Application for New or Modified Experimental Radio Station Authorization (Form 442) for Digital Aurora Radio Technologies

NOTE: Please contact Whit Hicks for more detail and further discussion about this project. Email: whicks@daradiotech.com.

RESPONSE TO ITEM #4

The ultimate goal of this project is to provide a terrestrial digital radio service to the citizens of Alaska. If the digital transmissions prove reliable enough Digital Aurora Radio Technologies will seek partnerships with content providers with priority given to nonprofit organizations.
Pending this authorization and funding availability, initial tests will likely be tasked and funded by the US Government Department of Defense, Joint Electromagnetic Technologies (JET) program. To comply with Section 5.63 (b) of Part 5 of Chapter I of CFR 47 a narrative statement of the test plan will be submitted prior to conducting tests requested by the Government.

RESPONSE TO ITEM #7

7a. Proposed Research and Experimentation

Purpose and benefit:

In general, the population of Alaska is underserved with respect to the ability to have a high quality, reliable public radio (audio) service. This is especially true for sparsely populated areas of the State.

The proposed service will eliminate that deficiency to the benefit of all the residents of the State.

Feasibility:

The way to satisfy this need consists of using a digital signal in the shortwave bands along with a transmitter/antenna combination compatible with it and with the capability to cover the State with a signal with an adequately high signal receiving power so that a digital receiver can pick up and properly decode the signal.

Statewide coverage can be accomplished using a properly designed antenna, the Government surplus FPS118 Over-the-Horizon (0TH) Radar Transmitter system and a digital signal generator transmitted from the Delta Junction area (Digital Aurora Radio Technologies' location).

Compared to an ordinary analog shortwave signal, the DRM signal can operate with the same coverage reliably and with "monophonic FM-like quality audio" in a 10 kHz channel using a transmitter power level approximately 1/5th of that needed for the analog signal.

Consumer radios are available that can decode a DRM signal. These receivers can be keyed to the broadcaster, and need not be tuned to the radio frequency used. This permits shortwave broadcasting at different frequencies throughout the time of day, season and solar activity without the listener being required to "tune into" a frequency.

In short, the entire "chain" from transmission through to reception is available for experimentation in Alaska. The need for experimentation rests on the fact that this type of delivery has not yet been tested in the high latitudes of Alaska.

In summary, one transmitter producing output average power of approximately 20 kW, in concert with an antenna that sends most of its radiated power into Alaska should be able to be received throughout the State. It remains to be seen, however, if this can be accomplished under actual field conditions under low and higher solar activity regimes. Thus, there is the need for a technical feasibility phase prior to any movement toward a regular broadcast service.
The equipment to be used is noted in response to item #10 and in the Figures that follow. The transmit antenna is designed specifically for this experiment.

7b. Specific objectives:
The DRM system has been extensively tested in latitudes lower than those that include Alaska. The system is being used for regular broadcasts in the shortwave bands in Europe and elsewhere, but not in the USA.

Therefore, there is a multifold reason for the planned experiments: (a) to determine the impact of high latitude ionospheric propagation in the shortwave bands on digital audio modulation using the DRM system; (b) to determine the transmission power levels required to provide an adequate signal so that DRM receivers can decode the audio with high reliability throughout the State, or most of the State; (c) to determine an antenna specification for delivery of the digital signal throughout the State.

An Alaskan experiment will fill a gap in assessing the performance of digital terrestrial shortwave broadcasting in the difficult high latitude environment.

7c. What is new and the experimental method:

The DRM system includes several "modes". These include a selection of audio bit rate, amount of forward error correction and modulation constellation (16 or 64 QAM, for example, for the audio). Two of the basic error correction components have been designed to work well with ionospheric propagation. In particular, they mitigate against the large multipath and Doppler conditions that occur with ionospheric propagation at high elevation angles.

Thus, an antenna with low power compatibility can be used. (See item #10 for our selection.)

The experimental method will consist of transmitting from a site near Delta Junction with an existing Continental Electronics Company transmitter and a newly designed antenna for reception at several key sites in Alaska. Signal-to-noise ratio, field strength, bit rate, and audio quality measurements will be carefully collected at these receiver sites. Over a 2 year period, covering all seasons and different sunspot activity numbers, the data base developed will provide an adequate assessment to decide on what type of broadcast service can realistically be implemented.

Coordination:

Since the planned experiment will use the shortwave broadcasting bands at more than one frequency over the time of the experiment, Digital Aurora Radio Technologies will coordinate with the High Frequency Coordination Conference (HFCC) to ensure that any frequency channels it will operate on will not interfere with other HF broadcasts.

DRM signals normally will be contained within a 10 kHz channel, the same as is used by today's analog broadcasting. Digital Aurora Radio Technologies may include in its final test plan a sequence of using a wider digital signal to investigate the impact on broadcast quality and expanded digital capabilities. The same coordination within the HFCC would be employed.

10. Equipment –

FPS-118 Transmitter

January 2007, Continental Electronics was commissioned to connect a Government Furnished (GFE) FPS118 Over the Horizon (0TH) Radar Transmitter, bring it up to operate in its originally intended CW mode, and then apply a digital bit-stream to the Transmitter to demonstrate its performance in the DRM digital transmission mode. Continental's test results clearly demonstrate the capability of the transmitter to broadcast programming in the DRM mode with excellent performance characteristics. The Transmitter was adjusted so that its spectral output lined up very closely with the spectral "mask" recommended by the ITU for this mode of transmission. A peak power of more than 100 kW was obtained from the 0TH Transmitter operating into a test (dummy) load on a representative mid-range frequency.

Custom Antenna

Analysis and Summary of Antenna Electrical Design and Terrain/Propagation Results

A significant amount of design and propagation analysis has been done in preparation for this long term experiment. It is embodied in a 278 page report. Examples have been extracted to indicate the design decisions and the expected propagation environment from the transmitter/antenna configuration located in Delta Junction to reception sites throughout Alaska. The propagation result examples are given first followed by antenna information.

Expected coverage:

Figure 1 is a map of Alaska, which is the target area for coverage with a 10 kHz (or possibly 20 kHz) digital radio signal. The Delta Junction location for the transmitter/antenna configuration is approximately 130 miles southeast of Fairbanks.

Figure 2 shows an example of the expected coverage of Alaska. On the grid, Alaska falls approximately from 135 to 175 degrees west in longitude and 50 to 72 degrees north in latitude. Therefore, it is clear from the coverage contours that nearly all of the energy is concentrated for reception in Alaska. The signal levels for latitudes below 50 degrees is into the Pacific off shore from Alaska; there is some “spillage” east of 140 degrees west that gets into the Yukon Territory; and the orange contour at very high latitudes is into the Arctic Ocean.

The digital signal requires a signal to noise ratio higher than 50 dB in 1 Hz in the expected environment. It can be seen from the color contouring and the ICEPAC legend that this is the case for Alaska. The green area, which is effectively all of the rest of North America, represents signal to noise ratios less than 50 dB, down to -197.5 dB, which means the signal level is too low for reception, even close to the target area where it rapidly drops off.

For reference, the example uses a 100 kW digital signal for a high sunspot condition (#100), a crossed dipole antenna similar to the design antenna at 5 MHz, and at 10 am in December. The propagation environment includes sporadic E ionospheric refraction.

Figures 3, 4, 5 & 6 illustrate point-to-point ICEPAC propagation results, one for each season, and each one for a different town in Alaska. All four assume a high sunspot number of 100 and a 100 kW transmission average power. As a rule of thumb for the digital signal, any signal-to-noise value above 50 dB in 1 Hz can be considered to provide a perfect signal. The horizontal axis is in UT, which is 8 or 9 hours ahead of local time in Alaska. The antenna field, which is described in the section below, is designed for efficient use at frequencies from 5 – 10 MHz.

Figure 3, for Anchorage in January, shows that a frequency selection between 5 and 10 MHz can always be found to give a more than adequate signal. Even if one considers a 10 kW signal, and subtracts 10 dB from these values, there is still plenty of margin.

Figure 4 is for Kodiak in April. Kodiak is on an island southwest of Anchorage about 500 miles southwest of Delta Junction. The 5 – 10 MHz frequency range will provide high enough signals for digital decoding.

Figure 5 is for Bethel in October. Bethel is near the coast about 600 miles southwest of Delta Junction. Again, the 5 – 10 MHz frequency range will provide an adequate signal for digital decoding.

Figure 6 is for Ketchikan in July. It is south, about 750 miles from Delta Junction. Similarly, the 5 – 10 MHz frequency range gives good signal levels for digital decoding.

Of course, major parts of the planned experiment will be to investigate (a) how well these propagation predictions reflect field conditions and (b) how low the transmit power can go below 100 kW without jeopardizing coverage in some parts of Alaska.

Interference potential:

As stated in the response to Item #7, the choice of specific frequencies and times of day for each will be coordinated thorough the HFCC, which meets twice a year to minimize harmful interference among broadcasts.

We also note that there is very little planned HF broadcasting into Alaska, as shown in the most recent HFCC/ITU schedules for coordinated HF broadcasting. Thus, there should be no difficulty in choosing one or more 10 kHz channels in each of the HF Broadcasting bands for our purposes.

We recognize that some of the radiation targeted for western Canada (CIRAF zone 02 and perhaps zone 03 may spill over into Alaska. We would monitor these channels before making a channel selection to see if there would be interference into our experiments.

In reverse, we will have to check on the potential for some spill over into western Canada from our transmissions. Again, we should easily be able to avoid causing interference by staying at least two adjacent channels away from any channels used by international broadcasters into that part of Canada.

Electrical design and modeling of antennas for each of the 3 HF antenna bands that cover the HF broadcasting bands:

The antenna designed and modeled consists of a crossed dipole configuration using 4 inch diameter pipe with 1 foot balls at the ends to prevent corona and arcing. It is robust and has a very good safety factor in regards to prevention of electric field air breakdown. It should perform well in Alaska. The model is based on antennas spaced horizontally 100 feet between centers and the interaction was essentially non-existent. Each antenna is the same basic design except for the scaling of dimensions. The diameter of the pipes and balls are kept the same for each to handle the power. An idea was added to each design to allow tuning of the antenna for a specific frequency in each of the bands (Figure 11). Since we do not know the exact frequency from the FCC at this time, this option was needed to allow field tuning by hand. It consists of a U-shaped stub with a shorting bar that can be slid up and down. When the bar is at the top of the stub, the antenna will be tuned to the highest frequency in the band. Likewise, when the bar is removed completely, then it is tuned to the lowest frequency in the band. All other frequencies in between these limits can be obtained by sliding the shorting bar to the appropriate position. A "bazooka type" balun has been specified. Furthermore, additional pieces of 75 ohm high power transmission line will be needed to provide the 90 degree phase shift between the crossed dipoles and 50 ohm matching. This phasing and the use of crossed dipoles will provide the omni directional horizontally polarized radiation pattern in azimuth so all areas will be covered equally. Models were done with appropriate lengths of 75 ohm transmission lines included (1/4 wavelength and ½ wavelength) to provide 90 degree phasing and a good impedance match. Results are also shown for these models in [Figure [7] 1.11 to 1.13]. It can be seen that the VSWR bandwidth is improved considerably when the 75 ohm phasing and matching lines are included in the model. This is good news for the actual physical configurations to be built since the antennas will be less sensitive and easier to achieve good VSWR performance once the phasing and matching lines are connected.

Table [1]: Comparison of predicted electric field levels and maximum permissible exposure limits

Frequency (MHz)	Calculated Electric Field from FEKO (V/m)	Maximum Permissible Exposure Levels (V/m)	
1 meter off ground		Controlled	Uncontrolled
5.05	94.3	364.8	163.1
7.35	135	250.6	112.1
9.623	154	191.4	85.6
Along tower vertically		Controlled	Uncontrolled
5.05	1197	364.8	163.1
7.35	1534	250.6	112.1
9.623	2446	191.4	85.6

As can be seen from Table 5-3, the field levels at 1 meter off the ground around the antenna at 5.05 MHz are below the MPE for both controlled and uncontrolled environments. At 7.35 MHz, it is below the MPE for controlled but exceeds the MPE for uncontrolled. The same is true at 9.623 MHz. The fields at all 3 frequencies vertically along the tower strongly exceed the MPE, but it should be mentioned that this highest level is only right below the feed point. Even below the feed point, the field levels can exceed the MPE. Fencing with controlled access and warning signs around all three antennas will mitigate this hazard. (See Figure 8)

Figures 9 and 10 contain sketches of the antenna field design.

11. Station Identification

A specific signal generator has not been selected at this time; however, there are "off the shelf" units available (example: Transradio DRM DM0D2).

12. Owner Operator

Digital Aurora Radio Technologies will be the operator and responsible entity for this project. Utilities and space will be leased for the project. The AN/FPS-118 transmitters are provided by the Government with the intention of being abandoned in place after the experiment is completed.

Figure 1 Map of Alaska

Figure 2 Coverage of Alaska from the Delta Junction Site

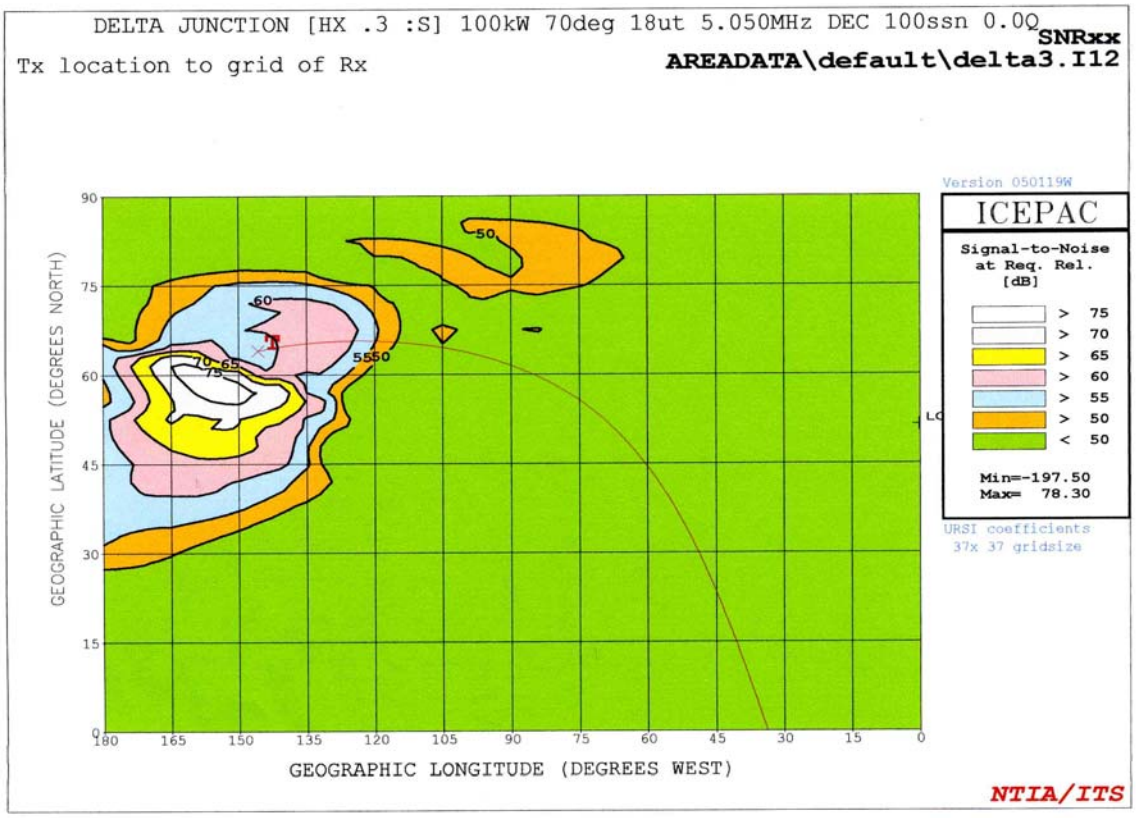

Figure 3 Propagation into Anchorage

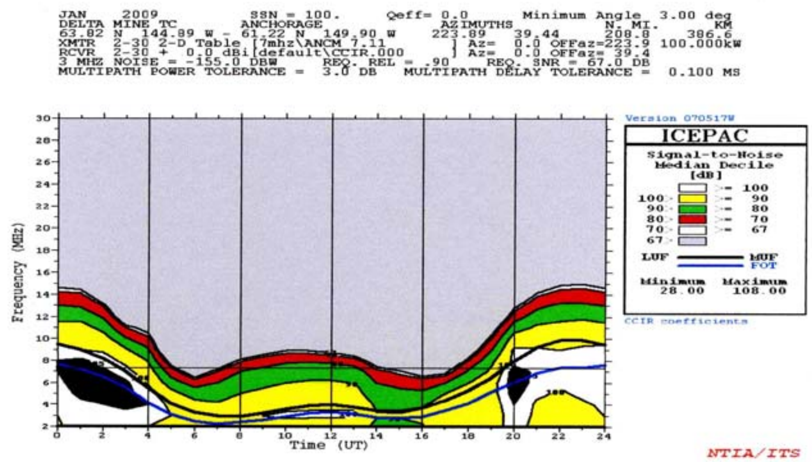

Figure 4: Propagation into Kodiak

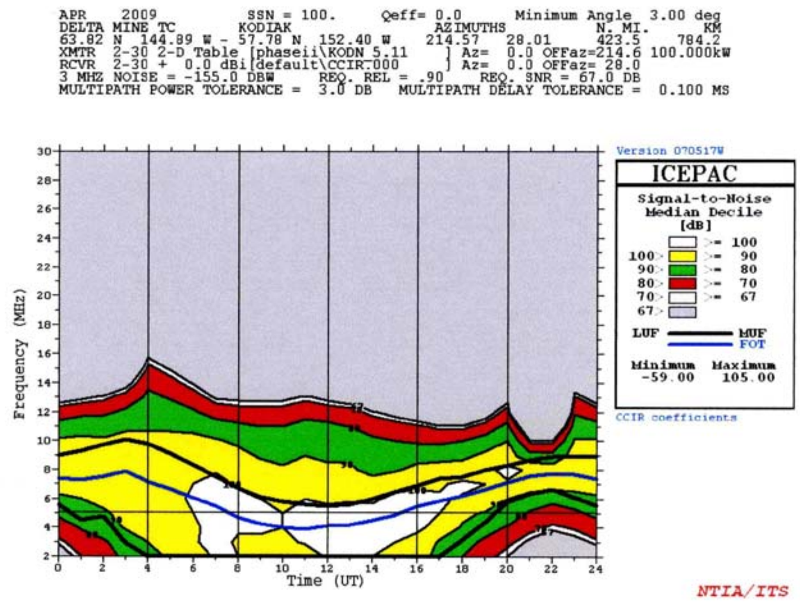

Figure 5: Propagation into Bethel

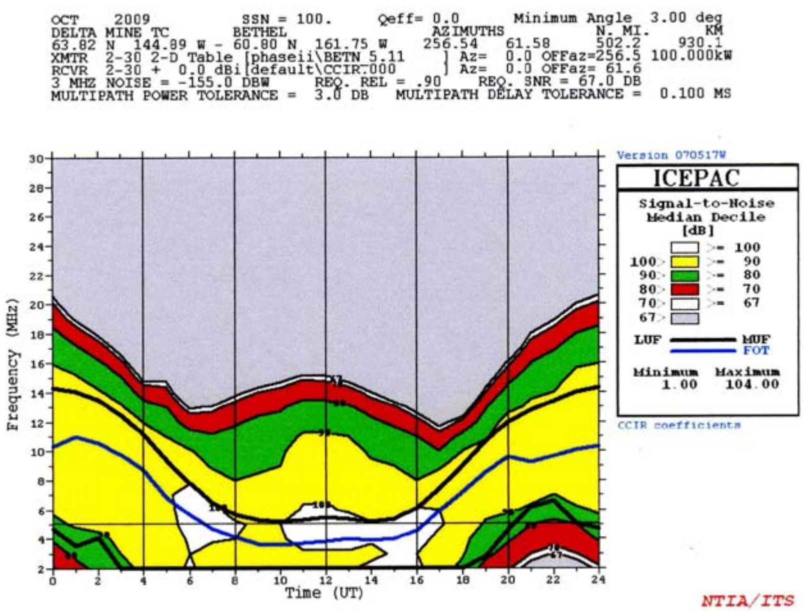

Figure 6: Propagation into Ketchikan

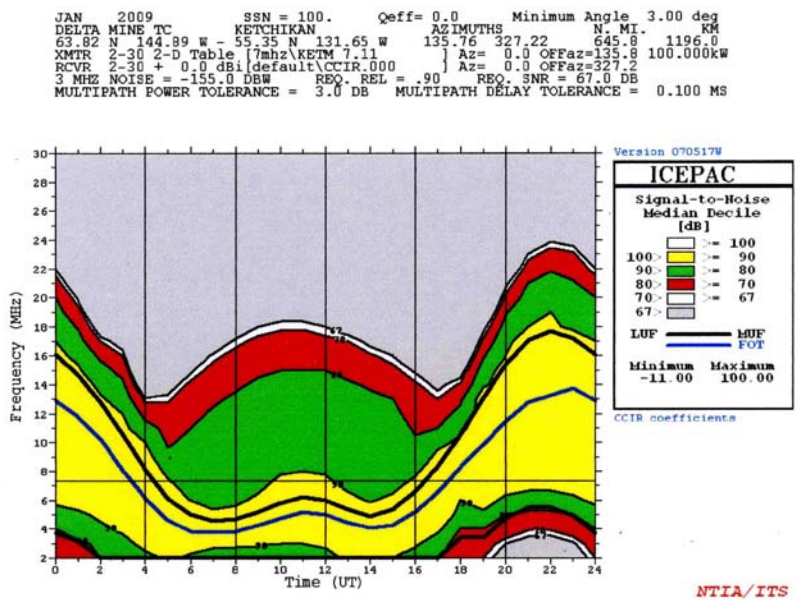

Figure 7: Example of VSWR Plot

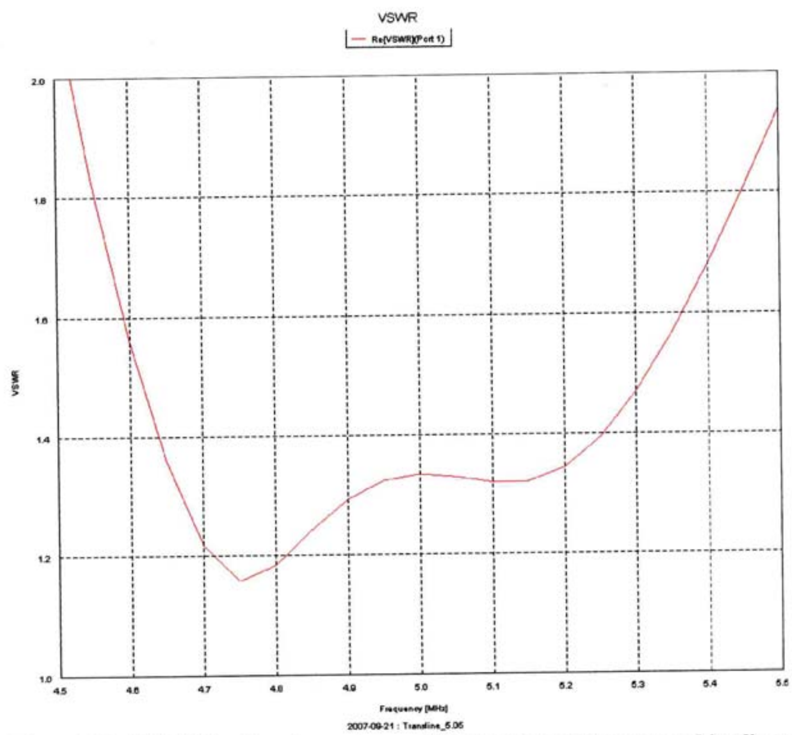

Figure 1.11. VSWR for 60 meter antenna with 75 ohm phasing and matching lines.

