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# A Review on Development and Analysis of Conformal Antennas for Aircraft Applications

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**ABSTRACT**

This paper present the review of various types of conformal antennas arrays design with different feeding mechanism and used different type of dielectric substrate to achieved desired structure with their performance based on their applications. This paper successfully explains the geometry based antennas performance and their characteristic. Conformal Antennas are a key part of military correspondence frameworks that utilization free space as a propagation medium. Many military missions require conformal antenna outlines. Microstrip antennas are appropriate as conformal antenna since they are thin and can be bended to fit forms. Here we discuss a variety of conformal microstrip patch antennas like as cylindrical, spherical, planar and circular with their novel feeding mechanism and explain the advantages overcome to other structure.

***Keywords:*** Microstrip patch antenna, Conformal antenna, Array antennas, Feeding Mechanism, Gain, Radiation pattern, beam width, B.W, VSWR.

## 1. INTRODUCTION

The advancement in the communication and navigation technologies going on rapidly, the implementation of conformal antenna plays an important role to enhance the transfer and receiver characteristic of antennas. Conformal antenna is an array that conform the shape, this shape is determined by the consideration other than the electromagnetic. As the changes on the correspondence and route frameworks of flying machines go on, new edge-cutting advancements are created and new ways to deal with the framework segments are needed. The structure of the conformal antenna might be of geometry like as barrel shaped, circular, and tapered and some other type depend on the shape of the surface but it has some disadvantages like as design complexity and matching the existing radiation pattern. In conformal antenna the area of transmission and reception is increase as compare to planar surface and hence, it provides the broad beam radiation pattern with large coverage area in comparison to other surface. In addition the development of conformal antenna is linked to a European project named as ANASTASIA (Airbone New and Advanced Satellite Techniques & Technologies in A System Integrated Approach), its aim to emerge new edge cutting technology in communication and navigation system to reduce the air traffic in the environment and to enhance the operational efficiency of conformal antenna for secure avionic communication application [5].

## 2. LITERATURE ANALYSIS

A literature review of several papers [1-43] is taken in to account to find out the current state of conformal antennas applications. The literature analysis of conformal antenna is categories on the basis of their geometrical size like as planar, cylindrical, spherical and circular. Most of the references successfully explain the analysis of planar and non-planar conformal antenna based on their curvature [1], [2]. The four

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types of feeding technique named as edge feeding, probe feeding, aperture coupling and proximity coupling are taken into account to design the conformal antenna for avionic applications. When the curvature of antenna is very large, the conformal antenna is analysis by using approximation technique while the accuracy and time consumption is taken in to account [3]. The Fourier transforms and Green's function are used to evaluate the spectral domain and moment method is used to analyze the current distribution of the patch to successfully explain the radiation patterns. The wraparound patch on a sphere surface is analyzed by the cavity model theory on the basis of equivalent current distribution [4].

The meta-material (Rtdroid, Teflon, Rogers) is used as a substrate to design the conformal antenna with optimized parameter, which shows extraordinary properties as compare to other substrate .The impact of negative index supports the antiparallel group velocity and phase velocity of the electromagnetic wave. The substrate with high relative permittivity is preferred to get broad beam radiation pattern however it is difficult to bend and this is much focusing factor to design the conformal antenna. To achieving larger bandwidth and formation of narrow beam, one of the reviewer Slyusar V.I.2009 [6] explain the uses of metamaterial along with the decrease of mutual coupling between array and it also reduce the size of radiator. further Vardaxoglou, J. C. et al. 2013[7] Analyzed cylindrical conformal antenna with metametarial to optimize the thickness at operating frequency of 2.3GHz, results reduce in diameter length and improve antenna performance, apart from that the electronic band gap and high impedance surface antennas with thickness of $\lambda/2$, and $\lambda/6$ provides small size, high directivity, broad horizontal radiation pattern with good impedance matching.

