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CAVITY BACKING IN SPIRAL ANTENNAS

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Abstract— Archimedean spiral antenna with different cavity-backing configurations have a vital role in determining the antenna characteristics. The antenna can be designed with different cavities to improve the half power beam width and axial ratio. In the paper the different methodologies and theoretical support by those cavities are presented. The results show that the antennas are better than those of traditional abnormal cavity-backed Archimedean spiral antennas with good features. The designed antennas can be used in the ultra-wideband communication system on the mobile carrier mainly in defence

Keywords— Archimeden spiral antenna, cavity-backing, antenna gain, MIMO, slot antenna, Hat-shaped reflecting cavity, chip resistors, PEC

INTRODUCTION

Wireless communication technologies continue to evolve and expand at a phenomenal pace. Many wireless applications thus require low cost and compact size [1] wideband antennas. Wideband antennas are widely used in many applications such as ground penetrating radars, tracking, sensing and imaging, multiple input and multiple output (MIMO) and diversity operations [2], [3], short pulse radar for automotive and robotics applications [4], [5]. The spiral antenna is an antenna with low profile and circular polarization with wideband characteristics. The frequency band of a spiral antenna depends only on the physical dimension of the antenna. However, spiral antennas require balanced feed structures and the input impedance of the spiral antenna can also vary from 140-200 Ω. Most standard feeders such as coaxial cables are unbalanced with 50 Ω input impedance. Therefore, balanced feeding structures which can also perform the impedance transformation are needed for spiral antennas. Spiral antennas also have a low gain.how ever s these spiral antennas are generally used for defence industry, its primarily should have a right hand polarization for the application including gps. In military appications wideband antennas with unidirectional pattern is preferred. But in spiral antenna bidirectional pattern is obtained. A reflecting cavity can be placed at the bottom of the antenna at a distance of one fourth of wavelength of the center frequency. So a study is made using different types of cavity backing in the spiral antenna that could obtain a pattern with good gain and axial ratio.

ARCHIMEDEAN SPIRAL ANTENNA

Spiral antenna belongs to the class of frequency independent antennas, those with a very large bandwidth. The fractional bandwidth can be as high as 40:1. This means that if the lower frequency is 1 GHz, the antenna could still be in band at 40GHz, and every frequency in between. Spiral antennas are usually circularly polarized. The spiral antenna's radiation pattern typically has a peak radiation direction perpendicular to the plane of spiral. The half-power beam width is approximately 70-90 degrees. The smallest and largest circumference of the spiral structure determine their respective upper and lower cut-off frequencies. Most of the previous research on spiral antennas was based on experiment and the band theory. Band theory is defined by the spiral antenna operating in the region where the circumference of the spiral is equal to a wavelength. In most cases, a spiral antenna consists of a thin metal foil spiral pattern etched on a substrate fed from the centre. Spiral antennas radiate bi-directionally. However, most of the applications require unidirectional radiation characteristics as well as having low profile. It can be resolved by adding a lossy cavity to the spiral antenna, backed by conductor, or adding absorbing materials. It absorbs the back radiation from the spiral providing for a wide bandwidth by reducing the reflection from ground plane.

ANTENNA DESIGN

The Archimedean spiral antenna has extremely wide bandwidth and its two arms are linearly proportional to the polar angle. The slot type Archimedean spiral is the dual of the strip type Archimedean spiral. Thin film wideband width planar antenna applications of 3D Monolithic Microwave Integrated Circuits (MMIC) use slot type spiral. A dual arm is obtained by duplicating the single arm along the normal axis with 180o degree rotation. Dual arm spiral antenna has symmetrical radiation pattern and better axial ratio compared to a single arm spiral antenna [25]. It requires a balanced feeding due to its balanced structure. Therefore, authors in [25] used a balun to obtain balanced structure from unbalanced source and it transforms the characteristic impedance of a transmission line to input impedance of the antenna.Figure1 shows the single arm and two-arm Archimedean spiral antenna with inner radius r1 and outer radius r2 and with width and spacing w and s respectively. The circular Archimedean spiral antenna produces a smooth change when the current adjusts with frequency. The two-arm Archimedean spiral antenna radiates from a region where the circumference of the spiral is approximately equal to one wavelength. This region is called an active region of spiral.

