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PANJGUR ENGINEERING STUDY

for the

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AGENCY FOR

INTERNATIONAL DEVELOPMENT

OCTOBER 1971

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PANJGUR ENGINEERING STUDY

I. INTRODUCTION

1.1 General: -- The present engineering study on the Panjgur remote controlled air/ground/air (RCAG) VHF station is sponsored by the United States Agency for International Development, Department of State, at the request of the Pakistan Civil Aviation Department.

1.2 Purpose and Scope: -- The purposes of this engineering study are: first, to inspect an existing radio communication system presently installed in West Pakistan, which was designed to provide air-to-ground communication service between the Karachi International Airport, and aircraft entering or leaving West Pakistan, via the CENTO Airway, at the Iranian border; and, second, to recommend the specific improvements or system redesign that would be necessary to provide a reliable communication network to serve this need.

The desired radio range is from 0 to about 300 nautical miles, over predominantly mountainous terrain; the aircraft usually fly at altitudes between 10,000 and 40,000 feet. The planes carry VHF radio equipment, designed for the Aeronautical Mobile Service (AMS), which operates in the assigned aviation frequency band of 118 to 136 mHz.

1.3 Background Information: -- The present system, installed in 1964, consists of two radio links operating in tandem. The first is a 230 mile point-to-point HF link between Karachi and Panjgur, and the second is a ground-to-air

VHF link between Panjgur and the aircraft flying in the vicinity. The relay station at Panjgur is remotely controlled by the incoming signals from Karachi and from the planes. Four voice channels are provided.

It was reported that the performance of this system has been unsatisfactory since it was installed. This was apparently due to HF propagation difficulties, excessive interference from undesired signals, high atmospheric noise, and equipment problems. This unsatisfactory condition persisted in spite of repeated efforts by the Civil Aviation Department and FAA experts to improve the performance. Eventually, the VHF ground-to-air link was shut down, and the HF link was used only for occasional point-to-point traffic. Thereafter, there was no reliable long distance communication between the incoming aircraft and the Karachi Airport. Air-to-ground VHF radio contact was limited to about 70 to 150 nautical miles depending on altitudes of aircraft approaching or leaving the Karachi area.

1.4 Organization of the Study: -- The study work was divided into the following areas for investigation:

1.4.1 Analysis of the Existing HF and VHF System

(a) HF propagation predictions, Karachi to Panjgur.

(b) HF assignments for this path.

(c) Parameters of HF equipment in use.

(d) HF antennas and lines.

(e) Condition of existing HF equipment.

(f) Interference from undesired signals.

(g) Atmospheric interference.

(h) Remote control problems.

(i) VHF equipment and antennas.

(j) Operating problems.

1.4.2 Possibility of Improvements to the Existing HF Link

(a) Better frequency assignments.

(b) Increased transmitter power.

(c) High gain antennas.

(d) Substitution of two longer HF hops, operating in tandem, using a relay station at Lahore, to replace the present 235 mile HF link.

(e) Same as in (d), above, but use of PTT coaxial system; Karachi/Lahore instead of HF link.

1.4.3 Troposcatter Propagation to Replace the HF Link

(a) A single tropo link, Panjgur Airport to Karachi Airport.

(b) A single tropo link, between elevated sites near Karachi and Panjgur, with microwave LOS links at one or both ends.

(c) Two tropo links in tandem, connecting Karachi and Panjgur, with a relay station located at Ormara on the southern coast of West Pakistan.

1.4.4 An "Extended Range" VHF link, ground-to-air, installed at an elevated site near Karachi, with microwave LOS link to Karachi Airport. Ground-to-air range about 300 nautical miles. Panjgur VHF link not required.

1.4.5 Inspection of possible sites for each of the alternatives described above. Major considerations were:

(a) High elevation.

(b) Minimum interference from and to nearby radio installations.

(c) Accessibility, availability, construction costs, security, etc.

II. CONCLUSIONS AND RECOMMENDATIONS

This section presents a summary of the principal conclusions of each part of the study, along with recommendations for improving the communications system.

2.1 Performance of the Existing HF Link: -- The HF equipment used on this link was inspected at both Karachi and Panjgur, and the link performance was observed at both terminals during actual operation. The radio equipment, including transmitters, receivers, and antennas, appears to be in good condition, and functioning as intended.

The link performance is unsatisfactory, chiefly because of the high level of interference from undesired signals. Propagation conditions are not as reliable as required for this type of service; this is due partly to the short length of the HF path. Some difficulty experienced in remote control functions has been attributed to the poor voice quality of the HF radio equipment.

This HF link is not being used as part of the air-to-ground communication system, because of these difficulties. Aircraft approaching or leaving the Karachi area must depend upon the VHF equipment installed at the airport, which has a limited range, inadequate for this purpose.

2.2 Improving the HF Link Performance: -- Some improvement in the HF link signal-to-noise ratio, and in the remote control operation, can undoubtedly be made by increasing the transmitter power (presently 1 KW), and improving the voice channel characteristics. These methods, however, would

not improve the overall reliability, in terms of percentage of time, enough to accomplish the desired result. In the presence of constantly increasing interference, due to radio spectrum crowding, it is a losing battle to resort to these methods. The improvement is usually temporary, since higher power will only aggravate the interference situation for other HF users, who will then respond similarly.

The technique of shifting from one frequency to another, to accommodate changing propagation conditions, is useful, and is followed widely. However, for unattended relay stations, such as Panjgur, this becomes complicated. In any case, this method usually provides little, if any, relief from undesired signal interference.

It is concluded that the HF link, either as it exists, or as improved by any practical means, cannot provide a reliable communication circuit between Karachi and Panjgur which would meet ICAO reliability standards.

2.3 Troposcatter Links: -- Troposcatter links can provide a highly reliable communication system between Karachi and Panjgur. However, these links are expensive to build, as they require diversity operation to overcome deep, rapid fading. The selection of troposcatter propagation over other methods usually becomes a matter of economics.

For the Karachi to Panjgur route, five separate tropo systems, having approvimately equal performance characteristics, were considered, to obtain

comparative cost figures. These systems and costs are summarized below: (See Paragraph 2.5)

	Description	Cost* (U.S. $)
1	One tropo link, 10 KW dual diversity, Panjgur Airport to Karachi Airport	$ 517,600
2	One tropo link, 1 KW dual diversity, Panjgur Airport to elevated site near Karachi, plus one UHF link to connect Karachi Airport to Karachi tropo site.	427,500
3	One tropo link, 100 W dual diversity, between elevated sites near Karachi and near Panjgur; plus two UHF links to connect the airports to the tropo sites at each end	473,700
4	One tropo link, 100 W dual diversity, Karachi Airport to Ormara Airport, plus one tropo link, 1 KW dual diversity, Ormara Airport to Panjgur Airport	702,600
5	One tropo link, 1 KW dual diversity, Karachi Airport to Pasni Airport, plus one tropo link, 1 KW dual diversity, Pasni Airport to Panjgur Airport	722,600

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* The costs and performance figures used are estimates, and should be confirmed in any final design phase.

2.4 Extended Range VHF System: -- The extended range VHF system would replace both the HF point-to-point link, and the Panjgur VHF ground-to-air link. It would consist of a VHF station located on a hilltop near Karachi, which would communicate directly with the aircraft over a long range, and a UHF link connecting the VHF station with the airport. The hilltop site could be unattended.

This link would eliminate Panjgur as a relay point. It would have a service range of over 300 nautical miles, extending northwest well beyond the Pakistan - Iran border. Two air-to-ground communication channels would be provided, by duplicating the VHF equipment; hence, communication between the Karachi Airport and each of two aircraft could be carried on simultaneously.

The service area would extend over a 42° angle lying between 270° and 312° with the apex at Karachi. The VHF station, plus the UHF link, would cost $201,900.00 (U.S. Dollars).

2.5 Local Currency Costs: -- The costs given above are in U.S. dollars. These figures do not include the costs of buildings, roads, or property. It is expected that these costs will be paid in local currency. The actual amount can be estimated after the decision has been made on the final system to be installed, and the sites have been selected.

2.6 Recommendations: -- It is recommended that the extended range VHF station be installed at Karachi, with the UHF connecting link to the Karachi Airport, as described in Section 4 of this report. The existing HF link could continue to function, as at present, for point-to-point traffic between the Karachi and Panjgur Airports.

III. FIELD SURVEY

3.1 Preparation

3.1.1 Maps: -- The path of the existing HF link between Karachi and Panjgur was plotted on U.S. Department of Commerce ONC Aeronautical Charts, Scale 1:1,000,000. These chargs are reproduced herein, and show the existing HF path (Fig. 1), and also the alternate troposcatter paths which were being studied (Fig. 2). Figure 3 shows the "Extended VHF" path, which provides direct air-to-ground contact between Karachi Airport and planes flying well beyond the Iranian - Pakistan border, northwest of Karachi. Topographic information is indicated by contours, shading, and by peak elevations, given in feet. This information was used to prepare path profiles for the several VHF and troposcatter paths under consideration.

3.1.2 HF Propagation Predictions: -- The path parameters of the existing HF link between Karachi and Panjgur, as well as those for the alternate route using a HF relay station at Lahore, were analyzed to obtain predicted hourly values of the maximum, minimum, and optimum radio frequencies, which could be used over each path. This was done for the months of February and June, 1971, to investigate the seasonal changes in HF propagation conditions. This analysis was performed by using an electronic computer and a program developed by the Environmental Science and Services Administration (ESSA) of the U.S. Department of Commerce. The predicted

