REPORT ON THE SURVEY FOR TROPOSPHERIC SCATTER COMMUNICATION LINK BETWEEN KUCHING AND JOHORE BAHRU MALAYSIA

[illegible] 1966

OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

FOREWORD

Upon the request of the Government of Malaysia, the Government of Japan decided to conduct a basic survey under the installation project of the microwave trans-horizon communication link to connect directly Kuching in East Malaysia with Johore Bahru in West Malaysia. The execution of selecting the radio station site and of the radio propagation test were entrusted to the Overseas Technical Cooperation Agency, Japan.

In view of the importance of developing communication work in Malaysia and also in order to insure an effective implementation of the survey, the Agency sent a survey team to Malaysia from August 7 through August 29, 1967 on the advance-survey mission and again from September 21 through November 21, 1967 on the plenary-survey mission. The team was consisted of nine experts and headed by Dr. Masaichi Hirai, Chief of Special Research Section for Satellite Communications, Radio Research Laboratories, Ministry of Posts and Telecommunications.

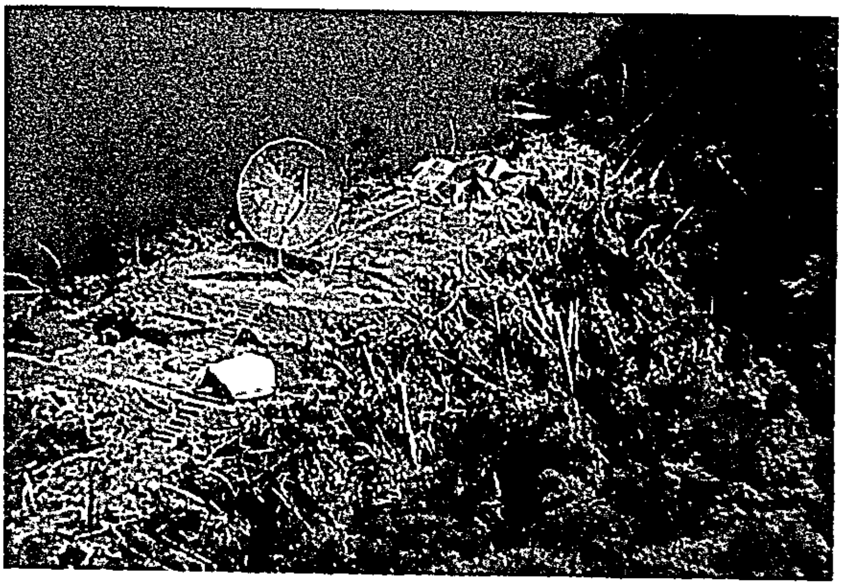
The survey was carried out smoothly and all members of the survey team safely returned to Japan. Now the survey report is ready to be submitted.

For overseas technical cooperation, the Agency was inaugurated in 1962 as the implementing institution under the direct control of the Government of Japan. Since then it has been executing various technical aids and cooperations on a Governmental basis by sending experts, accepting trainees and providing consulting services for the developing countries, and is steadily accomplishing its purpose. Nothing would be more gratifying to our Agency than to see this survey report aid in the promotion of telecommunication work, which is one of the important measures of the Government of Malaysia, and at the same time contribute to the promotion of friendly relations and economical exchange between Malaysia and Japan.

In conclusion, I would like to take this opportunity to express my gratitude to the officials of the Malaysian Government, who generously gave their support and cooperation to the team in the execution of this survey.

Shinichi Shibusawa
Director General
The Overseas Technical Cooperation Agency

February 1968



(GUNONG SERAPI RECEIVING STATION)

CONTENTS

DETAILS OF THE FIGURES AND TABLES

DETAILS OF THE PHOTOGRAPHS

I INTRODUCTION

1.1 Purpose and Outline of the Survey

All communications from Sarawak, East Malaysia, to West Malaysia and overseas are presently carried out through a feeble shortwave circuit installed between Kuching and Kuala Lumpur. This facility is not sufficient for the daily increasing demand of communications, and this situation is presenting a major obstacle to the Government of Malaysia in its attempt for promoting political, economical and cultural integration in East and West Malaysia.

The Telecommunications Department, the Government of Malaysia, has adopted a project for establishing a UHF tropospheric scatter communications system between Kuching and Johore Bahru under the First Malaysia Plan for the period of 1966 through 1970.

The proposed communication link has a propagation range of about 740 Km and will be the longest microwave link in the world. Therefore, this project requires a complete survey and a thorough study in advance. The Government of Malaysia, for this reason, made its request to the Government of Japan for a technical cooperation in this survey. In response to the request, this survey was conducted.

The survey was conducted in two phases, i.e. the advance survey and the plenary survey. The advance survey was conducted during a 23-day period from August 7 to August 29, 1967 by a team consisting of 4 Japanese members and many Malaysian members, coordinating the responsibilities of both countries in the scope of cooperation and drafting the plan for the implementation of the plenary survey. This survey facilitated the smooth execution of the plenary survey.

The plenary survey was conducted for a period of 62 days from September 21 through November 21, 1967 by a large team consisting of 9 Japanese members and many Malaysian members.

For the survey, the transmitting facilities were installed near the summit of Gunong Pulai (elevation 654.4 m) in Johore and the receiving facilities were installed near the summit of Gunong Serapi (elevation 910.8 m) in Sarawak, and the radio wave frequency used was 1840 MHz. As a result of this test, it was found that the receiving signal was considerably stronger than the estimated value and also that the realization of the practical communication link of 48 or more telephone channels is very promising.

The purpose of this report is to describe the progress of the survey, the results of propagation test and the proposal for the practical communication link on the basis of the test results and also to make an additional remark on the result of a study on the feasibility of transmitting television signals over this communication link.

1.2 Members Who Participated in the Survey

(a) Members who participated in the advance survey

— Members of the Japanese Team —

Chief :	Dr. Masaichi Hirai Radio Research Laboratories, Ministry of Posts and Telecommunications
Deputy Chief :	Mr. Bunzo Abe Radio Regulatory Bureau, Ministry of Posts and Telecommunications
Liaison Officer :	Mr. Yoshiro Matsuoka Kokusai Denshin Denwa Co., Ltd.
Coordinator :	Mr. Shigemaro Aoki Overseas Technical Cooperation Agency

— Members of the Malaysian Team —

(Headquarters of the Telecommunications Department)

Director, External Services:	Mr. Koh Ah Seng
Controller, External Services :	Dr. Lum Yun Foo
Assistant Controller:	Dr. Lim Ching Hwa

(Johore Regional Telecommunications Department)

Acting Controller :	Mr. David Variyan
Technical Assistant :	Mr. A.J. Skelchy

(Borneo Posts and Telecommunications Department)

Deputy Regional Director :	Mr. R.H. Allen, D.F.C.
Controller, Headquarters :	Mr. James Lee
Controller, 1st and 2nd Divisions:	Mr. S.D. Sissons
Engineering Assistant :	Tuan Haji Zahari

(b) Members who participated in the plenary survey

— Members of the Japanese Team —

Chief :	Dr. Masaichi Hirai Radio Research Laboratories, Ministry of Posts and Telecommunications
Deputy Chief :	Mr. Bunzo Abe
Liaison Officer :	Mr. Yoshiro Matsuoka Kokusai Denshin Denwa Co., Ltd.
In charge of Radio Propagation :	Mr. Syuntaro Niwa Radio Research Laboratories, Ministry of Posts and Telecommunications
In charge of Communication Link Design:	Mr. Shoji Kimoto Kokusai Denshin Denwa Co., Ltd.
In charge of Antenna :	Mr. Takayuki Kudo Denki Kogyo Co., Ltd.
In charge of Receiver :	Mr. Akira Shimizu Nippon Electric Co., Ltd.
In charge of Transmitter :	Mr. Makoto Takao Nippon Electric Co., Ltd.
Coordinator :	Mr. Shigemaro Aoki Overseas Technical Cooperation Agency

— Members of Malaysian Team —

(Headquarters of Telecommunications Department)

Director, External Services :	Mr. Koh Ah Seng
Controller, External Services :	Dr. Lum Yun Foq
Controller, Radio Transmission :	Mr. Ng Ek Poh
Assistant Controller :	Dr. Lim Ching Hwa
Assistant Controller :	Mr. Norman Foo·
Technician :	Mr. Victor Arul
Technician :	Mr. Soo Tuck Chew
Technician :	Mr. S. S. Sathiathasan
Technician :	Mr. V. Veera Ralraj

(Johore Regional Telecommunications Department)

Controller :	Mr. T. A. Narayanan
Assistant Controller :	Mr. David Variyan
Assistant Controller :	Mr. Ng Sui Onn

Assistant Controller :	Mr. Lim Thian Foh
Technical Assistant :	Mr. A.J. Skelchy
Technical Assistant :	Mr. P. Senthimanikam
Technical Assistant :	Mr. Quek Yee Nam

(Borneo Posts and Telecommunications Department)

Deputy Regional Director :	Mr. R.H. Allen, D.F.C.
Controller, Headquarters :	Mr. James Lee
Controller, 1st and 2nd Divisions :	Mr. S.D. Sissons
Engineering Assistant :	Mr. Ong Chin Yiang
Engineering Assistant :	Tuan Haji Zahari

II PROGRESS OF SURVEY

2.1 Progress of Advance Survey

The advance-survey team arrived in Kuala Lumpur on August 7, 1967. After conducting a desk studies and discussions on arrangements for the plenary survey, the team left for Gunong Pulai in Johore. There, a field survey was conducted and a test site was selected. Then, the team proceeded to Gunong Serapi in Sarawak where a field survey was conducted and a test site was selected. After returning to Kuala Lumpur, the team assembled the survey results, drafted a plan for the plenary survey and on August 28 submitted a report to the Headquarters of the Telecommunications Department. The members of the team returned to Japan on August 29. Detailed progress of the advance survey is described in Table 1 below.

Table 1 Progress of the advance survey

(Date)	(Work Accomplished)
Aug. 7 (Mon) 1967:	Survey team arrived in Kuala Lumpur.
Aug. 8 (Tue)	Consultation with officials concerned of the Headquarters of the Telecommunications Department was conducted on the survey plan.
Aug. 11 (Fri)	Team arrived in Johore Bahru.
Aug. 12 (Sat)	1) Consultation with officials of the Johore Regional Telecommunications Department was conducted on the survey plan. 2) Field survey started at Gunong Pulai.
Aug. 16 (Wed)	Team arrived in Kuching. Consultation with officials of the Borneo Posts and Telecommunications Department was conducted on the advance survey.
Aug. 17 (Thu)	Field survey started at Gunong Serapi.
Aug. 20 (Sun)	Survey on a heliport and transportation route for equipment and materials was conducted.
Aug. 21 (Mon)	Survey data were assembled and a consultation meeting was held with officials of the Borneo Posts and Telecommunications Department.
Aug. 22 (Tue)	Team arrived in Kuala Lumpur.
Aug. 23 (Wed)	Survey data were assembled and preparation of the survey report was started.

Aug. 28 (Mon)	The advance-survey report was submitted to the Headquarters of the Telecommunications Department.
Aug. 29 (Tue)	The advance-survey team arrived in Tokyo.

2.2 Progress of Plenary Survey

The equipment and materials required for the plenary survey were shipped to Kuching and to Johore Bahru on August 26 and 30, respectively. The plenary survey team arrived in Kuala Lumpur on September 25 and held a consultation meeting with officials of the Headquarters of Telecommunications Department on the following day. Then, the team left for Johore Bahru. About 8 days were spent on the construction of a transmitting station at the Gunong Pulai site. After arriving in Kuching, the team spent about 10 days on the construction of a receiving station at the Gunong Serapi site. The propagation test was started in the evening of October 13 as scheduled, and continued for full four weeks and was completed in the morning of November 11. Thereafter, the members started dismantling the facilities and at the same time made an analysis of the test results, incorporating the findings of the analysis in the interim report and submitted it to the Headquarters of Telecommunications Department on November 20. All members of the team returned to Japan on November 21.

The preliminary report had been forwarded on December 21, 1967. Detailed progress of the plenary survey is described in Table 2.

Table 2 Progress of plenary survey

(Date)	(Work Accomplished)
Aug. 26 (Sat) 1967 :	Equipment and materials were shipped for Kuching from Yokohama.
Aug. 30 (Wed)	Equipment and materials were shipped for Johore Bahru from Yokohama.
Sep. 21 (Thu)	One member of the survey team arrived in Singapore to inspect the equipment and materials.
Sep. 25 (Mon)	Survey team (8 members) arrived in Kuala Lumpur.
Sep. 26 (Tue)	1) Greetings at the Headquarters of Telecommunications Department, followed by a consultation meeting on the test plan. 2) Survey team arrived in Johore Bahru.
Sep. 27 (Wed)	1) Construction of the transmitting station started at the Gunong Pulai site. 2) Equipment and materials were moved from Kuching to the summit of Gunong Serapi.

Oct. 4 (Wed)	1) Installation of the equipment completed at the Gunong Pulai site. 2) Survey team arrived in Kuching.
Oct. 7 (Sat)	1) Survey team arrived at the Gunong Serapi site. 2) Installation of receiving equipment started at the Gunong Serapi site.
Oct. 12 (Thu)	1) Installation of equipment completed at the Gunong Serapi site. 2) Adjustment of antenna pointing performed at both the Gunong Pulai and Gunong Serapi sites.
Oct. 13 (Fri)	1) Adjustment of antenna pointing completed. 2) Propagation test (2 GHz) started at 18:00, Kuching local time.
Oct. 25 (Wed)	Readjustment of antenna pointing performed.
Oct. 31 (Tue)	Precise adjustment of antenna pointing performed.
Nov. 11 (Sat)	1) Propagation test (2 GHz) completed at 06:00, Kuching local time. 2) Dismantling of equipment started at both the Gunong Pulai and Gunong Serapi sites.
Nov. 13 (Mon)	Analysis of test results started at Kuala Lumpur.
Nov. 17 (Fri)	Packing of equipment completed at Johore Bahru.
Nov. 19 (Sun)	Packing of equipment completed at Kuching.
Nov. 20 (Mon)	Interim report on the test results was submitted to the Headquarters of Telecommunications Department.
Nov. 21 (Tue)	All members of the survey team arrived in Tokyo.
Dec. 5.(Tue)	Equipment arrived in Yokohama from Johore Bahru.
Dec. 21 (Thu)	Preliminary report on the test results was forwarded to the Government of the Malaysia.
Jan. 1 (Mon), 1968	Equipment arrived in Yokohama from Kuching.

III PROPAGATION TEST SITE

3.1 Geometrical Map and Topographies

The propagation test was performed between the transmitting station at the Gunong Pulai site in Johore and the receiving station at the Gunong Serapi site in Sarawak. Geometrical map of the propagation path is shown in Figure 1. The propagation path has a total length of 739.1 Km, of which approximately 541 Km runs over the sea and the remaining portion adjacent to both stations over the land.

A vicinity map of the transmitting station is shown in Figure 2 and topographies are shown in Figures 3 and 4. Gunong Pulai is located approximately 25Km to the northwest of Johore Bahru. The elevation of the summit is 654.4 m and the existing television broadcasting station and microwave relay station are located on this summit. There is a paved way to the summit. Photograph 1 shows the view around the summit. The transmitting station for the propagation test is located at a point approximately 130 m to the northeast of the summit of Gunong Pulai and the elevation of the antenna base is 619.1m. The neighbouring area is a mountain ridge running from north to south and provides a suitable site for the construction of a practical radio communication station.

A vicinity map of the receiving station is shown in Figure 5, and the topographies are shown in Figures 6 and 7. Gunong Serapi is located approximately 18Km to the west of Kuching. The elevation of the summit is 910.7m, and a Malaysian military observation station is located nearby. Photograph 2 shows the figure of Gunong Serapi viewed from Kuching; the highest mountain shown in the center of the photograph is Gunong Serapi. Only a narrow path for mountain climbers is provided between the foot and the summit, and all test equipment and materials had to be transported by helicopters. Photograph 3 shows a scene of such transportation. The receiving station for the propagation test is located at a point approximately 200m north of the summit, and the elevation of the antenna base is 801.1m. The neighbouring area is a mountain ridge sloping down in a northwesterly direction with an average gradient of 1/4. Therefore, for the construction of a practical radio communication station, careful engineering work is required.

3.2 Propagation Path

The profiles of the propagation path are shown in Figures 8, 9 and 10. The radio horizon from the Gunong Pulai site is located on the sea as shown in

Figure 8, while the radio horizon from the Gunong Serapi site is determined by a mountain ridge, approximately 500m above sea level, located near the borderline between Sarawak and the Republic of Indonesia.

The propagation-path parameters obtained from these data are summarized in Table 3. Here, the center of the antenna is set at 6.4m in elevation above ground level.

Table 3 Propagation path parameters

Item \ Station	Gunong Pulai Transmitting Site	Gunong Serapi Receiving Site
Height above sea level		
Ground surface	619.1m	801.1m
Antenna center	625.5m	807.5m
Latitude	1°36'09.8" N	1°35'14.4" N
Longitude	103°32'52.8" E	110°11'22.1" E
Distance to radio horizon	113.4Km	61.2Km
Height of radio horizon	0m	500m
Path length	739.1Km	
Surface refractivity (Winter)	375 N-units	
Scattering angle (winter)	59.1×10^{-3} rad	