Figure 8: Near field example

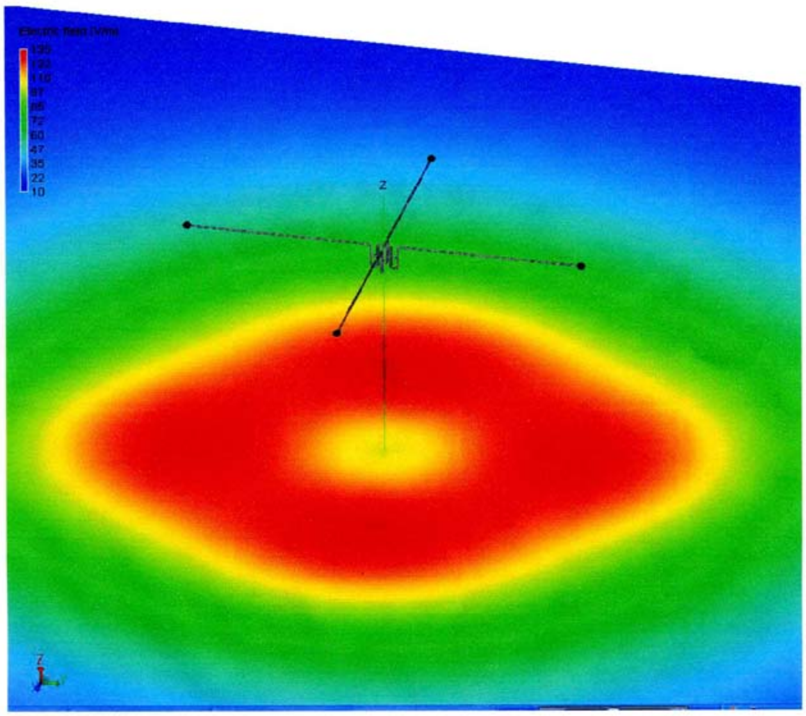

Figure 6.7. Nearfield values (V/m) at 7.35 MHz along XY plane, 4 feet off of ground level

Figure 9: Antenna field sketch, 3 dimensional

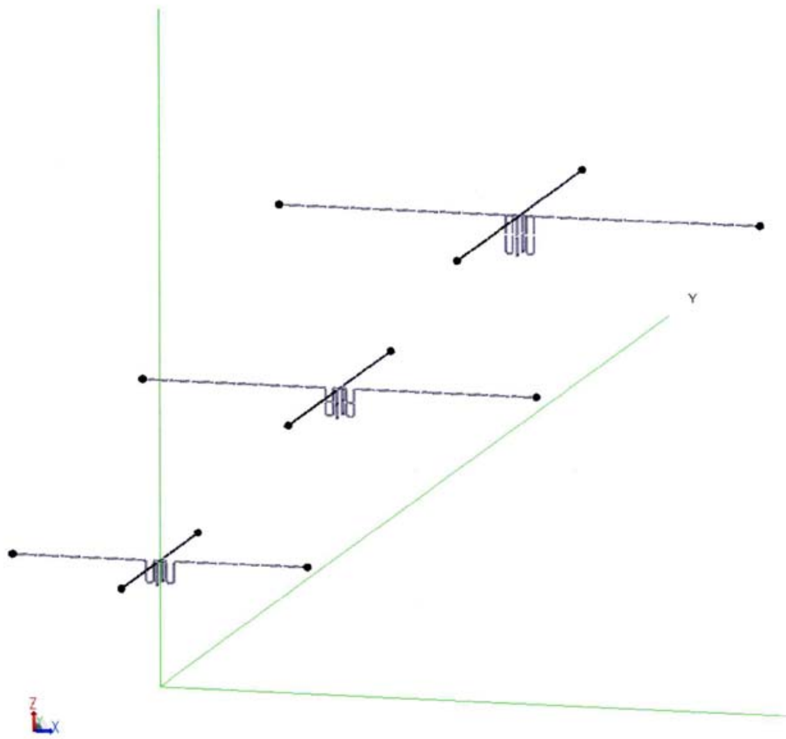

Figure 1.2. Three antennas in line with 100 feet spacing between centers.

Figure 10: Antenna field, side view showing elevation on the hill

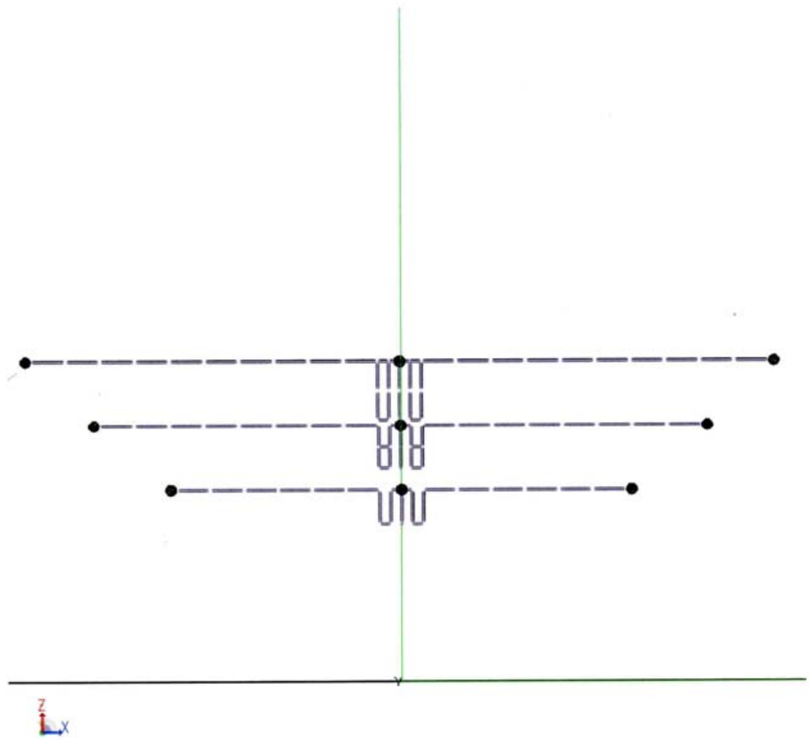

Figure 1.4. Side view of three antennas in line with heights of 39.4, 42.7, and 59.1 feet, respectively.

Figure 11: Antenna tuning stubs

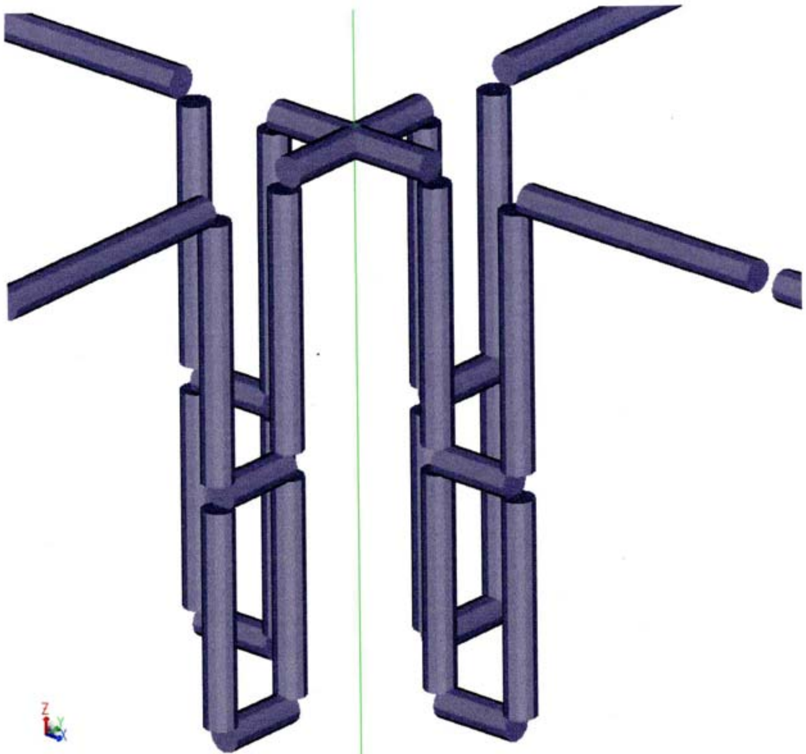

Figure 1.5. Center feedpoint section of antenna showing tuning stubs with shorting bars.

Appendix A. Antenna Radiation Elevation Patterns with Terrain Effects Including to each Location.