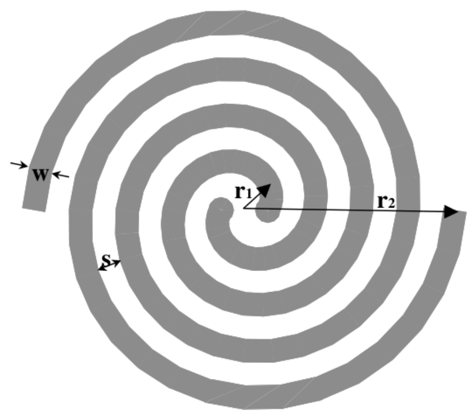

Figure1: Archimedean spiral antenna

CAVITY BACKING

Cavity backing in spiral antenna is generally done to make the bidirectional pattern unidirectional. Most of the applications require unidirectional radiation characteristics as well as having low profile. It can be resolved by adding a lossy cavity to the spiral antenna, backed by conductor, or adding absorbing materials. It absorbs the back radiation from the spiral providing for a wide bandwidth by reducing the reflection from ground plane. The lossy cavity improves the low frequency impedance behaviour and axial ratio of the spiral by reducing reflections from the end of the each arm of the spiral. Furthermore, [5] showed that in order to reduce the reflected currents from the arm ends of the unbalanced-mode Archimedean spiral antenna, a ring-shaped absorbent material may be applied to the cavity. It also absorbs the back radiation from the spiral giving a large pattern bandwidth by reducing the reflection from the ground plane that causes pattern nulls [8], [9]. However, lossy cavity creates gain reduction due losses. Moreover, lossy cavity gives extra depth and weight to the antenna. Without backing, spiral antennas have bidirectional radiation, which is not desirable. Therefore, conductor backed spiral antennas have been used in many applications to get an unidirectional radiation [10]. Reference [11], [12] and [13] showed that the conductor backed spiral antenna, where a metal ground plane is used as a conductor, has a 1:2:1 circular polarization bandwidth and to reflect unwanted power in order to get unidirectional path. However, in conductor backed spiral antenna, the conductor will reflect the radiated fields that enter the cavity. However, the reflected fields will destroy the forward travelling fields of the spiral antenna if the cavity depth is smaller than a wavelength. Another method to get unidirectional pattern in spiral antenna is adding absorbing materials. In absorbing material backed spiral antenna, the reflected fields from the cavity will be attenuated. Therefore, spiral antenna can have its wideband characteristics. One of the absorbing materials is a chip resistor which is used in a microstrip spiral antenna structure. The usage of microwave absorbing material is not approved for some applications due to the reduced gain. Reference [13] used three metal plates inside the hollow metal cavity to improve the bandwidth of the spiral antenna. However, a hollow metal cavity reflects the wave into the spiral and degrading the antenna performance, particularly at the low frequency. Thus, resistive loads were added at the end of each of the spiral arms to overcome the above problem. Moreover, it reduces the reflection from the end of each arm and improved the low frequency Voltage Standing Wave Ratio (VSWR) and axial ratio. Reference [14] investigated that the standing wave is appeared when the thickness of the substrate becomes thinner and it disrupts the radiation patterns. Furthermore, standing wave deteriorates the impedance matching and radiation patterns when the distance between the spiral antenna and the ground plane is less than $\lambda/2$. The thin thickness of the substrate reduced the gain at lower frequencies. Reference [15] therefore proposed a method to remove the standing wave by loading the antenna with chip resistors and it was placed inside the substrate. However, the resistive loading was not enough to remove the standing waves of higher frequencies. Thus, it was replaced along the spiral antenna. However, it made undesirable effects and much power was dissipated in the loads. Size of the spiral antenna is another issue that has been considered for many years. One way to reduce the size is through material loading. However, it can be a problem in some applications due to material loss and weight. Therefore, slow wave spiral techniques were developed to overcome the problems inherent in material loading. A slow wave spiral is produced by adding some type of high frequency profile, such as a zigzag or sine wave, to spiral antenna and increasing the circumference of the spiral antenna, such as the square spiral. Reference [16] assert that antenna size can be reduced by choosing a small starting angle φstart while keeping the spiral constant unchanged. However, changing the antenna height from bottom plane makes a variation to the antenna characteristics. Therefore, antenna height cannot be made extremely small without