White paper

Cost drivers in microwave antennas

Donald Gardner - product line manager, Microwave Systems

Contents

Introduction

Microwave antennas form an essential part of modern mobile communication networks, providing the majority of backhaul provision between cell sites and core networks. This paper explores the factors that drive cost of product in a microwave antenna, and consequently highlights why operators should be aware of total cost of ownership (TCO) and cautious of apparently low-cost product offerings.

Antenna design

The suitability of a given product's design must be considered within the context of both the required functionality of the product and the environmental conditions under which those functions must be delivered.

Microwave antennas are a critical part of mobile communications infrastructure and, therefore, must continue to operate to expected performance specifications even in severe environments—wind speeds in excess of 200 km/h, extremes of temperature and humidity, and high wind-induced vibration. Moreover, they should perform to the same standard throughout their expected life—typically 15 years or longer. Turning then to the electrical performance requirements, the antennas must transmit and receive RF signals fully compliant to regulatory standards (e.g., ETSI or FCC) and remain aligned with the antenna at the other end of the link over the full range of operational environmental conditions.

The RF path

The design of a microwave antenna breaks down into two broad areas—although there is some overlap between them. The first of these is the RF path, which mainly comprises the feed system, the reflector and the radome. Assuming the antenna is correctly designed, the key driver to consistent performance is control of shape, symmetry and size. Failure to accurately control the shape of various components will mean the antenna will not deliver the required gain, pattern, cross-polar performance (XPD) and return loss.

Similarly, failure to control the symmetry of the antenna means the antenna will not be uniformly illuminated; this has a major impact on pattern, XPD and—in the worst cases—antenna gain. Where the size requirements are not maintained, components will not assemble correctly, leading to potential RF leakage and loss of pattern compliance.

All tolerances in the RF path (aside from those required for accurate mechanical assembly of the antenna) are a function of antenna wavelength. Considering that a 6 GHz antenna has a wavelength of 50mm whilst an 80 GHz antenna has a frequency of 3.75mm, it becomes apparent that the dimensional tolerances on an 80 GHz antenna must be considerably tighter than a 6 GHz. However, when one considers that a 6 GHz antenna's diameter may be anything up to 4.5 meters while an 80 GHz antenna is likely to be no larger than 0.6 meters, the tolerances relative to the total size of the antenna converge.

These tolerances become even more significant when environmental conditions are included. Wind loading is a function of area rather than diameter; it is also a function of the square of wind speed. This means that the stiffness requirements (to maintain the required tolerances of shape and symmetry) may be broadly similar for a large 6 GHz antenna as for a much smaller 80 GHz antenna.

From the above, it can be seen there are several key cost drivers:

1. Components must be designed to proper tolerances to ensure that RF performance requirements are achieved.

2. The relationship between components must be tightly controlled to guarantee RF performance.

3. The overall design must be stiff enough to ensure that items 1 and 2 above are maintained over the operational performance envelope of the antenna.

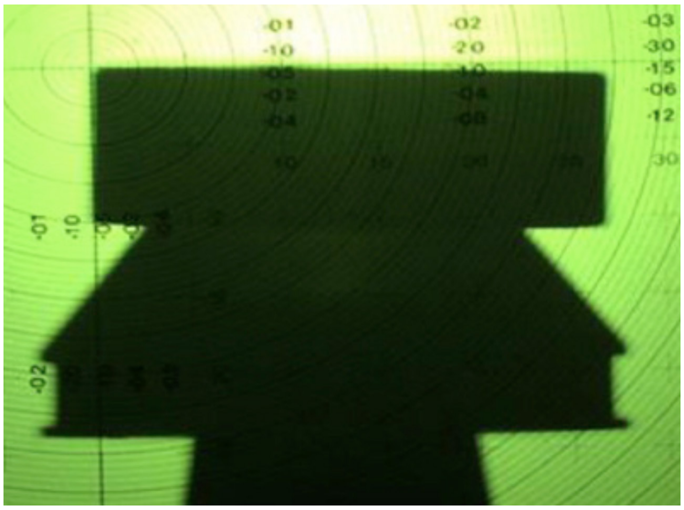

Figure 1: An example of asymmetry in an antenna feed assembly which results in nonuniform reflector illumination and regulatory pattern non-compliance.