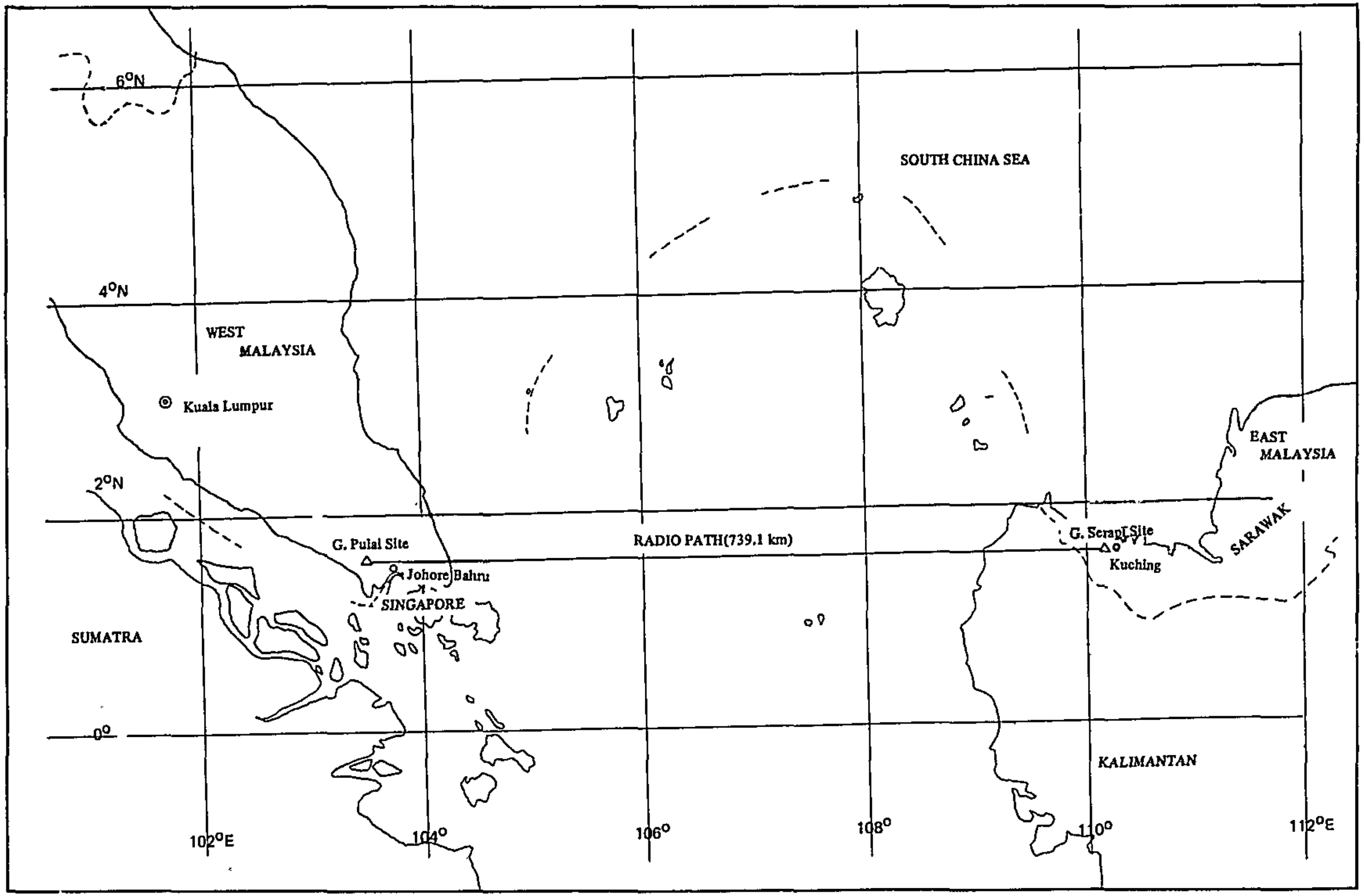


FIG. 1 GEOMETRY OF PROPAGATION PATH Scale: 1/5,000,000

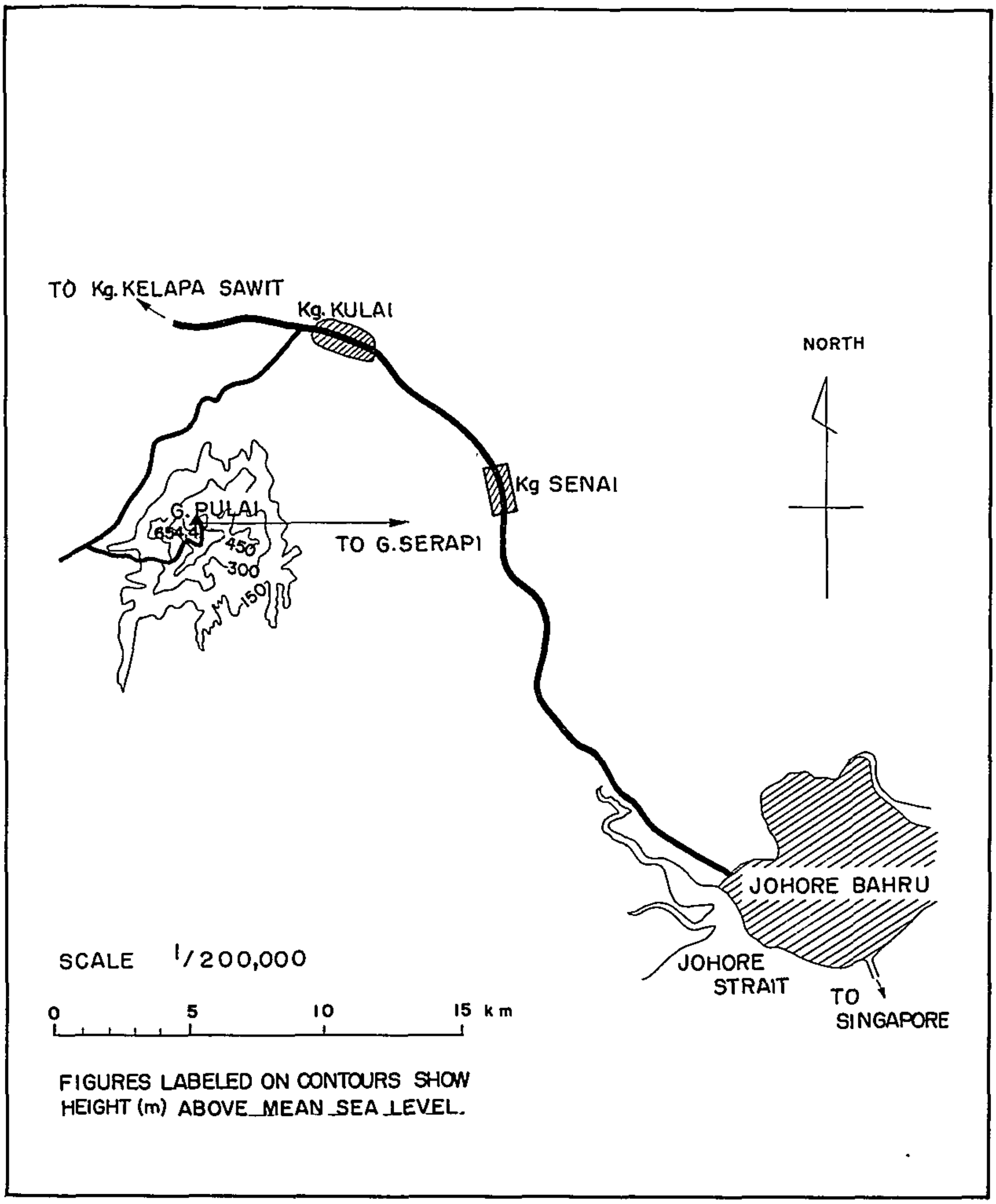


FIG. 2 MAP OF GUNONG PULAI AND JOHORE BAHRU

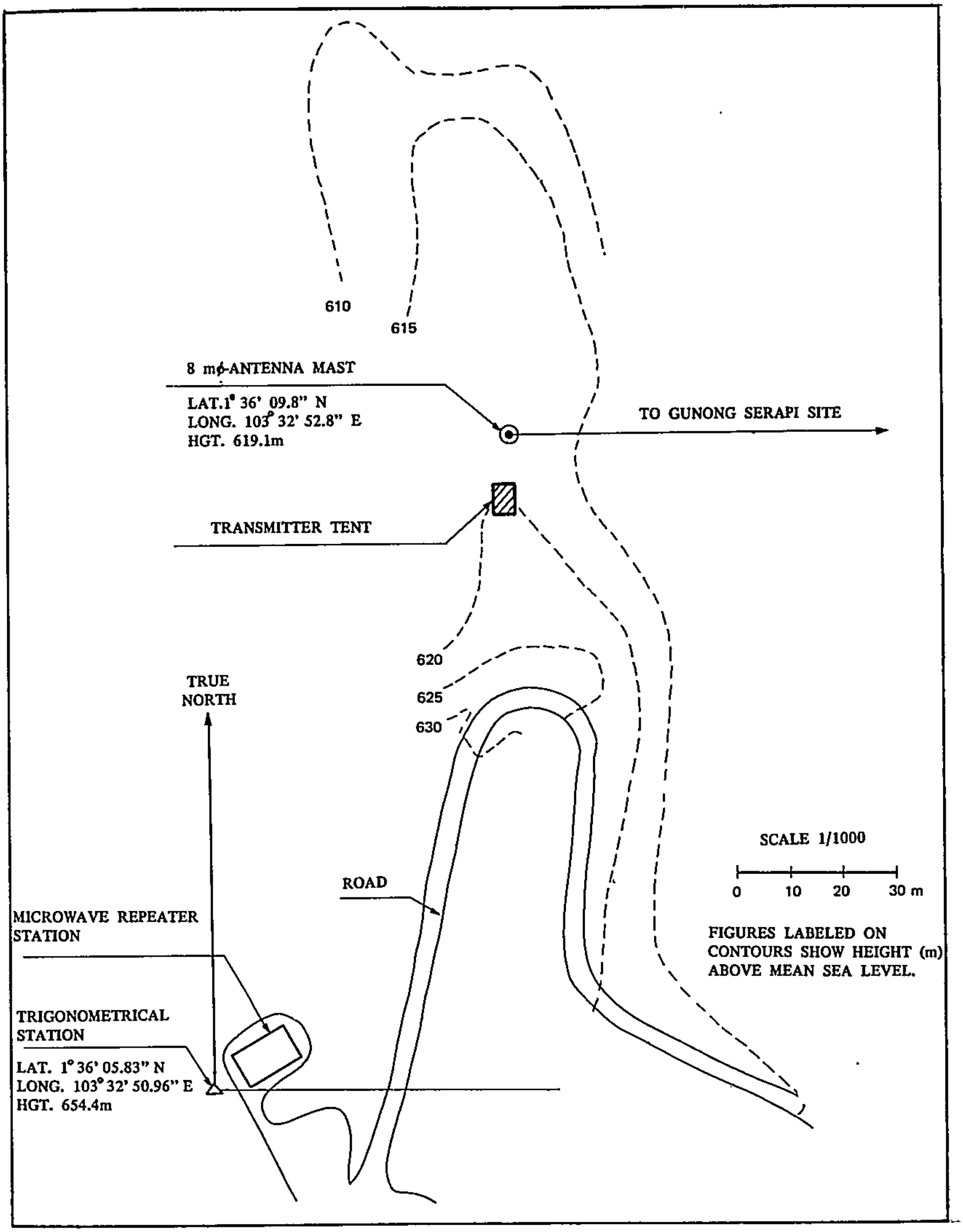


FIG. 3 TOPOGRAPHICAL MAP OF GUNONG PULAI SITE

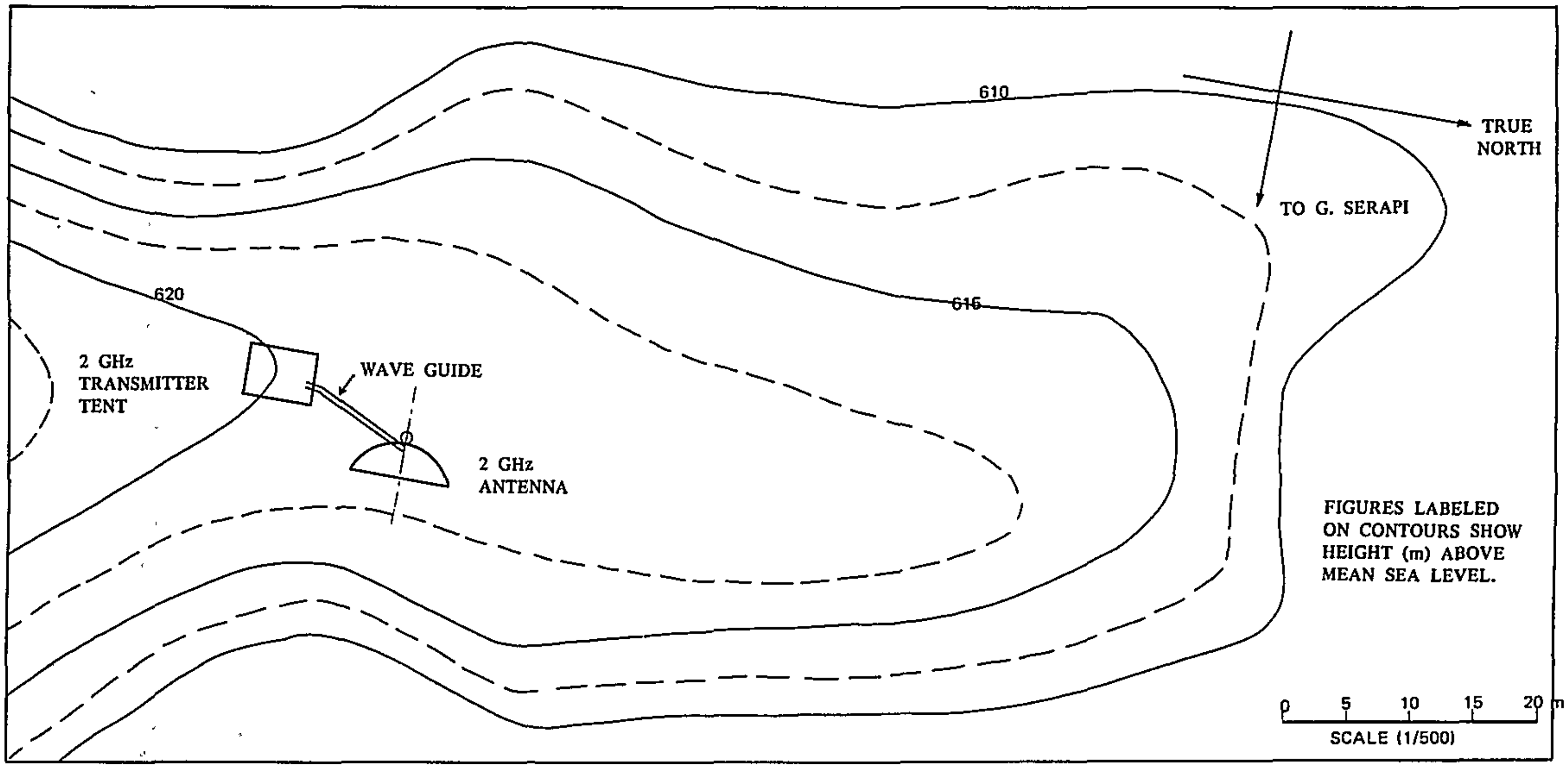


FIG. 4 TOPOGRAPHY AND LAYOUT OF TRANSMITTING FACILITIES AT GUNONG PULAI SITE

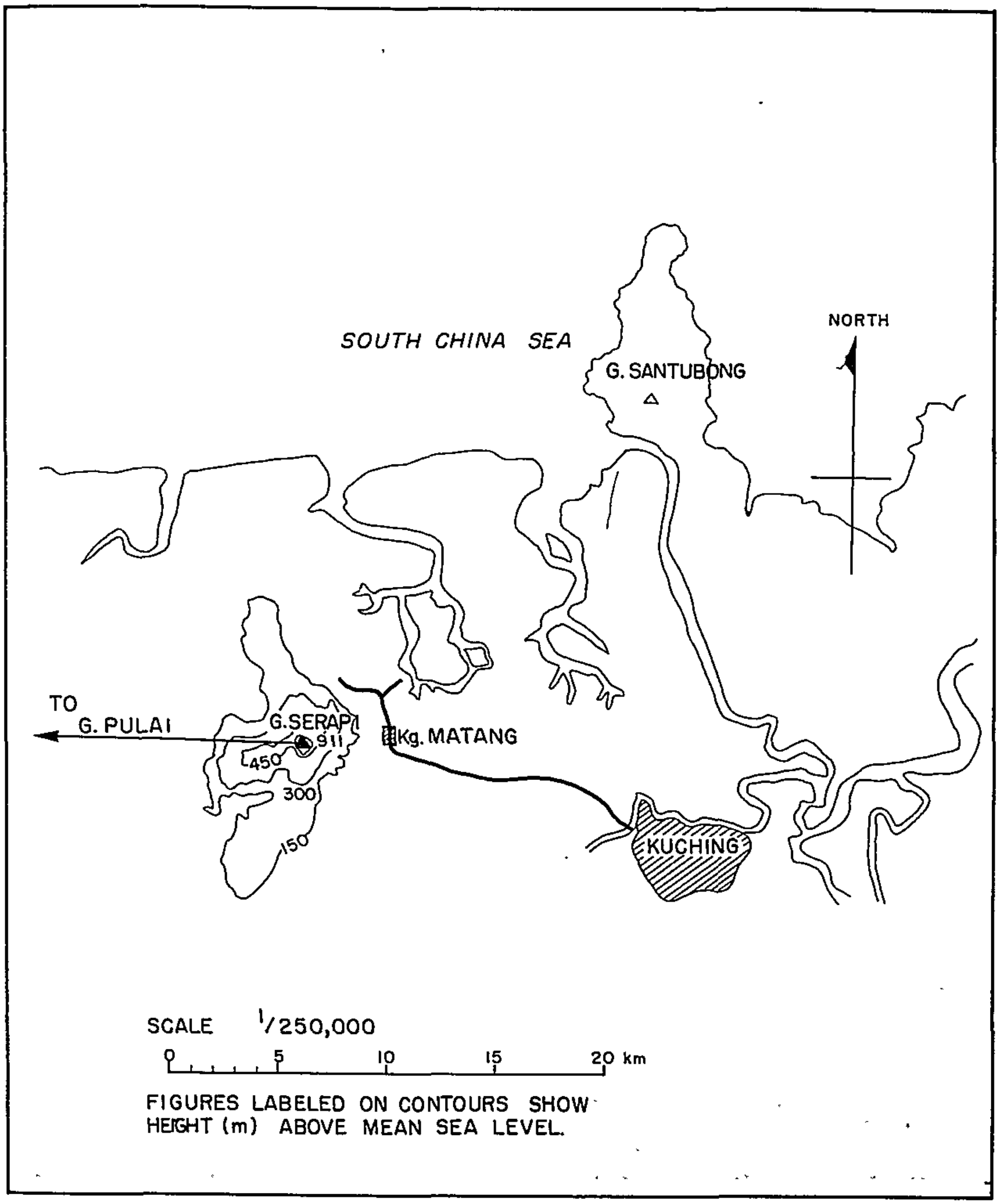


FIG. 5 MAP OF GUNONG SERAPI AND KUCHING

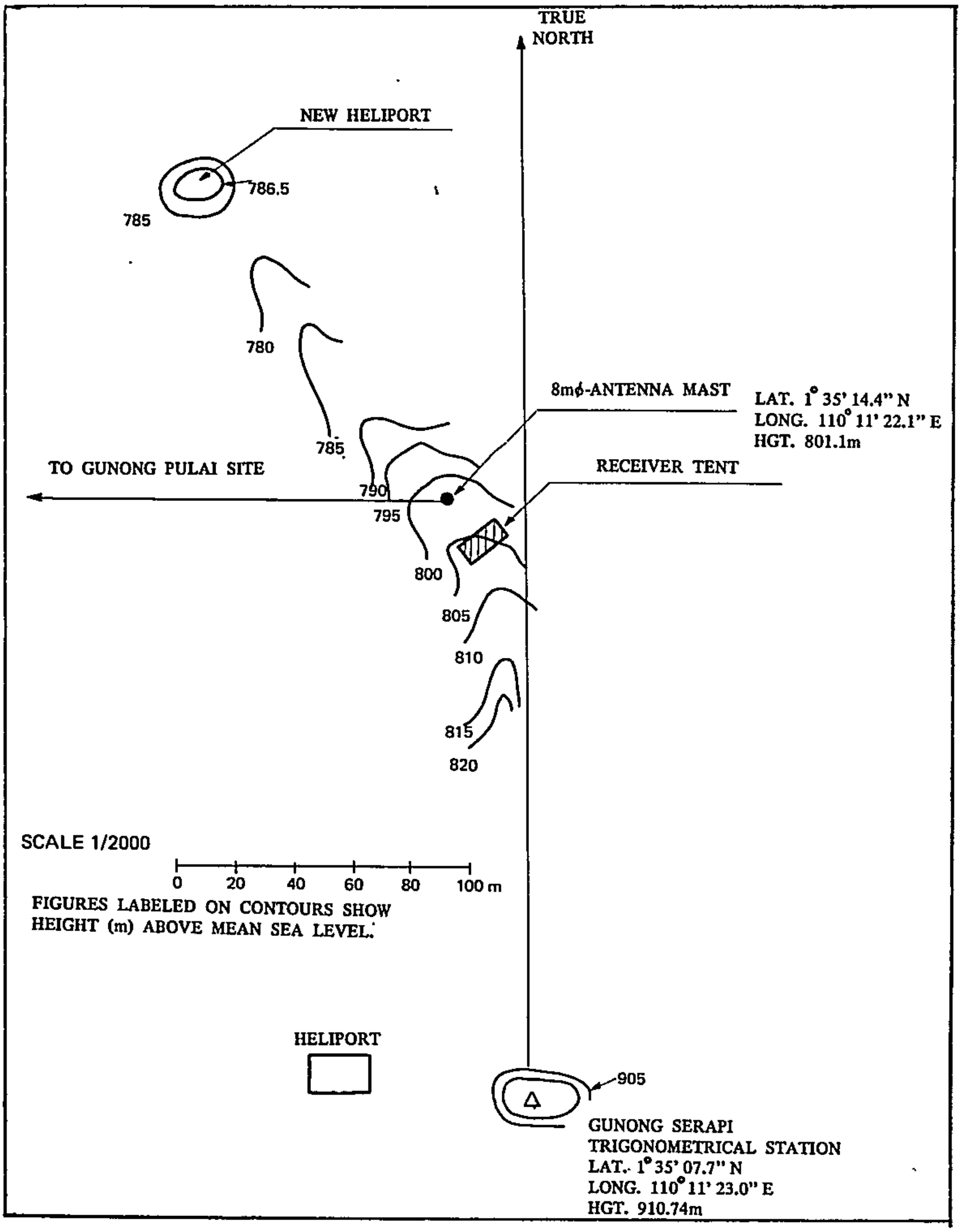


FIG. 6 TOPOGRAPHICAL MAP OF GUNONG SERAPI SITE

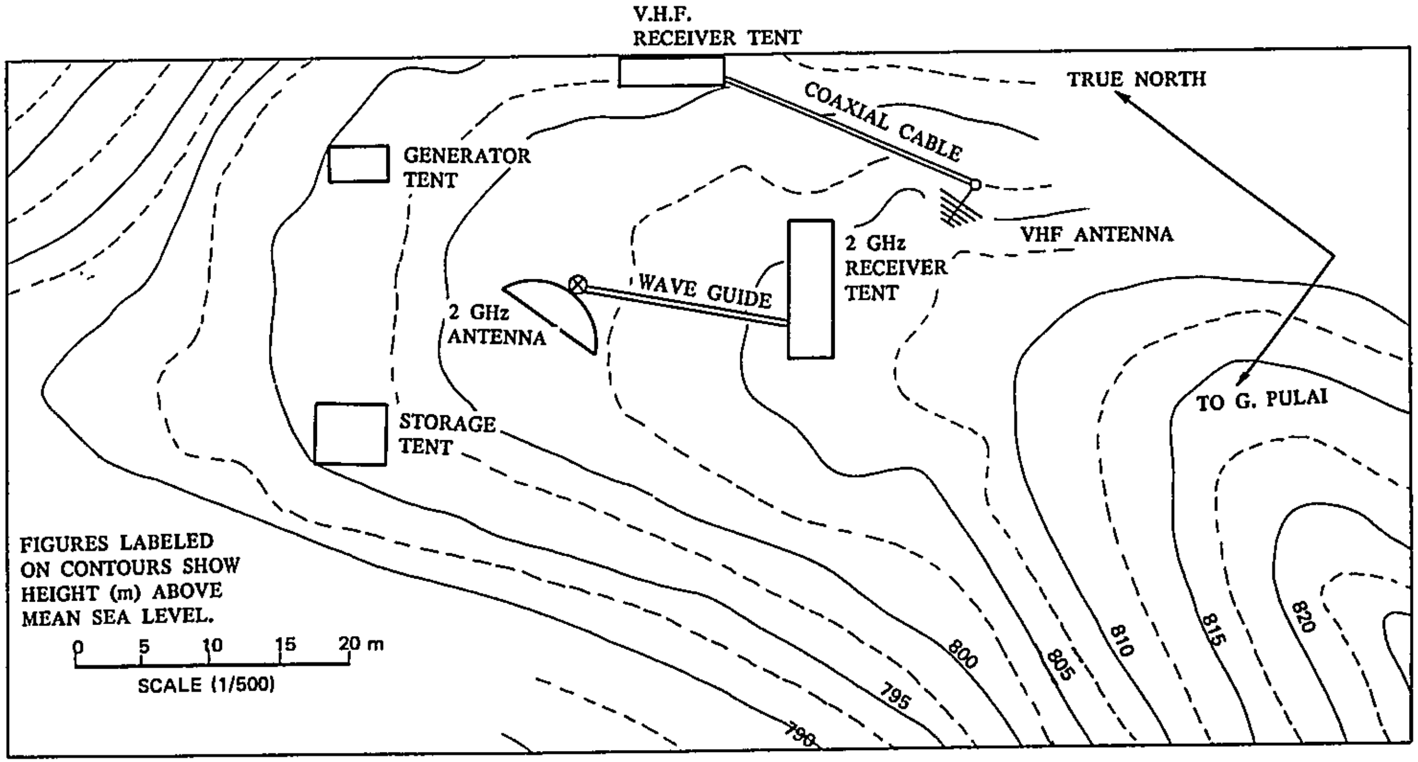


FIG. 7 TOPOGRAPHY AND LAYOUT OF RECEIVING FACILITIES AT GUNONG SERAPI SITE

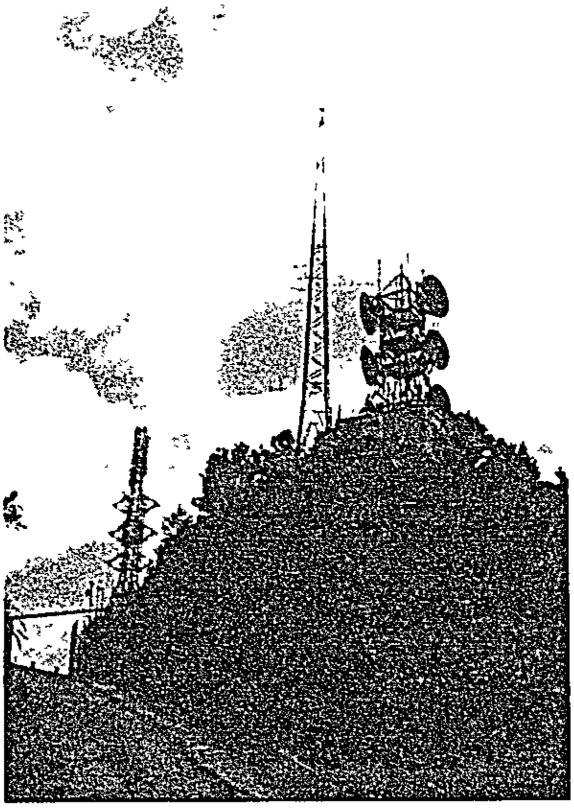


PHOTO 1. SENERY NEAR THE TOP OF GUNONG PULAI

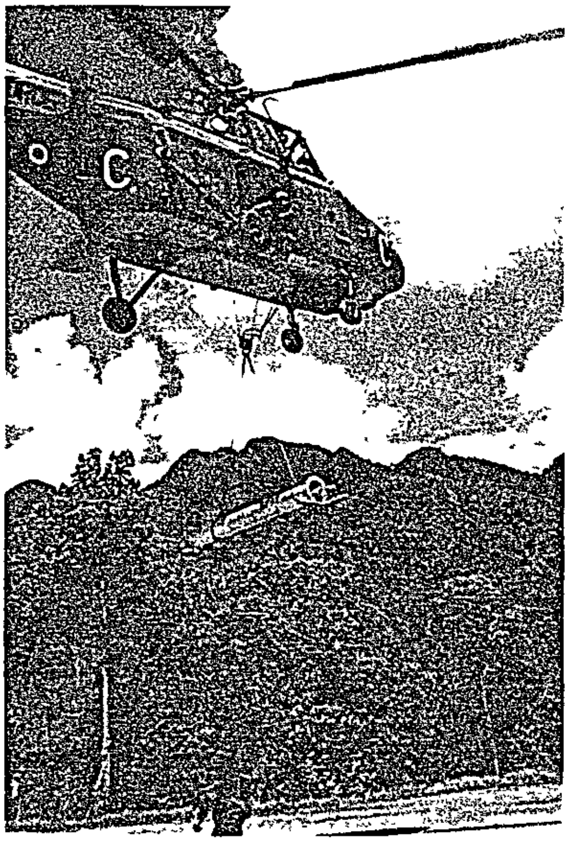


PHOTO 3.

