Project	**IEEE 802.16 Broadband Wireless Access Working Group**
Title	**Base Transceiver Station Antenna**
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Re:	This paper is a response to a December 1999 Call for Contributions, for 802.16's Meeting #5 (January 10-14 in Dallas, Texas). This paper is a response to a specific assignment to prepare recommendations for Base Transceiver Station Antenna Pattern and Mask equipment design parameters, resulting from Meeting #4.
Abstract	This document recommends the Radiation Envelope Patterns and gains for the Base Transceiver Station (BTS) Antennas.
Purpose	The purpose of this document is to provide recommendations for consideration, pertaining to the definition of BTS Antenna performance parameters.
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Release	
IEEE Patent Policy	

Title of Contribution

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5.0 Base Transceiver Station (BTS) Antenna

General

The document submitted at session #4 by Joel Holyoak (http://grouper.ieee.org/groups/802/16/coexistence/contrib/80216cc-99_21.pdf), covering Section 5 is considered an excellent baseline, from which further discussion and optimization is recommended. The content of this document addresses alternative recommendations relating to the sections contained herein, consistent with discussions held during session #4. Any sections of Joel's document not addressed here are considered acceptable.

5.1.1.3 Minimum Cross-Polar isolation (XPI)

Specification of a minimum cross-polar isolation (XPI) for the BTS antenna implies that the antenna is a dual polarized antenna. Practice shows that dual polarized antennas are receiving increased interest. It is recommended that the XPI of a dual polarized antenna should be agreed upon between the equipment supplier and the purchaser in line with the overall system design requirements. For guidance, XPI better than 25 dB is typical.

5.1.1.4 Inter-Port Isolation

Specification of inter-port isolation for the BTS antenna implies that the antenna is a dual polarized antenna. Practice shows that dual polarized antennas are receiving increased interest. It is recommended that the inter-port isolation of a dual polarized antenna should be agreed upon between the equipment supplier and the purchaser in line with the overall system design requirements. For guidance, interport isolation better than 25 dB is typical.

5.1.2 Radiation Pattern Envelop (RPE)

5.1.2.1.1.1 Class 1 –Co-Polar Azimuth

Coexistence is improved through the suppression of sidelobe energy, that would otherwise cause interference between sectors. The Class 1 azimuth roll-off specification should accommodate a variety of low cost antennas, which provide *standard* performance capabilities, as required to service a low interference environment. It is proposed that the ETSI Point-to-Multipoint specification EN301 215-2 Class CS-1 specification is consistent with the intent of Class 1 operating requirements, and provides a reasonable balance between sidelobe suppression and crosspol isolation.

In terms of α, where α equals ½ the sector size:

Angle off Boresight (deg)	Recommended Max. Gain (dBrel)	Recommended Min. Gain (dBrel)
0	0	-3
α		-3
α+5	0	
(2*α)+5	-10	
135	-12	
155	-15	
180	-25	

A minimum gain is specified to guarantee illumination within the sector. Elimination of nulls helps to keep remote stations from requiring the base station to transmit excess power that could affect coexistence.

Example for 90 degree sector antenna:

Angle off Boresight (deg)	Recommended Max. Gain (dBrel)	Recommended Min. Gain (dBrel)
0	0	-3
45		-3
50	0	
95	-10	
135	-12	
155	-15	
180	-25	

5.1.2.1.1.2 Class 1 – Cross-Polar Azimuth

In terms of α, where α equals ½ the sector size:

Angle off Boresight (deg)	**Recommended Max. Gain (dBrel)**
0	-22
α	-22
α+15	-25
180	-25

5.1.2.1.2 Class 2 Azimuth RPE

A Class 2 implementation involves a moderate to high interference environment. For this case, it is assumed that the antenna pattern of the sector antenna needs to be better controlled in terms of sidelobe and crosspol suppression, in order to limit interference. The following specification is based upon a modification to the ETSI specification, EN301 215-2 Class CS-2 specification, consistent with the intent of Class 2 operating requirements. This recommendation both promotes the development of improved technology, and encourages further improvements to existing *high performance* antennas. Further, it accommodates antennas that provide uniform coverage to slightly beyond the sector azimuth boundary, as is commonly desired for more uniform crossover levels. As consistent with Class 1, a minimum specification is included to guarantee uniform illumination within the sector. Antennas are commercially available that provide the recommended level of performance.

