NEXT-GENERATION ANTENNA DESIGN: MATERIALS AND PROCESSES ENABLE NEW POSSIBILITIES IN REDUCING SIZE, WEIGHT AND COST

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Unmanned vehicles are finding increasing usage in military engagements, not only for aerial applications but also for ground and underwater missions. Modern antenna designs can increase unmanned vehicle fuel efficiency through reduced antenna size, increased antenna conformality, and reduced antenna weight. For airborne UAVs, time on station is a critical mission parameter directly influenced by payload weight and aerodynamics. For unmanned ground vehicles, increased antenna conformality reduces the likelihood of accidental damage that occurs with externally protruding antennas.

As designers look toward smaller and more capable UAVs, SWaP-C (size, weight, power, and cost) requirements necessitate smaller, lighter, more power-efficient components and subsystems built using modern manufacturing methods. With every subsystem as a candidate for SWaP-C improvements, small savings on subsystems can add up to significant overall savings for a platform.

Recent advances in materials and fabrication technologies are now enabling improved antenna designs with reduced size, weight, aerodynamic drag, and cost. Key innovations influencing next-generation antenna designs include composite materials and novel selective metallization processes. These innovations combine to allow cost-effective realization of three-dimensional antennas that are mechanically robust and can withstand harsh environmental conditions.

Composites

A typical thermoplastic composite begins with high-performance engineered polymer to which fillers are added to enhance characteristics. For unmanned vehicle applications, the polymer is likely to be a high-temperature moldable thermoplastic, such as grades of PPS, PEI, or PEEK. Composite materials are strong and can be tailored to provide impact resistance, tensile strength, flexural strength, and other desirable properties. However, the choice of composites is affected by operating temperature and fluid resistance requirements, so a good understanding of the expected temperature extremes and environment of the antenna is necessary when designing composite parts.

Carbon fiber reinforced composites are addressing the need for lightweight, cost-effective, mass-producible electrically conductive parts. Conductive composites typically offer a 30 to 40 percent weight savings over aluminum parts. For antenna applications, uses of carbon fiber composites range from ground planes to enclosures.

Glass fiber composites are moldable and offer an economical solution for producing radomes and antenna substrates. Typical radomes are formed using E-glass reinforcement for economical designs or quartz fiber reinforcement when low loss is critically important. Glass fiber composites offer thinner, lighter parts than non-fiber reinforced designs. Glass fibers also increase the dielectric constant of most composites, enabling antenna size reduction when these composites are used as substrate materials. Composite materials can also be engineered to provide “designer” dielectric constants through the addition of various filling materials, such as hollow glass microspheres, conductive particles, or foaming agents.

For both carbon fiber and glass fiber composites, fiber length is an important design parameter. Longer fibers offer more strength but reduced ability to manufacture small features. Moldable long-fiber composites allow significant thickness reductions while maintaining equivalent strength of short fibers. Continuous-fiber reinforcements are attractive for further weight reduction on designs with large, smooth features.

3D Selective Metallization

The typical method of metallizing specific shapes on 3D surfaces is selective plating. This process requires labor-intensive application of physical masks to the surface of the part followed by a multi-step plating process. Because of the high labor content, selectively metallized parts are usually relatively expensive.

Alternative processes include laser direct structuring (LDS) and two-shot molded interconnect devices (MID). Both allow cost-effective 3D metallization, but both are constrained by the range of available substrate materials. In addition, injection molds are required for both these processes, increasing non-recurring expenses and lead times.

To overcome these substrate limitations, TE Connectivity has developed a process for selectively metallizing 3D surfaces of arbitrary substrate materials. The process starts with the application of a sprayable conductive coating to the surface of the part. Next, this coating is cured by radiative or thermal processes. Finally, the coating is ablated to the desired pattern using a computer numerical control (CNC) laser. This process results in 3D conformal shapes with metallization resolutions as fine as 100 microns and allows molded or machined parts to be used as substrates.

This 3D selective metallization process can be applied to a wide range of substrates – including plastics, chemically resistant composites, glass, ceramic, and metals – with acceptable adhesion, a temperature range from -65°C to +200°C, and corrosion resistance. The metallization is also durable and withstands shocks, vibration, fluids, and salt spray to the levels required for most aerospace applications. This process enables rapid development and manufacture of robust 3D antennas for harsh environments.

