How 4G & 5G Antennas Really Work

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How 4G & 5G Antennas Really Work If RF Signals Were An Opera

Picture yourself in an open space – a meadow if you will – on a quiet sunny day. In front of you, 30 meters away, is a full opera. They are singing the Canadian national anthem. Their singing is crisp and clear, just as it should be when you are dead center in front of opera singers.

Then, you start moving to the right. You are following the path of a semicircle, centered at the platform where opera singers are standing, with a radius of 30 meters. As you are moving along the semi-circle, the singing becomes quieter. This is normal – you are moving away from the center, and the sound does not reflect from a nearby wall or ceiling since you're in an open space.

When you reach the end of the semi-circle, you are in line with the opera singers, but still 30 meters away. The sound is quiet now. This is how a 4G antenna radiates on the horizontal plane. Most of the RF signal is delivered dead center in front of an antenna panel, then gradually becomes lower until it reaches its lowest point when you are lined up with the antenna.

Flying High with 4G

Now picture yourself and the opera levitating 30 meters above ground. You can still move, but this time only above and below the singers. You are still moving around a semi-circle with a radius of 30 meters, but the semi-circle is now vertical. Again, you will hear the Canadian anthem loud and clear when in front of the singers, but as you move above the sound is gradually going to get quieter. Finally, when you are levitating 30 meters above the singers, you will not be able to hear much at all. This is how a 4G antenna radiates on the vertical plane. Again, most of the signal radiation is dead center in front of the antenna panel, then it gradually loses intensity as you move away, above or below the antenna.

Getting Louder with 5G

Now, let us give each opera singer a bullhorn. The sound is much stronger now. Imagine you are still moving around in a horizontal or vertical semi-circle around the opera. This time, the singers are pointing their bullhorns in your direction as you move. Because the sound is following you, it stays as loud as it was when you were dead center in front of the opera, no matter where you are. This is how 5G antennas work. The bullhorn is 5G Beamforming, and opera singers moving their heads is dynamic Beamforming that tracks the user as they move away from the center of a 5G antenna panel.

How 5G can serve Multiple Users

We have just explained how 5G works with a single user exchanging data with the base station. The opera is a 5G base station, the listener is UE, and the Canadian national anthem is the data exchanged between the base station and the UE. But what happens when there is more than one UE? Let us assume there are two listeners. They are both located on that horizontal semi-circle. One is a bit to the left, and the other is a bit to the right of the opera. Both are still 30 meters away. The one to the left wants to hear the Canadian National Anthem, and the one to the right wants to hear the American National Anthem. This can be done in 3 different ways:

- All singers, still carrying bullhorns, turn to the left and sing the first verse of the Canadian anthem toward the first listener. Then, when they finish the first verse, the singers turn to the other listener and sing the first verse of the American national anthem. The listeners record their respective anthems on their smart phones while the opera sings in their direction and hit the pause button when they do not. The total duration of the performance is double the time it takes to listen to each anthem. Increasing the number of listeners from one to two slowed down the exchange of information. This is how 5G analog Beamforming works. While the data is exchanged with one UE, all other UEs are in the "pause" mode.

- The low register singers (bass, baritone) turn left and sing the Canadian national anthem, while the high register singers turn right to sing the American national anthem. When they are done, the low register singers turn to the right and sing the American national anthem, while the other half turn to the left and sing the Canadian national anthem. Each listener records both the low and high versions on their smartphone, and then use an app to parse the low and high register together. Again, it took twice then what it would take if only one listener was present. This is how digital 5G Beamforming with a beam frequency reuse factor of 2 works. Each beam uses only half of the frequency bandwidth at a time, either the low or high band.

- The number of opera singers doubles. Now we have two operas in one location, so it is a bit crowded on stage. Everybody has a bullhorn. The original opera members turn to the left and sing the Canadian national anthem, while the cloned opera members turn to the right and sing the American national anthem. Because they sing in the full register at the same time, both anthems can be sung simultaneously. This is how digital Beamforming with a beam frequency reuse factor of 1 works. Each beam uses full frequency bandwidth to deliver data to the user.

Safe Distances for 4G & 5G

Now let's go back to the original setup. One listener is 30 meters away, in front of the opera. No bullhorns. Let's suppose the listener starts moving closer, still dead center in front of the opera. The sound gets louder and louder. At some point the sound becomes too loud, and their ears start hurting. The user backs away until the hurting stops. Let us say it's 5 meters away from the opera. This is the minimum safe distance to listen to the opera without damaging your eardrums. Mobile wireless networks work the same way. A governing body determines the maximum electric field intensity in front of the antenna. Engineers can calculate the safe

distance from the antenna using the maximum electric field intensity. Coming closer than the calculated safe distance may cause harm to your body. The actual safe distance depends on many factors, and we will cover that in detail in one of our upcoming webinars.

Let us get back to the scenario at hand. We just mentioned that the safe distance is 5 meters while standing dead center in front of the opera. This is a 4G case, and we learned from that case that moving away from the dead center decreases the intensity of the sound. If we are 5 meters away but are all the way to the side, we hear much less. In that case, even if we come closer than 5 meters, our ears will not hurt. That is why it is safe to stand directly below a 4G panel antenna, even if the distance between you and the panel is less than the recommended minimum safe distance.

Lastly, let us look at the safe distance for 5G cases. This time, opera singers have bullhorns, and the sound is louder. Now, our ears start hurting 10 meters away from the singers. Not only is the safe distance larger, but it does also not change with the position of the listener, because the opera singers follow the listener as they move around. Thus, the safe distance is 10 meters in any direction relative to the center of the 5G antenna panel, including directly above and below antenna. This is how it works in the RF world in principle, although in reality the safe distance does vary a little with UE position relative to the panel. We will also cover this in one of our upcoming webinars.

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