


# The Spectrum Repack: Is there a move to VHF in your future?


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Broadcasters Clinic 2016

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# Maybe a move to VHF in your future?

A quick look back at the analog era model, what worked, what did not

How big is that VHF antenna?

Why one’s VHF reception failed after the DTV conversion, and how to fix it

How much Effective Radiated Power, (ERP), is now reaching your viewers

New challenges in getting through to your viewers

Elliptical polarization is your best dollar value

Summary

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# The good old days of VHF in the analog world

VHF worked well in the analog world. The picture was not perfect on the outer edges of the market…but it worked. Ghosting was common, something the digital world has solved. Outdoor antennas were the norm; you could walk into Sears, and come out with one a few minutes later. “Rabbit-Ears” antennas were sold everywhere. A once-common sight was the Radio Shack VU-90 Antenna. (I worked for Radio Shack for a few years, and sold tons of those “magical” antennas.)

VU-90

On the TV station side of life most stations on high band VHF, had a 12-bay batwing antenna, with a 30+ kW transmitter. For low band a 4 or 6 bay batwing got stations up to the maximum power of 100 kW. This was beach front property at the time.

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# The most important thing about the Analog TV Era

Grandma knew how to position the rabbit ears antenna on top of her TV. This was to get the best picture to watch the Lawrence Welk show…he was on channel 8. Life was good until the network moved to UHF. From her point of view the world had ended.

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# How big is that VHF antenna ?

Many of you who work at a UHF TV station may never have seen a VHF antenna up close and personal. Here’s a closer look at some... Since most VHF antenna technologies use 1 wavelength-spaced slots or elements, there is a simple formula that will get you close to the length of a VHF antenna.

11803 divided by F (where “F” is the center frequency of your channel in MHz) is the 1 wavelength spacing of slots or bays in inches.

Next take that spacing and multiply it by the number of bays that you are interested in. So for channel 7, we get 66.68 inches, and for a 6 bay antenna, we get 400 inches. Add in another 72 inches for above and below the bays and the answer is 472 inches or 39-1/3 feet.

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The antenna to the left is a 3 bay channel 8 antenna, and is 25 feet long. Not pictured is the bury section that the antenna is mounted to. The picture to the right is a 6 bay channel 13 antenna. This antenna has an omni-directional pattern. To produce a smooth azimuth pattern a larger diameter pylon is needed to ensure the proper coupling between the slots. It is 33 feet long.

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Here is a channel 3 batwing in final test. This is a 4-bay antenna. The channel 3 antenna supports a channel 11 antenna above it. To get a sense of scale the diameter of the bottom pylon section is 24 inches. One of the crane operators is standing next to the bottom of the antenna pylon.

The spacing between the bays is 187.4 inches or 15 – $5/8^{th}$ feet. The four bay array takes 57 feet of vertical space, plus 12 feet for the tower bury section.

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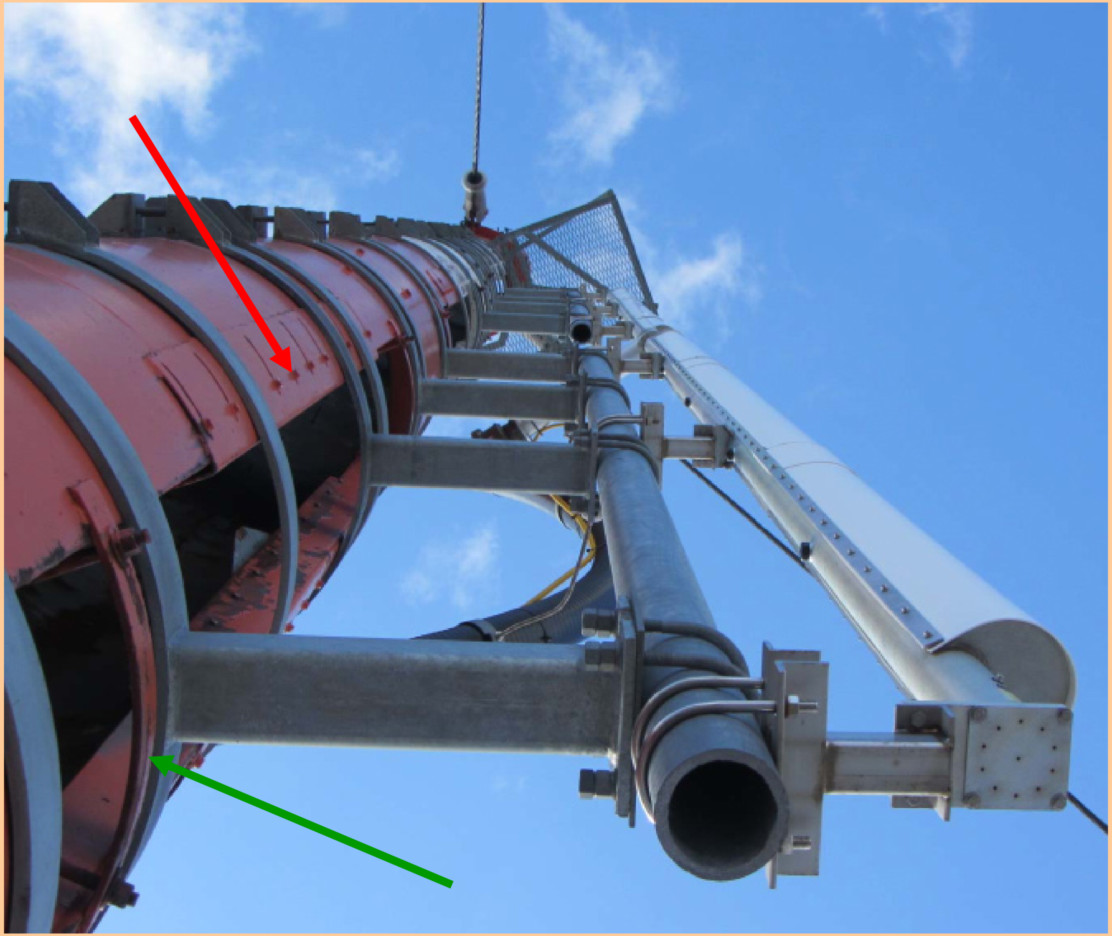