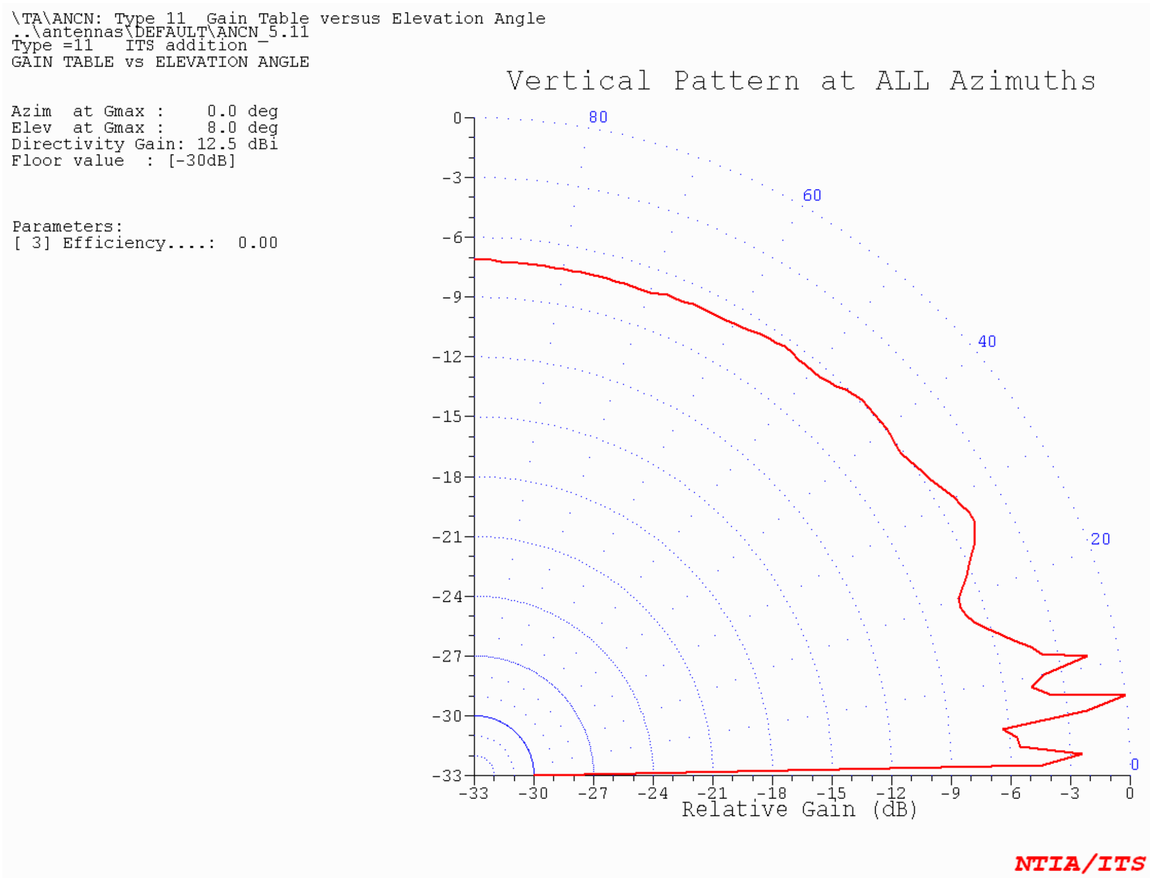

Figure 11 Vertical Pattern Anchorage Alaska 5.05 MHz Azimuth 224.0

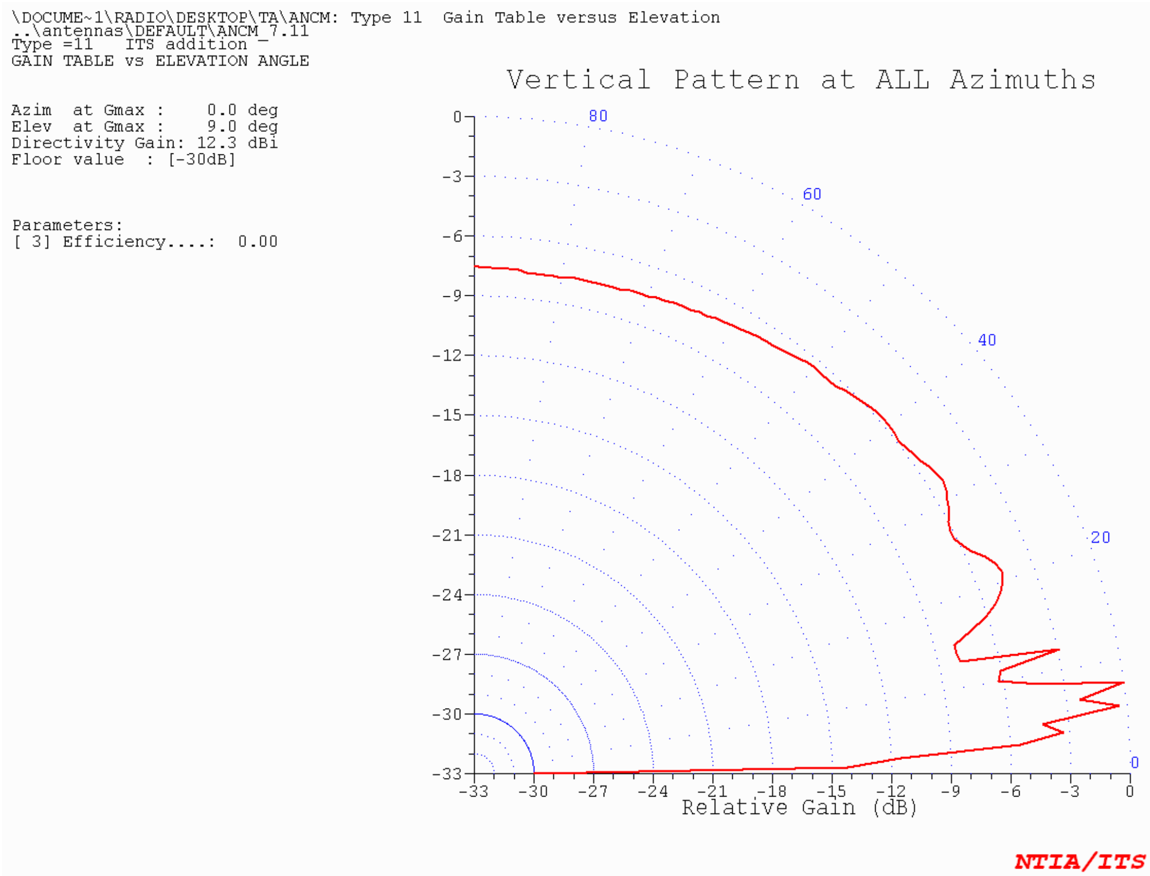

Figure 12 Vertical Pattern Anchorage Alaska 7.35 MHz Azimuth 224.0

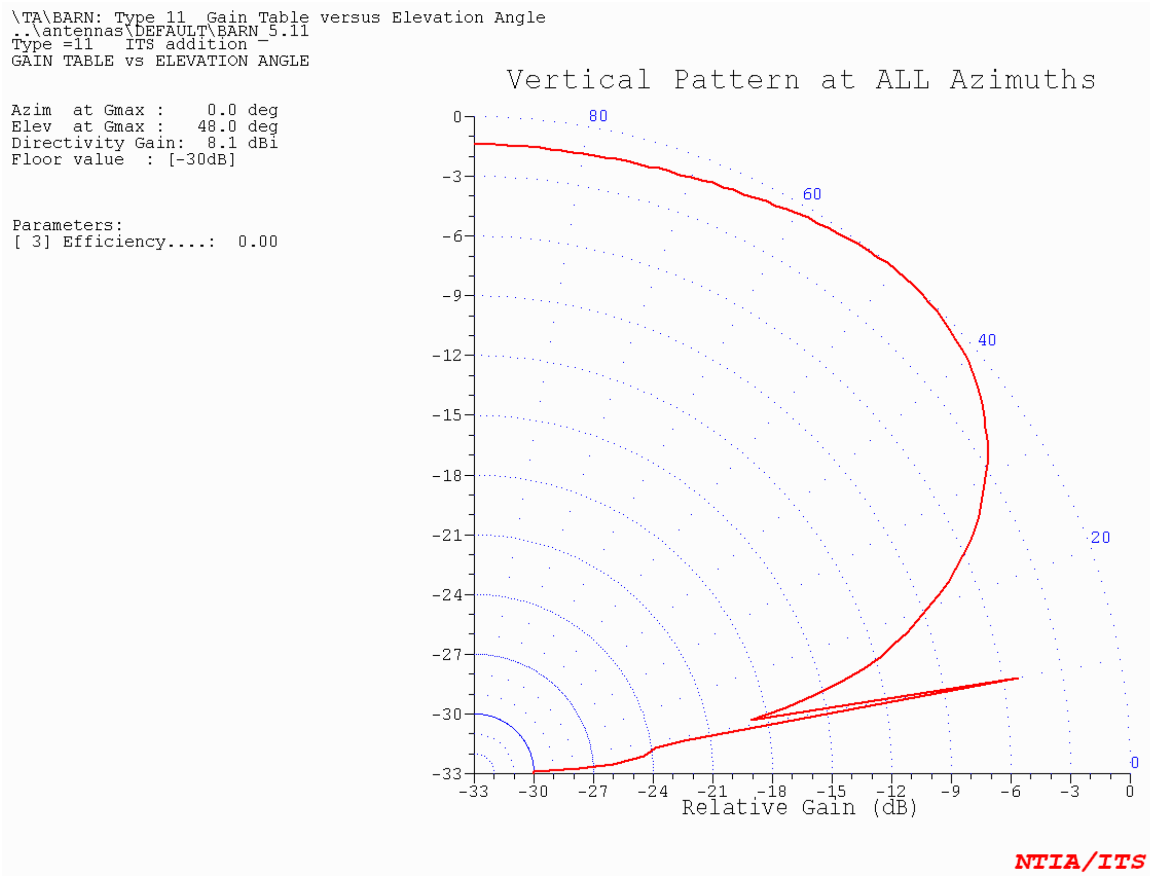

Figure 13 Vertical Pattern Barrow Alaska 5.05 MHz Azimuth 334.2

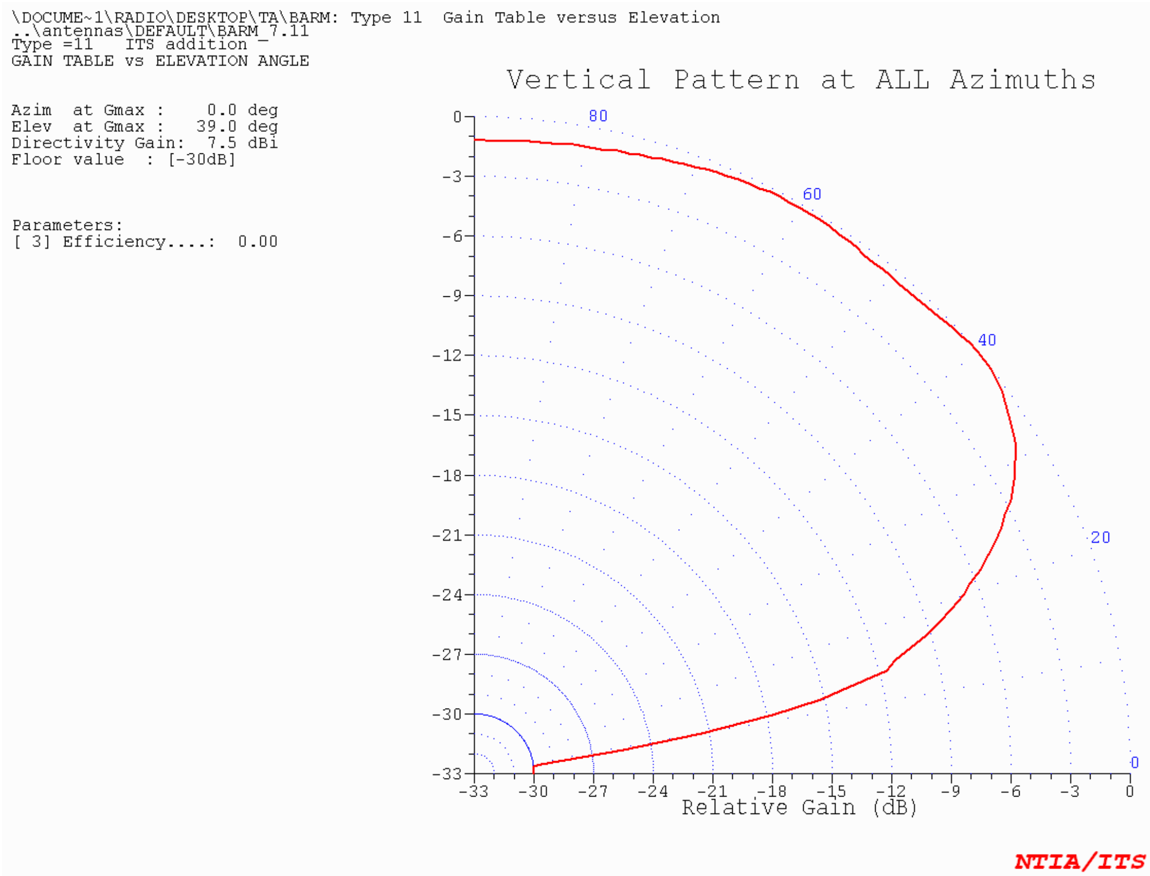

Figure 14 Vertical Pattern Barrow Alaska 7.35 MHz Azimuth 334.2

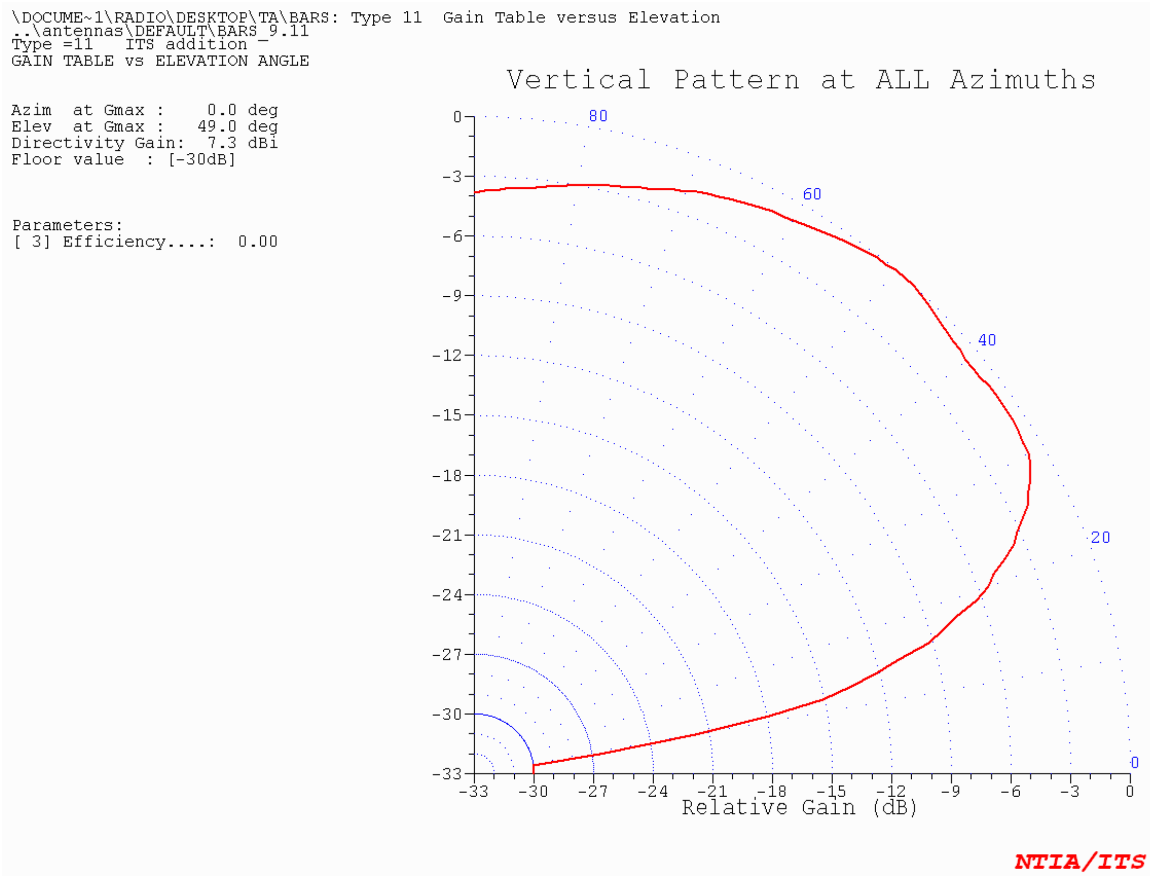

Figure 15 Vertical Pattern Barrow Alaska 9.623 MHz Azimuth 334.2

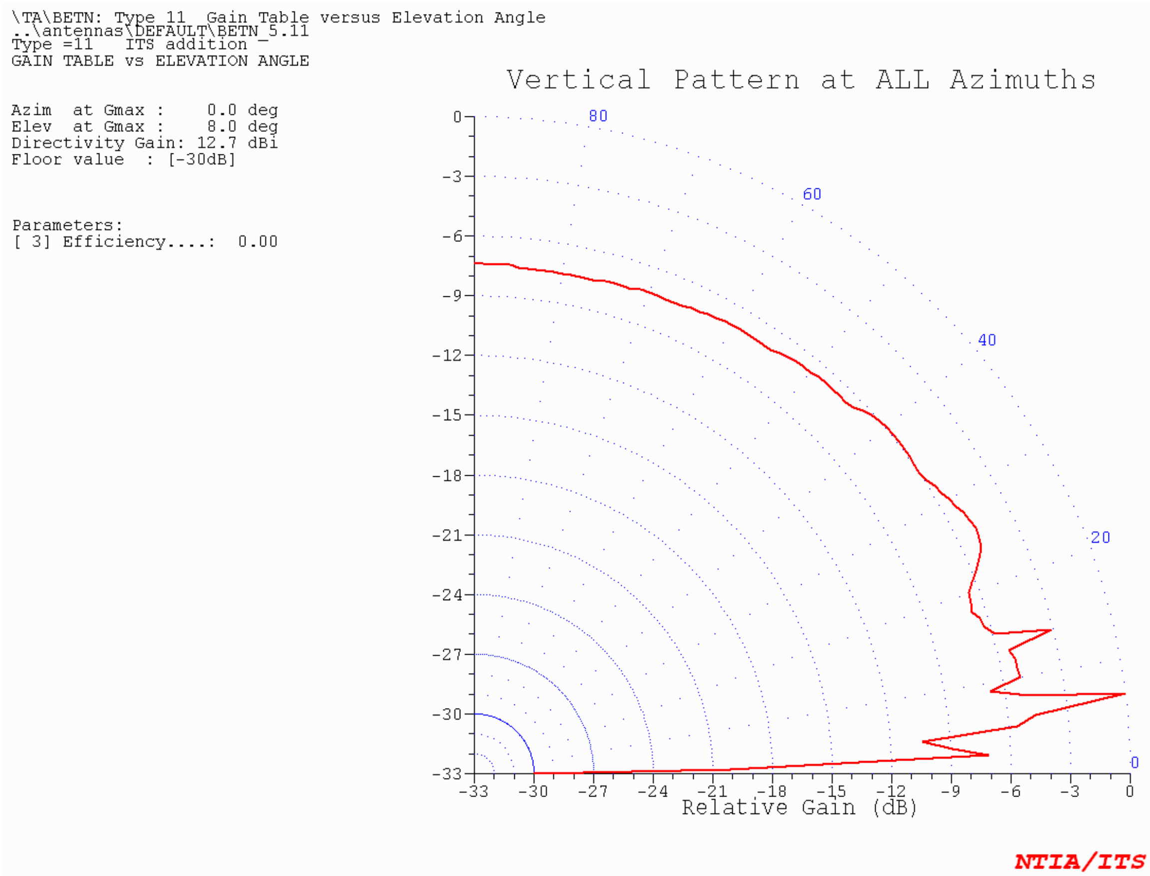

Figure1 6 Vertical Pattern Bethel Alaska 5.05 MHz Azimuth 256.8

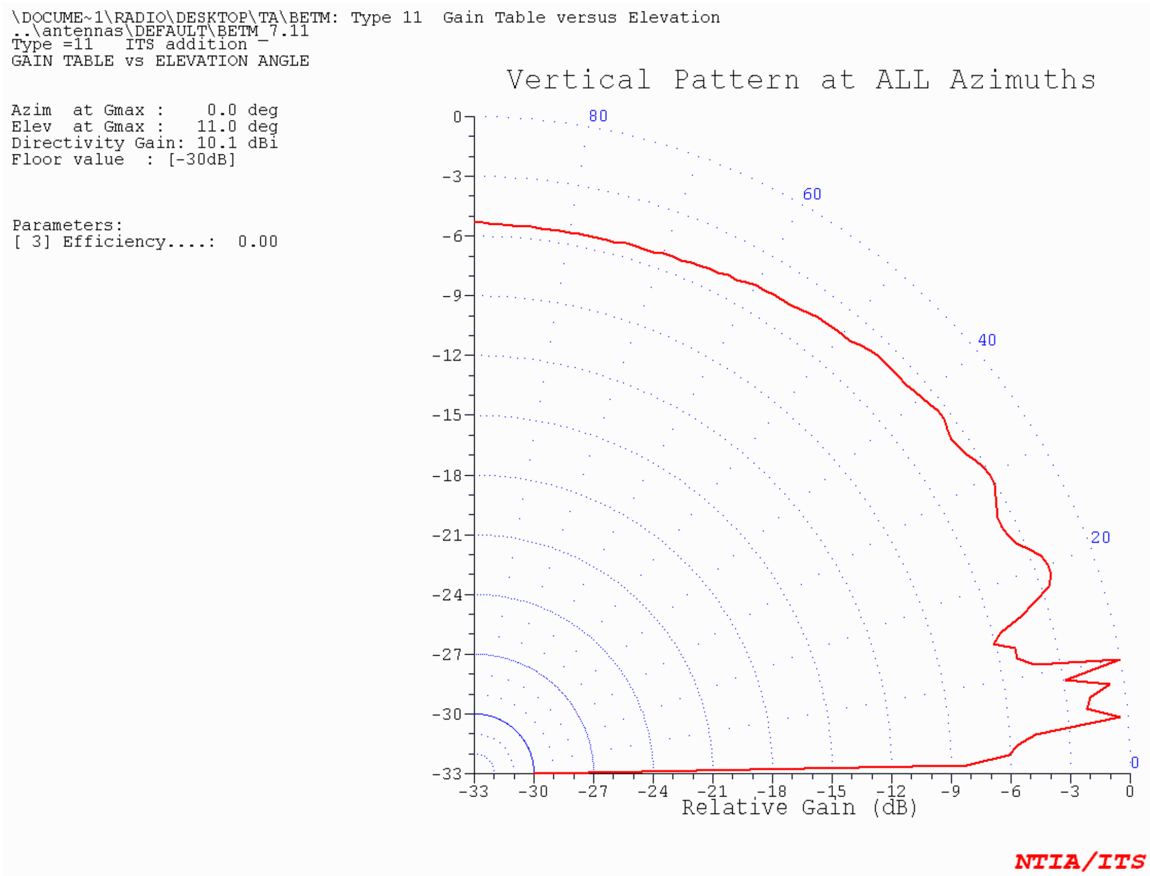

Figure 17 Vertical Pattern Bethel Alaska 7.35 MHz Azimuth 256.8

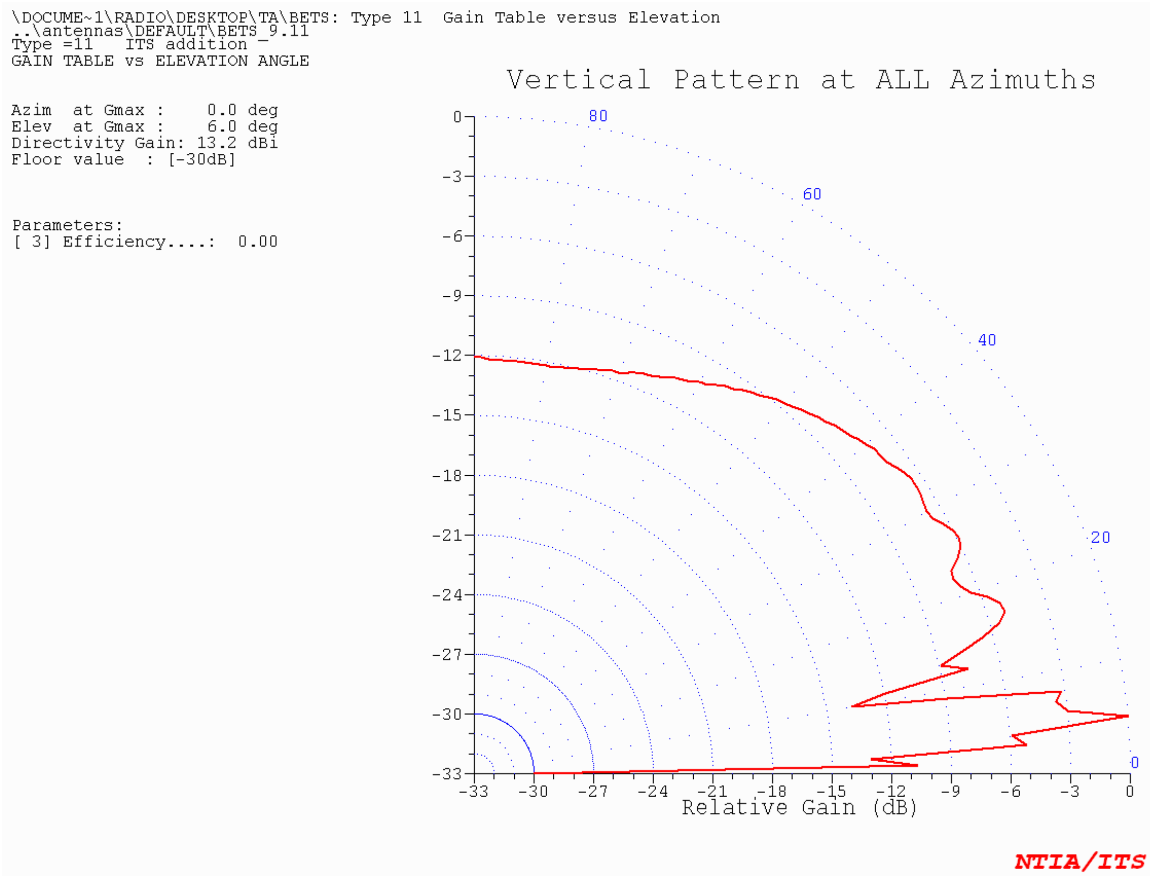

Figure1 8 Vertical Pattern Bethel Alaska 9.623 MHz Azimuth 256.8

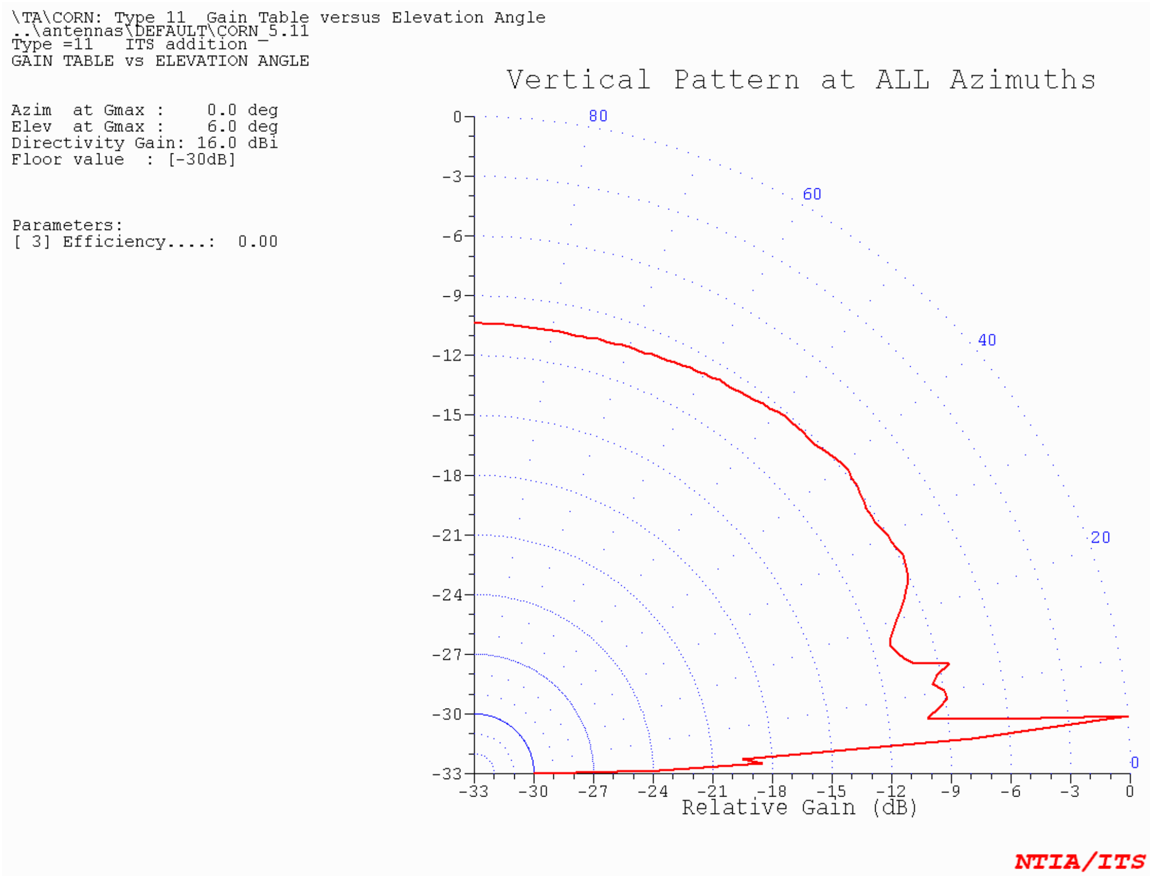

Figure 9 Vertical Pattern Cordova Alaska 5.05 MHz Azimuth 187.4

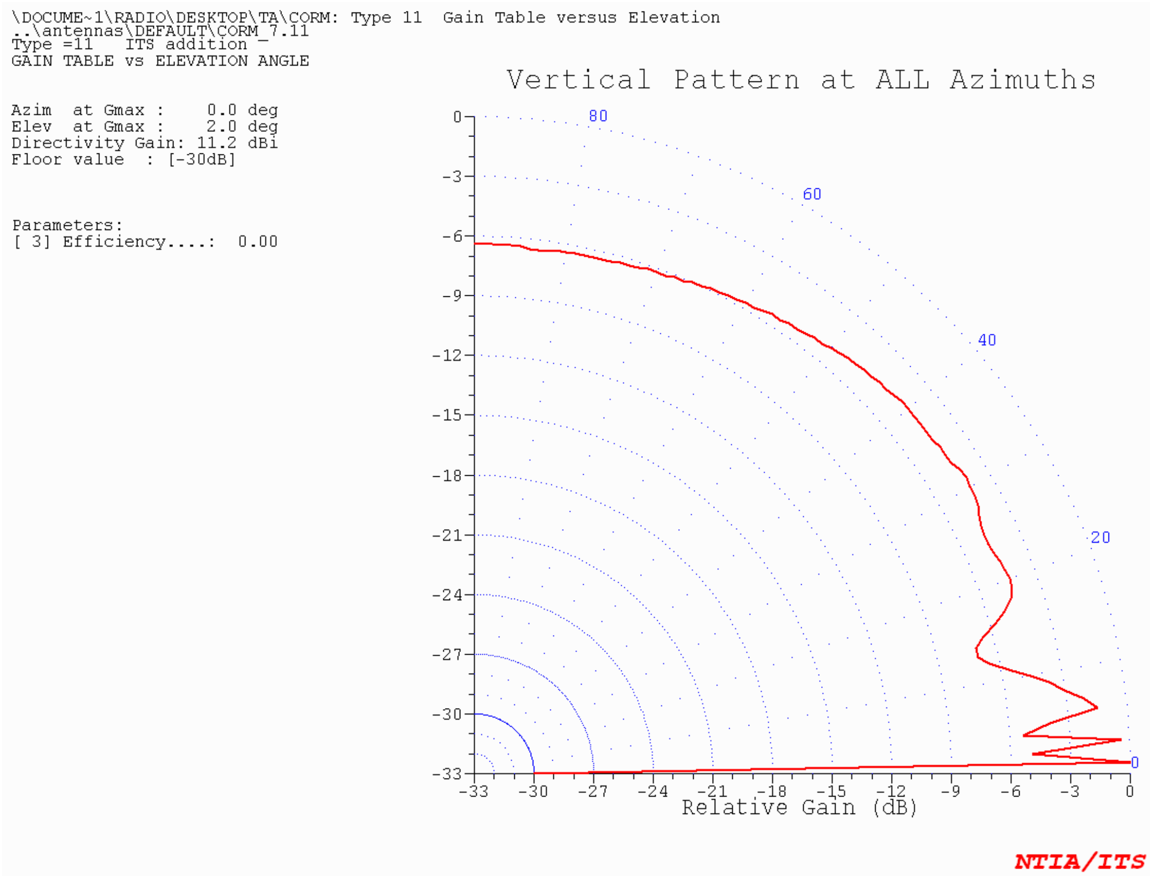

Figure 10 Vertical Pattern Cordova Alaska 7.35 MHz Azimuth 187.4

