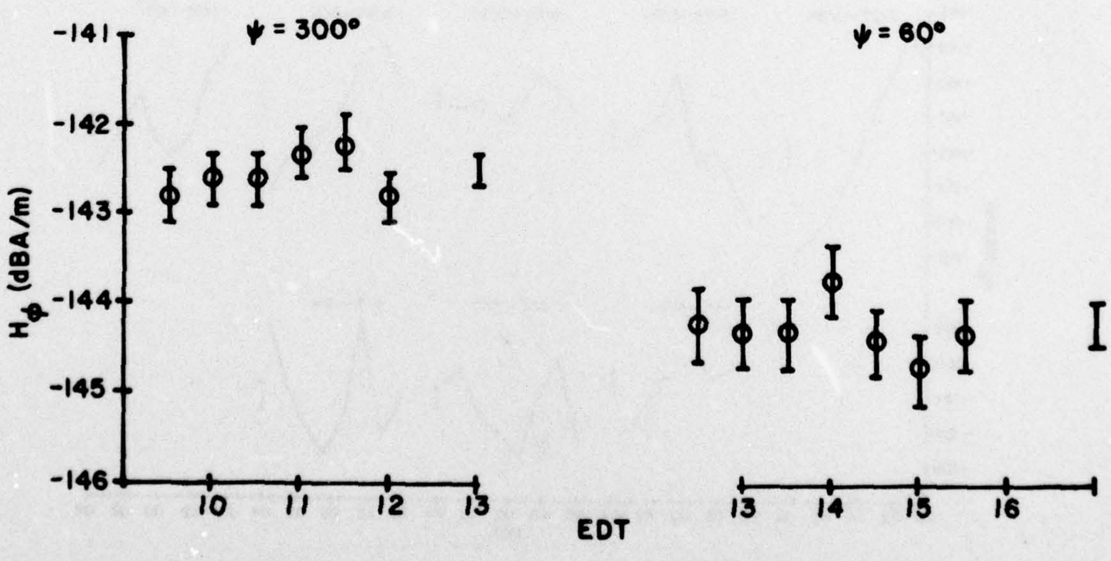

Figure 14. September, 76 Hz Average Daytime Field Strengths Versus Local Time

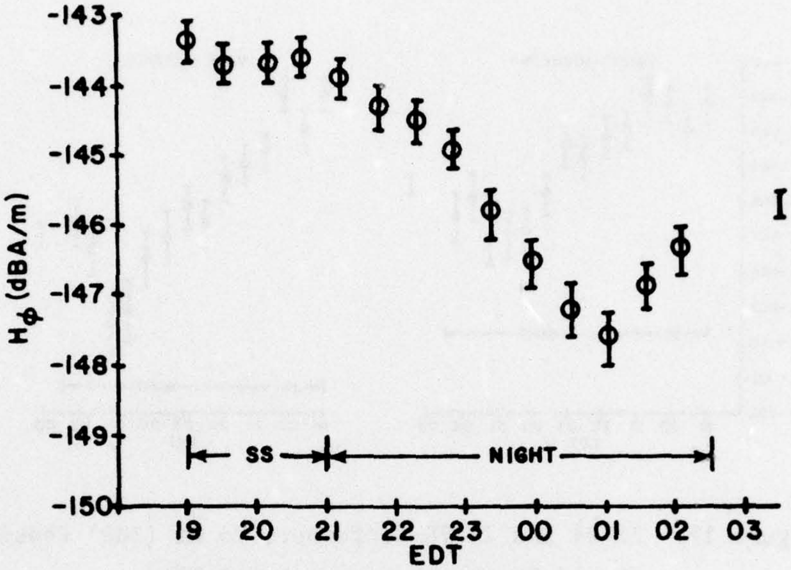

Figure 15. September, 76 Hz (300° Phasing)
Field Strength Averages Versus Local Time