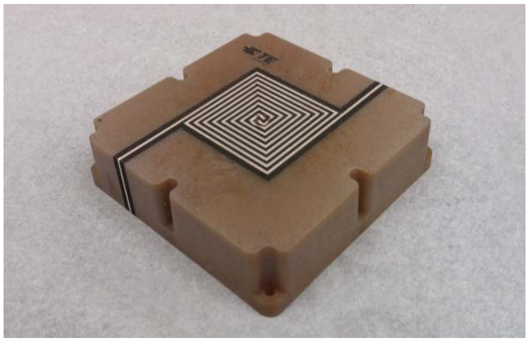

Figure 1. Conductive coatings can be flexibly and precisely applied to composite substrates. (Source: TE Connectivity)

Application to Antennas

Composites and 3D selective metallization technologies offer paths to reducing the size, weight, and cost of antennas for unmanned vehicle applications.

Composites provide a scalable method for manufacturing moldable, high-performance antenna substrates.se substrates can have arbitrary shapes and even include mechanical mounting provisions. This technology offers the antenna engineer design flexibility not afforded by traditional substrate materials.

Figure 2. Moldable modular antenna design using a glass-fiber reinforced composite substrate and conductive coating. (Source: TE Connectivity)

Selective metallization through conductive coatings can offer a good solution for creating circuit traces on composite parts which would more typically be etched using standard circuit board techniques. The conductivity of some conductive coatings can approach the conductivity of bulk copper, adding only minimal loss to the circuit while enabling more cost-effective manufacturing. However, this selective metallization process is particularly useful when applied to the manufacture of three-dimensional circuit topologies. Three dimensional RF couplers and direct circuit connections to antennas now become realizable through this technology.

Within the antenna assemblies, aluminum parts can account for a large portion of the total assembly weight. Composite ground planes offer 30-40 percent weight savings over traditional aluminum parts, with high manufacturability and often significant potential cost savings. Metal inserts can be provided for secure captivation of the antenna to the unmanned vehicle platform. Composite ground planes can be conductively coated if necessary to provide improved electromagnetic interference (EMI) shielding, grounding, or lightning strike protection performance. When the original aluminum parts required significant machining time to fabricate, composite ground planes can be quite cost competitive.

Figure 3. Modular antenna array, which exhibits wide use of composite materials and conductive coatings in its construction. (Source: TE Connectivity)

Traditional radome manufacturing involves hand layups of multiple material layers – a tedious, slow, and costly process that becomes difficult when intricate radome shapes are required. Recent advances in long glass fiber and continuous glass fiber composites offer approaches for achieving thinner, lighter weight radomes using injection molding. The ability to mold strong, lightweight radomes represents a significant change in the economics of antenna design and fabrication. When required, 3D selective metallization can provide lightning diversion or frequency selectivity features to these radomes.

In addition to the other advantages mentioned, conductive coatings also offer the possibility of printing antennas directly on structural composite parts of unmanned vehicles. As unmanned vehicles move toward incorporating composite body panels, conductive coatings offer an approach for functionalizing their surfaces. Antennas, RF traces, and DC wiring can now be directly printed onto components of the vehicles, rather than existing as stand-alone parts. This approach enables unprecedented integration of antennas into unmanned vehicles.

The Future of Antennas Has Arrived

Conductively-coated composite technology supports efficient production of advanced antennas with optimized size, weight, and performance. Injection molded composites present a reliable method for producing antenna substrates and radomes at scale. Selective metallization with conductive coatings allows the creation of three-dimensional antennas, circuit traces, and ground plane structures. These processes combine to offer electrically and mechanically robust antennas and arrays in conformal, lightweight form factors suitable for next-generation unmanned platforms.

Author's Bio

Kathleen Fasenfest is a Senior Electrical Engineer responsible for antenna product development at TE Connectivity, Global Aerospace, Defense & Marine. She has more than 10 years' experience designing antennas and microwave circuits for a variety of applications, including aerospace and defense markets.

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