PAPER NO. 447

FADING ON INDUS VALLEY MICROWAVE LINK

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I- This paper is an attempt to describe in general terms the experience gained regarding propagation conditions on Microwave frequencies in Pakistan. More precisely only the propagation in the line-of-sight mode has been considered in the 6000 MHz band. Like many latest scientific and engineering fields the records of the country are barren in this field also with the obvious result that for design of new microwave routes to meet the growing long distance telecommunication traffic needs, no definite data is available. Hence till recent past the design of the systems was worked out using assumed constants in calculation formulae.

Although the first radio relay system in the 2000 MHz band was installed in the country in 1964 but somehow propagation studies could not be carried out to collect such data. Microwave band of interest is spread from 2000 MHz to 10,000 MHz (now extended to 30,000 MHz) from practical point of view and each band namely 2000 MHz, 4000 MHz, 6000 MHz, 7000 MHz, 8000 MHz has distinct propagation features in peculiar climatic regions which can be gauged only by measurements in each band over long periods of time which is 1½ year to 2 years. One way to do it, was by using the special propagation test equipment. Second method which is equally fruitful is to gather data by continuously monitoring the performance of the installed and working Microwave Systems in the country alongwith meteorological conditions and work out design factor duly correlated with climatic and topographical conditions over the Microwave link route. This has been carried out on the largest link of the country i.e. Karachi-Rawalpindi M/W system operating in 6000 MHz and methodology and results are mentioned in this paper.

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II- Theory - Recapitulation

1. Atmospheric Effects

It may be known to the reader that like light rays the actual path of microwave rays propagation in the atmosphere is not a straight line but is in fact in shape of a curve. This path is curved because of bending of the waves due to changing reflective index of the atmosphere with the height above the earth. As the velocity of the microwave ray front propagation depends on the dielectric constants of the air any change in the value of this constant in the path of propagation results in different microwave velocity at various heights in the path of travel. Normally the dielectric constant or reflective index of the atmosphere decreases gradually with the increasing height above the ground and this increase is linear. The microwave frequencies propagating in such an atmosphere bend downwards the earth. This condition of the atmosphere is called the normal or standard atmosphere. However, certain meteorological conditions do occur which make dielectric constant increase with the increasing height. Propagation in such conditions makes the microwave beams to bend upwards away from the earth. This is called subnormal atmosphere. The normal atmosphere extends the range of line-of-sight propagation and produces an effect like flattening of the earth with respect to the radio beam. In other words an effective earth radius Re is experienced which is different than the actual earth radius R_o The relationship between the two is given by

$$Re = KRo$$

where K is a constant and for standard atmosphere has a

value K = 4/3.

In the subnormal atmospheric conditions the beam bending away from the earth produces an effect like causing the earth to bulge out as compared to its normal condition. This results in Re being less than Ro. Putting in equation form Re = KRo where $K < 1$. (0.5 to 0.7). Now value of K differs from one area to the other deperding on climatic conditions and over the year. To have properly working microwave system the correct values of K must be used. Its determination however depends on collection of Met: data.

A third condition of atmosphere is the existence of layers of atmosphere with non-linear or changing values of the refractive index.

In such conditions the refractive index is like that of normal atmosphere upto some height but after some distance above the ground it becomes subnormal as shown in Figure-2. Normally temperature and humidity decrease with the height but there are periods of time where humidity can increase after a certain height and similarly temperature which normally decreases with the increasing height on clear and cool night over rapidly cooling ground areas can produce temperature inversions. This temperature inversions can start from the ground level or from some height above the grounds. Such conditions produce super-refractive effects in radio M/W beams and in some cases can cause a phenomenon called ducting. The duct produced between the ground and super-refractive layer or between two layers traps the radio waves as if it is a radio transmission line (i.e. wave-guide) and can lead M/W beams to directions away from the receiving points causing fading.

The super- refractive layers can also cause multi path propagation i.e. the same signal from the transmitting station arrives at the receiving point via other paths in addition to the direct path. Depending upon the phase difference between the signals arriving on different paths, these vectors get summed up or cancelled causing abnormal fluctuation of the output received signal level causing "fading". (Fig.3). For more clarification the phenomenon of ducting is explained below by reproduction from a text.

i) Radiation

The surface heat loss produced by nocturnal radiation (under clear skies and calm or low surface winds) is a prime factor in the formation of temperature inversion, Low stratus clouds or extreme amounts of moisture (as in the tropics) tend to prevent loss by radiation which lessens the possibility of duct formation and for these reasons radiation ducts are more common in middle and northern latitudes like Pakistan than in the tropics.

ii) Advection

Movement of dry, warm air over a relatively cool sea or large body of water (or even wet, cold ground). The air in the immediate vicinity of the cold surface is cooled and water evaporates into it, bringing out the necessary conditions for a duct to form. The resulting stable condition tends to maintain itself, upward diffusion occuring only slowly so that advective ducts persist over longer periods

of time and over large areas. These ducts are common in most temperate and some tropical areas, specially on eastern side of land masses situated in the westernly wind belt.

Pakistan is a land of rivers. Particularly the M/W link under review, for most part, goes along the banks of river Indus, which forms a large body/stretch of waters with cloudless skies. Even the ground on the path is wet being irrigated. So conditions for inversion are very conducive.

iii) Subsidence

Slow settling of air forms a high pressure area. The air is heated by adiabatic compression as it descends and spreads out in a layer over the colder air mass below. This type of inversion may cause the formation of an elevated superrefractive layer (or duct) so that in the given area the temperature decreases normally above the ground, increases inside the layer and then again decreases above the layer. This is common occurrence in any area at high elevations, but is also occasionally observed at lower levels particularly in subtropics.

In the presence of ducting, the fading mechanism in the point to point microwave systems will depend on the geometry of the path, type of duct, its thickness and the value of the refractive index inside the duct. Several cases may be considered:

a) A duct may exist above both the transmitting and receiving antennas. In this case M/W beams reflections from the duct may arrive at the receiving antenna with such an amplitude and phase as to cancel the received signal and causing severe fading.

b) A duct located above the transmitting antenna but it is below the receiving antenna. In this case the transmitted beam will behave depending on its angle of incidence. It can be either trapped in the duct, reflected from the layer or may pass through it, but its direction will be changed and it can miss the receiving antenna.

c) A duct formed on the surface and which encompasses the transmitting antenna can make the signal travel by successive reflection from the ground and superrefractive layer attenuating it greatly. (It can also conduct the wave directly to

the receiving antenna if it is also inside this duct and a very strong received signal may result).

Our experience based on short term measurement of temperature and humidity at different heights in two stations indicate that ducts are formed in Pakistan at 30 ∿ 50 meter height. The transmit and receive antenna remain above the duct but the surface of the superrefractive layer is penetrated by beam in the middle of the path near the point of minimum clearance causing bending of rays and attenuating it. Occasionally it also results in reflections and fading.

2. Reflection from Ground

In addition hops traversing intensely irrigated farms e.g. rice fields or small vegetation areas have reflections from the ground.

As will be described later the hops over uneven dry arid (or barani) areas i.e. Mianwali-Rawalpindi section of the M/W link have no serious fading problem.

III- SYSTEM - GENERAL CHARACTERISTIC

Karachi-Rawalpindi/Faisalabad microwave system was installed in 1975. It operates in the 6 GHz band with a capacity of 960 telephone channel or a TV channel per R.F. bearer (One Karachi-Rawalpindi Telephony channel second Karachi-Faisalabad Telephony channel and one colour TV programme channel and a standby channel.) A fifth channel for Telephony has been added recently between Karachi and Shikarpur. The composition of the system is illustrated in the Figure-4. The system consists of one alignment from Karachi to Kot Addu but is later bifurcated into two directions i.e. to Rawalpindi and Faisalabad. The circuit length of the microwave system is as follows:

i) Main route	Number of hops	Distance
Karachi-Rawalpindi	31 hops	1292.2 km
Kot Addu-Faisalabad	5 hops	238.1 km

ii) Spur routes	Number of hops	Distance
Thano Bula Khan-Mirpur Khas	3 hops	114.7 km
Shikarpur-Sukkur	1 hop	35.9 km
Kot Addu-Multan	1 hop	57.3 km
Darya Khan-D.I. Khan	1 hop	21.1 km
Mianwali-Sargodha	3 hops	122.7 km
Sheikhupura-Gujranwala	1 hop	52.2 km
Total circuit length	46 hops	1934.2 km

The switching sections are also shown in Figure-4. The TP i.e. telephone channel or TV channel affected by fading or failure switch over to the standby channel in whole of the switching section.

IV- GEOGRAPHICAL POSITION AND TOPOGRAPHY

A map (Figure-5) shows all the stations of the system from geographically location stand point. Table-V gives the information about hop lengths and type of topography/terrain. The Microwave route starting from Sunn to Mianwali follows the river Indus which has wide expanse of water in it thus causing conditions favourable for ducting and formation of super-refractive layers. As shown in Table-V some of the hops are very close to the river.

V- DESIGN BASIS

Pakistan entered the microwave era in 1964 when Cento Microwave link was commissioned. This project was executed on turn-key basis using foreign consultancy service. It provided the ground for large scale training of T&T staff in the microwave technology, its maintenance and operation. This project was followed by Lahore-Rawalpindi M/W system which again was implemented on turn-key basis but no consultants were employed and supervision was done by Pakistani staff. This project provided opportunity to the staff for training in all solid-state microwave equipment, testing, maintenance and operation. At this stage the T&T developed the know-how in respect of the system, equipment installation

and line-up. So further advance was made in the next project i.e. Karachi Rawalpindi microwave system. Although huge in size (1934 km, 48 M/W stations) the turn-key mode was done away with and installation, testing and line-up of the equipment was carried out by T&T engineers under supervision of the contractor's engineers. Survey and System Design was done by the contractor's engineers. While working on this project T&T gained valuable experience in the evaluation of the link performance, probing for reasons of the difference between the designed performance limits and the actual results brought the engineers to design aspects of the microwave radio relay links. Designing of the link for a particular area on the other hand, requires use of certain factors which can be worked out from meteorological data and long term radio propagation test. As value of relevant factors in this regard are not available in respect of Pakistan, so the design of the links had to be carried out on certain assumptions which were not always true. As a result of this even experienced suppliers like M/s. NEC could not meet the performance limits on the Karachi-Rawalpindi link in the first step. So improvement measures had to be taken several times to meet performance limits. (Same thing happened with M/s. Toshiba on Lahore-Rawalpindi M/W link). Steps taken to evaluate the performance and selection of improvement measures has afforded an opportunity to T&T staff to understand the behaviour of microwave propagation in Pakistan to some extent. Although the data collected does not give us complete answer but still it has given us insight to collect data about various variables and in determination of their correlation. It may be made clear here that no equipment defect worth mention was encountered and only problem of excessive fading was experienced.

VI- PERFORMANCE SPECIFICATIONS

Pakistan T&T has adopted the CCIR specifications for this link. The CCIR has made recommendation concerning the amount of noise tolerable for given percentages of time for both Telephony and Television carried by microwave relay system.

For Telephony, CCIR Recommendation 395 may be summarised as stating that the psophometrically weighted noise power at a point of zero relative level in a circuit of L kilometres ($280 < L < 2500$ km) should not:

a) exceed 3 L picowatts mean power in any hour

b) exceed 3 L picowatts 1 min mean power for more than 20% of any month

c) exceed 47500 pw 1 min mean power for more than (L/2500)% of any month.

As the circuit differs from the CCIR hypothetical reference circuit the noise performance limits for different sections are calculated and given below:-

Table-I

Route		Number of hops	Circuit length	S/N + D (weighted) for 80% of time	Percentage of Time S/N should not fall below 40.7 dB unweighted
MAIN ROUTE	Karachi-Islamabad	31 TP-1	1,292.2	53.9dB	.052 %
	Karachi-Faisalabad	27 TP-2	1,164.1	54.1dB	.047 %
SPUR ROUTE	Kot Addu-Multan	1	57.3	64.3dB	.0112%
	Darya Khan-D.I.Khan	1	21.1	64.6dB	.0112%
	Mianwali-Sargodha	3	122.7	62.5dB	.0112%
	Sheikhupura-Gujranwala	1	52.2	64.5dB	.0112%
	Shikarpur-Sukkur	1	35.9	64.6dB	.0112%

For television CCIR Recommendation No.289 gives similar recommendations concerning the Signal/Noise ratios which should be

exceeded for all but specified percentages of any month. The calculated values for different sections in this regard are also produced below:

Table-II

Television Section	: Sp-p/Nrms= : (Weighted : value) : (dB) (X)	:For 20% :of :times :(X-4)dB	:For .1% :of time :(X-8)dB :
CCIR Hypothetical reference circuit.	52.0	56.0	44.0
Karachi-Rawalpindi	54.2	58.2	46.2
Karachi-Faisalabad	55.1	59.1	47.1
Karachi-Shikarpur	58.8	62.8	50.8
Faisalabad-Multan	60.7	64.7	52.7

VII- EVALUATION OF THE FADING PERFORMANCE OF THE LINK

i) Telephony (TP) Channel

After completion of the installation and testing of the equipment the microwave link was tested as a system on load in accordance with CCIR Recommendation No.395. In this case Noise loading tests (which simulate the loading of the TP channel upto its full capacity i.e. 960 telephone channel in this case) were carried out. On the received side the worst channel slot is monitored and the noise in the channel is recorded by means of electronic paper chart recorders continuously for one month. Although in steady state conditions the values of noise remained within the limit but evaluation over one month showed the following results.

(Table-III on next page)

Table-III

	: Spec.	: Actual:	Remarks
1: * KARACHI-RAWALPINDI ROUTE			
a) Time S/N(wt) should not fall below 53.9 dB	20%	26.8%	out of limit.
b) Time S/N(unwt) should not fall below 40.7 dB	.052%	0.63%	-do-
2: * KARACHI-FAISALABAD ROUTE			
a) Time S/N(wt) should not fall below 54.1 dB	20%	30%	-do-
b) Time S/N (unwt) should not fall below 40.7 dB	0.047%	0.49%	-do-
3: * MULTAN-KOT ADDU SPUR			
a) Time S/N (wt) should not fall below 64.3 dB	20%	18.88%	within limit
b) Time S/N (unwt) should not fall below 40.7 dB	.0112%	.092%	out of limit

*not the worst month.