This is a channel 5 Slotted Pylon Antenna that now holds a new Micronetixx channel 39 UHF Slot Antenna. The channel 5 pylon is 3-1/2 feet in diameter and was made by Canadian GE many, many years ago.

The center conductor was removed. For antenna buffs, if you look carefully there are two tuning aids still visible, the iris which fine tunes slot length (green arrow), and sliding slot windows (red arrow) that help to fine tune the antenna.

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This is an 8 bay channel 9 side mount antenna. The antenna is fed in the center with a 3-1/8” EIA flange. The winglets form a broad cardioid pattern. Each half of the antenna is 24 feet – the total length is 48 feet. With a 25 kW input rating this antenna could produce an ERP of over 320 kW.

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# VHF DTV does not work – let's see why

Let's look at one high-band DTV station that had significant viewer issues following their conversion. The station was given a DTV ERP of 9 kW, down from their 316 kW analog ERP. They used their existing 12-bay batwing antenna. For many viewers, it seemed as though the station had simply gone off the air. …Let's look at what happened. The antenna is on an 1100 foot tower and is about 1400 feet higher than the core of the city that is a few miles away.

## What did work well however:

- **Viewers with outdoor antennas from close in to the radio horizon**
- **Cable TV and satellite feed sites**
- **Viewers with indoor antennas 10 to 15 miles away**

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# New reception rules in ATSC 3.0

## Consumption will be everywhere

With that in mind, the station we are looking at will not be successful as it is designed. When viewers and data consumers can not get constant contact, they will turn away quickly.

So the station hands us the keys  and tells us to fix it. We can not change the low tech indoor antennas. Building design with low E glass and metal indoor framing systems are the new norm.

