



# The TV Spectrum Re-Packing Antenna Engineering Guide V2.0

Micronetixx is pleased to present this updated engineering guide to the TV Broadcast Industry. Many veterans of the Industry that work in the RF side of the business have never seen their antenna close up or taken a look under the radome to see what is in there. With the Spectrum Re-Packing coming up, and a fairly short time frame to plan the next generation of ATSC 3.0 ready operations, this guide will answer many antenna-related questions.

We will be giving you a look under the radome and sharing a lot of knowledge heard in our Engineering Department and on our shop floor everyday. After reading the Antenna Engineering Guide, you'll probably have some questions. Give us a call, we'll be glad to answer them.

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Some stations may select the option of moving to high band VHF from their current UHF channel. The antenna choices for high band VHF include Slotted-Pylons, Batwings, Lindenblad, Inverted-Vee, and Panel Antennas. The Slotted-Pylon Antennas, Inverted Vee and Lindenblad Antennas will operate well over one or two channels. Panel and Batwing antennas can cover the full band. Common bay-counts for high band antennas range from 2 to 12 bays. Each additional bay adds just over 5 feet of height or aperture to the antenna.

When an Omni-Directional pattern is needed, a top-mounted antenna is the way to go. There is no pattern distortion with top-mounted antenna models. The exception is Panel Antennas. If the tower width is no more than about 5 feet, and the edges of the panels can nearly contact one another, the antenna will produce less scalloping in the azimuth plane. Mounting the antenna on a wider tower increases scalloping, by as much as 6 dB at some azimuths – a large loss in signal.

Other omni-directional VHF antennas do not work well when side-mounted, as they are firing the same energy level in all directions. The tower members become parasitics and cause scalloping at some frequencies in the channel.

If a side-mounted option for an Omni-directional antenna is the only choice, then leg-mounting is your best bet.

The antenna should be mounted a minimum of 5 feet off the tower leg – farther out if possible. Because of the close coupling of the tower to the antenna, some de-tuning could result. Even if a pattern study has been run and the antenna tuned at the factory against a similar structure, de-tuning is still possible. A 4-Axis fine matcher will help walk the antenna back into tune.

For reference a high band omni VHF Slot Antenna uses a pylon that is between 16 and 20 inches in diameter. Add between 4 and 12 inches of radome, (for protection in hostile environments), and the antenna comes in with a diameter of up to 32 inches. That can quickly add a lot of non-symmetrical loading to the tower.

The top-mounted slot and batwing antennas do not need an independent support mast as all needed support is designed-in. A monopole is needed for the Inverted Vee, and Lindenblad designs. Depending on the number of bays and the wind zone, the monopole is usually in the range of 8 to 14 inches in diameter. (Check with your Structural Consultant or Tower Manufacturer to see what is needed.)

For Panel Antennas, the optimum approach is to install a new top-section of tower that is optimized for the Panel Antenna selected. A face width of 5 feet is optimum to produce the best Omni-Directional Pattern. Designing this is a team effort between Micronetixx and the tower vendor you select.

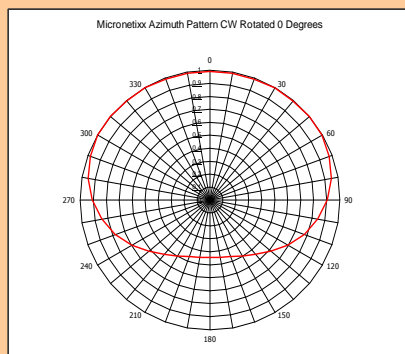
Now that we have taken a look at Omni-Directional VHF high band antennas, let's consider a few directional patterns. Most azimuth directional patterns are a form of cardioid, or even that approaching a peanut-shaped pattern. Azimuth pattern gains range from about 1.4 (1.46 dB) to 1.8 (2.55 dB).

The Inverted Vee, (or "Arrow-Dipole"), and Lindenblad antennas are normally omni-directional only. We can coax them a bit into the directional world, but our other antenna designs perform much better in a directional application.

...So our best designs for directionals are: Slotted Pylon, Panel, and Batwing Antenna. Let's take a look at each:

A properly sized **Pylon** with a single row of slots will typically produce an Omnioid Pattern; about 100% relative field in front of the antenna, (over an arc of about 65 degrees), and approximately 65-70 percent to the rear. To make the antenna more directional we attach precisely-positioned wing-like structures to the O.D. of the pylon near the slots.

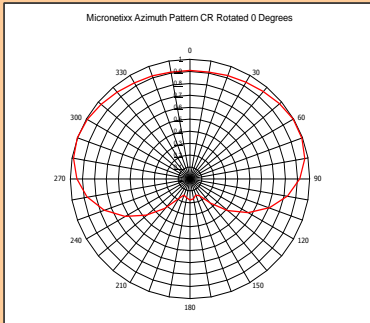
For relaxed cardioid patterns, these elements or wings are fairly short and are swept back toward the rear of the pylon. The azimuth gain will be between 1.4 (1.46 dB) to about 1.55 (1.90 dB). Relative Field Intensity to the rear of the antenna will be about 40 to 50 percent of Peak Field.



**Relaxed cardioid pattern**  
**Pattern name: CW**



As the wings or elements are made longer the cardioid pattern elongates and the radiation to the rear drops down to about 10 to 20 percent of peak relative field. The azimuth gain increases to about 1.7 (2.30 dB). Of all cardioid patterns we produce, this is the most popular.



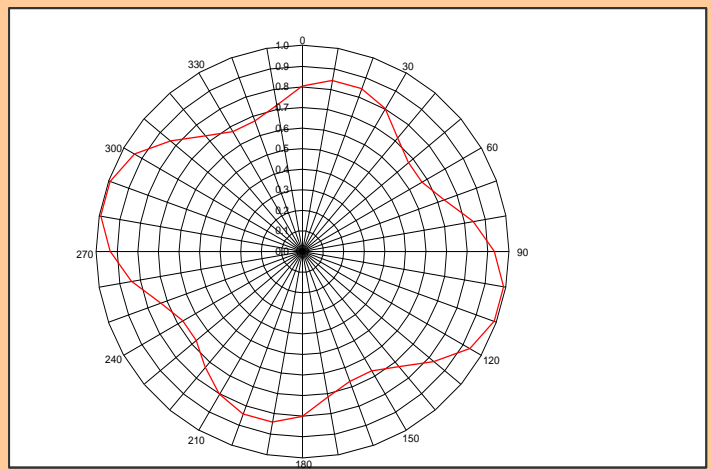
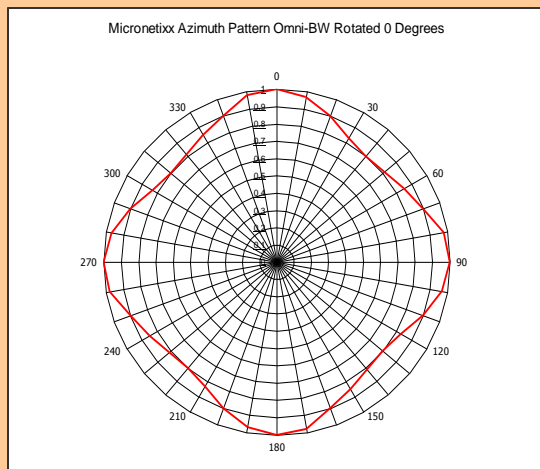
Micronetixx also offers custom azimuth patterns, as well as variations of the Pattern shown at the Left.

Using **Panel Antennas**, a number of directional patterns can be obtained. There are three primary methods to form directional patterns. One is the number of panels at each bay level; varying the relative percentage of RF power fed at given panel levels; while the third is the angle at which the panels are installed.

Narrow cardioid antennas are single columns of panels. They produce a single lobe of energy, with a half power beam width of about 60 degrees, and a azimuth power gain of about 5.3 (7.24 dB). The radiation off the back side of the panel is quite low averaging just a few percent of peak field.

Wider cardioid antenna pattern options are too numerous to count. Since most panel antennas have excellent front to back ratios, they perform very well in side mounted directional applications. Typical “scallop” variations in the pattern amplitude are usually under 2 dB.

The **Batwing Antenna** design has served many well for over 60 years. It has a nearly Omni-Directional azimuth pattern, producing at least 80% of peak field at any azimuth. Since we are discussing directional high-band antennas, where does the Batwing fit in? Since it is a quadrature-fed Antenna, by changing the input power ratio on the two opposing sides, the batwing array becomes directional. The left plot below is a standard batwing azimuth pattern. The right-hand plot is a slightly modified batwing antenna pattern with two of the maximas only at 85% of peak field.



The power division ratios can be modified so the batwing antenna pattern is similar to a peanut or bidirectional form.

We will cover elliptical and circular polarization starting on page 48. If you are planning the move to high-band VHF, we strongly suggest adding a vertical component to your signal. The Lindenblad, Slotted Pylon, and Panel can be configured to produce a rotationally-polarized pattern. The batwing is an H – Pol antenna. However, in some cases it will also radiate up to 10% of field in the vertical plane.

## Moving to Low Band VHF...



We have had some inquiries about what the move to Low-Band VHF entails. The first thing we discuss is the size of these antennas. They are almost 3 times the size of the High-Band antennas we discussed in the previous Section.



The picture at the left shows the final test of a Channel 3 Batwing Antenna. If you look closely you can see one of the crane operators standing next to the bottom of the pylon. The bottom section of the pylon is 24 inches in diameter. The bury section is 12 feet long. Each antenna bay is 9 feet high, and the bays are spaced 13-3/4 feet apart. The complete 4 bay antenna is 57-1/2 feet long.

We know that the Batwing Antenna is an option for Low Band VHF. With the size of this Antenna, it is a top-mounted-only solution.

There are several other options for low band VHF; the Lindenblad Antenna, and Panels. The Lindenblad Antenna is a top-mounted solution, while Panels are side-mounted. Did we forget the Slotted Pylon Antenna? No. We will explain...





This is a channel 5 Slotted Pylon Antenna that now holds a new Micronetixx Channel 39 UHF Slot Antenna. The channel 5 pylon is 4 feet in diameter and was made by Canadian GE many, many years ago.

As seen, a slotted low band pylon is possible. With enough money and spare tower capacity, this could be an option.

Most low-band stations will be omni-directional. The Lindenblad Antenna normally used for FM is scaled up in size to the channel required. Power handling is limited by the power division & feed system used on the antenna. An input power of up to 50 kW is possible. This antenna needs to be top-mounted on a new monopole. Depending on the number of bays, the diameter of the pole ranges from 12 to 16 inches. One bonus with the Lindenblad is excellent circular polarization. See page 11 for the Lindenblad Article.

Panel antennas are an option for low band VHF and can be configured in H-Polarized or C/P models. At low band the panels are large. One model is made for operation on channels 2 and 3, and a second model covers channels 4 to 6. The channel 2/3 panels are close to 12 feet square, while the channel 4/6 panels are about 9-1/2 feet square.

If you're planning a channel 2 or 3 operation, you will need a tower face width of 12 feet so the panel edges nearly contact, using a 3-around design. For a channel 4 to 6 application, a 10 foot face-width will do. If you're using a small-width tower, outrigging can be designed to get the best spacing.

Power handling ability of the panel antenna using 7/8" EIA inputs per panel is typically 5 to 7 kW per bay. Here, a 4-bay panel system could have an input power rating of 60 kW depending on the size and type of the main feed network.

As for bay count, 4 to 6 bays works well. Beyond that the size of the antenna can cause mechanical issues. For these applications, we add enough beam tilt so there is still about 92% of peak field at the radio horizon. In increased HAAT applications, dropping the peak field at the horizon down to 87 to 90% will help increase signal levels over the required range of elevation angles.

With low-band VHF, adding a vertical field component is worth the extra cost, especially in urban areas. One solution would be to utilize properly-driven vertical elements appropriately mounted below the H-Pol antenna, and power-divider driven to about 10% to 25% of the Input Power. This would provide the station with a vertical component – but it will not be true elliptical polarization. The Lindenblad, on the other hand, will produce a true elliptical or circular signal.

If you are planning to move to Low-Band, the extra money spent on additional transmitter power and a C/P or E/P antenna are well worth it.

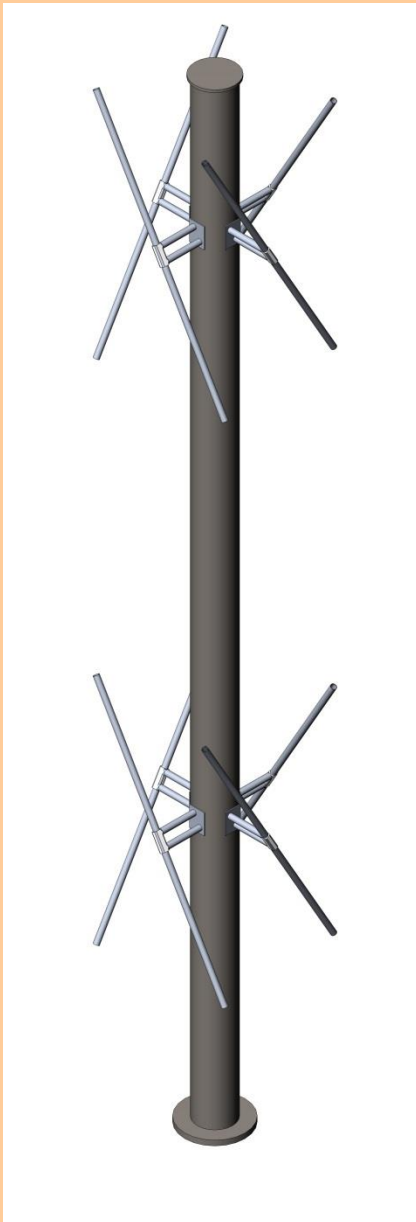
# The Lindenblad Antenna:



The Lindenblad Antenna was developed about 1940 by Nils Lindenblad of the RCA Laboratories. The antenna was a circular-polarized antenna that would minimize fade on ground to aircraft radio transmissions. With the start of WWII, future development efforts were shelved towards using the technology for TV transmissions. Over the years ham operators have come up with some innovative Lindenblad designs.

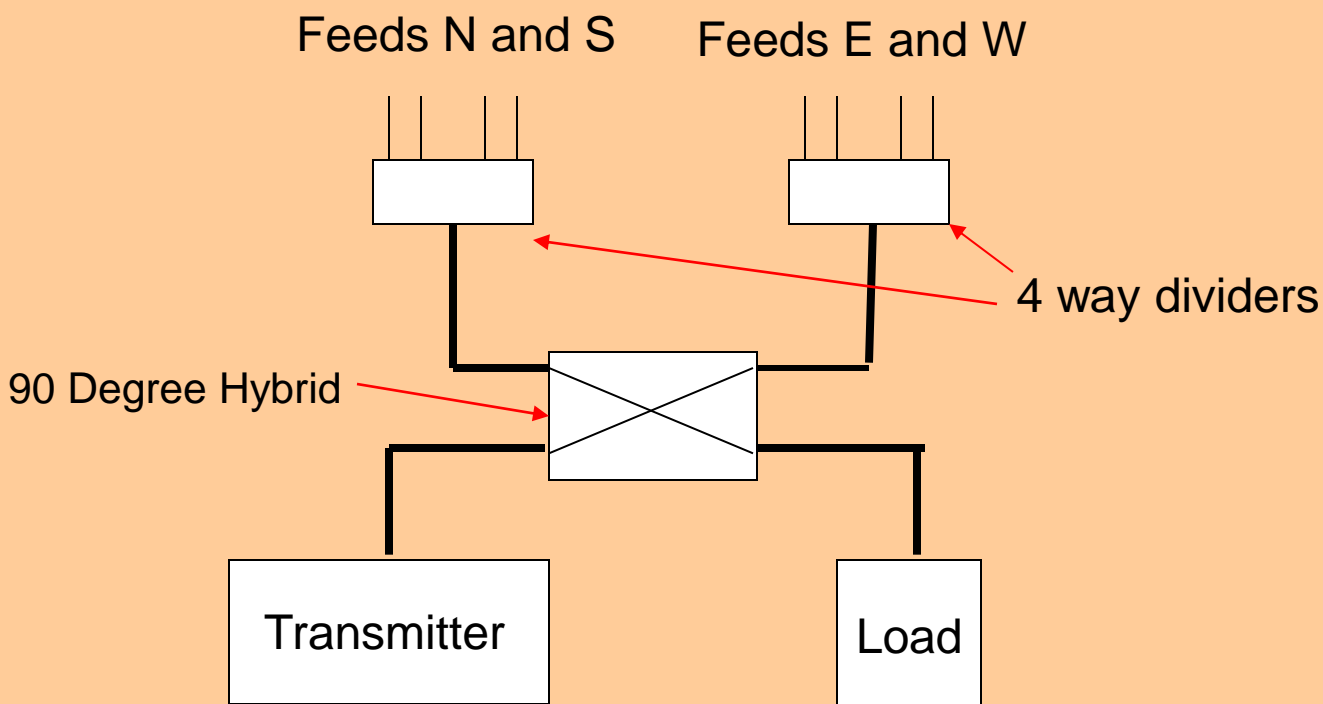
With the Spectrum Re-Pack, there has been more interest in stations moving to low band VHF. Those stations have started to ask about transmitting antennas, and what options are available to go to C/P.

We are introducing our newest antenna line, the LB Series. The Micronetixx LB Series is a top mounted antenna, that comes in 2, 3, and 4 bay configurations for low-band VHF. The antenna consists of a galvanized monopole holding mounted elements, a power divider and feed system, and large low-Q stainless steel elements.



**Two Bay Lindenblad**

The antenna uses a single feed, usually either a 3-1/8" or 6-1/8" EIA flanged input, depending on what line is installed on the tower. The RF input to the antenna is a 90 degree hybrid. That hybrid then feeds two equal power dividers, which in turn, feed the individual elements. The elements are fed in phase-quadrature relative to one another. The opposing elements are slant mounted at 30 degree angles to one another. Below is a schematic of a 2 bay (eight element) Lindenblad antenna.



With the Lindenblad Antenna being a branch fed antenna there is no differential group delay associated with the antenna – another plus for ATSC 3.0 operation!

These antennas at Low Band VHF are large. The elements are  $\frac{1}{2}$  wave long, and so a channel 2 Lindenblad element is approximately 104 inches in length.

The bays are spaced one wavelength apart, so for a Channel 2 Antenna that is about 207 inches. The elements are mounted to a support monopole, typically 12 to 16 inches in diameter. This monopole can be either flange or bury mounted. To help a C/P antenna launch an optimum signal profile, the bottom elements should be a minimum of a half wave length from the tower top. If there is a large structure such as an ice shield, the bottom element tips should be at least a wavelength above it. This will help the antenna produce a very omni-directional signal and maintain excellent H to V ratios over the channel.

How many bays are optimal? If the transmitter power is available, a two-bay antenna is an excellent choice. Its elevation pattern does an superb job in coverage at all depression angles. Also if you are replacing a top mounted UHF slot antenna, the loads presented by the Lindenblad are often lower.

The gain of a single Lindenblad bay is 0.49 (-3.10 dB). A two bay model has a gain of 1.00 (0.00 dB), a 3 bay model 1.50 (1.76 dB), and a 4 bay model 2.00 (3.01 dB). The input power rating is determined by the input power divider and feeder cable design. Input power ratings of 25 to 40 kW are normal. Finally, the Lindenblad elements are all at DC ground to ensure the best immunity from lightning.

If your station is moving to Low Band VHF, a Lindenblad is not much more expensive than a Batwing style antenna. Having a circularly-polarized signal can also increase received signal levels by up to 20 dB more than H-Pol only.



## Teaching an Old Antenna New Tricks



Most high band TV stations use batwing-style antennas. It is a design old enough to collect social security! Many of the antennas now in service are over 40 years old. As stations now on VHF look at replacing their current antennas, along with stations moving to VHF, the batwing antenna is worth taking a look at.

Micronetixx has taught the batwing a few new tricks. But first let's go over some of the basics of the design.

The batwing antenna has four elements per bay. The elements are fed in phase-quadrature relative to one another. On each opposing pair of elements, one side is fed with the center conductor of the feed line attached to the element. On the opposing element the ground of the feed line is connected to the element, (180° phase-related).

All of the Batwing elements are DC-grounded to the support pylon at both ends of the elements themselves, providing superb protection against lightning strikes.

