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A Dual Channel Radiowave Propagation Data Acqusition and Transmission System

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Prepared for: Naval Undersea Weapons Engineering Station, Keyport, Washington 98345

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Summary

This report describes a dual channel radiowave propagation data acquisition and transmission system developed for communication system performance monitoring at the Naval Undersea Weapons Engineering Station, Keyport, Washington. The Data System is collocated with a repeater in a two section UHF/VHF microwave telephone system and collects and stores statistical information on signal power for each of the two sections. These data may be transmitted upon command from the remote repeater site to another computer for processing. Data transmission is via the dial-up telephone network. Real-time remote display of signal levels is also possible.

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I. Introduction

A. Background

In an earlier report [1], the design of a (single channel) Radiowave Propagation Data Acquisition System was described. This system consisted of a sensor subsystem containing the RF hardware and a data acquisition and processing system containing the controller/processor and associated instruments.

The initial use of this system will be at NUWES, Keyport, WA to monitor the performance of a two section VHF/UHF telephone system employing a single mountain top repeater. The Propagation Data System will be co-located with the repeater and will thus have simultaneous access to the RF carriers transmitted from each of the two terminals in the telephone system. Thus, propagation data for each section of the telephone system may be obtained. This application, however, requires some capabilities which the Propagation Data System described in [1] does not have. Two channels are required to accomodate the two sections of the telephone system and because of the inaccessability of the site a data transmission capability is required.

B. Purpose

The purpose of this report is to describe the realization of a Dual Channel Radiowave Propagation Data Acquisition and Transmission System for use at NUWES, Keyport, Washington. The present system is an expansion of the system described earlier [1].

Section II of this report describes the telephone communication system and contains path loss calculations. Section III describes the hardware required to implement a dual channel system and to provide a data transmission capability. Section IV briefly discusses the software used with the Data System and the Appendices contain program listings.

II. System Calculations

The several torpedo ranges operated by NUWES are linked to the main base at Keyport by a FM/FDM VHF/UHF telephone system. The Nanoose Range is served by a 12 channel system with terminals at Bangor and Winchelsea Island linked through a repeater located on Lookout Mountain (el. 2667 ft.). Figure 1 shows the geographic layout of the communication system and the four transmission frequencies. System calculations which follow are based on minimum monthly median surface refractivity and assume an effective earth's radius

$$KR = \frac{R}{1 - .0466\ \exp(.005577N_s)}$$

which has been shown to accurately model the atmosphere under normal conditions in the continental USA [2].

The climactic conditions existing over the radio path are assumed similar to those at the nearest weather station, Tatoosh Island (48 24N,124 36W) which is located just off the tip of the Olympic Peninsula. Data from ref [3] and [4] show surface refractivity as follows:

Minimum N_s	290 (K=1.31)
Minimum monthly median N_s	320 (K=1.38)
Maximum monthly median N_s	340 (K=1.45)
Maximum N_s	355 (K=1.51)

The minimum monthly median surface refractivity occurs in the January-March period and the maximum monthly median refractivity accurs in August.

Path profiles for minimum monthly median refractive conditions for each path are shown in Figures 2 and 3. These profiles show smooth earth diffraction on the Winchelsea - Lookout path and knife edge diffraction over the first hill on the Bangor - Lookout path. The diffraction loss will vary somewhat between the extremes of surface refractivity ($290 \leq N_s \leq 355$). For the Winchelsea - Lookout path the variation of smooth earth diffraction loss has been calculated to be 8 db.

