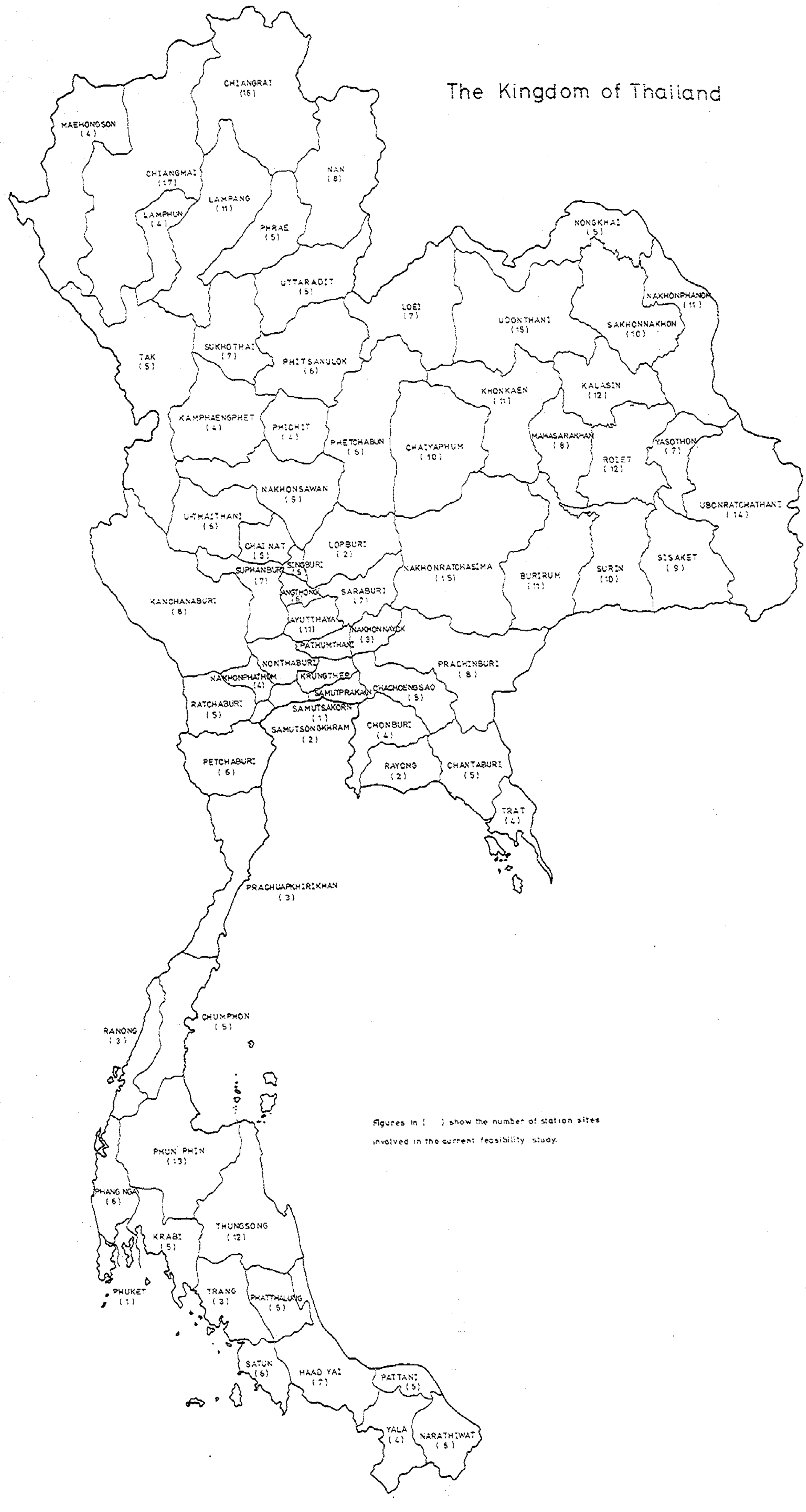
THE KINGDOM OF THAILAND

INTERIM FEASIBILITY REPORT
ON
RURAL LONG DISTANCE
PUBLIC TELEPHONE SERVICE
(VOLUME I)

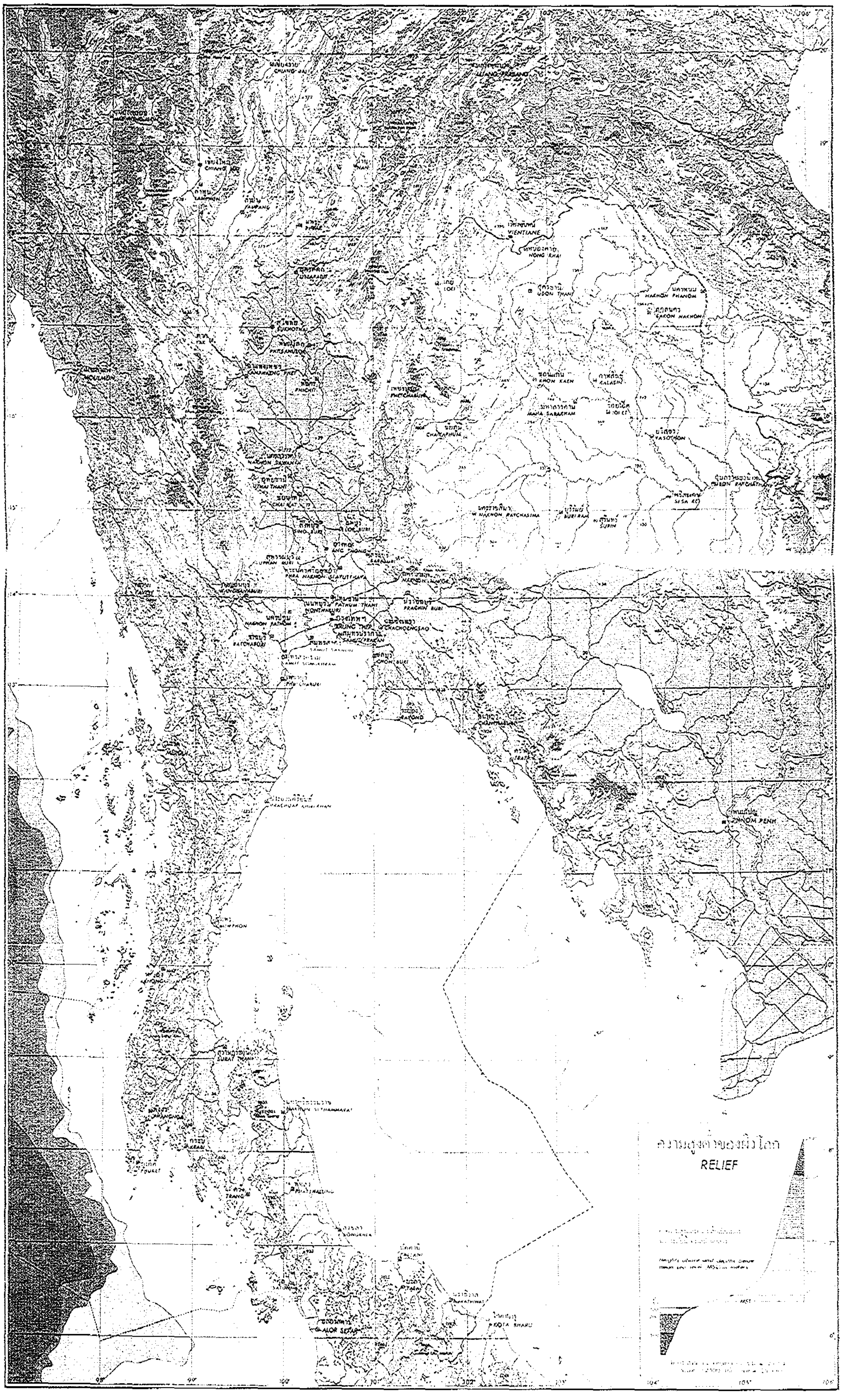
DECEMBER, 1978

JAPAN INTERNATIONAL COOPERATION AGENCY

The Kingdom of Thailand



Figures in ( ) show the number of station sites involved in the current feasibility study.



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Summary of Study; Conclusion and Recommendations

Summary of Study; Conclusion and Recommendations

1. Outline of Study

The Telephone Organization of Thailand (hereafter called TOT), the sole public corporation in charge of domestic telephone service management in Thailand, plans to establish the long distance telephone service inclusive of public telephone service, covering 469 rural districts throughout the country. This plan, known as the Rural Long Distance Public Telephone Service Project, constitutes an integral part of the National Economic and Social Development Plan, 1977 - 1981, of the Government of the Kingdom of Thailand.

TOT requested the Government of Japan to carry out the feasibility study with respect to the selection of technically and economically optimum system to implement the Project. The selection is to be made from among the three proposed systems named below.

1) UHF (900 MHz band) terrestrial radio system;

2) SHF (11/13 GHz band) terrestrial radio system;

3) Domestic satellite system.

Responding to the request from TOT, the Government of Japan dispatched to Thailand the Feasibility Study Team for Rural Long Distance Public Telephone Service (hereafter called Study Team) for a period of approximately five months beginning August 10, 1978.

Main study items comprised circuit requirements forecast, transmission route selection by systems, detailed studies of selected systems, and economic comparison among those systems. The conclusion reached is that UHF (900 MHz band) terrestrial radio system provides an optimum transmission system for Rural Long Distance Public Telephone Service.

The map that appears at the beginning of this Volume indicates the Provinces to which the 469 rural districts respectively belong, as well as the number of rural districts in each Province.

2. Results of Study

Results of study according to main study items are summarized below.

2-1 Circuit Requirements

Based on TOT data forecasting telephone demand potential up to 1990, total circuit requirements in the 469 rural districts, including 47 districts where mobile exchanges will be introduced, in 1984, 1989 and 1994 were forecasted. The year 1984 is the year in which this Project is scheduled to begin full operation. The years 1989 and 1994 are five years and 10 years after the Project service-in in 1984. The result of forecast follows :

	1984	1989	1994
Circuit requirements	2,513	3,763	8,218

The above forecast leads to judgment that, in 1989, telephone exchange be introduced in 18 districts and, 1994, in 187 more districts.

2-2 Optimum Transmission System

Based on the transmission route plan formulated by TOT, selection of optimum transmission routes was made, one for terrestrial radio system and the other for domestic satellite system.

(1) Terrestrial Radio System

In accordance with the TOT principle, two terrestrial radio system plans were selected. They are :

1) UHF (900 MHz band) system plan;

2) SHF (11/13 GHz band) system plan.

For each system, study was made with emphasis on FDM (Frequency Division Multiplex) system. PCM (Pulse Code Modulation) system application feasibility was also studied. Study of UHF system included study of over-the-horizon communication system application feasibility. This latter study was aimed at system construction cost curtailment by means of elimination of through repeater stations.

Comparative study of UHF and SHF systems in the performance and cost aspects led to this conclusion : For a terrestrial radio system comparable to domestic satellite system, UHF (900 MHz band) system is optimal.

(2) Domestic Satellite System

With regard to domestic satellite system, one transponder of PALAPA satellite of Indonesia is to be leased. On this condition, study was made mainly about transponder capacity and radio interference to the existing microwave system, in addition to traffic forecast. The finding is that optimum domestic satellite system comparable to UHF (900 MHz band) terrestrial radio system is a system that features the following :

1) DAMA (Demand Assigned Multiple Access) system using SCPC (Single Channel Per Carrier) system be applied. This is because the domestic satellite system of Thailand involves a large number of rural earth stations and the number of

circuits per station is small.

2) Control of DAMA, such as for circuit connection and tariff rate determination, be centralized at master earth station to be established in the suburbs of Bangkok.

3) In consideration of transponder capacity, radio interference with the existing terrestrial microwave system and so forth, terrestrial radio system be applied to 129 rural districts out of a total of 469 rural districts.

4) 146 districts, where telephone demand is so large that telephone exchanges will have to be introduced in the future, be changed over to terrestrial radio system in 1994, i.e., 10 years after the service-in of this Project.

2-3 Detailed Study of Objective Systems of Comparison

Detailed study of terrestrial radio system and domestic satellite system, with emphasis on their respective site selection requirements, design criteria, system configurations and system performances, proved that the principal design parameters of the two systems are as follows :

(1) Terrestrial Radio System

Radio frequency band	:	900 MHz
Transmission capacity	:	24 ch/120 ch
Transmitting power	:	5 W
Standby system	:	Equipment standby
Power supply	:	Battery floating

(2) Domestic Satellite System

		Master Earth Station	Rural Earth Station
Radio frequency band	:	(Up-link : 6 GHz; down-link : 4 GHz)	
Transmitting power	:	700 W	50 W
Antenna size	:	11 mø	4.5 mø
Power supply	:	ac non-break	Battery floating

2-4 Economic Comparison

The present worth of annual cost of the two systems is as follows :

Terrestrial Radio System	Domestic Satellite System
22,333	38,205
(124,072)	(212,250)

Unit : Million Japanese Yen

Parenthesized is the equivalent in thousand U.S. Dollars.

Economic comparison by present worth of annual cost demonstrates that terrestrial radio system commands greater advantage by a broad margin.

2-5 All-round Evaluation

Together with system cost evaluation by present worth of annual cost, system performance, system reliability, system extension flexibility and so forth were also evaluated. The result shows that, in all-round evaluation, terrestrial radio system predominates.

3. Conclusion and Recommendations

(1) Optimum Transmission System

Conclusion can be drawn in favor of UHF (900 MHz band) terrestrial radio system as optimum transmission system for Rural Long Distance Public Telephone Service.

Regarding modulation system, no much difference can be found between FDM system and PCM system from technical and economic viewpoints.

(2) Re-investigation of Telephone Demand

There is need for re-investigation of telephone demand potential throughout Thailand, including user consciousness survey with respect to telephone utility. This re-investigation must be intensive, and should preferably be carried out by 1989. And, based on the findings in this re-investigation, the type of telephone service required and the number of telephone circuits required should be reassessed so that they can suit actual needs among the user public. At present, local government offices in rural districts maintain communications by their in-house system of low performance level. It is desirable that such in-house communication system be changed over to high performance circuits of TOT through negotiations with the Ministry of Interior.

(3) Study of Over-the-Horizon Communication System Application Feasibility

In this Project, the number of telephone circuits required in each rural district is limited. Therefore, for the purpose of system cost economy, intensive study should be made concerning feasibility of rural over-the-horizon UHF system application.

(4) Use of Equipment Shelter

Use of equipment shelters as housing structures for communication equipment inclusive of power plant is desirable. This is to reduce construction cost and civil work period to the possible minimum.

(5) System Maintenance

In the aspect of system maintenance, the existing maintenance organization and practices can be applied to each Maintenance Center by increasing some maintenance staffs when this Project is completed.

At the same time, it is desirable to introduce centralized supervisory system at each Maintenance Center so that it can have troubles at supervised stations under its control automatically recorded.

(6) Reinforcement of Project Implementation Organization

This Project not only covers the whole territory of Thailand but also comprises various divisions of engineering expertises in a long period.

Therefore, in order to ensure satisfactory progress of project implementation, it is recommended to reinforce the organization of project implementation.

PART I. Overview

PART I Overview

1. Background and Objectives

The Government of Thailand is now carrying out the Fourth National Economic and Social Development Plan (1977 - 1981). This development plan, in its 10-point integral development strategies, envisages the decentralization of basic economic services.

This decentralization policy aims at integration of social overhead capital, such as transportation, communication and electric supply. At the same time, it purports to distribute such social overhead capital among rural areas and thereby assist the rural population in the improvement of their standard of living and the promotion of their production activities.

TOT, for its part, is putting into practice the Economic Development Project of TOT (1977 - 1984) based on the Fourth National Economic and Social Development Plan of the Government of Thailand. The Economic Development Project of TOT embraces as one of its objectives the construction of long distance telephone circuits, including public telephones, in major rural districts without telephones for the purpose of improving the telephone service in rural areas.

As the transmission route for the abovementioned telephone circuits to be constructed, TOT intends to adopt the most economical system out of the undermentioned three systems :

1) UHF (900 MHz band) terrestrial radio system;

2) SHF (11/13 GHz band) terrestrial radio system;

3) Domestic satellite system.

TOT requested the Government of Japan to arrange the feasibility study for these three systems in order to make the best possible selection.

The study, this time, was carried out for a period of approximately five months so as to recommend the optimum transmission system to TOT in connection with its intended telephone service provision in rural districts of Thailand.

2. Outline of Project

At present, principal cities in all parts of Thailand are connected by the trunk microwave links. Cities in rural districts are to be connected by the spur microwave links now being constructed.

However, in the 524 districts (amphoes) throughout the country, which are located at the extreme end of the central administrative organization, the telephone facilities of TOT for both local and long distance services seldom or never exist.

For this reason, TOT plans to construct the long distance telephone networks, including public telephones, in 422 rural districts out of a total of 524 rural districts and to construct mobile telephone exchanges and long distance telephone circuits in 47 other rural districts, in order to improve the telephone service in rural areas.

As the transmission route for such intended long distance telephone networks, TOT is inclined to adopt the terrestrial radio system (UHF) and is already carrying out the preliminary study for the major part of districts where the intended terrestrial radio system will be operated. In the case of adopting the domestic satellite system, TOT contemplates to utilize the satellite launched by Indonesia in 1976. In this case, TOT will have the PALAPA satellite transponder leased.

As the Phase I work, TOT plans to complete by 1984 the construction of long distance telephone networks, including public telephones, in 235 rural districts (out of the previously mentioned 422) and the construction of mobile exchanges and long distance networks in 25 other rural districts.

3. Study Guidelines

As stated previously, TOT has already begun preliminary studies, including field surveys, for the current Project. Furthermore, the funds concerned for Project implementation financing has already been reached. In view of such concretely set Project implementation schedule, the decision has been made for the following study guidelines :

(1) With respect to the system design, the Study Team carries out technical discussions with TOT to the greatest possible extent and, based on the conclusion agreed upon between both parties, continues to work.

(2) Data, drawings and all related information obtained or produced in the course of the feasibility study is so prepared that TOT can utilize them in the detail design to be executed after the Study Team has submitted its report.

(3) The study work, this time, includes traffic forecast and system design covering as many as nearly 500 stations, and this work has to be completed in a limited period of five months. Therefore, for necessary computations, the extra-large capacity computer and programmable small-sized calculators are used for the purpose of labor saving to the greatest possible extent and, at the same time, to produce accurate basic data with TOT can utilize to the best advantage.

4. Scope of Study

Based on the Scope of Work agreed upon between the Government of Thailand and the Preliminary Study Team, the scope of study consists of the following :

1) Formulation of basic engineering standards as the basic requirement of the current Project.
2) Forecast of telephone circuit demand.
3) Selection of transmission route for terrestrial radio system.
4) Selection of transmission route for domestic satellite system.
5) Detail study of transmission route and related field surveys.
6) Estimation of construction cost and economic comparison for construction plans.
7) Overall evaluation of optimum transmission system plan.
8) Project implementation plan.

According to the aforementioned Scope of Work, the number of rural stations, for which the study was to be made, was 422. However, at the subsequent request of TOT, it has been decided that the study be carried out for 47 other stations also where the mobile exchanges are scheduled to be introduced. Thus the total number of stations, for which the study was required, has increased to 469.

PART II. Basic Engineering Plan for Rural Long Distance Public Telephone Service

PART II Basic Engineering Plan for Rural Long Distance Public Telephone Service

1. General

For the optimum transmission route plan for Rural Long Distance Public Telephone Service, either the terrestrial radio system or the domestic satellite system can be considered, as is stated in Part IV and Part V.

In this study, the system designs for the said two systems were made in parallel, and the performance comparison and evaluation were carried out for the two systems. This Part II presents the result of study with respect to the basic engineering plan as the basic requirement for the two system designs, from the viewpoint of connection to the national network of Thailand and transmission engineering standard.

Study from the viewpoint of connection to the national network was made in the form of an overview of the basic telephone network plan of Thailand. At the same time, study was also made concerning how the Rural Long Distance Public Telephone Service should be operated.

Study from the viewpoint of transmission engineering standard was made in the form of study of the transmission loss assignment plan and the noise distribution plan, based on the National Transmission Plan and the pertinent CCITT/CCIR recommendations. Transmission criteria for Rural Long Distance Public Telephone Service were thus determined.

2. Connection of Rural Long Distance Public Telephone to National Network

Rural Long Distance Public Telephone Service means the extension of public telephone service to the areas where no telephone service exists. How and in what manner to connect such rural long distance public telephone to the national network is described below, based on the basic telephone network plan of Thailand.

2-1 Telephone Network Configuration in Thailand

2-1-1 Exchange Office Ranks

Telephone exchange offices in Thailand are divided into four ranks as shown in Figure 2-1.

There are four Tertiary Centers (TC) covering the whole of Thailand. Tertiary Areas (TA), however, number five. The Bangkok Metropolitan Area and the Central Area are served by the Bangkok TC, the Northeastern Area by the Nakhon Ratchasima TC, the Northern Area by the Phitsanulok TC, and the Southern Area by the Phun Phin TC.

2-1-2 Routing Arrangement

The long distance circuit is composed of the high usage route and the low loss route as shown in Figure 2-1.

2-1-3 Numbering Plan

The national numbering plan in Thailand is composed as follows :

Trunk prefix............"0"

Area code...............1 - 2 digits

Office code.............2 - 3 digits

Subscriber number........4 digits

The digit allocations to the Bangkok Metropolitan Area subscribers and the subscribers in other areas are shown below.

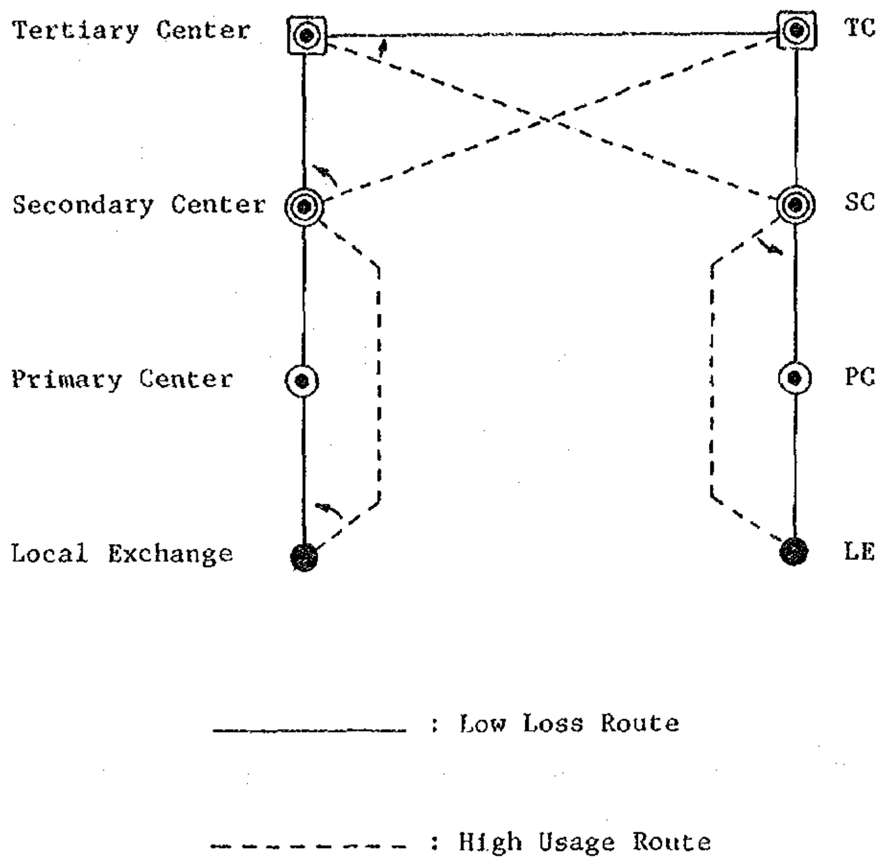


Figure 2-1 Exchange Office Rank & Routing Arrangement

For Bangkok Metropolitan Area Subscirbers :

```
"0"    +    A    +    BCD    +    EFGH
│           │         │           └ Subscriber number
│           │         └ Office code
│           └ Area code
└ Trunk prefix
```

For Provincial Subscribers :

```
"0"    +    AB    +    CD    +    EFGH
│           │          │          └ Subscriber number
│           │          └ Office code
│           └ Area code
└ Trunk prefix
```

Area Code "2" is allocated to the Metropolitan Area, "3X" to the Central Area, "4X" to the Northeastern Area, "5X" to the Northern Area and "7X" to the Southern Area.

2-1-4 Charging System and Tariff Rate

(1) Charging System

In Thailand, message recording after the introduction of STD (Subscriber Toll Dialing) service will be carried by two methods. One is the detailed billing system. The other is the bulk billing system.

The detailed billing system applies to toll calls to the outside of SA (Secondary Area). The bulk billing system is applicable to other calls.

(2) Tariff Rate

The local call tariff rate is 1.5 Baht per call (as of the end of 1978). Tariff rates applicable to long distance calls are listed in Table 2-1. Regarding the STD service tariff rate, detailed information could not be obtained because STD service is to be put into practice in or after 1980 and the related study is now being made by TOT. Only the relationship between the charging rank and the charging pulse interval has already been determined as shown in the above quoted table.

2-2 Types of Rural Long Distance Public Telephone Service

The conceivable types of Rural Long Distance Public Telephone Service are as follows :

(1) To build simple cottages, each with a telephone booth and a TOT clerk who will respond to the demand for calls from users.

(2) To install STD public telephone sets at main places of each city/town so that the public can use the nearby public telephone set.

(3) To install subscriber telephone sets on the counters of individual merchant houses which have concluded such contract with TOT, so that the shop keepers assume responsibility for telephone service operation and, at the same time, respond to the demand for calls from users.

In the case of (1), if a simple manual switching equipment to cater for calling/called users is installed in the cottage, long distance telephone service to/from several special subscriber premises (such as governmental offices) becomes possible. This

Table 2-1 Long Distance Call Charge

Manual Service (As of the end of 1978)

Distance (km)	First 3 Minutes (฿)	Additional Minute (฿)
Up to 25	3	1
25 - 50	6	2
50 - 75	9	3
75 - 125	12	4
125 - 200	15	5
200 - 350	18	6
350 - 600	24	8
600 - 900	30	10
Over 900	36	12

(During the night period (7 p.m. to 6 a.m.), each call charge is half the rate listed above.)

STD Service

Rank	Charging Pulse Interval (sec.)
1	15
2	10
3	7.5
4	6
5	5
6	4

(As of the end of 1978, detailed call charge plan for STD service has not yet been decided.)

signifies the operational flexibility of Rural Long Distance Public Telephone Service. Although the service cost increases in the form of manpower cost and switching equipment cost, such cost increase can possibly be compensated by the increased revenue from the circuit operation efficiency improvement, as well as the increased fringe benefit of telephone service in rural areas.

In this study, however, major emphasis is placed on the types (2) and (3) because these types are better suited for public telephone service.

In the case of (2), the multi-coin box becomes necessary as terminal equipment. In the case of (3), the ordinary telephone set or the multi-coin box as in (2) is the necessary terminal equipment. These telephone set terminals are to be connected by distribution wire to a mid-town radio terminal station or rural earth station.

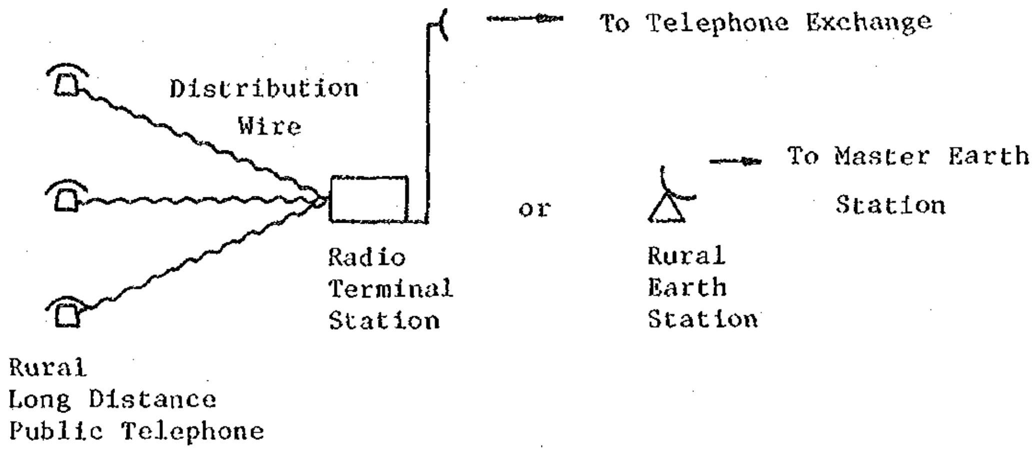
The connection from an outlying mountain-top radio terminal station is firstly by entrance cable to be terminated at a mid-town distribution box and then by distribution wire.

In case where direct cable from a telephone exchange office is used, the cable is to be terminated at a distribution box and from there the distribution wire is used for connection.

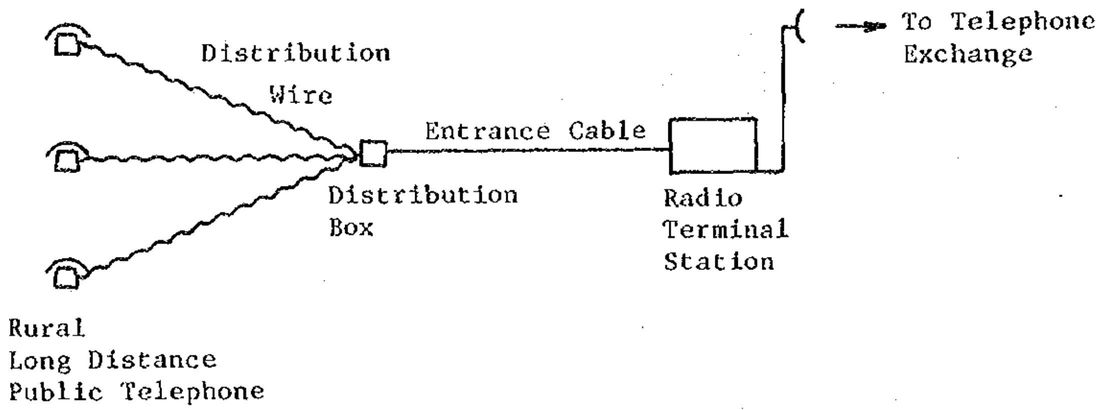
These connection configurations are illustrated in Figure 2-2.

2-2-1 Application of Terrestrial Radio System

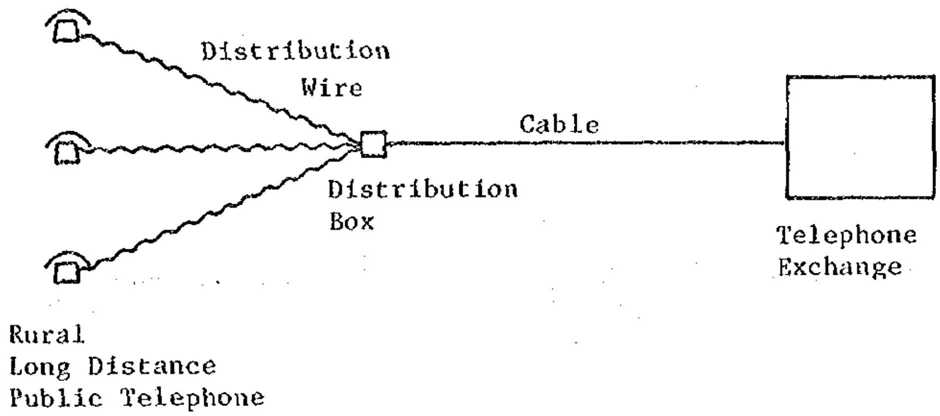
When the terrestrial radio system is applied, the telephone set terminal is to be accommodated in the subscriber terminal of the local exchange. In this case, the radio transmission route can be considered to be a set of subscriber lines. Therefore, the system can be handled in the same way as the



Case - 1



Case - 2



Case - 3

Figure 2-2 Rural Long Distance Public Telephone Service general public telephone service.

2-2-2 Application of Domestic Satellite System

The domestic satellite system is operated by the DAMA system as is explained later. The DAMA system enables the master earth station to hold a kind of swithching function. Calls from rural long distance public telephone are collected at the master earth station. Then the calls are connected to their respective destinations through Bangkok TC (Tertiary Center).

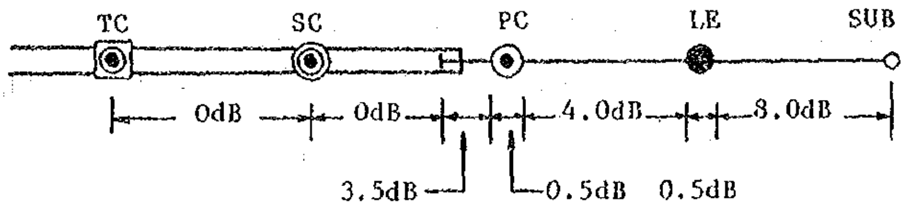
Coin collecting pulse transmission via satellite circuit becomes difficult due to speech path noise because the out-band of the speech path frequency band cannot be used so that the in-band has to be used. Therefore, the following method will be adopted :

At the master earth station the called party information is received from the rural earth station through the data channel. The tariff rank obtained from analysis of the call destination is sent back to the calling rural earth station where, based on the tariff rank received, the coin collecting pulse is sent out periodically to the public telephone set.

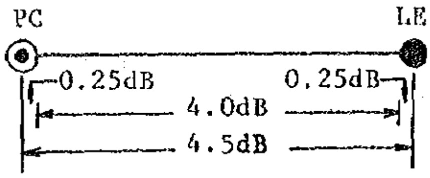
3. Transmission Loss Assignment Plan

The transmission loss assignment based on the National Transmission Plan of TOT appears in Figure 2-3.

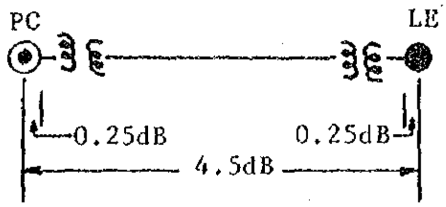
Transmission circuits to be established for this Project are the PC - LE 'and LE - SUB (Subscriber) circuits. For the transmission loss



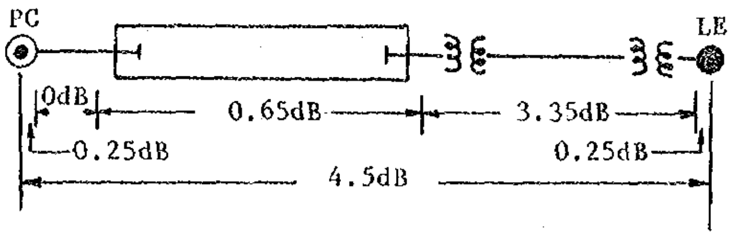
(1) National Transmission Plan



(2) Loss Assignment for PC-LE



(a) Cable Link



(b) Radio Link

Figure 2-3 Transmission Loss Assignment Plan assignment, the standard value of 4.5 dB (including the intra-office loss of 0.5 dB) for the PC - LE circuit is to be applied to both circuits. In this Project, the transmission circuit comprises the radio link and cable link.

There are two cases with respect to transmission loss assignment. One is the case where the automatic telephone exchange is introduced at LE and the other is the case where the subscriber is directly connected to PC (Primary Center). Even the latter is the case where the exchange (automatic or manual) will be introduced at LE in the future. Although at some stations the exchange will not be introduced in the future either, there are possibilities that even such stations may be equipped with the manual exchange in consideration of circuit operation efficiency. This is why the transmission loss assignment is set at the standard value of 4.5 dB.

1) Transmission Loss for Cable Link

The transmission loss limit common to all kinds of cables can be obtained as follows :

Cable loss + Coil loss + Lo_1 + $Lo_2 \leq$ 4.5 dB

where

Lo_1 , Lo_2 : intra-office loss (= 0.25 dB)

therefore

Cable loss $\leq$ 4.5 - (0.4 + 0.25 + 0.25)

$\lesssim$ 3.6 dB

2) Transmission Loss for Radio Link

The minimum transmission loss calculated with near-singing condition applied appears in Figure 2-3 (b).

4. Noise Distribution Plan

With respect to the noise distribution plan on the transmission route, TOT adopts and applies the CCITT-recommended value to the PC-PC circuit. (Refer to Figure 2-4.) However, since the noise standard on the PC-LE circuit could not be known exactly, the Study Team discussed with TOT and reached the decision that the noise be distributed as described below, based on the relevant CCITT recommendation.

(1) In the case of terrestrial radio system

1) When the transmission circuit is composed of a single radio path without obstacle to radiowave propagation (or with such obstacle, if any, that can minimize the propagation loss) ....2,000 pWOp

2) When the transmission circuit is composed of a single mountain diffraction propagation path..................10,000 pWOp

3) When the transmission circuit is composed of two or more radio propagation paths, the value shall not be specified but be determined as the situation requires on condition that the value adopted will not lead to an uneconomical design.

(2) In the case of domestic satellite system

In this case, the PC-LE transmission route consists of LE (rural earth station) → satellite → master earth station → terrestrial radio system (existing microwave system). Since this route includes the existing microwave system where the system performance is not exactly constant, it has been decided not to specify the noise objectives for the existing circuit but to assume a hypothetical reference circuit for the satellite link only and assign the CCIR-recommended value to this latter circuit. (For noise objectives

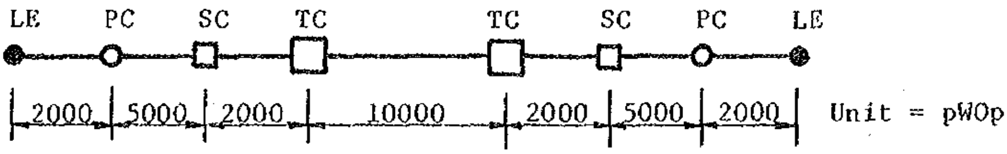


Figure 2-4 Noise Distribution Plan

of the satellite communication system, refer to Part IV.)

PART III. Circuit Requirements Forecast

PART III Circuit Requirements Forecast

1. General

This PART III presents the result of analysis in regard to the uptrend of telephone demand in the whole rural districts to be taken up in the study, the telephone exchange introduction plan in the case of telephone demand having exceeded a certain limit, the criteria for estimation of required telephone circuits, and the community survey result.

The circuit requirements forecast to prepare for the introduction of Rural Long Distance Public Telephone Service and of mobile exchanges has been carried out by the method described below. The reasons are that the study had to be made for vast territories covering the whole of Thailand and the period of study was limited so that the circuit requirements had to be forecasted not long after the study was commenced. District by district field investigations were omitted.

In the first place, the telephone demand forecasts as of 1984, 1989 and 1994 were made, based on the forecast data prepared by TOT. From the telephone demand potential thus obtained the traffic volume was estimated, taking into consideration the eventual changeover from the Rural Long Distance Public Telephone Service to the ordinary telephone service by introduction of telephone exchange. Furthermore, in accordance with the connection criteria, the circuit requirements were estimated.

On the occasion of site survey and path survey in four areas the community survey was also conducted to the extent the time schedule permitted. The background of telephone demand estimation, telephone exchange introduction plan, traffic forecast and circuit requirements forecast, which were carried out on the basis of relevant TOT data, are also presented. Finally, in Chapter 5, the community survey result is clarified and, at the same time, the estimates and forecasts made in Chapter 2 through Chapter 4 are evaluated.

2. Telephone Demand Forecast

Telephone demand forecast in Thailand is undertaken by TOT's Analysis and Forecasting Unit, Planning and Project Division, Office of Planning and Project. "Forecast of Telephone Demand 1977-1990", which the Study Team obtained, is the data published in August 1977. The long term planning of TOT now in progress is based on this data.

The forecast methodology used in this report consists of :

1) Field survey;
2) Questionnaire to local inhabitants;
3) Collection of information from commercial and industrial circles and governmental agencies.

(Information collected under Category 3) above includes information from the Housing Corporation concerning the residential land formation plan, information from building contractors concerning new office building construction plan, information from the Department of Local Administration and the National Statistical Office concerning the population, number of households, salary distribution and land usage, and information from the National Economic and Social Development Board concerning GNP (Gross National Product) and related affairs.)

The forecasts are made, based on the information thus collected and in comparison with the corresponding situations in other countries, as well as considering the behaviors of national politics and economy plus the TOT bond issue for telephone network construction and call tariffs.

The forecasts are made for a total of 10 years, i.e., for each year during the period from 1977 through 1984 plus 1978 and 1990.

The Study Team required the telephone demand expected in the service-in year of 1984 for the current Project and five and 10 years after the service-in year, i.e., 1989 and 1994. Since the telephone demand forecast of TOT is presumed to be in full consideration of all factors which will arouse the telephone demand, the demand estimates for the required years are calculated through the analysis of the telephone demand uptrend.

2-1 Analysis of Telephone Demand Uptrend

The study of "Forecast of Telephone Demand 1977-1990" published by TOT leads to a finding that the telephone demand uptrend can be divided into seven steps. The seven steps are as follows :

1) As seen in Figure 3-1, the initial low rate increase (r_1) is followed by the high rate increase (r_2)

.... ($r_1 < r_2$)

2) As seen in Figure 3-2, the initial low rate increase (r_1) is followed firstly by the medium rate increase (r_2) and then by the high rate increase (r_3)

.... ($r_1 < r_2 < r_3$)

3) As seen in Figure 3-3, the initial high rate increase (r_1) is followed firstly by the low rate increase (r_2) and then by the high rate increase (r_3) again

.... ($r_1 > r_2 < r_3$)

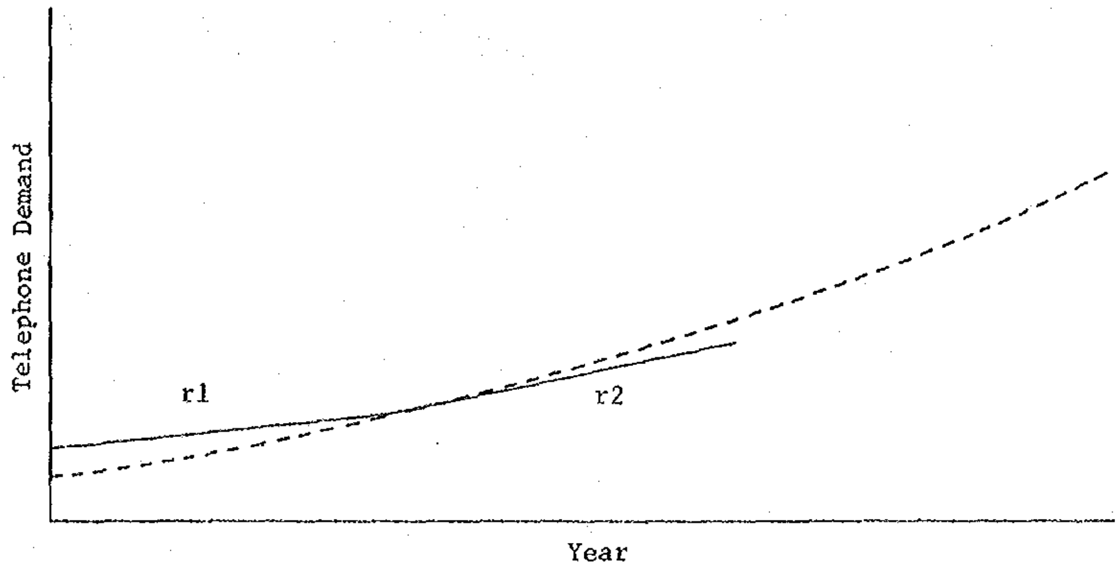


Figure 3-1 Telephone Demand Uptrend (E1)

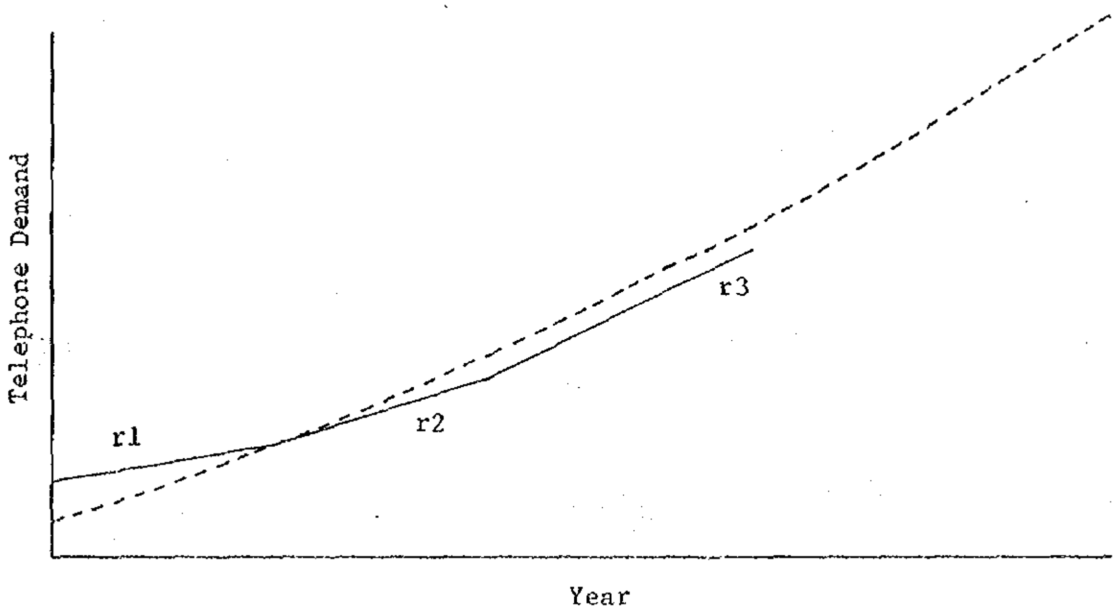


Figure 3-2 Telephone Demand Uptrend (E2)

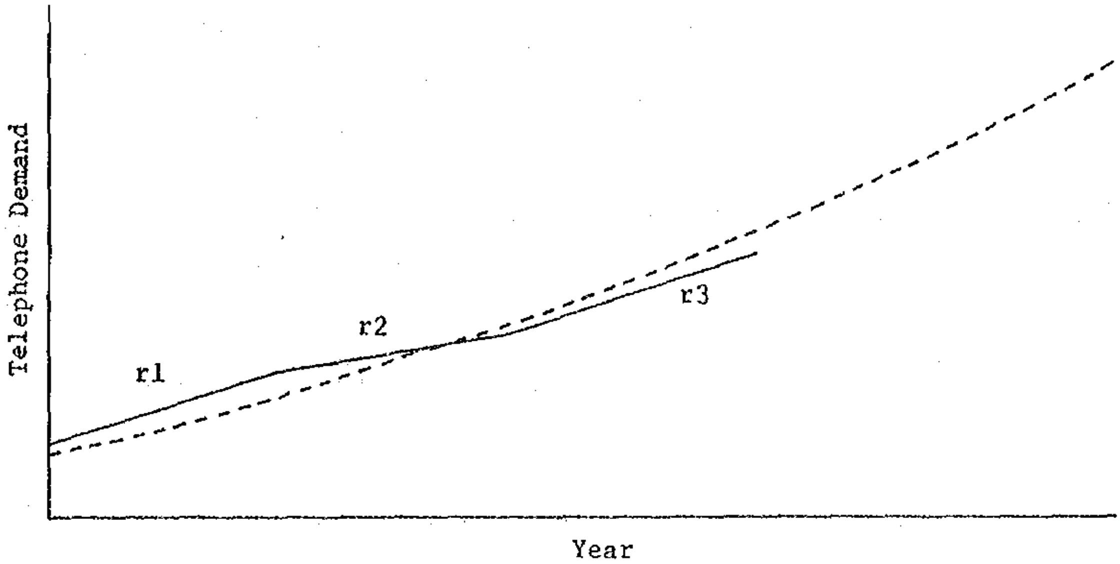


Figure 3-3 Telephone Demand Uptrend (E3)