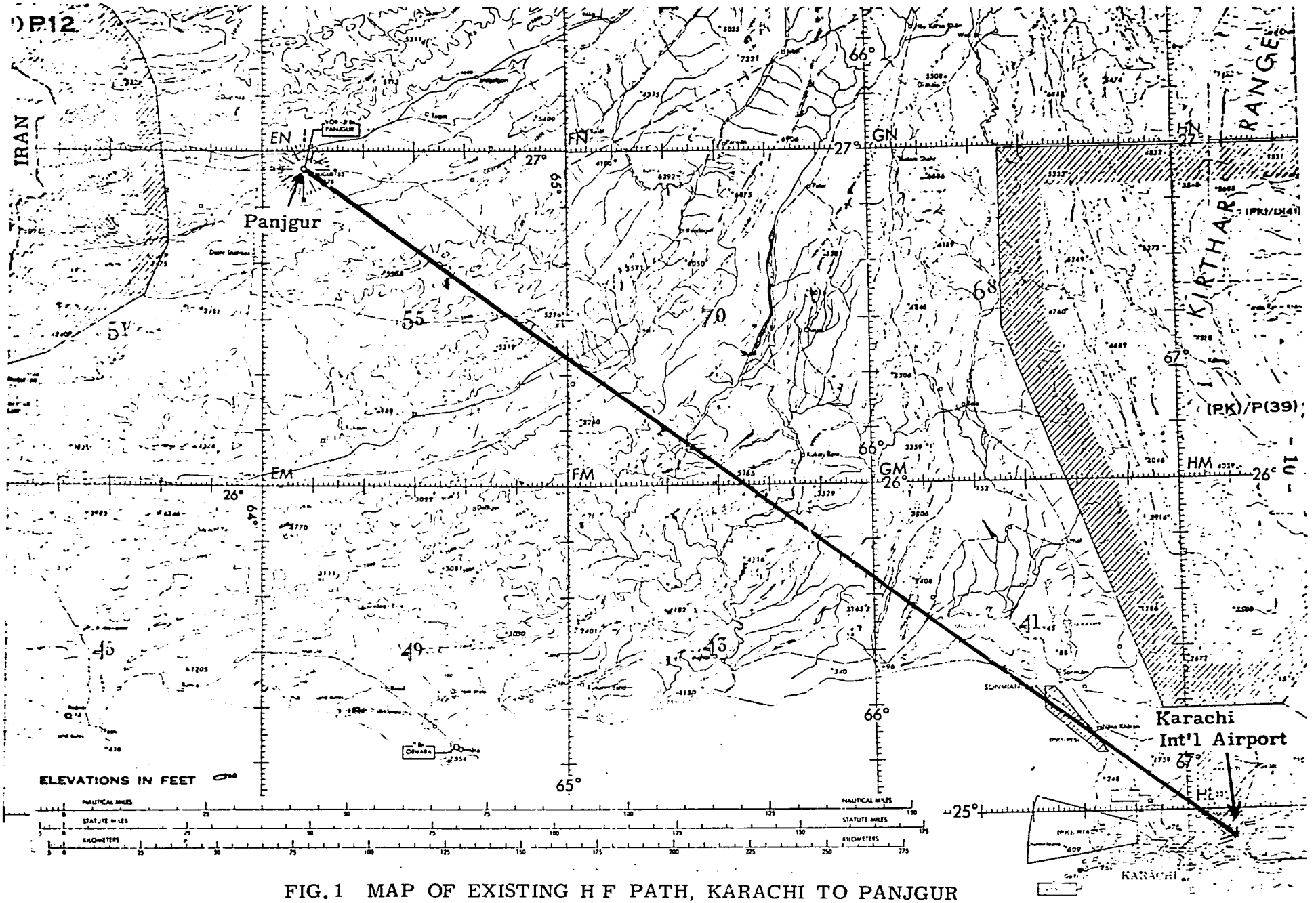


FIG. 1 MAP OF EXISTING H F PATH, KARACHI TO PANJGUR

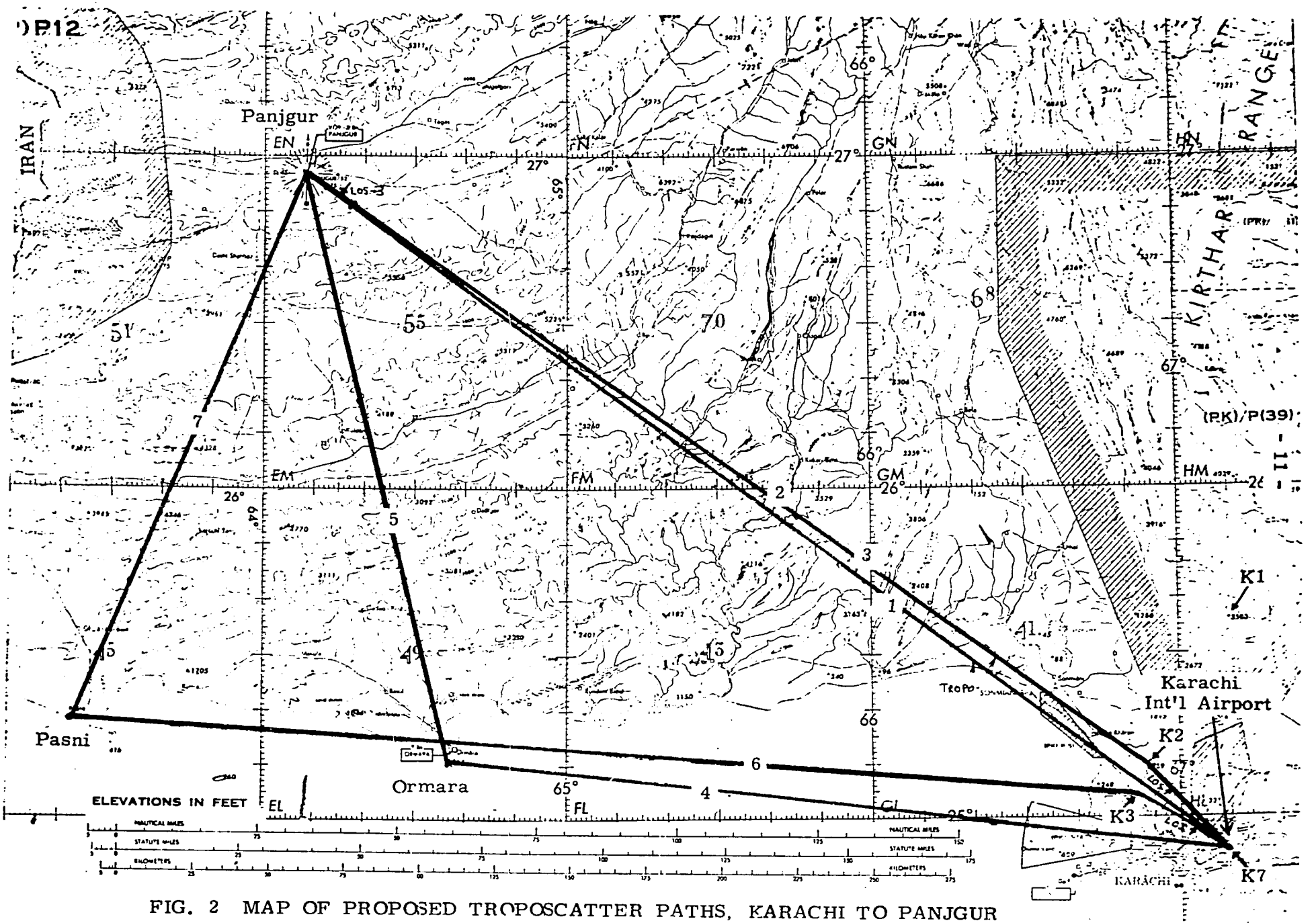


FIG. 2 MAP OF PROPOSED TROPOSCATTER PATHS, KARACHI TO PANJGUR

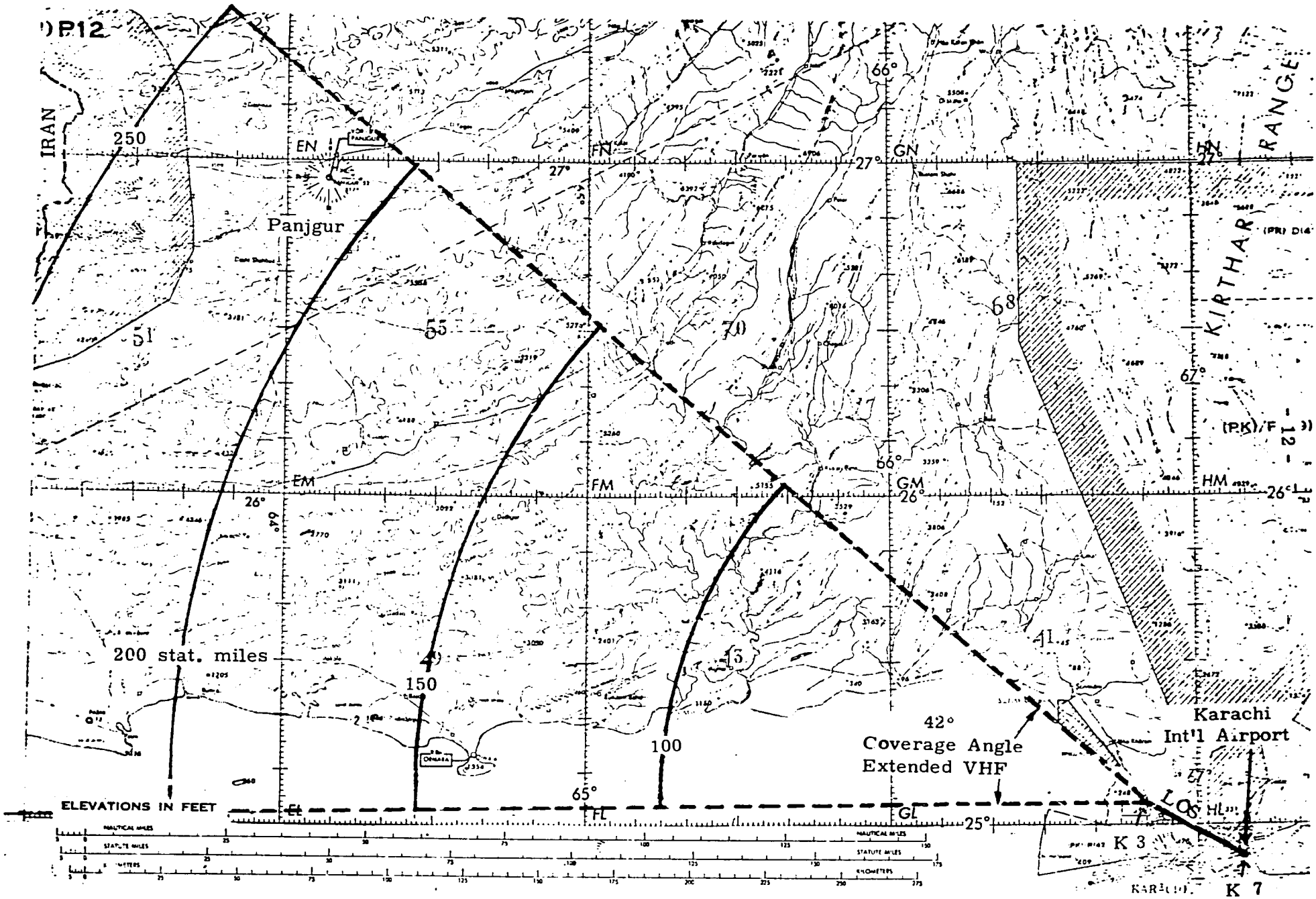


FIG. 3 MAP OF PROPOSED EXTENDED RANGE VHF COVERAGE AREA

values of MUF (maximum useable frequency), LUF (lowest useable frequency), and FOT (optimum traffic frequency), for these two routes are presented in Annex A, and are discussed later in this report.

3.1.3 Troposcatter Path Loss Analysis: -- Troposcatter path loss calculations were made on several routes between Karachi and Panjgur Airports. These computations were based upon path profiles constructed from topographical information contained in the aeronautical charts mentioned previously. From these computations, it was possible to determine the major equipment parameters required for each link to provide reliable service between the two airports. The parameters are given in a later table and the results are summarized in Section IV.

Site locations and elevations used were taken from the available maps. These computations were used to obtain a preliminary determination of the feasibility of replacing the existing HF link with one or more troposcatter links, and to serve as a guide in the selection and inspection of possible troposcatter sites during the field trip.

3.1.4 Preliminary Site Selection: -- For path distances of 200 miles or more, the performance of troposcatter links, and of extended-range VHF ground-to-air links, depends critically upon the elevation of the terminal sites, and of the radio horizon. It is desirable to obtain, at each terminal, as high an elevation as possible, consistent with site accessibility, freedom from obstructions and construction costs.

Another important consideration is the intensity of the ambient VHF and UHF radio noise in the vicinity. This factor alone is usually sufficient to eliminate any sites at or near a busy airport terminal, such as Karachi Airport.

A preliminary study of the maps of the areas around Karachi, Panjgur and the southern coast of West Pakistan was made, and several elevated sites were selected for field inspection and investigation. These are shown on Figures 2, 4, and 5, and are identified and described below.

3.2 Field Trip: -- On 24 July 1971, a MORCOM representative arrived in Karachi, Pakistan, from Washington, D. C. During the next 17 days he inspected the HF installations at Karachi and Panjgur Airports, and also visited a number of possible sites for VHF or troposcatter stations in the areas around Karachi, Panjgur, and the southern coast of West Pakistan. During this field trip, he consulted with the U. S. AID and the Civil Aviation Department officials of Pakistan, and collected a large amount of information on the existing civil aviation communication facilities located at Karachi and at Panjgur, as well as on methods for improving these facilities.

An initial meeting was held with Civil Aviation Department officials and a Senior USAID Engineer from Lahore to discuss the planned field survey in the Karachi area, the Karachi-Panjgur HF link performance, and to arrange for a survey trip to Panjgur and to sites on the southern coast of Pakistan. At the meeting, it was revealed that the VHF RCAG equipment installed at Panjgur Airport had been out of operation for some time, because of

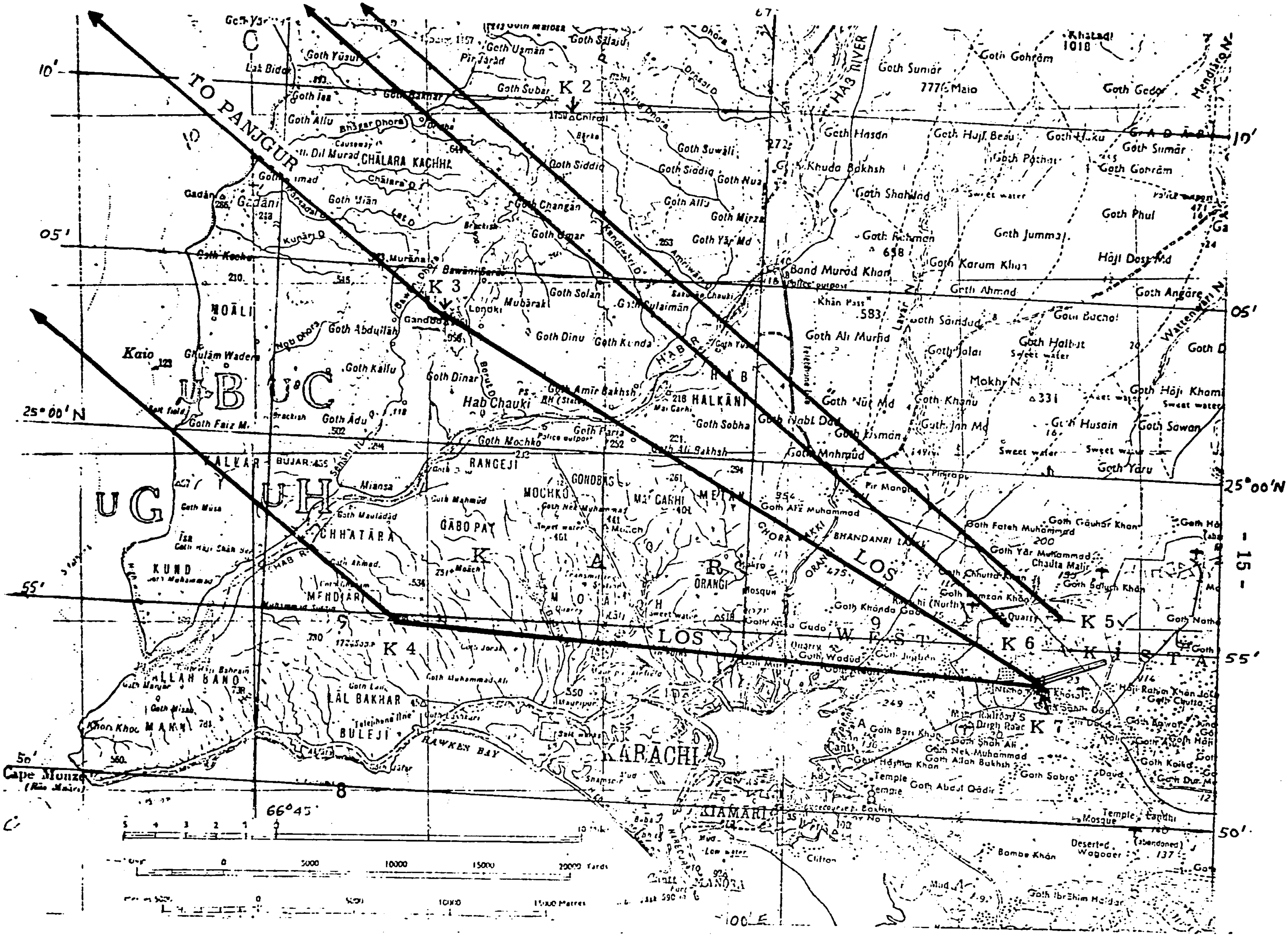


FIG. 4 MAP SHOWING TROPO SITES, KARACHI AREA

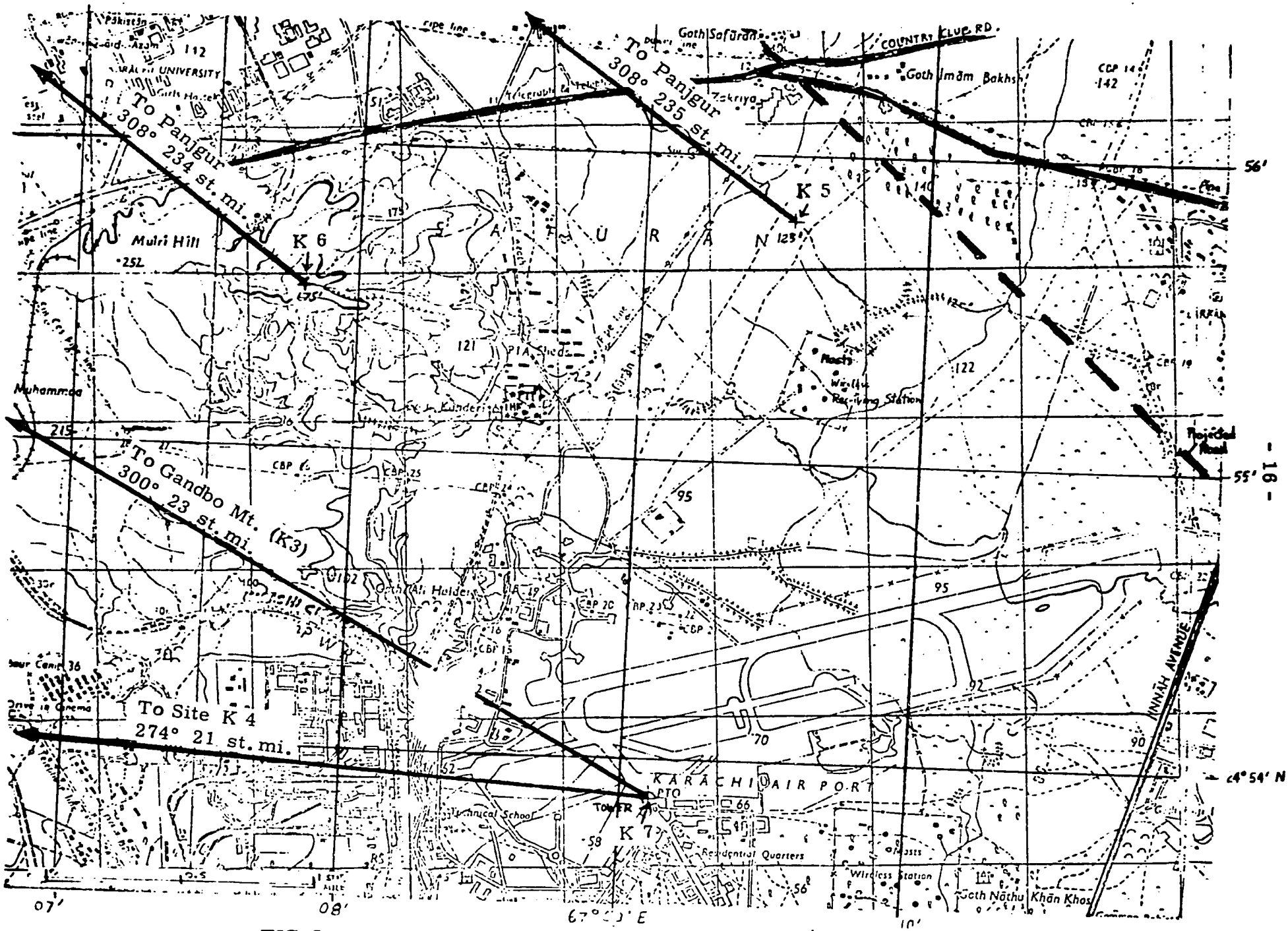


FIG. 5 MAP OF KARACHI AIRPORT AREA SHOWING PROPOSED SITES

the unsatisfactory propagation and equipment reliability of the HF SSB link which connects the RCAG system with the Karachi control tower.

A list of the high frequencies assigned by the IFRB for this link was obtained, and was compared with the HF propagation predictions which had been prepared in Washington, D.C. Each of these frequencies has been tried at one time or another over this link, without producing any major improvement in performance. The assigned frequencies, and the daily periods during which a propagation reliability of 90% or better was predicted, are listed below, for the months of February and June 1971.

TABLE 1
LIST OF
RADIO FREQUENCIES AND USEFUL
PROPAGATION PERIODS FOR HF PATH

Karachi to Panjgur

ESSA Predictions

Frequency	DAILY PERIODS (UNIVERSAL TIME)	
kHz	February 1971	June 1971
2597	00 - 24 U.T.*	00-09 and 12-24 U.T.
2727.5	00 - 24	00-09 and 12-24
2785	00 - 24	00-09 and 12-24
3194	00 - 24	00 - 24
6850	03 - 18	02 - 22
6885	03 - 18	02 - 22
6897	03 - 18	02 - 22
6955	03 - 18	02 - 22
7773.5	03 - 17	03 - 16
7988.5	03 - 17	03 - 16
8157	03 - 16	03 - 15

*Karachi time is Universal Time (GMT) + 5 hours.

The tabulation indicates that a propagation reliability of 90% or better could be achieved over this link, using the frequencies assigned during the entire 24-hour period. Past experience, however, seems to indicate that the unsatisfactory performance is due to a combination of propagation conditions, equipment problems, and, expecially, to interference from undesired signals.

Since some of the HF propagation instability (fading) is due to the relatively short (235 miles) distance, another possible alternative was discussed. This alternative would use the longer distance of 700 miles between Lahore Airport and Panjgur for the HF circuit, and would depend on voice channels leased from the PTT for the transmission of the voice and control signals from the Karachi tower to the HF terminal at Lahore.

Annex A also shows the HF propagation predictions for the Lahore to Panjgur circuit. This possibility, however, was rejected as not practical, due to excessive HF interference.

From the discussions, it became clear that most of the problem with the operation of the RCAG ground station at Panjgur resulted from the unsatisfactory HF circuit conditions, and from the use of a tone control and tone signalling equipment, which does not operate satisfactorily with the kind of low quality voice circuits offered by ground-to-air HF-AMS systems.