The received signal power may be calculated from

$$P_r = P_t - L_s$$

P_r = received signal power in dbm

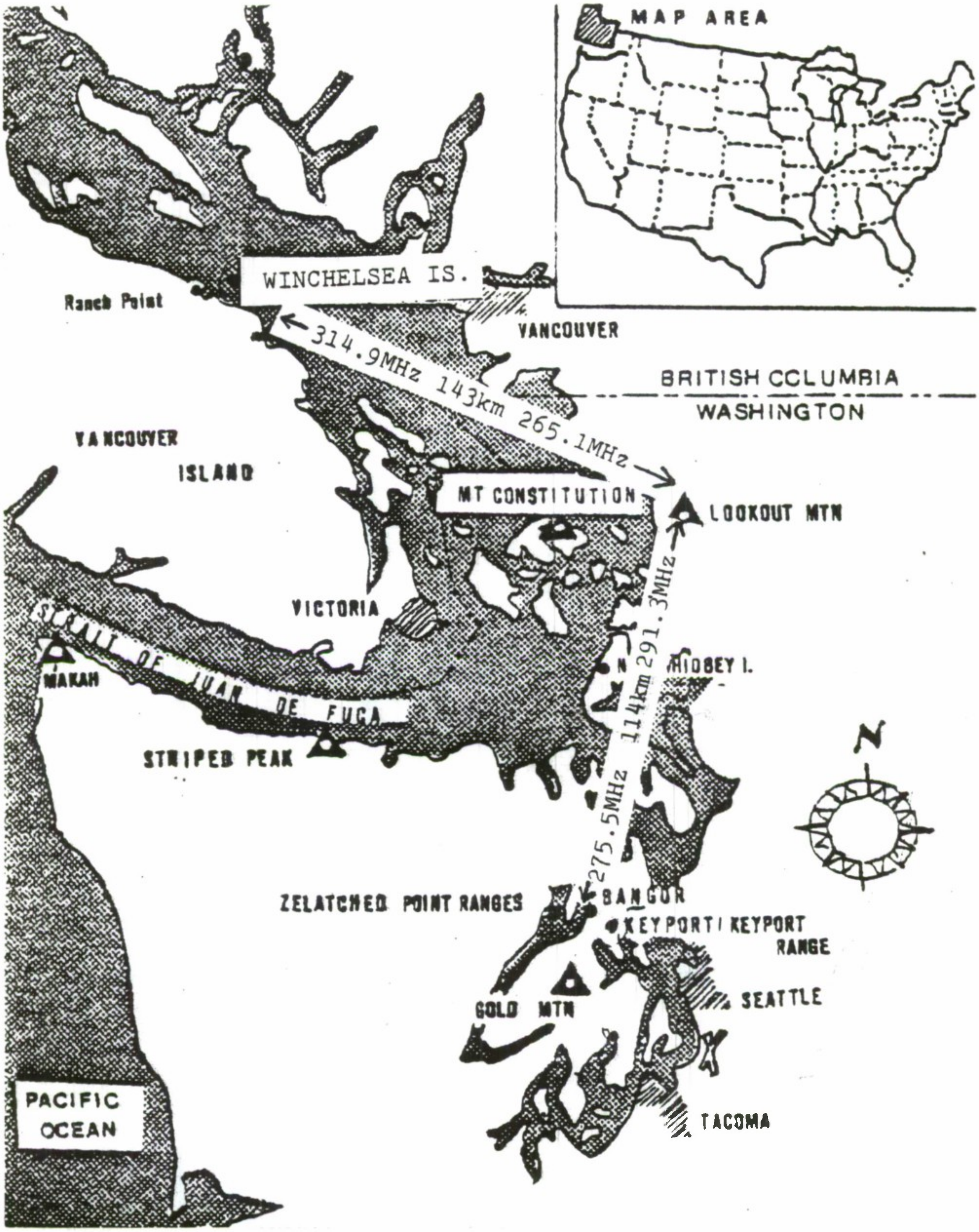

Figure 1. Bangor - Winchelsea Telephone System

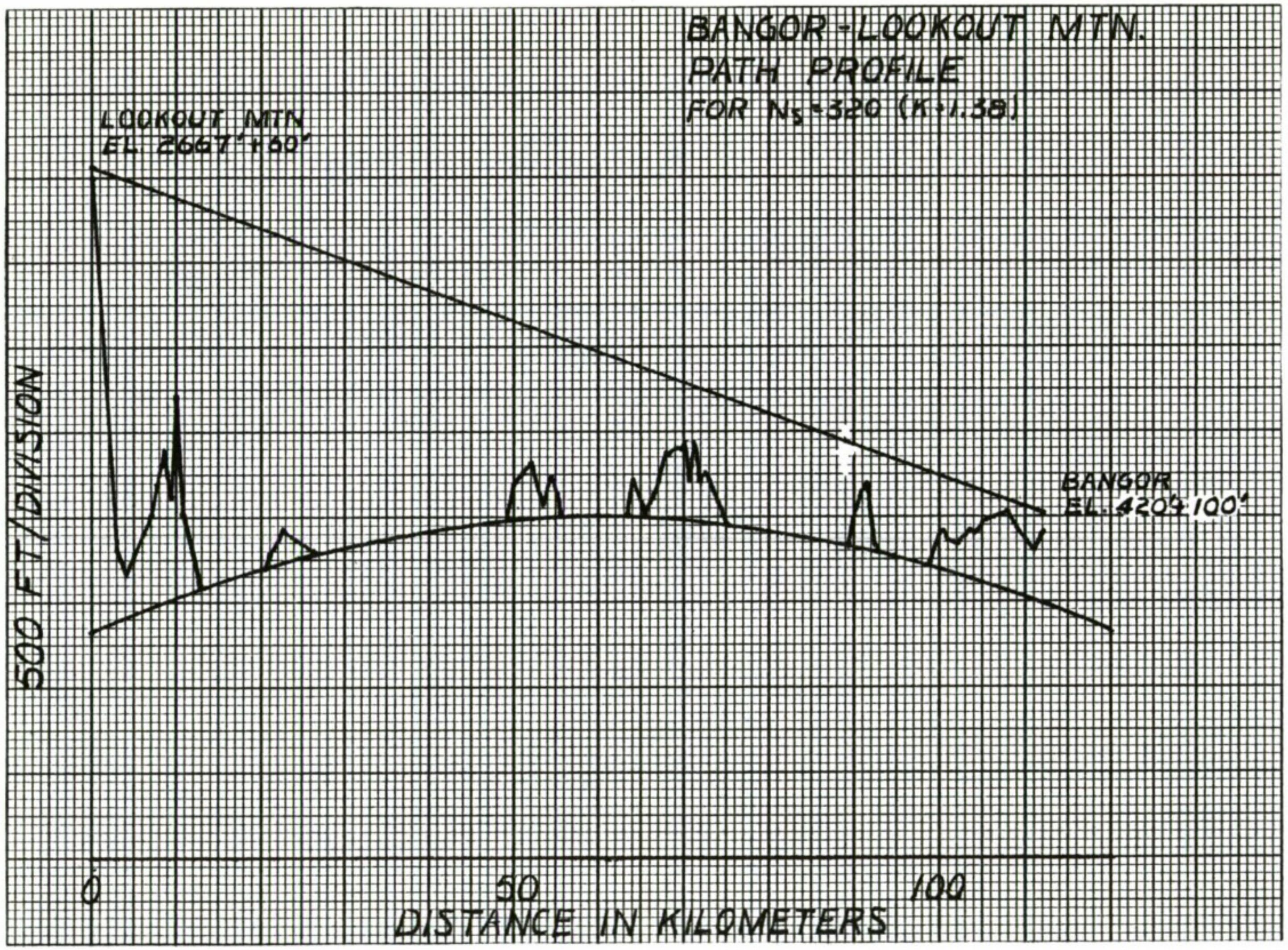

Figure 2. Bangor - Lookout Path Profile

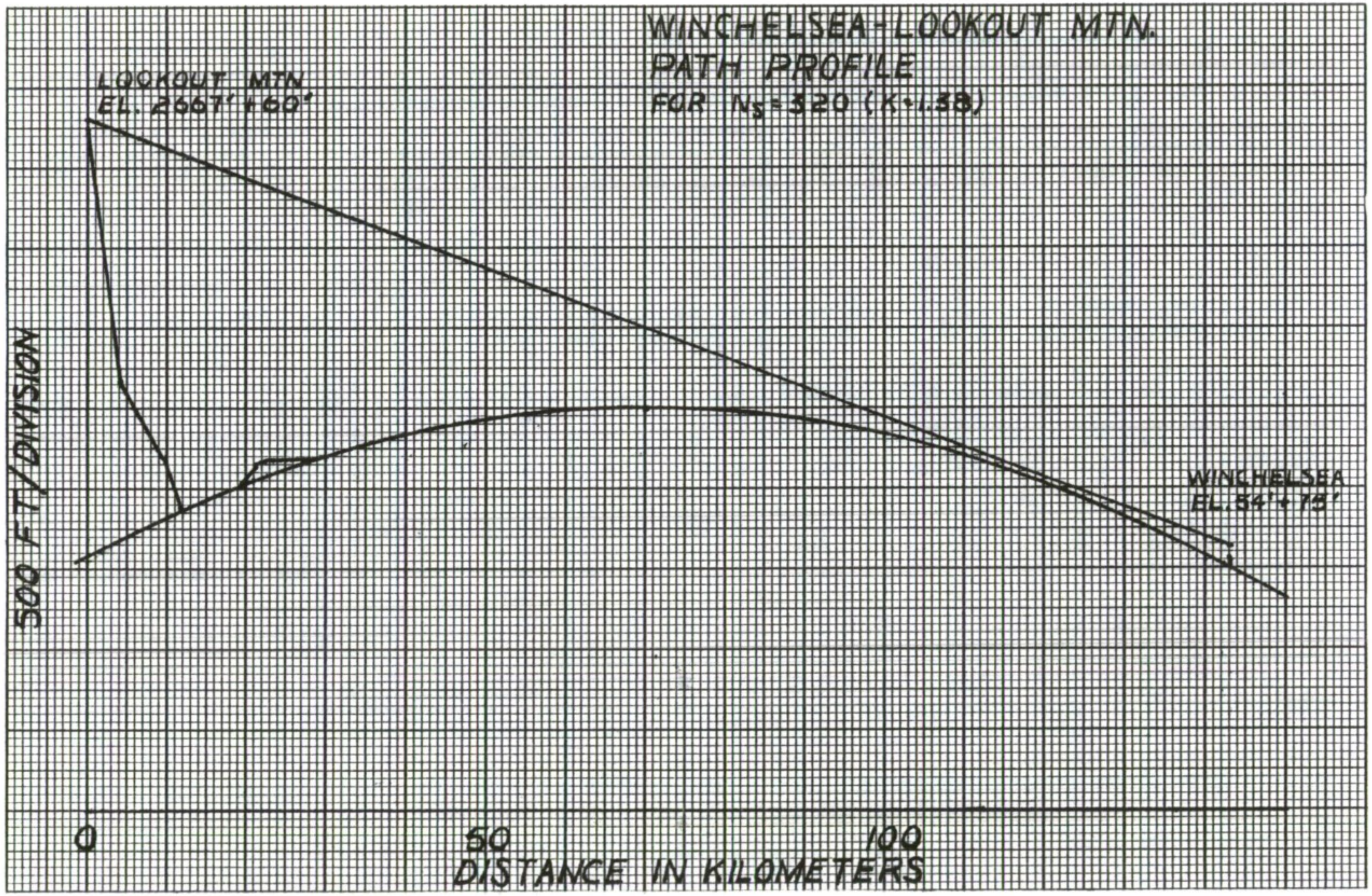

Figure 3. Winchelsea - Lookout Path Profile

P_t = transmit power in dbm

L_s = system loss in db

System loss is calculated as

$$L_s = L_{bf} + L_d - G_r - G_t$$

where

$$L_{bf} = 10 \log_{10}\left(\frac{4\pi d}{\lambda}\right)^2$$

L_d = diffraction loss
G_t = transmit antenna gain
G_r = receive antenna gain.

Table I lists the system parameters necessary to carry out the above calculations and Table II gives the results of the calculations for minimum monthly median refractive conditions (N_s = 320).

The calculations show that the received signal levels are -53.4 dbm from Bangor and -64.5 dbm from Winchelsea. Line losses have not been included. Signal levels measured on 9/28/78 were -54 dbm from Bangor and -60 dbm from Winchelsea indicating reasonable agreement with calculations. These calculations of minimum monthly median signal levels provide a point of reference

System Parameter	Bangor - Lookout	Winchelsea - Lookout
Transmit power	100 W	100W
Transmit Antenna Gain	12.5 db	12.5 db
Receive Antenna Gain	9 db	9 db
Frequency	291.3 MHz	265.1 MHz
Distance	114 km	143 km
Transmit Antenna El.	520 ft	248 ft
Receive Antenna El.	2727 ft	2727 ft

Table 1. Telephone System Parameters

Calculations	Bangor - Lookout	Winchelsea - Lookout
L_{bf}	122.9	124 db
L_d	2db (H/H_1=.29)	12 db
L_s	103.4 db	114.5 db
P_r	-53.4 dbm	-64.5 dbm

Table 2. Summary of Calculations of System Loss

for the specification of hardware for further signal monitoring as described in the following section.

III. Hardware Configuration for Data Acquisition

A. RF Hardware

This section addresses the adaptation of the basic Radiowave Propagation System described previously [1] to the present measurement problem. The present situation requires monitoring of signals on two different frequencies using a mechanically tuned receiver. Additionally the signals differ in power by about 10 db. The problem is therefore one which requires sampling the two signals and presenting the data to the receiver on a single frequency., It is also required that the anticipated variations of power level for both signals fall within the instantaneous dynamic range of the receiver.