VIII- COUNTER-MEASURE PLAN

In order to take counter-measure to improve the performance of the link it was necessary to analyse the data and determine the following:

1) Time of fading ——— Determination of worst month and worst hours

Fading on Microwave links depends on climatic conditions and follows a definite cycle and it is therefore necessary to conduct propagation measurement or collect fading data for a very long period to determine the worst month and worst hour. However, for this purpose, if in-band noise recording is carried out, the link cannot be utilized for traffic. To overcome this situation out-of-band noise recording is carried out simultaneously with the commercial traffic on the link as recommended by CCIR vide recommendation No.398-2. This has been done in

the present case also. The result of the noise recording has been plotted in the graphs attached. (Fig-6). As may be seen the worst month for all sections is generally October except Mianwali-Darya Khan section which appears to be a special case and January is the worst month there. In order to identify the worst hours in the fading the data of the worst month fade has been analysed and graphs are attached (Fig-7). As may be seen the worst fading hours occur just after sun-set and very early in the morning before sunrise. So the efficacy of any remedial measure has to be checked in the month of October. This was also confirmed by TV channel performance recording.

2) Determination of location of the fading

As already described each section of the Microwave link has a number of relay stations or hops. So we have to determine which are afflicted with fading. The first point is to examine length of each hop and its terrain. Longer hops with terrains conducive to reflection or formation of super-refractive layers are most likely trouble spots. A Table showing conditions of hops in Karachi-Rawalpindi and Karachi-Faisalabad is attached. The proper method to identify such hops is recording of the received signal level (AGC) to confirm the fading. However, in our case the following procedure was adopted.

At both ends of every section of the link supervision status of each relay stationis indicated. Whenever failure occurs at a station an alarm is sounded and indicated by lights for that particular station at the supervisory station where the number of times of failure/fading below switching level and their duration is noted. Then from the number of indications and their duration hops with excessive fading can be pin-pointed-(Fig.9).

3) Determination of type of fading

In theory, different type of fading have already been described. Now after location of the fading and identifying the hops which are suffering from excessive fading, determination of the type of fading is required so that relevant and appropriate counter-measure is taken to reduce/eliminate the fading. In this connection the pattern of fading as recorded on the chart is the best guide. Different types of fading exhibit different patterns of curves. The confirmation of the type of fading can be made by study of the terrain and topography and geographical conditions of the hop. Some sample charts showing fading pattern on different sections of Karachi-Rawalpindi/Faisalabad M/W link are attached (Fig.8). The type of

fading is mentioned on the each chart. Generally speaking duct type of fading due to temperature inversion is predominant. The fading due to reflections and multi path effects is also occurring.

4) Remedial Measure

As a result of above procedure hops with excessive fades were identified alongwith type of fading occurring on them. Accordingly, the following improvement plan was executed.

i) Space Diversity was added on 8 more hops of the link.

ii) Antenna size has been increased to give more gain on 10 hops.

iii) Low loss waveguide has been installed on 6 hops to increase the system gain.

iv) Low Noise Factor RF pre-amplifiers giving 3 dB improvement in Noise have been installed on 4 hops.

v) In order to increase the radio path clearance Tower height has been raised at 7 stations.

After this exercise the noise performance of the M/W link was again checked and performance values obtained are as under :-

Table-IV

Performance after Improvement Measures

	(3 L + X) pWop value CCIR —— 20%		47500 pW value CCIR —— .1%	
	Before*	After*	Before*	After*
Karachi-Rawalpindi	26.8%	6.1%	0.63%	Zero
Karachi-Faisalabad	30%	7.0%	0.49%	Zero
Kot Addu-Multan	18.80%	4.23%	0.092%	Zero
*not the worst month				

The Microwave link is now working satisfactorily although there is still room for further improvement (beyond the specified limits). With this end in view the noise performance monitoring is being continued and further improvement measures will be taken after identifying the troubled hops.

CONCLUSION

The data collected so far has made us wiser and added to the engineering expertise of the T&T personnel. The future microwave links are now being surveyed and designed by the T&T engineers themselves. However, the microwave field (being a mode of radio communication) is a dynamic field and each environment presents peculiar problems for planners and designers and therefore continuous studies have to be carried out and ready made solutions do not exist for all situations. But the more data available the better it is. So propagation performance of the existing links working in other frequency bands and in different geographical conditions is being monitored. However, the study will be incomplete unless the meteorological data in shape of temperature, relative humidity, barometric pressure is also recorded at the various heights above the earth along the propagation tests so as to establish correlation between radio propagation and Met data. For this purpose special propagation equipment alongwith meteorological instruments have been procured and tests will be run shortly. The data so recorded will go a long way in further development of microwave design know-how in the country which will enable us to design microwave links which are more economical and have higher propagation reliability figures.

Table-V. HOP CONDITIONS

Name of Hop	Hop distance (Km)	Topography
Karachi-Goth Taj	59.4	Farm,trees
Goth Taj-Thano Bula Khan	46.6	Hill
T.B. Khan-Khanot	49.9	Hill
Khanot-Sann	44.1	Waste
Sann-Sehwan	42.6	Forest
Sehwan-Dadu	37.0	Bush
Dadu-K.N. Shah	41.5	Rice field farm
K.N. Shah-Wagan	48.2	Rice field farm
Wagan-Rato Dero	46.2	Rice field farm
Rato Dero-Shikarpur	38.9	Farm
Shikarpur-Haji Bahar	36.9	Farm
Haji Bahar-Kandhkot	35.4	Farm
Kandhkot-Kashmore	39.7	Farm
Kashmore-Rojhan	39.0	Waste
Rojhan-K.H. Shah	44.4	Farm
K.H.Shah-Fazilpur	44.4	Farm
Fazilpur-Jampur	43.1	Bush
Jampur-D.G.Khan	43.3	Bush
D.G.Khan-S.Sadruddin	24.7	Bush
S.Sadruddin Kot Addu	32.1	Bush, river
Kot Addu-Jaman Shah	45.3	Farm
Jaman Shah-Karor	45.3	Farm, Waste
Karor-Sarai Krishna	41.0	Desert,Farm,Forest.
Sarai Krishna-Darya Khan	32.1	Forest, Farm
Darya Khan-Ghulaman	49.6	Desert
Ghulaman-Mianwali	50.7	Farm
Mianwali-Hill Top	25.0	Farm
Hill Top-Biddhar	42.7	Waste, Bush
Biddhar-Dhulian	40.6	Waste, Bush
Dhulian-Fatch Jang	48.3	Waste
Fatch Jang-Rawalpindi	39.9	Waste, Bush
Kot Addu-Kharkanwala	47.0	Desert
Kharkanwala-Kabuli	48.8	Desert
Kabuli-H.B. Shah	44.9	Farm
H.B.Shah-Gojra	48.1	Farm
Gojra-Faisalabad	49.3	Farm

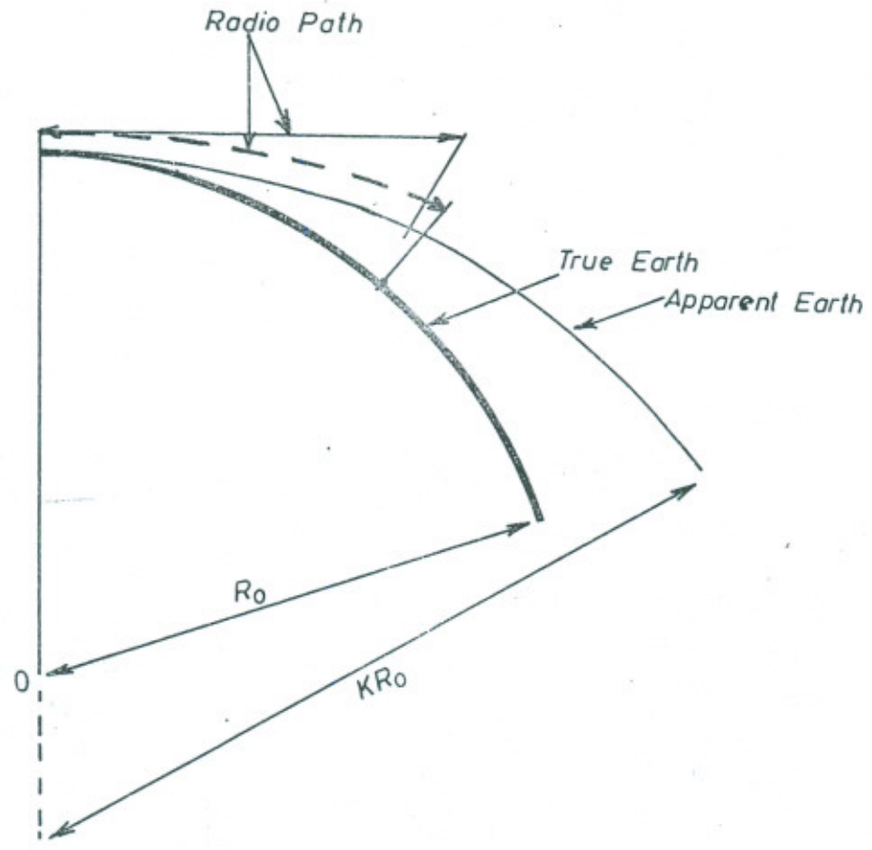
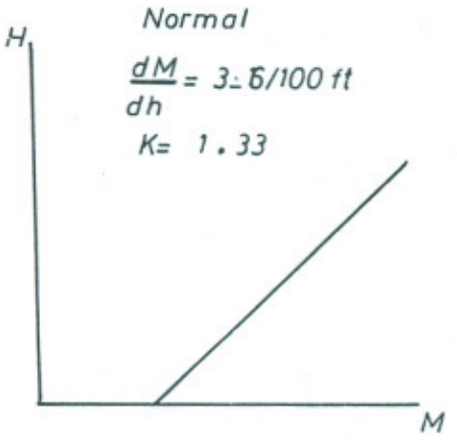
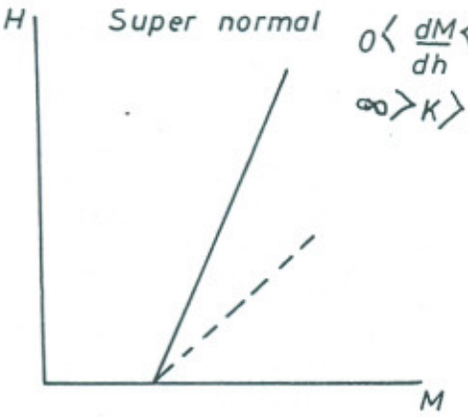
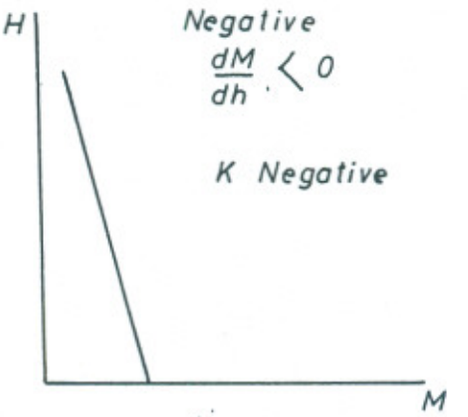


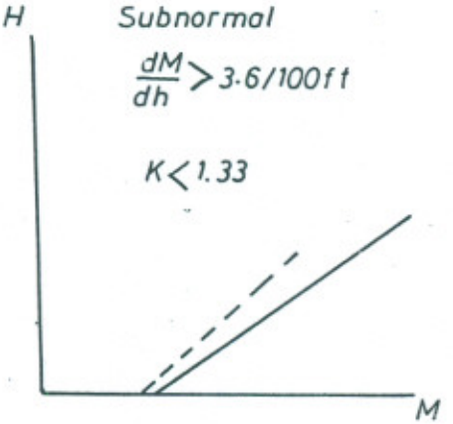
Fig: 1. Effect of atmosphere on radio propagation

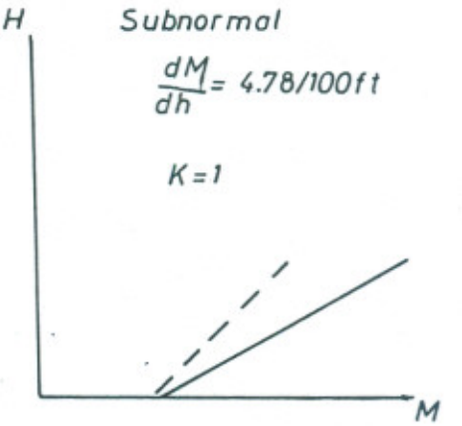






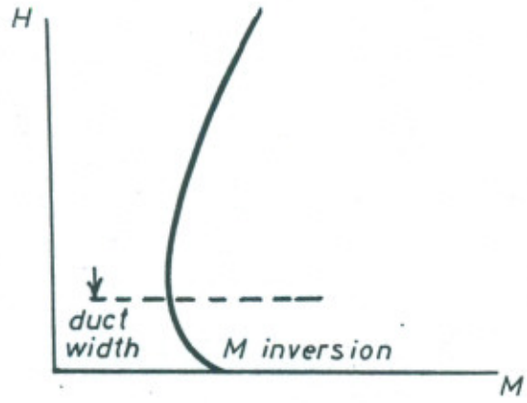




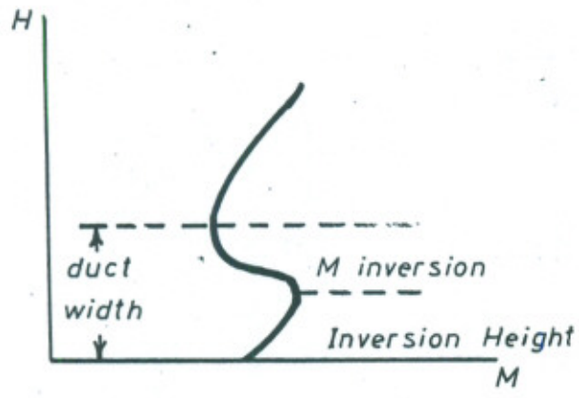


Atmosphere Refractive Index Gradient

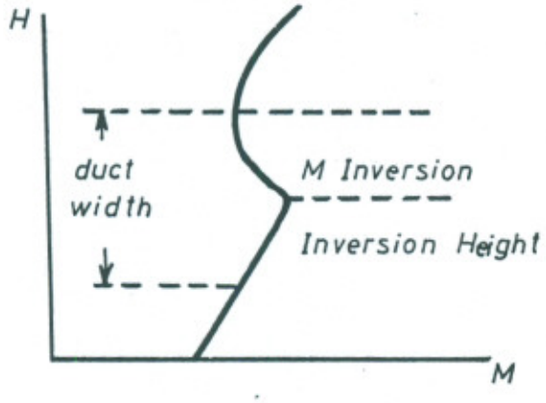
Fig: 2/1.



