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Stability of GMRT Optical Fiber System

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Abstract

The GMRT optical fiber link is stable to the order of 1 dB[1] over 40 hours (long term stability) and 0.4 dB over 50 minutes (short term stability). The short term phase variation is negligible ie. in the order of a tenth of a degree (@ 106 MHz). The long term phase measurements show a 24 hour cycle whose amplitude increases with fiber length as expected (a maximum of about 25° at 106 MHz).

1 KEYWORDS

Optical Transmitter, Optical Receiver, RF Loopback, Forward Link, Return Link, New Receiver Room (NRR).

2 SOME DEFINITIONS

RF Loopback - The forward link optical receiver [ORx(F)] output is looped back to the return link transmitter [OTx(R)] input.

Back to Back Configuration - Optical transmitter pigtail end is connected straight to an optical receiver, bypassing lengths of optical fiber cable.

Optical Loopback - At antenna base, the forward link optical fiber is coupled to the return link cable, bypassing the OTx-ORx pair at shell.

3 SCOPE

The report attempts to give a reasonable picture of the amplitude (electrical signal loss or gain) and phase variations occurring due to the optical fiber system. The variations of the LO signals in ABR system will be dealt in a separate note.

[1] Amplitude measurements in the note refer to the Electrical signal ratio, unless otherwise specified.

4 INTRODUCTION

The optical fiber link stability is of paramount importance to the GMRT as the communication between the central building and a remote antenna is solely dependent on its health. Hence, the primary aim was to study the link for any power fluctuation espcially due to installation irregularities like improper connector mating, bad fiber routing etc. Moreover, the phase difference between the antennas have to be constant for accurate mapping of astronomical objects, in the interferometric setup. Hence, the optical fiber system which carries the Local Oscillator reference signals to remote antennas and the IF signals from the base, should be stable during the observation time.

5 MEASUREMENT SET UP

Figure 1 illustrates the RF loopback test configuration. The test tone used is either 150 MHz (-20dBm) from a signal generator, 106 MHz LO reference signal of the forward link or 255 MHz signal synthesized at the NRR. The looped back signal is taken out from the optical receiver PIU at NRR through the LO round trip port [**Port 'C'**] available at the PIU back panel.

6 RESULTS

Table 1 gives the summary of amplitude and phase variations of the optical fiber system.

Two distinct features are noticed in the phase plots (refer **Figure 2**) which are classified as short cyclic variation (~50 min.) and long term variation (24 hour cycle). The short cyclic variation is due to the temperature variation inside the NRR. This pattern is clearly seen for nearby antennas while the other phenomenon which is due to the variation of fiber length with underground temperature, manifests as slow variation in phase over 24 hours for long lengths of optical cables.

Table 2 summarizes the short variation observed for various antennas. These variation correlate to a great extent with the temperature fluctuation at the NRR (**Figures 2 to 5**). Hence, further experiments were done to pinpoint the component causing this variation. A pair of OTx-ORx was connected back to back in the receiver room and the phase variations were acquired. Simultaneously, phase variation experienced by an equal length of RG223 cable (similar to the one used to connect the ORx output to the VVM [Vector Volt Meter]) was observed. It was found that phase variations in the second case was comparable to the one from the OTx-ORx back to back configuration (**Figure 6**). The test setup for this measurement is shown in **Figure 7**. We use the data from **Figure 2** to calculate the effect of temperature variation on the RG223 cables. For eg., at 13 hours on 4th of July [**Figure 4**], $\Delta T = 4^o$ C. Therefore,

$$\Delta\Phi = 360^o \times 5m \times 4^oC \times 10^{-4}/2.83m$$
$$= 0.25^o$$

But the measured phase change [from **Figure 3**] is about 0.4^o. Again, assuming a similar temperature change on 17th May 1997 [refer **Figure 6**],

$$\Delta\Phi = 360_o \times 5m \times 4^oC \times 10^{-4}/1.17m$$
$$= 0.6^o$$

But the measured value is about 1^o. So, the RG223 cable effect seem to explain only about half the value. Hence, another experiment was done on 19th May 1997 using the same setup as in **Figure 7**. Here, the effect of temperature on a long length ($\sim$ 10m) of optical fiber pigtail was studied. **Figure 8** shows the result, in which the plot **C** is of our current interest. When compared with the plot **C** of **Figure 6** where the pigtails were housed inside the OTx and ORx PIUs, we find no significant difference in the phase response. So, we suppose that the unexplained part of the phase change is due to the Mux. PIU [**Figure 7**]. This ofcourse, remains to be seen by bypassing that unit.

A passing look at **Figure 6** shows that phase changes are more whenever the ABR system is included in the device under test (DUT). Further investigation are planned to study the behavior a bit thoroughly.

Table 3 shows the effect of underground temperature variation on long length of optical fiber cables. The change in the path length effected by underground temperature fluctuation should linearly increase with fiber length (at a given test frequency). But owing to certain environmental factors like amount of solar radiation received, soil specific heat capacity, moisture content, soil type etc., the linear effect is not clearly seen.

Since, the phase difference (*B-A mode of VVM*) increases [refer **Figure 2**] generally between 17 Hours (5 PM) and 31 Hours (7 AM, following day), the soil temperature too must be increasing gradually during this period. This delayed temperature variation with respect to the ambient change may be due to the soil re-radiation at night time. This gradual increase is followed by a relatively faster cooling period which can be seen as a sudden decrease in phase, between 7 AM and 3 PM.

The path length variation which is measured can be used to calculate the amount of underground temperature variation for a given link if the temperature coefficient of the optical fiber is known. From D. S. Sivaraj's thesis *Optical Fiber Communication System for the GMRT*, [eqn. 3-75],

$$\Delta\Phi/\Phi = 0.78 \times \alpha_{tc} \times \Delta T$$

and

$$\Phi = 2\pi F \eta L / c$$

where,

L is the link length, [m],
F is the frequency of the test tone, [Hz],
η is the refractive index of fiber core,
c is the velocity of light [m/s], and
α_{tc} is the thermal coefficient of optical fiber cable.