The RF hardware used to implement the monitoring of two RF channels is shown in Figure 4. The two signals (f_1 = 265.1 MHz, f_2 = 291.3 MHz) are routed from their respective antennas to 3 db power splitters. The power splitters provide outputs to the communication system to permit its normal and undisturbed operation and to the acquisition system for signal monitoring. The outputs to the acquisition system are then routed to a power combiner, the output of which drives a low noise (F = 2.5 db) RF amplifier. The output of the low noise amplifier is split into two channels. In one channel a 265.1 MHz bandpass filter recovers the Winchelsea - Lookout signal and provides limited rejection of the Bangor - Lookout signal and any other out-of-band interference. In the other channel a 291.3 MHz bandpass filter passes the Bangor - Lookout signal while providing about 30 db rejection of the Winchelsea - Lookout signal. The Bangor - Lookout signal is mixed with a 556.4 MHz local oscillator signal and the intermediate difference frequency at 265.1 MHz is recovered by bandpass filtering. The LO provides about 30 db rejection of the Winchelsea - Lookout signal and in combination with the bandpass filter preceeding it gives about 60 db of channel separation. Thus the outputs from the two filters, both at 265.1 MHz, are the signals from Winchelsea and Bangor and these are provided as inputs to the SPDT PIN diode switch.

The primary inputs to the 265.1 MHz filters are the desired signals at 265.1 MHz. In each case, however, the signal from the opposite channel is also present with a frequency offset of 26.2 MHz. The filters provide only limited rejection of these undesired signals. The necessary rejection is provided by the receiver which is operated with the IF passband set to 500 kHz. The filters in both channels serve the purpose of suppressing the LO frequency and undesired mixer products.

The PIN switch is a critical component since it must change states rapidly and must also provide enough isolation so that the desired dynamic range may be realized. The switch chosen for this system was a General Microwave ultra wideband

