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A Systematic survey on Blade antennas for Airborne applications

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Abstract—This paper presents a comprehensive overview on Blade antenna, the very recent development in airborne applications. Blade antenna is well suited for airborne applications due to their compact size, light weight and aerodynamic shape leading to little drag. In this paper the different kinds of blade antennas, their applications, advantages, and comparisons are discussed chronologically.

Keywords—Blade antenna; airborne applications; blade monopole

I. INTRODUCTION

An antenna is one of the most significant components in wireless communications. An antenna is considered as a region of transition between a transmission line and free space. Antenna radiates or couple or concentrate or direct electromagnetic energy in the desired direction.In general the communication system performance can be improved with a suitable antenna design. An antenna is a metallic rod that converts radio-frequency fields into alternating currents or vice versa. Now days the wireless systems are expecting greater demands on antenna design [1]. The electric and magnetic field relations through a set of profound equations are expressively represented by James Clerk Maxwell [3]. Large number of books written on the antenna subject[4],[5].The different types of antenna classification is shown in the fig.1.

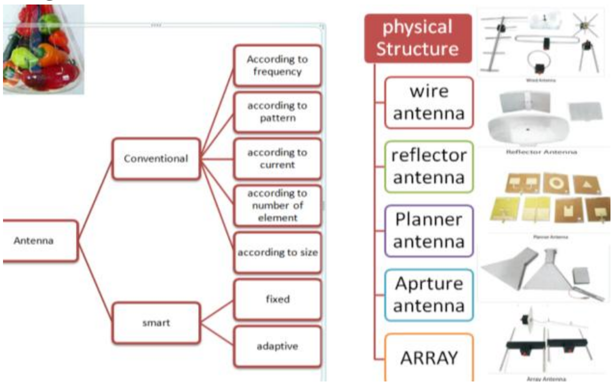

Fig. 1. Antenna Classification

The quick growth in wireless communication has demanded broadband antennas to prop up wireless devices for instance aero plane, radar systems, and satellite communications. The Blade antenna is a monopole type antenna primarily for use on aircrafts. It has better state of affairs and advantages that build greater improvement in recent years. Monopole antenna is a quarter-wavelength long Omni directional antennas.

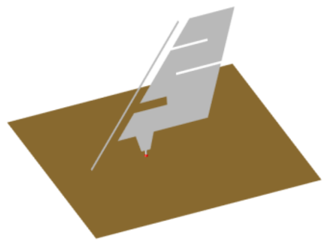

Fig. 2. Blade Antenna

A monopole antenna is one half of a dipole antenna, approximately mounted above some sort of good ground plane. A slanted monopole antenna is blade antenna. Blade is a grouping of narrowed rectangle and elliptical antenna shapes.

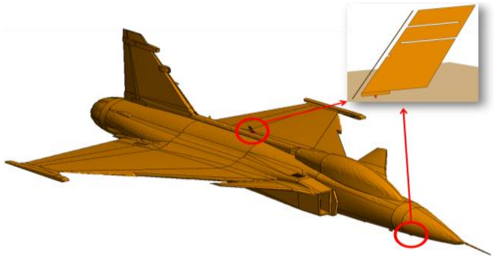

Fig.3. Blade antenna on Aircraft

Lot of schoolwork on blade antenna has lead to enormous movement in recent years. A blade antenna often is a monopole type of an antenna covered with trapezoidal radome or it is an attempt to create a broader band monopole. Blade antennas can also be used in broadband frequency, C-band, and S-band. Different types of antennas are available to suit aircraft application out of those many; one of the most accepted types is blade antenna.

II. BLADE ANTENNA BASICS

These days' Blade antennas are used in various platforms such as mobile surveillance,aircraft, spacecraft, jamming, spectrum monitoring and so on. As compared with conventional aircraft antennas and monopole antennas, blade antennas find more advantages. They are lighter in weight, convenient in shape, low profile and low volume. Blade can also provide linear and circular polarization with high gain. Blade antennas can be used in broadband frequency, C-band, and S-band. In designing the blade antenna the following factors such as the substrates to use, dielectric constant, feeding type, constant of the substrate and size of the antenna are likely to consider. Blade antenna can be able to withstand under adverse atmospheric conditions by using a radome to it and it also provides good insulation to the antenna. Most blade antennas are trapezoidal in shape.

