

PROPAGATION MEASUREMENTS IN ALASKA USING ACTS BEACONS

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Abstract--The placement of an ACTS propagation terminal in Alaska has several distinct advantages. First is the inclusion of a new and important climatic zone to the global propagation model. Second is the low elevation look angle from Alaska to ACTS. These two unique opportunities also present problems unique to the location, such as extreme temperatures and lower power levels. These problems are examined and compensatory solutions are presented.

1. Introduction

Alaska has always been, and will continue to be, at the forefront of high technology satellite resource usage. From the first U.S. tracking of Sputnik to the installation of more than 200 remote video and voice C-band earth stations throughout rural Alaska, the unique location and population diversity of Alaska require innovative solutions to realize the State's telecommunications needs. New technologies, such as ACTS, provide additional opportunities for new solutions. Alaska is reliant on satellites for communications to its remote regions, and the State is committed to providing educational and health communications throughout the state. The location of a large teleconnected research university with three major campuses (Fairbanks, Anchorage, and Juneau) and many smaller campuses across the State, the demand for transportable USAT earth stations and mobile satellite service (Hills, 1988), and the growing demand for video and audio communications throughout the State, all point to the need for expansion into Ka-band communications. Accordingly, propagation statistics for Ka-band frequencies in Alaska are essential. Alaska offers two major advantages to the ACTS Propagation Program. The first is the addition of a new and important climatic zone to the global propagation model. The second is the low elevation look angle to the satellite. These two advantages provide a unique opportunity for collection of Ka-band propagation data from ACTS.

2. History

Alaska was the first state to enter the satellite communications age. The first satellite, Sputnik, was launched into a highly inclined orbit (65°) and passed over Alaska on October 4, 1957. Given 2 hours of advance notice by NASA Goddard, the EE faculty and students assembled receivers and recorders. Bob Merritt, Engineer on the Radio Astronomy Techniques project at the University of Alaska Fairbanks (UAF), and now Professor Emeritus of Electrical Engineering, fabricated 2 dipole antennas, arranged them into a baseline interferometer, and connected the antenna system to both 20 and 40 MHz receivers. Using a chart recorder, Merritt and his team were able to give NASA 0.1 second accuracy on the Sputnik transit time. Additional studies with the Sputnik data provided an estimate of the electron density of the ionosphere along the propagation path to the ~120 mile altitude satellite. A few days after launch, the tumbling Sputnik was visually observed reflecting the sun in the predawn light.

NASA then funded Minitrack System at UAF. Minitrack consisted of an array of antennas and was used to provide precision tracking position data and telemetry for the overhead passage of satellites. Array calibration was performed by flying an airplane-

born transmitter over the site. NASA built its first 85-foot reflector at the Gilmore Creek Tracking Station, some 20 miles from Fairbanks. The reflector tracked NIMBUS, for the short lifetime of the satellite. Other data were downlinked from the TIROS weather satellites, LANDSAT, and SEASAT, as they passed overhead in highly inclined orbits. Also satellites, such as the Canadian ALOET were used in top side sounder experiments. The array and the reflector were also used to study ionospheric propagation effects at 135, 404, and 1705 MHz, where new high latitude effects were discovered. Gilmore Creek remains operational today.

Alaska participated with ATS-1, with its push-to-talk 135.6 and 149.2 MHz downlink and uplink frequencies. The Alaska Public Health Service contracted to provide emergency communications to remote villages inaccessible by road or any form of communications except unreliable (due to solar activity) HF radio. From these beginnings, Merritt and others developed the Alaska Village Satellite System, a C-band satellite star network connecting some 200 villages with audio connection to the state, and world, telephone grid (Hills, 1983). Later, this network was expanded to include delivery of 2 channels of television, one educational and one entertainment, to all the remote Alaskan villages with a population over 25 people. Today, systems similar to the Alaska Village System are being deployed in developing countries and in countries with rugged and remote regions. Propagation studies at C-band were conducted at Sitka, where some noteworthy features of high latitude propagation were measured.

Current activities include the Alaska SAR Facility, a receive only earth station to collect data from polar orbiting SAR satellites. The United States did not launch a SAR satellite, but an agreement has been reached with other countries giving US researchers access to SAR data in exchange for the collection of data by the Alaska downlink facility. The foreign countries and organizations include ESA (Earth Resources Satellite), Japan, and Canada (RADARSAT).