This expression is used to arrive at the underground temperature variation for various antennas during different weather conditions. See **Table 4** for results. This shows that the temperature at 1 meter below the surface varies about 0.4^o C in summer and about 0.1^o C in monsoon.

7 AKNOWLEDGEMENTS

I wish to thank Prof.G.Swarup for his guidance, Shri T.L.Venkatsubramani for his software, Ms. G.R.Bopardikar and P.R.Raybole for measurement help.

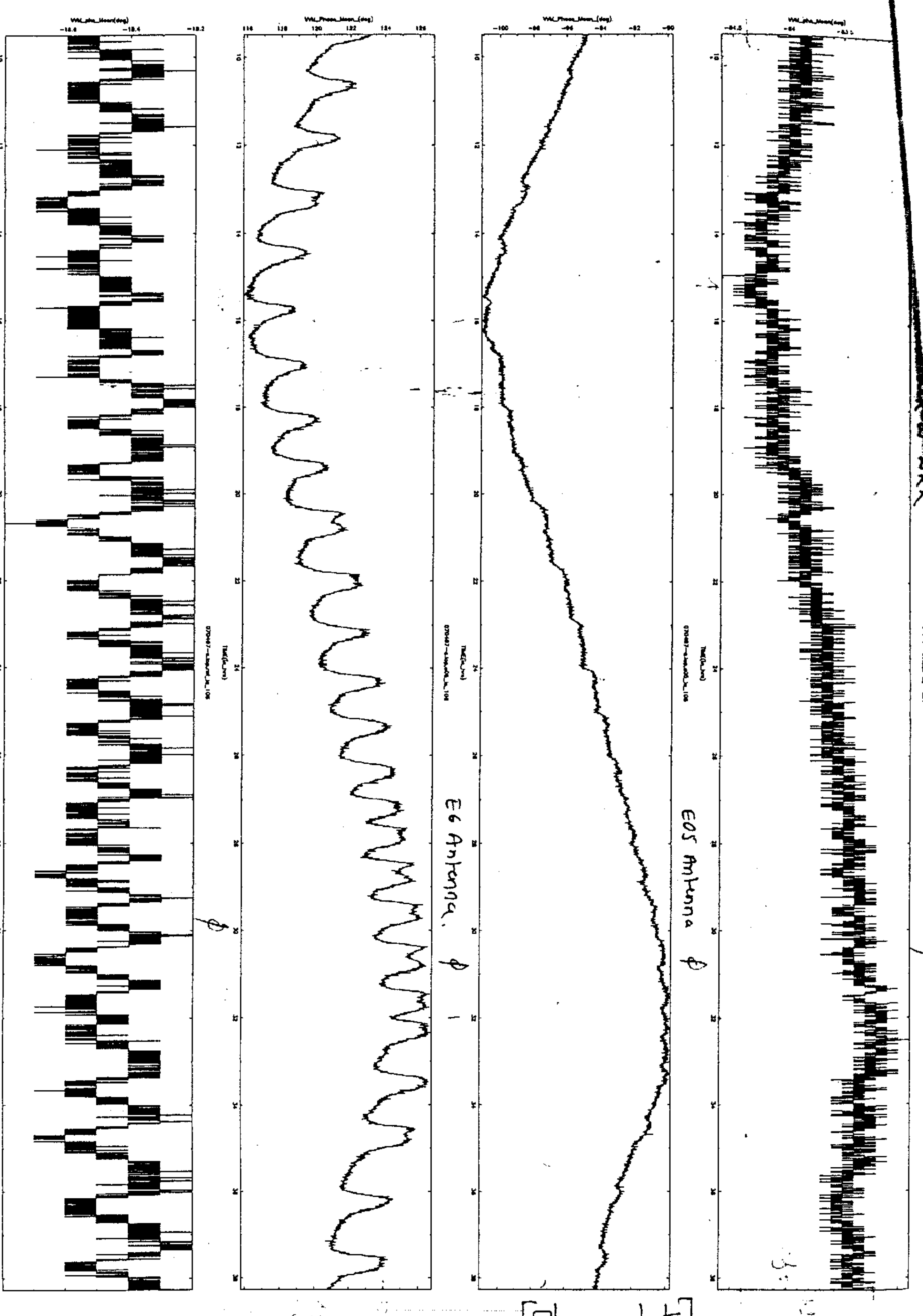


FIG. 2 [Phase plot]