Fig.4. Blade antenna

Variations have been made on this shape for aerodynamic purposes and notches have been introduced in order to achieve a better broadband performance.The blade antenna is designed with one oblique edge; the oblique edge helps to decrease the air drag on the antenna. These antennas can be linearly or circularly polarized and typically yield high gain. The slanted edge of the antenna helps to reduce its height and make it slanted on any angle based on the design requirements. In the extensive scope of antenna designs there are different structures of blade antennas, naturally there are three fundamental parts in the blade antenna [25]. They are the blade, the ground plane and the feed line.Generally blade antennas are fabricated with copper or aluminum material. A blade antenna often is a monopole type of an antenna covered with a trapezoidal radome. The termradome is a contraction from radar dome. Most of the radome are utilized and designed for aerodynamic purposes. Therefore, a blade antenna is a first-rate aspirant for communication systems on aircrafts. Monopole antennas are half the length of a dipole and ground supplies the other half. If it is installed above the ground, a ground plane can be used instead. For example for a car antenna, the car is a ground plane. The input impedance is half that of a dipole, about 35 ohms. Blade antennas are also monopole antennas with some oblique edges. They are advanced version of monopole antenna specially using for aerospace applications.

III. BRIEF REVIEW OF EARLY WORK ON BLADE ANTENNAS

A. Baratta and C. B. Andrade presented a paper on Installed Performance Assessment of BladeAntenna by Means of the Infinitesimal Dipole in IEEE LATIN AMERICA TRANSACTIONS, VOL. 14, NO. 2, FEB 2016.They modeled an accurate and simple model to predict the radiation pattern of a blade antenna installed on an aircraft. They fabricated an equivalent infinitesimal dipole model (IDM) based on the far field radiation pattern of the blade antenna on a ground plane.A. Baratta and C. B. Andrade,observed that by taking into consideration the basic geometry and some physical characteristics of the antenna to be modeled, their proposed approach has overcome one of the major problems of the classic IDM by reducing the number of parameters that to be optimized. They have chosen an aircraft in order to validate its application in electromagnetic large structures problemsas a case study. They concluded that a good agreement with the radiation patterns is obtained between the proposed model and a blade antenna, where its accuracy and reduction in computational cost is verified.

MeliksahYayan and OnurhanDuman presented a paper on Directional Blade Antenna with Increased SectorialGain, in 2015. They introduced and discussed the method for increasing the sectorial gainof a 3-notched directional blade antenna operating in C-band. MeliksahYayan and OnurhanDuman expected that by inserting an additional 4th notch and usinga cylindrical parasitic element all around the radiator,sectorialgain covering 70 degrees along the broadside radiation of theblade antenna is increased by approximately % 30. Their proposed antennaconfiguration is modeled and optimized by using CST MicrowaveStudio Suite, an EM simulation Software. Their observations reveled that, not only the return loss bandwidth is increasedfrom % 10 to %27 but also broadband minimum sectorialgain covering 70 degrees along the broadside radiation is alsoincreased by % 30 after adding a 4th slot on the radiatorproposed in [1] and placing a cylindrical parasitic all aroundthe blade antenna.

Ardra George and J.GeethaRamani presented a paper on Survey on Various Designs of Monopole Blade Antenna in IFRSA's International Journal Of Computing Vol. 5, issue 4, October 2015. In this paper they presented a survey on Blade monopole antenna and their historical perspectives. They discussed about the Blade monopole antenna, types, application and comparison of blade antenna over conventional monopole antenna.

In 2015 Hai Lu et.al, presented a fast prototyping approach that combineaccurate electromagnetic simulation and 3-D printing technology[14] in order to rally the necessities. The very unique feature of this type of approach is the specifictransformation of coil model in electromagnetic simulations to mechanical design that can be man-made directly by 3-D printing and it is studied experimentally in this work.

AmnaIkram, Jean-Jacques Laurin presented a paper on "The Increase of the Directivity of a Low Profile Aircraft Antenna" in the 8th European Conference on Antennas and Propagation (EuCAP 2014). They alleged that their paper introduces a novel design to enhance the directivity of a low profile antenna for distance measuring equipment (DME) avionic system. A horizontal grooved ground plane is used by them to improve the antenna directivity. Their proposed design has a height of $\lambda/10$. Its radiation pattern is comparable with a monopole of $\lambda/4$ on the same ground plane size. Therefore they concluded that, with the use of a low profile antenna we can reduce the aircraft air drag without any significant change in its radiation characteristics.A new technique to increase the directivity of low-profileantennas at the horizon has been studied. Their proposed antenna was simulated in the High Frequency Structure Simulator (HFSS),fabricated and tested. The height of the proposed fabricatedantenna from the top of the ground plane to the top plate of theantenna is 34.5mm, which also includes the thickness ofmiddle plate. At the lowest frequency of DME band theelectrical height of the antenna is 0.11λ. It has a radiationpattern similar to that of a monopole but it has the advantage ofheight reduction from 0.25λ to 0.11λ. Even with its reducedheight, this antenna has more gain or directivity than thequarter-wave monopole (or blade antenna) at horizon. They concluded that basedon simple calculations, its drag coefficient remains small andcomparable to that of blade used for DME.The side view of the antenna placed on the grooved ground surface is shown in the figure.