The other two alternatives, troposcatter propagation and extended range VHF, were next discussed. Since both of these methods require elevated sites for long distance paths, it was decided to investigate some of the hills and mountain ranges within line-of-sight range of the Karachi Airport, for suitable radio relay sites.

The first field trip for selection of possible radio terminal sites was directed towards a chain of high hills, culminating in a 3,500 ft. mountain about 50 miles north of Karachi. This high elevation, as well as some other smaller peaks further south (2,600 ft., 1,900 ft., and 1,760 ft.), however, was found to be too remote, with no trails or dirt roads close to the foot of the mountains, and rather inaccessible because of steep slopes and valleys.

A number of other areas for radio sites was also considered.

One mountain area, named Gandbo Mountain, was especially recommended for survey, because of its convenient location on the hard surfaced Bela road about 20 miles west of Karachi. Gandbo was well suited for road construction purposes because of large broad natural steps on the west side, and a saddle on the east side of the mountain ridge.

The survey team proceeded to survey this hill and found everything as described: an excellent location, with the foot of the saddle close

to the main hill and about 500 feet off a very good hard top road. This point is located about 19 road-miles from Karachi center.

The nearest settlement, a busy market place and development center, named Hab Chauki, is four miles east towards Karachi on the road crossing the Hab River; it has a police post, a small manual telephone exchange connected to Karachi via one open-wire circuit, and its own electric power supply.

A close survey of this site led to the following observations:

- Soil and terrain condition: -- The soil is a mixture of various sizes of limestone, sand and clay, and mainly on eastern slopes, of a loose consistency.

  Large out-croppings of limestone in the form of wide bands spaced about 100 feet apart appear on the north-west side. The mountain consists of a ridge about 3,000 feet long with four peaks -- the highest, counting from the NNW end, is 1,050 ft. high; the third about 900 ft. and the last 950 ft. The ridge slopes down in SE and NE directions at approximately 35° to 40° and in NW direction at 25° to 30°.

  A relatively flat area of approximately 1,300 ft X 75 ft extends about 75 to 100 ft. below the three last peaks, well suited for power building, staff quarters and diesel storage tanks.

- Access Road: -- A number of smaller hills, the highest approximately 700 ft. high on the east side, and very close to the main mountain ridge, form a convenient saddle which could be used as a natural base for an approach road up to an elevation of about 450 ft. at the mid-point. From there, the road would have to be cut into the steep (35°) side for 1,300 ft. at an estimated 1:15 slope, turning around the end of the ridge some 400 ft. below the last (4th) peak and

continuing on towards the second peak (970 ft), utilizing the above described natural stone steps for most of the 3,000 ft, at a possible 1:15 slope.

To reach the foot of the saddle from the Bela road, approximately 500 ft. on level, cleared ground has to be built, followed by another 2,000 ft. up the 200 ft. to 400 ft. wide saddle to its highest elevation of 450 ft.

Site Grading: -- A relatively flat plateau of approximately 1,300 ft. by 75 ft., about 50 to 100 ft. below the last three peaks, has to be graded and filled to some extent to provide level area for communications and power buildings.

In order to accommodate a troposcatter terminal, level and solid area for the foundations for two 28 ft. dishes and feed horns spaced about 100 ft. apart would have to be prepared.

For an extended range VHF station, two similar solid areas for two 70 ft. self supported towers on both sides of the communications building would be required. The site area should have a 1.5% grade for storm drainage.

The UHF dish for the line-of-sight (LOS) link to Karachi Airport control tower could be mounted on top of the highest of the towers.

Available Power: -- The high tension power line from Karachi ends 11 miles from Gandbo Mountain, and no further extension is expected.

Water: -- At the foot of the smaller hills, a few huts are grouped around a dug well which delivers potable, rather "sweet" water.

Another field survey was undertaken of a range of hills ten miles long, and with elevations up to 700 feet, extending to Cape Monze, 23 miles southwest of Karachi. There is an existing civil aviation site

(NDB) facility located at Cape Monze.

A good hard-surfaced road led from Karachi to Hawkes Bay, and further on to a nuclear power plant. The mountain range was visible four to five miles beyond. However, only a barely passable dirt trail extended beyong this point. The survey was abandoned due to the poor road conditions.

On the return trip, a relatively easy approach to a break in the mountain range was observed northwest of Hawkes Bay, about five miles from the good road.

A passable dirt road led to the base of a 700 ft. hill. The northwest side has a gradual slope, and might permit an access road at reasonable cost.

If for some reason the Gandbo Mountain site, ten miles to the north, is not available, this 700 ft. hill would be the second choice for a radio link terminal.

Surveys of sites at Ormara, Pasni, and Panjgur were made, using a chartered twin-engine aircraft.

Ormara, 165 miles west of Karachi, was planned as the first stop, but after flying over the abandoned air-strip, the pilot chose not to try a landing. A 1,500 ft. elevated plateau with a very level and wide rectangular area, but steep slopes on all sides, could accommodate a radio site and

possibly also an air-strip. However, the logistic problems of maintaining equipment and staff at this location appeared to be too great.

An existing dirt road between Ormara and Pasni, another 80 miles to the west, is reported to be in bad condition. Ormara was therefore deleted, at least for the time being, from the list of possible tropo repeater station sites.

Pasni was the first landing on the flight to Panjgur. The airport is located far out of town and on a very level plain, near sea level. Vertical horizon angle shots were taken in the direction of Panjgur and Karachi as accurately as possible, under hazy conditions. There is ample space for a troposcatter terminal at Pasni.

The survey party left for Panjgur at about 11:00 A.M. and arrived at 1:00 P.M. The airport is situated some miles away from the town of Panjgur and the wide open area would provide ample space for a tropo terminal. A tropo site on one of the distant hills, however, is not recommended, due to the inaccessibility of the mountains.

The theodolite for horizon measurements was placed on top of the communications building. The same hazy conditions as seen in Pasni, but supposedly due to fine sand particles, were observed. This delayed the completion of the angle shots towards Karachi until after 5:00 P.M. The HF SSB equipment and antennas at Panjgur were inspected. The general impression was

that equipment and antenna installations were well done, and despite the worn look of the transmitters, receivers, and other equipment, seemed to work properly. The Karachi HF station was contacted and received well, but interfering telegraphy stations and occasional static resulted in very low signal to noise conditions.

During the short listening tests, no signal fading occurred. Fading does not seem to be pronounced during the few times the HF circuit is used for message traffic.

The fore-field of the transmitting antenna towards Karachi is clear of obstructions. The communications and power building, as well as the NDB antenna structure, are in the HF receiving antenna field, and undoubtedly have some effect on the strength of the incoming signals.

The tower heights for both antennas are 60 ft. This should be low enough for the working frequencies (which are below 8.5 mHz) to give the high take-off angles required for the short 230 mile path.

The survey party left Panjgur at about 6:00 P.M. to return to Karachi Airport, which was reached 1 1/2 hours later.

The VHF communications coverage between Karachi tower and the chartered aircraft was given a brief test on the first leg of the trip towards Ormara and on the return flight from Panjgur. It was found, as expected, that at the recommended altitude of 1,000 ft. between Karachi and Ormara, the

signal was lost at about 40 miles from the control tower. On the return, at approximately 9,000 ft. altitude and some 150 miles from the tower, no answer was received. After reaching the coast of Cape Ras Malan, still at about 8,000 ft. to 8,500 ft. altitude, Karachi responded which would indicate a 130 miles VHF range.

In order to anticipate future radio interference problems arising from the use of Gandbo Mountain as a high power radio terminal site, a meeting was held with PTT officials to obtain information on existing and planned communication systems for the Balutchistan area. This includes the towns of Ormara, Pasni, and Jiwani, on the coast, and Bela, Turbat, and Panjgur in the mountainous districts.

The Director General of the PTT discussed plans for a low power HF network for the Balutchistan province. It is anticipated that a VHF or microwave system will be installed, later on, along the southern coast of Pakistan.

The average cost of access roads to typical hilltop sites was estimated at 200,000 rupees per mile, by the Director for Microwave Development.

There was general agreement at this meeting, on the following points:

a. HF communications links in this area are unable to provide the quality of service required, due to excessive interference from undesired signals.

b. Reliable communications between Panjgur and Karachi Airports could be provided by a troposcatter system of one or two links. The existing VHF relay station at Panjgur could provide ground-to-air communication to aircraft within radio range of Panjgur.

c. An extended range VHF station located on an elevated site near Karachi Airport could provide direct communication with aircraft flying west and northwest of Karachi, within a range of about 300 miles. A LOS link between the VHF site and Karachi Airport would be required to complete the circuit.

d. The first choice of elevated sites inspected near Karachi, for either tropo or VHF, was Gandbo Mountain. The second choice was a hill 700 ft. high some five miles off the road to Cape Monze.

e. A tropo station located at Karachi Airport would be unsatisfactory, due to electronic interference with other equipment.

f. It would be advisable to measure the elevation of Gandbo Mountain, and also to verify the elevations along the line of sight path from Gandbo to Karachi Airport.

g. The final selection of either troposcatter or "extended range VHF" as a communication method depends upon a detailed study of the performance and cost of each method.

A second trip to Gandbo Mountain was made, and the peak elevations along the LOS path were checked. The Gandbo peak elevation is 1,090 ft; the control tower elevation at Karachi Airport is 150 ft. The measurements of terrain elevations taken along the path show that an unobstructed path exists for LOS signals between these two points.

The area in the vicinity of the Karachi Airport was investigated for possible sites for a troposcatter terminal. The only locations which might deserve further consideration were located about two miles from the runway, north of the airport (See Figure 5). These sites are each within a mile of HF radio communication stations adjacent to the airport and, hence, might create interference problems.

The HF radio station installed at the Karachi Airport, which is used to communicate with Panjgur, was inspected. The voice signals received from Panjgur were readable, but suffered from heavy interference from radio telegraph signals. The transmitting and receiving equipment was clean but old and well used. The transmitting antenna originally used for Panjgur has been disconnected, and a half-wave dipole closer to the building was being used instead.

A preliminary report on the results of the Karachi-Panjgur Field Survey was prepared on 9 August 1971, and presented to the Civil Aviation Department and USAID.

IV. DESCRIPTION OF ALTERNATIVES

4.1 Improving the Existing HF Link; Karachi to Panjgur: -- The high frequencies listed on Page 17 of this report, and the ESSA predictions of propagation conditions which are given in Annex A, indicate that reliable propagation should exist for 90% or more of the time, throughout the 24-hour day, and throughout the year. The figures were computed for 5 kw of transmitter power, a halfwave dipole antenna, and a signal to noise ratio of 50 DB.

The transmitter power presently used over this link is 1 kw; however, 5 kw has been tried for brief periods in the past, with no substantial improvements in performance.

From the field information obtained from the local engineers and from listening tests, it is concluded that the major causes of failure in communication between Karachi and Panjgur are:

(a) Excessive interference from undesired HF signals; and

(b) Trouble with the remote control system used, due to poor voice channel quality.

The problem of excessive interference from undesired HF signals is familiar, and the usual solutions, such as shifting frequencies, using higher gain antennas and more power, are at best only temporarily effective. This situation continues to grow worse as spectrum crowding increases, and this alternative is recommended only when no other practical method exists.

4.2 Use of Two HF Links in Tandem, via Lahore: -- This possibility was conceived in order to take advantage of the better HF propagation conditions which exist over longer paths (e.g., 635 miles, Karachi to Lahore, vs 235 miles, Karachi to Panjgur). However, since the problem is not chiefly due to poor HF propagation, but to excessive interference, this solution is not recommended, since it would not reduce the interference from undesired signals.

The same conclusion applies to the idea of leasing some voice channels in the existing PTT cable between Karachi and Lahore, in conjunction with a single 700 mile HF link from Lahore to Panjgur. The HF interference would not be reduced significantly from the present level.

4.3 Troposcatter Propagation:

4.3.1 Troposcatter propagation could be used to provide reliable point-to-point communication between Karachi and Panjgur. There are several possible ways of doing this, which have been considered in detail.

The several paths which were analyzed are shown in Figure 2, where the individual tropo links are identified by numbers 1 to 7. The various locations in the Karachi area (designated K-1 to K-7), which were considered for tropo sites, and which were investigated in the field, are shown on Figures 2, 4, and 5 and they are described in Table 2.

Table 3 is a listing of the troposcatter path parameters, for the seven links shown on Figure 2. These figures are summarized, and the equipment

TABLE 2

LIST OF TROPOSCATTER AND VHF SITES
in
KARACHI AREA

Map Symbol	Site Name	Site Location	Elevation A.M.S.L.	Vertical Horizon Angle Toward Panjgur	Notes
K-1	--	47 S. Ml. North of Airport	3,500 ft.	-13'	Inaccessible
K-2	Chiroli Mt.	24.5 S. Ml. N N.W. of Airport	1,759 ft.	-19'	Inaccessible
K-3	Gandbo Mt.	23 S. Ml. N.W. of Airport; 25° 03'30" N; 66° 50'20" E	1,051 ft.	-14'	First choice for VHF or Tropo
K-4	--	21.1 S. Ml. W. of Airport; 24° 55' N; 66° 49' E	698	-14.5'	Second choice for VHF or Tropo
K-5	--	2.3 S. Ml. N N.E. of Airport; 24° 55' 52" N; 67° 9' 32" E	125 ft.	+25'	1/2 mile N. of Airport HF Receiver Station
K-6	Muiri Hill Quarry	2.3 S. Ml. N.W. of Airport; 24° 55' 32" N; 67° 07' 47" E	175	+19'	
K-7	Control Tower	24° 53' 53" N; 67° 09' 06" E	60 ft.	+18'	Karachi International Airport

TABLE 3

TROPOSCATTER PATH PARAMETERS

f = 2,000 mHz $\overline{Ns}$ = 359

Ns = 324 (Jan)

Ns = 394 (June)

Item	Path Parameter	Units	Path Number (See Figs. 2, 6) (1)	(2)	(3)	(4)	(5)	(6)	(7)
1	Path Distance	St. Ml.	236	212	199	160	126	218	123.5
2	Elevation, Tx site	Feet	75	1,750	1,750	75	3,175	1.090	3,175
3	Elevation, Tx antenna	Feet	100	1,775	1,775	100	3,200	1,115	3,200
4	Elevation, Tx horizon	Feet	1,000	4,000	4,000	475	4,500	0	4,000
5	Distance, Tx site to Tx horizon	St. Ml.	23	102	102	11.5	8.5	47	10
6	Elevation, Rx site	Feet	3,175	3,175	4,150	1,500	1,500	12	12
7	Elevation, Rx antenna	Feet	3,200	3,200	4,175	1,525	1,525	37	37
8	Elevation, Rx horizon	Feet	4,500	4,500	4,300	0	2,500	550	4,346
9	Distance, Rx site to Rx horizon	St. Ml.	11	11	20	55	25	7	46.5
10	Tx antenna tilt angle	Deg.	+0.30	-0.315	-0.315	+0.291	+1.61	-0.513	+0.815
11	Rx antenna tilt angle	Deg.	+1.22	+1.22	-0.040	+0.599	+0.41	+0.83	+0.743
12	Scatter angle	Deg.	+4.08	+3.20	-1.804	+1.432	+3.39	+.269	+2.90
13	Average path loss, all year	DB	235	225.3	210.8	205.2	222.7	220.5	217.6
14	Average path loss, January	DB	242	232.3	217.8	212.2	229.7	227.5	224.6
15	Average path loss, June	DB	228	218.3	203.8	198.2	215.7	213.5	210.6
16	Parabolic ant. diam. (each end)	Feet	28	28	28	28	28	28	28
17	Antenna gains, free space	DB	85	85	85	85	85	85	85
18	Aperture to medium coupling loss	DB	4.5	4.5	4.5	4.5	4.5	4.5	4.5
19	Total RF line losses	DB	5	5	5	5	5	5	5
20	Transmitter power output	KW	10	1	0.1	0.1	1	1	1
21	Receiver input pwr., average all year	DBM	-89.5	-89.8	-75.3	-79.7	-87.2	-85	-82.1
22	Receiver input pwr., January	DBM	-96.5	-96.8	-82.3	-86.7	-94.2	-92	-89.1
23	Receiver input pwr., June	DBM	-82.5	-82.8	-68.3	-72.7	-80.2	-78	-75.1

performance parameters are given on the chart of Figure 6.

The equipment parameters given are not necessarily the best compromise between performance and cost for each link. They may be used as a guide in arriving at desired results.

4.3.2 Path 1: -- This is a single troposcatter link between Karachi Airport and Panjgur Airport. It would require 10 kw transmitters, using dual space diversity, and 28 foot diameter parabolic antennas, operating on 2 GHz. Because of the proximity of the tropo site to the other radio installations at Karachi Airport, there might be some interference problems. Another objection is the high path loss (235 db), which results in low values of received carrier intensity (C.I.) even when using 10 kw transmitters.