RF Loopback Test Set up

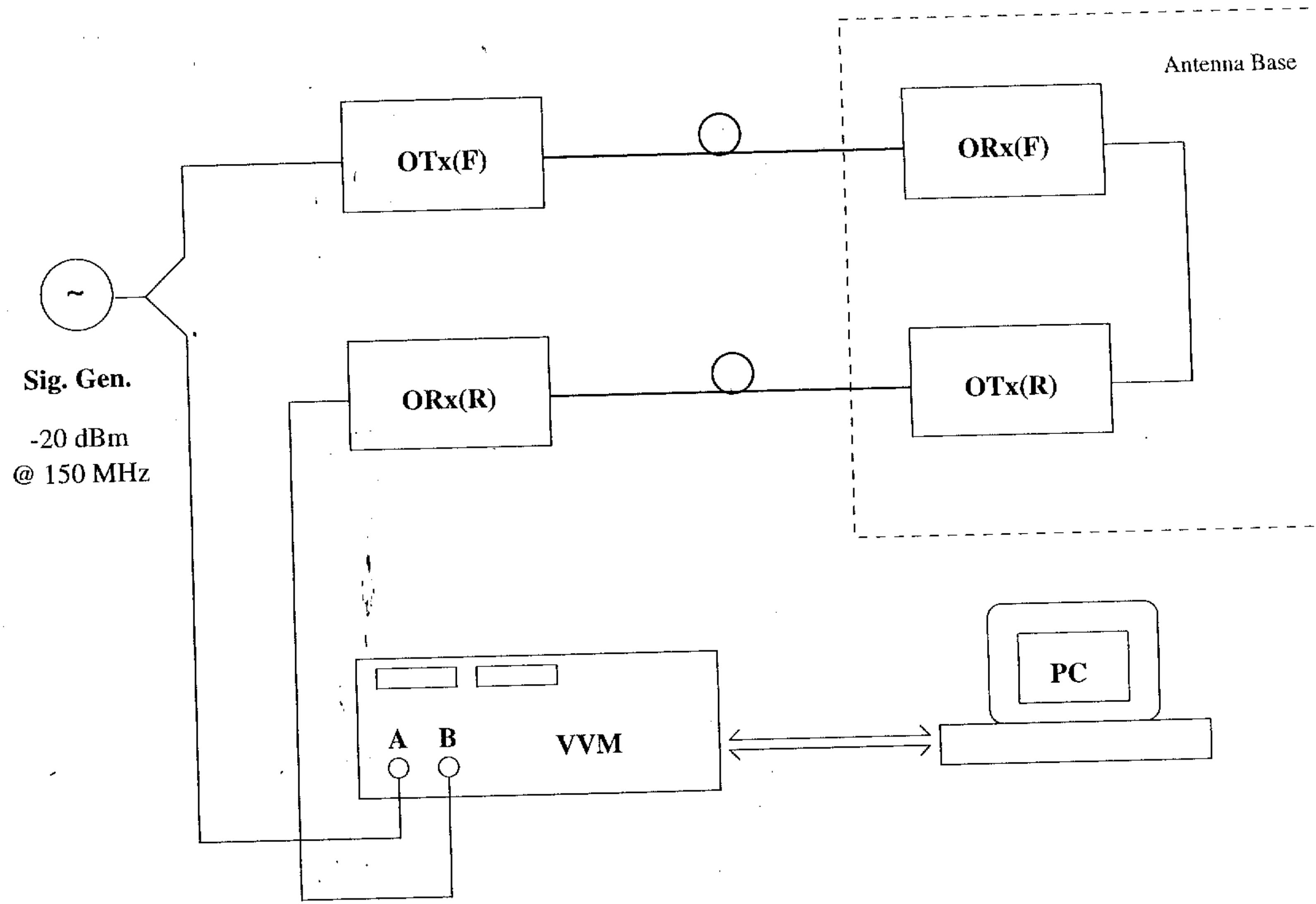
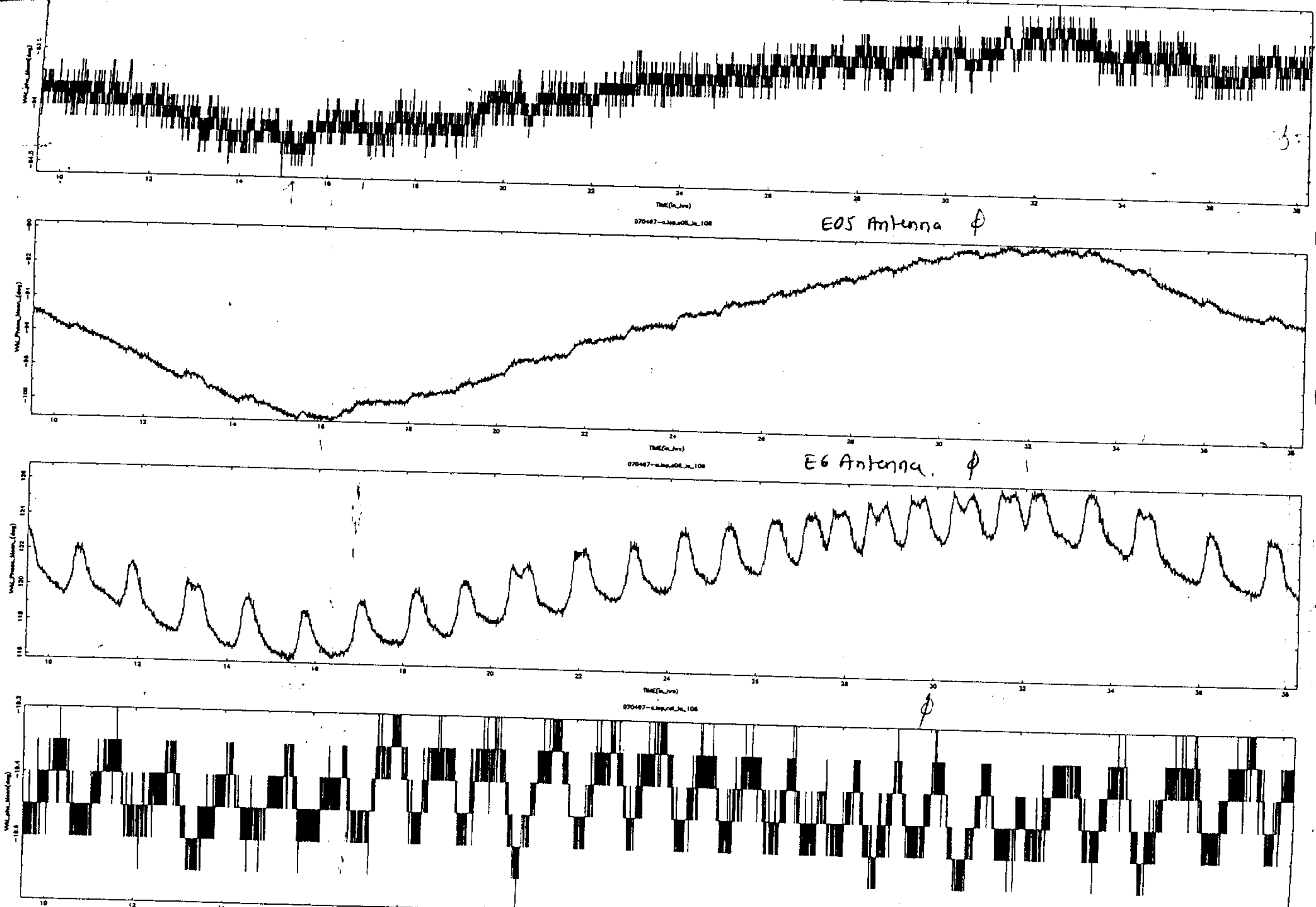


Figure 1.