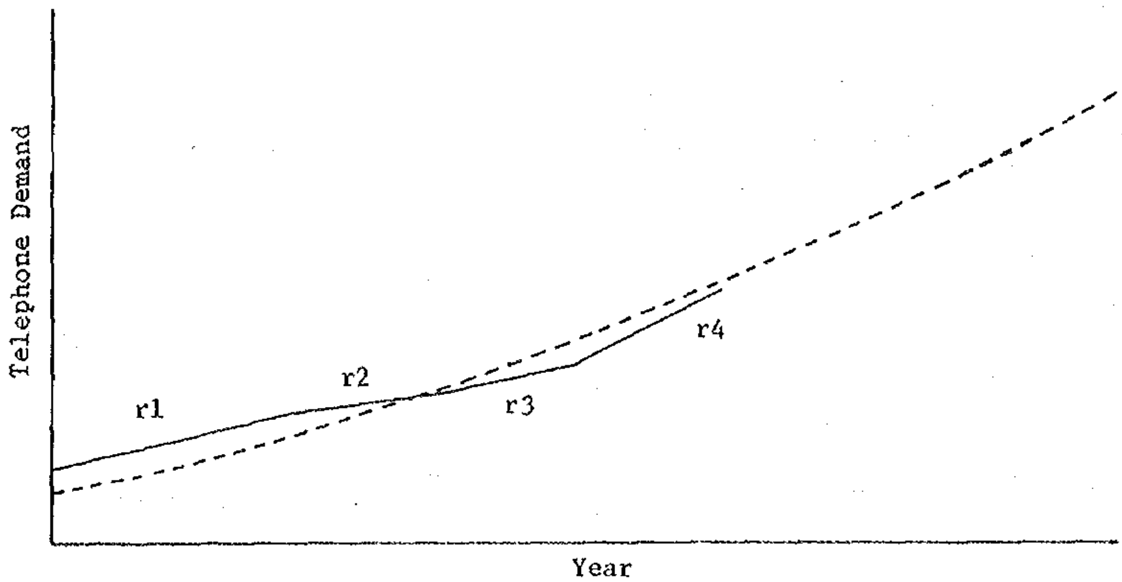


Figure 3-4 Telephone Demand Uptrend (E4)

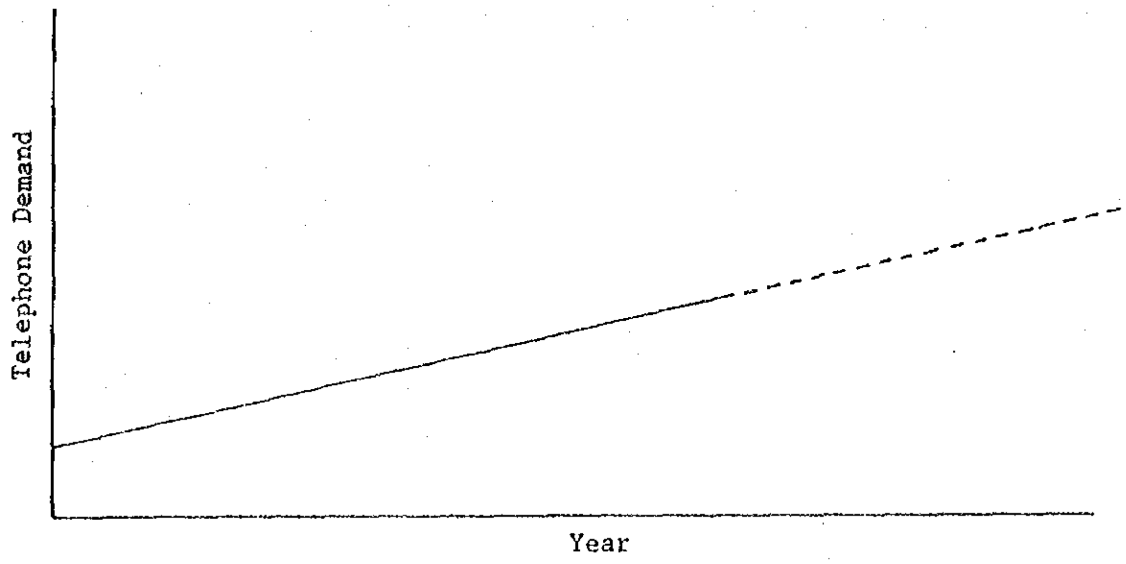


Figure 3-5 Telephone Demand Uptrend (L1)

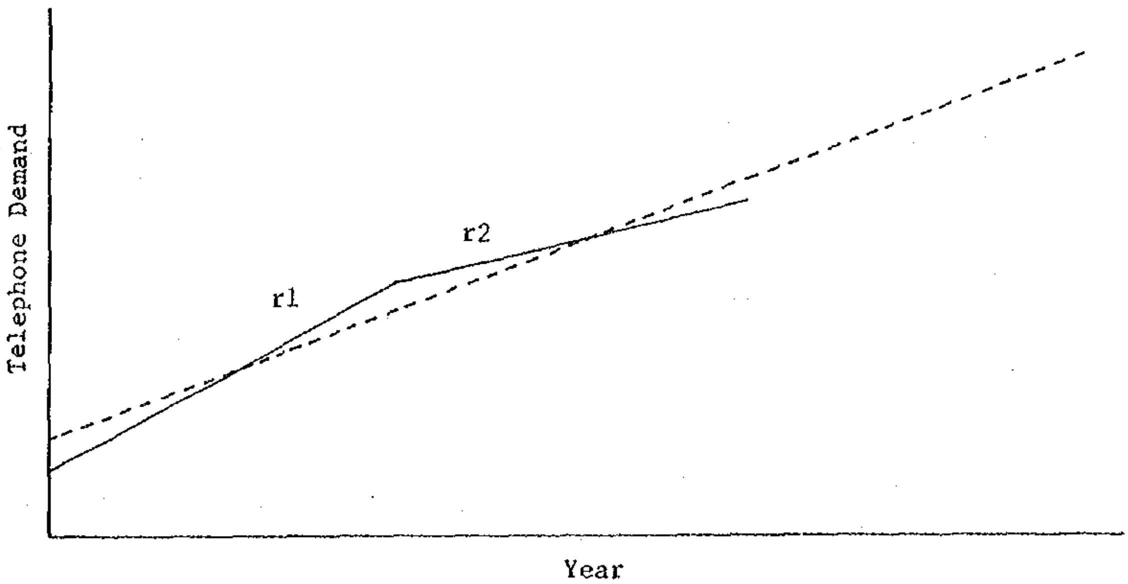


Figure 3-6 Telephone Demand Uptrend (L2)

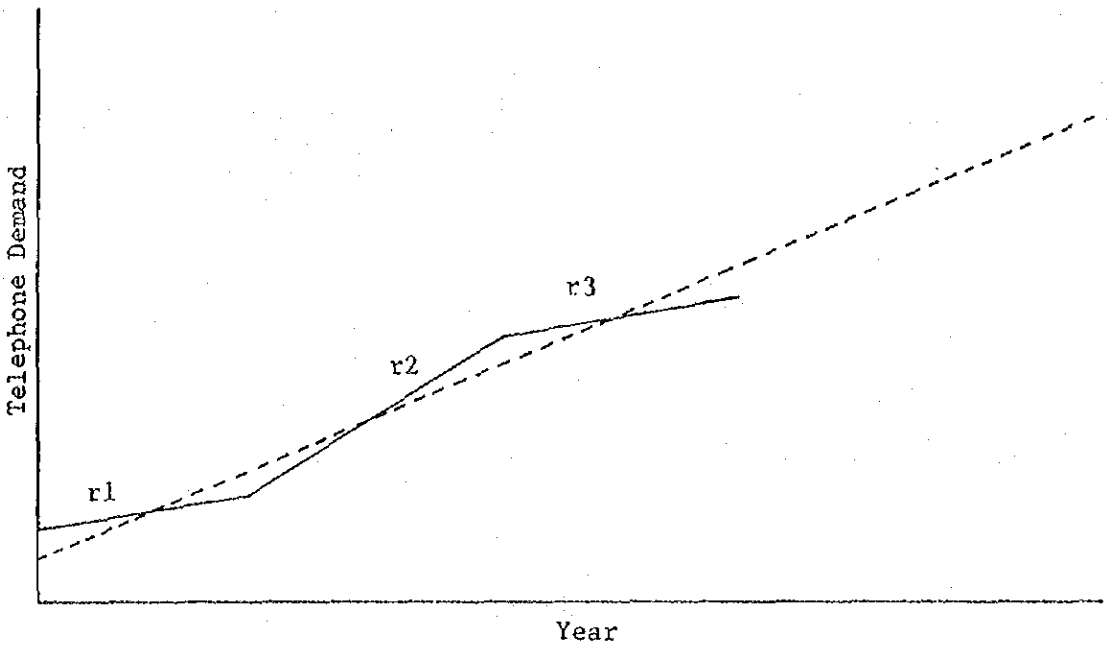


Figure 3-7 Telephone Demand Uptrend (L3)

4) As seen in Figure 3-4, the initial high rate increase (r_1) is followed firstly by the low rate increase (r_2), then by the medium rate increase (r_3) and finally by the high rate increase (r_4)

.... ($r_1 > r_2 < r_3 < r_4$)

5) As seen in Figure 3-5, the fixed rate increase continues.

6) As seen in Figure 3-6, the initial high rate increase (r_1) is followed by the low rate increase (r_2)

.... ($r_1 > r_2$)

7) As seen in Figure 3-7, the initial low rate increase (r_1) is followed firstly by the high rate increase (r_2) and then by the low rate increase (r_3) again

.... ($r_1 < r_2 > r_3$)

2-2 Telephone Demand Forecast

The telephone demand in 1984 is set at the value used in "Forecast of Telephone Demand 1977-1990" published by TOT. The demand estimates for years of 1985, 1986, 1988 and 1989 are not shown in the TOT publication so that the demand estimate for the year of 1989 is calculated from the demand uptrend mentioned in Paragraph 2-1 and the demand estimates for 1984, 1987 and 1990.

As regards the telephone demand forecast for 1994, two kinds of regression analyses are made for each of the seven steps of demand uptrend. More precisely :

1) In case the demand uptrend is of four kinds as shown in Figures 3-1 to 3-4, the demand in 1994 is forecasted by means of exponential regression.

2) In case the demand uptrend is of three kinds as shown in Figures 3-5 to 3-7, the demand in 1994 is forecasted by

means of linear regression.

Exponential regression and linear regression were conducted by the method of least squares. For all regressions, the decision factor was greater than 0.95.

As regards the demand estimates in the areas not covered by the telephone demand forecast of TOT, the rate of increase in 1989 as compared with 1984 and the rate of increase in 1994 as compared with 1984 were obtained by referring to the telephone demand uptrend in the whole of Thailand except the Bangkok Metropolitan area. The increase rates thus obtained for the years 1989 and 1994 were respectively multiplied to the demand estimate for 1984.

The demand estimates by areas for the years of 1984, 1989 and 1994 appear in Volume II-1 "Telephone Demand Forecast". In the Remarks column are shown the demand uptrends by areas. E1, E2, E3 and E4 correspond to Figures 3-1 to 3-4 and L1, L2 and L3 to Figures 3-5 to 3-7. For the areas marked with an asterisk (*) the demand uptrend could not be known from TOT data so that the Provincial average increase rate was used for those areas.

3. Telephone Exchange Introduction Plan

According to the TOT policy, Rural Long Distance Public Telephone Service will be introduced in the telephoneless districts if the demand in 1984 does not exceed 400 telephones, whereas ordinary telephone service with telephone exchange will be provided in no-telephone districts should the demand exceed 400 telephones.

This study also includes the telephone exchange introduction plan aimed at the realization of transmission system that satisfies required transmission capacity even if telephone exchange is introduced among the 422 target districts of Rural Long Distance Public Telephone Service, based on the telephone demand forecast made in the preceding Chapter 2.

Years in which telephone exchange will be introduced are set to be 1989 and 1994, i.e., five years and 10 years after 1984 when Rural Long Distance Public Telephone Service is scheduled to come into being.

Telephone exchange to be introduced in 1989 is to satisfy the estimated demand for 400 telephones or more, the same as envisaged by TOT at present.

Telephone exchange to be introduced in 1994 is to satisfy the estimated demand for 200 telephones or more in consideration of quantitative and qualitative increase of telephone service as the result of the advancement of national economy.

More specifically, in 1989, telephone exchange will be introduced in 18 districts out of the 422 districts where Rural Long Distance Public Telephone Service is to be provided in 1984, and, in 1994, in further 187 districts. By this arrangement, ordinary telephone service by use of telephone exchange will be put into practice in those districts.

In Volume II-2 "Exchange Introduction Plan", the plan by years by districts is presented in the number of telephone exchange terminals. The number of terminals mentioned here does not specify the number of terminals to be installed for the purpose of introducing telephone exchange but is intended to determine the transmission route capacity. In other words, the number of terminals mentioned is the number of terminals that matches the estimated telephone demand five years after the introduction of telephone exchange. And this is to secure the sufficient transmission route capacity on the presumption that the number of terminals to be installed on telephone exchange introduced still remains undecided.

Therefore, the number of telephone exchange terminals given for the year 1989 is the number of terminals that matches the telephone demand estimate for 1994 or five years after 1989, and the number of terminals given for the year 1994 is the number of terminals that matches the telephone demand estimate for 1999 or five years after 1994.

The telephone demand estimate for the year of 1999, instead of being forecasted district-wise, has been obtained by multiplying to the demand forecast for the whole of Thailand except Bangkok the rate of increase of 1.5 times for the period from 1994 to 1999.

As for the districts where the mobile exchanges are to be introduced in 1984, the number of terminals to be installed at the time the exchanges are introduced has been determined but the plan for subsequent increase of terminals remains undecided. Hence, the number of terminals installed is shown on the assumption that the terminals will be increased in 1989 and 1994.

4. Estimation of Telephone Circuits Required

4-1 Estimation Criteria for Telephone Circuits Required for Rural Long Distance Public Telephone Service

For Rural Long Distance Public Telephone Service, only the originating traffic from public telephones has to be considered. However, it is difficult to know to what extent the public telephones installed in the districts where no telephone service is provided will be utilized.

Therefore, on the presumption used by TOT to the effect that for each unit of the demand for 50 telephones the originating traffic of 0.5 Erl. takes place, the district by district traffic estimations are carried out. Volume II-3 "Telephone Traffic Forecast" presents the traffic volume breakdown by districts.

In Rural Long Distance Public Telephone Service, the number of circuits is equal to the number of public telephones to be installed, so that the number of circuits required is estimated by the delay system. For calculation, Erlang C Formula is used. The probability of delay is set at 0.1.

Table 3-1 shows the relationships among telephone demand, originating traffic volume, and number of circuits required. The number of telephone circuits required by districts, estimated from Table 3-1, can be found in Volume II-4 "Telephone Circuit Requirements".

4-2 Estimation Criteria for Telephone Circuits Required for Ordinary Telephone Service by Use of Telephone Exchange

Telephone demand in the areas where telephone exchange will be introduced can be expected mainly from governmental and related offices and the sectors of commerce and industry where the rate of telephone utilization is considered to be high. Demand for residential house telephones can seldom be expected. Therefore, the originating and terminating traffic estimation is based on the assumption that the calling rate per subscriber is 0.1 Erl. (Originating calling rate : 0.05 Erl. ; terminating calling rate : 0.05 Erl.)

The traffic volume from the districts with telephone exchange introduced to their parent Primary Centers and vice versa is

Table 3-1 Circuit Requirements Standard for Rural Long Distance Public Telephone Service

Telephone Demand	OG Traffic in Erl.	Circuit Requirements
0 - 50	0.5	2
51 - 100	1.0	3
101 - 150	1.5	4
151 - 200	2.0	5
201 - 250	2.5	6
251 - 300	3.0	6
301 - 350	3.5	7
351 - 400	4.0	8

OG : Outgoing

assumed to be 20% of the total orginating and terminating traffic volume, and on this assumption the number of circuits required has been estimated. The traffic volume between the districts with telephone exchange introduced and their parent Primary Centers is given in Volume II-3 "Telephone Traffic Forecast".

Also used in the estimation of the number of circuits required is the assumption that service be on lost call cleared basis. Erlang B Formula is used at the probability of loss set to 0.01. Table 3-2 presents the relationships among the number of telephone exchange terminals, the total originating and terminating traffic volume, the outgoing and incoming traffic volume to/from Primary Centers, and the number of circuits required estimated by the conditions mentioned above. The number of circuits required is given in Volume II-4 "Circuit Requirements Forecast".

5. Community Survey Result and Forecast Result Evaluation

At the beginning, it must be noted that the community survey was conducted when time was available during the field survey. The objective was to collect reference data for the correct evaluation of various parameters required for the circuit requirements forecast.

The community survey was made by two methods. One was to collect information of general nature. The other was to sound views among the sectors where the telephone demand was considered to be relatively large. Those sectors included shopkeepers, restauranteurs and banking business managers.

Table 3-2 Circuit Requirements Standard for Telephone Exchange

Line Capacity	ORG/TRM Traffic in Erl.	OG/IC Traffic in Erl. to/from PC	Circuit Requirements Total (OG + IC)
200	10.0/10.0	2.0/2.0	14 (7 + 7)
400	20.0/20.0	4.0/4.0	20 (10 + 10)
600	30.0/30.0	6.0/6.0	26 (13 + 13)
800	40.0/40.0	8.0/8.0	30 (15 + 15)
1000	50.0/50.0	10.0/10.0	36 (18 + 18)
1200	60.0/60.0	12.0/12.0	40 (20 + 20)
1400	70.0/70.0	14.0/14.0	46 (23 + 23)
1600	80.0/80.0	16.0/16.0	50 (25 + 25)
1800	90.0/90.0	18.0/18.0	56 (28 + 28)
2000	100.0/100.0	20.0/20.0	60 (30 + 30)
2200	110.0/110.0	22.0/22.0	64 (32 + 32)

ORG : Orignating

TRM : Terminating

OG : Outgoing

IC : Incoming

5-1 Community Survey

Information of general nature was collected at District Offices and Post & Telegraph Offices, using the format shown in Table 3-3. The sounding of views concerning the telephone service was carried out by asking the following questions :

1) At present, no telephone system exists here. By what means do you communicate with people in the Provincial center and Metropolitan area?
2) When telephone service is commenced, do you utilize it?
3) For what purpose do you use the telephone?
4) When telephone service - not ordinary telephone service but Rural Long Distance Public Telephone Service - is commenced, do you utilize it?

As mentioned previously, time available for the community survey was limited so that a full survey could not be made. The collected views, though not numerically sufficient as samples for analysis, are considered to have reflected the trend of thinking among inhabitants toward telephone service. The survey result is summarized in Table 3-4. The points clarified by this survey are as follows :

1) In the areas where banks exist, economic activities are brisk. Telephone demand is also large.
2) The major part of telephone demand orginates from business fields. Demand for residential house telephones is scarce.
3) Governmental offices, such as District Offices, hold the in-house communication system. However, the system performance is inferior in many cases. For those offices, therefore, telephone service of good performance provided by TOT is necessary.

Table 3-3 Community Survey Format

(1) Population

(2) Number of families

(3) Number of houses

(4) Number of shops (including restaurants)

(5) Number of business offices, hotels

- Governmental offices
- Police stations
- Military stations
- Private company offices
- Hotels, and number of rooms
- Banks

(6) Number of factories

(7) Rural Development Plan

- Road
- Housing
- Factory
- Irrigation
- Electric power supply
- Potable water supply

(8) Number of mails delivered and collected per day

(9) Number of telegraphs sent and received per day

(10) Percentage of people who own TV set

(11) Number of cars

(12) Number of motor bicycles

(13) Existing private or governmental use telecommunication facilities

Table 3-4 Summary of Community Survey (1/3)

Site Name (Code)	Population	Families	Houses	Shops	Offices NOTE 1	Rural Develop Plans	Mails IN/OUT	Telegraphs IN/OUT	TV Set (%) NOTE 2	Cars	Motor-Cycles	Private Telecom. Systems	Interviewed Persons
Bang Ban (351601)	8,655	1,500	1,515	48	7	6	U.A.	U.A.	4.0	60	130	2	U.A.
Lat Bua Luang (351602)	1,690	400	342	57	6	3	200 NOTE 3	10 NOTE 3	25.0	15 NOTE 4	20	3	1
Maharat (351603)	2,859	551	U.A.	45	9	1	30/30	5/7	14.5	30	40	3	1
Nakhon Luang (351604)	7,325	1,500	1,340	35	9	8	180 NOTE 3	10 NOTE 3	50.0	(30%) NOTE 2	(30%) NOTE 2	4	1
Ban Phraek (351605)	2,561	475	U.A.	40	7	U.A.	50/85	2/2	80.0	(5%) NOTE 2	(90%) NOTE 2	3	2
Bangpa Han (351606)	2,414	603	412	88	8	2	200/50	6/3	32.8	41	60	3	U.A.
Bang Sai (351607)	6,776	1,315	U.A.	84	7	1	70/30	2/2	95.0	10 NOTE 5	50	4	1
Phak Hai (351608)	19,901	2,047	2,014	120	17	3	300/100	10/10	34.2	40	55	3	1
U-Thai (351609)	3,105	754	511	76	7	8	120 NOTE 3	4 NOTE 3	20.0	40	100	3	1
Khon Buri (442101)	8,124	1,269	U.A.	462	31	6	400/500	16/15	80.0	300	1,269	3	U.A.
Prathai (442102)	4,706	746	681	57	12	3	300/300	10/10	100.0	200 NOTE 6	1,500 NOTE 6	3	1
Non Thai (442103)	5,055	1,615	847	63	16	7	300/250	3/3	10.0	40	100	5	1
Khong (442104)	3,000-6,000	U.A.	U.A.	200	10	U.A.	200/150-160	4/6	20.0	10-15	100	2	1
Dan Khun That (442106)	5,321	700	U.A.	150	28	1	360/320	15/10	80.0	(25%) NOTE 2	(80%) NOTE 2	4	4
Khan Thale So (442107)	3,199	511	U.A.	40	42	U.A.	100/100	5/3	20.0	(10%) NOTE 2	(30%) NOTE 2	4	U.A.

U.A. : Unavailable

Table 3-4 Summary of Community Survey (2/3)

Site Name (Code)	Population	Families	Houses	Shops	Offices NOTE 1	Rural Develop Plans	Mails IN/OUT	Telegraphs IN/OUT	TV Set (%) NOTE 2	Cars	Motor-Cycles	Private Telecom. Systems	Inter-viewed Persons
Kham Sakae Saeng (442108)	6,564	836	U.A.	100	12	2	90/65	6/6	15.0	(25%) NOTE 2	(25%) NOTE 2	3	U.A.
Huai Thalaeng (442109)	4,228	775	U.A.	110	17	4	170/150	6-7 NOTE 3	6.5	20	120	4	1
Saeng Sang (442110)	3,143	478	U.A.	100	9	6	200/100	1 NOTE 3	20.0	50	150	4	U.A.
Sung Noeng (442111)	8,076	1,459	U.A.	108	14	2	300/300	10/10	80.0	(10%) NOTE 2	(30%) NOTE 2	5	3
Chakkarat (442112)	4,019	500	374	250	8	5	200/150	7/3	60.0	150	450	3	1
Non Sung (442113)	7,968	1,276	U.A.	100-150	21	U.A.	U.A.	U.A.	7.8	50	100	2	2
Omkoi (531302)	2,000	270	U.A.	5	4	2	U.A.	U.A.	NONE	7-8	NONE	2	U.A.
Doi Tao (531303)	11,279	2,496	2,907	37	11	5	150/100	13 NOTE 3	0.4	16	100	5	2
San Sai (531305)	12,595	U.A.	U.A.	20	6	5	200/300	7/7	20.0	(20%) NOTE 2	(60%) NOTE 2	1	1
Doi Saket (531306)	9,000	2,200	U.A.	30	16	4	400/250	10 NOTE 3	60.0-70.0	(10%) NOTE 2	(90%) NOTE 2	2	3
Mae Taeng (531308)	6,000	1,200	U.A.	6	7	1	300/200	10/10	50	150	1,600	2	1
Chiang Dao (531309)	7,973	1,263	1,148	26	17	15	300 NOTE 3	8/8	2.7	21	105	2	1
Sa Moeng (531310)	3,417	616	U.A.	5	6	12	15 NOTE 3	1 NOTE 3	NONE	25	65	3	-
Mae Rim (531311)	10,486	1,900	2,012	92	12	3	1,200 NOTE 3	30 NOTE 3	10.0	100	300	3	1
Hot (531312)	4,506	1,000	728	71	15	4	250-300 NOTE 3	20 NOTE 3	2.0	100	300	4	2

U.A. : Unavailable

Table 3-4 Summary of Community Survey (3/3)

Site Name (Code)	Popula-tion	Fami-lies	Houses	Shops	Offices NOTE 1	Rural Dovelop Plans	Mails IN/OUT	Tele-graphs IN/OUT	TV Set (%) NOTE 2	Cars	Motor-Cycles	Private Telecom Systems	Inter-viewed Persons
Hang Dong (531313)	18,766	9,388	U.A.	20	8	2	230/200	10/10	80.0-90.0	(20%) NOTE 2	(90%) NOTE 2	2	1
Mae Chaem (531314)	2,460	300	U.A.	22	7	5	120 NOTE 3	7-8 NOTE 3	NONE	20	160	3	U.A.
San Kam Phaeng (531315)	16,746	2,693	U.A.	141	11	U.A.	700/400	30/20-30	80.0	(15%) NOTE 2	(90%) NOTE 2	3	2
San Patong (531316)	6,144	1,460	U.A.	50	9	U.A.	800/900	25/25	80.0	U.A.	U.A.	3	2
Chom Thong (531317)	11,834	2,200	U.A.	258	32	5	500/500	30/30	5.5	(10%) NOTE 2	(90%) NOTE 2	3	3
Don Sak (771106)	10,500	1,500	1,400	1,200	9	4	220 NOTE 3	8 NOTE 3	30.0	100	1,100	3	U.A.
Ko Phangan (771109)	5,399	950	U.A.	20	7	1	U.A.	U.A.	0.7	5	200	4	U.A.
Ko Samui (771113)	6,084	1,137	1,018	U.A.	25	U.A.	U.A.	U.A.	26.4	70	500	5	U.A.

Note 1 : Governmental offices and private company offices including factories.
Note 2 : Percentage to number of houses.
Note 3 : Total number of IN and OUT.
Note 4 : Number of boats is 30.
Note 5 : Number of boats is 1,300.
Note 6 : Number in whole district.
U.A. : Unavailable.

4) For Rural Long Distance Public Telephone Service, the majority opinion considers it to be better than no telephone. However, since telepnones are to be utilized primatily to gain convenience in doing business, there is a strong request for ordinary telephone service instead of Rural Long Distance Public Telephone Service. For, the former can be used whenever necessary and it can also handle terminating calls from other parties.

People who desire to have telephone service opened are pepole who, at present, proceed to the nearby telephone office by car, autobicycle or bus every time they want to use telephones.

Following is the introduction of rural long distance public telephones in service at San Kam Phaeng and San Patong in Chiangmai area. This service was witnessed during the community survey.

At San Kam Phaeng, two rural long distance public telephones are installed, one in the District Office and the other in the market. Both these public telephones are accommodated in the toll board of Chiangmai Exchange Office by the telegraph circuit of the Post & Telegraph Office.

System performance is extremely poor because the telegraph circuit is utilized so that, for both public telephones, the rate of use is not high : reportedly four times per day on the average. However, on the days when the system performs well, the rate of utilization is said to reach as many as 100 times per day. The tariff rate is two Baht per call regardless of the duration of call.

The public telephone at San Patong is operated by 150 MHz single channel radio system. One male operator is in charge of system operation. This public telephone system is installed in a cottage which, together with an antenna tower, is located in the leased land of TOT.

In the cottage are the reception desk and the telephone booth. The tariff rate here is the same as that for general toll calls or, more precisely, the basic rate for the first three minutes and the additional rate for each additional one minute. Payment is made to the operatior at the end of each call.

System performance is not exactly good because of no small noise and transmission loss. A trial call to Bangkok, however, was devoid of special difficulty.

The average rate of utilization is 30 times per day. One half of calls is to Chiangmai and the other half to Bangkok.

5-2 Forecast Result Evaluation

As seen in Table 3-4, the community survey carried out this time ended to a large extent in the collection of general information. However, from such general information could be obtained more or less contributory data to the forecasts made in Chapters 2 through 4 of this Part III on the basis of TOT data. Following is the evaluation of the forecast results, based on the community survey findings.

The community survey was made at 38 sites. For at least six sites out of the 38 sites, where Rural Long Distance Public Telephone Service is expected to be introduced, the forecast results are considered to be rather too conservative.

The six sites are as follows :

1) Ayutthaya Area - Phak Hai
2) Nakhon Ratchasima Area - Khon Buri, Dan Khun That, Sung Noen
3) Chiangmai Area - San Sai, Mae Rim

The fact common to five sites excluding San Sai of Chiangmai area is that the economic activities are considerably brisk. At each of these five sites, two banks exist and merchant houses number approximately 100. The volume of mails and telegraphs handled at these five sites is much larger than at other sites.

Community survey interviewees expressed strong desire for early construction of telephone system, attesting to a considerably large telephone demand potential.

San Sai in Chiangmai area is a town with a large number of big income earners. According to a report, it is a town second only to Chiangmai in the amount of tax payment. Near the town is a university. It is reported that at least 100 residents desire to have telephones installed for personal use. Therefore, in this town, large telephone demand can be expected from the different angle from the five sites earlier mentioned.

Contrarily, at some of mountain districts in Chiangmai area, telephone demand is considered to be not so large as forecasted. Omkoi is one of such sites.

The District Offices maintain their in-house radio communication system. However, in view of the poor system performance of such system and the ever-increasing information traffic volume on the system, it is worth consideration to replace the system with TOT's leased circuit or the telephone system. This is all the more important from the viewpoint of preventing the uneconomical dual operation of the existing system and the projected Rural Long Distance Public Telephone Service.

This Project requires an early implementation, so that it seems to be difficult to complete reappraisal of the contents of Project before its service-in. The remedy will be to carry out a detailed investigation concerning nationwide telephone demand by 1989, i.e., five years after this Project comes into service and, at the same time, to rescrutinize all aspects of Rural Long Distance Public Telephone Service in the light of findings in the user consciousness survey. No less important will be the exchange of views among the governmental organizations concerned for the purpose of centralization of communication systems.

PART IV. Transmission Route Selection for Terrestrial Radio System

PART IV Transmission Route Selection for Terrestrial Radio System

1. General

This Part IV firstly describes the basic requirements for the terrestrial radio system route plan, the selection of optimum transmission route plan based on the plan prepared by TOT, and the circuit assignment on the selected route. Secondly, comparison is made, technically and economically, between UHF system and SHF system, including over-the-horizon communication system, to be applied to the selected route. The result of study concerning the advisability of applying the cable system to part of the route is also stated. Lastly, the optimum terrestrial radio system comparable to the domestic satellite system is identified.

In the study of UHF system to be applied, feasibility assessment is made not only for FDM (Frequency Division Multiplex) system but also for PCM (Pulse Code Modulation) system.

The study of SHF system to be applied includes the investigation of precipitation in all parts of Thailand as referred to radio propagation in 11/13 GHz band in the tropical zone. Consideration is made so that, with the application of investigation result to system design, transmission performance estimate can be conducted accurately in conformity with the local meteorological condition as far as possible.

2. Circuit Assignment and Optimum Transmission Route Selection

By applying the number of telephone circuits estimated in Part III to the original route plan of TOT, area by area circuit assignment and optimum transmission route selection have been carried out. Basic requirements established for such circuit assignment and transmission route selection are as follows :

(1) Transmission route from each rural station is, in principle, located as shown in TOT's route plan except where such is technically difficult.

(2) In case where mobile exchange is to be introduced at nearby rural station in intermediate stage (1989) and final stage (1994), transmission route is established via such rural station.

(3) For mobile exchange transmission route, backbone circuit only is established to PC (SC or TC). High usage circuit is not established.

(4) In case where establishment of direct radio circuit to a PC is difficult but radio circuit establishment to the existing telephone office in another area is possible, the latter is adopted when economic consideration permits.

(5) For transmission route selection in four areas, i.e., Chiangmai, Ayutthaya, Nakhon Ratchasima and Phun Phin areas, the Study Team makes detailed study including field survey. Transmission route selection in other areas is, in principle, based on TOT plan.

(6) Transmission route selection related to the existing microwave system is made by the following principles :

   1) Dropping from through repeater station on the existing main route is avoided. UHF system is newly established alongside the existing route.

   2) Dropping from repeater station on the existing spur route is made in due consideration of idle circuit availability and circuit demand increase possibility on the existing route. If the branching from the existing route is not advisable, UHF

system is newly established alongside the existing route.

3) There are circuits that partly run via existing transmission route. However, the existing equipment modification required for such circuits is not included in this Study.

The transmission route plan selected by the foregoing conditions and the circuit assignment diagram appear in Figure 4-1 and Volume II-7 "Route Plan for Terrestrial System" and Volume II-9 "Circuit Assignment Diagram for Terrestrial System", respectively. For the aforementioned four areas subject to detailed study, a typical channel accommodation plan is attached to Volume II-11 "Typical Channel Accommodation Plan".

3. Comparative Study of Transmission Systems to Be Applied

As in Volume II-9, the required final stage transmission capacity per transmission route in the case of terrestrial radio system is 20-120 channels. (Exceptions of approximately 10 sections are excluded.) Out of radio systems which can be used for small capacity transmission route, UHF system and SHF system are taken up for study. These two systems are designated in the Scope of Work as the objective items of this Study. Applications of both systems now in use are introduced below.

	Frequency Band	Transmission Capacity
(1) UHF System		
1) FDM System	400/900/1,500 MHz	24/60/120 ch
2) PCM System	900/1,500 MHz	48/60/120 ch
(2) SHF System		
1) FDM System	2/7 GHz	60/120/300 ch
	11/13 GHz	120/300/600 ch
2) PCM System	2/7 GHz	192/240/480 ch
	11/13 GHz	192/240/480 ch

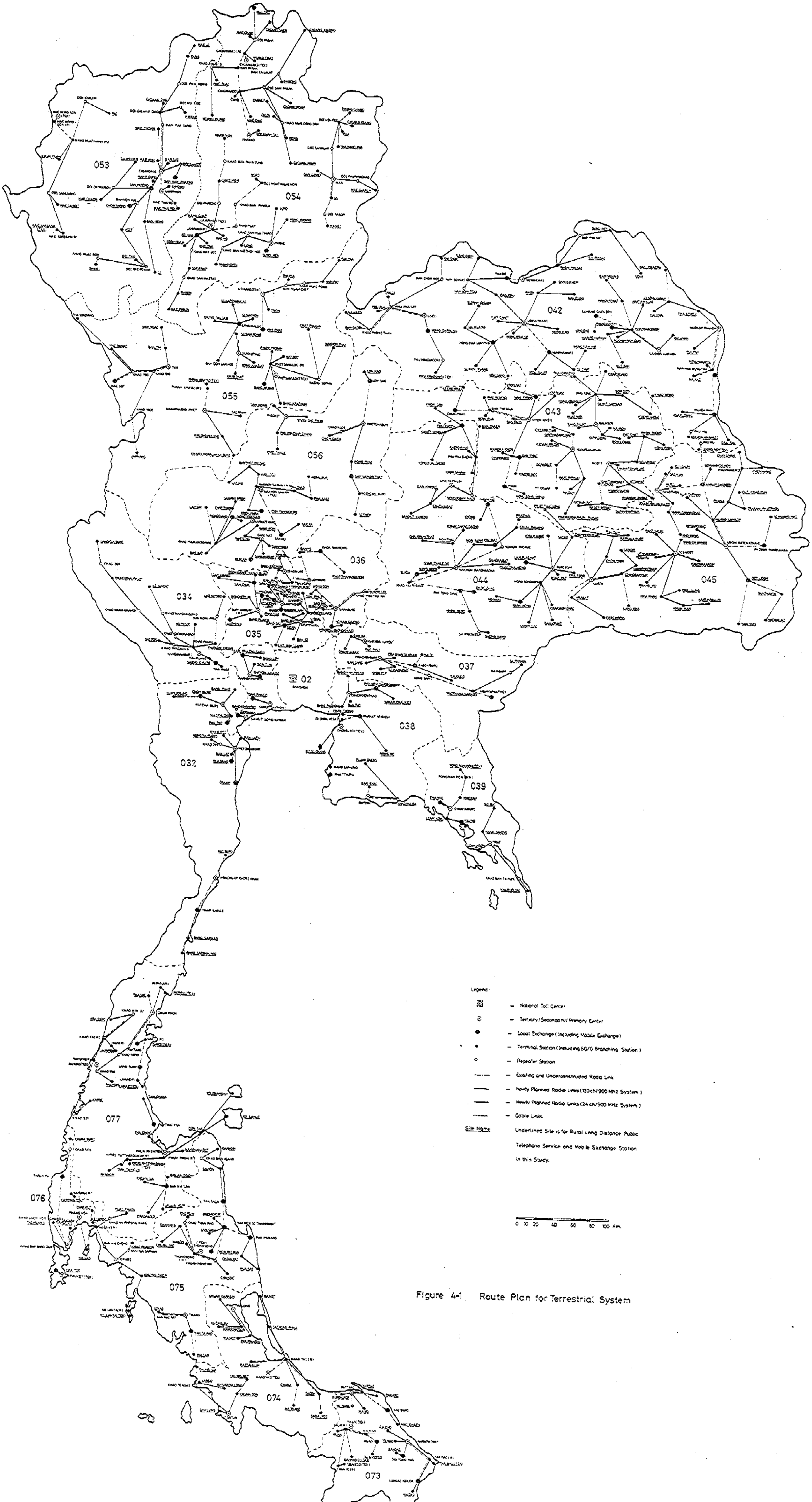


Figure 4-1 Route Plan for Terrestrial System

Out of the systems mentioned above, 900 MHz band UHF system and 11/13 GHz band SHF system are taken up in this Study for technical and economic comparisons. These two are the items, of which TOT requested the Study Team to make special study for application to this Project. Meanwhile, technical and economic conditions that apply to 11 GHz band and 13 GHz band are nearly the same so that 11 GHz band is taken up in this Study.

3-1 Comparison between UHF System and SHF System

UHF system and SHF system differ greatly in two respects : radio propagation characteristics and radio spectrum utilization method. Technical and economic aspects of both systems in due consideration of the said differences are compared in the case of FDM-FM system.

3-1-1 Technical Comparison

In the radio system, transmission capacity per RF channel varies, depending upon radio frequency used. In 900 MHz band the capacity is around 120 channels. In 11 GHz band the capacity is as large as 2,700 channels. CCIR recommends RF channel arrangements for 11 GHz band in case where transmission capacity per RF channel is 600 to 1,800 channels. Thus, generally, 11 GHz band is fit for large capacity circuits. Needless to say, 11 GHz band radio equipment of small capacity, such as 120 and 300 channels, is also available. However, such equipment is rather an exception for special use.

Radio propagation characteristics differ between UHF band and SHF band. Free space propagation loss in 11 GHz band is approximately 20 dB greater than that in 900 MHz band. The variation range of received power due to fading is also greater in SHF band than in UHF band. Therefore, to produce transmission performance of similar level, SHF band requires greater antenna capability and greater transmission power than UHF band.

In the system design that uses radio frequency of 10 GHz or more, radio absorption by rainfall cannot be ignored. For this reason, radio hop distance becomes limited to the extent the standard hop distance depends upon the number of times of circuit interreuptions during heavy rain. The influence of rainfall on radio propagation is described later.

The difference between UHF system and SHF system is found in the types of equipments that constitute the respective systems also. The difference in the types of antennae, feeders and radio equipments required is rather conspicuous.

Judging from the foregoing, it can be said that, technically, UHF band is better suited than SHF band for small capacity transmission of up to 120 channels or thereabouts. On the other hand, SHF band is suitable for medium and large capacity transmission of 600 channels or more. Especially 11 GHz band is best qualified for short distance, large capacity transmission.

3-1-2 Influence of Rainfall on Radio Propagation

Annual precipitation in Thailand is shown in Figure 4-2. The precipitation is extremely large, ranging from 1,000 mm to 4,000 mm per year.

Generally, rainfall can be divided in two types. One is squall with thunder (Mode 1). The other is rainfall of other type (Mode 2). Each mode features exponential distribution. It is in the case of Mode 1 rainfall that above 10 GHz radiowave attenuation on radio path due to rainfall reaches several tens

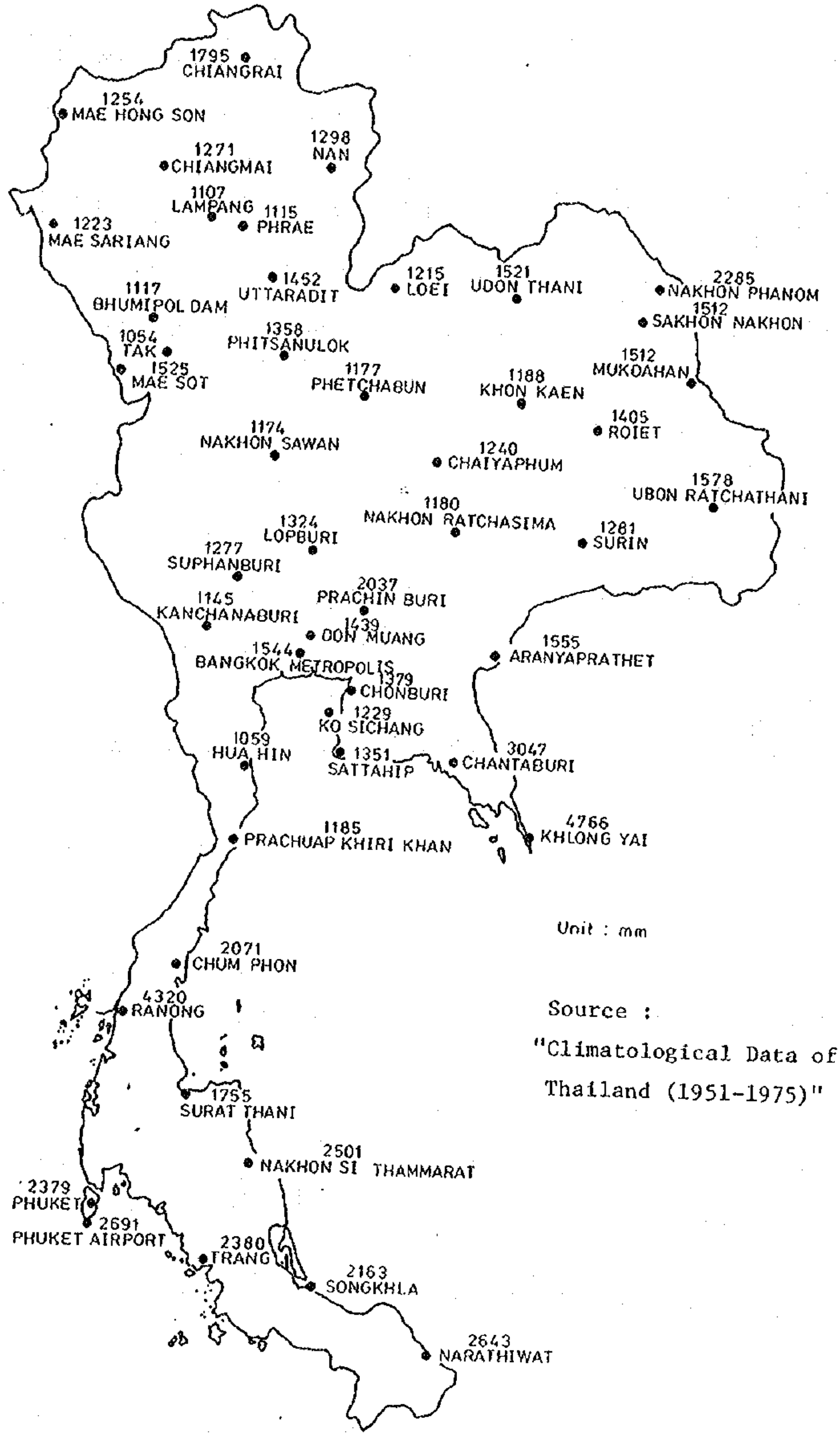


Figure 4-2 Annual Precipitation in Thailand

of dB. Usually, this phenomenon continues for several minutes to several tens of minutes.

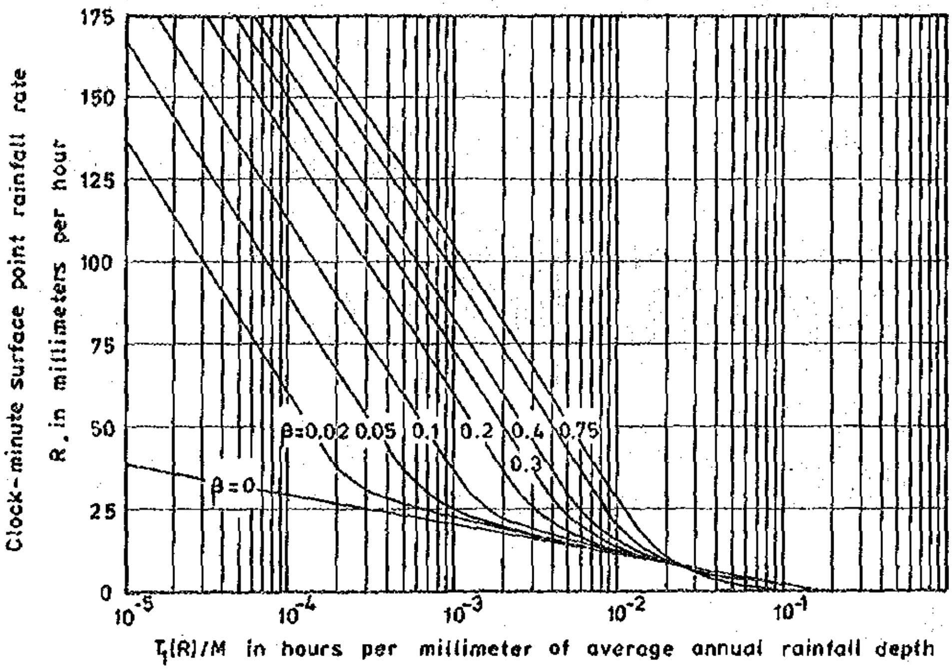
Observatories where short-time rainfall rate, e.g., one-minute rainfall rate, is being observed constantly are not many. The Metropolis Observatory in Bangkok is the sole such observatory that exists in Thailand. There, five-minute rainfall rate is being observed. Therefore, short-time rainfall rate in all parts of Thailand cannot be known unless it is presumed by some means. One example of how to presume short-time rainfall rate from annual precipitation is made known in an article entitled "Cumulative Time Statistics of Surface-Point Rainfall Rates" that recently appeared in IEEE Transactions.

According to this literature, one-minute rainfall rate R_1 (mm/h) is related to annual rainfall depth M and Mode 1 rainfall ratio to the total depth, i.e., parameter β, and is distributed as shown in Figure 4-3. As is evident in this illustration, when $R_1 \geqq 40$ mm/h and $\beta \geqq 0.02$, Mode 2 rainfall can be ignored and R_1 can be obtained by the following equation :

$$R_1 = (\ln (0.03 \beta M/T_1(R_1))) / 0.03 \text{ (mm/h)}$$

where $T_1(R_1)$ denotes the time (h) of one-minute rainfall rate exceeding R_1. It is also reported that parameter β at various places in the world is as seen in Figure 4-4. One-munite rainfall rate in Thailand, estimated by the foregoing methodology, is given in Table 4-1.