4.3.3 Path 2: -- This tropo path is between Panjgur Airport and Karachi site K-2 -- a 1,750 ft. hill, 25 miles NW of the Airport. A microwave or VHF link would be required over the line-of-sight path down to the Karachi Airport control tower (Site K-7).

Due to the elevated site, this tropo link could operate with 1 kw transmitters. The hilltop site would function as an unattended relay station.

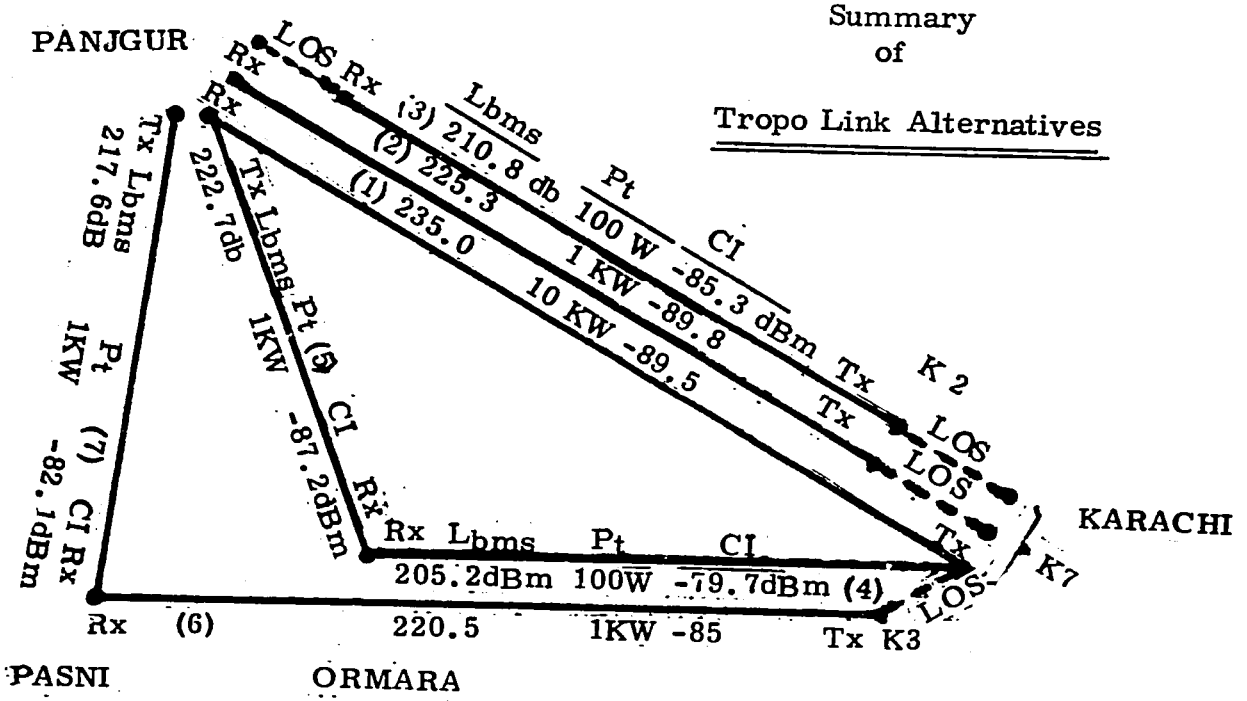
It was learned that there were no roads leading to the area of Site K-2, so further consideration of this site was postponed.

4.3.4 Path 3: -- This tropo path is between Karachi Site K-2 (see above) and a mountain top site about 4,000 ft. high, and ten miles SW of Panjgur.

FIGURE 6

Summary
of

Tropo Link Alternatives



NOTE

(1), (2) Identify Paths. See Table 3 -- Tropo Path Parameters; also see Figures 2, 4, and 5 for site locations.

EQUIPMENT PARAMETERS

f = 2 gHz
Ant. = Parabolic, 28' diam.
Ant. Ht. = 25' above gnd.
Total RF line loss = 5 db
C I values are for all year average
For January, C I values are 7 db lower.
For June, C I values are 7 db higher
RCVR threshold point ≈ - 105 DBM
(B_{If} = 400 kc, N. F. = BDB)
Fade Margin = C. I. (DBM) + 105 DB

MEDIAN VOICE CHANNEL S/N RATIO (THERMAL)

For freq. modulation
Dual Diversity
CI = - 90 DBM (Typical)
Baseband Freq. = 20 kc
RCVR N. Fig. = + 3 DB
Test tone RMS Devn. = 100 kc

Med. V.C. S/N = 63 DB (Thermal Noise)

The Panjgur site was selected from the aeronautical charts, and was later found to be inaccessible.

4.3.5 Paths 4 and 5: -- This is a two-hop tropo route from Karachi Airport to Ormara Airport to Panjgur Airport. It was proposed and analyzed in an effort to avoid the long, direct route over the mountains between Karachi and Panjgur. The relay point at Ormara is a 1,500 ft. hill three miles south of the Airport. The field inspection disclosed that the Ormara Airport was abandoned, and the area was almost inaccessible by road.

4.3.6 Paths 6 and 7: -- This is a two-hop tropo route from Karachi Airport to Pasni Airport to Panjgur Airport. The Pasni site was inspected during the field trip, and the path parameters were computed and are given in Figure 6 and Table 3.

While all three sites are accessible, the equipment cost makes this alternative less desirable than some of the other tropo paths considered.

4.3.7 The most practical tropo path considered appears to be that shown as number 2. Since the Karachi Site K-2 is inaccessible, another site would have to be chosen. From the site survey, Table 2, probably the Gandbo Mt. site (K-3) would be suitable for this purpose. This change of sites is not expected to change the path loss figures significantly.

4.4 Extended Range VHF: -- The extended range VHF plan would provide direct VHF two-way communication between a site near Karachi Airport, and aircraft flying into Pakistan from the west and northwest. A line-of-sight UHF relay link would connect the elevated VHF site with the Karachi Airport control tower. This plan would not require the use of the relay station (RCAG) at Panjgur.

The extended range VHF method is most effective when used between an elevated ground site and aircraft flying at high altitudes. Ranges of over 350 nautical miles are achieved under such circumstances. Weather conditions do not affect the path performance significantly.

The propagation path parameters have been computed for an extended range VHF station located at Gandbo Mountain, 22 miles NW of Karachi Airport; they are given in Table 4. The values shown are for the air-to-ground direction of transmission, which is the limiting direction. A 25 watt transmitter, with a zero gain antenna, is assumed for the aircraft. The ground station uses a high gain VHF antenna, which radiates a fan-shaped pattern about 45° wide and 10° thick. This pattern may be directed northwest from Karachi, to provide maximum coverage over the angle between 275° and 320°. The radiated RF power is concentrated in the northwest direction along the CENTO Airway beyond Panjgur.

Table 4 gives coverage ranges for the main direction of the antenna beam and for directions along the beam half-power points.

TABLE 4

SERVICE RANGE OF EXTENDED RANGE VHF AIR-GROUND STATION

KARACHI INTERNATIONAL AIRPORT - WEST PAKISTAN (3)

			Aircraft on Ant. Beam Center Line				Aircraft 22° off Ant. Beam ℄ (4)			
1	Tx site location		--Gandbo Mt. --			23 miles Northwest of Karachi --				
2	Tx elevation	Feet	35,000	25,000	15,000	8,000	35,000	25,000	15,000	8,000
3.	Tx horizon distance	N. Mi	235	200	154	112	235	200	154	112
4	Rx site location									
5	Rx elevation	Feet	1,100	1,100	1,100	1,100	1,100	1,100	1,100	1,100
6	Rx horizon distance	N. Mi	42	42	42	42	42	42	42	42
7	Free space distance	N. Mi	277	242	196	154	277	242	196	154
8	Total path distance (2)	N. Mi	325	290	250	220	305	275	240	200
9	Tropo path distance	N. Mi	48	48	54	66	28	33	44	46
10	Free space path loss	DB	-131	-129	-128	-127	-130	-129	-128	-126
11	Additional tropo loss	DB	-43	-43	-44	-46	-39	-41	-42	-43
12	Tx pwr. out	Watts	25	25	25	25	25	25	25	25
13	Tx ant. gain	DB	0	0	0	0	0	0	0	0
14	Rx ant. gain	DB	+22	+22	+22	+22	+19	+19	+19	+19
15	Total RF line loss	DB	-6	-6	-6	-6	-6	-6	-6	-6
16	Rx Ein. (1)	UV	0.50	0.55	0.56	0.50	0.55	0.50	0.50	0.54

(1) For a typical modern VHF receiver, an input signal of 0.5 UV with 30% amplitude modulation will produce a S.N.R. of 10 db, with 0.1 watts output.

(2) This range is computed for air-to-ground direction, using 25 watt transmitter power in the aircraft. Ground-to-air signals, using 1 kw transmitter, will produce $0.5 \times \sqrt{(1000/25)} = 3.1$ UV at airplane RCVR input, for same distances. Plane receivers will operate at 2.0 UV input, or higher; hence, the range given in Line 8, above, is the limiting value for two-way communication.

(3) Computation method used in accordance with information supplied by Aeronautical Radio, Inc., Annapolis, Md.; values are for 108 - 154 mHz band.

(4) This is the half-power point on the ground antenna horizontal pattern.

Figure 7 is a map showing the computed coverage range of this VHF communications system, for aircraft flying at various altitudes between 8,000 ft. and 35,000 ft. MEA (Minimum Enroute Altitude). For the ranges shown, the ground station will receive, from the aircraft, a 0.5 microvolt receiver input signal. This is the minimum signal which will operate the ground station receiver satisfactorily, producing a 10 db S/N ratio.

The ground station uses a 1 kw transmitter, which, with the high gain antenna, will deliver a minimum signal of 3.0 microvolts at the aircraft receiver input, for the ranges shown on the map. The aircraft receiver normally requires a 2.0 microvolt minimum input signal.

Figure 7 shows a maximum range of 325 nautical miles; this is considerably greater than the range of the existing HF link between Karachi and Panjgur, combined with the range of the VHF ground-to-air relay station at Panjgur (assuming that this system were operating as intended). The VHF range may be increased somewhat, if the aircraft uses more than 25 watts transmitter power. It may decrease somewhat, in certain areas, and at lower altitudes, because of the shadowing effects of high mountain peaks.

The VHF station should preferably be located on a high elevation, with a line-of-sight path to the Karachi Airport. During the field trip, the Gandbo Mt. site was inspected and selected as first choice for either a VHF or a tropo station site in the Karachi area. This hill is 1,051 ft. high, and has a clear line-of-sight to the airport tower.

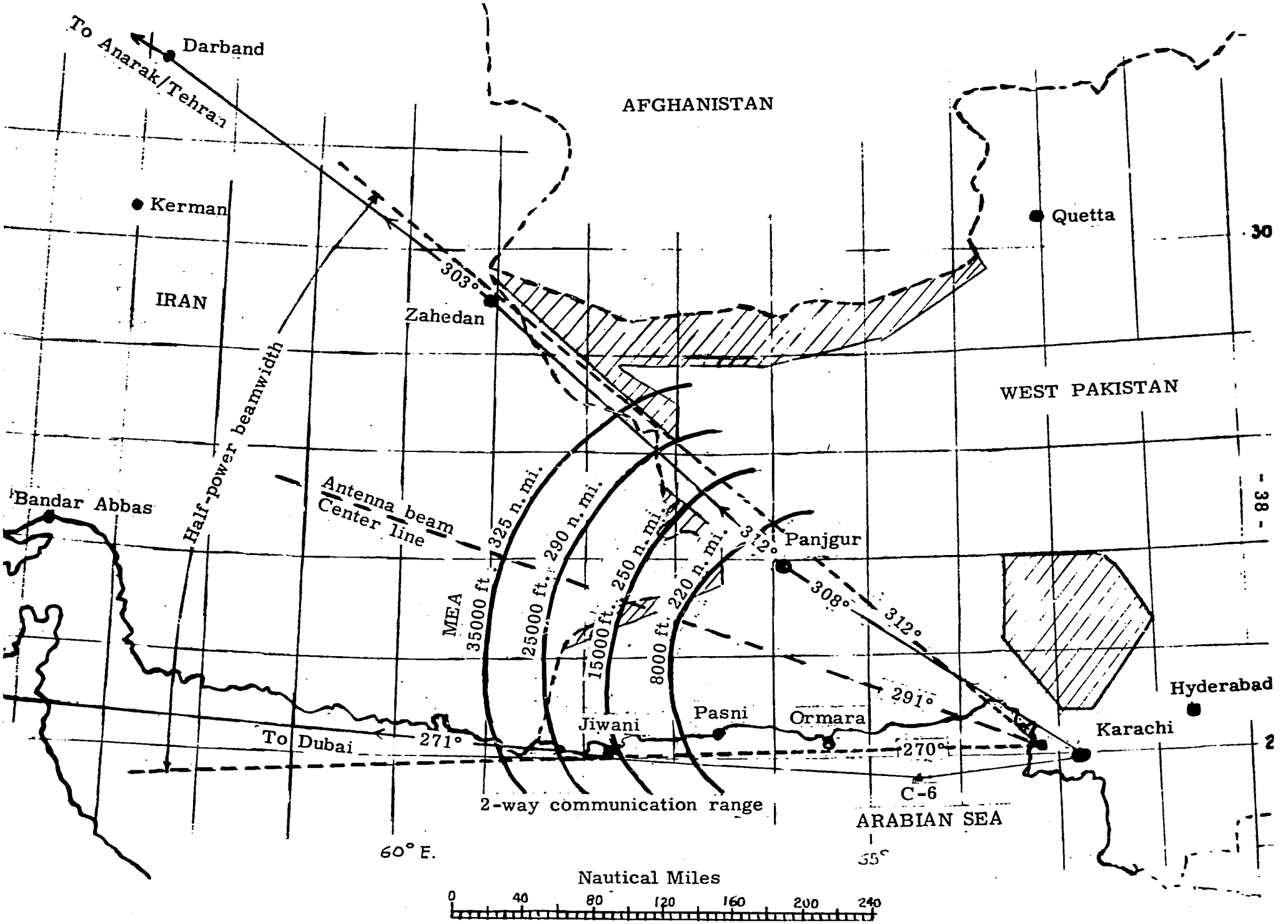


FIG. 7 EXTENDED RANGE VHF SERVICE AREA

V. DESCRIPTION OF EXTENDED RANGE AIR-GROUND VHF SYSTEM:

5.1 The VHF Link: -- The extended range VHF system consists of two radio links operating in tandem: the first, a two-way air-to-ground extended range VHF link between the aircraft and the elevated ground station near Karachi; and the second, a two-way short range point-to-point UHF link between the VHF ground station and the Karachi International Airport.

The VHF station may transmit to, or receive from, aircraft flying within an azimuth angle of approximately 42° at altitudes of 8,000 to 40,000 feet or more, and at distances from 0 to 325 nautical miles. The VHF ground station transmitter and receiver will handle a single voice channel, and, since they do not operate simultaneously, they use the same carrier frequency, and the same high gain antenna.

The VHF ground station is unattended, and is remotely controlled from the airport control tower, using audio tone signals transmitted over the UHF link. The VHF station is normally in receiving status. When it is desired to call, or to respond to, a distant aircraft, the airport control operator uses a "push-to-talk" switch which places the VHF station in transmitting status. Upon completing his message, he releases the swtich, and the VHF station returns to receive status.

The VHF ground station operates in the 118 to 136 mHz aviation frequency band, on the two frequencies allocated to Karachi Airport for use in the A.M.S. The aircraft operator, before calling Karachi, adjusts his equipment

to one of the two frequencies, and the airport control operator on which console the call is received replies on the same frequency.

In order to provide this communication with at least two aircraft simultaneously, flying in the control area, the VHF ground station will be equipped with duplicate VHF transmitting and receiving facilities, including antennas. Two separate carrier frequencies will be used; otherwise, the equipment will be identical.

Each transmitter and each receiver will be furnished with a standby unit, in case of failure. Automatic transfer devices will be used to switch from the main units to the auxiliary units.

Diesel-engine power supplies will be installed at the VHF ground station. Auxiliary units will also be provided, with automatic transfer devices.

Figure 8 is a functional block diagram showing the major components of the extended range VHF system. All operating functions of the VHF station are controlled from the tower control-room, or from the tower equipment room, located at Karachi Airport.

The VHF antenna is a high gain multi-element design, using vertical dipoles and reflector screens. Figure 9 is a drawing showing the general dimensions and assembly of this antenna. The main lobe power gain is 22 DB, referred to an isotropic antenna.

Figure 10 is a copy of a measured horizontal-plane radiation pattern of this type of antenna. The half-power beam width (HPBW) is 42°.