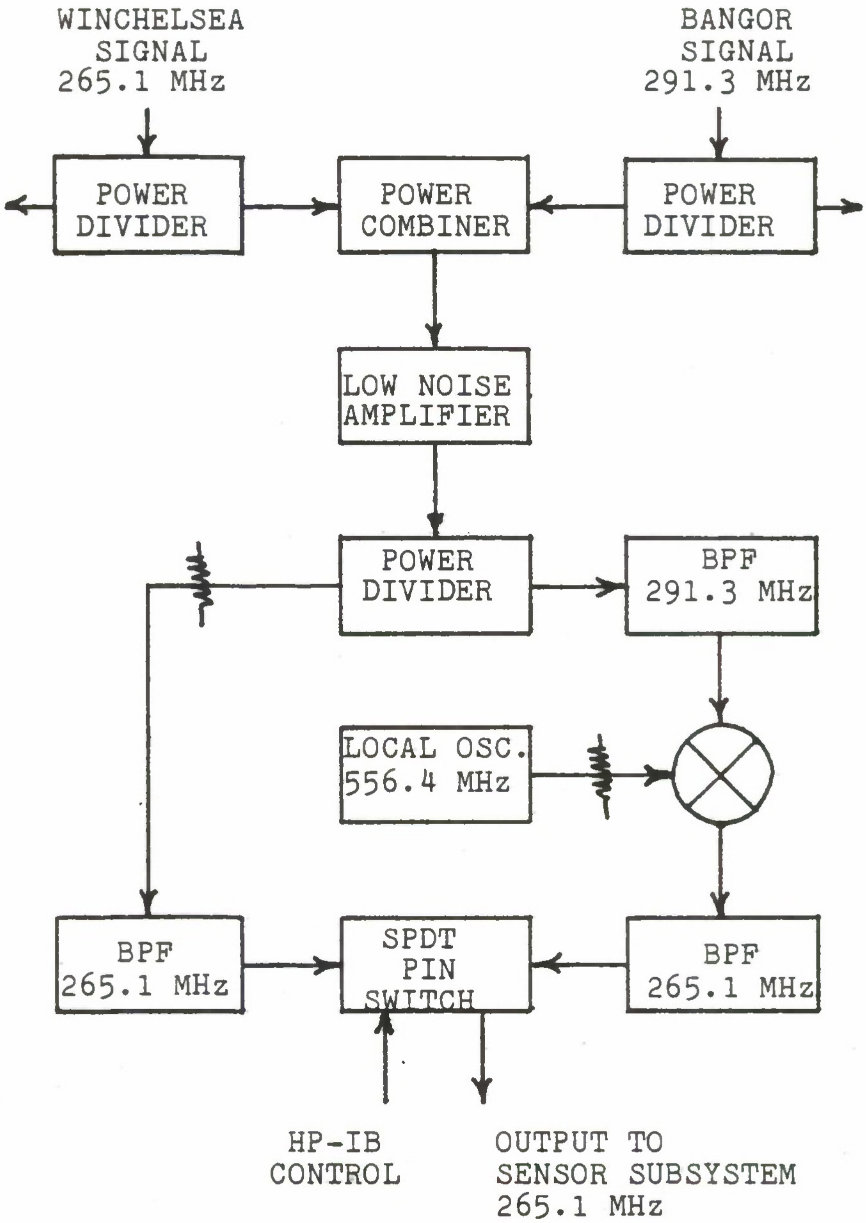

Figure 4. RF Hardware Block Diagram for Two Channel Switching Subsystem.

(.2-18 GHz) switch with integral driver. The isolation at 265.1 MHz is in excess of 60 db and the switching time is less than 500 ns. The switch logic control signal is received from the HP 9825 controller via the HP-IB (IEEE 488) bus using an interface designed for that purpose. The two switch states are set by executing the trigger commands, trg 726 or trg 727.

The output of the PIN switch is fed to the receiver in the Sensor Subsystem. Either of the two signals, Winchelsea or Bangor may be selected by the switch. The receiver must be adjusted to provide an instantaneous dynamic range which will accomodate the expected variations in signal amplitude. The dynamic range requirements are minimized if both signals are input to the receiver with approximately the same median level. This may be accomplished by independent adjustment of the gain in each channel. For the hardware configuration shown in Figure 4 the gain difference between the two channels is due to the conversion loss of the mixer (approximately 6 db) and the difference in the insertion loss of the filters in the two channels. The stronger of the two signals (Bangor) is routed through the channel containing the mixer and the additional attenuation in the opposite channel is selected to make the median signal levels approximately equal at the output of the PIN switch.

The output from the PIN switch is routed to the receiver. From this point each of the two signals is processed as described in [1].

B. Data Transmission Hardware

The transmission of data from the remote (Lookout Mountain) controller to a local computer at NPS Monterey is accomplished as shown in Figure 5. The primary task which is performed is the transmission of data stored in the tape files of the Lookout Mountain controller to another HP 9825 computer via the dial-up telephone network. The data is stored in the same tape files of the second HP 9825. A copy of the tape files in the Lookout Mountain controller is therefore obtained. A brief description of the operation of this subsystem follows.

The transfer of data is initiated by manually dialing the number of the telephone at the remote location. The remote modem answers automatically and places an audio carrier on the line. The local phone is then placed in the data mode which connects the local modem to the line. The local computer program is then run. The program prompts the operator for the necessary input data. Contact is then established with the remote controller and data is passed.

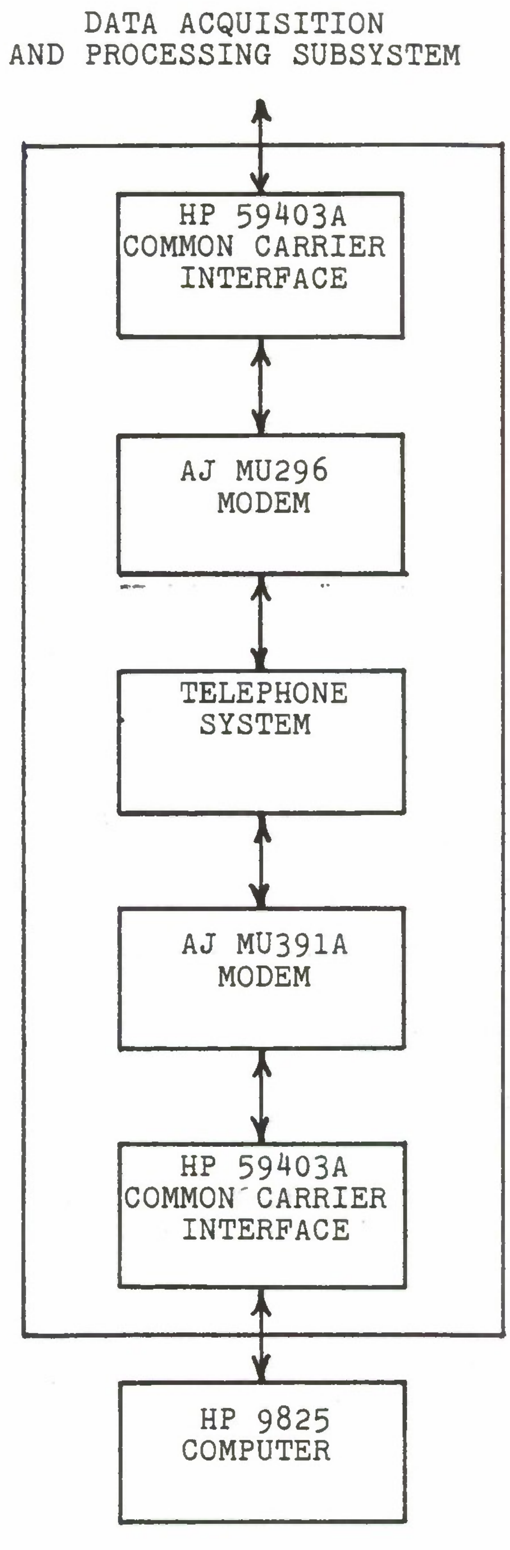

Figure 5. Digital Hardware Block Diagram for Data Transmission Subsystem.

The transmission speed for the data is relatively slow compared to the speed with which the remote controller can operate. The remote controller is therefore able to continue acquiring new data during the time it is not transmitting previously stored data.

In addition to the primary function of transmitting stored data, the system also provides the option of real-time readout of the signal levels at the output from each antenna. This permits the signal levels to be checked at any time without waiting for the storage of data which only occurs once each day at 2400 hours.