Mounting and alignment

The second area of design is the mounting and alignment of the antenna. Here, both stiffness and strength are required, respectively, to ensure RF function and structural integrity. The overall antenna structure cannot deflect from the link path by more than a minimal amount (typically 0.3 of the 3 dB beamwidth of the antenna) at the limit of operational wind speed if link performance is to be maintained.

At the same time, the antenna's alignment mechanisms must provide easy and repeatable adjustment during installation but provide rigid connections once fully secured. In addition, protection systems such as radomes must fulfil their function without impacting on the RF performance.

Again, there are cost implications to these performance requirements:

1. Design to ensure mechanical integrity up to survival specification

2. Ensure electrochemical compatibility to prevent corrosion and degradation over the life of the antenna

Materials and qualification

Once the basic design has been developed and materials selected, the design must then be further refined to the specific grades of material. This process includes careful selection and initial qualification of particular grades of plastics to ensure that not only is RF performance maintained but there is adequate resistance to UV degradation over the expected life of the product. To guarantee this, it may be necessary to ensure only virgin grades of material are used and regrind of moulding waste is prohibited. Similarly with metals, close control of alloying elements is required. One classic case is the use of copper in aluminum alloys. They are generally used to increase strength; however, the downside is that using them reduces ductility and corrosion resistance.

Such careful selection of material also adds costs to the supply chain—vendor processes must be closely monitored to prevent contamination of materials. Incoming material must be audited and chemically checked to ensure only the specified grades have been supplied.

After the design has been completed and its materials specified, the initial product must be fully verified. This includes detailed RF qualification before and after physical testing up to the required environmental limits.

In addition, the product undergoes extended testing to ensure that it achieves its stated life expectancy. This testing will include many thousands of cycles of both operational and survival wind loading as well as extensive corrosion testing.

Manufacture

In many cases, the required tolerances on components cannot be achieved by production processes. In this case, special fabrication techniques and fixtures are used to achieve the required level of performance. One classic example of this is the use of dent tuning in fabricated rectangular waveguide components. In this technique, small dents are deliberately made in the structure during testing to compensate for minor mismatches between components. However, it is essential that the assembly and test process is considered holistically and that the antenna achieves all the performance parameters—not simply the one targeted by a specific process. In fact, without careful consideration to fixture and process design, antenna cross-polar performance could be severely degraded in the quest to achieve a good return loss, for example.

Poor manufacturing processes result in noncompliance to specification. The figure below shows a tested non-CommScope product that breaches regulatory specifications in several places. Further analysis indicated that, in addition to poor manufacturing processes causing the issues in the 0-90 degree region (blue arrows), compromises in the design—presumably for cost purposes—meant that, in the 90-180 degree region, the antenna would not be able to meet regulatory specification despite compliance being claimed.

It is not realistic to measure every microwave antenna electrically for all parameters, since this requires the use of a test range. Instead, reliance is placed on measurement of mechanical characteristics such as compliance of reflector shape to tolerance as well as electrical tests such as return loss. However, to support this, a random sample of factory production is then subjected to full electrical test—the same tests as used to verify the initial design to ensure that all product consistently meets specification.

