Confronting The Antenna Challenges In Today's Military Applications

Introduction

Microwave components like antennas, filters, amplifiers and mixers are building blocks which are utilized in many existing defense weapons and Department of Defense (DoD) systems. While high-tech research and development programs for the DoD may have slowed of late, these components are continuing to find new life as the military re-tools its missions and objectives to better fight the "war on terror." Emerging applications in communications, monitoring and screening will all be built on the backs of microwave components (see Figure 1). For the antenna, in particular, that demand poses a number of significant challenges. Only a decade ago, specific band antennas met the needs of most communications, electronic warfare (EW) and surveillance applications. These days though, with new and emerging transceiver technologies as well as military applications, antenna engineers are now being confronted with increasingly difficult concerns regarding directionality, frequency variations, isolation, and testing. In many case, use of microwave absorbers and dielectric materials can offer today's antenna engineers the solutions they need to quickly and cost-effectively address these challenges.

Figure 1. The AIMS antenna group, used shipboard, is comprised of an antenna, antenna position programmer and a below-deck control unit used to locate and identify aircraft as friend or foe. The AIMS antenna consists of 64 radiating elements arrayed in a circle (at right in black) and uses the ECCOSTOCK® SH dielectric material around the ship's mast. Unlike conventional IFF systems, which employ mechanically rotated antennas, the AIMS antenna elements remain stationary while the beam is steered electronically to scan a full 360 degrees around the ship. The beam can also be positioned selectively in any direction within microseconds and has a continuous scan rate of up to 90 revolutions per minute. AIMS is used on U.S. Navy CG 47 class cruisers, DDG 51 class destroyers, LHD 1 class helicopter assault ships, LPD 17 landing platform docks, and the CVN 68 class aircraft carriers.

Understanding The Challenges

The four main challenges that engineers designing antennas for modern military applications now face are:

- Directionality

One of the greatest challenges in antenna design today is directionality (e.g., the ability to tune out all other antennas). To better understand the magnitude of this challenge, consider the example of radar systems which are widely used for "find and track" missions on a variety of Air Force platforms. The radar antenna transmits electromagnetic energy at a target and then receives the returning radar signature. The return from a moving target provides the target's range, heading and velocity.

Here, the antenna is critical to radar system performance and therefore must be properly designed. It must radiate a high concentration of energy within a very narrow angular field of view (e.g., a highly directional beam of energy) and be much larger than the RF wavelength. As the beam becomes more directional though, the size of the target detected by the radar decreases and some energy will leak into undesired directions, forming small auxiliary beams referred to as sidelobes. Consequently, in order to mitigate interference from jammers and energy scattered off the ground, as well as form other antennas, the antenna engineer must not only deal with the issue of directionality but also with reducing the power attributed to this leakage.

- Frequency Variations

Frequency is a critical parameter which can affect an antenna's performance. Typically, an antenna is tuned for a specific frequency and therefore, is effective for a range of frequencies usually centered on a resonant frequency. However, because the antenna's other properties (e.g., radiation pattern and impedance) change with frequency, its resonant frequency may merely be close to the center frequency of these other more important properties. Consequently, the antenna engineer must utilize a design that minimizes frequency variations.

- Isolation

Like directionality, isolation poses a significant challenge when designing antennas. It is often necessary in situations where multiple antennas are either back-to-back or side-by-side and may interfere with one another. A prime example is the military communications satellite. Here, designers and operators have long sought out ways to reduce the vulnerability of there systems to both intentional, as well as unintentional interference. Techniques such as spread-spectrum modulation, antenna sidelobe reduction, and adaptive interference cancellation have emerged as methods for mitigating interference.

- Testing

A key challenge for today's antenna engineer is how to integrate antennas into systems to meet a broad range of requirements and how to test those antennas (e.g., black box testing), prior to integration and deployment in a specific application. Consider, for example, an antenna that has been installed on a Humvee. Prior to its integration into the

Humvee, the antenna must be tested in such a manner as to ensure that it will work as expected. This task is made all the more difficult by a number of factors, including increasing antenna specifications and the integration of system and antenna functions at the platform level.

