INTEGRATION OF AIRBORNE EARLY WARNING RADAR PLATFORMS ON AIRCRAFT

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Abstract. The need for a long-range and complete Air Picture has long since motivated the presence of airborne early warning (AEW) radar platforms. Later developments, such as stealth and advancing threats at low altitudes or hypersonic speeds have nothing but reinforce the need for increased-performance AEW. However, the high costs for the platform, integration, and operations restrict the number of platforms to a point where these high-value assets become sensitive to preemptive actions by an adversary. Therefore, SAAB has within the NFFP7 framework launched a series of studies aiming at smaller, adapted, and cost-efficient unmanned AEW platforms with extreme endurance. Thus, the aerodynamic performance of the carrier plus radar must be optimized, which implies that the projected area of the radar must be minimized. In this project, we study the possibility of integrating the antenna layer in the fuselage structure of the aircraft, thus gaining (i) body width and (ii) a more optimal wet geometry.

Keywords: Airborne early warning (AEW), Sensor integration, surveillance radar, wide coverage antenna, phased array antenna.

INTRODUCTION

An Airborne Early Warning (AEW) system is an airborne solution equipped with radar and other sensors. It detects and tracks targets like aircraft, ships, and vehicles at vast distances and allowing defences to be alerted as early as possible before the intruder reaches its destination, giving the air defences the maximum time in which to operate. It is also capable of providing command and control information to other unites and act as the air traffic controller at the battlefield. Apart from military applications, AEWs can be used in other surveillance applications like detecting illegal drones, drug smuggling, deforestation and illegal mining, used in search and rescue in emergencies, illegal fishing, pirates and many more.

The AEWs play a vital role in air defence and other operations. The primary role of an AEW aircraft is to provide the detection of low-flying aircraft. Surface radar is good at delivering ample early warning of high-flying aircraft; however, if aircraft is flying low, the radar horizon is reduced to less than 20 kilometres (McCarry, 2001). It minimizes the warning time to the point where defending fighters do not have enough time to intercept the intruders before they reach the target. Modern aircraft often fly at a very low level — as little as 10 metres, use stealth and hypersonic aircraft and fly behind hills and down valleys, using terrain features to mask their approach. It further decreases the radar horizon and warning time. To overcome the horizon limitation, one needs to get the radar higher. An AEW at the altitude of ten kilometres above the surface of the earth can 'see' everything from directly below out to a range of hundreds of kilometres. Additionally, since the platform is highly mobile, the effective coverage area of an AEW is even larger than the range of the radar taken by itself (Berkner, 1946). The AEW System may have secondary roles such as signal interception, act as a communications relay, detect targets at land and sea, locate bearings of jammers, or to provide surveillance over regions for which surface-based radar coverage is not available.

The design requirements for an AEW radar comes from the role and objectives of the AEW System, of which the radar is only one (though important) element. The high costs for the AEW platform, integration, and operations restrict the number of platforms to a point where these high-value assets become sensitive to preemptive actions by an adversary. Smaller, adapted, and cost-efficient unmanned AEW platforms with extreme endurance might help to deploy adequate numbers of platforms. The aerodynamic performance of the carrier plus radar must be optimized together, which implies that the projected area of the radar must be minimized. In this project, we study the possibility of integrating the antenna layer in the fuselage structure of the aircraft, thus gaining (i) body width and (ii) a more optimal wet geometry.

AEWS MAIN SENSOR

The physical size of the antenna becomes too big for practical aircraft platforms below upper UHF frequencies, and the two ways propagation loss is very high above S-band for the long-range detection, especially in poor weather (Clarke, 1985). Therefore most AEWs use L or S-bands antenna for the long-range detection. Commonly, two different antennas configurations are used in AEW. 1) A fixed beam antenna like the reflector antenna in AVS21 (Watts, 2017) or the fixed beam antenna array in Boeing E-3A (Clarke, 1985), and 2) A beam-scanning antenna like the phased array antenna in SAAB Erieye (Heed, 2000). The fixed beam antenna only radiates at one direction, and it is mechanically steered to the desired radiation direction. In contrast, the beam scanning antenna is mechanically fixed to the aircraft body, and it is electronically steered to the desired radiation direction. In this project, we shall study a body-wide fixed antenna geometry similar to the SAAB Erieye.

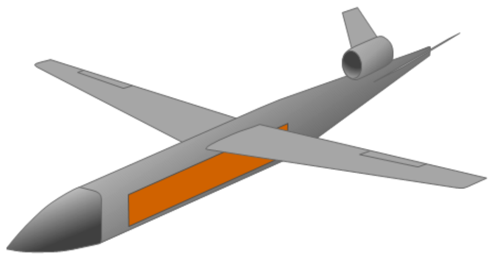

Figure 1. A concept model of the purposed fuselage integrated antenna (in the orange colour) on an aircraft.

