Research Article

Self-Complementary Two Arm Archimedean Spiral Antenna for Aircraft Applications

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Abstract

The wideband antennas play significant role in the communication fields especially in satellite and military applications. Since the satellite or aircraft is in motion, the size of the wideband antenna as well as the polarization is very important. Electro-magnetic band gap structures and artificial magnetic conductor structures are usually used to enhance the spiral antenna properties. But these structures are absorbing materials and the bandwidth will be reduced. Here, a spiral antenna is designed, simulated and fabricated for aircraft applications with bandwidth enhancement. The circular polarization of this spiral antenna provides improvement for the gain and radiation of antenna. The complexity in the antenna structure is eliminated and the efficient impedance matching technique used in the work provides better performance. This antenna gives a better reflection coefficient and VSWR for the entire frequency band. The proposed antenna is fabricated using FR-4 substrate.

Keywords: spiral antenna, impedance matching transformer, reflection coefficient

1. Introduction

Wideband antennas have received much attention in present wireless communications and broadcasting systems. With a wide bandwidth, the signals can be transmitted by ultrashort impulses or by using multiband groups. More information and applications can be carried through the radio frequency channels with a high data rate and accuracy. Also, there are numerous military and commercial sensing systems that require wide bandwidth to increase the range accuracy, imaging resolution, jamming/anti-jamming, and hardware flexibility. For various modern radars and aircrafts, such as air defence, air traffic control, astronomy, doppler navigation, terrain avoidance, and weather mapping, the design of wideband antennas would have different considerations and specifications in order to meet the requirements of specified signals and waveforms. Spiral antennas have many advantages than other wideband antennas as it uses circular polarization. The circular polarization of the spiral antenna helps to obtain a better gain and radiation pattern even the aircraft is in motion. A less complicated antenna structure is easy to design, simulate and fabricate. In addition to that, the losses will be less The design of spiral antennas include geometry of antenna and impedance transformer .The spiral antenna is made by winding the finite-ground strip line structure into one arm of the spiral, and extending the center conductor through the middle of the spiral(the balun) into the complimentary arm of the spiral. There are two spirals in an archimedean spiral antenna and current flows through these two arms. These arms are placed 180 degree out of phase each other. At a certain point in antenna, the current through two arms become in phase and these currents are constructively adds up. And antenna radiates from that point. Hence, there is a specific point to the radiation of each frequency.

2. Design of spiral antenna

The parameters that effect the radiation of the spiral antenna are the outer radius, inner radius, flare Rate (The rate at which the spiral grows with angle) and number of turns (N). The inner radius is denoted by r1 and outer radius is given by r2. Let s be the spacing between arms, N is the no.of turns and s and w are equal where w is the width of the spiral arms.

$$s = w = \frac{r_2 - r_1}{4N} \tag{1}$$

The upper frequency of the spiral antenna is 18GHz and lower frequency is 2GHz. The upper frequency depends on inner radius and lower frequency depends on outer frequency.

$$lower frequency = \frac{c}{2\Pi r^2}$$
(2)

And the upper frequency is given by following equation.

upper frequency = $\frac{c}{2\Pi r_1}$ (3)

Transmission line equations are used to find the width of line, effective dielectric constant, characteristic impedance, and attenuation. The effective dielectric constant can be interpreted as the dielectric constant of a homogeneous medium that equivalently replaces the air and dielectric regions of the microstrip line.

3. Design of impedance matching transformer

A tapered impedance transformer is designed for the spiral antenna. This impedance transformer is used to remove the unwanted standing waves and it gives a good voltage standing wave ratio. The width of each section is calculated using design equations of impedance matching transformer. Then the impedance corresponding to the width is calculated using transmission line equations.



Fig.1 Design of tapered impedance transformer

The optimized values of width of tapered section and its impedance is given in the following table 1.