Single Surface
duct
(S.S duct)



Ground based
S duct
(E S duct)



Elevated S Duct
(E E Duct)

Atmosphere Refractive Index Gradient

Fig: $2/_2$.

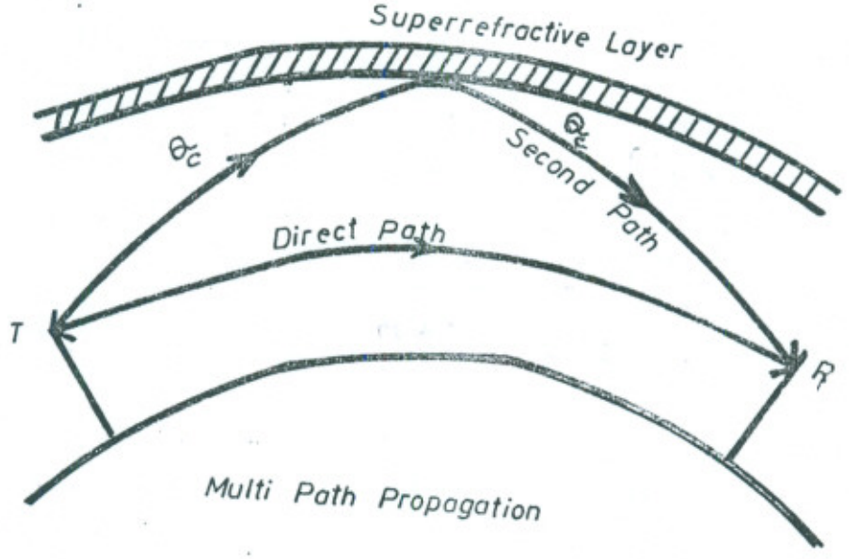
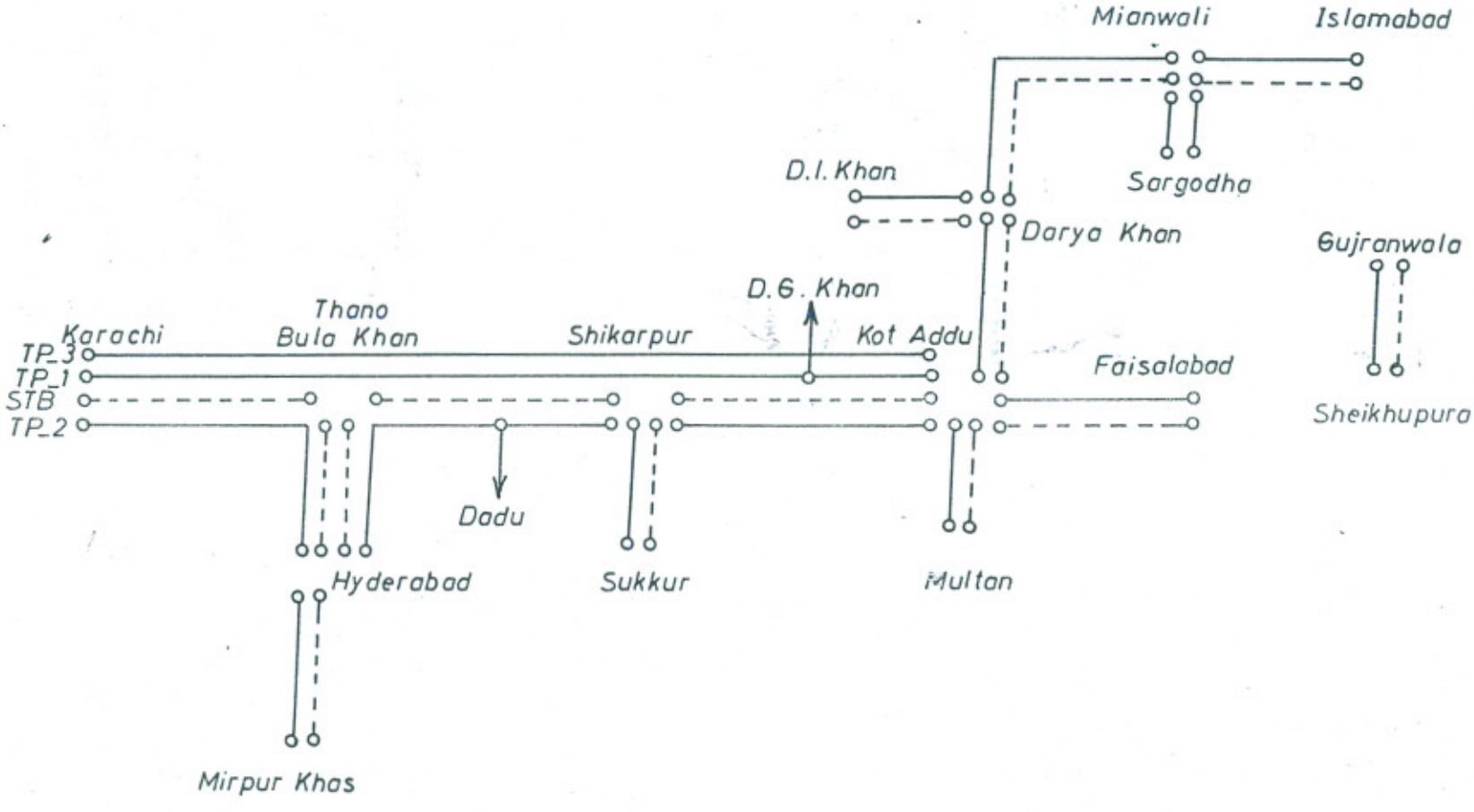

Superrefractive Layer
Second Path
Direct Path
T
R
Multi Path Propagation

Fig: 3.



Channel Plan & Switching Sections
Fig:4.