One of the approaches of designing the body-wide antenna for an aircraft is to use very thin conformal antennas like those in (Kemkemian et al., 2013) and (Qiang et al., 2017). The main advantage of this approach is that the fuselage can be build using the conventional method, and the antenna can be installed on top of the fuselage later. However, this approach is not suitable for wide scanning antenna arrays. Wide-angle scanning antenna arrays are not very thin (Jonsson et al., 2013); as a result, installing them on top of the conventional fuselage will create protrusion in the fuselage and change the aerodynamic of the aircraft significantly. Therefore, such antennas should be integrated with the fuselage, and the aerodynamic performance of the aircraft plus radar must be optimized together. One of the early published research on the fuselage integrated phased array antennas were (Yee and Furlong, 1981). It gives us the importance of fuselage integrated antennas and the antenna design approach at that time. More recently, a fuselage integrated antenna array was studied under NFFP4 (Swedish National Aeronautics Research Programme 4) project (Ellgardt, 2009). However, the study focused on a wide-band antenna and to reduce the radar cross-section for the antenna's cross-polarization. As a result, the antenna was not low profile.

In this project, we are investigating a low volume, lightweight, high endurance load-carrying fuselage integrated antenna. Figure 1 shows a conceptual model of an aircraft consisting of the desired antenna. It shall be a large, high gain, wide scanning, fixed phased array antenna consisting of antenna elements in the order of thousands. The size of the antenna shall be comparable to the size of the aircraft. Hence, the reduction of weight and volume of the radar sensor will help us to reduce the weight, volume, and drag of the aircraft and improve the sensor coverage. As a result, we expect to have increased mission time, lower operating costs, and better coverage due to the freedom of sensor integration. Research results of the project could be applied to unmanned ISR platforms, large AEWs, small UAV AEWs and mid-life fighter upgrades.

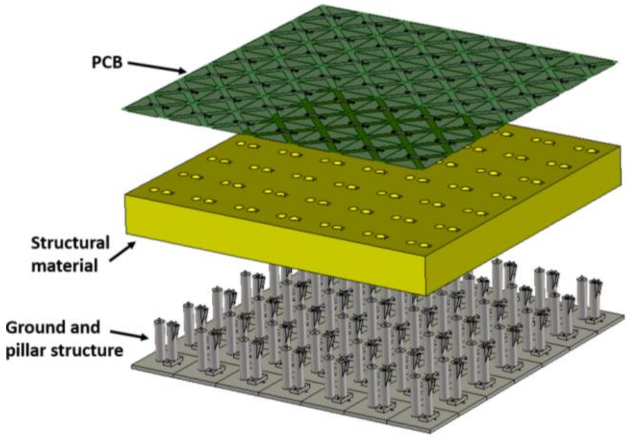

Figure 2. One of the purposed concepts for the structural integration of connected cross bowtie antenna array.

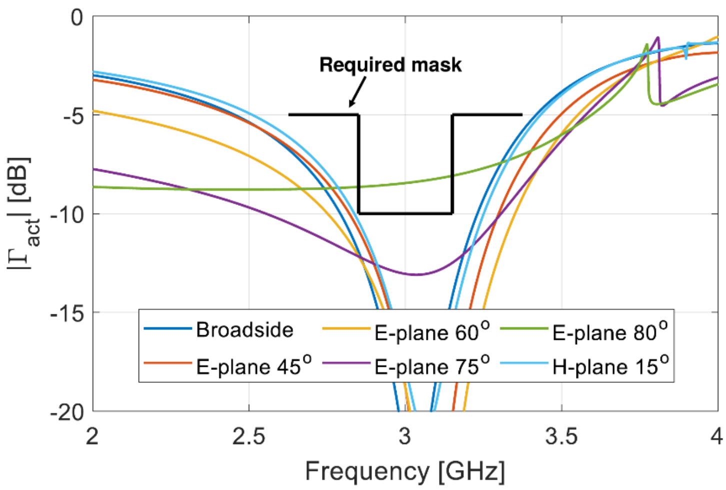

Figure 3. The active reflection coefficients of the uniformly excited infinite phased array of the connected cross bowtie antenna array.

For the project, we selected a cross bowtie antenna element (Khanal et al., 2019) as one of the possible solutions. Figure 2 shows the purposed concept for structural integration of the cross-bowtie antenna element. The antenna has two parts, 1) A PCB consisting of the radiating elements: bowties elements and 2) Ground and pillar structure consisting of a ground plane and the feeding structure: coaxial pillars and solid (metal) pillars. A pair of the coaxial and solid pillars act as a balun transforming single-ended antenna port to the differential port of the bowties. We have purposed to use Rohacell sandwich or similar material as a structural material. The structural material is sandwiched between the PCB and ground and pillar structure to provide the antenna with the rigidity and mechanical strength.

Figure 3 shows the active reflection coefficient of an infinitely large cross bowtie antenna array. Here we can see that the antenna array is capable of providing coverage up to ±75° in azimuth (E-plane) and ±15° in elevation (H-plane) with the desired performance: active reflection coefficient of -10 dB and -5 dB at 10% and 25% bandwidth respectively. Next phase of the project is to build a prototype antenna and study its electrical and mechanical performance.

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