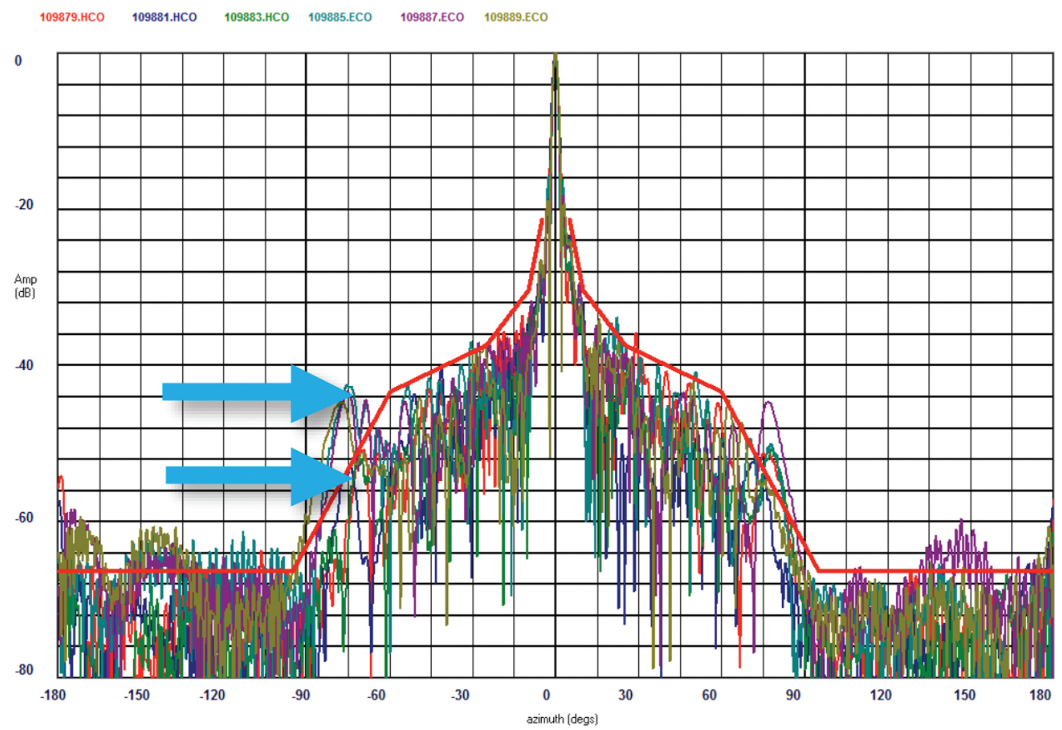

Figure 2: Testing reveals a radiation pattern (RP) outside of specification, rendering the antenna noncompliant.

Packing and shipping

The conditions to which a product is subjected during storage and transportation are considerably different from those experienced during use. This means that product packaging must fulfil several functions:

- It must protect the product in its dismantled state from any damage during transit;
- It must ensure no components are lost; and
- It must provide protection against the environment during transit and storage.

The product packaging is therefore not a secondary and separate concern, but must be considered as an integral part of the overall design. It is therefore essential that the packaged product goes through a similar qualification process against the appropriate standards to ensure the actual product arrives on site undamaged.

Total cost of ownership

Total cost of ownership (TCO) involves much more than the cost of the antenna itself. It also includes the initial costs of site acquisition; tower or mast requirements; electronic equipment such as radio, antennas and installation; as well as the ongoing operational cost of the network.

Over the full life of the antenna, the antenna purchase price is, in fact, a very small percentage of the TCO. However, attempting to identify and remedy poor performance in the network caused by antennas not meeting performance is likely to be extremely expensive. The costs associated in deploying field crews alone may be an order of magnitude larger than any initial antenna cost—even before the costs in lost traffic are taken into consideration.

Thus, we arrive at one of the issues inherent in any large organization: different parts pursuing potentially conflicting goals. The purchasing group may be pursuing a minimal total capital spend; however, without a full awareness of the parameters of the product they are purchasing, initial savings may result in a far greater negative impact elsewhere in the organization. No one would claim that initial capital costs are not important; it is absolutely essential that they are fully controlled. However, it must be done in the context of total rather than simply initial cost.

The question then is how this can be done. The solution is relatively simple—all items in the backhaul chain must be treated with due diligence rather than as commodity items weighed in isolation. It means knowing the provenance of all such equipment—that is, who actually manufactures it, to whose designs, and under what system of controls. Only this broader understanding reveals TCO and facilitates smart spending decisions.

Conclusion

As wireless networks grow to cover more area and deliver more capacity, the cost of microwave backhaul becomes an increasingly urgent issue. A number of low-cost, low-quality antennas are available on the market that seem to present an irresistible bargain; yet, without the rigorous design, material selection, construction methods and exhaustive testing used to produce superior antennas, the cost in performance and reliability greatly outweighs the initial capital savings.

WP-109700.1-EN (03/17)