Radiowave attenuation due to rainfall is described fully in CCIR Rep.233-3. According to this report, it is possible to estimate radiowave attenuation on radio path of arbitrarily chosen

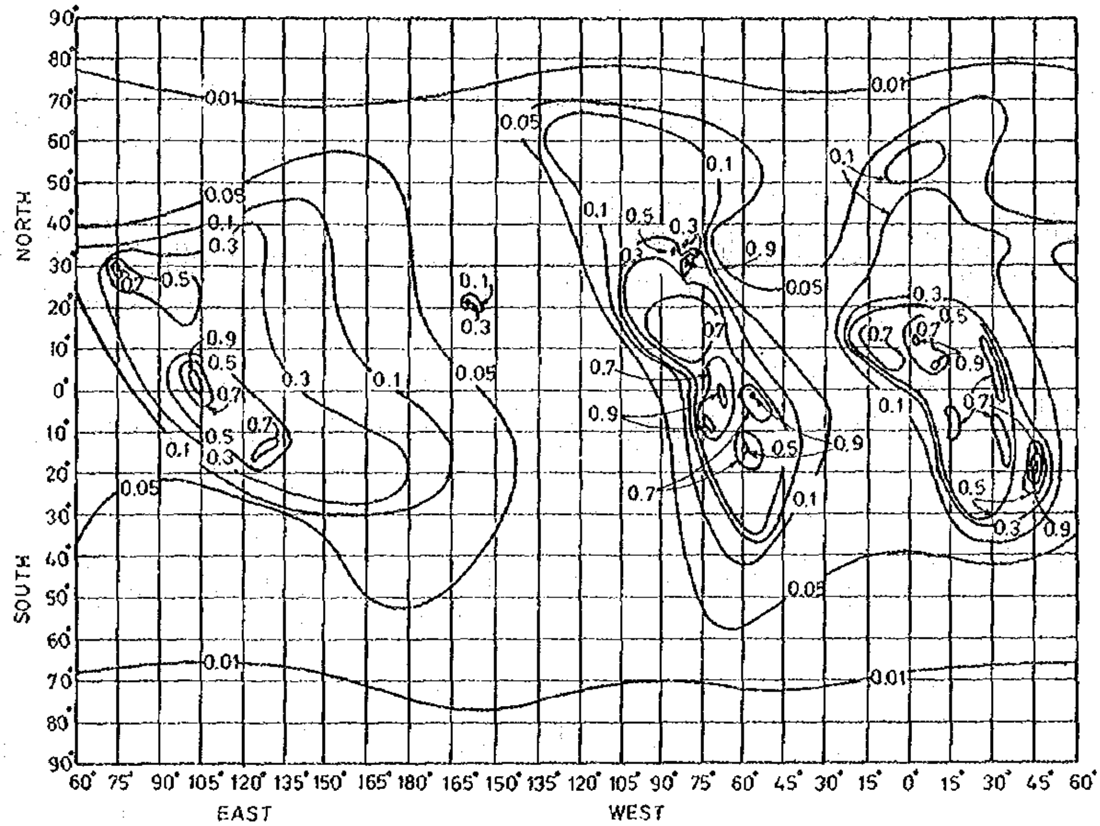


$T_1(R)$ is the number of hours of rainy minutes for which the surface point rainfall rate exceeds R mm/hr in an average year at a median location. The ordinate is R_1 and the abscissa is $T_1(R)/M$, where M is the annual mean rainfall depth in mm.

$\beta = M_1/M$ = the ratio of Mode 1 rainfall depth, M_1, to the total depth, M

(Source : "Cumulative Time Statistics of Surface-Point Rainfall Rates")

Figure 4-3 Normalized Cumulative Time Distributions of Rainfall Rates



THE PARAMETER $\beta = \frac{M_1}{M}$, THE RATIO OF 'THUNDERSTORM' RAINFALL, M_1, TO TOTAL RAINFALL, M

(Source : "Cumulative Time Statistics of Surface - Point Rainfall Rates")

Figure 4-4 The Parameter β for Annual Precipitation

Table 4-1 Estimated One-minute Rainfall Rates in Thailand

Place	Precipitation M (mm)	Parameter β	One-minute Rainfall Rate Ri (mm/h)		
			0.01%	0.02%	0.05%
Chiangrai	1795	0.6	120	97	67
Chiangmai	1271	0.5	103	80	49
Uttaradit	1452	0.5	107	84	53
Nakhon Sawan	1174	0.5	100	77	46
Udon Thani	1521	0.5	109	86	55
Khon Kaen	1188	0.5	100	77	47
Ubon Ratchathani	1578	0.4	102	79	49
Nakhon Ratchasima	1180	0.4	93	70	39
Prachin Buri	2037	0.4	111	88	57
Don Muang	1439	0.4	99	76	46
Bangkok	1544	0.4	102	79	48
Chantaburi	3047	0.5	132	109	78
Prachuap Khiri Khan	1185	0.4	93	70	39
Chum Phon	2071	0.5	119	96	65
Surat Thani	1755	0.5	113	90	60
Phuket	2379	0.7	135	112	81
Songkhla	2163	0.7	132	108	78
Narathiwat	2643	0.7	138	115	85

length, using two kinds of charts. When attenuation in 11 GHz band of Don Muang area at percent time of 0.02%, for instance, is estimated, based on the foregoing rainfall rate estimation result, the following values can be obtained :

Path Distance (km)	Attenuation (dB)
10	24
15	34
20	43
25	50
30	58

Thus, when it is assumed that the allowable circuit interruption rate per year per radio hop is 0.02%, the threshold margin required in 11 GHz is 34 dB for radio path of 15 km and 43 dB for radio path of 20 km.

3-1-3 Economic Comparison

Radio relay system is composed of the following segments :

1) Antenna tower
2) Antenna
3) Feeder
4) Radio equipment
5) Carrier multiplex equipment
6) Power plant
7) Building
8) Access road

For economic comparison between UHF system and SHF system, costs of component 3) and of components 5) through 8) of each system can be safely assumed to be on practically the same level.

For antenna tower, when guyed tower is used, cost increases in proportion to tower height. In UHF system design, obstruction loss to a certain degree can usually be allowed, so that antenna height for UHF system can be somewhat less than for SHF system. Hence the cost can also be reduced that much.

For UHF system, either Yagi antenna or grid type parabolic antenna is usually adopted. This type of antenna costs 30% to 50% lower, compared with plate type parabolic antenna which is used for SHF system.

For radio equipment, solid type equipment is now used for both UHF system and SHF system. In both cases, the equipment is almost the same in outward appearance and size. However, the equipment which is used for SHF system requires technique of higher level than that for UHF system. This is because SHF system uses high radio frequency and requires waveguide circuit. Naturally, equipment cost increases.

Judging economically from the foregoing, the conclusion is that, in the case of small capacity transmission, cost per channel is higher with SHF system than with UHF system. As an aid in determining the system to be adopted in this Project, UHF system cost and SHF system cost (main equipment costs on FOB base) for Ayutthaya area were estimated. Result obtained is shown in Table 4-2.

3-2 Comparison between FDM System and PCM System

Signal multiplexing methods differ completely between FDM system and PCM system. For this reason, both systems hold merits and demerits in many respects. Such merits and demerits, as seen from technical and economic viewpoints, were identified for radio relay system using 900 MHz band.

Table 4-2 Cost Comparison between UHF and SHF Systems

(for Ayutthaya area at initial stage)

(Unit : Million Japanese Yen)

Item	UHF System	SHF System
A. Radio System	83	263
B. Supervisory System	19	19
C. Carrier Multiplex System	80	80
D. Tower	25	25
E. Power Plant	57	61
F. Installation Material	9	16
G. Shelter for Equipment	33	33
Total FOB cost	306	497

3-2-1 Technical Comparison

Technical features of FDM system and PCM system can be found in Table 4-3. Descriptions in this table, however, are of general nature so that, for small capacity radio links used in this Project, some of descriptions require circumspection when comparison is made.

For PCM system, the multi-level modulation research has been carried out, aimed at improvement of radio spectrum utilization efficiency. This research is to elevate the modulation level as from the basic two-level PSK modulation to four-level and eight-level modulations. Nowadays, the four-level PSK modulation is most popular. It is adopted in the 60/120 channels, small capacity PCM radio system also. In the frequency bandwidth occupied in small capacity radio link, there is no much distinction between FDM system and PCM system (four-level PSK modulation) as shown below.

	FDM System	PCM System
60 ch system	2.5 MHz	2.0 MHz
120 ch system	3.2 MHz	4.1 MHz

For both FDM system and PCM system, adjacent RF channel spacing in small capacity radio link of 120 channels or thereabouts is almost the same. The reason is that, in the frequency bandwith occupied in small capacity radio link, no much difference exists between the systems as previously stated.

With regard to cross polarization in PCM system, it must

Table 4-3 Technical Comparison between FDM and PCM Systems

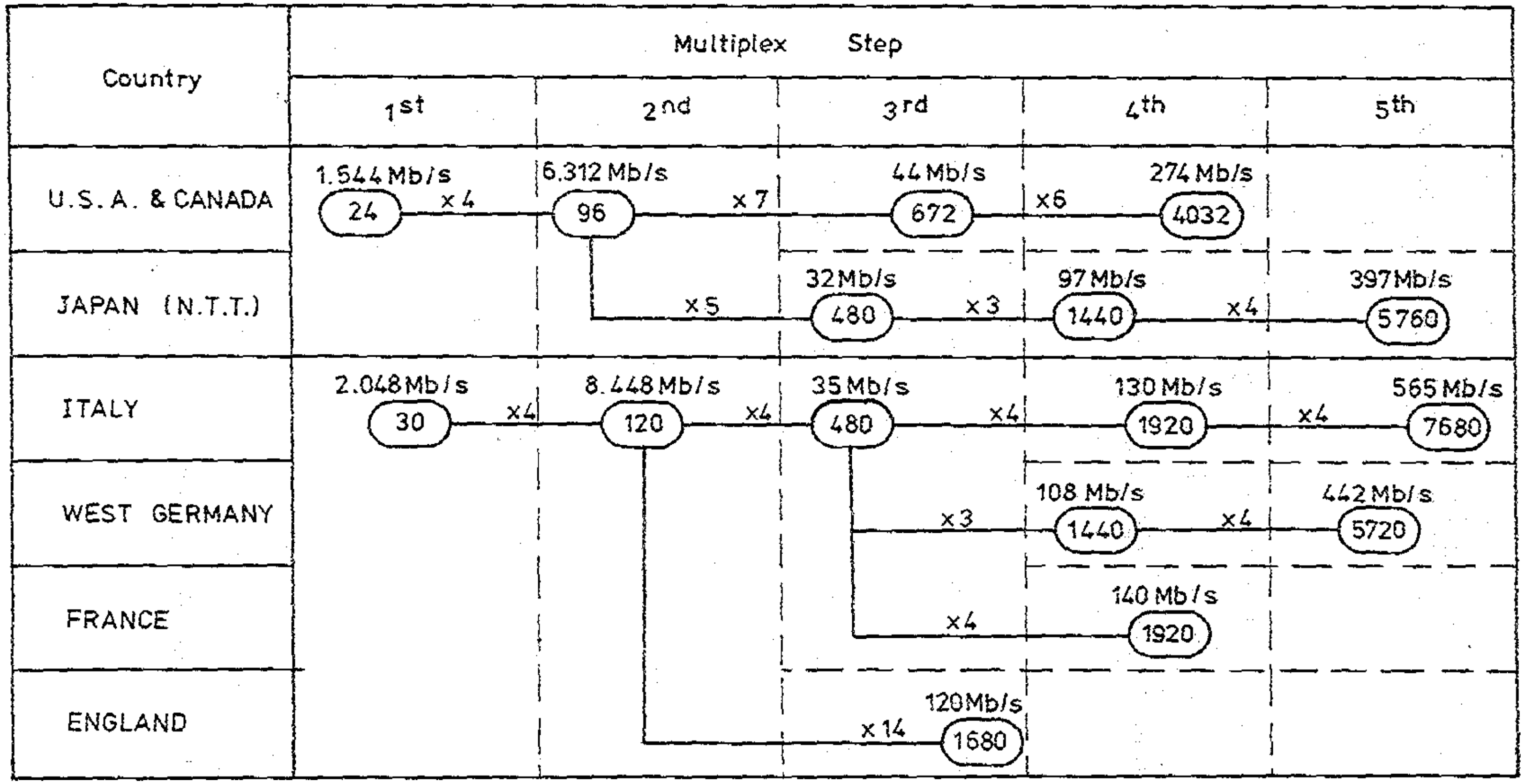
Item	FDM System	PCM System
1. Method of multiplexing	Frequency division multiplexing (FDM)	Time division multiplexing (TDM)
2. Type of multiplex signal	Analog	Digital coded from analog
3. Type of modulation	Frequency modulation (FM)	Phase modulation (PSK)
4. Method of relay	Amplification of analog signal	Regeneration of digital signal
5. Frequency bandwidth occupied per telephone channel	Narrow	Broad
6. Adjacent RF channel spacing (Δf)	Small : 3 fm (fm: top frequency of baseband)	Large: $1.5S < \Delta f \leqq 2S$ (S: digital symbol rate)
7. To use one frequency to make 2 systems by cross polarization	Impossible	Possible
8. Required C/N or transmitting power	Large	Small
9. Noise increase due to relay	Yes	No
10. Signal processing to baseband	Simple	Complex
11. Filter for multiplex equipment	Necessary	Not necessary

be pointed out that in SHF band it is possible because cross polarization discrimination of parabolic antenna is available to the extent of 15 dB or more whereas in UHF band it is impossible because available cross polarization discrimination of antenna is usually not more than few dB. For this reason, in UHF band, the interleaved frequency plan becomes necessary.

In FDM system, system performance is evaluated by noise volume in signal. Thus, on short distance circuits as in this Project, 1,000 or 2,000 pW0p noise volume is allowed. (Refer to CCITT Rec. G123 and CCIR Rec. 379-2.) In PCM system, system performance is evaluated by B.E.R. (Bit Error Rate), and B.E.R. in small percentage of time becomes an especially important factor to determine system performance. PCM system still has a much shorter history of utilization than FDM system. Therefore, no international recommendation has yet been made concerning allowable B.E.R. in radio link where PCM system is adopted. Commonly, for the values of allowable B.E.R. and the percentage of time, 10^{-3} to 10^{-6} and 0.1% to 0.01% are respectively used. (Refer to CCIR Rep. 378-2.)

In this Study, 10^{-6} and 0.02% per hop are respectively used as design objectives.

Overall technical judgment from the foregoing arrives at a conclusion that no much difference can be found between FDM system and PCM system. Meanwhile, in PCM system, as in FDM system, signal multiplexing requires several steps. The hierarchy plan for this purpose, which is now used in each country of the world, is given in Figure 4-5. If PCM system is



Note : Figure in circle means equivalent number of telephone channels.

Figure 4-5 Hierarchy Plan of PCM System in Each Country adopted in this Project, it is appropriate, considering required transmission capacity, to use 2,048 Mb/s (30 channels) in the first stage.

3-2-2 Economic Comparison

For FDM system and PCM system, trial cost estimates at various transmission capacities are made in Figure 4-6. These costs do not include such items as supervisory equipment, antenna tower, and building, wherein no difference in terms of cost can be recognized between the two systems.

As is evident in Figure 4-6, items wherein the cost difference between the two systems is great are two : radio equipment and multiplex equipment. In the case of small capacity radio link, radio equipment cost is greater in PCM system, being 1.5 to 1.6 times the cost that is incurred in FDM system. Contrarily, multiplex equipment cost is smaller in PCM system, the cost this time being 1.0 to 0.6 times the cost incurrable in FDM system. The reason is that, in FDM system, the filters of good performance and various kinds of carrier generators are required at each step of signal multiplexing, whereas in PCM system signal multiplexing requires only one simple pulse generator.

A conclusion that is reached from the foregoing is that, in the cost aspect, there is no great difference between FDM system and PCM system though, as seen in Figure 4-6, up to transmission capacity of 24 channels the cost is smaller in FDM system and, when transmission capacity exceeds 60 channels, the cost is smaller in PCM system.

Cost estimates for both systems in Ayutthaya area as an exemplary case appear in Table 4-4. Cost estimates in this table

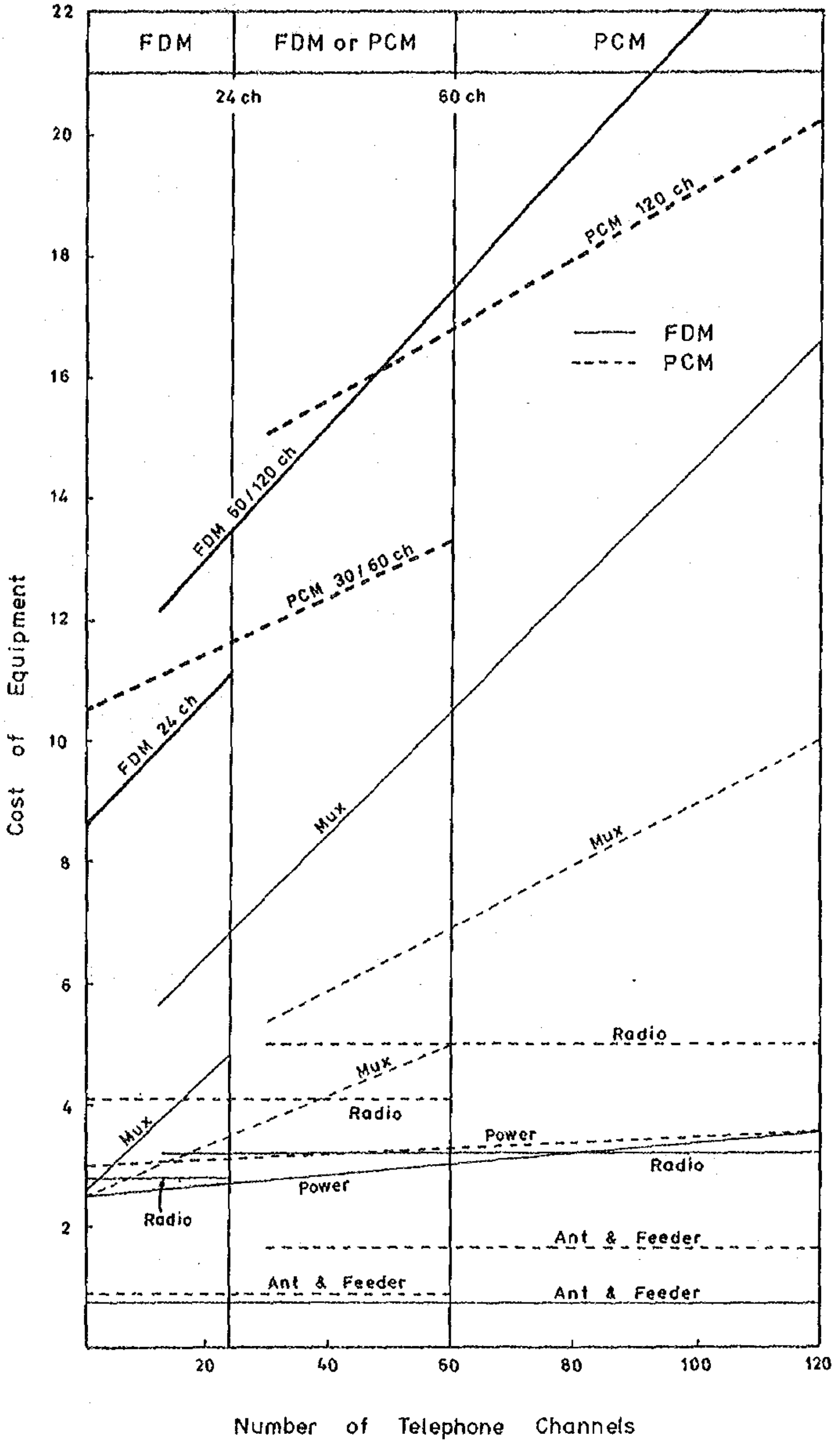


Figure 4-6 Cost Comparison between FDM and PCM Systems in 900 MHz Band

Table 4-4 Cost Comparison between FDM and PCM Systems

(for Ayutthaya area at initial stage)

(Unit : Million Japanese Yen)

	Item	FDM System	PCM System
A.	Radio System	83	112
B.	Supervisory System	19	19
C.	Multiplex System	80	59
D.	Tower	25	25
E.	Power Plant	57	55
F.	Installation Material	9	9
G.	Shelter for Equipment	33	33
	Total FOB cost	306	312

consist of pricipal equipment costs (FOB base) at initial stage (1984). Figures quoted above idicate that the cost difference between FDM system and PCM system is only 2%. Thus, economically, no difference can be recognized between the two systems.

In this Project, two additional investments are required, one at middle stage (1989) and the other at final stage (1994). Overall study of three investments required to complete this Project, i.e., initial investment plus two additional investments, has disclosed practically no cost difference between the two systems.

3-3 Study of Over-the-Horizon (O/H) System

This Project involves no small number of cases where several telephone channels will be established from the Primary Center to a rural site several hundreds km distant. Such sections are located in mountain areas for the most part. If all radio paths are to be line-of-sight paths, a considerable number of repeater stations are required. Therefore, feasibility study was carried out to see whether the application of over-the-horizon (O/H) system on transmission routes in mountain areas where required transmission capacity is up to 24 channels is advantageous or not.

3-3-1 System Parameters

Since recently, many kinds of O/H equipments have been developed. Especially the equipment that uses UHF band radiowave can now be obtained at relatively low cost.

Generally, O/H system requires large transmitting power. These days, transmitting power of 100 W or thereabouts can be obtained by use of all solid state power amplifier. Shown below is one example of system parameters for the equipment which is considered to be usable in this Project.

1)	Frequency	: 900 MHz band
2)	Transmission capacity	: 24 ch (SS-FM)
3)	Transmitting power	: 47 dBm (50 W)
4)	Noise figure	: 3 dB
5)	IF bandwidth	: 1.5 MHz
6)	Threshold level	: -105 dBm
7)	Baseband frequency	: 12 - 108 kHz
8)	Frequency deviation	: 100 kHz r.m.s./ch
9)	Figure of merit	: 188 dB
10)	Objective threshold margin	: 23 dB with FD
11)	Standard antenna	: 6 mφ parabolic
12)	Branching loss	: 5 dB

3-3-2 System Design Examples

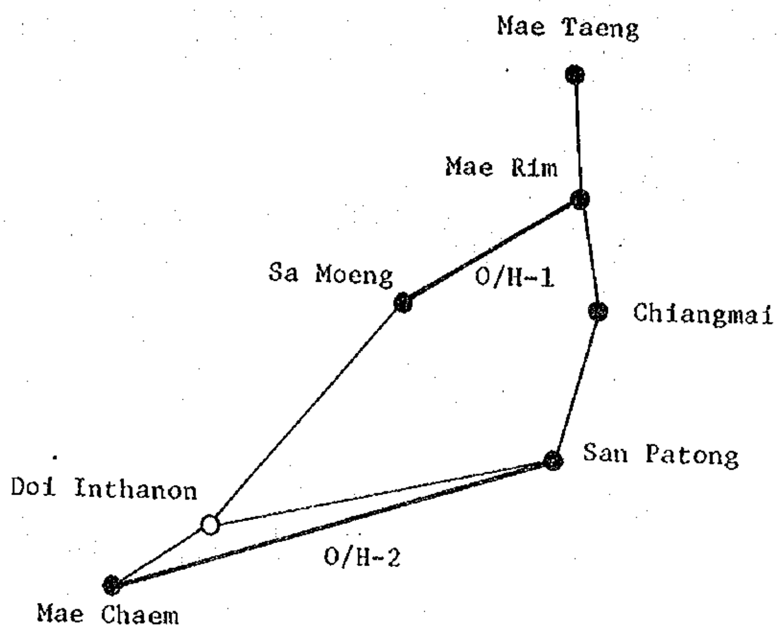
Radio paths where the application of O/H system was considered to be possible in detailed studies made in four sample areas are the following three :

1) Sa Moeng - Mae Rim (24.9 km)
2) Mae Chaem - San Patong (57.5 km)
3) Khon Buri - Saeng Sang (28.0 km)

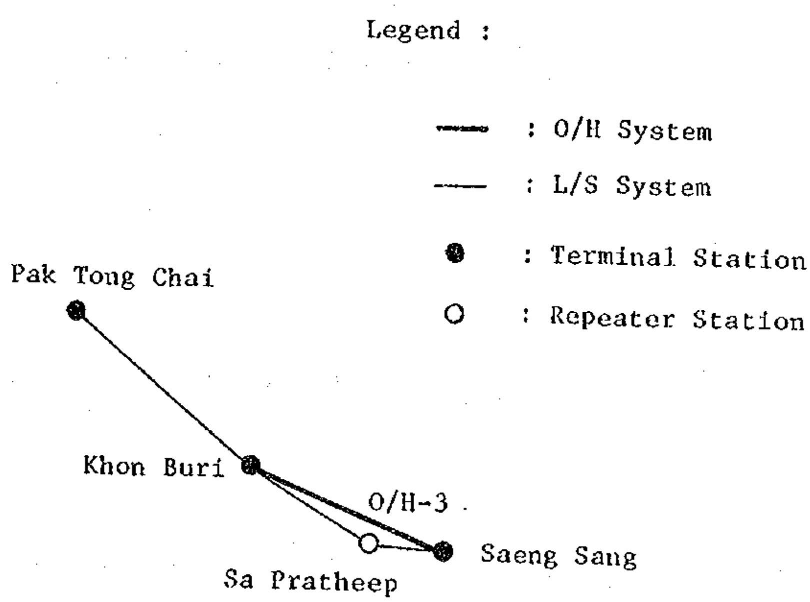
Each of these radio paths corresponds in distance to two line-of-sight paths as shown in Figure 4-7. These radio paths need no repeater station when O/H system is applied.

1) Propagation Loss

Path profiles of the three radio paths appear in Figure 4-8 through Figure 4-10. All of them are mountain diffraction paths. Diffraction loss is considered to be fairly large.



(a) Chiangmai Area



(b) Nakhon Ratchasima Area

Figure 4-7 Route Plan for O/H System

PROFILE MAP
(4 / 3 RADIUS)

ROUTE: ______________________

DRAWING NO.: ______________________

FULL SCALE	
DISTANCE	HEIGHT
60km	250m
○ 120km	○ 1000m
240km	4000m

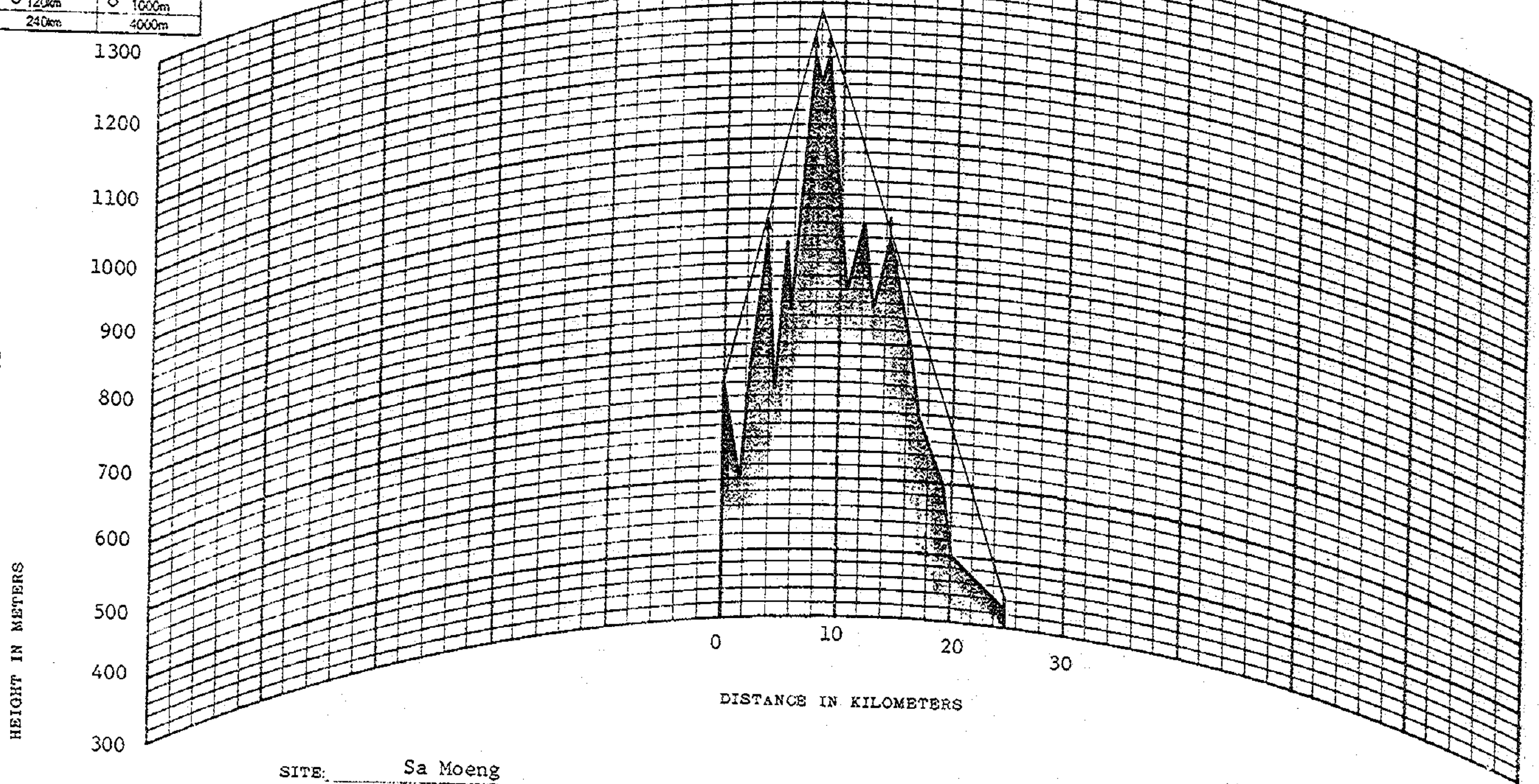


Figure 4-8

SITE: Sa Moeng
LATITUDE: ______
LONGITUDE: ______
GROUND ELEVATION: 630 m
ANTENNA HEIGHT: 5 m

DISTANCE: 24.9 km
HOP NO.: 0/H-1

SITE: Mae Rim
LATITUDE: ______
LONGITUDE: ______
GROUND ELEVATION: 330 m
ANTENNA HEIGHT: 5 m

PROFILE MAP
(4 / 3 RADIUS)

ROUTE: ______

DRAWING NO.: ______

FULL SCALE

DISTANCE	HEIGHT
60km	250m
120km	1000m
O 240km	O 4000m

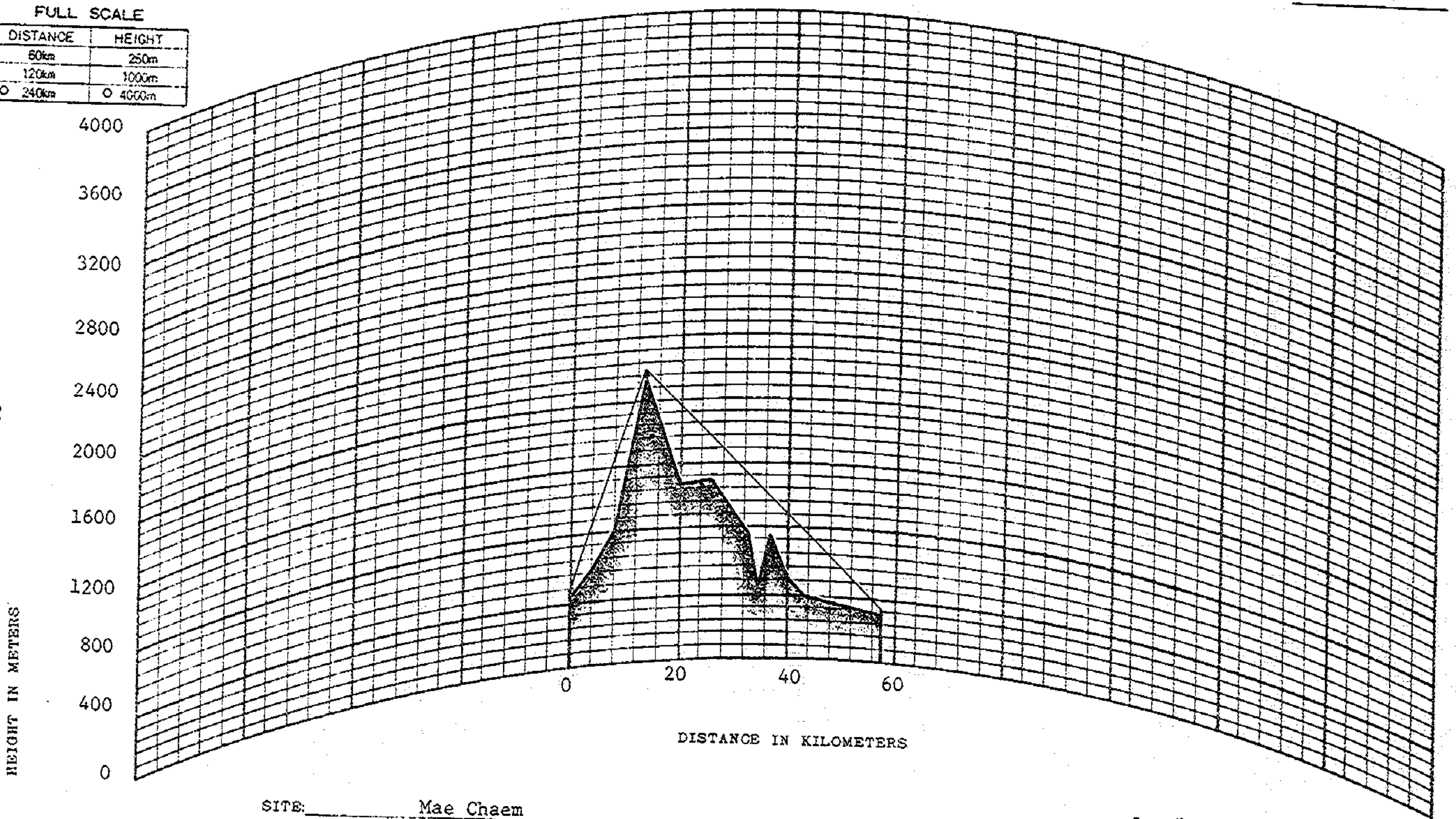


Figure 4-9

SITE: Mae Chaem
LATITUDE: ______
LONGITUDE: ______
GROUND ELEVATION: 467 m
ANTENNA HEIGHT: 5 m

DISTANCE: 57.5 km

ROP NO. : O/H-2

SITE: San Patong
LATITUDE: ______
LONGITUDE: ______
GROUND ELEVATION: 297 m
ANTENNA HEIGHT: 5 m

PROFILE MAP
(4 / 3 RADIUS)

ROUTE: ____________

DRAWING NO.: ____________

FULL SCALE

DISTANCE	HEIGHT
o 60km	o 250m
120km	1000m
240km	4000m

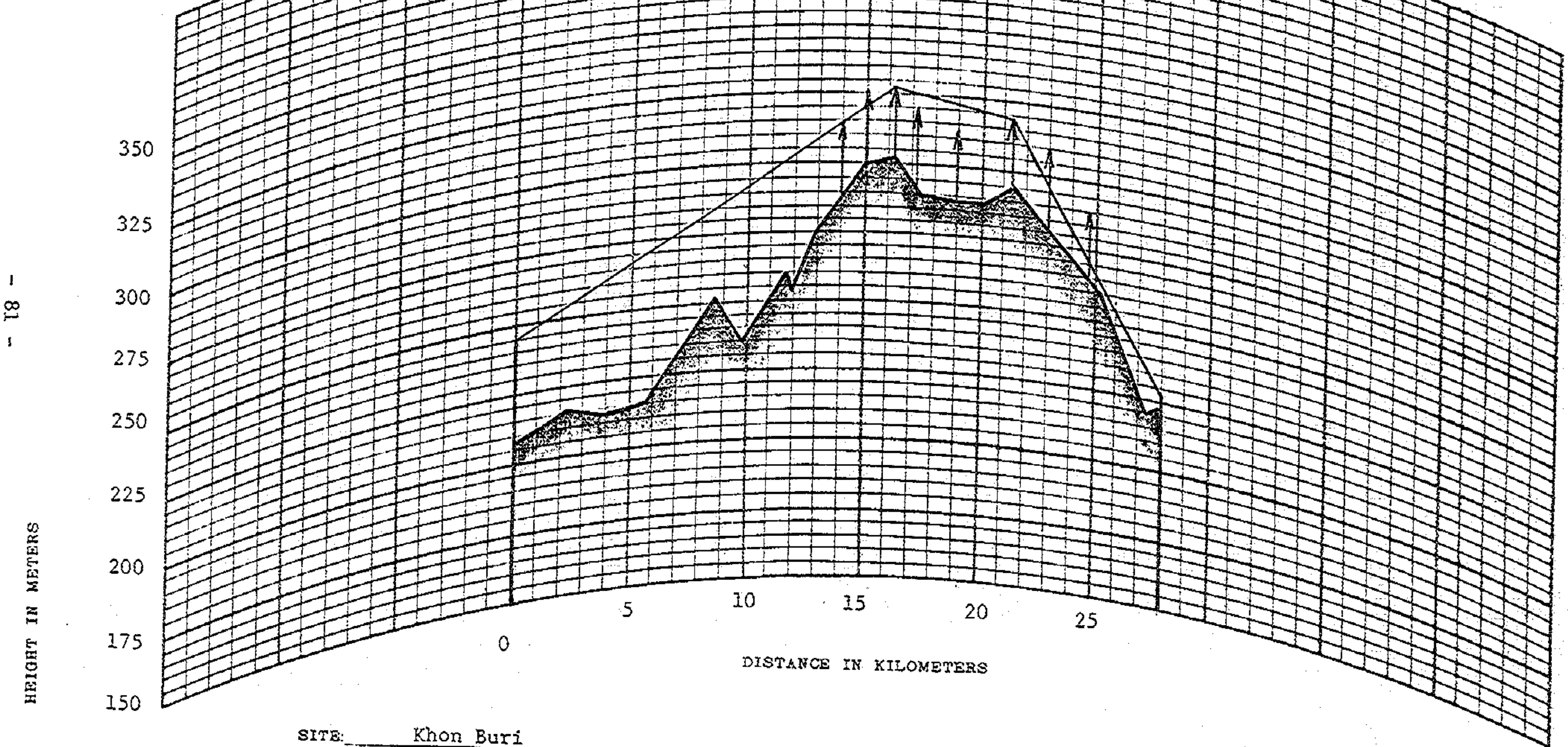


Figure 4-10

SITE: Khon Buri
LATITUDE: ____________
LONGITUDE: ____________
GROUND ELEVATION: 207 m
ANTENNA HEIGHT: 38 m

DISTANCE: 28.0 km

HOP NO.: 0/H-3

SITE: Saeng Sang
LATITUDE: ____________
LONGITUDE: ____________
GROUND ELEVATION: 223 m
ANTENNA HEIGHT: 5 m

Diffraction loss can be estimated by different methods. One of such methods, which produces the value close to the measured value, is the NBS Technical Note technique. Result of propagation loss estimation by this technique for the three radio paths are as follows :

Path	Free Space Loss (dB)	Diffraction Loss (dB)	Total Loss (dB)
Sa Moeng - Mae Rim	119.4	85	204.4
Mae Chaem - San Patong	126.7	64	190.7
Khon Buri - Saeng Sang	120.4	56	176.4

2) System Performance

To obtain the same degree of system performance in O/H system as in line-of-sight (L/S) system, large scale equipment is required. Therefore, in this Study, the objective signal to noise ratio per radio hop is set at 50 dB (N_p = 10,000 pWOp).

Result of system performance calculation for the aforementioned three radio paths appears in Table 4-5. For two paths out of the three, antenna size is not very large, or, more precisely, 6 mϕ or 8 mϕ. However, for Sa Moeng - Mae Rim path, antenna size is as large as 16 mϕ and hence, facility is considered to be too large for small capacity radio link of 24 channels.

3-3-3 Comparison with Line-of-Sight System

System construction costs by line-of-sight (L/S) system and over-the-horizon (O/H) system for two radio sections of Mae Chaem - San Patong and Khon Buri - Saeng Sang are given in Table 4-6.

Table 4-5 System Performance of O/H Link

Item \ Path	Sa Moeng - Mae Rim	Mae Chaem - San Patong	Khon Buri - Saeng Sang
Antenna Size	16 mØ / 16 mØ	8 mØ / 8 mØ	2.4 mØ / 6 mØ
Path Distance	24.9 km	57.5 km	28.0 km
Total Propagation Loss (50%)	204.4 dB	190.7 dB	176.4 dB
Net Loss (50%)	128.4 dB	127.5 dB	128.8 dB
Figure of Merit	188.0 dB	188.0 dB	188.0 dB
Signal / Thermal Noise	59.6 dB	60.5 dB	59.2 dB
Signal / Total Noise (50%)	55.3 dB	55.6 dB	55.2 dB
Fading Depth (99.9%)	14.0 dB	18.0 dB	14.0 dB
Signal / Total Noise (99.9%)	45.3 dB	42.4 dB	45.2 dB
Tx Output Power	47.0 dBm	47.0 dBm	47.0 dBm
Rx Input Level (50%)	-81.4 dBm	-80.5 dBm	-81.8 dBm
Margin to Threshold	23.6 dB	24.5 dB	23.2 dB

Table 4-6 Cost Comparison between L/S and O/H Systems

(Unit: Thousand Japanese Yen)

Name of Section	Mae Chaem - San Patong		Khon Buri - Saeng Sang	
Kind of System	L/S System	O/H System	L/S System	O/H System
Number of Radio Hops	2	1	2	1
Cost :				
Telecom. Facility	88,000	177,500	77,000	140,000
Access Road	7,000	-	14,500	500
Land	5,000	4,000	4,500	3,000
Total	100,000	181,500	96,000	143,500

For both sections mentioned in the above table, O/H system costs 1.5 to 1.8 times more than L/S system. Thus, in the economic aspect, the former commands no advantage. Worthwhile to note in this comparison is that in the said two sections, access roads to through repeater stations required for L/S system are short, i.e., 0.3 km and 0.7 km, respectively. Usually, in the mountain area, through repeater station requires 2 - 5 km access road. In this Project also, the average access road length per repeater station is 2.4 km. In Thailand, access road construction cost amounts to an equivalent of some 20 million Yen/km. Therefore, when the length of access road to through repeater station exceeds 3 km, O/H system sometimes cost less than L/S system.

In the case of Mae Chaem - San Patong section, Doi Inthanon repeater station required for L/S system is a branching station in the direction of Sa Moeng. This fact poses problem in relation to route establishment if O/H system is adopted in this section.

In view of the foregoing, in none of four sample areas where detailed studies were conducted, the application of O/H system is considered to be appropriate. However, for the application of O/H system in other areas than the said four areas, positive studies will have to be made at the stage of detail design in the future.

3-4 Study of Cable System Application

When determining the section where to apply cable system, economic comparison between radio system and cable system must first be made in consideration of required transmisssion capacity and transmission route distance. However, decision by economic comparison alone seems to be not practical. There is another factor that must be considered : In Thailand, as in other developing countries, the loss of cable by stealth takes place not infrequently. Nor has the Study Team been specially requested by TOT to examine in which section to apply radio system and in which section to apply cable system. Therefore, the Study is restricted to the selection of optimum kind of cable system to be applied in the sections where TOT has already decided to adopt cable system.

There are seven sections where TOT plans to adopt cable system for Rural Long Distance Public Telephone Service and for introduction of mobile exchanges. There also are 19 sections where, according to TOT plan, entrance cable will be used from the terminal radio station to the center of service area. In three out of the seven projected cable sections the existing cable can be utilized. New cable laying is necessary in four remaining cable sections and 19 entrance cable sections totaling 23 sections.

In Saeng Chuto - Kanchanaburi section in Kanchanaburi area, one of the sections where the existing cable can be utilized, 30 channels PCM equipment only is to be additionally installed.

In 10 out of the 23 new cable laying sections the required final stage transmission capacity is not more than five circuits. Therefore, cable of small number of pairs will be newly laid in those 10 sections. To the remaining 13 sections, decision has been made to apply voice cable system with the number of pairs that fills the final stage requirement. This decision is to simplify the cable system within the range not to affect adversely the result of the aforementioned economic comparison, and this, in turn, is because cable laying distance is short and transmission capacity is relatively small. The decision has resulted from the comparative study of the following three system plans :

1) Voice cable system.
2) Voice cable system in initial stage to be replaced by cable PCM system during the period in which mobile exchanges will be introduced.
3) Cable PCM system.

Cable laying is by direct burying so as to prevent loss by stealth. Entrance cable for Rural Long Distance Public Telephone Service will be terminated in the distributing box to be installed on the pole at the center of service area. Cable to be used is armoured jelly-filled PEF cable. Loading is of H-88 type.

Number of pairs and conductor diameter have been determined, based on the transmission loss assignment plan. Transmission loss of cable (at 1 kHz, 30° C) is calculated as follows :

1) In case of non-loaded system

0.65 mm cable	1.04 dB/km
0.9 mm cable	0.74 dB/km

2) In case of loaded system

0.65 mm cable	0.55 dB/km
0.9 mm cable	0.28 dB/km

The precedence of application is :

0.65 mm cable, non-loaded

0.65 mm cable, loaded

0.9 mm cable, loaded

Transmission loss of impedance matching coil is set at 0.2 dB per piece. Entrance to telephone exchange is by six-wire lead-in.

Table 4-7 Cable System Plan for Terrestrial Radio System (1/3)

Area (Code)	Section	Dist. in Km	Circuit Requirements in 1984/1989/1994	Required Trans. Loss in dB	Cable System Applied in 1984	Cable System Applied in 1994	Remarks
Kanchanaburi (3413)	Saeng Chuto -Kanchanaburi	28.5	36/50/64	4.0	PCM 2 SYS	PCM 1 SYS	Note 1
Rayong (3808)	Ban Khai - Rayong	12.0	4/5/20	4.0	54 - .9L	-	
Chonburi (3815)	Ban Lamung - Phatthaya	6.5	2/3/3	4.0	-	-	Note 2
Chantaburi (3905)	Pong Nam Ron -Pong Nam Ron (R)	2.9	4/4/20	3.35	74 - .65NL	-	Note 3 & 4
Udon Thani (4201)	Nam Som - Nam Som (R)	5.5	3/3/4	3.35	28 - .9L	-	Note 3
Khon Kaen (4309)	Nong Rua - Ban Thasala	6.0	2/3/3	3.35	28 - .9L	-	Note 3
Kalasin (4321)	Sahat Sakhan-Phu Sing	3.4	3/4/5	3.35	28 - .65L	-	Note 3
Burirum (4412)	Huai Rat - Burirum	11.0	3/4/5	4.0	28 - .9L	-	
Mae Hong Son (5301)	Mae Sariang -Mae Sariang (R)	3.3	5/6/26	3.35	100 - .65L	-	Note 3 & 4
Lamphun (5322)	Mae Tha - Mae Tha (R)	2.0	3/3/4	3.35	28 - .65NL	-	Note 3

Table 4-7 Cable System Plan for Terrestrial Radio System (2/3)

Area (Code)	Section	Dist. in Km	Circuit Requirements in 1984/1989/1994	Required Trans. Loss in dB	Cable System Applied in 1984	Cable System Applied in 1994	Remarks
Lamphun (5322)	U-Mong - Lamphun	9.0	3/4/5	4.0	28 - .9L	-	
Chiangrai (5401)	Phan - Khao Ban Doi	2.0	8/30/40	3.35	150 - .65NL	-	Note 3 & 4
Khamphaeng Phet (5523)	Phran Kratai -Phran Kratai (R)	2.1	6/7/30	3.35	100 - .65NL	-	Note 3 & 4
Yala (7301)	Than To - Than To (R)	3.9	2/3/3	3.35	28 - .65L	-	Note 3
Narathiwat (7314)	Rangae - Tan Yong Mas	1.8	2/3/3	4.0	-	-	Note 5
Narathiwat (7314)	Tak Bai - Tak Bai (R)	1.5	4/6/36	3.35	150 - .65NL	-	Note 3 & 4
Krabi (7501)	Ao Luk - Ao Luk (R)	3.0	4/5/23 (20+3)	3.35	74 - .65L	-	Note 3,4&6
Krabi (7501)	Ko Lanta - Ko Lanta (R)	4.0	2/3/3	3.35	28 - .65L	-	Note 3
Trang (7523)	Sikao - Ban Mai Fat	4.0	3/4/4	3.35	28 - .65L	-	Note 3
Phang Nga (7601)	Kapong - Kapong (R)	5.5	3/4/5	3.35	28 - .9L	-	Note 3

Table 4-7 Cable System Plan for Terrestrial Radio System (3/3)

Area (Code)	Section	Dist. in km	Circuit Requirements in 1984/1989/1994	Required Trans. Loss in dB	Cable System Applied in 1984	1994	Remarks
Phuket (7609)	Kra Too - Phuket	8.0	20/26/30	4.0	54 - .9L	-	
Chum Phon (7701)	Pathiu - Pathiu (R)	4.0	5/6/26	3.35	100 - .65L	-	Note 3
Chum Phon (7701)	Sawi - Sawi (R)	4.5	26/30/40	3.35	150 - .65L	-	Note 3 & 4
Chom Phon (7701)	Lamae - Lamae (R)	1.4	3/5/26	3.35	100 - .65NL	-	Note 3 & 4
Ranong (7707)	La-Un - La-Un (R)	3.0	5/6/26	3.35	100 - .65NL	-	Note 3 & 4
Phun Phin (7711)	Khiri Ratthanikhom -Khiri Ratthanikhom(R)	2.5	4/5/29(20+5+4)	3.35	100 - .65NL	-	Note 3 & 7

Note 1 : Existing cable is available for PCM system.
Note 2 : Subscriber cable has been installed from Phatthaya exchange.
Note 3 : Cable circuit is used as entrance circuit between radio terminal and distribution point or exchange.
Note 4 : Entrance circuit between radio terminal and exchange is on 6-wire basis.
Note 5 : Subscriber cable has been installed from Tan Yong Mas exchange.
Note 6 : When exchange will be installed in AO Luk, 3 circuits from Plai Phaya will be accommodated.
Note 7 : When exchange will be installed in Khiri Ratthanikhom, 5 circuits from Ban Takhun and 4 circuits from Phanom will be accommodated.

