Maximizing Your SINR:

KP ProLine Horns and Sectors

White Paper

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Maximizing your SINR: KP ProLine Horns and Sectors

The 5GHz spectrum from 4.9 to 6.4GHz is used globally in fixed and mobile wireless, land/mobile/radio (LMR) systems, public safety, Wi-Fi and more. Its popularity and eventual global standardization are partially attributed to its effective propagation distance of 10-25km and the availability of many channels of large bandwidths. Regardless of application, a reliable communication link between an access point (AP) radio and client premise equipment (CPE) or user equipment (UE) requires high signal-to-interference and noise ratio (SINR). Effectively, SINR dictates how loud your signal is over everything else in the ether. A high SINR means the CPE/UE can hear your AP better, and vice versa. To achieve a high SINR in 5GHz point-to-multipoint communication, operators have two options: a sector antenna or horn antenna.

Sector Antenna

Sector antennas are typically long, narrow, and rectangular in shape, and are either partially or fully enclosed inside of a UV-resistant radome. Their interior is composed of multiple antenna elements connected and arranged in a vertical array. They can be single or multi-band and support 2, 4, 8, or even more ports. Despite having 3dB azimuth beamwidths of 33°,45°, 60°, 90°, or 120°, sector antennas are afforded high gain from their narrow elevation beamwidths, which can be as low as 4°. Therefore, a sector's vertical height dictates its gain and, in a world where gain is king, they have proliferated as the workhorse in point-to-multipoint application. Despite having larger azimuth beamwidths, KP's sector antennas are optimized to have front-to-back (F/B) greater than 35dB and reduced side lobes, which mitigates self-interfaces and allows reuse of spectrum on the same tower. Sector antennas are well suited for both rural and suburban environments in which coverage must reach from 200 yards to tens of miles.

Horn Antenna

Horn antennas are relatively smaller in size and can be either circular, rectangular, or elliptical in shape. KP's ProLine horn antennas consist of a flared metallic circular waveguide that is powder coated on the outside and contains longitudinal corrugations along the inside. A UV-resistant radome encloses and protects the antenna. Symmetric height and width provide equal elevation and azimuth beamwidth, with 6dB beamwidths of 30°, 45°, and 60° available. KP ProLine Horn antennas are highly efficient and low loss, providing high gain despite their small size. They are optimized to have no side lobe levels and excellent F/B ratios across the 4.9 to 6.4GHz band.

SINR

Signal-to-interference and noise ratio attempts to quantify the power received in the desired communication signal strength over the amount of power in both interference and noise. In its simplest form, it can be represented in decibel (dB) units as: SINR=S-I-N, where S, I, and N is the power in the desired signal, interference, and noise, respectively. The unit of measure is dBm, dBW, or any other relative dB unit. The goal of a network operator is to maximize SINR, which allows the highest modulation rates, highest throughput, and subsequently the fastest and most reliable service to the end user. To set a benchmark value, SINR > 20dB is an excellent link and SINR < 0dB is an unusable link. A SINR > 20dB will allow the radio to achieve the highest modulation and coding scheme (MCS) and thus the best bit rate and robustness of data transmission.

Increase Signal Strength (S)

Increasing the received signal strength indicator (RSSI) in the link is an effective “brute force” method to raise SINR. Focusing on the AP side, this is achieved by choosing higher gain antennas or increasing transmitted power; both of these techniques increase the effective radiated power (EIRP). EIRP quantifies the maximum amount of power a radio transmitter and antenna radiate in a specific direction. It is calculated by adding the radio’s conducted power and the antenna’s gain together in dB scale. For health and safety reasons, the maximum EIRP and conducted power is restricted in many regions and is often dependent on the operating frequency-band. Table 1 shows FCC limits for the unlicensed 5GHz band (as of September 2020).

FCC Band	Frequency	Max.Conducted Power	Max. EIRP
U-NII-1 (Low)	5150 – 5250 MHz	1 W | 30 dBm	4 W | 36 dBm
U-NII-2A (Mid)	5250 – 5350 MHz	0.25W | 24 dBm	1 W | 30 dBm
U-NII-2B	5350 – 5470 MHz	-	-
U-NII-2C	5470 – 5725 MHz	0.25W | 24 dBm	1 W | 30 dBm
U-NII-3	5725 – 5850 MHz	1 W | 30 dBm	4 W | 36 dBm

Table 1: Maximum conducted power and EIRP for the U-NII bands.

