ATR Designs Get Rough and Tougher

Entrenched as the de facto avionics enclosure standard, ATR designs are bringing right-sized ruggedness to new levels.

Ram Rajan, VP of Engineering
Elma Electronic

Rugged COTS enclosure products are playing an increasingly pivotal role in the strategic thinking of defense and military planners. Clearly there's a decisive new emphasis on unleashing the latest technological advances into the combat theater of operations like "locate, identify and destroy" missions. That signifies a considerable investment in sophisticated equipment geared toward electronic warfare. With that in mind, unmanned air vehicles (UAVs) like the Predator, are not only used in locate and identify, but also in destroy missions successfully. Such skilled and innovative projections of military power are made possible by the use of ruggedized electronic equipment.

Along those lines, the Air Transport Racks (ATR) fill an important niche in such mission-critical applications. ATR has been a de facto standard form-factor for aircraft board electronic equipment since its beginnings in the World War II days of 1940 when it was outlined in ARINC SK-230, the precursor to the present ARINC 404A. Two important ARINC drawings, the SK-141-10 and the SK-141-17, detailed the critical dimensions and tolerances for the initial three basic form-factors, via the 1/2, 1 and 1 1/2 ATR.

The drawings became the basis for ARINC 404A. Any equipment built per the ARINC standard complies with the specified case sizes even if made by different manufacturers. They can be used interchangeably in equipment mountings and radio racks made by other manufacturers of ATR equipment. ATR chassis are very popular solutions for meeting today's demanding requirements of avionic applications. A well-designed ATR chassis should also comply with the various military standards that are a prerequisite for these avionic applications. From the three initial case sizes, other sizes were standardized, like the 1/4 and 3/4 inch width sizes and short and long depths. Table 1 lists all the case sizes and their dimensions.

Key Design Criteria

Aside from the ARINC 404 mechanical guidelines, there are four key areas involved in an effective ATR design: operating temperature, humidity and altitude, structural integrity and EMC. The operating temperature and altitude at which the ATR equipment is expected to function has a significant impact on the type of cooling method chosen for the thermal solution. For all high altitude applications—greater than 55,000 ft.—or in applications where the operating temperature range is very

ATR Case Dimensions

ATR Size	W +/– .03 in	L1 +/– .04 in	L2 (Max) in	H (Max) in
Dwarf	2.25	12.52	12.62	3.38
1/4 Short	2.25	12.52	12.62	7.62
3/8 Short	3.56	12.52	12.62	7.62
3/8 Long	3.56	19.52	19.62	7.62
1/2 Short	4.88	12.52	12.62	7.62
1/2 Long	4.88	19.52	19.62	7.62
3/4 Short	7.5	12.52	12.62	7.62
3/4 Long	7.5	19.52	19.62	7.62
1 Short	10.12	12.52	12.62	7.62
1 Long	10.12	19.52	19.62	7.62
1 1/2	15.38	19.52	19.62	7.62

Table 1 The ATR chassis form-factor boasts a variety of width sizes and short and long depths.

Figure 1 This 3/4 ATR from Elma Electronic is a forced air convection solution. The hermetically sealed thermostats and fan fail alarm options quickly identify over-temperature conditions.

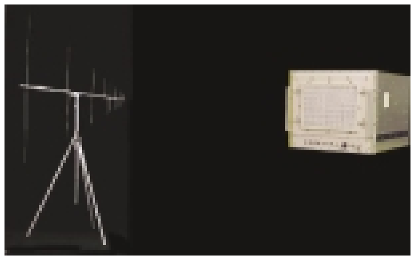

Figure 2 Shown here is radiated Emissions testing in progress.

wide (like -55 to 85°C), conduction cooling is the perfect solution. This requires the use of conduction-cooled boards which are full MIL-grade and therefore quite expensive.

The chassis also requires features like wedge locks in the card guides, ducts for coolant medium and good environmental seals. Such conduction-cooled ATR systems will adequately meet the requirements, but they come at a high price in terms of cost and development time. On the other hand, if the operating temperature range is more narrow (-20 to + 65°C) and the altitude is less than 55,000 ft., forced air convection cooling (flow-through type) is ideal. This enables the use of COTS boards and modular COTS solutions for the chassis that are readily available and offered at a reasonable price. So, we are focusing our study on the design of convection-cooled ATR chassis.

The air-moving device in the convection-cooled chassis should meet the operating temperature and humidity range while delivering a high flow rate at the prevailing pressure. This is critical especially at altitudes above 15,000 ft. to 50,000 ft., where air density is reduced. A practical and effective design would be to locate the air-moving device at the rear of the ATR enclosure creating a negative pressure environment that is conducive to flow-through type of cooling.

The air intake, which can be either in the front or the sides, should incorporate a high-performance air filter. This is very essential if the equipment is on aircraft operating in a desert-like environment—prone to dust and other contaminants. Figure 1 shows an example of a 3/4 ATR based on a forced air convection solution and incorporates an efficient, washable, electrostatic air filter that provides a high degree of dust-arresting capability. Hermetically sealed thermostats and fan-fail alarm options quickly identify any over-temperature conditions brought upon by fan failures, clogged air filters and so forth. These measures greatly enhance system reliability, a key for mission-critical applications

Structural Integrity

Structural integrity of the enclosure is another major consideration in ATR designs. Owing to their application environments, the equipment will be subject to high vibration (random or sinusoidal) as well as shock levels. The mechanical frame must be robust, yet light enough to be deployable. Conduction-cooled ATRs are usually machined enclosures or welded double-walled enclosures with machined card guides. These provide excellent resistance to shock and vibration, but end up weighing more and are quite expensive.