In other cases, four-wire lead-in will be used. Table 4-7 shows the projected cable sections and their distances, as well as the number of circuits and transmission loss of each section and the type of cable to be applied in each section.

4. Selection of Optimum Terrestrial Radio System

In order to apply terrestrial radio system in this Project, full consideration is necessary for the fact that the required transmission capacity of each radio route is as small as 20 - 120 channels. As stated in Paragraph 3-1, SHF system application in such small capacity route is less advantageous economically when compared with UHF system application. Especially 11 GHz band is not appropriate choice, considering the way the radio frequency is being utilized internationally. Hence the judgment that UHF system, especially of 900 MHz band, is the optimum system for this Project.

Regarding whether to apply PCM system or not, discussions have been conducted several times during this Study. As stated in Paragraph 3-2, no substantial difference in system economy can be found between PCM system and FDM system as a system for small capacity UHF system.

In the technical aspect also, no specific difference can be recognized between the said two systems. However, FDM system is studied in detail to compare with the Domestic Satellite System. For, in the existing backbone microwave route and spur microwave route, FDM system is adopted. The reason is that mutual connection between newly established and existing radio links at group or supergroup stage can more easily be achieved when FDM system only is used. If the connection has to be made between FDM system and PCM system on multiplex signal base, special interface equipment (coder and decoder) is required, and cost naturally increases.

Meanwhile, cost of PCM system is expected to come down as the result of new technical development. Therefore, it is considered to be advisable to so arrange the tender for this Project that the bidders will make their offers for PCM system also as an alternative plan, and to determine at the stage of evaluation of proposals the transmission system to be finally adopted.

Concerning in which section to apply O/H system, decision is withheld in this feasibility study as is stated in Paragraph 3-3. Decision will be made in the course of detail design in the future.

Based on findings in the foregoing study, it has been decided to apply the following systems as optimum systems to realize terrestrial radio system :

(1) 7,000 MHz 300 ch system (route capacity : 3 + 1)

(2) 900 MHz 120 ch system (route capacity : 2 + 0)

(3) 900 MHz 24 ch system (route capacity : 2 + 0)

(4) cable system

(5) 30 ch cable PCM system

Note : System (1) will be applied only in case 120 ch system cannot be applied at the final stage. (One radio hop only.)

System (2) will be applied in case 24 ch x 1 system is not sufficient to deal with final stage traffic.

System (3) will be applied mostly in case final stage capacity is up to 20 ch.

System (4) is based on TOT plan, in principle.

System (5) will be branched from existing Kanchanaburi - Tha Maka route at Saeng Chuto rural site.

Optimum terrestrial radio system selected by the foregoing consideration is given in Figure 4-1 and Volume II-7 "Route Plan for Terrestrial System".

PART V. Transmission Route Selection for Domestic Satellite System

PART V Transmission Route Selection for Domestic Satellite System

1. General

This Part V describes how the domestic satellite system is being utilized in the countries where the system has been adopted, with a view to providing useful information for the operation of Rural Long Distance Public Telephone Service in Thailand if this service is to be put into practice via satellite system. At the same time, explanation is made with respect to the general concept of DAMA (Demand Assigned Multiple Access) which is a relatively new technology.

Description is also made concerning the basic requirements for the decision of route plan for the domestic satellite system in Thailand. In addition, the lease rate, lease conditions and related subjects with regard to the PALAPA transponder of Indonesia are described.

In the transmission route selection, consideration was made so that the selected transmission route would be as realistic as possible with the adoption of terrestrial radio system for part of the route, for instance. This is the result of careful studies including the analysis of traffic forecast until 10 years ahead (ending 1994) and concerning radio interference with the existing microwave links. Transmission capacity of PALAPA transponder to be leased was also duly considered.

2. Domestic Satellite System

2-1 Overview of Domestic Satellite System Operations in Major Countries

As the result of rapid progress of the satellite communication technology, the system construction cost has been reduced to the extent the system can be utilized on the paying basis even for short distance communication. The progress of industries, as well as the development of natural resources and educational/cultural enlightenment, has catapulted the demand for telecommunications and, to meet such demand, the domestic satellite system is being introduced in many countries as part of national telecommunications networks.

The satellites to be exclusively used for domestic communication have been put into service by four countries including Canada, Indonesia, the Soviet Union and U.S.A.

The International Telecommunications Satellite Consortium (INTELSAT) is being managed for international satellite communication business as its principal objective. Leasing of satellite transponders is also on its service line. The leased satellite transponders are being utilized for domestic satellite system by many countries.

The satellite itself is of short life and its transponder costs much. However, by the progress of the satellite attitude and position control technology, the use of spot beam antenna has become possible. The increase of Effective Isotropically Radiated Power (EIRP) of the satellite has made it possible to reduce the size of earth station antenna. All this contributes to the greater satellite communication economy.

The satellite transponder utilization efficiency has been improved. This has resulted from the development of the Single Channel Per Carrier (SCPC) system for small transmission capacity link. By the voice activation technique the utilization efficiency for output power of the satellite transponder has been improved, and the channel capacity increase per transponder has become possible. Furthermore, in the case of establishing communication channels among a large number of earth stations where the volume of communication is small, the DAMA system can be applied to improve the satellite channel utilization efficiency remarkably.

The improvement of satellite transponder reliability is reducing the need for maintaining the redundancy configuration. This is the point worthwhile to mention in terms of operation economy of the satellite communication system.

Following is the country by country introduction of domestic satellite systems in operation. Information obtained will be used, wherever applicable, in the planning of domestic satellite system for Thailand.

2-1-1 Algeria

The domestic satellite system in Algeria was constructed for the purpose of interconnection between Algiers, the capital city, and 13 main communities in the Sahara Desert zone. The master earth station is at the same site as the standard INTELSAT earth station approximately 70 km distant from Algiers. This master earth station holds capacity for 12 telephone/telex channels and one television channel. Each of 13 rural earth stations holds capacity for two to four telephone/telex channels and one television signal.

Besides the fixed system mentioned above, there also is the transportable television transmit facility available to a rural earth station for transmission of special programmes of remote origin.

This Algerian domestic satellite system operates via leased one of INTELSAT satellite transponders. This system can accommodate one television channel (PAL system) plus 65 telephone/

telex channels (bothway) by use of 36 MHz band transponder. Since it is relatively small in capacity but has to carry telephone traffic in many directions, the SCPC system is adopted.

Furthermore, to improve the telephone channel utilization efficiency and to prepare for telephone transmission system expansion in the future, the DAMA system is also applied.

The DAMA system holds control capacity for a maximum of 31 stations and for a maximum of 16 channels at each station.

System performance in terms of signal-to-noise ratio is 50 dB for telephone, 45 dB for video and 53 dB for television sound.

2-1-2 Canada

The domestic satellite system of Canada started operation in 1973 with 34 earth stations. The principal objective is to provide communication service to the natural resources development areas in the northern part of the country where the severe climatic conditions prevail.

Canada is the first country that put into practice the large scale domestic satellite system. It holds its own communication satellite series nicknamed "ANIK".

"ANIK-I, II and III" (including one for backup use), each operating with 6 GHz band up-link and 4 GHz band down-link, are in the geostationary orbits. In the near future, "ANIK-B" with 14/12 GHz band transponders is scheduled to be launched and, at the same time, apporximately 90 new earth stations will also be constructed. When "ANIK-B" joins the existing "ANIK-A" series, the Canadian satellite system capacity will be remarkably augmented.

Services offered include telephone, telex and data transmission services plus television and radio programme transmission.

In the areas where telephone and telex traffic demand is large (in these areas more than 12 channels are assigned), services are being offered by the FDM-FM-FDMA system. In remote areas with small traffic demand (where the number of channels assigned is up to 12) the DELTA-PSK-SCPC system is adopted.

Since the pre-assignment system is employed for transmission circuits to the areas with small traffic demand, the connection between remote stations is via circuit that utilizes the double hop of the satellite link.

2-1-3 Indonesia

The domestic satellite system of Indonesia is composed of its own communication satellite PALAPA. It started with 40 earth stations. The system began operation in 1976.

The PALAPA satellite launching was to meet the increased traffic demand between the main islands and small islands in the neighborhood, and to serve as a backup system for the existing terrestrial radio system. To expand television service was another important objective of the PALAPA launching.

The PALAPA satellite system consists of one operational satellite and one spare satellite. Both are in the geostationary orbits. These satellites are designed to cover the five ASEAN countries. Each satellite holds 12 transponders. Nine out of 12 transponders of the operational satellite are allocated to the domestic satellite system of Indonesia.

This communication system is capable of wide ranged services including telephone and telegraph signal transmission, data transmission, and television/radio programme transmission. It is operated by Perusahaan Umum Telekomunikasi of Indonesia (PERUMTEL). Besides serving for public communications, it provides leased communication system for governmental agencies, educational communities, and manufacturing plants.

Telephone signal transmission systems are twofold. One is the FDM/FM system for interconnection of cities with large traffic demand. (A total of 19 stations are used.) Circuits are pre-assigned. The other is the SCPC system to serve the sparsely populated areas. (The number of stations used is 21.) The DAMA system is further adopted so as to achieve the effective utilization of satellite transponders and circuits.

The DAMA system introduced holds the control capability for a maximum of 120 remote earth stations with 3,000 channel units in order that it can successfully cope with the telephone demand increase in the future.

Television programme receiving facility is installed at 34 out of 40 earth stations, and two out of those 34 earth stations are equipped with television programme transmit facility also.

2-1-4 Norway

The domestic satellite system is adopted as a means of communication related to the North Sea oil field development.

The oil field zone lies several hundreds km distant from the mainland of Norway. As a means of communication to and from such oil field zone, the troposcatter system and the satellite system were studied. The final choice was the latter.

For, the establishment of troposcatter system circuits to the remote, wide spread oil field area requires multiple diversity to improve circuit reliability and this leads to the increase of transmitting output. Consequently, the frequency allocation becomes difficult. This is why the satellite system was chosen.

One half of transponder of the spare unit of INTELSAT is leased to constitute the satellite system. By the SCPC system and the pre-assignment system, the telephone and data transmission services are being carried out. For modulation the DELTA-PSK (2-phase) system is adopted.

This Norwegian satellite system is so designed that in the event the leased transponder comes into trouble, the operation can be changed over to another transponder or a transponder of another INTELSAT system.

2-1-5 The Philippines

The Philippines consists of many islands and its population is widely distributed.

At the time of expansion and improvement of the domestic long distance communication networks, the domestic satellite system was introduced for interconnection between Manila, the capital city, and 11 other densely populated major cities. This system came into service partially in 1978. It is a joint cooperative venture among the three parties, i.e., Philippine Overseas Telecommunications Corporation, Philippine Long Distance Telephone Company and Kanlaon Broadcasting System.

The Philippine domestic satellite system uses one half of PALAPA satellite trnasponder leased from Indonesia. The SCPC-FM system plus the centralized control type DAMA system are adopted for telephone signal transmission.

Television signal transmission by this satellite system is also planned. When this plan materializes, television service to 80% of urban population becomes possible.

2-1-6 Conditions for Domestic Satellite System Introduction

The countries which have introduced the domestic satellite system include, besides those mentioned above, the Soviet Union, U.S.A. and Malaysia. Many of these countries are the countries where the following conditions apply :

(1) The communication network has to be composed by linking many islands.

(2) For the expansion of the existing terrestrial communication networks, especially for the television signal transmission, the terrestrial system entails much construction and maintenance costs.

(3) The national territories are extensive and the population is not uniformly distributed. There are many sparsely populated districts or the natural resources to be developed are deposited in remote districts, and there is need to establish a communication system to such districts.

(4) The natural environment is severe. Freezing and floods take place frequently to make inland transportation difficult. Hence, the construction work of terrestrial system requires a long period.

(5) In the case of a system wherein the number of channels per circuit between two points is small but the number of points to be connected is large, and if the system is to be constructed by the terrestrial system, the cost per

circuit increases and makes the system economically disadvantageous.

When the domestic satellite system is introduced, it can be utilized not only for public communication services, such as telephone and telex services, but also for leased circuits of governmental offices and business organizations, as well as for television programme transmission. Such multilateral service availability makes it possible to reduce the working cost of the satellite system in many cases.

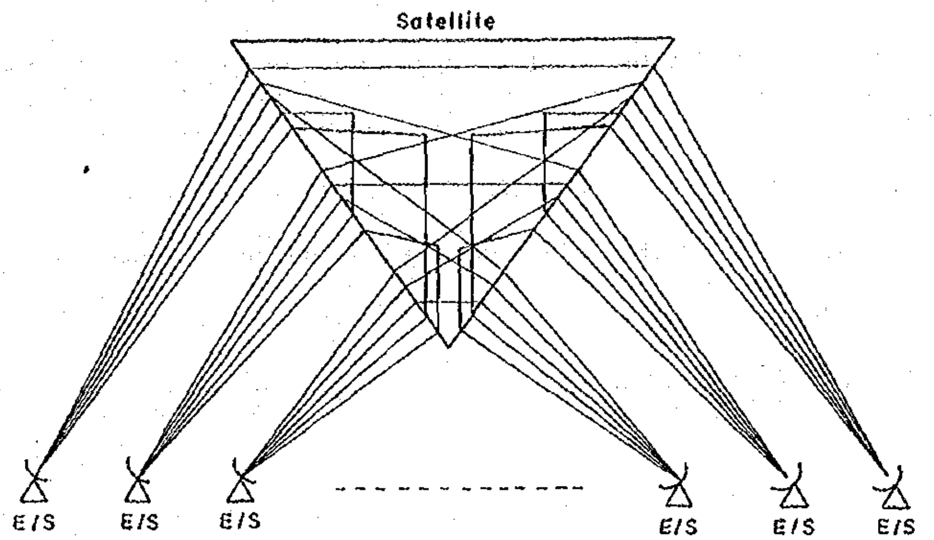
2-2 Outline of DAMA System

DAMA (Demand Assigned Multiple Access) system is a system in good contrast with PA (Pre-assigned) system. When the DAMA system is introduced, the satellite comes to hold a kind of switching function. This makes the effective use of costly satellite channel possible.

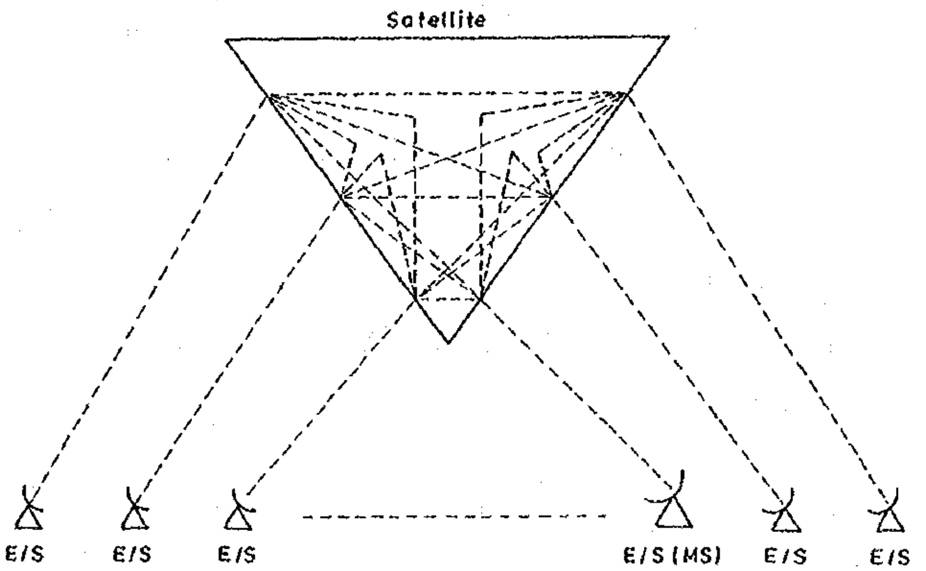
When the circuit is established by the PA system, the satellite channel has to be assigned at all times to between the predetermined earth stations. Thus the channel utilization efficiency degrades as the number of circuits becomes small. This kind of circuit establishment is certainly uneconomical.

The DAMA system was developed to remedy such disadvantage of the PA system. It is considered to be the optimum system to handle traffic between many stations where traffic demand is small. Figure 5-1 illustrates the difference between the PA system and the DAMA system.

The DAMA system is so featured that all channels which can be used by one transponder be pooled at the master earth station and, only when the circuit establishment between earth stations becomes



(A) PA System - Circuits are always assigned between earth stations.



(B) DAMA System - Circuits are assigned between earth stations when required by control from Master Earth Station (MS).

Figure 5-1 Explanatory Illustrations for PA and DAMA Systems necessary, the channel required for circuit formation is assigned from among the pooled channels. When the call ends, the assigned channel is returned to the master earth station to be pooled again until it is needed for the next circuit formation. By this means the channel utilization efficiency can certainly be improved.

The channel assignment to between earth stations is made at the master earth station in all cases. Channels on the transponder, which can be used, are registered in the master DAMA facility installed at the master earth station. From the master earth station a signal is sent periodically to rural earth stations to know whether the channel allocation is required or not.

When any rural earth station requires the channel assignment, the rural earth station responds to the inquiry from the master earth station by sending the channel request signal together with necessary information for channel assignment.

The master earth station transmits the channel request signal received to the master DAMA facility where the signal is analyzed to know between which earth stations the circuit assignment is required. At the same time, an idle channel to be assigned is chosen from among the pooled channels, and necessary information including the frequency of the chosen channel is sent out to two rural earth stations to be connected.

The rural earth stations control the received information concerning the assigned channel by the rural DAMA facility and establish the circuit. After completion of communication, the channel is returned to the master earth station where it is pooled again as an idle channel in the master DAMA facility.

Decision has been made to apply the DAMA system to the domestic satellite system as the study objective in this Project. The reason is that the number of earth stations is large whereas the traffic volume per earth station is small.

2-3 Satellite Transponder

At present, for the domestic satellite system, the satellite that operates with 6/4 GHz bands is used. In many cases, the satellite holds 12 transponders arranged at 40 MHz intervals. Each transponder holds 36 MHz band in the 500 MHz bandwidth.

At the satellite, the received signal of 6 GHz having the 500 MHz band is amplified and converted to a 4 GHz signal. The converted signal, after being amplified, is divided into 36 MHz band signals. Each of these signals is further amplified and transmitted to the earth stations.

In the transponder, many signals are commonly amplified so that intermodulation takes place. To minimize the noise due to this intermodulation the saturation level of the amplifier is set high in order that the sufficient back-off level can be obtained. In the transmitter unit, the input from the receiver unit is separated into the odd number channel group and the even number channel group.

In this case, the center frequency interval between each two adjoining channels of the same group is set at 80 MHz so that the separation is easy.

The COMSTAR system, which is used by the U.S.A., carries 24 transponders and holds twice as large communication capacity as the Canadian and Indonesian satellite systems. This large communication capacity comes from the fact that both vertical polarization and horizontal polarization are used at the same time.

The recent trend is to apply 14/11 GHz and 30/20 GHz frequency bands to the satellite system, and this is to avoid mutual interference between the terrestrial system and the satellite system due to the common use of 6/4 GHz band in the terrestrial system. However, even the newly applied frequency bands cannot keep the satellite system completely free from disadvantages, such as propagation loss due to rainfall and receiver noise temperature rise.

As the result of the improvement of satellite transponder reliability, it has become possible to do without the spare satellite unit and thereby reduce the system cost. A country where communication traffic demand is small can, without launching its own satellite, lease a transponder of the INTELSAT system or the satellite of another country.

The domestic satellite has its antenna directivity adjusted to fit the size of the country that owns the satellite. Therefore, in the neighbor countries, the satellite EIRP somewhat deteriorates.

The INTELSAT transponder for lease is of global beam so that its EIRP is approximately 10 dB lower when compared with the domestic satellite system which is based on spot beam. Hence, the large diameter antennas are necessarily required at earth stations.

Table 5-1 presents the PALAPA satellite characteristics.

3. Route Plan for Domestic Satellite System in Thailand

3-1 Basic Route Plan Requirements

For the route plan for the domestic satellite system in Thailand, two plans can be considered. One is to centralize the system control function at the master earth station in Bangkok.

Table 5-1 Characteristics of PALAPA Satellite (1/2)

Weight	
Launch (excluding adapter)	1265 lb
End of life weight	562 lb
Satellite longitude service arc	75^o to 85^oE
Booster	Delta 2914
Communication subsystem	
Number of transmission channels	12
Channel bandwidth	36 MHz
TWT output power (one per channel)	5 W
Frequency bands	
Receive	5927 to 6403 MHz
Transmit	3702 to 4178 MHz
EIRP, G/T	See Figures 5-5 & 5-6
Telemetry subsystem	
Number of telemetry channels (including analog and digital data)	24
Number of telemetry carriers (beacons)	2
Transmit frequencies (to be assigned)	4198 MHz
Command subsystem	
Number of commands	64
Number of receive frequency (redundant receivers)	1
Receive frequency	6420 MHz
Electrical power subsystem	
Solar array dc power	
Beginning of life (equinox)	319 W
After 7 years (equinox)	259 W

Table 5-1 Characteristics of PALAPA Satellite (2/2)

Batteries	
Number of batteries	2 (7 Ah each)
Power available at rated depth-of-discharge(adequate for 10 transmission channels)	210 W
Reaction control subsystem	
Total hydrazine propellant	142.5 lb
Stationkeeping	
North-south position control	$\pm 0.1^{\circ}$
correction interval(typical)	4 wk
East-west position control	$\pm 0.1^{\circ}$
correction interval(typical)	4 wk
Attitude control	$\pm 0.17^{\circ}$
correction interval(typical)	2 wk
Despin control subsystem	
Primary system : pilot beacon tracker pointing accuracy	$\pm 0.1^{\circ}$
Backup despin system(BUDS) : earth sensor pointing accuracy	$\pm 2^{\circ}$

The other is to provide gateway earth stations at several points on the existing microwave route and thereby distribute traffic among such gateways.

When the gateway earth station system is compared with the terrestrial radio system in terms of system economy, it requires much larger initial cost and is not desirable as far as this Project is concerned. Therefore, as the domestic satellite system to be compared with the terrestrial radio system, the master earth station system is adopted.

Insofar as the projected domestic satellite system is to have the same transmission capacity and the same grade of service as the terrestrial radio system, the route plan must satisfy the undermentioned basic requirements. These requirements reflect the result of studies with emphasis on the telephone demand forecast and the radio interference study.

(1) To apply the DAMA system. This is because, as stated in Paragraph 2-2 the domestic satellite system of Thailand uses a large number of earth stations whereas the number of circuits per earth station is generally small.

(2) To lease the PALAPA satellite (of Indonesia) transponder.

(3) To adopt the terrestrial radio system (partially the cable system) for the transmission route to/from the rural sites specified below. This is based on the result of study of PALAPA satellite transponder capacity and radio interference from earth stations to the existing microwave system.

1) The 47 stations where the mobile exchange is to be introduced from the beginning and the rural stations (RS) where telephone demand is relatively large and where the

telephone exchange will be introduced five years after the system construction, i.e., in 1989, based on the telephone demand forecast.

2) RS in the neighborhood of the existing microwave radio stations and RS which can rather be included in the terrestrial radio system from the viewpoint of route layout in relation to 1) above.

3) RS which can be easily accommodated in the adjacent PC or LE by cable.

4) RS where the establishment of earth stations is not feasible by reason of radio interference with the existing microwave system.

(4) To incorporate RS, where the telephone exchange introduction is scheduled 10 years after the system construction, i.e., in 1994, based on the telephone demand forecast, in the terrestrial radio system in that year.

Figure 5-2 is the flow chart of the foregoing basic requirements.

When these basic requirements are applied, the optimum route plan for the domestic satellite system in Thailand turns out to be the compound route plan consisting of the satellite system plus the terrestrial radio system for part of the route. By this route plan, 129 stations out of the 469 objective stations of this Study are to be incorporated in the terrestrial radio system.

The study of cable system application, including entrance cable, shares the same philosophy as the terrestrial system study in Part IV 3-4. (Refer to Table 5-2.)

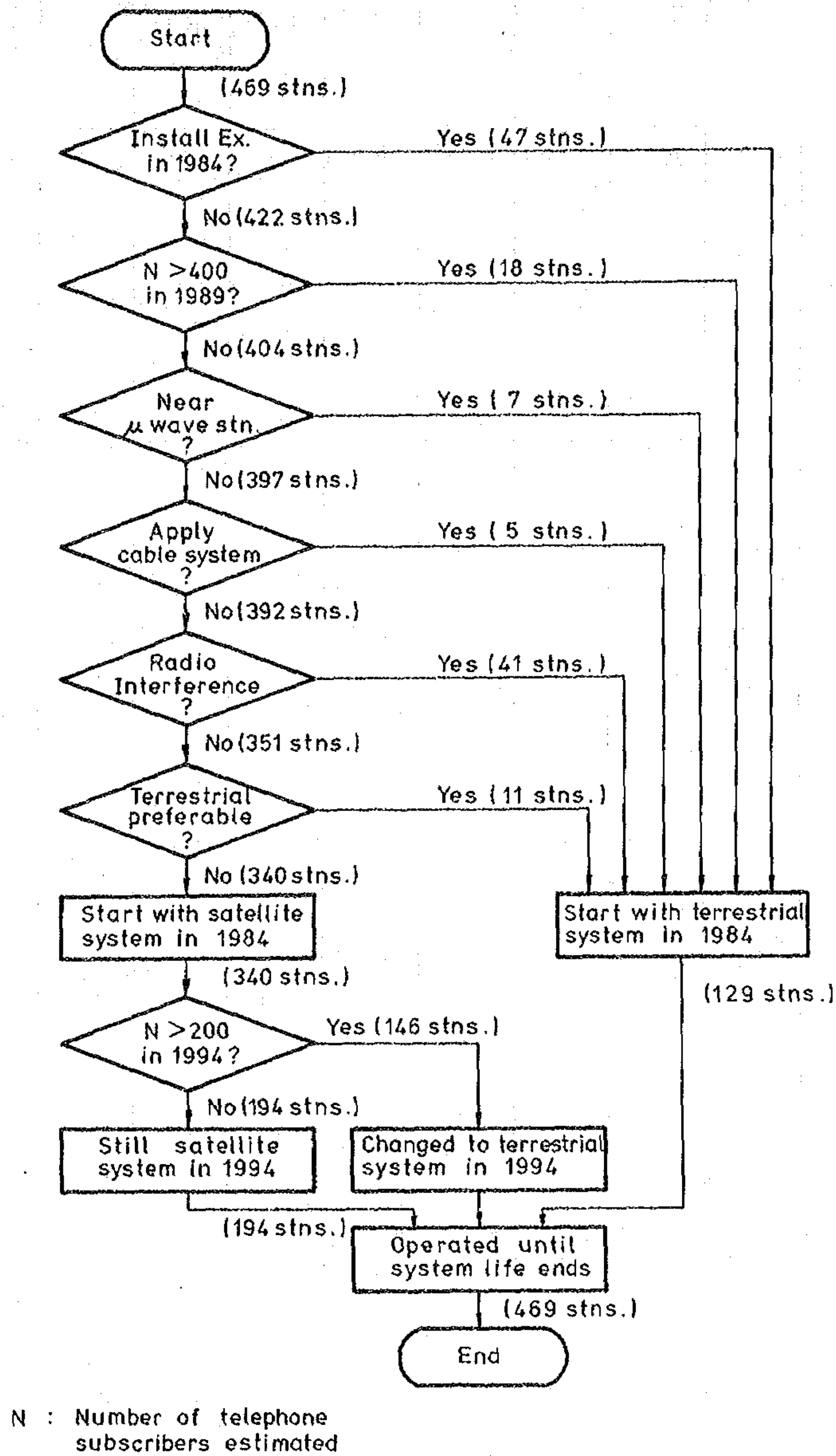


Figure 5-2 Basic Philosophy of Route Plan for Satellite System

Table 5-2 Cable System Plan for Domestic Satellite System (1/2)

Area (Code)	Section	Dist. in Km	Circuit Requirements in 1984/1989/1994	Required Trans. Loss in dB	Cable System Applied in 1984	1994	Remarks
Kanchanaburi (3413)	Saeng Chuto -Kanchanaburi	28.5	36/50/64	4.0	PCM 2 SYS	PCM 1 SYS	Note 1
Rayong (3808)	Ban Khai - Rayong	12.0	4/5/20	4.0	54 - .9L	-	
Chanburi (3815)	Ban Lamung-Phatthaya	6.5	2/3/3	4.0	-	-	Note 2
Chantaburi (3905)	Pong Nam Ron -Pong Nam Ron (R)	2.9	-/-/20	3.35	-	100 - .65NL	Note 3 & 4
Mae Hong Son (5301)	Mae Sariang -Mae Sariang (R)	3.3	-/-/26	3.35	-	150 - .65L	Note 3 & 4
Lamphun (5322)	U-Mong - Lamphun	9.0	3/4/5	4.0	28 - .9L	-	
Chiangrai (5401)	Phan - Khao Ban Doi	2.0	8/30/40	3.35	150 - .65NL	-	Note 3 & 4
Khamphaeng Phet (5523)	Phran Kratai -Phran Kratai (R)	2.1	-/-/30	3.35	-	150 - .65NL	Note 3 & 4
Narathiwat (7314)	Rangae - Tan Yong Mas	1.8	2/3/3	4.0	-	-	Note 5
Narathiwat (7314)	Tak Bai - Tak Bai (R)	1.5	-/-/20	3.35	-	100 - .65NL	Note 3 & 4

Table 5-2 Cable System Plan for Domestic Satellite System (2/2)

Area (Code)	Section	Dist. in km	Circuit Requirements in 1984/1989/1994	Required Trans. Loss in dB	Cable System Applied in 1984	Cable System Applied in 1994	Remarks
Krabi (7501)	Ao Luk - Ao Luk (R)	3.0	-/-/20	3.25	-	100 - .65NL	Note 3 & 4
Phuket (7609)	Kra Too - Phuket	8.0	20/26/30	4.0	54 - .9L	-	
Chum Phon (7701)	Pathiu - Pathiu (R)	4.0	-/-/26	3.35	-	150 - .65L	Note 3 & 4
Chum Phon (7701)	Sawi - Sawi (R)	4.5	26/30/40	3.35	150 - .65L	-	Note 3 & 4
Chum Phon (7701)	Lamae - Lamae (R)	1.4	-/-/26	3.35	-	150 - .65NL	Note 3 & 4
Ranong (7707)	La-Un - La-Un (R)	3.0	-/-/26	3.35	-	150 - .65NL	Note 3 & 4

Note 1 : Existing cable is available for PCM system.
Note 2 : Subscriber cable has been installed from Phatthaya exchange.
Note 3 : Cable circuit is used as entrance circuit between radio terminal and distribution point or exchange.
Note 4 : Entrance circuit between radio terminal and exchange is on 6-wire basis.
Note 5 : Subscriber cable has been installed from Tan Yong Mas exchange.

The route plan formulated by the basic routing requirements clarified in the foregoing is shown in Figure 5-3. The circuit assignment diagram also appears in Volume II-10 "Circuit Assignment Diagram for Satellite System". The channel accommodation plan for the same four areas as of the terrestrial system route plan is attached to Volume II-11 "Typical Channel Accommodation Plan".

3-2 Channel Plan

3-2-1 Scale of Domestic Satellite System in Thailand

(1) Number of Earth Stations

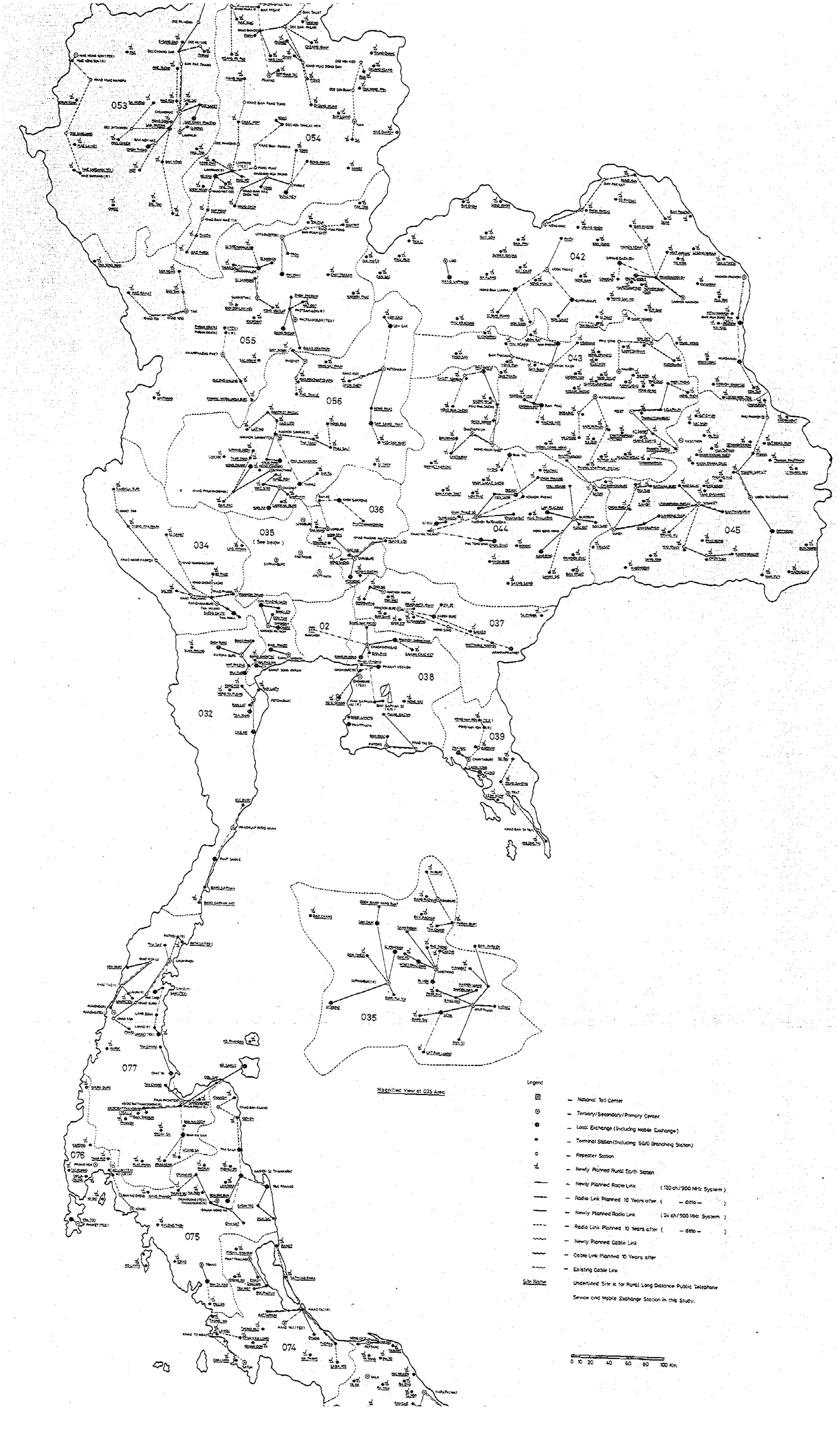
The number of sites required for Rural Long Distance Public Telephone Service by the satellite system is, in the first half of the Project period, 340 rural earth stations and one master earth station. The similar number in the latter half of the period is 194 rural earth stations and one master earth station, excluding 146 stations where the equipment replacement to facilitate the incorporation to the terrestrial radio system is expected pursuant to the introduction of telephone exchange in and after 1994.

(2) Traffic Volume

Forecasted traffic volume originating from rural earth stations is :

1984	406.0 Erl.	(1.19 Erl./RS)
1989	560.0 Erl.	(1.65 Erl./RS)
1994	275.5 Erl.	(1.42 Erl./RS)

The decrease in 1994 is because, in that year, not a few objective stations of the service will be transferred to


053
054
055
056
042
043
044
045
036
035
(See below)
034
02
037
038
039
032
Magnified View of 035 Area
035
077
076
075
074
Legend
– National Toll Center
– Tertiary/Secondary/Primary Center
– Local Exchange (Including Mobile Exchange)
– Terminal Station (Including SG/G Branching Station)
– Repeater Station
– Newly Planned Rural Earth Station
– Newly Planned Radio Link (120 ch/900 MHz System)
– Radio Link Planned 10 Years after (– ditto –)
– Newly Planned Radio Link (24 ch/900 MHz System)
– Radio Link Planned 10 Years after (– ditto –)
– Newly Planned Cable Link
– Cable Link Planned 10 Years after
– Existing Cable Link
Site Name
Underlined Site is for Rural Long Distance Public Telephone Sevice and Mobile Exchange Station in this Study.
0 10 20 40 60 80 100 Km.

the terrestrial radio system and only the small scale rural earth stations will continue to be operated by the satellite system.

(3) Number of Speech Channel Units to Be Installed in Rural Earth Stations

The total number of speech channel units to be installed in rural earth stations is :

1984	1,144 CHU (3.36 CHU/RS)
1989	1,413 CHU (4.16 CHU/RS)
1994	749 CHU (3.86 CHU/RS)

The number of channel units appearing above is the number of speech channel units only. In addition to these speech channel units, two channel units per rural earth station are required. One is for signal transmission/receiving to/from the master earth station, and the other for engineering service channel (order wire).

3-2-2 Channel Capacity Required for Satellite

(1) For Speech Channel

Rural earth stations are scattered all over Thailand. They number as many as 340 in the first half of the Project period and 194 in the latter half. To apply the satellite system to Rural Long Distance Public Telephone Service is to use the satellite as a kind of subscriber line concentrator. The busy hour traffic from earth stations will vary from station to station. The channel capacity required for the satellite depends upon the variation of busy hour traffic from one rural earth station to another. This is the key point for economic operation of the domestic satellite system.

In this Study, the station to station busy hour variation could not be fully ascertained. However, it cannot be considered that any two rural earth stations share exactly the same busy hour, so that the busy hour variation coefficient is set at 0.8 whereby to obtain the channel capacity required for the satellite.

Based on the busy hour variation coefficient of 0.8, the busy hour traffic that passes the satellite is calculated to be

1984	406.0 x 0.8 = 324.8 Erl.
1989	560.0 x 0.8 = 448.0 Erl.
1994	275.5 x 0.8 = 220.4 Erl.

When the grade of service is set at 1/100, the number of speech channels required for the satellite is calculated to be

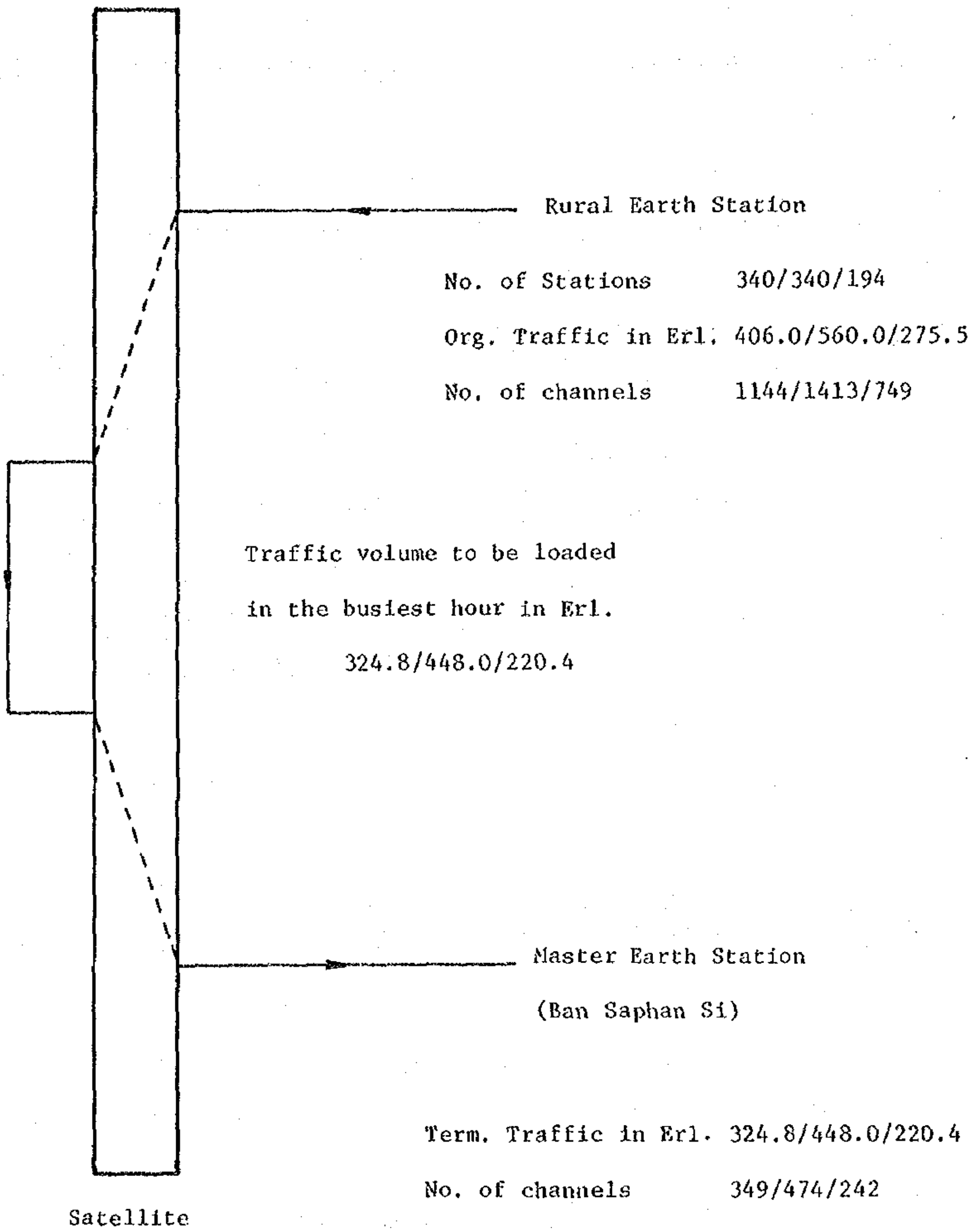
1984	349 ch
1989	474 ch
1994	242 ch

Meanwhile, the number of channels shown above is equal to the number of speech channel units to be installed in the master earth station.

This relationship is explained in Figure 5-4.

(2) For Data Channel

The DAMA system introduction necessitates the installation of data channel for transmission and receiving of necessary information between each rural earth station and the master earth station, besides the speech channels.



Note 1. Figures are for 1984/1989/1994

Note 2. No. of channels indicated does not include the data channels for demand assignment control, and the engineering service channels.

Figure 5-4 Traffic Flow and Channel Plan for Domestic Satellite System

In case the FM-SCPC modulation system is adopted, it is considered that the data channel with the working speed of approximately 2,400 BPS will be employed. Concerning the burst format for data transmission and receiving, there is no international standard. Therefore, on the assumption that the 120 BPS or thereabouts is necessary for the burst which will comprise front guard, carrier detection, bit synchronization, data, check code and back guard, and in consideration of the fact that the traffic volume from one rural earth station may sometimes be small, it is so arranged that one data channel be commonly used by 30 rural earth stations.

Hence, the number of necessary data channels is 12. Although it is possible to reduce the number of data channels in accordance with the reduction of the number of rural earth stations, the arrangement this time is to maintain 12 data channels at all times. For, reducing the number of data channels requires the data alteration of the DAMA system, and, moreover, a rural earth station, if withdrawn from the rural sites where the terrestrial radio system will be introduced, may be used for another area where no telephone service will be provided even then.

(3) Number of Channels Required for Satellite

As the result of the preceding (1) and (2) studies the number of channels required for the satellite will be

1984	349 + 12 = 361 ch
1989	474 + 12 = 486 ch

1994 242 + 12 = 254 ch

For engineering service (order wire), idle channels are assigned.

3-3 PALAPA Transponder

The Indonesian communication satellite, PALAPA I, was launched in 1976. At present, two units, one operational and the other spare or backup, are in the geostationary satellite orbits. They are located at 83° and 76°, East Longitude, respectively. Antenna coverage and G/T contours are shown in Figures 5-5 and 5-6, respectively. They cover five ASEAN countries. The satellite attitude and position on the orbit are periodically regulated from the master earth station. Each satellite unit holds 12 transponders, each having 36 MHz transmission bandwidth. The 6 GHz broad band transmitter unit holds the spare system though the output unit holds no spare system. The design life span of the PALAPA satellite is seven years. Figure 5-7 and Figure 5-8 present the PALAPA satellite radio frequency arrangement and functional block diagram, respectively.

Nine transponders (Channel Nos. 1 - 8 and No. 11 of the operational satellite unit) are used for domestic communication in Indonesia. Idle transponders of the spare satellite unit will be leased to the ASEAN countries. At present, the Philippines uses half transponder by lease.