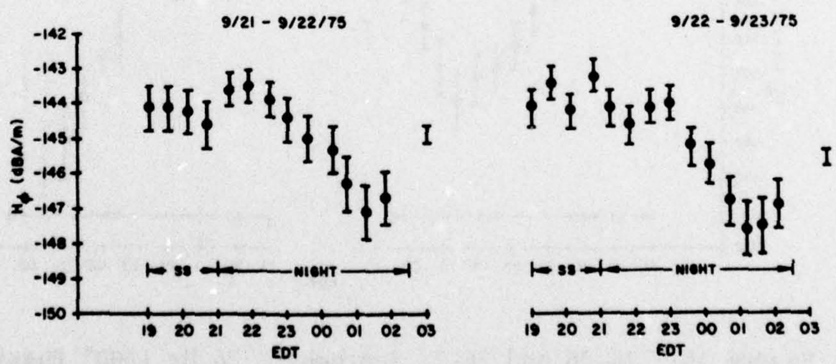

Figure 16. 21-22 and 22-23 September, 76 Hz (300° Phasing)
Field Strengths Versus Local Time

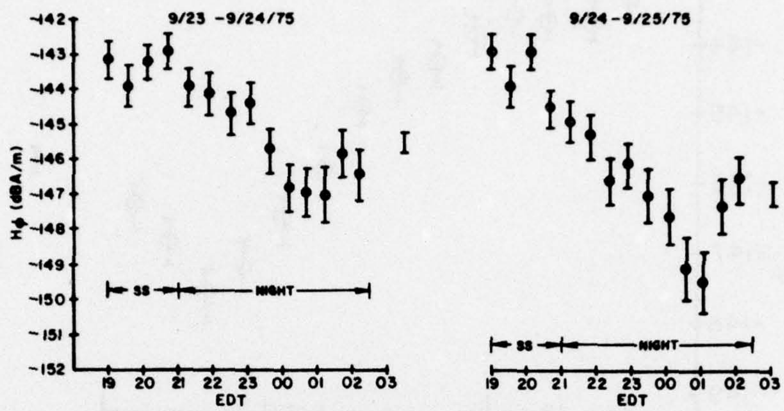

Figure 17. 23-24 and 24-25 September, 76 Hz (300° Phasing) Field Strengths Versus Local Time

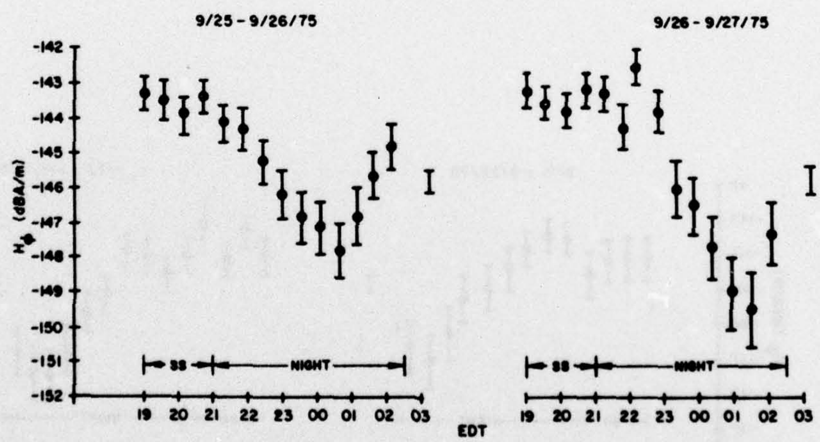

Figure 18. 25-26 and 26-27 September, 76 Hz (300° Phasing) Field Strengths Versus Local Time

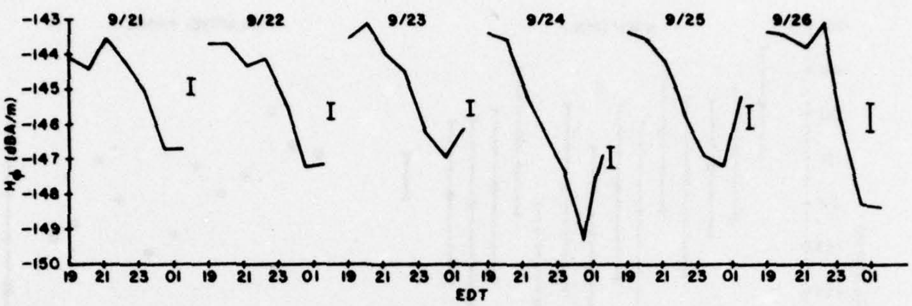

Figure 19. 21-27 September, 76 Hz (300° Phasing) Field Strengths Versus Local Time (Effective Integration Time = 1 hour)

