DIRECT SATELLITE COMMUNICATIONS

INTERIM REPORT

by

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ABSTRACT

Mobile radio communications in Alaska are not always effective along our highways, marine system, and remote field sites. This ineffective mobile radio communications coverage is due in part to the lack of repeaters in appropriate locations and an excess of users on certain frequencies. Lower frequencies can propogate over hilly areas whereas higher frequencies tend to travel in straight lines and are shielded by hills, ridges, and tall buildings.

A new communications system called Mobile Satellite Service (MSS) may be available for use in the State in three or four years. The MSS system utilizes a satellite link between the transmitting station to the receiving station. The system is best suited for areas with few path obstructions therefore use in remote, rural areas where other forms of communication are unavailable or unreliable is very appropriate.

This interim report identifies candidate applications in the State and determines coverage which will be provided in Alaska by each of the proposed satellites.

The final report will give specific recommendations for feasible applications and include a technical and economical analysis of mobile satellite operations in Alaska, specifying technical requirements and defining potential operating difficulties.

TABLE OF CONTENTS

Introduction....................1

System Structure....................2

Candidate Applications....................3

Vehicles on the Highway System....................3

Remote Locations....................4

Other....................5

Proposed Satellites....................5

Shadow Analysis....................11

Graphical Analysis....................13

Conclusion....................16

INTRODUCTION

Dramatic technological developments are expected to make mobile satellite service (MSS) available within a few years. The new service, which appears to have great potential for Alaska, will make it possible to communicate with radios which are installed in vehicles (mobiles) or radios that can be carried in backpacks (transportables) virtually anywhere on the continent. It is anticipated that the impact on communication services in rural and remote areas will be substantial.

The Federal Communications Commission (FCC) recently moved one step closer to making MSS a reality. The Commission is considering rules which would authorize the new technology, which could be in service as early as 1988 or 1989. Before an operational system can be implemented, however, the FCC must allocate the necessary frequencies and license a system operator.

The National Aeronautics and Space Administration (NASA) has been working for some years to foster the development of MSS, and the Canadian government has been similarly interested. Twelve companies want to provide mobile satellite service in the United States. Canada is making plans to initiate its own service, and U.S.-Canadian cooperation is seen as a strong possibility.

Direct satellite-to-mobile service will be made possible by one or more satellites in geosynchronous orbit operating in the 800 MHz and 1.5 GHz bands with high effective radiated power. Narrowband, power efficient modulation techniques will be needed. Mobile units will need low noise receiver front ends and antennas with modest gain. Other ground stations, fixed or transportable, will be able to use the system if they have the same attributes.

The new technology should perform best in nonurban areas, where there will be few path obstructions. In urban areas, where buildings can cause path blockage and multipath problems, performance will not be as good. Mobile satellite service is seen as a way to dramatically improve many communication services outside metropolitan areas, filling the gaps left by present terrestrial systems.

SYSTEM STRUCTURE

Communication satellites transmitting radiated power levels high enough to be usable by mobile and transportable stations will make mobile satellite service feasible. Operation will be at UHF, in the 800 MHz range and, perhaps, at L-band (1.5-1.6 GHz). Direct communication links will be established between a satellite and: mobiles, transportables, gateway earth stations, base earth stations, and a control earth station. Each base earth station will serve a dispatch console, and each "gateway" will provide connection to the public switched telephone network. The control earth station, an operations center, will perform satellite and network control.

The network structure will accommodate four kinds of communication.

1. Mobile to mobile
2. Mobile to dispatcher
3. Mobile to public switched telephone network
4. Satellite and network control

The network must serve a large number of mobiles, a smaller but still large number of base stations and gateways, and the operations center.

Because UHF spectrum is in short supply, it is likely that UHF will be used only for communication with mobile units. SHF, either C-band (6/4 GHz) or Ku-band (14/12 GHz), will be used by base stations, gateways and the control station. It is possible that L-band will be used to serve some mobile units, and aeronautical mobiles in particular.

