Optimizing TV Transmitting Antennas for ATSC-M/H Mobile TV

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An under the “Radome” look at antenna design to optimize ATSC-M/H transmission

We will take a look at:

- ✓ Azimuth Pattern Polarization Differences
- ✓ How the elevation pattern is built and customized
- ✓ Why adding a vertical component to the antenna is needed
- ✓ How the vertical component is formed and controlled
- ✓ Elliptical versus Circular Polarization
- ✓ Four antenna system designs for DTV / ATSC-M/H
- ✓ Summary

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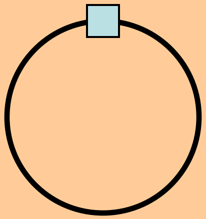
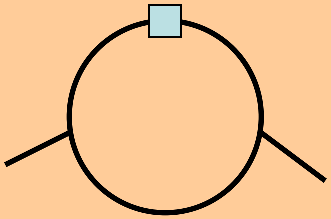
Azimuth Pattern Differences

In many cases there are distinct differences in a slot antenna's horizontal and vertical azimuth pattern. Vertical and horizontal polarized currents flow at different values around the pylon and directional parastitics – hence different patterns form.

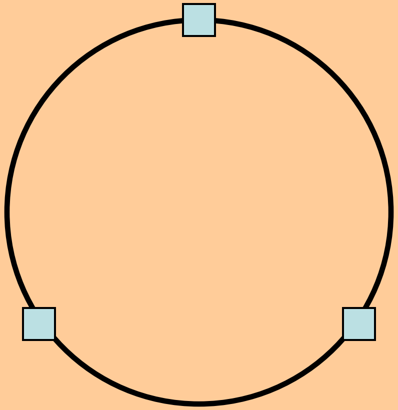
Omnioid



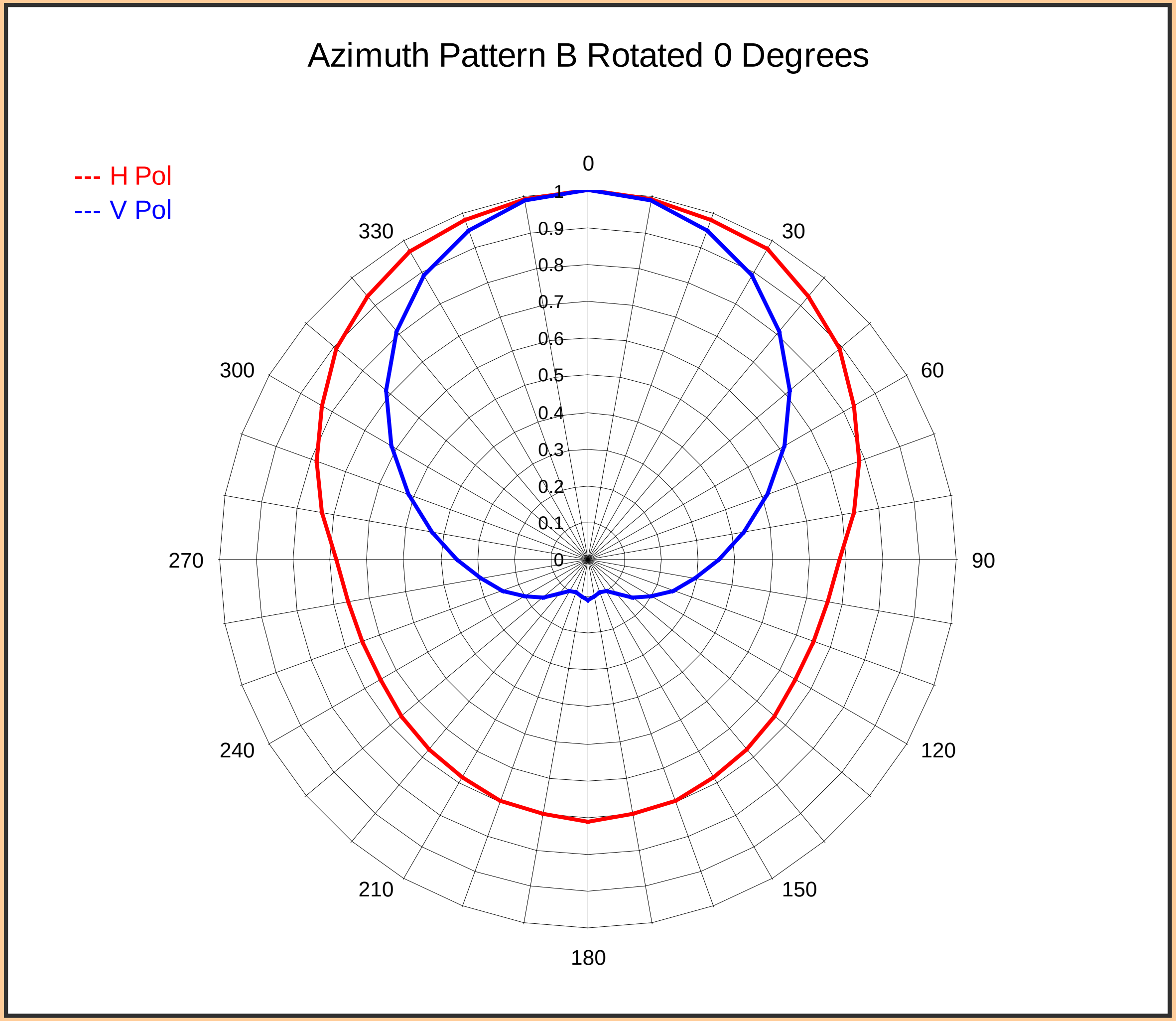
Cardioid



Omni-directional



□ = slot location



Here is a comparison plot of the horizontal and vertical azimuth patterns of the popular Omnioid pattern. This pattern uses a single slot and no parastitics. In the vertical plane there is much less current flowing around the back side of the pylon, hence little field is produced. H Pol azimuth gain is 1.70, V Pol is 3.10.

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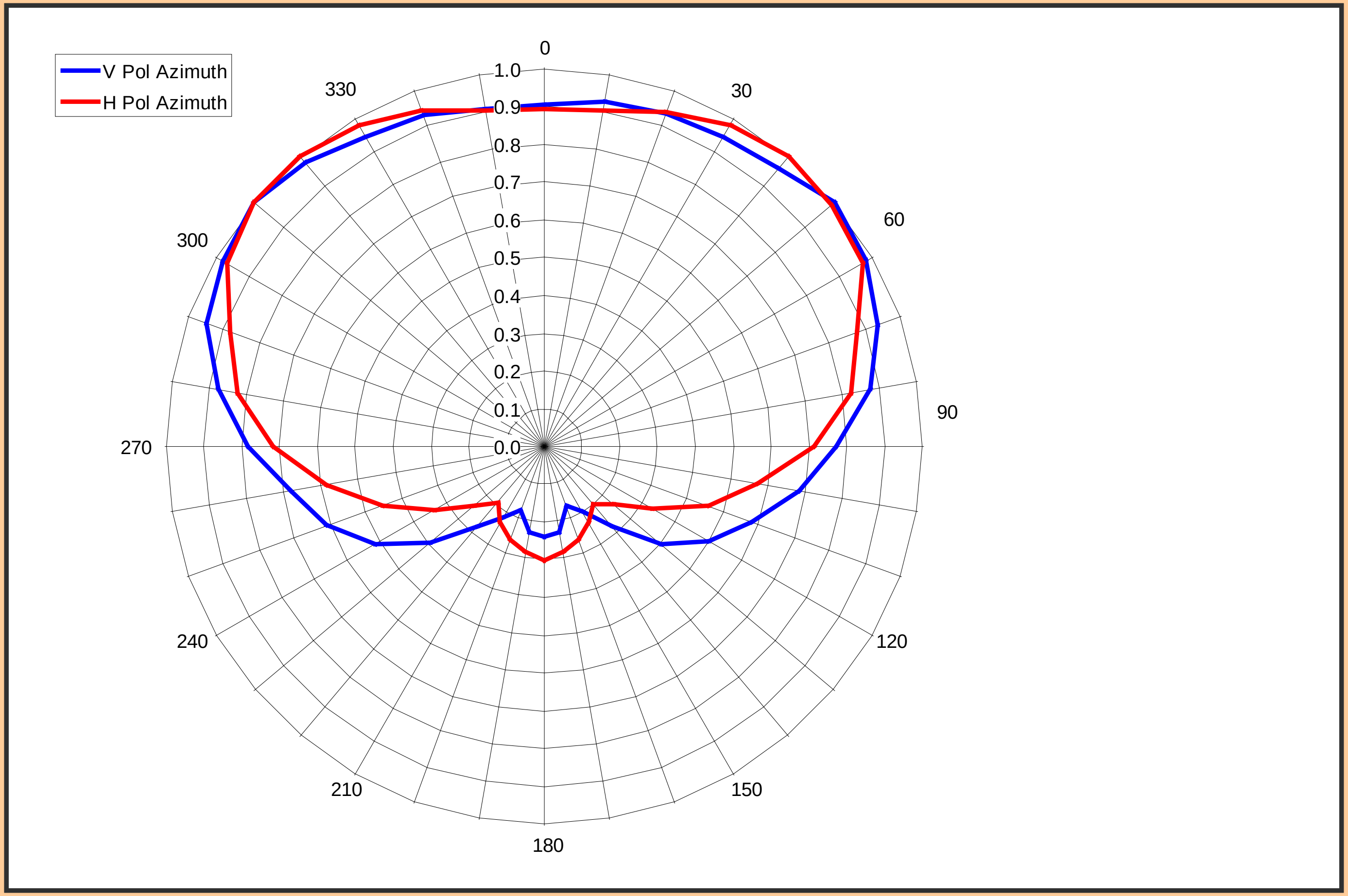

A wide cardioid on channel 18. Pylon diameter to parastitic length were optimized to keep the H and V Pol azimuths close. H Pol azimuth gain is 2.01, V Pol azimuth gain is 1.87.

