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Design of a FLAP antenna for in-flight satellite communication

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***Abstract*—** Modern satellite demands wide band communication channels for static and dynamic mobile terminals. For mobile terminal like airplane to satellite communications, conformal electronically scanned phased array FLAPS will be preferred over parabolic reflector antenna for efficient satellite tracking and to minimize life cycle cost, size, weight, aerodynamic drag and limited wind resistance. Flat parabolic surface (FLAPS) has a good geometrically flat surface and behaves electromagnetically as tough as it were a parabolic reflector. Although flat, it converts a quasi-spherical wave from the feed into a focused beam, similar to that of a parabolic dish. The FLAPS consists of an array of dipole scatterers. FLAP antenna has significant power transfer efficiency and can be able to beam a large amount of energy. In this work a FLAP antenna has been designed to operate in X-band and the various parameters are studied showing the antenna ability for in-flight communication system.

Keywords- *Satellite communication; FLAP; Parabolic dish; dipole*

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I. INTRODUCTION

At high frequency the satellite communication is the basis for earth-space and space-space interaction. Operating at high frequency range of 1-50 GHz, satellite communication systems require capable antenna for the information exchange. Various applications such as direct TV, Wi-Fi, Radio, Mobile, DTH etc. are accessed with the help of satellites which can be LEO, MEO, GEO, polar, and many more [1].

Commercial and military aircraft may use in-flight satellite communications to access services such as television services (DirecTV or the like), radio (XM radio or the like), high speed internet, telecommunications and other communication services. A high-gain antenna mounted on the aircraft may continuously track a geo-synchronously-orbiting satellite during light. Currently, the antenna may be either a phased-array or mechanically-scanned antenna depending on the services, features and performance requirements. For inflight communication where the users traveling an aircraft want the use of technology, there need to be an antenna embodied on aircraft which could keep the track of near-by GSS and extract the information from it to provide accessibility to the users. For this the antenna should be able to track, sense, conform, and radiate-receive. In this field of application, FLAPS (flat parabolic surface) finds the dimension for use [2].

A phase-array antenna, such as an electronically scanned array (ESA) or similar antenna may scan very quickly and can be manufactured in a relatively flat and conformal package. A mechanically-scanned antenna may be inexpensive and provide consistent antenna beam performance independent of scan angle. FLAPS are synonym and advanced parabolic dish

which are a phased array antenna. It flattens the dish to conform the aircraft surface. Also for tracking and scanning, a phased array of dipole is designed on the surface of antenna which is maintained at a height of approximate λ=8 from the ground plane. The phased dipole array helps radiating to and from the antenna due to the self-complimentary nature of dipoles and RF reactance. With these features a phased dipole array is designed on different ground structures and the basic VSWR parameter is studied for performance. Other performance parameters such as return loss and gain are also considered [3].

The paper is organized as follows; Section II describes the FLAPS and parabolic dish. Section III discusses the design technique of FLAP structure with results and discussion in Section IV and followed by conclusion in Section V.

II. FLAPS

A FLAP antenna includes a RF feed and a shaped reflector formed in a desired shape to reflect the electromagnetic radiation to and from the RF feed. The FLAP is made as a flat surface which is configured with a transceiver to track, scan, receive and radiate. Difference in FLAP and parabolic dish structures are shown in Fig: 1 as;

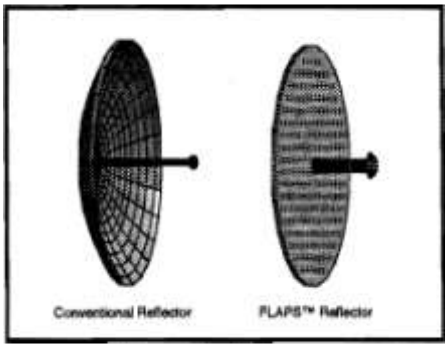

Fig. 1. Comparison of FLAP with Parabolic dish structure [1]

The FLAPS elemental scatterer performs the function of a radiating element and a phase shifter in a space fed phased array. Since dipoles of different lengths will produce a phase shift in the incident wave, arranging the distribution and the lengths of the dipoles will serve to Steer, focus or shape the reflected wave. In a simple application, a parabolic surface can be directly replaced with FLAPS. It is possible to design FLAPS as a substitute for any conventional reflector used in antenna design. FLAPS surfaces can be up to 95% efficient. As we already discussed that for phased array purpose we require an array of dipoles mounted on a ground surface. The unit cell for any FLAP antenna is shown in Fig: 2;

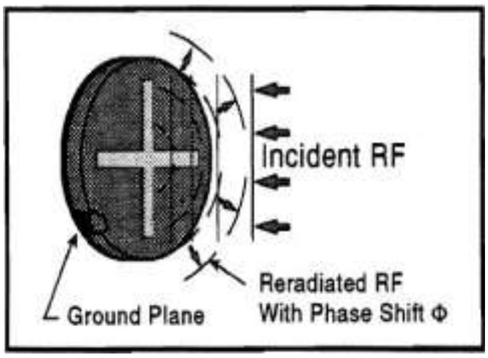

Fig. 2. Unit Cell of radiating FLAP antenna[1]