ANTENNA MAST CARRIED TO GUNONG SERAPI STATION BY A HELICOPTER

PHOTO. 2 GUNONG SERAPI VIEWED FROM KUCHING

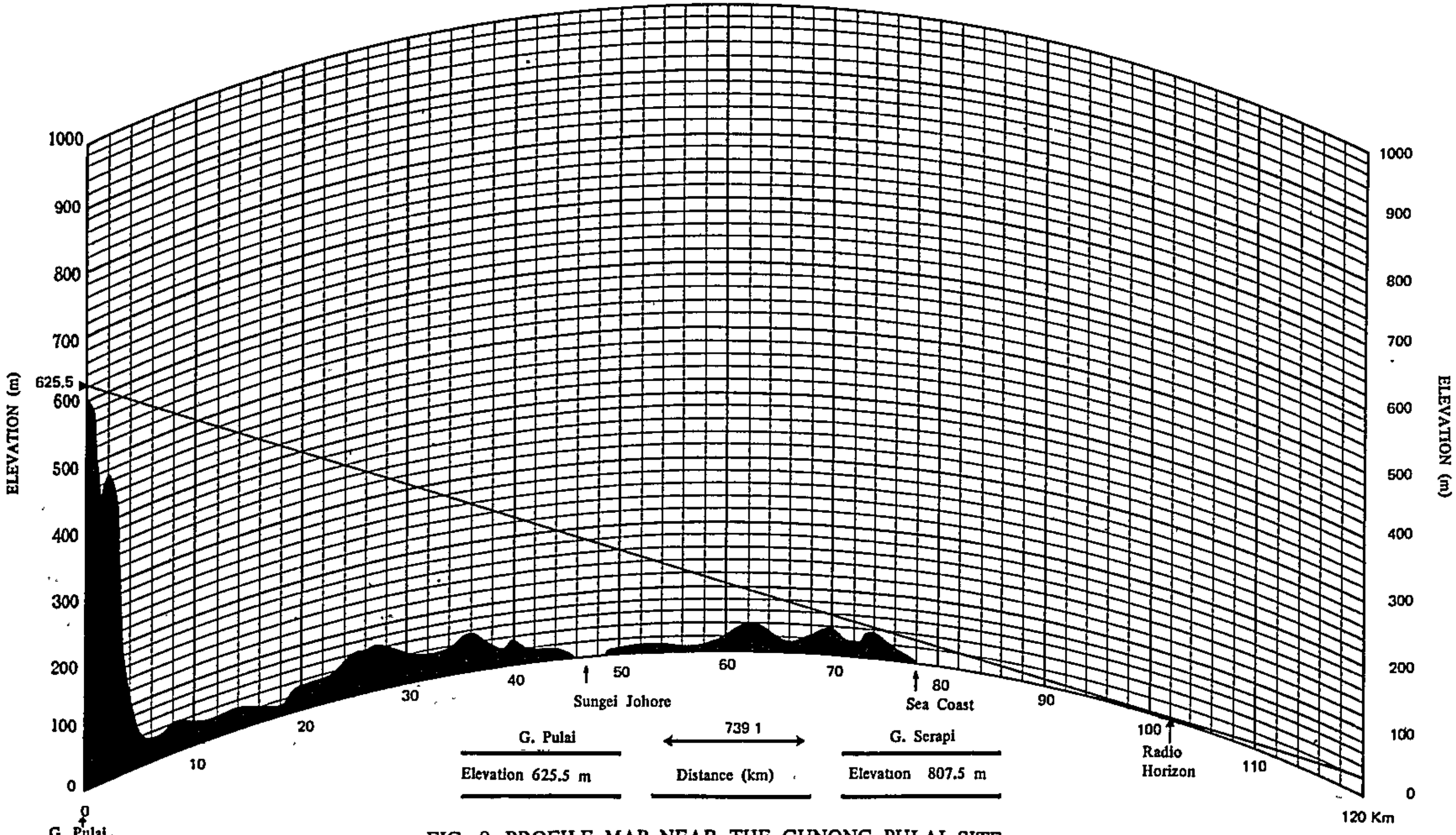


FIG. 8 PROFILE MAP NEAR THE GUNONG PULAI SITE

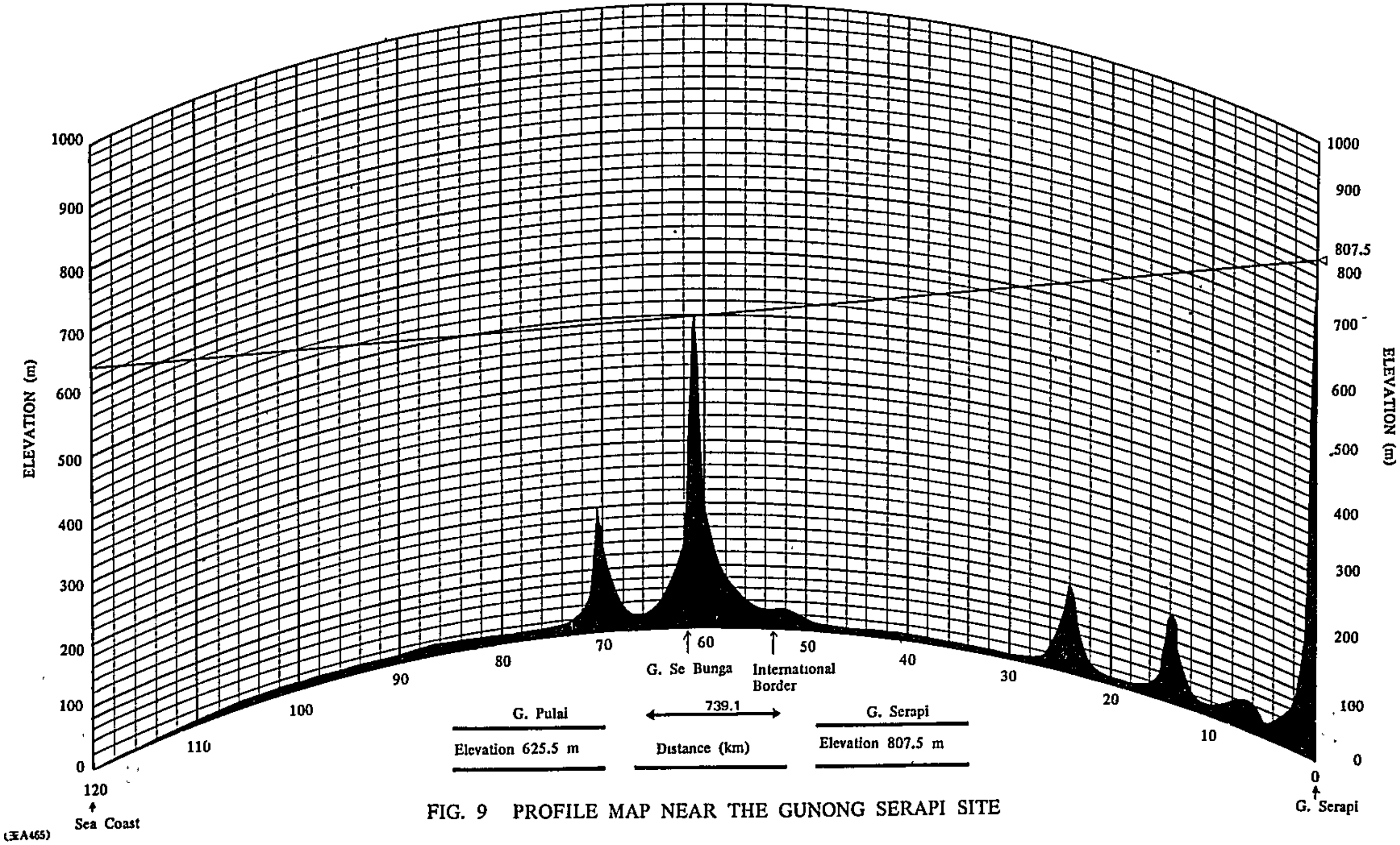


FIG. 9 PROFILE MAP NEAR THE GUNONG SERAPI SITE

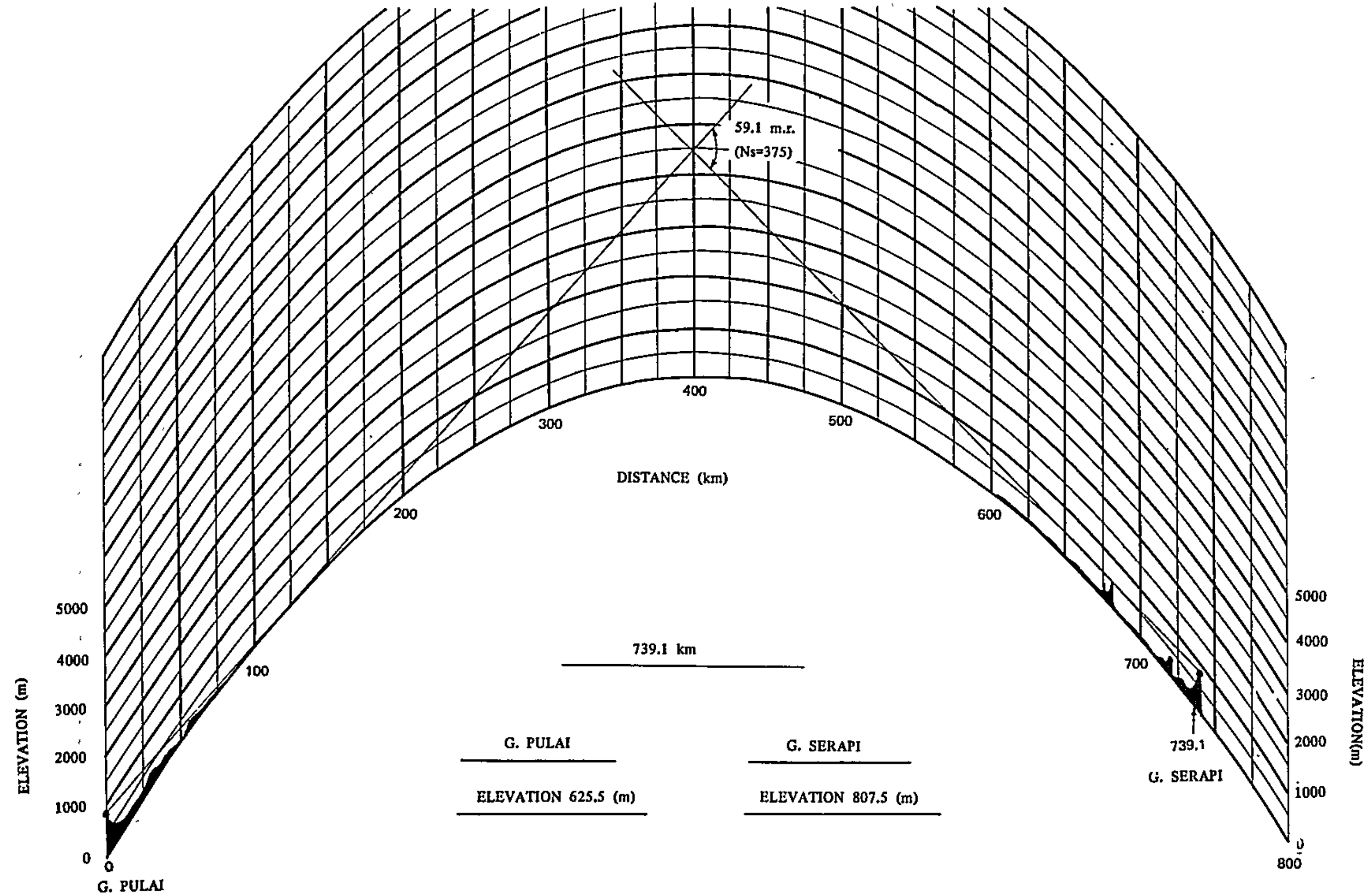


FIG. 10 PROFILE OF RADIO PROPAGATION PATH BETWEEN GUNONG PULAI AND GUNONG SERAPI

IV PROPAGATION TEST FACILITIES

4.1 Transmitting Facilities

From the convenience of the power supply, the transmitting facilities were set up at the Gunong Pulai site in Johore. The transmitting station is shown in Photograph 4. The transmitting facilities, of which the frequency is 1840 MHz, the output power 1 KW, the type of emission Fo (unmodulated carrier wave), and an antenna gain 40.1 db, consist of oscillator, exciter, power amplifier and antenna. Photograph 5 and Table 4 show the transmitter and its principal performance, respectively.

The schematic diagram of the transmitter is shown in Figure 11, while its performance is as follows.

The frequency of the crystal oscillator is 1.064815 MHz, and its stability is such extremely high as within 1×10^{-7}/hour. This stability is indispensable in limiting the frequency bandwidth of the receiving facilities to 1 KHz. Therefore, the crystal oscillator is contained in a highly-stabilized crystal-oven in which temperature variance is kept within 0.01°C.

Table 4 The principal characteristics of the transmitting facilities

Transmitter	
Output power	1 KW
Frequency	1840 MHz
Frequency stablility	within 1×10^{-7}/hour
Type of emission	Fo (unmodulated)
Spurious level	-60 db
Power consumption	approximately 5 KVA
Antenna	
Type	parabolic, transportable
Diameter	8 m
Gain	40.1 db
Feeder loss	0.9 db

The signal produced by the oscillator is multiplied by 24 to produce 25.5555 MHz and is sent to the exciter, where it is multiplied by 72 to give 1840 MHz signal, which is then amplified by the light-house tube LD-583. After eliminating undesired radiation signals by the use of a bandpass filter, it is finally fed into the power amplifier.

Klystron VA-802 B is used in the power amplifier, providing approximately 40 db gain and output power of 1 KW.

The antenna is a parabolic antenna with a diameter of 8m, and its gain is measured as 40.1 db. As shown in Figure 12, the antenna is a transportable and knockdown type, especialy designed to be constructed without special foundation work and is provided with a reflector made of lath mesh. As the feeder, the wave guide WRJ-2 (15m) is used, producing a loss of 0.9 db.

The primary power for the transmitting facilities, as shown in the schematic diagram of Figure 13, is supplied by the 100 KVA diesel generator for television broadcast.

Layout of the facilities in the transmitting station as a whole is shown in Figure 4. The transmitter is accommodated in a tent as shown in Photograph 6.

4.2 Receiving Facilities

A picture of the receiving station at Gunong Serapi is shown in Photograph 7.

The receiving facilities, of which the frequency is 1840 MHz, the noise figure 3 db, the bandwidth 1 KHz, and antenna gain 40.0 db, consist of a parametric amplifier, pre-IF amplifier, local oscillator, demodulator, measuring equipment and an antenna. The receiver and its principal performance are respectively shown in Photograph 8 and Table 5. The schematic diagram of the parametric amplifier and the receiver (main) are separately shown in Figures 14 and 15.