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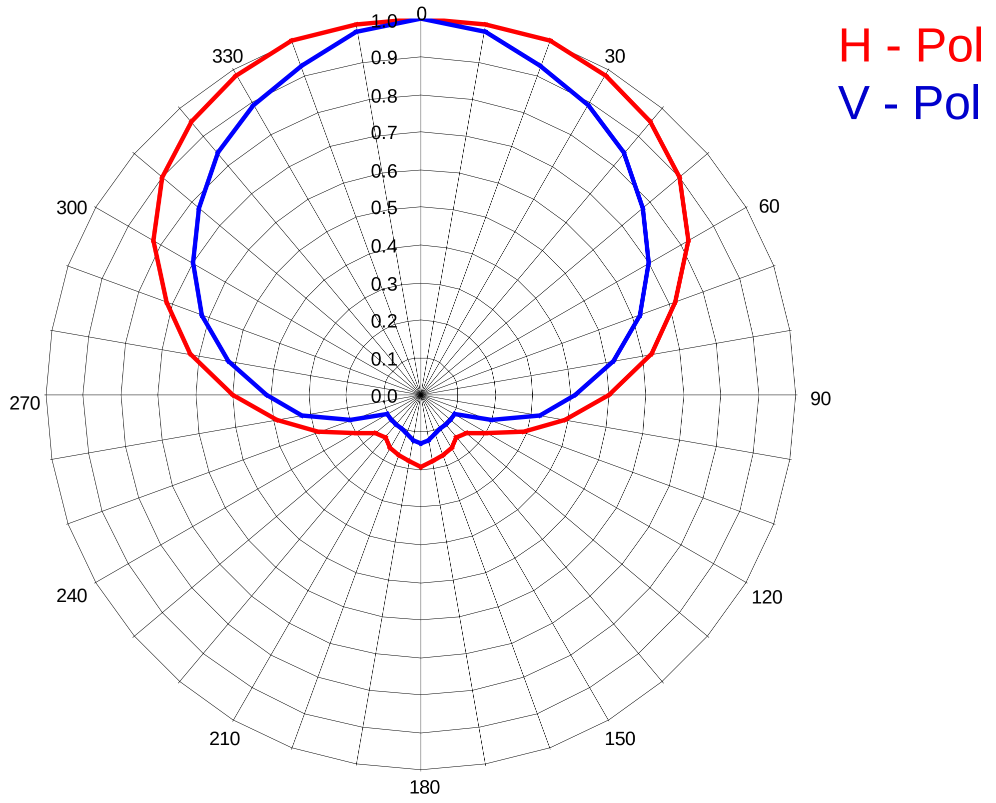

Here is a medium Cardioid pattern with an H – Pol azimuth gain of 2.42 and a vertical azimuth gain of 3.02.

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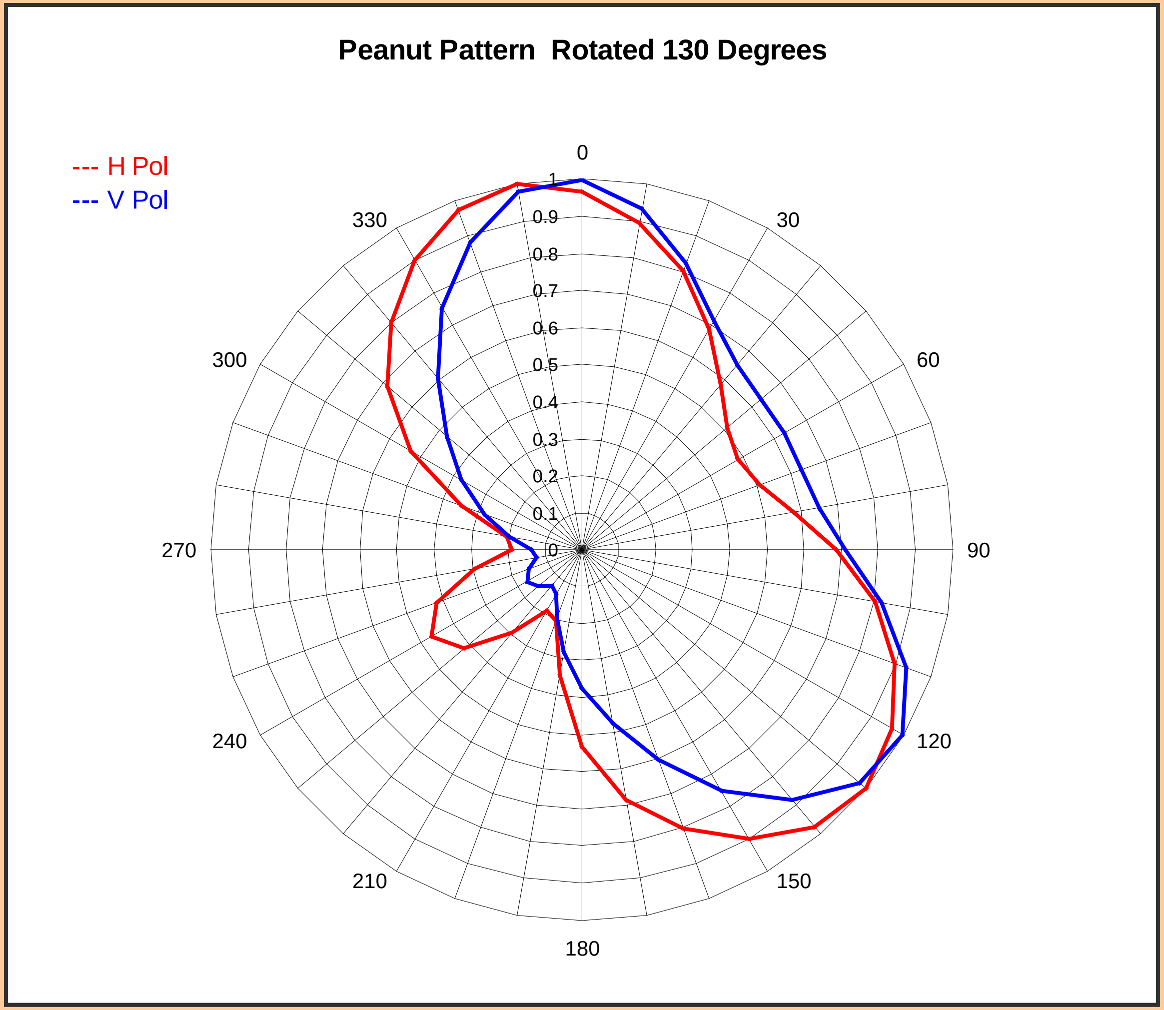

Here is the azimuth plot comparison of a peanut pattern Antenna. The H Pol azimuth gain is 2.20 and the V Pol azimuth gain is 2.45.