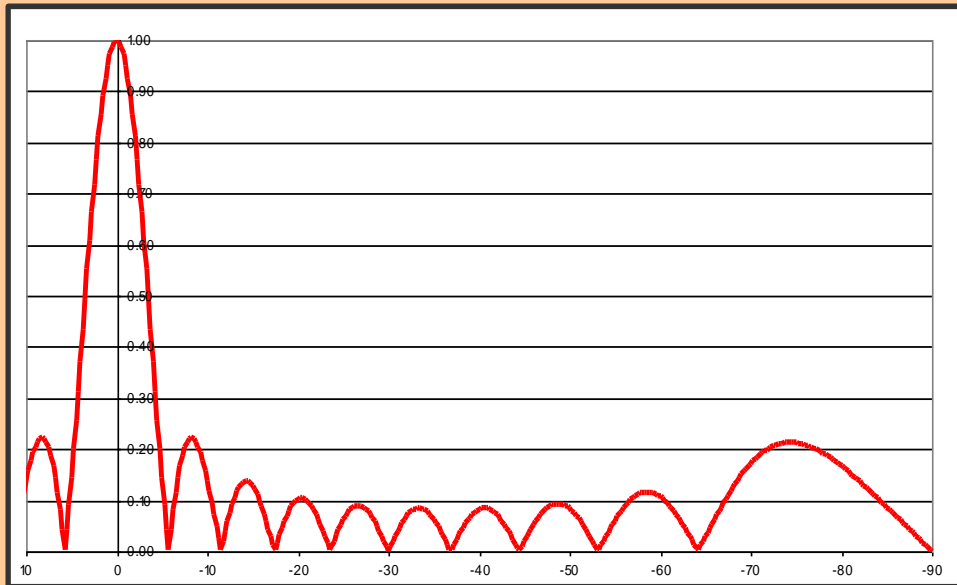


The rectangular area between the inside edge of the element and the support pylon is excited with RF energy, which makes the element radiate. The impedance of the antenna is set by the distance of the support pylon to the inside edge of the element. The typical impedance is 75 to 77 Ohms. The feed harness for the antenna pictured has not yet been installed.

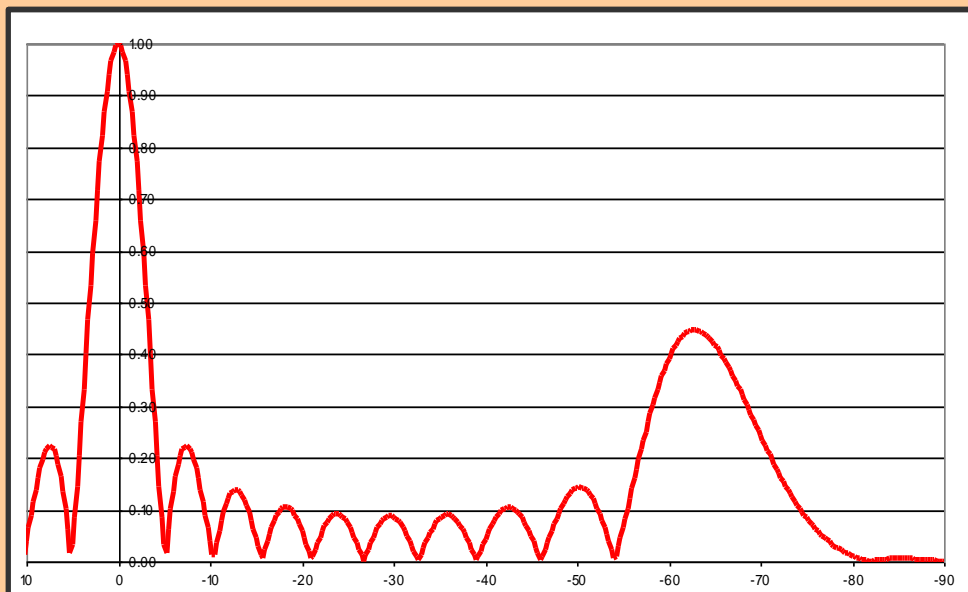
Let's look at an off the shelf batwing antenna. For a high-band model the elements are built to resonate about 5% lower in frequency than channel 7 (174 to 180 MHz). Inter bay spacing of the elements is set for about one Wavelength at channel 7 as well.

The Batwing Antenna does a good job of covering channel 7 (174 to 180 MHz) to channel 13 (210 to 216 MHz). The antenna does produce a good Omni-directional pattern over the band. The minima or lowest percentage of peak field is around 80%. So what about the elevation pattern? Since the antenna is set at a 1 wavelength, (360 degree), spacing at channel 7, going up in frequency, the spacing between bays is more than 1 wavelength. On the next page we will plot the Batwing elevation pattern at two frequencies.

The Batwing Antenna does a good job of covering channel 7 (174 to 180 MHz) to channel 13 (210 to 216 MHz). At channel 7 the elevation pattern of a 10-bay batwing antenna would look like the plot below. (We did not add any beam tilt or null fill to these example patterns.)



The plot below is the same 10-bay antenna, operating at channel 11. The spacing at channel 11 (198 – 204 MHz) is more than the  $1\lambda$  spacing, used at channel 7.



The gain of the Batwing Antenna at channel 7 is about 10.5 (or 10.21 dB), while the gain at channel 11 is about 9.5 (or 9.77 dB). The increased spacing between bays and the formation of the large grazing lobes decreases the array gain.

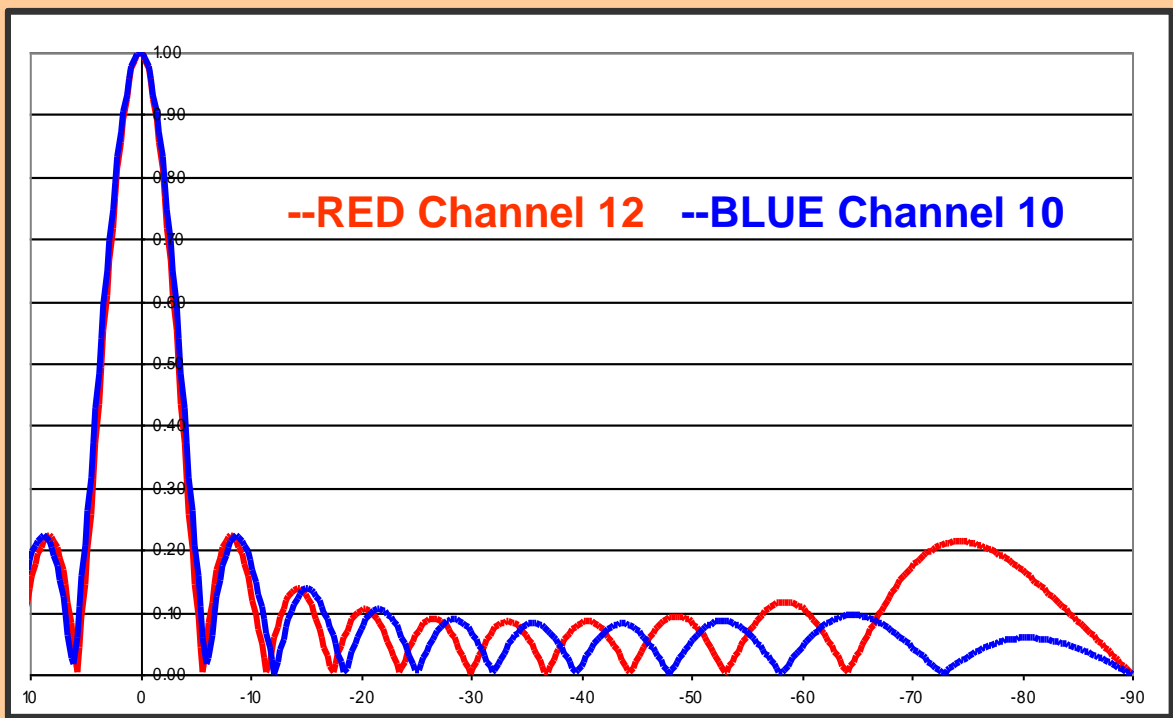
## **An Improved Batwing Antenna:**

So how do you improve a 60+ year-old technology? Let's look at a case where a channels 10 and 12 wish to share a common antenna. The antenna needs to have a gain of 9 to 10 to achieve licensed ERP with the transmitter they intend to use. Power handling is not an issue with the batwing design as the size of the feed system, and power divider rating is the limiting factor.

We could provide this pair of stations an off the shelf channel 7 to 13 design. Its length would be 62-1/2 feet, (19.1 meters).

Since the antenna would only be used on channels 10 and 12, we then scale the antenna for those two channels. The batwing elements would be built to resonate slightly below channel 10. For spacing, we would space the bays at  $1\lambda$  on channel 12. The spacing at channel 10 would be less, (about  $0.94\lambda$  or 339 electrical degrees). The gain at both channels would be close to 10.5. The main beam shape on both channels is nearly identical as well. With the closer bay-to-bay spacing the new antenna is 7-1/4 feet, (2.21 meters), shorter than the off-the-shelf antenna design, providing superb operation along with a significantly-reduced weight and wind load signature.

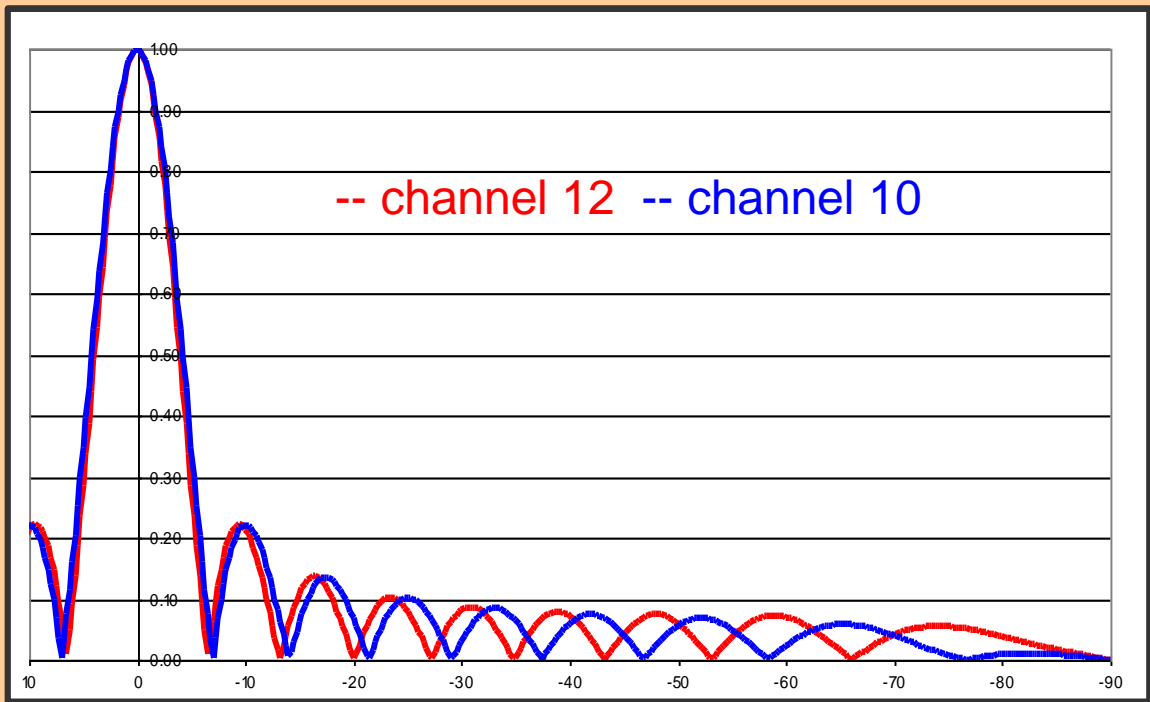
Plotted on the next page are elevation patterns of the  $360^\circ$  spaced array, at channel 12, (and 339-degree spacing at channel 10). The main beams are very similar, with the channel 10 pattern being slightly more broad below -2 degrees of depression angle. The high angle grazing lobe decreases to about 6% of relative field on channel 10, due to the wave fronts not adding in half wave increments.



Now let's shorten up the antenna even more. We will space the antenna at  $7/8\lambda$  (or 315 degrees) on channel 12. The spacing will reduce to  $0.82\lambda$  (296 degrees) on channel 10. This antenna will be  $13-7/8$  feet (4.22 meters) shorter than the stock channel 7 to 13 design. The elevation gain has dropped slightly to about 10 (10.00 dB) on channel 12 and 9.6 (9.82 dB) on channel 10. The off-the-shelf 10 bay batwing has a gain of about 9.7 (9.86 dB) on channel 10.

The main beam profiles are almost identical, with the channel 10 pattern being a percent or two wider. In addition to being a much shorter and lighter antenna, the high angle grazing lobes are gone. The antenna produces less than 10% of field from -25 to -90 degree depression angles. If your site is located on a short tower, the RFR footprint will be up to 15 dB lower. The elevation patterns for this antenna are presented on the next page.





Now we know that an old antenna technology can be “Taught New Tricks”. The scaled batwing antenna is shorter and lighter, and has superb elevation patterns on both channels. If you’re contemplating a move to VHF or want an upgrade from your decades-old antenna, give us a call. We will design a system that will totally optimize your coverage.

## VHF Does Not Work? ...Let’s Look at Why



Some of our DTV antenna customers are looking ahead at the possibility that they may need to move to high-band VHF after the Spectrum Re-Pack. Some have heard horror stories about the loss of coverage when stations went from analog to digital. While the poor coverage of high-band VHF seems to be the main story, are there success stories out there? Let’s look at a problem story first...

In the good old days of analog TV many high band stations were given a licensed power of 316 kW or 25 dBk. Many of these stations used a 12 bay antenna and a transmitter with a 30 to 35 kW power rating.

Depending on the station tower height and the type of receive antenna that the viewer had, a viewable range of up to 100 miles was not that uncommon. We then entered the digital era, allocated power levels for high band DTV stations were often lowered by a factor of 10 or more.

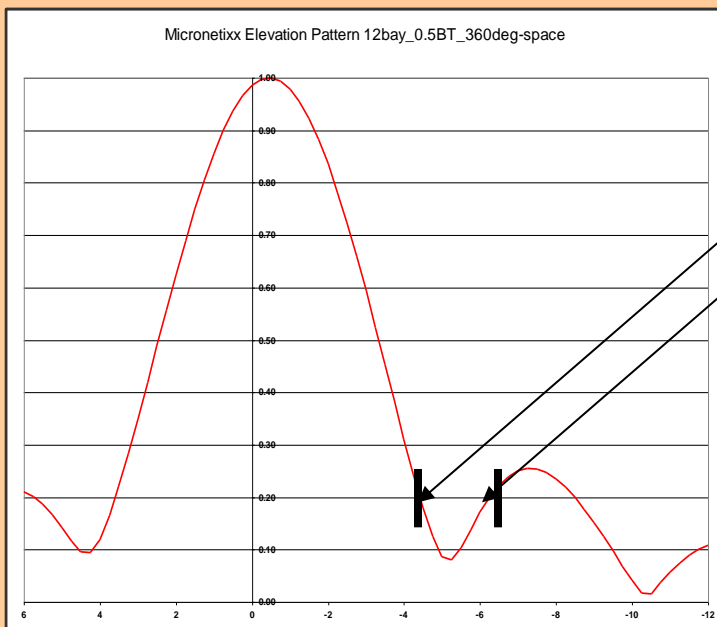
Those viewers who were getting just OK reception in analog with an indoor antenna, now faced the “blue screen of death” with their set top boxes. Getting rid of the old rabbit ears and buying a “hopped-up” UHF-only indoor antenna did not solve the problem either. Those antennas could offer up to 10 dB of loss or more as compared to rabbit ears.

Moving into a new house in many cases made things worse for those who wanted to get high band TV stations with an indoor antenna. Many new homes have low-E glass windows that use a sputtered metal coating to raise reflection of heat (and DTV signals too!). Between these windows and modern insulation that has a thin metal barrier, the signal loss inside the house increased. What was transmitted as an H-pol signal might arrive as a V-Pol signal at the receive antenna. And that polarization might change, depending on how many or where people were in the viewing room. Back in the analog days there were tons of Radio Shack VU-90 antennas mounted on roof tops. Those antennas at high band had about 3 to 4 dB of gain and an 8 to 10 dB front-to-back ratio.

People then turned to cable and satellite. Many of the old TV antennas were either removed or fell from storms. Most people today, if asked about what the antenna on the roof does, could not give a correct answer.

As broadcasters there are some things we can do to help solve many of the reception problems listed above. In planning a new high-band VHF facility, the antenna system can certainly be designed to provide maximum coverage, helping to obtain optimum satisfaction of the viewers.

Let's look at one high-band DTV station that had significant viewer issues following their conversion. The station was given a post-transition 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.



Core of the city is between these depression angles

12 Bay antenna, 6 to -12 degree plot

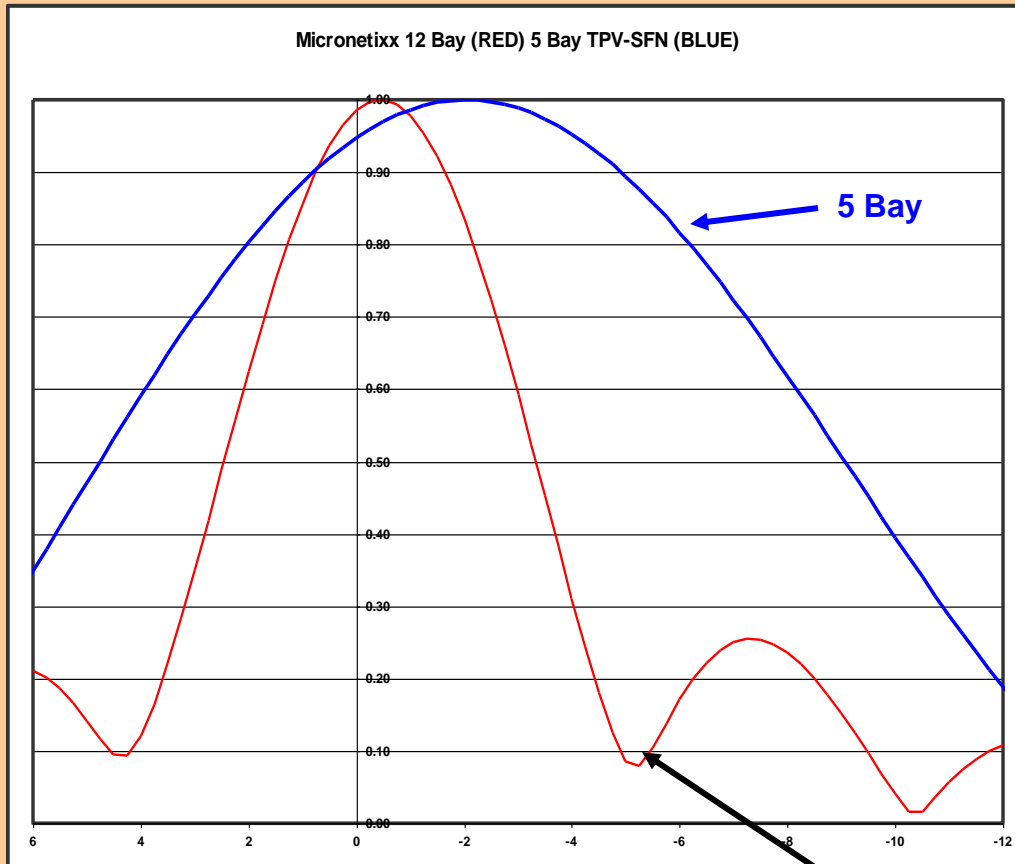
The areas that were effected the most were in the city center at depression of between -4.5 and -6.25 degrees. The first null of the antenna is at -5.25 degrees and has a relative field value of only 8%. That translates to an effective ERP at this angle of only 57.6 Watts. Over the area that lies between -4.5 and -6.25 degrees, the effective ERP is no more than 291 Watts. In the analog days the ERP would have been as high as 10.23 kW – a signal loss of over 15 dB. With the attenuation of building materials in homes and less than unity gain receiving antennas, it is easy to see what the problem is. Worse, with the Re-Pack, the station will not get a power increase.

So here we are in 2016, and with a new digital standard that will likely change how video and data are sent. Since the reception model has changed (and will change more with time), the transmission model needs to be changed as well.

There are two things we have learned in supplying VHF antennas. One is to use elliptical or circular polarization. Dollar for dollar that is the best investment a station can make. The second is to go with a low gain transmitting antenna. The higher HAAT or urban locations really benefit.

We took a closer look at the 12-bay antenna performance and what was causing the reception issues. The station has just handed us the keys and said “get us the best reception possible”. On the next page we will make a few antenna comparisons.