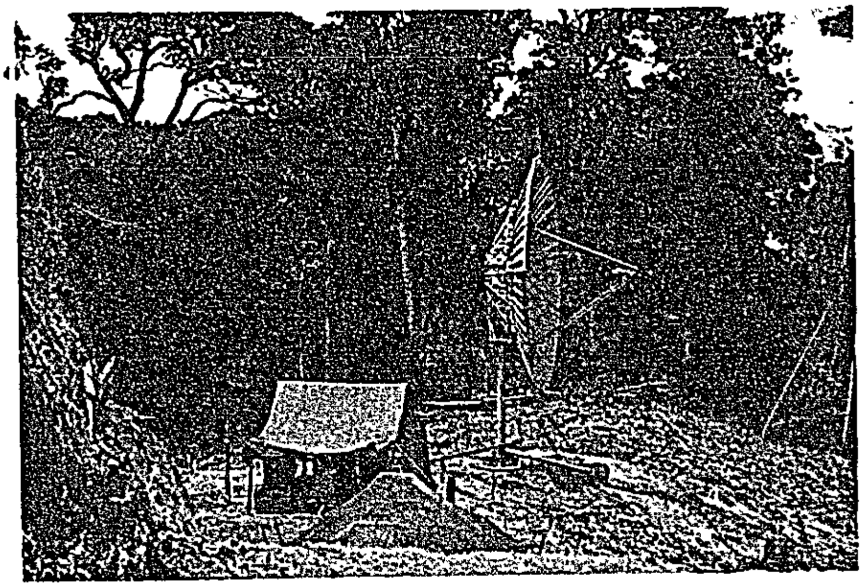


PHOTO 4. GUNONG PULAI TRANSMITTING STATION

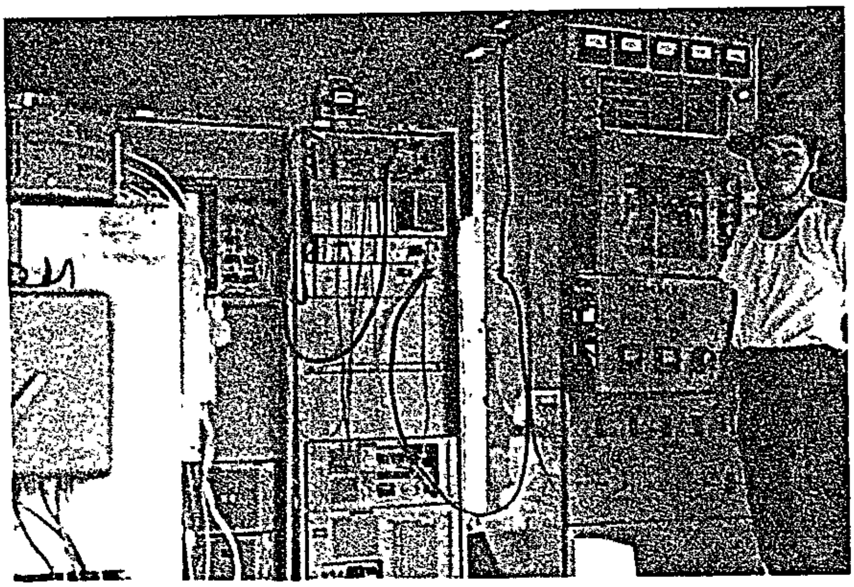


PHOTO 6. TRANSMITTER IN GUNONG PULAI STATION

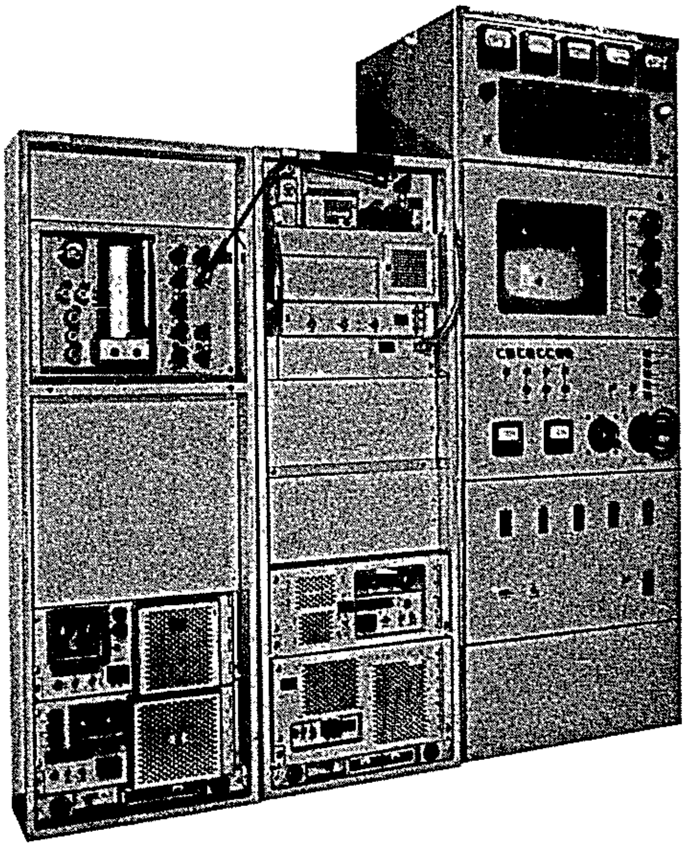


PHOTO. 5 2 GHz 1 KW TRANSMITTER

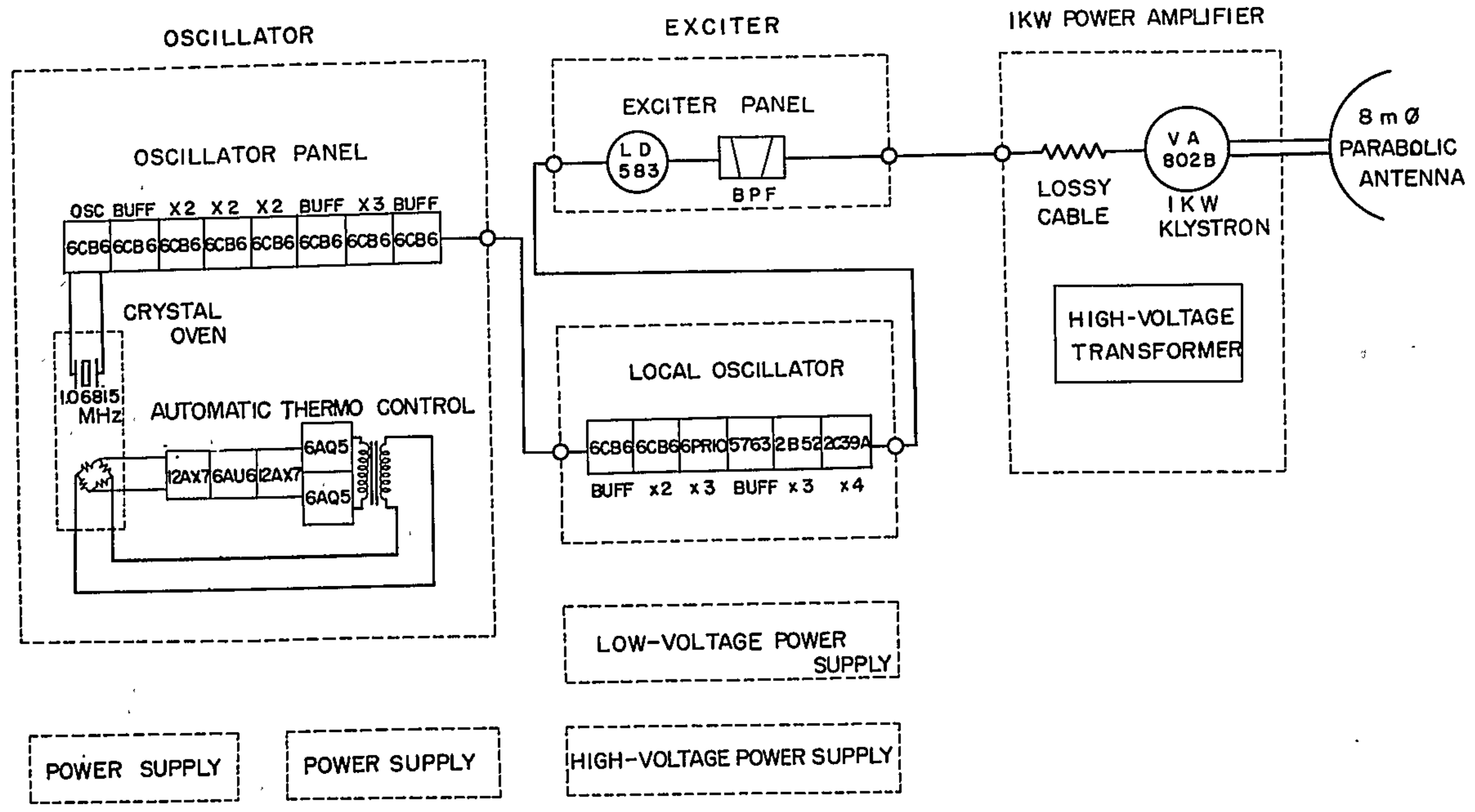


FIG. 11 SCHEMATIC DIAGRAM OF TRANSMITTING SYSTEM

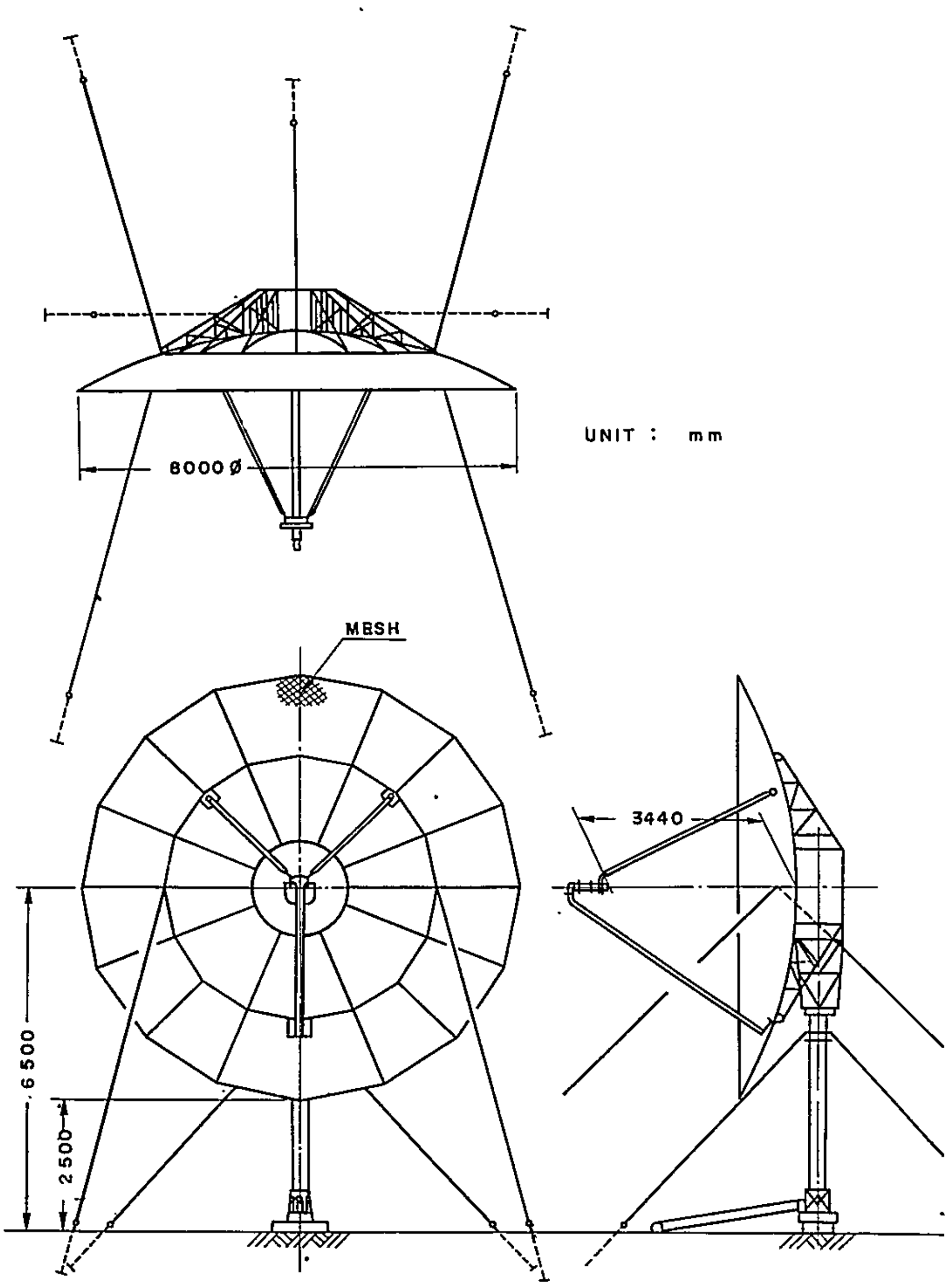


FIG. 12 TRANSPORTABLE PARABOLIC ANTENNA

Table 5 Characteristics of the receiving facilities

Receiver	
Frequency	1840 MHz
Noise figure	3 db
Bandwidth	1 KHz
Frequency stability	within 1 x 10^{-7}/hour (with AFC)
Threshold level	-141 dbm
Antenna	
Type	parabolic, transportable
Diameter	8m
Gain	40.0 db
Feeder loss	3.0 db

The signal from the antenna is fed into the parametric amplifier, which is of a two-stage reflecting type, with varactor diodes of 1S362, and the details of which are as follows; noise figure 3 db, bandwidth 5 MHz, gain 30 db approximately. The output signal is supplied to the receiver (main), where the signal is mixed with the first local signal with frequency stability within 10^{-7}/hour, giving the first intermediate frequency signal (IF) of 112 MHz.

The 5th IF signal of 20 KHz obtained by 4-fold consecutive frequency conversion is guided to the demodulator, where the received signal level is detected and the output is fed into the recorder. In parellel with the level-detection circuit is provided an AFC loop with a discriminator, by which the 5th IF signal is kept within 20 KHz $\pm$ 0.5 KHz.

By virtue of both the low-noise characteristic of the parametric amplifier and the narrow bandwidth characteristic, the noise level of the receiver is very low which results in input-terminal value as low as - 141 dbm. The antenna and feeder used are of the same kind as those used in the transmitting facilities, but the antenna gain is 40.0 db and the loss of feeder (21m) is 3.0 db.

As for the primary power of the receiving facilities, 3 sets of 3 KVA transportable diesel generators were used. The schematic diagram is given in Figure 16.

The layout of the receiving facilities, inclusive of VHF propagation test facilities implemented along with the present survey, is shown as in Figure 7. The receiving facilities are housed in a tent as shown in Photograph 9.