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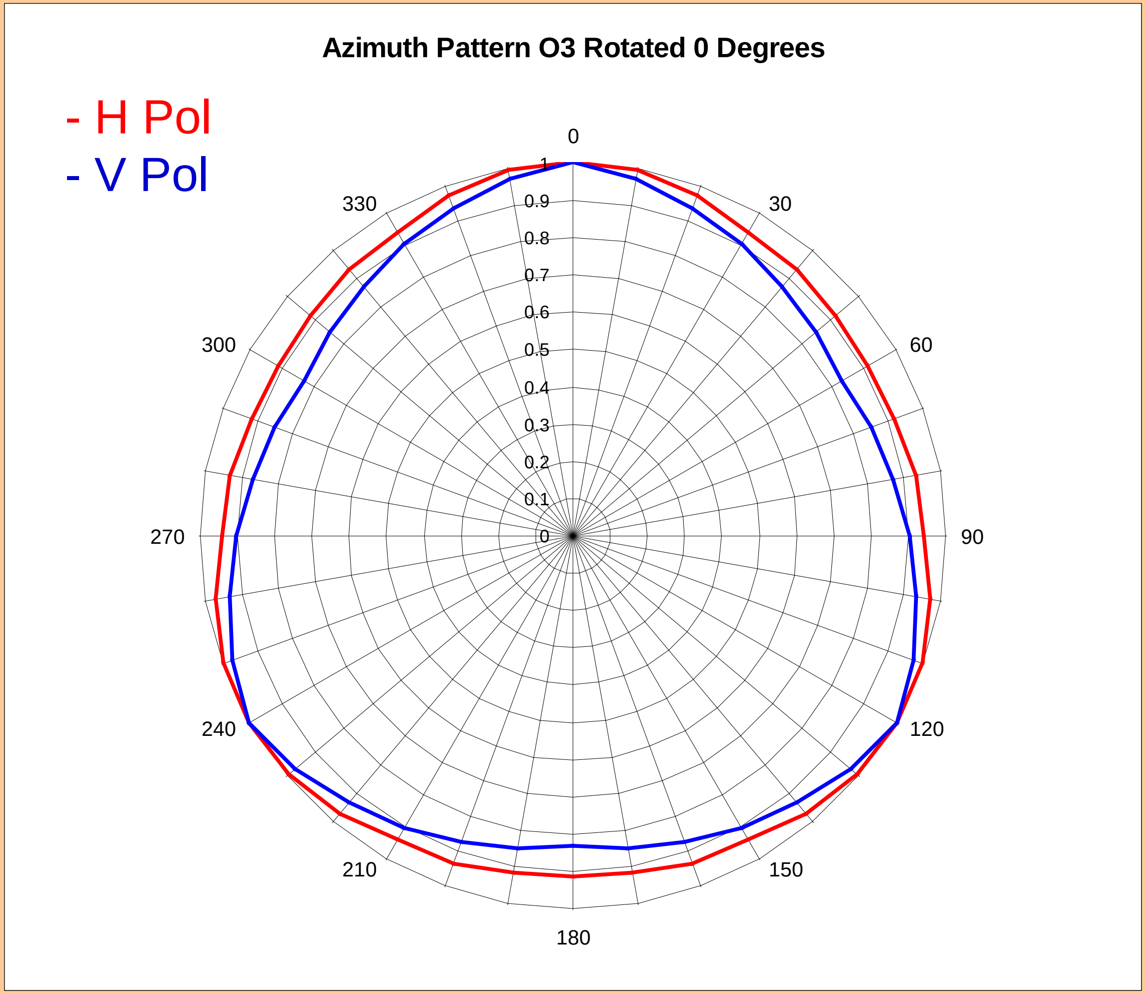

Three slot around Omni-directional azimuth pattern. With a given pylon diameter as frequency goes up the vertical pattern will scallop more.

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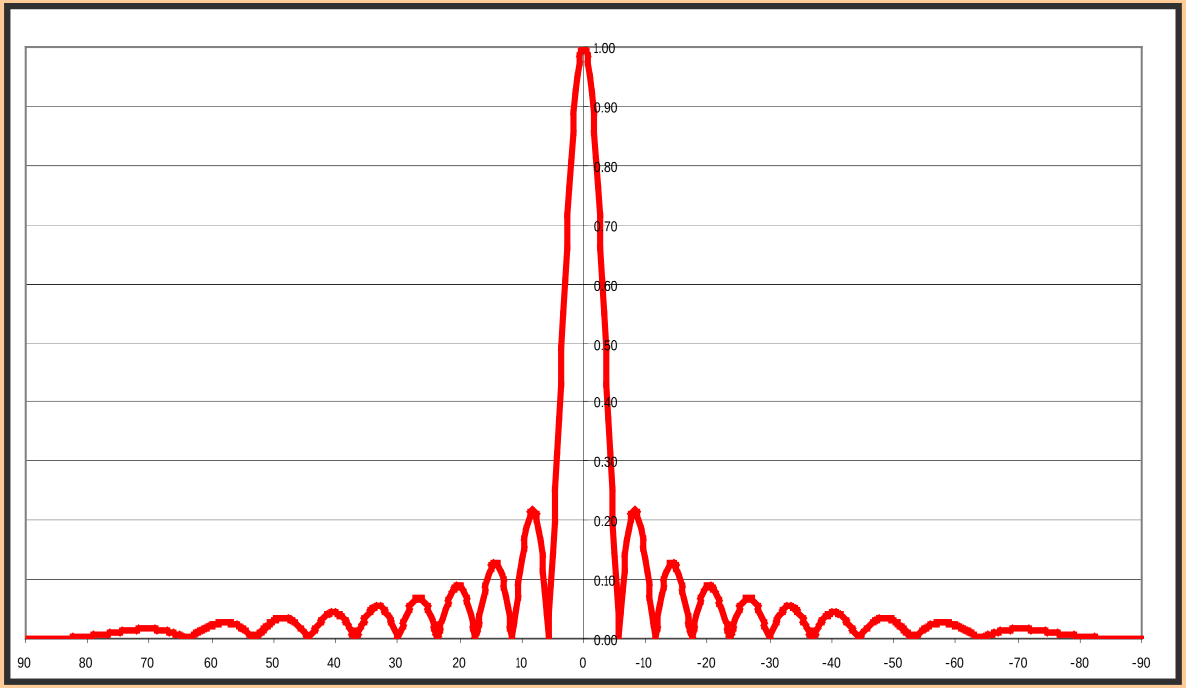
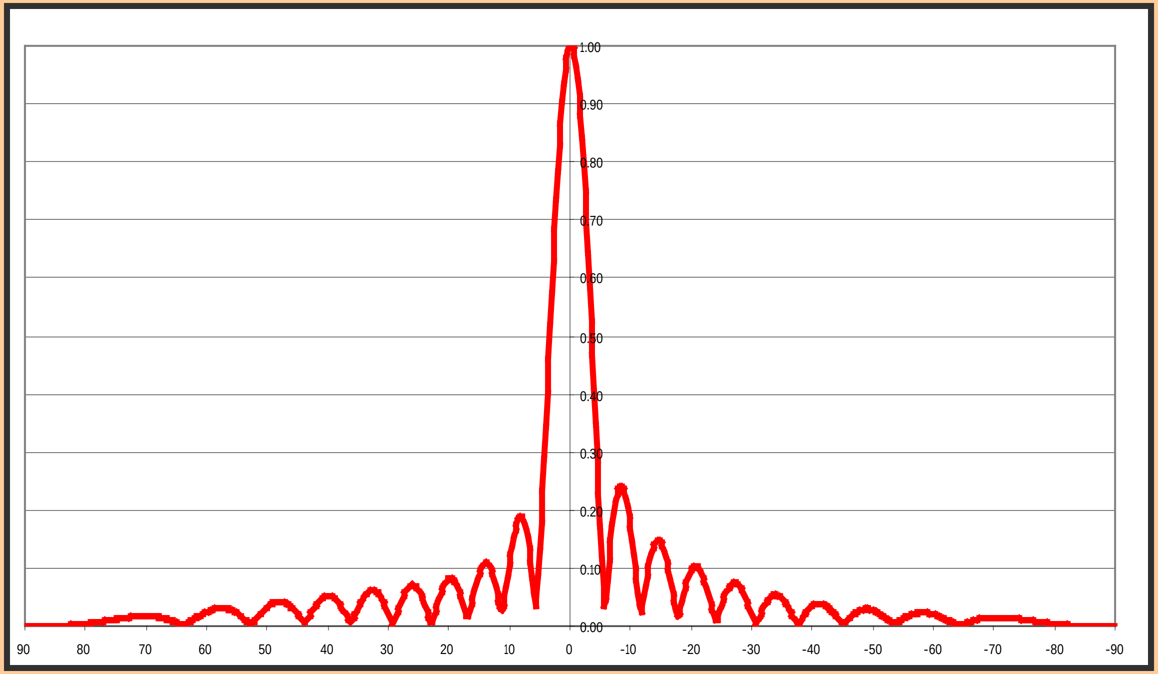
How Elevation Patterns Are Created

Let's look at how null fill and beam tilt are formed on a 10 bay slot antenna. We will use a specially spaced low RFR design for this demonstration.



Example 1

10 Bays
No Beam Tilt
No Null Fill
Gain = 12.36 (10.92 dB)
Array Electrical Length is 3420 degrees



Example 2

10 Bays
0.25 Degree Beam Tilt
3.3% First Null Fill
Gain = 12.27 (10.89 dB)
Array Electrical Length is 3380 degrees

The upper two slots have had their spacing reduced by 20 degrees. The array now has 0.25 degrees of electrical beam tilt and the first null has been raised from 0.0% of peak field to 3.3%. The second, and third nulls have been increased slightly from 0.0%. The elevation gain has dropped slightly to 12.27 and the electrical length of the array has dropped by 40 degrees to 3380 degrees.

