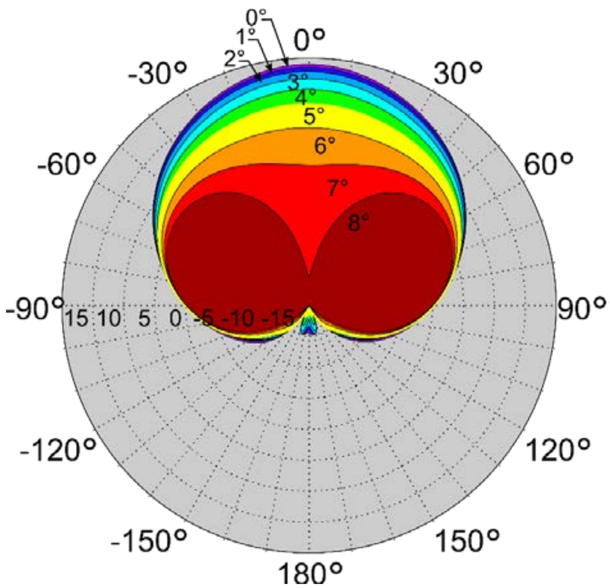
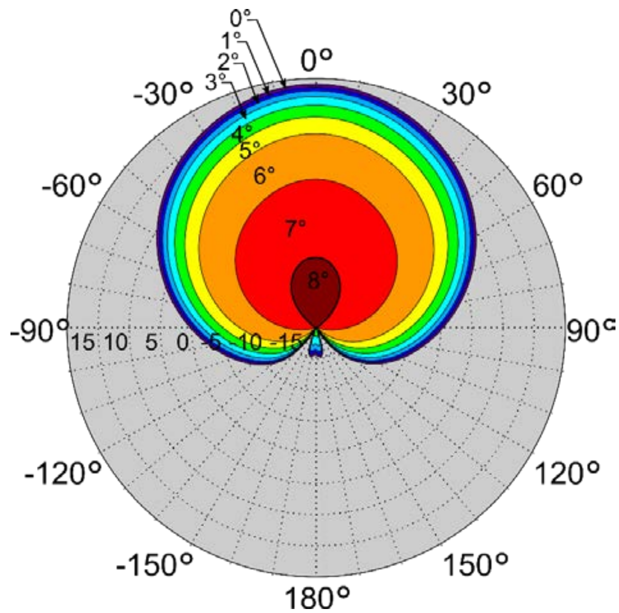
Downtilt: How to set it

As operators expand their fixed-wireless networks from a single to multiple base stations, mitigating interference between neighbouring base stations (inter-cell interference) is extremely important for reusing frequencies (channels) between the cell sites. While interference can be decreased using software-enabled measures in the radio (i.e., output power), there exists base-station pattern control techniques that can achieve the same effect. This is particularly important when overlaying your network because the cell sites become denser and the coverage area of each cell can be significantly reduced.

Mechanical Downtilt



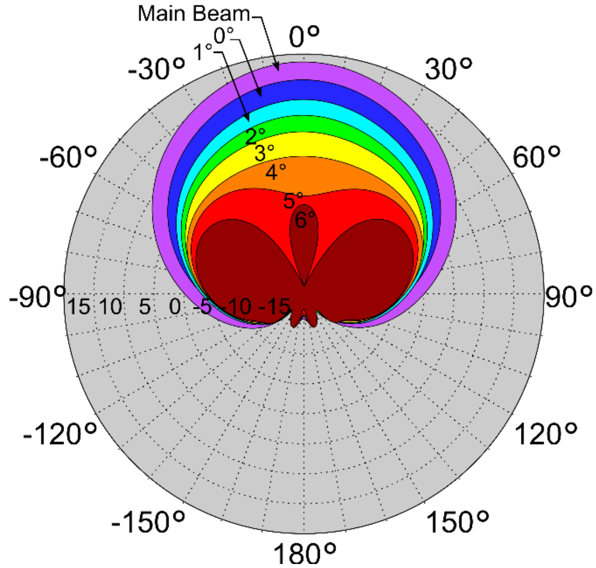
Electrical Downtilt



One method to reduce the interference between cell sites is to decrease a cell site's coverage area through tilting the antenna's vertical (elevation) pattern downwards towards the ground. The most popular and easiest method is by mechanically tilting the entire antenna downwards with adjustable brackets. For instance, the brackets supplied by KP's sector antennas can achieve a large degree of mechanical downtilt. [*Tip: Place a digital level against the back of the sector antenna to get the most accurate downtilt reading.*] The downfall of mechanical downtilt is that coverage isn't reduced uniformly around the antenna's azimuth. Coverage is reduced more in at bore sight and less towards angles away from bore sight. This can be clearly seen in the above figure on the left and the phenomena is termed pattern blooming. This figure shows the pattern in the horizontal (azimuth) plane of a sector antenna with an azimuth half-power beamwidth (HPBW) of 65° and an elevation HPBW of 7°. As the mechanical downtilt increases, the pattern flattens out and HPBW increases. For instance, at 6°mechanical downtilt, the pattern resembles that of a sector antenna with a HPBW of 120°.