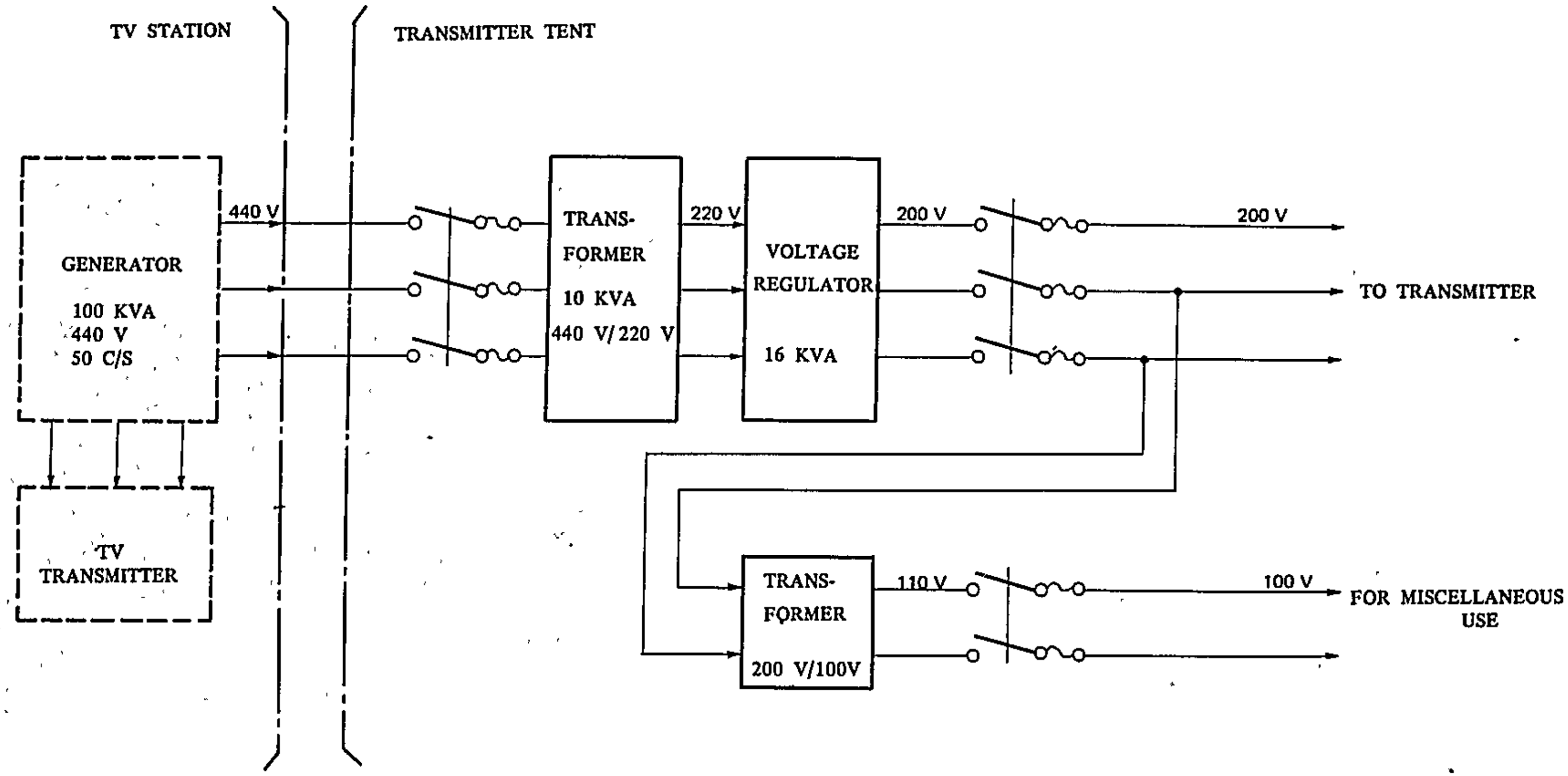


FIG. 13 ELECTRIC POWER SOURCE AT GUNONG PULAI SITE

PHOTO 7. GUNONG SERAPI RECEIVING STATION

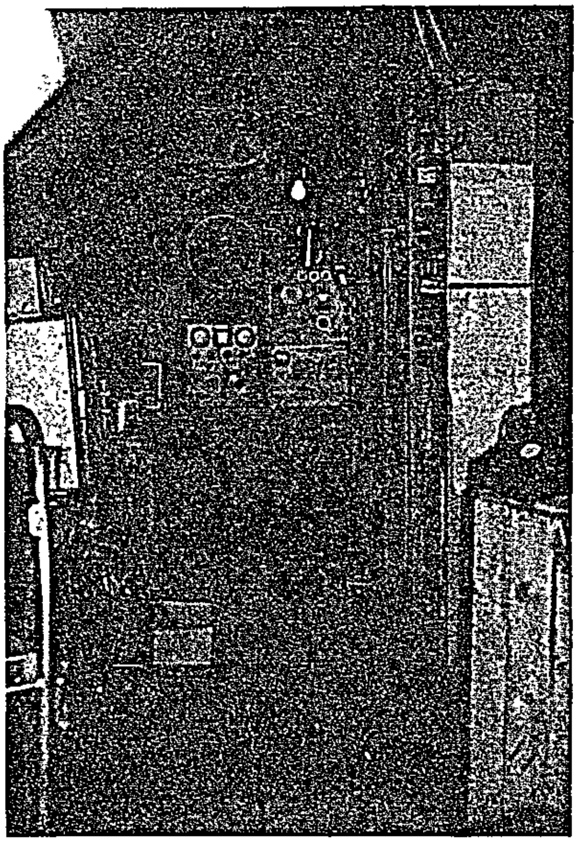


PHOTO 9. RECEIVING EQUIPMENT IN GUNONG SERAPI STATION

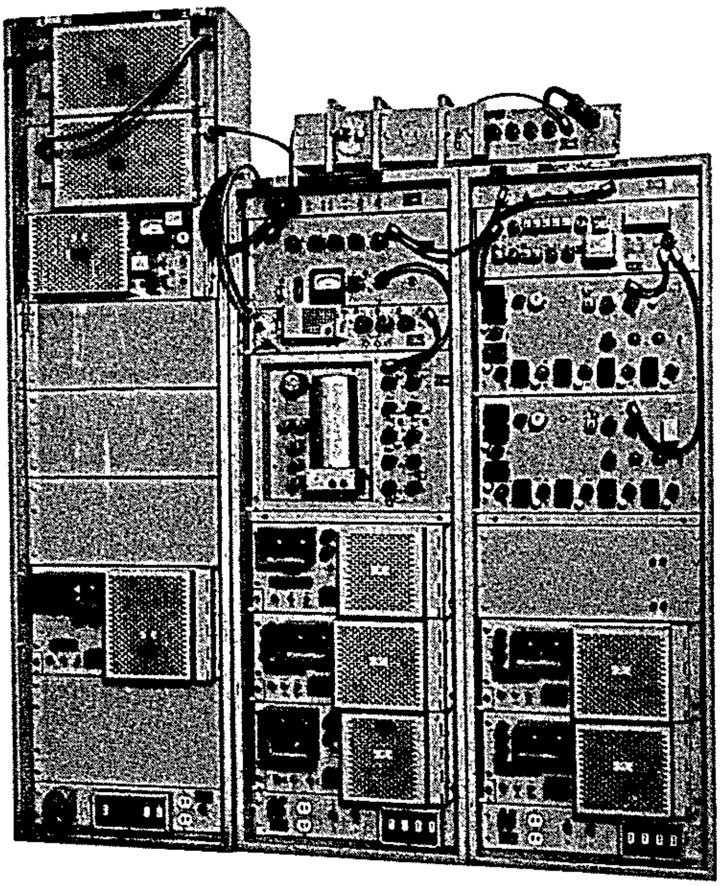


PHOTO. 8 2 GHz RECEIVER

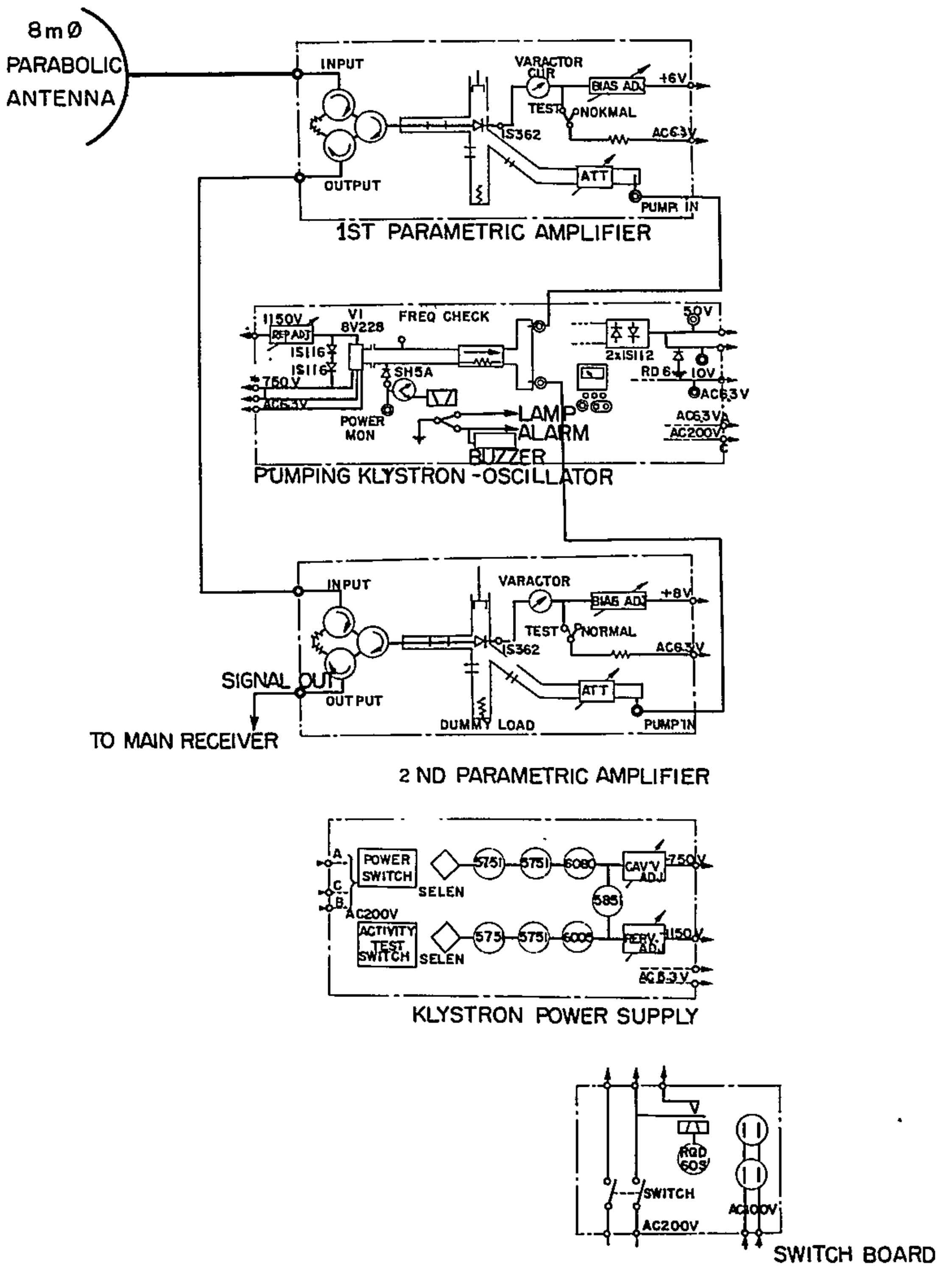


FIG. 14 SCHEMATIC DIAGRAM OF PARAMETRIC AMPLIFIER

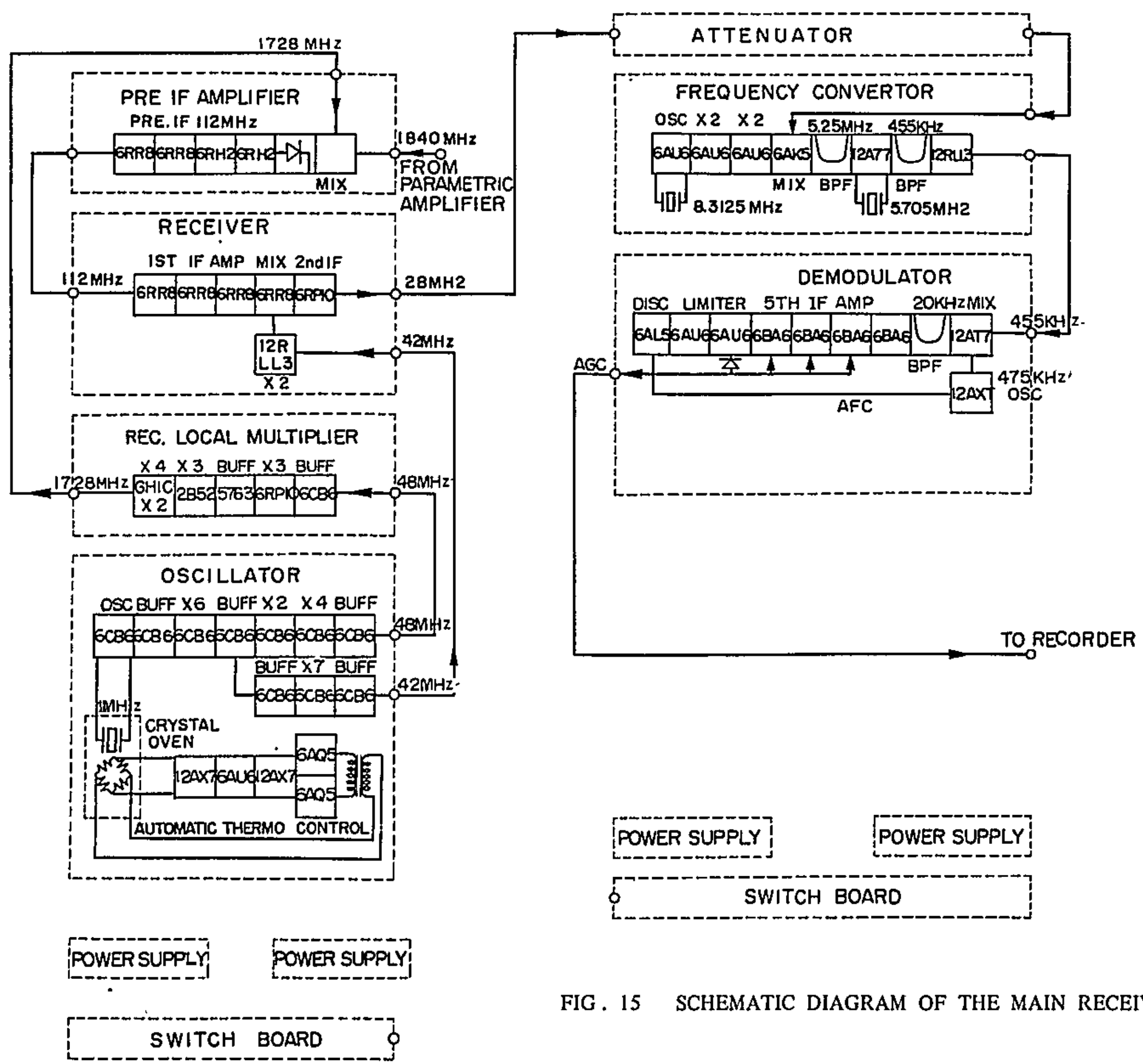


FIG. 15 SCHEMATIC DIAGRAM OF THE MAIN RECEIVER

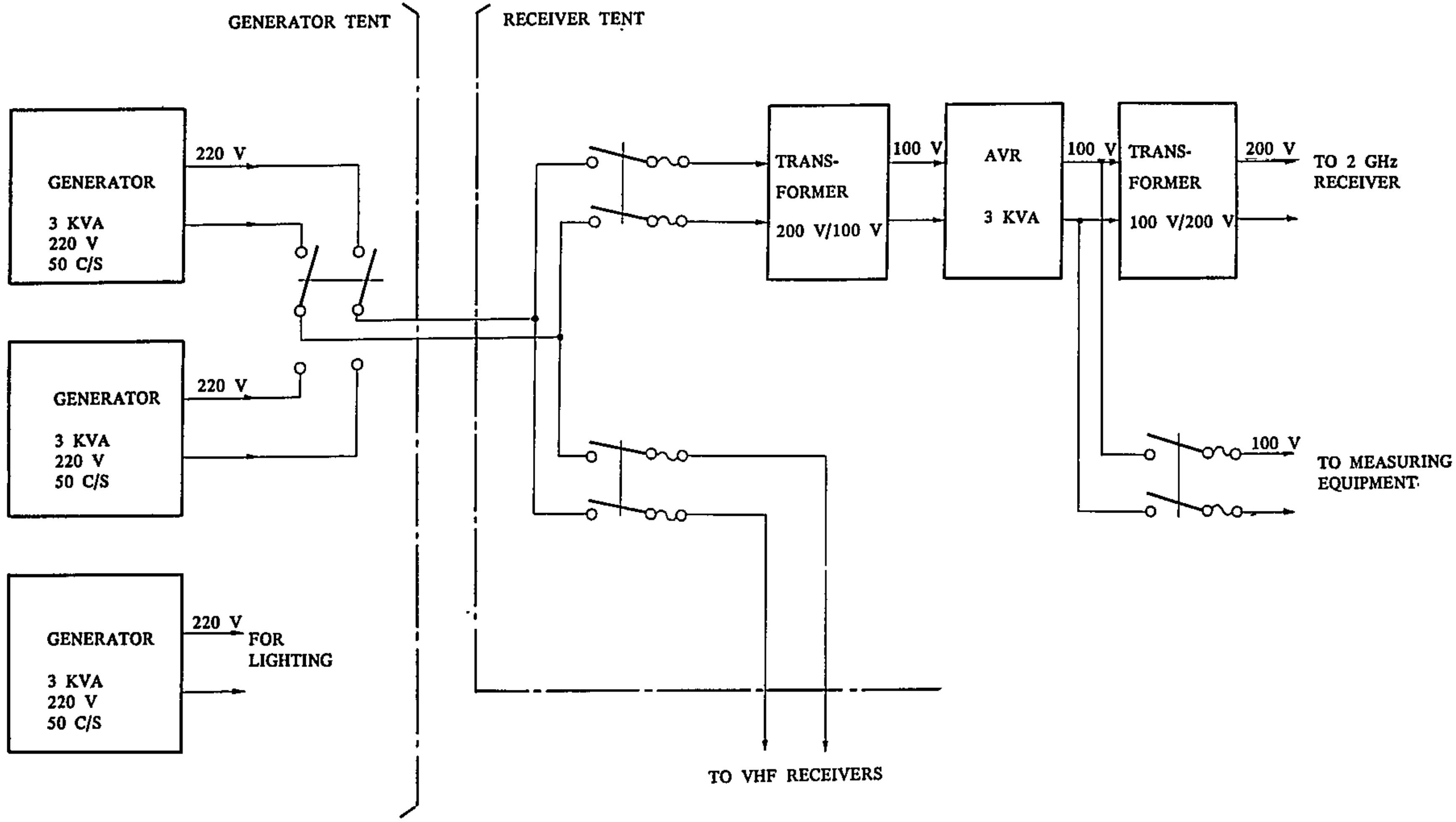


FIG. 16 ELECTRIC POWER SOURCE AT GUNONG SERAPI SITE

V Results of Propagation Test

5.1 Summary of Temporal Variation of Basic Transmission Loss and Surface Refractivities

Photographs 10 and 11 illustrate samples of recordings of the intensity of signals received. The three recordings in Photograph 10, each of which was made for the period of approximately one hour, show slow, intermediate and fast fadings, respectively. The speed of variation is diverse, but the median or mean level for the duration of one minute does not vary within a period of about one hour. The three kinds of recordings in Photograph 11 were made respectively for 5 minutes, which are representatives of different rapidities of fluctuation.

From the recordings of the received signal level, basic transmission loss is calculated, and its variation with time is shown in Figures 17-a to 17-e. The basic transmission loss is deduced on the assumption that antenna-to-medium coupling loss was 6.9 db during the entire period.

From the above, it is found that the basic transmission loss (hourly median) varies in a considerably wide range and also that the maximum value of the loss is recorded during the day, showing quite distinguishable diurnal variation.

In those figures, hourly surface refractivities observed in Singapore and Kuching near both ends of the propagation path are also plotted. The surface refractivities vary in the range of 355 to 395 with a lower value during the day. The low surface-refractivities registered during the day is ascribed to sunlight that raises atmospheric temperature and lowers relative humidity. There appears to be a correlation between the variation of basic transmission loss and surface refractivities. However, it should be noted the fact that time differences exist between them.

5.2 Diurnal Variation of Basic Transmission Loss and Surface Refractivities

In order to study a diurnal variation of basic transmission loss, cumulative probability distribution of the hourly median basic transmission loss at a particular time each day is deduced, and its 10% value, 50% value, 90% value are plotted in terms of Kuching local time, as shown in Figure 18 (the upper).