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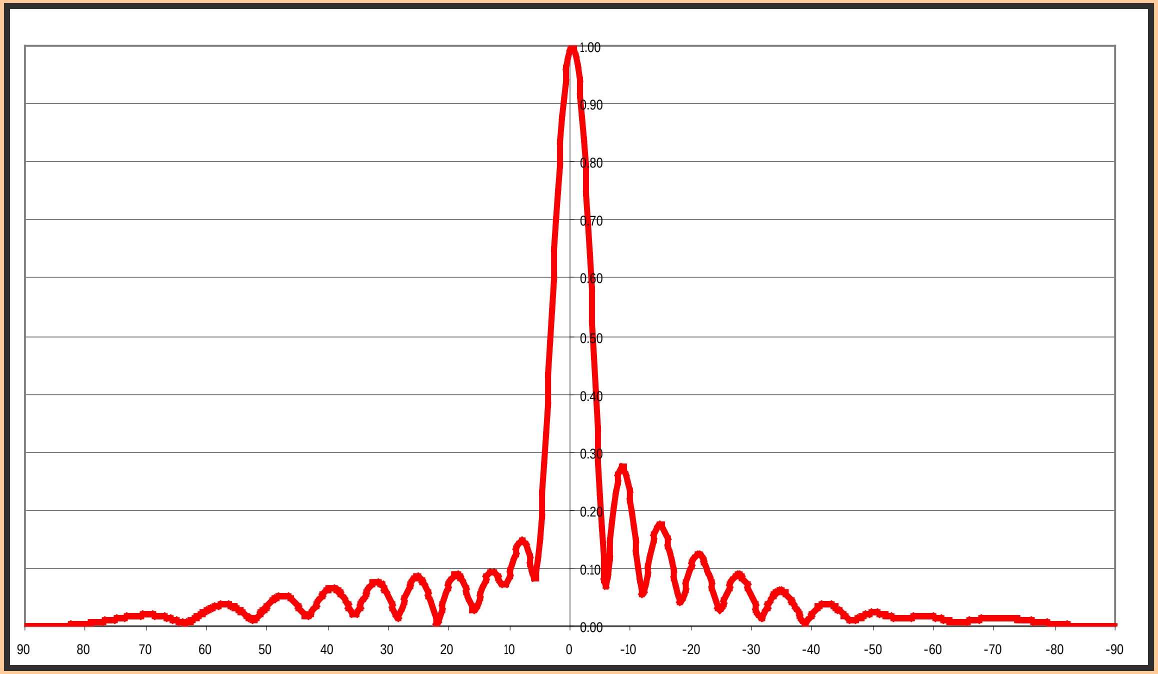

Example 3

10 Bays
0.50 Degree Beam Tilt
6.7% First Null Fill
Gain = 11.85 (10.74 dB)
Array Electrical Length is 3324 degrees

The upper two slots have had their spacing reduced by 48 degrees. The array now has 0.50 degrees of electrical beam tilt and the first null has been raised from 3.3% of peak field to 6.7%. The second through fifth nulls have been increased slightly from 0.0%. The elevation gain has dropped slightly to 11.85 and the electrical length of the array has dropped by 96 degrees to 3324 degrees.

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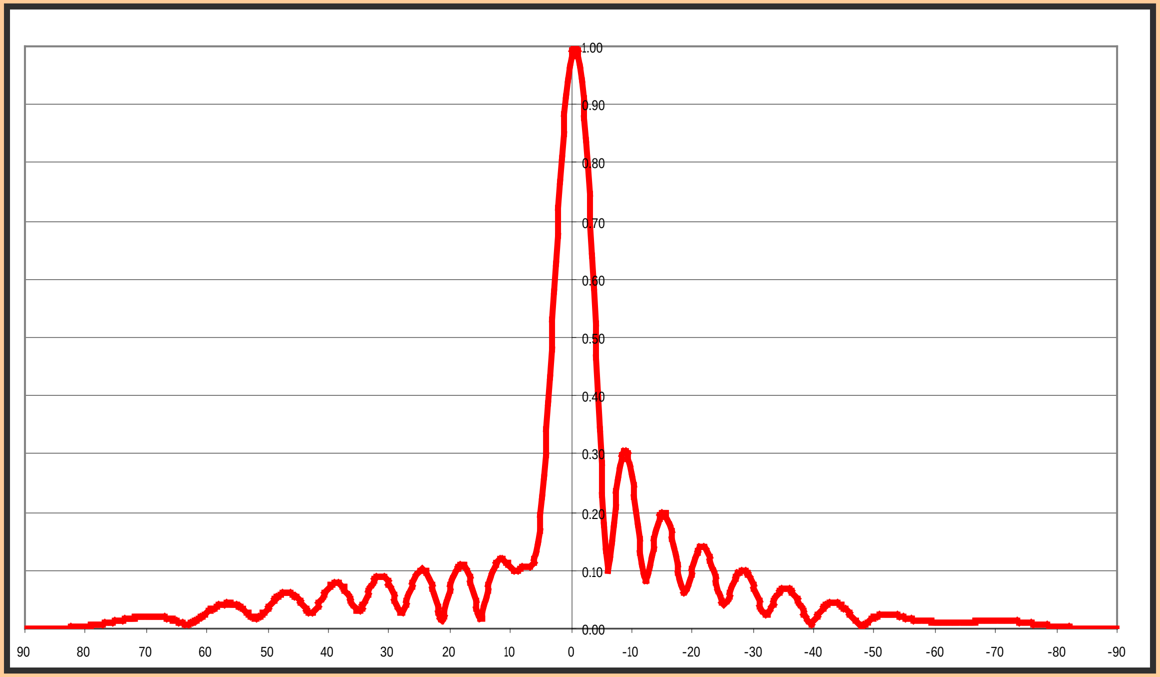

Example 4

10 Bays
0.70 Degree Beam Tilt
10% First Null Fill
Gain = 11.18 (10.48 dB)
Array Electrical Length is 3268 degrees

The upper two slots have had their spacing reduced by 76 degrees. The array now has 0.70 degrees of electrical beam tilt and the first null has been raised from 6.7% of peak field to 10.0%. The second through fifth nulls are increasing nicely The elevation gain has dropped to 11.18 and the electrical length of the array has dropped by an additional 56 degrees to 3268 degrees.

Adding a Vertical Component

With ATSC-M/H in action your viewers are on the move in dynamic reception environments. The antenna in most cases is not in a horizontal position

The main reason for the desirability of circularly- or elliptically-polarized transmit antennas is because, with a linearly-polarized transmit antenna, as the television signals propagate from the transmitting to the receiving site, the polarization can be rotated due to the influence of external magnetic fields from sources such as the earth itself or large metallic structures like buildings that may have a magnetic moment.

This is referred to as Faraday Rotation. If the signals arrive cross-polarized from the transmitting to the receive antenna, the attenuation can be severe enough to cause the loss of signal at the television receiver. Adding a vertical component to your signal can greatly enhance reception of your station.

How do we add the vertical component ?

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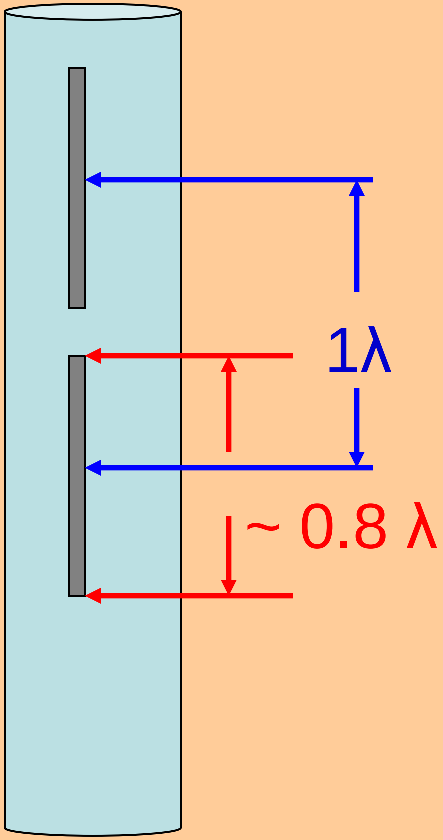
Review: How a slot antenna works

The slot antenna is a TEM-Mode coaxial structure. Coupling structures inside the pylon will distort and couple to the fields in this coaxial antenna, causing a voltage to be applied directly across each of the slots in the antenna. This voltage alternates from plus to minus and back again at the channel frequency of operation.

