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ACTIVE ELECTRONICALLY SCANNED ARRAY RADARS PART 1: OVERVIEW

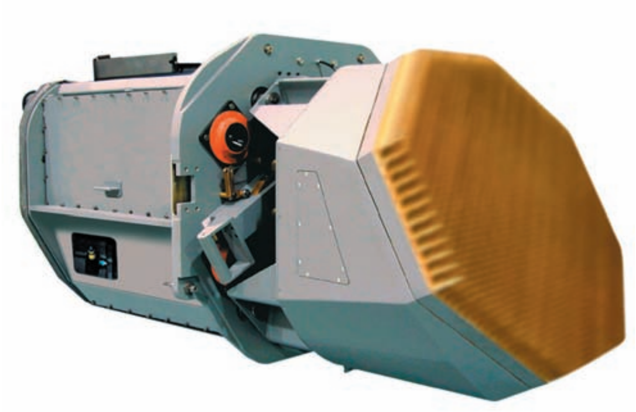
In this two-part Pathfinder series, we will be looking at a significant evolution in airborne technology that will soon be part of the Air Force's inventory–the active electronically scanned array (AESA) radar. Since their inception in the 1960s in ballistic missile early warning systems, AESA radars have been heralded as extraordinary multi-tasking pieces of equipment able to act not only as multi-mode radars but also as electronic warfare scanners, jammers, airborne modems and even as electromagnetic weapons able to fry electronic circuitry. A simple overview of how AESA radars work is provided in this part, while Part 2 discusses how significant this technology will be in the airborne environment.

What exactly are AESA radars? In principle, radar works by transmitting a small pulse of electromagnetic energy and then detecting any portion of the pulse reflected back. To transmit the pulse, some form of an antenna is required. Traditionally, for airborne applications, these antennas have been mechanically rotated parabolic dishes whose size ranged from about 30 centimetres in small fighter aircraft to over 9 metres in Airborne Early Warning and Control aircraft. While the radar principle will work over a wide range of frequencies, most airborne applications use microwaves, as they require smaller antennas and this frequency band provides good angular and range resolution. To locate a target, the parabolic antenna (and hence the electromagnetic beam) is repeatedly moved through a pre-programmed search pattern. To change the radar's mode of operation–from, say, air-to-air to air-to-ground–requires a mechanical readjustment of the antenna, which means there is a break in radar coverage.

APN-59 radar showing the mechanically switchable parabolic antenna heads (USAF).

AESA radars, on the other hand, are flat grids made up of thousands of tiny modules that can transmit and receive radio energy, called TR modules, linked together by high-speed processors. (Think of a pizza with thousands of small olives all lined up and you will get the idea.) These TR modules are digitally controlled, self-contained solid-state devices made up of a transmitter, a receiver, a power amplifier, a phase delay unit and a small spike-like antenna. Typically, four TR modules are mounted on a 2.5 centimetre cube giving a density of about 3,000 modules per square metre, once mounting brackets are factored in. Each TR module has a peak power of about 10 W with an average power of about 2 W; therefore a square metre of TR modules will have a peak power of about 30 kW and an average power of about 6 kW. By way of comparison, a GSM mobile phone has a peak power of about 2 W and an average power output of about 250 mW.

The advantages of this simple building block approach to radar design are many. Vastly simpler mechanical designs are possible, as there is no rotational movement of the antenna head. In addition, as the antenna does not rotate the radar occupies less space. Less space means that either a larger antenna can be fitted into a given volume, thereby improving the radar's range and angular resolution, or it weighs less–always an important factor in aircraft design. Because the receiver is always aligned with the transmitter (unlike a rotating radar where the antenna head will have rotated when distant returns are received), AESA radars have much longer ranges than equivalent conventional radars. As there are fewer moving parts, an AESA radar is also less prone to mechanical failure. Further, as an AESA radar has multiple transmitters and receivers, this means that it does not have a single point of failure but instead can gracefully degrade. AESAs are able to lose approximately five percent of the TR modules before the radar unit in them requires repair due to decreased performance.



The F/A-18 E/F's APG-79 AESA radar

The beam of an AESA radar is steered by electronically adjusting the phase of a row or column of TR modules compared to their neighbours using the phase delay units. This electronic control allows the radar's beam to be steered with vastly greater agility and precision than mechanically steered radars, taking micro-seconds (10^{-6}s) rather than tens of seconds (10s) to reposition the beam. Fast scan rates allow AESA radars to operate in multiple modes (air-to-air, air-to-ground, synthetic aperture radar, weather, jamming etc) in near real-time. Fast scan rates, along with variable power output and no side lobes, means that AESA radars are resistant to electronic counter-measures (ECM), as it is difficult for an ECM device to find the correct azimuth and elevation of the transmitter's main lobe to attack. They also have a low probability of interception, as the radar only 'looks' in any particular direction for a very small fraction of a second. As the radar antenna of an aircraft is a significant radar reflector in its own right, the faceplate of AESA radars in military aircraft are often tilted upwards, typically 15 degrees, to reduce its own radar cross-section to ground-based radars (see Figure 2).

There are, however, drawbacks to AESA radars. The power efficiency of a TR module is approximately 50-67 per cent. As a result, the modules produce a lot of heat, which must be removed to improve reliability. Due to the high density of modules in a typical radar, air-cooling is impractical, so most AESA radars are liquid cooled which adds to the complexity, power requirements and weight of the system. With TR modules reportedly costing around US$2000 each and with a typical AESA radar requiring several thousand modules, an antenna alone might cost US$4 million. However, as the technology improves and more aircraft are fitted with AESA radars (especially in the civil sector), manufacturing costs will reduce significantly.

So, in many respects, AESA radars are an aircraft designer's dream. Not only do they provide additional functionality, they do so with improved performance and reliability with less weight, size and power consumption.

- *AESA radars are an aircraft designer's dream, requiring less space and providing longer range with less risk of mechanical failure*
- *They can act not only as multi-mode radars but also as EW devices and even electromagnetic weapons*
- *As manufacturing costs come down, AESA radars will be more common in military aircraft*

"It was a pity that there was no radar to guide one across the trackless seas of life."

Arthur C. Clarke (1917-2002),
British science writer

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