**What we can do is get more signal into impaired locations**

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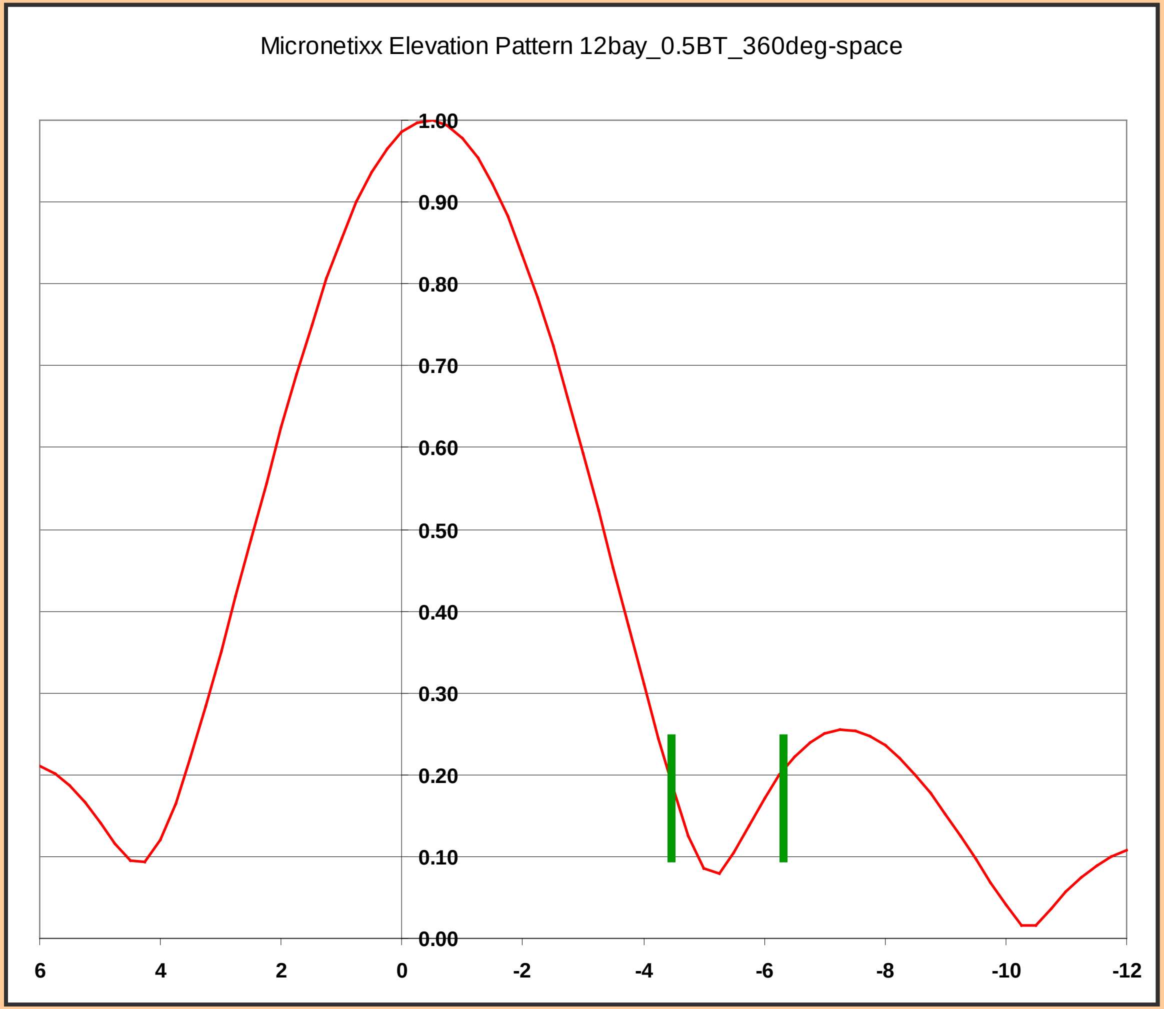


The core of the city is between -4.25 and -6.25 degrees (between the two green lines), right at the first null of the antenna (-5.25 degrees). With a 9 kW ERP, the effective ERP in the core is between 58 and 290 Watts. In the good old analog days the ERP in the core would have been between 2 and 12 kW.

Now add in some additional factors that kill reception. We will take a look on the next slide. The station has given us the keys and said “fix it”.

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# VHF Reception Killers

- No outdoor antenna – penalty up to 20 to 30 dB
- New Indoor antenna with a loss of 10 dB or more on VHF
- New amplified indoor antennas with low IM point
- Newer buildings are better Faraday cages (Low E glass)
- More building density = More Faraday rotation = dead spots
- Blue screen of death = no way to hunt down a signal
- Very few viewers know how to solve a reception problem

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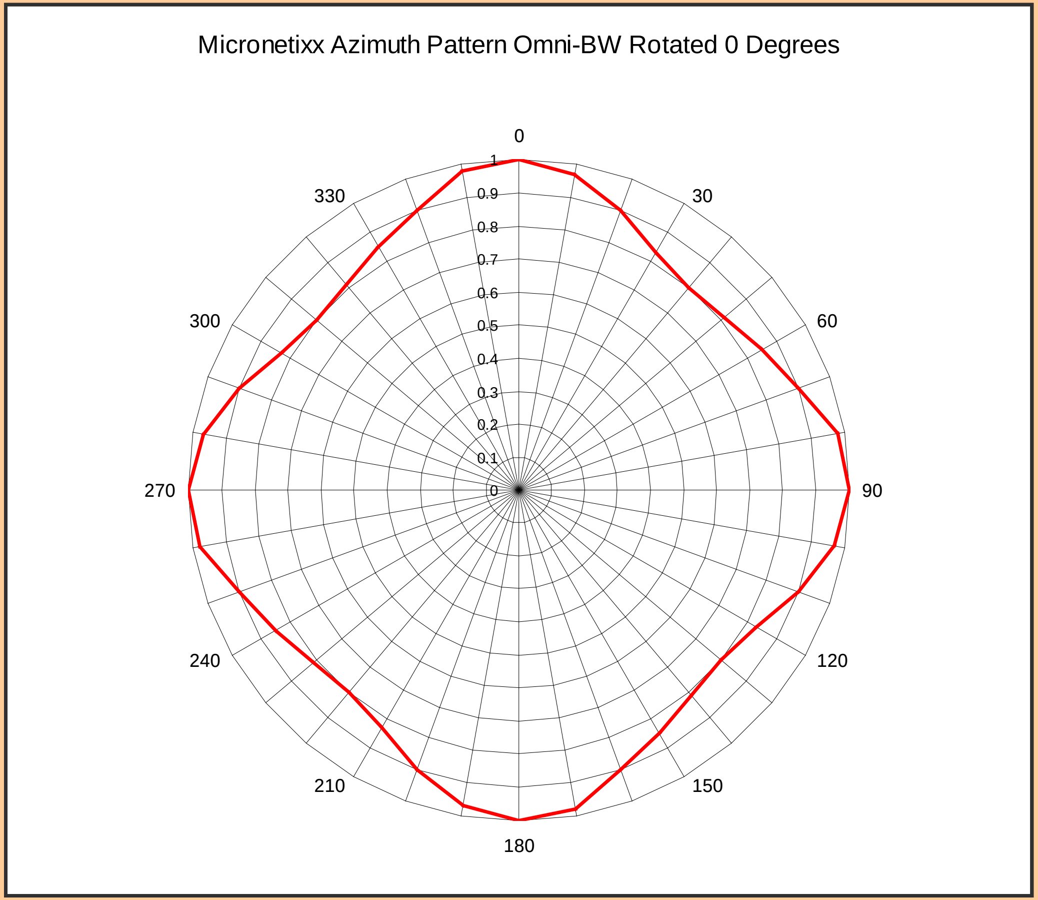
# An additional penalty