To minimizing the return loss and enhancing the gain, Tavassolian, N. et al. 2008[8]proposed dipole antenna on liquid crystal polymer substrate at 2.4 GHz ,results good performance and return loss are same for all three antennas which are conformed at 90 degree around cylindrical surface. And Another author Kumari, R. et al.2013[9] proposed a compact sized Dual-band patch antenna with FR-4 substrate in the range of 7.5079 GHz and 10.94 GHz, achieved the return loss (< -10 dB) and the gain is increased from 0 to 12GHz. Further Jae Hee Kim et al.2016 [10] present a microstrip patch antenna using holey dielectric substrate to enhance the gain, achieved a gain of 2.3 dB, while the substrate is added over the microstrip antenna at frequency of 5.8 GHz.

For various applications, the conformal antenna is designed by using metamaterial to show proficient characteristic. For RFID applications one of the author named M. H. Mokhtar et al. 2013[11]designed compact slotted microstrip patch antenna with FR4 substrate and the proposed Antenna size (35×26×1.67 mm) is reduce by 50% from its conventional size and achieved gain of 2.5 dB at 2.40 GHz. Another author

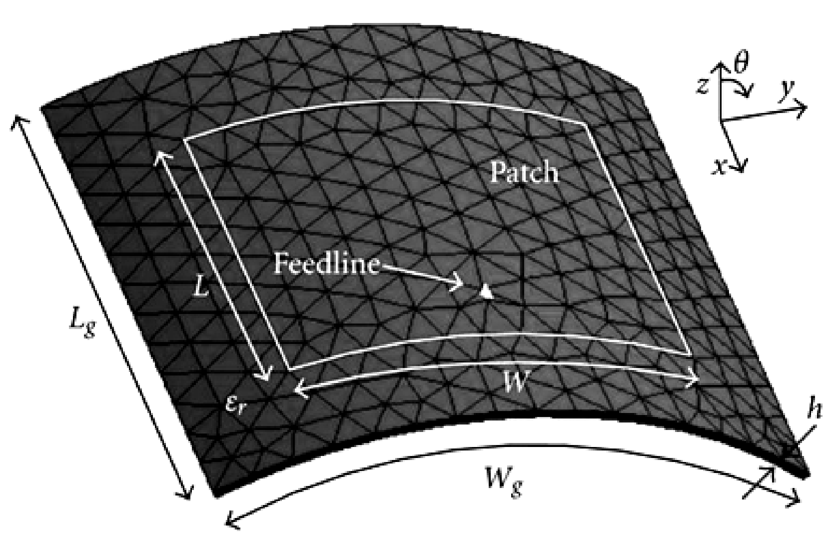


**Figure 1: (courtesy : www.google.com )**

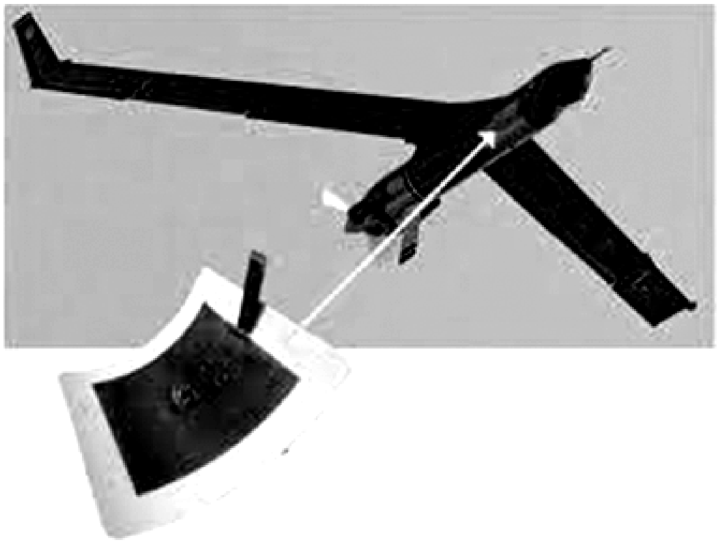

**Figure 2: (courtesy : www.google.com )**

Ghorbani, K. 2014[12] analyzed reduced size (0.18λ) conformal antenna of ring slot geometry with resonance frequency of 1.7dbi using carbon fiber reinforced polymer for aircraft, to reduce interference and maintain aerodynamic performance. The achieved gain is very close to rectangular slot of 0.5λ.The below mentioned figures shows the structure of conformal antenna for aircraft application.