Electrical downtilt is another method for tilting a sector antenna's vertical pattern without physically tilting the antenna on its mounting point. Instead, downtilt is achieved internally by introducing 'electrical' phase between the antenna elements inside the sector antenna. The benefit of this approach is that the pattern is reduced uniformly around the antenna's azimuth and pattern blooming does not occur. This can be seen in the above figure on the right in which the pattern reduces in all azimuth directions as the electrical downtilt angle is increased. This corresponds to a coverage area that shrinks uniformly. Electrical downtilt can either be fixed at a set downtilt angle or controlled manually or remotely using an independent motor. Whereas the later provides more control on the coverage area, it can often double or triple the price of a single antenna and comes with a noticeable reduction in antenna gain.

Mechanical Downtilt + 3.5° Fixed Electrical Downtilt with KP-3DP65S-45



Part Number	Gain (dBi)	Azimuth HPBW (degrees)	Elevation HPBW (degrees)
KP-3DP65S-45	18	65	7

KP offers a range of sector antenna products that have built in fixed electrical downtilt. The above figure looks at the impact of mechanical downtilt on KP-3DP65S-45 whose relevant specs are given in the above table. The main beam (purple region) corresponds to the azimuth pattern in the elevation's 3.5° electrically down tilted main beam and represents the azimuth pattern seen in the coverage area. The dark-blue region pattern corresponds to the pattern seen on the horizon by other cell sites (i.e., the horizontal pattern considered when determining interference) when there is 0° of mechanical downtilt. It is evident that 3.5° of electrical downtilt provides a uniform reduction of gain of approximately 3.5 dBi on the horizon (15 dBi total). Pattern blooming becomes significant past 3° of mechanical downtilt, which corresponds to 6.5° of total downtilt.

The range of tolerable mechanical downtilt will depend on the antenna's vertical HPBW and pattern and your network's acceptable level of pattern blooming. As a general guideline, it is recommended that the maximum downtilt (mechanical + electrical) should not exceed the 10 dB beamwidth of the elevation's main beam. Provided below is a table of maximum total downtilt:

HPBW (degrees)	Max Total Downtilt (degrees)
4	3
5	4
6	5
7	6
8	7
10	8
14	9
16	10
20	14