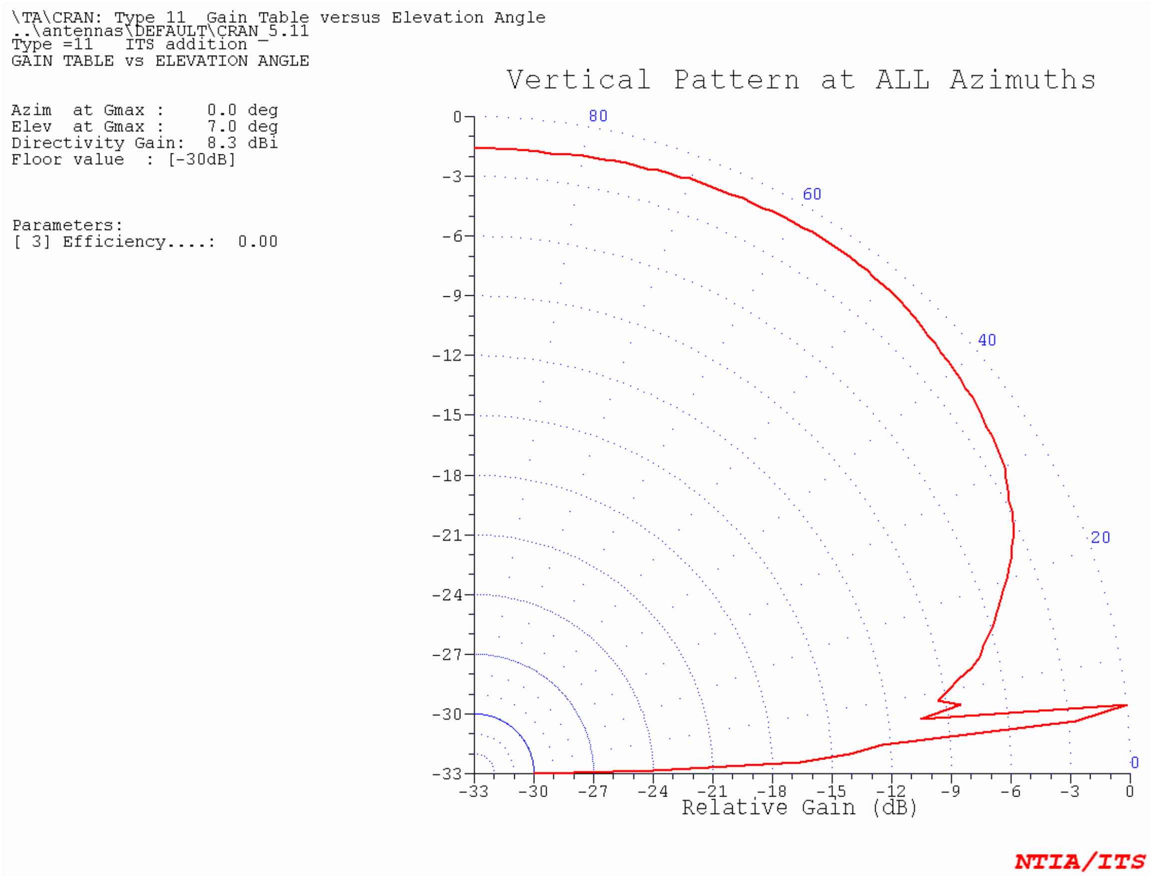

Figure 11 Vertical Pattern Craig Alaska 5.05 MHz Azimuth 139.4

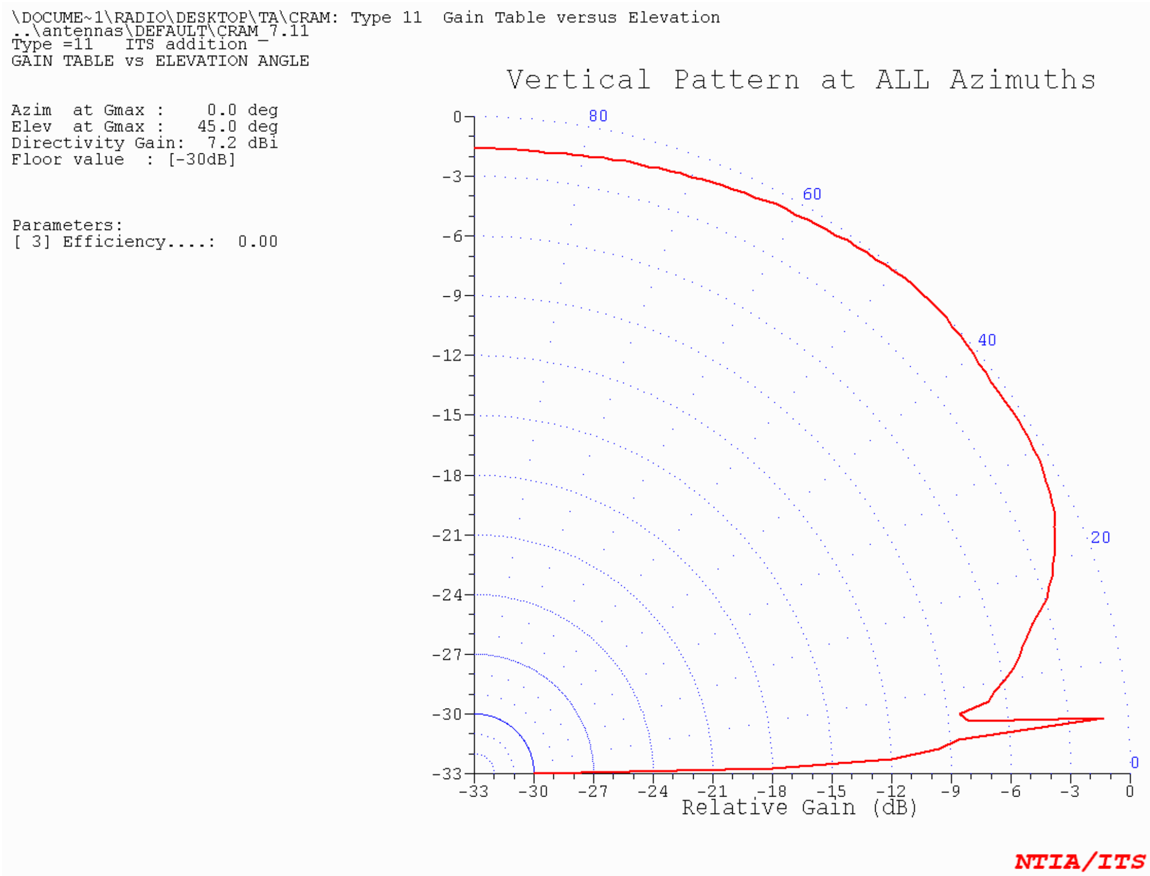

Figure 12 Vertical Pattern Craig Alaska 7.35 MHz Azimuth 139.4

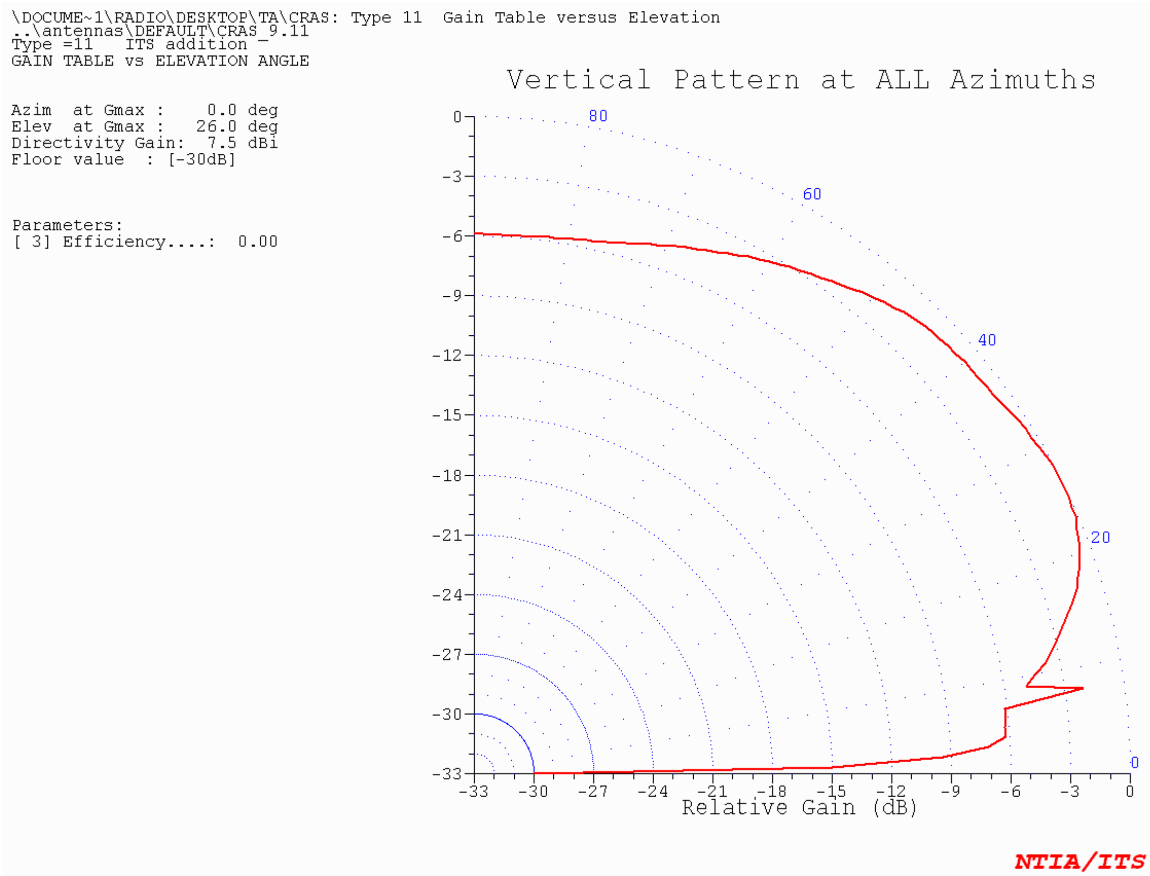

Figure 13 Vertical Pattern Craig Alaska 9.623 MHz Azimuth 139.4

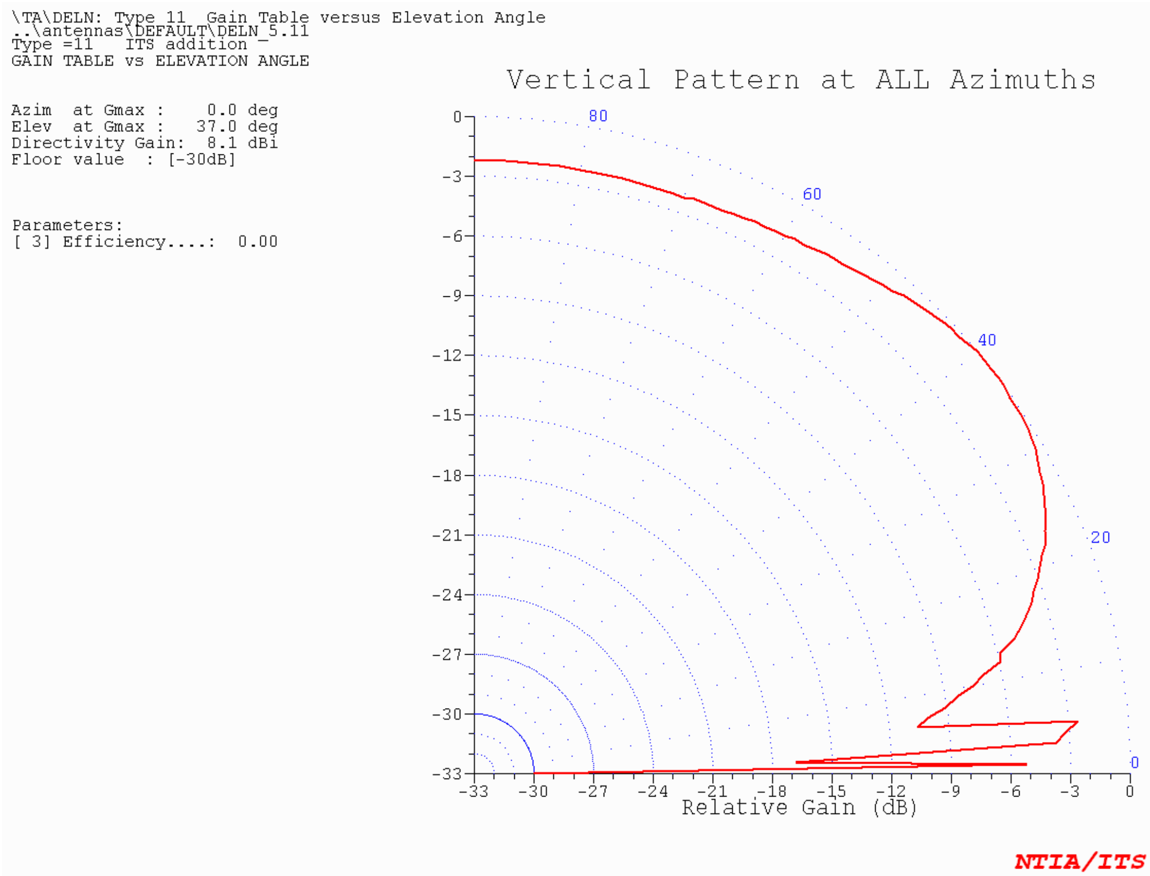

Figure 14 Vertical Pattern Delta Junction Alaska 5.05 MHz Azimuth 300

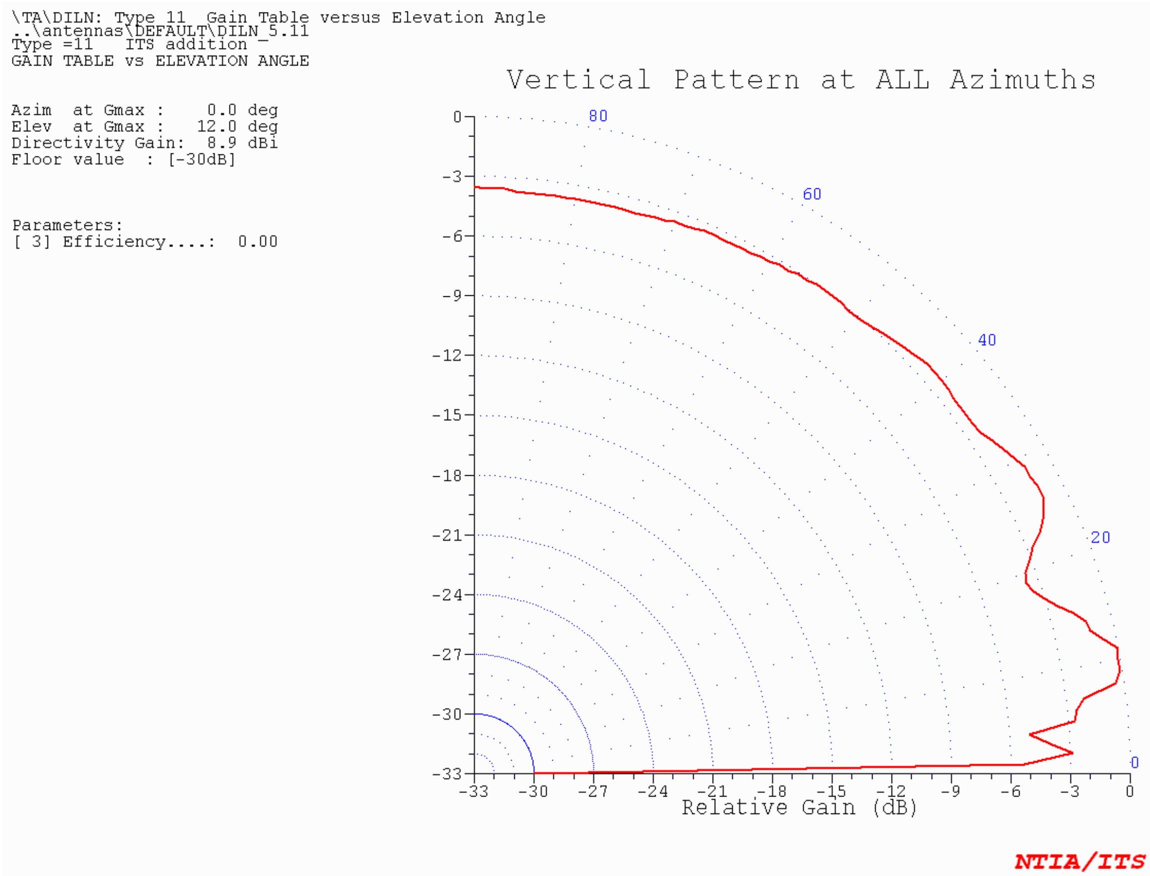

Figure 15 Vertical Pattern Dillingham Alaska 5.05 MHz Azimuth 239.8

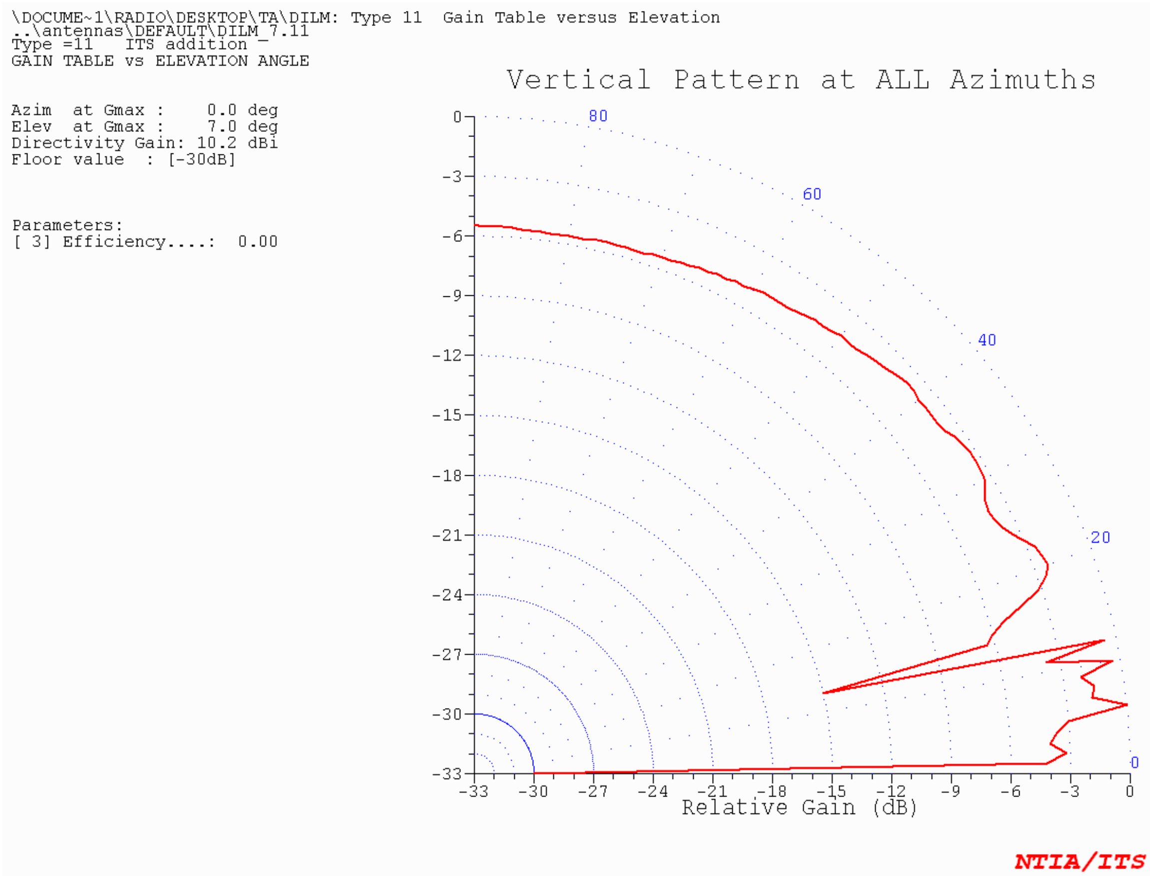

Figure 16 Vertical Pattern Dillingham Alaska 7.35 MHz Azimuth 239.8

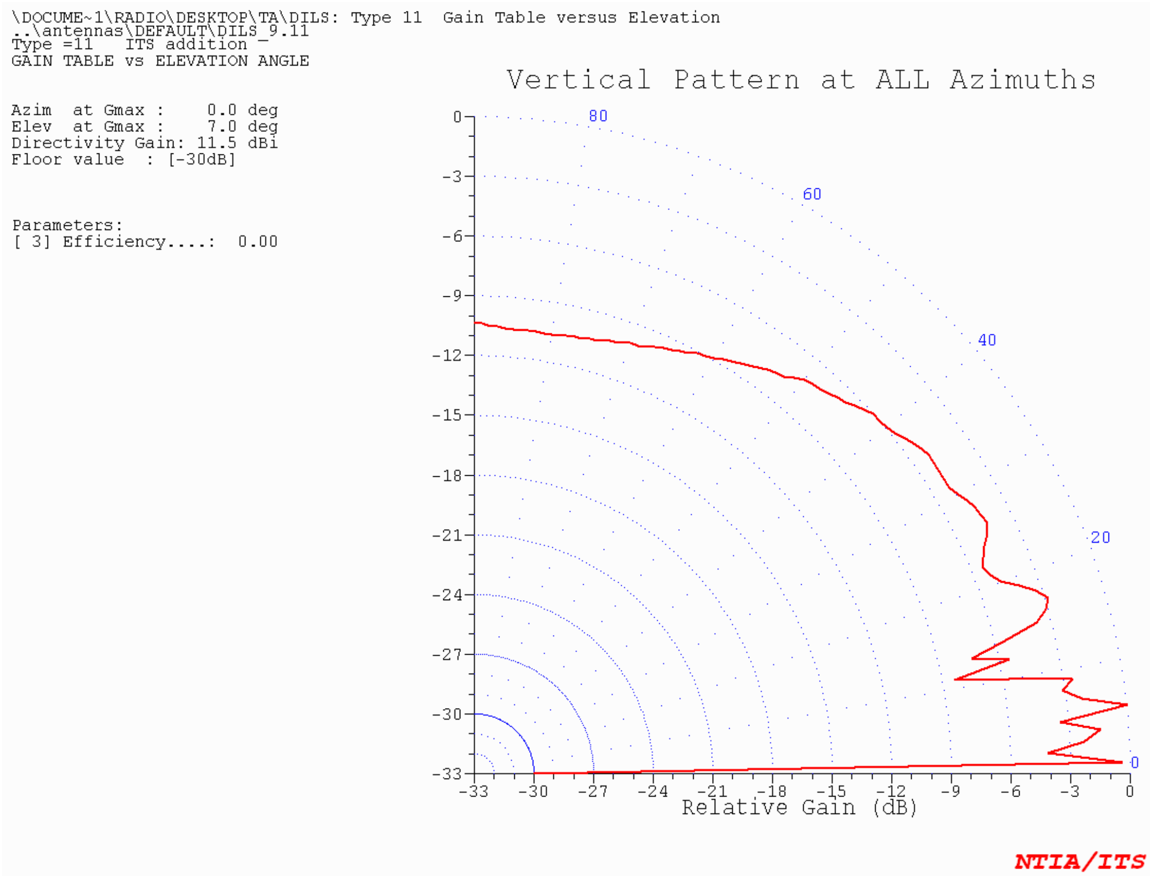

Figure 17 Vertical Pattern Dillingham Alaska 9.623 MHz Azimuth 239.8

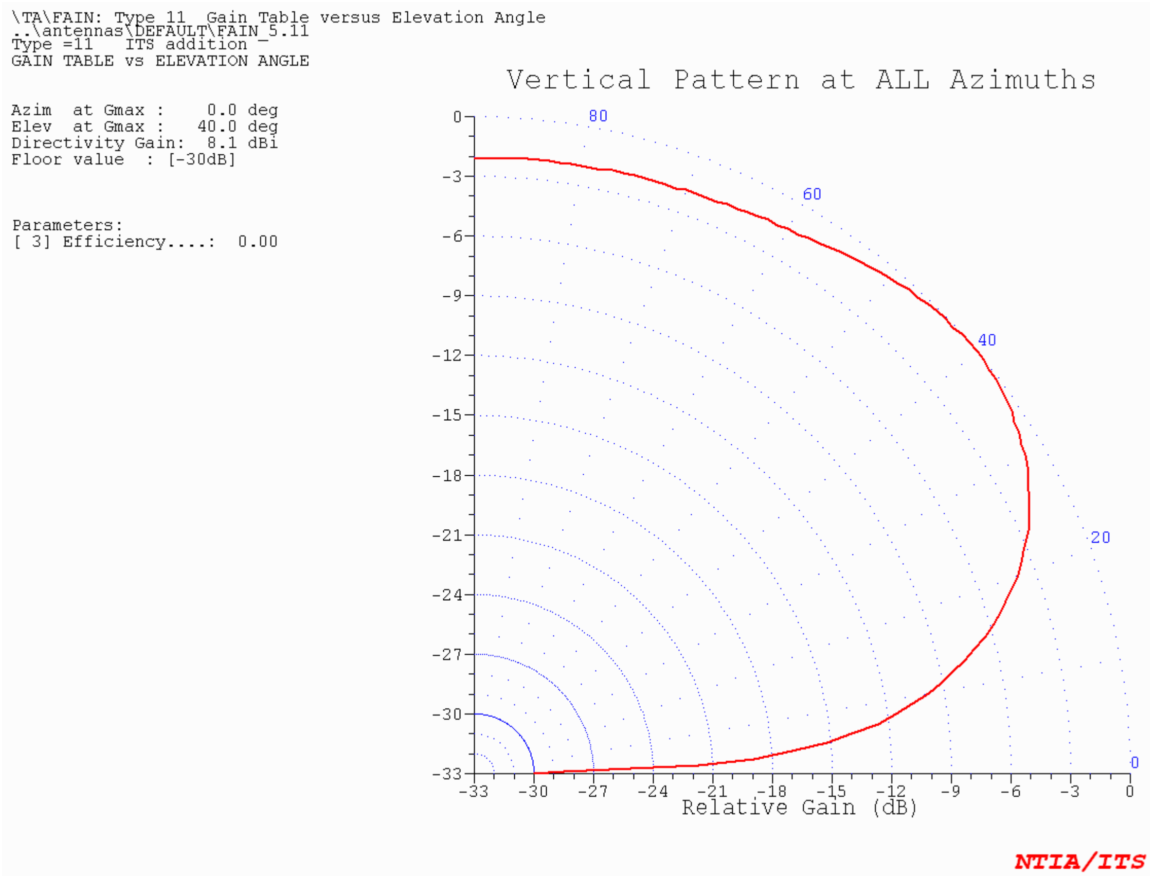

Figure 18 Vertical Pattern Fairbanks Alaska 5.05 MHz Azimuth 311.3

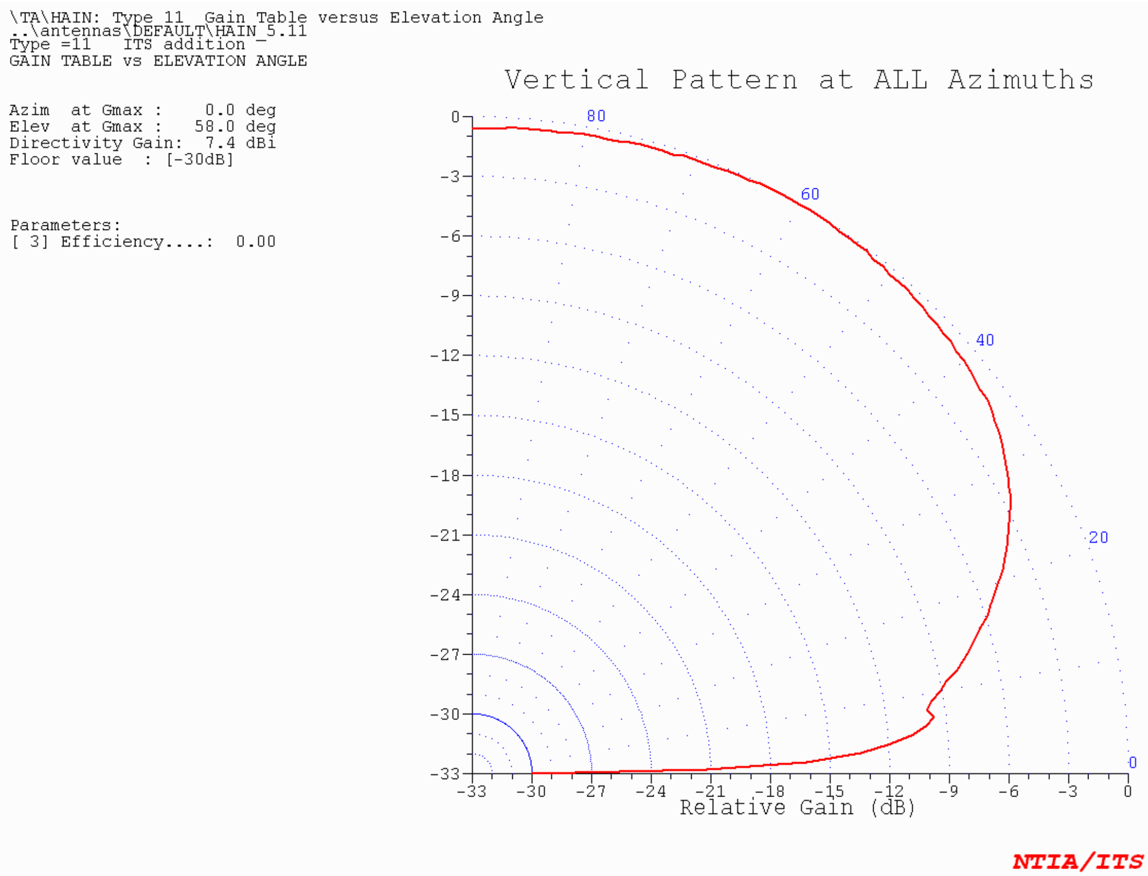

Figure 30 Vertical Pattern Haines Alaska 5.05 MHz Azimuth 131.3

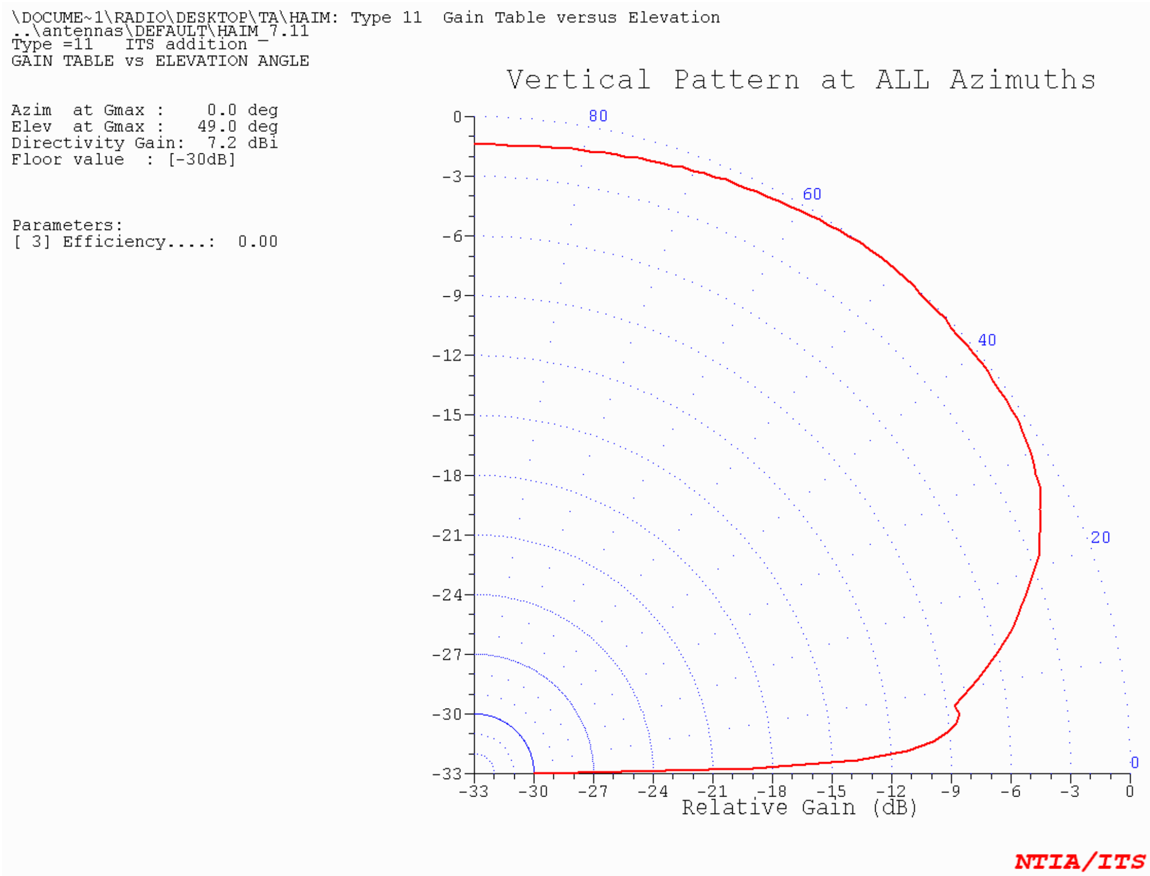

Figure 19 Vertical Pattern Haines Alaska 7.35 MHz Azimuth 131.3