The transmission of data occurs in part over the Bangor-Lookout section of the system being monitored. It is therefore required that this section of the system be operating with an adequate signal level in order for data to be transmitted. However, even if the signal level is inadequate for data transmission, the signal levels will still be monitored and the data may be transmitted time-late.

C. System Block Diagram

Figure 6 shows a simplified block diagram of the complete system as configured for the NUWES measurements. The Switching Subsystem (Figure 4) allows continuous sequential sampling of the two RF signals received on Lookout Mountain. The output goes to the Sensor Subsystem [1] which provides a detected output that follows variations in carrier signal amplitude. This output is sampled by the Data Acquisition and Processing Subsystem. The computer in this subsystem provides the necessary control, calculates the desired statistical measures, stores the data and transmits it on command from another computer. The actual transmission of data is accomplished through the Remote and Local Data Transmission Subsystems which link the two computers together via the telephone lines.

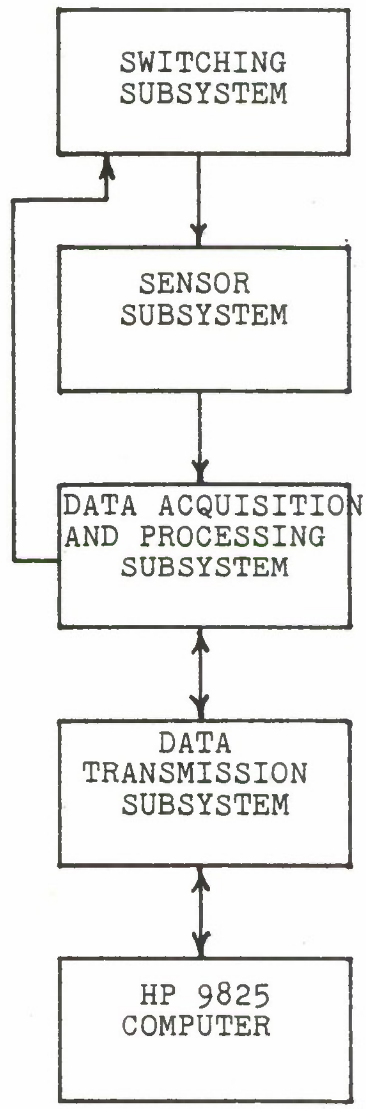

Figure 6. Complete System Block Diagram

IV System Software

The software developed for use with the system described in this report consists of three separate programs.

A. Acquisition System Program

This program resides in the controller/processor at the remote monitoring location. It is an expanded version of the program described in [1] as necessary to accomodate two RF signals. In addition it contains the subroutines necessary for the transmission of stored data or real time readout of signal levels.

B. Data Transmission Program

This program is loaded from tape into a local HP 9825 desktop computer when data is to be transmitted from the remote computer. The program contains all the prompts necessary for the operator to accomplish the task. At the conclusion of this program the desired data files will have been transferred from the remote computer tape to the local computer tape. In the case of real-time readout of signal levels, the dbm levels appear in the local computer display.

C. Data Printing Program

This program provides a paper tape printout of the data for each of the two channels after it has been transferred to the tape files of the local computer. The data is coded to permit more rapid transmission. The coding is done before the data is stored on tape at the remote computer. The data printing program provides the necessary decoding in the local computer prior to printing.

A detailed discussion of system software may be found in ref. [5] and this is not repeated here. Program listings appear in the Appendices.

Conclusions and Recommendations

A. Conclusions

The Dual Channel Radiowave Propagation Data Acquisition and Transmission System described here is capable of continuous monitoring of the strength of two radio signals. The system is designed to collect data without disturbing the communication system being monitored. The system is configured from commercially available hardware except for a PIN switch interface which was custom designed.

The Data System samples each signal at a rate of approximately 3.33 samples/second and computes signal power for each sample. Average and median signal power is calculated for each hour of the day and fades of depth 10 db to 30 db relative to the median for the previous hour are counted. A daily distribution of signal power is generated and all processed data are stored on tape at the conclusion of each day. Tape files hold data for four months after which old data is overwritten.

The Acquisition and Processing Subsystem controller may be interrupted. On interrupt, the controller will transmit the data stored in tape files or the present signal power levels as requested by a second computer. This operation is carried out over the telephone lines.

The system will run unattended and has the capability to bootstrap itself in the event of a power failure. The digital clock has backup battery power. After a power failure a ten minute warmup period is provided to allow all equipment to stabilize before signal monitoring is resumed.

In prolonged periods of laboratory testing the system has operated reliably.

B. Recommendations

In any future implementation of a similar system, Hewlett-Packard's new replacement for the HP 59403A CCI should be considered for use. This newer unit should be more transparent, require less programming for its operation and should thus be easier to incorporate into the system.

References

[1] J. B. Knorr, "A Radiowave Propagation Data Acquisition System", technical report NPS62-79-001, Naval Postgraduate School, Monterey, California 93940, October 1978.

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[3] B. R. Bean et al, Climactic Charts and Data of the Radio Refractive Index for the United States and the World. U. S. Government Printing Office, Washington, D.C., 1960.

[4] B. R. Bean et al, A World Atlas of Atmospheric Radio Refractivity. U. S. Government Printing Office, Washington, D.C., 1966.

[5] P. Ruputz, "Remote Acquisition of Atmospherically-Propagated Radio-Frequency Communication Channel Performance Data by way of Dial Up Telephone Networks" M.S. thesis, Naval Postgraduate School, Monterey, California 93940, June 1979.

