# RE-SHAPING WIND LOAD PERFORMANCE FOR BASE STATION ANTENNAS

ANDREW®
an Amphenol company

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## ABSTRACT

As tower space becomes increasingly scarce and some infrastructure pushes its limits, the demand for antennas that can better withstand wind loads is more crucial than ever. Andrew's re-designed base station antennas are crafted to be exceptionally aerodynamic, minimizing the overall wind load imposed on a cellular tower or similar structures.

## INTRODUCTION TO THE PHYSICS OF WIND LOAD

Wind load is the force generated by wind on the exterior surfaces of an object. In aerospace and automotive industries, only unidirectional wind in the frontal direction is of concern. In the world of base station antennas, wind direction is unpredictable. Therefore, we must consider 360 degrees of wind load.

Wind force on an object is complex, with drag force being the key component. Drag can be pressure drag, friction drag and/or vortex drag. Pressure drag is usually the most dominant force.

Pressure drag is created when the air pressure against the leading side of the object is higher than the trailing side. This differential creates the pressure drag. When the pressure differential is reduced, drag force is reduced. As seen in **Figure 1**, airflow leaves a wake behind the object. The more streamlined the object is, the lower the pressure differential and, therefore, the less the drag.

For this reason, much effort and research have gone into the design of aerodynamic surfaces and features to delay flow separation and keep the local flow attached to the object for as long as possible. When the surface features are optimized for its size and location, drag force can be greatly reduced. One example is the golf ball and its dimple features **(Figure 2)**.

To reduce wind load in base station antenna designs, the key is to delay flow separation and reduce wake.

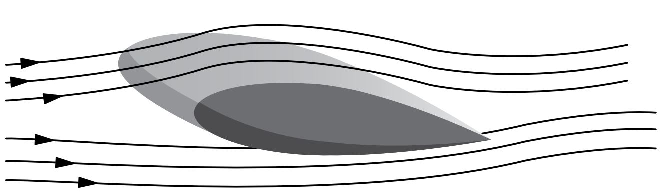

Figure 1: Airfoil shape minimizes drag

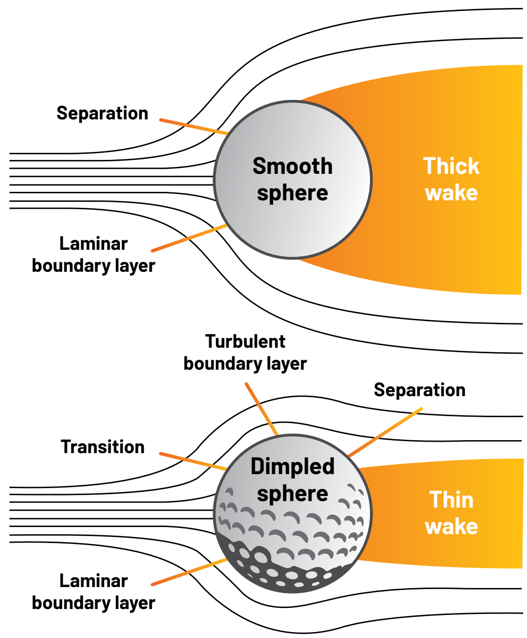


Figure 2: Golf ball dimples reduce wake

## Bernoulli's equation for the pressure in a fluid

$$P_1 + \rho g y_1 + \tfrac{1}{2}\rho v_1^2 = P_2 + \rho g y_2 + \tfrac{1}{2}\rho v_2^2$$

This equation can be simplified, as only the third term on each side is related to pressure drag. Furthermore, force is related to pressure:

$$P = F/A \rightarrow F = PA$$

In a simplified form, the basic wind load formula is:

$$F_w = \tfrac{1}{2} \cdot \rho \cdot V^2 \cdot Cd \cdot A$$

Where:

**$F_w$ = Wind load force (lbf, N)**
**$\rho$ = Air density (0.0765 lb/ft$^3$, 1.226 kg/m$^3$)**
**$C_d$ = Drag coefficient**
**V = Wind velocity (ft/s, m/s)**
**A = Cross-sectional area normal to wind direction**

## How do we reduce wind load for base station antennas?

In the basic formula above, at any given wind speed,
the key variable is drag coefficient, $C_d$. Andrew's enhanced antenna designs focus on lowering $C_d$.

# MATHEMATICAL SIMULATIONS AND TESTING

Using a thorough understanding of the physics and aerodynamics behind wind load, we optimize the antenna design to minimize wind load. This involves using numerical methods such as computational fluid dynamics (CFD) analysis during the design phase to optimize the geometry. CFD simulation allows us to analyze different shape and geometry details early during the design phase. Those variables can then be optimized to provide the best wind load performance. The final design is validated using wind tunnel testing.