TIME(in_hrs)
E05 Antenna φ
E6 Antenna φ
φ

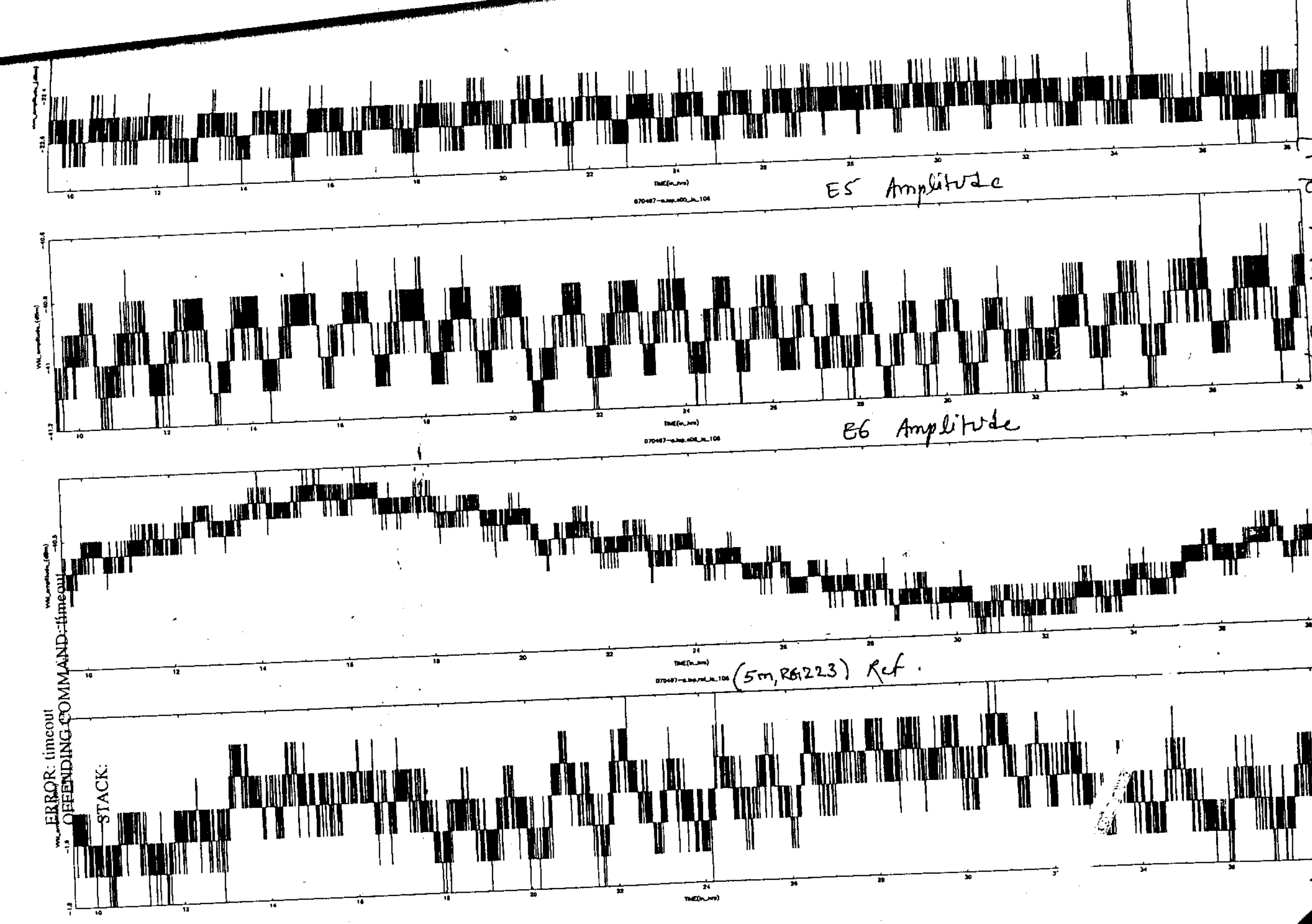
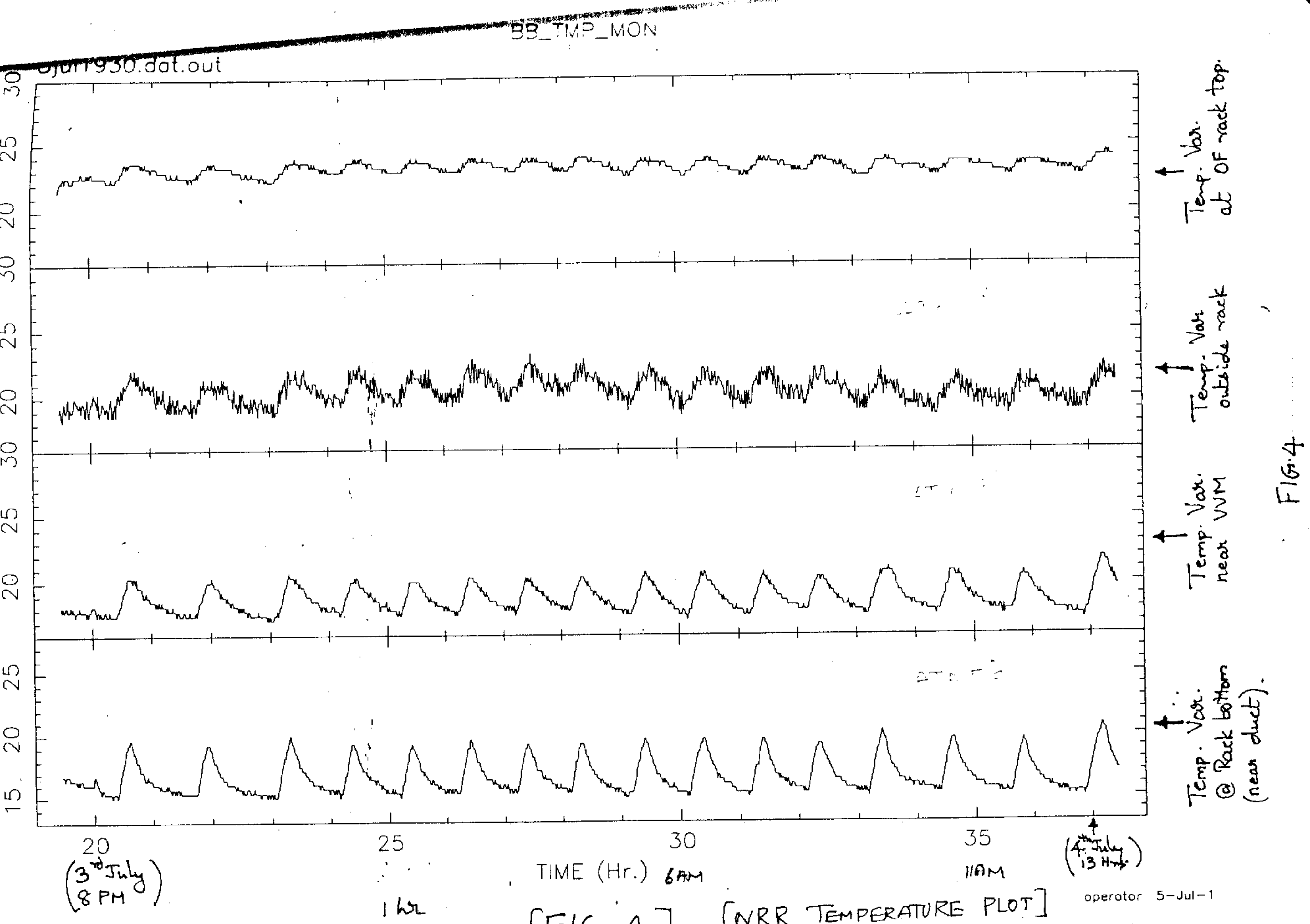