Batwing antennas are Omni-directional to a point. There are 4 full peak maximas at 100% of peak field and 4 minimas dropping down to 80% of peak field.

So in the core area where we had an ERP of between 58 and 290 Watts, people located in a minima now only get between 45 Watts and 230 Watts. That is one more dB toward the “blue screen of death”.

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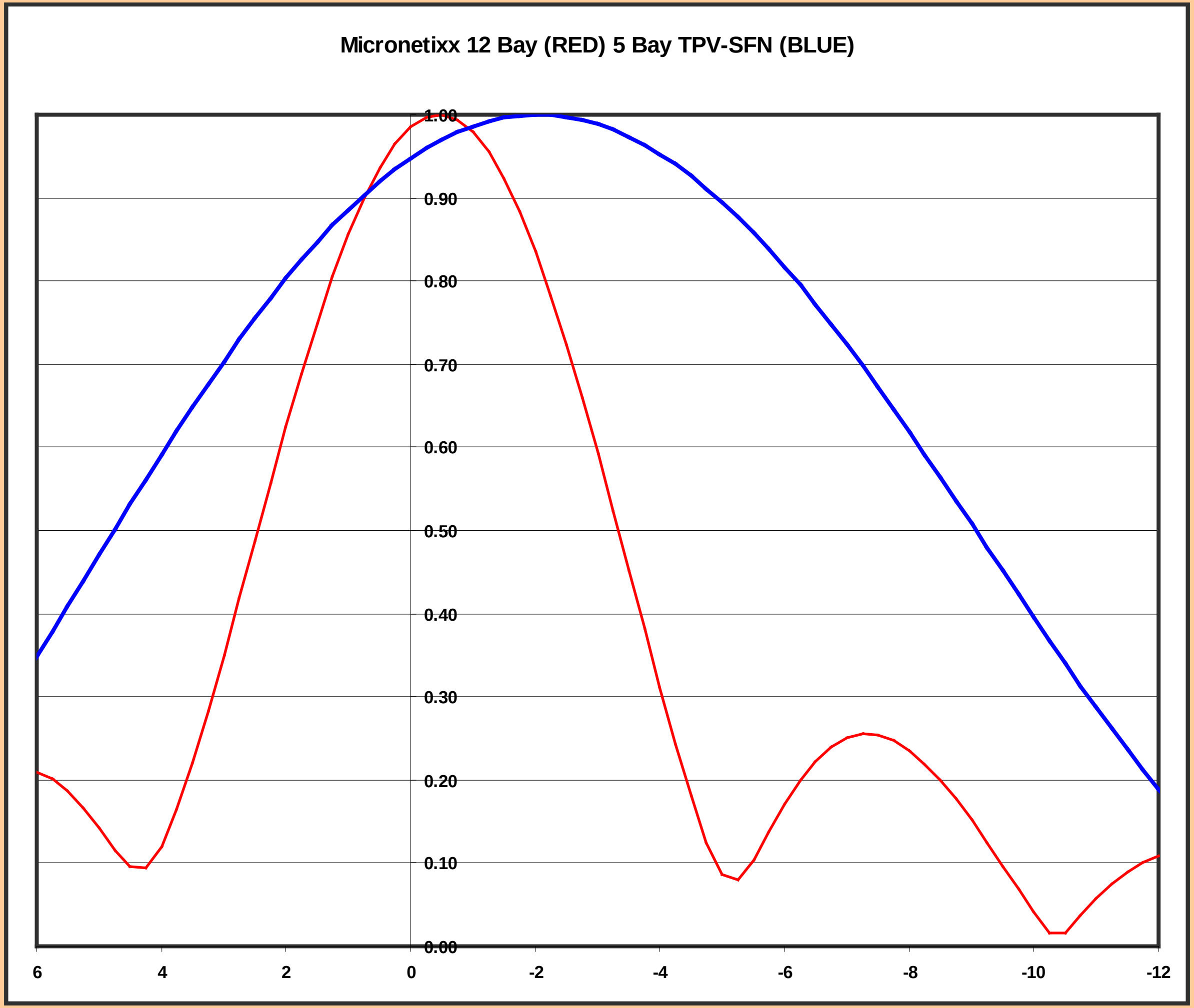