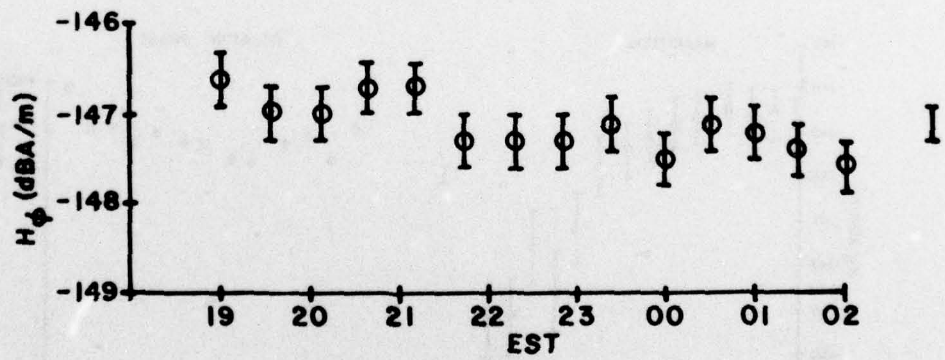

Figure 20. October, 76 Hz Field Strength Averages Versus Local Time

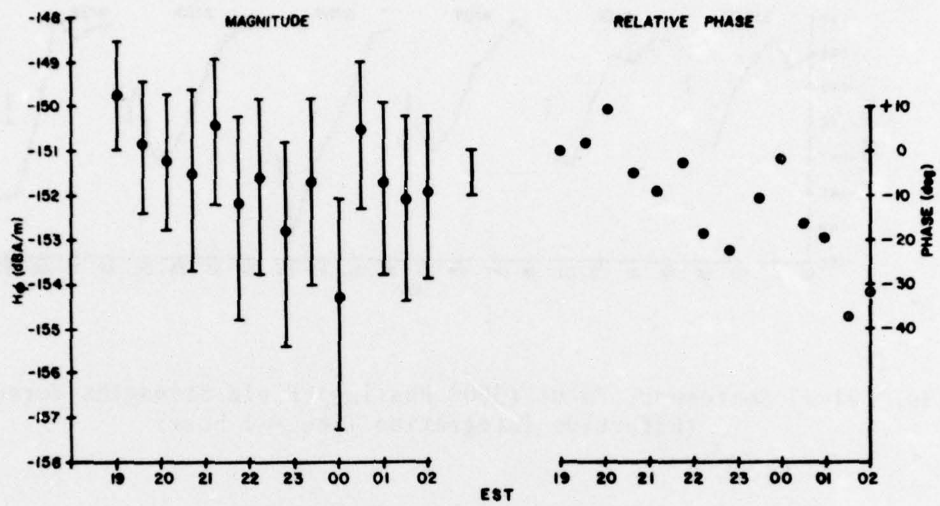

Figure 21. 27-28 October, 76 Hz Field Strengths Versus Local Time

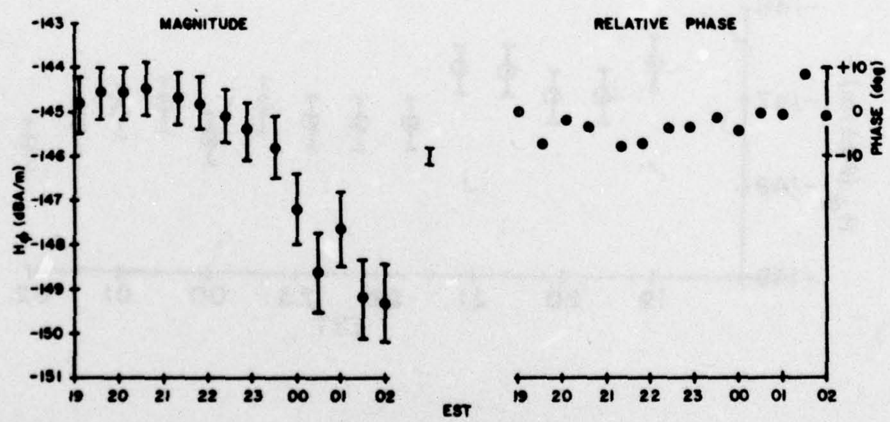

Figure 22. 28-29 October, 76 Hz Field Strengths Versus Local Time