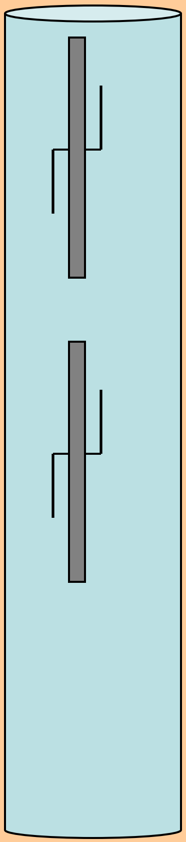
The length of the slots are adjusted so that the oscillating electric fields that develop across the gap that the slot creates will launch a radiating system of fields, propagating away from the antenna.

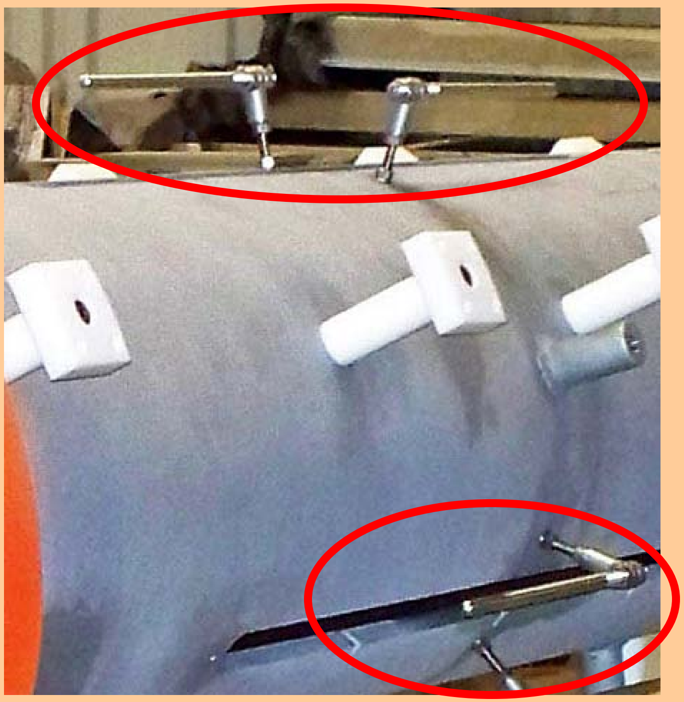
If the coaxial pylon antenna is oriented vertically, with the slots cut in the outer conductor oriented vertically as well, the electric fields across these slots will be oriented horizontally.



The E/P or C/P slot antenna

Polarizer elements are mounted on either side of the slot. The polarizers are about 1/8 λ each and launch a vertically polarized electromagnetic field ¼ of a cycle or 90 degrees later than the horizontal field in quadrature. When axial the ratio between the two fields is equal we have Circular Polarization (C/P). When the horizontal field is stronger than the vertical we have elliptical polarization. For ATSC-M/H a 70/30 to 50/50 H to V ratio is ideal





Channel 13 C/P Antenna

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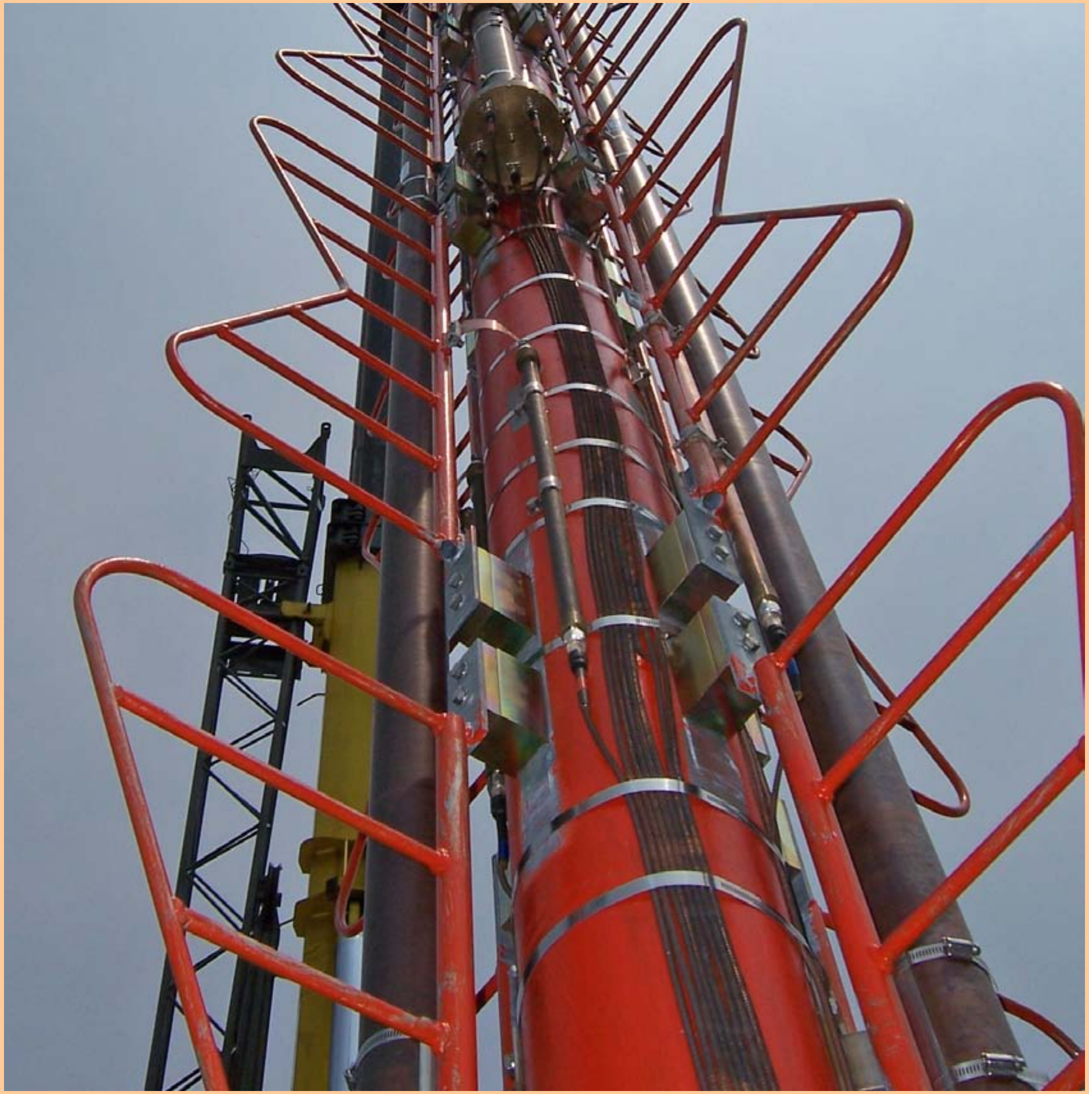

Did you know:

Depending on the bay count and relative frequency versus element spacing, a Batwing style antenna can produce up to a 10% vertical component.

Pictured here is a scaled to frequency channel 11 VHF batwing antenna.

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How much vertical gain should we use and where do we aim the antenna at ?

First we need to answer some questions to help define the antenna parameters:

1. What ERP is needed, preferred transmitter size, and transmission line loss ?
2. Who and where are we trying to cover with both OTA and ATSC-M/H ? May not be the same goal !
3. Where is the transmitter (or multiple transmitter sites) in relation to the viewers ?
4. Urban or rural area ?

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Let’s Look At Four Sample Projects

Project 1 – A 48 kW DTV station in a city of 350,000 transmitting from an office building in the center of the city. 95% of the population is within 10 miles of the transmitter and the topography is flat. Antenna is 400’ AGL. Most ATSC-M/H users would be within 3 miles of the transmitter.

Project 2 – A 15 kW LD station in a city of 2,000,000 transmitting from a mountain ridge that’s 1800 feet higher than the valley. The core population runs from the edge of the mountain to about 6 miles from the transmitter.

Project 3 – a 400 kW DTV that is transmitting from a mountain at 7,700 feet AMSL. The core of the city 7.3 miles away is a big tourist draw and would make up the bulk of ATSC-M/H users.

Project 4 – **Super-Duper World** in Orlando wants to run ATSC-M/H up I-75 to the Georgia line in an distributed network. A number of 250 to 350 foot cell towers are available. Each station would be a 15 kW LD facility. Fairly flat land along the highway.

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Project 1 – a 48 kW DTV station at 400’ AGL

! There are two large universities within 3 miles – prime mobile TV viewers

You have a 5 kW transmitter and a tower on top a building in downtown. 95% of your viewers are within 10 miles – the other 5% are outside that area.

Antenna Pattern ? Omnioid or Omni ? ! Remember the different patterns of an Omnioid versus Omni-directional ? Omni please !

Vertical Component ? – a 70/30 power split would provide an excellent vertical component. So your vertical ERP would be 3/7 * 48 kW or 20.57 kW. Your total ERP in both planes would be 68.57 kW. You have a 5 kW transmitter feeding a very short run of line. 68.57 kW/5 kW comes up to a minimum antenna vertical gain of 13.71.