Doing some elevation pattern comparisons, we decided to consider a 5 bay TPV-SFN slot antenna pattern, after calculating how low in gain we could go with the transmitter they had. We then added beam tilt so the antenna would have about 95% of peak field at the radio horizon. Adding 2 degrees of electrical beam tilt give us an elevation gain of 6.2 (7.92 dB).

**So what did we gain?**

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In a previous slide, we showed the elevation pattern of the 12 bay batwing antenna now in use. The first null was right over the downtown core of the city. Let's compare signal levels with the new 5-bay antenna.

| Depression Angle (degrees) | Current ERP | New Antenna ERP | Signal Difference |
|---|---|---|---|
| 0.00 | 8.75 kW | 8.09 kW | -0.34 dB |
| -0.50 | 9 kW | 8.47 kW | -0.26 dB |
| -3.00 | 3.16 kW | 8.80 kW | +4.45 dB |
| -4.25 | 475 Watts | 7.95 kW | +12.23 dB |
| -5.25 | 58 Watts | 6.92 kW | +20.76 dB |
| -6.25 | 290 Watts | 5.69 kW | +12.92 dB |
| -8.00 | 501 Watts | 3.45 kW | +8.38 dB |
| -10.00 | 15 Watts | 1.40 kW | +19.70 dB |

With the 5-bay design we have increased signal levels in the core from 12.23 dB to 20.76 dB. 99% of viewers are in the in the depression angle range of the radio horizon to -10.00 degrees.

Note: These calculations are easy to do. You take the square of the field value at the angle you want to study and multiply it by the peak field ERP (i.e. $0.535^2 * 9$ kW = 2.58 kW).

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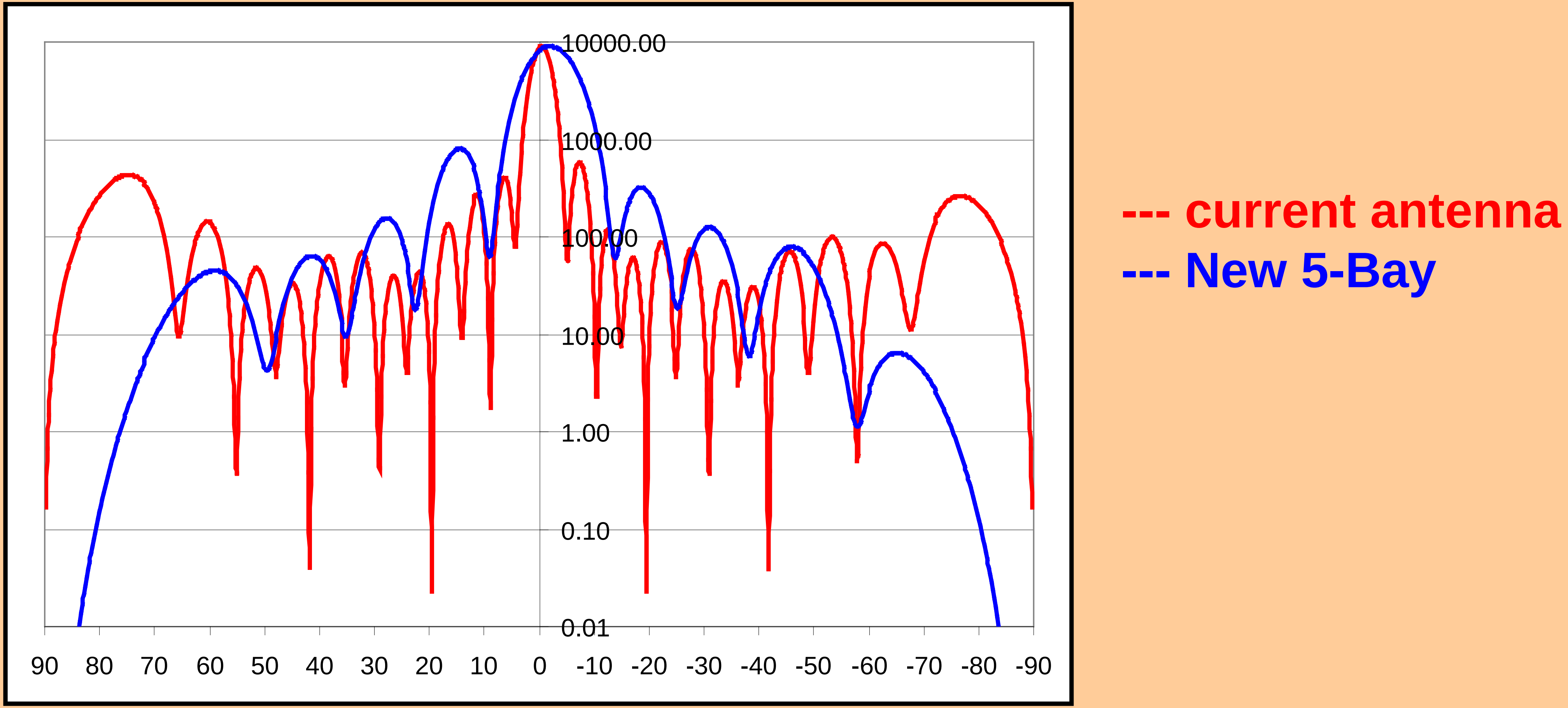