The same calculations are made of the surface refractivities observed at

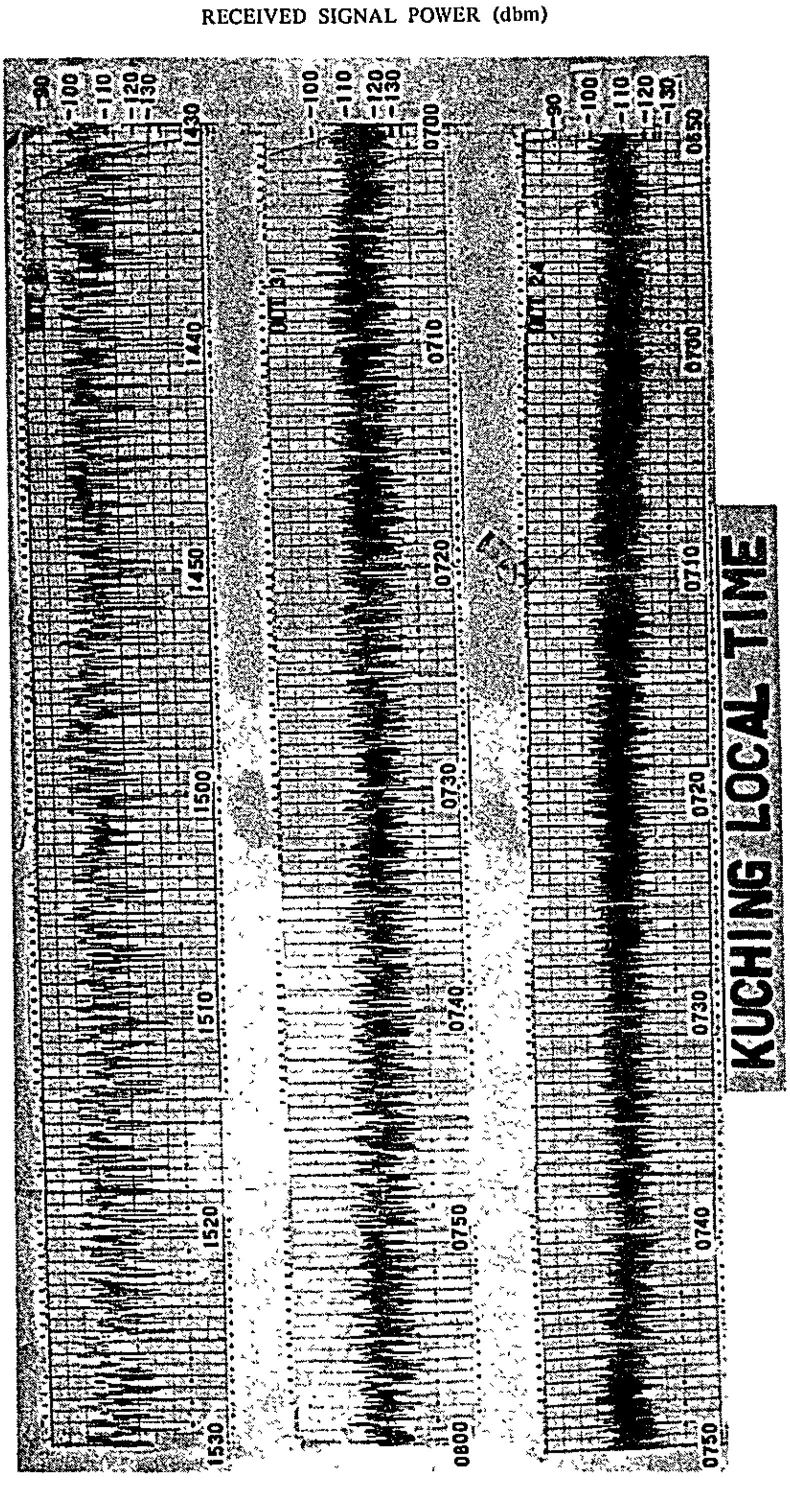


PHOTO. 10 SAMPLES OF ONE-HOUR RECORDINGS OF RECEIVED SIGNAL LEVEL

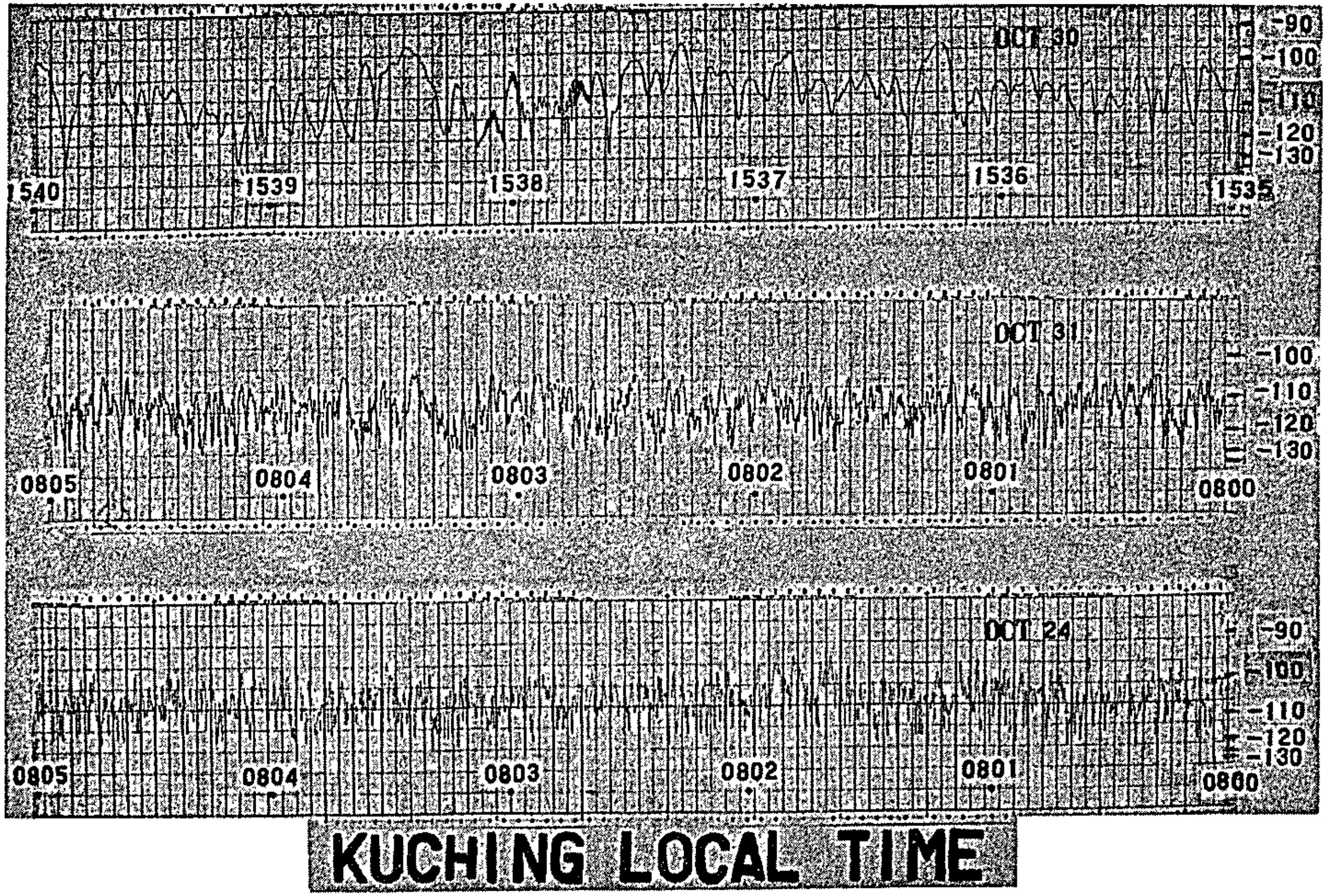


PHOTO. 11 SAMPLES OF 5-MINUTE RECORDINGS OF RECEIVED SIGNAL LEVEL

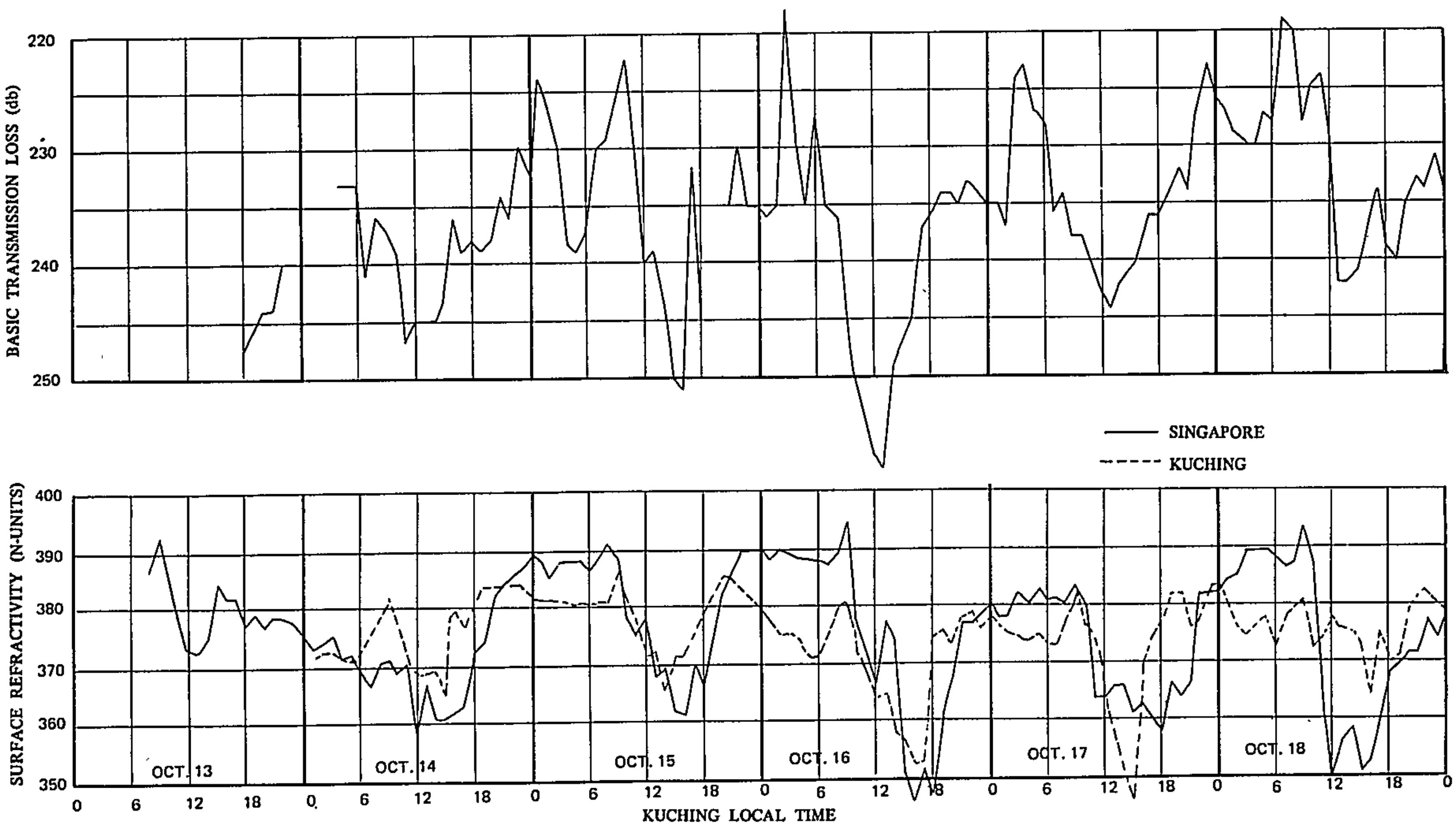


FIG. 17-a TEMPORAL VARIATIONS OF BASIC TRANSMISSION LOSS AND SURFACE REFRACTIVITY

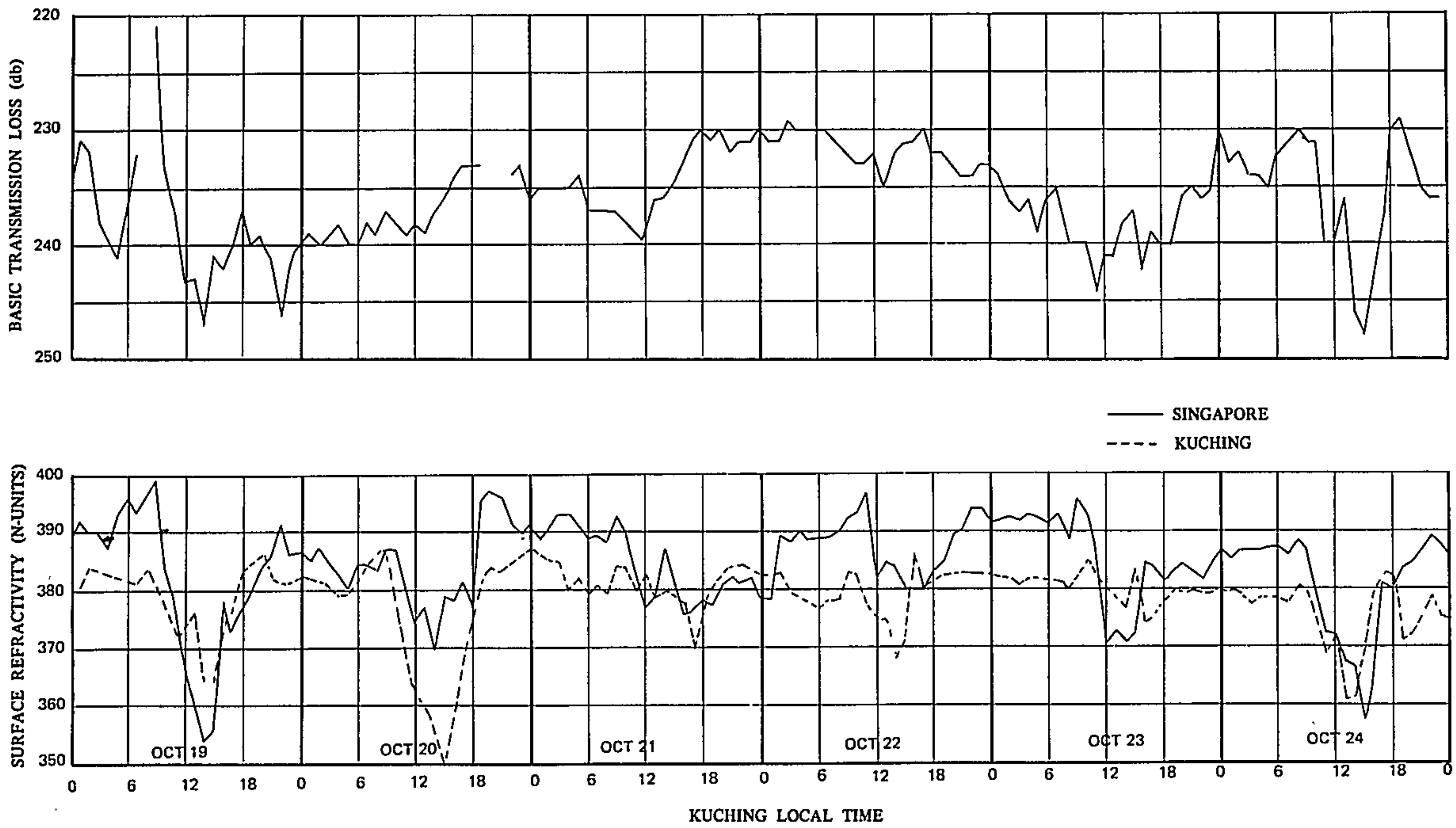


FIG. 17-b TEMPORAL VARIATIONS OF BASIC TRANSMISSION LOSS AND SURFACE REFRACTIVITY

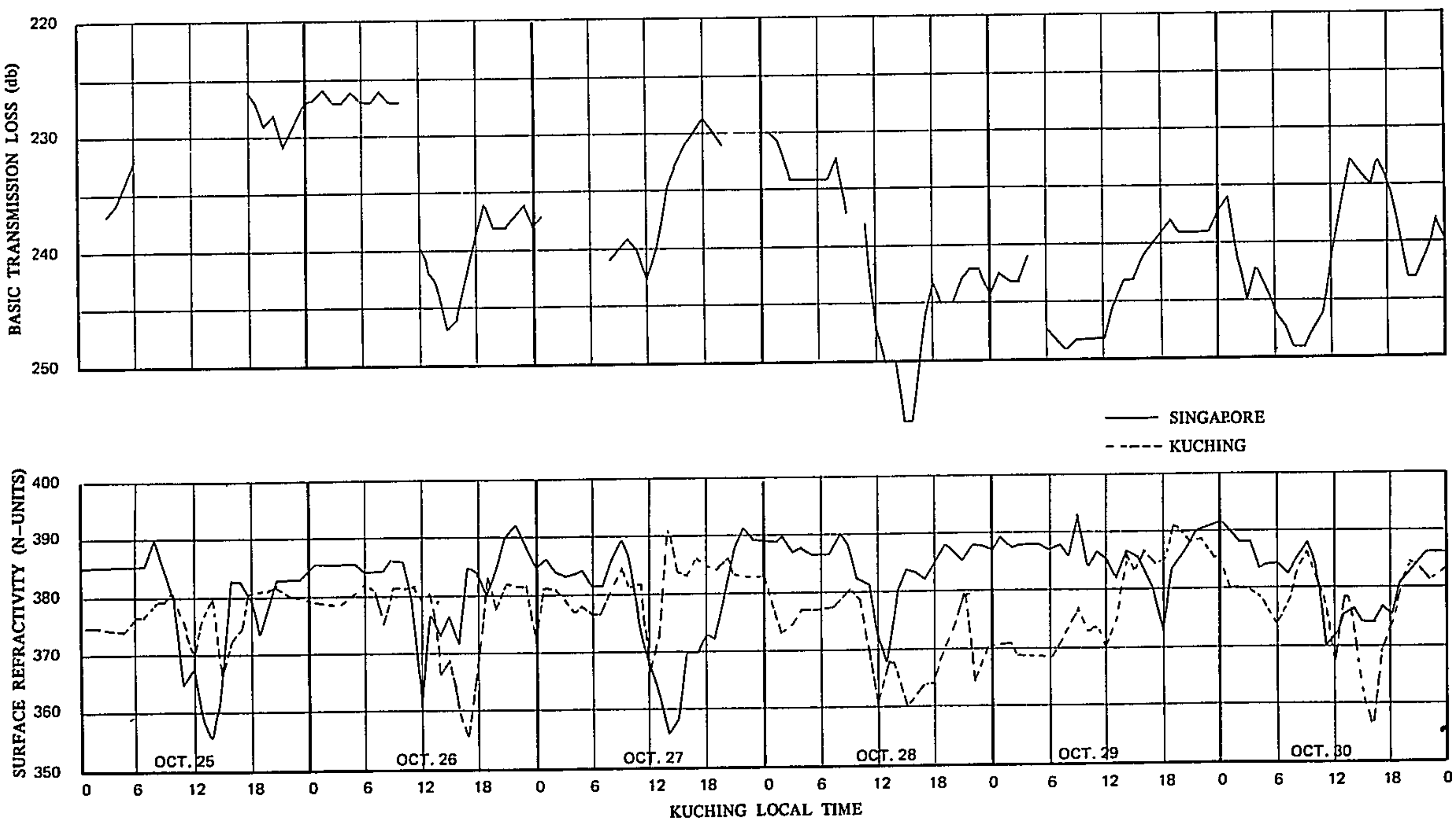


FIG. 17-c TEMPORAL VARIATIONS OF BASIC TRANSMISSION LOSS AND SURFACE REFRACTIVITY

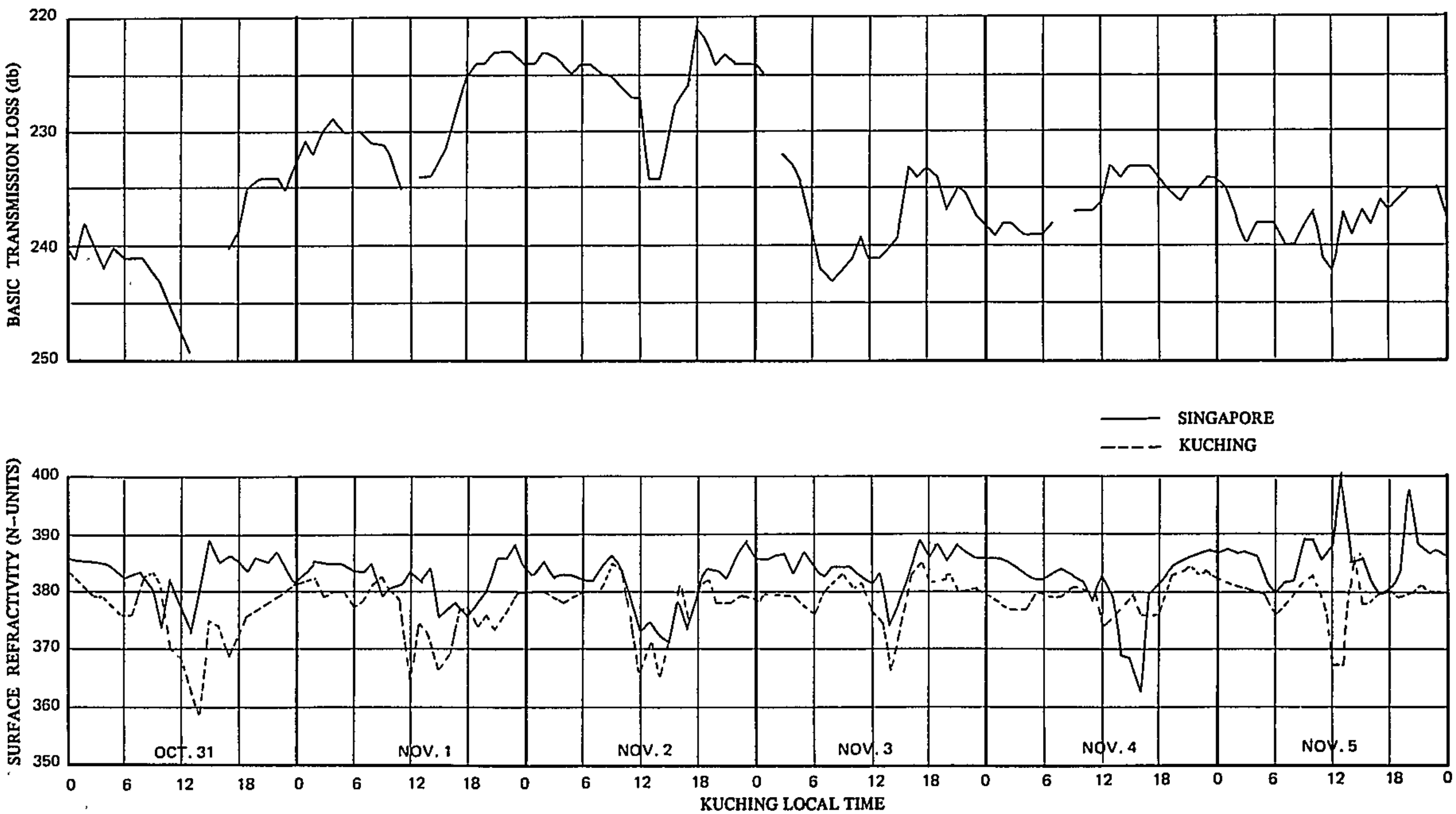


FIG. 17-d TEMPORAL VARIATIONS OF BASIC TRANSMISSION LOSS AND SURFACE REFRACTIVITY

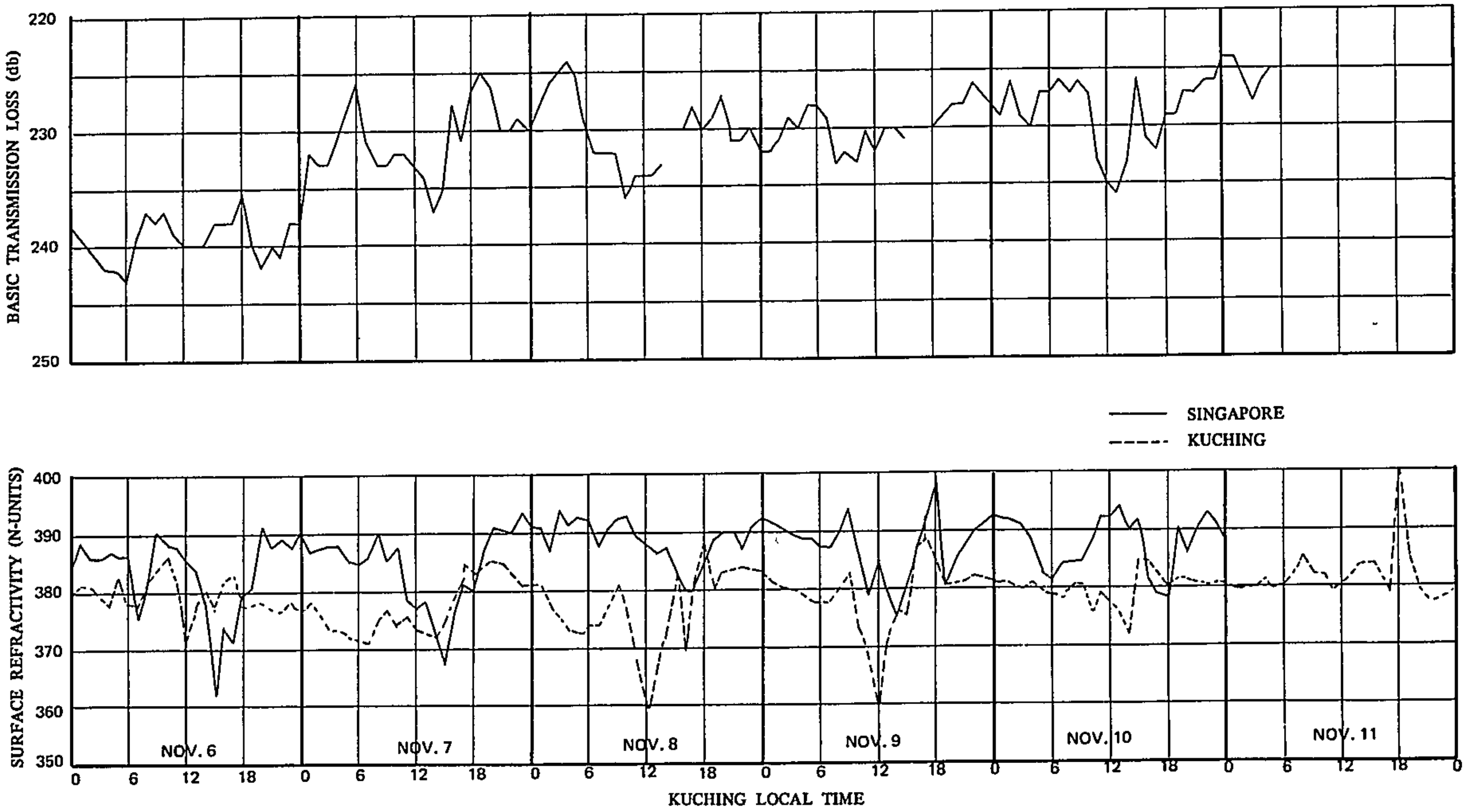
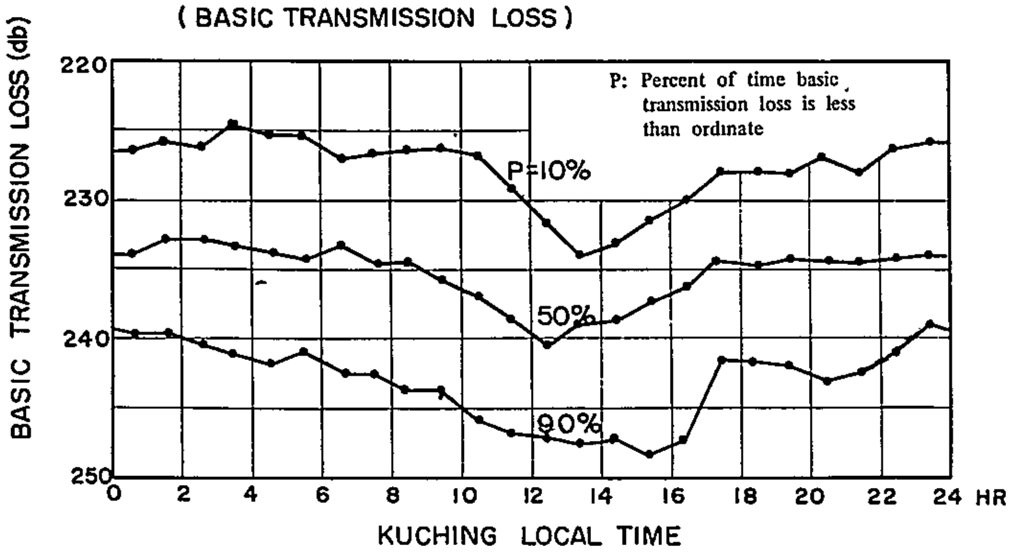


FIG. 17-e TEMPORAL VARIATIONS OF BASIC TRANSMISSION LOSS AND SURFACE REFRACTIVITY



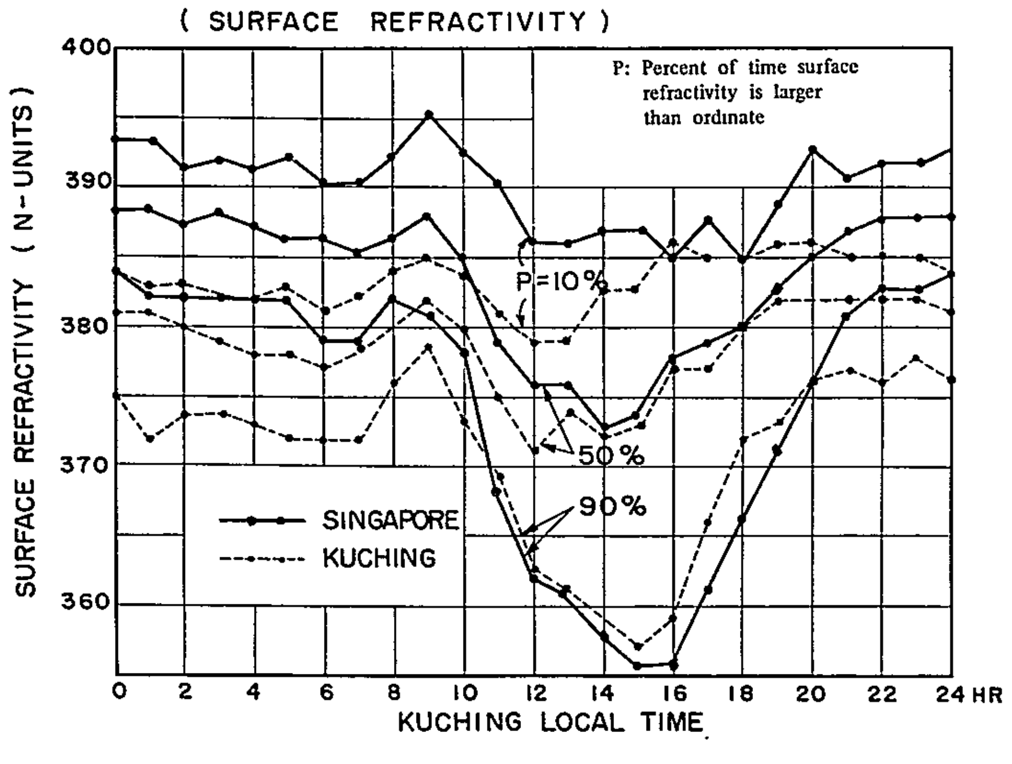


FIG. 18 DIURNAL VARIATIONS OF BASIC TRANMISSION LOSS AND SURFACE REFRACTIVITY

Singapore and Kuching, of which the results are shown in Figure 18 (the lower). However, it should be understood that the surface refractivities are not given in terms of hourly median, but are the values observed every hour on the hour.

The following are pointed out from the above figures.

(a) The basic transmission loss and the surface refractivities mark respectively maximum and minimum during the day. However, the two sets of variation mark time difference between each other. It is a noteworthy fact in designing the link that maximum basic transmission loss is registered during the day when telephone traffic is heavy.

(b) The hourly variation-range of the basic transmission loss (the difference between 90% and 10% values) is about 15 db , which does not vary with time.

(c) The variation range of the surface refractivities (the difference between 10% and 90% values) is considerably wide, and each range in the morning and evening is about 10 N-units, while during the day it reaches as high as 30 N-units.

5.3 Fading Rate and Fading Range

Figure 19 shows statistics on the fading rate and fading range of the received signals. These were deduced from the analysis of one-minute observation recordings made at approximately 08:00 and 20:00, Kuching local time. (See Photograph 11). On the data, the fading rate is more or less within 0.14 to 0.80 cycles per second, while the fading range is approximately 13 db. The latter fact suggests that the short-term fading follows well the Rayleigh distribution.

5.4 Cumulative Probability Distribution of Basic Transmission Loss and Surface Refractivities

Figure 20 shows the cumulative probability distribution of the basic transmission loss observed for about four weeks from October 13 to November 11, 1967. The solid curve represents hourly-median distribution, while the dotted curve represents one-minute median one. The following are noteworthy.

(a) Both one-minute and hourly medians follow well a decibel normal distribution.

(b) The distribution of one-minute median value coincides well with that of

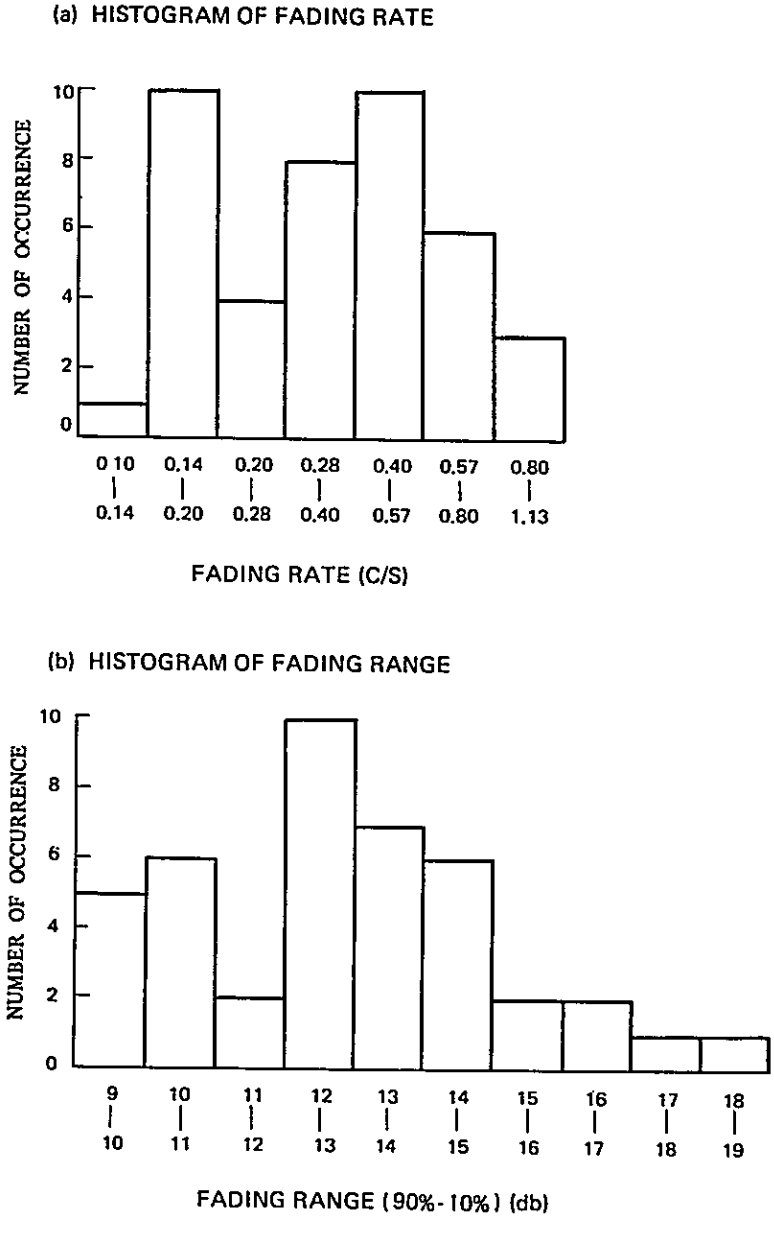


FIG. 19 HISTOGRAMS OF FADING RATE AND FADING RANGE

hourly median one. This means that the variation of one-minute median value within an hour is very small compared to that of the hourly median value over the entire period concerned.

(c) The median value over the entire period of one-minute median value is 234.8 db, which is smaller approximately by 11 db than the value presumed on the basis of the CCIR Report 244-1 [1) 2)] of the 11th plenary Assembly.

(d) The difference between 90% value and 10% value during the entire period is 16.5 db, which is smaller approximately by 6.5 db than the value estimated using the data in Figure 11 (Variation of transmission loss with effective distance in a maritime subtropical climate (type 3)) in the aforementioned CCIR Report.

Deduction of the abovementioned basic transmission loss was done on the assumption that the antenna-to-medium coupling loss was 6.9 db during the entire period. Cumulative probability distributions of surface refractivities observed every hour on the hour at Singapore and Kuching are given in Figure 21.

The following are noteworthy.

(a) The distribution of surface refrectivities is apparently a combination of two normal distributions with different standard deviations above and below the median. The distribution differs considerably from that of basic transmission loss given in Figure 20.