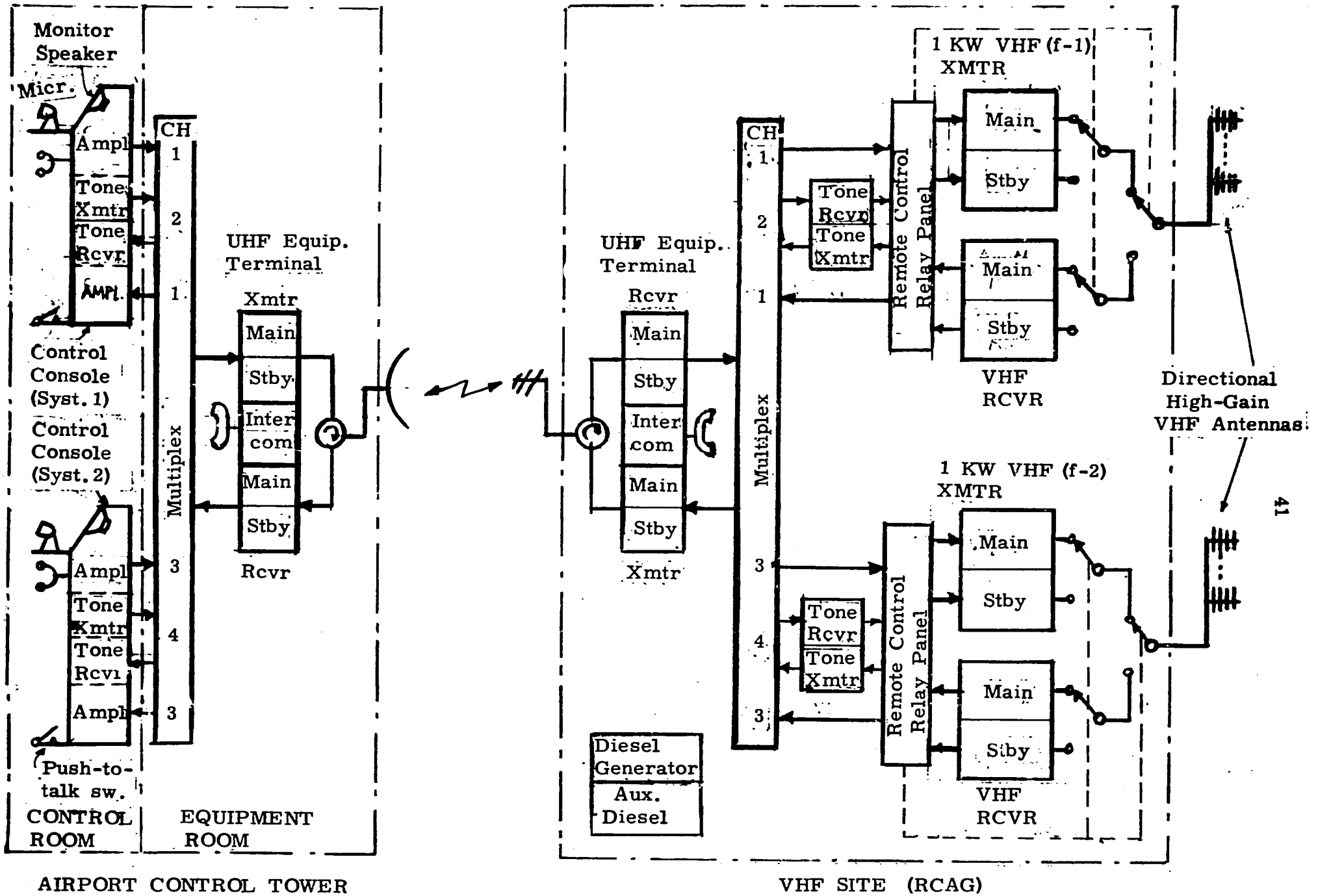


FIG. 8 BLOCK DIAGRAM OF PROPOSED EXTENDED RANGE VHF SYSTEM

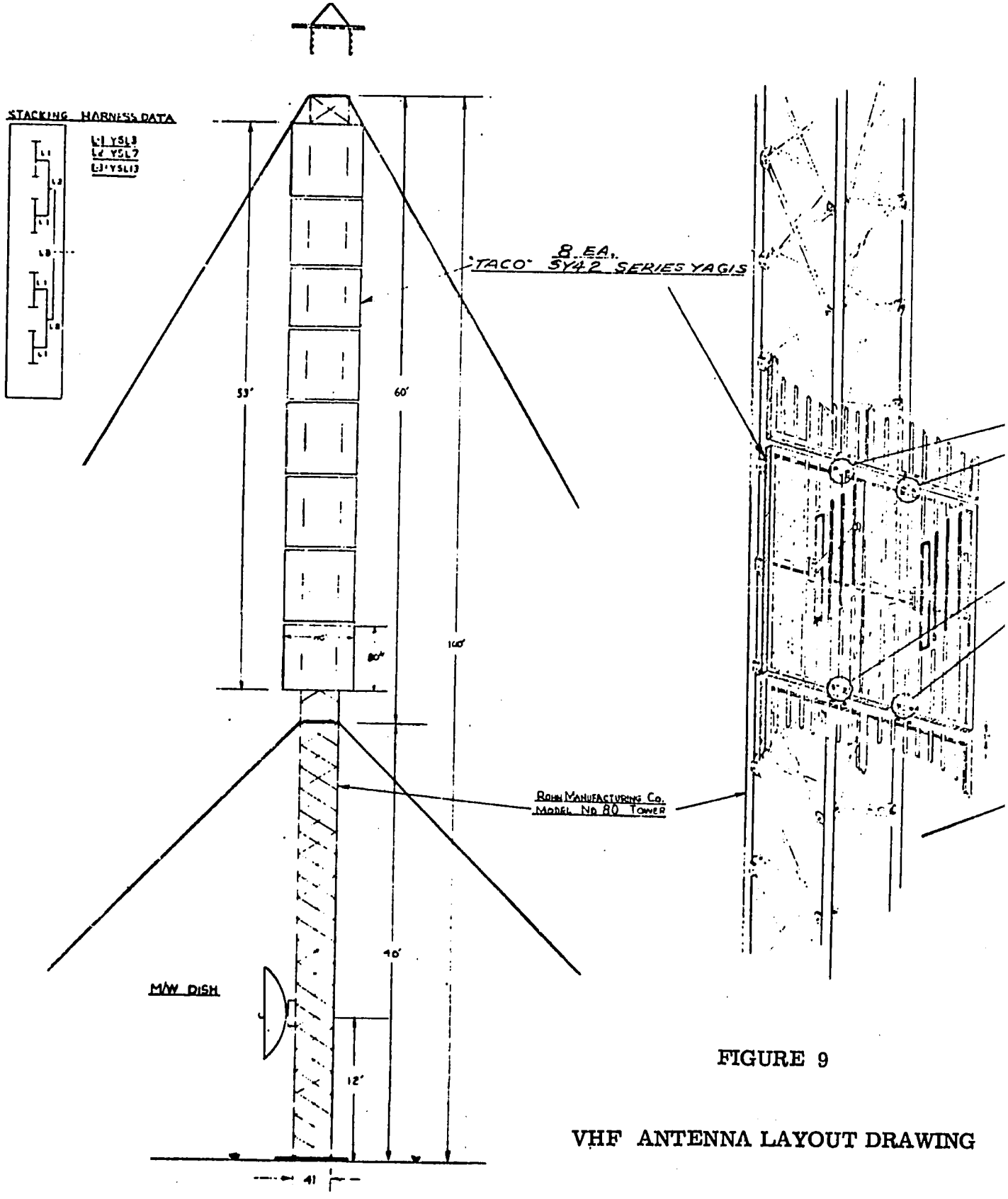


FIGURE 9

VHF ANTENNA LAYOUT DRAWING

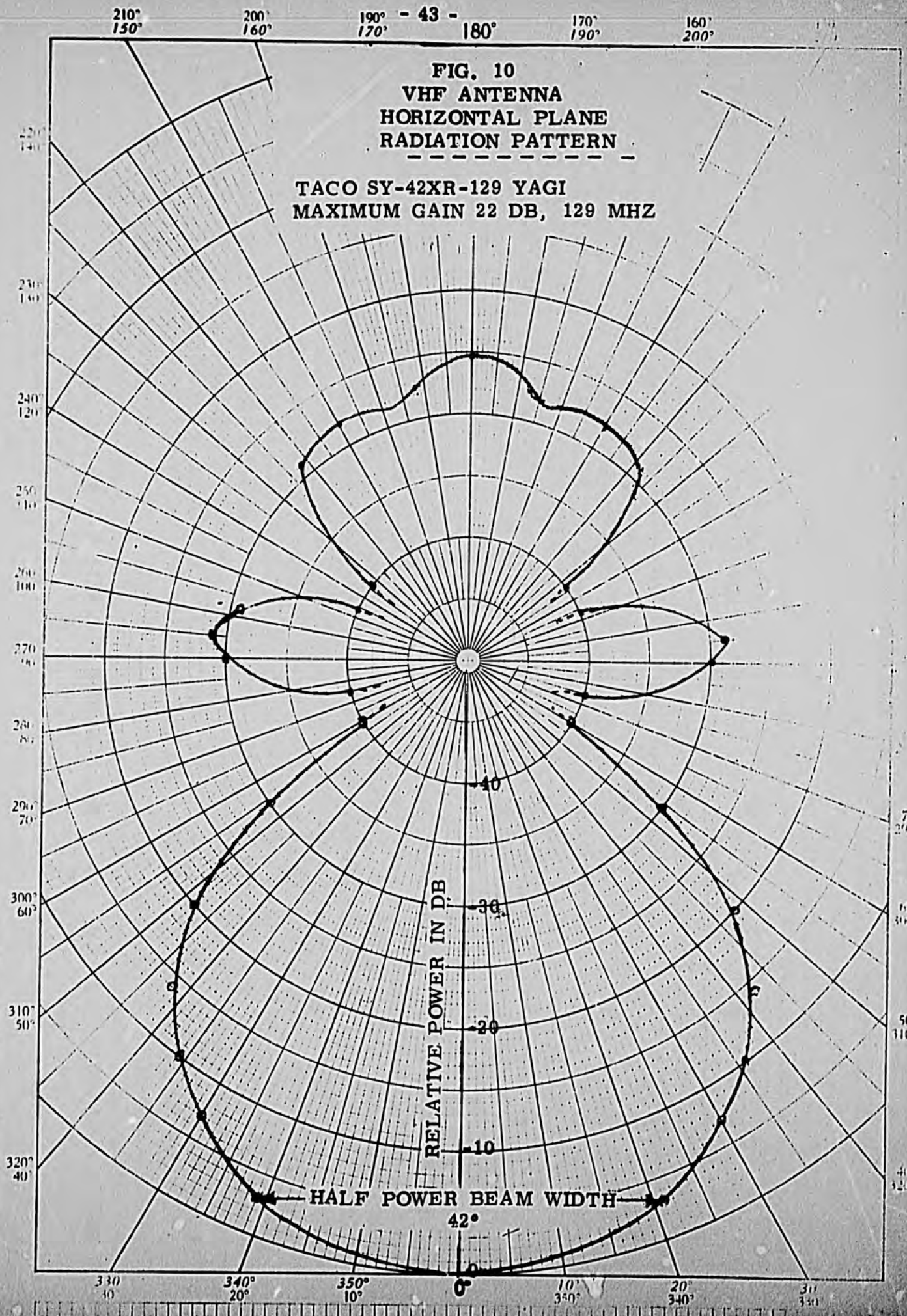


FIG. 10
VHF ANTENNA
HORIZONTAL PLANE
RADIATION PATTERN

TACO SY-42XR-129 YAGI
MAXIMUM GAIN 22 DB, 129 MHZ

The high gain, and the wide horizontal angle, is achieved by compressing the vertically radiated power, resulting in a fan-shaped horizontal plane pattern. The vertical 3 - db beamwidth is of the order of 10°. Thus, this antenna is particularly well designed for this air-to-ground VHF service, since it covers a wide horizontal angle, with very little power being lost at the higher vertical angles.

5.2 The UHF Link: -- The UHF link operates between the Karachi Airport and Gandbo Mt., a distance of 23 statute miles. It provides two-way communication for five voice channels (two for A. M. S.; two for control tones; and one intercom between sites). The equipment operates on 450 mHz, using a 15 watt FM transmitter at each end. Transmitters and receivers at each end are provided with standby units, and automatic transfer devices, in the event of failure.

Multiplex equipment to carry five voice channels is provided at each terminal.

The UHF equipment uses a different carrier frequency for each direction of transmission, and is operated continuously. The antenna are either parabolic or high gain Yagi type.

Figure 11 is a terrain profile of the line-of-sight path for this UHF link. The topographic data were obtained by direct measurements along the path, during the recent field trip.

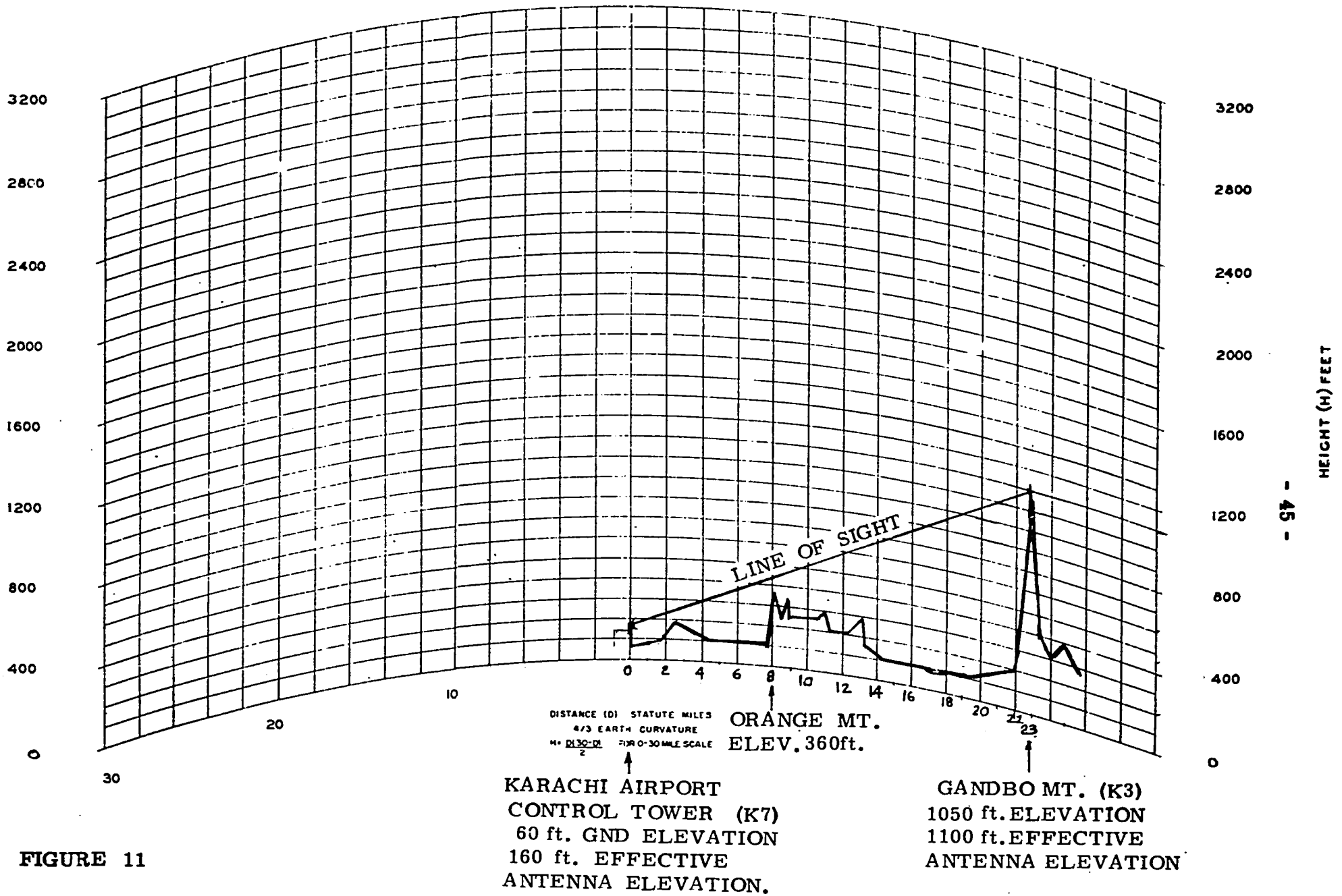


FIGURE 11

TERRAIN PROFILE FOR UHF PATH

KARACHI AIRPORT TO GANDBO MTN.

Table 5 is a summary of the UHF path parameters for this link. These figures show that a 38 db fade margin will exist, to accommodate changes in propagation. This margin should provide a propagation reliability in excess of 99%.

5.3 Site Plan: -- Figure 12 is a map of the Gandbo Mountain location, showing terrain contours, access roads, and radio path directions. A proposed site for the VHF ground station is indicated thereon. This site was selected, during the field survey trip, as the most suitable location for a troposcatter or VHF station in the Karachi area. It is indicated on Figure 4 as site K3.