A minimum of a 14 bay antenna would be needed !

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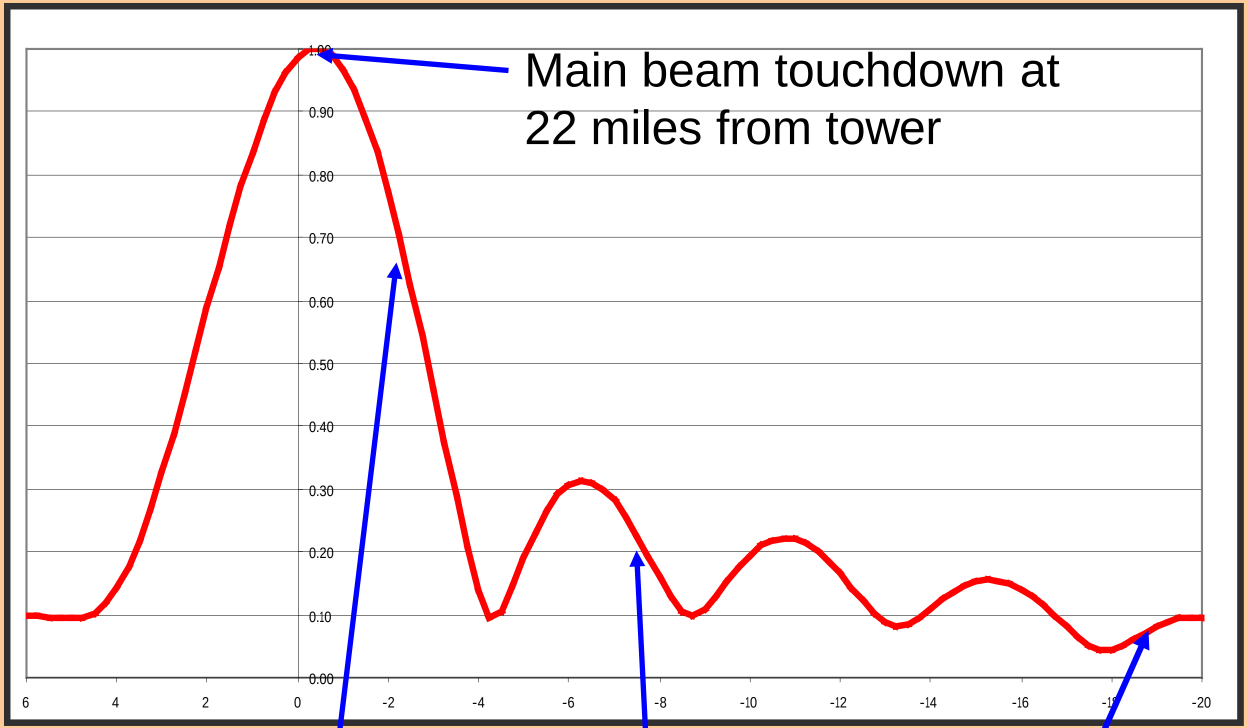
Here is the 14 bay elevation pattern with 0.5 degrees of beam tilt we are going to use. We wanted fairly uniform field down to about -20 degrees to blanket the downtown area.



This point is 2 miles from the tower

This point is 1200’ from the tower

This point is 4000’ from the tower

Project 1

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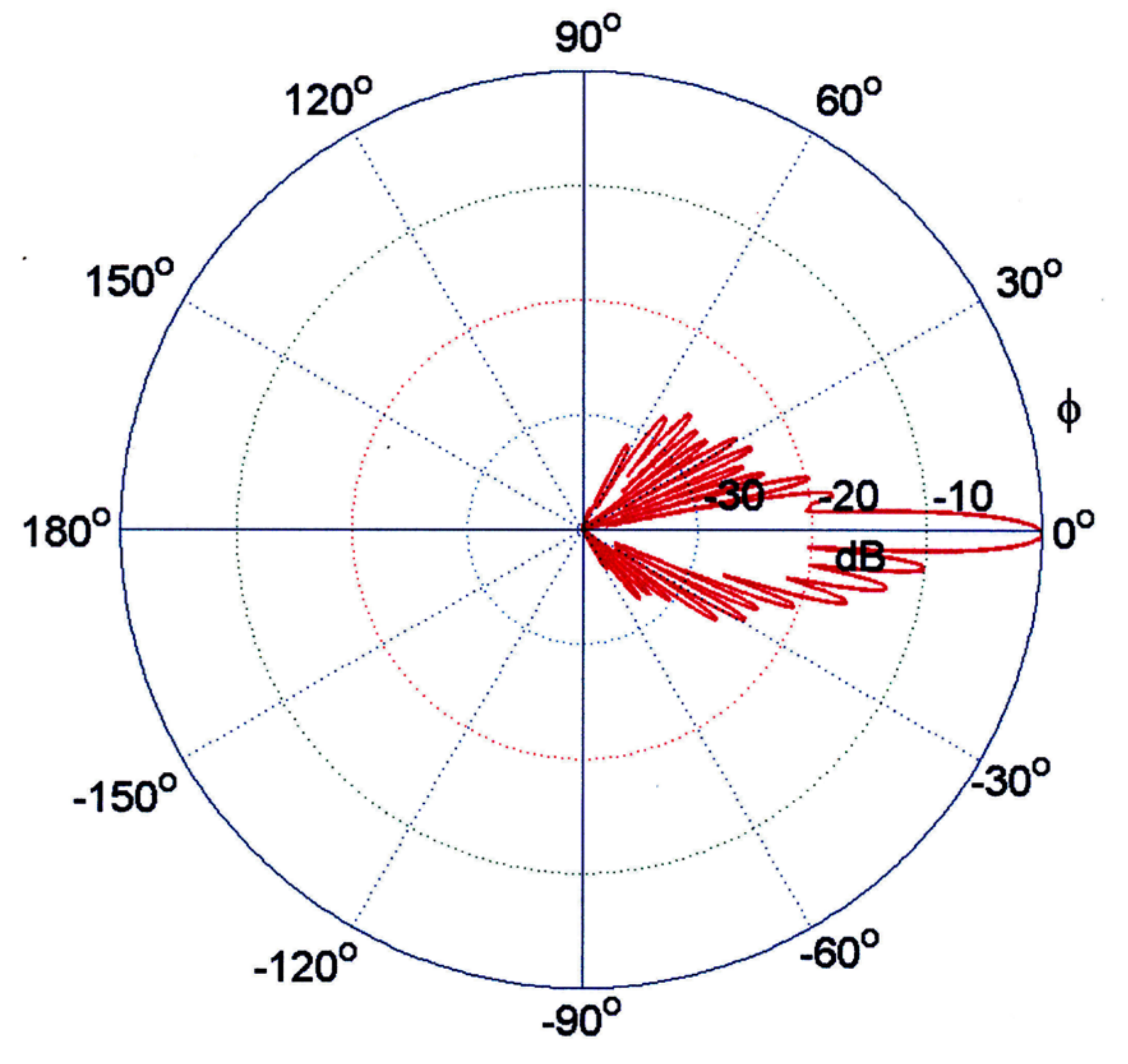