When designed as an offset reflector, the feed may be offset up to 60% from the flat surface. Bandwidths of 3 to 10 % are achievable with a designed center frequency in the range from 1 to 100 GHz. Unlike conventional reflectors or planar arrays, FLAPS, which are frequency specific, exhibit Low Radar Cross Sections in all directions and at RF frequencies other than the frequency of design. Because a FLAP with a resonant dipole ground plane is RF transparent at frequencies out of the design band, no incident RF is reflected. The radar cross section can be further reduced by adding radar absorbing material behind the FLAPS to prevent RF from reflecting off the other surfaces behind the antenna.

III. ANTENNA DESIGN

For the satellite communication FLAP antenna is designed on a rectangular structure in this work. For conformal nature of antenna materials such as rubber and FR4 epoxy have been studied.

Initially a fishnet structure has been designed on FR4 and Rubber with ε_r as 4.4 and 3 respectively. The antenna has been designed on a rectangular substrate with dimensions of the order of 2λ. The fishnet is drawn as a factor of λ /8. The antenna design is shown in Fig: 3;

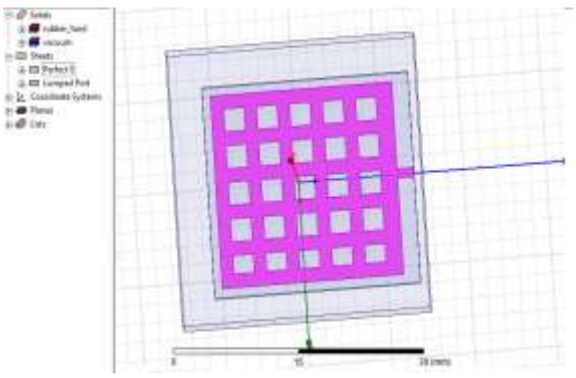

Fig. 3. Design of FLAP with fishnet structure

This design was further optimized where the fishnet was replaced by crossed dipole having dimensions of the order of λ/4. The crossed dipole antenna design is shown in Fig: 4;

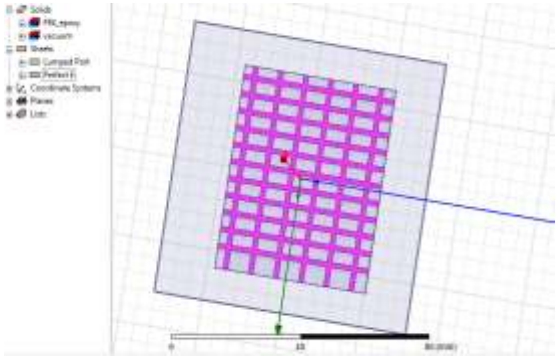

Fig. 4. Antenna design of FLAP with crossed dipole structure

The VSWR and Return loss for the two designs are discussed in the next section.

IV. RESULTS AND DISCUSSION

The designs discussed in this section are studied with FR4 and Rubber_hard as substrate(thickness=1.6mm). FR4_epoxy is a dielectric material with ε_r=4.4 and dielectric loss tangent of .02 and Rubber_hard has ε_r=3 and bulk conductivity of 1e-015 Siemens/m. The performance parameters such as VSWR, Return loss etc. are studied.

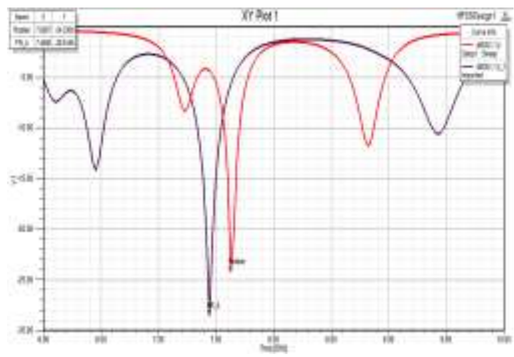

Fig. 5. Comparison of S11 for FLAP with fishnet structure

Fig: 5 compares the return loss (S11) for rubber and FR4 substrate at 7GHz. S11 comes out to be -28.5dB for FR4 and -24.2dB for rubber. FR4 shows better results than rubber with a difference of 4dB return loss.