additional measures to reduce the variation in the antenna characteristics [17]. The electrical antenna height (Hant/ λ) decreases when the frequency decreases and the spiral becomes strong due to the reflected EM fields impinging on it. The current along the conducting spiral arms are affected by these reflected EM fields. The impinging EM fields can become weaker by increasing antenna height which increases the electrical antenna height. However, it is not possible for low profile antennas. Therefore, [18] proposed a method to use a ring shaped strip absorber to remove the EM fields reflected from the bottom of the cavity. Furthermore, ring shaped strip absorber was reduced to arc shaped strip absorber by considering the size of the antenna. Reference [9] suggests that thick dielectric, low dielectric constant , and low insertion loss is always desired for broadband purposes and increased efficiency. In addition, slow wave techniques are employed to move the radiation zone closer to the centre of the spiral for a specific wavelength. As a result, this reduces the velocity of propagation along the length of the spiral, which reduces the low frequency cut-off of the spiral providing for size reduction. Reference [20] argues that when the length of the longitudinal direction of the antenna decreases, the operation bandwidth of the antenna increases. Furthermore, the low frequency cutoff can be reduced by terminating the end of each arm of the spiral with resistive loads to remove the reflections from the end of the spiral. However, it reduces the efficiency and gain. Spiral antennas are classified into several types; square spiral, star spiral, Archimedean spiral, and equiangular spiral. The square spiral antenna has the same advantage as circular Archimedean spiral antenna at the lower frequencies. However, the square spiral geometry seems to be less frequency independent at high frequencies [19]. A star spiral provides as much size reduction same as the square spiral and it allows tighter array packing that the square spiral does not exist [19]. However, one of the major disadvantages of the star and square spiral antenna is its dispersive behaviour. Archimedean spiral is the most popular configuration due to its wide bandwidth and allowing tighter array spacing. The equiangular planar spiral antennas have similar characteristics to the Archimedean spiral. by using an elliptical configuration, it is possible to regulate the beam-width in the two orthogonal planes by compromising to some extent the purity of the circular polarization. Beam steering properties can be incorporated by using phased arrays of spiral elements and improve upon the axial ratio performance of similar structures to be used in wideband satellite communications systems. Also, to make Archimedean spiral antennas more power efficient, electromagnetic band gap materials to be incorporated into the cavities of spiral antennas.[20] . A ring shaped strip absorber is placed under the spiral arms to restore the wideband characteristics of the antenna. Subsequently the strip absorber is divided into two arc shaped strip absorber and the volume of each is decreased by reducing angles. It is chosen that when this arc angle is chosen greater than 90 degree the antenna characteristics of 180 degree are reproduced. . It is noted that at low frequencies the presence of cavity causes a noticeable variation in antenna characteristics. [20] . The antenna has the broad beam width that more than 80° and low axial ratio that less than 4dB and are better than those of traditional abnormal cavity-backed Archimedean spiral antennas when it is is configured with a hat-shaped reflecting cavity and chip-resistor loads to improve the half power beam width and axial ratio.[21] The loading of chip-resistors at the outer edge of the spiral, as well as developing a hat-shape cavity that enhances the antenna performance.[20] A novel hybrid backed cavity with the EBG structure in the outer region and PEC in the center region can effectively improve spiral antenna gain and broaden operating frequency band[7].

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CONCLUSION

An Archimedean spiral antenna with cavity backing is surveyed and analysed with various conditions. This shows that cavity backing can not only make the pattern unidirectional but also it can improve the gain axial ratio and other parameters significantly by change in the design pattern

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