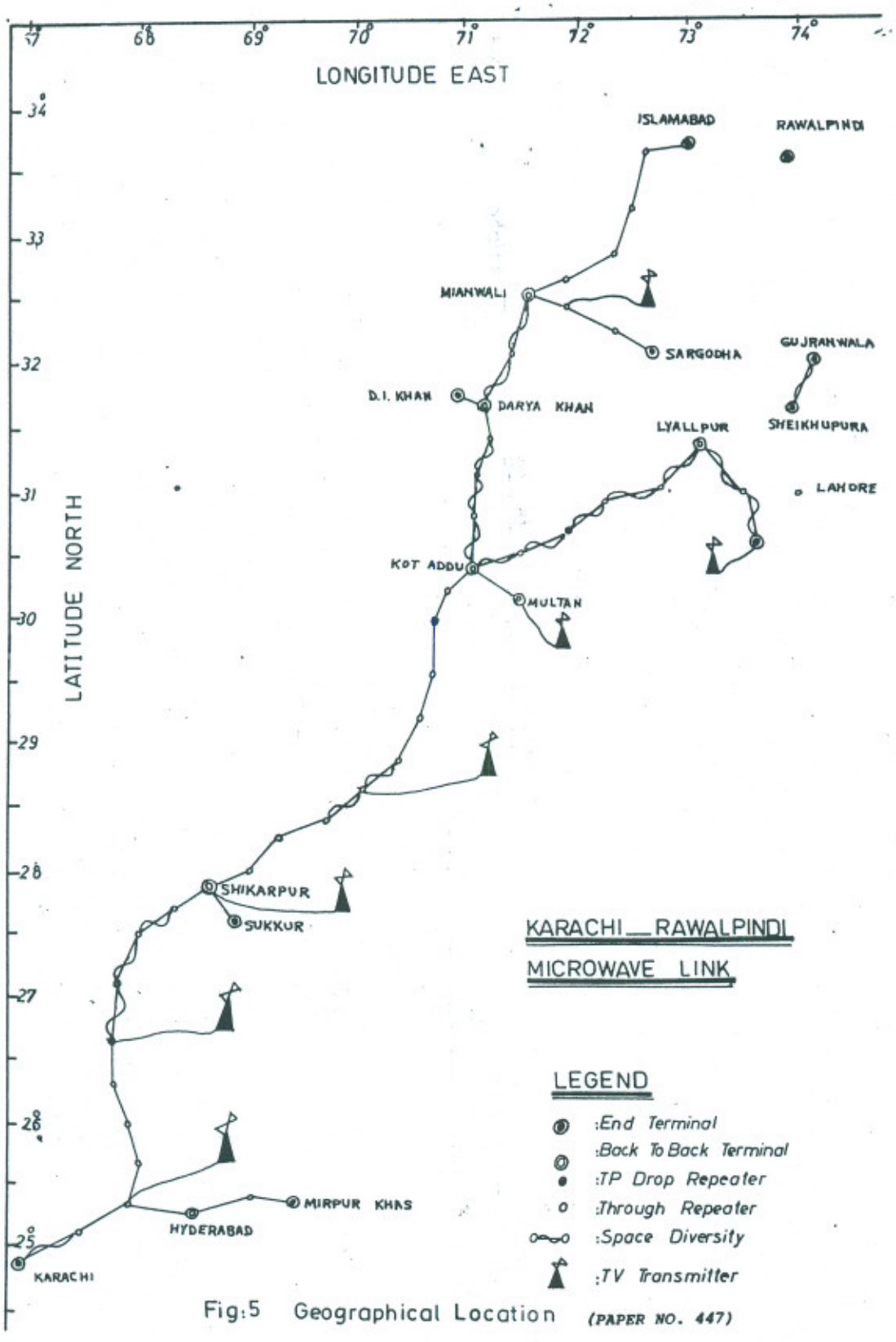


Fig:5 Geographical Location

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Out Band Noise Recording

Karachi ___ Rawalpindi M/W Link

Kotaddu ___ Darya khan

TP 960 Channel (3L+200)pw

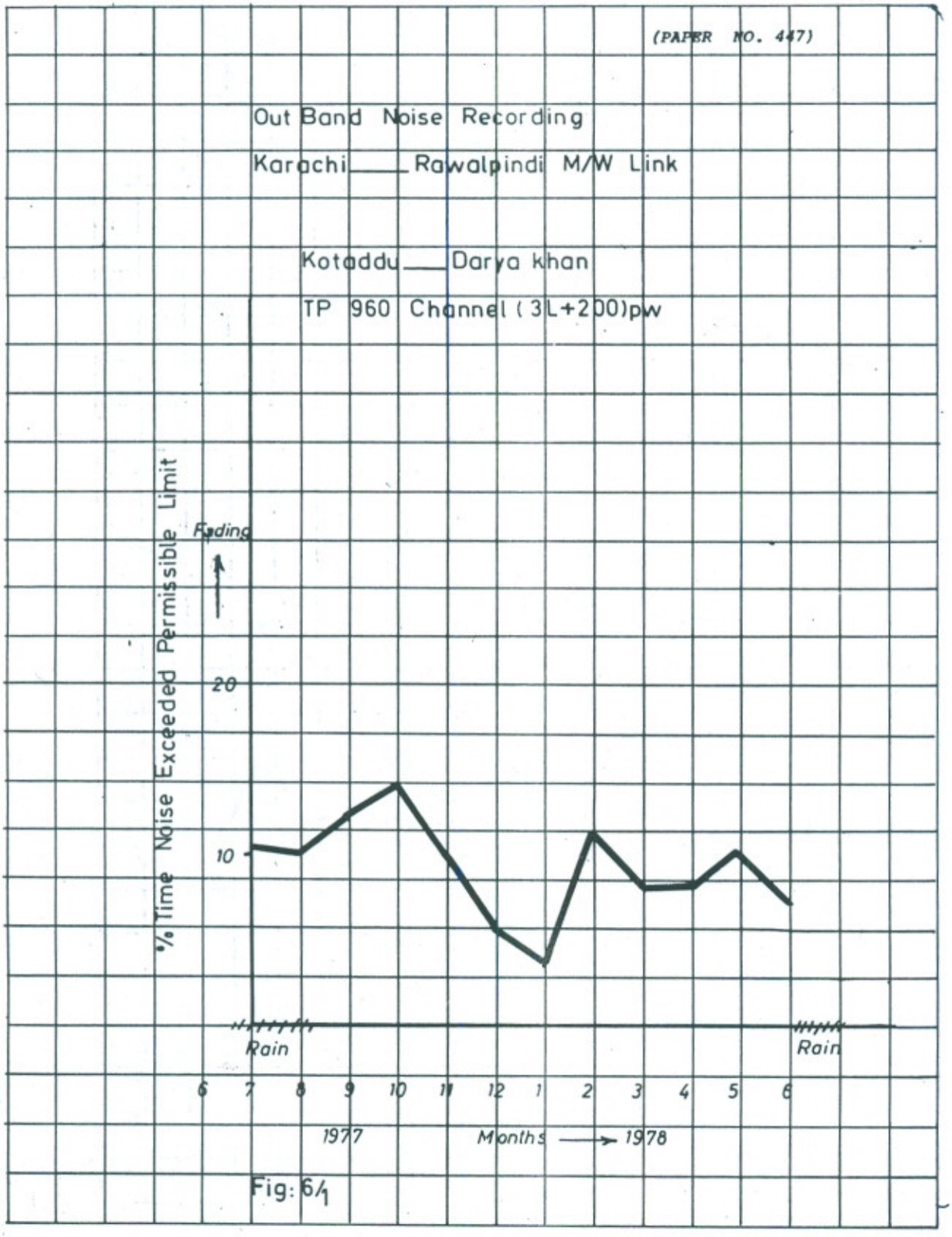


Fig: 6/1

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Out Band Noise Recording

Karachi – Rawalpindi Microwave Link

Karachi – Kotaddu

TP 960 Channel (3 L–200 PW

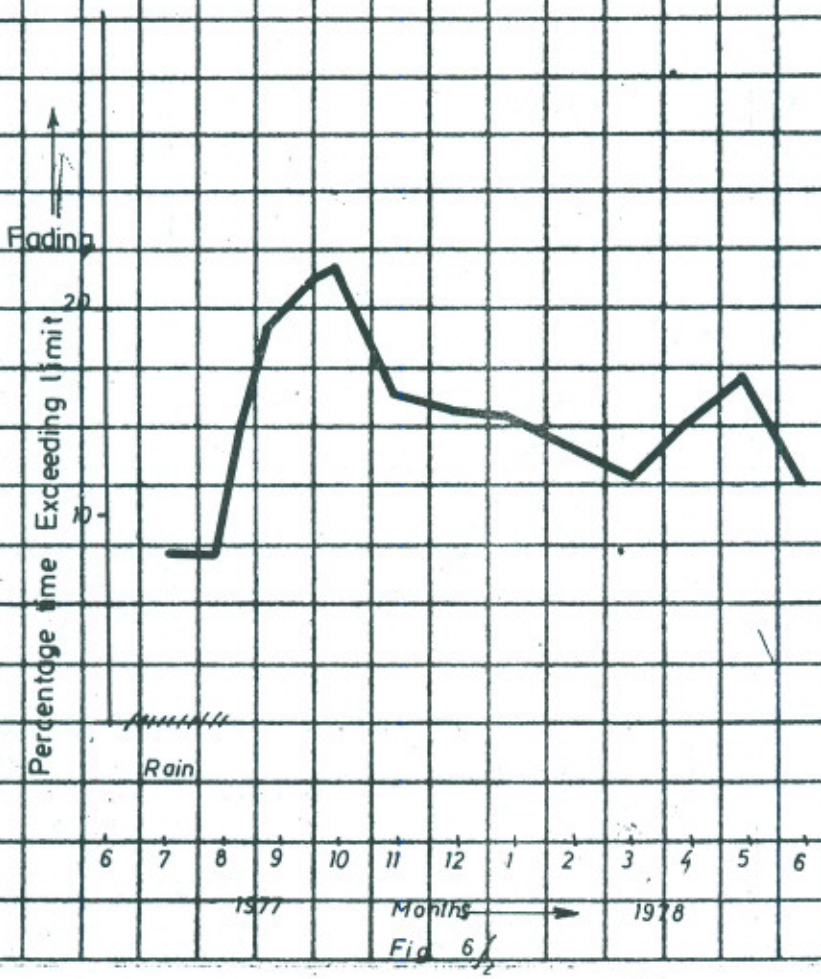


Fig 6

(PAPER NO. 447)

Out Band Noise Recording

Karachi–Rawalpindi Microwave link

Distribution

Mianwali – Daryakhan

TP 960 Channel (3L+200)PW

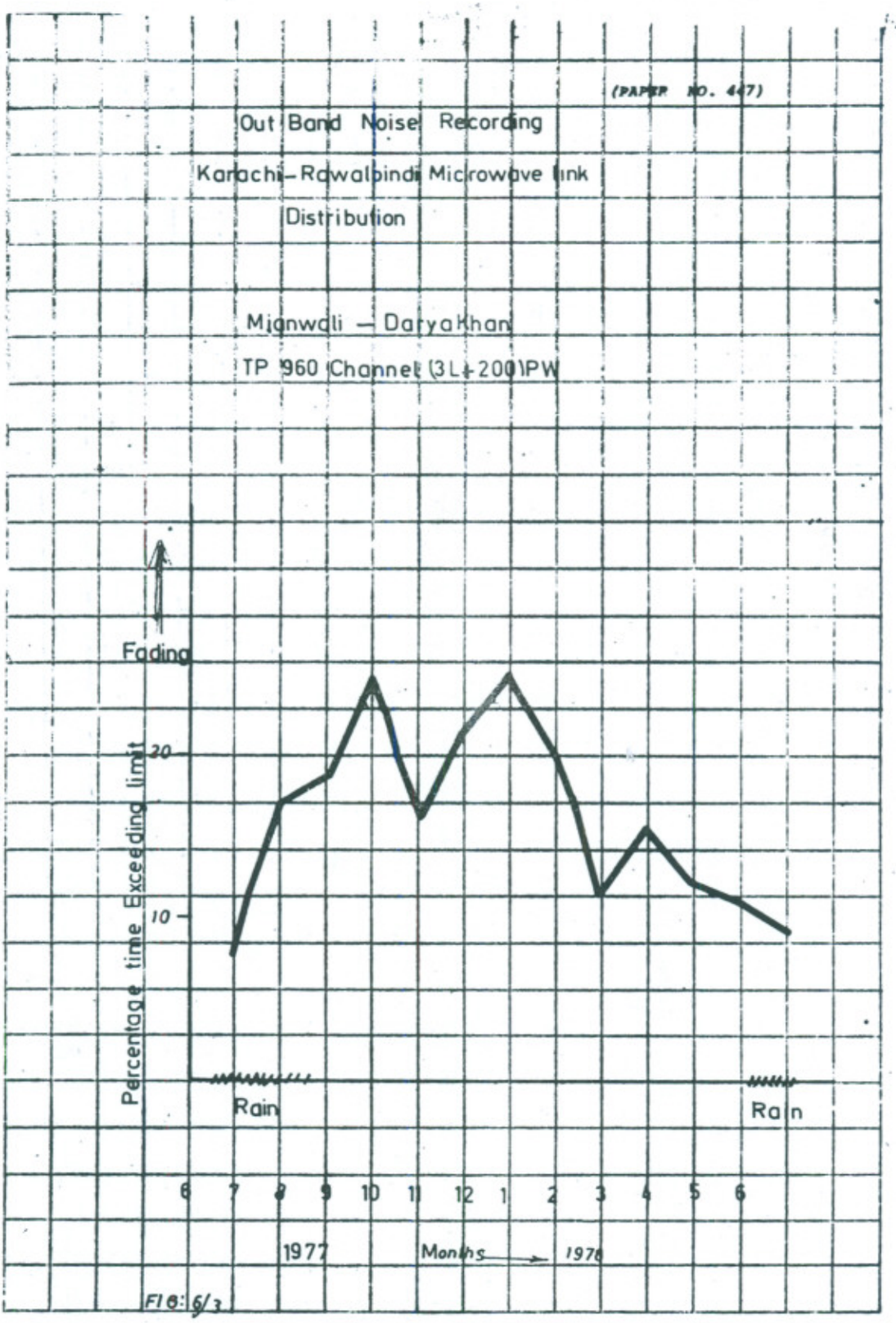


FIG: 6/3

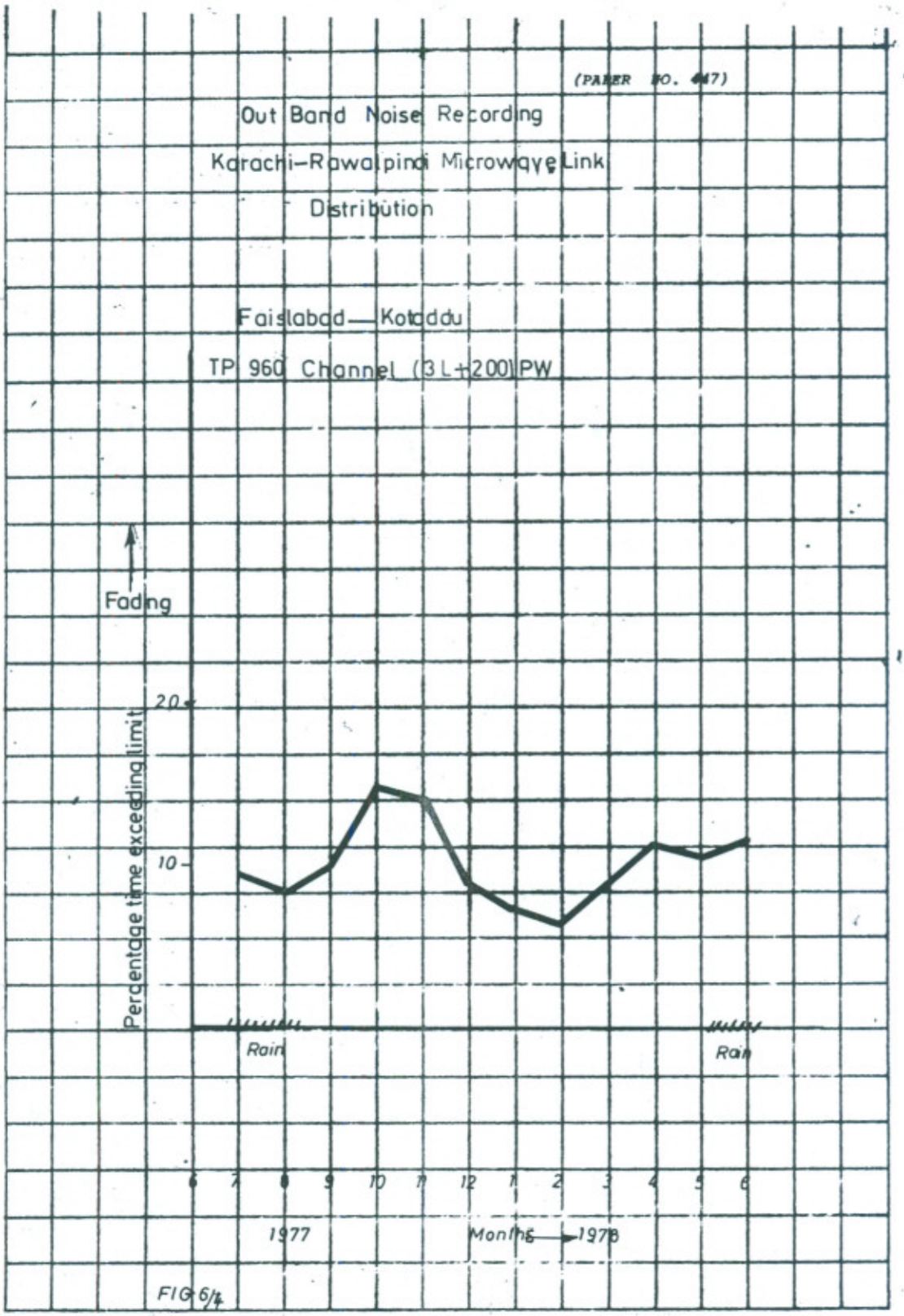

(PAPER NO. 447)
Out Band Noise Recording
Karachi–Rawalpindi Microwave Link
Distribution
Faislabad — Kotaddu
TP 960 Channel (3 L+200) PW
Fading
20
10
Percentage time exceeding limit
Rain
Rain
6 7 8 9 10 11 12 1 2 3 4 5 6
1977
Months
1978

FIG 6/4

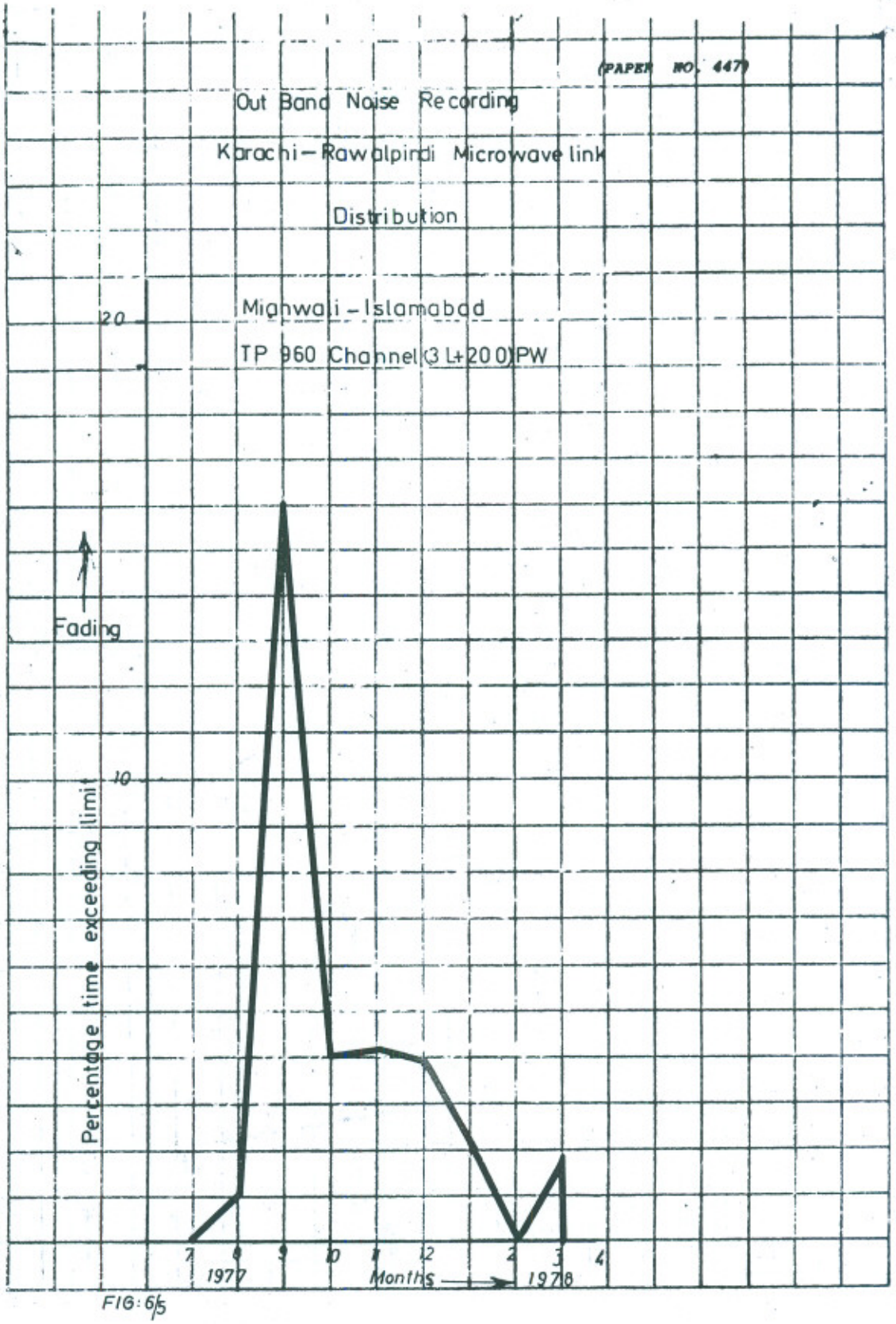

Out Band Noise Recording
Karachi – Rawalpindi Microwave link
Distribution
Mianwali – Islamabad
TP 960 Channel (3 L+200) PW
20
10
Fading
Percentage time exceeding limit
7
8
9
10
11
12
2
3
4
1977
Months
1978