So let's experiment: We will consider the elevation pattern of the old 12-bay antenna. Doing some back of the envelope calculations, we will shoot for a raw elevation gain of 6 for the new antenna. Our 5-bay **TPV-SFN** will provide a gain of about 6.2. We want the antenna to produce about 95% of peak field at the horizon. The SFN Array along with 2.0 degrees of beam tilt is the answer !



The city center that was in the null down at -5.25 degrees, now gets 87% of peak relative field. The ERP went from 57.6 Watts to 6.9 kW, just over a 20 dB improvement. Field levels at other depression angles average over 10 dB higher signal strength. On the next page we'll look at how much transmitter power is needed to make this work. The numbers will surprise you !



The station uses 1150 feet of EIA line, with an efficiency of 83.08%. The current 12-bay antenna has a gain of 12.0, (or about 10.8 dB). To get a 9 kW ERP requires a TPO of 900 Watts. The new 5-bay antenna has a gain of 6.2, (or 7.9 dB). To make 9 kW ERP now takes a TPO of 1.75 kW.

Adding elliptical polarization is the final icing on the cake. We have found a 70/30 power split work very well. Divide 30 by 70 and the result is 0.428. Add 1.00 to that (=1.428). Then multiply 1.428 by the H-POL only TPO of 1.75 kW. The result is a new TPO 2.50 kW.

The current antenna has a weight of 9100 pounds, a wind load of 115 square feet and is 74 feet long. The new 5 bay Micronetixx **TPV-SFN** antenna weighs 4400 pounds, has a wind load of 81 square feet and is just over 30 feet long.

The added elliptical component will ensure the best coverage for your viewers. Between the 10 dB average improvement in signal level from the lower gain elevation pattern and up to 20 dB more signal from the vertical component (much lower cross polarization losses), the lower gain new antenna will provide superb coverage.

If you would like to compare elevation patterns of varying antennas to evaluate your station, our on-line antenna engineering program, Micronetixx's **AntennaSelect™** Antenna Design Program is available free of charge. Click: [www.antennaselect.com](http://www.antennaselect.com). Also, see page 82 in this Guide for more information on Micronetixx **AntennaSelect™**.



With the spectrum Re-Pack not too far down the road, a question arises; How big will the new antenna be? Still, with the unknowns of a band clearing plan and new channel assignments, the answers are still not there. So let's look at a few cases or "what ifs", and demonstrate how to do some basic antenna length calculations.

Let's look at a station that is on channel 41, using a side mounted 24-bay UHF slot antenna. We will use our mechanical data to start with. Other manufacturers' data may vary by a foot or two depending on the feed system and antenna technology they use.

Our channel 41 antenna comes in at 41.8 feet long and is center-fed. Looking ahead, channel 27 looks like a possibility. With standard slot antennas the bay-to-bay spacing is one wavelength. At channel 41 the spacing is 18.76 inches, (11803/641 MHz). Therefore, 23 bay to bay spacings times 18.76 inches works out to be just under 36 feet. Add another 5-1/2 feet for the center feed point, and extra spacing past the end slots, and the answer is very close to the 41.8 feet in the engineering database.

So we now calculate the length of the channel 27 antenna. The wavelength of channel 27 is 21.42 inches (11803/551 MHz). Multiply that by 23, and the answer is 41 feet. Add in the additional 5-1/2 feet for extra spacing, and the total length of the antenna is about 46.7 feet.

So looking at the tower drawing, there is not 45 feet plus of free space where the old antenna is. (Murphy's law is alive and well!) So if we went to a smaller antenna – let's say a 22-bay, how long would the antenna be? Since we are dropping two bays we would take 2 times 21.42 inches (the wavelength at channel 27). So the answer is 42.84 inches. Subtract that from the 46.7 feet and the new antenna is just over 43 feet long. It fits in the free space!

Now what did we lose in gain? The elevation gain of slot antennas ranges from 1.0 per bay to about 1.05 per bay, depending on beam tilt and null fill selection. So using 1.03 per bay as a reference, the 24-bay antenna has an elevation gain of 24.72 (13.93 dB), while the 22-bay antenna will have a gain of 22.66 (13.55 dB).

Project 2 - Let's consider one of our small end fed antennas. At channel 27, an 8-bay antenna is 16-/12 feet long (7 bay to bay spacings, plus 48 inches). (We build these antennas in 1-bay increments.) To figure the length of these antennas, add or subtract the wavelength (at channel 27; 21.42 inches), for each bay changed. A 7-bay antenna would be 14.8 feet long, while a larger 11 bay antenna would be 21.8 feet long. The same average gain applies to these antennas. If you are coming up tight on space and a little low in gain, our **SFN** Antennas in the previous article may be your answer. They have an elevation gain per bay of 1.10 to 1.15. A 7-bay standard antenna would have an elevation gain of about 7.21 (8.58 dB), while an **SFN** Antenna would have a gain of 7.84 (8.94 dB).

Need some numbers crunched? Give us a call and we will come up with some innovative ideas for the times ahead.

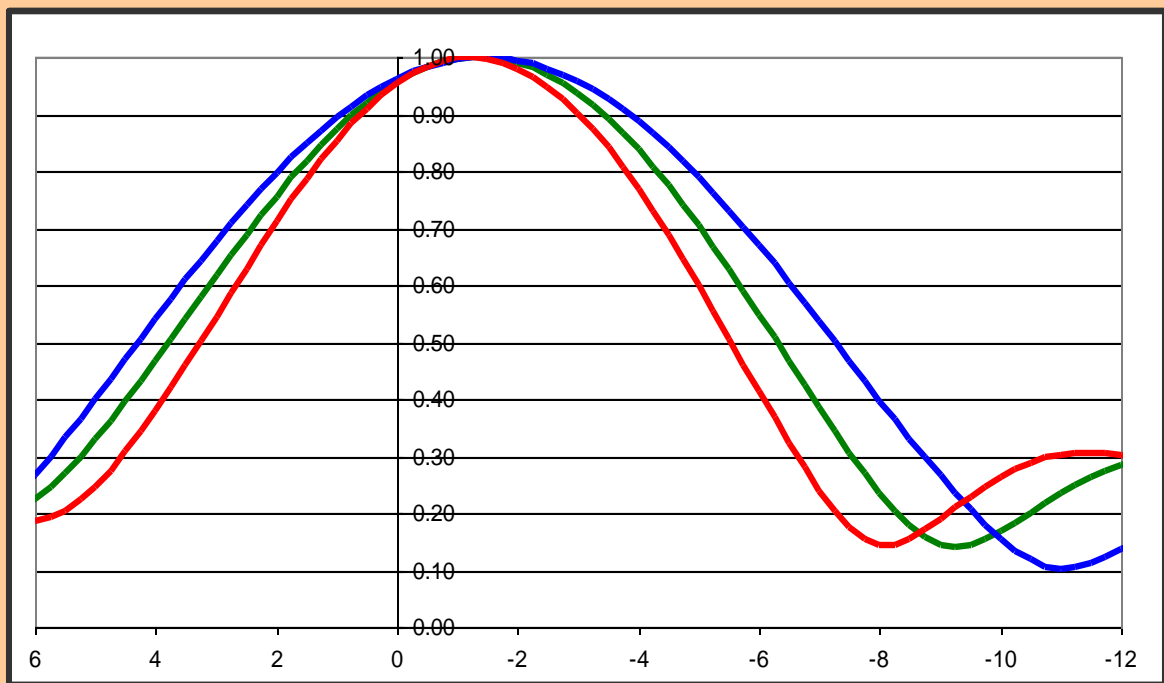


Back many years ago when a peak analog ERP of 5 MW was a goal, the largest transmitter would get married to the longest and highest gain antenna. The pencil thin main beam would head to the radio horizon. Almost everyone had an outdoor antenna, so this model worked well. The real winner in this model was the electric company! On page 16, we looked at a problem that a VHF station had, and solved the problem with both a lower gain antenna and also adding Elliptical Polarization.

With the next generation of broadcasting, the old model of a viewer in a fixed location decreases quickly. The TV signal needs to be where the viewers are and where they are going.

So let's look at a few examples: The first one we'll consider is a Class A station, 1000 feet above the valley floor and 5 miles from the city center. The cable heads for the region are up to 40 miles away from the station. There is minimal population to the rear of the transmitter site. So for the first cut, we'll go with a broad cardioid pattern, with an azimuth gain of 1.92 (2.83 dB). We will need 100 feet of transmission line, and will go with 1-5/8" foam flex line with an efficiency of 89.74%. We'll use Elliptical Polarization with a 70/30 power split. The total power transmitted then becomes 21.43 kW ( $30 \div 70 + 1.00$ , times 15 kW H-Pol). Let's look at a few elevation patterns and compare the results.

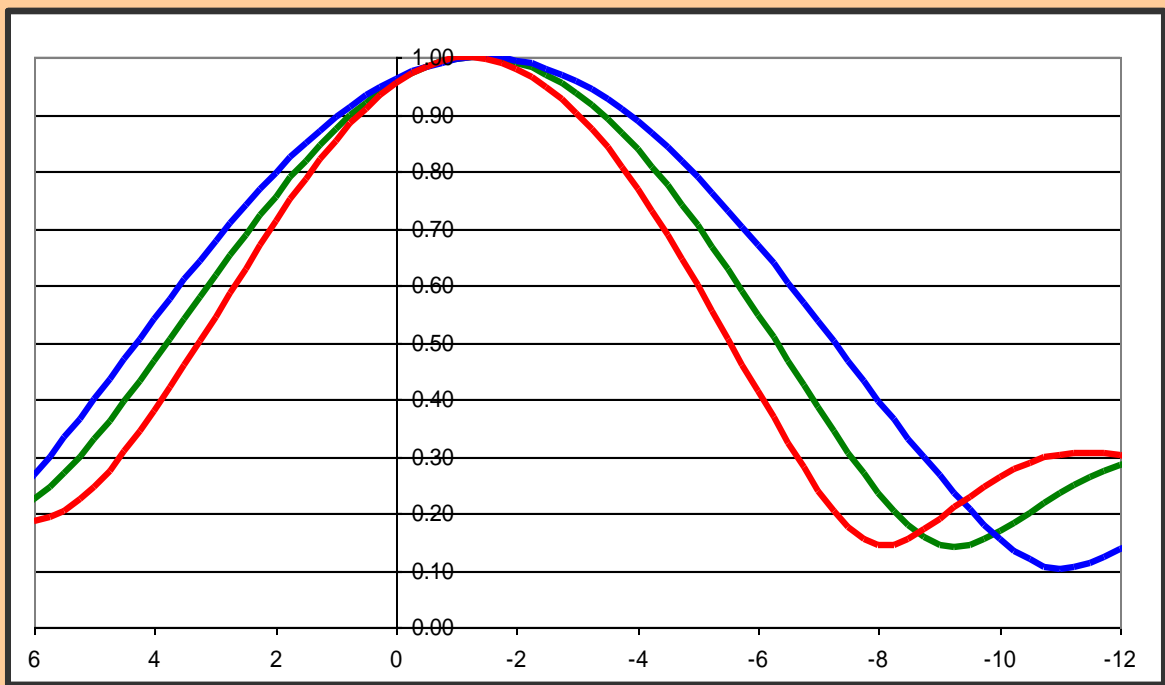
The core of the city is between a depression angle of -1.75 and -2.25 degrees. Closer in locations are at higher depression angles and farther away locations are at lower depression angles. There are 3 elevation patterns plotted below, all using electrical beam tilt. The red plot is an 8-bay antenna with a 1.25 degree tilt, the green plot is a 7-bay with a 1.25 degree beam tilt, and the blue plot is a 6-bay with a 1.5 degree beam tilt.



So which elevation pattern would work out the best in this case? We used a 2 kW transmitter as a model and all three would work power-wise.

All three patterns provide excellent coverage over the core of the city, with almost 100% of peak field. Past the downtown core, coverage would also be excellent out to the radio horizon, which is at 95% of peak field.

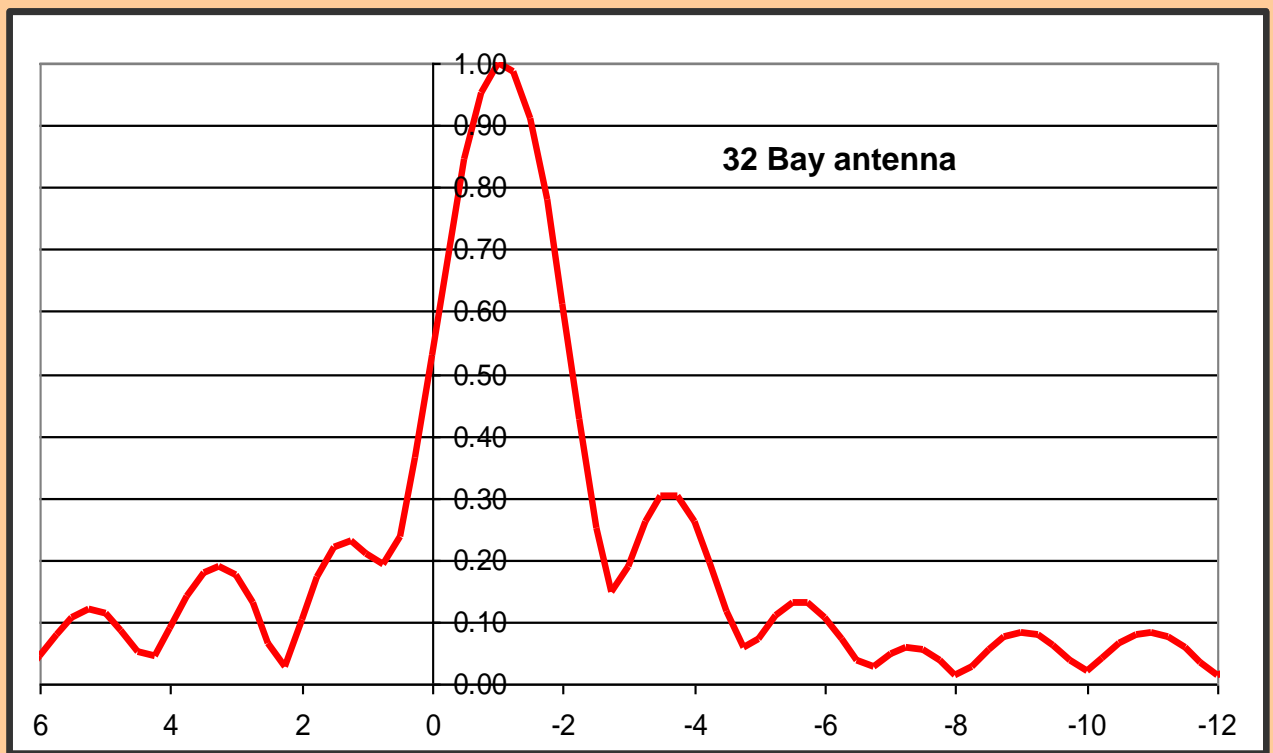




The transmitter site is on top of a mountain. If there is population close to the base of the mountain, (let's say in the -6 to -10 degree depression angle range), the 6-bay wins out. At -8 degrees the 8-bay antenna would be putting out an effective ERP of only 306 Watts, while the 6-bay model would deliver an ERP of 2.37 kW – almost a 9 dB increase in signal.

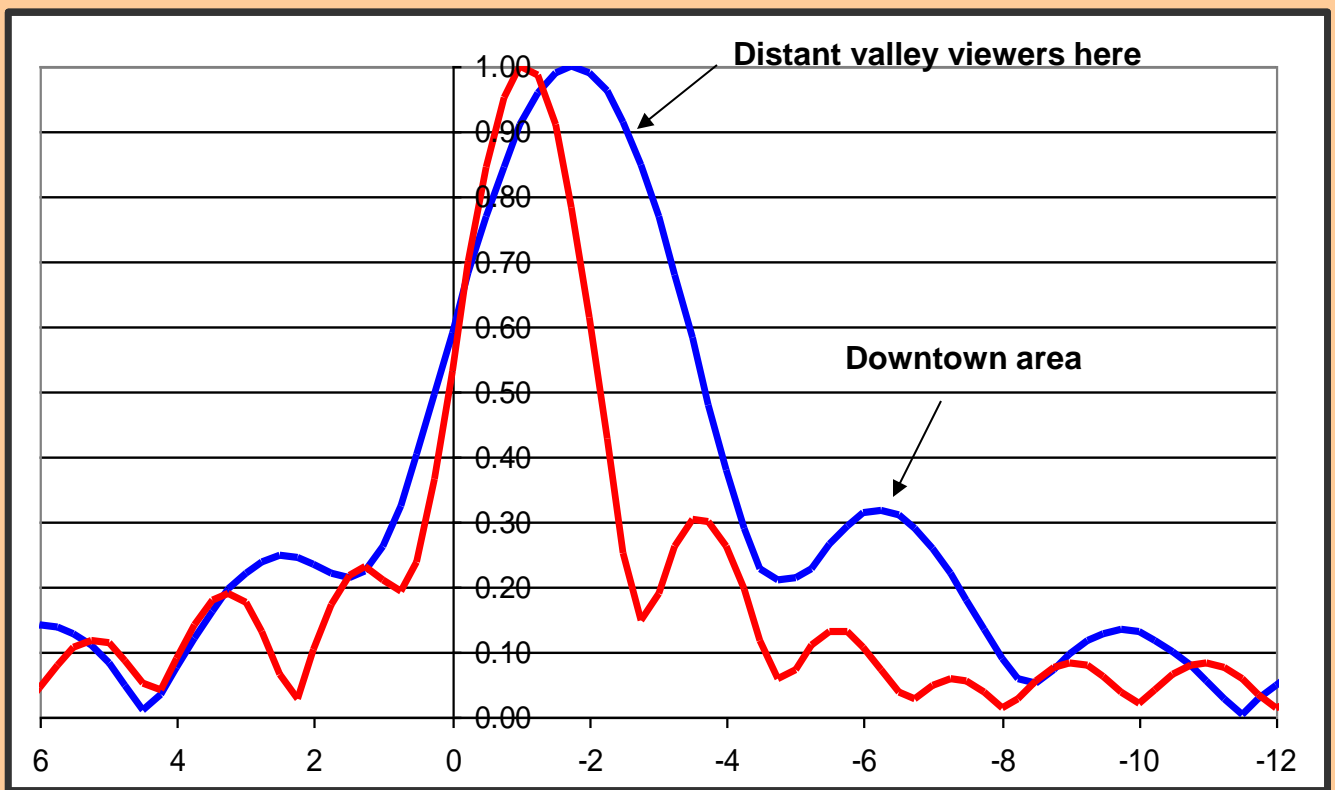
### **A Megawatt on a Mountain...**

Back in the early years of the DTV build out the main focus was building out to full power. In one station's case this meant a dual cabinet transmitter and a 32-bay antenna. Taking another look at the station today, more than half of the signal is wasted going in places where the population is simply not there. The station sits nearly 7500 feet above sea level. You can seemingly see forever from the transmitter site!



The coverage in the valley even with 1000 kW is not great. The farthest population in the valley is 18 miles away (-2.5 degrees down) and the effective ERP is only 63 kW there. In the downtown core area (between -5.75 and -7.0 degrees), the average ERP is just 10 kW.

Doing some back-of-the-envelope math, we have enough transmitter power to go down to an antenna with an elevation gain of 20. Micronetixx **SFN** Antenna Family is an excellent choice as it has a higher unit elevation gain. That will let us use an 18-bay model. There are two problem areas; One is getting as close as possible peak signal out to the fringe areas of the valley. So that means increasing the beam tilt so that the signal is at a maximum around -2.5 degrees. We also want to increase the signal level around the downtown area.