3. ACTS Propagation Opportunities

The placement of an ACTS propagation terminal in Alaska offers several unique opportunities for the collections of Ka-band data. The first is the climatic zone of the state. According to the Crane global model (Crane, 1985), Fairbanks is in region B1, close to the region A boundary. Very little data has been collected in either of these two climatic zones, and yet they are important for several reasons. Convergence of the global model will be benefitted by data from all the zones. Scientific research work in the arctic and antarctic regions is increasing rapidly, partially due to the global warming issue. Rapid data transfer to the supercomputers used for global modelling will require satellite links. Furthermore, basic communications in these isolated and often harsh areas of the world is heavily dependent upon satellite links. Design of reliable communications links requires adequate knowledge of propagation statistics. Therefore, collection of propagation data from this Alaska climatic zone is of utmost importance.

A second opportunity lies in the advantage of a low elevation look angle from Fairbanks to ACTS. At no other location in the United States does the opportunity exist for low elevation propagation studies. The power level from ACTS is still fairly high in Alaska, as shown in Figure 1 from GE Astro (Cashman, 1990). Alaska delivers a large range of look angles across the state ($0^\circ < \theta < 22^\circ$), as shown in Figure 2. Fairbanks provides a look angle of 7.9° to ACTS, scheduled for a geosynchronous orbital slot at 100° West Longitude. While a look angle of 7.9° is not considered extremely low, it does require propagation through more than 7 air masses, many more air masses, by a factor of >3 , than possible anywhere in the contiguous 48 states. Hawaii provides a look angle on the order of 20° , but is much farther down on the radiation pattern from ACTS.

A third opportunity would be a short term study of extremely low elevation Ka-band propagation effects. The location of a mobile terminal at a site such as Barrow,

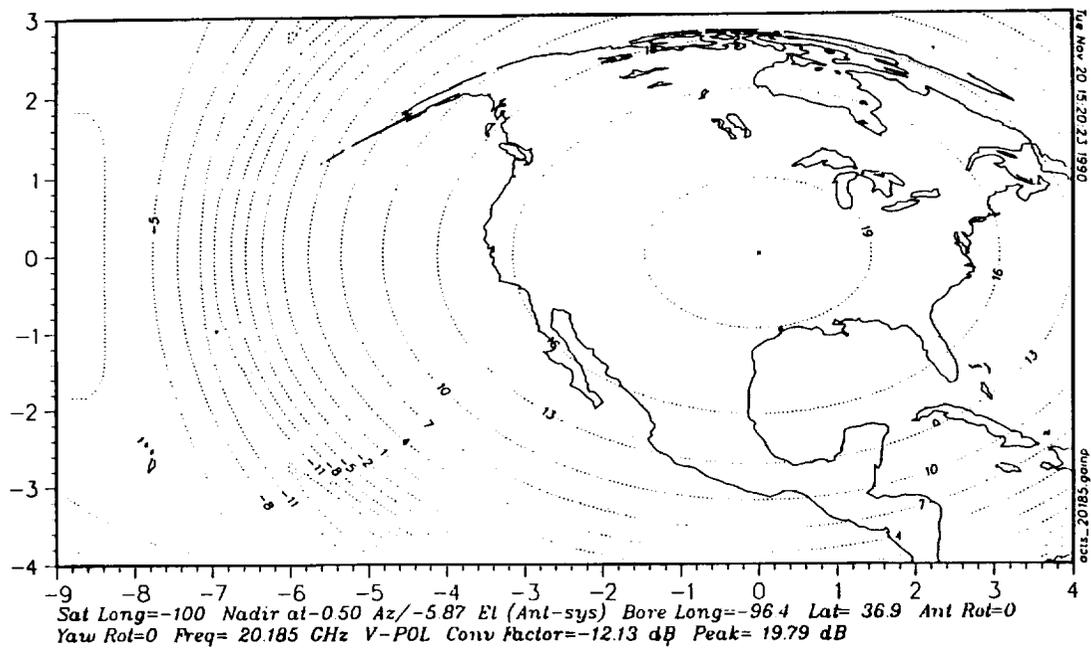


Figure 1. ACTS 20.185 GHz Beacon EIRP Levels in dBW.