FIG: 6/5

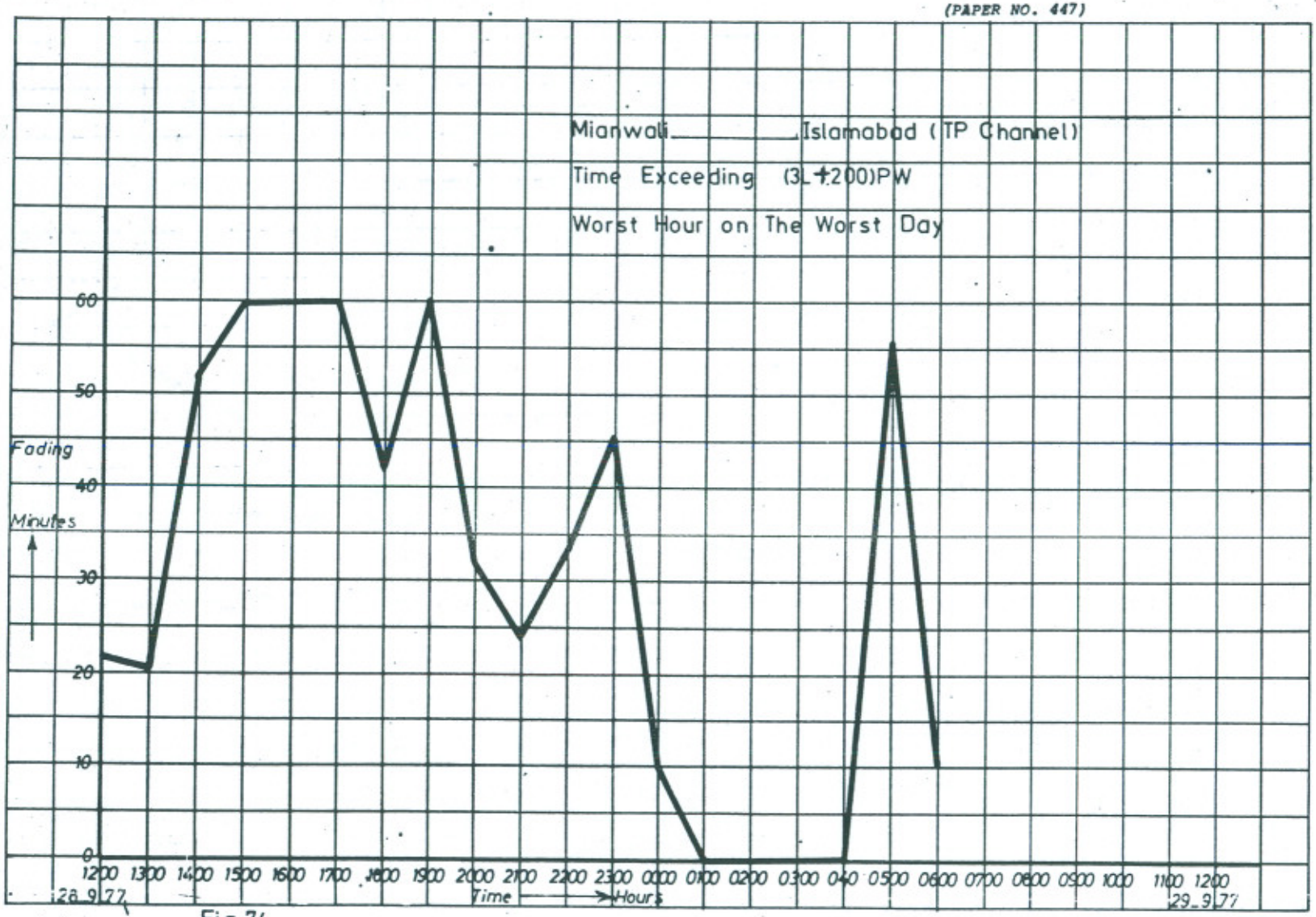

Mianwali Islamabad (TP Channel)
Time Exceeding (3L+200)PW
Worst Hour on The Worst Day
Fading
Minutes
60
50
40
30
20
10
0
1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 0000 0100 0200 0300 040 0500 0600 0700 0800 0900 1000 1100 1200
Time → Hours
28.9.77
29.9.77

Fig. 7/4

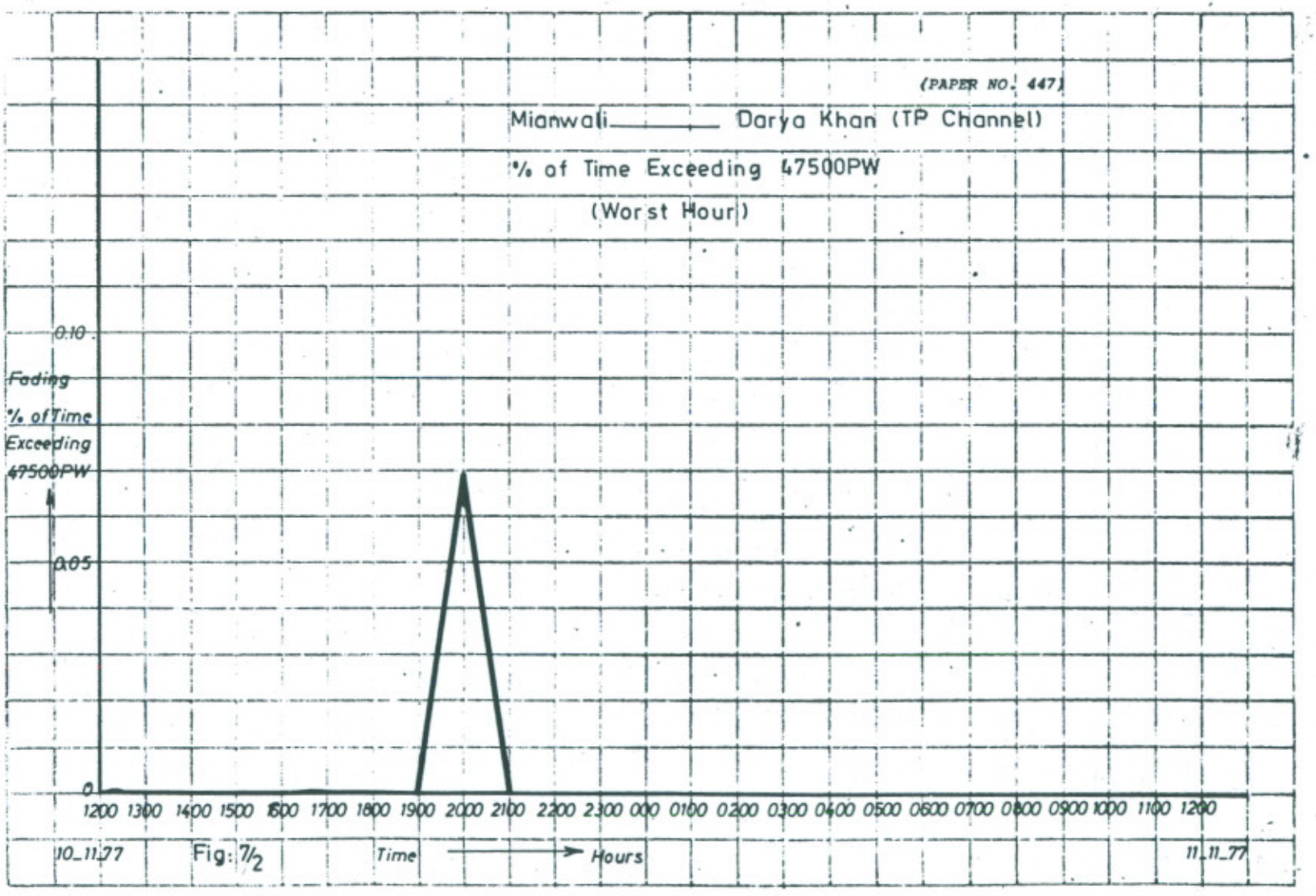

Mianwali——— Darya Khan (TP Channel)
% of Time Exceeding 47500PW
(Worst Hour)
0.10
Fading
% of Time
Exceeding
47500PW
0.05
0
1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 000 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200
10_11_77
Time
Hours
11_11_77

Fig: 7/2

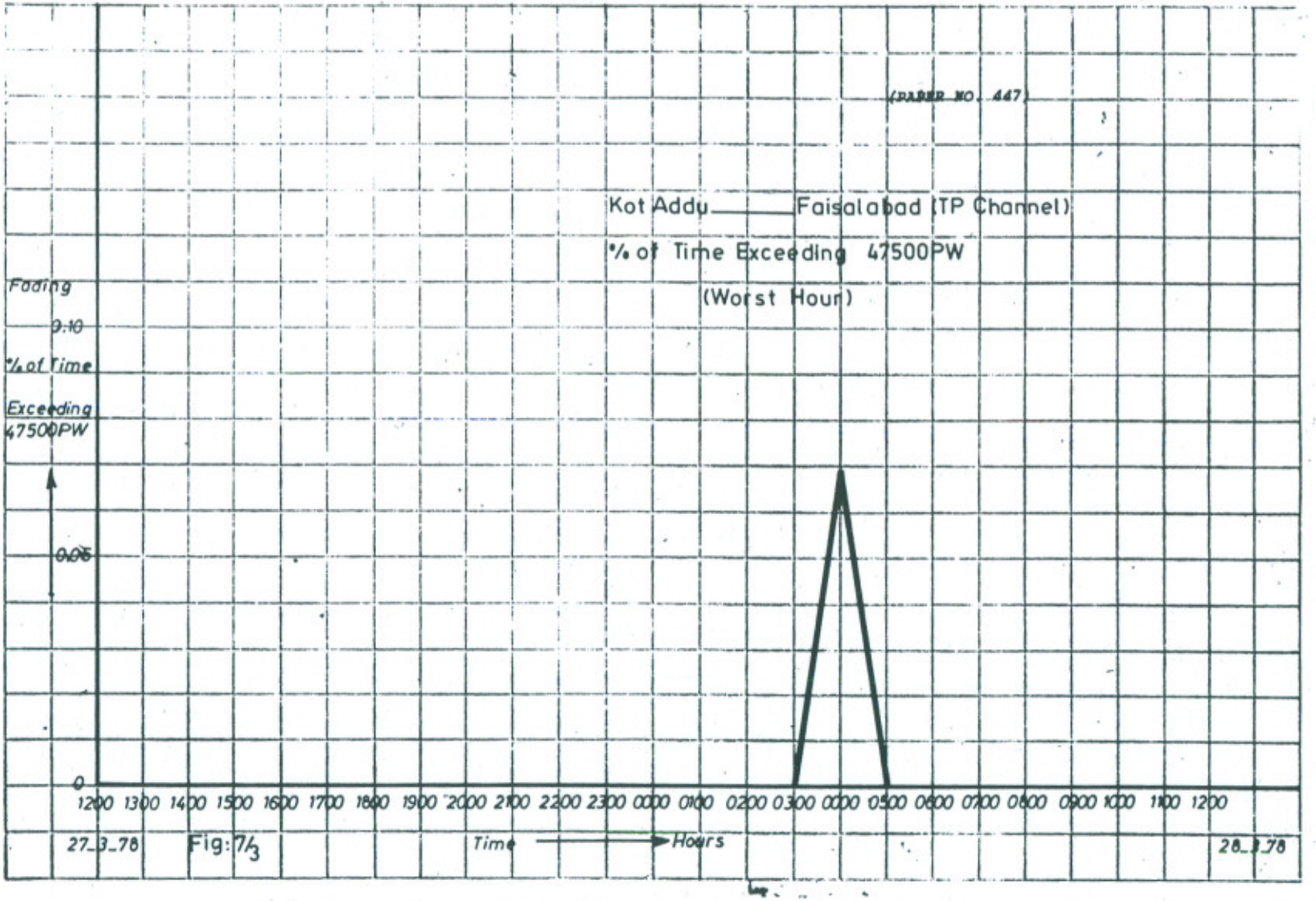
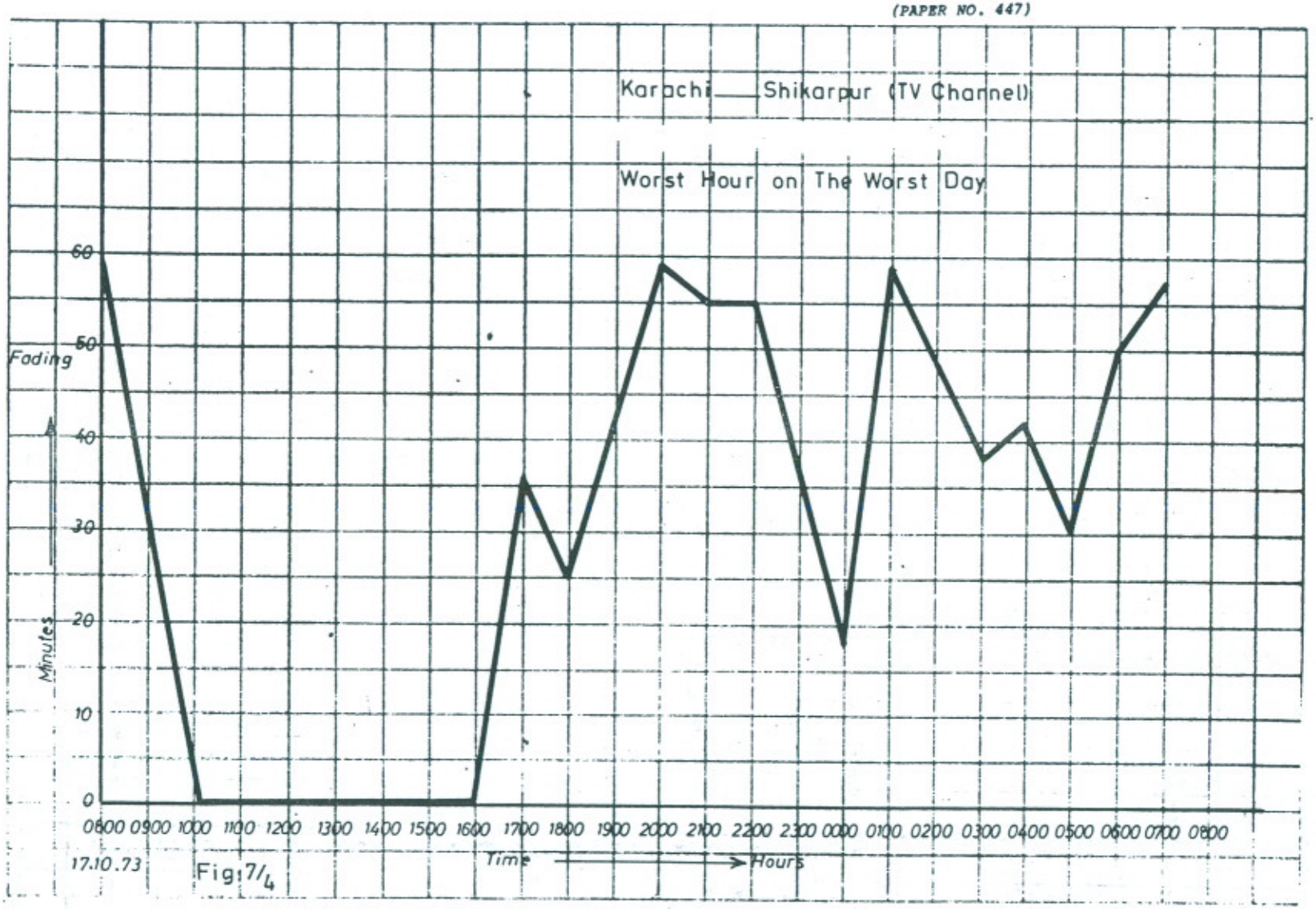