### 2.1. Cylindrical Surface

A Research review on the basis of cylindrical geometry is present in this section and the design of antenna is categories according to the use of four different types of feeding techniques to optimize the antenna parameter and enhance their radiation characteristic. For fabrication point of view microstrip feed line is easy as compared to aperture coupled feed and proximity coupled feed because other required alignment as well as soldering. Aperture coupled feed provide bandwidth of about 21% while other feeding techniques provide 2-5% and 13% respectively for rectangular microstrip patch.

Loffler, D. et al.1997[13] analyzed SDMA technique for 16×4 microstrip patch phased array on a cylindrical surface for base station at operating frequency of 10 GHz, and beam forming technique is used to distribute the same frequency simultaneously in different direction with additionally advantage is to reduce the power consumption. Further Wiesbeck, W. et al. 2002[14] analyzed C band cylindrical microstrip 8×2 array conformal antenna with operating frequency of 5.2 GHz, achieved the side lobe level is batter than-10db and cross polarization is batter than-27db over the desired bandwidth and beamforming techniques are used to minimize the sidelobe level and achieved near omnidirectional pattern. Further Nikolas C. et al.2005 [15] developed cylindrical phased array conformal antenna at 10Ghz, provide steerable main lobe and nulls in predefined direction and also control side lobe with beam forming technique. Further. Further Vasili S. et al. 2013[16]designed 4*4 cylindrical conformal antenna array which operate at 60 Ghz and achieved reconfigurability, wide bandwidth of 0.6 Ghz according to -10db matching level, however gain value decreases from 19.2db to 12.8db.The more antennas array can be used to enlarge the coverage area near omnidirectional pattern with high gain values. He Zhu et al .2016[17]proposed a four-element slot cylindrically conformal array in the range of 3 to 3.4 GHz, 10 dB impedance bandwidth is achieved, and the maximum axial radiation gain is 5.12 dBic.

Alexander S. et al.2013 [18] analyzed cylindrical microstrip array with 5 pairs of coupled slotted strip framed patch, which are proximity feed in microstrip line to achieve low level of cross polarisation(< -40 db). Heckler, M.V.T. et al.2013 [19] analyzed cylindrical antennas with 2D discretization scheme to get rapid response while the field variation in radial direction is taken in to account. The orientation of the field vector shows the strength of power radiated in particular direction with time varying component. According to the shape of the trace the shape of the polarization may be of linear, circular and elliptical. Ping Wang et al.2013 [20] analyzed cylindrical conformal antenna, have low cross-polarization level and 3db beam width with batter end-fire radiation pattern used in surface mounted communication system. Further another author Jin Zhang et al. 2016 [21]proposed a dual-polarization patch antenna array in the range of1.88 to 2.9 GHz along with a bandwidth of 41.7% and achieved cross-polarization is below -20dB, while the antenna height of array is 0.144λ. To analyze the impedance coupling one of the author Chi-Wei Wu et al.2003 [22] analyzed the mutual impedances of cavity-backed rectangular patch antennas, results the coupling decreases with increasing surface curvature. The maximum coupling for E and H-plane occurs at specific curvature and least curvature respectively for a surface.

### 2.2. Circular Surface

The circularly cylindrical omnidirectional patch antenna gives near $360^0$ coverage in horizontal plane and dipole like radiation pattern in vertical plane, which is feed by coaxial probe to achieve circular polarization at 1.92GHz. Pelletti, C. et al.2013 [24] Proposed a technique for circular antenna array with rectangular patch to describe the induced current over large, finite surface, which is not comfortable with conventional methods. Further Kuiwen Xu. et al. 2015[23]Analyzed beam forming approach for circularly symmetric conformal aperture, achieved rotationally symmetric radiation pattern in satellite and flight vehicle application and capable of synthesizing differently shaped beam. This approach is time efficient for large circularly symmetric array.

Quanwen Hou et al. 2014[26] proposed a circular patch antenna at 5 GHz, achieved omnidirectional pattern in azimuth plane with max. Gain of 4.2db, and 10db Bandwidth at 140 MHz. Further Tahsin Ferdous Ara Nayna et al. 2014[25] analyzed rectangular and circular shape patch antennas, the rectangular patch shows 3.0 dB higher return losses than circular patch antenna and rectangular patch antenna has an improved VSWR of 1.18 as compared with circular patch VSWR value of 1.27, In addition the circular patch provides 8% higher B.W as compare to rectangular patch and shows the side lobe value of less than 2dB.. Symon K.et al.2013 [27] proposed circularly polarized compact (0.2λ0 by 0.2 λ0) antenna at 400 Mhz, provides $90^0$ phase difference between radiating folded-shorted patches and used for microsatellite application.