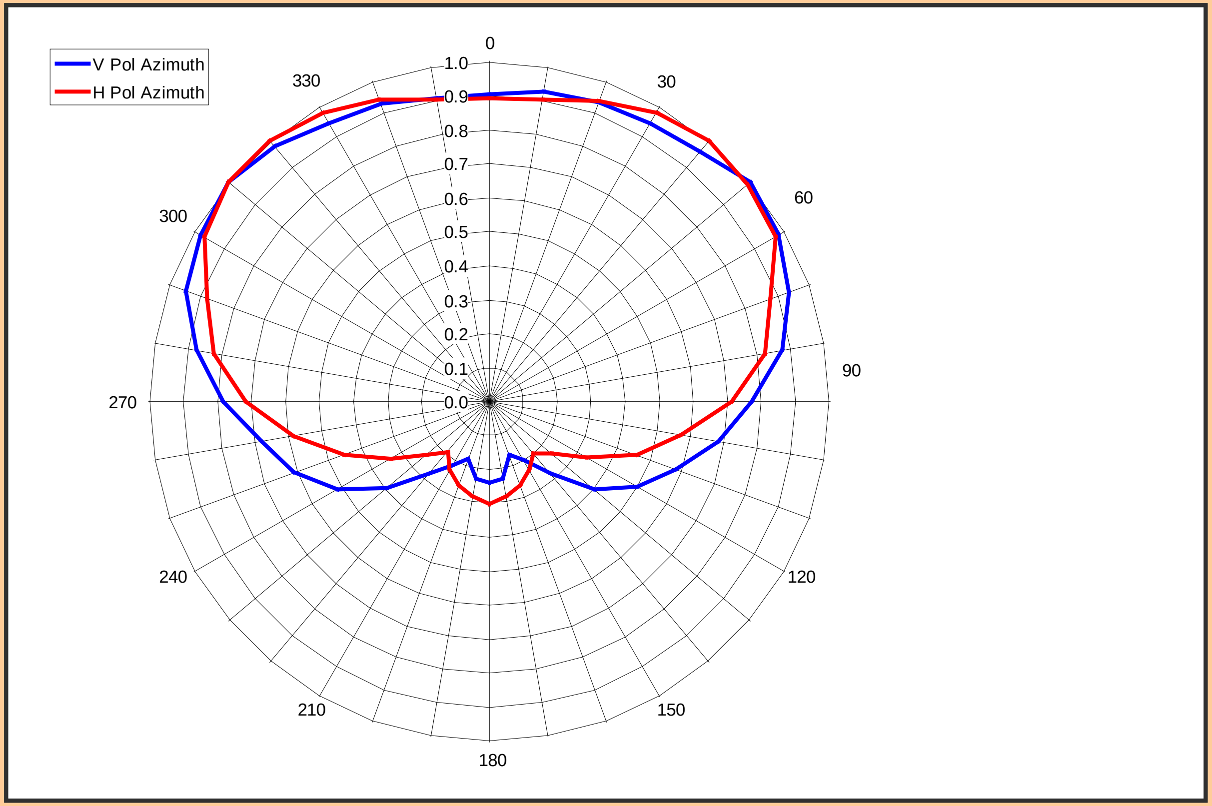
Here is the same 14 bay antenna with the elevation plot shown in a Polar format, This is a low RFR specially spaced antenna.

Project 1

Project 2 – A 15 kW LD station on a ridge

A 15 kW LD station is on a ridge 1800 feet from the valley floor. The close in population is 16 degrees below the horizon – the distant population is up to 30 miles out at the horizon. Half of the population is within 10 miles.

A broad cardioid pattern works well since the H and V Pol patterns are close.



We have 2.5 kW TPO available – so a fairly low gain antenna will work.

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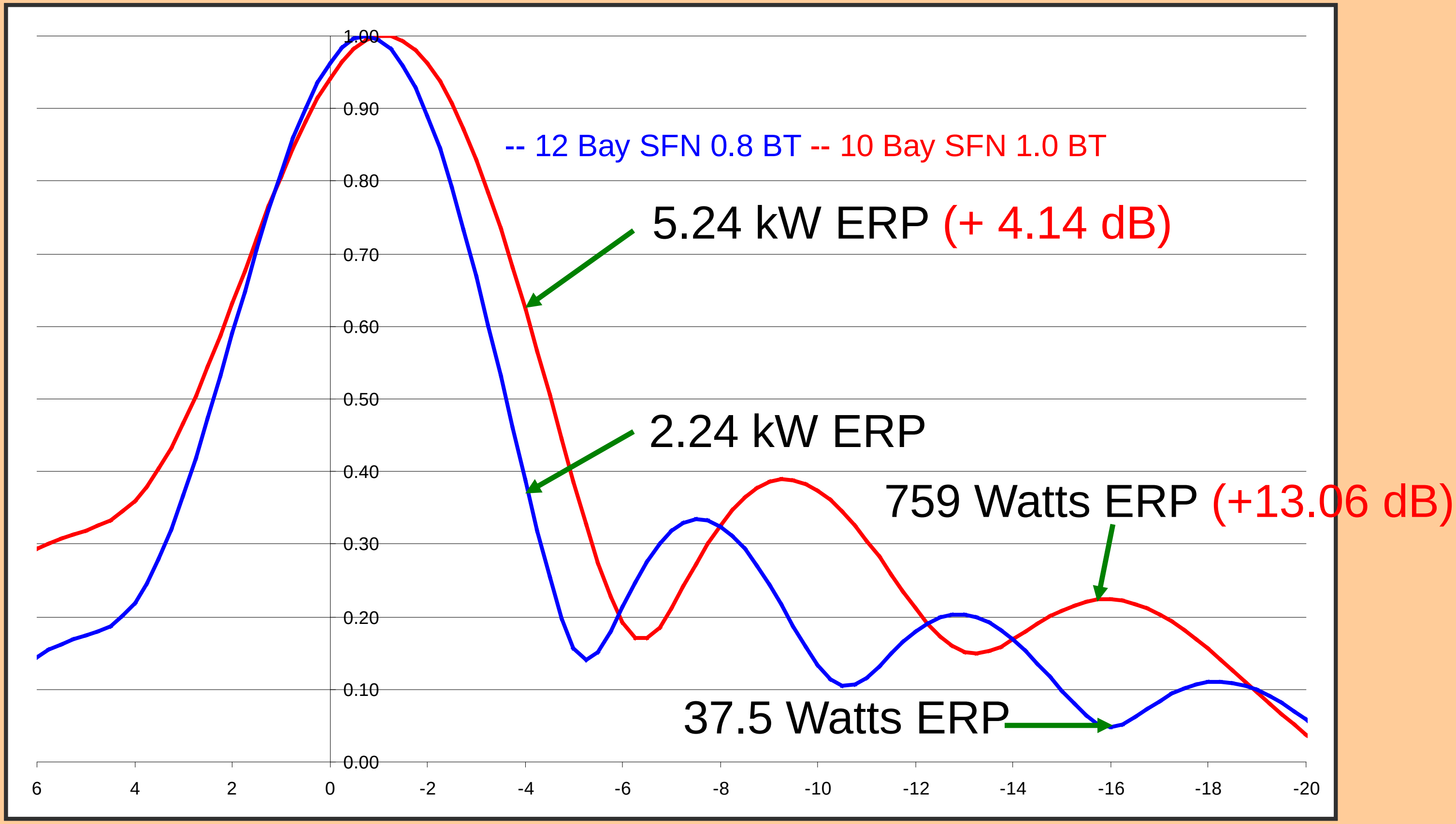

Here are two elevation patterns to look at – One is a 10 bay, the second is a 12 bay. The distant points in the valley where viewers are is between 0.0 and -0.7 degrees. The downtown core is at -4.0 degrees, the close in population starts at -16.0 degrees

✓ The 10 bay is the winner !

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Project 3 – A 400 kW DTV Station

From a 7500 foot high mountain the station needs to cover the valley which has population starting at 4.8 miles from the transmitter site to 17.7 miles away at the end of the valley. The core of the city (7.3 miles away) is a large tourist draw, is about a mile in diameter and would be the largest concentration of ATSC-M/H users. The transmitter also feeds more than 20 translators and numerous CATV headends within 100 miles.

Where are the viewers ?

Close in 4.8 miles away – depression angle -7.50 degrees
Downtown Core 7.3 miles away – depression angle -5.75 degrees
Far Valley 17.7 miles away – depression angle -2.25 degrees
Out of city CATV's and Translators up to 100 miles away -0.5 to -1.75 degrees

Solve These Problems That The Station Has

! A dual cabinet 40 kW transmitter that only likes being a 25 kW one
! High Tower rental costs - $$ by the foot
! Antenna on public land – RFR needs to be contained