The second choice of sites in this area is shown on Figure 4 as site K4.

Figure 13 is a suggested floor plan and equipment layout for the VHF ground station.

TABLE 5

SUMMARY OF UHF PATH PARAMETERS

Karachi Airport to Gandbo Mountain

SITE A: Control Tower, Karachi Airport

SITE B: Gandbo Mountain

Latitude	25° 53' 53" N	26° 03' 30" N
Longitude	67° 09' 06" E	66° 50' 20" E
Bearing to B	300°	-- to A 120°
Frequency	450 mHz	

Antennas 6 ft. diameter parabolic

	UNIT	SITE A	SITE B
Feeder length	Ft.	50	200
Feeder and Filter loss	DB	-2	-3
Plane earth loss	DB	- 128	
Shadow loss	DB	- 5	
Total loss	DB	- 138	
Antenna gains (2)	DB	+ 31	
Transmitter output pwr.	DBM	+ 42	(15 W)
Receiver input pwr.	DBM	- 65	
Receiver threshold	DBM	- 103	
Fade margin	DB	+ 38	
Fade margin required for 99% reliability	DB	+ 18	

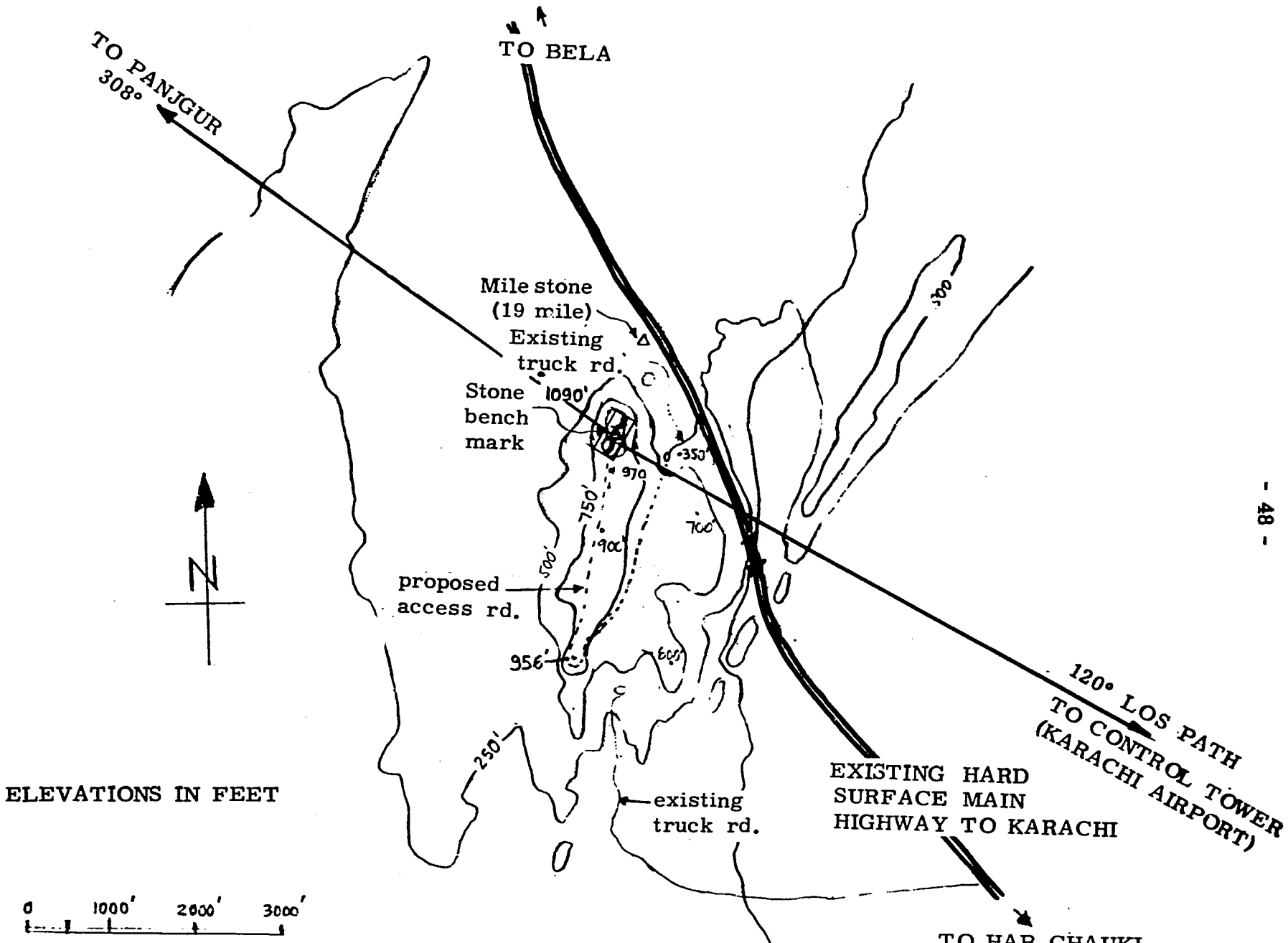


FIGURE 12

PROPOSED SITE PLAN GANDBO MTN.

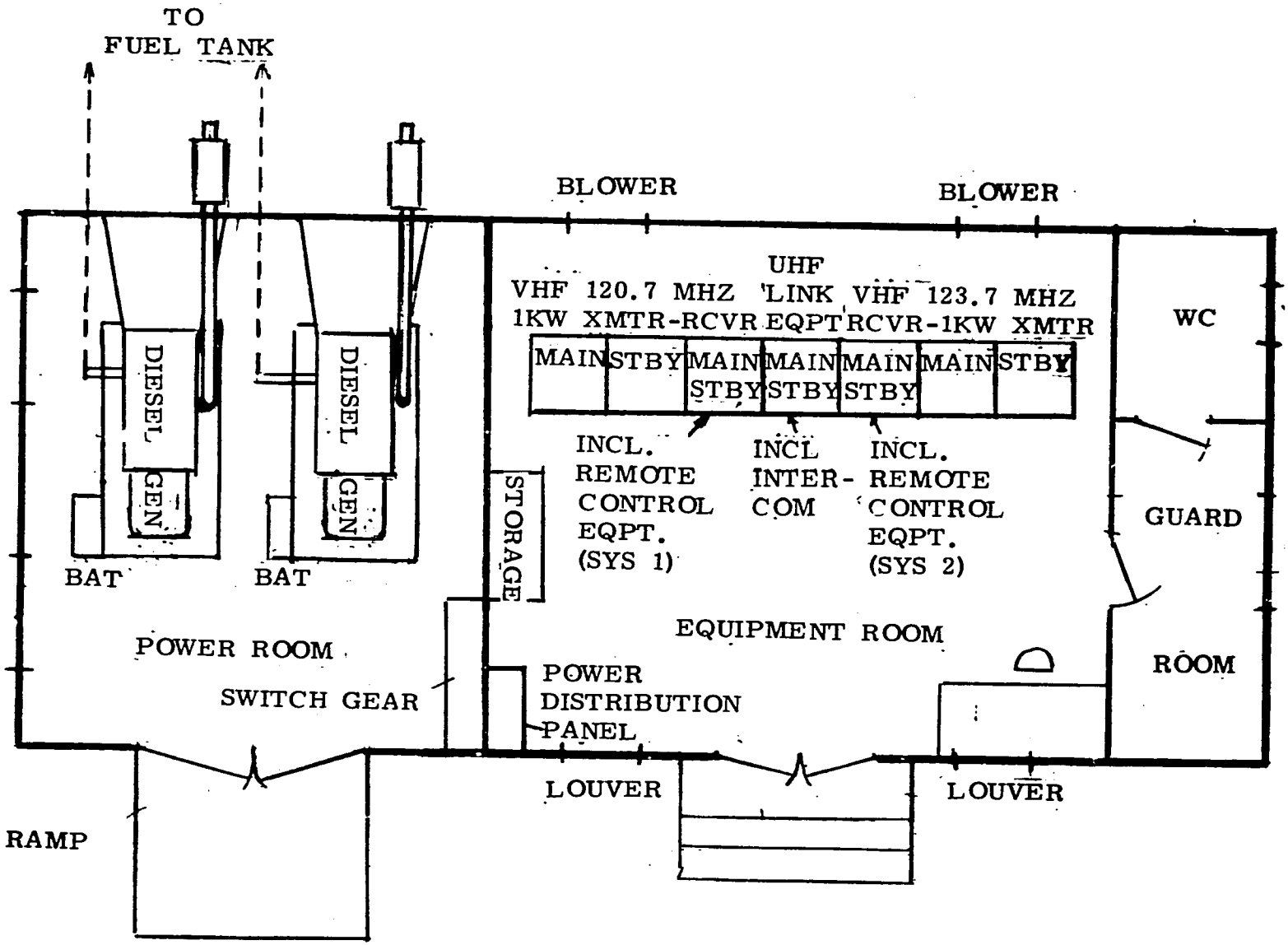


FIG. 13 FLOOR PLAN OF VHF STATION

VI. COST ESTIMATES

6.1 Improvements in Existing HF System: -- The difficulties with the existing HF system are due chiefly to interference from undesired signals, and, to a smaller extent, to propagation problems associated with the relatively short 235 mile HF path. There is little that can be done to improve this condition; therefore, no cost estimates have been prepared for this alternative.

6.2 Troposcatter Propagation to Replace the HF Link: -- Several troposcatter alternatives are described in Section IV, each of which would provide a reliable point-to-point communication system to replace the existing HF link. These systems are made up of one or more individual troposcatter links, using transmitter powers of 100, 1000, or 10,000 watts, and one or two line-of-sight UHF links (See Figure 6). The estimated costs of these individual links are itemized in the following tables:

10,000 watt Dual Diversity Tropo Link	Table 6
1,000 watt Dual Diversity Tropo Link	Table 7
100 watt Dual Diversity Tropo Link	Table 8
15 watt 5 Channel UHF LOS Link	Table 9
1,000 watt Extended Range VHF Station	Table 10

The cost of the individual troposcatter alternatives may be estimated by selecting the appropriate link costs, and adding them up:

Tropo Path (Figure 6)	System Makeup	Estimated Cost
(1)	1 - 10 KW Tropo Link (Table 6)	$517,600.00
(2)	1 - 1 KW Tropo Link (Table 7) and 1 - UHF LOS Link (Table 9)	427,500.00
(3)	1 - 100 W Tropo Link (Table 8) and 2 - UHF LOS Links (Table 9)	473,700.00
(4)(5)	1 - 1 KW Tropo Link (Table 7) and 1 - 100 W Tropo Link (Table 8)	702,600.00
(6)(7)	2 - 1 KW Tropo Links (Table 7)	722,600.00

TABLE 6

Estimated Cost
of

10 KW Dual Diversity
Tropo Scatter Link
(2 Terminals)

		Cost (US $)
2	Tropo radio terminal, each with 1 - 10 KW amplifier, 1 - exciter, 2 - receivers, 2 - low noise pre-amp. etc.	$150,000
2	VF multiplex equipment - 5 channel Farinon LD - 1	10,000
2	Order wire units, including signal unit	1,600
4	Antenna, 30 -ft. dia., parabolic	60,000
4	30 ft. self-supported (stub) towers	14,000
400 ft.	1 5/8" diameter, air-dielectric coax cable	1,600
1 lot	EIA flanges, transitions, jumper cable and feeder installation material	800
1 lot	equipment installation material	3,000
2	Dehydrators	1,600
1 lot	equipment spare parts for three years maintenance	20,000
1 lot	test equipment	15,000
2	Power systems, each with: 2 - 75 KVA diesel generators, transfer gear, distribution wiring, blowers, storage tanks and fuel pumps	76,000
	Equipment Total	$353,600
	Installation, test, training	110,000
	Engineering	30,000
	Inspection and testing of system	6,000
	Packing, shipping, port charges, delivery to site.	18,000
	GRAND TOTAL	$517,600

TABLE 7

Estimated Cost
of

1 KW Dual Diversity
Tropo Scatter Link
(2 Terminals)

		Cost (U.S.$)
2	RF power amplifier (2 gHz band), 1 KW RF output (including Klystron tube, packing)	$40,000
2	Dual diversity radio terminal, Farinon SS 2000W incl: 1 - exciter, 2 - receiver, 1 - diversity combiner	30,000
2	VF multiplex equipment - 5 channel Farinon LD - 1	10,000
2	Bandpass filter for receiving system	900
4	Low noise, high gain, solid state pre-amplifier	4,400
2	Circulator for receiver isolation	400
2	Order wire unit including signal unit	1,600
4	Antenna, 30-ft. diameter, parabolic	60,000
4	30-ft. self-supported (stub) tower	14,000
400 ft.	transmission line 1 5/8" diameter, air-dielectric coax cable	1,[illegible]
1 lot	EIA flanges, transitions, jumper cables and feeder installation material	800
1 lot	equipment installation material	2,000
2	Dehydrators	1,600
1 lot	equipment spare parts for three years maintenance (5%)	9,000
1 lot	test equipment	8,000
2	Power systems, each with 2 - 30 KVA diesel generators, switch gear, distribution wiring, blowers, fuel storage tanks and pumps, etc.	40,000
	Total	$224,300

TABLE 7 (continued)

	Cost (U.S.$)
Amt. Brought Forward	$224,300
Installation, test, training	90,000
Engineering	30,000
Inspection and testing of system	4,000
Packing and shipping, port charges, delivery to site.	13,000
GRAND TOTAL	$361,300

TABLE 8

Estimated Cost
of

100 Watt Dual Diversity
Tropo Scatter Link
(2 Terminals)

		Cost (U.S.$)
2	RF power amplifier, 2 GHz band, 100 watt output including TWT: power supply (Varian)	$ 26,000
2	Dual diversity radio terminal, Farinon SS 2000 W (2 GHz) E/W: 1 - exciter, 2 - receivers, 1 - ratio div. combiner	30,000
2	VF multiplex equipment - 5 channel Farinon LD - 1	10,000
2	Bandpass filter for receiving system	900
4	Low noise, solid state pre-amplifier (TDA)	4,400
2	Circulator for receiver isolation	400
2	Order wire unit including signal unit	1,600
4	Antenna, 30-ft. diameter paraboloidal, 2 GHz band	60,000
4	30-ft. self-supported (stub) tower	14,000
400 ft.	transmission line, 1 5/8" diameter, air-dielectric coax cable	1,600
1 lot	EIA flanges, transitions, jumper cable and feeder installation material	800
2	Dehydrator	1,600
1 lot	equipment spare parts for three years maintenance	9,000
1 lot	equipment installation material (overhead ducts, conduits, wires, etc.)	2,000
1 lot	test equipment	8,000
2	Power systems, each with 2 - aircooled 25 KVA diesel generators, switch gear, distribution wiring, blowers, fuel storage tanks and fuel pumps, etc.	35,000
	Total	$205,300

	Cost (U.S.$)
Amount Brought Forward	$205,300
Installation, test, training	90,000
Engineering	30,000
Inspection and testing of system	4,000
Packing and shipping, port charges, delivery to site.	12,000
GRAND TOTAL	$341,300

TABLE 9

Estimated Cost
of

UHF Radio Link
(2 Terminals)

		Cost (U.S.$)
2	UHF radio terminal, 15 W RF output, including hot standby, order wire, Farinon TR 450	$ 18,000
2	Order wire unit, including signalling	1,600
2	VF multiplex, 5 channel terminal, Farinon LD	10,000
2	Antenna, 6-ft. diameter, parabolic, 450 mHz band	1,500
1	120 ft. guyed tower, including antenna mounting	5,500
1	Antenna mounting material for airport control tower	500
200 ft.	transmission line, 7/8" heliax coaxial cable	600
1 lot	feeder and equipment installation material (overhead ducts, conduits, wires, tower lighting, etc.)	1,000
1 lot	spare parts for equipment (three years)	2,000
1 lot	test equipment	2,000
	Total	$ 42,700
	Installation, test, training	15,000
	Engineering	4,000
	Inspection and testing of system	2,000
	Packing and shipping, port charges, delivery to site.	2,500
	GRAND TOTAL	$ 66,200

TABLE 10

Estimated Cost

of

1 KW Extended Range VHF Facility
(One Ground Station)

		Cost (U. S. $)
2	1 KW VHF transmitter/receiver systems, each with:	
	2 - 1 KW VHF transmitter (main & standby) (10V1-A)	
	2 - VHF receiver (main & standby) (85)	
	1 - Cabinet containing antenna/input switching panel	
	1 - Control console with loud speaker, microphone, remote control and alarm system	
	Total	$ 50,000
2	Extended range, directional VHF antennas, each with:	
	8 TACO screen reflector YAGI antennas	
	Total	10,000
1 lot	equipment and feeder installation material	1,000
2	100' Rohn #83, triangular towers, guyed at 40' and 100' level to accommodate the 53 ft. TACO antenna assembly	5,000
400 ft.	transmission line, 7/8" Heliax cable	1,200
1 lot	spare parts for equipment for three years	2,000
1 lot	test equipment	500
2	25 KVA aircooled diesel generators, with switch gear, distribution, wiring, blowers, fuel storage tanks and pumps.	17,000
	Total	$ 86,700

TABLE 10 (continued)

	Cost (U.S.$)
Amount Brought Forward	$ 86,700
Installation, test and training	30,000
Engineering	5,000
Inspection and testing of three-way system (special aircraft)	5,000
Packing and shipping, port charges, delivery to site	9,000
GRAND TOTAL	$135,700

There will be some variations in costs, due to differences in suppliers, tower requirements, installation conditions, etc.; however, the figures given are representative, and adequate for making comparisons between the alternative plans proposed.