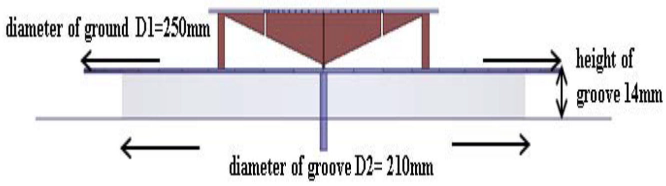

Fig. 5.Antenna placed on the grooved ground surface

Kaiyue Zhang presented a thesis on Modelings, Simulations, Measurements and Comparisons of Monopole-Type Blade Antenna in 2014. Kaiyue Zhang investigated two commercial blade antennas for aircraft applications. In his work the computed results are compared with measurements performed in the ASU Electro-Magnetic Anechoic Chamber (EMAC). The antennas are modeled as mounted on a13-inch diameter circular ground plane, which corresponds to that of the measurements.Two electromagnetic modeling codes are used in his work to model the antennasand predicted their radiation and impedance characteristics by using FEKO and WIPL-D Pro.The classical wire monopole was alsomodeled using high-frequency methods, GO and GTD/UTD, mounted on both arectangular and a circular ground plane. A good agreement between the patterns ofthis model and FEKO has been obtained. The final versions of the solvers used in this work are FEKO WIPL-DPro v11 and WIPL-D Pro CAD 2013. Features of the simulation solvers are presentedand compared.Simulation results of FEKO and WIPL-D Pro have good agreements with themeasurements for radiation and impedance characteristics. WIPL-D Pro has a muchhigher computational efficiency than FEKO. The work concluded that by making reasonable modifications to the radome and coil, the Reasonable Approximation Modelis obtained. The S-band Reasonable Approximation Model exhibits very good agreement with the measurements. The radiation patterns in the principal planes arealmost identical to the measurements. Similarly, the predicted and measured returnlosses are in good agreement.

In 2011 Brendan D.Pell,[13], presented the concept of the modern vehicular antennas frequently configured in Blade or shark –fin housings, or as planar roofmounted antennas. The work is focused to improve the appearance of the finished vehicle by painting these antennas on the or covering. In the work the narrow band and the wide band antennas are investigated and the effect of these coatings on impedance bandwidth and the radiation is observed [23].

In 2010, EmrahÖNCÜ, expressed[12] the concept of Single Stub Tuning Application via Semi-RigidCoaxial Cables for

VHF and UHF MonopoleAntennas on RASAT. The studies reveled that for maximum power transfer impedance matching is an important subject in communication systems. Besides, minimum complexity is another important concept in order to obtain cheaper, reliable and feasible matching networks. The work used a single stub matching implementation method applied while improving the return loss characteristic of blade antennas used in VHF/UHF communication system of RASAT is presented. RASAT is the first observation satellite designed and manufactured in Turkey.

The design and fabrication of a blade monopole antenna operating in 30 MHz – 600 MHz is presented by BijanAbbasiArand, Reza Shamsaee andBehzadYektakhah in 2009.BijanAbbasiand his team mates said that Blade antennas are ideal antenna structures in airborne applications since they have light weight and are in aerodynamic shape. They studied and presented a special type of Blade antenna structure with an oblique edge which shows the improved impedance bandwidth in comparison to a normal blade antenna with the same total height and no oblique edge. Their proposed antenna is matched to a 50 Ω system with VSWR < 2 in the range 30 MHz – 600 MHzTheir experimental results revealed that the antenna pattern is Omni-directional with the maximum gain (G) of 5.6 dBi at 600 MHz and G > 0 dBi in the frequency range 150 MHz – 600 MHz

BijanAbbasiArand, Reza Shamsaee andBehzadYektakhah designed and fabricated a broadband monopole blade antenna with oneoblique edge covering 30 MHz – 600 MHz.The final Blade antenna structure with an oblique edge with Teflon holders and impedance matching circuit is simulated by HFSS and also measured in anechoic chamber to obtain VSWR and gain pattern. Theirsimulation and measurement results for theantenna with the matching circuit show VSWR < 2 in therange 30 MHz – 600 MHz concluded that the oblique edge of the bladeimproves the impedance bandwidth for the antenna withno matching circuit.