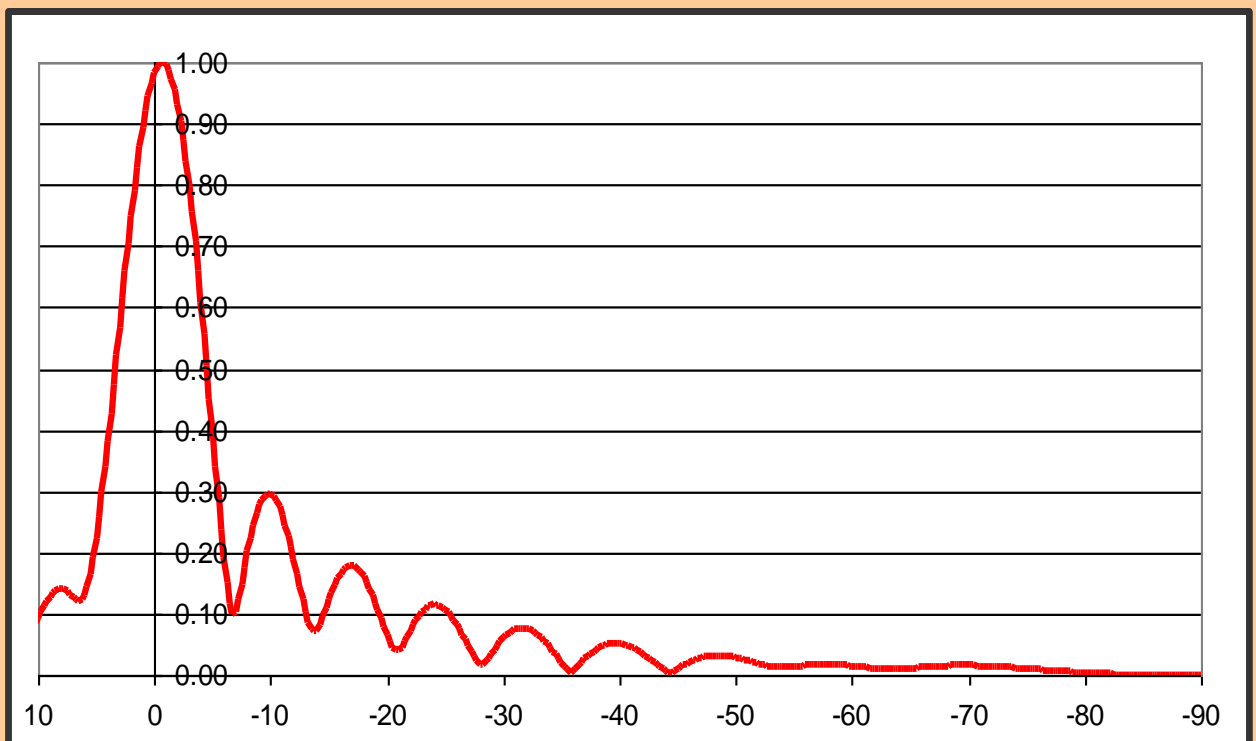
The plot above shows the old 32 bay antenna (**RED**), versus the proposed 18 bay antenna (**BLUE**). The 18-bay antenna produces an ERP of 837 kW at -2.5 degrees. This is an 11.2 dB signal improvement from the old antenna. Now for downtown, the new antenna will help out tremendously, as the average ERP goes from 10 to 90 kW – a 9.5 dB average signal increase!

If even more signal was needed downtown, consider dropping the ERP of the station to maybe 500 kW and going with a smaller bay-count antenna. You would want an antenna whose main lobe covered downtown. The beam tilt would be increased as well. For the signal near the horizon, even having 150 to 200 KW is enough to feed distant cable heads and translators. And if there is spare transmitter power, adding even a little vertical component will help.

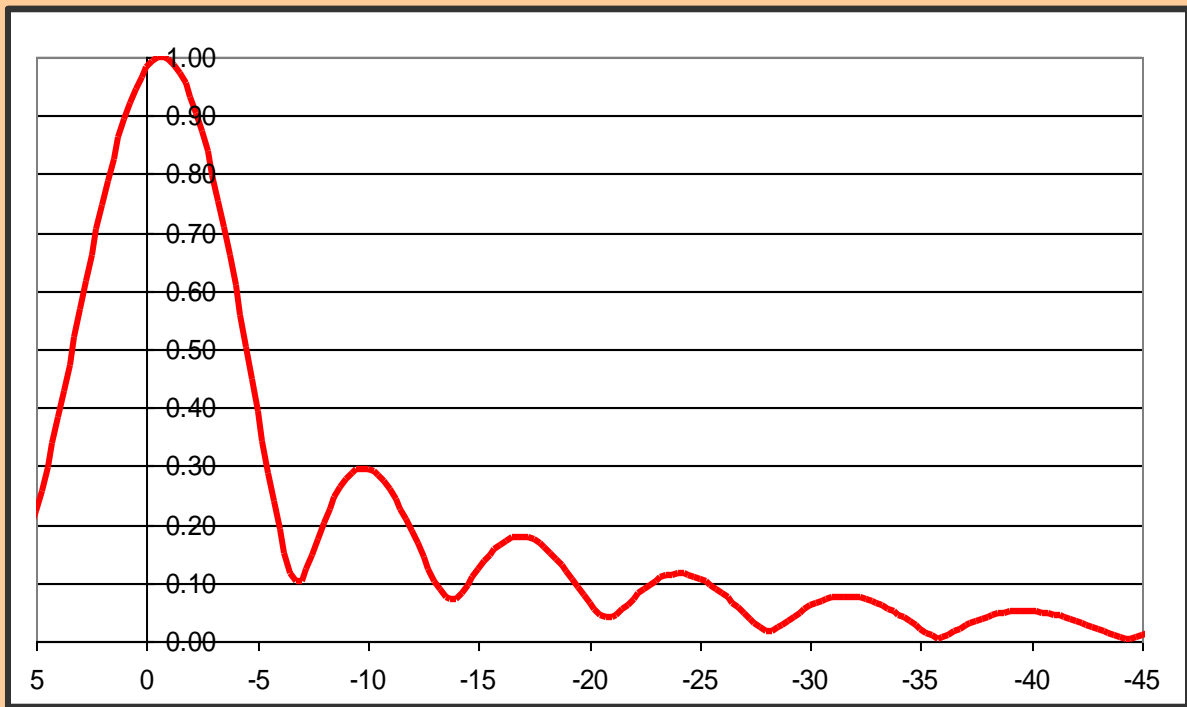
## A Downtown DTV Transmitter Site

This station is located downtown, a roof-mounted antenna on the tallest building in the city. The ERP will be 75 kW and the antenna will be 450 feet above the street. The terrain is fairly flat. A 10 kW transmitter will be used for the modeling, with a short run of 3 inch air flex cable with an efficiency of 92%. With those numbers the antenna would need to have a minimum elevation gain of 8.1 to make the full ERP. Since we do want to add a vertical component, let's add another 25% antenna gain. So the minimum gain needed for adding 25% Elliptical component is now 10.12.

We will model the project using a 9-bay antenna, with an elevation gain of 10.49. Since we are not that high off the ground, a beam tilt of -0.75 degree will work fine.



Since we are located in the center of the city, let's consider how much signal is going where:



From the radio horizon to 1-1/2 miles from the transmitter site, the antenna provides 70 % of peak field (which is half power or 37.5 kW) or better. A ½ mile away is at a depression angle of -10 degrees, where there is 30% of peak field. At a quarter mile away, the depression angle is now -19 degrees. And finally 450 feet away from the site, the depression angle is -45 degrees.

With the antenna producing at least 5% of peak field down to -27 degrees (just 875 feet away), coverage will be very solid, with an ERP of 187 Watts hitting the ground. The magic here is our half-wave spaced **SFN Series** of antennas. We can taper the elevation pattern to produce excellent coverage in an urban market.



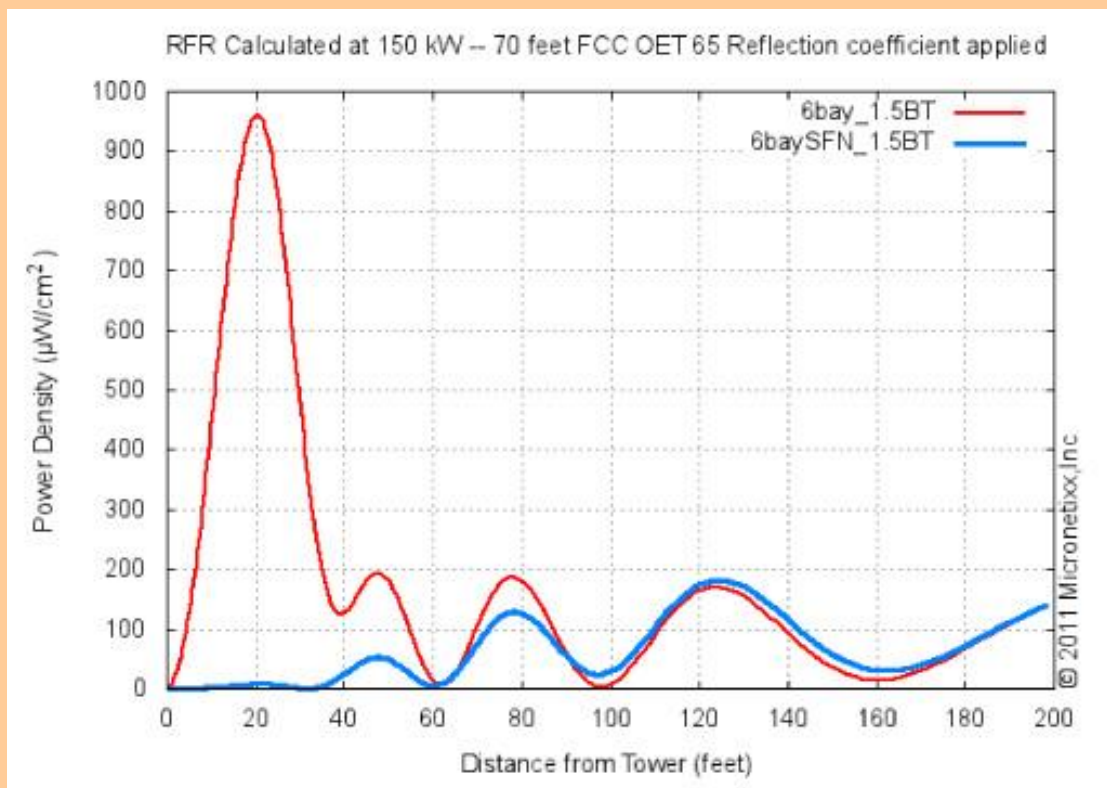
Many communications sites are full or nearly full. “Tower” is a four letter word that can bring out the pitchforks when permission to build a new one is sought. With the Spectrum Re-Pack, optimal tower space may be at a premium. In some cases stations going from UHF to VHF will need more vertical real estate to mount a longer antenna. Stations on the higher end of the current UHF band may find themselves on the low end of the band, and needing more vertical space. The available real estate may be farther down the tower or closer to the roof of a building.

This sets up another problem - RF Radiation, (RFR), hitting the ground or a rooftop. An additional site user may push RF levels over the legal limit. And where will the “hot spots” be from the new antenna?

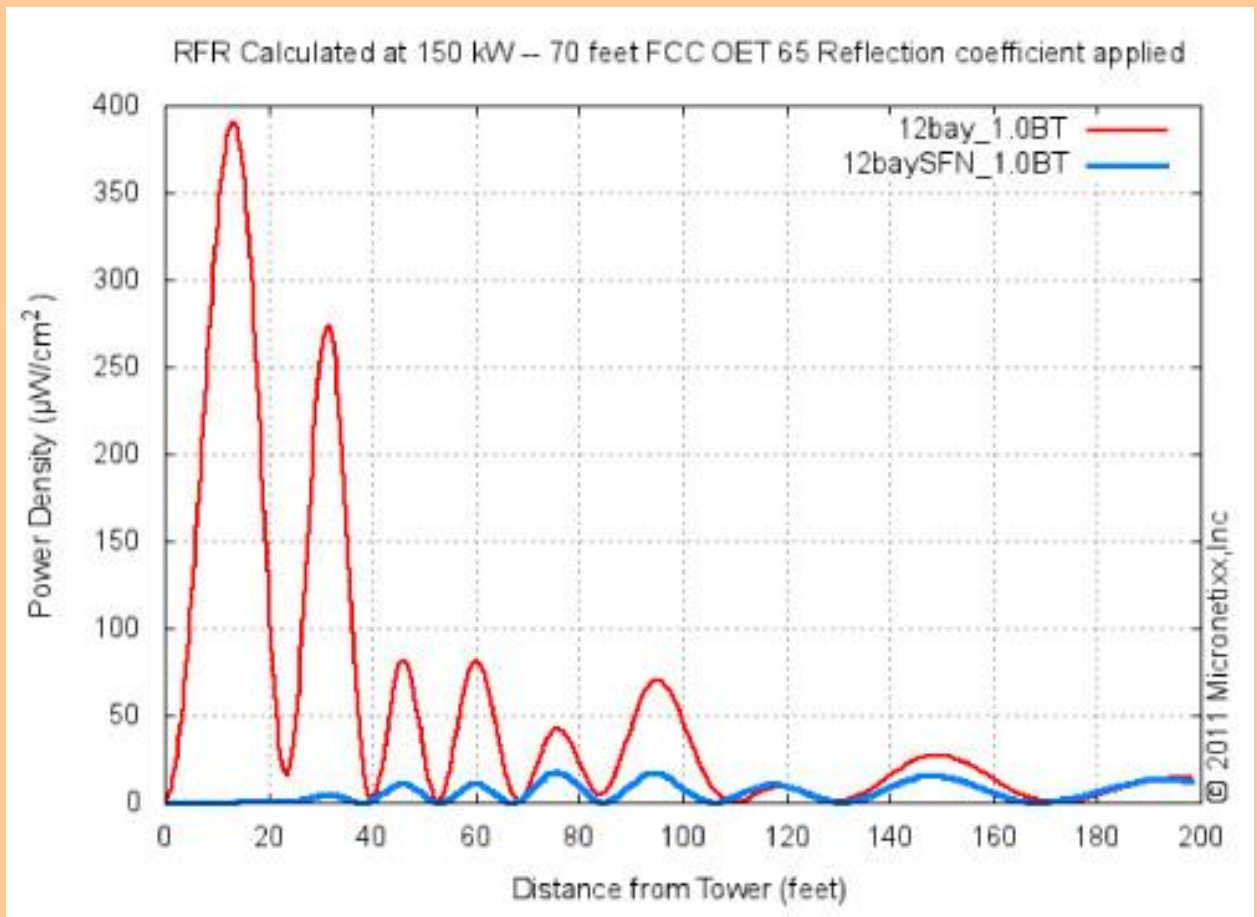
Micronetixx makes a family of slot antennas for both UHF and High-Band VHF, using what we call our **SFN** Technology in our lines of slotted pylon antennas. The technology reduces the high depression angle radiation up to 25 dB as compared to standard-spaced slot antennas.

We will take a look at several antennas, and model them for RFR levels using a tool in our on line antenna engineering program, **AntennaSelect™**. This tool will plot the distance and power density from RFR in a matter of seconds. We will discuss **AntennaSelect™** fully, starting on page 82.

So let's RFR-model a few antennas and see how much power density is going where. We'll look at a set of 6 bay, 12 and 18 bay elevation patterns, and compare standard spaced antennas along with Micronetixx's **SFN** Technology Antennas. We will use channel 20, with an ERP of 150 kW, center of radiation of 70 feet above ground and a reflection coefficient of 1.6 . RF density levels, (below), are plotted at two meters above ground.

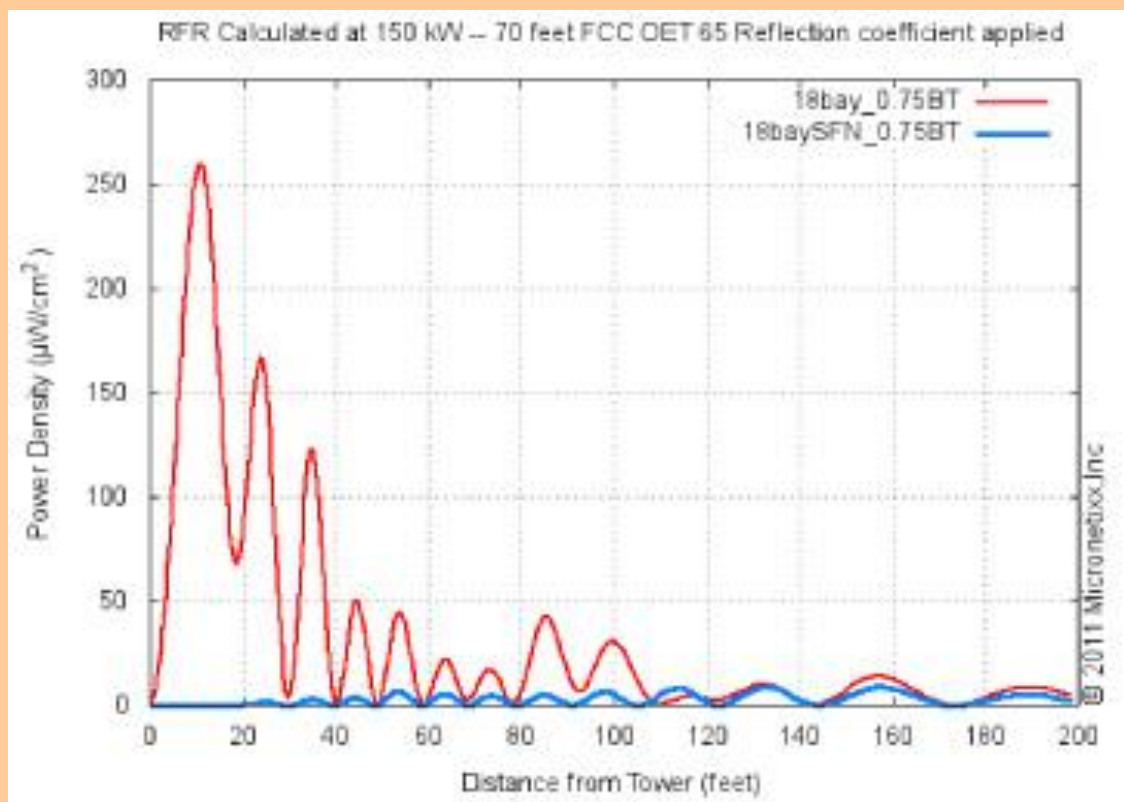


The maximum power density is about 4 times the legal Maximum Public Exposure, (MPE), limit using a standard-spaced antenna. The **SFN** Antenna produces only about 3% of MPE near the tower base! Normally you would not want to use a 6 bay antenna to get a 150 kW ERP – that would take about 27 kW or so of TPO. The large lobe is from the highest depression angle grazing lobe.

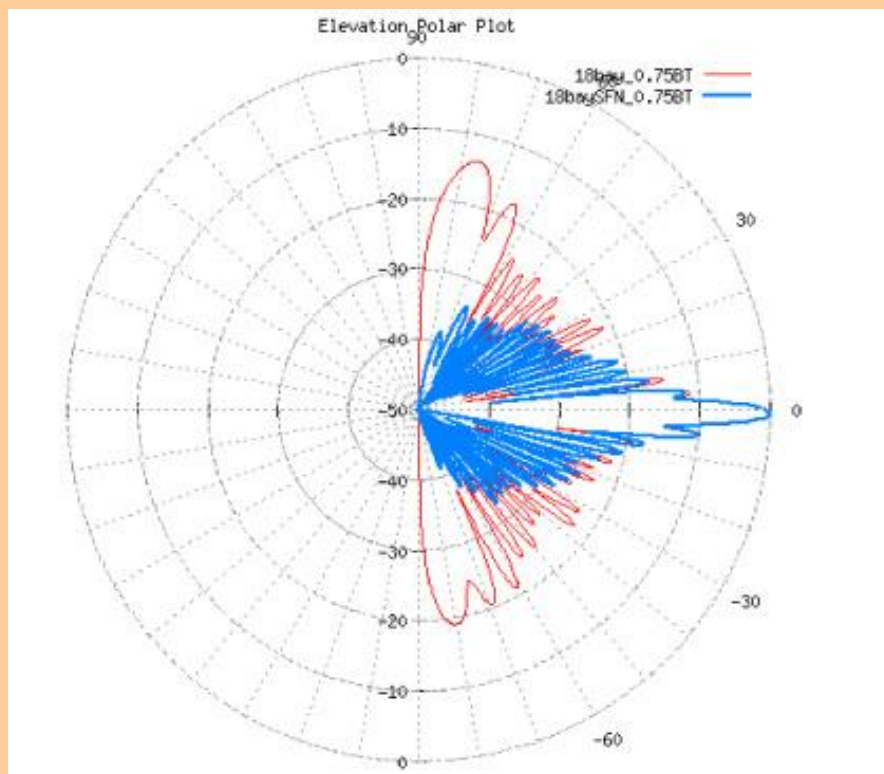


The 12-bay standard antenna has about half of the energy coming from the last grazing lobe. Even at that level it is over 100% of MPE. The 12-Bay **SFN** Antenna produces less than 5% of MPE within 200 feet of the tower base. Compare the width of the RFR hot spots with the 6-bay antenna on the previous page. As the bay-count increases, the RFR lobes become more narrow.

On the next page is the 18-bay antenna RFR comparison, plus a Polar plot of the elevation patterns. The polar plot will help you visualize at what depression angles the RFR lobes appear.