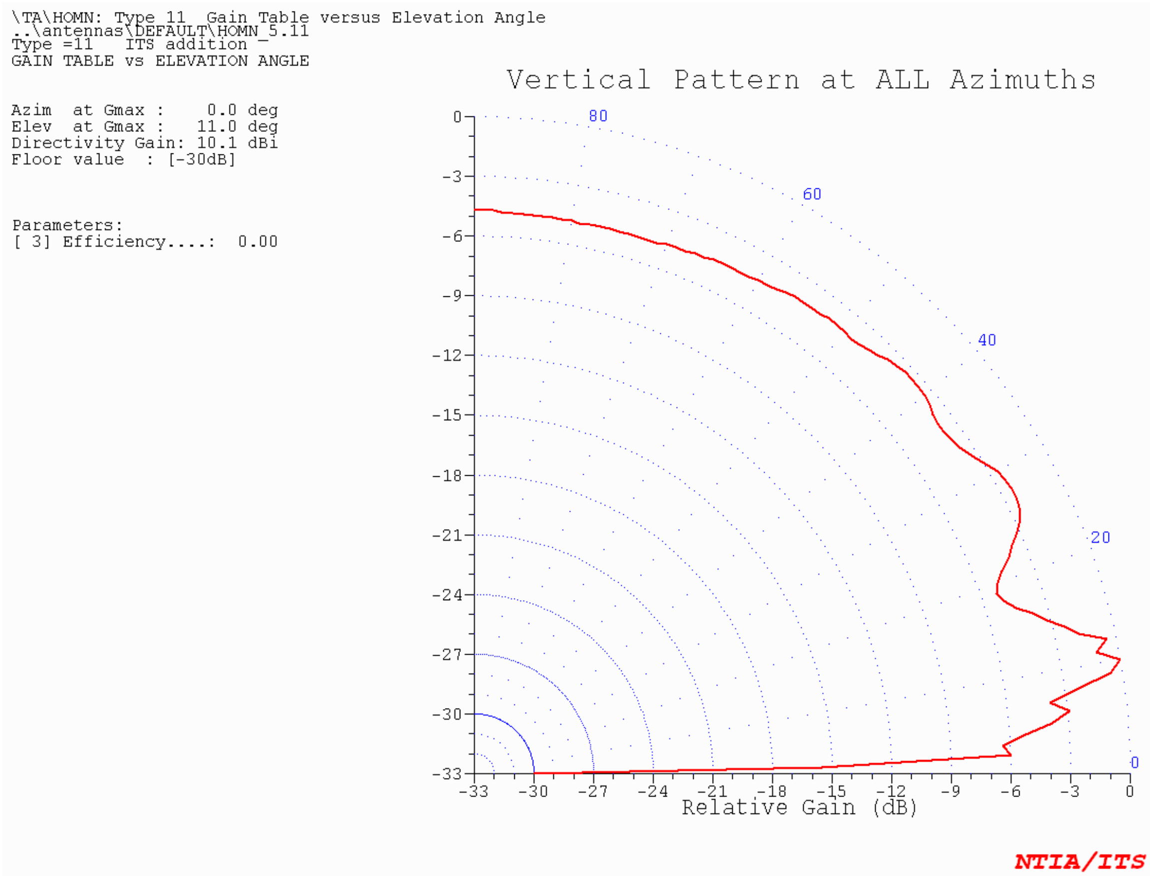

Figure 20 Vertical Pattern Homer Alaska 5.05 MHz Azimuth 220.1

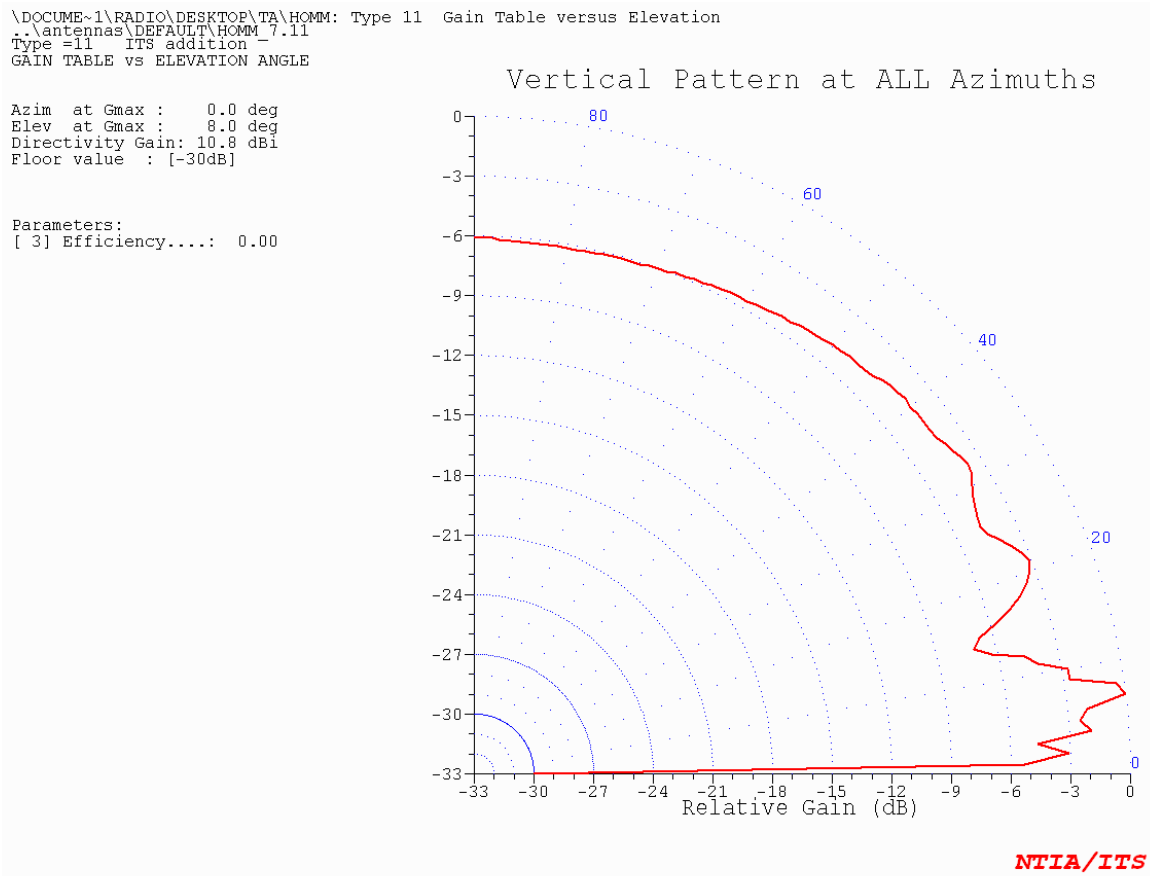

Figure 21 Vertical Pattern Homer Alaska 7.35 MHz Azimuth 220.1

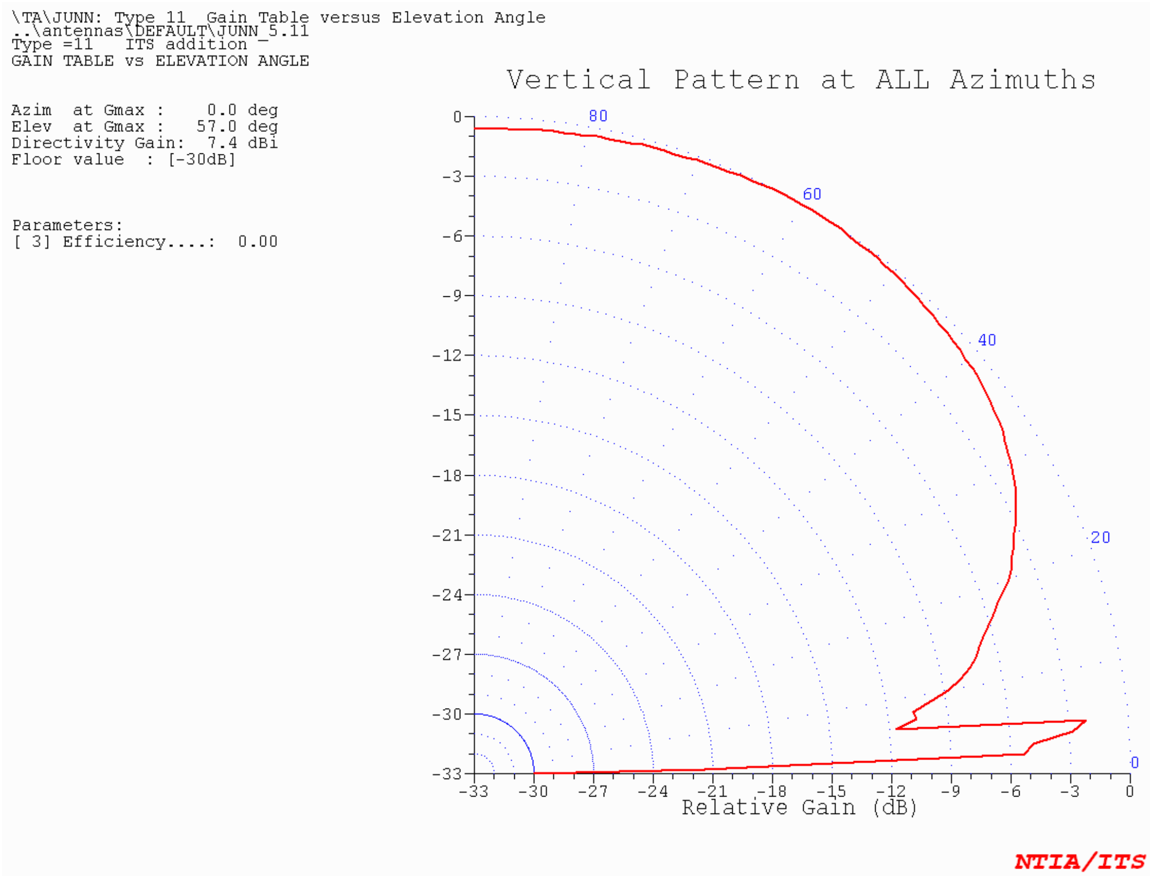

Figure 22 Vertical Pattern Juneau Alaska 5.05 MHz Azimuth 132.8

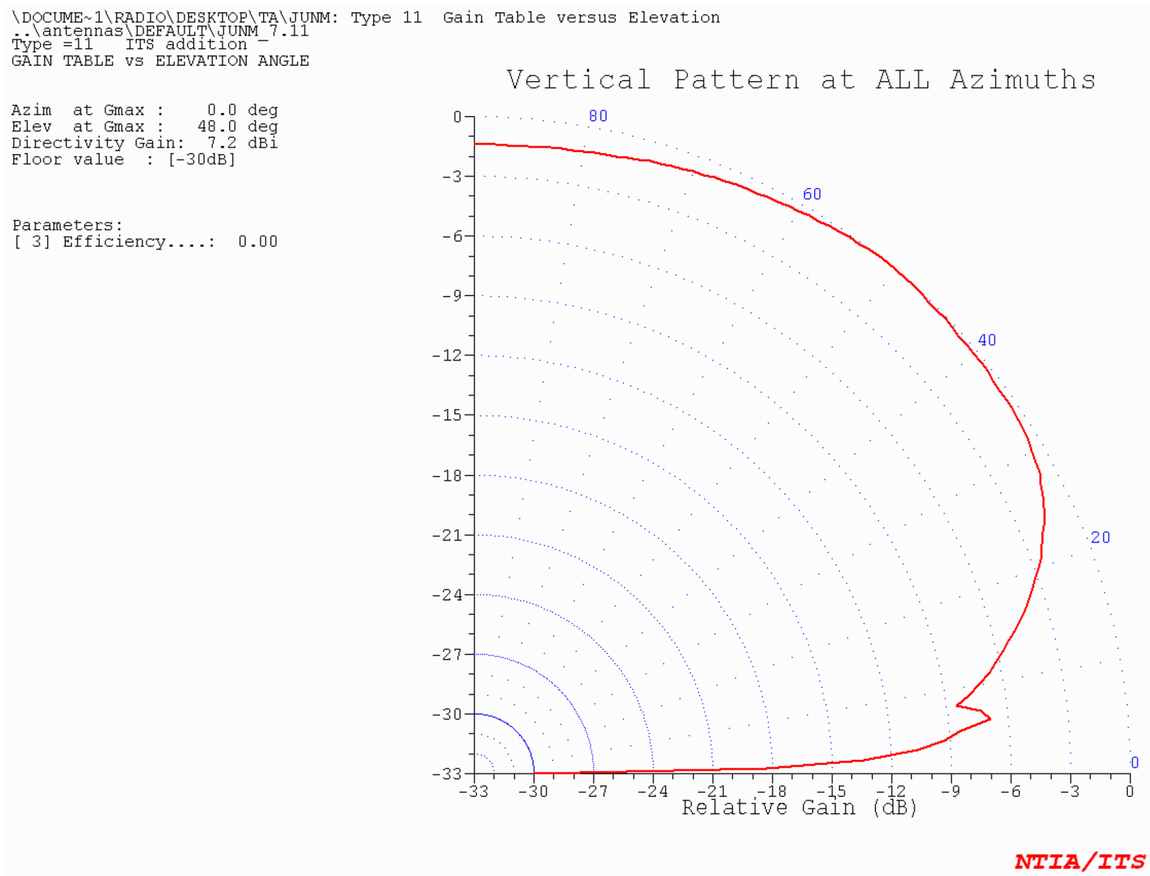

Figure 23 Vertical Pattern Juneau Alaska 7.35 MHz Azimuth 132.8

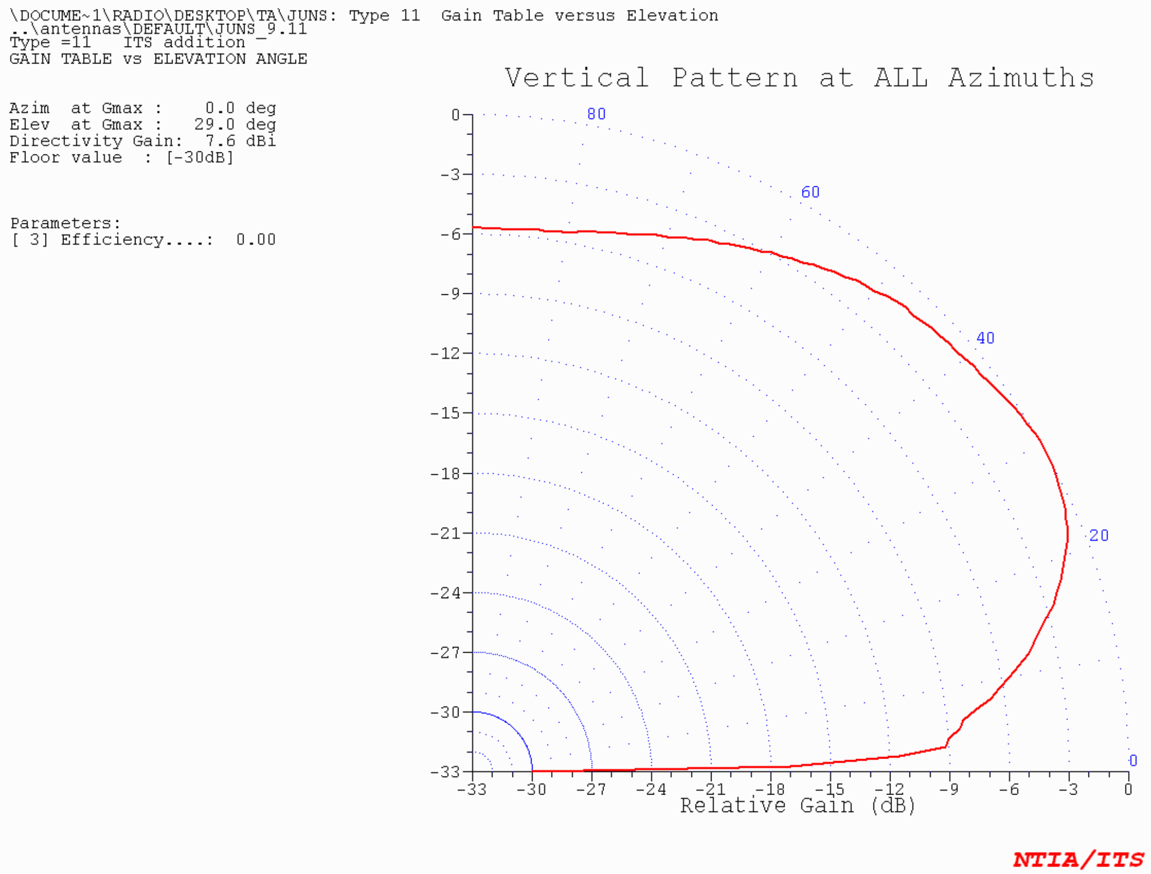

Figure 24 Vertical Pattern Juneau Alaska 9.623 MHz Azimuth 132.8

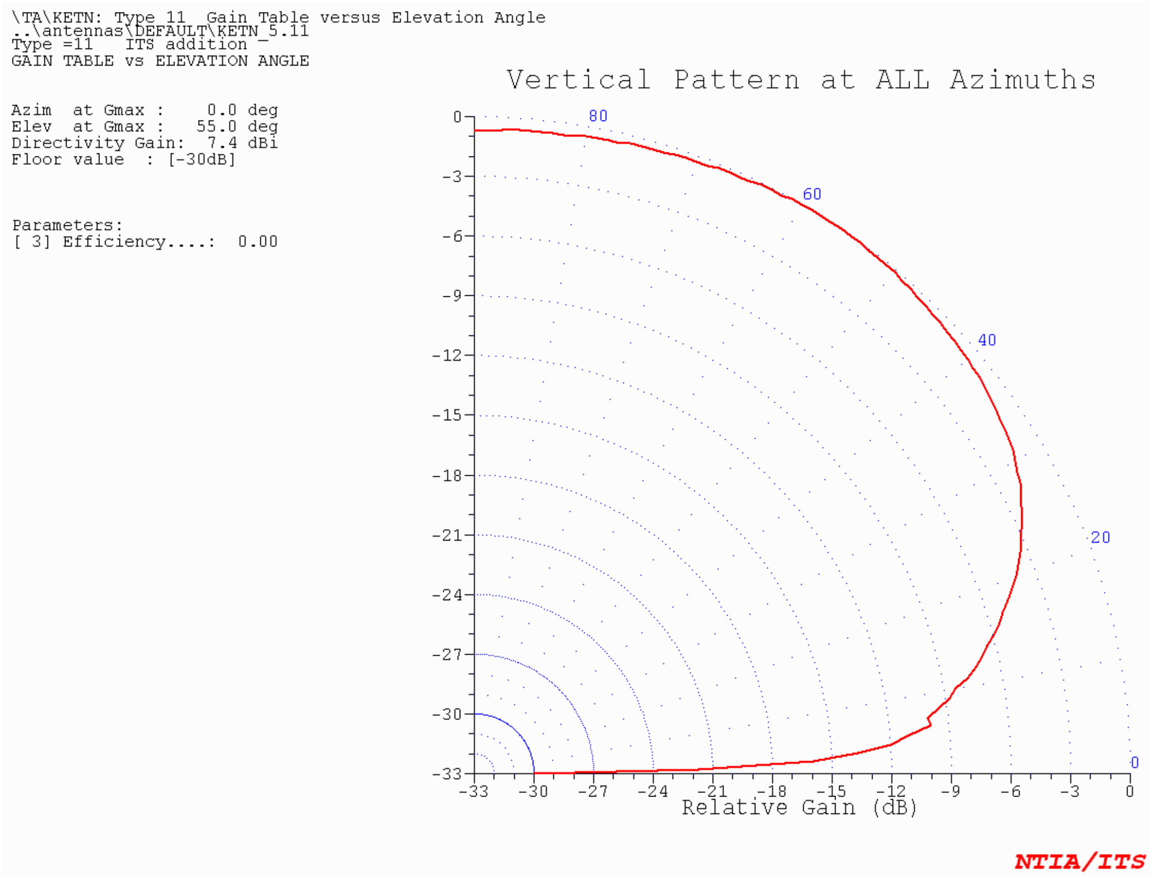

Figure 25 Vertical Pattern Ketchikan Alaska 5.05 MHz Azimuth 135.8

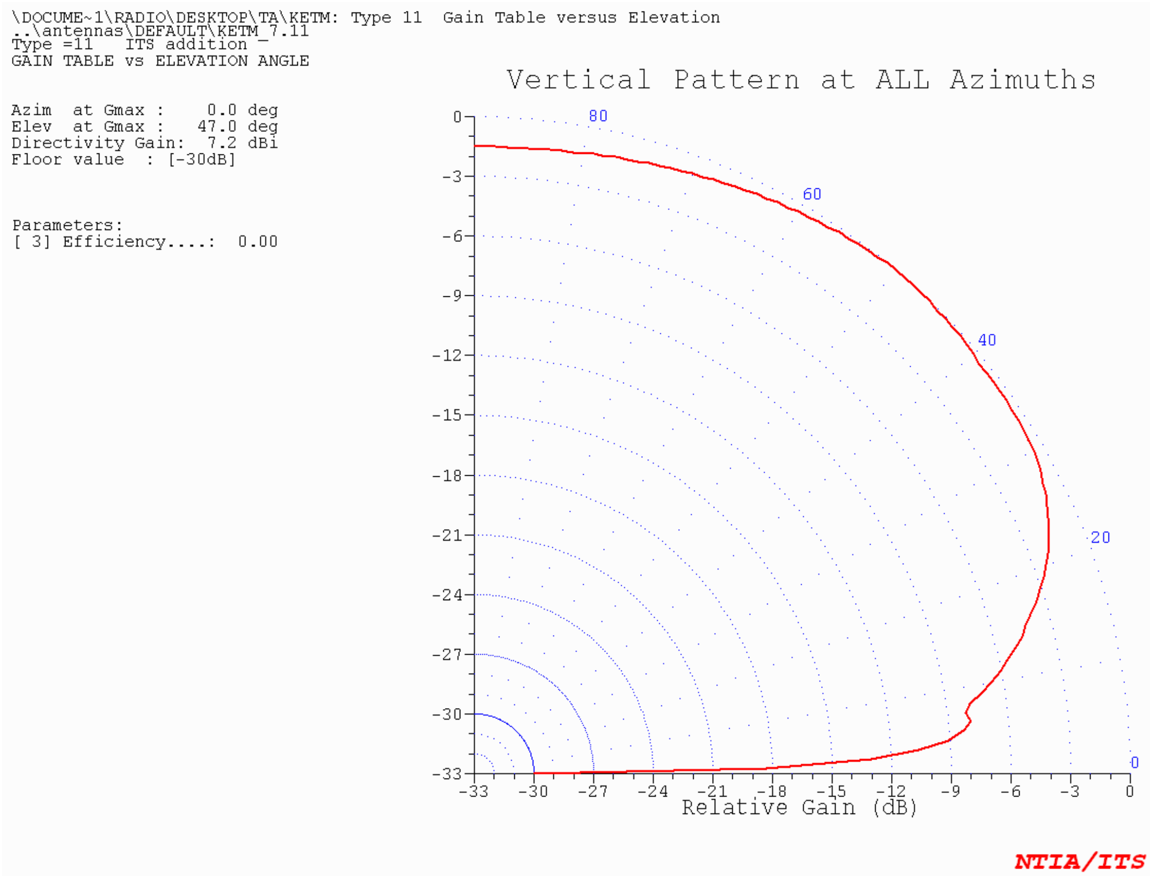

Figure 26 Vertical Pattern Ketchikan Alaska 7.35 MHz Azimuth 135.8

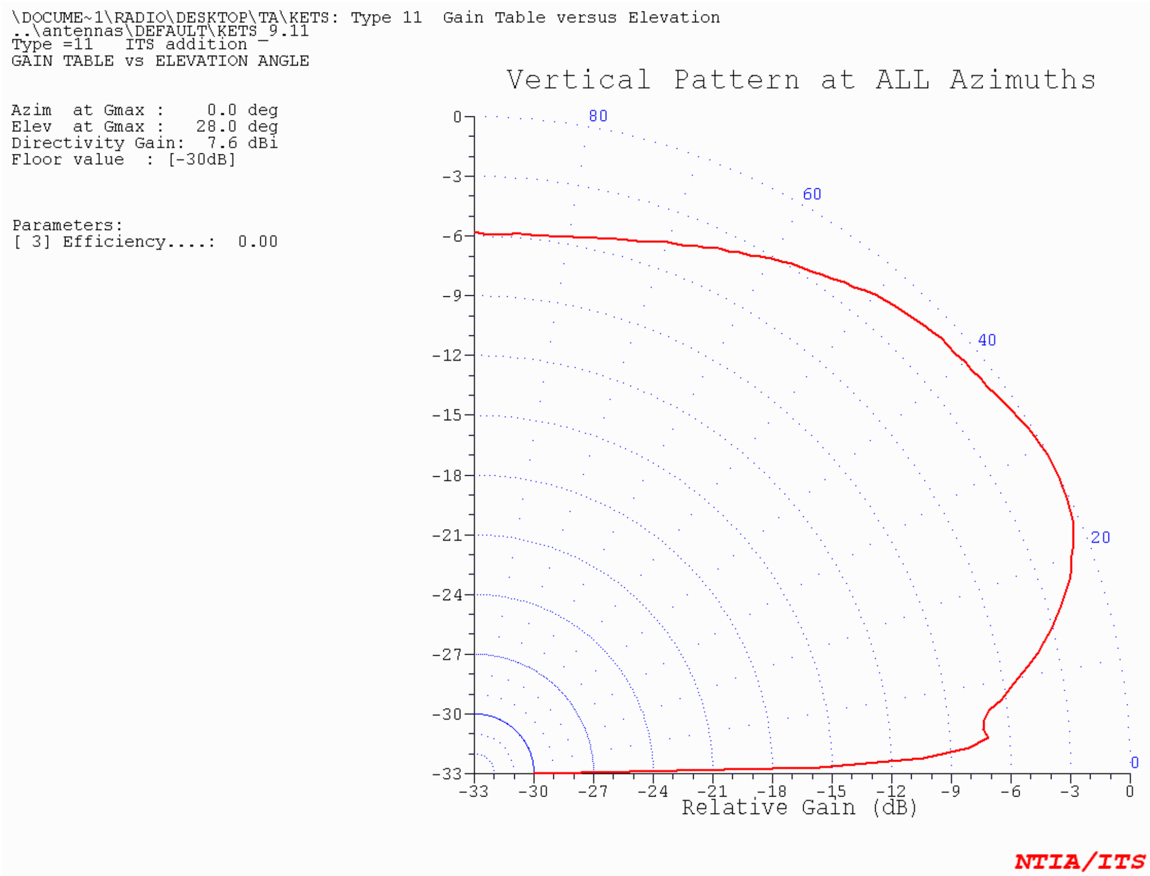

Figure 27 Vertical Pattern Ketchikan Alaska 9.623 MHz Azimuth 135.8

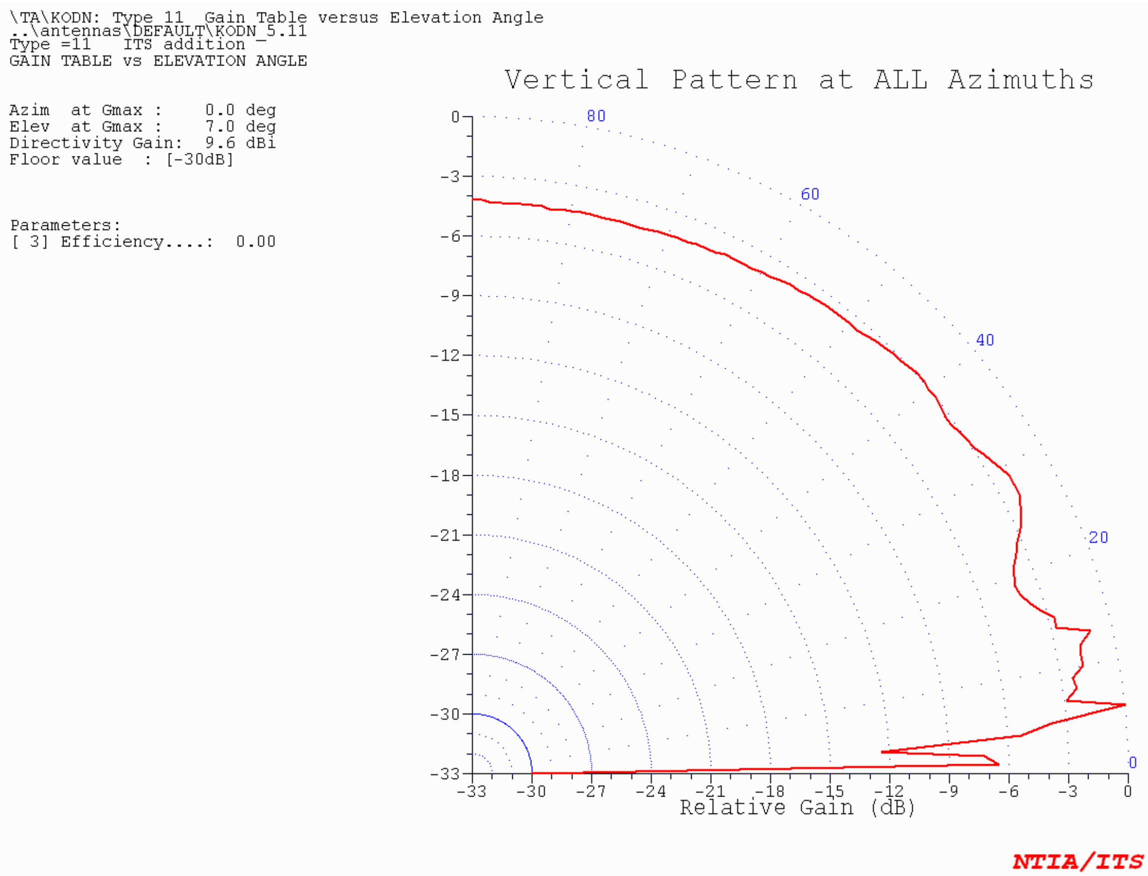

Figure 28 Vertical Pattern Kodiak Alaska 5.05 MHz Azimuth 214.6

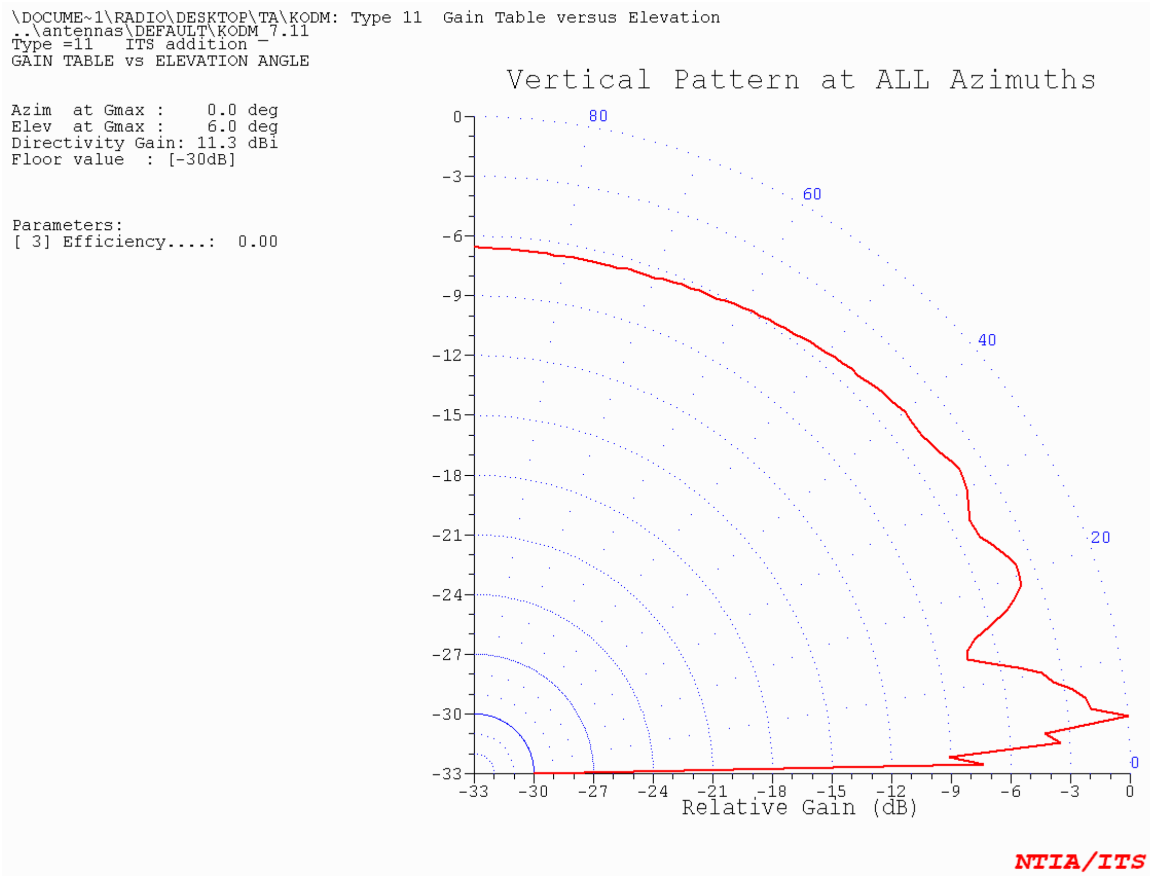

Figure 29 Vertical Pattern Kodiak Alaska 7.35 MHz Azimuth 214.6