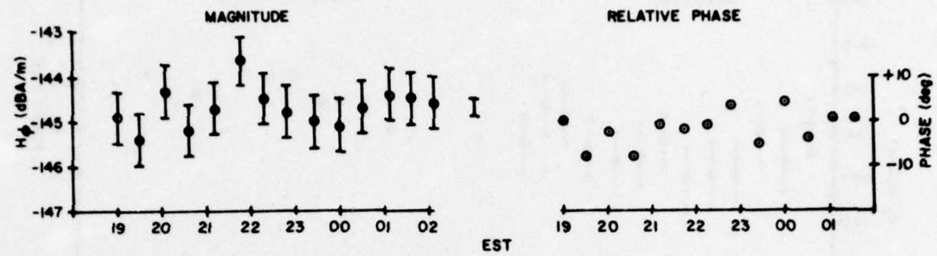

Figure 23. 29-30 October, 76 Hz Field Strengths Versus Local Time

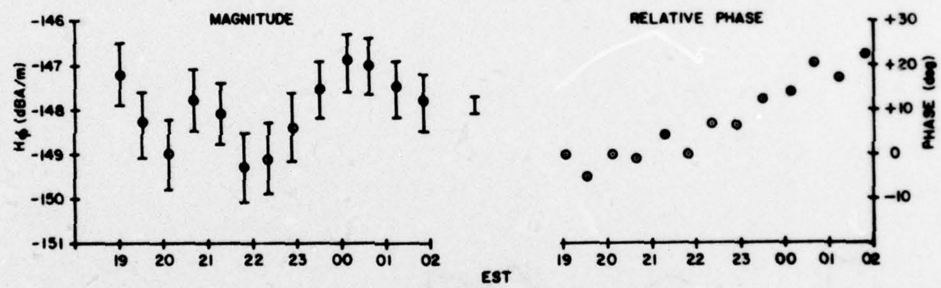

Figure 24. 30-31 October, 76 Hz Field Strengths Versus Local Time

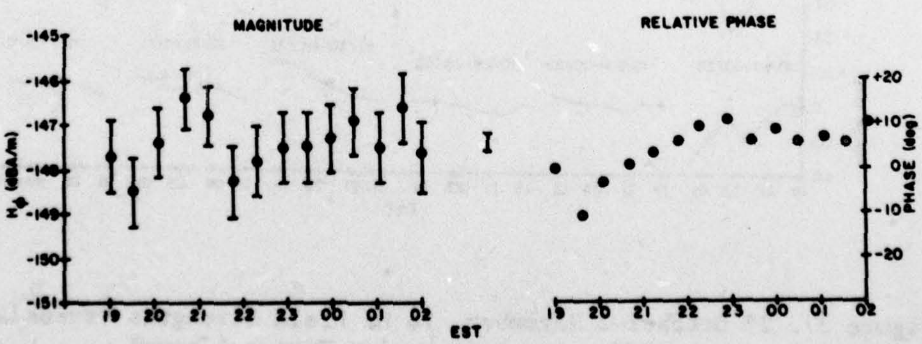