Mobile transmissions on UHF will be translated by the satellite to SHF and then retransmitted to a base station or gateway. Similarly, fixed station (base station or gateway) uplink transmissions on SHF will be translated to UHF and then retransmitted to a mobile. All mobile-to-fixed and fixed-to-mobile transmissions will involve a single hop, but mobile-to-mobile transmissions will require a double hop. One mobile's transmission on UHF will be retransmitted to the base station on SHF. It will then be switched at the dispatch console and transmitted back to the spacecraft on another SHF frequency, and retransmitted to the second mobile on yet another UHF frequency.

CANDIDATE APPLICATIONS

Based on interviews with state personnel, a number of very promising applications of MSS by state agencies have been identified. These can be divided into three categories: communication with vehicles on the highway system, communication with remote locations, and other communications.

Vehicles on the Highway System

The Department of Public Safety and the Department of Transportation and Public Facilities (DOT&PF) both have major needs for communication with vehicles operating on the highway system, the former to support the Alaska State Troopers and the latter to support highway construction and maintenance operations. In addition, ambulances, which are not state vehicles, also have a critical need for such communication. Two-way voice communication with a dispatcher is needed in all cases. In addition to the above vehicular needs, it would be helpful for project engineers on DOT&PF construction sites to have telephones. Further, MSS will make possible emergency roadside telephones in remote areas.

A two-way voice communication system is presently operated by the Department of Administration's Division of Telecommunications Operations. This system uses VHF radio, in conjunction with a microwave relay system, to provide highway coverage. Although most areas of the highway system presently have adequate coverage, significant gaps exist along the Dalton, Richardson, Steese, Alaska and Edgerton highways.

It is possible that MSS can be used to fill in some of the existing gaps in coverage. It is also possible that, in the future, MSS will provide a more cost-effective and/or reliable communications system than the one presently being used.

Remote Locations

The Department of Fish and Game and the Department of Natural Resources both have significant requirements for communication with field personnel in remote locations.

Fish and Game operates about 100 temporary camps each year. These are staffed by biologists and other field personnel. The camps are operated in connection with fish counting and other management and research activities. Fish and Game also operates a number of vessels in conjunction with the same activities. All of these require two-way voice communication. The availability of telephone service would also be desirable in many situations. No present data communication requirement has been identified, but this may be needed in the future in connection with data entry and data access.

Two-way voice communication services are presently provided to remote Fish and Game personnel through the use of a variety of systems, depending on individual circumstances. In truly remote situations, single sideband radio, which is often unreliable, is the only option. MSS, on the other hand, has the potential to be a single, reliable communication system for use by temporary camps, boats, and research and management personnel located at permanent facilities.

Within the Department of Natural Resources, the Division of Geological and Geophysical Surveys and the Division of Forestry both have the need for communication to remote locations. Geological and Geophysical Surveys operates remote seismic monitoring stations which transmit low speed data. These must presently be located so that they can be connected by VHF to existing microwave facilities. MSS could also provide the communication link, and with MSS, the stations could be located virtually anywhere.

The Division of Forestry has responsibility for firefighting over the southern part of Alaska. Firefighters very often work in remote locations, and they have the need for two-way voice communication with their dispatch centers. The need to communicate is obviously quite critical. Various systems are presently used, depending on circumstances. MSS has the potential to substantially improve the ease and reliability of these communications.

Other Candidate Applications

Ships operated by the Marine Highways System, within the Department of Transportation and Public Facilities, have the need to communicate with shore facilities. Voice communication, presently provided through the Coast Guard VHF system and through single sideband radio, is considered generally adequate, but there are some gaps in coverage between Seattle and Ketchikan. The Marine Highway System is interested in expanding its computer-based reservations system to include computer terminals and personal computers located aboard the ships. These must be linked, through a data communication circuit, to a computer on shore. MSS appears to be an ideal way to provide the necessary data communication link.

The Division of Emergency Services, which is within the Department of Military and Veterans Affairs, has a need for communication services when disasters occur. If other communication facilities are unavailable because of disaster conditions, MSS appears to provide an excellent way of establishing the vital links. Single sideband radio is presently used, but, as mentioned above, its reliability is not always adequate.