### 2.3. Planar surface

Microstrip patch antennas is one of the familiar antenna in all antennas because it has low profile, low fabrication cost, light weight and easy to install but it has some drawback like as low gain and low bandwidth due to surface wave excitation and dielectric losses. The author reviewed several papers to find out the technique to enhance the gain and bandwidth with optimized parameters and focused on different feeding techniques. Gokce, B. et al.2009[28] designed a new feeding technique for UMTS in 1900-2200 MHz frequency range and achieved impedance bandwidth of 18.3%(1.88-2.26 GHz) with reduce patch size, shows good coverage of UMTS band. Further David H.et al. 2007[29]proposed helmet portable radio antenna in the range of 750-2700 MHz of required bandwidth of 113%, gives coverage of 750Mhz through 2.7 GHz frequency band.

Another author Strojny, B.T. et al.2009 [30] proposed GPS and VHF/UHF antennas, The RHCP gain of GPS antennas was similar for integrated and non-integrated cases while the cross polarization is increased by 10db in upper hemisphere and return loss was increased by integration but still< -10 db for L1, L2 band. Further For WLAN application Mamta Devi Sharma et al. 2012[31] proposed a low profile patch antenna using probe feed and aperture feed, the bandwidth of around 16.4% with 6 dB gains and VSWR of 1.5 is achieved with probe feed, and bandwidth of around 24% with 1.04 VSWR is achieved at 2.45 GHz.

Norbahiah Misran et al. 2008[34] designed an antenna for wireless communication by using multiple slot microstrip patch, 27.89% fractional bandwidth is achieved with 10.01 dBi gain. Lin W. et al. 2013[33] designed unidirectional monopole conformal antenna for impulse radar system with peak width of 200 ps and the range of impedance bandwidth is 0.67 Hz - 2.15Ghz for adopting the bullet structure with $S_{11}$ < -10db, and achieved the fidelity of antenna is 0.8 with the main beam and FBR in time domain is 2.8:1. Another author Shiwen Y. et al. 2013[32]describe a technique to optimize time sequence and static phase excitation for 4D conformal cylindrical antenna array, achieved sidelobe level, sideband levels and flat-top pattern, all are below -20db while the mutual coupling is taken in to account.

To achieved the bandwidth author named Dafalla, Z.I. et al. 2004[35] designed rectangular microstrip patch antenna with co-axial fed at 1 GHz and achieved return loss of – 27.2db, VSWR of 1.1 and matching impedance $Z_{11}$ is 4.81. Further Knott, P. 2006[36] designed 3 element patch array on a common substrate at 9.5 GHz, which are circularly polarized, achieved -10db bandwidth at 2.5 GHz and mutual coupling is below -30db in X-band. Further Wen Tao Li. et al. 2010[37] proposed a conformal antenna and achieved bandwidth of exceeding 12% for VSWR d" 2 at centre frequency of 3.2 Ghz and covers the range of 3.0 to 3.51 Ghz (15.67%) with reduced mutual coupling. Further Kumar, A. et al. 2014[38] proposed the gain enhancement technique in square microstrip antenna, the use of metallic rings enhanced the gain by 4.3 dB and achieved 2 % improvement in impedance Bandwidth. Further Peter K. et al. 2013[39]Proposed seven element antenna arrays mounted on an aircraft for vibration control using piezo-ceramic patches in the frequency range of 90 to 450 Hz at sound pressure of 107db and achieved vibration reduces up to 10db, which is much better than conventional antennas.