While solutions do exist to deal with these four challenges, such as the use of a microwave absorber or dielectric, many engineers are reticent to employ them. Often times, engineers would simply prefer to try and design an antenna that does not require such solutions. Although the resulting antenna designs may be sufficient for a testing environment, when enclosed in a housing for protection, other RF issues can arise – making the need to employ a material like an absorber all the more critical. Antenna engineers therefore, are often left with two options. If time permits and money is not an issue, the solution might simply be to do a redesign. In some cases, that redesign will also mean several changes to the board level design, which may require housings to be re-machined or re-cast – contributing to yet additional time and cost. The other, perhaps more viable option, is to use a microwave absorber or dielectric material.

Microwave absorbers are essentially blocks of materials which are used to absorb microwave energy. Increasingly they are used to enhance shielding performance at higher frequencies and to aid in solving a wide variety of problems such as internal cavity resonances, antenna pattern shaping and high-frequency interference; thereby increasing antenna performance.

Dielectric materials, otherwise known as electrical insulators, are substances such as a liquid, solid or gas which are highly resistant to electric current. Solid dielectrics tend to be very good insulators and play an important role in antenna design and implementation by helping to shape and manage the electric fields of antenna patterns. Because field energy is concentrated and stored within the dielectric material with fairly high density, external objects or fields have relatively little effect and don't affect the inherent resonance of the antenna.

Emerson & Cuming Microwave Products Value Proposition

Emerson & Cuming Microwave Products is a world leader in the development and manufacture of microwave absorbing materials and dielectric materials for low loss RF and microwave applications. As a company strongly committed to addressing the challenges facing today's antenna engineers, it now offers a range of solutions suitable for use in designing antennas for military applications. These solutions include:

- Microwave Absorbers

Emerson & Cuming Microwave Products offers free-space absorbers designed to absorb (or similarly, not reflect) propagating plane waves that might otherwise reflect off a conductive surface. Its ECCOSORB® HR and AN product lines are especially well suited for reducing antenna reflections, while the ECCOSORB® LS is an excellent insertion loss absorber for isolation.

- ✓ ECCOSORB® AN – Broadband, Flexible, Multi-Layer Gradient Loaded Foam Sheet Microwave Absorbers

This family of lightweight, flexible, broadband, open-cell foam absorbers is comprised of carbon-loaded, laminated polyurethane sheets with a frequency range of 600 MHz to 40 GHz (see Figure 2). Designed to reflect less than -20 dB of normal incident energy above specified frequencies and relative to a metal plate, ECCOSORB® AN is suitable for use in reducing crosstalk between adjacent antennas and shrouding antennas to improve the antenna patterns and undesired backlobes. For isolation of components or antennas by means of insertion loss, it can be used without a metal backing.

Figure 2. This ECCOSORB® ANW-73/ML removable absorbent cover was constructed to fit tightly over an aircraft nosecone for ground-based radar testing. It acts as a radiation shield that can be easily slid on and off the nosecone during testing. The "W" stands for weatherproofing and refers to the covers inclusion of a neoprene based fabric material which meets MIL-PRF-26096F and is resistant to fuels, lubricants and hydraulic fluids.

ECCOSORB® AN absorbers do not support fungal growth (per MIL-STD-810E) and can be readily cut on a band saw, with scissors or a sharp knife. While ECCOSORB® AN absorbers are not waterproof, a special vinyl-based CERSEAL coating can be applied to prevent moisture uptake. CERSEAL adds durability to foam and imparts abrasion and puncture resistance. It is also an excellent low cost alternative for weatherproofing custom fabricated parts with compound surfaces.

- ✓ ECCOSORB® HR – Broadband, Lightweight Single Layer Gradient Loaded Foam-Sheet Microwave Absorbers

ECCOSORB® HR is a lightweight, flexible, flat-sheet broadband absorber. Fabricated as a reticulated (open-cell) polyurethane foam sheet with a controlled conductivity gradient carbon loading system, it is electrically conductive, has a frequency range of 5 to 40 GHz and features excellent broadband performance. Such capabilities make it ideal for antenna

shrouds for low side-lobe reflector antennas and in isolation of adjacent antennas and array elements. The ECCOSORB® HR is not weatherproof.