The long term lease rates for PALAPA satellite transponders are as follows :

For a minimum period of 1 year : US$850,000 per year

For a minimum period of 3 years : US$800,000 per year

For a minimum period of 5 years : US$750,000 per year

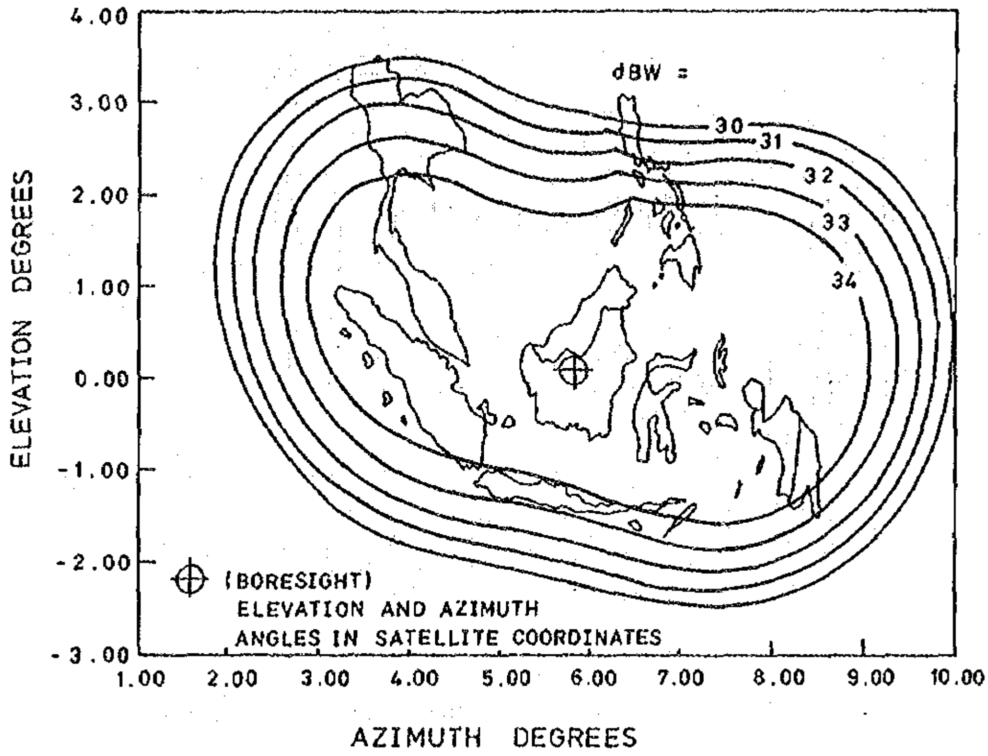


Figure 5-5 PALAPA Satellite Transmit Antenna Coverage Contours

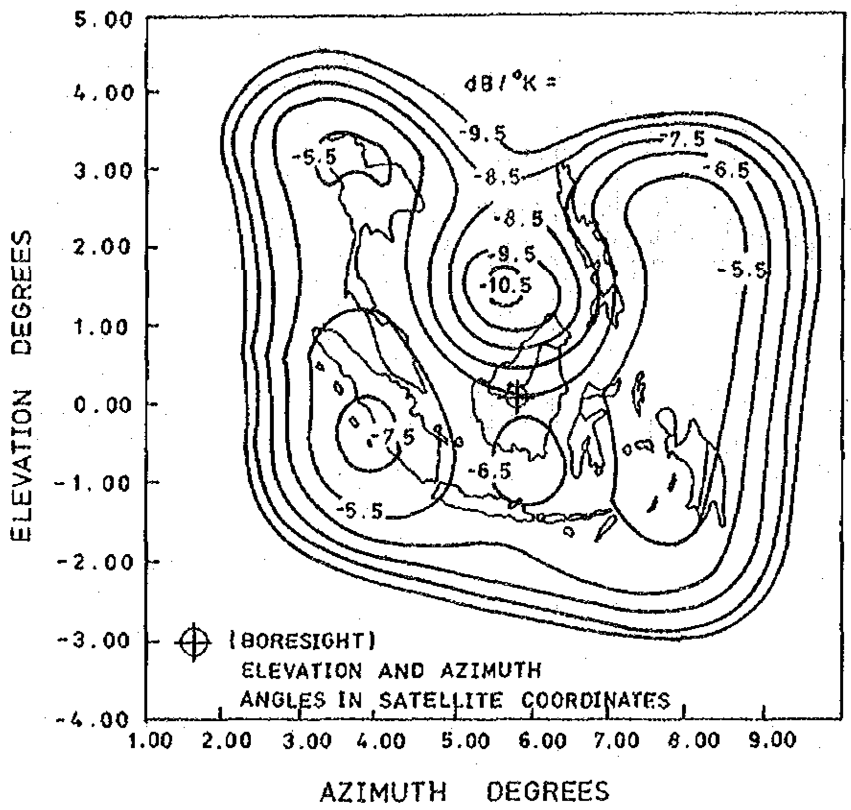


Figure 5-6 PALAPA Satellite G/T Contours

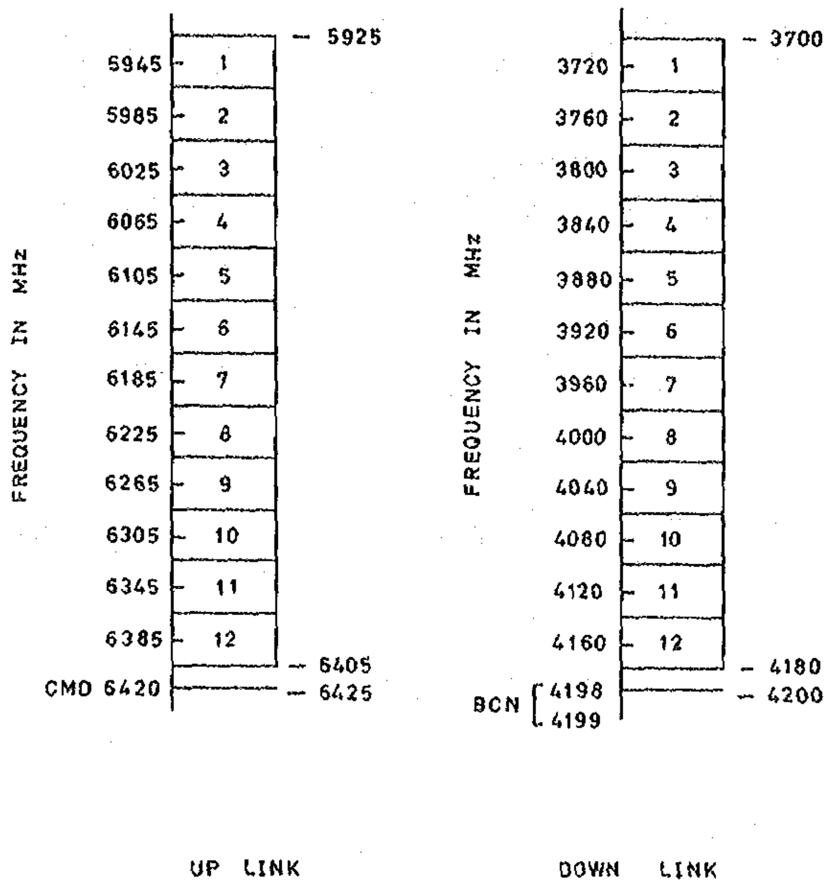
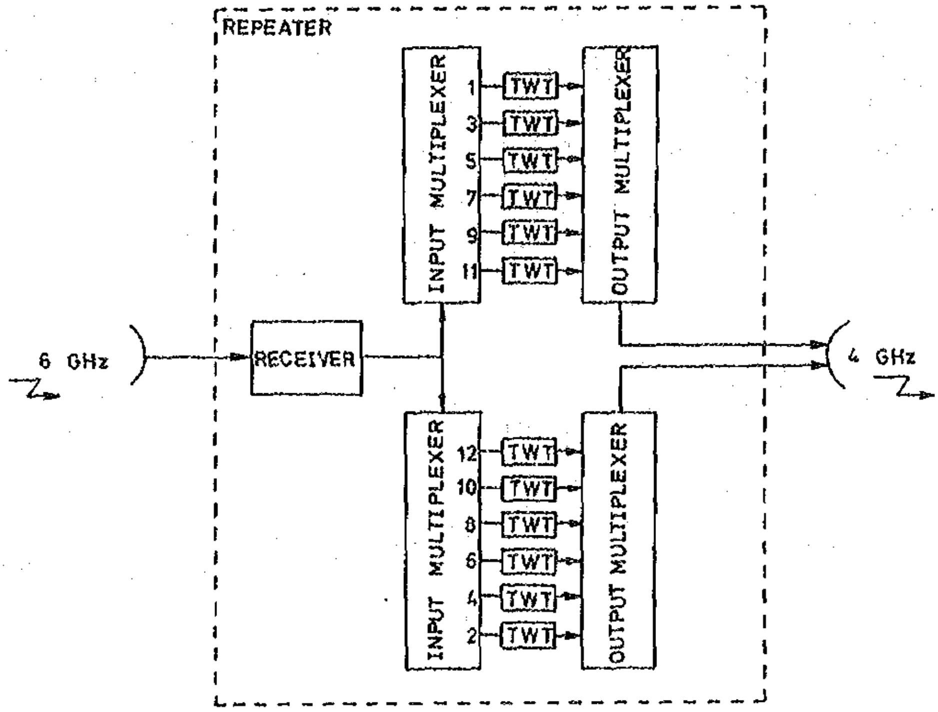


Figure 5-7 Radio Frequency Arrangement of PALAPA Satellite



Note : Redundant receivers are provided, but the output stages are not redundant.

Figure 5-8 Functional Block Diagram of PALAPA Satellite

The partial transponder lease rate is proportionate to the bandwidth used.

In case of trouble with any leased transponder of the spare satellite unit, the operation will be switched over to another transponder of the same satellite unit. When all transponders of the spare satellite unit come into trouble, the operation will be switched over to the transponders of the operational satellite unit. Indonesian authorities will do their utmost for smooth functioning of such emergency arrangement.

PART VI. Detailed Transmission Route Study and Field Survey

PART VI Detailed Transmission Route Study and Field Survey

1. General

This Part VI carries out the sampling review of the UHF system design so far made by TOT and the confirmation thereof by the field survey findings. The establishment of design criteria and the system performance estimation are also made. Furthermore, studies are conducted for the typical RF channel arrangement plan with respect to the UHF system as well as the radio system configuration and the capacity of power plants required.

The route plan for the cable system that constitutes part of the terrestrial system is illustrated on a map of a scale of 1 to 50,000.

The site selection for earth stations of the projected domestic satellite system, design criteria for earth stations, and system performance are also described. Regarding the radio interference from earth stations, the forecast was made, using an extra-large capacity computer, and the methodology of forecast and the result obtained are introduced in this Part VI.

In the detailed system study by sampling, consideration is made in order that the design procedures, calculation results, drawings and related data will be fully usable to TOT.

2. Terrestrial Radio System

2-1 TOT Survey Result Review and Field Survey

In accordance with the Scope of Work arrangement with TOT, the Study Team has carried out a detailed review of UHF system route plan, path profiles and system designs in the representative four areas with a total of 75 radio stations. These four areas have been picked up from TOT's preliminary study of the UHF system plan, for which TOT has carried out the survey for the whole districts of Thailand. The four areas are the Chiangmai area (northern area), Ayutthaya area (central area), Nakhon Ratchasima area (northeastern area) and Phun Phin area (southern area). Figure 6-1 is the detailed study flow chart.

The four areas were selected, based on the agreement between the Study Team and TOT to the effect that a review be made by the Study Team on TOT's survey result, with major emphasis on the following subjects :

1) Site selection in mountain district - Chiangmai area
2) Radio frequency interference - Ayutthaya area
3) Site selection in plain land - Nakhon Ratchasima area
4) Oversea propagation path design - Phun Phin area

The detailed review of TOT's study result and the corroborative field survey by the Study Team were carried out according to the following basic principles :

(1) TOT would rearrange in good order the findings in its detailed investigations and deliver those data to the Study Team. Based on those data, the Study Team would make its own detailed study.

(2) For the terrestrial radio system design, the Study Team would propose to TOT what it considered to be optimal, based on its experiential data. This proposal would be discussed jointly by the Study Team and TOT from the technical viewpoint in order to have the final design methodology agreed upon between both parties.

(3) System performance determined by the mutual discussion between

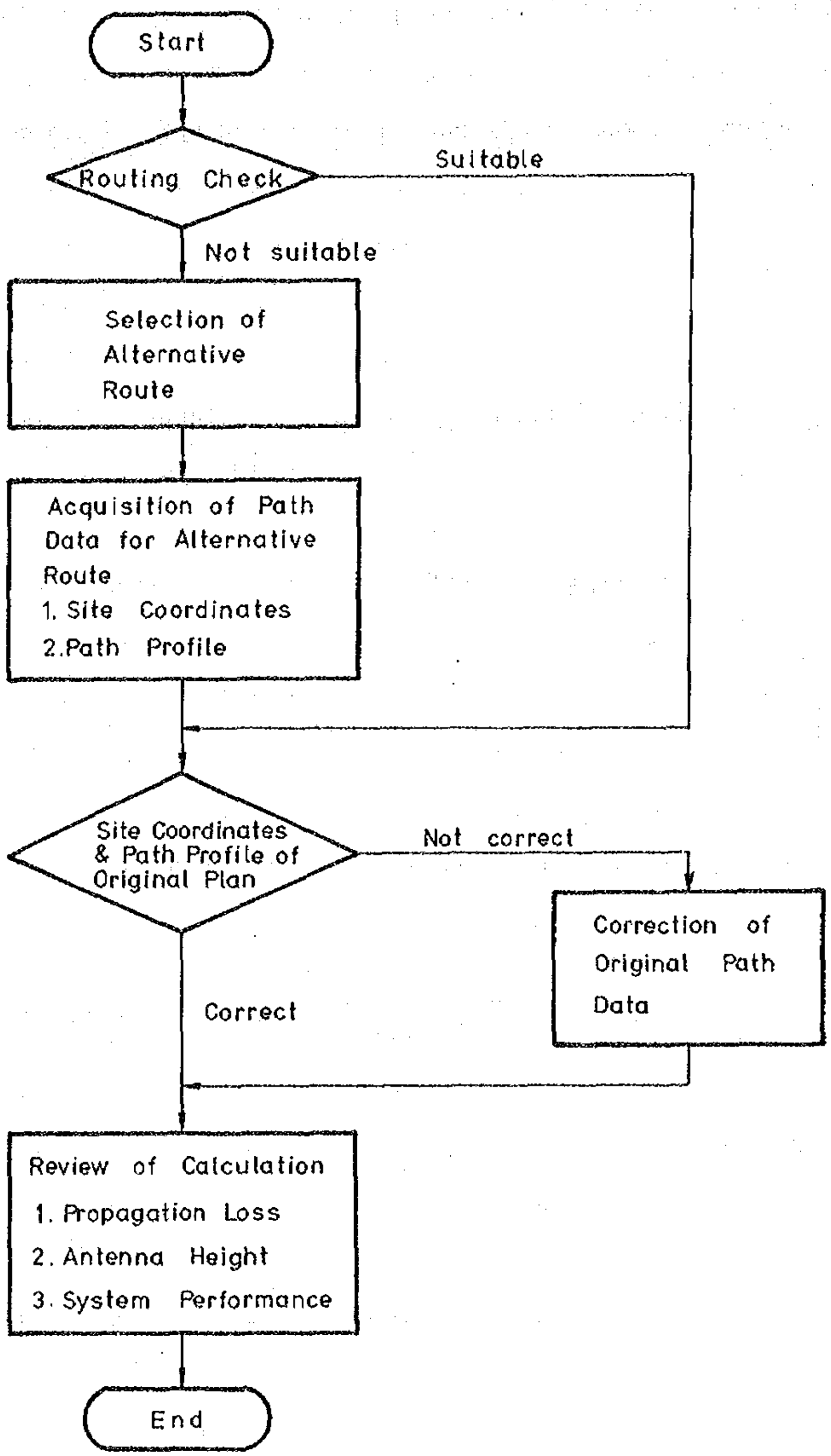


Figure 6-1 Study Flow of UHF Radio Relay System Planned by TOT

the Study Team and TOT should satisfy the relevant CCITT/CCIR recommendations or conform with other authoritative standard.

(4) Efforts should be made to achieve the system construction economy by reducing the number of repeater stations to the possible minimum with the adoption of over-the-horizon system also.

(5) Field survey items should include, besides technical investigations, the interviews with local inhabitants (community survey) to know the telephone demand among them, in order to use information obtained as reference data for forecast and financial evaluation. (Refer to Part III-5.)

Following are the findings in the review of TOT study result and in the newly conducted field survey:

(1) TOT field survey has so far been completed for approximately 160 stations out of a total of 422 scheduled rural sites and 47 scheduled mobile exchange stations. For the remaining stations, only the map study has been completed.

(2) Many of rural sites where TOT has so far completed the field survey do not have the locations finally decided. However, the most part of rural sites are scheduled to be constructed in plain land towns so that, wherever in the towns their final locations may be, the radio propagation will in no way be disturbed.

(3) The UHF route plan made by TOT is considered to be generally acceptable as it is based on the experience of site selection for the existing microwave system. However, when the UHF band radio propagation characteristics are taken into account in system design, greater system operation economy can be realized

with the elimination of through repeater stations, for instance.

(4) As regards the telephone demand forecast in and after 1989 for this Project, there is need for reinvestigation aimed at demand forecast readjustment. (Refer to Part III-5.)

In the following Chapter 2-2 through Chapter 2-5 appears the detailed study result for the terrestrial radio system.

2-2 Design Criteria Establishment and System Performance Estimation

2-2-1 Determination of Radio Station Location and Antenna Height

From the optimum transmission route obtained in Part IV-2 (refer to Figure 4-1) the four areas, i.e., Chiangmai area, Ayutthaya area, Nakhon Ratchasima area and Phun Phin area, have been picked up and the locations of all 75 radio stations in these four areas have been plotted on the map of a scale of 1 to 50,000. The coordinates have been read out and from their values the basic propagation path parameters, including path distance and azimuth, have been calculated with the aid of a small sized, programmable calculator. The result of calculations appears in Volume II-13 "Path Propagation Data".

The revised path profile maps are attached to Volume III Survey Report.

For the antenna height determination criteria, the following have been decided as the result of technical discussion with TOT :

(1) To use 4/3 for coefficient of effective earth's radius (K).

(2) To set the minimum antenna height at 30 m in urban and plain areas and 15 m at mountain-top repeater stations.

(3) To set path clearance at the obstruction point at 5 m when the path distance is 30 km or less and at zero when the path distance exceeds 30 km.

(4) To calculate the height pattern in case the strong reflected wave exists on the propagation path and determine the optimum antenna height in due consideration of the variation of K (K = 1 to 3).

(5) To consider the height of obstacle, such as trees or buildings, in the neighborhood of the radio station when determining the antenna height, in case the propagation path is the mountain diffraction path.

A list of antenna heights in the four areas, calculated by the above criteria, appears in Table 6-1. Meanwhile, the average antenna tower height in the four areas is 46 m.

2-2-2 System Performance Estimation

(1) Allowable Noise and Noise Distribution

The noise objectives established in Part II-4 are to be distributed as follows per radio hop :

Allowable median noise : 2,000 pW0p for single hop

- 2,000 pW0p (S/Np = *57 dB)
  - Radio link 1,540 pW0p (58.1 dBmOp)
    - Thermal noise at RX input — 1,000 pW0p (60 dBmOp)
    - Equipment thermal noise — 100 pW0p (70 dBmOp)
    - Intermodulation noise — 200 pW0p (67 dBmOp)
    - Interference noise — 240 pW0p (66.2 dBmOp)
    - Echo & propagation distortion noise — Negligible
  - MUX noise 460 pW0p (63.4 dB)

*50 dB in the case of mountain diffraction path. For short term noise, no specification is provided. Suffice it to say that the 99.9% value is estimated as a reference value

Table 6-1 List of Antenna Height for 4 Areas (1/3)

Radio Path		Antenna Height (m)
(Ayutthaya area)		
3516-1	Ayutthaya - Nakhon Luang	38 - 38
-2	Nakhon Luang - Ban Phraek	33 - 33
-3	Nakhon Luang - Maharat	33 - 33
-4	Ayutthaya - U-Thai	43 - 43
-5	Ayutthaya - Bang Ban	33 - 33
-6	Bang Ban - Bangpa Han	33 - 33
-7	Bang Ban - Phak Hai	33 - 33
-8	Ayutthaya - Sena	45 - 33
-9	Sena - Bang Sai	33 - 33
-10	Sena - Lat Bua Luang	33 - 33
-11	Ayutthaya - Ban Si	33 - 33
(Nakhon Ratchasima area)		
4421-1	Nakhon Ratchasima - Non Sung	50 - 33
-2	Non Sung - Phi Mai	33 - 33
-3	Phi Mai - Chum Phuang	33 - 33
-4	Chum Phuang - Prathai	33 - 33
-5	Bua Yai - Khong	40 - 43
-6	Nakhon Ratchasima - Non Thai	55 - 33
-7	Non Thai - Kham Sakae Saeng	33 - 33
-8	Non Thai - Dan Khun That	43 - 43
-9	Nakhon Ratchasima - Chakkarat	55 - 63
-10	Chakkarat - Huai Thalaeng	63 - 58
-11	Kham Thale So - Nakhon Ratchasima	33 - 35
-12	Si Kiu - Sung Noen	33 - 33
-13	Pak Tong Chai - Chok Chai	43 - 48

Table 6-1 List of Antenna Height for 4 Areas (2/3)

Radio Path	Antenna Height (m)
-14 Pak Tong Chai - Khon Buri	38 - 38
-15 Khon Buri - Sa Pratheep	38 - 68
-16 Sa Pratheep - Saeng Sang	63 - 73
(Chiangmai area)	
5313-1 Chiangmai - Ban Pak Thang	40 - 15
-2 Ban Pak Thang - Doi Chiang Dao	30 - 18
-3 Doi Chiang Dao - Doi Pha Hong	18 - 18
-4 Doi Pha Hong - Fang	18 - 33
-5 Fang - Mae Ai	33 - 33
-6 Doi Chiang Dao - Chiang Dao	18 - 33
-7 Doi Chiang Dao - Doi Mu Soe	18 - 18
-8 Doi Mu Soe - Phrao	18 - 33
-9 Mae Rim - Chiangmai	68 - 40
-10 Mae Rim - Mae Taeng	68 - 57
-11 Chiangmai - San Sai	38 - 33
-12 Chiangmai - Doi Saket	35 - 33
-13 Doi Saket - San Kam Phaeng	33 - 33
-14 Chiangmai - San Patong	40 - 58
-15 San Patong - Ban Non Hai	78 - 78
-16 Ban Non Hai - Hot	50 - 45
-17 Hot - Doi Pae Po Mak	63 - 48
-18 Doi Pae Po Mak - Khao Huai Bon	48 - 86
-19 Khao Huai Bon - Omkoi	63 - 78
-20 San Patong - Hang Dong	60 - 33
-21 Ban Non Hai - Chom Thong	30 - 33
-22 Doi Pae Po Mak - Doi Tao	15 - 33

Table 6-1 List of Antenna Height for 4 Areas (3/3)

Radio Path	Antenna Height (m)
-23 San Patong - Doi Inthanon	40 - 33
-24 Mae Chaem - Doi Inthanon	58 - 58
-25 Doi Inthanon - Sa Moeng	58 - 33
(Phun Phin area)	
7711-1 Phun Phin (R) - Don Sak	10 - 33
-2 Don Sak - Ko Samui	33 - 33
-3 Don Sak - Ko Phangan	53 - 33
-4 Phun Phin (Tex) - Kanchanadit	47 - 43
-5 Phun Phin (Tex) - Tha Chang	36 - 33
-6 Chai Ya - Tha Chana	45 - 33
-7 Phun Phin (R) - Khiri Ratthanikhom	10 - 35
-8 Khiri Ratthanikhom - Ban Takhun	58 - 33
-9 Khiri Ratthanikhom - Phanom	68 - 43
-10 Ban Na San - Khian Sa	55 - 63
-11 Ban Na San - Ban Na Doem	55 - 48
-12 Ban Na San - Wiang Sa	43 - 33
-13 Ban Na san - Prasaeng	58 - 33
-14 Phun Phin (Tex) - Phun Phin (R)	25 - 10

for system design.

(2) Equipment Parameters

Equipment parameters used in the system design are as follows :

Transmission capacity	: 24 ch, 120 ch
Radio frequency	: 900 MHz
Transmitting power	: 37 dBm
Frequency deviation	: 35 kHz r.m.s./ch (24 ch)
	100 kHz r.m.s./ch (120 ch)
Baseband frequency	: 12-108 kHz (24 ch)
	60-552 kHz (120 ch)
Noise figure	: 7 dB
IF bandwidth	: 1.5 MHz (24 ch)
	5 MHz (120 ch)
Threshold level	: -95 dBm (24 ch)
	-90 dBm (120 ch)
Equipment thermal noise	: 100 pWOp
Equipment intermodulation noise	: 200 pWOp
MUX equipment noise	: 80 pWOp (SG TR)
	80 pWOp (G TR)
	300 pWOp (CH TR)

(3) Noise Calculation

Median noise in the radio section including carrier multiplex equipment is calculated by the following expression :

$$N_p = N_{ta} + N_{te} + N_{im} + N_{if} + N_{pm}$$

where

N_p : Total noise (psophometrically weighted)

N_{ta} : Thermal noise

$$N_{ta} = 10^a$$

$$\text{where} \quad a = \frac{(90 - S/N_{ta})}{10}$$

N_{te} : Equipment thermal noise

N_{im} : Equipment intermodulation noise

N_{if} : Interference noise

N_{pm} : Carrier multiplex noise

Signal to thermal noise ratio, S/N_{ta}, can be obtained by the following expression :

$$S/N_{ta} = F_m - L_n$$

$$= P_t - F + 20 \log (S_o/f_p) + 141.6 + K_{emp} - L_n$$

where

F_m : Figure of merit (dB)

P_t : Transmitting power (dBm)

F : Noise figure (dB)

S_o : Frequency deviation (kHz r.m.s./ch)

f_p : Highest baseband frequency (kHz)

K_{emp} : Emphasis improvement factor (= 4 dB)

L_n : Net loss between transmitter and receiver (dB)

(4) Propagation Loss Calculation

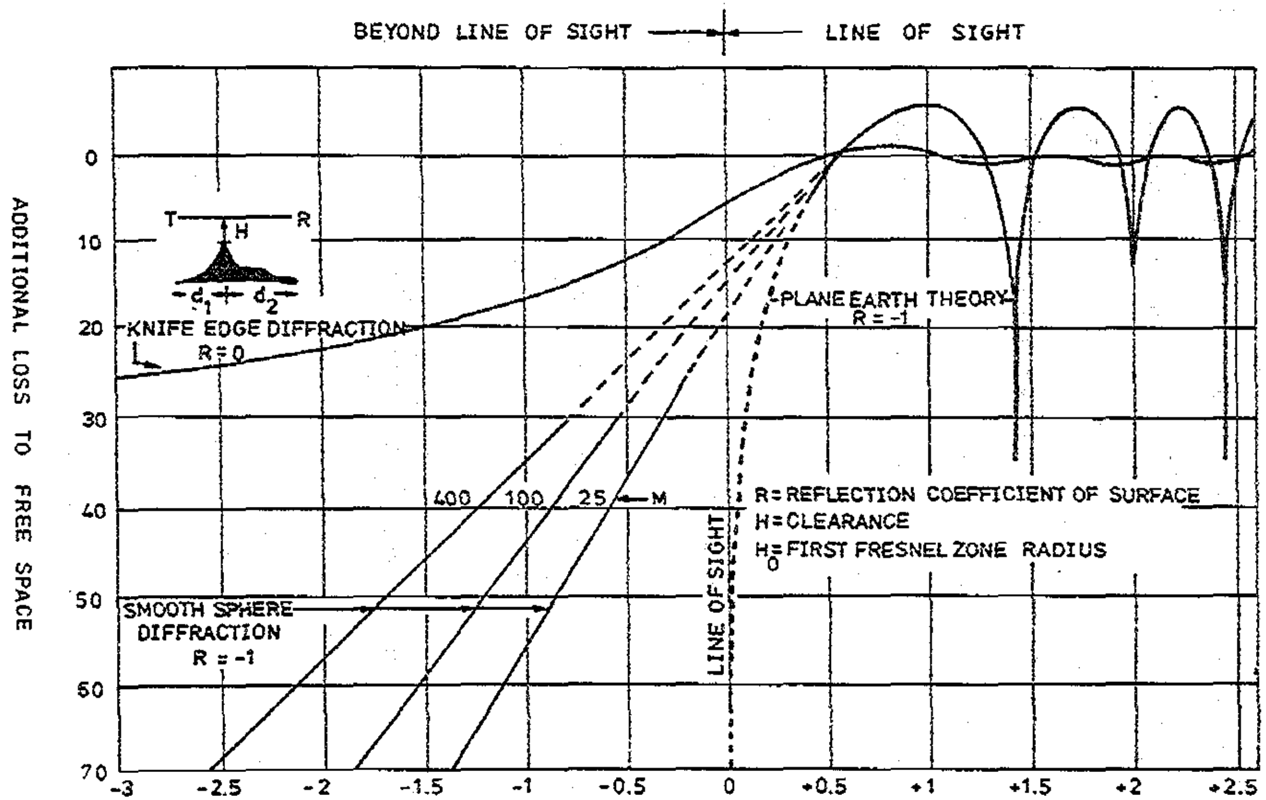
From Figure 6-2 the additional propagation loss to the free space loss can be obtained.

(5) Threshold Margin

The objective threshold margin on each path is 33 dB or more.

(6) Short Term Noise Calculation

Fading depth, A_F (99.9%), is obtained by the following



$$U = \frac{H}{H_0} = \frac{\text{CLEARANCE}}{\text{FIRST FRESNEL ZONE}}$$

Source : "Antenna Engineering Handbook"

Figure 6-2 Transmission Loss vs Clearance expression to estimate short term noise, N_{ta} (99.9%) :

A_F (99.9%) = 10 log L x f (dB)

where

L : Path distance (km)

f : Radio frequency (GHz)

The result of noise calculations by the foregoing conditions appears in Table 6-2 and Volume II-14 "System Performance Calculation".

2-2-3 Radio Frequency Assignment Plan

Radio frequency assignment must be accomplished in such a way that noise due to radio interference between radio links will be smaller than the allowable value. Radio interference includes the following types :

1) Co-channel interference
2) Adjacent channel interference
3) Transmitter spurious interference
4) Receiver spurious interference
5) Intermodulation interference
6) Transmitter to receiver interference

Out of these types of interference, types (1) and (5) require special consideration in the case of radio links that use UHF band.

Since antenna directivity characteristic in UHF band is inferior to that in SHF band, it is inevitable to use different radio frequencies between stations that do not have the interference radiowave attenuated to a great extent by intermediate obstacle. In this Project, 10 or so different radio frequencies per area are required for transmitting and

Table 6-2 List of System Performance for 4 Areas (1/3)

Radio Path	S/Np (50%)	S/Np (99.9%)
(Ayutthaya area)	dB	dB
3516-1 Ayutthaya - Nakhon Luang	59.4	55.5
-2 Nakhon Luang - Ban Phraek	60.1	54.7
-3 Nakhon Luang - Maharat	59.8	54.7
-4 Ayutthaya - U-Thai	59.3	55.8
-5 Ayutthaya - Bang Ban	59.4	55.4
-6 Bang Ban - Bangpa Han	59.7	55.2
-7 Bang Ban - Phak Hai	59.6	54.1
-8 Ayutthaya - Sena	59.2	52.8
-9 Sena - Bang Sai	59.2	55.4
-10 Sena - Lat Bua Luang	59.5	52.9
-11 Ayutthaya - Ban Si	59.0	53.1
(Nakhon Ratchasima area)		
4421-1 Nakhon Ratchasima - Non Sung	59.1	51.6
-2 Non Sung - Phi Mai	59.7	51.8
-3 Phi Mai - Chum Phuang	59.3	52.1
-4 Chum Phuang - Prathai	60.1	53.1
-5 Bua Yai - Khong	59.2	52.8
-6 Nakhon Ratchasima - Non Thai	59.6	52 9
-7 Non Thai - Kham Sakae Saeng	60.7	54.8
-8 Non Thai - Dan Khun That	60.3	51.3
-9 Nakhon Ratchasima - Chakkarat	59.7	52.4
-10 Chakkarat - Huai Thalaeng	60.5	53.3
-11 Kham Thale So - Nakhon Ratchasima	59.4	53.6
-12 Si Kiu - Sung Noen	59.5	54.6
-13 Pak Tong Chai - Chok Chai	60.3	54.8

Table 6-2 List of System Performance for 4 Areas (2/3)

Radio Path	S/Np (50%)	S/Np (99.9%)
	dB	dB
-14 Pak Tong Chai - Khon Buri	59.4	50.9
-15 Khon Buri - Sa Pratheep	60.3	53.9
-16 Sa Pratheep - Saeng Sang	60.4	55.2
(Chiangmai area)		
5313-1 Chiangmai - Ban Pak Thang	60.4	51.7
-2 Ban Pak Thang - Doi Chiang Dao	61.2	54.0
-3 Doi Chiang Dao - Doi Pha Hong	61.0	48.8
-4 Doi Pha Hong - Fang	60.4	52.6
-5 Fang - Mae Ai	60.4	55.0
-6 Doi Chiang Dao - Chiang Dao	59.6	53.4
-7 Doi Chiang Dao - Doi Mu Soe	61.3	51.7
-8 Doi Mu Soe - Phrao	60.1	56.1
-9 Mae Rim - Chiangmai	59.2	55.2
-10 Mae Rim - Mae Taeng	60.4	53.5
-11 Chiangmai - San Sai	59.5	55.1
-12 Chiangmai - Doi Saket	59.5	54.3
-13 Doi Saket - San Kam Phaeng	60.4	55.8
-14 Chiangmai - San Patong	62.4	50.8
-15 San Patong - Ban Non Hai	59.9	51.5
-16 Ban Non Hai - Hot	60.1	51.2
-17 Hot - Doi Pae Po Mak	61.2	50.4
-18 Doi Pae Po Mak - Khao Huai Bon	61.5	51.3
-19 Khao Huai Bon - Omkoi	60.2	56.6
-20 San Patong - Hang Dong	59.2	55.7
-21 Ban Non Hai - Chom Thong	60.2	57.0
-22 Doi Pae Po Mak - Doi Tao	60.4	55.1

Table 6-2 List of System Performance for 4 Areas (3/3)

Radio Path	S/Np (50%)	S/Np (99.9%)
	dB	dB
-23 San Patong - Doi Inthanon	59.9	51.3
-24 Mae Chaem - Doi Inthanon	60.5	55.5
-25 Doi Inthanon - Sa Moeng	55.3	43.5
(Phun Phin area)		
7711-1 Phun Phin (R) - Don Sak	60.1	49.2
-2 Don Sak - Ko Samui	59.8	50.4
-3 Don Sak - Ko Phangan	60.3	50.7
-4 Phun Phin (Tex) - Kanchanadit	59.5	52.1
-5 Phun Phin (Tex) - Tha Chang	59.1	52.5
-6 Chai Ya - Tha Chana	59.2	53.1
-7 Phun Phin (R) - Khiri Ratthanikhom	59.8	50.7
-8 Khiri Ratthanikhom - Ban Takhun	60.1	53.8
-9 Khiri Ratthanikhom - Phanom	60.5	54.0
-10 Ban Na San - Khian Sa	59.4	53.4
-11 Ban Na San - Ban Na Doem	59.7	56.2
-12 Ban Na San - Wiang Sa	59.2	52.9
-13 Ban Na San - Prasaeng	59.7	53.0
-14 Phun Phin (Tex) - Phun Phin (R)	61.2	60.6

receiving, respectively.

Study of TOT's RF channel arrangement plan (808.2 to 873.7 MHz and 900.5 to 958.5 MHz) has revealed that the number of RF channels that can be used in one area is 8 or thereabouts, and this number is not sufficient in this Project. Therefore, the TOT plan mentioned above has to be altered to such RF channel arrangement as shown in Figure 6-3. This channel arrangement uses 790 to 960 MHz frequency band.

When assigning these radio frequencies among radio links, attention must be paid to the following points :

(1) In principle, one Primary Center area constitutes one zone. Either frequency group, L or H, is assigned to each zone.

(2) Different frequency groups are used between adjacent zones.

(3) In case odd and even numbers of RF channels are commonly used in one zone, minimum spacing between RF channels which are used at one station must be 5 MHz.

(4) Consideration must be made so that intermodulation interference will not take place between RF channels which are used at one station.

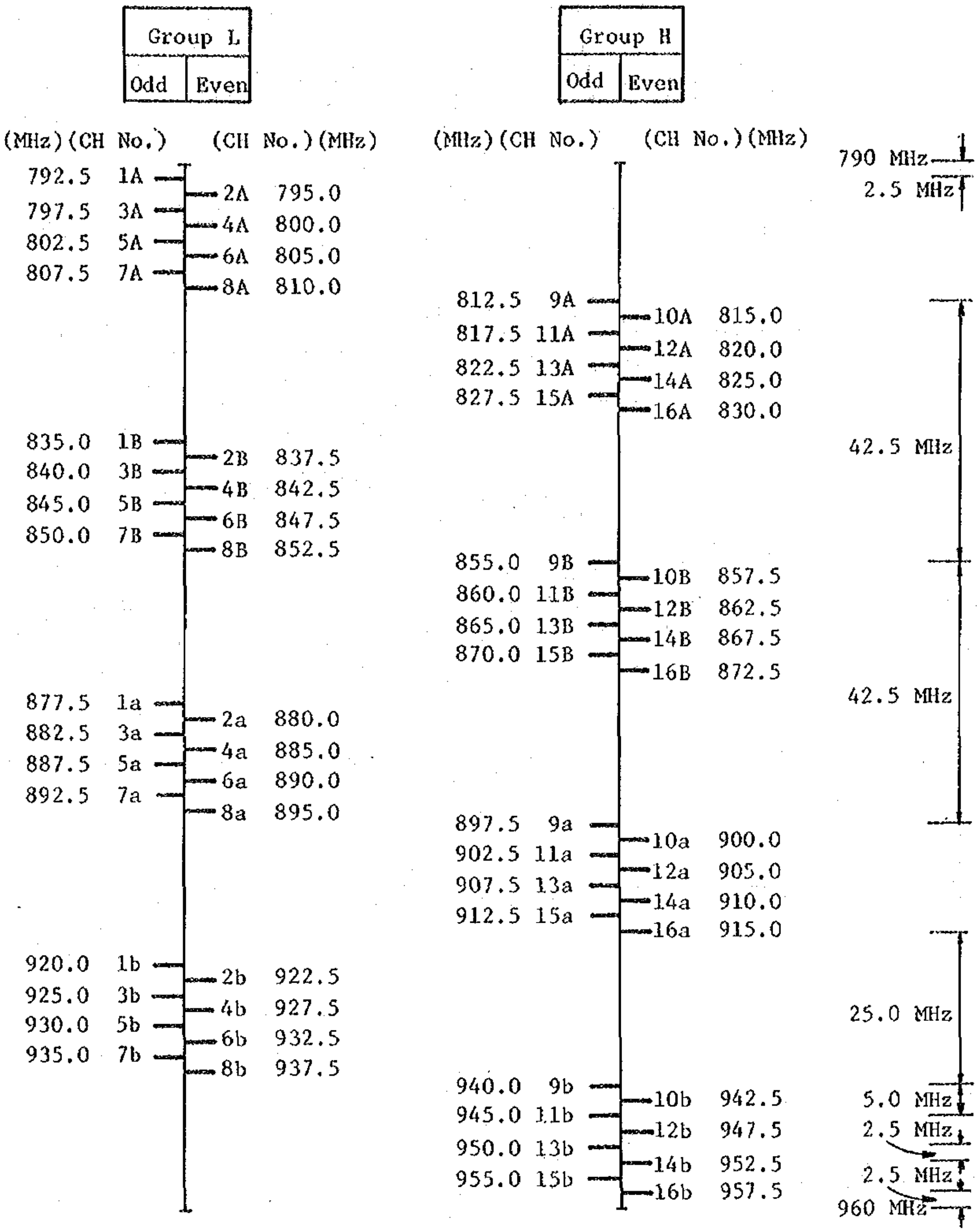
(5) It is essential to calculate interference noise volume of each radio link and make sure that the noise volume is below the allowable limit.

The radio frequency assignment plan applicable to Ayutthaya area, for example, is presented in Figure 6-4.

2-3 Study of Power Plant

2-3-1 Power Plant Type

In order to know the capacity of essential load (communication equipment load) at each station to be constructed in this



Note : A and B or a and b of channel number should be combined and used for transmitting and receiving and vice versa.

Figure 6-3 Radio Frequency Channel Arrangement in 900 MHz Band

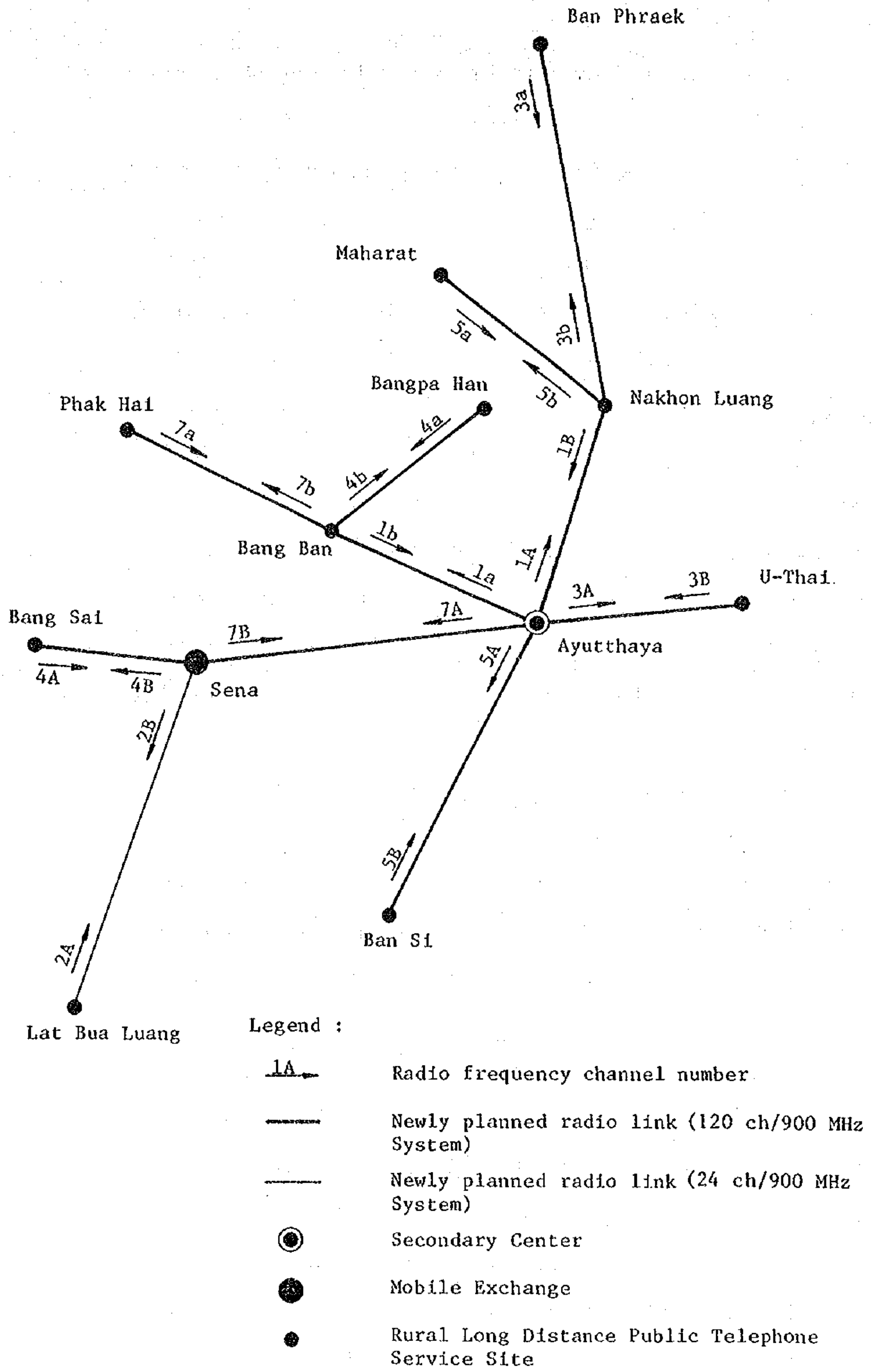


Figure 6-4 Frequency Assignment Plan for Ayutthaya Area

Project, the essential load analysis has been made for 75 stations in the four sample areas.

The result of analysis is as follows :

Type of Station	Essential Load
TC/SC/PC (4)	1,000 - 3,600 W
Multiple terminal (21)	500 - 1,100 W
Single terminal (43)	400 - 900 W
Baseband repeater (7)	400 - 500 W

In this Project, power plant will be installed at 639 stations. Out of them, 518 stations can have commercial power supply available for 24 hours. Usually, when commercial power is available, the commercial power plus battery (BATT) floating system is adopted. This system is to float BATT with commercial power while it is being rectified and supplied to the load. In this Project, the adoption of this system is advisable.

For power supply to 121 stations (70 terminal stations and 51 repeater stations) where commercial power is unavailable for 24 hours, various systems can be considered. Power supply systems to small capacity load now in common use are as follows :

1) Solar battery system.

2) Thermoelectric generator system.

3) Engine generator (EG) plus BATT floating system.

1) and 2) are suitable for power supply to load of up to 300 W. When the load power exceeds 300 W, it is economical to use 3) system. Therefore, the adoption of EG plus BATT floating system even in case the commercial power supply is unavailable is preferable in this Project. When this system is adopted, it is advisable to install two EG units so that they can operate

alternately at weekly intervals, for instance.

Out of 639 stations where dc power source is to be installed in this Project, 147 are the existing radio stations. Each of these 147 stations is equipped with a standby engine generator even if commercial power is available. On the other hand, out of 492 stations to be newly constructed, 371 can expect commercial power supply, but this commercial power supply is subject to failure due to supply system trouble, electric work and so forth. Fact-finding at several places disclosed that 10 minutes to one hour power failure would occur from time to time.

This fact notwithstanding, it is not advisable from the viewpoint of Project cost economy to have all 371 stations equipped with standby engine generators. Instead, it will be preferable to have trailer type engine generators, which can be drawn by maintenance vehicles, distributed among 35 Maintenance Centers except the Bangkok Maintenance Center. An average of one such trailer type engine generator should preferably be assigned to each maintenance center.

The ac power requirement at each station to be newly constructed in the four sample areas is calculated to be 1.8 - 6.9 kVA. Therefore, the capacity per unit of trailer type engine generators to be assigned to the 35 Maintenance Centers can be safely calculated to be 7.5 kVA, barring few exceptions.

2-3-2 Power Plant Capacity

Power plant capacity has been calculated by the following conditions :

(1) Holding time of storage battery should be four hours at the attended station and eight hours at the unattended station.

(2) Storage battery should be of lead acid type.

(3) Battery should be charged by the maximum 12 hours charging rate current.

(4) Rectifier should be of half-redundant type and should have capacity large enough to endure the charging current or the load current, whichever the larger.

(5) Since the ac load at each station in the four sample areas, where commercial power is unavailable, is in the range of 4.2 - 6.9 kVA, each engine generator unit should have capacity of 7.5 kVA.

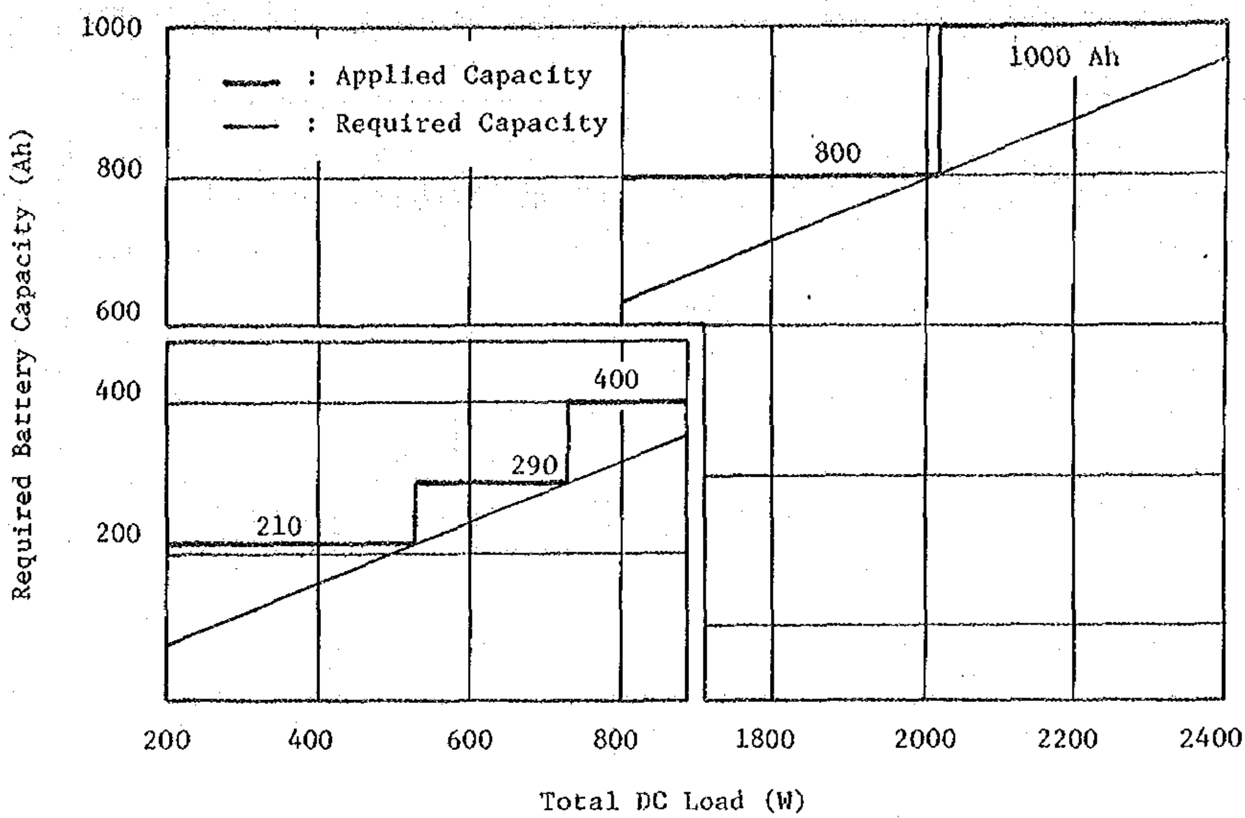
Figure 6-5 and Figure 6-6 are the charts by which to obtain the required battery capacity and rectifier capacity to meet the total dc load. Power plant capacities of 57 stations in the four sample areas, calculated by the foregoing conditions, are shown in Table 6-3.

2-4 Typical Radio System Configuration and Site Layout

Figure 6-7 presents typical terrestrial radio system configuration. Figure 6-8 and Figure 6-9 carry typical site layout and equipment floor layout, respectively, for the terrestrial radio system.