**Figure 3** shows the difference between a large wake region behind a rectangular block versus an actual Andrew antenna with a small, collapsed wake that is wind load efficient.

Wind tunnel testing is conducted at qualified third-party wind tunnel testing facilities (**Figure 5**) to validate the mathematical simulation results as shown in **Figure 4**.

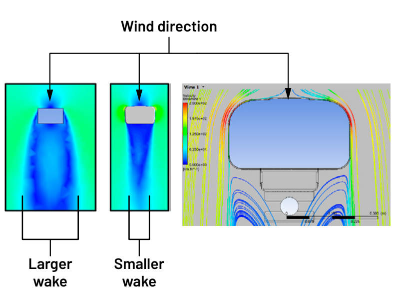


Figure 3: CFD comparison of rectangular box vs. Andrew's enhanced antenna design

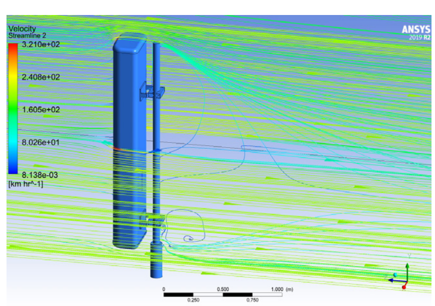


Figure 4: CFD simulation of Andrew's enhanced antenna design

Figure 5: Examples of setup for wind tunnel testing

## ANDREW'S UNIQUE AERODYNAMIC SOLUTIONS

### Wake reducer

Andrew's innovative design focuses on controlling air flow using wake-reducing surface nodes optimized for our antennas. These features work on the flow boundary layer to keep the flow attached to the antenna longer, thus delaying flow separation and reducing the wake.

In comparing a baseline model without these features, the modified near-wall boundary layer in the new design enables a much smaller wake—resulting in wind load reduction.

The aerodynamically enhanced surface nodes, shown in **Figure 6**, enable wind to flow around the object as shown in **Figure 7**. Wind can also flow above and below an object. Our solution also focuses on optimizing end flow.

The CFD simulation, as shown in **Figure 8**, demonstrates the impact difference between a "normal" end cap and one with Andrew wind load reducing end caps. The aerodynamic profile delays separation of the end flow and therefore promotes efficient free-end flow.