FIG. 3 [Amplitude Plot]



[FIG·4] [NRR TEMPERATURE PLOT]

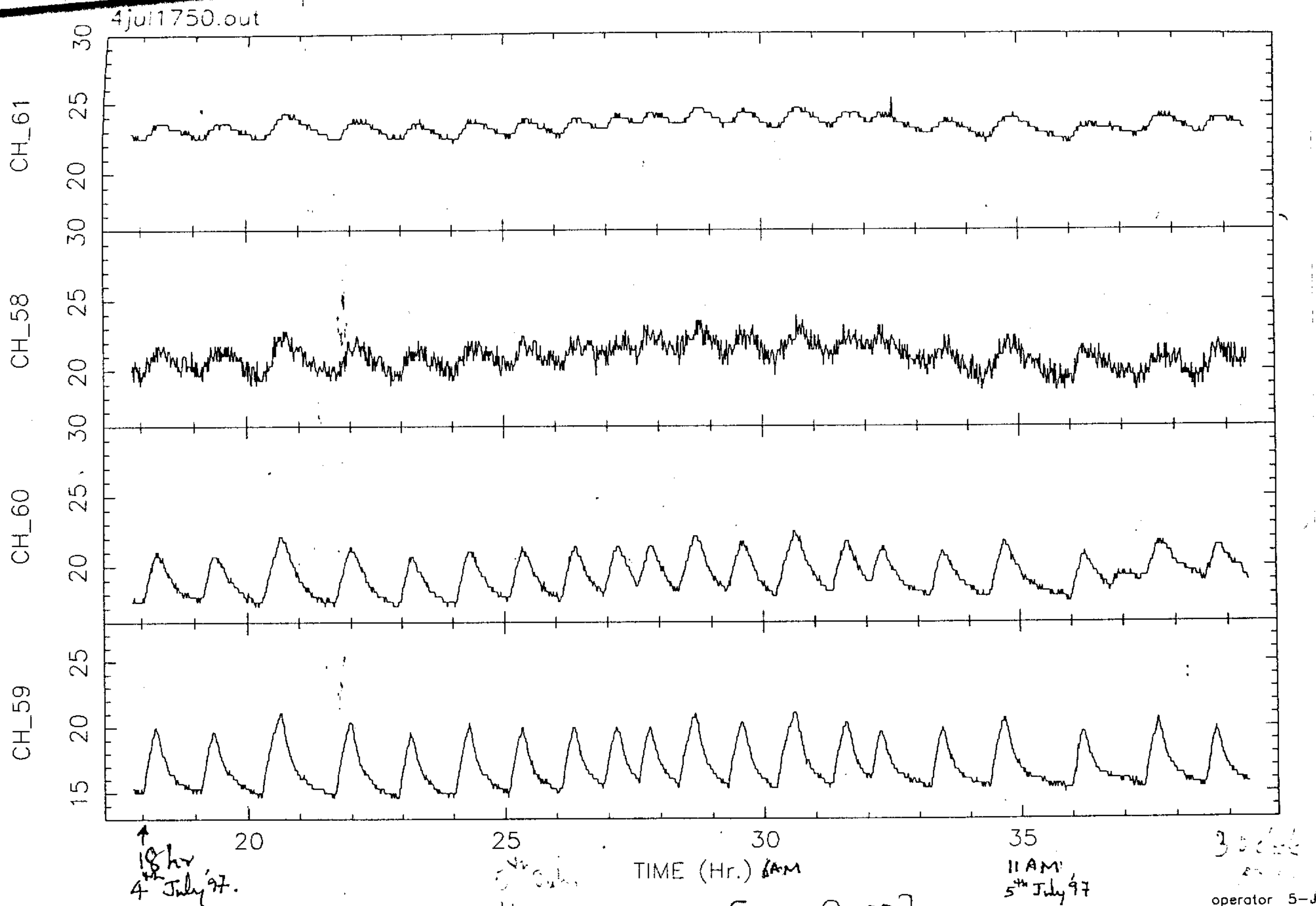
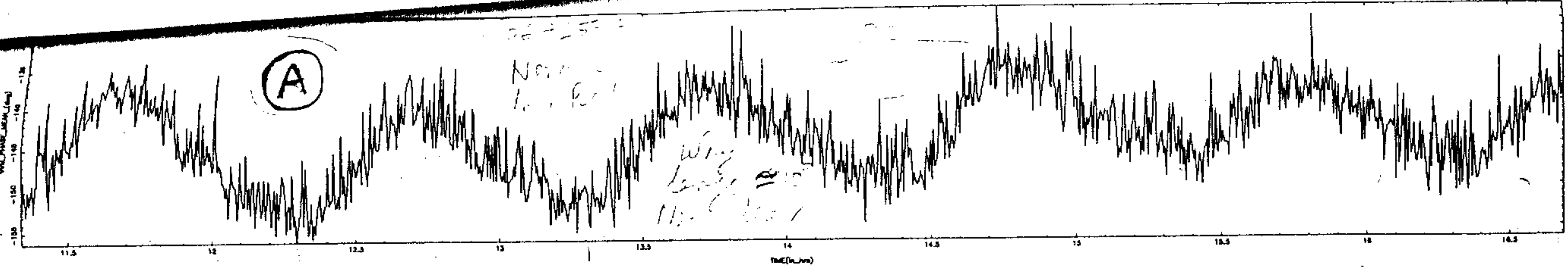
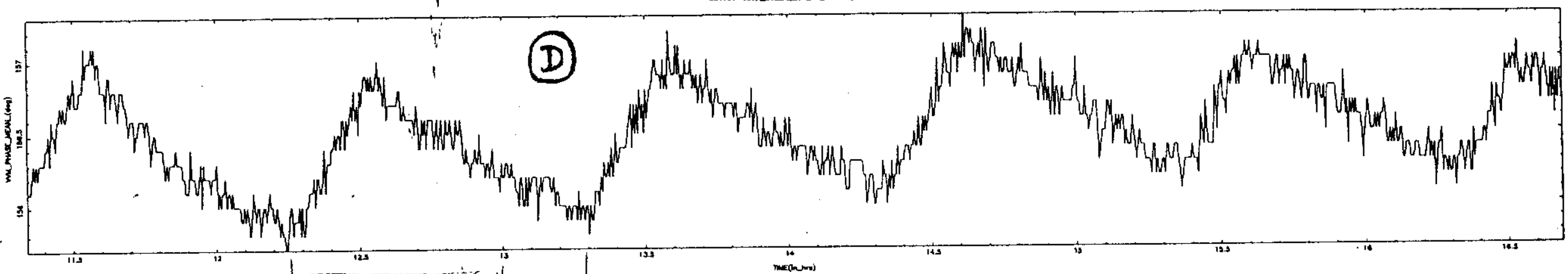