2-5 Cable Route Study

The Study Team had no time to carry out field survey to determine optimum cable route. Therefore, map study based on TOT data was conducted to select the route where cable length required could be the minimum. In case where access road would have to be newly constructed, on-the-map route selection was made in consideration of the difference of elevation and gradient (not exceeding 1/10) between the existing road and the mountain-top terminal radio



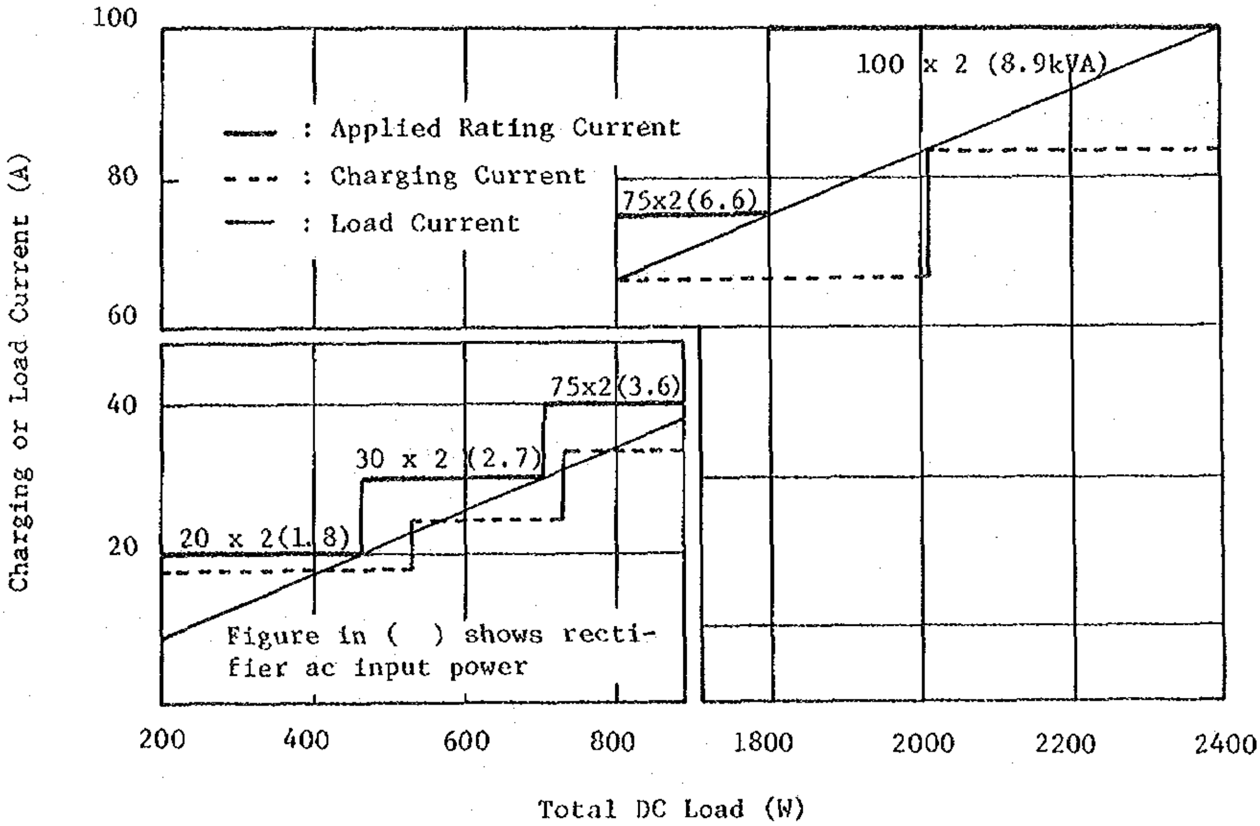
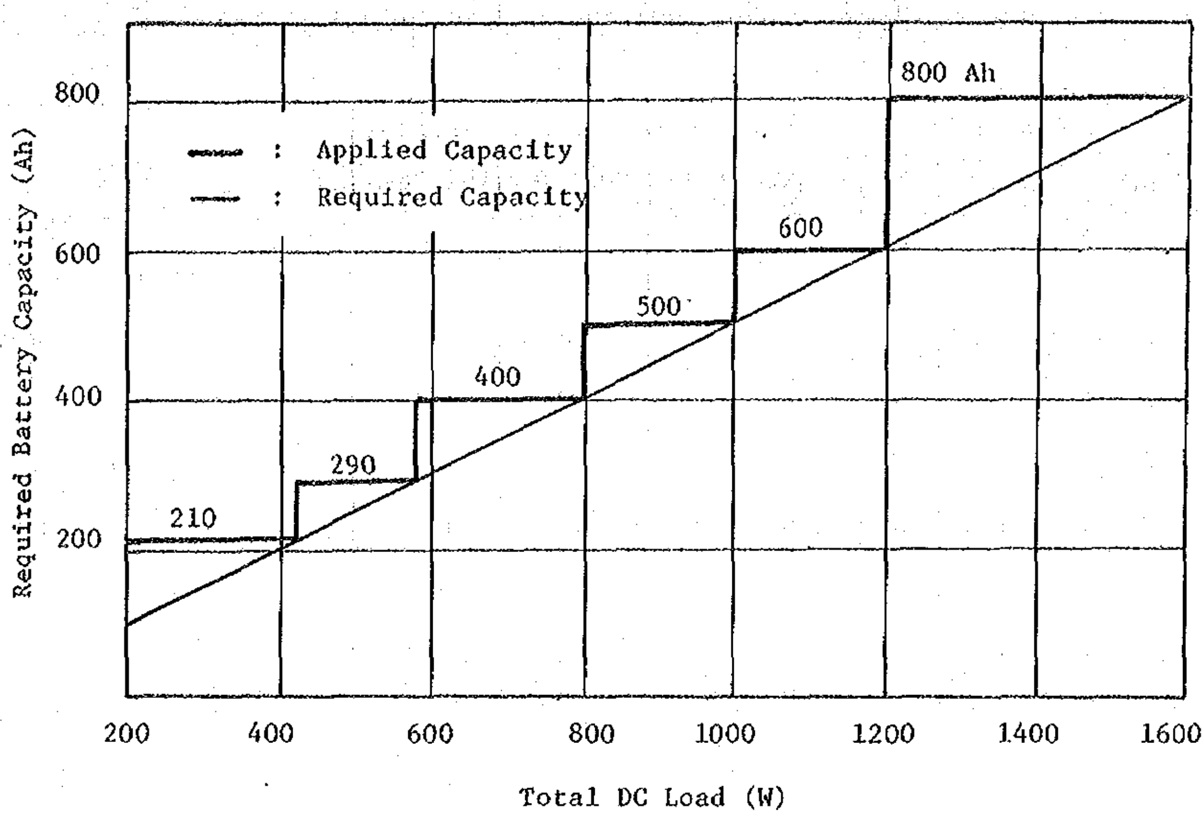


Figure 6-5 Battery and Rectifier Capacities for Attendant Station



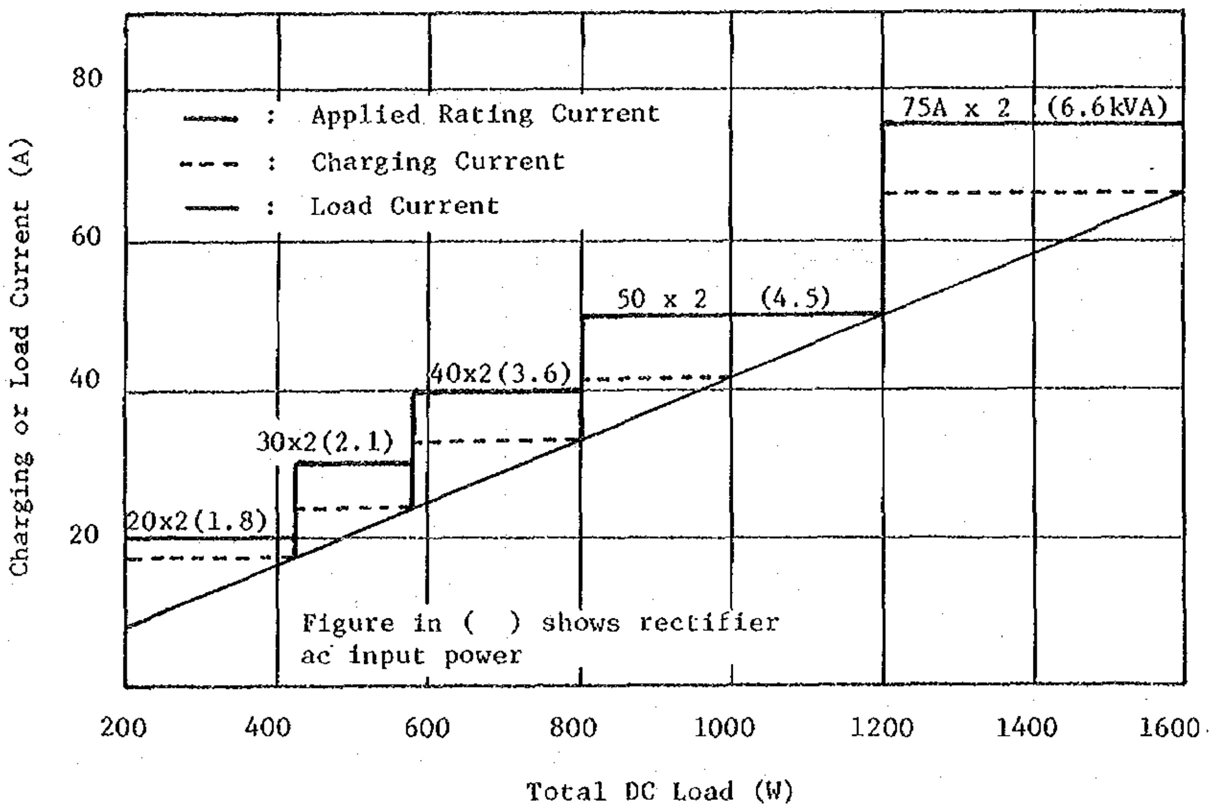


Figure 6-6 Battery and Rectifier Capacities for Unattendant Station

Table 6-3 List of Power Plant for 4 Areas (1/4)

Station	Total DC Load (W)	Battery Cap. (Ah)	Rectifier Cap. (Ax2)	AC Load (kVA)		
				Essential	Non-ess.	Total
(Ayutthaya area)						
Ayutthaya	2563	1200	150	13.3	Existing	13.3
Bang Ban	1070	600	50	4.5	1.7	6.2
Lat Bua Luang	510	290	30	2.7	2.4	*5.1
Maharat	780	400	40	3.6	1.7	5.3
Nakhon Luang	1070	600	50	4.5	1.7	6.2
Ban Phraek	830	500	50	4.5	1.7	6.2
Bangpa Han	830	500	50	4.5	1.7	6.2
Bang Sai	780	400	40	3.6	1.7	5.3
Phak Hai	780	400	40	3.6	1.7	5.3
U-Thai	780	400	40	3.6	1.7	5.3
Ban Si	830	500	50	4.5	1.7	6.2
Sena	940	500	50	4.5	1.7	6.2
(Nakhon Ratchasima area)						
Nakhon Ratchasima	2167	1000	100	8.9	Existing	8.9
Khon Buri	560	290	30	2.7	1.7	4.4
Prathai	440	290	30	2.7	1.7	4.4
Non Thai	680	400	40	3.6	1.7	5.3
Khong	780	400	40	3.6	1.7	5.3
Chum Phuang	970	500	50	4.5	1.7	6.2
Dan Khun That	440	290	30	2.7	1.7	4.4
Kham Thale So	440	290	30	2.7	1.7	4.4
Kham Sakae Saeng	440	290	30	2.7	1.7	4.4
Huai Thalaeng	440	290	30	2.7	2.1	4.8

Note : Figure with * mark shows that the station requires engine generators (7.5 kVA x 2).

Table 6-3 List of Power Plant for 4 Areas (2/4)

Station	Total DC Load (W)	Battery Cap. (AH)	Rectifier Cap. (Ax2)	AC Load (kVA)		
				Essential	Non-ess.	Total
Saeng Sang	440	290	30	2.7	2.1	4.8
Sung Noen	510	290	30	2.7	1.7	4.4
Chakkarat	560	290	30	2.7	2.1	4.8
Non Sung	1020	600	50	4.5	1.7	6.2
Phi Mai	740	400	40	3.6	1.7	5.3
Chok Chai	390	210	20	1.8	1.7	3.5
Bua Yai	600	290	30	2.7	Existing	2.7
Si Kiu	370	210	20	1.8	Existing	1.8
Pak Tong Chai	580	290	30	2.7	Existing	2.7
Sa Pratheep	390	210	20	1.8	2.8	*4.6
(Chiangmai area)						
Chiangmai	3564	1400	150	13.3	Existing	13.3
Mae Ai	440	290	30	2.7	1.7	4.4
Omkoi	440	290	30	2.7	2.8	*5.5
Doi Tao	440	290	30	2.7	2.4	*5.1
Fang	1000	500	50	4.5	1.7	6.2
San Sai	510	290	30	2.7	1.7	4.4
Doi Saket	920	500	50	4.5	1.7	6.2
Phrao	780	400	40	3.6	2.4	*6.0
Mae Taeng	780	400	40	3.6	2.1	5.7
Chiang Dao	780	400	40	3.6	1.7	5.3
Sa Moeng	510	290	30	2.7	2.4	*5.1
Mae Rim	920	500	50	4.5	2.1	6.6
Hot	950	500	50	4.5	2.1	6.6

Note : Figure with * mark shows that the station requires engine generators (7.5 kVA x 2).

Table 6-3 List of Power Plant for 4 Areas (3/4)

Station	Total DC Load (W)	Battery Cap. (Ah)	Rectifier Cap. (Ax2)	AC Load(kVA)		
				Essential	Non-ess.	Total
Hang Dong	780	400	40	3.6	1.7	5.3
Mae Chaem	510	290	30	2.7	2.8	*5.5
San Kam Phaeng	620	400	40	3.6	1.7	5.3
San Patong	2112	1200	100	8.9	2.1	11.0
Chom Thong	670	400	40	3.6	1.7	5.3
Doi Pha Hong	390	210	20	1.8	2.4	*4.2
Doi Mu Soe	390	210	20	1.8	2.4	*4.2
Doi Chiang Dao	850	500	50	4.5	2.4	*6.9
Ban Pak Tang	390	210	20	1.8	Exsiting	1.8
Doi Inthanon	710	400	40	3.6	2.8	*6.4
Ban Non Hai	510	290	30	2.7	2.8	*5.5
Doi Pae Po Mak	510	290	30	2.7	2.4	*5.1
Khao Huai Bon	390	210	20	1.8	3.8	*5.6
(Phun Phin area)						
Phun Phin (Tex)	1030	500	50	4.5	Existing	4.5
Khian Sa	440	290	30	2.7	2.1	4.8
Prasaeng	510	290	30	2.7	1.7	4.4
Phanom	440	290	30	2.7	1.7	4.4
Tha Chang	780	400	40	3.6	1.7	5.3
Tha Chana	780	400	40	3.6	1.7	5.3
Don Sak	1070	600	50	4.5	1.7	6.2
Khiri Ratthanikhom	1070	600	50	4.5	Existing	4.5
Ban Na Doem	440	290	30	2.7	1.7	4.4
Ko Phangan	440	290	30	2.7	2.4	*5.1

Note : Figure with * mark shows that the station requires engine generators (7.5 kVA x 2).

Table 6-3 List of Power Plant for 4 Areas (4/4)

Station	Total DC Load (W)	Battery Cap. (Ah)	Rectifier Cap. (Ax2)	AC Load(kVA)		
				Essential	Non-ess.	Total
Ban Takhun	440	290	30	2.7	1.7	4.4
Wiang Sa	780	400	40	3.6	1.7	5.3
Kanchanadit	510	290	30	2.7	1.7	4.4
Ko Samui	680	400	40	3.6	1.7	5.3
Phun Phin (R)	560	290	30	2.7	Existing	2.7
Chai Ya	600	290	30	2.7	Existing	2.7
Ban Na San	990	400	50	4.5	Existing	4.5

Note : Figure with * mark shows that the station requires engine generators (7.5 kVA x 2).

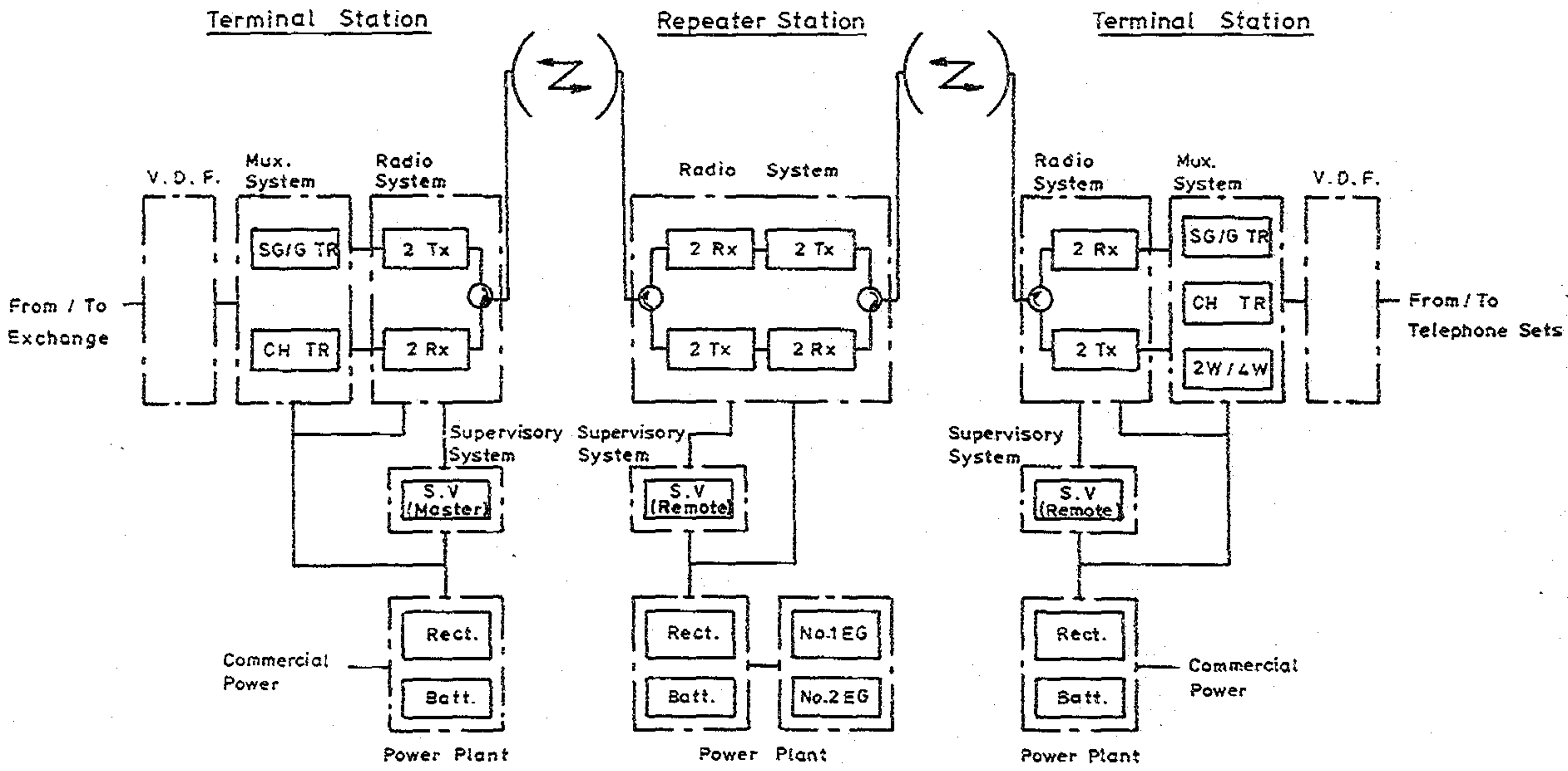
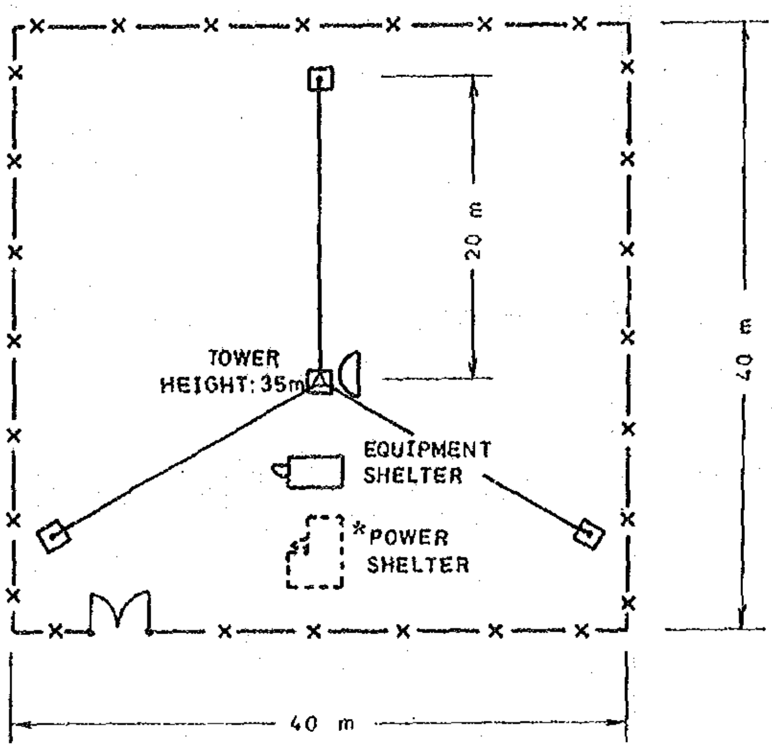
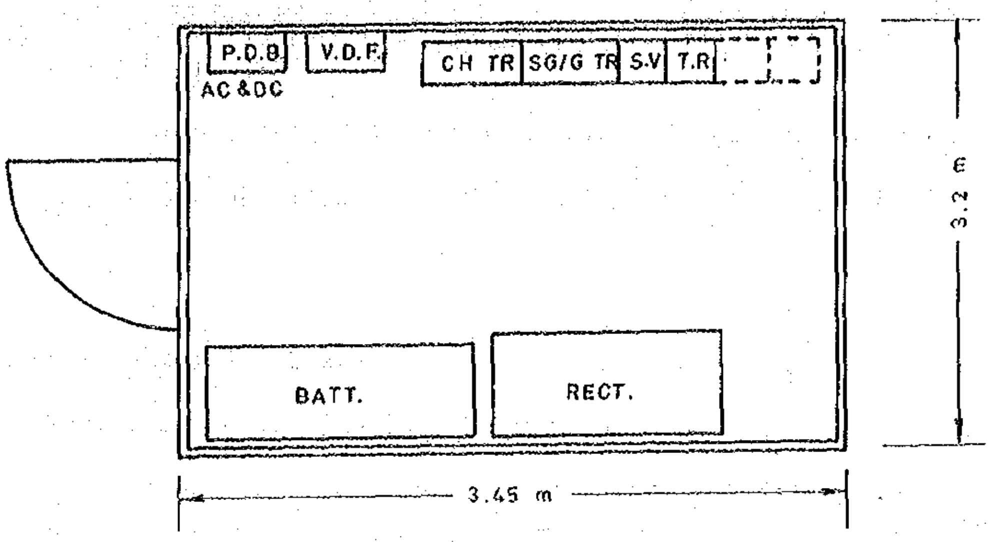


Figure 6-7 Typical Terrestrial Radio System Configuration

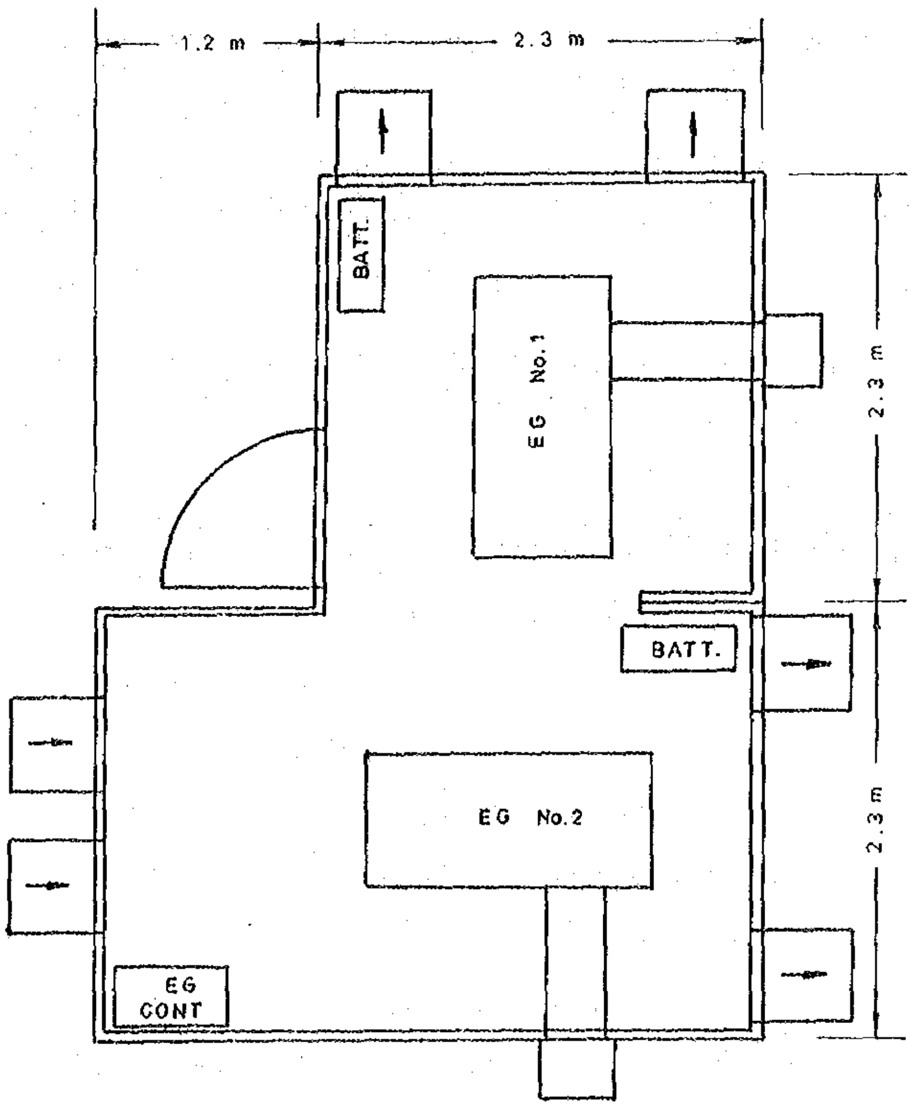


Note : * Power shelter with dual engine-generator will be installed where the commercial power is not available.

Figure 6-8 Typical Site Layout for Terrestrial System



(a) Equipment Shelter



(b) Power Shelter

Figure 6-9 Typical Equipment Floor Layout for Terrestrial System station site.

Volume II-15 "Cable Layout Plan" describes the cable route in each cable section.

3. Domestic Satellite System

3-1 Master Earth Station Site Selection

At present, in Bangkok, the existing terrestrial microwave systems (6 GHz lower band) extending to northern, northeastern and southern parts of Thailand are concentrated. Therefore, in order to avoid mutual radio interference between these existing systems and the projected domestic satellite system, the master earth station of the latter has to be established sufficiently distant from the Bangkok Metropolitan area.

TOT holds a plan to construct a new microwave system that extends from Bangkok to Rayong southeast of Bangkok. From the viewpoint of saving the domestic satellite system construction cost and of avoiding radio interference with the existing terrestrial radio system, it is desirable to utilize part of the planned Bangkok - Rayong microwave system as a terrestrial approach link between Bangkok and the master earth station.

For this purpose, however, the planned microwave system should be of different frequency band from that to be used in the domestic satellite system. The field survey carried out this time placed special emphasis on this point. For the selection of the master earth station site, the field survey was conducted for two locations in the neighborhood of the land where the Ban Saphan Si radio repeater station (the second radio repeater station from Bangkok) is scheduled to be constructed. These two locations can be connected by coaxial cable to the abovementioned radio repeater station. The proposed site A (Ban Saphan Si shown in Figure 6-10) commands greater advantage than the other in the undermentioned respects, though there is no much difference between the two as far as the radio interference to the existing microwave system is concerned.

(1) To gain the access road, the existing road has only to be repaired. This means small access road construction cost.

(2) Coaxial cable length required to connect the radio repeater station and the master earth station is short.

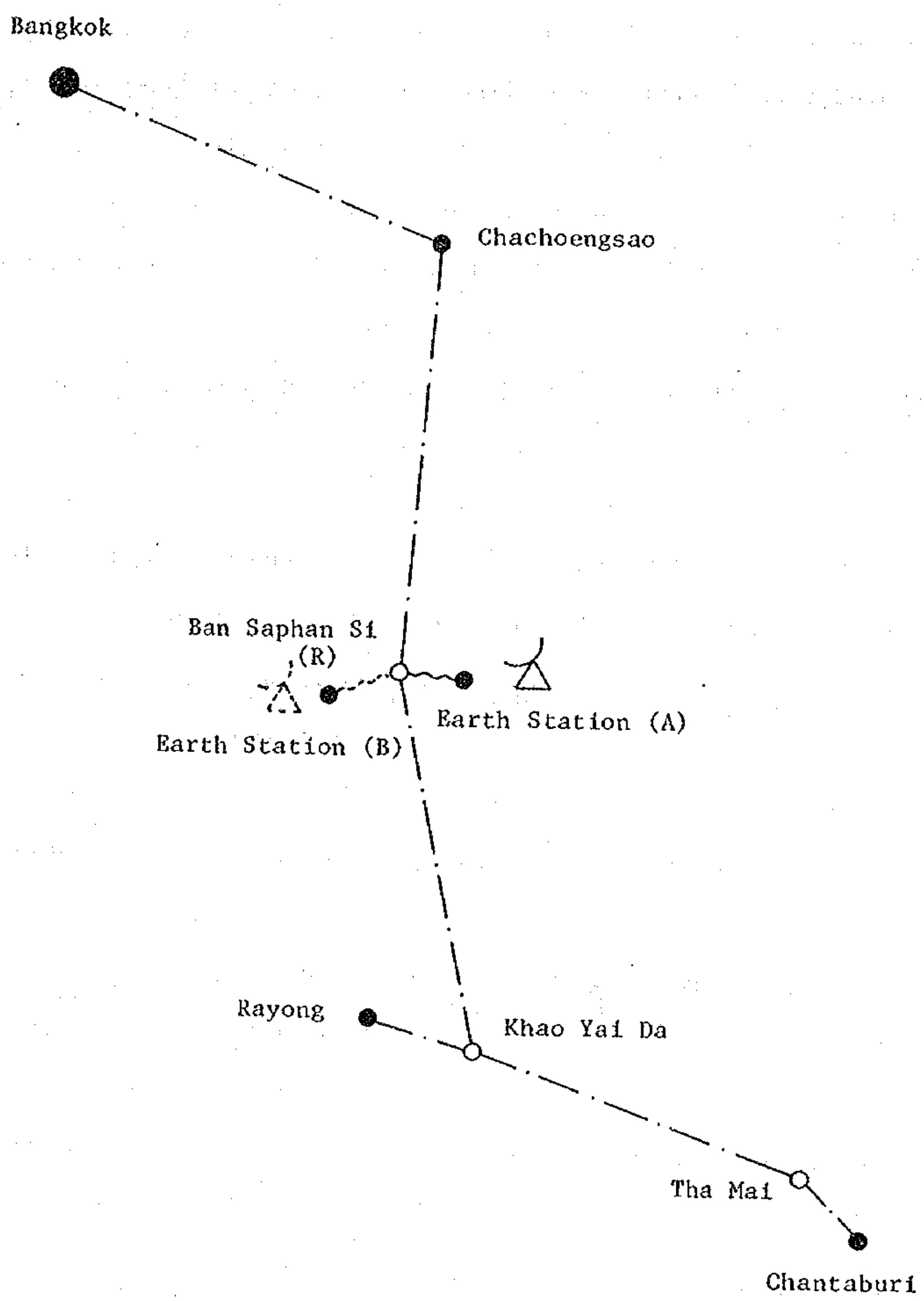
(3) Drainage in the rainy season is good.

However, no information could be obtained with respect to the site location, radio frequency, transmitter output and so forth of the radio system operated by other administration than TOT. If the domestic satellite system is to be adopted in this Project, such information is essential for the radio interference study.

It is desirable to make the field survey for other site or sites than the aforementioned two for the purpose of determining the technically and economically optimum site for the master earth station.

3-2 Rural Earth Station Site Selection

Field survey result shows that the most part of rural station sites selected by TOT on the assumption that the terrestrial radio system be introduced for the projected Rural Long Distance Public Telephone Service are located in plain town areas without obstacles to radio propagation. Therefore, even if the rural earth stations are established at those sites, it seems that no problem relating



Earth Station (A) : Ban Saphan Si (E/S)
-Ditto- (B) : Ban Hin Lat (E/S)

Figure 6-10 Terrestrial Approach Link for Bangkok Master Earth Station to radio propagation to and from the satellite will arise.

However, with regard to the possible radio interference from the rural earth stations to the existing microwave system that uses the same radio frequency band as the rural earth stations, there is need for a thorough study aimed at the selection of proper sites for rural earth stations. (Refer to Section 3-4 of this Part VI.)

As in the case of the site selection for the master earth station, information concerning the communication system of other administration than TOT must be obtained when introducing the domestic satellite system and, based on such information, a complete study on inter-system radio interference must be made.

3-3 Design Criteria Establishment and System Performance Estimation

3-3-1 Circuit Performance Requirements

For the designing of domestic satellite system, hypothetical reference circuit and system performance requirements must be specified. However, there is no CCIR recommendation applicable to the domestic satellite link.

System establishment and maintenance costs for the satellite communication service depend critically upon overall signal to noise performance requirements. Therefore, the performance requirements for telephone circuits recommended by CCIR are referred to as the sole system performance standards for the domestic satellite system.

(1) Hypothetical Reference Circuit for Telephony

CCIR recommends the hypothetical reference circuit for use in the intercontinental telephony transmission via communication satellite, which is as follows :

1) The hypothetical reference circuit for the satellite

system consists of one earth-satellite-earth radio link as shown in Figure 6-11.

2) The circuit includes one pair of modulator and demodulator. The modulator translates the baseband to the radio frequency carrier. The demodulator translates the radio frequency carrier to the baseband. However, the circuit does not include frequency division multiplex equipment.

(2) Noise Objectives for Frequency Division Multiplex Telephony

CCIR recommends that in the hypothetical reference circuit for the satellite link the allowable noise power at the zero relative level point on a telephone channel should not exceed :

1) 10,000 pW psophometrically weighted mean power in any hour;

2) 10,000 pW psophometircally weighted one-minute mean power for more than 20% of any month;

3) 50,000 pW psophometrically weighted one-minute mean power for more than 0.3% of any month; and

4) 1,000,000 pW unweighted (with an integrating time of 5 ms) for more than 0.3% of any month.

The overall noise in a hypothetical reference circuit includes thermal noise produced in the up-link and down-link, noise caused by the transmitter/receiver at the earth station and by the satellite transponder, and interference noise from a terrestrial microwave link.

(3) Noise Budget Allowable to Domestic Satellite System

The noise power of 10,000 pW allowable to the domestic

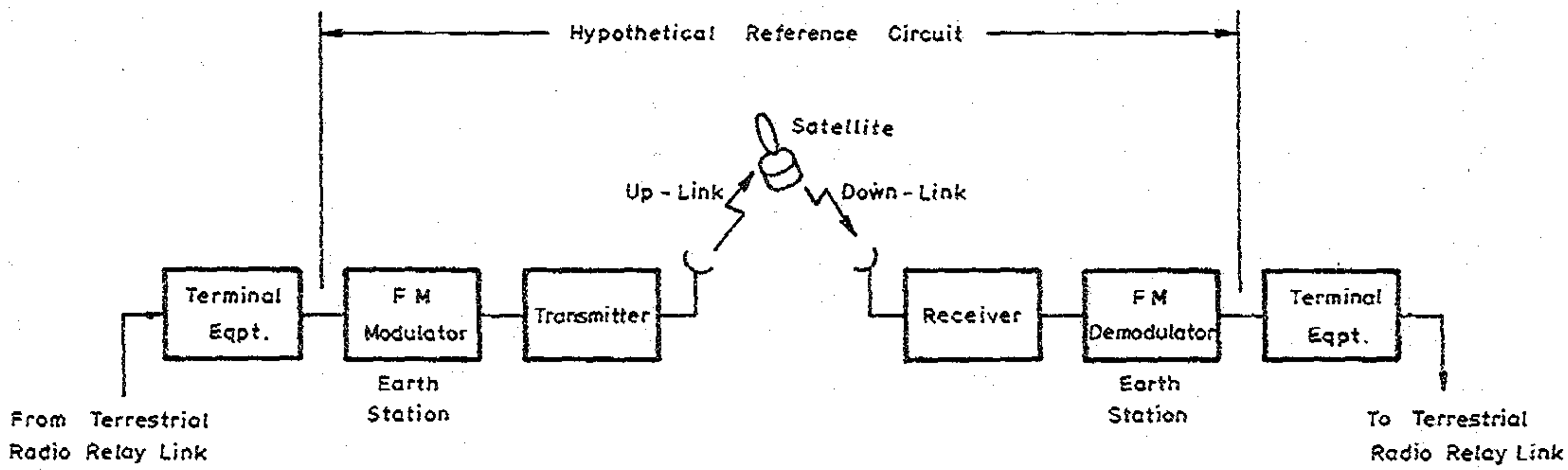


Figure 6-11 Hypothetical Reference Circuit for Satellite System

satellite telephony circuit is to be assigned to the satellite link and equipment listed in Table 6-4.

3-3-2 System Performance Estimate

(1) Noises Produced in Satellite Link

Signal to total weighted noise performance on the satellite link is given by

$$(S/N)_t = (C/T)_t - 10 \log k + 10 \log \frac{3f_r^2}{f_m^3 - f_a^3} + E_m + W \text{ (dB)} \quad \ldots\ldots\ldots (6.1)$$

where

$(S/N)_t$	:	Signal to total weighted noise ratio (51.3 dB)
$(C/T)_t$	:	Carrier to total noise temperature (dBW/^{o}K)
K	:	Boltzmann's constant (1.38×10^{-23} J/^{o}K)
f_r	:	Test tone r.m.s. frequency deviation (4,310 Hz r.m.s.)
f_m	:	The highest frequency of telephone channel (3,400 Hz)
f_a	:	The lowest frequency of telephone channel (300 Hz)
E_m	:	Emphasis improvement factor (5.8 dB)
W	:	Psophometric weighting factor (2.5 dB)

By the application of actual parameters the above equation can be reduced to

$$(S/N)_t = (C/T)_t + 208.4 \text{ (dB)} \quad \ldots\ldots\ldots (6.2)$$

Required $(S/N)_t$ for the satellite link is 51.3 dB.

Accordingly, carrier to total noise temperature at operating point (where total noise temperature corresponds to 7,500 pWOp) is $(C/T)_t = (S/N)_t - S - 208.4 \ldots\ldots\ldots (6.3)$

$$= 51.3 - 17 - 208.4$$

$$= -174.1 \text{ (dB/}^o\text{K)}$$

Table 6-4 Noise Budget Allowable to Domestic Satellite System.

Item	Noise Power (pWOp)
Satellite link Up-link thermal noise Intermodulation noise in satellite Down-link thermal noise	7,500 (-51.3 dBmOp)
Equipment noise in transmitting and receiving earth stations	1,500 (-58.2 dBmOp)
Interference noise from other system	1,000 (-60.0 dBmOp)
Total noise	10,000 (-50.0 dBmOp)

where

S : Gain of syllabic compander (dB)

There are three kinds of noises which must be considered in the satellite link in order to satisfy the assigned noise power of 7,500 pW0p. The three kinds of noises are :

1) Up-link Thermal Noise

The up-link thermal noise is given by substituting the up-link C/T as defined in Equation (6.4) with that in Equation (6.2). The up-link C/T is given by

$$(C/T)_U = (EIRP)_E - L_U + (G/T)_s \quad (dBW/^oK) \ldots\ldots\ldots (6.4)$$

$$= W_s - BO_i - ((EIRP)_{s\ sat} - BO_o - (EIRP)_{sat})$$

$$-10 \log \frac{4\pi}{\lambda^2} + (G/T)_s$$

where

$(EIRP)_E$: Earth station EIRP (dBW)

L_U : Up-link transmission loss including satellite and earth station pointing errors, and atmospheric absorption (dB)

$(G/T)_s$: Figure of merit of satellite transponder ($dB/^oK$)

W_s : Input flux density of a single carrier for saturation of satellite transponder (dBW/m^2)

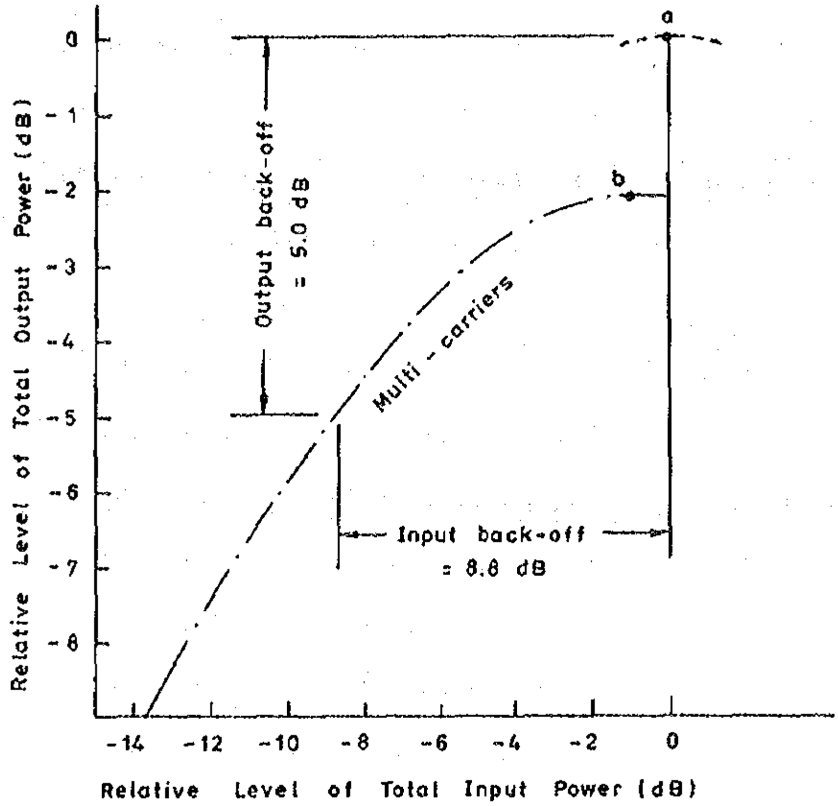
BO_i : Input back-off of satellite transponder (dB)

$(EIRP)_{s\ sat}$: EIRP at saturation of satellite transponder (dBW)

$(EIRP)_{sat}$: Satellite EIRP per carrier (dBW)

BO_o : Output back-off of satellite transponder (dB)

(For BO_i and BO_o, refer to Figure 6-12.)



Note

a : Saturation Power at Single Carrier Input

b : Saturation Power at Multi-Carrier Input

Figure 6-12 Input-Output Characteristics of Transponder

2) Satellite Intermodulation Noise

In the multiple-access operation by SCPC-FM carriers, a number of carriers are simultaneously amplified by a common amplifier in the satellite transponder. In this case, the amplifier must be operated near its saturated output power for the purpose of efficient use of satellite EIRP. As a consequence, intermodulation noise due to multi-carrier operation is produced in the satellite transponder. This intermodulation noise is caused by amplitude non-linearity and by AM/PM conversion. In the SCPC-FM system, the carrier start-stop system, whereby a carrier is transmitted only during voice activities, is adopted so as to use the available satellite power efficiently. The voice activity factor is approximately 40% in the case of 1,000 carriers. This means that 400 carriers are accessed and amplified simultaneously in the transponder. Therefore, the necessary total EIRP of all earth stations can be given by

$$(EIRP)_{Et} = W_s - BO_i + L_U - 10 \log \frac{4\pi}{\lambda^2} \text{ (dBW)} \quad \ldots\ldots (6.5)$$

where

W_s : Input flux density which gives saturated output power of satellite transponder

BO_i : Level difference between W_s and operational point. Amplifier of satellite transponder is operated below its saturation output power so as to keep intermodulation noise low.

L_U : Up-link transmission loss

Input back-off is the ratio of the single carrier input power which yields the saturated output power to the total input power of the multi-carriers at their operating point. Output back-off is the ratio of the saturated output power by the single carrier input to that by multi-carriers input.

$(C/T)_{IM}$ is given by

$(C/T)_{IM} = (EIRP)_{sat} - N_o + K$ (dBW/°K)........(6.6)

where

N_o : Intermodulation noise power density (dBW/Hz)

(Refer to Figure 6-13.)

3) Down-link Thermal Noise

The down-link thermal noise consists of the thermal noise of antenna, feeder and receiver of a receiving earth station. It is given by

$(C/T)_D = (EIRP)_{sat} - L_D + (G/T)_D$........(6.7)

where

$(EIRP)_{sat}$: Satellite EIRP per carrier (dBW)

L_D : Down-link transmission loss including satellite and earth station pointing errors (dB)

$(G/T)_D$: Figure of merit of receiving earth station (dB/°K)

(2) Total Carrier to Noise Trmperature Ratio in Satellite Link $(C/T)_t$

$(C/T)_t$ is expressed by

$$(C/T)_t = \log \frac{1}{(T/C)'_U + (T/C)'_I + (T/C)'_D} \quad ....(6.8)$$

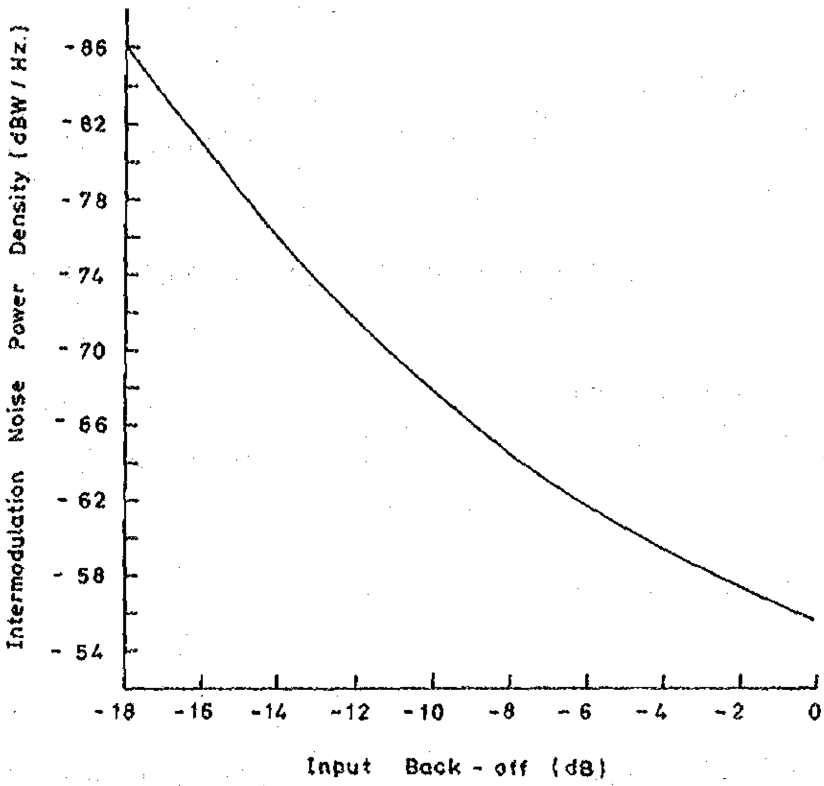


Figure 6-13 Intermodulation Noise Power Density Produced in PALAPA Satellite Transponder

where $(T/C)'_U$, $(T/C)'_I$ and $(T/C)'_D$ are inverse numbers of values which are expressed in antilogarithm of $(C/T)_U$, $(C/T)_I$ and $(C/T)_D$, respectively.

(3) Overall Signal to Noise Ratio in Satellite System

Estimated overall noise can be obtained by the following equation :

$N_T = N_t + N_E + N_I$.........(6.9)

where

N_t : Noise produced in up-link, transponder and down-link

N_E : Equipment noise produced at the earth station

N_I : Interference noise from other system(s)

(4) Threshold Margin

Threshold margin is a tolerance of received carrier level to the threshold level.

In the satellite system, carrier to noise ratio varies according to the meteorological condition, especially the rainfall. Therefore, it is necessary to have appropriate threshold margin.