**ERP (Watts) versus depression angle plot**
**full +/- 90 Degree Plot**

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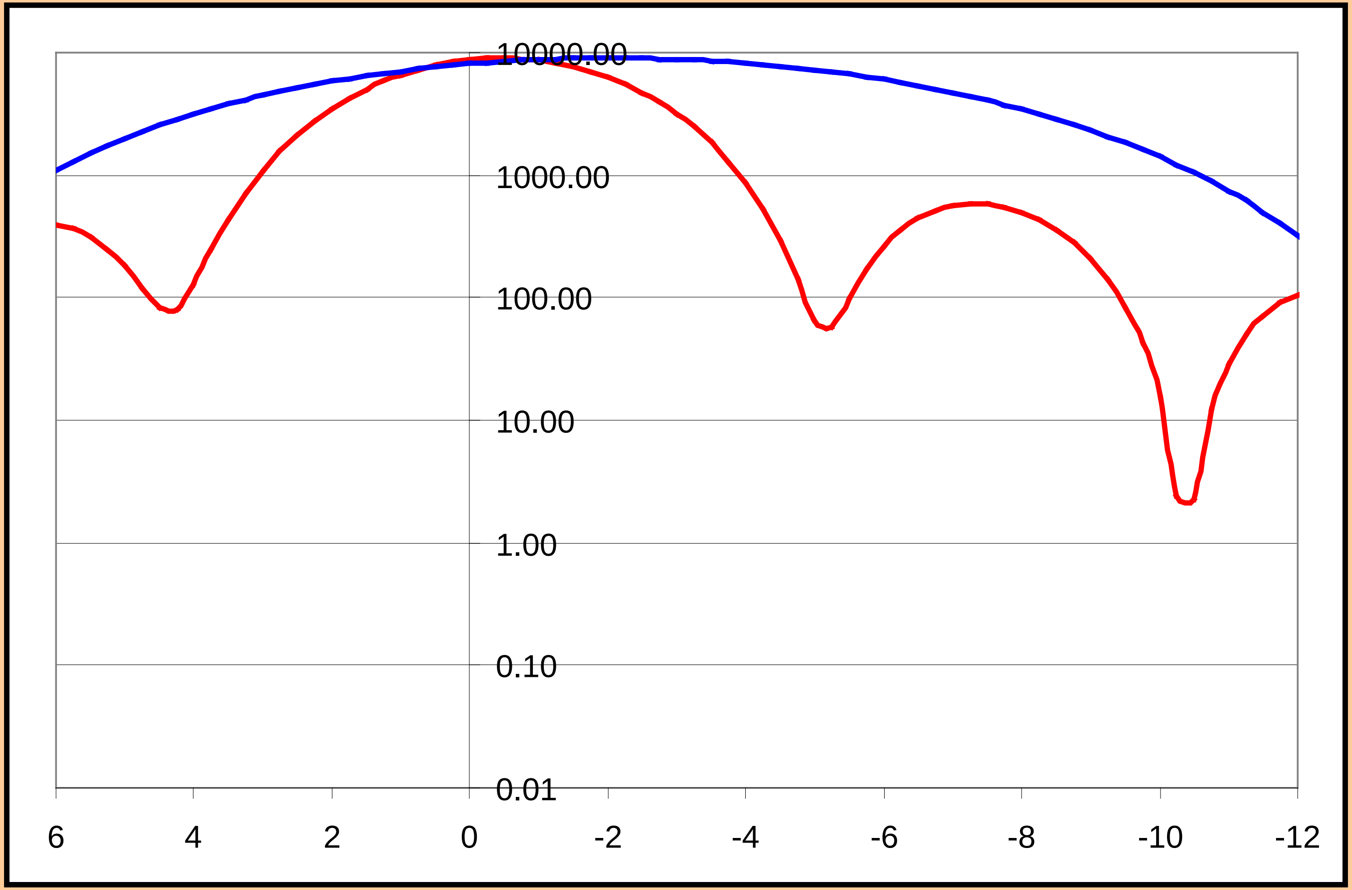