(PAPER NO. 447)
Kot Addu——Faisalabad (TP Channel)
% of Time Exceeding 47500PW
(Worst Hour)
Fading
0.10
% of Time
Exceeding
47500PW
0.05
0
1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 0000 0100 0200 0300 0400 0500 0600 0700 0800 0900 1000 1100 1200
27_3_78
Time → Hours
28_3_78

Fig: 7/3



17.10.73 Fig: 7/4

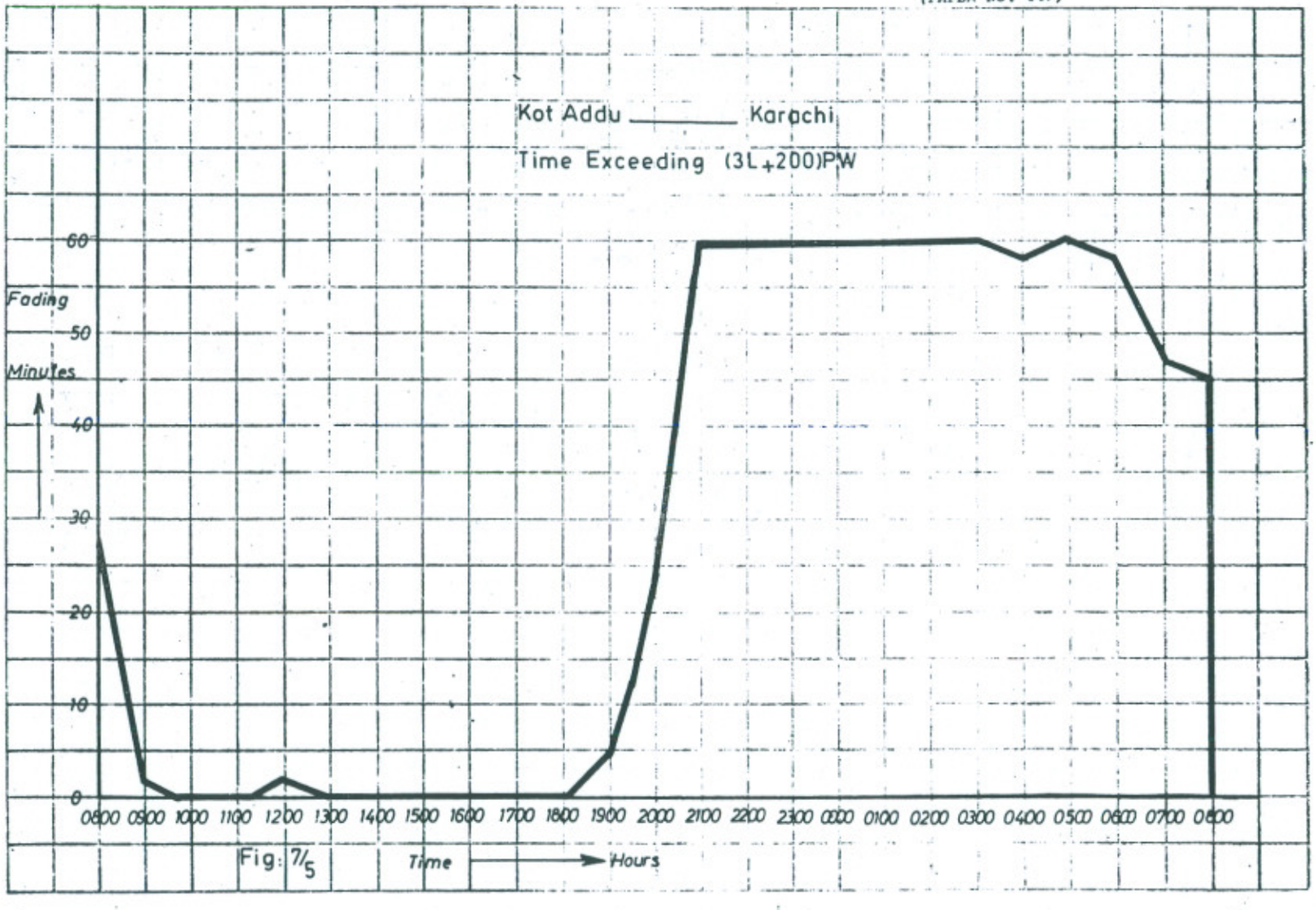

Kot Addu _____ Karachi
Time Exceeding (3L+200)PW
Fading
Minutes
60
50
40
30
20
10
0
0800 0900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 0000 0100 0200 0300 0400 0500 0600 0700 0800
Time
Hours

Fig: 7/5

KARACHI SHIKARPUR (TV CHANNEL)

3/5/78 MULTIPATH FADING

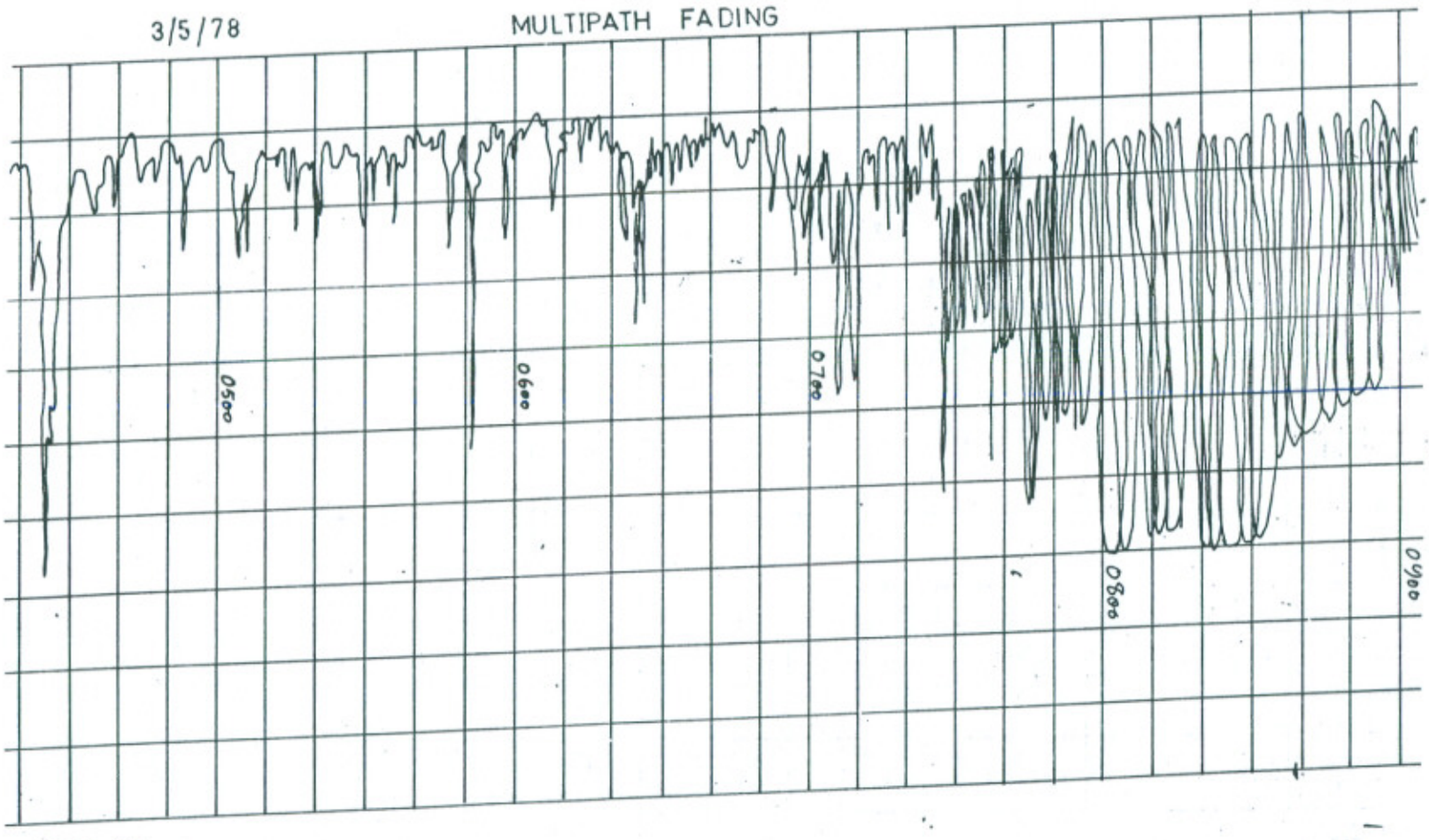


FIG 8/1

KARACHI SHIKARPUR (TV CHANNEL)

15/10/78 TO 16/10/78 REFLECTION FROM GROUND

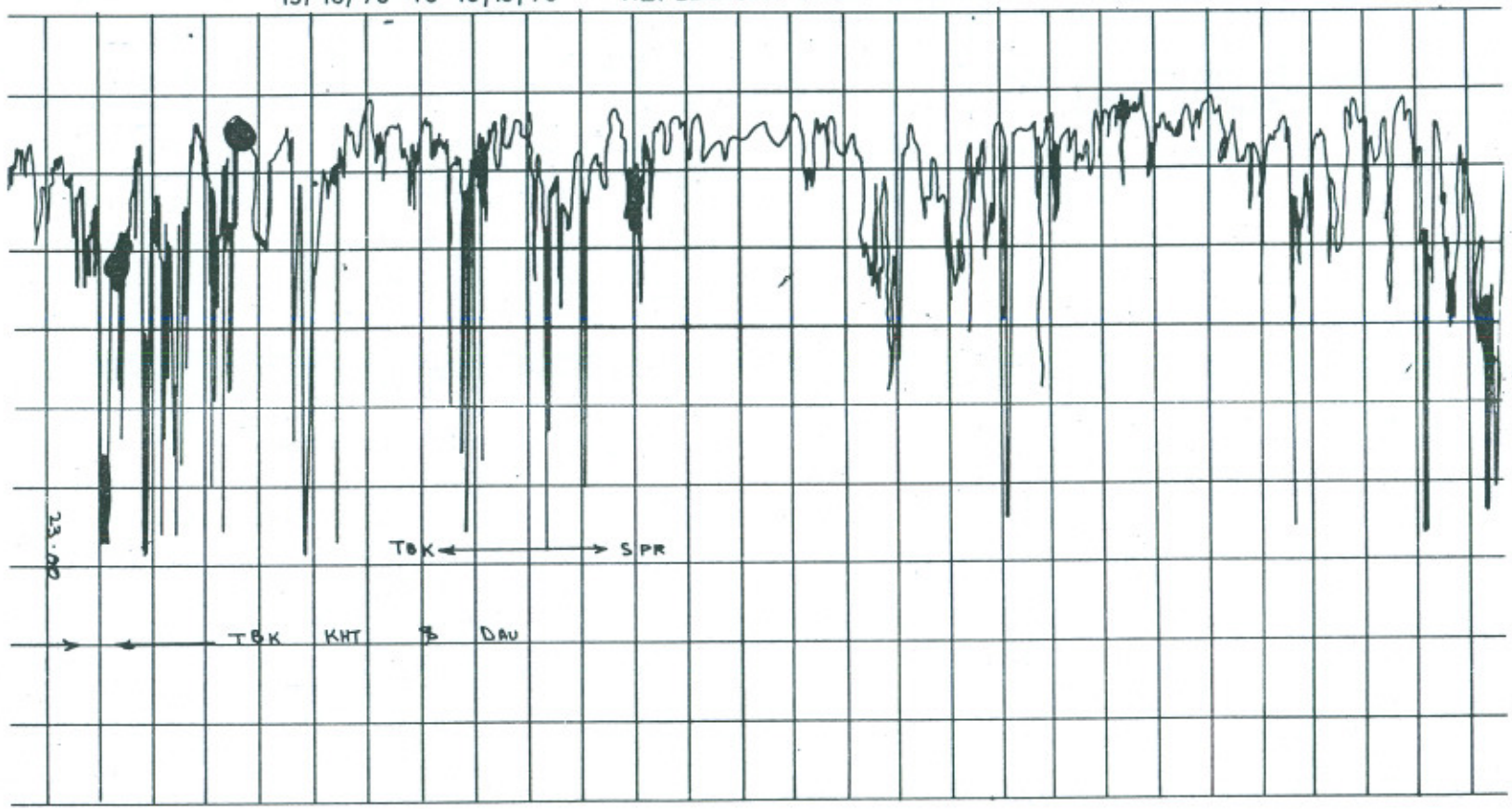


FIG 8/2

KARACHI SHIKARPUR (TV CHANNEL)