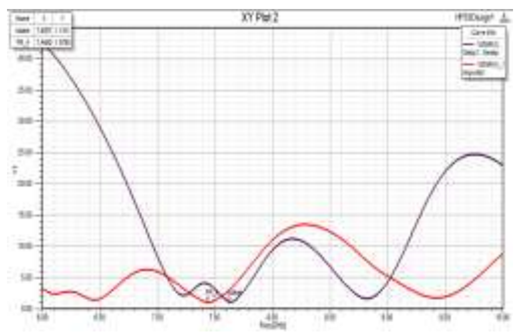

Fig. 6. Comparison of VSWR for FLAP with fishnet structure

Fig: 6 compare the VSWR for rubber and FR4 substrate at 7GHz. It changes from 1.07:1 to 1.13:1 from FR4 to rubber. From the optimized dimensions of fishnet structure crossed dipole antenna was designed. Due to the presence of conductivity, rubber acts as a conductor and therefore radiation efficiency is less than FR4 because of absence of dielectric nature. Further from simulations it was seen that FR4 proves out to be better than rubber, so the crossed dipole was designed with FR4 material.

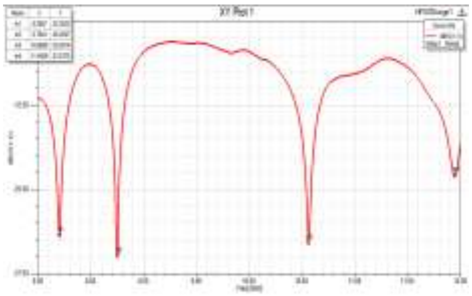

Fig. 7. S11 for FLAP with crossed dipole structure

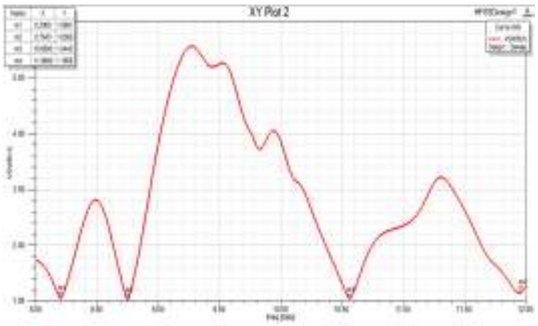

Fig. 8. VSWR for FLAP with crossed dipole structure

Fig: 7 and Fig: 8 shows the return loss (S11) and VSWR for FR4 substrate based FLAP antenna for X-Band. The average values for S11 and VSWR comes out to -31dB and 1.07:1 respectively in whole band. From the simulated results we can also say that the FLAP antenna in X-band acts as a multiband antenna operating at various frequencies in the range of 8-12 GHz.

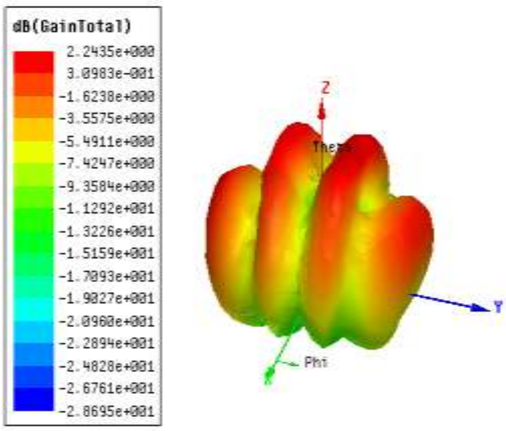

Fig. 9. 3-D gain plot for crossed dipole FLAP

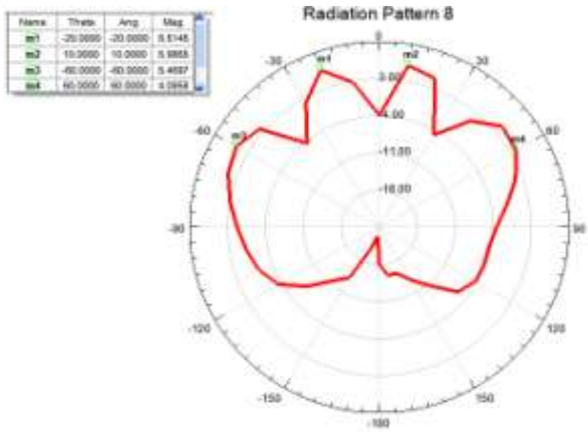

Fig. 10. Directivity for crossed dipole FLAP

Fig: 9 shows the 3-D polar plot of gain which comes out to maximum 2.24dB and has a directive pattern. The directivity of the crossed dipole FLAP is shown in Fig: 10 where at different elevation angles directivity of the antenna changes from 4 to 6 dB.

V. CONCLUSION

FLAP antenna is a new class of antenna which provides a geometrically flat surface and can replace a parabolic reflector structure. It has distinct advantages of cost, performance, ease of installation, optimum power beaming and low profile conformal design to achieve efficient satellite tracking and synchronization. This antenna will neither disturb the performance flow nor the mechanical structure. It can be used for airplanes, helicopters, unmanned aerial vehicles (UAVs) and various ground and sea vehicles. VSWR being the basic performance parameter has been studied for both the designs and considerable results have been obtained. In coming future analogous FLAP to parabolic i.e. a circular FLAP and also different dipole configurations can be studied and designed.

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