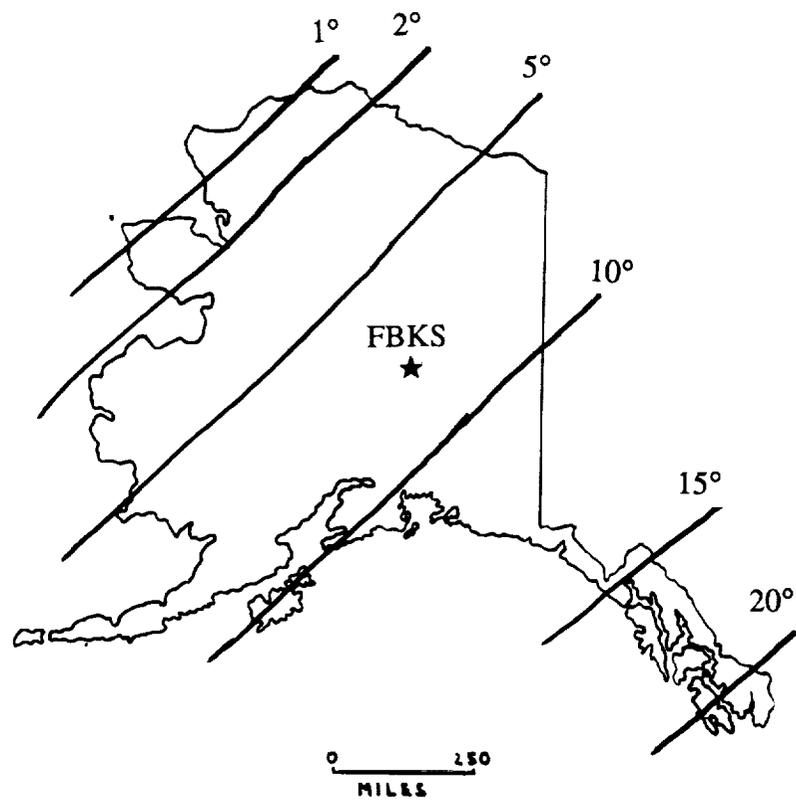


Figure 2. ACTS Elevation Look Angles in Alaska.

with a look angle of 1.2° , would provide a supply of very low angle data. The standard ACTS beacons could be used for this experiment, or the steerable antenna could furnish a greater EIRP for the time that it could be allocated.

Clearly, there are attractive advantages to the placement of an ACTS propagation terminal in Alaska. An examination of the link budget from Fairbanks explains how well such a propagation terminal would function.

4. Link Budget

As seen in Figure 1, the ACTS EIRP in Fairbanks is less than in the contiguous states. There are three components of the link budget which are affected by the location of the receive site, which will cause the received beacon power to be less in Fairbanks than in the contiguous states. These three components are beacon antenna gain (given as EIRP), free space or path loss, and clear sky loss. We will compare the ACTS beacon levels available in Fairbanks with those available in two representative lower 48 locations, specifically Blacksburg and Seattle. Defining dB_{BB} as decibels relative to Blacksburg and dB_{SEA} as decibels relative to Seattle, Table 1 presents the EIRP levels in Fairbanks relative to Blacksburg and Seattle. Additionally, Fairbanks is located farther from ACTS than either Blacksburg or Seattle, thereby increasing the path loss by the amounts listed in Table 1. The third component is clear sky attenuation due to gaseous absorption by the atmosphere on the path length. Calculations according to the NASA Propagation Handbook (Ippolito, et al.) show that there is slightly more clear sky loss in Fairbanks during the worst case summer conditions as displayed in Table 1. In the winter months, there will be only miniscule clear sky losses in the cold, dry Alaskan air. The total worst case Fairbanks beacon power level deficit relative to Blacksburg and Seattle is tabulated in the last column of Table 1.

Table 1. Fairbanks Signal Levels Relative to Blacksburg and Seattle.

Frequency GHz	EIRP		Path Loss		Clear Sky		Total Deficit	
	dB_{BB}	dB_{SEA}	dB_{BB}	dB_{SEA}	dB_{BB}	dB_{SEA}	dB_{BB}	dB_{SEA}
20.2	-7.5	-5.0	-0.7	-0.5	-0.2	0.0	-8.4	-5.5
27.5	-7.0	-5.5	-0.7	-0.5	-0.2	0.0	-7.9	-6.0

All other parameters of a link budget calculation would be identical between the various locations. Given identical receiver stations, the C/N available in Fairbanks will be less than that available in Blacksburg or Seattle by 5.5 to 8.4 dB, as given in Table 1. There are two methods of making up this deficit, namely the use of a larger ground station antenna and/or the use of a lower noise receiver. The advantages/disadvantages of these two methods will now be examined.