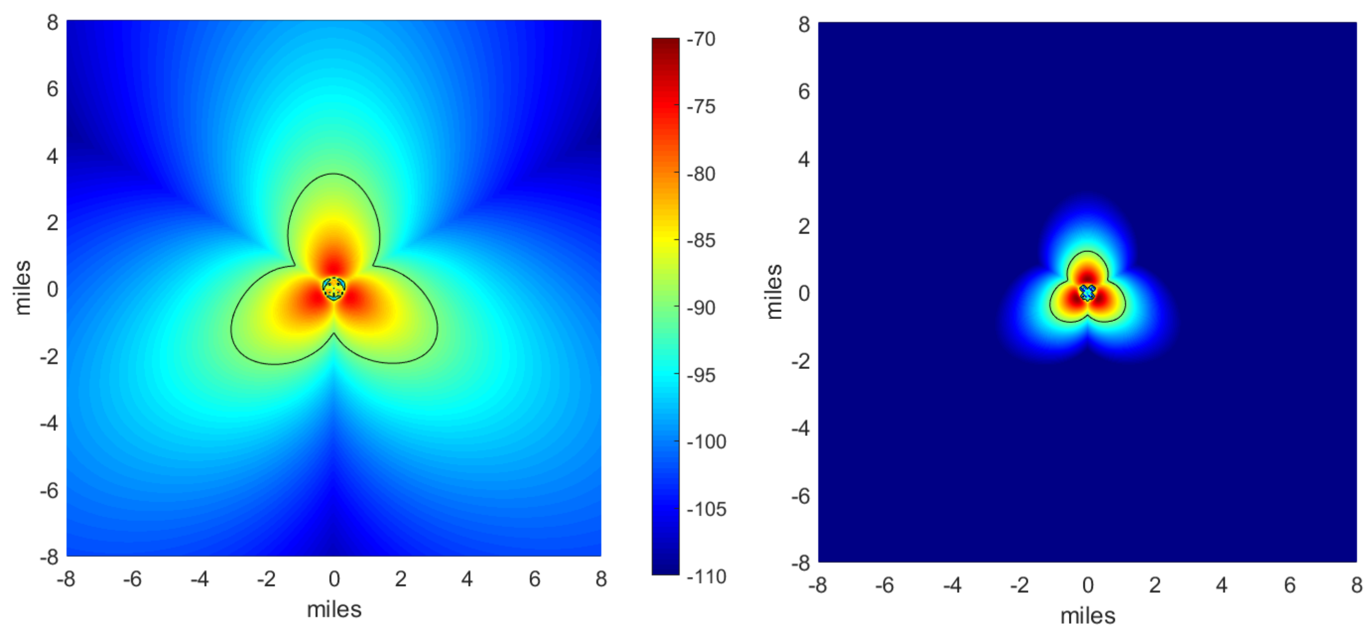
Antenna Height=100 feet					Antenna Height=150 feet					Antenna Height = 200 feet				
Total Downtilt	Inner Radius		Outer Radius		Total Downtilt	Inner Radius		Outer Radius		Total Downtilt	Inner Radius		Outer Radius	
(°)	miles	km	miles	km	(°)	miles	km	miles	km	(°)	miles	km	miles	km
0	0.31	0.50	OH	OH	0	0.46	0.75	OH	OH	0	0.62	1.00	OH	OH
1	0.24	0.39	OH	OH	1	0.36	0.58	OH	OH	1	0.48	0.77	OH	OH
2	0.20	0.32	OH	OH	2	0.30	0.47	OH	OH	2	0.39	0.63	OH	OH
3	0.17	0.27	OH	OH	3	0.25	0.40	OH	OH	3	0.33	0.54	OH	OH
4	0.14	0.23	2.17	3.49	4	0.22	0.35	3.26	5.24	4	0.29	0.46	4.34	6.99
5	0.13	0.20	0.72	1.16	5	0.19	0.31	1.08	1.75	5	0.25	0.41	1.45	2.33
6	0.11	0.18	0.43	0.70	6	0.17	0.27	0.65	1.05	6	0.23	0.36	0.87	1.40
7	0.10	0.16	0.31	0.50	7	0.15	0.25	0.46	0.75	7	0.20	0.33	0.62	1.00

*Note: These values represent a first order approximation and assumes a smooth terrain and elevation beamwidth of 7°. OH=Over Horizon. Formula: Radius=Height/[tan(Downtilt Angle ± Beamwidth/2)]

The maximum range of downtilt for sector antennas with smaller HPBW may not seem significant, but they are sufficient for many applications. The above table shows the inner and outer -3dB radius for different tower lengths as the total downtilt angle (mechanical + electrical) is increased. On a 200 foot tower with an antenna elevation beamwidth of 7°, the recommended max downtilt angle of 6° corresponds to an outer 3dB radius of 1.4 km and a cell size well below the standard deployment.

Total Downtilt = 3.5° electrical + 0° mechanical

Total Downtilt = 3.5° electrical + 3° mechanical)



The above figure displays the pathloss plots at ground level for 3 x KP-3DP65S-45 arranged around a tower assuming a CPE gain of 11dBi, frequency of 3550MHz, tower height of 100 feet, and flat terrain with no foliage and buildings. The black line corresponds to the -90dB pathloss contour. For 0° mechanical downtilt and fixed 3.5° electrical downtilt, the signal strength will be greater than -90dB up to 3.4miles (figure on the left). By adding another 3° mechanical downtilt for a total of 6.5°, the -90dB contour is now at 1.2miles (figure on the right). Furthermore, at 3 miles from the tower the signal strength is now well below -110dB. Depending on the radio's sensitivity to inter-cell noise, this would allow you to deploy a new tower close the first tower.

About the Author: Justin G. Pollock (PhD) is a Senior Antenna Engineer at KP Performance Antennas Inc. and oversees the design, fabrication, and testing of industry-leading antenna technologies for fixed-wireless broadband. He has co-authored 19 refereed journal and conference papers to leading publications in the field of RF/microwave engineering, antennas, physics, and optics.

Company Information: KP Performance Antennas Inc. is a manufacturer of broadband antennas and accessories. Dedicated to serving the needs of the Wireless Internet Service Provider (WISP) market, KP Performance Antennas offers purpose built products that reliably perform in the field. KP Performance Antennas product line consists of Yagi, Grid, Omni, Dish, Sector, and other-style antennas that operate in the 900 MHz, 2.4 GHz, 3 GHz, and 5 GHz frequencies. KP Performance Antennas is an Infinite Electronics company.

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