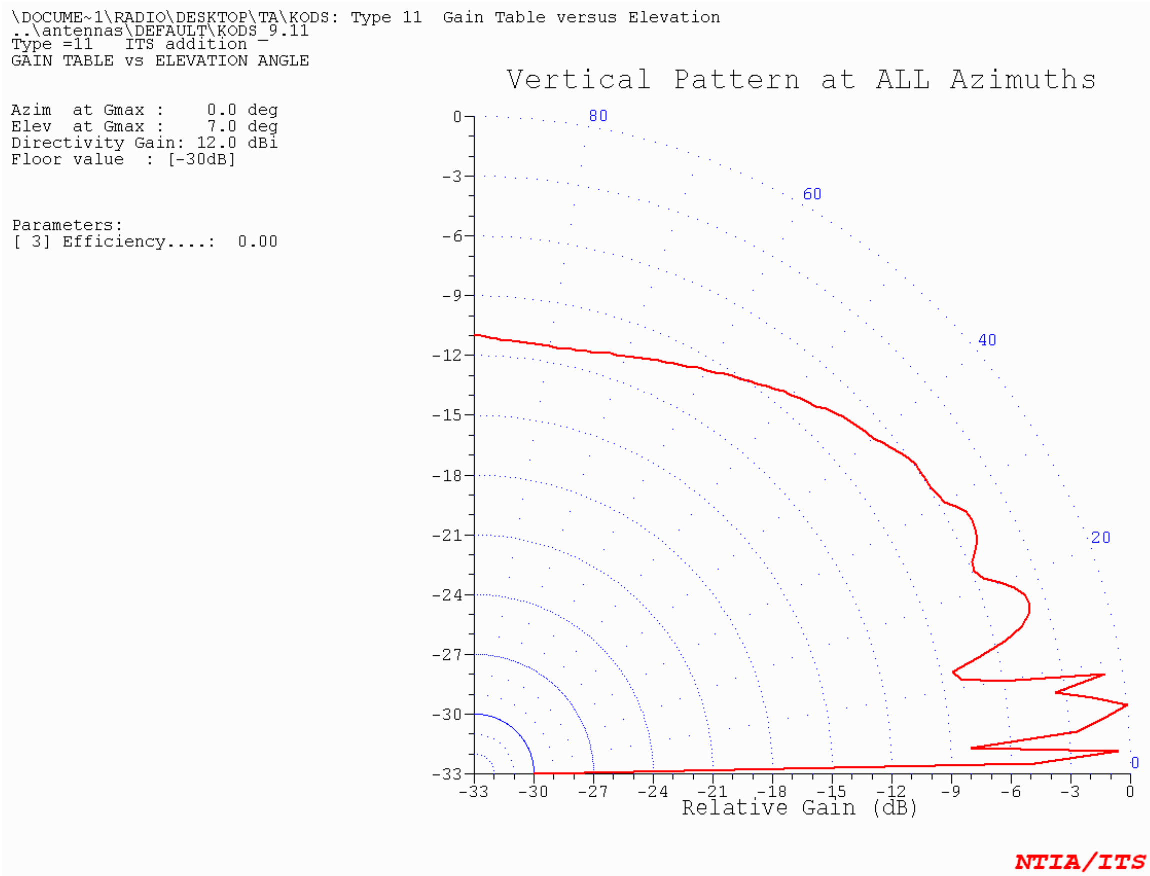

Figure 30 Vertical Pattern Kodiak Alaska 9.623 MHz Azimuth 214.6

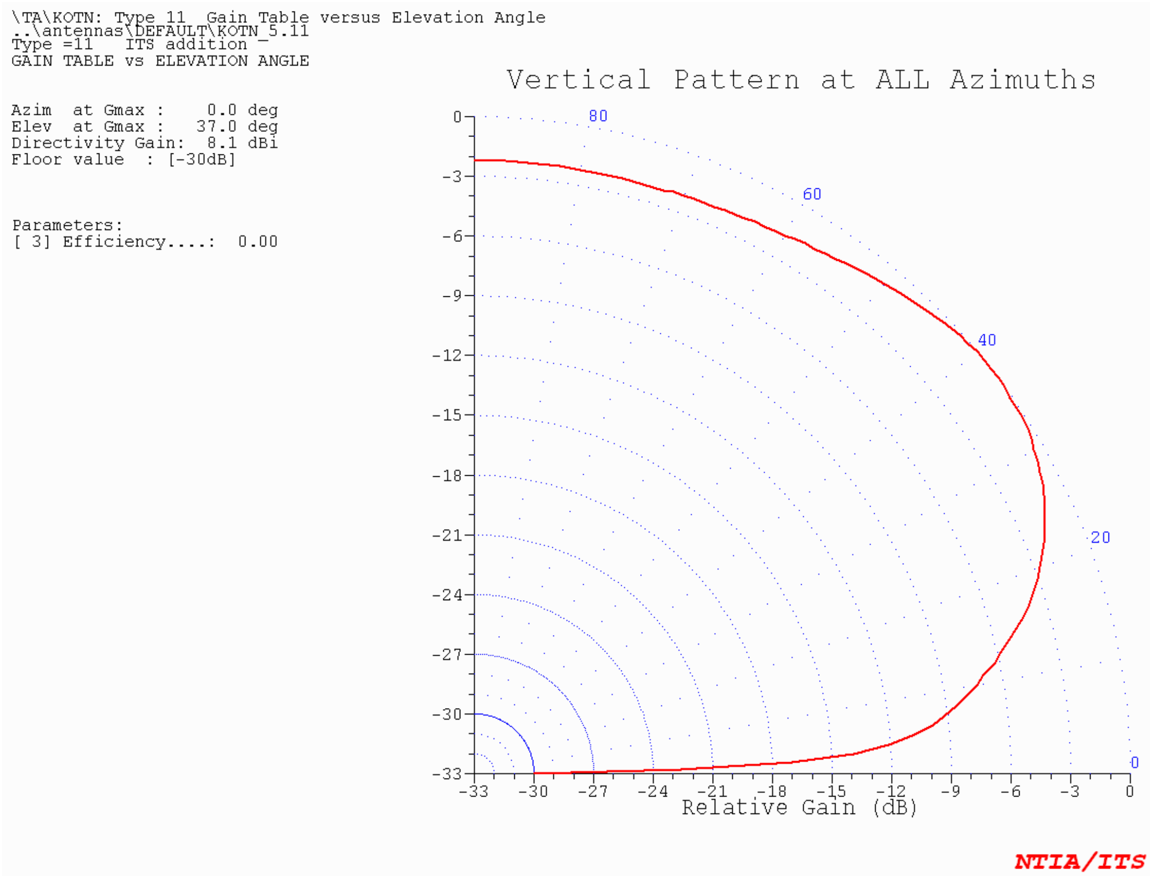

Figure 31 Vertical Pattern Kotzebue Alaska 5.05 MHz Azimuth 300.6

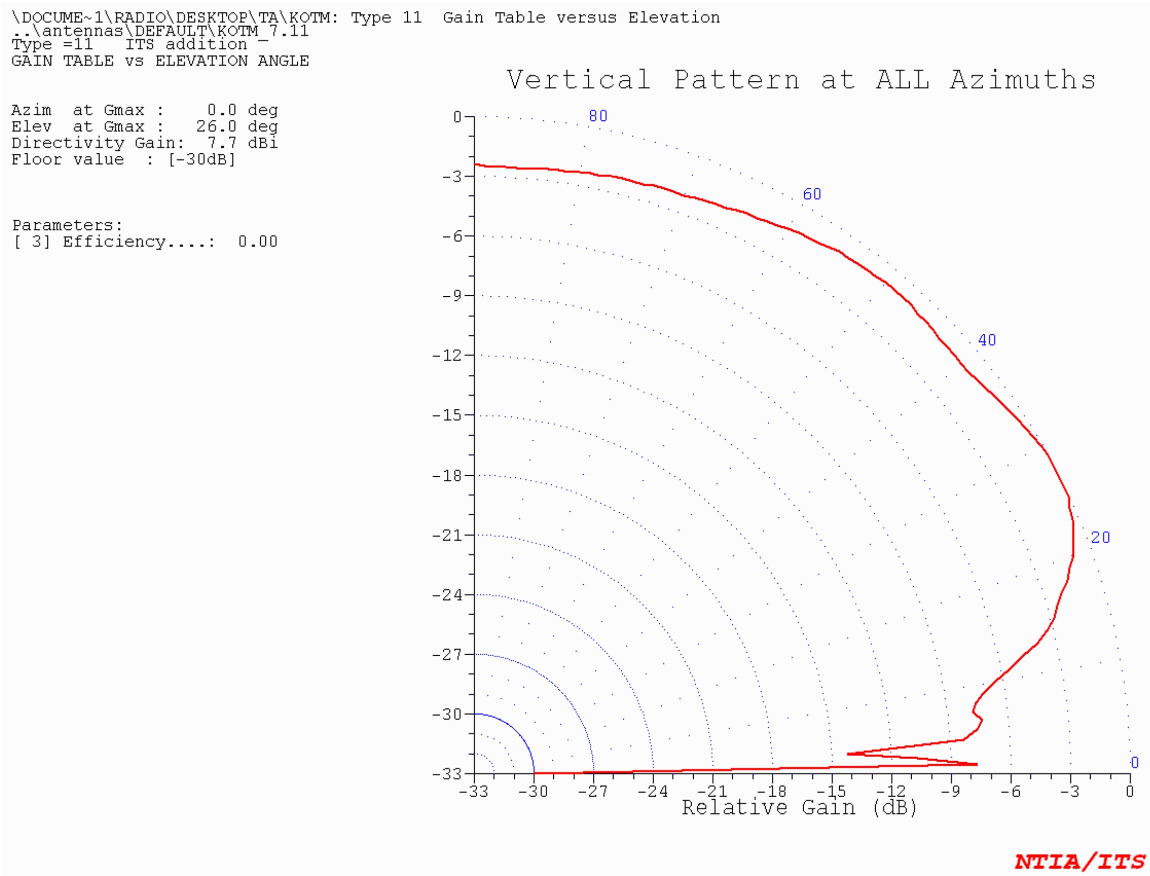

Figure 32 Vertical Pattern Kotzebue Alaska 7.35 MHz Azimuth 300.6

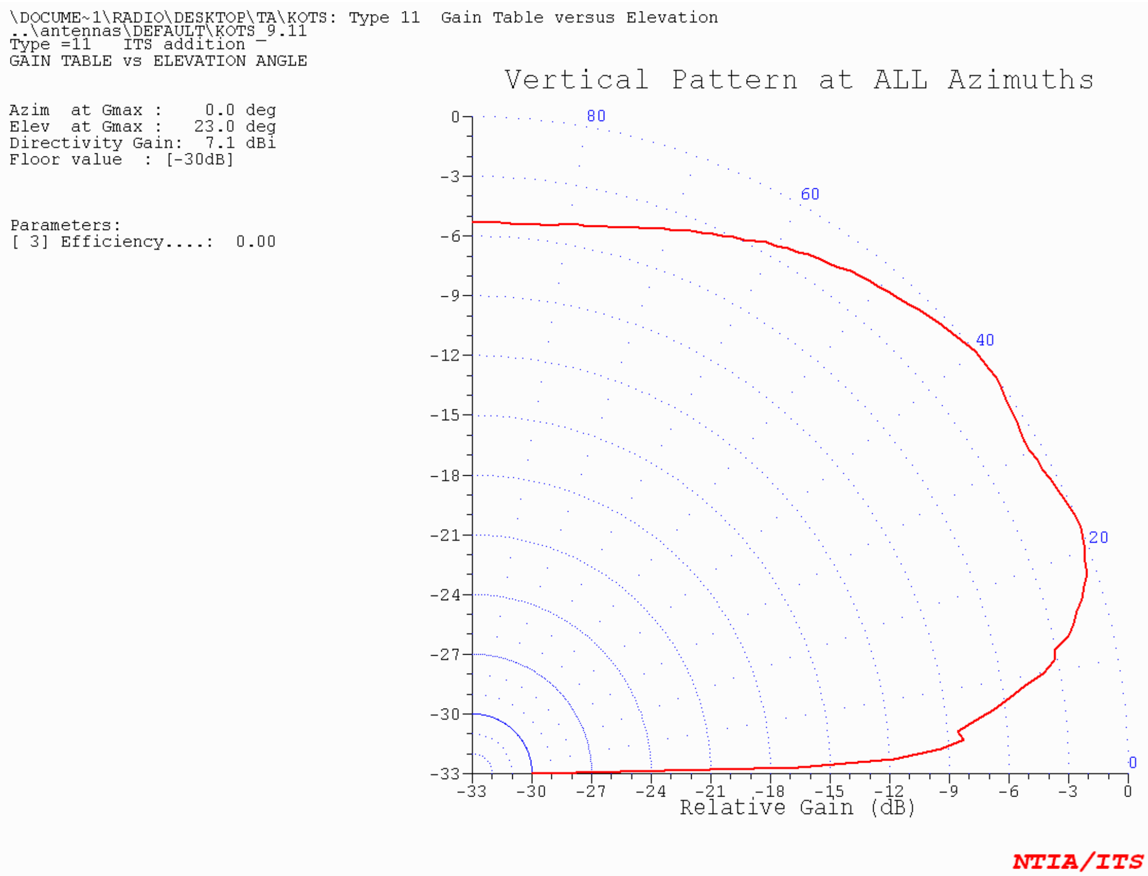

Figure 33 Vertical Pattern Kotzebue Alaska 9.623 MHz Azimuth 300.6

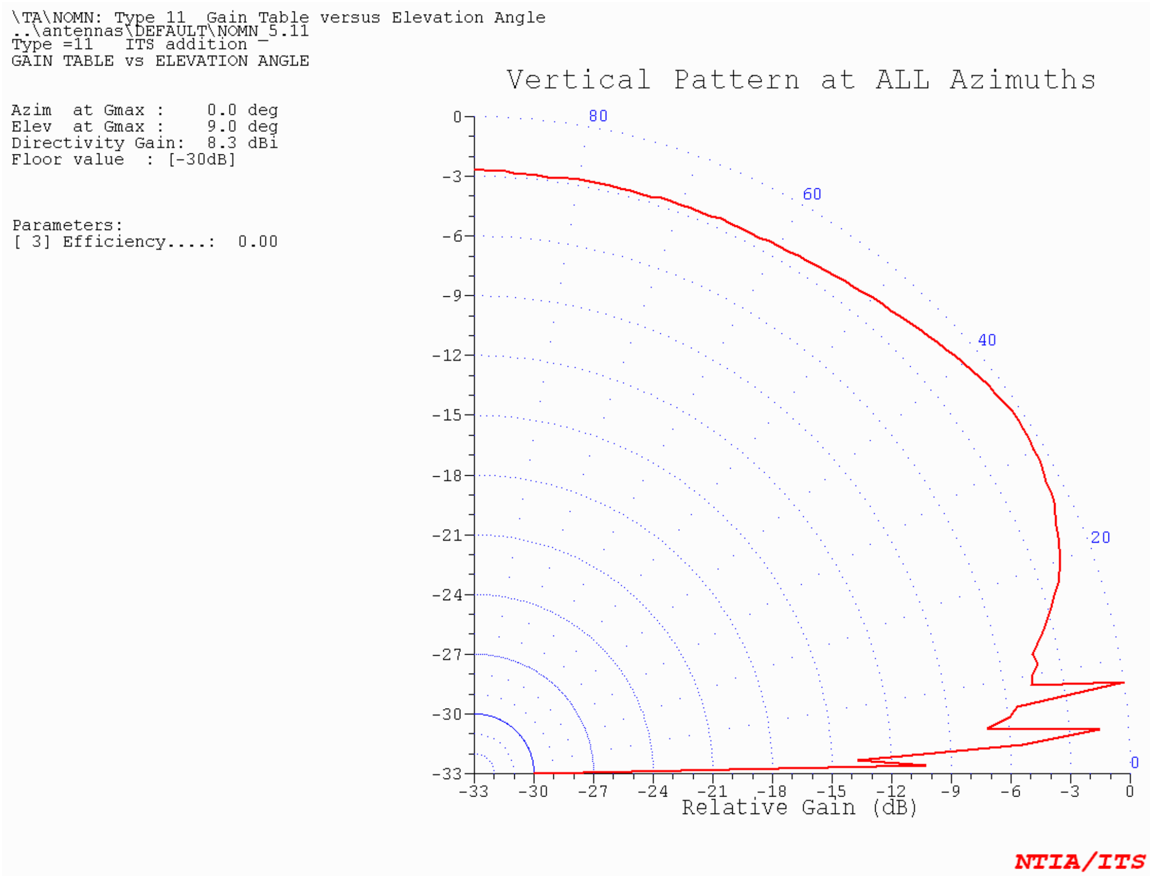

Figure 34 Vertical Pattern Nome Alaska 5.05 MHz Azimuth 283.6

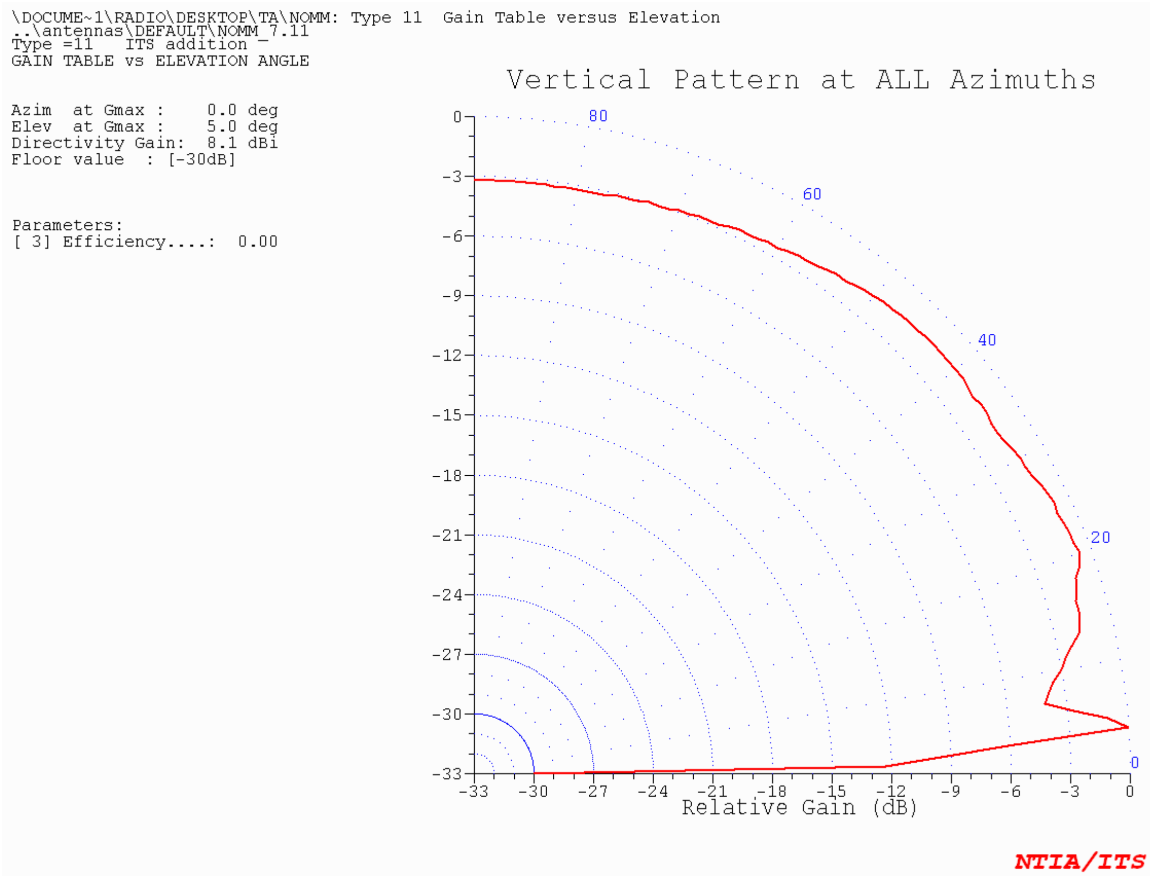

Figure 35 Vertical Pattern Nome Alaska 7.35 MHz Azimuth 283.6

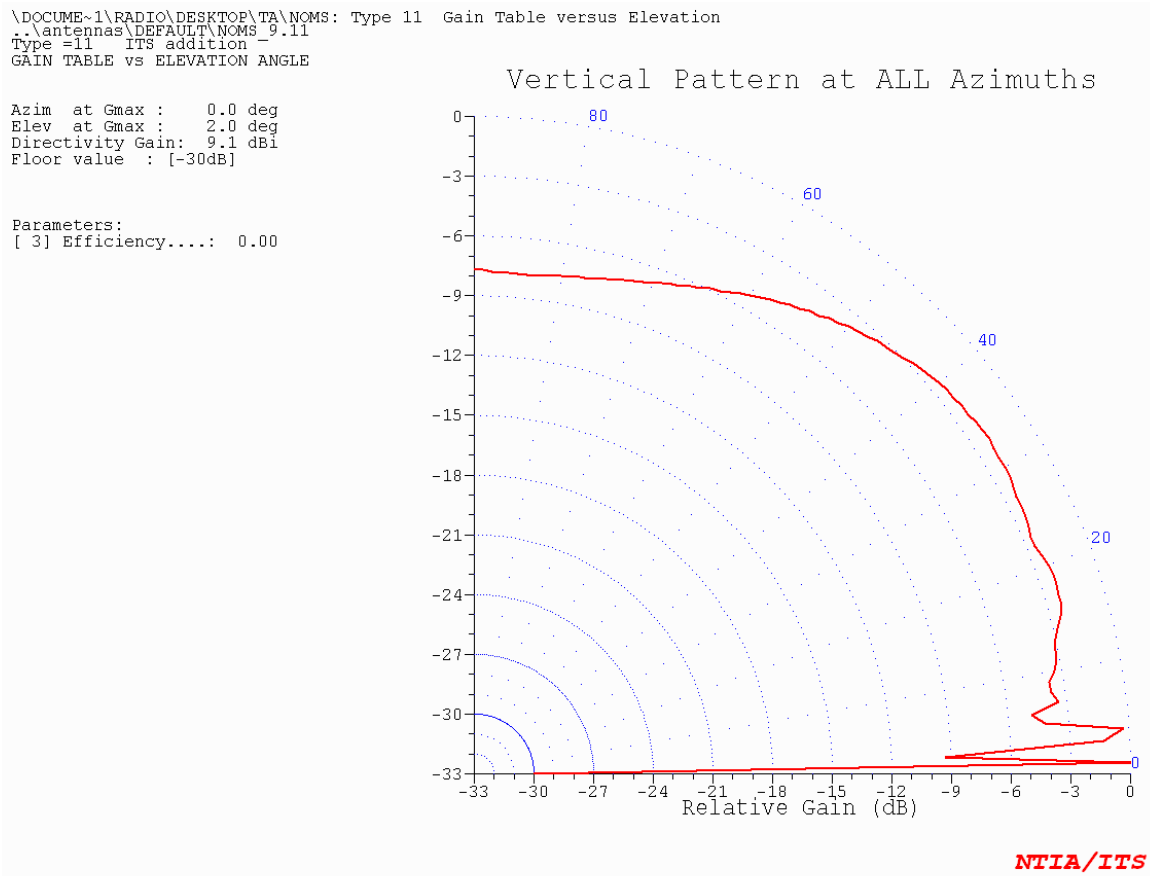

Figure 36 Vertical Pattern Nome Alaska 9.623 MHz Azimuth 283.6

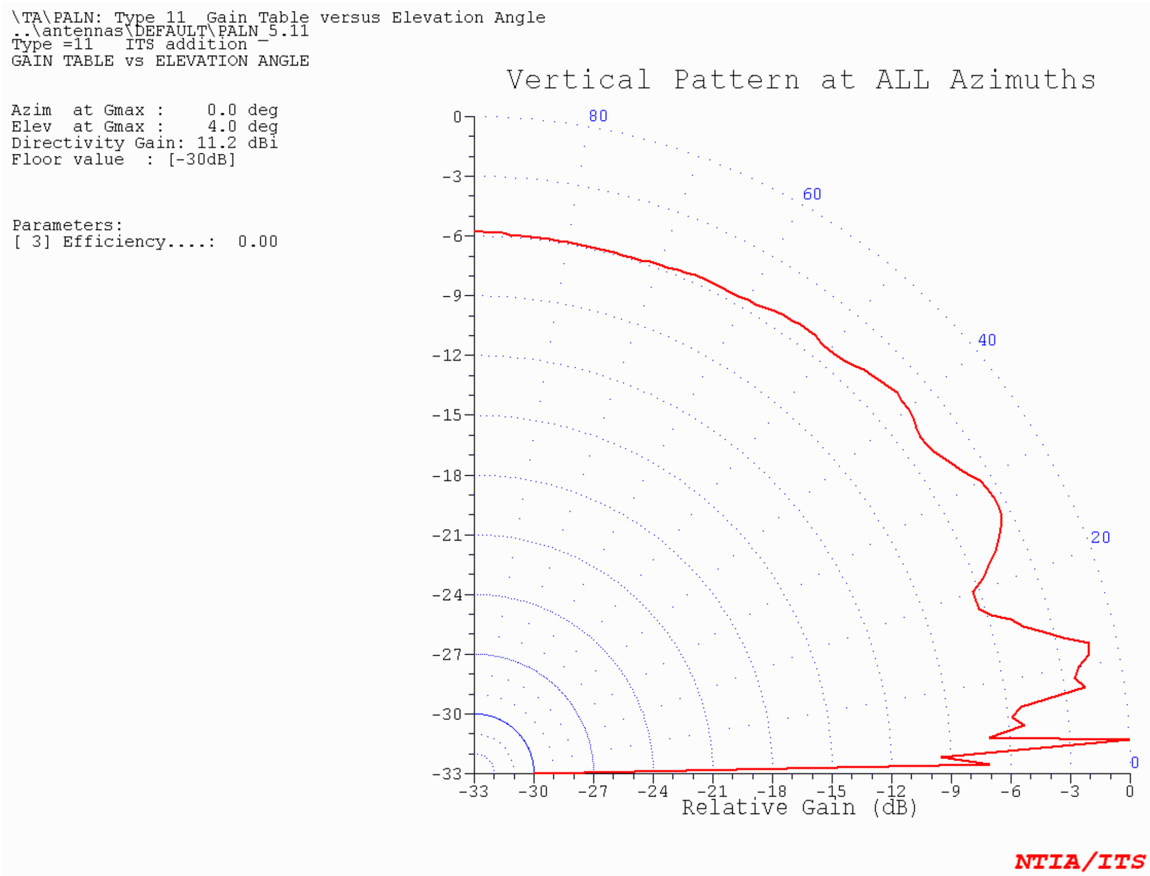

Figure 37 Vertical Pattern Palmer Alaska 5.05 MHz Azimuth 223.0

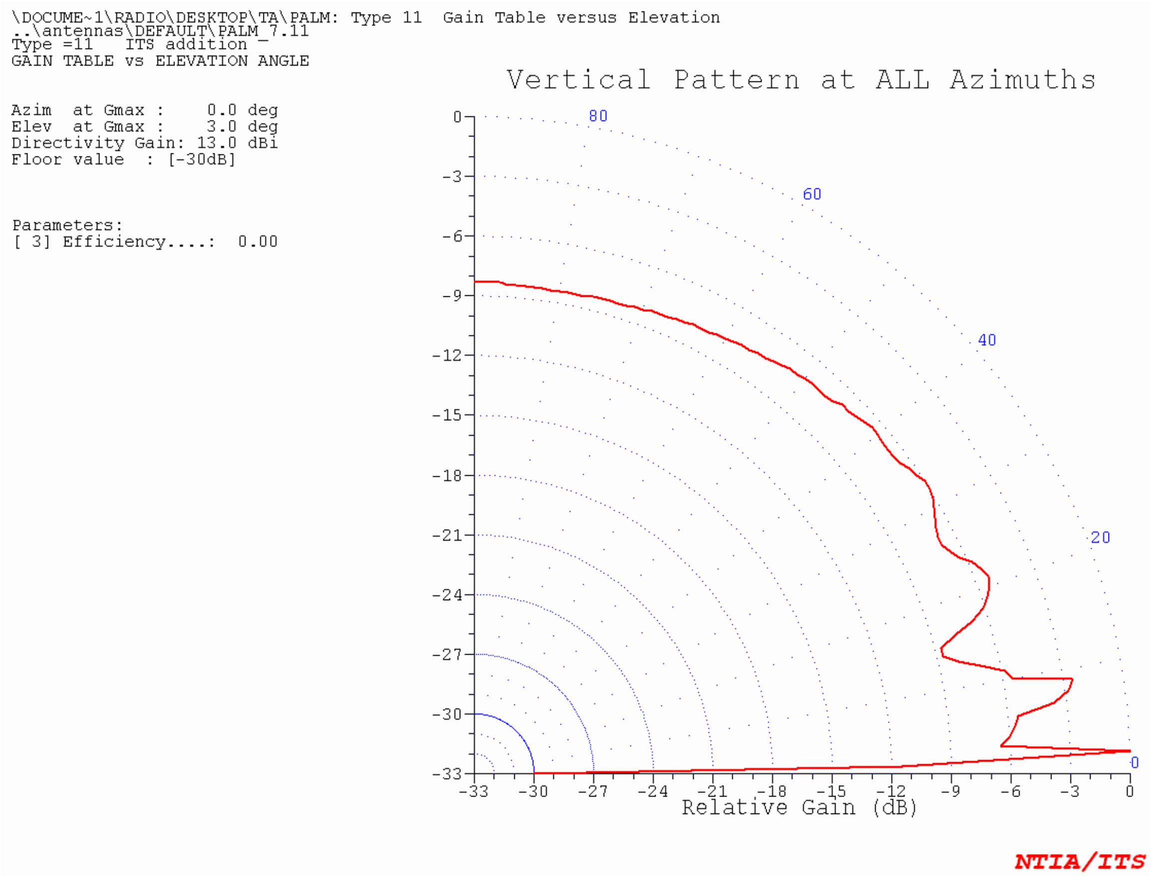

Figure 38 Vertical Pattern Palmer Alaska 7.35 MHz Azimuth 223.0

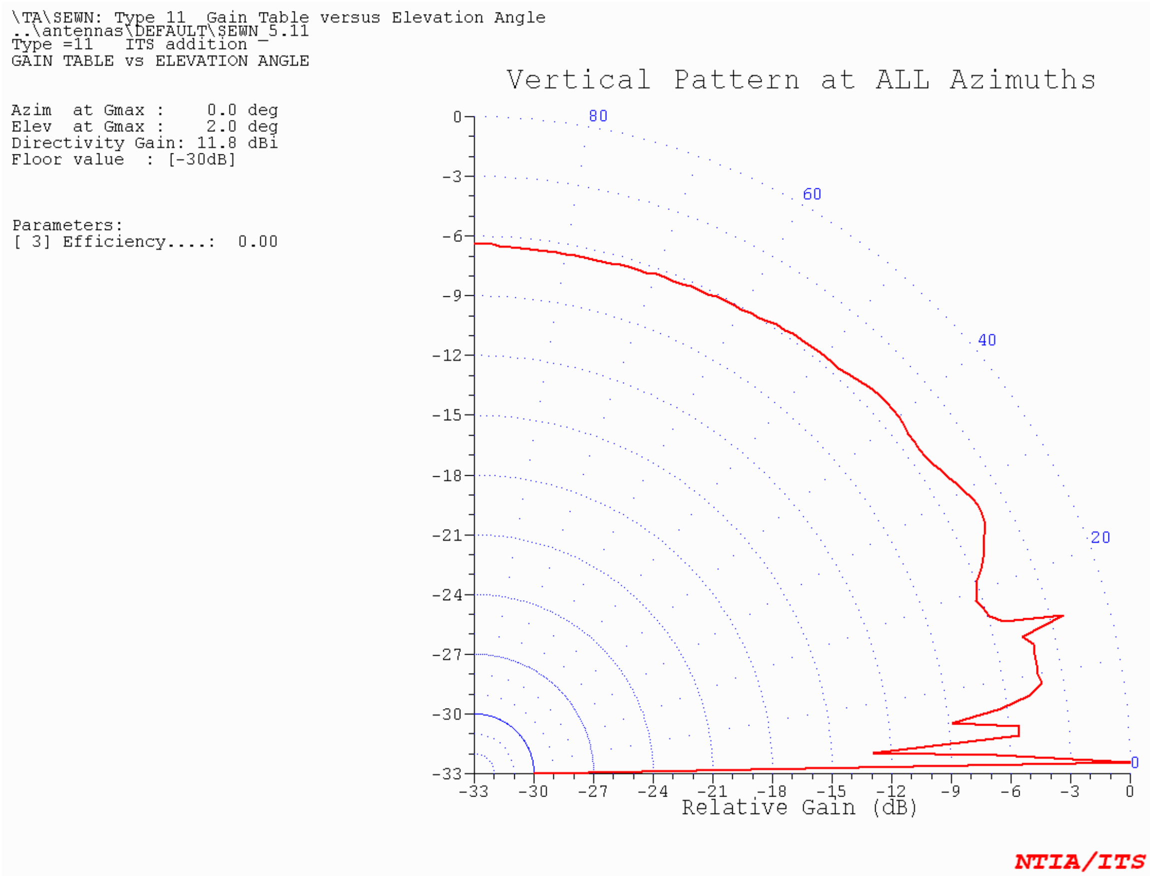

Figure 39 Vertical Pattern Seward Alaska 5.05 MHz Azimuth 212.1