18-Bay RFR density plot of the two antennas



Polar plot of the two 18-bay antennas

The 18-bay standard antenna on the previous page produces about 80 percent of maximum MPE from its last grazing lobe, while the **SFN** Antenna produces just over 1% of MPE within 50 feet of the tower base.

The polar plot is a helpful tool to visualize the antenna's substantive radiation angles. Even with an 18-bay standard antenna there is a lot of wasted radiation above the radio horizon, (+ 30 to + 90 degrees), as well as below the radio horizon (30 to -90 degrees). The **SFN** Antenna design cancels out the high angle grazing lobes. There is very little difference in the main lobe of either antenna.

All of the plots for this article were taken from our antenna engineering tool, **AntennaSelect™**. You can see and learn more about it on page 82.

## **Some UHF Auxiliary Antenna Numbers**



Some stations will need auxiliary antennas to use to keep existing operations on line or broadcasting on a new channel, while new high power facilities are built. We have received a number of questions about cost-effective solutions for the transition. So let's take a look at some slot antenna designs and see what they can do.

Power handling of a slot antenna is first determined by the input RF flange size used on the antenna. Secondly, the design of the coupling structures and the diameter of the antenna pylon come into play. Let's run some numbers on the next page.



Here are some input flange sizes along with their power ratings. We have used a safety factor for all of the calculations. These numbers are for UHF.

7/8" EIA Input	1.5 kW
1-5/8" EIA Input	5 kW
3-1/8" EIA Input	12 kW
4-1/16" EIA input	25 kW
6-1/8 EIA Input	50 kW

Our most popular input connector size is a 3-1/8" EIA flange. That matches the 3" to 4" pylon diameter of most side mount UHF slot antennas.

The most cost-effective slot antenna is the Omnioid design. There are two ways to figure the azimuth gain of this antenna. First is an average gain of 1 (0.00 dB) or its peak directional gain of 1.7 (2.30 dB) . The design provides 100% of peak relative field over a 60 degree arc in the front and about 65% of peak field in the rear of the antenna. When filing with the FCC, the omnioid antenna can be filed as a directional or omni-directional antenna.

Taking an 8-bay slot antenna using an elevation gain of 8.51 (9.30 dB) and also using the peak gain of the Omnioid pattern gives us an overall peak gain of 14.45 (11.6 dB). With the 3-1/8" EIA input, the antenna could produce an ERP of 173 kW (22.39 dBk)\*.

**\* Using our [DX-2000](#) UHF slot antenna, with 12 kW Input.**



At channel 14 that antenna would be just under 19 feet long, weigh 135 lbs, and have a wind load area of 13-1/2 square feet. At channel 29 the antenna would be 16-1/2 feet long, weigh 115 lbs and have a wind load area of 11.5 square feet.

If we consider a 4-1/16" EIA antenna RF input, the maximum ERP from the 8 bay antenna would be 347 kW (25.4 dBk). That figure may be limited however, by the capacity of the transmission line being used. The weight of the antenna would increase by about 15 pounds and the wind load area would increase by about 2 square feet.

Now lets look at a true Omni-Directional slot antenna. This antenna uses 3 slots per level. Using the same 8-bay elevation pattern (gain of 8.2), the total gain of this antenna would be 8.2 (9.14 dB). So our 3-1/8" input antenna could produce a maximum ERP of 98.4 kW (19.9 dBk). The 4-1/16" model could produce a maximum ERP of 205 kW (23.1 dBk).

To get a true Omni-Directional pattern to develop properly, the diameter of the antenna pylon needs to be increased. This is due to the distance between the slots at the same level. If the radiating slots are placed too close together, it becomes difficult to control currents flowing on the pylon outside surface. A pylon diameter of 6 to 8 inches is needed, versus 3 inches for the Omnioid model. The true Omni-Directional antenna is more expensive due to the larger pylon diameter and three times the slot-count and couplers used compared to the Omnioid design.

The height of the Omni-directional antenna is the same as that of the Omnioid antenna. The weight and wind load area increase due to the larger-diameter pylon and a full wrap-around radome. The average weight of the Omni-directional model is about 200 lbs, with a wind load area of 16 to 18 square feet.

One other factor to consider when putting up a side mounted Omnioid or Omni-Directional antenna, is the use of a Micronetixx Four-Axis Fine Matcher. Antennas are tuned at the factory in free space. In special cases when ordered, a pattern study and tuning the antenna against a structure are done. Mounting these antennas close to tower members can cause them to de-tune slightly. The Four-Axis Fine Matcher lets the installer walk the antenna back to near perfect tuning, by counteracting the coupling the antenna has to the structure it is mounted to. The matchers are not expensive, and at UHF are only about 18 inches long and are built to the same input size of the antenna.

For the repack we have come out with an line of side mount UHF antennas. The **DX** series are 8 bay antennas and have an Omnioid pattern. Three power levels are available using a 3-1/8", 4-1/16", or 6-1/8 EIA input. The **DX-2000** (3-1/8") input can produce a maximum ERP of 173 kW. If the space you need to mount the antenna too is on a short tower or on a building rooftop, we have a low RFR version of the DX, with up to 17 dB less RFR at high depression angles available (exp. **DX-2000-LR**).

# DTV ERP Changes When Switching UHF Channels



For UHF channels that are at 38 and above, a new channel number will be assigned. Some stations that are currently on channel 36 or below will also be moving. Stations moving to a lower channel assignment will also have a lower ERP to match their coverage area. The FCC uses a simple formula to calculate the lower ERP.

$$41 - (20 \log_{10} (615 \text{ MHz}/F))$$

Where F is the frequency of the new channel assignment

New Repacked Channel		Percentage of ERP from Pre-Packed channel to new repack channel													
		Pre-Pack channel number													
		38	39	40	41	42	43	44	45	46	47	48	49	50	51
	MHz	617	623	629	635	641	647	653	659	665	671	677	683	689	695
14	473	77	76	75	74	74	73	72	72	71	70	70	69	69	68
15	479	78	77	76	75	75	74	73	73	72	71	71	70	70	69
16	485	79	78	77	76	76	75	74	74	73	72	72	71	70	70
17	491	80	79	78	77	77	76	75	75	74	73	73	72	71	71
18	497	81	80	79	78	78	77	76	75	75	74	73	73	72	72
19	503	82	81	80	79	78	78	77	76	76	75	74	74	73	72
20	509	82	82	81	80	79	79	78	77	77	76	75	75	74	73
21	515	83	83	82	81	80	80	79	78	77	77	76	75	75	74
22	521	84	84	83	82	81	81	80	79	78	78	77	76	76	75
23	527	85	85	84	83	82	81	81	80	79	79	78	77	76	76
24	533	86	86	85	84	83	82	82	81	80	79	79	78	77	77
25	539	87	87	86	85	84	83	83	82	81	80	80	79	78	78
26	545	88	87	87	86	85	84	83	83	82	81	81	80	79	78
27	551	89	88	88	87	86	85	84	84	83	82	81	81	80	79
28	557	90	89	89	88	87	86	85	85	84	83	82	82	81	80
29	563	91	90	90	89	88	87	86	85	85	84	83	82	82	81
30	569	92	91	90	90	89	88	87	86	86	85	84	83	83	82
31	575	93	92	91	91	90	89	88	87	86	86	85	84	83	83
32	581	94	93	92	91	91	90	89	88	87	87	86	85	84	84
33	587	95	94	93	92	92	91	90	89	88	87	87	86	85	84
34	593	96	95	94	93	93	92	91	90	89	88	88	87	86	85
35	599	97	96	95	94	93	93	92	91	90	89	88	88	87	86
36	605	98	97	96	95	94	94	93	92	91	90	89	89	88	87

Stations moving to a lower frequency will see an ERP reduction of between 2 and 32 percent. The worst case is a station on channel 51 moving to channel 14. If they were running a full 1000 kW ERP, the new ERP would be 680 kW, which should produce the same coverage contours.

For stations that are on the lower portion of the UHF band on channel 36 and below, and are moving, they may see either a lower ERP if moving down in frequency. Moving to a higher channel however would allow a higher ERP to a point. If a station were at 1000 kW on a lower channel and moved to a higher channel, they would still be limited to 1000 kW – a decrease in coverage. The worst case scenario would be a station going from channel 14 to 36 that is at 1000 kW on channel 14. They could still do 1000 kW at channel 36, however they are losing 22% of frequency adjusted ERP. So far the stations that are reporting a channel change will only be moved less than 5 channels – less than a 6% ERP difference up or down.

Pre-Repack Channel	Percentage of ERP from prepack channel																									
	Repacked Channel Number																									
	MHz	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36		
14	473	473	479	485	491	497	503	509	515	521	527	533	539	545	551	557	563	569	575	581	587	593	599	605		
15	479	99		101	103	104	105	106	108	109	110	111	113	114	115	116	118	119	120	122	123	124	124	127	128	
16	485	98	99		101	102	104	105	106	107	109	110	111	112	114	115	116	118	119	120	121	122	124	125		
17	491	96	98	99		101	102	104	105	106	107	109	110	111	112	113	115	116	117	118	120	121	122	123		
18	497	95	96	98	99		101	102	104	105	106	107	108	110	111	112	113	114	116	117	118	119	121	122		
19	503	94	95	96	98	99		101	102	104	105	106	107	108	110	110	112	113	114	115	117	118	119	120		
20	509	93	94	95	96	98	99		101	102	104	105	106	107	108	109	111	112	113	114	115	117	118	119		
21	515	92	93	94	95	96	98	99		101	102	103	105	106	107	108	109	110	112	113	114	115	116	117		
22	521	91	92	93	94	95	97	98	99		101	102	103	105	106	107	108	109	110	112	113	114	115	116		
23	527	90	91	92	93	94	95	97	98	99		101	102	103	105	106	107	108	109	110	111	113	114	115		
24	533	89	90	91	92	93	94	95	97	98	99		101	102	103	105	106	107	108	109	110	111	112	114		
25	539	88	89	90	91	92	93	94	96	97	98	99		101	102	103	104	106	107	108	108	110	111	112		
26	545	87	88	89	90	91	92	93	94	96	97	98	99		101	102	103	104	106	107	108	109	110	111		
27	551	86	87	88	89	90	91	92	93	95	96	97	98	99		101	102	103	104	105	107	108	109	110		
28	557	85	86	87	88	89	90	91	92	93	95	96	97	98	99		101	102	103	104	106	107	108	109		
29	563	84	85	86	87	88	89	90	91	93	94	95	96	97	98	99		101	102	104	104	105	106	107		
30	569	83	84	85	86	87	88	89	91	92	93	94	95	96	97	98	99		101	102	103	104	105	106		
31	575	82	83	84	85	86	87	91	90	91	92	93	94	95	96	96	98	99		101	102	103	104	105		
32	581	81	82	83	85	85	87	88	89	89	91	92	93	94	94	94	97	98	99		101	102	103	104		
33	587	81	81	83	84	85	86	87	88	89	90	91	92	92	92	95	96	97	98	99		101	102	103		
34	593	80	81	83	83	84	85	86	87	88	89	90	90	90	93	94	95	96	97	98	99		101	102		
35	599	79	80	81	82	83	84	85	86	87	88	88	88	90	91	92	93	94	95	96	97	98	99	101		
36	605	78	79	80	81	82	83	84	85	86	86	86	86	89	90	91	92	93	94	95	96	97	98	99		

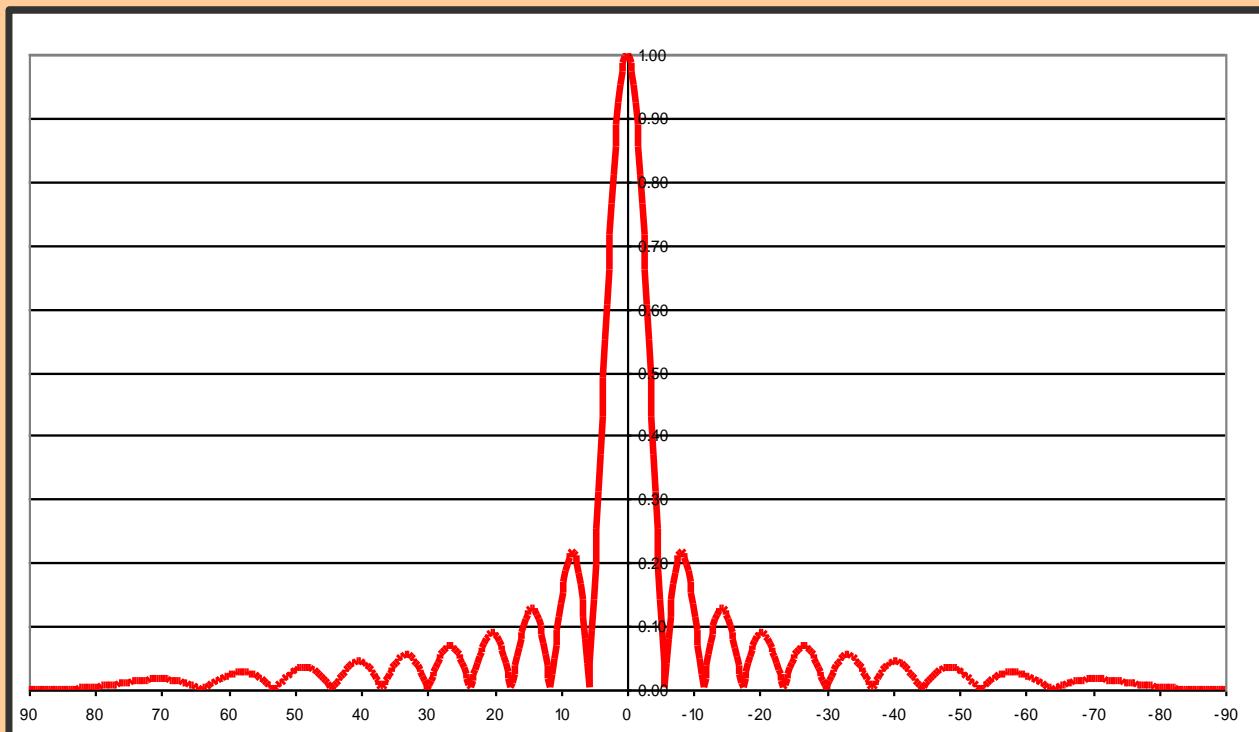
So how do we control null-fill and beam tilt in the antenna?

### First: Two Definitions:

**Beam-Tilt:** The amount of tilt in degrees that the main lobe is tilted downward by electrically lead-phasing the top elements of the array, or by mechanically tilting the antenna downward. Electrical and Mechanical beam-tilt can be used at the same time to increase the over all depression of the main lobe. A center-fed antenna can be beam-tilted by offsetting the input tee centering to lead-phase the top half of the array.

**Null Fill:** The amount of field that is added between the main lobe and the first and/or second secondary lobes. Null fill keeps the field values from going to zero close to the main beam. Values of 5% to 20% are common and are added by varying the spacing the top elements of the array.

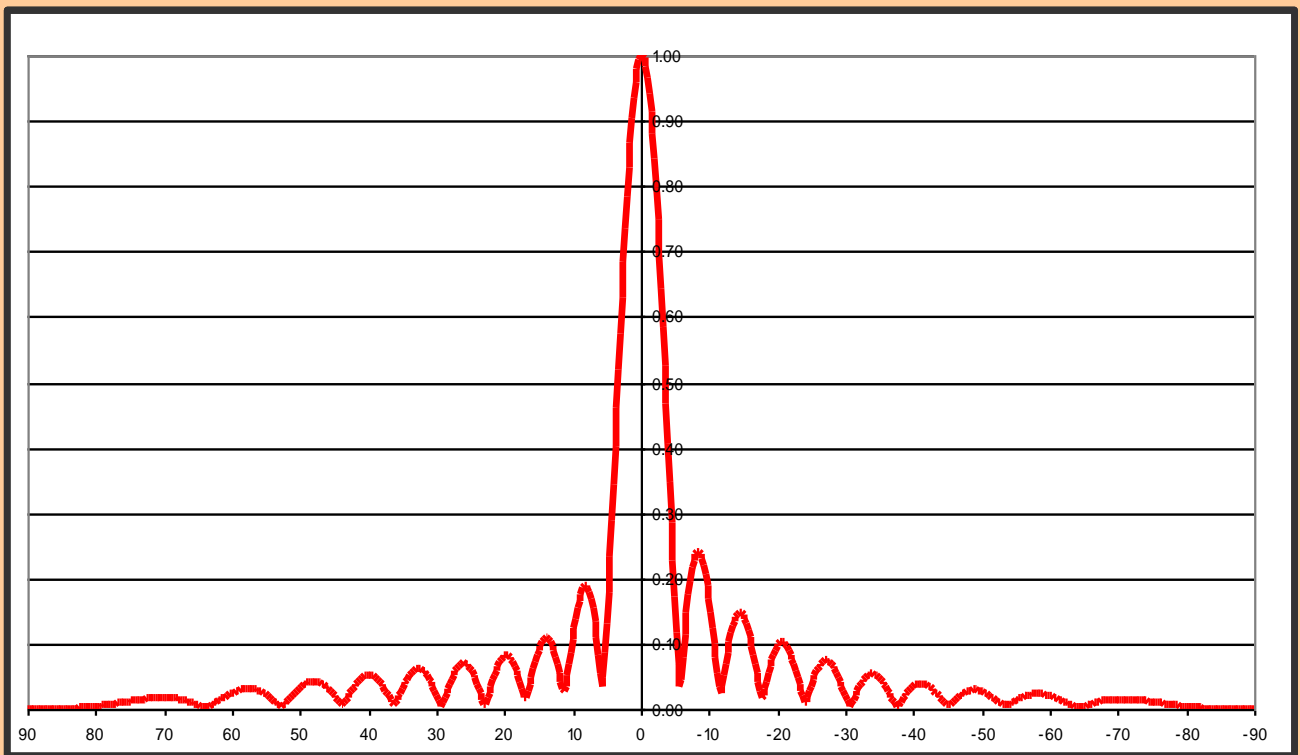
We will do an exercise and model a 10-bay **SFN** Series Antenna. Let's start with an antenna with no beam tilt or null fill, and gradually modify the elevation pattern to see the changes in each step.



Here is a 10-bay elevation pattern with no beam-tilt or null-fill. The elevation gain is 12.36 (10.92 dB). The electrical length of the array is 3420 degrees; (19 interbay spacings times 180 degrees).

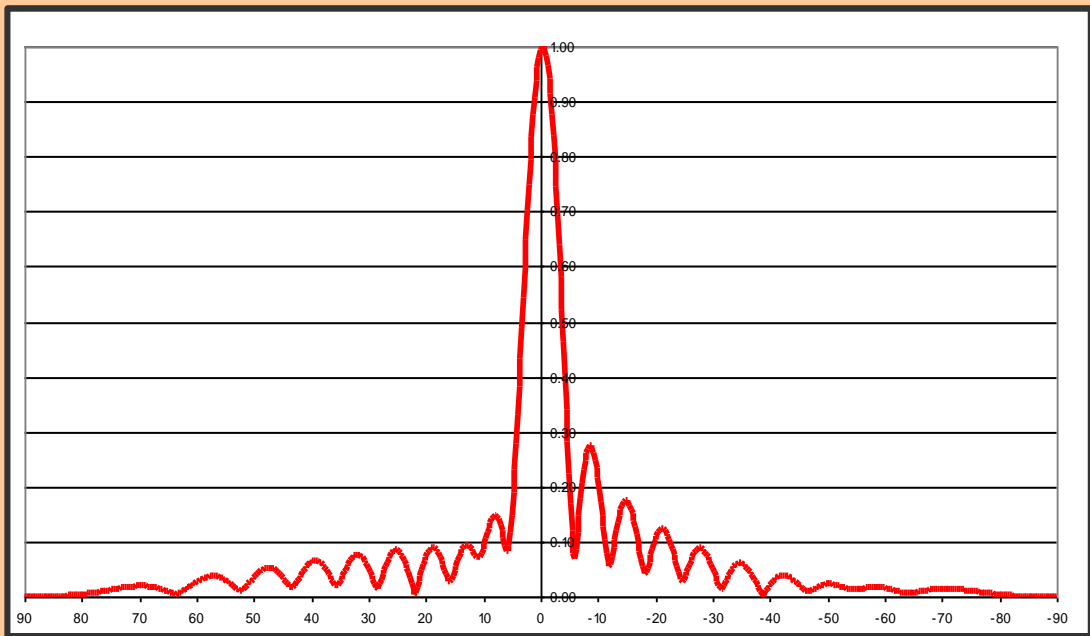
For the first step, the upper two slots have had their phasing reduced by 20 degrees. The array now has 0.25 degrees of electrical beam tilt and the first null has been raised from 0.0% of peak field to 3.3%. The second, and third nulls have been increased slightly from 0.0%. The elevation gain has dropped slightly to 12.27 and the electrical length of the array has dropped by 40 degrees from 3420 to 3380 degrees ( 2 X 20 degrees).