Figure 25. 31 October-1 November, 76 Hz Field Strengths Versus Local Time

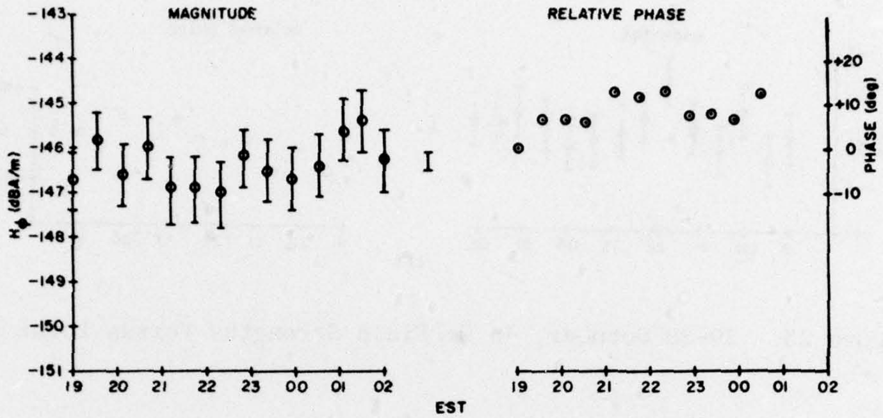

Figure 26. 1-2 November, 76 Hz Field Strengths Versus Local Time

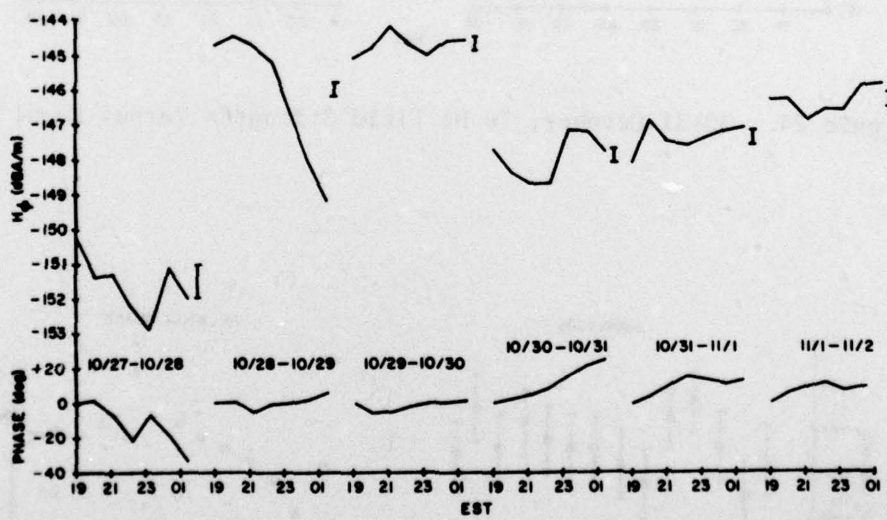

Figure 27. 27 October-2 November, 76 Hz Field Strengths Versus Local Time
(Effective Integration Time = 1 hour)