(b) The median values of surface refractivities are 385 in Singapore and 379 in Kuching. The surface refractivities (median) in October and November in Singapore were studied using Reference 3, to give an approximate figure of 383. Consequently, the weather conditions during the present propagation test is regarded as more or less the same as those of an average year.

5.5 Relation between Basic Transmission Loss and Atmospheric Refractivity Gradient

The Singapore Meteorological Observatory has been conducting weather observation by radio sonde at 08:00, Kuching local time (07:30, Singapore local time). The atmospheric refractivity gradients during the radio-propagation test period were calculated using the above data. The results are given in Figure 22. The following are distinguished as noteworthy.

(a) Except for the observed value on October 25, refractivity gradients decrease exponentially with altitude. These coincide well with the figures given in Reference 3.

(b) A peculiar characteristic was noticed in the value observed between 1500m and 4000m in altitude on October 25, which correlated to peculiarities in relative-humidity-gradient. The electric field then turned out to be unusually high, and its hourly median was recognized to be approximately by 20 db higher than the entire-period median. Consequently, it is thought this abnormally high electric field was ascribed to elevated duct associated with this abnormal refractivity gradient. (However, due to the antenna-pointing adjustment, the consecutive measurement was interrupted, and thus no record during that period is seen in Figure 17-c.)

The most portion of the propagation path runs over the sea. Therefore, it is supposed that the path is subject to generation of maritime duct in not only high elevation but also low elevation. However, no clear-cut evidence such as the datum on October 25, is found from the results of observation. This seems to be due to the facts that the meteorological data obtained were not satisfactory for this kind of analysis, since the meteorological observatory in Singapore was out of the propagation path and the sonde observations were conducted only once a day.

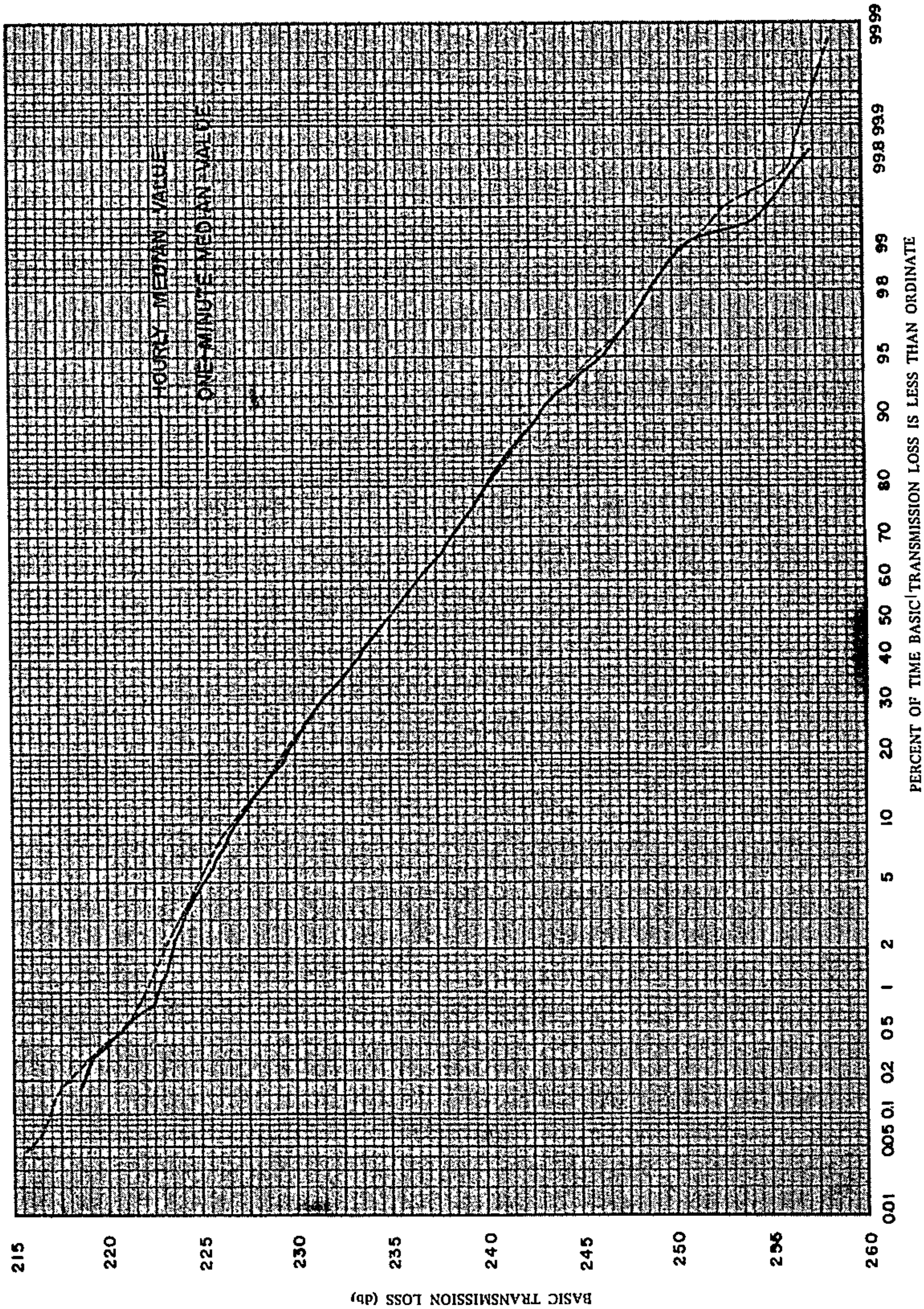


FIG. 20 CUMULATIVE DISTRIBUTION OF BASIC TRANSMISSION LOSS

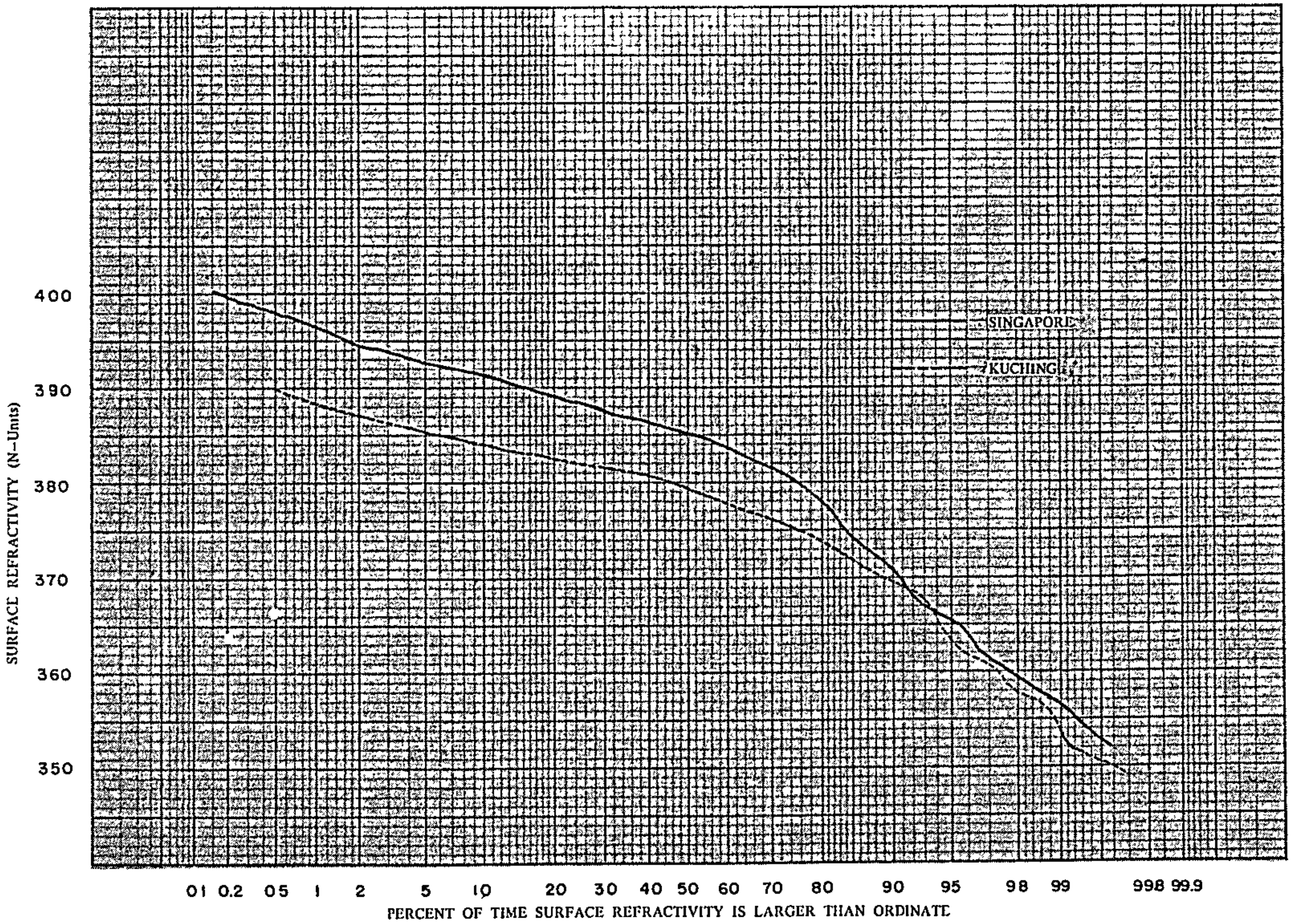


FIG. 21 CUMULATIVE DISTRIBUTION OF SURFACE REFRACTIVITY

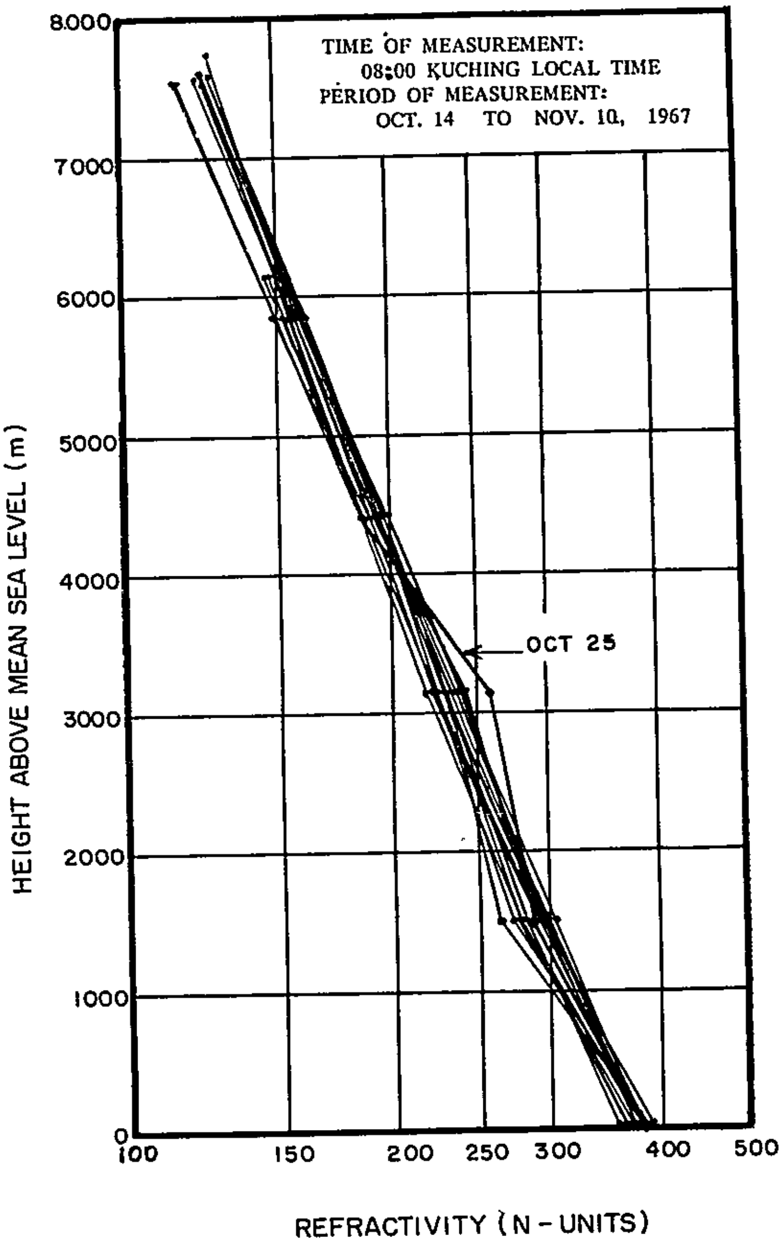


FIG. 22 ATMOSPHERIC REFRACTIVITY WITH HEIGHT AT SINGAPORE

VI PLAN FOR PRACTICAL COMMUNICATION LINK

6.1 Design Criteria

From the Tender Document, "Tender for Kuching-Johore Bahru Tropospheric Scatter System", issued on May 24, 1967 by the Headquarters of Telecommunications Department, the Government of Malaysia, the signal-to-noise ratio requirement of the practical link is summarized as shown in Table 6.

Table 6 Signal-to-noise ratio requirement of Kuching-Johore Bahru practical communication link

Probability	Signal-to-noise ratio*	Remarks
80.0 %	51.3 db and above	one-minute mean, weighted value
99.5 %	43.0 db and above	one-minute mean, weighted value
99.95%	37.0 db and above	5×10^{-3} second mean, unweighted value
* Worst month value. Bandwidth 4 KHz. Baseband 12-204 KHz.		

As is well known, the noises that determine the signal-to-noise ratio of the link are generated in the facilities themselves and also come from the outside. The former includes thermal noise, intermodulation noise as well as basic noise, while the latter includes intermodulation noise due to multipath propagation as well as various noises from earth, atmosphere and celestial bodies. As to the present link, the thermal noise generated in the facilities, the intermodulation noise due to multipath propagation and solar noise are of problems. The solar noise matters because of particular geographical condition of the link running east-west in the vicinity of the equator. As the solar noise is generated during short periods around the equinoxes, the noise should be considered separately.

In designing the practical communication link, as due procedure, a reference system had better to be set up on which examinations are given, to formulate the final plan which meets the objective. For this, the system given in Table 7 is proposed.

At first, the proposed site should be studied in terms of facility layout and then such a study will be followed by examination of the performance of the facilities.

Table 7 System parameters of Gunong Pulai-Gunong Serapi communication link

Frequency	2 GHz
Transmitter power	20KW
Antenna diameter	25m
Feeder loss	1.5 db
Modulation index (peak)	1.0 rad/ch
Receiver noise figure	2.5 db
Diversity	Quadruple, Ratio squarer type
Number of telephone channels	48 ch
Frequency separation between telephone channels	4.0 KHz
Effective bandwidth of telephone channel	3.1 KHz
Basic noise	300 pW/ch

6.2 Layout of Facilities

Figures 23 and 24 are the proposed plans for facility layout at Gunong Pulai and Gunong Serapi stations. In the proposed layout, efforts were made for the most economical civil works required for antenna installation, by the maximum use of topography. Consequently, in Gunong Serapi where the gradient of site ground is considerable, two sets of antennas are installed at spots with an altitude difference of approximately 25m instead of a horizontal installation.

6.3 Estimated Performance

Figures 25 and 26 show expected values of signal-to-noise ratio during winter (worst season) using the facilities indicated in Table 7 [4)-7)]. Figure 25 shows the values calculated in terms of one-minute mean value (psophometrically weighted value) of noise and should be compared with the 80% and 99.5% values of the specification standards shown in Table 6. Figure 26 pertains to instant value (approximately 5-millisecond mean value, unweighted) of noise, and should be compared with the 99.95% value of the specification standards.

In either of the above figures, the signal-to-noise ratios are expressed in terms of thermal noise, intermodulation noise, basic noise and the total. They are marked respectively as S/Nt, S/Ni, S/Nb and S/(Nt + Ni + Nb). The thermal noise concerned here pertains to that generated in receiving facilities, while the intermodulation noise concerned here pertains only to the noise due to multipath propagation. As for the basic noise, it includes all noises other than those mentioned above and gives the figure of 300 pW/ch (weighted) as shown in Table 7. The noise due to the radiation from the sun will be studied in the next section, as its incidence is limited to particular periods.

In Figures 25 and 26, the following are noteworthy:

(a) The signal-to-noise ratio requirements specified in the Tender Document are mostly met by the facilities shown in Table 7, except for the 99.95% value.

(b) The facilities given in Table 7 do not include a compandor. The compandor, if used, would improve signal-to-noise ratio by about 15 db, and thus would make the requirement for the 99.95% value met, and leave a considerable margin in the system concerned as a whole.

6.4 Effect of Solar Noise

The communication link concerned here runs almost parallel to the latitude line of 1°35' N, and consequently the sun intervenes the antenna beam around the spring and winter equinox. The noise wave radiated from the sun is received by the antenna, then, resulting in a lower signal-to-noise ratio of the link. In this section, therefore, the intensity and probability of the noise wave are being studied.

The brightness temperature of the sun at the 2 GHz is approximately 10^5 °K[8] and the radiation range of the noise wave is measured approximately as 0.6° in the visual angle from the earth. The beamwidth of antenna in the present link is about 0.4°. As the antenna beam is pointed almost to the horizon, the absorption and attenuation of the solar wave due to the atmosphere is estimated approximately as 1.8 db[9], while the attenuation with the feeder is 1.5 db and the noise figure of the receiver is presumed to be 2.5 db as indicated in Table 7. Therefore, the temperature of thermal noise reduced to that at input terminal of the receiver amounts to 47,340°K when the antenna beam is projected right into the solar face, while the thermal noise temperature to 350°K when the sun is away from the antenna beam. As the intermodulation noise (median) of 460°K and basic noise of 230°K are added to the above, the total noise temperature would amount to 48,030°K with the solar noise and 1040°K without solar noise. Consequently, the signal-to-noise ratio (median) inclusive of the solar noise would be lower by about 16.6 db than that without the solar noise.

The probability of the sun intervening the antenna beam is considered next. Naturally such a phenomenon is limited to on and around the spring and autumn equinox and it occurs early in the morning at the Gunong Pulai station in Johore while in the evening at the Gunong Serapi station in Sarawak. In order to make the study easy, the antenna beamwidth is assumed as just 0.4°. As a result of this study, the phenomenon is presumed to occur at each station approximately for 4 minutes a day, and for 4 days around the spring and autumn equinox.

To sum up the above, the degradation in the signal-to-noise ratio is 16.6 db at maximum when solar noise is received by the antenna. However, the interval is short with annual percentage as small as 0.01%. Further, as the time when the phenomenon takes place can be predicted with accuracy, appropriate measures may be taken against the trouble. Consequently, in practice, the impact of the solar noise would not present a major problem.