4/5-78 MULTIPATH WITH POWER FADE

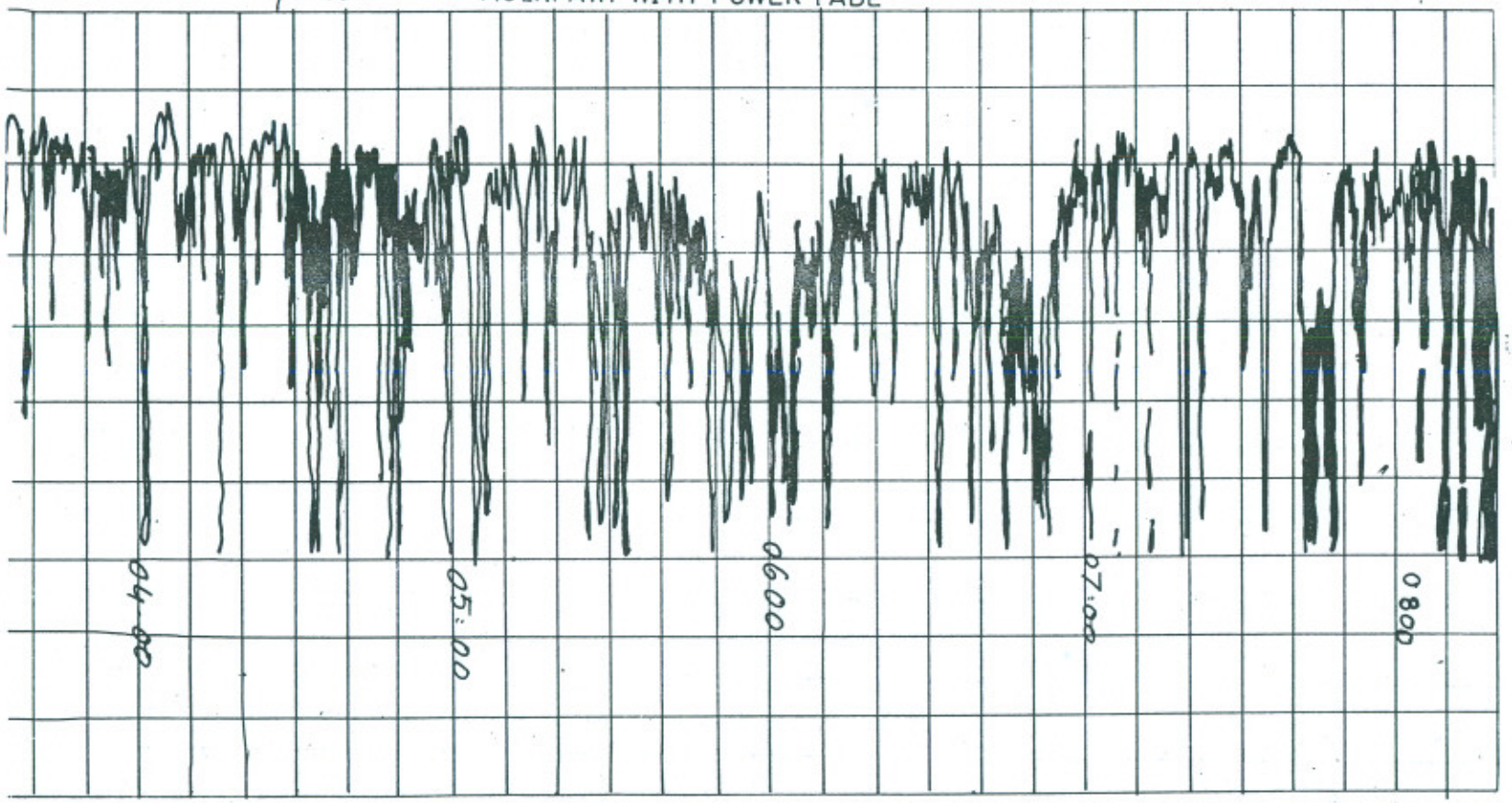


FIG: 8/3

KARACHI KOTADDU (TP-1)