In 2007, Marta Cabedo - Fabres, et al. presentedorder to demonstrate that the Theory of Characteristic Modes can be used to perform a systematic design of different types ofantennas. Characteristic modes are real current modes that can be computed numerically for conducting bodies of arbitraryshape. Since characteristic modes form a set of orthogonal functions, they can be used to expand the total current on thesurface of the body. They discussed about what makes characteristic modes really attractive for antenna design isthe physical insight they bring into the radiating phenomena taking place in the antenna. Their study confirmed that the resonance frequency of modes,as well as their radiating behavior, can be determined from the information provided by the Eigenvalues associated with thecharacteristic modes. Moreover, by studying the current distribution of modes, an optimum feeding arrangement can be foundin order to obtain the desired radiating behavior is the noteworthy contribution from their study [9].

In 2006, L. Mattioni and G. Marrocco [8] presented a software tool for designing loaded antennas equipped with matching networks for broadband or multibandapplications. The software implements a genetic algorithm to automatically optimize the large set of parametersinvolved in the design procedure. The graphical interface has been designed in MATLAB® to be used together with thepopular NEC solver. However, the possibility of handling reduced-port models of the antenna permits the use of any kind ofnumerical solver for the electromagnetic analysis. Some examples of broadband and multi-band antenna designs in acomplex environment demonstrate the potential of the too[8].

In 2005, James E. Richie, presented the work on Antennas mounted to vehicles at VHF frequencies in comparison to whip and loop antennas.The antenna placement is the major concern in this work and it investigates the use of side-mounted loops on rectangular conducting platforms. From the experimentation he concluded that those tall thin platforms radiate similar to a dipole. In addition, as the thickness increases, the loop antennas can radiate in a nearly Omni directional fashion if the antenna-mounted sides of the platform are not too wide. In effect, a narrow platform width implies return currents for a loop antenna that remain mostly vertical [7].

In a research work carried in 2002, an application of physical optics and the methods of equivalent currents to the calculation of radar cross section of a helicopter rotor have been assessed in an experimental way. [6] The problem is treated using a quasi – stationary approach in this work. The calculation is parameterized as a function of locations of the radar transmitter and the receiver in relation to the rotor center. Blade geometry is taken into account using a triangular meshing generated by the I-DEAS meshing software. The far field and the near field of the antenna geometry are assed in this work.

Makoto Ono and Yoshihiro Takeichi in 1990's presented a paper on a oneeighth-wave blade antenna with metal leading edge. In the paper they very first investigated the change of the feed-pointimpedance of a reduced height monopole due to the grounded metal leading edge. Later they presented a procedure to obtain wide band impedancematching on an antenna under the existence of agrounded metal leading edge. In the end they applied this theory to the VHF airborneantenna, producing wide band impedance matchingon a one-eighth-wave blade antenna.Makoto Ono and Yoshihiro Takeichi concluded that the Q of a reduced-height radiator is increasedwhen a grounded conductor is located close by. They observed that areduced-height radiator of low Q for wide bandimpedance matching can be obtained by means of a planar radiator with horizontal notches cut on it. Their proposed theory has been effectively practical tobuild up a one-eighth-wave blade antenna that is used for aircraft.The effect of the impedance due to grounded parasitic element is shown in the figure.

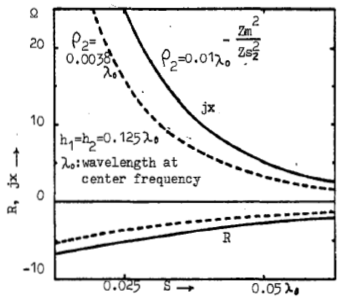

Fig.6. Impedance change due to grounded parasitic element

IV. CONCLUSIONS

A brief systematic survey on Blade antennas for airborne applications is presented in this paper. It is observed that the Blade antenna is well suited for airborne applications and with little modifications to the shape of the Blade antenna reasonable antenna performance can be obtained. It is noticed that the antenna pattern of the monopole antenna is Omni directional.

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