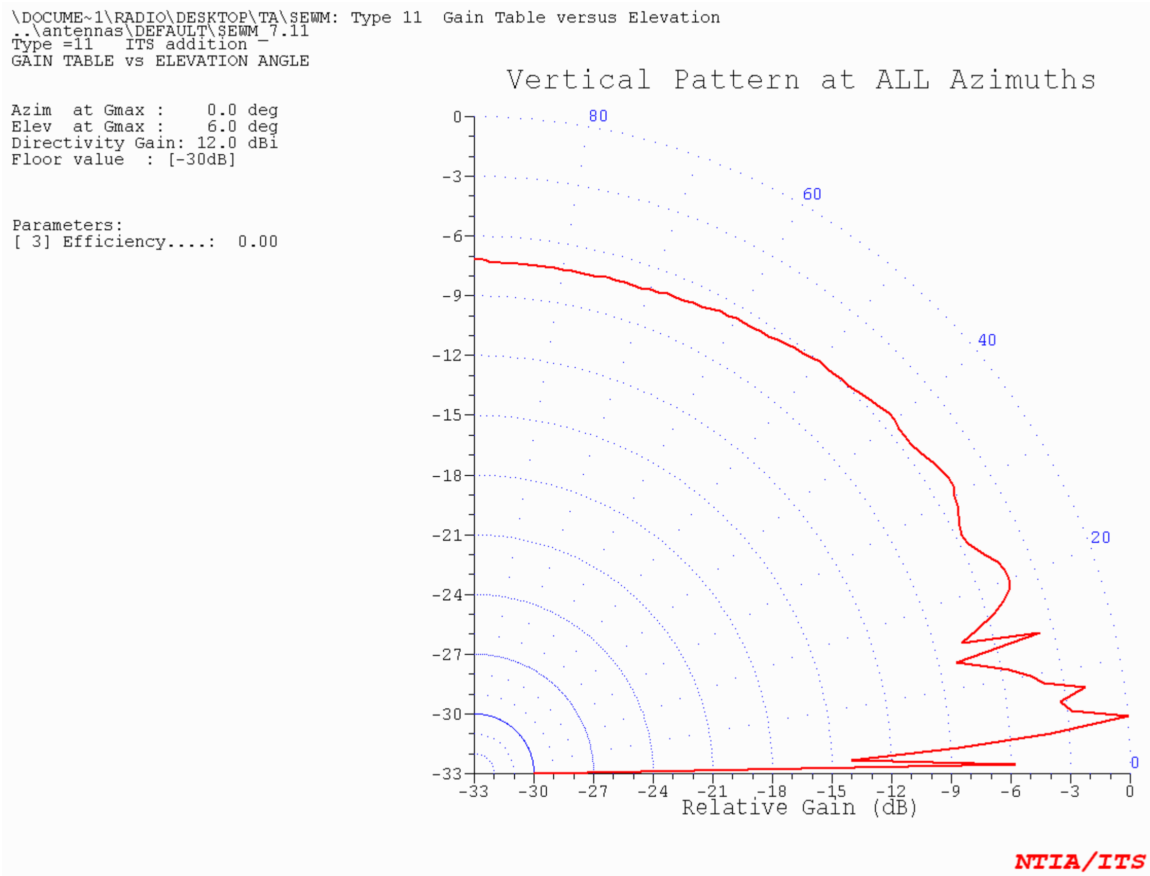

Figure 40 Vertical Pattern Seward Alaska 7.35 MHz Azimuth 212.1

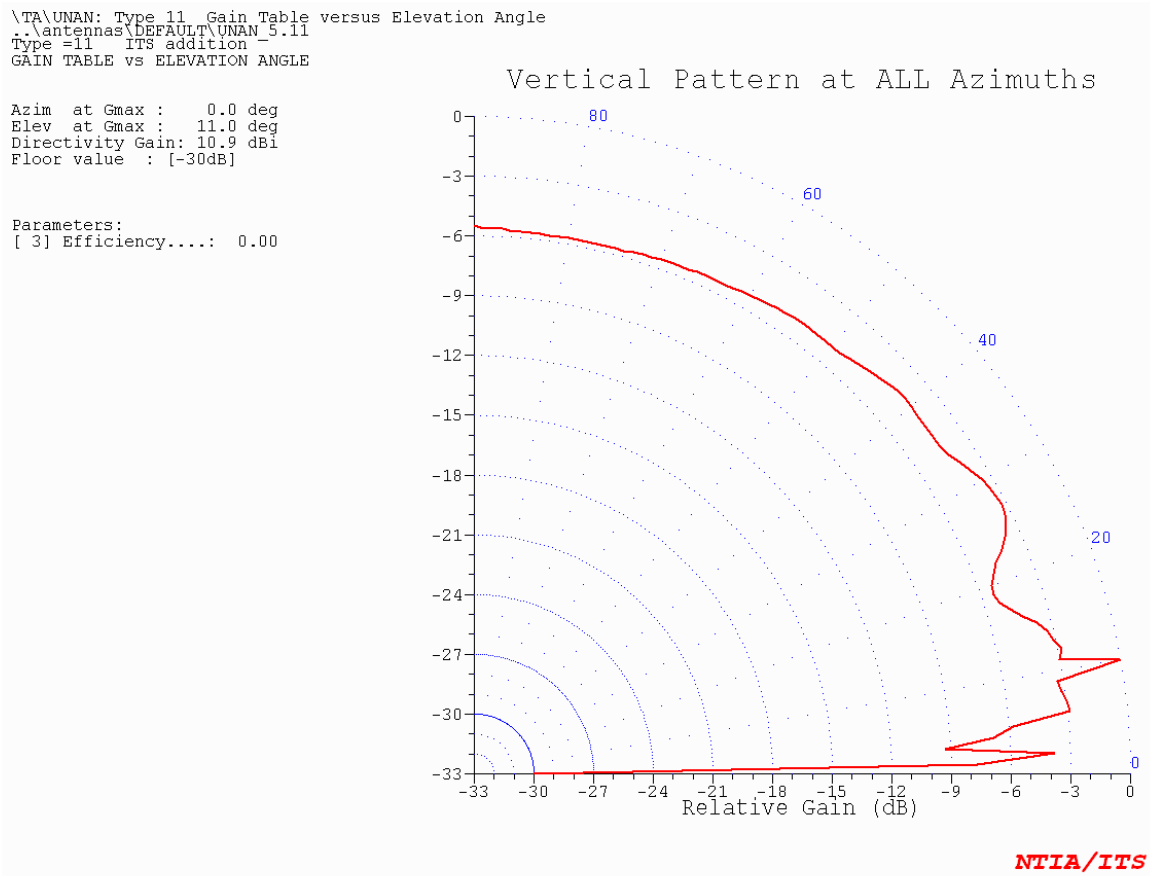

Figure 41 Vertical Pattern Unalaska Alaska 5.05 MHz Azimuth 238.1

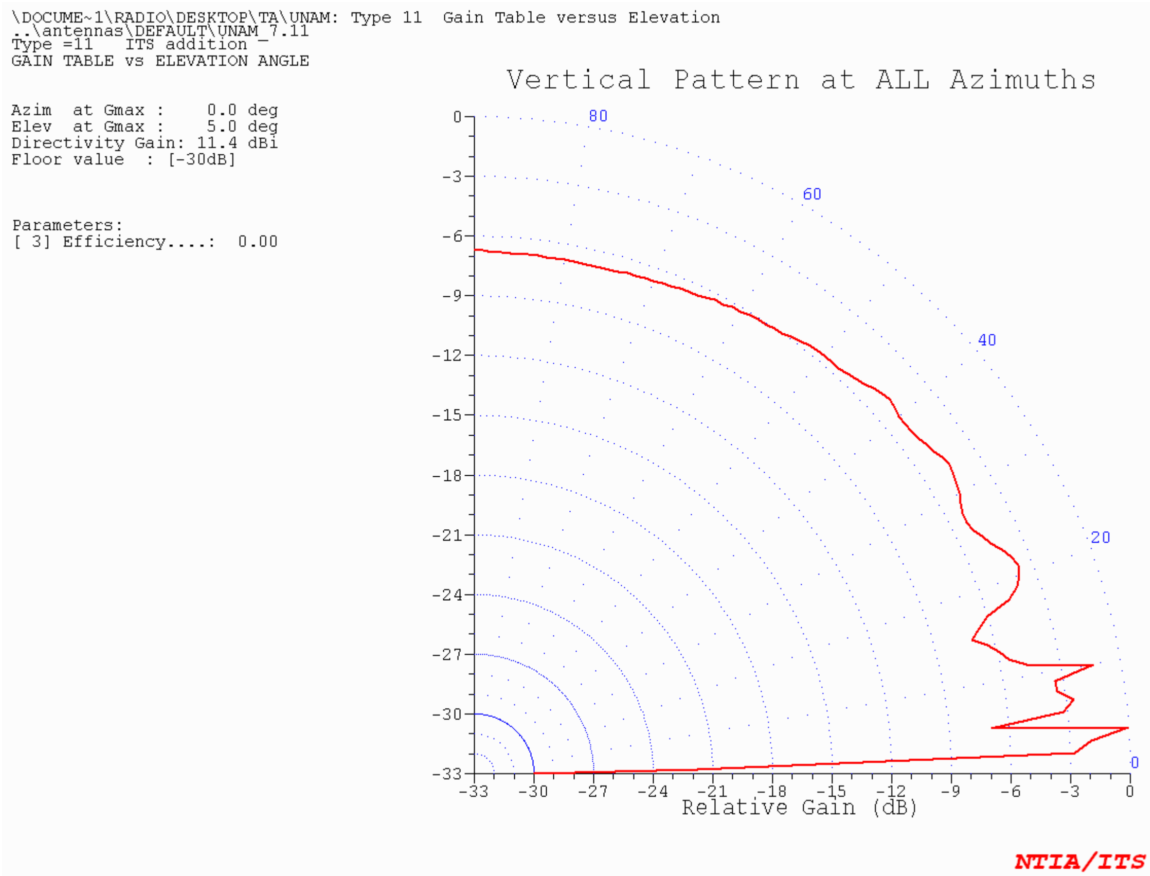

Figure 42 Vertical Pattern Unalaska Alaska 7.35 MHz Azimuth 238.1

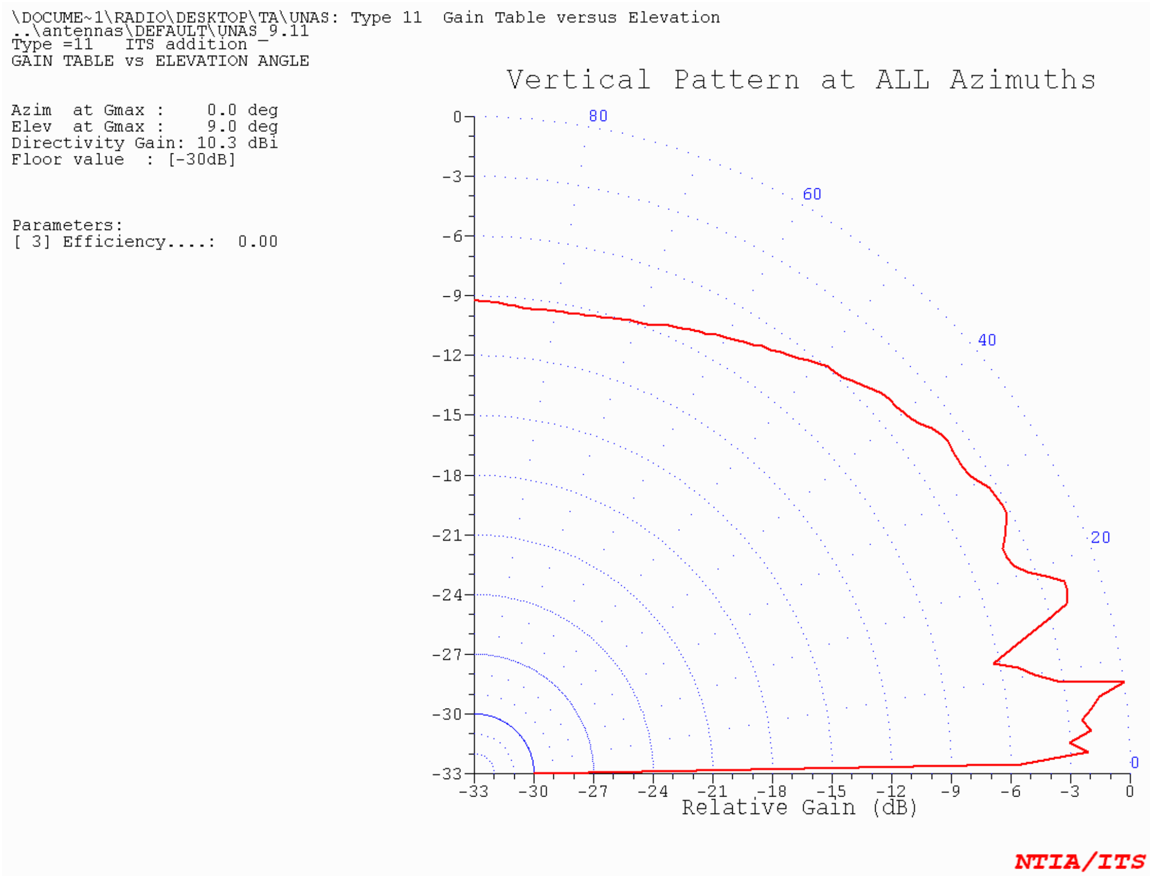

Figure 43 Vertical Pattern Unalaska Alaska 9.623 MHz Azimuth 238.1

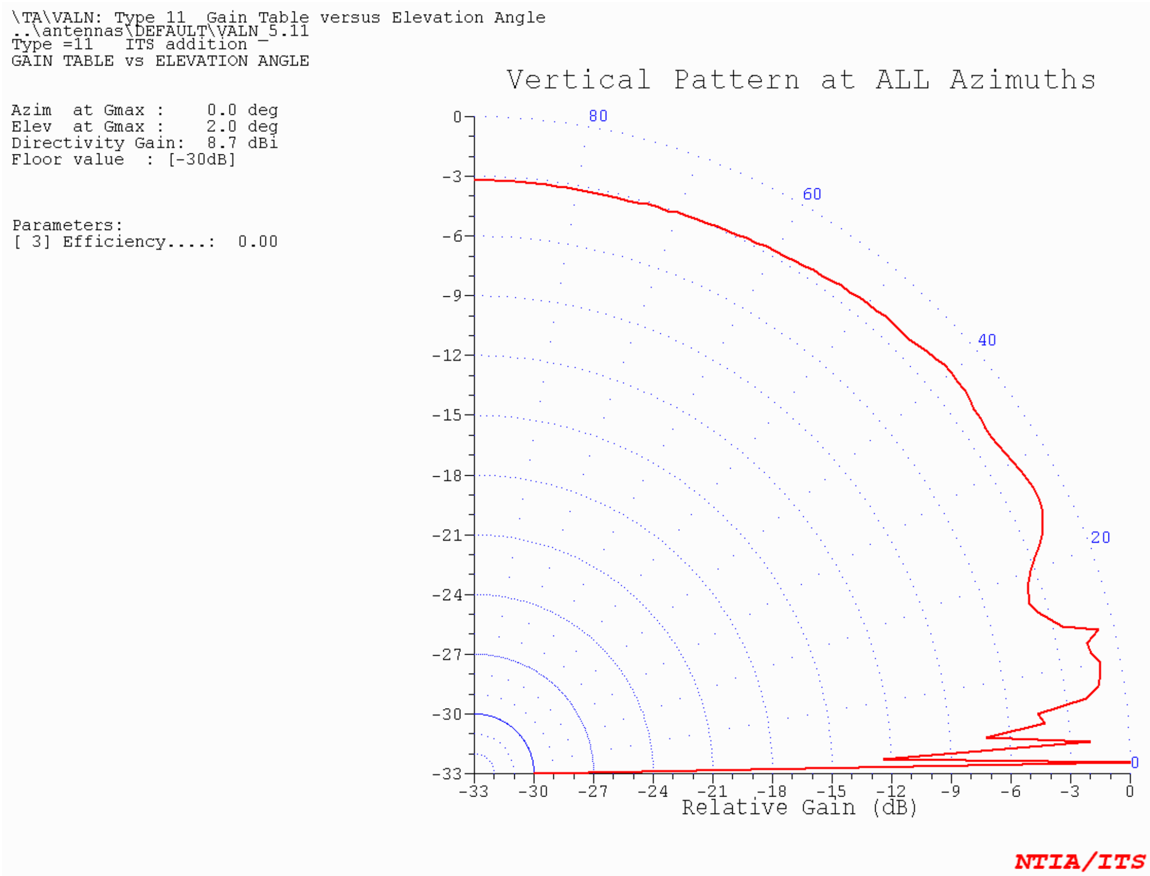

Figure 44 Vertical Pattern Valdez Alaska 5.05 MHz Azimuth 193.9

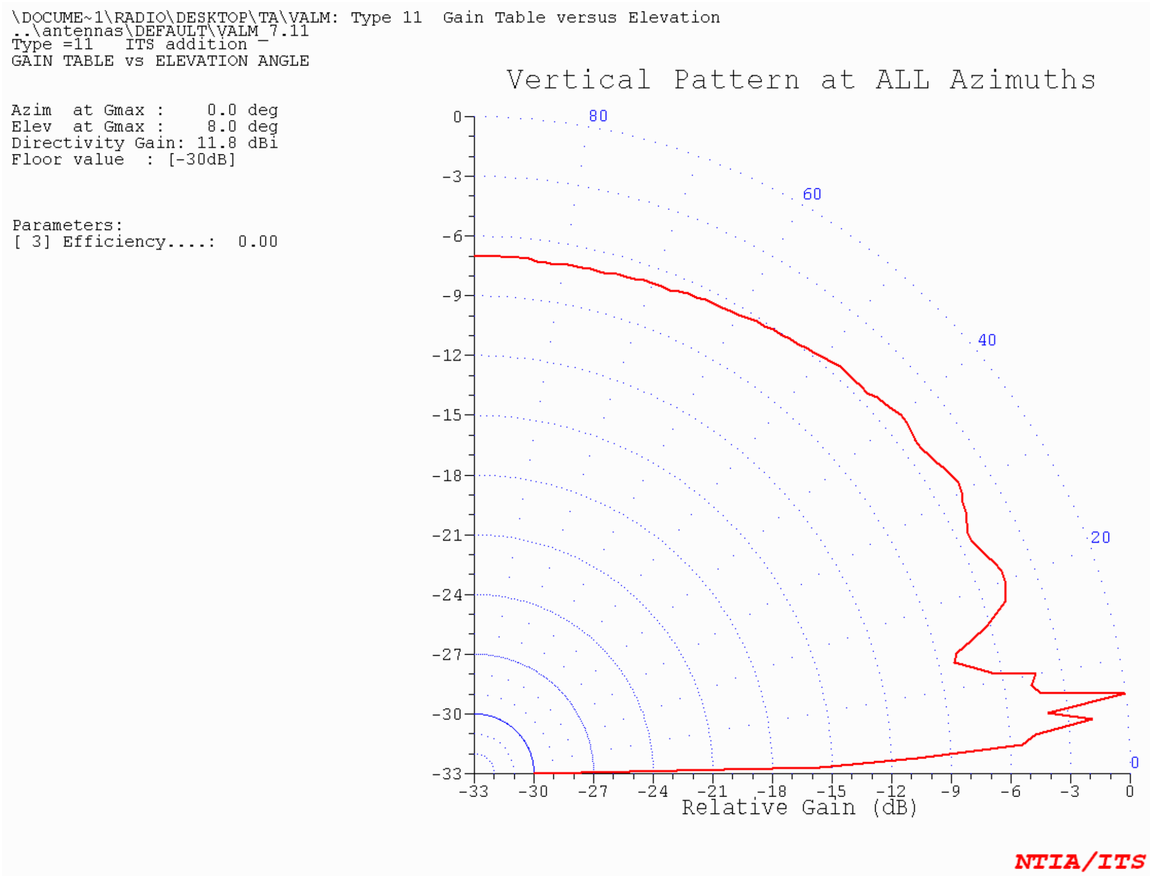

Figure 45 Vertical Pattern Valdez Alaska 7.35 MHz Azimuth 193.9

Location	5.05 MHz	7.35 MHz	9.623 MHz
Anchorage	12.5	12.3	
Barrow	8.1	7.5	7.3
Bethel	12.7	10.1	13.2
Cordova	16.0	11.2	
Craig	8.3	7.2	7.5
Delta Junction	8.1		
Dillingham	8.9	10.2	11.5
Fairbanks	8.1		
Haines	7.4	7.2	
Homer	10.1	10.8	
Juneau	7.4	7.2	7.6
Ketchikan	7.4	7.2	7.6
Kodiak	9.6	11.3	12.0
Kotzebue	8.1	7.7	7.1
Nome	8.3	8.1	9.1
Palmer	11.2	13.0	
Seward	11.8	12.0	
Unalaska	10.9	11.4	10.3
Valdez	8.7	11.8	
Average total	9.66	5.67	1.03