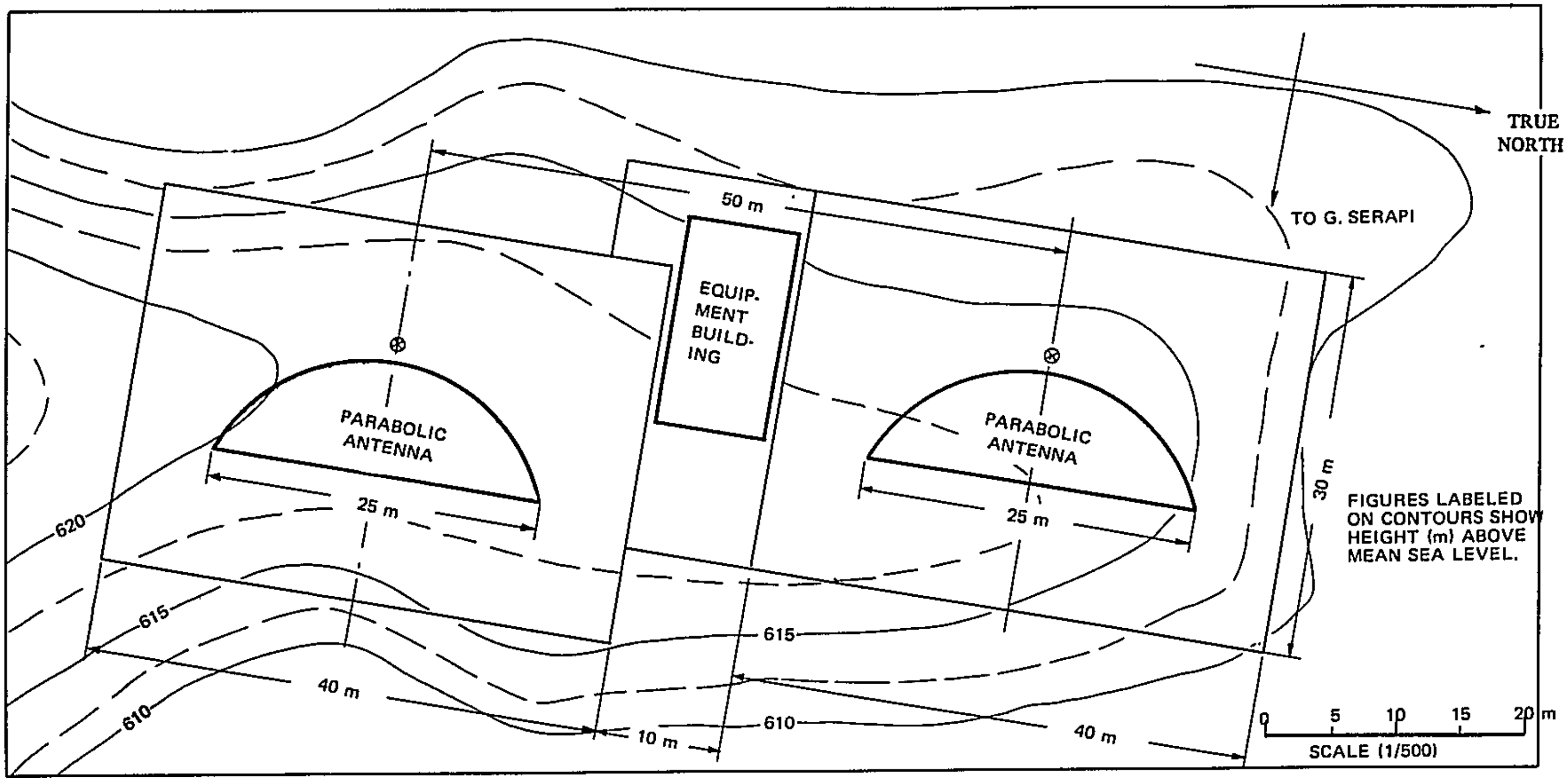


FIG. 23 TENTATIVE PLAN OF THE LAYOUT OF FACILITIES AT GUNONG PULAI SITE

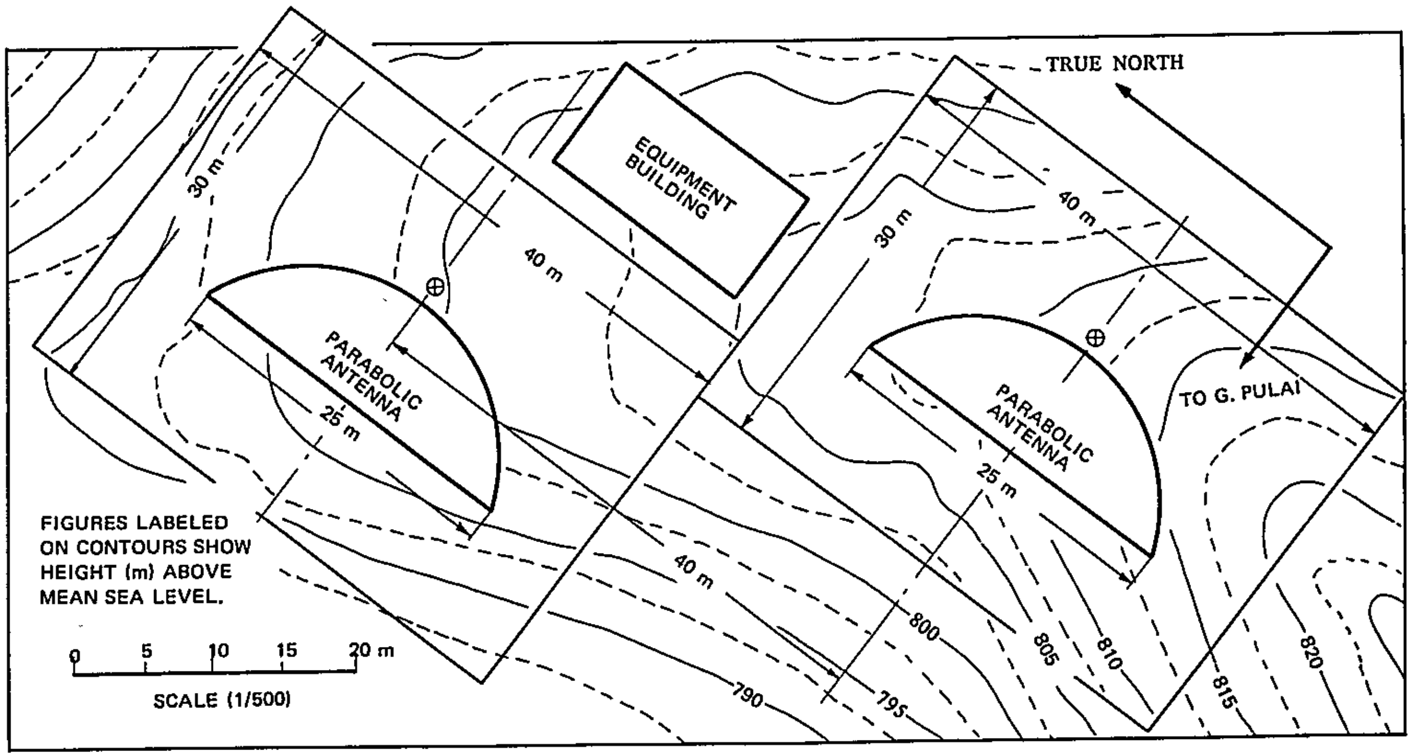


FIG. 24 TENTATIVE PLAN OF THE LAYOUT OF FACILITIES AT GUNONG SERAPI SITE

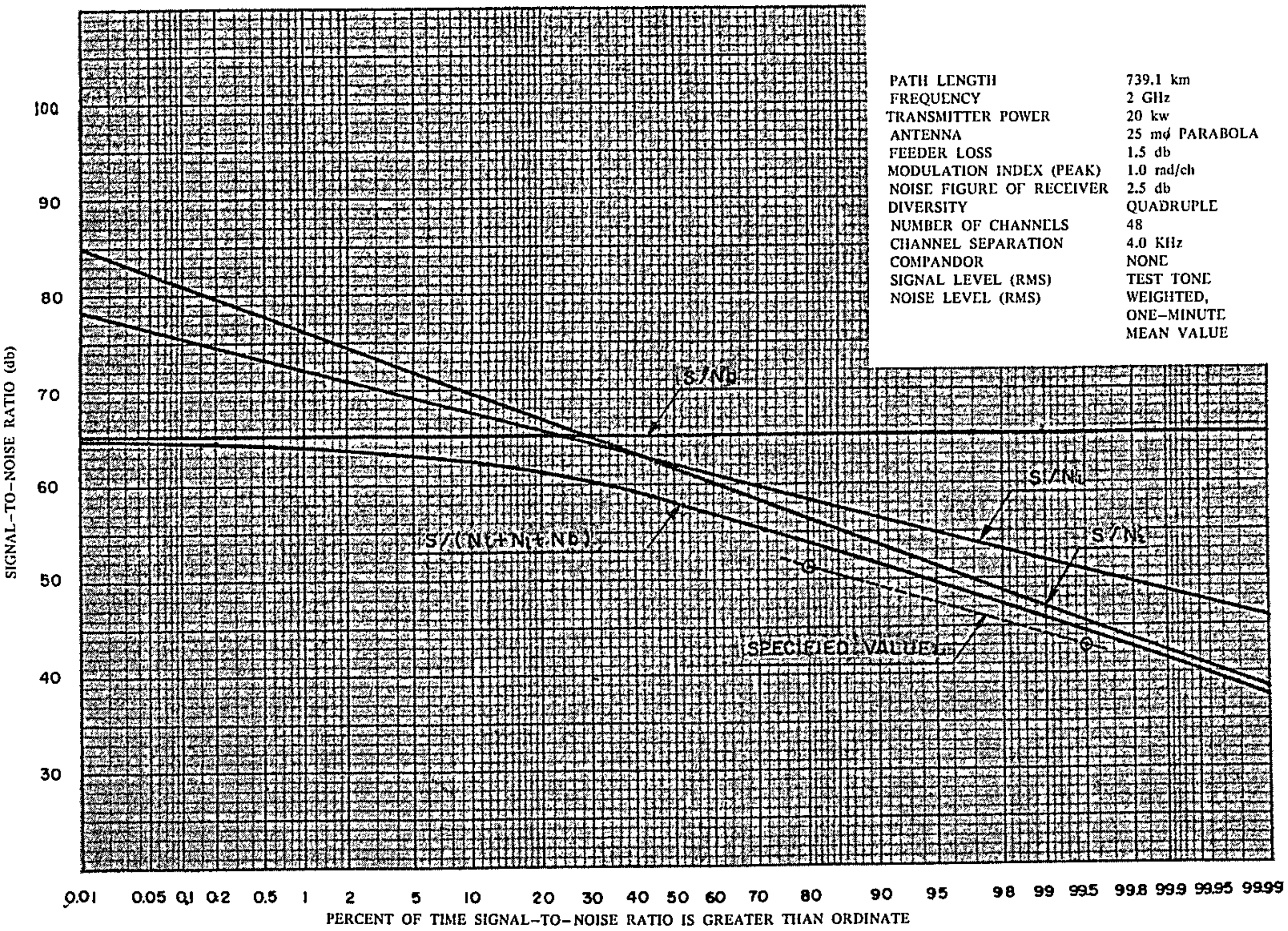


FIG. 25 ESTIMATED CUMULATIVE DISTRIBUTION OF SIGNAL-TO-NOISE RATIO (ONE-MINUTE MEAN VALUE) FOR THE COMMUNICATION LINK BETWEEN GUNONG PULAI AND GUNONG SERAPI

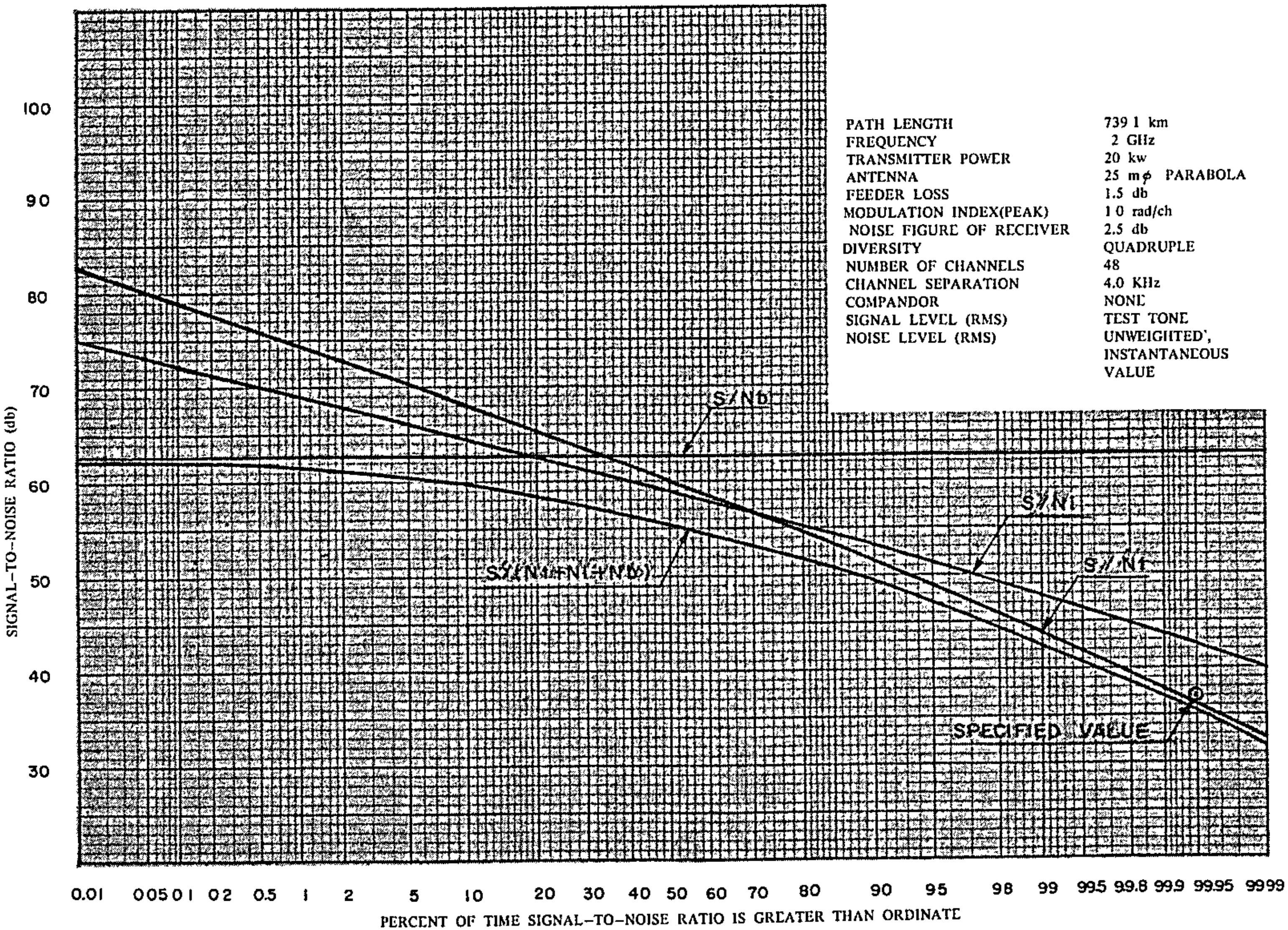


FIG. 26 ESTIMATED CUMULATIVE DISTRIBUTION OF SIGNAL-TO-NOISE RATIO (INSTANTANEOUS VALUE) FOR THE COMMUNICATION LINK BETWEEN GUNONG PULAI AND GUNONG SERAPI

VII STUDY ON TELEVISION TRANSMISSION

The frequency bandwidth of television signals is 4 to 6 MHz, which is by far larger than 204 KHz of the bandwidth of the aforementioned 48-channel telephone circuit. In order to transmitting such a large-bandwidth signal through the present link, indispensable are transmitting facilities with by far greater power, receiving equipment with higher sensitivity, antennas with higher gain, and new techniques for video-signal bandwidth compression. In this section, a study is attempted on the picture quality obtainable by the use of the best techniques available at present.

An antenna as large as possible has many advantages, producing a larger gain and a narrower beam, and, consequently, resulting in smaller amounts of thermal noise as well as of intermodulation noise due to multipath propagation. However, in general, the larger the aperture of a parabolic antenna becomes, the lower the surface accuracy becomes and the larger the antenna-to-medium coupling loss is associated. Therefore, the size of an antenna is limited in practice.

Use of higher frequency results in a larger antenna-gain and a narrower antenna-beam. Consequently, the same advantages and disadvantages result as aforementioned, among which adverse effect of surface accuracy is substantial. Further, the basic transmission loss in propagation increases at a rate proportional to more than the cube of the frequency. Consequently the maximum frequency to be used is also limited in practice,

If frequency deviation of frequency modulation is increased, the signal-to-noise ratio improves, while the signal-to-intermodulation noise ratio declines. Therefore, the frequency deviation also has the optimum value.

Considering the above conditions, the facilities as shown in Table 8 are designed as the best ones available at present.

The quality of the picture transmitted by the use of the above facilities is studied and shown in Figure 27. In the figure, the picture quality is expressed in terms of signal-to-noise ratio, in which the signal is given in terms of peak-to-peak value of picture signal, while the noise level in terms of weighted value. For the video-signal transmission, three values of 1, 2 and 4 MHz are considered, taking into account a future adoption of bandwidth compression techniques.

Table 8 Parameters of television transmission circuit

(a) Transmitting facilities	
Frequency	2000 MHz band (two waves)
Transmitter power	50 KW (two units)
Antenna	40 m φ (two sets)
Feeder loss	1.5 db
Frequency deviation (peak-to-peak value)	0.415 MHz
Emphasis	14 db
Video bandwidth	1, 2 and 4 MHz
(b) Receiving Facilities	
Frequency	2000 MHz band (two waves)
System noise temperature	300°K
Antenna	40m φ (two units)
Feeder loss	1.5 db
De-emphasis	14 db
Diversity	(Octuple, Linear-adder type)
Demodulation	FM feedback
Video bandwidth	1, 2 and 4 MHz
System basic noise	3.0×10^{-7} mW (weighted)

As a result of experiments, it is recognized that quite good picture quality can be obtained even with the video bandwidth of 2 MHz, that the optimum signal-to-noise ratio is 57 db and above, and also that the lowest allowable value is 45 db. Referring to Figure 27, probabilities with signal-to-noise ratio of 57 db or more and 45 db or more when picture bandwidth is 2 MHz are studied, and the values of 5% and 82% are obtained respectively. The television transmission with such small probability is not considered to be practically feasible.

In the above study, the thermal noise and the intermodulation noise, if their weighted values are the same, are assumed to cause picture-quality deterioration of an identical degree. The validity of this hypothesis is left with some doubts. In considering low-quality picture, of which the probability corresponds to 90% or 99%, however, the above question does not matter eventually, as the thermal noise is a dominant factor in such a case.

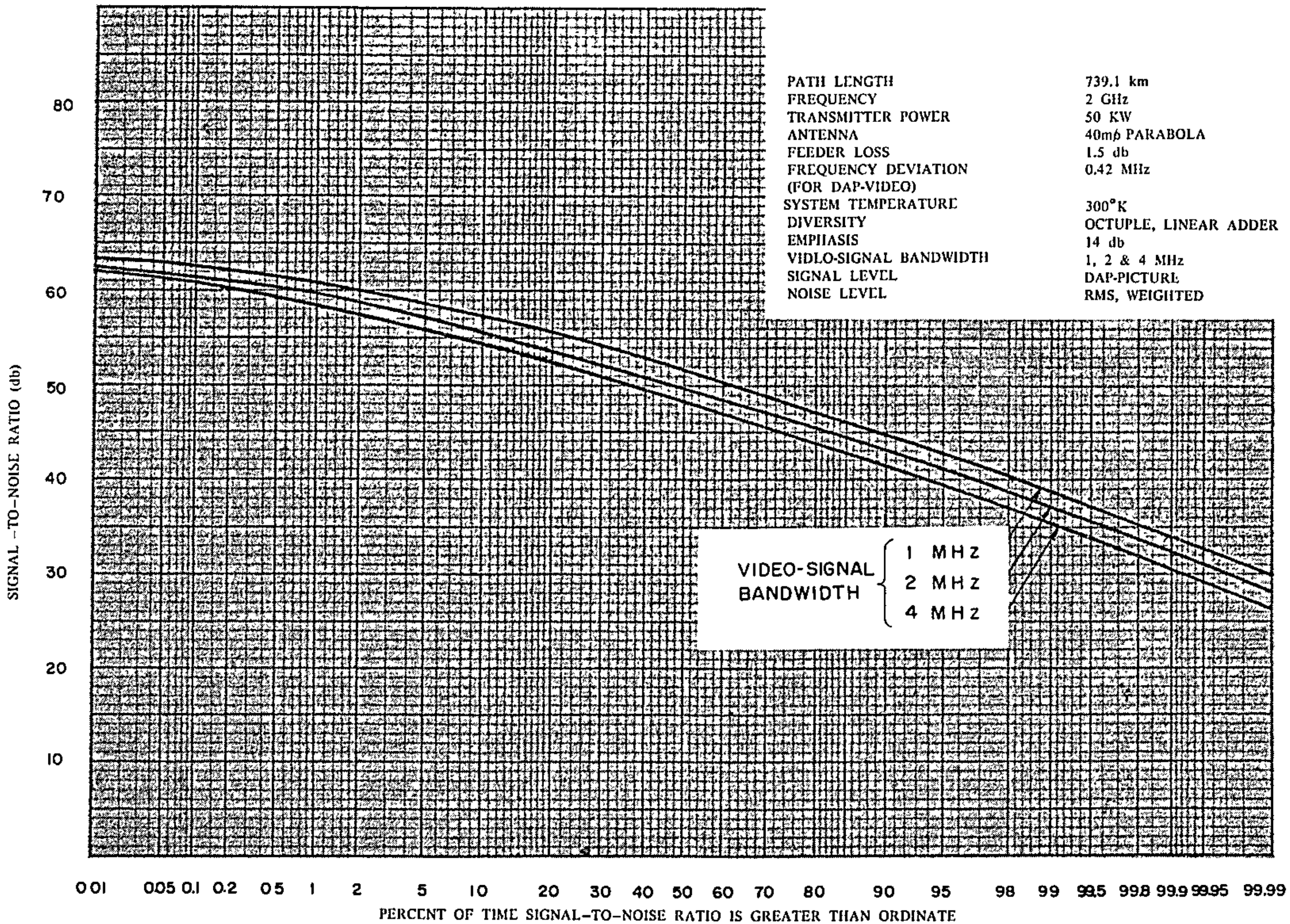


FIG . 27 ESTIMATED CUMULATIVE DISTRIBUTION OF SIGNAL–TO–NOISE RATIO (INSTANTANEOUS VALUE) FOR TELEVISION TRANSMISSION BETWEEN GUNONG PULAI AND GUNONG SERAPI

To sum up the results of the above study, it can be concluded that the television transmission for practical needs are not technically feasible, regardless of the high techniques, as in Table 7, employed. As a breakthrough, revolutionary techniques are required. Pertaining to this point, further development of bandwidth compression technique of video signal is greatly anticipated.

VIII CONCLUSION

The radio propagation test for the survey on the tropospheric scatter communication link between Gunong Pulai and Gunong Serapi was successfully carried out for about four weeks from October 13 to November 11, as scheduled.

As a result of this survey, the propagation characteristics of 1840 MHz wave were revealed, and the feasibility of the plan to set up the telecommunication link of 48 or more telephone channels was established.

The link concerned here is troubled with the disturbance due to the solar noise. The occurence probability of the disturbance is, however, below 0.01% through a year, and its time can be predicted with accuracy. Consequently, the phenomenon is considered to present little problem in practice.

Television transmission through the link is very difficult. To establish the transmission, a bandwidth compression of video signal is required, and the revolutionary technical development in the field is necessary.

The survey mission sincerely wishes earlier completion on the practical communication link which would not only improve the situation of communications between East and West Malaysia, but also contribute to the cultural exchange in the regions.

ACKNOWLEDGEMENT

During the survey the survey mission was assisted by many organizations as well as individuals. The following are principal agencies concerned.

(Japan)

Ministry of Foreign Affairs

- Economical Cooperation Department
- Embassy in Malaysia

Ministry of Posts and Telecommunications

- Administrative Directors' Office of Telecommunication
- Radio Regulatory Bureau
- Radio Research Laboratories

Overseas Technical Cooperation Agency

Kokusai Denshin Denwa Co., Ltd.

Nippon Electric Co., Ltd.

Denki Kogyo Co., Ltd.

(Malaysia)

The Headquarters of Telecommunications Department

Johore Regional Telecommunications Department

Borneo Posts and Telecommunications Department

Royal Malaysian Air Force

Civil Aviation Department

(Singapore)

Meteorological Department

The success of the survey which is beyond expectation should be attributed to the cordial assistance and cooperation extended to the mission by the sources concerned. The survey mission deeply expresses its appreciation.

R E F E R E N C E S

1) CCIR Report 244 - 1, Estimation of tropospheric-wave transmission loss, Documents of XIth Plenary Assembly, Oslo, 1966, Volume II Propagation.

2) P.L. Rice, A.G. Longley, et al., Transmission loss predictions for tropospheric communication circuits, Technical Note No. 101 (Revised), Vol. 1, Issued May 7, 1965, Revised May 1, 1966.

3) B.R. Bean, B.A. Cahoon, C.A. Samson and G.D. Thayer, A world atlas of atmospheric radio refractivity, ESSA Monograph 1, 1966.

4) C.A. Parry, On the prediction of the inherent bandwidth capability of the tropospheric scatter link, IEEE International Convention Record, Vol. 11, Part 8, pp. 215 - 232, 1963.

5) C.D. Beach and I.M. Trecker, A method for predicting interchannel modulation due to multipath propagation in FM and PM tropospheric radio systems, B.S.T. J., Vol. 37, No. 1,pp. 1 - 36, Jan., 1963.

6) E.D. Sunde, Intermodulation distortion in analog FM troposcatter systems, B. S.T.J., Vol. 38, No. 1,pp. 399 - 435, Jan., 1964.

7) M. Hirai, Y. Kurihara, et al., Transmission loss in UHF and VHF overland propagation beyond the horizon, Jour. Radio Research Labs., Vol. 10, No. 51, pp. 357 - 422 Sept., 1963.

8) D.C. Hogg and W.W. Mumford, The effective noise temperature of the sky, Microwave Journal, Vol. 3, Mar., 1960.

9) CCIR Report 205 - 1, Factors affecting the selection of frequencies for telecommunications with and between spacecraft.