FIG. 5 [TEMP. @ NRR]



051797-c.lop_osc_lo_255_ref_3meters_cable



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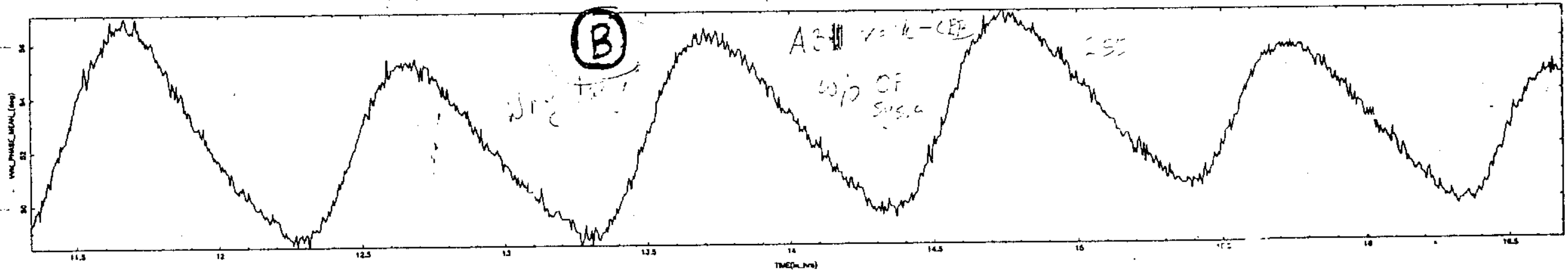
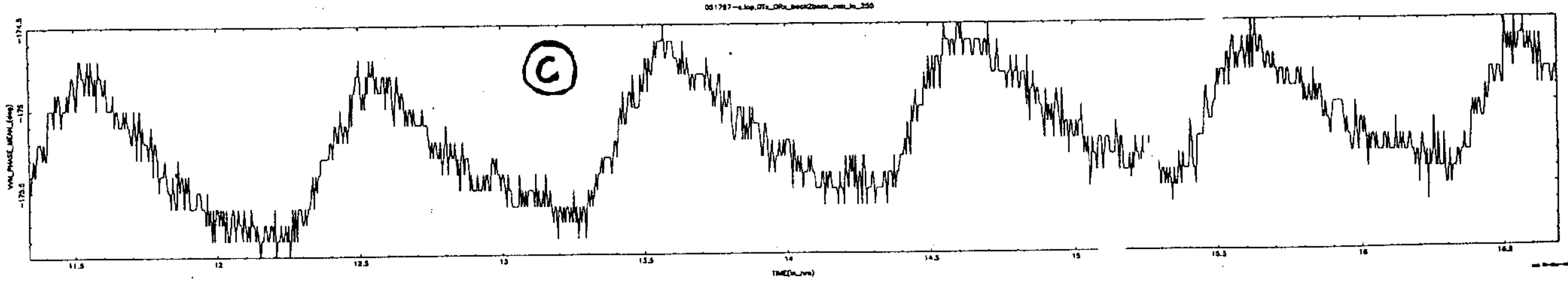