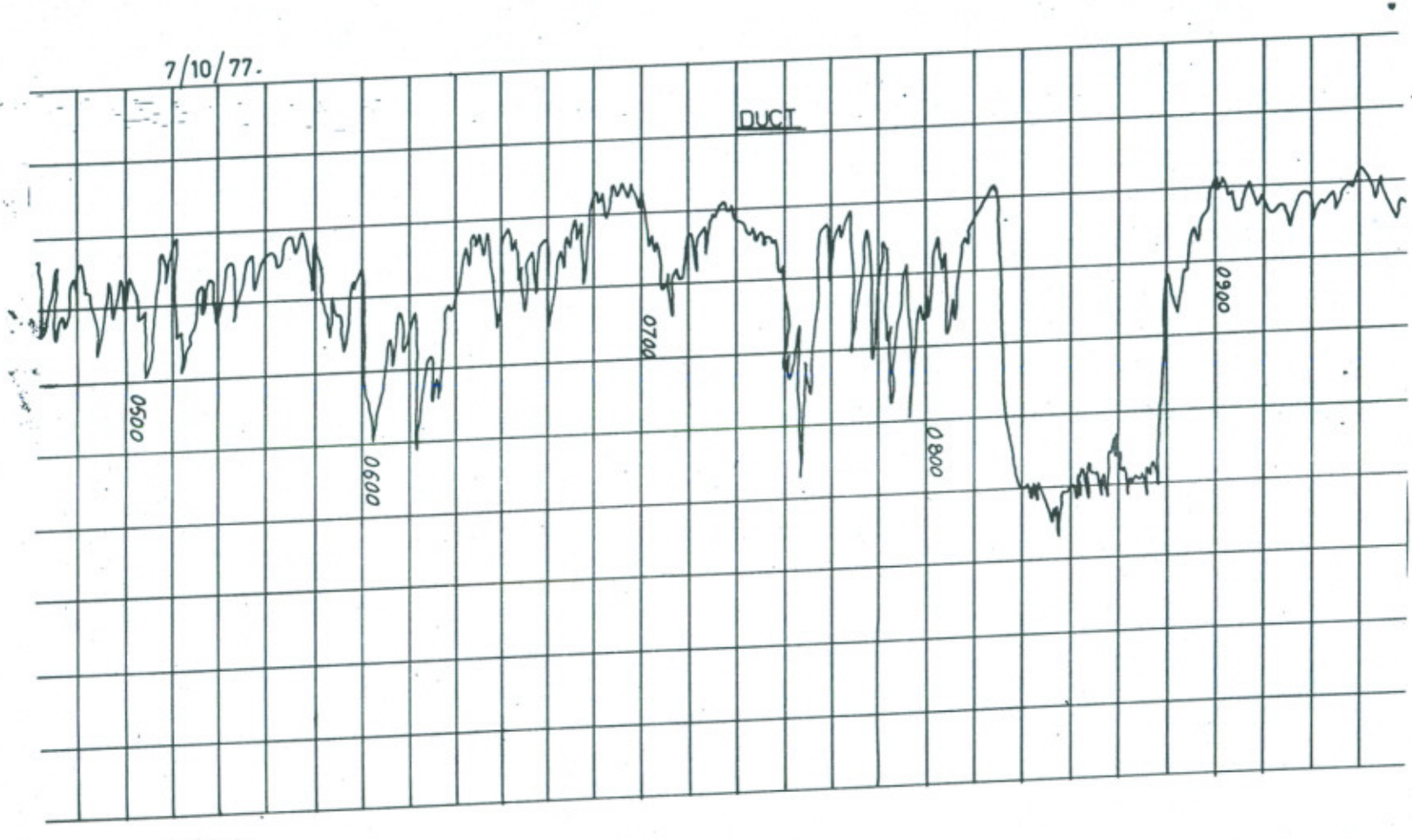


FIG 8/4

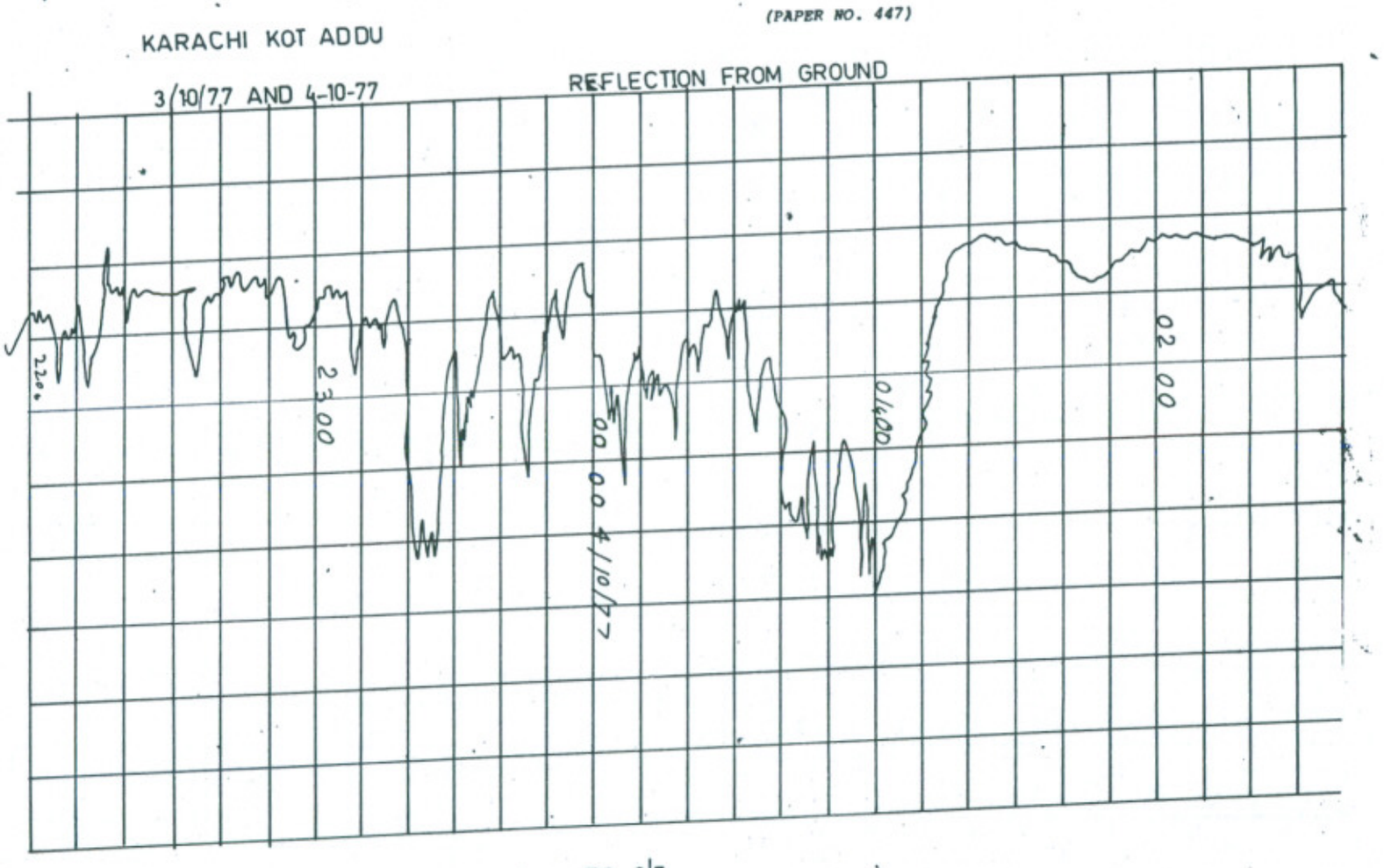

KARACHI KOT ADDU
3/10/77 AND 4-10-77
REFLECTION FROM GROUND
2200
23.00
00.00 4/10/77
01.00
02.00

FIG 8/5

KARACHI - KOTADDU

29/9-77

REFLECTION FROM GROUND/WATER

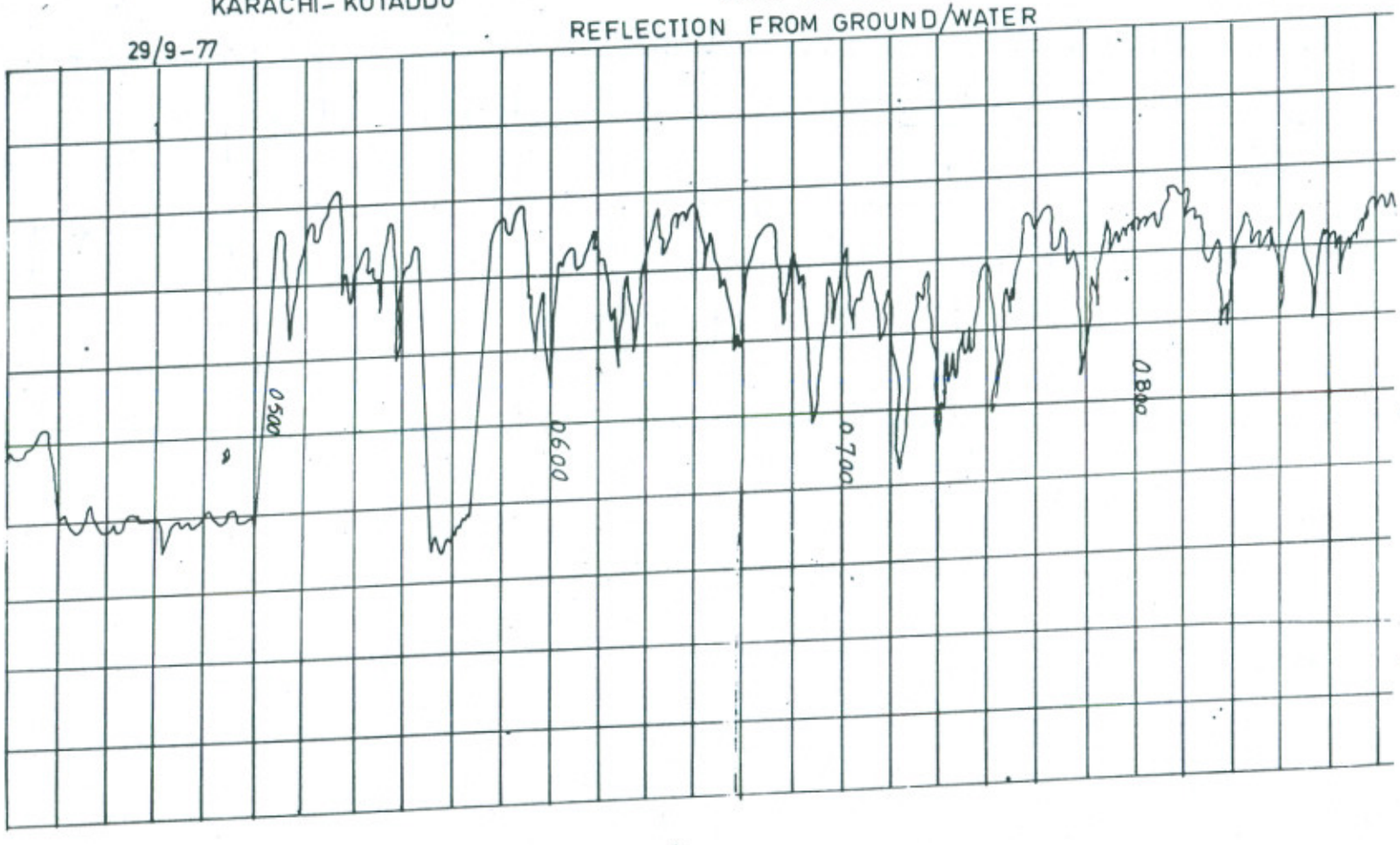


FIG. 8/6

KARACHI SHIKARPUR

16/10-78 TO 17/10-78 MULTIPATH FADE

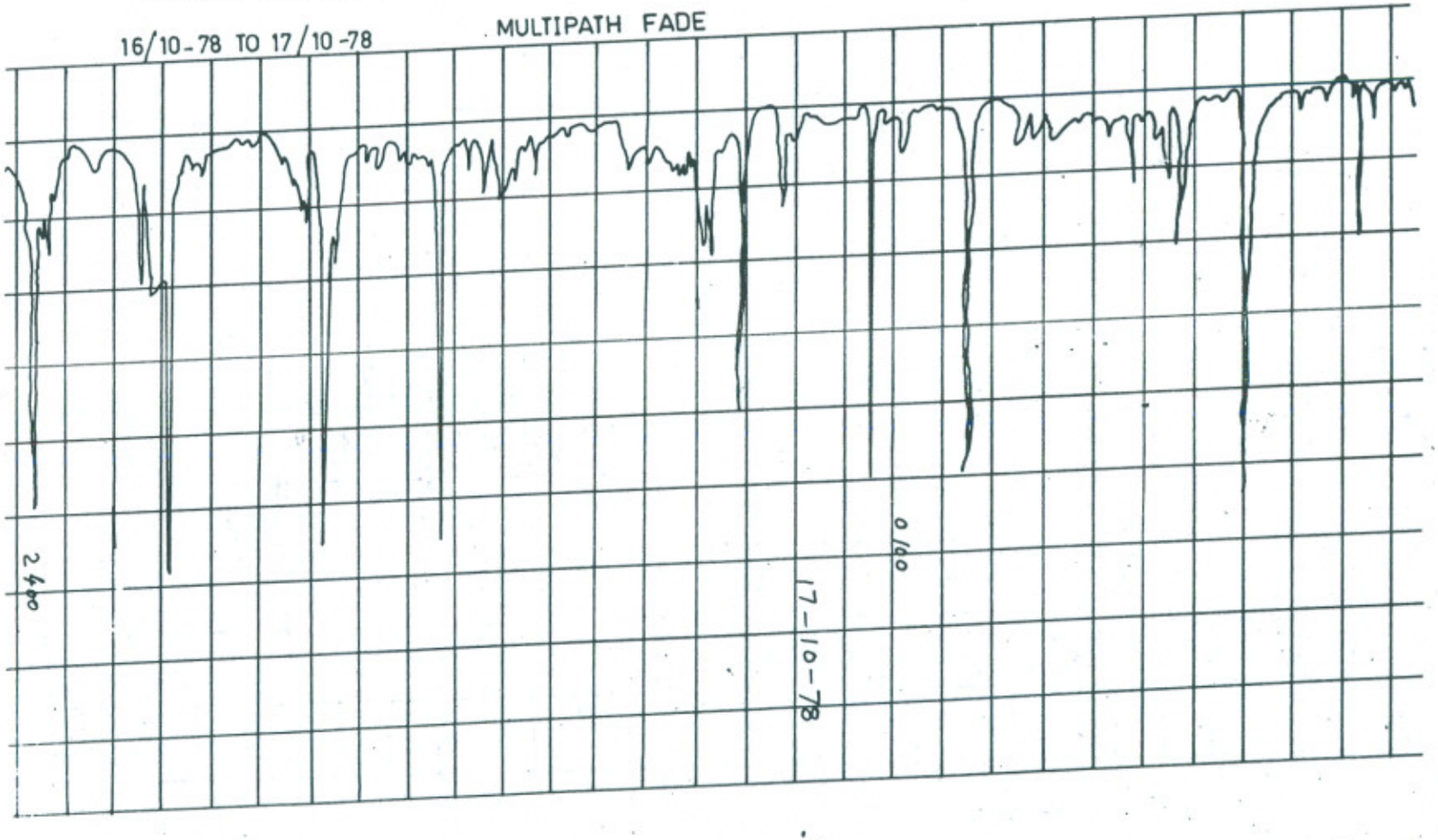


FIG 8/7

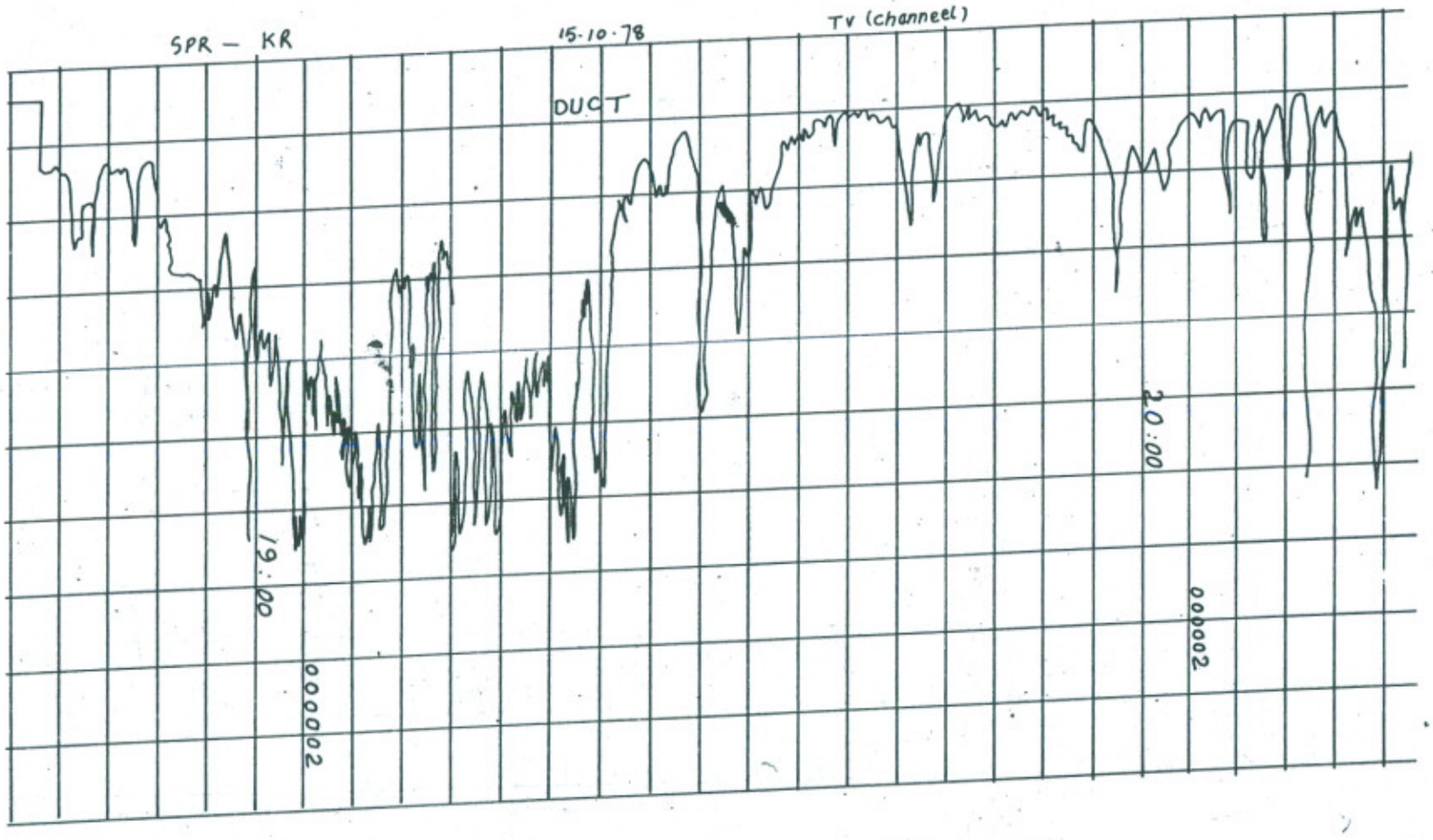


FIG 8/8

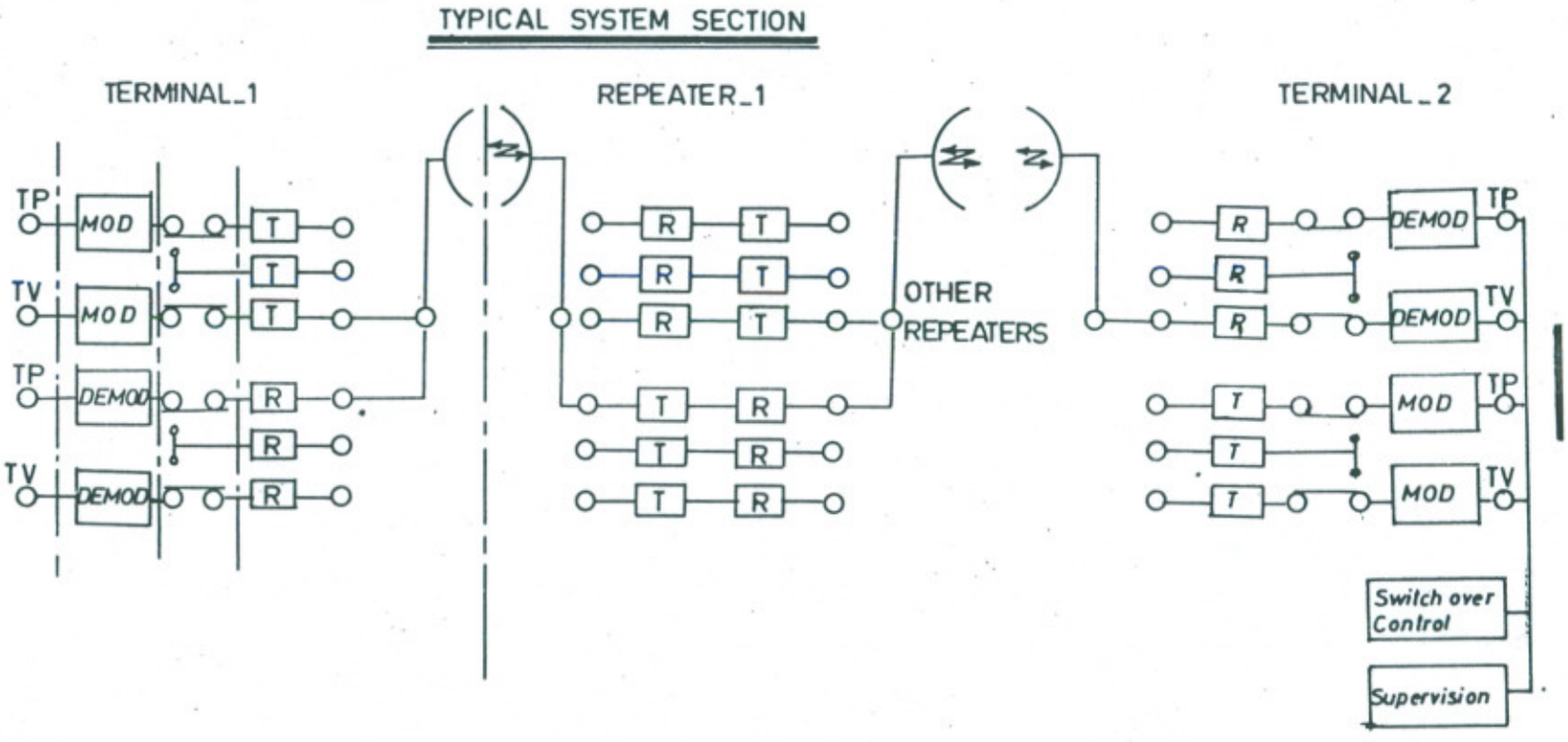


FIG: 9 (SYSTEM CONCEPT)