Int. J. Electron. Commun. (AEÜ) 71 (2017) 53–71

Contents lists available at ScienceDirect

International Journal of Electronics and Communications (AEÜ)

journal homepage: www.elsevier.com/locate/aeue

Regular paper

A Novel Approach towards the Designing of an Antenna for Aircraft Collision Avoidance System

Debajit De *, Prasanna Kumar Sahu

Department of Electrical Engineering, National Institute of Technology, Rourkela, India

ARTICLE INFO

Article history:
Received 21 September 2016
Revised 31 October 2016
Accepted 2 November 2016

Keywords:
TCAS/ACAS
Monopole antenna
Microstrip Antenna
S Parameter
VSWR
Impedance
E-Field
Gain
Beamwidth
Side lobe

ABSTRACT

TCAS/ACAS (Traffic/Aircraft Collision Avoidance System) is an airborne system designed to increase cockpit awareness of nearby aircraft and to service as a last defense against mid-air collisions between the aircrafts. In the existing system, four monopole stub elements are used as TCAS directional antenna and one blade type element is used as TCAS Omni-directional antenna. The transmission and reception frequencies of the TCAS antenna are 1.03G Hz and 1.09G Hz respectively. The existing TCAS antenna has some drawbacks such as low gain, large beamwidth, frequency and beam tuning/scanning issues etc. Antenna issues like unwanted signals reception may create difficulties in identifying the possible threats. In this paper, the focus is on the design and development of a novel Microstrip Antenna Array which can be used for TCAS/ACAS application. Two proposed antenna models are presented here – a Unit Element Dual Feed Microstrip Dual Patch Slotted Antenna and a Compact Microstrip Antenna Array. These are designed in CST tool to meet the current needs of aircraft Collision Avoidance System and to overcome the possible limitations associated with the existing techniques. The performance and other antenna characteristics have been explored from the simulation results followed by the antenna fabrication and measurement. A good Reflection Coefficient and VSWR with proper 50 Ω Impedance Matching, narrow Beamwidth, perfect Directional Radiation Pattern, high Gain and Directivity at the operating frequencies make this proposed antenna a good candidate for TCAS application. The proposed antenna would be expected to meet the requirements of the advanced avionics standards in terms of design simplicity, lightweight and high performance.

1. Introduction

The Aircraft Collision Avoidance System provide a solution of reducing the risk of mid-air collisions between aircraft. TCAS is a family of airborne systems that function independently of ground-based air traffic control (ATC) to provide collision avoidance protection. The TCAS concept makes use of the radar beacon transponders carried by aircraft for ground ATC purposes and provides no protection against aircraft that do not have an operating transponder [1]. After many years of extensive analysis, development, and flight evaluation by the Federal Aviation Administration (FAA), Civil Aviation Authorities (CAAs), and the aviation industries, Traffic Collision Avoidance System (TCAS) was developed to reduce the risk of mid-air collisions between aircraft [2]. The main feature of TCAS, which was first proposed by Dr. John S. Morell in 1955, is that the function is according to time criteria and not the distance. From several successive replies, TCAS calculates a time to reach the CPA (Closest Point of Approach) with the intruder, by dividing the range by the closure rate [3]. In 1983, J. D. Welch and V. A. Orlando of Lincoln Laboratory in M.I.T, USA had published first official report on functional overview of TCAS system [4]. In this report, the presented a review of the functions performed by any collision avoidance system and then a definition of the way in which these functions are implemented in the TCAS II. This section concludes with a summary of TCAS II design parameters.

TCAS/ACAS employs radio signals for surveillance of nearby aircraft, and in dangerous encounters, it warns the aircraft pilot by means of cockpit displays and auditory alarms. To detect the presence of nearby aircraft, TCAS transmits interrogations at a steady rate, nominally once per second, and employs a receiver for detecting the replies to these interrogations from the transponders on nearby aircraft as shown in Fig. 1. Fig. 2 shows the basic block diagram of overall TCAS system. TCAS consists of the Mode S/TCAS Control Panel, the Mode S Transponder, the TCAS Computer, Antennas, Traffic and Resolution Advisory Displays, and an Aural

* Corresponding author.
E-mail addresses: de.debajit118@gmail.com (D. De), pksahu@nitrkl.ac.in (P.K. Sahu).