PROPOSED SATELLITES

In order to make mobile satellite service technically feasible, a spacecraft must provide sufficient radiated power in the direction of the coverage area. Radiated power depends on the power available aboard the spacecraft and the gain of the spacecraft antenna. It is anticipated that, in the future, very large high gain antennas will be used to provide a multitude of spot beams. First generation satellites, however, will involve more modest antennas and, at most, a few beams.

The leading contenders to be mobile satellite carriers are Skylink Corporation and Mobile Satellite Corporation (Mobilesat). Skylink and Mobilesat each proposed in 1983 a first generation system which includes two spacecraft in geosynchronous orbit. Skylink's plan uses orbital positions 105°W and 135°W, and Mobilesat's plan uses 85°W and 125°W.

Circular polarization will be used because of Faraday rotation caused by the E- and F-layers, a significant effect at 800 MHz. Further, some degree of cross polarization isolation can be achieved using left-hand circular (LHC) and right-hand circular (RHC) polarization. This will facilitate frequency reuse in later generation systems.

In its application filed with the FCC in 1983, Skylink proposed to uplink using the 821-825 MHz band and downlink using the 866-870 MHz band. Each Skylink spacecraft would provide an east beam and a west beam, and each beam would provide both LHC and RHC polarization. Figures 1 and 2 show the two beams of the spacecraft located at 135°W. Figure 1 shows the LHC beams and Figure 2 shows the RHC beams.

In each case, the peak effective isotropic radiated power (EIRP) on beam center is +59.4 dBW (decibels referenced to one watt). Each contour line in Figures 1 and 2 represent a power level differential of 1 dB. Thus, the first line is 1 dB below beam center, the second line 2 dB below beam center, etc. Under maximum channel loading conditions, the voice channel power levels on beam center are:

to base station terminals: + 23.4 dBW/channel
to portable remote terminals: +27.4 dBW/channel
to mobile remote terminals: +33.4 dBW/channel

Figures 1 and 2 can be used to find the corresponding power levels off beam center.

Mobilesat, on the other hand, proposed in 1983 to use four segments of the 800 MHz band (821-825 MHz, 845-851 MHz, 866-870 MHz, and 890-896 MHz) for land mobile communication, two segments of L-band (1545-1559 MHz and 1646.5-1660.5 MHz) for air mobile communication, and two segments of Ku band (14 and 12 GHz) for communication with gateways. Land mobiles would transmit and receive on 800 MHz. Air mobiles would transmit and receive on L-band. Gateways would transmit and receive on Ku band for communication with both land and air mobiles. Mobilesat's proposed 800 MHz coverage from 125°W is shown in Figure 3 and L-band coverage from the same orbital position is shown in Figure 4.