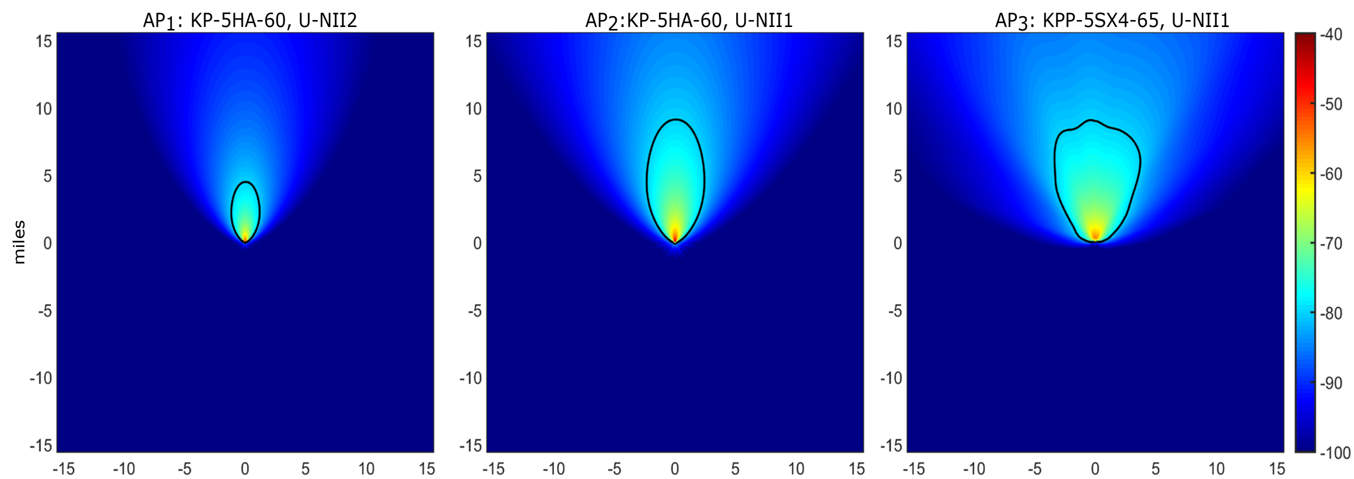

Figure 1: RSSI RF Coverage of AP_1, AP_2 and AP_3.

ID	Channel	Antenna PN	Antenna (dBi)	Conducted Power (dBm)	EIRP (dBM)	Coverage Area with SINR > 20dB (sq miles)	Maximum Distance with SINR > 20dB (miles)
AP_1	52 U-NII-2A	KP-5HA-60	13.8	16.2	30	9	4.5
AP_2	40 U-NII-1	KP-5HA-60	13.8	22.2	36	33	9.1
AP_3	40 U-NII-1	KPP-5SX4-65	17.0	19	36	49	9.1

Table 2: RF Performance of AP_1, AP_2, and AP_3.

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Figure 1 depicts the RSSI values of three different APs specified in Table 2 in a region with an effective noise floor of -100dBm. The noise is constant and not coming from just one specific direction. Each AP shares the same model of AP and CPE radio in which the CPE has an integrated antenna of 14dBi gain. The black contour in each image corresponds to SINR >20dB, which allows the link to achieve highest MCS values.

The 60° horn antenna (AP_1) operating in U-NII-2A has the lowest EIRP of 30dBm and is able to capture a coverage area of 9 square miles with maximum distance of 4.5 miles at the antenna's boresight. Increasing RSSI to improve SINR will require moving to the U-NII-1 band to allow for higher EIRP value. This is shown for AP_2 which operates at channel 40 with 6dBm higher conducted power, achieving a maximum EIRP of 36dBm. As a result, the coverage area increases almost fourfold to 33 square miles, doubling the maximum distance. To reiterate, this is achieved by simply changing channels to enable the radio to output more power, boosting the signal even more above the noise floor.

Now that we are at the maximum EIRP limit, changing to a sector antenna with higher gain will require dropping the conducted power by 3.2dBm in order to maintain EIRP<36dBm. Despite this, the sector antenna's broad beamwidth and higher gain still allow for an even greater coverage area, although the maximum distance remains the same. It is worth reiterating that the horn's 60° beamwidth is referenced to the 6dB drop-off versus the sector antenna's 3dB drop off. This is why the horn provides higher RSSI values near the antenna's broadside, whereas the sector spreads the coverage out over larger azimuth angles.