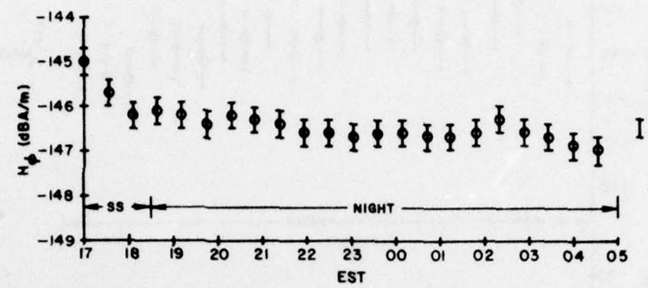

Figure 28. November, 76 Hz Field Strength Averages Versus Local Time

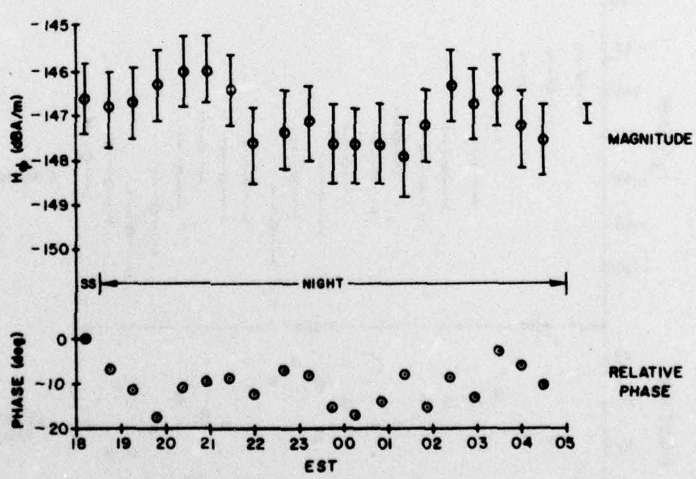

Figure 29. 18-19 November 76 Hz Field Strengths Versus Local Time

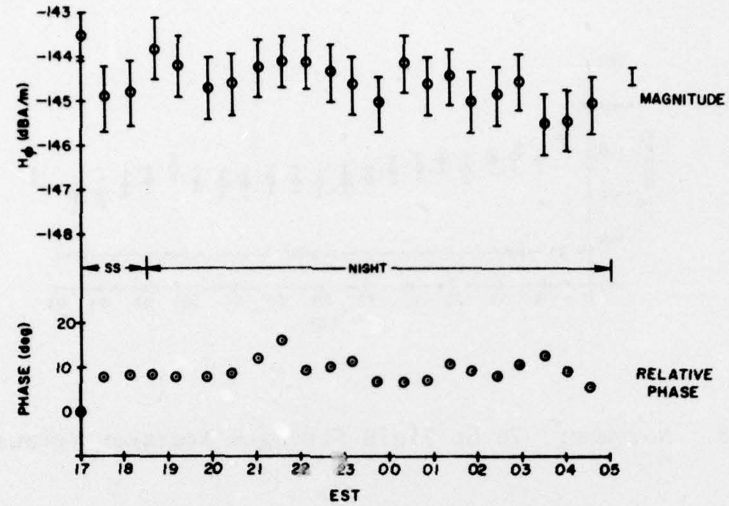

Figure 30. 19-20 November, 76 Hz Field Strengths Versus Local Time

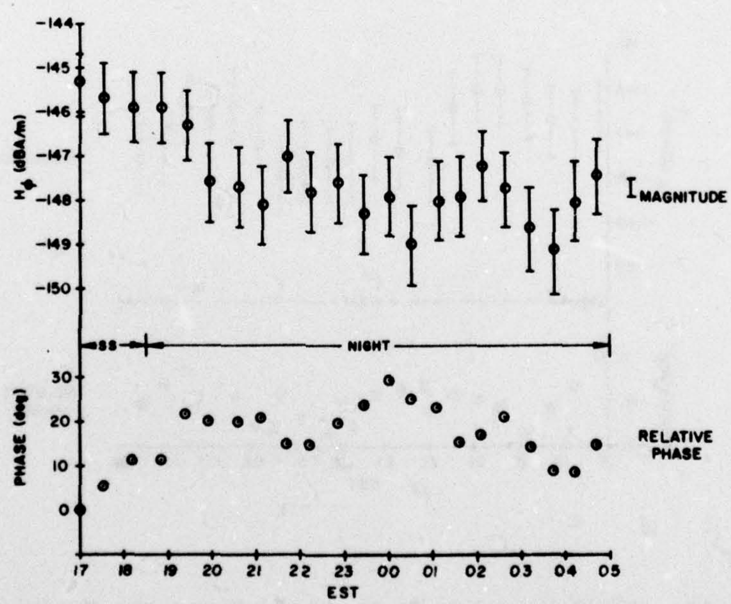

Figure 31. 20-21 November, 76 Hz Field Strengths Versus Local Time