051797-c.lop.OTx_ORx_back2back_osc_lo_256



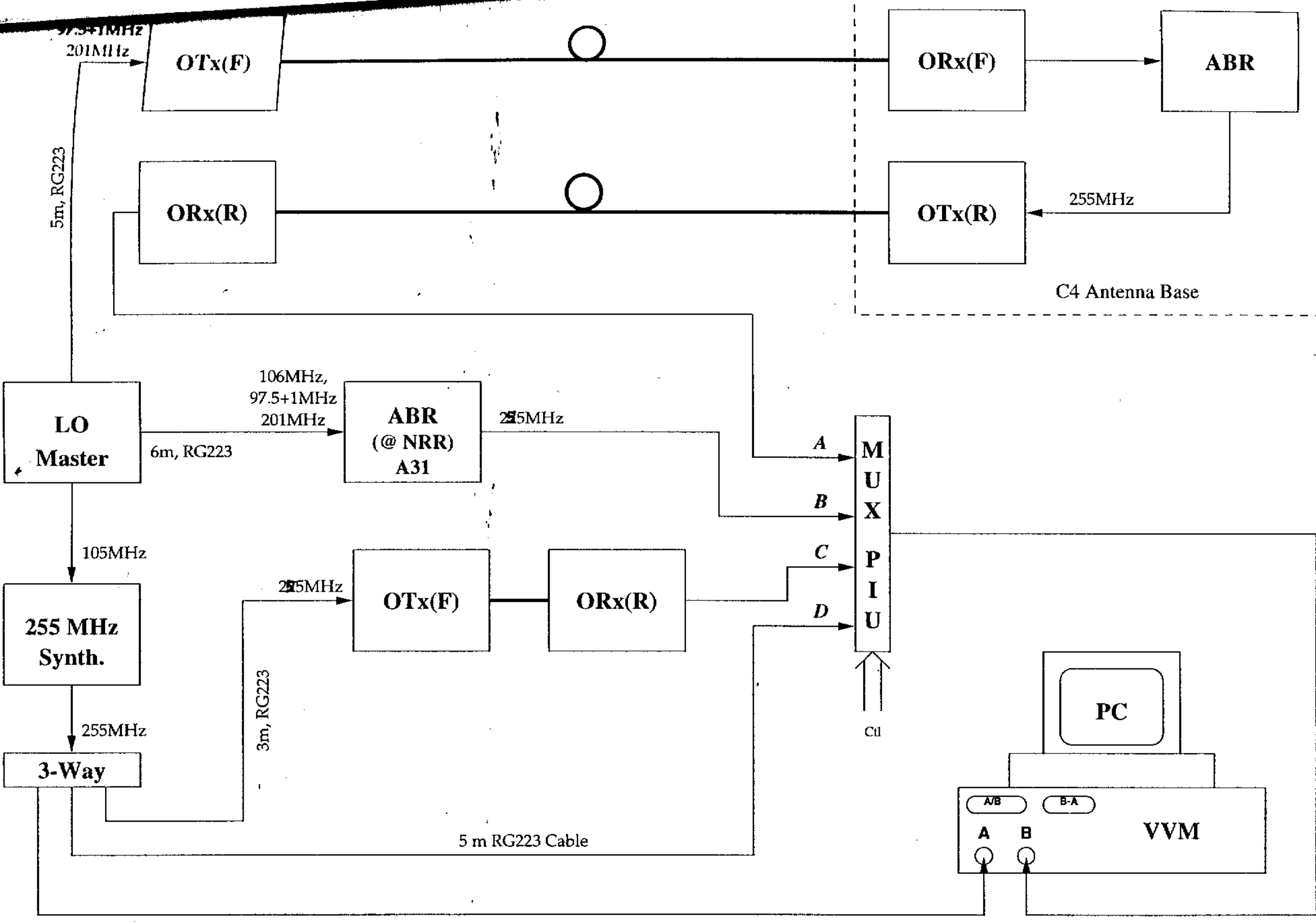


Figure - 7

Srini/of Iph

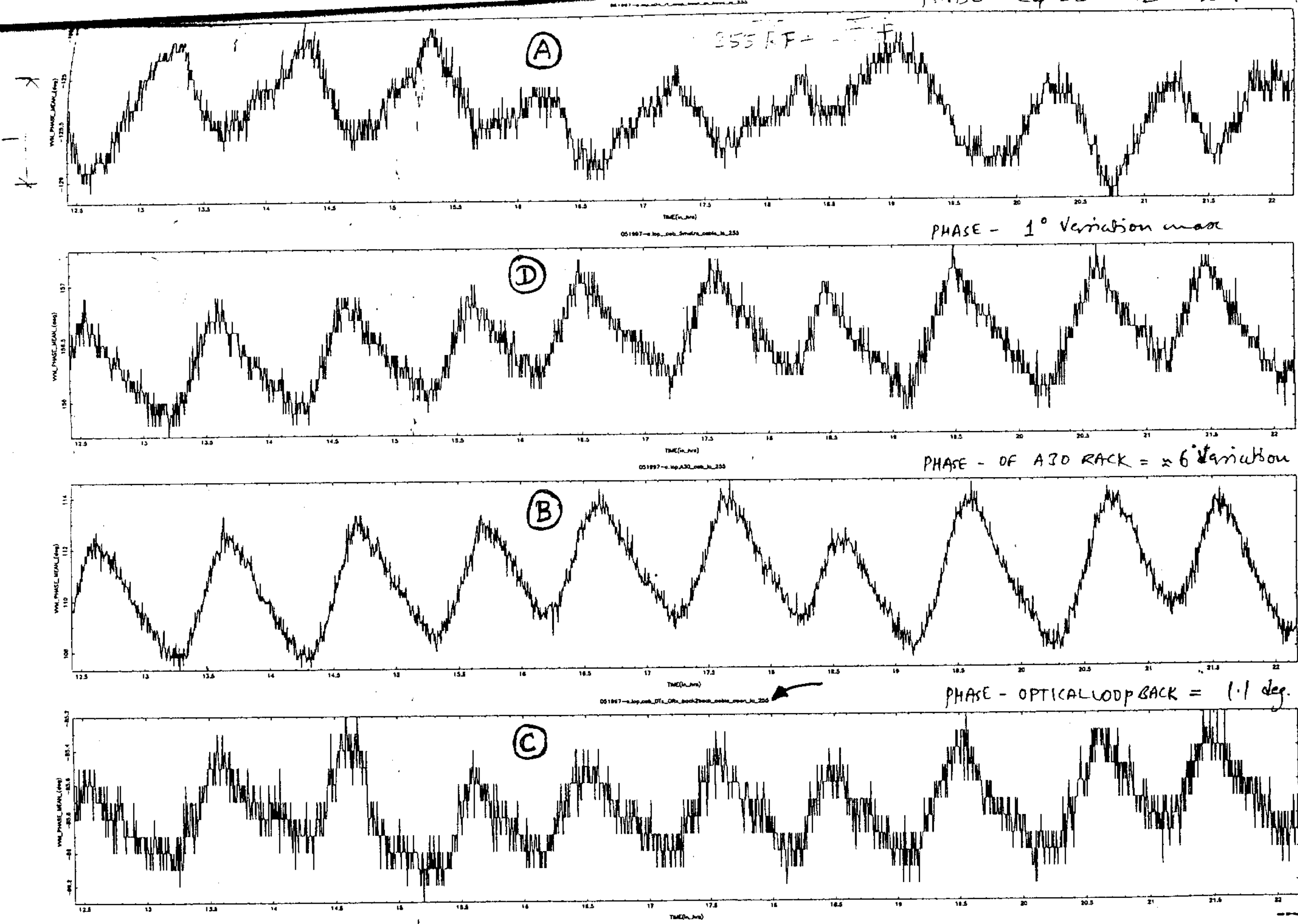

A
PHASE - 1° Variation max
D
PHASE - OF A30 RACK = ≈ 6° Variation
B
PHASE - OPTICAL LOOPBACK = 1.1 deg. Var
C
VNA_PHASE_MEAN_(deg)
TIME(in_hrs)
12.5
13
13.5
14
14.5
15
15.5
16
16.5
17
17.5
18
18.5
19
19.5
20
20.5
21
21.5
22

FIG. 8

TABLE - 1

Antenna	Max. Power Var. [dB]	Max. Phase Var. [deg]	Observation Period [Hr]	Remarks
C0	0.4	3	15	@ 150 MHz
C2	0.4	4	8	"
C5	0.6	5.5	25	"
C9	0.6	3.5	22	"
C10	0.7	3.4	18	"
C11	0.7	3.5	18	"
C13	0.7	7	18	"
W1	0.5	4.5	35	"
W2	0.6	9	22	"
W3	0.8	13	15	"
W4	1	10	15	"
E3	0.8	8	4.5	"
E4	0.5	26	16	@ 106MHz
E5	1	20	44	"
E6	1	24	45	"
S1	3.3	3	17	"
S4	0.5	21	44	"
S6	1.1	21	44	"

Amplitude and Phase variations observed for various optical fiber links under loopback condition.

riations include the effect due to twice the fiber length encountered under loopback condition.

TABLE - 2

Antenna	Approx. Cycle Period [Min.]	Amplitude Chng. [dB]	Phase Chng. [Deg]
C0	50	0.2	2
C2	50	0.4	1.5
C5	50	0.2	1
C9	50	0.1	0.6
C10	50	0.4	1
C10	24	0.6	2.5
C11	24	1	2
C11	50	0.8	-
C13	20	0.3	1
C13	60	0.2	1
W1	42	0.2	0.8
W2	24	0.6	1.5
W3	24	0.3	1
W4	50	0.1	1
E4	50	0.3	1
E5	60	0.4	3
E6	60	0.5	3
S1	60	2	0.8
S4	60	0.5	2
S6	60	0.6	3

These short term variations are correlated with temperature fluctuations in NRR.

TABLE - 3