Note: ETSI values are included for comparison purposes only and will be excluded when the document is finalized.

In terms of α, where α equals ½ the sector size:

Angle off Boresight (deg)	**ETSI EN301 215-2 Class CS-2 (dBrel)**	**Recommended Max. Gain (dBrel)**	**Recommended Min. Gain (dBrel)**
0	0	0	-3
α			-3
α+5	0	0	
α+15	-20		
2*α		-20	
110	-23		
3*α		-30	
140	-35		
155		-30	
180	-35	-30	

Example for 90 degree sector antenna:

Angle off Boresight (deg)	**ETSI EN301 215-2 Class CS-2 (dBrel)**	**Recommended Max. Gain (dBrel)**	**Recommended Min. Gain (dBrel)**
0	0	0	-3
45			-3
50	0	0	
60	-20		
90		-20	
110	-23		
135		-30	
140	-35		
155		-30	
180	-35	-30	

5.1.2.1.2.2 Class 2 – Cross-Polar Azimuth

In terms of α, where α equals ½ the sector size:

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-2 (dBrel)	Recommended Max. Gain (dBrel)
0	0	-25
α	-25	-30
α+15	-30	
105	-30	
140	-35	
180	-35	-30

5.1.2.1.2.3 Class 3 – Co-Polar Azimuth

A Class 3 implementation involves a very high interference environment. For this case, it is assumed that the antenna pattern of the sector antenna is required to provide significantly suppressed sidelobes and crosspol, as compared to Classes 1 and 2. Further, it is expected that this *ultra high performance* antenna must provide both faster azimuthal roll-off (steeper mainlobe skirts) near-in, as well as suppressed sidelobes far-out. The following specification is based upon a modification to the ETSI specification, EN301 215-2 Class CS-2 specification, consistent with the intent of Class 3 operating requirements. This recommendation ensures that the rate of sidelobe suppression increases with decreasing sector angles. Thus the narrower beam antenna will be forced to provide the same degree of sidelobe suppression as expected of the wider beams. This result is easily shown in the examples below.

This recommendation both promotes the development of improved technology, and encourages further improvements to existing ultra high performance antennas. Antennas are commercially available that provide this recommended level of performance.

As consistent with Classes 1 and 2, a minimum specification is included to guarantee uniform illumination within the sector.

In terms of α, where α equals ½ the sector size, and ROUND[] means rounded to the next integer value:

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-2 (dBrel)	Recommended Max. Gain (dBrel)	Recommended Min. Gain (dBrel)
0	0	0	-3
(α)			-3
(α+5)	0	0	
(α+15)	-20	-20	
ROUND[2.44*α]		-23	
110	-23		
140	-35	-35	
180	-35	-35	

Example for 90 degree sector antenna:

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-2 (dBrel)	Recommended Max. Gain (dBrel)	Recommended Min. Gain (dBrel)
0	0	0	-3
45			-3
50	0	0	
60	-20	-20	
110	-23	-23	
140	-35	-35	
180	-35	-35	

Example for 45 degree sector antenna:

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-2 (dBrel)	Recommended Max. Gain (dBrel)	Recommended Min. Gain (dBrel)
0	0	0	-3
22.5			-3
27.5	0	0	
37.5	-20	-20	
55		-23	
110	-23		
140	-35	-35	
180	-35	-35	

Example for 22.5 degree sector antenna:

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-2 (dBrel)	Recommended Max. Gain (dBrel)	Recommended Min. Gain (dBrel)
0	0	0	-3
11.3			-3
16.3	0	0	
26.3	-20	-20	
28		-23	
110	-23		
140	-35	-35	
180	-35	-35	

5.1.2.1.3.1 Class 3 – Cross-Polar Azimuth

In terms of α, where α equals ½ the sector size, , and ROUND[] means rounded to the next integer value:

Angle off Boresight (deg)	**ETSI EN301 215-2 Class CS-2 (dBrel)**	**Recommended Max. Gain (dBrel)**
0	-25	-30
α	-25	
α+15	-30	-30
ROUND[2.44*α]		-35
105	-30	
140	-35	-35
180	-35	-37

Example for 90 degree sector antenna:

Angle off Boresight (deg)	**ETSI EN301 215-2 Class CS-2 (dBrel)**	**Recommended Max. Gain (dBrel)**
0	-25	-30
45	-25	
60	-30	-30
110		-35
105	-30	
140	-35	-35
180	-35	-37

Example for 45 degree sector antenna:

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-2 (dBrel)	Recommended Max. Gain (dBrel)
0	-25	-30
22.5	-25	
37.5	-30	-30
55		-35
105	-30	
140	-35	-35
180	-35	-37

Example for 22.5 degree sector antenna:

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-2 (dBrel)	Recommended Max. Gain (dBrel)
0	-25	-30
11.3	-25	
26.3	-30	-30
27.5		-35
105	-30	
140	-35	-35
180	-35	-37

5.1.2.2 Elevation Radiation Pattern Envelopes, Sectored

5.1.2.2.1 Coexistence Issues

The elevation pattern should be specified both above and below the horizon, to provide isolation, improve coexistence, and to ensure efficient use of radiated power. It is proposed that the maximum radiation pattern envelope be defined above the horizon and the minimum radiation pattern envelope be defined below the horizon. In addition, informative information on the maximum radiation pattern envelope will be given for angles below the horizon.

Further, it is recommended that for all classes, the elevation pattern be specified to provide maximum latitude on the part of the equipment supplier, to provide low cost and high performance antennas, of varying beamwidth, gain, and pattern shaping for optimal ground coverage.

5.1.2.2.2 Reference Directions

This specification will follow accepted practices for the specification of elevation radiation pattern envelopes that provide for the 0 degree angle to be directed at the horizon, the 90 degree angle directed overhead, and the –90 degree angle directed downward.

It may be necessary in practical deployments to use electrical or mechanical tilt, or a combination of these two, to achieve the required cell coverage, taking into account the surrounding terrain, for example.

The elevation pattern is considered appropriate to the commonly used range of 0 to –10 degrees for downtilt. A further downtilt of up to +/- 10 degrees may be suitable for some situation. A tilt is translated onto the corresponding patterns as a θ shift along the elevation angle axis.

5.1.2.2.3 Class 1 Elevation RPE

A Class 1 implementation involves a low interference environment. For this case, it is assumed that the antenna pattern of the sector antenna need not be as tight as for a higher interference environment. The Class 1 elevation roll-off specification should accommodate a variety of low cost antennas, which provide *standard* performance capabilities, as required to service a low interference environment. It is proposed that the ETSI Point-to-Multipoint specification EN301 215-2 Class CS-1 specification is consistent with the intent of Class 1 operating requirements, and provides a reasonable balance between sidelobe suppression and crosspol isolation.

5.1.2.2.3.1 Class 1 – Co-Polar Elevation

Above and below the peak of the elevation beam :

Angle off Boresight (deg)	**ETSI EN301 215-2 Class CS-1 (dBrel)**
0	0
± 5	0
± 15	-15
± 90	-25
± 180	-25

5.1.2.2.3.2 Class 1 – Cross-Polar Elevation

The elevation crosspol recommendation is based upon the ETSI specification EN301 215-2 Class CS-1 specification. This specification is consistent with the intended *standard* level of antenna performance utilized in a low interference environment.

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-1 (dBrel)
0	-22
180	-25

Use linear interpolation between limits.

5.1.2.2.4 Class 2 Elevation RPE

A Class 2 implementation involves a moderate to high interference environment. For this case, it is recommended that the antenna pattern of the sector antenna above the horizon should be further suppressed to limit interference. Above the horizon, the ETSI specification EN301 215-2 Class CS-2 is consistent with the intended *high performance* level of antenna performance utilized in an interfering environment.

Above the peak of the elevation beam (above the horizon):

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-2 (dBrel)
0	0
5	0
15	-15
90	-25
180	-35

Below the horizon, it is proposed that a modified ETSI Point-to-Multipoint specification EN301 215-2 Class CS-2 specification is consistent with the intent of Class 2 operating requirements, and provides a reasonable balance between sidelobe suppression and crosspol isolation. Furthermore, the recommended elevation specification provides the antenna supplier with reasonable latitude in terms of providing an appropriate elevation beamwidth and pattern shaping, for a given application. The recommended elevation specification relating to below the horizon, provides for a maximum and minimum envelope, ensuring that the antenna provides sufficient ground coverage, while also ensuring that excessive energy is avoided. A reasonable range between the two limits provides the antenna supplier with sufficient latitude to provide low cost compliant antennas.