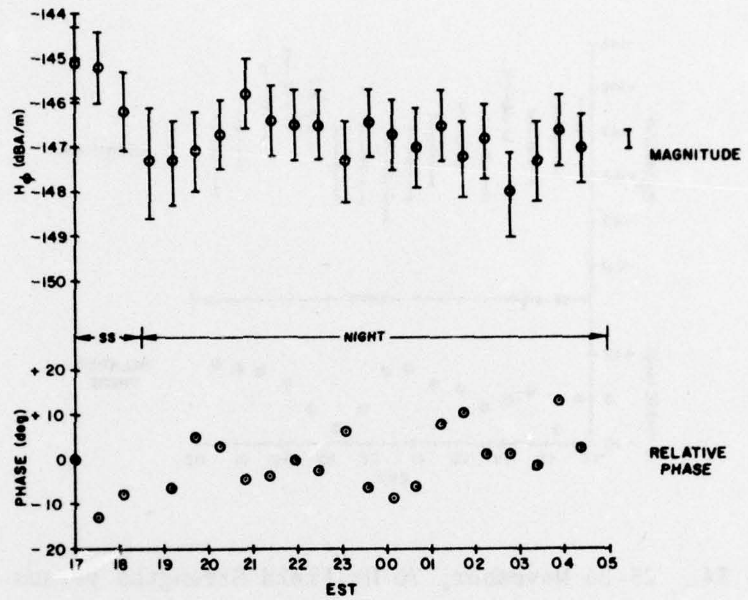

Figure 32. 21-22 November, 76 Hz Field Strengths Versus Local Time

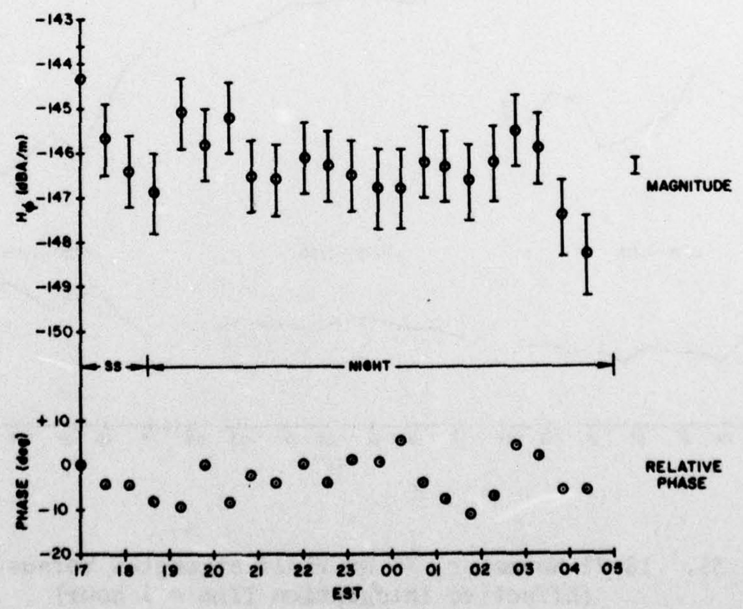

Figure 33. 24-25 November, 76 Hz Field Strengths Versus Local Time

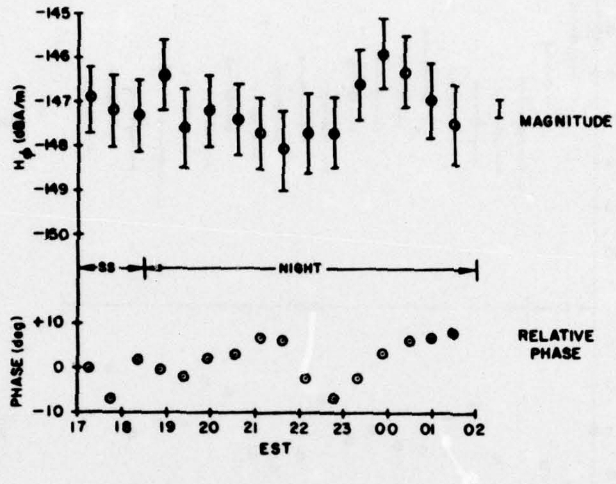

Figure 34. 25-26 November, 76 Hz Field Strengths Versus Local Time

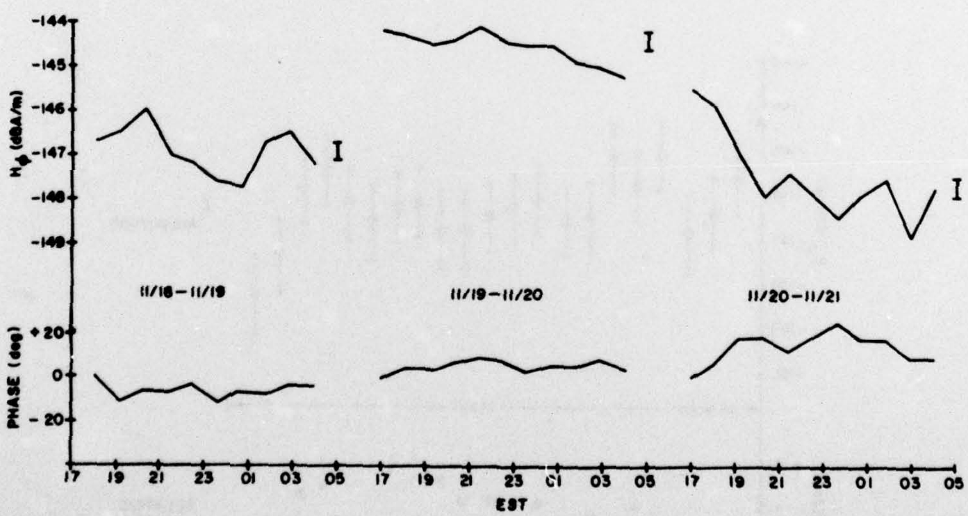