Threshold level of threshold extended demodulator is expressed by

$(C/T)_{TH} = 5 \log f_{rms} - 181.3$ (dBW/^{o}K).........(6.10)

where

f_{rms} : r.m.s. frequency deviation of telephone signal (kHz)

Accordingly, the threshold margin M (dB) is defined by

$M = (C/T)_t - (C/T)_{TH}$ (dB)..........(6.11)

(5) Rain Margin

The rain margin M_R is expressed by the following equation :

$$M_R = 10 \log \frac{(T/C)'_{TH} - (T/C)'_T - (T/C)'_D}{(T/C)'_D} \quad \text{..........(6.12)}$$

where each $(T/C)'$ is an inverse number of the value which is expressed in antilogarithm of (C/T).

3-3-3 System Design Examples

The telephony transmission performance estimates in the direction from Bangkok master earth station to rural earth station and in the opposite direction are shown below. Estimates are made for transmission performance expected when the system parameters shown in Table 6-5 are used.

(1) Carrier to noise temperature ratio in each circuit (master earth station to rural earth station circuit)

1) Up-link thermal noise

$$(C/T)_U = (EIRP)_{EM} - L_U + (G/T)_s$$

$$= W_s - BO_i - (EIRP)_{s\ sat} - BO_o - (EIRP)_s - 10 \log \frac{4\pi}{\lambda^2} + (G/T)_s$$

$$= -80 - 8.8 - (30 - 5.0 - 0.8) - 37 + (-6.5)$$

$$= -156.5 \ (dBW/^{\circ}K)$$

(where $(EIRP)_{EM}$ is EIRP of master earth station.)

2) Satellite intermodulation noise

$$(C/T)_{IM} = (EIRP)_{sat} - N_o + K$$

$$= 0.8 - (-65.5) - 228.6$$

$$= -162.3 \ (dBW/^{\circ}K)$$

3) Down-link thermal noise

$$(C/T)_D = (EIRP)_{sat} - L_D + (G/T)_{ER}$$

$$= 0.8 - 196.4 + (21.9)$$

$$= -173.7 \ (dBW/^{\circ}K)$$

Table 6-5 System Design Parameters

Satellite

Maximum EIRP	: 30 dBW
Saturation flux density	: -80 dBW/m^2
Input-output characteristics of transponder	: Refer to Figure 6-12.
Intermodulation noise power density produced in a transponder of PALAPA Satellite	: Refer to Figure 6-13.
G/T	: -6.5 $dB/^{o}K$ (Refer to Fgiure 5-6.)
Input back-off	: 8.8 dB (Output back off : 5.0 dB)
Transponder bandwidth	: 36 MHz/Transponder (Available bandwidth : 30 MHz)

Earth Station

	Master Station	Rural Station
EIRP (dBW)	50	45
Antenna diameter (mϕ)	11	4.5
G/T (dB)	31.7	21.9
LNA noise temperature(^{o}K)	55	90

Satellite Communication System

System	: SCPC-FM with carrier start-stop system
Number of carriers	: 1,000 (Carrier separation : 30 kHz)
Voice activity factor	: 40%
r.m.s. test tone freq. deviation	: 3.41 kHz r.m.s.

(where $(G/T)_{ER}$ is G/T of rural earth station.)

4) Carrier to total noise temperature ratio

$$(C/T)_t = \log \frac{1}{(T/C)'_U + (T/C)'_I + (C/T)'_D}$$

$$= -174.1 \text{ (dBW/}^oK)$$

$(S/N)_t = 208.4 - 174.1 + 17 = 51.3$ dB (7,415 pW0p)

The result of system performance calculations in the direction from rural earth station to master earth station, made by the same method as aforementioned, appears in Table 6-6.

Figure 6-14 presents the relationship between (C/T) of each component and total circuit $(C/T)_t$ in the event the satellite trnasponder input back-off is varied. By decreasing the input back-off, i.e., by increasing the transmission power, thermal noise can be reduced. However, intermodulation noise increases and total circuit $(C/T)_t$ varies according to the input back-off. It is important to obtain the input back-off point where $(C/T)_t$ becomes maximal and thereby determine the transmission output of the earth station.

3-4 Study of Radio Interference from Earth Stations

3-4-1 Basic Philosophy

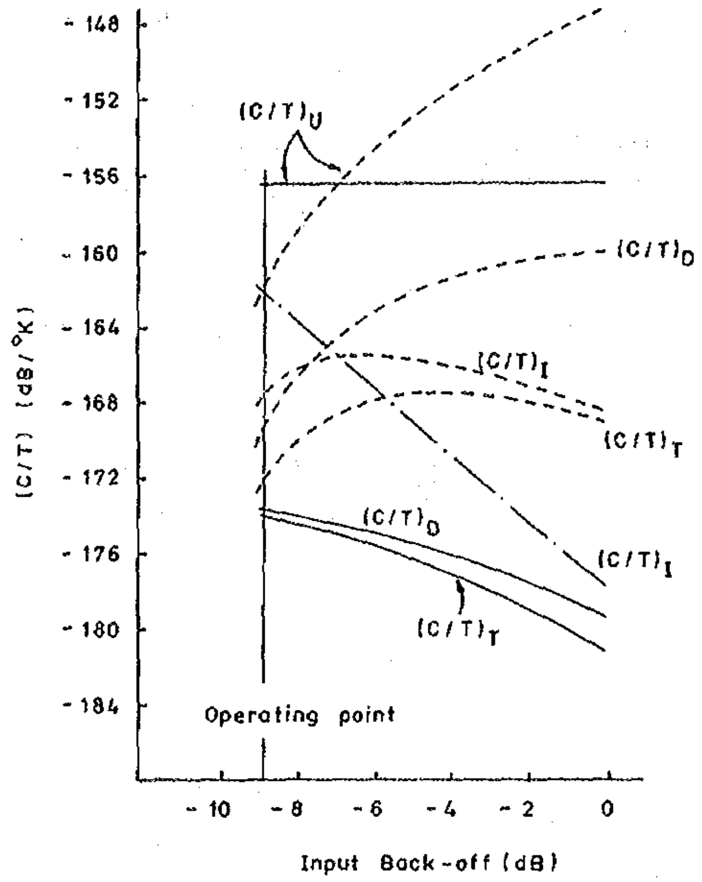
(1) Interference Paths

Radio frequencies to be used at each earth station are 6 GHz for up-link (earth station to satellite) and 4 GHz for down-link (satellite to earth station).

Conceivable interference paths are the following four :

Table 6-6 Overall Signal to Noise Ratio

Noise / Circuit	Radio Link Noise (pWOp)	Eqpt Noise in the E/S (pWOp)	Interference Noise (pWOp)	Total Noise (pWOp)	Objectives (pWOp) Margin (dB)
Master E/S to Rural E/S	7,415	1,500	1,000	9,915 (50.0 dB)	10,000 (0 dB)
Rural E/S to Master E/S	4,170	1,500	1,000	6,670 (51,8 dB)	10,000 (1.8 dB)

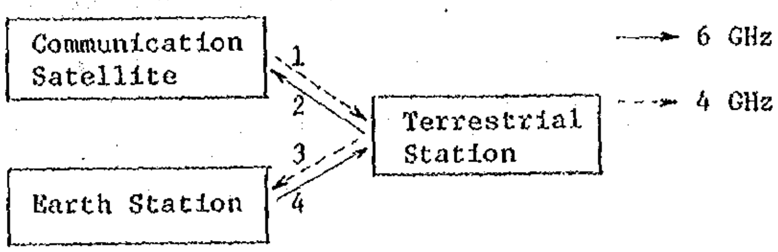


Note : Master Earth Station EIRP is fixed at 50 dBW. Rural Earth Station EIRP varies in the range from 41.2 to 51.0 dBW.

—— : Carrier from Master to Rural Earth Stations

---- : Carrier from Rural to Master Earth Stations

Figure 6-14 Selection of Optimum Operating Point of Transponder



The radio interference study carried out this time pertains to Path 4 in the above illustration. Radio interference on this path is apt to affect public communications. Three other interference paths are not taken up for study here.

(2) Standard Parameters

Parameters of equipment to be installed at each earth station and of equipment already installed at each existing terrestrial radio station are not necessarily uniform. Sometimes they differ from station to station. Therefore, to ease comparison of the degrees of interference suffered and to obtain a macro-perspective of system performance, the standard equipment parameters are specially used.

(3) Paths to be Studied

Relationships between the earth stations apt to exert harmful radio interference and the existing terrestrial radio stations to suffer such radio interference vary, depending upon the curvature of the earth and the path condition. It follows that not all path combinations between the 423 earth stations and the existing 70 terrestrial stations pose problems.

Therefore, preliminary study is made with regard to the distance between each earth station and each existing terrestrial radio station, as well as the line-of-sight condition. Paths within the predetermined distance between the said two categories of stations and paths in the line-of-sight condition are selected, and detailed analysis is made for interference parameters that exist on such paths.

(4) DU Ratio

The degree of interference is evaluated by the level ratio (dB difference) at the receiving antenna between the desired wave (D) which the existing terrestrial radio station receives from its neighbor stations (1 to 4 stations) and the interference wave, i.e., the undesired wave (U), which the existing terrestrial radio station receives from the earth station. The said level ratio is expressed by "D/U (DU ratio)".

(5) Allowable DU Ratio

Allowable D/U is to be determined, based on the types of communication systems involved and, this time, especially on the international and national standards of the satellite system and existing terrestrial microwave system. The allowable D/U standard for this Project is 79 dB. This value holds true only when the interference propagation path is in free space condition. Actually, the propagation path is bothered by trees and, moreover, the shielding effect of approximately 10 dB can be expected. Therefore, D/U of 79 dB corresponds to D/U of 89 dB.

3-4-2 Preconditions of Study

The preconditions of interference study are as follows :

(1) Scope of Study

1) To study geographic conditions between the 423 earth stations and the existing 70 terrestrial stations for all station-to-station combinations (423 x 70 = 29,610).

2) To select as target stations of radio interference study the existing terrestrial radio stations that belong to either of the following categories in the relationships to each earth station :

a) Being located in a circle with a radius of 100 km from any earth station.

b) Being located on the line-of-sight (K = 4/3 : standard refraction) from any earth station.

For details, refer to Figures 6-15 and 6-16.

(2) Radio Frequency

4 GHz...Center frequency : 4,003.5 MHz

6 GHz...Center frequency : 6,175.0 MHz

(3) Earth Station Parameters

Radiation power......................30 dBm

Antenna height above ground..........4.5 m

Antenna gain.........................46.5 dB (4.5 mø)

Antenna directivity..................Refer to Figure 6-17

(4) Terrestrial Station Parameters

Radiation power......................40 dBm

Antenna height above ground..........Possible maximum at each station site is adopted.

Antenna gain.........................42.3 dB (3.0 mø)

Antenna directivity..................Refer to Figure 6-17

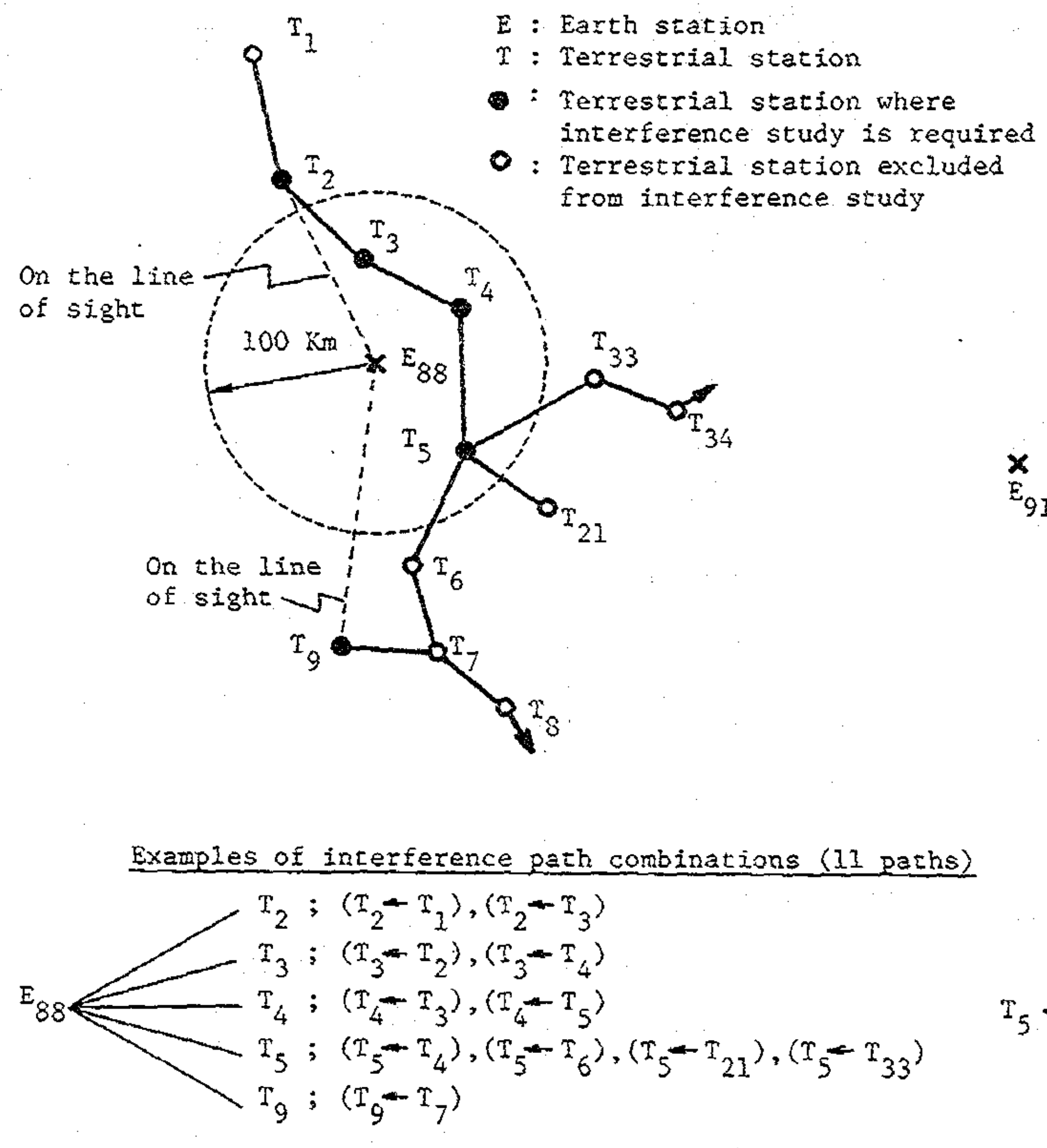


Figure 6-15 Terrestrial Stations to Suffer Interference from Earth Station

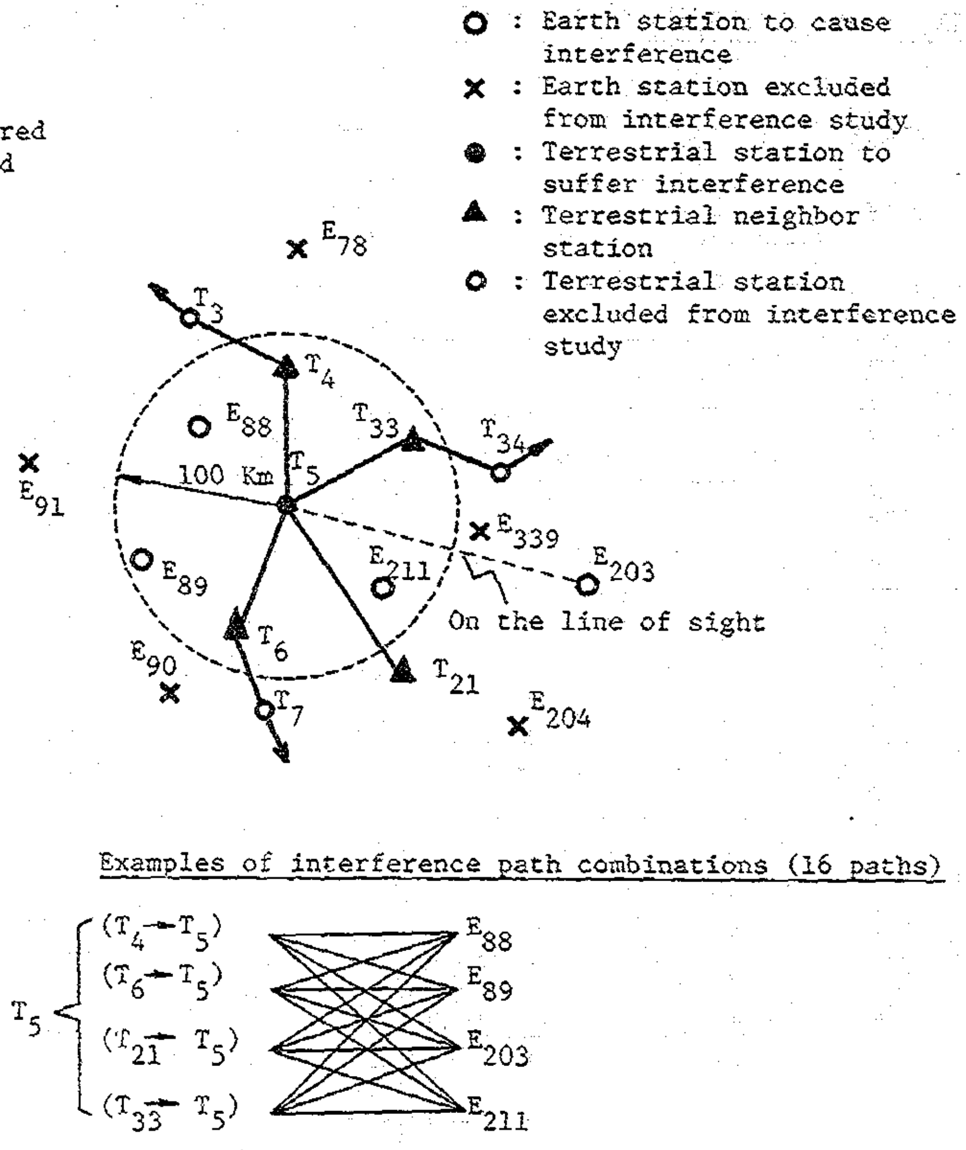


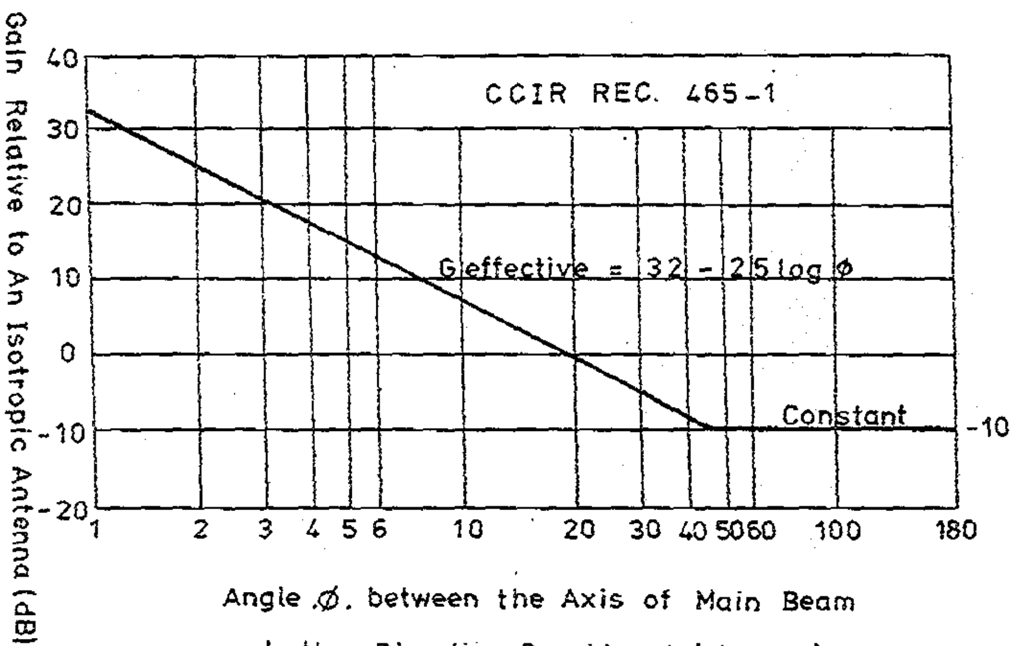
Figure 6-16 Interference Analysis of Terrestrial Stations

Rural Earth Station Antenna Directivity

(1) Frequency 2 ~ 10 GHz

(2) D/λ >100

D : Antenna diameter, λ : Wave length



Standard Directivity Of Terrestrial Station Antenna

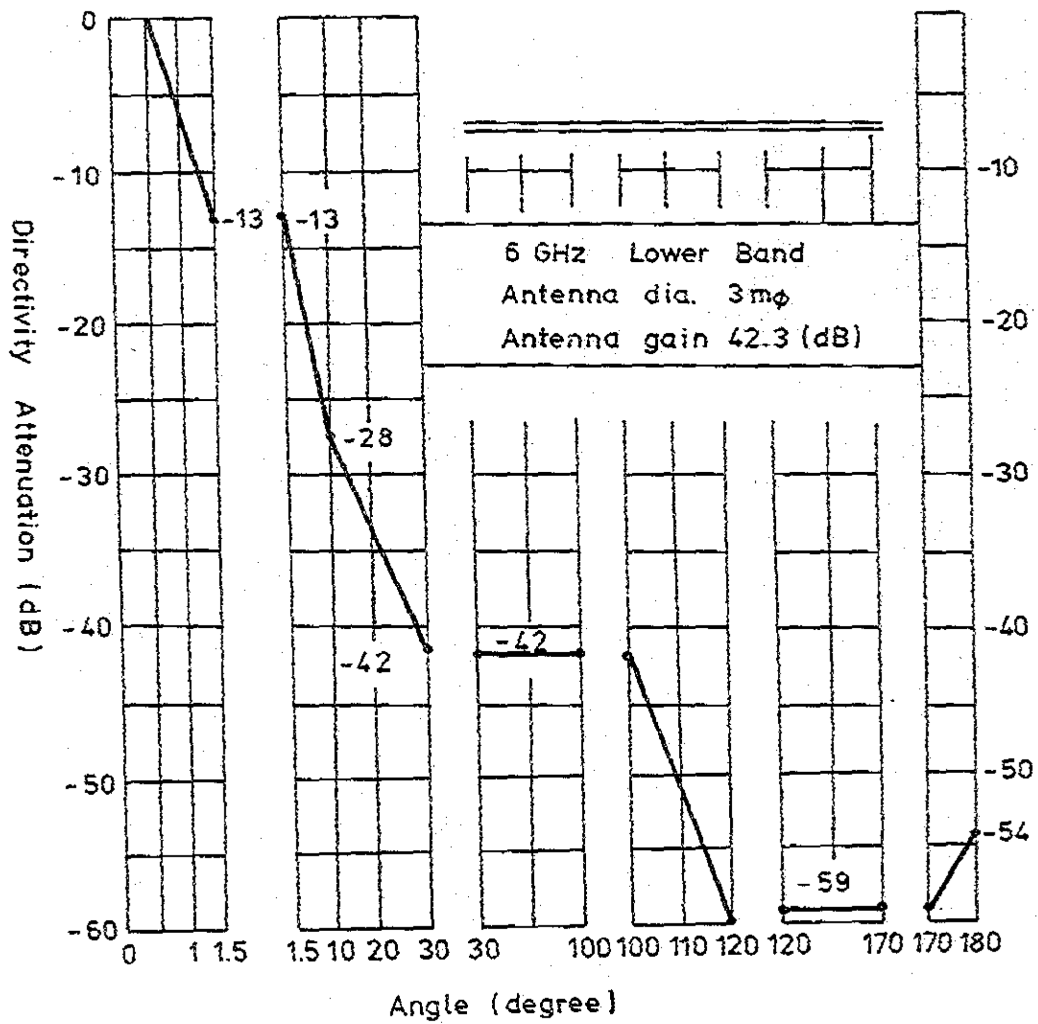


Figure 6-17 Antenna Directivity Used in Interference Study

(5) Radio Propagation Path

All free space.

3-4-3 Result of Study

The result of calculations for a total of 127,746 station-to-station path combinations, using an extra-large capacity computer, discloses that 41 station sites shown in Table 6-7 do not satisfy the requirements described in Section 3-4-1 and hence the earth station construction at those 41 sites is impracticable.

3-5 Typical Earth Station Configuration and Site Layout

Typical master earth station configuration and typical rural earth station configuration are given in Figures 6-18 and 6-19. Typical site layout and equipment floor layout for the said two categories of stations appear in Figures 6-20 to 6-23.

3-6 Cable Route Study

Cable route study was made, using the same methodology as that used in the terrestrial system study. The cable layout plan is described in Volume II-15 "Cable Layout Plan".

Table 6-7 Rural Earth Stations to Cause Interference

Area Code	Station Name	Area Code	Station Name
32 01 02	Ban Lat	54 22 05	Mae Mo
32 15 02	Bang Saphan	54 32 01	Long
35 16 09	U-Thai	55 08 02	Si Nakhon
36 13 01	Muang Lek	55 22 02	Bang Krathum
36 13 02	Sao Hai	55 22 04	Phom Phiram
36 13 06	Nong Don	55 27 02	Tron
37 05 01	Na Di	73 13 03	Nong Chik
38 01 01	Bang Nam Prieo	73 13 06	Yaring
38 01 02	Ban Pho	74 01 04	Tra Mot
38 08 01	Pluak Daeng	74 01 07	Khao Chaison
38 15 02	Phan Thong	74 05 01	Rattaphum
42 01 06	Non Sa-at	74 05 02	Thepha
44 01 10	Phen	74 05 05	Chana
44 12 03	Kra Sung	75 05 08	Cha-Uat
44 12 04	Khu Muang	77 01 02	Tha Sae
44 21 11	Sung Noen	77 01 03	Phato
44 21 12	Chakkarat	77 07 01	Kra Buri
45 22 08	Kanthararom	77 11 05	Tha Chana
45 22 09	Uthumphon Phisai	77 11 07	Khiri Ratthanikhom
45 30 09	Samrong Thap	77 11 08	Ban Na Doem
54 22 02	Ngao		

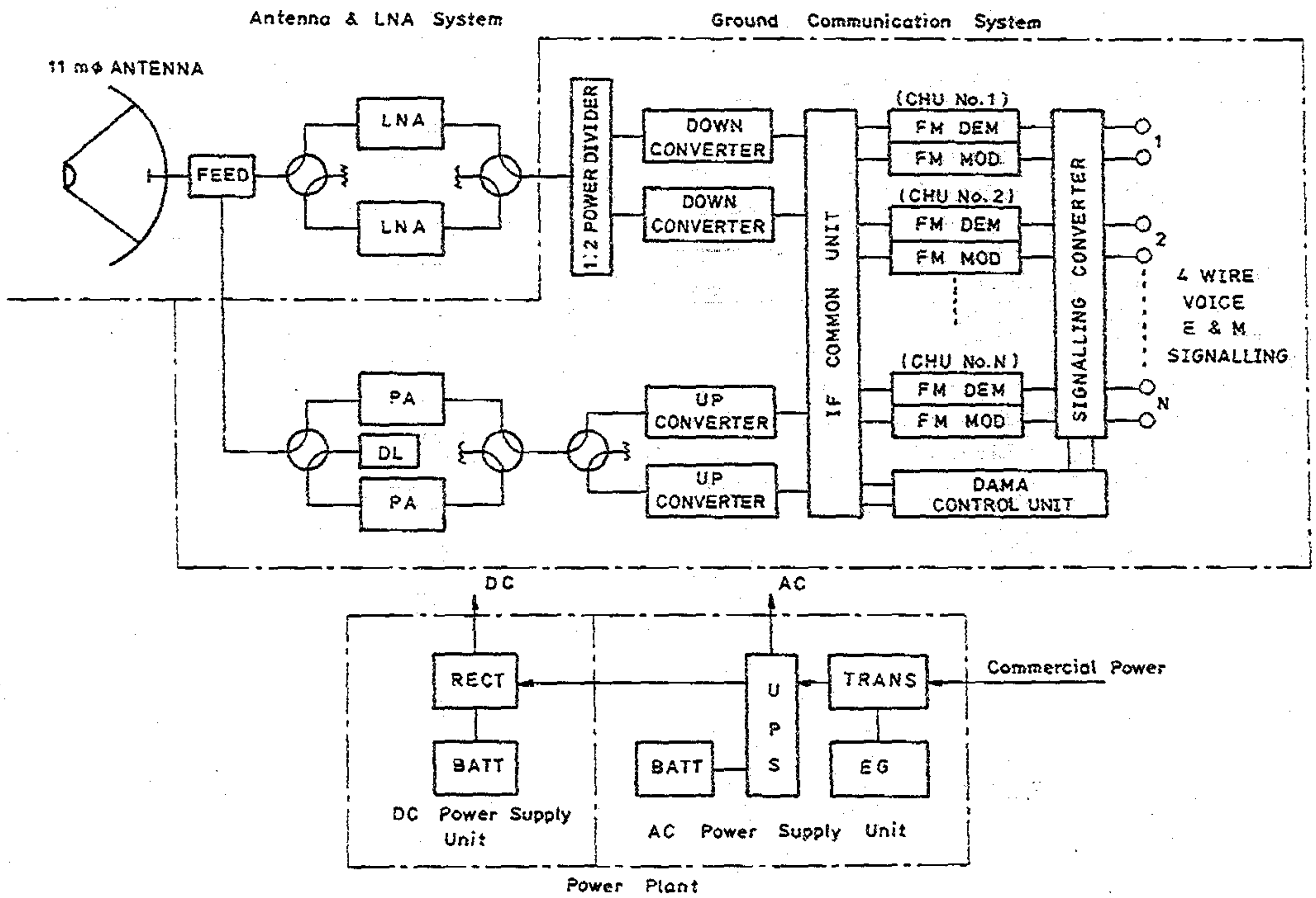


Figure 6-18 Typical Master Earth Station Configuration

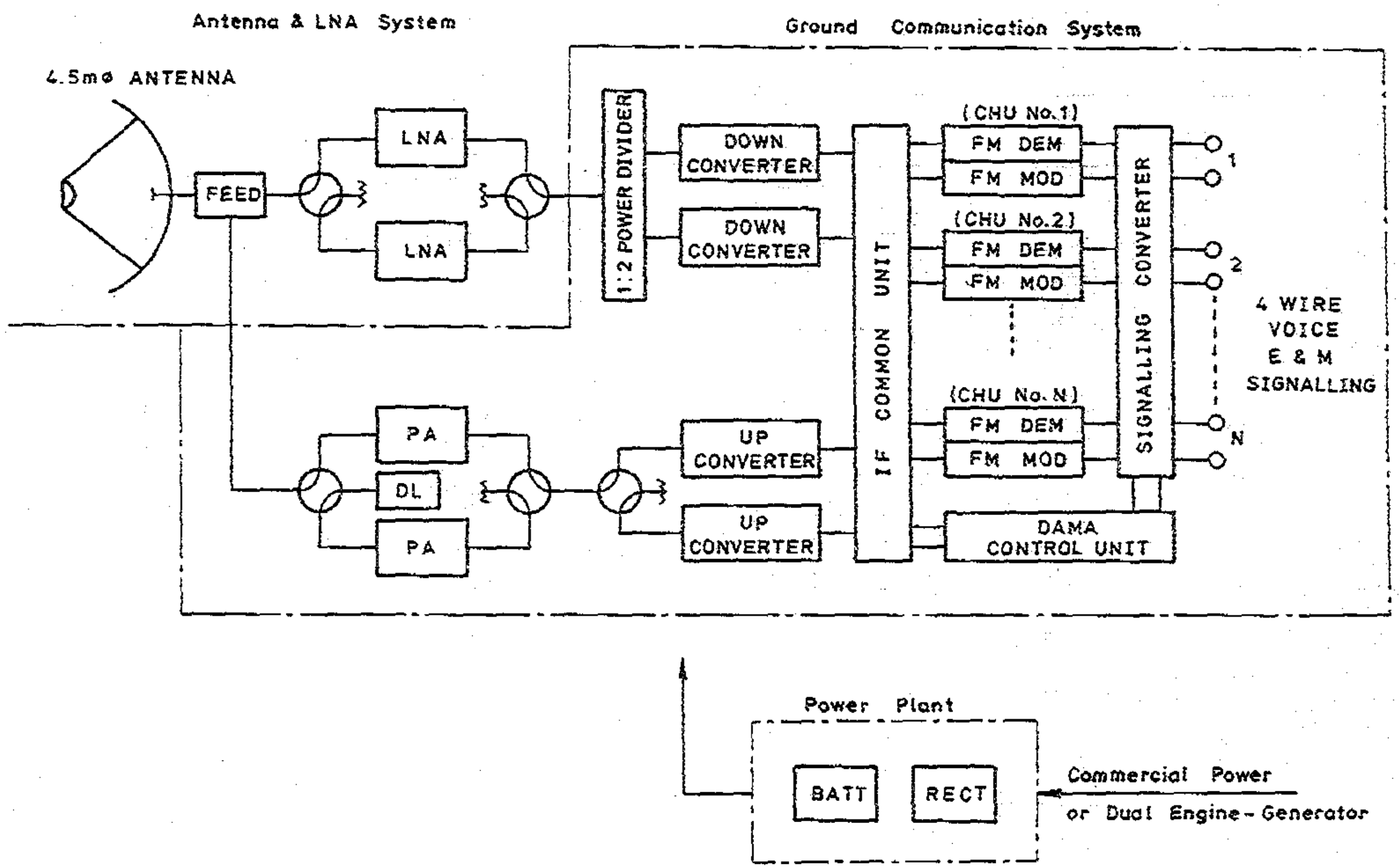


Figure 6-19 Typical Rural Earth Station Configuration

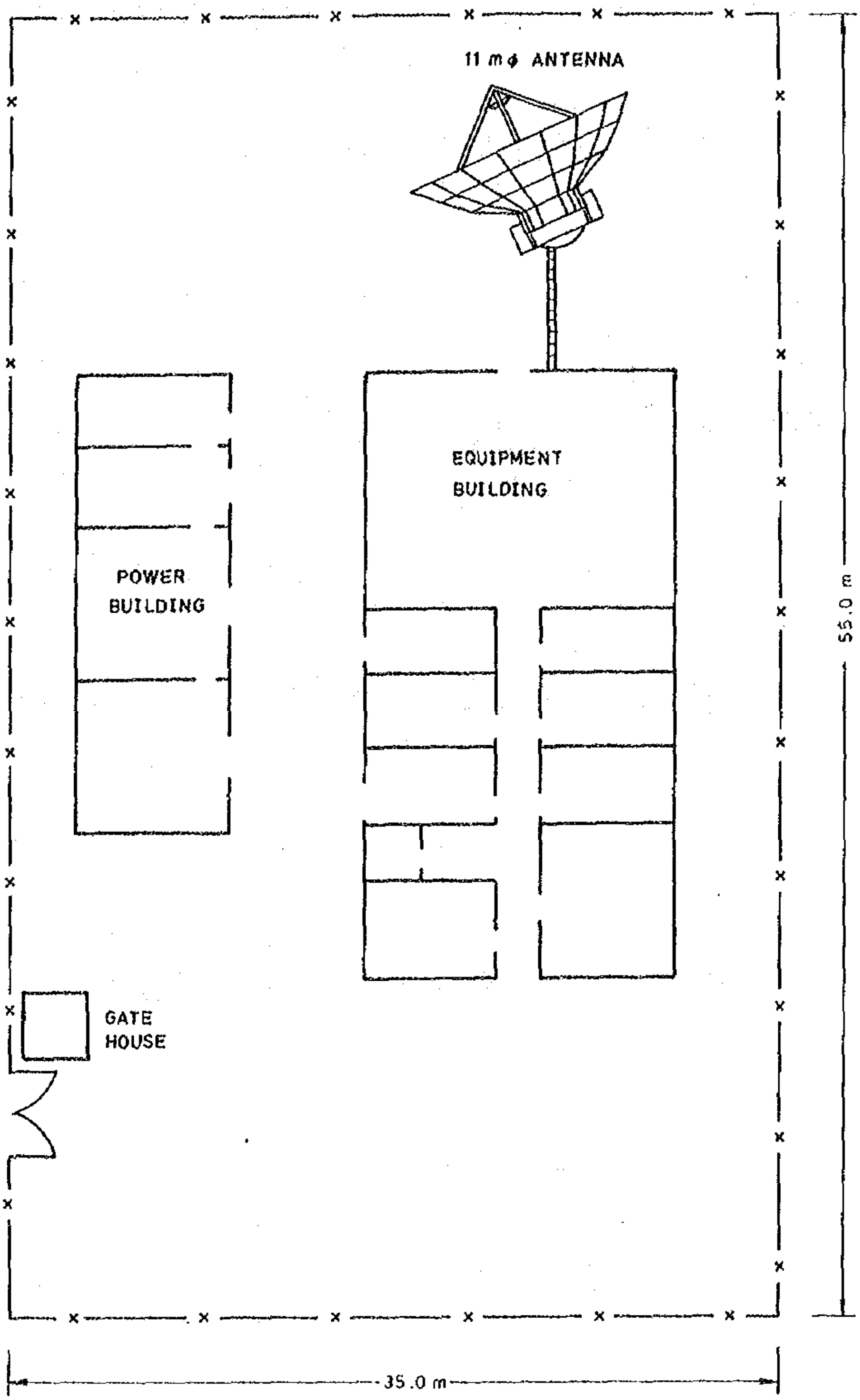
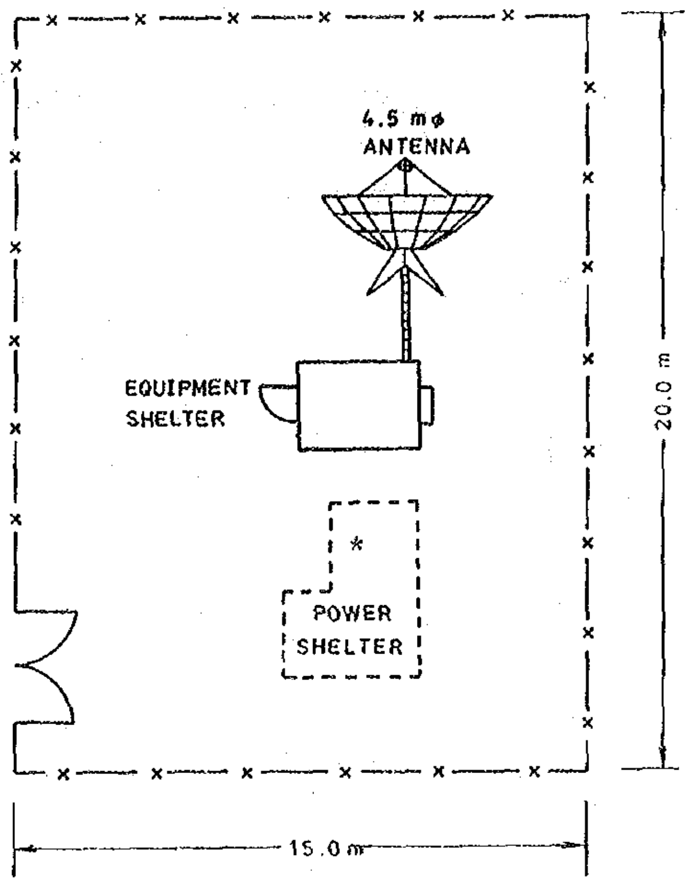
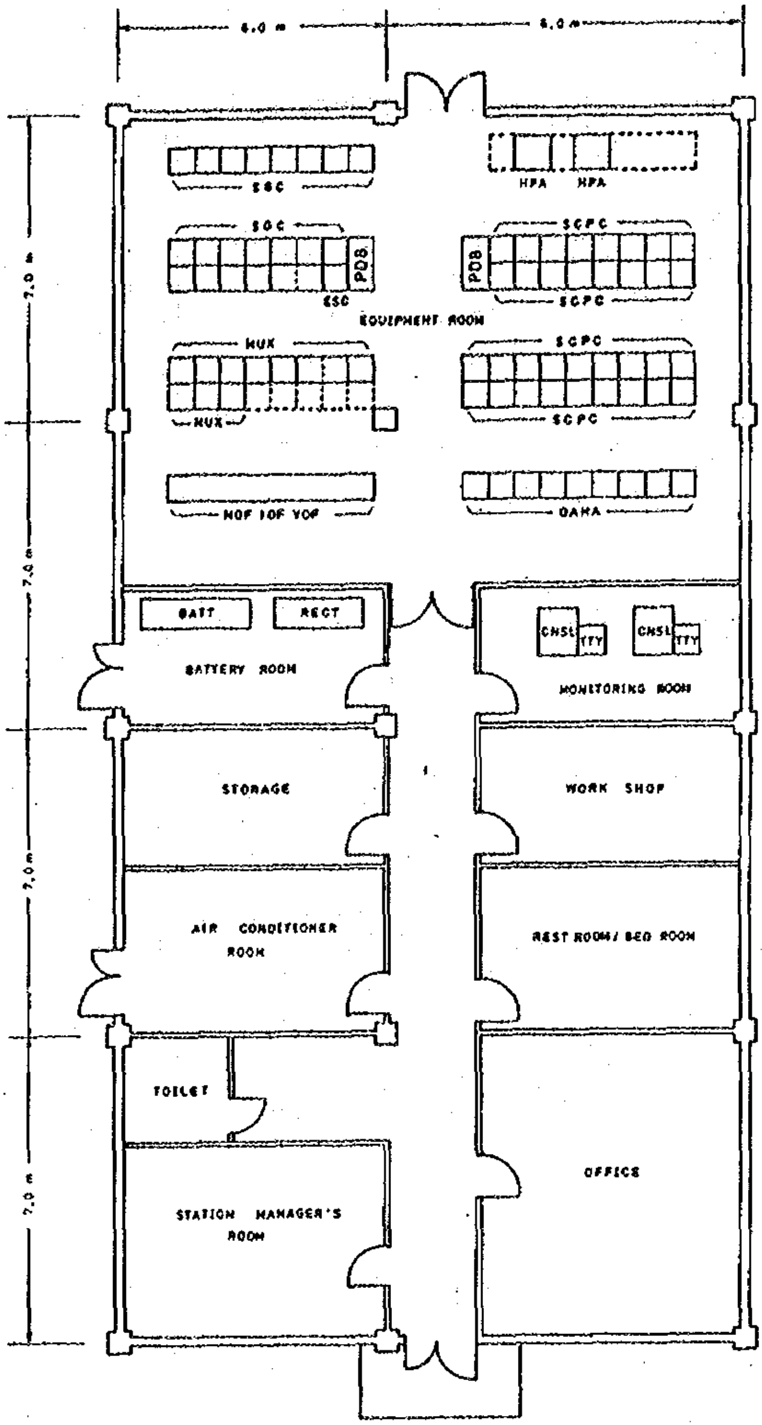


Figure 6-20 Typical Site Layout of Master Earth Station



Note : * Power shelter with dual engine-generator will be installed where the commercial power is not available.

Figure 6-21 Typical Site Layout of Rural Earth Station



NOTE

HPA : HIGH POWER AMPLIFIER
SCPC : SCPC TERMINAL EQPT.
PDB : POWER DISTRIBUTION BOARD
DAMA : DAMA CONTROL EQPT.
SGC : SIGNAL CONVERTER
MUX : MULTIPLEX TERMINAL EQPT. FOR TERRESTRIAL APPROACH LINK
CNSL : CONSOLE.
TTY : TELETYPE
RECT : RECTIFIER.
BATT : BATTERY.

Figure 6-22 Typical Equipment Floor Layout of Master Earth Station (1/2)

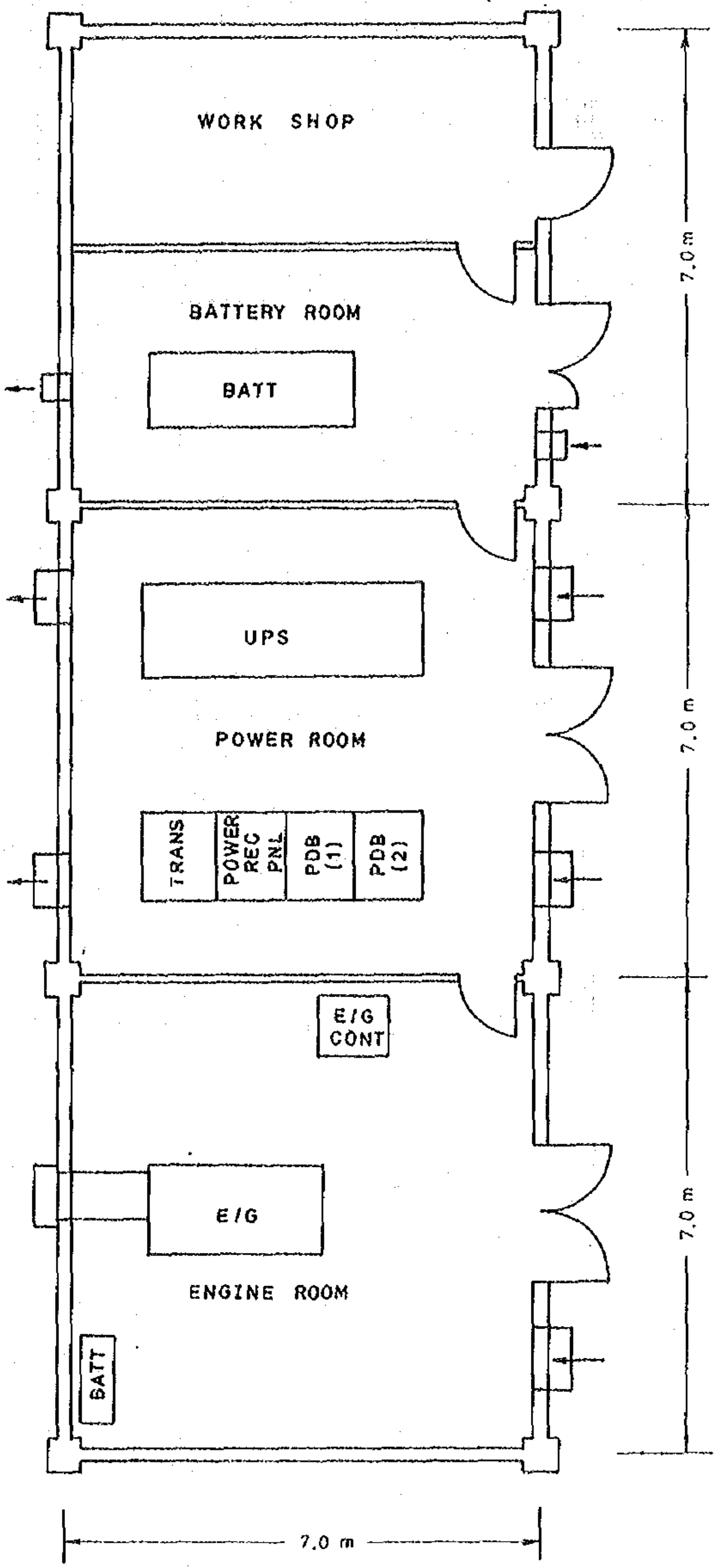
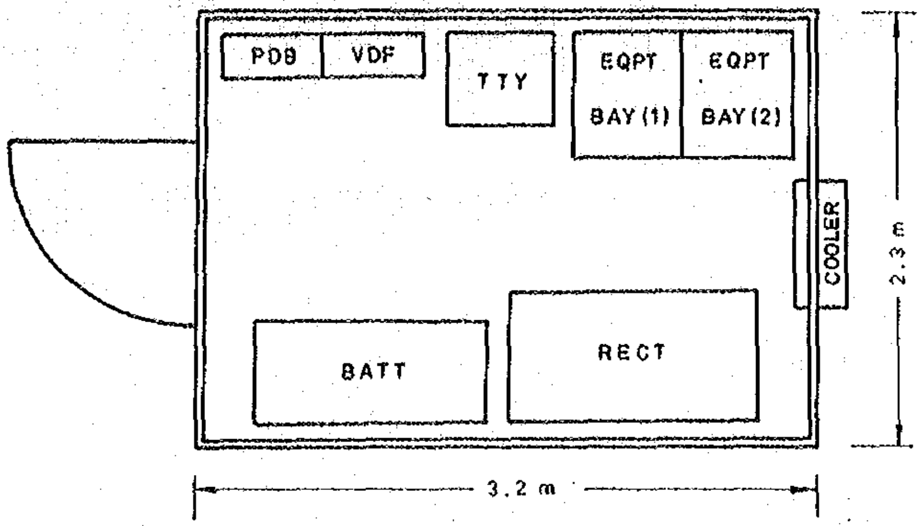
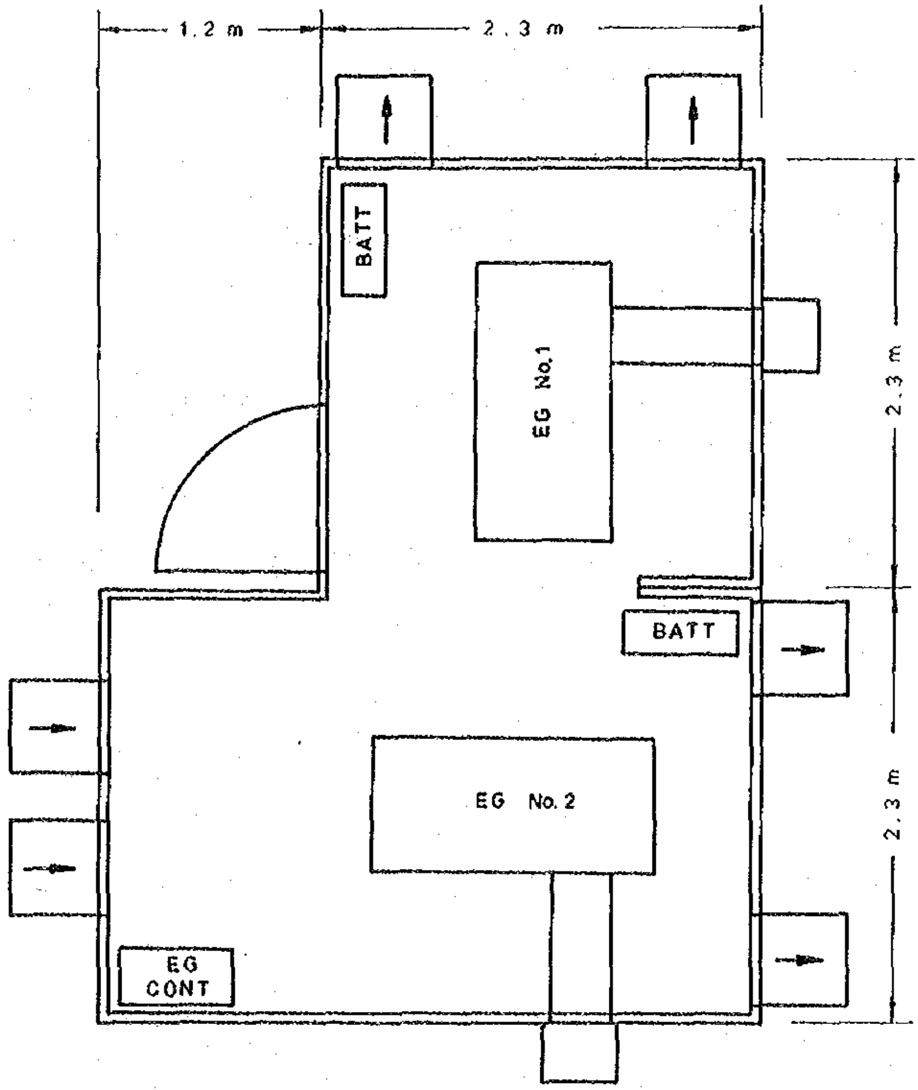


Figure 6-22 Typical Equipment Floor Layout of Master Earth Station (2/2)



(a) Equipment Shelter



(b) Power Shelter

Figure 6-23 Typical Equipment Floor Layout of Rural Earth Station

PART VII. System Maintenance

PART VII System Maintenance

1. General

This Part VII describes the maintenance organization and practices for the existing terrestrial microwave system and, based on them, the maintenance philosophy used in this study.