--- current antenna

--- New 5 bay

**ERP (Watts) versus depression angle – 6 to -12 degree plot**

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# Elliptical Polarization

## ✓The best dollar value is going to elliptical polarization

Let's discuss elliptical and circular polarization. We will model elliptical polarization using a slot antenna. 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. (Micronetixx Patented Design couples to both E and H fields.)

The length of the slots is 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.

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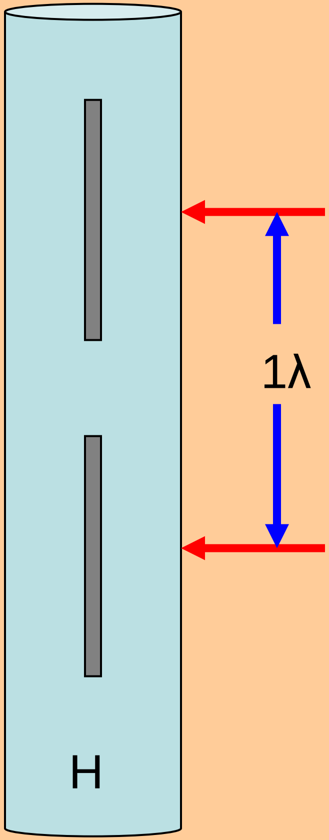
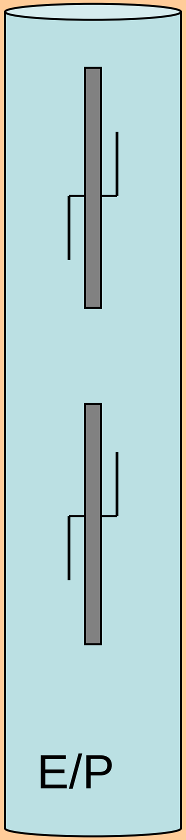



Length of slot ~ 0.8λ

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 slot field, in quadrature. When the axial 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 DTV broadcasts a 70/30 horizontal to vertical ratio is ideal. This ratio requires 42.8% more TPO than what would have been needed with an H–Pol only transmission.

If there is not enough transmitter power available for the 70/30 power ratio, even doing a 90/10 H to V power split will greatly help. This is true for both VHF and UHF stations.

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When deciding on an Elliptically-Polarized antenna, here are some important items to look for. First the polarizers should be DC-Grounded at the middle of the slot. This is to allow the polarizers to fully excite the vertical field and store no energy any time during a cycle. Stored energy causes group delay, which is something we want to minimize as much as possible with Digital Transmission. Also the loaded Q of the polarizer should match the frequency response of the field originating from the slot. Old designs that use a single rod mounted on Teflon blocks above a slot were an OK answer in the analog days. Not so much today. Plus, the all DC-Grounded design is highly immune to lightning damage.

## What is Faraday rotation and how does it relate to DTV transmissions ?

Faraday rotation is when a linearly-polarized signal bounces off a building, or terrain and the reflected surface changes or rotates its polarization. The new polarization may be at an angle or up to a 90 degree difference. The angle of the Faraday rotation can change every few inches or feet. A fixed linearly-polarized receiving antenna that is not oriented at the same angle as the altered signal may face a signal impairment of up to 20 dB.

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| Depression Angle (degrees) | Current ERP | 15 dB Faraday loss ERP |
|---|---|---|
| 0.00 | 8.75 kW | 277 Watts |
| -0.50 | 9 kW | 316 Watts |
| -3.00 | 3.16 kW | 99 Watts |
| -4.25 | 475 Watts | 16.7 Watts |
| -5.25 | 58 Watts | 1.83 Watts |
| -6.25 | 290 Watts | 11.27 Watts |
| -8.00 | 501 Watts | 16 Watts |
| -10.00 | 15 Watts | 0.47 Watts |

Going back to the example of the 12 bay antenna, lets look at the Faraday rotation impairment at the same 8 degree depression angles. We will use a default Faraday impairment of 15 dB. The values shown are the equivalent ERP with the 15 dB impairment of a linearly-polarized transmitting antenna and the receive antenna that get the rotated signal.