AP_2 and AP_3 are now at the maximum allowed EIRP value and neither gain nor transmit power can be used to improve SINR any further. Doing so will cause a visit by the FCC or equivalent regulatory body. Further SINR improvements will require reduction of the noise floor and interference.

Decrease Interference (I)

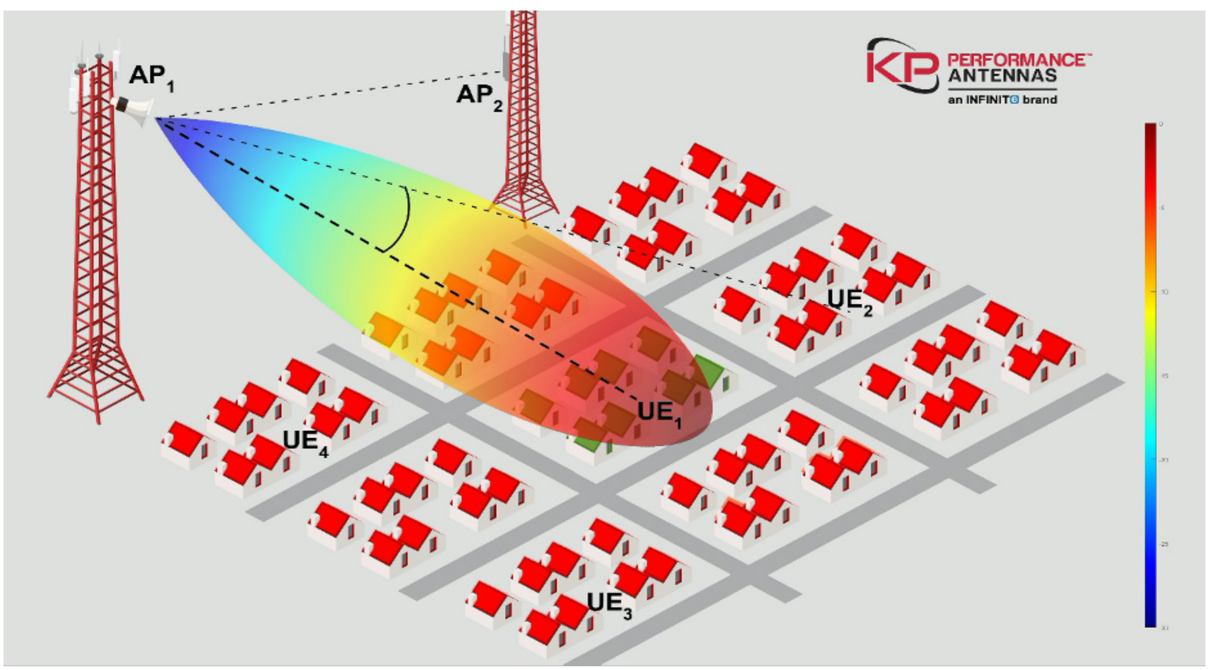

Figure 2: Horn antenna at AP_1 providing service to a neighborhood (UE_1) surrounded by other neighborhoods (UE_{2-4}) and another AP_2 all transmitting interference on the same channel as AP_1.

Whereas in the previous scenario the source of the interference was unknown, in many situations the offending transmitter(s) can be triangulated to originate from a certain direction. In these cases, the antenna's pattern and side lobes play a critical role in network performance. Take for instance an access point (AP_1) providing coverage to a small neighborhood that is plagued by interference from AP_2 providing coverage to an adjacent neighborhood—with UEs sharing the same channel. This is illustrated in Figure 2. Clearly, the surrounding equipment (AP_2, UE_2 , UE_3, UE_4) located at different azimuth (φ) and elevation (θ) will cause interference in which AP_2 will be the worst offender due to its higher EIRP. For simplicity's sake, the effect of antenna downtilt and elevation differences between equipment is not considered.