### 2.4. Spherical antenna

The literature analysis based on spherical geometry is present in this section. One of the author named Schippers, H. et al. 2008[40] analyzed a low profile hemisphere antenna array for Ku band and achieved the bandwidth of 2 GHz with dual linear polarization, also achieved the increment in the bandwidth of the order of 30-35% with an improved amplitude profile. The broadband radiation pattern is achieved with beam forming network by using adaption of classical least square synthesis. Further Dan Sun et al. 2010 [41] Designed a 13 × 19 elements spherical conformal antenna array in Ku band with proximity coupled stack patches on a cavity backed ground plane results multiple coupled resonance which enhance the bandwidth up to 40% and VSWR < 2 and can be used in communication system in aircraft and Radar.

Abdul Mueed et al. 2012[42] analyzed spherical conformal antenna with cavity-backed proximity coupling, results the bandwidth is exceeds up to 30 % in X- band, however with reduced thickness, the gain is unfluctuating in dielectric sphere than the metallic sphere with increased thickness and can be used for missile, satellites and UAV applications. Another author Ankur Sharma and Samir Dev Gupta 2015[43] designed a spherical conformal antennas on spherical and planar surface at 10 GHz, results the S-parameter is -19db for planar and for spherical surface, it reduce to -8.287 at resonance frequency and this design can be implemented on the some part of the aircraft structure.

## 3. OUR ANALYSIS

The microstrip patch antenna for cylindrical surface, provide high radiation efficiency with good directivity and reduction in the antenna diameter than their planar antennas. The cylindrical geometry also provides low level of cross polarisation in comparison of other structures and VSWR can be minimized. Here the more number of antennas can be used to get the omnidirectional pattern with high gain values and the appropriate range of bandwidth can be achieved. The circularly cylindrical structure gives near $360^0$ coverage in horizontal plane and dipole like radiation pattern in vertical plane, and novel approach of feeding can be used to achieve circular polarization. The spherical surface antenna array easily controls the phase excitation.

The analysis shows that the spherical microstrip patch antennas provide batter main lobe and less side lobe pattern as compare to planar surface. The hemispherical antenna array provides dual linear polarization, and achieved increment in the bandwidth with an improved amplitude profile. The broadband radiation pattern is achieved with beam forming network by using adaption of classical least square synthesis.

The microstrip patch antenna in cylindrical and spherical geometry can be used as a conformal antenna .Therefore the curvature surface provides batter performance in terms of antenna parameter like gain, bandwidth, beamwidth and reductions in losses. Moreover, by using these geometries as a conformal antennas we can reduce the cross polarization and improve the range of bandwidth with increased amplitude profile.

The analysis of dielectric substrate indicate that the use of high relative permittivity substrate is preferred to get broad beam radiation pattern and the use of metamaterial decrease the mutual coupling between array and it also reduce the size of radiator. However it increase the thickness and it is difficult to bend. Therefore it is much focusing factor to design the conformal antenna.

## 4. CONCLUSION

In cylindrical patch antenna the 10 dB impedance bandwidth is achieved, along with the maximum axial radiation gain of 5.12 dBic in the frequency range of 3 to 3.4 GHz. and for another frequency range i.e. at 60 GHz, the 4*4 array of cylindrical conformal antenna provide the wide bandwidth of 0.6 GHz at -10db matching level and more antennas array can be used to enlarge the coverage area near omnidirectional pattern with high gain values.

The bandwidth is enhanced up to 40% with proximity coupled stack patches for spherical antennas as well as achieved the value of return loss is less then 2db and the comparison between planar and spherical surface shows that the S parameter for conformal antenna is reduces up to-8.287 in spherical surface as compare to planar surface and this design can be implemented on to the aircraft. The beam forming approach for circularly symmetric conformal surface provide symmetric radiation pattern for avionic application and capable of synthesizing differently shaped beam.

In planar surface the use of the metallic rings enhanced the gain of antenna by 4.3dB as compared to conventional and 2 % improvement in impedance bandwidth is achieved. The circular patch antenna coupled with annular ring at 5 GHz provides gain of 4.2db with near about $360^0$ coverage areas, and bandwidth of 10db at140 MHz. The analysis of rectangular and circular shape patch antennas shows that, the rectangular patch antenna shows 3.0 dB higher return losses than circular patch antenna and rectangular patch antennaVSWR value of 1.18 as compare to circular patch with VSWR of 1.27, however, the circular patch antenna provides 8% higher B.W with less side lobe power of nearly 2.0dB than rectangular patch antenna.

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