✓ ECCOSORB® LS – High Loss , Flexible, Foam Microwave Absorber

The ECCOSORB® LS absorber is the company's most widely known, used and recommended urethane foam sheet product. It features high loss, low density, is very flexible, and can be easily cut with a knife, scissors or die. A carbon loading system makes it electrically conducive. While it is not weatherproof, it can be treated with an optional weather-resistant CERSEAL coating. Compared to thinner, more expensive rubber absorbers, ECCOSORB® LS is a very low cost solution and is useful in isolation of antennas by insertion loss.

- Dielectric Materials

Emerson & Cuming Microwave Products features a number of low-loss dielectric materials which can be used in antenna design, namely ECCOSTOCK® HiK and SH.

✓ ECCOSTOCK® HiK - Low Loss, Adjusted Dielectric Constant Stock

ECCOSTOCK® HiK is a series of low-loss plastic stock with adjusted dielectric constants up to 15 (see Figure 3). It does not support fungal growth (per MIL-STD-810E) and offers low out gassing properties for space applications. Its low water absorption makes it suitable for outdoor use. ECCOSTOCK® HiK is ideal for use in patch antennas and tuning elements.

Figure 3. ECCOSTOCK® HiK is a low-loss dielectric material. The smallest slugs/barrels, pictured here, were used in a phased-array antenna for Boeing's Connexion program.

✓ ECCOSTOCK® SH - Rigid High Temperature Plastic Foam Sheet Stock

ECCOSTOCK® SH is polyurethane foam which remains rigid and is able to withstand high temperatures; -70°C to 135°C, as well as a 163°C short term service temperature (see Figure 4). As a result, it is ideal for use as a high-temperature structural member or thermal barrier in electrical/electronic applications. It features typical thermal conductivities of around 0.14 (BTU)(in)/(ft^2)(hr)(°F), 0.03 Watts/(meter)(°C). Unlike other commercially available polyurethanes, ECCOSTOCK® SH has an extremely low dissipation factor and low dielectric constant. And because it is closed cell foam, it can be easily machined. In addition, it does not support fungal growth (per MIL-STD-810E).

Figure 4. ECCOSTOCK® SH polyurethane foams are used for thermal insulation or spacing materials in antennas.

Complementing the leading features and functionality of the ECCOSORB® microwave absorbers and ECCOSTOCK® dielectric materials, is the company's unique value proposition. Emerson & Cuming Microwave Products:

- Has a long history of excellence and expertise in making components for the military. It was founded in 1948 with this goal in mind.
- Offers the benefits associated with the infrastructure of a large company (e.g. R&D facilities etc…), but with the personal customer service and responsiveness of a small company.
- Was the first to become ISO certified (ISO 9001:2000) and to use automation in manufacturing. This automation increases yields up to 95-100%, ensures electrical consistency and enables the company to run upwards of 20,000 square feet per day.
- Offers global manufacturing via facilities in Randolph, Massachusetts and Westerlo, Belgium.
- Has excellent global R&D facilities (e.g. an engineer can show up with a new application and the company can turn around a new material for it in literally just a few days).

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Conclusion

Antennas are today used in a broad range of military applications such as communications satellites and for "find and track" missions. While these modern uses of antennas present challenges with regard to directionality, frequency variation, isolation, and testing for the antenna designer, microwave absorbers and dielectric materials are now providing a viable way to deal with and mitigate these challenges. With its industry-leading microwave absorber and dielectric materials, Emerson & Cuming Microwave Products is uniquely well positioned to meet the needs of engineers designing antennas for military applications now and in the future.

For more information on this topic, visit Emerson & Cuming Microwave Products at www.eccosorb.com. For sales or technical inquires, email sales@eccosorb.com and jdelprete@eccosorb.com, respectively.