Appendix I. Acquisition System Program

```
0: gto "startup"
1: fxd 2;dsp
 "W:",A,"dbm
   B:",N,"dbm"
2: oni 7,"call"
3: eir 7,0
4: on err "reset
 "
5: if flg1;wrt
 721.1,A,N;wait
 200
6: red 708,A$
7: if num(A$[2])
 #32;gto 6
8: trg 727
9: trg 722;red
 722,A
10: trg 726
11: trg 722;red
 722,N
12: val(A$[7,
 8])→D
13: if flg0 and
 val(B$[3,6])=0;
 gto 18
14: val(B$[7,
 8])→F
15: if D#F;gsb
 "new hour"
16: if val(A$[5,
 6])#val(B$[5,
 6]);gsb "new
 day"
17: eir 7
18: A$→B$
19: if A=0;C[2,
 0]+1→C[2,0];
 gto 34
20: 10log(abs(A)
 )→A
21: .95*A-47.5+
 .00000382(A+
 33.5)↑5→A
22: if A<-90 or
 A>-45;C[2,0]+
 1→C[2,0];gto 34
23: C[3,0]+10↑(A
 /10)→C[3,0]
24: C[1,0]+1→C[1
 ,0]
25: int(A)→H
26: A[H]+1→A[H]
27: if flg0;A→E→
 B;gto 34
28: if A<E-10
 and E-10<B;C[5,
 0]+1→C[5,0]
29: if A<E-15
 and E-15<B;C[6,
 0]+1→C[6,0]
30: if A<E-20
 and E-20<B;C[7,
 0]+1→C[7,0]
31: if A<E-25
 and E-25<B;C[8,
 0]+1→C[8,0]
32: if A<E-30
 and E-30<B;C[9,
 0]+1→C[9,0]
33: A→B
34: if N=0;Q[2,
 0]+1→Q[2,0];
 gto 1
35: 10log(abs(N)
 )→N
36: .9*N-40.5+
 .00000436(N+
 34)↑5→N
37: if N<-90 or
 N>-45;Q[2,0]+
 1→Q[2,0];gto 1
38: Q[3,0]+10↑(N
 /10)→Q[3,0]
39: Q[1,0]+1→Q[1
 ,0]
40: int(N)→V
41: N[V]+1→N[V]
42: if flg0;N→S→
 P;val(A$[9,10])
 →C[10,0]→Q[10,
 0];cfg 0;gto 1
43: if N<S-10
 and S-10<P;Q[5,
 0]+1→Q[5,0]
44: if N<S-15
 and S-15<D;Q[6,
 0]+1→Q[6,0]
45: if N<S-20
 and S-20<P;Q[7,
 0]+1→Q[7,0]
```

```
46: if N<S-25
 and S-25<P;Q[8,
 D]+1→Q[8,D]
47: if N<S-30
 and S-30<P;Q[9,
 D]+1→Q[9,D]
48: N→P
49: gto 1
50: "new hour":
51: for I=1 to
 32
52: char(159)→P$
 [I,I]
53: next I
54: " new hour
 "→P$[12,21]
55: dsp P$
56: if flg0;gto
 74
57: if C[1,F]>0
 and C[3,F]>0;
 10log(C[3,F]/
 C[1,F])→C[3,F]
58: if Q[1,F]>0
 and Q[3,F]>0;
 10log(Q[3,F]/
 Q[1,F])→Q[3,F]
59: C[1,F]/2→C
60: Q[1,F]/2→Q
61: 0→J→K
62: for I=-45
 to -90 by -1
63: A[I]+E[I]→E[
 I]
64: N[I]+S[I]→S[
 I]
65: if flg3;gto
 68
66: A[I]+J→J
67: if J>C;I→C[4
 ,F]→E;sfg 3
68: if flg4;gto
 71
69: N[I]+K→K
70: if K>Q;I→Q[4
 ,F]→S;sfg 4
71: 0→A[I]→N[I]
72: next I
73: cfg 3,4
74: trk 1;rcf 0,
 A$,C[*],E[*],
 Q[*],S[*]
75: ret
76: "new day":
77: for l=1 to
 32
78: char(159)→P$
 [I,I]
79: next I
80: " new day
 "→P$[12,20]
81: dsp P$
82: ""→F$
83: B$[3,4]→F$[l
 en(F$)+1,len(F$
 )+2]
84: B$[5,6]→F$[l
 en(F$)+1,len(F$
 )+2]
85: char(127)→F$
 [len(F$)+1,len(
 F$)+1]
86: sfg 2
87: "WWWW"→F$[le
 n(F$)+1,len(F$)
 +4];gto 89
88: cfg 2;"BBBB"
 →F$[len(F$)+1,
 len(F$)+4]
89: char(127)→F$
 [len(F$)+1,len(
 F$)+1]
90: for J=0 to
 23
91: for I=1 to
 10
92: if flg2;C[I,
 J]→R;0→C[I,J];
 gto 94
93: Q[I,J]→R;
 0→Q[I,J]
94: if I=3;abs(R
 *100)→R
95: if I=4;abs(R
 )→R
96: gsb "charact
 er"
97: next I
98: next J
99: for K=-90
 to -45
100: if flg2;
 E[K]→R;0→E[K];
 gto 102
```

```
101: S[K]→R;0→S[
 K]
102: gsb "charac
 ter"
103: next K
104: if flg2;
 gto 88
105: "EEEE"→F$[l
 en(F$)+1,len(F$
 )+4]
106: if val(B$[3
 ,4])mod4=0;trk
 1;31+val(B$[5,
 6])→W;gto 110
107: if val(B$[3
 ,4])mod2=0;trk
 0;31+val(B$[5,
 6])→W;gto 110
108: if (val(B$[
 3,4])+1)mod4=0;
 trk 1;val(B$[5,
 6])→W;gto 110
109: trk 0;val(B
 $[5,6])→W
110: rcf W,F$
111: ret
112: "character"
 :
113: if R<1 or
 R>1953124;gto
 125
114: if R>=15625
 ;gto 117
115: if R>=125;
 gto 120
116: gto 123
117: int(R/15625
 )→M
118: gsb "conver
 sion"
119: R-M*15625→R
120: int(R/125)→
 M
121: gsb "conver
 sion"
122: R-M*125→R
123: int(R)→M
124: gsb "conver
 sion"
125: char(127)→F
 $[len(F$)+1,
 len(F$)+1]
126: ret
127: "conversion
 ":
128: if char(M)=
 char(10);char(1
 25)→F$[len(F$)+
 1,len(F$)+1];
 gto 131
129: if char(M)=
 char(13);char(1
 26)→F$[len(F$)+
 1,len(F$)+1];
 gto 131
130: char(M)→F$[
 len(F$)+1,len(F
 $)+1]
131: ret
132: "call":
133: for I=1 to
 32
134: char(159)→P
 $[I,I]
135: next I
136: " call "→P$
 [14,19]
137: dsp P$
138: time 1000;
 on err "disconn
 ect"
139: wait 1000
140: wtb 718,"L"
141: wait 1000
142: rds(717)→G
143: wait 1000
144: red 721,Z$
145: wait 1000
146: if Z$[1,
 1]="1";sfg 1;
 gto 169
147: if Z$[1,
 1]="0";gto 149
148: gto "discon
 nect"
149: if Z$[2,
 2]#"0" and Z$[2
 ,2]#"1";gto
 "disconnect"
150: if val(Z$[3
 ,4])<1 or val(Z
 $[3,4])>62;gto
 "disconnect"
151: trk val(Z$[
 2,2])
```

```
152: ""→F$
153: ldf val(Z$[
 3,4]),F$
154: par 2
155: wrt 721,
 F$[1,len(F$)]
156: par 0
157: gto "discon
 nect"
158: "disconnect
 ":
159: for I=1 to
 32
160: char(159)→P
 $[I,I]
161: next I
162: " disconnec
 t "→P$[11,22]
163: dsp P$
164: wait 1000
165: wtb 718,"C"
166: wait 1000
167: cli 7
168: cfg 1
169: iret
170: "startup":
171: cli 7
172: for I=600
 to 1 by -1
173: fxd 0;dsp
 "    Startup
 in",I,"seconds.
 "
174: wait 1000
175: next I
176: dim P$[32]
177: for I=1 to
 32
178: char(159)→P
 $[I,I]
179: next I
180: " startup
 "→P$[12,20]
181: dsp P$
182: dim B$[12],
 A[-90:-45],N[-
 90:-45]
183: dim A$[12],
 C[10,0:23],E[-
 90:-45],O[10,
 0:23],S[-90:-
 45]
184: dim Z$[4],
 F$[2000]
185: trk 1;ldf
 0,A$,C[*],E[*],
 O[*],S[*]
186: A$→B$
187: sfg 0
188: gto "reset"
189: "reset":
190: cli 7
191: for I=1 to
 32
192: char(159)→P
 $[I,I]
193: next I
194: " reset
 "→P$[13,19]
195: dsp P$
196: wait 1000
197: wtb 718,"C"
198: wait 1000
199: cli 7
200: if flg0=0;
 cfg
201: fmt 1,2f8.2
202: rem 7
203: llo 7
204: wrt 722,
 "T2"
205: gto 6
*3684
```