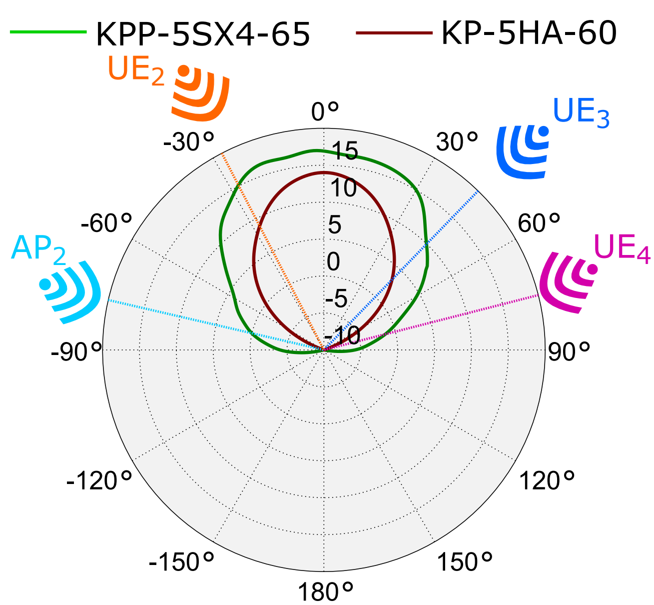

Figure 3: Radiation pattern of KP sector antenna

Antenna	AP_2 (dB)	UE_2 (dB)	UE_3 (dB)	UE_4 (dB)
KPP-5SX4-65	4	13	18	10
KP-5HA-60	20	21	27	24

Table 3: SINR of AP_1 with respect to the received interference signal strength from nearby equipment when using KP's sector or horn antenna.

Figure 3 compares the azimuth radiation patterns of the same 65° sector antenna of 17dBi gain and a 60° horn antenna with 13.8dBi gain. It is important to note that the radiation plot shows the patterns referenced to their respective maximum gain value. The incoming angular direction of interference from each source is indicated on the plot.

Even though each antenna has different gain, the conductive power is set to maximize EIRP at 36dBm in channel 40, and the RSSI between AP_1 and UE_1 is -70dBm for both antennas. The noise floor is 90dBm.

If there was no interference, the SINR would be greater then 20dB, the link optimized, and you are free to choose the antenna based on other considerations. However, AP_2 is transmitting at -80° off mechanical boresight and causing interference. When the signal reaches AP_1, the signal strength (S_R) from the transmitter degrades through pathloss to a value of S_R=-75dBm.

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Now, this is where things get interesting. The antenna's side lobe level will provide additional "spatial filtering" of the interfering signal. The received interference signal strength (I_R) at AP1 is calculated as $I_R = S_R - G_\varphi$, where G_φ is the side lobe level at the angle between mechanical boresight of AP1 and the interfering device. For KPP-5SX4-65, the side lobes at -80° is +1dB, resulting in an interference signal I_R= -74dBm. Therefore, the SINR between AP1 and UE1 will be only 4dB and the link will perform poorly.

Replacing the sector with the horn, the side lobe level at φ=-80° improves from +1dB to -15dB, resulting in a I_R=-90dBm and SINR an acceptable 20dB. Table 3 compares the interference signal strength for each antenna and all interfering devices. Two points are significant:

1. Although AP2 is the worst offending interfering equipment due to its higher conducted power, the UEs are just as problematic due to their closer relative angle to mechanical boresight. As a result, the horn's sharp drop of gain outside its prescribed 60° 6dB beamwidth and non-existent side lobes cause a significant improvement in SINR.

2. The horn provides significant improvement in SINR but at the expense of lower RSSI values for UEs near the edge of its coverage area—not, however, at mechanical boresight. This is because the gain of a horn drops more sharply in the azimuth plane then an equivalent sector antenna.

Conclusion

Choosing the appropriate antenna also depends on a number of factors not discussed here, including CapEX/OpEx, form factor/aesthetics, wind loading, and co-location. However, when optimizing SINR and operating at EIRP limits, a general guideline is that the sector antenna's high gain is ideal for covering large distances and wide areas with a consistently high link strength. A horn antenna's focused beam can cover similar distances but with a narrower coverage area. The horn's patterns are tailored for suppressing noise or interference to boost SINR. Whereas this work focused on outside interference, horns also help reduce self-interference, lending to their use in densification, co-location, frequency sharing, gap filling in coverage, and more. Their small size and versatility allow them to be mounted inconspicuously on any infrastructure singularly or in large clusters. If the goal is to maintain a high SINR to ensure your network achieves peak-possible modulation rates in a noisy environment, a horn antenna is the best choice.

For more information on KP Performance Horn and Sector antennas, please visit www.kpperformance.com or contact us at +1 (855) -276-5772.