Single-Layer Spherical Lens for 5G Wireless Networks

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Fifth generation (5G) communication systems will provide a dramatic increase in data rates over existing technologies while allowing network access for many devices simultaneously. This will require high gain, multi-beam multiple-input multiple-output (MIMO) antennas to meet system demands for coverage and capacity. Furthermore, the high data rates anticipated for 5G and the availability of spectrum encourage the use of microwave and millimeter wave (mmWave) frequencies much higher than those used by mobile technologies of previous generations.

Researchers in academia and industry are actively investigating massive MIMO technology using large, active antenna arrays with potentially hundreds of elements to meet system demands. With many elements dedicated to only a few user terminals, highly directive beams can be steered in a desired direction to provide the data rates promised by 5G. While research has shown this to be a promising approach for next generation mobile networks, there are some challenges as well. Antenna arrays can be costly and complex to design and fabricate, and even when off-the-shelf components are used to reduce cost, it can be difficult to successfully make all components work well together. In some cases, the array can become very inefficient to the point where more energy is lost in the system than radiated by the antenna. Arrays can also present challenges if wide scan angles are needed. The array will generally exhibit scan loss at wide scan angles reducing gain and impacting the achievable data rate. Arrays can also be difficult to impedance match over a wide range of scan angles, and if precautions are not taken, the active VSWR can spike at certain scan angles. When this happens, large amounts of energy may be reflected back into the array damaging sensitive electronics.

Here we present the spherical lens with many high gain beams for 5G networks (patent pending). The ideal lens would be the familiar Luneburg lens where the dielectric constant at the center of the lens is 2 and decreases to 1 at the edge of the lens. However, it is found that aperture efficiencies of nearly 70% can be achieved with a single-layer (constant ϵ_r) lens for a low cost solution. The key is a properly designed feed antenna spaced appropriately from the lens surface. The use of a lens also allows a high gain beam from a single antenna element so that many elements do not need to be combined to achieve a desired gain. Furthermore, the spherical lens generates a focal surface rather than a focal point so that many antennas can be positioned around the lens for many high gain beams. The total number of beams is selected by desired beam crossover levels and lens size. However, the gain and beam crossover can be adjusted by combining feed antennas which can also provide beam steering if desired. One other added benefit of the lens is that the necessary size and machining cost of the lens decrease as frequency increases. As a result, a mmWave lens antenna could be much more economical than a mmWave phased array for 5G systems. The single-layer lens is a practical approach for 5G systems and necessitates the development of suitable, broad-beam feed antennas from microwave to mmWave frequencies.