Appendix II. Data Transmission Program

```
0: dim A$[40],
 B$[40],D$[3],
 F$[2000],J$[12]
 ,P$[16],Z$[4]
1: fmt 1,2f8.2
2: for I=1 to
 40;"-"→A$[I,I];
 next I
3: fxd 0
4: gsb "*"
5: gsb "*"
6: prt "Lookout
 Mountain"
7: prt "**Data
 Request**"
8: gsb "*"
9: gsb "*"
10: spc 2
11: gsb "*"
12: prt "**Instr
 uctions**"
13: gsb "*"
14: spc 1
15: prt "*Press
 CONTINUE"
16: prt "after
 requested"
17: prt "data
 is entered."
18: spc 1
19: prt "*Enter
 dates"
20: prt "as mmdd
 yy."
21: spc 1
22: prt "*Answer
  question"
23: prt "with y
 or n."
24: ldf 63,B$
25: spc 2
26: gsb "*"
27: prt "*Operat
 or Input*"
28: gsb "*"
29: spc 1
30: enp "→Want
 real-time?",
 A$[40,40]
31: jmp flg13#1
32: if A$[40,
 40]="y";"1"→Z$[
 1,1];gto 115
33: if A$[40,
 40]="n";"0"→Z$[
 1,1];gto 36
34: " Answer y
 or n  "→P$;gsb
 "input"
35: if flg0;cfg
 0;gto 29
36: spc 1
37: enp "→Todays
  date:",A$[8,
 13]
38: jmp flg13#1
39: spc 1
40: prt "*System
  startup"
41: prt "date
 was:"
42: prt B$[1,6]
43: spc 1
44: enp "→Want
 to revise start
 up date?",A$[7,
 7]
45: jmp flg13#1
46: if A$[7,7]="
 y";gto 50
47: if A$[7,7]="
 n";B$[1,6]→A$[1
 ,6];gto 53
48: " Answer y
 or n  "→P$;gsb
 "input"
49: if flg0;cfg
 0;gto 43
50: spc 1
51: enp "→Startu
 p date:",A$[1,
 6]
52: jmp flg13#1
53: if val(A$[8,
 9])>4;gto 59
54: str(8+val(A$
 [8,9]))→D$
55: D$[2,3]→A$[2
 6,27]
56: str(val(A$[1
 2,13])-1)→D$
```

```
57: D$[2,3]→A$[3
 0,31]
58: gto 62
59: str(val(A$[8
 ,9])-4)→D$
60: D$[2,3]→A$[2
 6,27]
61: A$[12,13]→A$
 [30,31]
62: A$[10,11]→A$
 [28,29]
63: if val(A$[10
 ,11])=1;gto 69
64: str(val(A$[1
 0,11])-1)→D$
65: D$[2,3]→A$[3
 5,36]
66: A$[8,9]→A$[3
 3,34]
67: A$[12,13]→A$
 [37,38]
68: gto 77
69: "31"→A$[35,
 36]
70: if val(A$[8,
 9])=1;gto 74
71: str(val(A$[8
 ,9])-1)→D$
72: D$[2,3]→A$[3
 3,34]
73: gto 77
74: "12"→A$[33,
 34]
75: str(val(A$[1
 2,13])-1)→D$
76: D$[2,3]→A$[3
 7,38]
77: A$[1,6]→J$[1
 ,6]
78: A$[26,31]→J$
 [7,12]
79: gsb "julian"
80: if flg2;cfg
 2;A$[1,6]→A$[26
 ,31]
81: for I=27 to
 31 by 2
82: if num(A$[I,
 I])=32;A$[I-1,
 I-1]→A$[I,I];
 "0"→A$[I-1,I-1]
83: if num(A$[I+
 7,I+7])=32;A$[I
 +6,I+6]→A$[I+7,
 I+7];"0"→A$[I+
 6,I+6]
84: next I
85: spc 1
86: prt "*Files
 available"
87: prt A$[26,
 38]
88: spc 1
89: enp "→First
 date:",A$[14,
 19]
90: jmp flg13#1
91: A$[14,19]→J$
 [7,12];A$[26,
 31]→J$[1,6]
92: gsb "julian"
93: if flg2;cfg
 2;" Date too
 early "→P$;gsb
 "input"
94: if flg0;cfg
 0;gto 88
95: A$[33,38]→J$
 [7,12];A$[14,
 19]→J$[1,6]
96: gsb "julian"
97: if flg2;cfg
 2;" Date too
 late "→P$;gsb
 "input"
98: if flg0;cfg
 0;gto 88
99: spc 1
100: enp "→Last
 date:",A$[20,
 25]
101: jmp flg13#1
102: A$[20,25]→J
 $[7,12];A$[14,
 19]→J$[1,6]
103: gsb "julian
 "
104: if flg2;
 cfg 2;" Date
 too early "→P$;
 gsb "input"
105: if flg0;
 cfg 0;gto 99
```

```
106: A$[30,35]→J
 $[7,12];A$[20,
 25]→J$[1,6]
107: gsb "julian
 "
108: if flg2;
 cfg 2;" Date
 too late  "→P$;
 gsb "input"
109: if flg0;
 cfg 0;gto 99
110: rcf 63,A$
111: val(A$[14,
 15])→P
112: val(A$[16,
 17])→Q
113: val(A$[20,
 21])→R
114: val(A$[22,
 23])→S
115: dsp "Dial
 site. Continue
 when contact."
116: stp
117: dsp "Workin
 g."
118: wtb 717,"L"
119: wait 1000
120: if Z$[1,
 1]="1";gto "rea
 ltime"
121: spc 2
122: gsb "*"
123: prt "*Data
 Transfer**"
124: gsb "*"
125: spc 1
126: if P>R;gto
 131
127: for I=P to
 R
128: gsb "transf
 er"
129: next I
130: gto 137
131: for I=P to
 12
132: gsb "transf
 er"
133: next I
134: for I=1 to
 R
135: gsb "transf
 er"
136: next I
137: wait 1000
138: wtb 717,"C"
139: wait 1000
140: cli 7
141: dsp "Comple
 te."
142: end
143: "transfer":
144: if Imod4=0;
 "1"→Z$[2,2];
 str(31+Q)→D$;
 gto 148
145: if Imod2=0;
 "0"→Z$[2,2];
 str(31+Q)→D$;
 gto 148
146: if (I+1)mod
 4=0;"1"→Z$[2,
 2];str(Q)→D$;
 gto 148
147: "0"→Z$[2,
 2];str(Q)→D$
148: D$[2,3]→Z$[
 3,4]
149: "Track  ,
 File   :"→P$[1,
 16]
150: Z$[2,2]→P$[
 7,7];Z$[3,4]→P$
 [14,15]
151: prt P$
152: ""→F$
153: rct 728
154: wait 1000
155: ras 7,64
156: wait 3000
157: jmp bit(5,
 rds(7))
158: wrt 731,Z$
159: wait 1000
160: jmp bit(4,
 rds(7))
161: red 731,F$
162: ras 7,0
163: trk val(Z$[
 2,2])
164: rcf val(Z$[
 3,4]),F$
165: prt F$[1,4]
```

```
166: spc 1
167: if I=R and
 Q=S;gto 174
168: if Q=28
 and I=2 and
 val(A$[12,13])m
 od4#0;gto 173
169: if Q=29
 and I=2;gto 173
170: if Q=30
 and (I=4 or
 I=6 or I=9 or
 I=11);gto 173
171: if Q=31;
 gto 173
172: Q+1→Q;gto
 144
173: 1→Q
174: ret
175: "realtime":
176: spc 1
177: prt "*Press
  STOP to  end
 real-time."
178: spc 2
179: pct 728
180: wait 1000
181: rms 7,64
182: wait 3000
183: jmp bit(5,
 rds(7))
184: wrt 731,Z$
185: rms 7,0
186: jmp bit(4,
 rds(7))
187: red 731.1,
 A,N
188: fxd 2;dsp
 "W:",A,"dbm
   B:",N,"dbm"
189: wait 200
190: gto 186
191: "julian":
192: if val(J$[5
 ,6])>val(J$[11,
 12]);sfg 2;gto
 197
193: if val(J$[5
 ,6])<val(J$[11,
 12]);gto 197
194: if val(J$[1
 ,2])>val(J$[7,
 8]);sfg 2;gto
 197
195: if val(J$[1
 ,2])<val(J$[7,
 8]);gto 197
196: if val(J$[3
 ,4])>val(J$[9,
 10]);sfg 2
197: ret
198: "*":
199: prt "******
 *********"
200: ret
201: "input":
202: spc 2
203: prt "XXXXXX
 XXXXXXXXXX"
204: prt " Inval
 id entry: "
205: prt P$
206: prt "XXXXXX
 XXXXXXXXXX"
207: spc 1
208: sfg 0
209: ret
*24031
```