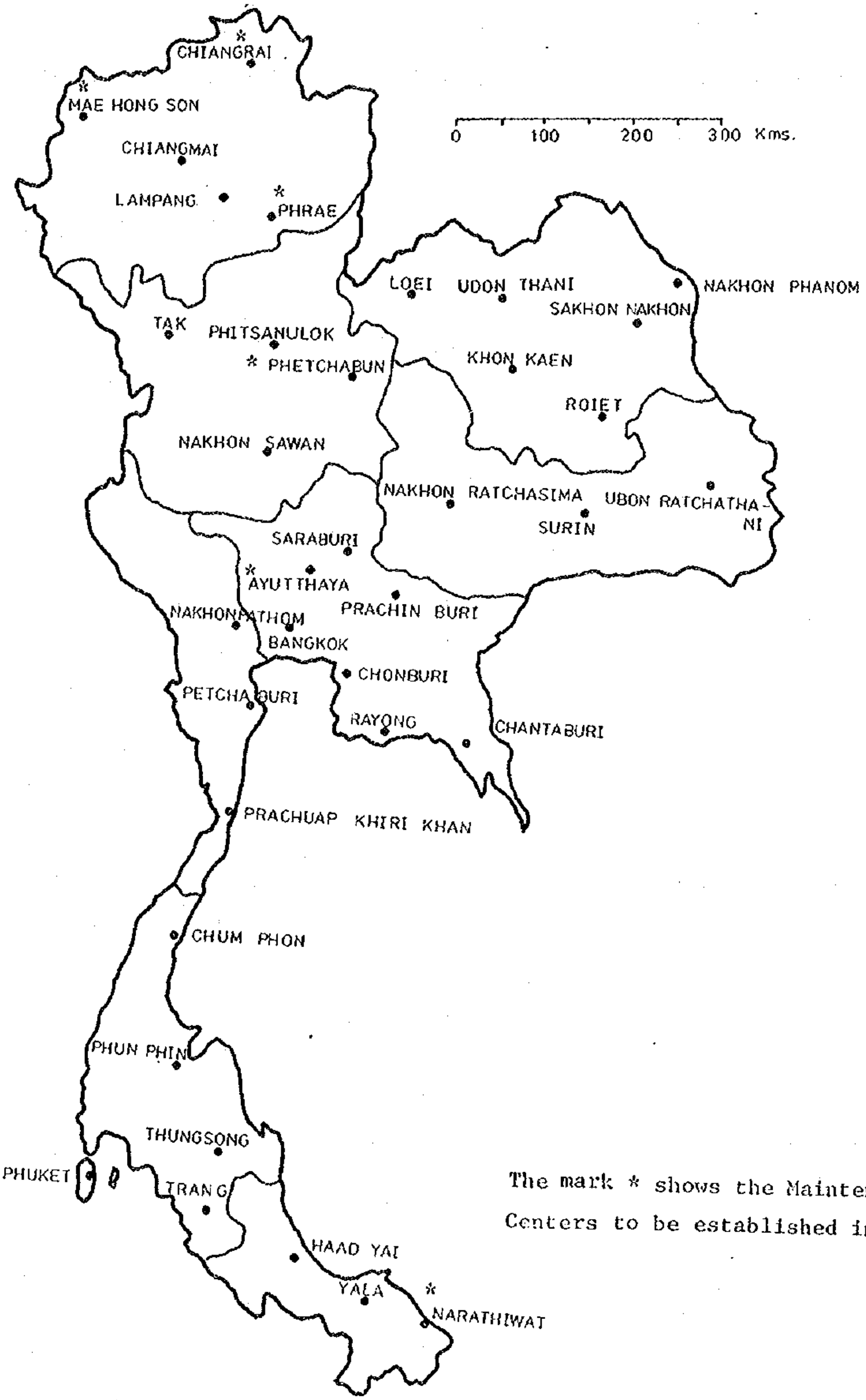
This projected system, no matter whether it will be implemented by the terrestrial radio system or the domestic satellite system, requires a large number of station sites. For this reason, it is so planned that the unattended operation system be adopted to the possible maximum for the radio stations including the earth stations, not to speak of through repeater stations, so that the effective system maintenance with a minimum manpower requirement will be possible.

Since TOT holds approximately 15 years experience in the maintenance of its existing trunk microwave system, the existing maintenance organization will be utilized as much as possible so that only the necessary personnel recruitment will be sufficient for maintenance service for the projected system.

2. Maintenance Organization and Practices

2-1 Existing Maintenance Organization and Practices

TOT's existing maintenance organization for the trunk microwave system consists of eight maintenance districts covering the whole country as shown in Figure 7-1. Each maintenance district holds Maintenance Centers. The total number of Maintenance Centers for the whole country is 30 (which will increase to 35 when the spur link project now in progress is completed in 1979).



The mark * shows the Maintenance Centers to be established in 1979

Figure 7-1 Locations of Maintenance Centers

Maintenance practices which include the supervision of system operation, keeping of measuring equipment and spare panels in good order, trouble-shooting, and periodic tests, are undertaken by the maintenance staff on permanent duty at the Maintenance Centers.

Remote supervisory items for each Maintenance Center are as follows :

1) Radio equipment failure
2) Multiplex major failure
3) Multiplex minor failure
4) Power supply failure to repeater
5) Fuse alarm
6) Cable alarm
7) Charger high-low alarm
8) ac power failure
9) Engine generator failure
10) Door open
11) Aircraft warning light failure

At each Maintenance Center, an average of 10 maintenance personnel are on duty on around-the-clock basis in three shifts. After the completion of the spur link project now in progress, the assignment of five additional persons on the average at each Maintenance Center is scheduled. Each unattended repeater station is located within the radius of approximately 50 km from the Maintenance Center. The maintenance team from the Maintenance Center can reach an unattended repeater station in distress within two hours on the average.

Trouble-shooting beyond the ability of the Maintenance Center, such as replacement of parts in a panel, is carried out at the

Repair Center located in the National Toll Center in Bangkok. Equipment unit repaired at the Repair Center is sent back in 48 hours to the Maintenance Center from which it came. The average number of repairs per month at the Repair Center is 100 panels.

At the Repair Center, spare parts of 10,000 kinds are kept in store at all times. Inventory management for such spare parts plus the repair of panels in trouble and annual periodic system test are carried out by 35 staff personnel.

The annual spare parts purchase budget of the Repair Center amounts to approximately 15 million Baht. Spare parts to be purchased comprise radio equipment parts, multiplex equipment parts including PCM equipment parts, and power plant parts. Out of the spare parts purchase budget referred to above, 2 million Baht is set aside for procurement of parts to be used for equipment installed in the Metropolitan Area of Bangkok, the capital city.

2-2 Maintenance Philosophy for Rural Long Distance Public Telephone Service

2-2-1 Terrestrial Radio System

The maintenance organization is, basically, to make a full use of 35 Maintenance Centers scattered throughout the country, provided that the necessary additional maintenance personnel will be recruited. The number of stations to be supervised (unattended repeater stations) envisaged in this Project is 17 per Maintenance Center and the average access time required for a maintenance team is two hours.

Therefore, assuming that the periodic inspection of repeater stations is carried out once every three months, the recruitment of some maintenance staffs per Maintenance Center will be sufficient. Difficult repairs and overhauls of equipment units, which cannot be performed at the Maintenance Center, are to be undertaken by the Repair Center in Bangkok as in the case of similar repairs and overhauls of equipment units used in the existing microwave system.

The maintenance philosophy adopted in this study features the following :

(1) Maintenance practices, including system supervision, procurement of measuring equipment and spare units/parts, trouble-shooting, and periodic tests, will be undertaken at 35 Maintenance Centers.

(2) One Maintenance Center will supervise an average of 17 supervised stations (unattended repeater stations) located in 2-3 Administrative Provinces. Maximum access time required for a maintenance team will be six hours.

(3) Engineering service channels for maintenance use will consist of omnibus order wire and remote supervisory circuit, and for each of them one telephone channel will be assigned. To provide the engineering service channel, carrier multiplex equipment will be additionally installed in part of the existing microwave system.

(4) One maintenance vehicle for periodic test/inspection will be assigned at each Maintenance Center.

(5) Two respective sets of measuring equipment, spare units/parts, instruction handbooks and so forth will be distributed to each Maintenance Center, and one respective set of the same to the Repair Center in Bangkok.

(6) One trailer type engine generator of 7.5 kVA capacity to

be used during power failure at a supervised station will be assigned at each Maintenance Center.

(7) Though not included in this study, it is preferable to install centralized supervisory equipment at each Maintenance Center for the purpose of automatic recording of troubles at supervised stations under its control.

2-2-2 Domestic Satellite System

The maintenance philosophy for the domestic satellite system is esstially the same as that for the terrestrial radio system. Engineering service channel is planned as follows :

(1) One dialling order wire channel will be established between each rural earth station and master earth station.

(2) Each Maintenance Center will be equipped with supervisory display unit to facilitate supervision of the operating condition of rural earth stations under its control.

Supervisory signal transmission route will consist of RS → Satellite → MS → existing microwave system → MC, where RS stands for rural earth station, MS for master earth station, and MC for Maintenance Center.

One telephone channel of the existing microwave system will be assigned to each Maintenance Center for transmission of supervising signals. This telephone channel will be used for order wire circuit also.

(3) Master earth station will make centralized supervision of all rural earth stations. Troubles at rural earth stations will be automatically recorded.

PART VIII. Construction Cost Estimates and Economic Comparison by Systems

PART VIII Construction Cost Estimates and Economic Comparison by Systems

1. General

This Part VIII deals with construction cost estimates for Rural Long Distance Public Telephone Service by terrestrial radio system and by domestic satellite system, and presents economic comparison between the two systems.

Construction cost estimates are mainly based on overseas international tender prices. However, for rural communication service by the domestic satellite system, the examples to depend upon for construction cost estimate are few internationally so that the assistance from a Canadian telecommunications consulting firm having substantial experience in the utilization of the domestic satellite system was solicited for part of cost estimate work.

The methodology used in construction cost estimates was firstly to calculate in detail the construction cost for 75 stations included in the four objective areas of detailed study, i.e., northern, central, northeastern and southern areas of Thailand, according to the types of stations. Then, the average cost per station or per radio hop was calculated and by this average cost, in principle, the total construction cost for all stations involved in this Project was calculated.

Economic comparison between terrestrial radio system and domestic satellite system was made in terms of present worth of annual cost. For the satellite transponder lease rate and related lease conditions, data obtained directly from the Directorate General of Posts and Telecommunications of Indonesia was used.

2. Construction Cost Estimates

2-1 Project Size

Parameters that indicate the Project size, which are essential for the construction cost estimates, are shown below. Those parameters include the number of required transmission systems, total number of stations, and total access road length.

2-1-1 Terrestrial Radio System

(1) Terrestrial Radio Link		1984	1989	1994
1) Radio System				
New radio station		491	491	491
Existing radio station		137	137	137
Radio hop		529	529	529
Radio system		531	531	543
Total distance of radio hops in km	approx.	12,000	12,000	12,000
2) Supervisory System				
Supervised station		604	604	604
Supervising station		35	35	35
3) Carrier Multiplex System				
Total telephone channels		2,513	3,763	8,218
4) Tower				
New tower (guyed tower)		491	491	491
Existing tower to be replaced		19	19	19
5) Power Plant				
dc power plant		639	639	639
Dual engine generator		121	121	121
Trailer type engine generator		35	35	35

	1984	1989	1994
6) Building			
Shelter for radio equipment	491	491	491
7) Access Road			
Repeater station that requires access road	46	46	46
Total length of access roads in km	111.5	111.5	111.5

2-1-2 Domestic Satellite System

(1) Satellite Link	1984	1989	1994
1) Master Earth Station	1	1	1
Total telephone channels	349	474	242
Power plant	1	1	1
2) Approach Link			
Total telephone channels (including engineering service channels)	384	509	277
Length of coaxial cable in km	2.5	2.5	2.5
3) Rural Earth Station	340	340	146
Total telephone channels	1,144	1,413	749
dc power plant	340	340	146
Dual engine generator	65	65	49
4) Building			
Building for master earth station	2	2	2
Shelter for rural earth station	340	340	146

(2) Terrestrial Radio Link

	1984	1989	1994
1) Radio System			
New radio station	113	113	303
Existing radio station	77	77	114
Radio hop	134	134	329
Radio system	134	134	337
Total distance of radio hops in km approx.	3,000	3,000	7,000
2) Supervisory System			
Supervised station	169	169	391
Supervising station	33	33	35
3) Carrier Multiplex System			
Total telephone channels	1,369	1,369	2,350
4) Tower			
New tower (guyed tower)	113	113	303
Existing tower to be replaced	11	11	16
5) Power Plant			
dc power plant	178	178	351
Dual engine generator	12	12	66
Trailer type engine generator	35	35	35
6) Building			
Shelter for radio equipment	113	113	303
7) Access Road			
Repeater station that requires access road	8	8	33
Total length of access roads in km	26.6	26.6	93.6

2-2 Construction Cost Estimate Conditions

Construction cost estimates are subject to the following conditions :

1) Construction work will be carried out by the Contractor on full turn-key basis.

2) For station buildings except that of master earth station, equipment shelters will be used. This applies to both the terrestrial radio system and the domestic satellite system.

3) For power plant, both TOT information and field survey result concerning commercial power availability are taken into consideration. One trailer type engine generator for emergency use will be assigned to each of 35 Maintenance Centers.

4) In case the UHF system is additionally established on the existing microwave system, the station buildings, towers and ac power source of the existing system will be utilized.

5) Construction cost for extension of the existing microwave system is not included in the cost of this Project.

6) Cable length in the cable section is estimated by selecting cable route on a map of a scale of 1 to 50,000.

7) Entrance cable will be terminated in the distribution box installed on the pole. Drop wire and telephone set costs are not included in the cost of this Project.

8) Access road length required for each radio repeater station is based on data supplied by TOT.

9) At the rural stations where switching equipment will be introduced, 2W/4W terminating set will not be installed on the radio equipment side. It will be installed on the

switching equipment side.

10) For civil work cost, such as building and road construction cost, similar cost on TOT record is used.

11) Costs pertaining to access road construction, inland transportation, part of installation, and on-the-job training are defrayed from the local currency budget.

2-3 Cost Estimates

Project cost estimates by terrestrial radio system and by domestic satellite system are given in Table 8-1 through Table 8-3.

3. Economic Comparison by Systems

Economic comparison between terrestrial radio system and domestic satellite system is carried out in terms of present worth of annual cost. Conditions by which the economic comparison is made are as follows :

(1) The period of comparison is 15 years.

(2) With respect to the maintenance cost for communication equipment, there is no much difference between the two systems, so that this item is withdrawn from the list of comparison. Only the access road maintenance cost is taken up for consideration.

(3) In the terms of operation and hence in the cost of operation also, there is no much difference between the two systems. Only the satellite transponder lease rate is taken up for consideration.

(4) Service life of communication equipment is based on ITU data.

(5) Both systems need additional financial investment for their respective system extensions five years and 10 years after the service-in.

Table 8-1 Project Cost of Terrestrial Radio System (1/3)

1984

Item	Foreign Currency Portion		Local Currency Portion
	Thousand Japanese Yen	Equivalent US Dollars	Hundred Thai Baht
1. Terrestrial Radio System			
A. Radio, Multiplex & Power	13,298,253	73,879,183	-
B. Tower	1,555,791	8,643,283	-
C. Installation Materials	468,337	2,601,872	-
D. Maintenance Facilities	766,119	4,256,217	-
E. Sub-total (FOB)	16,088,500	89,380,555	-
F. -ditto- (CIF)	16,651,598	92,508,878	-
G. Tower Erection	301,702	1,676,122	703,971
H. Installation & Testing	723,983	4,022,128	1,689,294
I. Training	2,600	14,444	665
J. Access Road	-	-	2,230,000
K. Sub-total	17,679,883	98,221,572	4,623,930
2. Cable System			
A. Cable & Other Materials (FOB)	150,387	835,483	-
B. -ditto- (CIF)	155,650	864,722	-
C. Installation & Testing	39,355	218,639	91,828
D. Sub-total	195,005	1,083,361	91,828
3. Basic Cost	17,874,888	99,304,933	4,715,758
4. Contingency			
A. Physical	536,247	2,979,150	141,473
B. Price	1,787,489	9,930,494	707,364
C. Sub-total	2,323,736	12,909,644	848,837
5. Total Project Cost	20,198,624	112,214,577	5,564,595

Exchange Rate : US$ 1 = 180 Japanese Yen

Table 8-1 Project Cost of Terrestrial Radio System (2/3)

1989

Item	Foreign Currency Portion		Local Currency Portion
	Thousand Japanese Yen	Equivalent US Dollars	Hundred Thai Baht
1. Terrestrial Radio System			
A. Radio, Multiplex & Power	177,349	985,272	-
B. Tower	-	-	-
C. Installation Materials	6,207	34,483	-
D. Maintenance Facilities	-	-	-
E. Sub-total (FOB)	183,556	1,019,755	-
F. -ditto- (CIF)	189,980	1,055,444	-
G. Tower Erection	-	-	-
H. Installation & Testing	8,260	45,889	19,273
I. Training	-	-	-
J. Access Road	-	-	-
K. Sub-total	198,240	1,101,333	19,273
2. Cable System			
A. Cable & Other Materials (FOB)	-	-	-
B. -ditto- (CIF)	-	-	-
C. Installation & Testing	-	-	-
D. Sub-total	-	-	-
3. Basic Cost	198,240	1,101,333	19,273
4. Contingency			
A. Physical	5,947	33,039	578
B. Price	19,824	110,133	2,891
C. Sub-total	25,771	143,172	3,469
5. Total Project Cost	224,011	1,244,505	22,742

Exchange Rate : US$ 1 = 180 Japanese Yen

Table 8-1 Project Cost of Terrestrial Radio System (3/3)

1994

Item	Foreign Currency Portion		Local Currency Portion
	Thousand Japanese Yen	Equivalent US Dollars	Hundred Thai Baht
1. Terrestrial Radio System			
A. Radio, Multiplex & Power	850,152	4,723,067	-
B. Tower	-	-	-
C. Installation Materials	29,755	165,306	-
D. Maintenance Facilities	-	-	-
E. Sub-total (FOB)	879,907	4,888,373	-
F. -ditto- (CIF)	910,704	5,059,467	-
G. Tower Erection	-	-	-
H. Installation & Testing	39,596	219,978	92,391
I. Training	-	-	-
J. Access Road	-	-	-
K. Sub-total	950,300	5,279,445	92,391
2. Cable System			
A. Cable & Other Materials (FOB)	5,846	32,478	-
B. -ditto- (CIF)	6,050	33,611	-
C. Installation & Testing	176	978	410
D. Sub-total	6,226	34,589	410
3. Basic Cost	956,526	5,314,034	92,801
4. Contingency			
A. Physical	28,696	159,422	2,784
B. Price	95,653	531,406	13,920
C. Sub-total	124,349	690,828	16,704
5. Total Project Cost	1,080,875	6,004,862	109,505

Exchange Rate : US$ 1 = 180 Japanese Yen

Table 8-2 Project Cost of Domestic Satellite System (1/3)

1984

Item	Foreign Currency Portion		Local Currency Portion
	Thousand Japanese Yen	Equivalent US Dollars	Hundred Thai Baht
1. Satellite System			
A. Master Earth Station (including Terrestrial Approach Link)	1,555,346	8,640,811	78,000
B. Rural Earth Station	23,201,440	128,896,889	-
C. Maintenance Center (Supervisory System)	129,500	719,444	-
D. Installation Materials	829,370	4,607,611	-
E. Maintenance Facilities	1,313,474	7,297,078	-
F. Sub-total (FOB)	27,029,130	150,161,833	-
G. -ditto- (CIF)	27,975,150	155,417,500	-
H. Installation & Testing	1,364,782	7,582,122	3,184,490
I. Training & System Maintenance	61,000	338,889	665
J. Sub-total	29,400,932	163,338,511	3,263,155
2. Terrestrial Radio System			
A. Radio, Multiplex & Power	3,879,698	21,553,878	-
B. Tower	421,013	2,338,961	-
C. Installation Materials	138,660	770,333	-
D. Maintenance Facilities	355,150	1,973,056	-
E. Sub-total (FOB)	4,794,521	26,636,228	-
F. -ditto- (CIF)	4,962,329	27,568,494	-
G. Tower Erection	88,322	490,678	206,085
H. Installation & Testing	215,753	1,198,628	503,424
I. Training	2,600	14,444	665
J. Access Road	-	-	532,000
K. Sub-total	5,269,004	29,272,244	1,242,174
3. Cable System			
A. Cable & Other Materials (FOB)	65,930	366,278	-
B. -ditto- (CIF)	68,237	379,094	-
C. Installation & Testing	15,571	86,506	36,332
D. Sub-total	83,808	465,600	36,332
4. Basic Cost	34,753,744	193,076,355	4,541,661
5. Contingency			
A. Physical	1,042,612	5,792,289	136,251
B. Price	3,475,374	19,307,633	681,249
C. Sub-total	4,517,986	25,099,922	817,500
6. Total Project Cost	39,271,730	218,176,277	5,359,161

Exchange Rate : US$ 1 = 180 Japanese Yen

Table 8-2 Project Cost of Domestic Satellite System (2/3)

1989

Item	Foreign Currency Portion		Local Currency Portion
	Thousand Japanese Yen	Equivalent US Dollars	Hundred Thai Baht
1. Satellite System			
A. Master Earth Station (including Terrestrial Approach Link)	170,683	948,239	-
B. Rural Earth Station	240,755	1,337,528	-
C. Maintenance Center	-	-	-
(Supervisory System)			
D. Installation Materials	14,400	80,000	-
E. Maintenance Facilities	-	-	-
F. Sub-total (FOB)	425,838	2,365,767	-
G. -ditto- (CIF)	440,742	2,448,567	-
H. Installation & Testing	19,163	106,461	44,713
I. Training & System Maintenance	-	-	-
J. Sub-total	459,905	2,555,028	44,713
2. Terrestrial Radio System			
A. Radio, Multiplex & Power	146,357	813,094	-
B. Tower	-	-	-
C. Installation Materials	5,122	28,456	-
D. Maintenance Facilities	-	-	-
E. Sub-total (FOB)	151,479	841,550	-
F. -ditto- (CIF)	156,781	871,006	-
G. Tower Erection	-	-	-
H. Installation & Testing	6,817	37,872	15,906
I. Training	-	-	-
J. Access Road	-	-	-
K. Sub-total	163,598	908,878	15,906
3. Cable System			
A. Cable & Other Materials (FOB)	-	-	-
B. -ditto- (CIF)	-	-	-
C. Installation & Testing	-	-	-
D. Sub-total	-	-	-
4. Basic Cost	623,503	3,463,906	60,619
5. Contingency			
A. Physical	18,705	103,917	1,819
B. Price	62,350	346,389	9,093
C. Sub-total	81,055	450,306	10,912
6. Total Project Cost	704,558	3,914,212	71,531

Exchange Rate : US$ 1 = 180 Japanese Yen

Table 8-2 Project Cost of Domestic Satellite System (3/3)

1994

Item	Foreign Currency Portion		Local Currency Portion
	Thousand Japanese Yen	Equivalent US Dollars	Hundred Thai Baht
1. Satellite System			
A. Master Earth Station (including Terrestrial Approach Link)	-	-	-
B. Rural Earth Station	-	-	-
C. Maintenance Center (Supervisory System)	-	-	-
D. Installation Materials	-	-	-
E. Maintenance Facilities	-	-	-
F. Sub-total (FOB)	-	-	-
G. -ditto- (CIF)	-	-	-
H. Installation & Testing	-	-	-
I. Training & System Maintenance	-	-	-
J. Sub-total	-	-	-
2. Terrestrial Radio System			
A. Radio, Multiplex & Power	5,319,096	29,550,533	-
B. Tower	579,690	3,220,500	-
C. Installation Materials	186,508	1,036,156	-
D. Maintenance Facilities	182,559	1,014,217	-
E. Sub-total (FOB)	6,267,853	34,821,406	-
F. -ditto- (CIF)	6,487,228	36,040,156	-
G. Tower Erection	110,044	611,356	256,769
H. Installation & Testing	282,053	1,566,961	658,124
I. Training	-	-	-
J. Access Road	-	-	1,340,000
K. Sub-total	6,879,325	38,218,473	2,254,893
3. Cable System			
A. Cable & Other Materials (FOB)	47,376	263,200	-
B. -ditto- (CIF)	49,034	272,411	-
C. Installation & Testing	12,042	66,900	28,099
D. Sub-total	61,076	339,311	28,099
4. Basic Cost	6,940,401	38,557,784	2,282,992
5. Contingency			
A. Physical	208,212	1,156,733	68,490
B. Price	694,040	3,855,778	342,449
C. Sub-total	902,252	5,012,511	410,939
6. Total Project Cost	7,842,653	43,570,295	2,693,931

Exchange Rate : US$ 1 = 180 Japanese Yen

Table 8-3 Project Cost of Domestic Satellite System with Non-Redundancy
(1989 & 1994 Refer to Table 8-2)

Item	Foreign Currency Portion		1984 Local Currency Portion
	Thousand Japanese Yen	Equivalent US Dollars	Hundred Thai Baht
1. Satellite System			
A. Master Earth Station (including Terrestrial Approach Link)	1,555,346	8,640,811	78,000
B. Rural Earth Station	16,373,560	90,964,222	-
C. Maintenance Center (Supervisory System)	129,500	719,444	-
D. Installation Materials	590,394	3,279,967	-
E. Maintenance Facilities	960,131	5,334,061	-
F. Sub-total (FOB)	19,608,931	108,938,505	-
G. -ditto- (CIF)	20,295,244	112,751,356	-
H. Installation & Testing	1,046,776	5,815,422	2,442,478
I. Training & System Maintenance	61,000	338,889	665
J. Sub-total	21,403,020	118,905,667	2,521,143
2. Terrestrial Radio System			
A. Radio, Multiplex & Power	3,879,698	21,553,878	-
B. Tower	421,013	2,338,961	-
C. Installation Materials	138,660	770,333	-
D. Maintenance Facilities	355,150	1,973,056	-
E. Sub-total (FOB)	4,794,521	26,636,228	-
F. -ditto- (CIF)	4,962,329	27,568,494	-
G. Tower Erection	88,322	490,678	206,085
H. Installation & Testing	215,753	1,198,628	503,424
I. Training	2,600	14,444	665
J. Access Road	-	-	532,000
K. Sub-total	5,269,004	29,272,244	1,242,174
3. Cable System			
A. Cable & Other Materials (FOB)	65,930	366,278	-
B. -ditto- (CIF)	68,237	379,094	-
C. Installation & Testing	15,571	86,506	36,332
D. Sub-total	83,808	465,600	36,332
4. Basic Cost	26,755,832	148,643,511	3,799,649
5. Contingency			
A. Physical	802,675	4,459,306	113,989
B. Price	2,675,583	14,864,350	569,947
C. Sub-total	3,478,258	19,323,656	683,936
6. Total Project Cost	30,234,090	167,967,167	4,483,585

Exchange Rate : US$ 1 = 180 Japanese Yen

(6) For interest rate, the interest rate of 7.9% per annum is used.

(7) Although the annual increase of commodity prices and labor cost is the general trend, it is presumed that this price and labor cost uptrend can be offset by the equipment productivity improvement. This presumption is to simplify the comparison.

Present worth of annual cost is given by the following equation :

$$P = ((C - S) \times A + S \times i + C_m + C_o) \times B$$

where P : Present worth of annual cost

C : Initial cost

S : Net salvage

n : Number of years

i : Interest rate (7.9%)

C_m : Maintenance cost

C_o : Operation cost

A : Annuity from present amount

$$\left(\frac{i\,(1 + i)^n}{(1 + i)^n - 1} \right)$$

B : Present worth of annuity

$$\left(\frac{(1 + i)^n - 1}{i\,(1 + i)^n} \right)$$

$$\begin{bmatrix} (C - S) \times A & : \text{Amortization cost} \\ (C - S) \times A + S \times i + C_m + C_o & : \text{Annual cost} \end{bmatrix}$$

Present worth of annual cost calculations for terrestrial radio system and domestic satellite system by the above equation appear in Table 8-4 through Table 8-6.

Table 8-4 Present Worth of Annual Cost for Terrestrial Radio System   Unit : Million Japanese Yen

Period (year)	Facility	Initial cost	Service life (year)	Net salvage	Annuity from present amount	Amortization cost	Maintenance/ operation cost	Annual cost	Present worth of annuity	Present worth of annual cost
1-15	Radio & Mux	20,074	15	0	0.1161	2,331	-	2,331	8.6120	20,075
6-15	(Extension of Mux)	218	15	73	0.1161	23	-	23	4.6087	106
11-15	Radio & Mux	1,043	15	695	0.1161	95	-	95	1.8715	178
1-15	Cable	287	17	0	0.1089	31	-	31	8.6120	267
11-15	-ditto-	7	17	0	0.1089	1	-	1	1.8715	2
1-15	Access road	2,230	Inf.	2,230	0.0790	176	22	198	8.6120	1,705
									Total :	22,333

Table 8-5 Present Worth of Annual Cost for Domestic Satellite System Unit : Million Japanese Yen

Period (year)	Facility	Initial cost	Service life (year)	Net salvage	Annuity from present amount	Amortization cost	Maintenance/ operation cost	Annual cost	Present worth of annuity	Present worth of annual cost
1-15	Earth Stations	19,348	15	0	0.1161	2,246	135	2,381	8.6120	20,505
1-10	-ditto-	13,316	15	4,439	0.1161	1,381	-	1,381	6.7405	9,309
1-15	Radio & Mux	5,979	15	0	0.1161	694	-	694	8.6120	5,977
6-15	(Extension of Mux)	180	15	60	0.1161	19	-	19	4.6087	88
11-15	Radio & Mux	7,794	15	5,196	0.1161	712	-	712	1.8715	1,333
6-15	(Extension of Terminal)	471	15	157	0.1161	49	-	49	4.6087	226
6-10	-ditto-	34	15	23	0.1161	3	-	3	2.7372	8
1-15	Cable	120	17	0	0.1089	13	-	13	8.6120	112
11-15	-ditto-	89	17	0	0.1089	10	-	10	1.8715	19
1-15	Access road	532	Inf.	532	0.0790	42	5	47	8.6120	405
11-15	-ditto-	1,340	Inf.	1,340	0.0790	106	13	119	1.8715	223
									Total :	38,205

Table 8-6 Present Worth of Annual Cost for Domestic Satellite System with Non-Redundancy

Unit : Million Japanese Yen

Period (year)	Facility	Initial cost	Service life (year)	Net salvage	Annuity from present amount	Amortization cost	Maintenance/ operation cost	Annual cost	Present worth of annuity	Present worth of annual cost
1-15	Earth Station	14,384	15	0	0.1161	1,670	135	1,805	8.6120	15,545
1-10	-ditto-	9,540	15	3,180	0.1161	990	-	990	6.7405	6,673
1-15	Radio & Mux	5,979	15	0	0.1161	694	-	694	8.6120	5,977
6-15	(Extension of Mux)	180	15	60	0.1161	19	-	19	4.6087	88
11-15	Radio & Mux	7,794	15	5,196	0.1161	712	-	712	1.8715	1,333
6-15	(Extension of Terminal)	471	15	157	0.1161	49	-	49	4.6087	226
6-10	-ditto-	34	15	23	0.1161	3	-	3	2.7372	8
1-15	Cable	120	17	0	0.1089	13	-	13	8.6120	112
11-15	-ditto-	89	17	0	0.1089	10	-	10	1.8715	19
1-15	Access road	532	Inf.	532	0.0790	42	5	47	8.6120	405
11-15	-ditto-	1,340	Inf.	1,340	0.0790	106	13	119	1.8715	223
									Total :	30,609

PART IX. All-round Evaluation of Optimum Transmission System Plan

PART IX All-round Evaluation of Optimum Transmission System Plan

1. General

This Part IX makes an all-round comparative study of the terrestrial radio system plan (hereafter called Plan A) and the domestic satellite system plan (hereafter called Plan B) which were reviewed in all their essential aspects in the preceding Parts.

The all-round evaluation of both Plan A and Plan B from economic and technical viewpoints is intended to arrive at a conclusion concerning what the optimum transmission system for Rural Long Distance Public Telephone Service should be.

2. Itemwise Evaluation

For all-round evaluation of relative merits of a transmission system, the economic evaluation in terms of present worth of annual cost and the performance evaluation are necessary. The former takes up for evaluation the annual cost including initial cost, maintenance cost and operation cost. The latter considers transmission quality, system reliability, system extension flexibility and so forth.

Following is the result of item by item comparative study of Plan A and Plan B.

2-1 Comparison by Present Worth of Annual Cost

The present worth of annual cost is :

Plan A : 22,333 million Japanese Yen
(124,072 thousand U.S. Dollars)

Plan B : 38,205 million Japanese Yen
(212,250 thousand U.S. Dollars)

Plan A costs less than Plan B by 15,872 million Japanese Yen.

This advantage of Plan A reflects the fact that Plan B requires higher construction cost per rural station and hence higher amortization cost.

Although the initial cost of earth stations and the satellite transponder lease rate are considered to be remarkably reduced in the future as the result of continued technical renovation and productivity improvement, both these costs will remain at practically the same level as shown in this study about the time the tender announcement for this Project is made in 1979-80.

If the non-redundant configuration which does not use standby equipment is adopted for the rural earth station system configuration, the present worth of annual cost decreases by 7,596 million Japanese Yen. In this case, however, the comparison cannot be made on equal base to the terrestrial radio system plan that uses standby equipment.

Therefore, in this study, the non-redundant configuration with its cost estimate is taken up for the purpose of reference only but is not included in the system comparison.

2-2 Transmission Performance and System Reliability

The objective signal to noise ratios of both Plan A and Plan B, established in Part VI, are reproduced below.

	Plan A	Plan B
Terrestrial section	57 dB	57 dB
Satellite link	-	50 dB

As far as the signal to noise ratio is concerned, Plan A commands greater advantage by several dB over Plan B.

Delay time is another demerit of Plan B in the aspect of transmission performance. More precisely, radio propagation from ground to satellite and back to ground takes approximately 0.3 seconds, and this means that the response of the other party is delayed by approximately 0.6 seconds.

As regards the reliability of communication equipment, there is no much difference between Plan A and Plan B because the full redundant configuration is adopted in both plans. Qualitative comparison of system reliability between Plan A and Plan B follows.

Traffic estimation is made on the assumption that one half of originating calls from each RS (rural earth station) is to Bangkok, the capital city, and the other half is to the nearby PC (Primary Center).

In this case, the traffic route configuration is as follows :

Plan A :

(1) Traffic to Bangkok :

RS → PC —existing microwave system→ Bangkok

(2) Traffic to nearby PC :

RS → PC

Plan B :

(1) Traffic to Bangkok :

RS → satellite → MS (Master earth station)

(2) Traffic to nearby PC :

RS → satellite → MS —existing microwave system→ PC

As shown above, in Plan A, calls to Bangkok are through the existing microwave system and calls to nearby PC is via UHF system which uses several repeater stations. However, in Plan B, calls to Bangkok are via satellite link and calls to nearby PC are via one satellite link plus the existing microwave system.

That is to say, in both plans, almost the same volume of calls is carried on the existing microwave system, though the call destinations are different, one being Bangkok and the other the nearby PC.

Therefore, it can be safely presumed that, in the system reliability also, there is little to choose between the two plans.

2-3 Maintenance/Operation Cost

Both Plan A and Plan B contemplate to maintain rural stations as unattended stations and to keep the maintenance staff at 35 Maintenance Centers. Thus, for maintenance personnel cost, no substantial difference can be found between the two plans. Master earth station in Plan B needs some 20 maintenance engineers.

Plan A requires 46 more through repeater stations than Plan B so that the number of maintenance personnel required increases to that extent, resulting in almost the same maintenance manpower level as in Plan B. Hence no major difference between the two plans in the maintenance staff cost.

For other maintenance/operation cost, Plan B envisages higher operation cost corresponding to the satellite transponder lease rate whereas Plan A anticipates road and tower repair/improvement cost increase.

2-4 System Extension Flexibility

Plan A features that the terminal section of transmission route holds transmission capacity of 24 telephone channels and the section where circuits are concentrated holds transmission capacity of 120 telephone channels. Therefore, compared with Plan B wherein not more than several circuits are used, Plan A can more easily cope with a greater increase of circuit demand than expected if it arises in the future.

2-5 Work Period

Both Plan A and Plan B use equipment shelters for rural station buildings so that in the period required for equipment installation at rural stations, no much distinction exists between the two plans.

In Plan A, antenna tower erection work takes time; however, in Plan B, time requirement for master earth station construction is large. After all, in the required work period, neither plan is considered to predominate over the other. Meanwhile, it is hypothesized that by the time the equipment installation at rural stations begins, access roads to all those stations would have been completed by TOT.

Plan A also features that partial system service-in can be expected, beginning in the area where construction work and acceptance test have been completed. However, in Plan B, partial system service-in is impossible before the construction of master earth station and gateway exchange to be established in Bangkok as pivotal facilities of the whole system is completed.

3. All-round Evaluation Result

All-round evaluation of itemwise individual study results arrives at the following conclusions :

(1) For the transmission system of Rural Long Distance Public Telephone Service, UHF terrestrial radio system of 900 MHz frequency band is the optimum system, considered from both technical and economic angles.

(2) For the applicable UHF (900 MHz frequency band) terrestrial radio

system, no much difference can be found between FDM system and PCM system.

(3) Domestic satellite system will have its construction cost broadly reduced as the technical research and development make further progress and the greater productivity improvement is achieved. Therefore, when the introduction of domestic satellite system is planned in the future, the most effective use of the satellite shall be considered. This can be realized by utilizing the system for wide-range signal transmission, such as telegram, telex, data and television signal transmission, without restricting the system utilization to telephone channel transmission alone.

PART X. Project Implementation Plan

PART X Project Implementation Plan

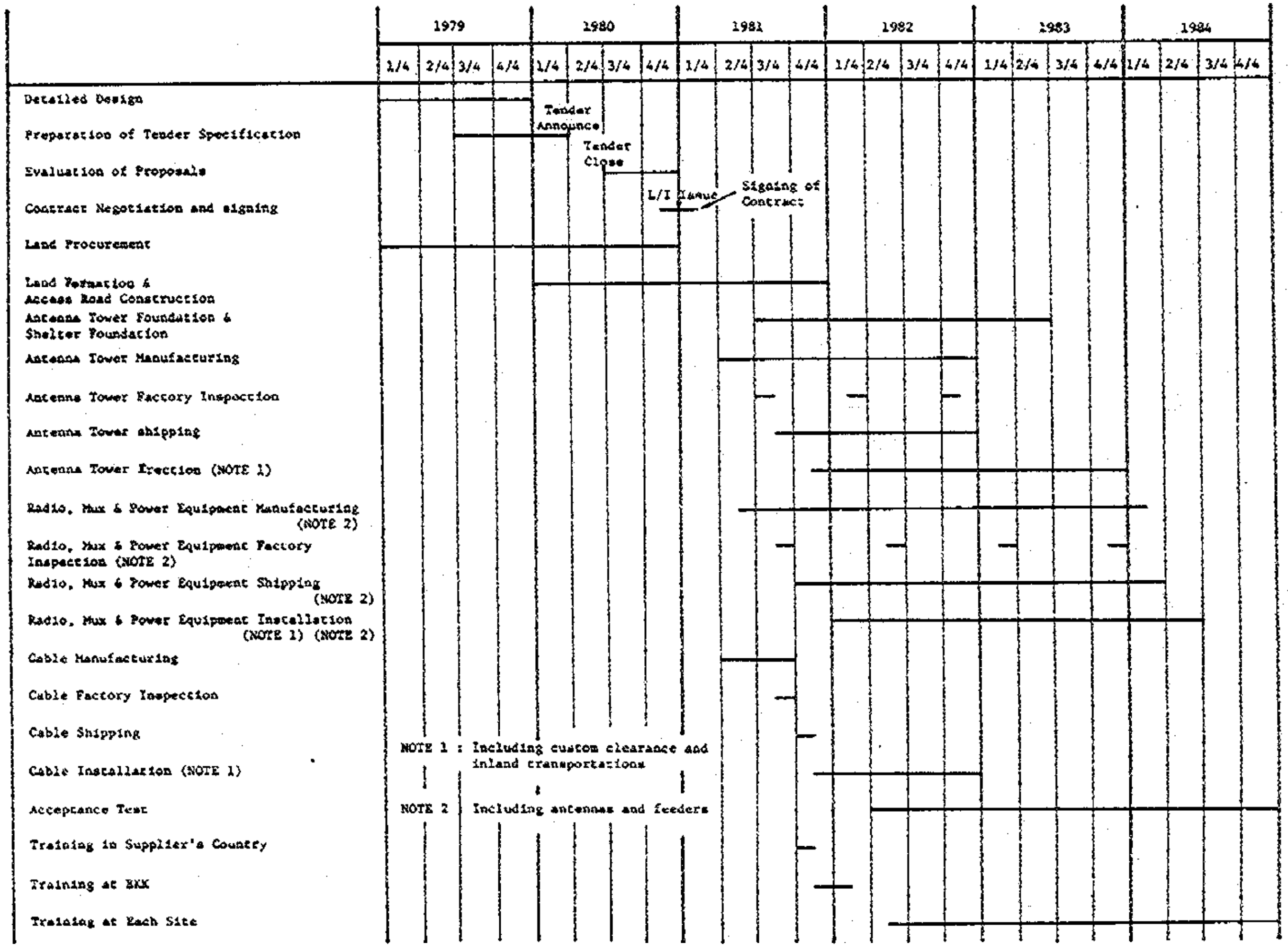
This Project not only covers the whole territory of Thailand but also comprises various divisions of engineering expertises in a long period. Therefore, to ensure satisfactory progress of project implementation, it will be necessary to reinforce the project implementation organization.

A tentative work schedule chart for implementation of Rural Long Distance Public Telephone Service project is given in Table 10-1. This work schedule chart uses 1984 as the work completion target year in accordance with the TOT plan.

Items considered are as follows :

1) The construction work will be carried out by the Contractor on a full turn-key basis except land formation and access road construction.
2) As much time as required will be spent for detail design by which to make Tender Specifications.
3) In case the traffic reappraisal cannot be completed in time for tender announcement, the result of reappraisal will be taken into account in subsequent extension works.
4) The system will begin service in one area after another where construction work has been completed.

Table 10-1 Tentative Construction Schedule for Rural Long Distance Public Telephone Service



A P P E N D I C E S

APPENDIX 1 Study Team Organization

The Study Team is composed of six persons including the Team leader. All Team members are The Nippon Telecommunications Consulting Co., Ltd., employees. The six Team components and their respective responsibilities are listed below.

Name	Responsibility
Kenichi HATANO	Team leader
Hiroshi SEKIKAWA	Carrier transmission engineering
Junichi KUROBE	Radio engineering
Katsuhiko SATO	Radio engineering
Ryoji SASAKI	Satellite communication engineering
Nobuo NAKAJIMA	Network engineering

APPENDIX 2 Work Itinerary

August 10, 1978	:	Departure from Tokyo and arrival in Bangkok.
August 11, 1978	:	Courtesy calls to Japanese Embassy and JICA Office, and consultative meetings. Courtesy visit to Managing Director of TOT.
August 12, 1978 to September 10, 1978	:	Consultations with TOT, collection of data, feasibility study.
September 11, 1978 to September 30, 1978	:	Field survey of four areas by two groups. (Detailed itinerary in Volume III : Survey Report)
October 1, 1978 to December 10, 1978	:	Feasibility study work and compilation of Interim Report (draft).
December 11, 1978 to December 24, 1978	:	Examination of Interim Report (draft) by JICA Mission.
December 25, 1978 to December 28, 1978	:	Correction and finalization of Interim Report.
December 29, 1978	:	Presentation of Interim Report to TOT.

Data and information used in the Study are listed below.

From Telephone Organization of Thailand

Traffic Distribution for Rural Long Distance Public Telephone Service

Transmission Loss Distribution Plan

Inter-Exchange Signalling Plan

Radio Frequency Assignment for Existing System

Regulation on Telephone Service Charges and Deposit

Statistical Report 1976

Annual Report 1976

Radio Frequency Assignment Plan for 900 MHz Band

National Numbering Plan

Basic Concept for Maintenance and Operations

The Economic Development Project of TOT (1977-1984)

The Economic Development Project of TOT (1977-1984), Additional Plan

Radio Link Route Map (Planned up to 1984)

System Channel Diagram for Long Distance Circuit

Coordinates of Existing Radio Stations of TOT

Coordinates of Rural Sites and Population

Traffic and Long Distance Network for STD Project 1977-1984

Forecast of Telephone Demand 1977-1990

Rural Long Distance Public Telephone Service Routing Plan

Basic Distance-Interval for Trunk Call Rates

From Others

National Economic and Social Development Board ; "The Fourth National Economic and Social Development Plan (1977-1981)"

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