Figure 6: Aerodynamic surface nodes significantly reduce wake

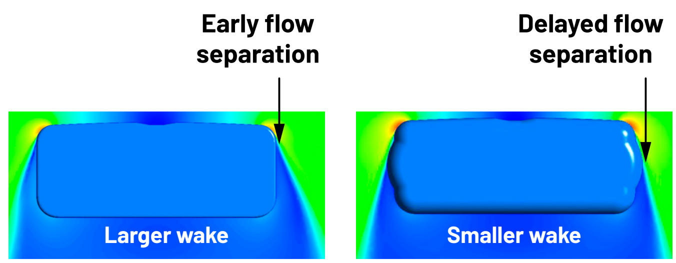


Figure 7: Improved airflow separation with aerodynamic surface nodes

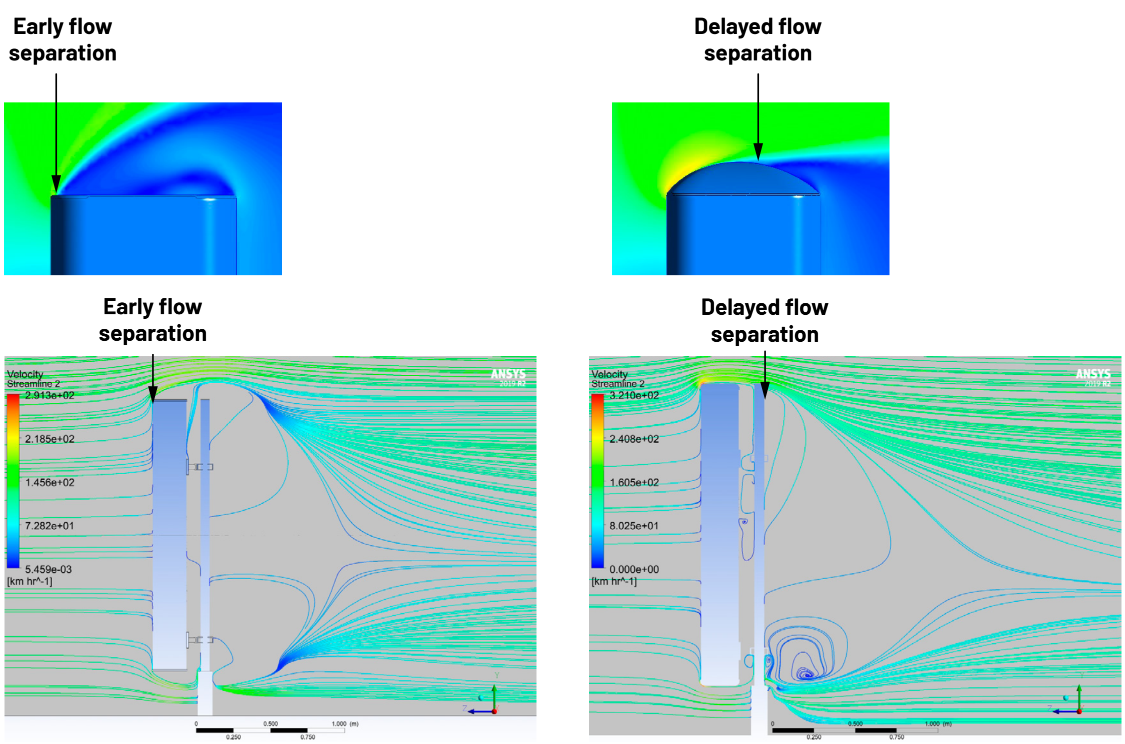


Figure 8: Improved end flow

### Wind load reduction results

Third-party wind tunnel testing validates the aerodynamic design of the new wind load reducing features, as shown in **Figure 9**. These aerodynamic solutions show 30 percent overall wind load reduction in wind tunnel testing, compared to the baseline design. These wind load reductions can be very critical at cell sites where tower capacity is at or near its limits.

Wind tunnel tests are conducted in line with the latest NGMN-P-BASTA Recommendation on Base Station Antenna Standards. The antenna is installed on a pole.

The test wind speed is 150 km/h. Measurements are taken at every 10 degrees of wind angle.

While some solutions on the market focus on wind load reduction in one direction only (similar to the geometry used in the auto industry), Andrew's solution is omnidirectional. By improving aerodynamic efficiency in all 360 degrees, the design improves wind load performance regardless of the wind direction, making it uniquely tailored for base station antennas.

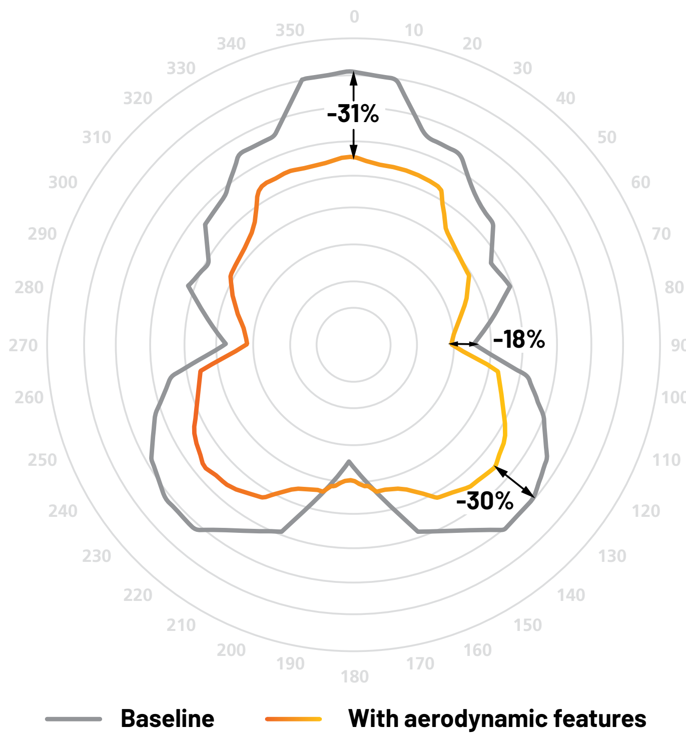


Figure 9: Wind tunnel test results with enhanced end caps and wake-reducing surface nodes

# SUMMARY

Andrew strives to help mobile network operators optimize cell site performance.

Our unique aerodynamic designs significantly enhance our antenna's wind load performance, reducing it by 30 percent compared to baseline designs. This innovation is crucial in modern infrastructure, as it improves wind flow efficiency and helps wireless operators lower leasing costs while maintaining quality of service (QoS).

Since 1937, ANDREW, an Amphenol company, has driven the evolution of wireless technology. Trusted by mobile network operators and enterprises globally, we work closely with our customers to deliver innovative solutions that enhance connectivity experiences both outdoors and indoors. Our dedicated global team is committed to advancing the industry, fueled by the vision that a better-connected future is possible.

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