Add in the penalties we listed on slide 13, and you can see there is little to no signal left to receive. So let's now model the new 5-bay antenna with elliptical polarization. The power division is 70/30 (70 % horizontal, 30% vertical). So we have a right hand spinning vertical plane that is at least 42.8% of field. Taking the 9 kW ERP and multiplying it by 1.428, gives us a combined maximum ERP of 12.85 kW. Multiply that by 0.3 and the vertical plane ERP is 3.85 kW. Even with Faraday rotation, there will always be 42.8% of the peak field energy available at any polarization angle.

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| Depression Angle (degrees) | 5 Bay H ERP | 5 Bay V ERP | 12 Bay Faraday Impaired ERP | Net Signal Difference |
|---|---|---|---|---|
| 0.00 | 8.09 kW | 3.47 kW | 277 Watts | +10.97 dB |
| -0.50 | 8.47 kW | 3.62 kW | 316 Watts | +21.58 dB |
| -3.00 | 8.80 kW | 3.76 kW | 99 Watts | +23.50 dB |
| -4.25 | 7.95 kW | 3.40 kW | 16.7 Watts | +22.00 dB |
| -5.25 | 6.92 kW | 2.96 kW | 1.83 Watts | +32.07 dB |
| -6.25 | 5.69 kW | 2.43 kW | 11.27 Watts | +21.91 dB |
| -8.00 | 3.45 kW | 1.47 kW | 16 Watts | +19.62 dB |
| -10.00 | 1.40 kW | 600 Watts | 0.47 Watts | +31.06 dB |

**This chart compares the ERP of the current 12-bay antenna, with a Faraday impairment, and a new 5-bay E/P antenna with a 70/30 power split.**

The improvement of signal level in the downtown core is about 22 dB, with the worst spot at -5.25 degrees, showing just over 32 dB of improvement. Reception from indoor antennas, mobile devices, (and yes cars), will be greatly improved with very few impaired receiving locations. At -10.00 degrees, the transmitter tower will be just a mile away.

Now what about the transmitter needed? The current antenna needs a 900 Watt TPO, the new 5 bay E/P antenna needs 2.5 kW.

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# Could we do any better at this site?

We could do a little better, however the cost tradeoffs start to diminish the benefits. First we could look at a 3-bay antenna. The core area where we had the very poor reception would see a 1.0 to 1.5 dB increase in signal level over the 5-bay antenna. Transmitter power increase?  About 4.2 kW using elliptical polarization – just over double. Fringe or far fringe coverage – a wash, under a 1/10$^{th}$ of a dB.

Now if this site had been at Farnsworth Peak (Salt Lake City), Mt. Wilson (Los Angeles) or Sandia Crest in Albuquerque, the answer would have been yes – a three bay antenna. There are significant number of viewers 10 to 20 degrees below the radio horizon. We could also add to the list El Paso, Denver and Boise to our high elevation transmitter sites. As for in city transmitter sites like New York, Chicago and San Francisco, low gain VHF elliptical polarized antennas would provide the best performance.

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# Summary

- Rule 1 – Elliptical or Circular Polarization
- Lower gain antennas with more transmitter power is the way to go
- Ensure that antenna minimas or nulls do not fall on where viewers are
- With ATSC 3.0 viewers or consumers are everywhere and on the go
- Work with your RF Consultant and antenna supplier for the best solution

**One more thing – make sure you're your antenna is:**

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Color Approved

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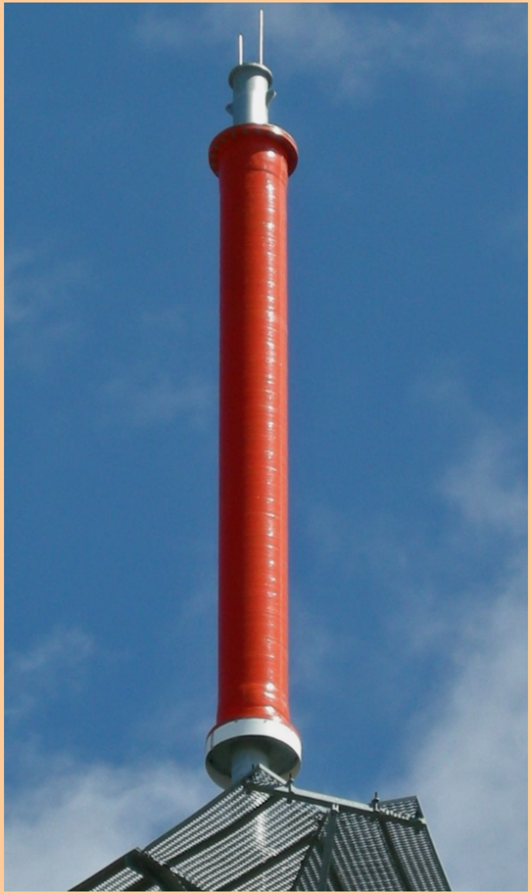
# Thank You!



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