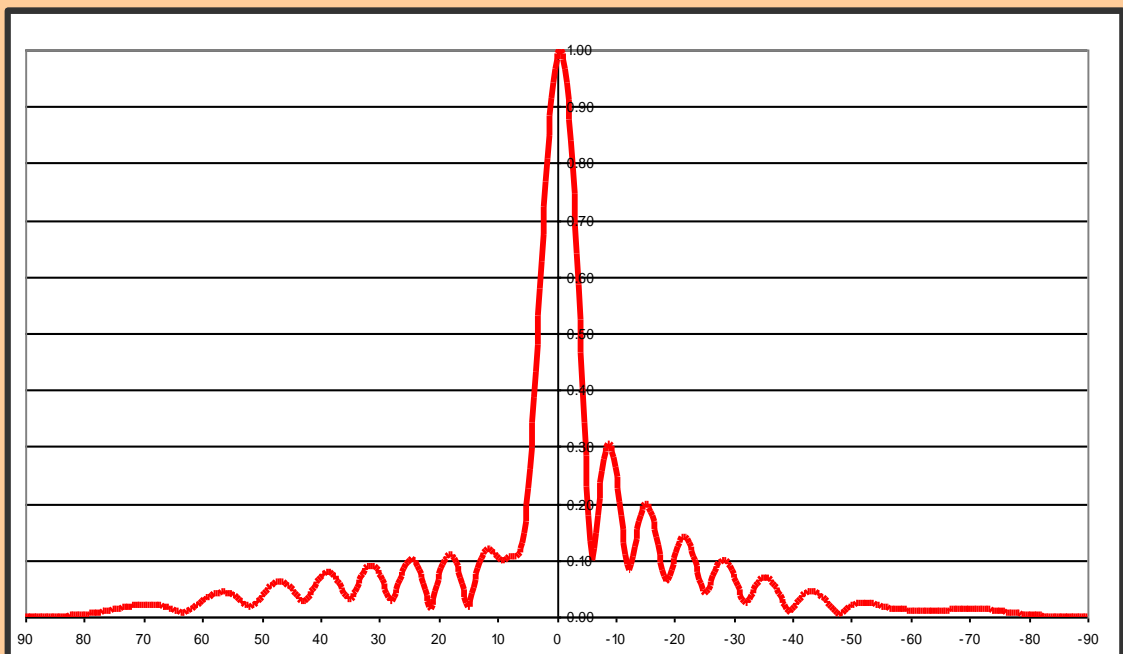


Here is the elevation plot of the 10 bay antenna with 0.25 degree of beam tilt applied. Notice the first secondary lobes above and below the main lobe are now uneven by about 5%. Also the first through third minimas above and below the main lobe do not return to zero percentage of field

In the example on the next page, the upper two slots are lead-phased and short-spaced 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. The plot is on the next page.



In the plot below, the upper two slots are lead-phased and short-spaced 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 relative 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.



The examples shown on the last few pages are just a few of thousands of the elevation patterns we have run with our advanced Micronetixx **AntennaSelect™** program. We love to run special patterns to ensure the best results for the end customer. Better yet, we do this free of charge. We can design a great antenna for you – give us a try!

## **Elliptical/Circular Polarization – Yes!**

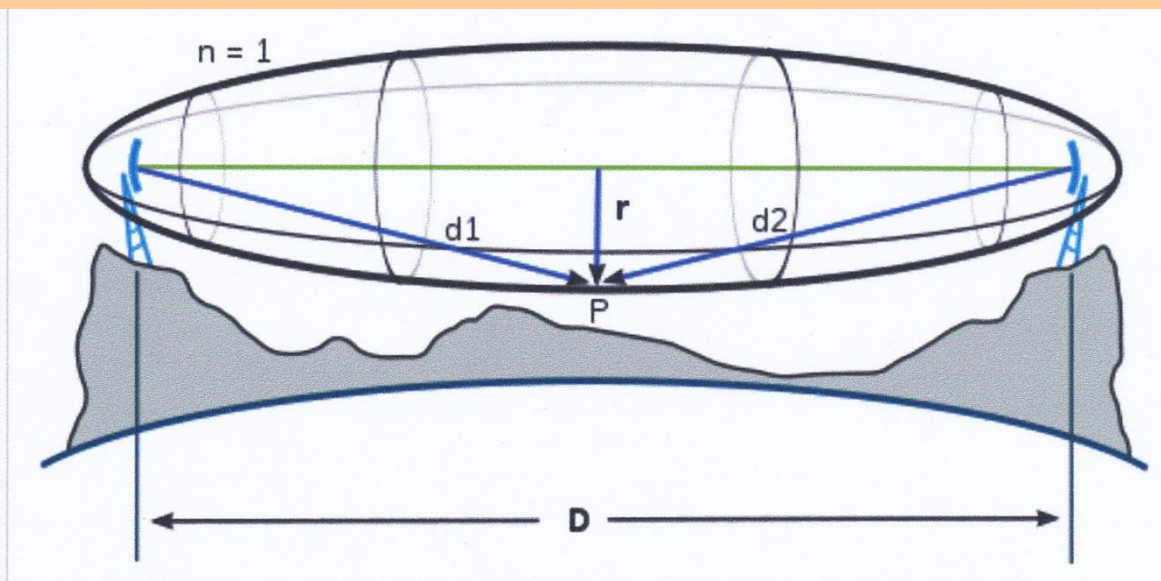


We do get excited talking about the benefits of Elliptical and Circular Polarization for DTV broadcast antennas. E/P or C/P is the best way to ensure that your signal is available just about everywhere in your service area.

The new model for DTV Broadcasting suggests that future users and viewers will be at home, in the office, on public transit or on foot; (and the way things are going...in the car too!). A fixed polarization antenna is going to be rare.

We also manufacture FM antennas! We have been told many times by our customers how much better a C/P signal covers than just using a linearly-polarized vertical whip. In urban or built-up areas, the enemy of reception is called Faraday Rotation. Transmitting in H–Pol only and getting picked up on a tablet outside, or having a reliable signal inside a house is not ensured anymore.

What is Faraday rotation? When the Fresnel Zone is disrupted by buildings, or terrain, the polarization orientation of the signal can change due to Faraday Rotation. If a signal is transmitted in only one polarization, its polarization can rotate, and therefore drop out at a given reception spot.



Fresnel zone:  $D$  is the distance between the transmitter and the receiver;  $r$  is the radius of the first Fresnel zone ( $n=1$ ) at point  $P$ .  $P$  is  $d_1$  away from the transmitter, and  $d_2$  away from the receiver.

The above diagram shows a depiction of the Fresnel Zone. If there is an impairment in the zone, Faraday Rotation can occur, once or many times along the signal path. If we, for example, transmit only an H-Polarized signal, at impaired reception points the received signal, with rotation, can be vertically polarized, or at a slanted angle. We are all familiar with multipath on FM while driving, we get a very short signal interruption. A person walking down the street may encounter Faraday Rotation for a 10 foot or 50 foot stretch of sidewalk. And that signal rotation could vary every other foot. That could cause a service disruption for 5 to 10 seconds. The “blue screen of death” comes to mind. Depending on the orientation of the receive antenna, Faraday rotation can cause a loss of up to 20 dB in received signal.

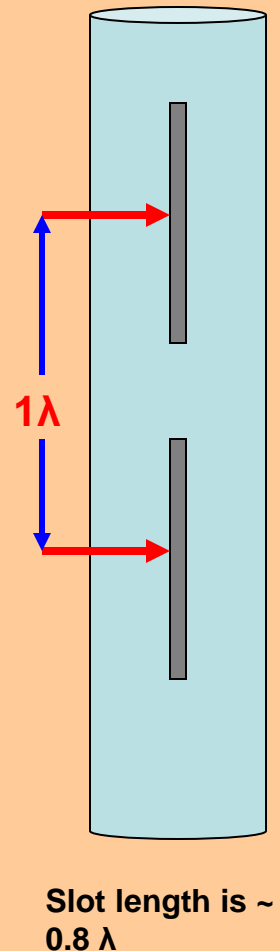
With true in-phase quadrature E/P or C/P transmission, the signal is constantly rotating at a 90 degree right hand relationship. When an E/P signal gets rotated, there is still signal at every polarization in the impaired area. Service drop outs become much more rare, and the receive antenna polarization does not really matter.

So how do we do elliptical (or circular) polarization on a VHF or UHF slot antenna? Let's go over the basics of slot antenna design first. We will skip the math and heavy physics.

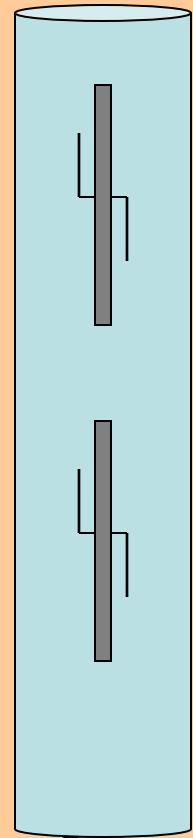
The slot antenna is a TEM-Mode coaxial structure. Coupling structures inside the pylon will distort and couple to the fields in this coaxial antenna, causing a voltage to be applied directly across each of the slots in the antenna. This voltage alternates from plus to minus and back again at the channel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

The length of the slots 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.



Polarizer elements are mounted on either side of the slot. The polarizers are about  $1/8 \lambda$  each and launch a vertically polarized electromagnetic field  $1/4$  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.

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 a 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 today. Also, the all DC-Grounded design is highly immune to lightning.



Another important design with polarizers is they need to be under a slot cover or radome structure. Antenna designs that have external polarizers are effected by the weather. For example frost or light ice buildup on external polarizers will affect tuning and the launch-ratio of the antenna.

How much more will an elliptically polarized antenna weigh? Using an 8-bay side-mounted UHF antenna as a model for E/P or C/P, the added weight is under 10 lbs. Depending on the azimuth pattern of the antenna, the radome might increase in size slightly by about 2 square feet.

### **Group Delay in DTV Transmitting Antennas**



One of the most overlooked parameters when evaluating complete transmission systems, including antennas, is the Group Delay, (sometimes referred to as Envelope Delay). When a signal from a broadcast transmitter is routed through components in the system such as transmission lines, filters, switches and finally to the antenna for transmission, these components in the signal path can alter the characteristics of the transmitted signal. If the alteration is severe, (especially for digital signals, where excessive bit error rates can occur), disruptions in the service or degradation to the quality of the service can result. One of these critical parameters is the rate of change of phase shift as a function of frequency within a channel. This is the specific definition of **Group Delay**.

Traditionally, Group Delay is evaluated for cavity filters, since filters are capable of storing, (and hence delaying), the signal energy for different amounts of time within the channel, as a function of a specific frequency evaluated, across the channel.

**Mathematically, Group Delay is defined as:**

$$\tau_g = -(1/2\pi) * d\phi/df$$

Where  $d\phi/df$  is the derivative of the transmission phase with respect to frequency, (usually evaluated over the operating frequency band). Within a DTV channel bandwidth, the implications for broadcasters could be substantial, depending on the Group Delay characteristics of the entire transmission path, including the antenna, since the phase characteristics of the digitally encoded baseband signal over the channel are crucial. One of the extremely important parameters that we test with great care for every digital television antenna manufactured at Micronetixx is the transmission Group Delay characteristics of the antenna.

In many cases, if the radiation moment magnitude of a particular radiating element of an antenna is small per excitation voltage cycle, the element, and the complete antenna system will exhibit high stored energy per cycle, (also defined as the "Q" of the antenna system). If the energy is stored in the electric and magnetic fields in and around the antenna, the signal is delayed. If the time delay due to this stored energy is different at different frequencies within a channel, then an abnormally high Group Delay parameter can result.

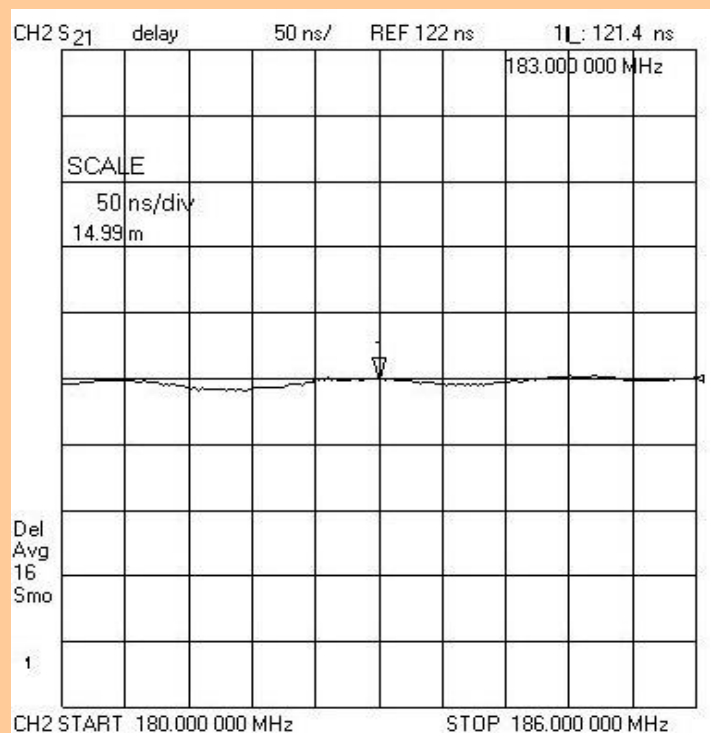
We use proprietary very low Q coupling structures in our slotted antennas, with all elements at DC ground. This ensures that there is little to no stored energy in any of the elements at any place on the operational band.

At Micronetixx, we measure and ensure that the Group Delay characteristics of every DTV antenna that we manufacture will not affect an otherwise beautifully transmitted television signal. With ATSC 3.0 coming soon, and other possible advanced modulation systems are being developed, minimizing Group Delay will be even more important.

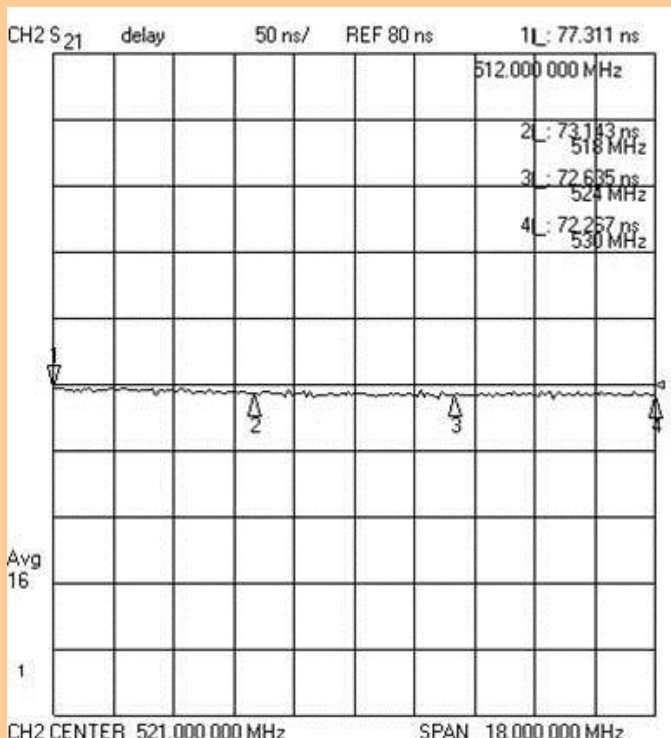
Here are a few plots of the measured Group Delay of antennas we have built:



$S_{21}$  or Group Delay of a 6 bay UHF slot antenna. This antenna is elliptically polarized, and has a peak differential delay of only 2.5 nS across the channel. Our E/P antennas are fed in true quadrature phase, with all elements being DC grounded.



The plot above is for a top mounted high-band VHF elliptically polarized antenna. Even with the large pylon diameter, differential group delay is no more than 8.5 nS over the channel.



This plot is for a three channel wide UHF slot antenna, using our **SFN**<sup>TM</sup> slot technology. Even with the wide bandwidth of the antenna, our low Q coupling system functions in a very linear manner across all three channels. The differential group delay across any one channel is under 3 nS.

Branch fed antennas like our TLB–TMB–THB VHF batwings, and our TPV inverted vee highband VHF antennas also have very low differential group delay. With ATSC 3.0, keeping each component of the transmission system linear as possible should be job one when planning the system.

We test the group delay of every TV antenna we build, and document it your test report. When shopping for your antenna, ask if the manufacturer tests and documents this. We do !

## **Aluminum Pylon Antennas**



Most of the antennas we build are side-mounted models and are constructed from Aluminum. The material is available in a number of shapes and sizes, all with excellent mechanical tolerances. The material works well with high power RF, even 300 kW of power at 900 MHz!

The side-mounted antennas come in two forms, an end-fed antenna with the RF input at the bottom of the antenna, and a center-fed antenna with the input in the middle of the array. The center-fed model uses a hardline tee to feed the upper and lower pylon sections. We do not use any flex feeders on our side mount antennas.

So how do we get from raw material to a finished antenna? First the circular pipe we use for the pylon is slotted and

drilled. We then have a number of piece parts like the flanges, radome stops and mounting tabs welded in place. Welding the pieces to the pylon yields the best mechanical strength and RF integrity for the antenna. There are NEVER any pop-rivets used in ANY of our designs. Aluminum is a great material, but does have one problem. Corrosion ! The picture below is a small section of Aluminum that sat outside for 6 months. If you are in a marine environment, the process happens even quicker.



In addition to DTV and FM antennas, we build a large range of high power components for the industrial and defense sectors. Some of these components conduct over 300 kW of RF at 900 MHz. The product needs to look great over a long life and work well too.

To protect Aluminum, a tough surface treatment system called a chromate conversion is used. Of the various processes, the MIL-C-5541-CLASS 1A treatment system provides the best corrosion resistance. At Micronetixx, we have a multi-step process in accordance with that MIL Standard, to finish and protect Aluminum surfaces of all the products we make. Once we have fabricated the product, step one is to buff the mill surfaces with an orbital sander.



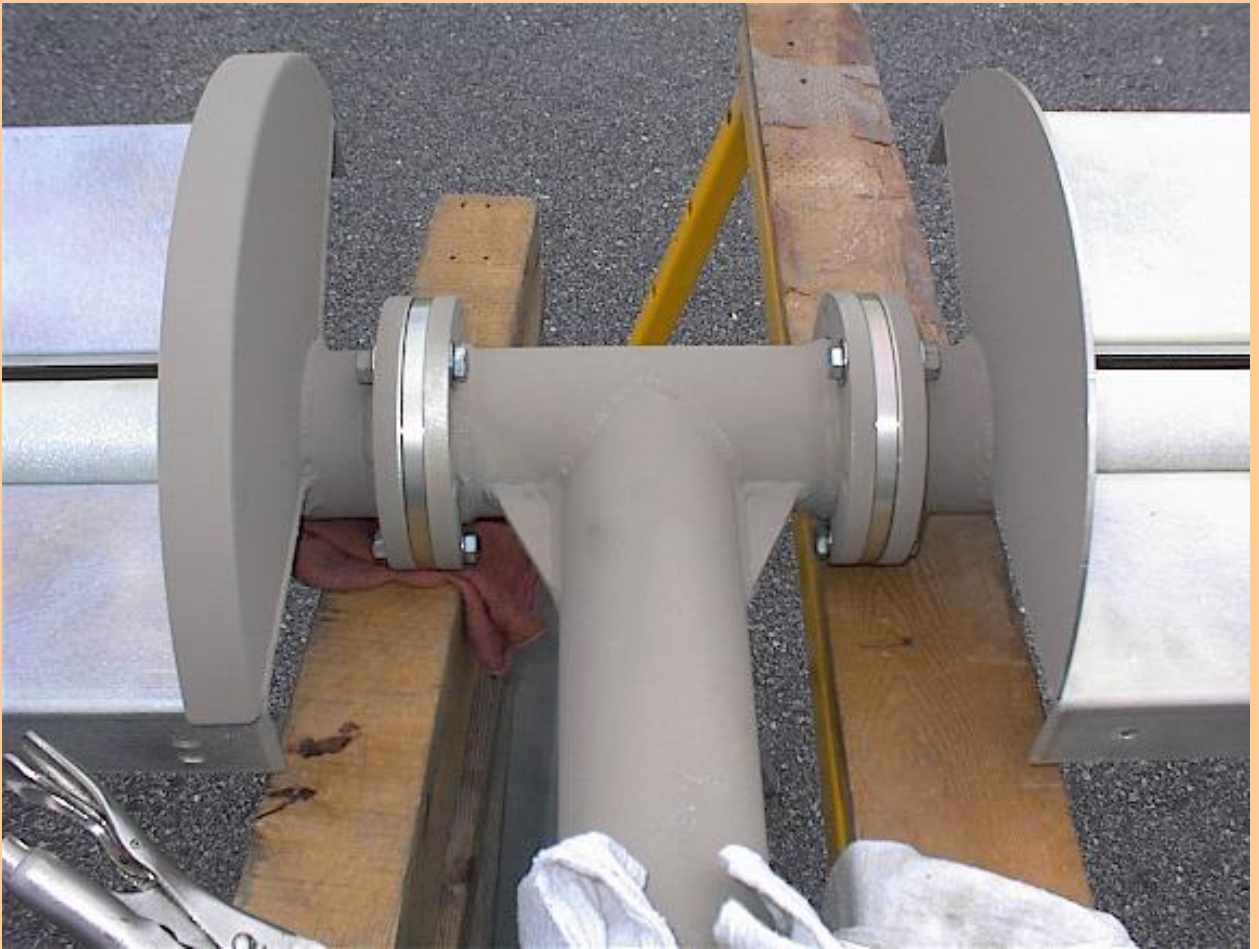
The buffing operation does two things:

It removes the hard layer of aluminum on extruded components and cleans surfaces of impurities deposited by handling the material, and processing it. Secondly, the burnished surface will permit a much more uniform treatment in the chromate process. If the piece is to be painted, the extra step we take ensures superior adhesion of paint. The photo below shows the burnished finish.