6.3 Extended Range VHF Link: -- This system consists of one terminal of the air-to-ground VHF link, plus one UHF LOS link. The estimated cost is as follows:

			Estimated Cost
1	1 KW VHF Station (Table 10)		$135,700.00
1	UHF LOS Link (Table 9)		66,200.00
		Total	$201,900.00

6.4 These estimated costs do not include the costs of buildings, access roads, or acquiring property; these costs must be determined locally, and must be considered.

ANNEX A

HIGH FREQUENCY PROPAGATION PERFORMANCE PREDICTIONS

1. Description of Tabulated System Performance Predictions

A description of the circuit parameters used in the calculations of the system performance predictions is shown in the heading of each page of data. Starting at the top of the page after the page number, this heading is as follows:

The first line contains the month and year and the solar activity level as indicated by the 12-month running average Zurich sunspot number. The second and third lines contain the name and coordinates of the transmitter and receiver location, the azimuthal bearings in degrees of the receiver from the transmitter and vice versa, and the length of the circuit in statute miles and kilometers. The fourth and fifth lines describe the physical parameters of the antenna system for each terminal and the orientation of the antenna's main beam relative to the great-circle path. The minimum angle indicates the lowest vertical angle considered in the mode selection process.

The sixth line contains the power output of the transmitter, the man-made noise level assumed for the receiver location, in decibels relative to 1 watt in a 1 Hz bandwidth at a frequency of 3 MHz, and the hourly median signal-to-noise ratio required to provide the type of service requested. The seventh and eighth lines contain the list of frequencies to be considered in the hourly calculations.

2. Description of Graphical Representation

On the graph associated with the tabulations are plotted the maximum usable frequency (MUF), the frequency which has a 50 percent probability of having a sky-wave path, as an asterisk; the optimum traffic frequency (FOT), the frequency which has a 90 percent probability of having a sky-wave path, as a plus sign; and the lowest useful

frequency (LUF), the lowest frequency which has a reliability of 90 percent or greater, as a dot. When no frequency is predicted to attain a 90 percent reliability, an "X" is shown at the bottom of the graph. The MUF and FOT values are plotted for every hour of the day and the LUF values for every other hour of the day. Any values greater than or equal to 30 MHz are plotted on the top line of the graph. All plotted values are tabulated on the right-hand side of the graph. A dash in the tabulations correspond to an "X" on the graph.

MORCOM SYSTEMS INC.
1740 N STREET, N.W.-WASHINGTON, D.C. 20036

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FEBRUARY 15, 1971 10 CM FLUX 123 (SSN 75)

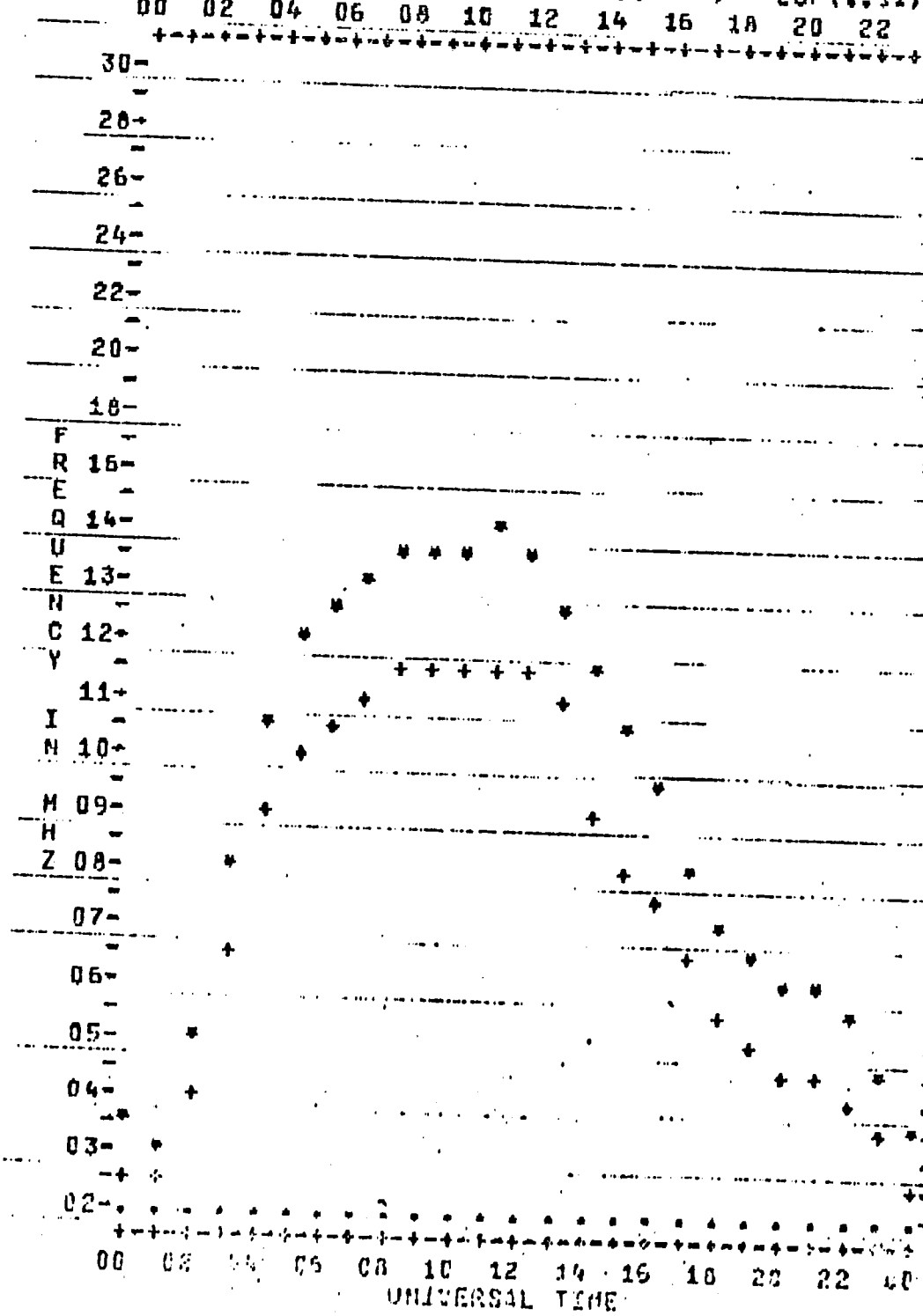
KARACHI TO PANJGUR

			AZIMUTHS		MILES	KM.
24.90N - 67.15E	26.95N - 64.14E		307.79	126.47	234.6	377.6

MINIMUM ANGLE 0.0 DEGREES

XMTR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0
RCVR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0
POWER= 5.00KW 3 MHZ NOISE=-165.60DBW TIME= 90 PERCENT REQ.S/N=50.00DB

MUF(****) - FOT(++++) - LUF(....)



UT	MUF	FOT	LUF
01	3.4	2.6	-2.0
02	5.1	4.3	-2.0
03	8.1	6.9	-2.0
04	10.7	9.1	-2.0
05	12.1	10.3	-2.0
06	12.7	10.8	-2.0
07	13.1	11.2	-2.0
08	13.5	11.5	2.1
09	13.7	11.7	-2.0
10	13.9	11.8	-2.0
11	14.0	11.9	-2.0
12	13.7	11.6	-2.0
13	12.9	11.0	-2.0
14	11.9	9.3	-2.0
15	10.8	8.4	-2.0
16	9.6	7.5	-2.0
17	8.3	6.5	-2.0
18	7.3	5.7	-2.0
19	6.5	5.1	-2.0
20	6.2	4.8	-2.0
21	6.0	4.7	-2.0
22	5.7	4.3	-2.0
23	4.8	3.6	-2.0
24	3.6	2.8	-2.0

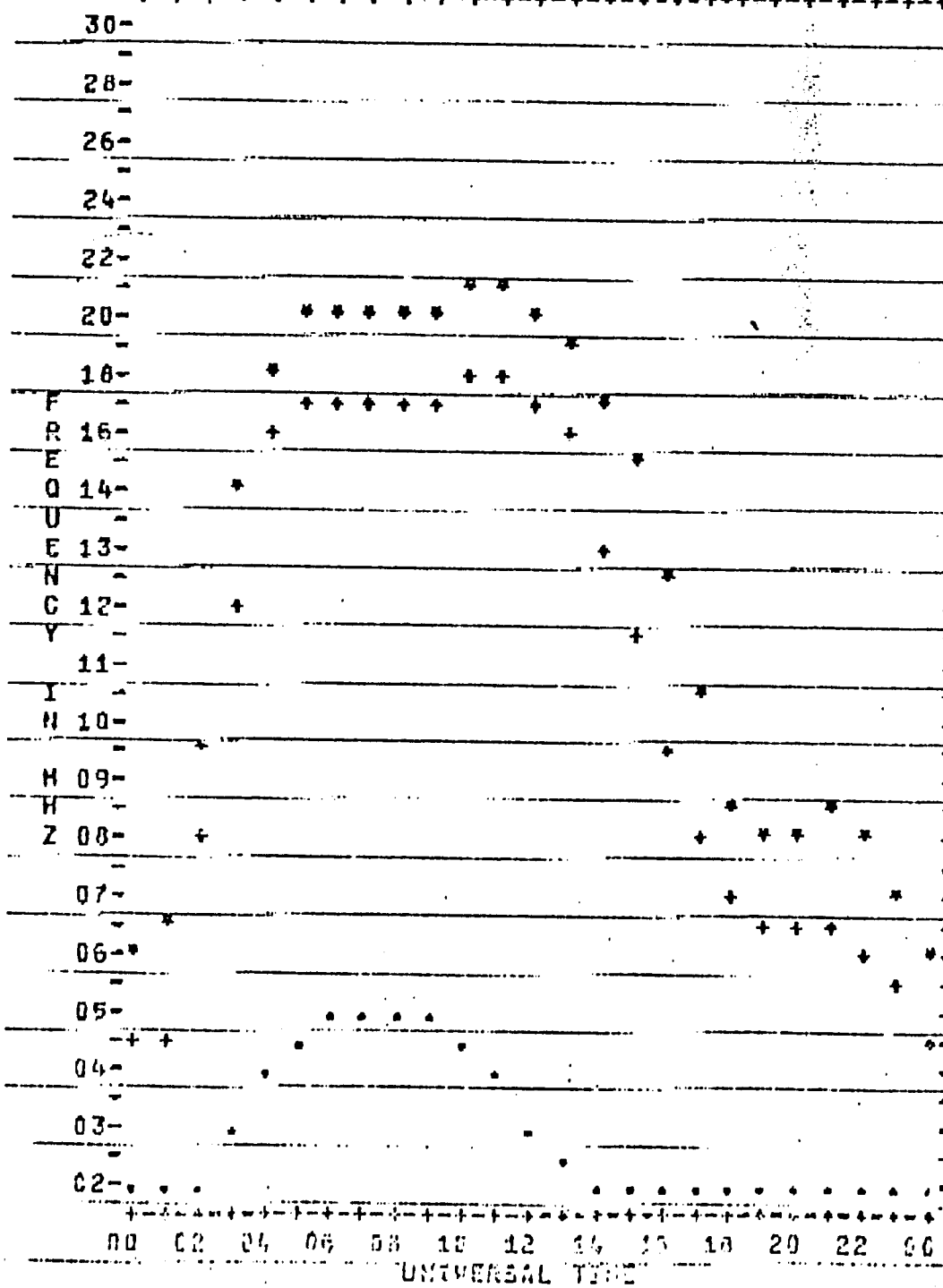
FEBRUARY 15, 1971 10 CM FLUX 123 (SSN 75)

PANJGUR	TO LAHORE	AZIMUTHS	MILES	KM.
26.95N - 64.14E	31.52N - 74.40E	60.51 245.54	694.1	1117.0

MINIMUM ANGLE 0.0 DEGREES

XMTR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0
RCVR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0
POWER= 5.00KW 3 MHZ NOISE=-165.60DBW TIME= 90 PERCENT REQ.S/N=50.00B

MUF(****) - FOT(++++) - LUF(....)



UT	MUF	FOT	LUF
01	6.5	4.9	-2.0
02	9.6	8.1	-2.0
03	14.4	12.3	3.1
04	18.4	15.7	4.0
05	20.0	17.0	4.7
06	19.9	17.0	5.1
07	19.8	16.8	5.3
08	19.9	16.9	5.3
09	20.2	17.2	5.1
10	20.6	17.5	4.8
11	20.8	17.7	4.2
12	20.3	17.3	3.4
13	18.9	16.0	2.5
14	17.0	13.2	-2.0
15	14.9	11.6	-2.0
16	12.6	9.8	-2.0
17	10.5	8.2	-2.0
18	8.9	7.0	-2.0
19	8.3	6.5	-2.0
20	8.4	6.5	-2.0
21	8.6	6.7	-2.0
22	8.3	6.3	-2.0
23	7.2	5.5	-2.0
24	6.1	4.6	-2.0

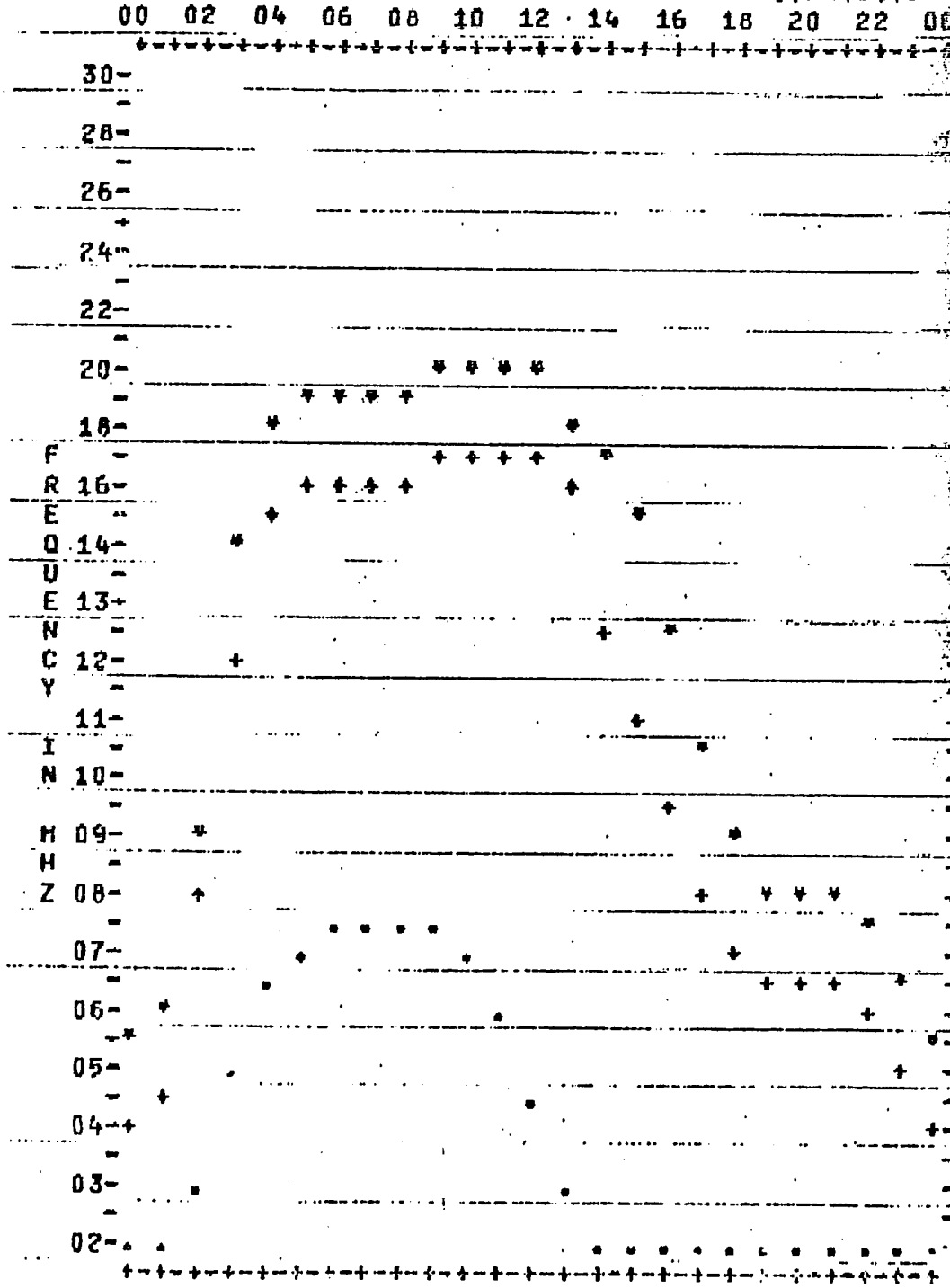
FEBRUARY 15, 1971 10 CM FLUX 123 (SSN: 75)

LAHORE	TO KARACHI	AZIMUTHS		MILES	KM.
31.52N - 74.40E	24.90N - 67.1[illegible]	225.75	42.32	635.4	1022.5

MINIMUM ANGLE 0.0 DEGREES

XMTR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0
RCVR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0
POWER= 5.00KW 3 MHZ NOISE=-136.5DBW TIME= 90 PERCENT REQ.S/N=50.0DB

MUF(****) - FOT(++++) - LUF(....)