Below the peak of the elevation beam:

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-1 (dBrel)	Recommended Max. Gain (dBrel)	Recommended Min. Gain (dBrel)
0	0	0	-3
-5	0	0	-10
-10		-10	-20
-15	-15	-11	-24
-20		-12	-28
-30		-15	-34
-45		-16	-40
-90	-25	-38	-80
-180	-25	-38	-80

5.1.2.2.4.2 Class 2 – Cross-Polar Elevation

This recommended specification is based upon the ETSI specification EN301 215-2 Class CS-2 specification. This specification is consistent with the intended *high performance* level of antenna performance utilized in a moderate to high interference environment.

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-2 (dBrel)
0	-25
180	-35

5.1.2.2.5 Class 3 Elevation RPE

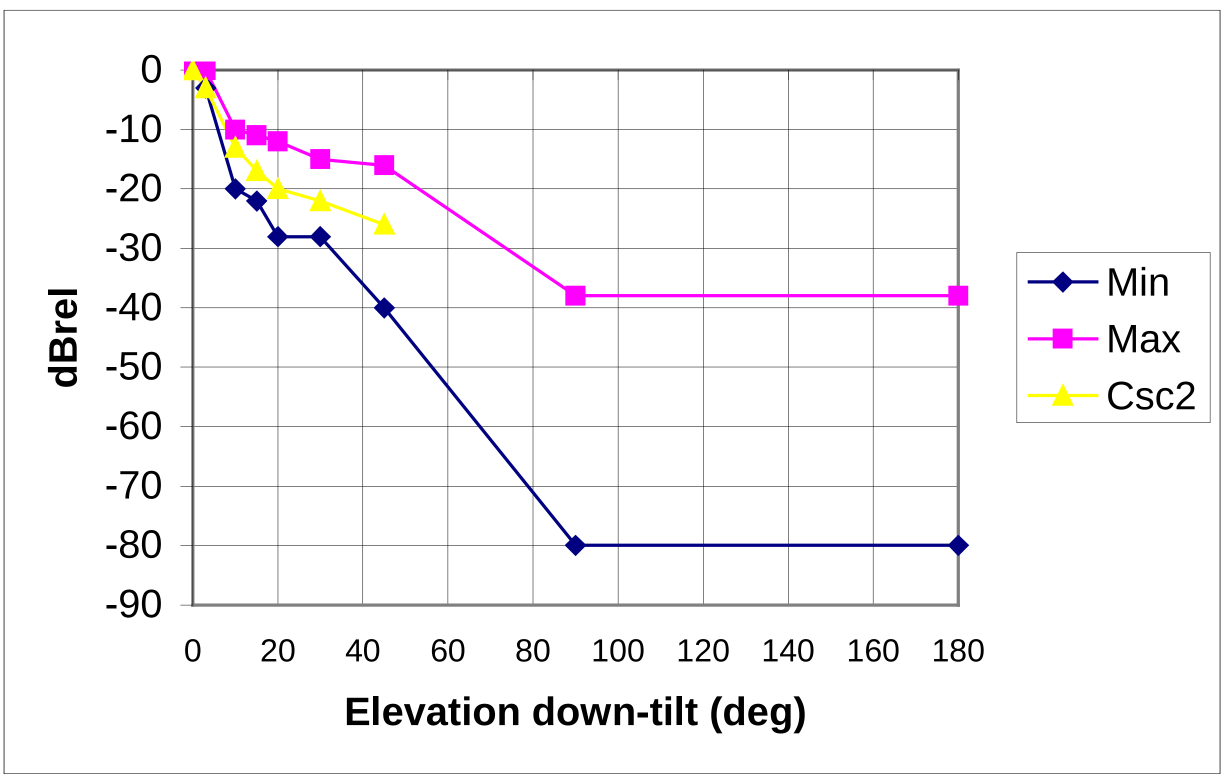
A Class 3 implementation involves a very high interference environment. Clearly, the elevation pattern can and must be used to reduce interference to satellites. Above the horizon, the recommended specification for the Class 2 antenna appear sufficient to eliminate interference with satellites.