Appendix III. Data Printing Program

```
0: dim D$[16],
 F$[2000],P$[16]
1: ent "Enter
 desired track."
 ,A
2: jmp flg13#1
3: ent "Enter
 first file.",B
4: jmp flg13#1
5: ent "Enter
 last file.",C
6: jmp flg13#1
7: for I=B to C
8: trk A;ldf I,
 F$
9: spc 4
10: "Track"→P$[1
 ,5]
11: str(A)→P$[6,
 7]
12: ", File"→P$[
 8,13]
13: str(I)→P$[14
 ,16]
14: prt P$
15: "Data date:
 "→P$[1,12]
16: F$[1,4]→P$[1
 3,16]
17: prt P$
18: for J=11 to
 len(F$)
19: if F$[J,J]=c
 har(126);char(1
 3)→F$[J,J]
20: if F$[J,J]=c
 har(125);char(1
 0)→F$[J,J]
21: next J
22: spc 2
23: "Winchelsea
 "→P$[1,12]
24: F$[1,4]→P$[1
 3,16]
25: prt P$
26: 10→K;gsb
 "decode"
27: spc 2
28: "Bangor
 "→P$[1,12]
29: F$[1,4]→P$[1
 3,16]
30: prt P$
31: pos(F$,"BBBB
 ")+5→K;gsb "dec
 ode"
32: next I
33: dsp "Finishe
 d."
34: end
35: "decode":
36: for L=0 to
 23
37: spc 1
38: "-"→P$[5,5]
39: ":"→P$[10,
 10]
40: L*100→S
41: (L+1)*100→T
42: if L=0;"0000
 -0100"→P$[1,9];
 gto 49
43: str(S)→D$
44: if S<1000;
 "0"→P$[1,1];
 D$[2,4]→P$[2,
 4];gto 46
45: D$[2,5]→P$[1
 ,4]
46: str(T)→D$
47: if T<1000;
 "0"→P$[6,6];
 D$[2,4]→P$[7,
 9];gto 49
48: D$[2,5]→P$[6
 ,9]
49: prt P$[1,10]
50: for M=1 to
 10
51: gsb "numbers
 "
52: if R=0;gto
 65
53: fxd 2
54: if M=3;R/-
 100→R;prt "avg
 dbm",R;gto 65
55: fxd 0
```

```
56: if M=1;prt
 "# valid",R;
 gto 65
57: if M=2;prt
 "# bad",R;gto
 65
58: if M=4;-1*
 R+R;prt "med
 dbm",R;gto 65
59: if M=5;prt
 "#10 db fades",
 R;gto 65
60: if M=6;prt
 "#15 db fades",
 R;gto 65
61: if M=7;prt
 "#20 db fades",
 R;gto 65
62: if M=8;prt
 "#25 db fades",
 R;gto 65
63: if M=9;prt
 "#30 db fades",
 R;gto 65
64: if M=10;prt
 "*System Startu
 p*"
65: next M
66: next L
67: spc 1
68: prt "SIG
 DISTRIBUTION"
69: prt "sig
 pwr  #samp"
70: for N=-90
 to -45
71: gsb "numbers
 "
72: fxd 0
73: str(N)→P$[1,
 3]
74: "dbm"→P$[4,
 8]
75: str(R)→P$[9,
 16]
76: prt P$
77: next N
78: ret
79: "numbers":
80: if F$[K+1,K+
 1]#char(127);
 gto 83
81: 0→R
82: K+1→K;gto 92
83: if F$[K+2,K+
 2]#char(127);
 gto 86
84: num(F$[K+1,
 K+1])→R
85: K+2→K;gto 92
86: if F$[K+3,K+
 3]#char(127);
 gto 89
87: num(F$[K+1,
 K+1])*125+num(F
 $[K+2,K+2])→R
88: K+3→K;gto 92
89: if F$[K+4,K+
 4]#char(127);
 gto 92
90: num(F$[K+1,
 K+1])*15625+
 num(F$[K+2,K+
 2])*125+num(F$[
 K+1,K+1])→R
91: K+4→K
92: ret
*31473
```

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