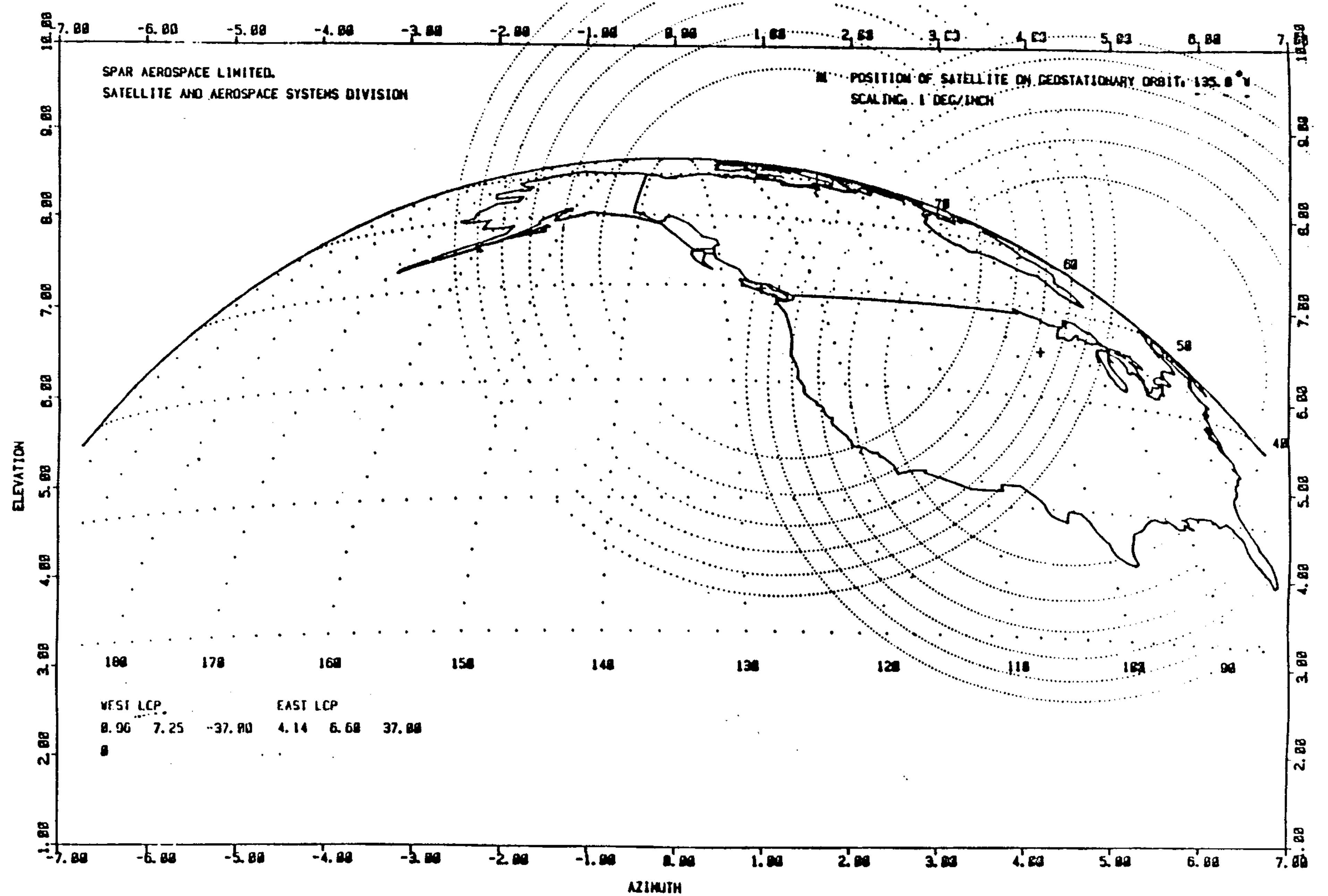

FIGURE 1

Skylink left hand circular (LHC) beams
Source: Skylink FCC application

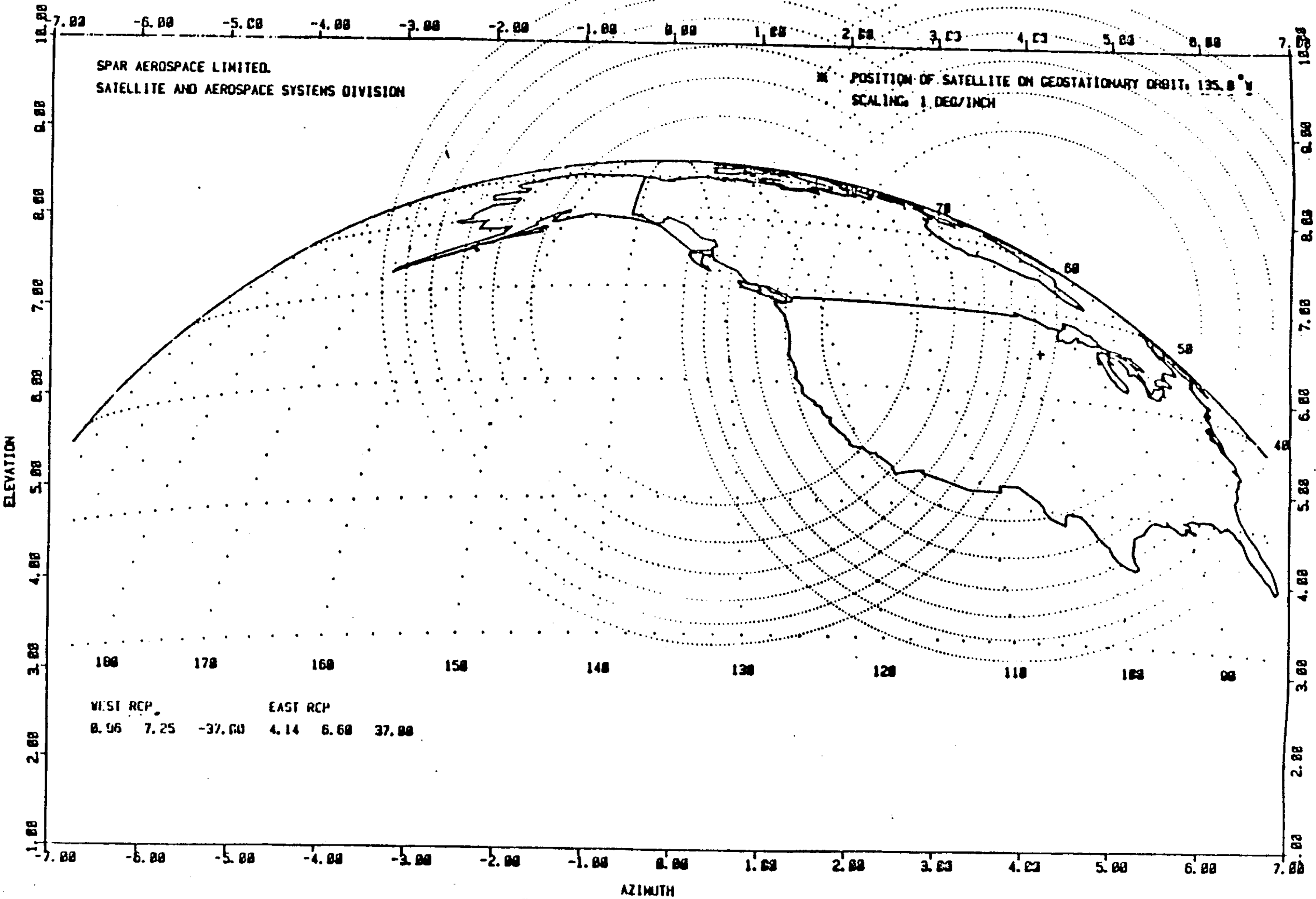

FIGURE 2

Skylink right hand circular (RHC) beams
Source: Skylink FCC application

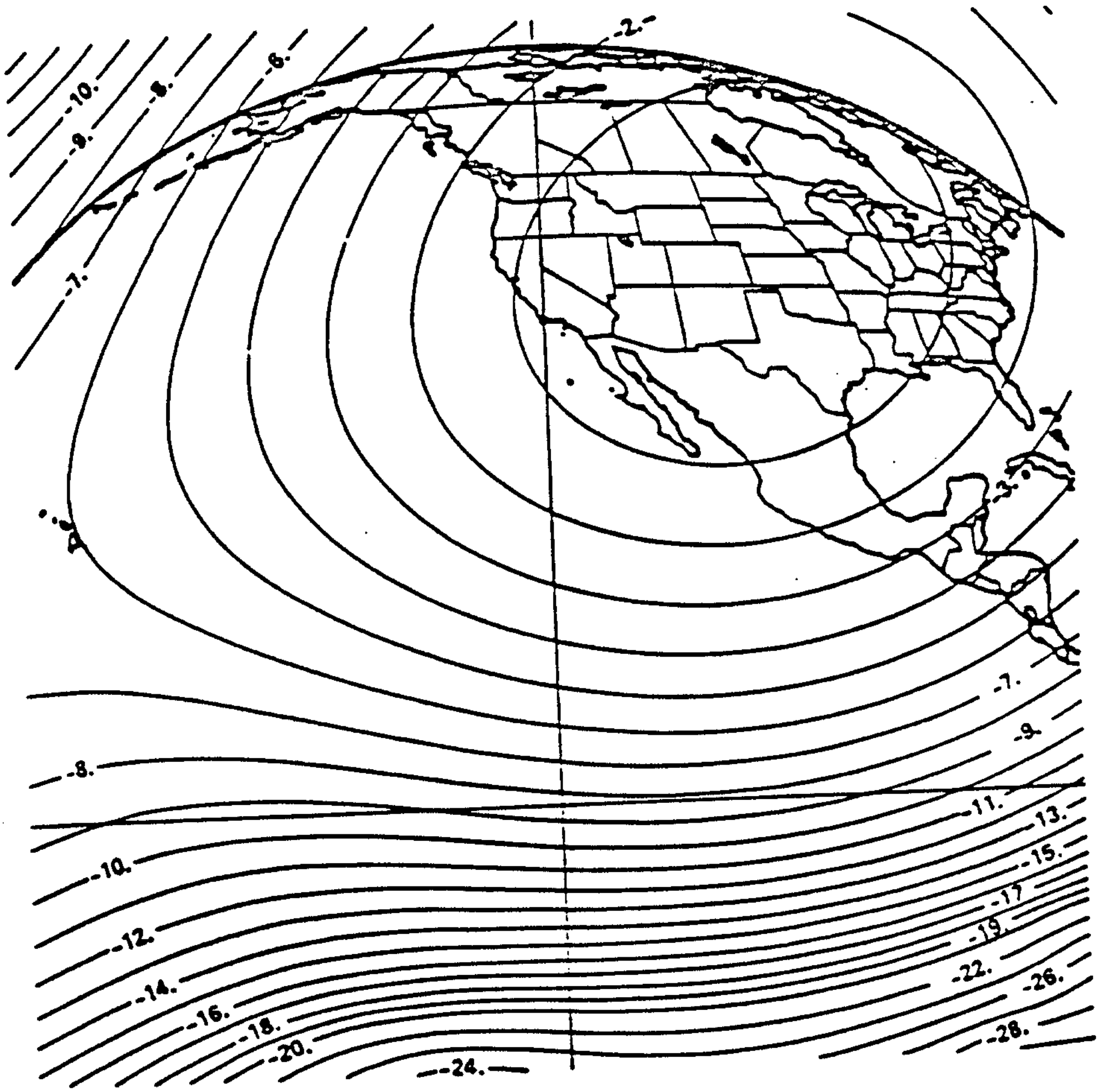

FIGURE 3

Mobilesat 800 MHz beam
Source: Mobilesat FCC application

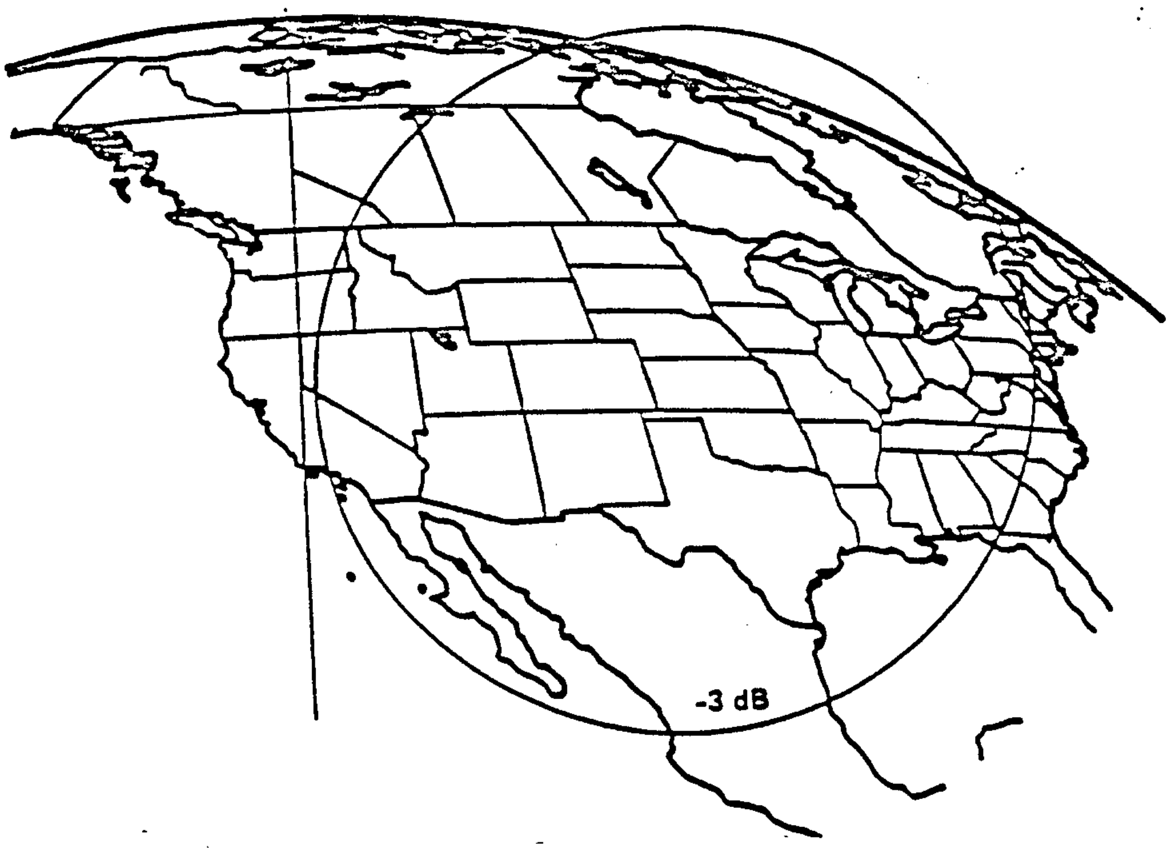

FIGURE 4

Mobilesat L-band beam

Source: Mobilesat FCC Application

The spacecraft proposed by Mobilesat would provide a beam center EIRP of 53 dBW with operation solely at 800 MHz or 58 dBW with operation solely at L-band. Operation at both frequencies would mean lower power levels. Power reductions (in dB) for off beam center operation are shown in Figure 3.