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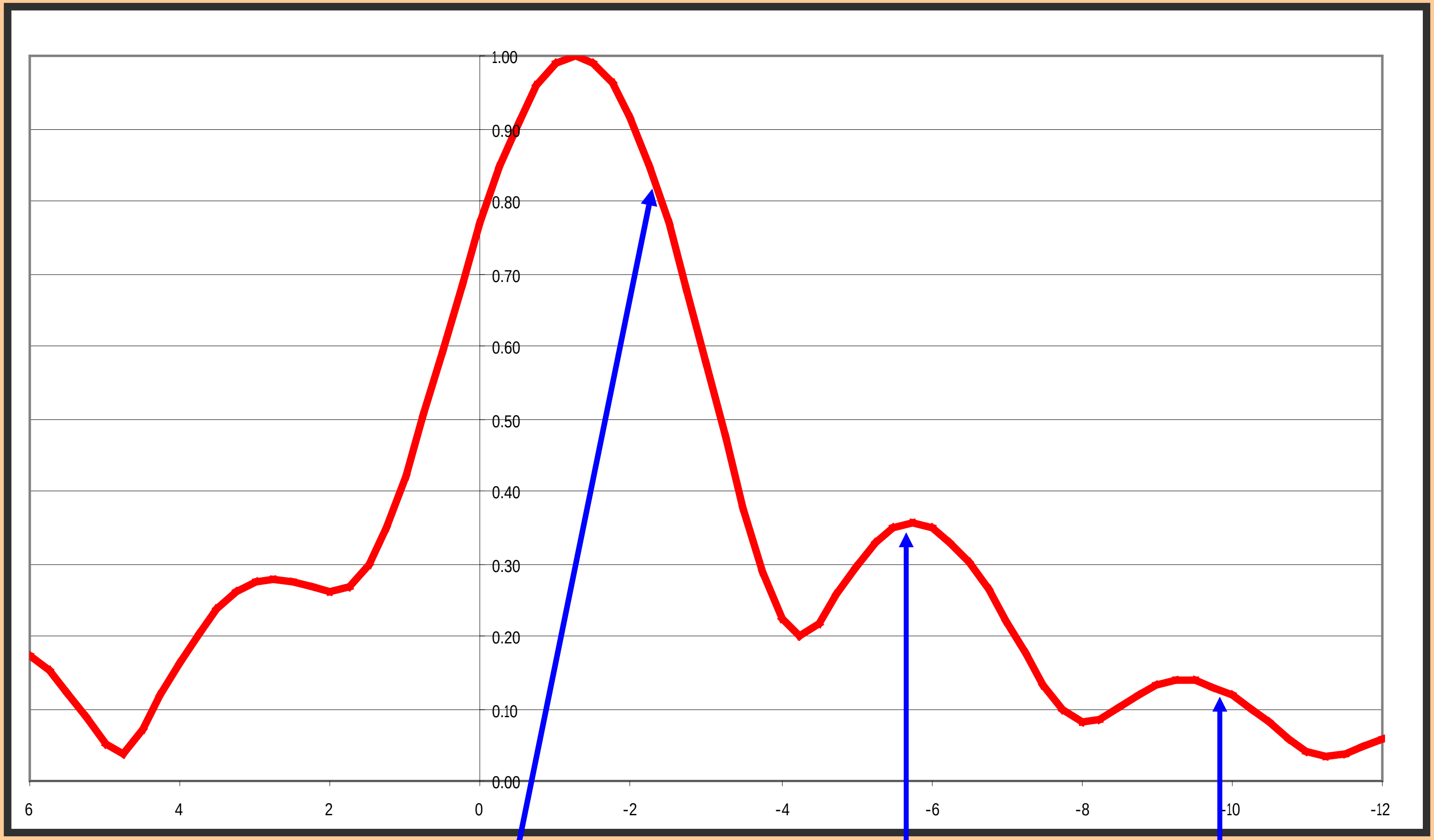
Project 3 – Using an 18 bay low RFR antenna



This point is 17.75 miles from the transmitter

This point is 7.3 miles From the transmitter

This point is 4.8 miles from the transmitter

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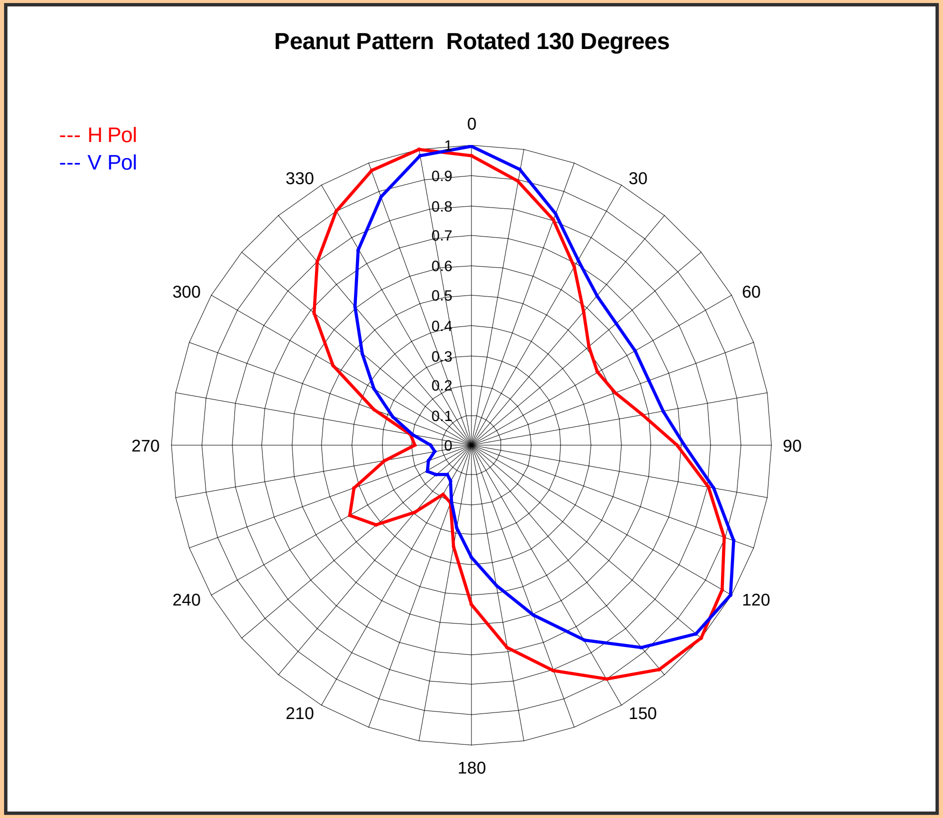
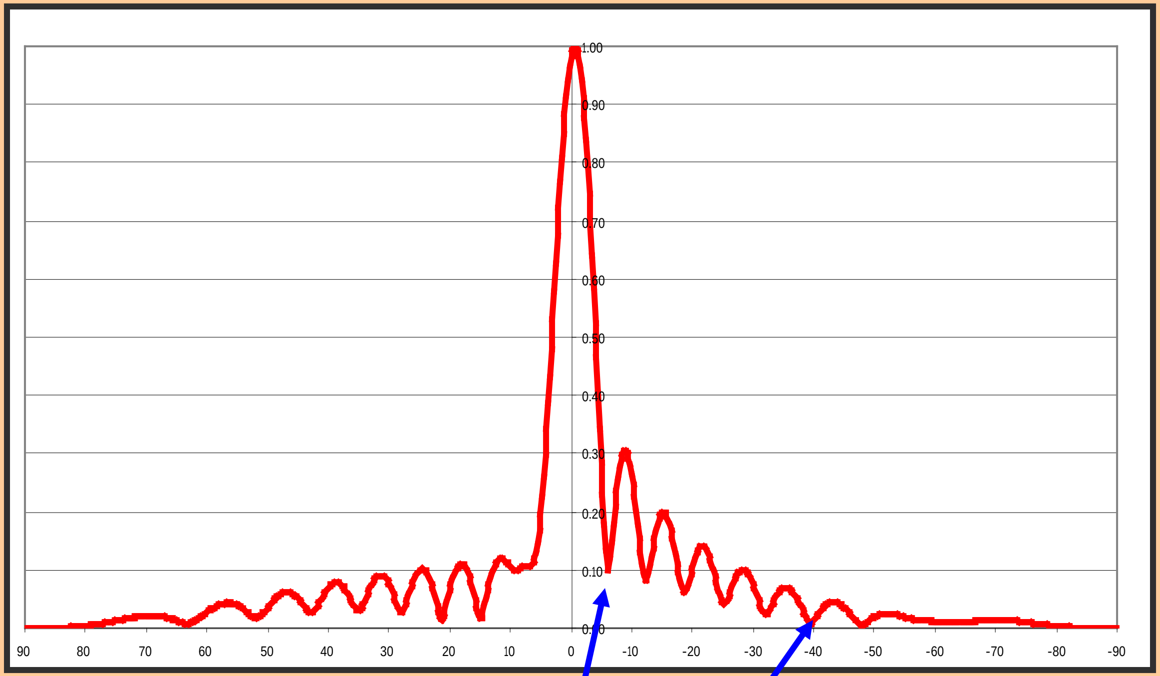
Project 4 – Super Duper World SFN’s

Provide ATSC-M/H along I-75 to the thousands of cars that use the highway each day. Each site will be a 15 kW LD site with the antenna 250 to 300 feet AGL. A 1.5 kW transmitter is planned for each site. A wide peanut pattern with a horizontal azimuth gain of 2.20 has been filed on for each site.



Because of the way the parastitics are placed, the horizontal and vertical azimuth patterns are close. This is perfect for maximizing the signal along the highway.

Project 4 – The elevation pattern



The 10 bay pattern we created earlier is perfect for the job. The field does not go to zero until it hits -40 degrees.

This point is 2450’ from tower

This point is 290’ from the tower

With 0.7 degrees of beam tilt the main beam hits the ground 4 miles from the tower – the field value at the radio horizon is still 98.2%

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Summary

✓ Plan your directional pattern carefully to ensure the vertical coverage is where it needs to be.

✓ The cost/benefit ratio maxes out with a 70/30 V/H split. Urban areas are a better case for C/P.

✓The E/P or C/P antenna may increase the tower loading over a H Pol only model due to radome size.

✓Lower gain antennas provide wider main beams and allow fuller control null fill.

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Thank You !

Lewiston Maine – our hometown

Questions ?

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