We are the only high power broadcast antenna manufacturer to use this process. After the burnishing process is complete, the Aluminum pylon is given an alkaline bath in a long trough stainless steel tank. This allows emersion of the entire assembly in one pass. After the alkaline bath the product is given a rinse in a second long tank. The product is then dipped in a warm solution of a chromate conversion chemical to finish it. The solution in the tank is kept at a constant temperature via a series of pumps and heaters. Chemical tests are done on a regular basis to ensure proper strength of the alkaline wash and Chromate.

We believe that our Chromate tanks are the longest in New England. The chromate tanks and circulation system were designed by our engineers. The buffed and chromate-coated surfaces have excellent electrical conductivity and paint adhesion qualities. We have powder coated a number of these antennas with either paint or powder coat for even longer surface life. The picture below is a painted center fed side mount antenna.



Corroding and pitted aluminum surfaces also can create another issue in high RF fields – Passive Intermodulation (PIM). With our chromate treatment of all aluminum surfaces, PIM generation in our antennas is eliminated.

We use steel pylons for our top mounted antennas. It is common to have pylons that are 40 feet long or longer. The pylon material is a steel pipe usually in the 12 to 16 inch diameter range for UHF, with a wall thickness of approximately ½ inch. For VHF high-band antennas the diameter may be increased to up to 20 inches.

The steel pipe will need to be drilled (and in the case of slotted antennas) the slots cut. Once the pylon prep work is done, other elements like flanges and gussets can be welded in place, then are X-Rayed for Safety.

The next step which is done out of house, is galvanizing. Galvanizing is a process to apply a zinc coating to all surfaces of the antenna pylon. There are a number of steps needed to properly Galvanize the pylon. After the antenna pylon is done in manufacturing, the pylon is trucked to a Galvanizing plant. The first step is to immerse the pylon in a tank that has a caustic solution. This removes dirt, paint and grease from the surfaces of the pylon. The pylon is then rinsed off. The unit is immersed in a second tank to remove off mill scale. Mill scale is a thin bluish-black film formed during the steel fabrication. If it is not removed it will begin to break loose after being exposed to the elements. An acid bath is used to remove the scale. The pylon is then rinsed off.

At this point the pylon is given a close up inspection to see if it is clean and all mill scale has been removed. Small spots of scale that remain are sandblasted off. Next the pylon is coated with a flux that is allowed to dry. This protects the bare steel from oxidizing and helps the galvanizing zinc bath in wetting and adhering to the steel.

The pylon is now ready for galvanizing. A large tank holding a solution of molten almost pure zinc (98.5 to 99.995% pure) is heated up to between 840 to 850 degrees Fahrenheit. The pylon is slowly lowered into the tank. The pylon is kept in the tank until its entire length has reached the ambient temperature of the molten zinc. The now-shiny pylon is raised from the tank slowly allowing the excess zinc to drain back into the tank. The pylon is then carefully cooled and finally, thoroughly inspected.

If there was proper prep and cleaning of the pylon, a durable 4-mil thick coat of zinc should be on all surfaces. Now comes the fun part. A number of tapped holes on the pylon will be partly plugged with zinc. The holes will need to be cleaned out before the pylon is ready to ship back to us. Depending on how many holes there are it can be a time consuming process.

How long before the antenna pylon will show any signs of rust?



For a properly galvanized pylon with a 4 mil thick coating, the life can be as little as 25 years in a hot humid environment or over 50 years in a rural fairly arid climate. With galvanizing when the zinc coating gets down to 5 to 10% of its original thickness, that becomes the effective service life of the antenna pylon if not painted.

## **Wedding Cakes and Antennas:**



At Micronetixx we supply “Wedding Cakes” on some of our antennas. The use of “Wedding Cakes” we make, allow top-mounted pylon antennas to be stacked on top of each other or be used as part of a bury section. The wedding cake is between 12 and 36 inches high and has enough room to allow a transmission line to be routed through it and into the bottom end of the top mounted antenna.



The picture to the left shows a close up of a wedding cake that is part of a bury section. The antenna is mounted on top of the wedding cake and is bolted in place. The transmission line comes in at a 45 degree angle and attaches to an EIA flange at the bottom of the antenna.

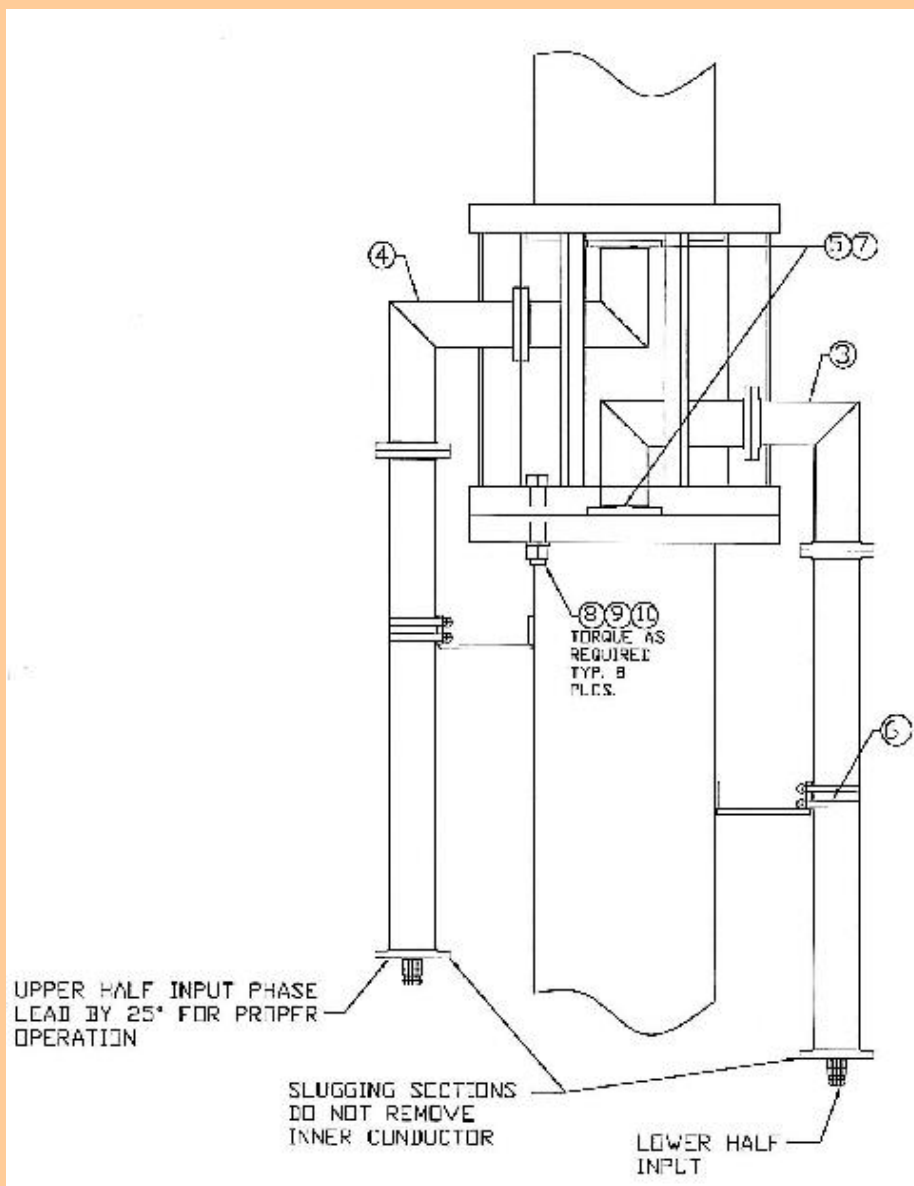
The picture to the right shows a section of a wedding cake used to support a small UHF top mount antenna. In the lower left side of the picture, part of the EIA input flange is visible. This design used thick plate steel for the legs. Gussets were added to the bottom of the UHF antenna pylon for additional strength.



There is enough vertical room in this wedding cake to clear a 3-1/8" EIA transmission line and elbow. There are several designs that could have been used. The wedding cake could be part of the bottom antenna pylon, be a separate section or be integrated into the top antenna pylon. All three methods have excellent mechanical strength.

When the wedding cake is designed there are two goals that have to be met. The first is the mechanical strength to withstand high loads imposed when there are severe wind conditions. The second goal is to ensure that the coaxial components will fit inside the wedding cake. Finally, there has to be enough room to tighten each bolt on the input flange and any other components, such as T/L elbows.





This is a drawing of the dual feed system VHF antenna wedding cake. There were three design goals that had to be met here. The first and most important is mechanical strength. The second is having enough room inside the wedding cake to install the EIA flanged components. The third was the length of the wedding cake to ensure proper spacing between the slots of both halves of the antennas, as this affects the elevation pattern when run as a single antenna array.

Slotted pylon antennas need to have their slots protected from the elements. There are a number of methods to do this.

The most basic approach is to use plastic inserts that fit into the slot to seal it. Antennas for a number of years used this design. There are some drawbacks however. At each slot there are high-intensity electric fields present. The plastic material has a very small relative permittivity ( $\epsilon_r$ ) or dielectric constant. With the strong fields passing through it, the slot covers can heat up. When there is rain present, the dielectric constant will increase slightly. This can affect the overall tuning of the antenna. Ice can cause more problems as the tuning of the antenna will be affected to a greater degree. If there are columns of slots, let's say four around on the pylon, the icing may not be equal over all columns.

This can cause more detuning problems to the antenna, possibly causing a significant rise in V.S.W.R. . When the antenna is new, the slot covers are clean and have a low dielectric constant. As they age, the sun can begin to break down or pit the outer surface of the slot cover. Dust in the air, or soot from industrial emissions can begin to form in these pits. Depending on the makeup of the dust or soot and where it is deposited on the slot cover, detuning can occur. The contaminating material may also increase the dielectric loss in the slot cover, causing unwanted heating.

If it gets hot enough it can fail by melting and falling out of the slot. This exposes the coupling structure at each slot and the inner conductor to direct contact with the elements.

A regular inspection of the antenna should be done with these types of slot covers. Since they are so small, they would not be visible from the ground – so a climb up is needed. Letting water hit the couplers could cause corrosion, and the coupler could fail, causing a burn out.

The next step up in slot covers is a small formed plastic strip that runs the length of the slotted area of the antenna. The strip is a few inches wide and an inch or two high. It is held in place by screws or by hold-down strips. The plastic material forming the strip is usually UV stabilized and may be pigmented. With this design there is less heating of the material and less detuning sensitivity during rain or icing periods.

One problem with these slot covers is if the antenna is elliptically or circularly polarized. The polarizer elements over the slot will be outside the cover. Also the slot cover may not allow for optimum placement of the polarizers over the radiating center.

In conditions where ice can be problematic, ice build up on the polarizer changes the 90 degree phase difference between the slot and V-Polarizer. This affects the proper launch of the vertical signal component in quadrature with the horizontal component. What was elliptically polarized becomes less-desired dual-linear polarization.

The ice will affect the tuning as well since the frozen ice is electrically loading the V-Polarizer element. The ratio of H to V signal component will change and the antenna will detune slightly. These same affects hold true for antennas that have just the simple slot covers. In icing conditions where elliptical or circular polarization is used, the detuning and H to V ratios will degrade even faster.

At Micronetixx, all of our side and top mount slot antennas employ a partial or full 360 degree radome system. Our radome material of choice is UV-stabilized H.D. polyethylene. There are several reasons why this material is our choice; First, it has an excellent service life, and is stable over a wide range of temperatures.

UV-Stabilized H.D. Polyethylene is also an excellent material to form into arcs to wrap around an antenna pylon. It has excellent dimensional stability in all operating environments. For operation in icy and snowy areas, the material is slippery enough to minimize ice build up. Most of our side mounted directional slot antennas, use arced radomes over the front two-thirds of the antenna. The arced shape of the structure also helps to lessen ice build up.

Most radomes we deliver are white. At 500 feet up a tower it becomes very hard to see the antenna as it blends into the sky. If a customer needs a radome color like international orange, the pigments are imbedded into the material and do not fade over time. The down side of Polyethylene is paint will not adhere to the slippery surface.

While we are talking about materials for radomes, what about using Teflon®? Teflon® has a slightly lower dielectric constant compared to Polyethylene, but it is far less rigid mechanically. In addition, if a color is needed, the pigmentation is much more irregular than Polyethylene.



To form the radome on this Omnioid UHF slot antenna, we use a radome stop that is mounted to the top end of the antenna. For this design the radome material is bent into a U shape and slipped under the edge of the radome stop. It is held in place by a pair of Aluminum strips that run the length of the pylon, machine screw fastened every few inches. This provides a slot clearance of at least 3-1/2 inches. The U-shape of the radome reduces the tendency of ice build-up as well.





If the antenna is either Circularly or Elliptically polarized and is going to be installed in a area where there will be ice or snow build up, the radome can be extended outward and shaped more like a tear drop.

On the previous page we looked at radomes on side mounted directional slot antennas. These radomes wrapped around the front half or two-thirds of the antenna. The shape of the ends of the radome were formed by radome stops. Now what do we do with an Omni-Directional antenna that has no radome tie down strips? This antenna could be top or side mounted. Depending on where the antenna is to be located, and its polarization, the radome would need to be between 3 and 10 inches off the pylon radiating structures.



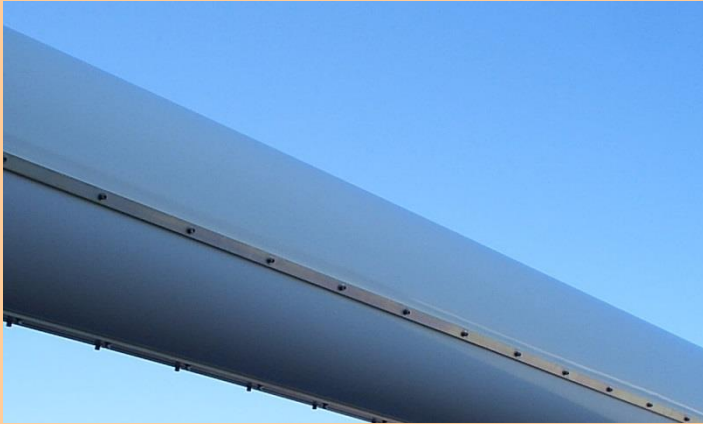
**Channel 13 top mount slot antenna**

To support the radome system, a series of pegs are mounted on the pylon, and the radome is formed around the antenna. The radome is then bolted to each of the pegs.

Depending on the diameter and wind speed rating of the antenna, there are 3 or 4 columns of these pegs mounted to the pylon. This approach forms a very circular radome system with excellent rigidity, as seen above.



This UHF slot antenna has a 360-degree radome system. The radome is supported in three places. It is attached to the ends of parasitic elements in two places and a strip in the rear of the antenna, as illustrated below.



This antenna is designed for a basic wind speed of 150 M.P.H. and is mounted 9700 feet above sea level. The heavy duty Polyethylene radome system is rugged and resists ice build up.

Sometimes an antenna needs to blend into the background of its supporting structure. Custom-pigmented Polyethylene is available, but getting an exact color match can be problematic. The antenna below needed to have its color matched with the side of the building it would be mounted to, as it is an historic structure. Paint does not adhere to Polyethylene, so the solution was to use a fiberglass radome and paint the radome halves with color-matched paint.

Here is the finished painted antenna in final test. This is a center-fed 8-bay SFN series UHF low RFR slot antenna, with an input rating of 12 kW for installation on the Empire State Building in New York.



Pressurized radomes are used where it is desired to keep the antenna elements inside the radome either in dry air or a gas. A dehydrator or gas cylinder in the transmitter building keeps the pressure inside the transmission line and antenna slightly higher than ambient outside air pressure. This keeps outside air from seeping into the transmission system. Of the radome systems used for TV broadcast antennas, the pressurized system is the most expensive to build.

The reason for that is the pressurized radome system is mechanically more complex, and the radome itself is more expensive. Pressurized radomes need to be sealed at each end to keep dry air or gas from escaping. Most often fiberglass is used to build the radome sections. In a long antenna array such as a 24 bay UHF slot antenna, the radome will need to be built in sections and flanged together. Diameters from 12 inches (30.5 cm) to 24 inches (61 cm) are common.

Keeping the radome sealed in the antenna's operating environment requires some additional engineering. First, the expansion of the antenna pylon which is constructed from aluminum or steel will be higher than the fiberglass radome sections over a range of temperatures. The pylon has a lot more strength than the radome, and if there is no compensation for expansion and contraction the radome can easily be damaged.

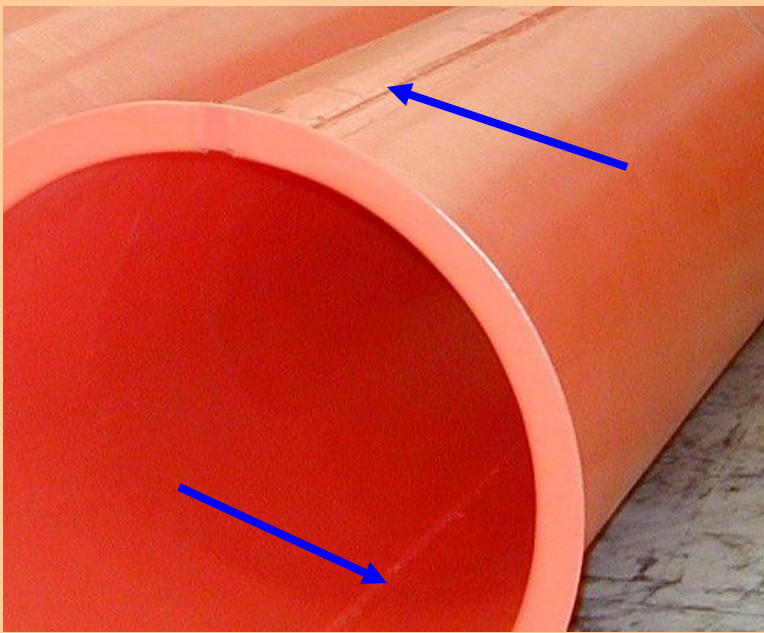
One method to compensate for the differential expansion and contraction is to use a bellows. A bellows system installed on one end of the pylon allows it to expand and contract with little mechanical force difference exerted on the radome over temperature. The radome rides over the pylon.

A second issue with a pressurized radome is how do you seal the ends to keep air from escaping? At Micronetixx we use thick sheets of silicone rubber to form gaskets at each end of the dome. The material is cut into a ring shape and placed on the flanges of the radome.

The material has an excellent service life and responds well to large changes in temperature. Holes are cut into the material to match the bolt pattern of the radome system. There is a large surface contact area that ensures an excellent seal to keep dry air in and moisture out.

The third issue with a pressurized radome is to keep it from cracking at the flanges. We take an extra step to keep that from happening.