In January 1985, although Skylink and Mobilesat had already filed applications to provide mobile satellite service, the FCC called for applications from all companies interested in providing the service. A total of 12 companies, including Skylink and Mobilesat, filed applications in April 1985. These applications have not been analyzed in detail, but their salient points are summarized in Table 1. The applications that appear to have the most promise for Alaska are the ones that include the most westerly orbital positions. These are the applications submitted by:

Global Land Mobile Satellite, Inc.
Hughes Communications Mobile Satellite Services, Inc.
MCCA American Satellite Service Corp.
Mobile Satellite Corp.
Mobile Satellite Service, Inc.
Skylink Corp.

SHADOW ANALYSIS

Even if Alaska is illuminated at adequate power levels by an MSS spacecraft, effective utilization of the spacecraft can be disrupted by terrain shadowing. This phenomenon will occur when terrain features block or disrupt the radio path between the spacecraft and the mobile or portable unit. Shadowing has the potential to be a serious problem for Alaska because, at northern latitudes, communication satellites in geosynchronous orbit appear at low elevation angles; i.e., they appear close to the horizon.

The shadowing problem has been studied carefully by means of a graphical technique which uses topographic maps. The results of this work indicate that shadowing is not likely to be a serious problem on

TABLE 1. Characteristics of Proposed Systems.

Applicant	800 MHz	1.5 GHz	Proposed orbital positions (degrees West longitude)
Global Land Mobile Satellite, Inc.	Yes	Yes	94°, 129°
Globesat Express	Yes	No	*
Hughes Communications Mobile Satellite Services, Inc.	Yes	Yes	135°
MCCA American Satellite Service Corp.	Yes	No	66°, 96°, 126°
McCaw Space Technologies, Inc.	Yes	Yes	101°
Mobile Satellite Corp.	Yes	Yes	85°, 125°
Mobile Satellite Service, Inc.	Yes	Yes	85°, 125°
North American Mobile Satellite, Inc.	Yes	No	One position between 120° and 130°
Omninet Corp.	Yes	Yes	89°, 119°
Satellite Mobile Telephone Co.	Yes	Yes	75°, 120°
Skylink Corp.	Yes	Yes	75°, 136°
Wismer & Becker Contracting Engineers/ Transit Communications, Inc.	No	Yes	80°, 113°

* Uses 50 "small, inexpensive" satellites in random, nongeosynchronous orbits.

most of the Alaska highway system or on the Alaska Marine Highway System.