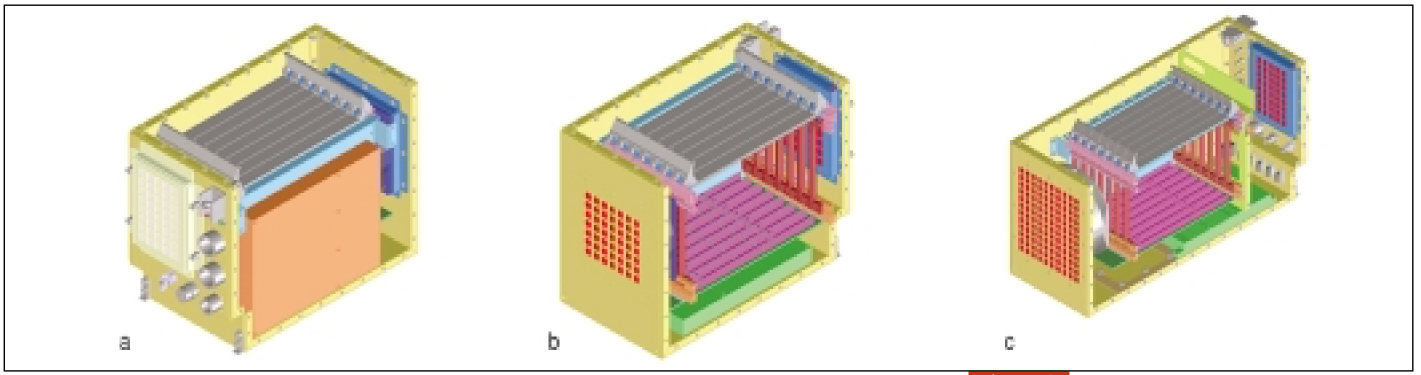

Figure 3 The models above illustrate a design using formed flanges and the bolted construction. This facilitates flat EMI gaskets for added attenuation while ensuring modularity.

Moreover, they do not lend themselves to modularity.

A viable and proven design for convection-cooled ATRs is the use of formed aluminum sheet metal in 2 mm thickness for the frame. A standard aluminum extrusion-based Eurocard card cage inside reinforces this frame adequately while ensuring a low mass. The significant advantage of this approach is the inherent flexibility to develop modular and cost-effective solutions in a shorter timeframe. The capability to design removable panels for maintenance access is another plus. The side walls are easily removable, a feature that helps in system assembly and maintenance.

Keeping the center framework as a separate formed sheet metal item ensures modularity. This approach makes it easy to expand the ATR design from the 1/4 to the 1 1/2 design by changing only the center frame and keeping the side access panels the same. In most cases, an isolation mechanism is not required since the ATR mounting tray already has isolators for meeting the vibration profiles. However, if one is required, the isolation mounts have to be installed within the confines of the ATR case size.

Soup to Nuts EMC

Electro Magnetic Compatibility (EMC) of the enclosure is of utmost importance to the system's integrity and should be dealt with systematically from the component level (boards, power supplies, line filter, fans) to the enclosure subsystem level. An electronic device is considered to be electro-magnetically compatible with its environment if it is neither susceptible to the spurious emissions (both conducted and radiated) from neighboring equipment nor exceed certain levels of such emissions into its environment.

Figure 2 shows radiated emissions testing in progress on a COTS chassis to determine its shielding effectiveness. The shielding effectiveness (SE) is a measure of the degree of attenuation (in decibels) that an enclosure provides to unintended electro-magnetic radiation. An 80 dB attenuation means that the enclosure attenuates 99.99 % of EMI. To achieve these levels, several critical factors should be considered in the design of the enclosure. For example, the material, material thickness, material conductivity, overlapping flanges to minimize seams, EMI gaskets with high attenuation and good environmental performance, optimum bolt spacing, optimum aperture size, proper electrical bonding with mating surfaces, and so on.

Sophisticated software is available to calculate the SE of enclosures to different frequencies. The Elma ATR design is an example of an ATR based on the aforementioned factors. The choice of 2 mm aluminum throughout the enclosure ensures a high conductivity, while the aluminum extrusions for the card cage minimizes the use of dissimilar metals, a source for galvanic corrosion. The 3D models shown in Figure 3 illustrate this design using formed flanges and the bolted construction, which facilitates flat EMI gaskets for added attenuation. Honeycomb filters located at the air intake and exhaust apertures provide over 80 dB attenuation while ensuring maximum percentage of open area for airflow.

The entire ATR chassis has a conductive, corrosion-resistant coating per MIL-C-5541, class A. Other elements of such a chassis include power supplies and fans that meet MIL-STD-461D levels of conducted and radiated emissions, shielded and hermetically sealed switches, LEDs and fuse holders and optimum routing of power wiring to reduce electrical noise. If additional filtering for conducted emissions is needed, a Mil-STD-461-compatible line filter integrated into the power input meets the requirements. ▌▌

Elma Electronic
Fremont, CA.
(510) 656-3400.
[www.elma.com].