Figure 35. 18-21 November, 76 Hz Field Strengths Versus Local Time
(Effective Integration Time = 1 hour)

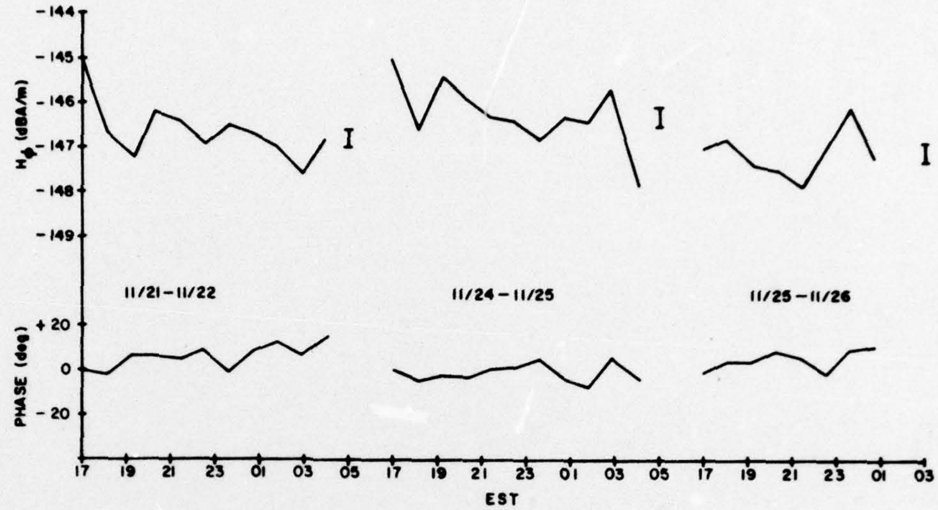

Figure 36. 21-26 November, 76 Hz Field Strengths Versus Local Time (Effective Integration Time = 1 hour)

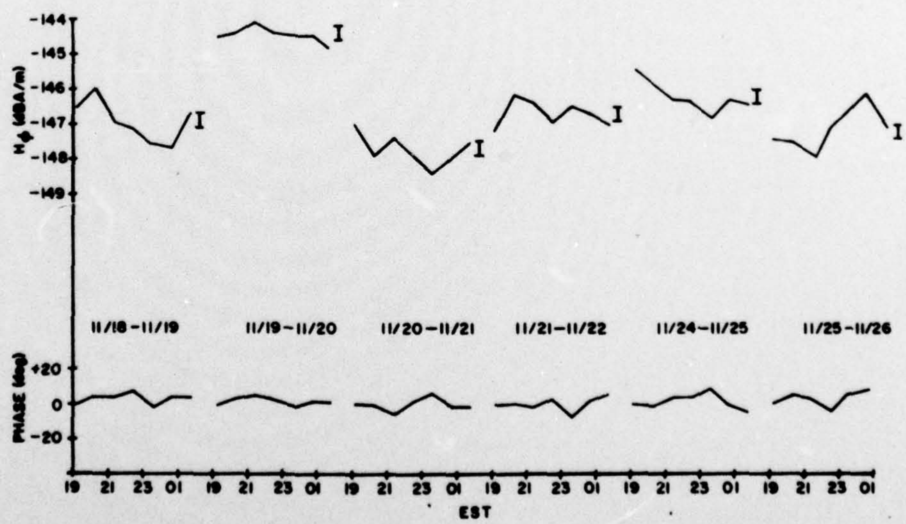

Figure 37. 1900-0230 November, 76 Hz Field Strengths (Effective Integration Time = 1 hour)

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