Below the horizon, it is proposed that a further modified ETSI Point-to-Multipoint specification EN301 215-2 Class CS-1 specification is consistent with the intent of Class 3 *ultra-high performance* operating requirements, and provides a reasonable balance between sidelobe suppression and crosspol isolation. Furthermore, the recommended elevation specification provides the antenna supplier with reasonable latitude in terms of providing an appropriate elevation beamwidth and pattern shaping, for a given application. The recommended elevation specification relating to below the horizon, provides for a maximum and minimum envelope, ensuring that the antenna provides sufficient ground coverage, while also ensuring that excessive energy is avoided.

Below the peak of the elevation beam:

Angle off Boresight (deg)	**ETSI EN301 215-2 Class CS-1 (dBrel)**	**Recommended Max. Gain (dBrel)**	**Recommended Min. Gain (dBrel)**
0	0	0	-3
-5	0	0	-10
-10		-10	-20
-15	-15	-11	-22
-20		-12	-28
-30		-15	-28
-45		-16	-40
-90	-25	-38	-80
-180	-25	-38	-80

This is described graphically as follows:



5.1.2.2.5.1 Class 3 – Co-Polar Elevation

5.1.2.2.5.2 Class 3 – Cross-Polar Elevation

Class 3 antennas require further levels of cross-polar suppression. It is recommended that a modified ETSI EN301 215-2 Class 2 specification is consistent with the level of performance as required for Class 3 operation.

Angle off Boresight (deg)	ETSI EN301 215-2 Class CS-2 (dBrel)	Recommended Max. Gain (dBrel)
0	-25	-25
5		-25
15		-35
90		-38
180	-35	-38

Use linear interpolation between limits.

5.1.3 Minimum Boresight Gain

The BTS sector antenna boresight gain shall exceed the minimum gain as defined in the following table, for all frequencies in the specified frequency range. These gain values are independent of Class, as higher classes of antennas do not at all imply a reduction of beamwidth, as necessary to increase gain. This recommended specification is based upon the ETSI specification EN301 215-2.

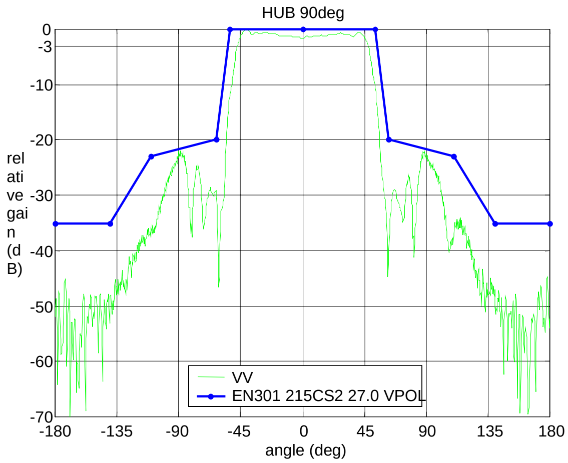
Sector Angle (deg)	ETSI EN301 215-2 Min. Gain (dBi)	Recommended Min. Gain (dBi)
15	16	
30	15.5	
45	14.5	18
60	13.5	
90	12.5	15
135	11	
180	9.5	12

Use linear interpolation between limits.

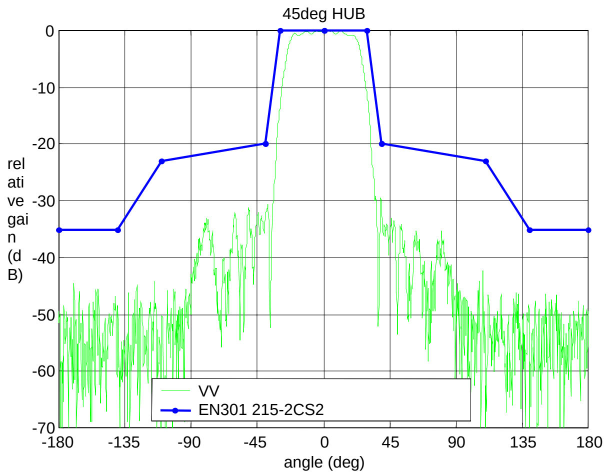
APPENDIX A – Measured Patterns

As requested by the Session #4 chair, the patterns provided below are representative of existing *ultra-high performance* antennas. These patterns are a basis for the aforementioned recommendations, and validate the concept that antennas can in fact be produced that will satisfy the Class 3 requirements.