Graphical Analysis

In order to estimate what fraction of the highway system and the Marine Highway System will be shadowed, a special graphical analysis technique was developed. The technique uses a set of rulers which can be used on standard topographic quadrangles available from the U.S. Geological Survey. The rulers take into account the properties of radio propagation and enable one to quickly determine whether a radio path exists between a particular point on a map and a spacecraft in a particular orbital position. When the results are "borderline," a pessimistic approach is used, and it is estimated that shadowing will occur.

This technique has been used to check for shadowing problems on the state's highways and on the Marine Highway routes. An orbital position of 125°W has been assumed. This is a favorable position for Alaska but not the most favorable position (proposals range as far west as 136°W). Orbital positions further east will give more shadowing, and those further west will give less shadowing.

As indicated in Table 2, for most of the state's highways, only a small fraction of total mileage is hidden from view if the spacecraft is located at 125°W. Exceptions are the Dalton Highway -- an estimated 17.3 percent of its length will be shadowed -- and the Seward Highway -- an estimated 13.2 percent of its length will be shadowed. It is estimated that 7.1 percent of the state's total highway mileage is shadowed.

The Alaska Marine Highway System routes were examined using the same graphical technique, and with one exception, no shadowing was found. The exception is in the Gastineau Channel near Juneau, where there is a possibility of shadowing.

In order to evaluate the accuracy of the graphical technique, the Parks and Seward highways were field checked for shadowing using a compass and an inclinometer. The field results are compared with the graphical results in Table 3. For both highways, field measurements

TABLE 2. Shadowing mileage estimates.

Highway	Estimated mileage shadowed (miles)	Total highway mileage (miles)	Percentage of miles shadowed (percent)
Alaska	3.25	232	1.4
Dalton	72.0	416	17.3
Edgerton and Copper River	7.5	81	9.3
Elliott	5.5	152	3.6
Glenn	15.0	189	7.9
Haines	0.0	87	0.0
Parks	11.7	323	3.6
Richardson	23.0	364	6.3
Seward	16.75	127	13.2
Steese	9.0	162	5.6
Sterling	4.0	136	2.9
Taylor	10.0	161	6.2
Tok Cutoff	2.5	125	2.0
TOTALS	180.2	2,555	7.1

TABLE 3. Shadowing mileage field results.

	Shadowed Mileage			Percent of Mileage Shadowed	
Highway	Field measured (miles)	Estimated (miles)	Total mileage (miles)	Field measured (percent)	Estimated (percent)
Parks	9.3	11.7	323	2.9	3.6
Seward	15.2	16.75	127	12.0	13.2
TOTALS	24.5	28.45	450	5.4	6.3

gave fewer shadowed miles than graphical measurements. This is consistent with the pessimistic approach described above.

During the field work, it was noted that, in some cases, small terrain features close to the highway had been missed by the graphical procedure. This happens when the terrain feature is smaller than the contour interval of the topographic map used. In some cases, these features cause shadowing undetected by the graphical technique.

In light of these results, the graphical analysis provides a reasonable, but far from precise, indicator of shadowing difficulties.

CONCLUSION

Based on the analysis completed to date, MSS appears to hold great promise for use by state government. Potential applications have been identified for several different agencies. Use of an MSS spacecraft will be possible if it is launched into a favorable orbital position and if it provides reasonable radiated power levels in the direction of Alaska. Except in the cases of the Dalton and Seward highways, serious shadowing difficulties are not anticipated.

Phase II of this project will examine the technical requirements for mobile and transportable units to be used in Alaska. Cost estimates will be developed for use of MSS, and the economic feasibility of the candidate applications will be evaluated.