Table 2: Maximum Antenna Gains (dBi) in Elevation Angle for Each Azimuth Direction to the Locations Given at Each Frequency. (If the entry is left blank, then that frequency would not be used for propagation to that location.)

	5.05 MHz	5.05 MHz	7.35 MHz	7.35 MHz	9.623 MHz	9.623 MHz
	100 kW	20 kW	100 kW	20 kW	100 kW	20 kW
Anchorage	1.78	.36	1.70	.34		
Barrow	.65	.13	.56	.11	.54	.11
Bethel	1.86	.37	1.02	.20	2.09	.42
Cordova	3.98	.80	1.32	.26		
Craig	.68	.14	.52	.10	.56	.11
Delta Junction	.65	.13				
Dillingham	.78	.16	1.05	.21	1.41	.28
Fairbanks	.65	.13				
Haines	.55	.11	.52	.10		
Homer	1.02	.20	1.20	.24		
Juneau	.55	.11	.52	.10	.58	.12
Ketchikan	.55	.11	.52	.10	.58	.12
Kodiak	.91	.18	1.35	.27	1.58	.32
Kotzebue	.65	.13	.59	.12	.51	.10
Nome	.68	.14	.65	.13	.81	.16
Palmer	1.32	.26	2.00	.40		
Seward	1.51	.30	1.58	.32		
Unalaska	1.23	.25	1.38	.28	1.07	.21
Valdez	.74	.15	1.51	.30		
Average	1.09	0.22	0.66	0.13	0.11	0.02

Table 3: ERP in Megawatts for transmitter powers of 100 kW and 20 kW to each location. This is the maximum ERP in elevation angle at each azimuth to each location.