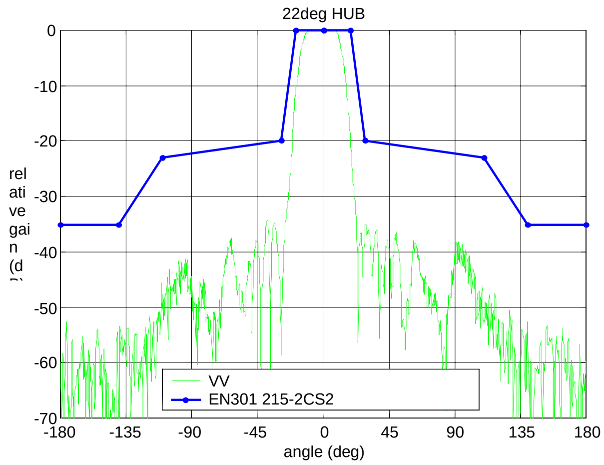
90 deg. Hub (Azimuth) copol, vs. ETSI CS-2 specification:



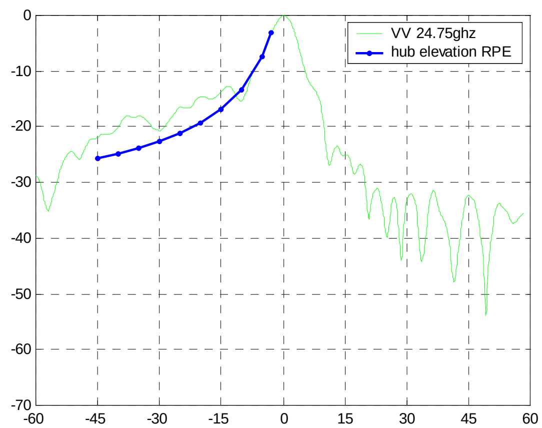
45 deg. Hub (Azimuth), vs. ETSI CS-2 specification:



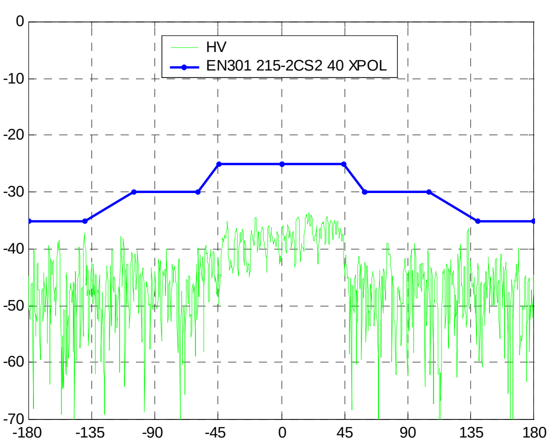
22.5 deg. Hub (Azimuth), vs. ETSI CS-2 specification



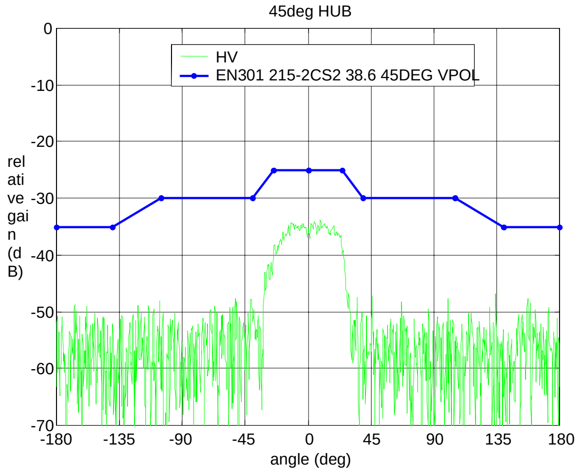
Typical Elevation Pattern:



Typical 90 degree hub, Azimuth Crosspolar Pattern, vs. CS-2 specification



Typical 45 degree hub, azimuth Crosspolar Pattern, vs. CS-2 specification



Typical Elevation crosspolar pattern