http://dx.doi.org/10.1016/j.aeue.2016.11.002
1434-8411/

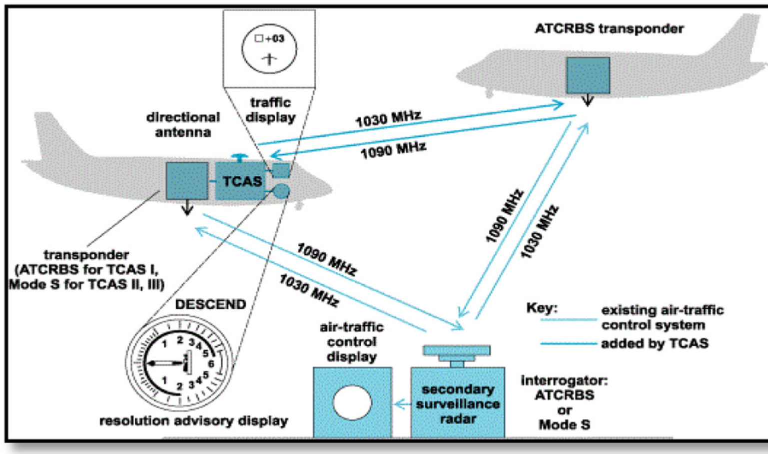

Fig. 1. Air-to-air surveillance.

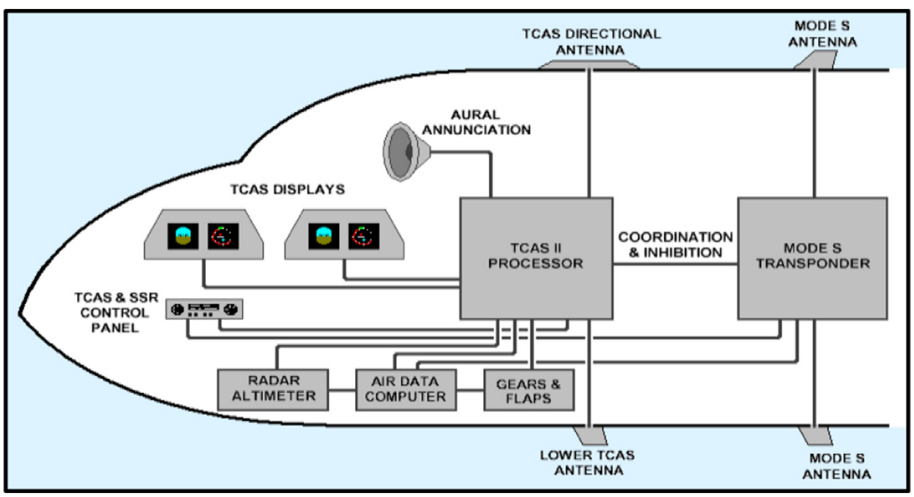

Fig. 2. TCAS/ACAS system block diagram.

Annunciator. Control information from the Mode S/TCAS Control Panel is provided to the TCAS Computer via the Mode S Transponder [5].

In 1991, K. S. Sampath, R. G. Rojas and W. D. Burnside of ElectroScience Laboratory in Ohio State University, USA had discussed 2 different implementations of the TCAS Antenna [6]. In this paper, 8 elements circular antenna array with a monopulse principle and a 4 element antenna with an amplitude comparison scheme are presented. The purpose of this paper is to study the effect of aircraft itself on the performance of TCAS in estimating the bearing angle of the intruder aircraft. The performance of the 4 elements TCAS was not as good as the 8 elements but the 4 elements amplitude system is much simpler in its implementation than the 8 elements monopulse system. In 2011, W. H. Harman and M. L. Wood of Lincoln Laboratory in M.I.T, USA have proposed a Triangle TCAS Antenna [7]. This report describes an antenna of 3 elements in the shape of a triangle. It illustrates the concept of the triangle antenna as compared with the conventional TCAS antenna. The triangle antenna offers an advantage in angle of arrival accuracy as affected by receiver noise.

Presently, TCAS/ACAS uses a directional antenna, mounted on top of the aircraft. An Omni-directional transmitting and receiving antenna is mounted at the bottom of the aircraft to provide the range and altitude data to TCAS from traffic that is below the aircraft. In addition to the two TCAS antennas, two antennas are also required for the Mode S transponder. These antennas enable the Mode S transponder to receive interrogations at 1.03 GHz and to reply for the received interrogations at 1.09 GHz [1].

Fig. 3 shows the Directional Antenna, which contains an array of four passive, steerable, radiating elements mounted at 0°, 90°, 180°, and 270° in relationship with the vertical axis of the antenna. This whole assembly is mounted directly to the fuselage of the aircraft. During Mode S and C interrogation message transmission, the directional antenna transmits 1030 MHz pulses on the four radiating elements. During TCAS receptions, each of the four directional

Fig. 3. Directional antenna.