Antenna	Measurement Date	Time of Phase Min. [Hour]	Time of Phase Max. [Hour]	Phase Chng. [Deg]	Remarks
C5	15 Jan 97	14	31	4.7	☀
C9	03 Jan 97	16	31	2.4	—
C13	03 Jan 97	21	31	1.5	—
C13	04 Jul 97	15	32	1.2	☁
W1	03 Aug 96	15	30	3.5	—
W2	22 May 96	18	31	11	☀
W2	03 Jan 97	17	32	9.5	—
W3	16 May 96	18	31	7.6	☀
W3	29 May 96	17	31	14	☀
E4	20 Jan 97	17	32	22.5	☀
E4	22 Jan 97	18	32	23.5	☀
E5	15 Apr 97	17	31	17	☀
E5	21 Apr 97	15	31	18	☀
E5	04 Jul 97	16	32	11	☁
E6	15 Apr 97	18	31	17	☀
E6	21 Apr 97	15.5	31.5	19	☀
E6	04 Jul 97	15.5	31.5	8	☁
S4	15 Apr 97	18	31	15	☀
S6	15 Apr 97	15	31	18	☀
S6	21 Apr 97	15	31	16	☀

This table shows the duration and amount of the gradual phase change as the underground soil temperaure varies

☁ Cloudy day

☀ Sunny day

TABLE - 4

Antenna	Measurement Date	Round Trip Fiber Length 'L' [m]	Path Length Phase [Deg]	Change in Path Length [Deg]	△ Temp. [°C]
C5	15 Jan 97	2064	3436	4.7	0.80
C9	03 Jan 97	1738	5787	2.4	0.48
E4	20 Jan 97	20850	69430	22.5	0.39
E4	22 Jan 97	20850	69430	23.5	0.38
E5	15 Apr 97	29956	99753	17	0.32
E5	21 Apr 97	29956	99753	18	0.21
E5	04 Jul 97	29956	99753	11	0.13
E6	15 Apr 97	36220	120613	17	0.16
E6	21 Apr 97	36220	120613	19	0.18
E6	04 Jul 97	36220	120613	8	0.08
S4	15 Apr 97	27338	91036	15	0.19
S6	15 Apr 97	39744	132348	18	0.14
S6	21 Apr 97	39744	132348	16	0.14

this table the measured path length variations for various antennas under loopback condition are used to compute the change in underground temperature.