First our pressurized radome systems are formed from wrapped layers of fiberglass material. There are no welded or glued seams. On the next page, an illustration depicts a welded fiberglass tube. Radomes and pylon lengths do change with temperature . This design is much too brittle and will not deliver the service life we expect from Micronetixx Antennas.



Note the two seams running up the tube. Over time these can easily crack. Even a small crack will allow dry air to escape, and moisture to leak in.

The second issue with using a radome designed like the tube above involves the flanges on the ends of the radome. This type of design has two drawbacks; First, the flange material is thin, making a suboptimal seal against the gasket material. Even a slight over tightening of the bolts can cause the flange material to bend. The second drawback is the 90 degree angle of the material where the flange meets the tube. This is a major stress point on the radome structure.

To solve these problems we design our radomes with thicker junction areas at the flanges. Also the flanges themselves are much thicker than the radome tube itself. We also add depressions at each bolt hole to allow the use of oversized washers underneath the bolt heads. This allows us to tighten the bolts down, compressing the gasket material to ensure a good, reliable seal. The picture on the next page illustrates the bottom of one of our pressurized radome systems.



The picture to the left shows the Radome flange on a side mounted UHF slot antenna. The flange area is thickened to provide superb strength. The first 6 inches of the radome itself have extra layers of Fiberglass to strengthen the structure and eliminate cracking.

Fiberglass radomes have a service life of at least 20 to 25 years. The sun will, over time, begin to break down the outer layers of the radome surface. With enough breakdown of the surface the fiberglass belts themselves become exposed. Moisture can get into these belts and when there is a freeze/thaw cycle, break down the material even more.

Something we do at Micronetixx is to paint the radomes with a water-tight paint. The radome is burnished to enhance paint adhesion and it is then painted, greatly extending the service life.

Pressurized radomes can extend the life of the antenna itself, especially in marine environments. If the antenna is kept under pressure, the elements of the antenna should look like they just left the factory floor, even after being in service for years.





Rigid-bolted transmission line is a solid solution for feeding antennas on supporting structures from the transmitter building. Rigid-bolted like is a coaxial structure, where there are two round cross-section conductors, (usually metal pipes), placed one inside of the other. The smaller diameter pipe fits inside of the larger one, and is held at the longitudinal axial center of the larger outer pipe, (hence the name: coaxial line), with insulators. Unlike semi-flexible coaxial transmission lines, rigid-bolted transmission line is supplied and assembled in sections. These line sections are approximately twenty feet in length. The sections are placed end-to-end and are joined at the ends by flanges that are bolted together. Since both the inner and outer conductors need to be electrically connected continuously, there is a requirement at each end-flange for connectors to electrically join the coaxial conductors.

As the RF signal from the transmitter travels inside of the coaxial line, the currents move along smoothly as long as there are no interruptions in the conductor symmetry of the inner and outer conductors. However, whenever there is any interruption in the conductor symmetry, there will usually be a disturbance in the electric and magnetic fields that comprise the RF signal as it propagates along the line.



This disturbance will usually result in a percentage of the RF signal being reflected back toward the transmitter. As a consequence of this factor, there will be a small amount or percentage of the RF power from the transmitter that will be reflected back toward the transmitter at each flange where the rigid-bolted coaxial line sections are joined. In well-designed line, great care is taken to minimize the percentage or magnitude of reflected the RF signal that is generated at each flange connection. However, it nearly impossible to eliminate these small flange joint reflections completely.

Reflections in RF transmission lines are what are known as vector quantities. That means that these reflected waves have two properties associated with them; one is the magnitude, or strength of the reflected wave, and the other is the direction or phase of these reflected RF waves. If consistency is maintained during the manufacturing of the line, both the magnitude and the phase of the small reflections from each of the flange joints along the line is nearly the same. However, since all RF signals from the transmitter have a wavelength associated with them, (based on the operating frequency of the station), as these reflected signals propagate back toward the transmitter, the phase of these flange joint reflections will rotate around in circles, (like a turntable), making one complete revolution, and repeating at each half-wavelength along the transmission line.

If the length of each section of line between flange joints is such that the phases of the reflections from all of the flange joints are close to the same, the magnitude portions of the reflection from each flange joint in the transmission line run will add together.

**Continued on next page**

This is a highly undesirable situation, and can actually act like a band-stop filter directly at the frequency band of your station, and presenting undesirably high V.S.W.R. to the transmitter. Therefore, the lengths of the individual transmission line sections should be adjusted such that the phases of the reflections from flange joint to flange joint are opposite, or 180 degrees out of phase as they impinge on adjacent flange joints, thereby canceling each other at the operating frequency of the broadcast station, and eliminating that highly undesirable situation. That is why the individual lengths of transmission line in a rigid-bolted line run should be carefully selected according to the station's operating frequency

The frequencies where these flange joint reflections occur are called **critical frequencies**. With common broadcast transmission line lengths, these critical frequencies are spaced between 24.52 and 25.81 MHz apart. Each additional section of line adds an additional critical frequency.

Using a single 19 foot section of transmission line, the first critical frequency is 25.81 MHz, adding second section of line creates a second critical frequency of 51.62 MHz, and adding a third section of line yields a critical frequency of 77.43 MHz. If you were planning a transmission line for operation on channel 5, this critical frequency would fall right inside the 76 to 82 MHz band for that channel.

Note: The critical frequencies do not change with line size or impedance – only the individual length matters.

The chart below shows the Critical Frequencies of four popular lengths of transmission line. The formula to calculate the critical frequencies is;

$$F_c = (490.4/L) * n$$

Where L is line length and n is number of line sections

<b>Critical Frequencies in MHz</b>				
# of line Sections	Transmission Line Section Lengths			
	19 Feet	19-1/2 feet	19-3/4 Feet	20 Feet
<b>1</b>	25.81	25.15	24.83	24.52
<b>2</b>	51.62	50.30	49.66	49.04
<b>3</b>	77.43	75.45	74.49	73.56
<b>4</b>	103.24	100.59	99.32	98.08
<b>5</b>	129.05	125.74	124.15	122.60
<b>6</b>	154.86	150.89	148.98	147.12
<b>7</b>	180.67	176.04	173.81	171.64
<b>8</b>	206.48	201.19	198.64	196.16
<b>9</b>	232.29	226.34	223.47	220.68
<b>10</b>	258.11	251.49	248.30	245.20
<b>11</b>	283.92	276.64	273.13	269.72
<b>12</b>	309.73	301.78	297.96	294.24
<b>13</b>	335.54	326.93	322.79	318.76
<b>14</b>	361.35	352.08	347.63	343.28
<b>15</b>	387.16	377.23	372.46	367.80
<b>16</b>	412.97	402.38	397.29	392.32
<b>17</b>	438.78	427.53	422.12	416.84
<b>18</b>	464.59	452.68	446.95	441.36
<b>19</b>	490.40	477.83	471.78	465.88
<b>20</b>	516.21	502.97	496.61	490.40
<b>21</b>	542.02	528.12	521.44	514.92
<b>22</b>	567.83	553.27	546.27	539.44
<b>23</b>	593.64	578.42	571.10	563.96
<b>24</b>	619.45	603.57	595.93	588.48
<b>25</b>	645.26	628.72	620.76	613.00

The chart below shows the line lengths that will work at each channel.

Center Frequency	Channel	Transmission line section lengths			
		19 feet	19-1/2 feet	19-3/4 feet	20 feet
57	2	4	3	2	1
63	3	4	3	2	1
69	4	1	2	3	4
79	5	X	X	X	1
85	6	4	3	2	1
177	7	X	X	X	1
183	8	X	3	2	1
189	9	4	1	3	2
195	10	2	1	X	X
201	11	2	X	X	1
207	12	X	2	3	1
213	13	4	1	3	2
473	14	2	X	X	1
479	15	3	X	2	1
485	16	X	2	1	X
491	17	X	1	2	X
497	18	2	3	X	1
503	19	2	X	3	1
509	20	2	3	1	4
515	21	X	1	2	X
521	22	X	2	X	1
527	23	2	X	X	1
533	24	2	X	1	3
539	25	X	1	2	X
545	26	X	1	X	X
551	27	2	X	X	1
557	28	3	X	2	1
563	29	X	1	2	X
569	30	X	1	X	X
575	31	2	X	X	1
581	32	3	X	1	2
587	33	3	1	2	X
593	34	X	1	X	X
599	35	X	X	X	1
605	36	1	X	2	3

Numbers in the boxes are the first to 4<sup>th</sup> choice for each channel.  
An X choice will not work on that channel

For each channel and line length there is a rating of 1 to 4 or an X for a given line length at that channel. The rating of 1 is the best fit for the channel with critical frequencies being the farthest away from the channel edges. A rating of 2, 3, or 4 will work, but the critical frequencies are closer to the channel of interest. A minimum of a few Megahertz from the critical frequency to the band edge is needed. An X means that length of transmission line sections will not work on that channel . Channel 5,7,26,30 and 35 are the most unlucky channels, as only one line section length will work on those channels. If you are looking at dual channel operation, about 75% of possible station pairs can use the same transmission line section length.

There are methods to simulate the use of uneven line lengths to move critical frequencies away from the desired band of operation. Sometimes shifting a critical frequency up or down by 5 MHz or so will allow a good two or three channel low V.S.W.R performance.

So what about short cut sections of line ? What is the critical frequency of those sections. The good new is since the transmission line system only has one or two cut line sections, there will not be but a few critical frequencies. A 7 foot cut line section has for example a critical frequency of 70.05 MHz, while a 4 foot section has one at 122.60 MHz. Use the same formula shown on page 78 to calculate these values. If there was two 7 foot cut line sections, there would be two critical frequencies, 70.05 and 140.10 MHz.

# **Manufacturing Times for Antennas**

## **Side Mounted UHF Slot Antennas:**

Micronetixx has all the skill sets required to build side mounted slot antennas under our roof. All the piece parts needed to assemble the antennas are made in our shop. We have designed our antennas so that many common parts or assemblies can be made ahead of time and stocked. We also have vendors not in the broadcast business that can build parts and assemblies as needed. Our current delivery time is 4 to 8 weeks depending on the complexity of the antenna. We can deliver basic stand-by antennas in very rapidly, and in an emergency case, much faster.

## **Top Mounted UHF Slot-Type and Other Antennas**

The top mounted antennas take longer due to the extra steps needed. Every one of our top mounted antennas is P.E. stamped after a thorough design review. We have the equipment to build 100% of these antennas in-house, except for galvanizing. However sometimes that is not the fastest way. We have excellent relations with steel fabrication companies that are not in the broadcast business, including several located close to galvanizing facilities. That alone may save a week or more in the process. The average delivery time for a top mounted antenna is 8 to 14 weeks. We forecast enough capacity to keep those delivery times valid during the Re-Pack.



Micronetixx has a powerful and unique antenna planning program that is available online. It is called **AntennaSelect™** and was first launched in 2010. This program allows you to design a TV transmitting antenna from our engineering database. It is completely free to sign up and use. The web address is: [www.antennaselect.com](http://www.antennaselect.com)

We decided to do an online application, versus distribute the program via CD, or make users update a static program. This lets us push new data online as it becomes available. There are a number of powerful tools in **AntennaSelect™** to help you quickly design an antenna. Comparing azimuth and elevation pattern is easy via our scratchpad entry menu. You can export data such as elevation and azimuth patterns to Excel Spreadsheets. You can design your antenna system, do system calculations and then save your project. There is a great “what if” calculator called QuickCalc, which allows you to compare antenna gains, transmission line types, and transmitter output levels to evaluate a design approach.

You can also finish a design project and email it to us directly from the site, with comments and/or questions. The email goes directly into Engineering, who can quickly come up with answers. This feature can save a lot of time for both end customers and those in the consulting industry. Instead of phone tag and having to describe what is needed for a project, this facility gets it done quickly and efficiently.

**Input Parameters**

Channel:	23	Frequency:	527 MHz	Mount:	Side
Type:	CS-2030 Low/Medium Power	Service:	DTV	Rotation:	90
Azimuth Pattern:	E Cardioid - 180 Degree (1.95 gain)	Total Gain:	24.47	Gain (dB):	13.89
Elevation Pattern:	12bay_0.75BT (12.55 gain)				
Customer:	Lakeview ETV				
Description:	New transmitter site				

Save Data  
 Clear  
 Printable Form  
 Power Calculations

☒ Azimuth ☐ Elevation  
**Azimuth Design Scratchpad**

Select  
 A Omni-Directional (1.00 gain)  
 B Omnioid (1.70 gain)  
 C Tri-Lobe-Bell (1.70 gain)  
 D Cardioid-270 Degree (1.90 gain)  
 E Cardioid - 180 Degree (1.95 gain)

Selected Patterns	Rotation	Choose
Pattern 1 > D	0	Select
Pattern 2 > E	90	Select Clear Pattern

Percentage Relative Field Value
 

D at 0° —  
 E at 90° —



Open in Separate Window  
 Tabulate Data

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Here is the main page of **AntennaSelect™** showing the beginning phase of a design project. Two cardioid patterns were selected for comparison using the design scratchpad. The project can be saved and power calculations run.

Input Parameters

Channel:	23	Frequency:	527 MHz	Mount:	Side
Type:	CS-2030 Low/Medium Power	Service:	DTV	Rotation:	90
Azimuth Pattern:	E Cardioid - 180 Degree (1.95 gain)	Total Gain:	24.47	Gain (dB):	13.89
Elevation Pattern:	12bay_0.75BT (12.55 gain)				
Customer:	Lakeview ETV				
Description:	New transmitter site				

Save Data

Clear

Printable Form

Power Calculations

☐ Azimuth ☒ Elevation

Elevation Design Scratchpad

Select

- 8bay\_0.5BT (8.25 gain)
- 8bay\_0.75BT (8.15 gain)
- 8bay\_1.0BT (8.05 gain)
- 8bay\_1.5BT (7.95 gain)
- 8bay\_2.0BT (7.75 gain)

Selected Patterns

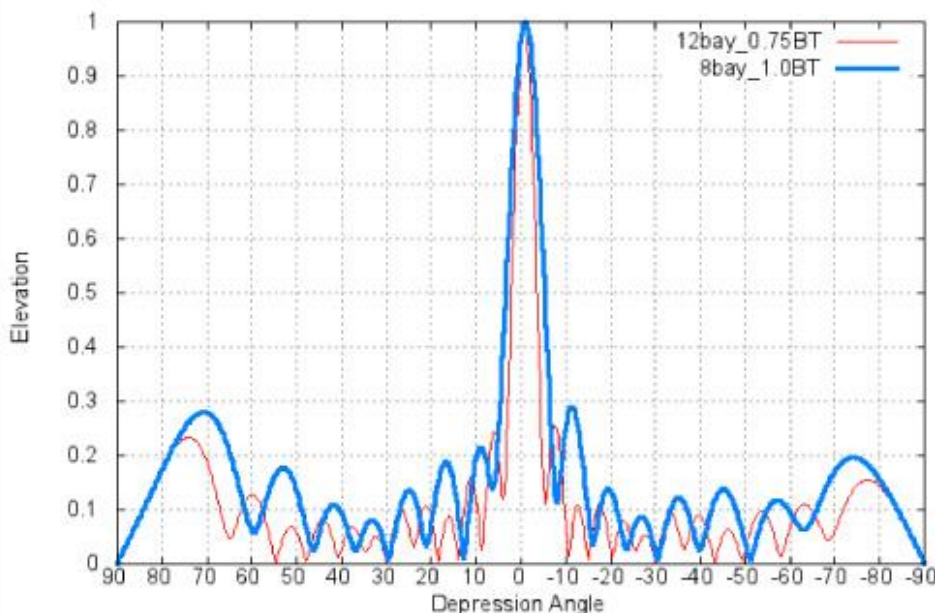
Pattern 1 > 12bay\_0.75BT (12.55 gain)

Pattern 2 > 8bay\_1.0BT (8.05 gain)

Clear Pattern

☐ Polar Plot

Elevation Pattern



Open in Separate Window

Zoom

Tabulate Data

RFR Plot

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Here is a comparison of two elevation patterns selected from the elevation scratchpad. You can also compare standard and low RFR elevation patterns. Any selected azimuth or elevation pattern may be exported to Excel Spreadsheets by clicking the spreadsheet symbol to the right of the input parameter area.



### Radio Frequency Radiation Worksheet

Please fill in the Service, ERP, and Height data then use the button to generate RFR or MPE Chart.

Channel: 19 Elevation Pattern: 10bay\_1.0BT (10.12 gain)

Service: ☒ DTV

☐ NTSC

% Aural

Reflection: ☐ None

☒ FCC OET 65 (1.6)

☐ Other

Reflection (1.0 - 4.0)

ERP (kW):

Height:

☐ M

☒ F

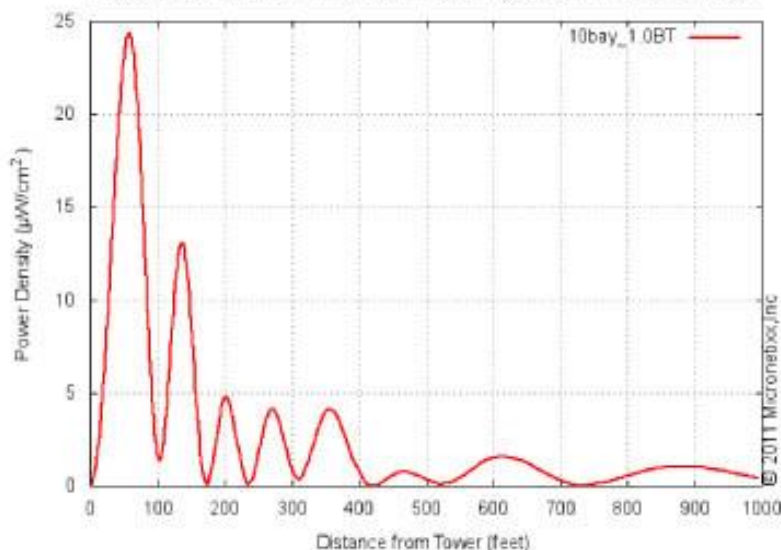
RFR Graph

Exposure%

Zoom

Zoom

RFR Calculated at 100 kW -- 250 feet FCC OET 65 Reflection coefficient applied



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Among the many features found in **AntennaSelect™**, the RFR calculator makes it easy to see if an antenna will be within power density rules for a given application. You select the antenna model or models from the main page. Enter your ERP, height above ground and reflection coefficient. You can change the plot by selecting either the power density or percentage of MPE, (Maximum Public Exposure). The plot can easily be saved and exported to a PDF File.

## Quick Calc Worksheet

Please fill in the Channel followed by Azimuth Gain and Elevation Gain to begin. Use Tab to navigate.

### Antenna Gain Specifications

Channel  Azimuth Gain   
Elevation Gain  Antenna Gain

[Printable Form](#)

[Clear](#)

[Email Question](#)

### Power Worksheet

Line Type   
Line Length (ft)   
Line Efficiency %  Line Loss (dB)

Use the following two lines to provide names and efficiency values for Filters, Combiners, etc.

Mask Filter  Efficiency (%)  (dB)   
Combiner  Efficiency (%)  (dB)

Total Transmission System Efficiency (%)

Total  
Transmission  
System Loss  
(dB)

### Select Power Calculation

☐ ERP ☒ TPO

#### TPO Calculation

Transmitter Power Output Calculated   
(kW)

Transmitter Power Output   
(dBk)

Antenna Input Power (kW)

Antenna Input Power (dBk)

Antenna Gain

Antenna Gain (dB)

Specify Station ERP (kW)

Station ERP (dBk)

### Optional Project Identification

Customer:

Project ID:

Description:

Consultant:

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Here is our “what if” calculator. You can use QuickCalc as a scratchpad to design an RF system. Enter the channel, elevation gain, azimuth gain, type of transmission line and any additional losses, (such as with Filters). You can try new gains and transmission line losses. The form can then be printed out.



# **MICRONETIXX** COMMUNICATIONS

We hope you have found our TV Spectrum Repacking Antenna Engineering Guide useful. Antennas and the technologies they use do not get discussed regularly. With the spectrum Re-Pack right around the corner, more knowledge will help in planning a next generation transmission site.

When you are ready, contact us and let us know what your goals and objectives for your station are. We will custom-engineer an optimum antenna solution. Again, those who like to do some of your own engineering, our on-line antenna design tool, **AntennaSelect™** can generate system designs sometimes in only a few minutes. [www.antennaselect.com](http://www.antennaselect.com) is the website to visit. E-Mail: [bammons@micronetixx.com](mailto:bammons@micronetixx.com). Or [info@micronetixx.com](mailto:info@micronetixx.com).



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