Table 1 Width and impedances of impedance matching
 transformer

Impedance	50	70	90	110	150	170	175
Width w	4.8	2.6	1.7	1.2	1.1	0.9	0.8

4. Simulation results in CST Microwave studio

The design and simulation of spiral antenna and impedance matching transformer is carried out in CST Microwave studio. It gives better results than HFSS and the long simulation time provides accurate results. The computer memory requirement is high for CST Microwave studio. The results are shown below.

A spiral antenna with 2GHz (lower frequency)and 18GHz(upper frequency) is designed and simulated. It gives more than 5.5dB gain in the entire bandwidth and good radiation pattern. The reflection coefficient for a practical antenna should be less than -10dB and this antenna gives a very good reflection coefficient. The structure of the spiral antenna in CST is shown in the figure 2. The reflection coefficient is shown in figure 3. The polar plot of spiral antenna at different frequencies is shown in the following figures. The next step was design an impedance transformer for the antenna. The structure of impedance transformer is shown in figure 5. A tapered type impedance transformer is designed and its output is shown in figure 6. The spiral antenna and impedance transformer combined in the next step and it is shown in figure 7 .This is the final structure and its reflection coefficient is shown in figure 8. The value of VSWR should be less than 3. Here, the obtained VSWR is less than 2.5 and it is highly recommended for practical applications and it is shown in figure 9. The antenna is fabricated using FR4 substrate and it is given in figure 11.



Fig.2 Designed spiral antenna in CST



Fig.3 Reflection coefficient of spiral antenna



5.53 dB = 180.0 dea Angular width (3 dB) = 76.1 deg.

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Fig. 4 Polar plots of designed spiral antenna at different frequencies

Fig. 10 3D gain at 10 GHz

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Fig. 10 3D gain at 16 GHz



Fig. 10 3D gain at 18 GHz



Fig. 11 Fabricated spiral antenna with impedance match using FR4 substrate

Conclusions

The self-complementary two arm archimedean spiral antenna for aircraft applications has designed, simulated and fabricated.

This antenna has a reduced size compared to the antenna given by Chunheng Liu (2010) and it is the most important factor in wideband applications. The use of artificial magnetic conductors (AMC) and perfect electric conductors(PEC) are eliminated in the work and it enhanced the bandwidth. The losses are minimum for this antenna because no absorbing materials are used in the structure. Also this antenna has a good VSWR and gain and it can work efficiently in wideband applications. It is the result of reduced standing waves and it is achieved by using a tapered impedance multi-section transformer. The antenna performance can be boosted using some powerful impedance matching techniques and substrate materials. But the simulation time will be high and it depends on the system properties.

References

- Chunheng Liu, Yueguang Lu, Chunlei Du, Jingbo Cui, and Ximing Shen.,(2010.)The Broadband Spiral Antenna Design Based on Hybrid Backed-Cavity, IEEE Trans.on Antennas and Propagation., vol. 58, NO. 6.
- D. J. Kern et al, The Design Synthesis of multiband artificial magnetic conductors using high impedance frequency selective surface (Oct. 2010), IEEE Trans. Antennas Propag., vol. 53, no. 1, pp. 817.
- Dominikus J. Muller, Student Member, IEEE, and Kamal Sarabandi, Fellow (February 2007)IEEE,Design and Analysis of a 3-Arm Spiral Antenna, IEEE Trans. On Antennas and Propagation., vol. 55, no. 2.
- P. C.Werntz and W. L. Stutzmann, (1989)Design, analysis and construction of an archimedean spiral antenna and feed structure", Proc. IEEE, vol. 1,pp. 308.
- E. Gschwendtner, J. Parlebas, and W. Wiesbeck,(Jul. 1999) Spiral antenna with frequency independent coplanar feed for mobile communication systems, Proc. Antennas and Propagation Society Int. Symp., vol. 1,pp. 560
- Constantine A. Balanis, (1997) Antenna Theory Analysis and Design, John Wiley & sons Inc., Newyork.
- David M. Pozar, Microwave Engineering, Wiley Publications, fourth edition.