UT	MUF	FOT	LUF
01	6.1	4.7	-2.0
02	9.4	8.0	3.2
03	14.2	12.1	5.3
04	17.9	15.2	6.6
05	19.1	16.2	7.1
06	19.1	16.2	7.6
07	19.1	16.2	7.7
08	19.3	16.4	7.7
09	19.7	16.7	7.5
10	20.1	17.1	7.0
11	20.3	17.3	6.1
12	19.7	16.8	4.9
13	18.3	15.5	3.4
14	16.5	12.9	-2.0
15	14.6	11.4	-2.0
16	12.6	9.8	-2.0
17	10.5	8.2	-2.0
18	9.0	7.0	-2.0
19	8.3	6.5	-2.0
20	8.3	6.5	-2.0
21	8.4	6.6	-2.0
22	7.9	6.0	-2.0
23	6.7	5.1	-2.0
24	5.6	4.2	-2.0

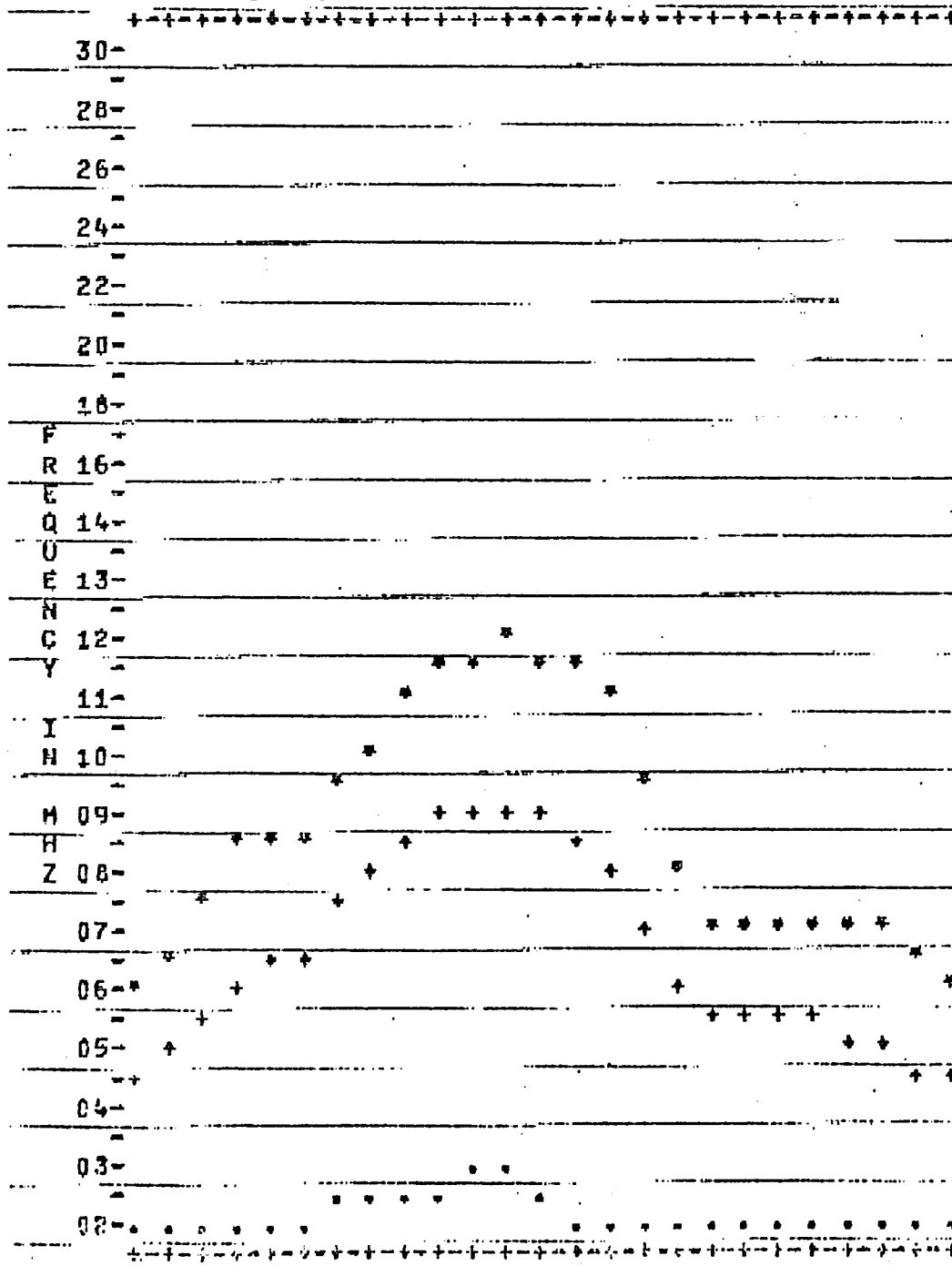
JUNE 15, 1971 10 CM FLUX 114 (SSN 64)

KARACHI	TO PANJGUR	AZIMUTHS	MILES	KM.
24.90N - 67.15E	26.95N - 64.14E	307.79 126.47	234.6	377.6

MINIMUM ANGLE 0.0 DEGREES

XMTR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0
RCVR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0
POWER= 5.00KW 3 MHZ NOISE=-165.60DW TIME= 90 PERCENT REQ.S/N=50.0DB

HUF(****) - FOT(++++) - LUF(....)



JUNE 15, 1971 10 CM FLUX 114 (SSN 64)

PANJGUR TO LAHORE AZIMUTHS MILES KM.

26.95N - 64.14E 31.52N - 74.40E 60.51 245.54 694.1 1117.0

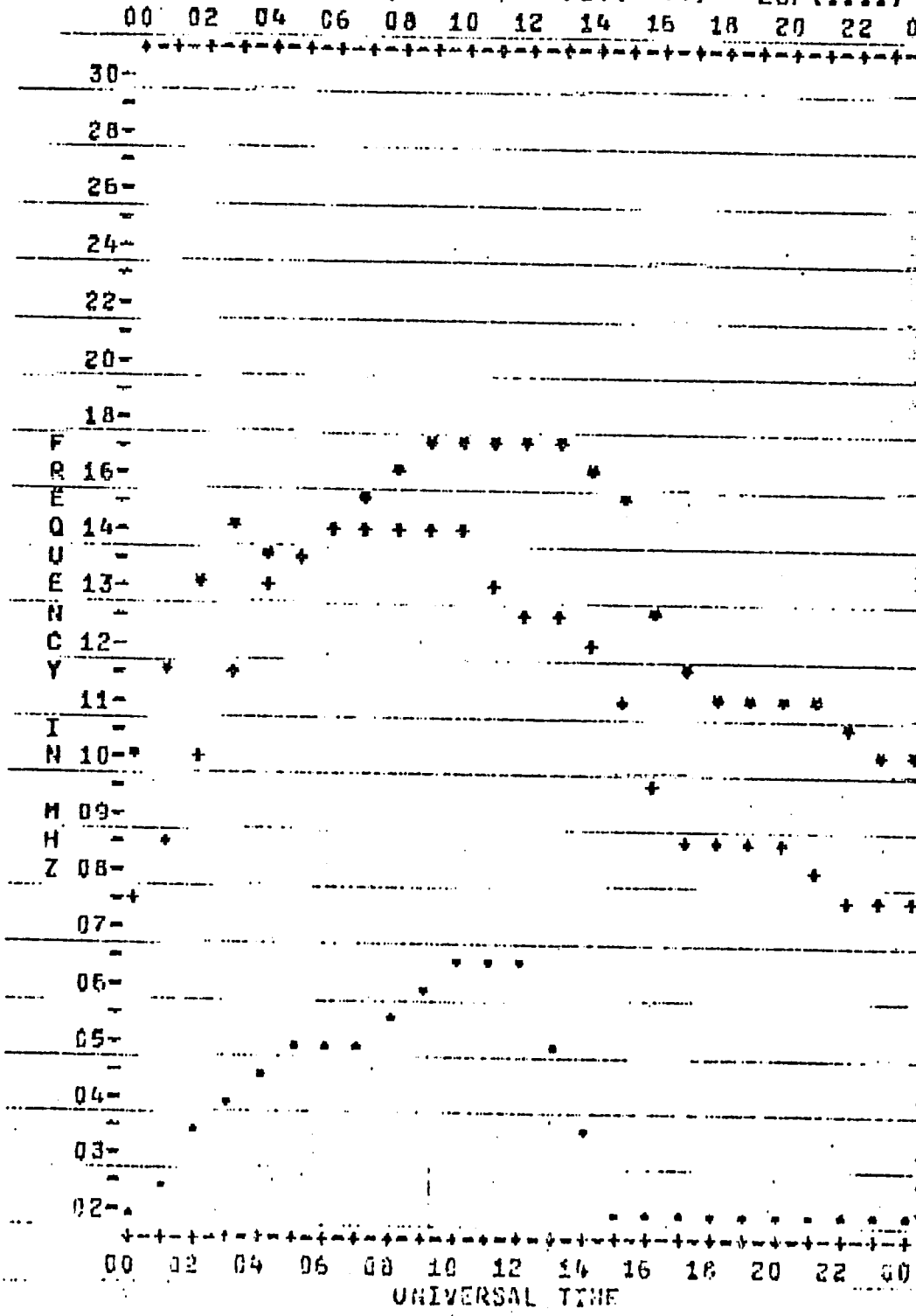
MINIMUM ANGLE 0.0 DEGREES

XMTR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0

RCVR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0

POWER= 5.00KW 3 MHZ NOISE=-165.60DW TIME= 90 PERCENT REQ.S/N=50.000

MUF(****) - FOT(++++) - LUF(....)



UT	MUF	FOT	LUF
01	11.6	8.5	2.7
02	13.4	10.1	3.7
03	14.3	11.9	4.4
04	13.8	13.2	4.9
05	13.9	13.9	5.1
06	14.0	14.0	5.2
07	15.2	14.1	5.3
08	16.1	14.2	5.7
09	16.6	14.3	6.0
10	16.8	14.0	6.5
11	16.7	13.1	6.9
12	16.6	12.8	6.6
13	16.6	12.8	5.3
14	16.3	12.1	3.9
15	14.9	11.0	-2.0
16	12.8	9.5	-2.0
17	11.5	8.5	-2.0
18	11.2	8.6	-2.0
19	11.2	8.7	-2.0
20	11.1	8.6	-2.0
21	11.0	8.4	-2.0
22	10.8	7.9	-2.0
23	10.4	7.6	-2.0
24	10.4	7.6	-2.0

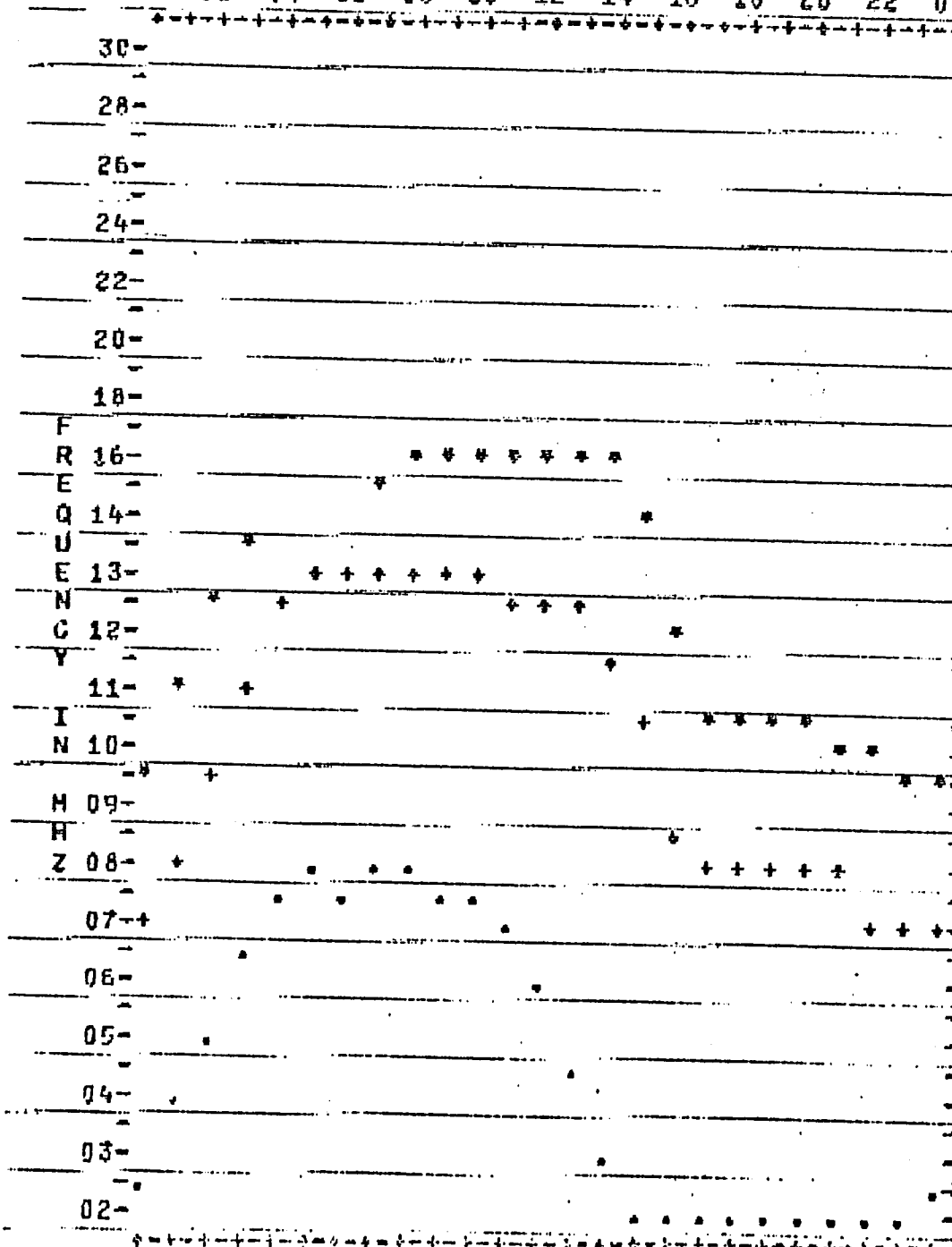
JUNE 15, 1971 10 CM FLUX 114 (SSN 64)

LAHORE	TO KARACHI	AZIMUTHS	MILES	KM.
31.52N - 74.40E	24.90N - 67.15E	225.75 42.32	635.4	1022.5

MINIMUM ANGLE 0.0 DEGREES

XMTR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0
RCVR 2.0 TO 30.0 HORIZ HW DIPOLEH -0.25 L -0.50 A -0.0 OFF AZ 0.0
POWER= 5.00KW 3 MHZ NOISE=-136.50DBW TIME= 90 PERCENT REQ.S/N=50.0DB

MUF(****) - FOT(++++) - LUF(....)



UT	MUF	FOT	LUF
01	11.1	8.1	4.0
02	12.8	9.6	5.4
03	13.5	11.4	6.6
04	12.9	12.6	7.7
05	13.1	13.1	8.2
06	13.4	13.2	7.8
07	14.7	13.3	8.2
08	15.6	13.4	8.1
09	16.1	13.4	7.7
10	16.4	13.1	7.5
11	16.3	12.6	7.0
12	16.2	12.5	6.0
13	16.2	12.5	4.8
14	15.8	11.7	3.4
15	14.2	10.5	-2.0
16	12.1	8.5	-2.0
17	10.8	8.0	-2.0
18	10.6	8.1	-2.0
19	10.6	8.1	-2.0
20	10.5	8.1	-2.0
21	10.3	8.0	-2.0
22	10.2	7.4	-2.0
23	9.0	7.2	-2.0
24	9.8	7.2	2.7