A large fraction of the power level deficit can be readily restored with the use of a larger antenna. Harris Corporation manufactures both 1.2-m and 2.4-m antennas for their LBR-2 ACTS terminal. Harris lists a 6.0 dB increase in gain for the larger antenna (Koenig, 1990). Both antennas are of the same offset reflector geometry, and use the same feed horn. The surface tolerance error for both reflectors is the same, < 11 mils rms. This surface error would give a surface tolerance loss of 0.24 dB at 20.2 GHz and

0.45 dB at 27.5 GHz, still well up on the gain vs. frequency curve. There are differences between the two antennas. The first is the difference in wind loading. The 2.4-m antenna can remain operational for winds >40 mph, whereas the 1.2-m antenna is operational for winds of 60 mph. The no-damage state for the two antennas are >80 and 100 mph, respectively. This does not represent any limitation or danger in Fairbanks, because of the low level of local winds. A more serious effect is the smaller beamwidth of the larger antenna. ACTS is specified to be maintained within $\pm 0.05^\circ$ in both azimuth and elevation of its assigned orbital position. The maximum offset from the assigned position is therefore 0.07° . GE Astro expects the station keeping to be tighter than the maximum specified above. Calculations of estimated antenna beamwidths, given in degrees, are listed in Table 2, below.

Table 2. Antenna Beamwidths in Degrees

Antenna Diameter	1.2 m		2.4 m	
Frequency (GHz)	20.2	27.5	20.2	27.5
0.25 dB BW	0.26	0.19	0.13	0.10
1 dB BW	0.49	0.36	0.24	0.18
3 dB BW	0.89	0.65	0.45	0.33
10 dB BW	1.62	1.19	0.82	0.60

Examining the worst case situation, the beamwidth of the larger antenna at the higher frequency, and extrapolating between the tabulated values, the maximum variation in received beacon level due to satellite movement within the antenna beam is found to be <0.5 dB. GE Astro expects the satellite drift to be $<\pm 0.03^\circ$, which would give a maximum variation at the higher frequency of <0.25 dB. The lower frequency beacon variations would be less by about a factor of 2.

The second method of increasing the signal-to-noise ratio in Fairbanks is to use a lower noise receiver. The most straight forward way to accomplish this is to add low noise preamps at 20.2 and 27.5 GHz before the respective mixers. There are several disadvantages to this approach, however. First, to effect a 6 dB C/N difference requires a change in the system temperature by a factor of 4. The system temperature of the proposed VPI receiver is ~ 1800 K, estimating $T_{ANT} \approx 80$ K. A quick calculation gives a noise figure of <3.7 dB for the lower noise receiver. Another disadvantage is that gain variations in the amplifier would induce calibration problems into the data. With the temperature extremes of Fairbanks, there would most certainly be amplifier gain variations.

Using either the larger antenna or the lower noise receiver, it is possible to get back most if not all of the signal reduction caused by the remote location of Alaska. Furthermore, the fade depth in the Fairbanks climatic zone is not expected to be as deep as those found in coastal climatic zone.

5. Problems specific to Fairbanks

There are several problems specific to Alaska. The first is the extreme temperatures. The temperature range extends for a record high of 99° F to a record low of -67° F. Typical yearly variations include highs in the 80's to lows in the 40 belows.

While the upper temperatures will be experienced at other ACTS propagation terminal sites, the lows will not. The outdoor components must be maintained within their specified thermal ranges. One solution would be to wrap the receiver with heat tape and another layer of insulation. The amount of excess heat applied would be held constant, ie turned on all winter, off in summer, so that temperature induced gain variations would not be a problem.

The lower levels of received beacon power were already addressed in the link budget discussion, Section 5. A larger antenna and/or a lower noise receiver prove to be relatively straight forward solutions.

A potentially more serious problem is caused by the change in pointing of the satellite throughout the day. This would cause variations in the received beacon power, due to the time changing antenna gain contours. Fortunately, because of its spot beam capabilities, ACTS is specified to keep true pointing within $\pm 0.025^\circ$, which will induce negligible variations in received power levels.

6. Conclusions

Alaska presents a unique opportunity to the ACTS Propagation Program. The understanding of high latitude effects is vital to reliable communications system design. Major advantages to the location of an ACTS propagation terminal in Alaska are the inclusion of a new and important climatic zone to the global propagation model. Also the low elevation angle would give a longer propagation path through the atmosphere in general, and clouds, rain, and snow events in particular. The beacon power levels are reduced from those of lower 48 sites. However, the C/N ratios available can be increased to comparable values through the use of a larger antenna or a lower noise receiver. The choice of a larger antenna seems to present a more stable and less troublesome solution. Any problems due to the location or climate of Alaska can be solved. Therefore, there are no technical obstacles to prevent the placement of an ACTS propagation terminal in Alaska, only great opportunities to contribute to the understanding of high frequency propagation.

7. References

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