Seminar

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Institute for Plasma Research

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Title: Guided and Leaky Modes Characteristics of Dielectric Loaded Helix Structure

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Abstract

The electromagnetic characteristics of helical structure owing to its skewed boundary condition, which supports hybrid modes as well as circular rotation of the field, finds various applications starting from microwaves to optical communications [1]. In microwave spectrum, helix is widely used in traveling wave tubes (TWTs) and wide bandwidth and moderate gain antennas [2]. Most of the reported studies on EM analysis of helical structure is either analytical, empirical or experimental in guided mode only where electromagnetic wave is confined inside the helix region [3].

The guided and leaky mode characteristics for planar as well circular rod type dielectric structures are relatively well known. However, the investigation to the leaky modes characteristics coupled with guided modes for a dielectric loaded Helix structure is not explored at all despite the fact that helix structure exhibits unique characteristics. Also, computational and numerical study of EM wave visualization of Helix structure using commercially available software is less explored. The present thesis work addresses these critical issues both analytically and experimentally. A generalized analytical and computational numerical theory, for both the guided and leaky modes, has been developed to investigate the dispersion and radiation properties of dielectric loaded helix with and without radial thickness. Based on the theory, a two possible configuration of antennas is designed using CST Microwave Computational software i.e. one for end-fire radiation and second for leaky mode radiations.

In the first work, propagation and radiation characteristics of Dielectric Loaded Helical Antenna (DLHA) have been investigated theoretically, computationally and experimentally. The main objective of this work was to investigate the far field radiation properties of DLHA. The analytical theory for radiation due to polarization current method is discussed for the first time in case of DLHA. The effect of variation of the pitch angle of the helical antenna on propagation constant and radiation properties are also investigated. The radiation beam becomes sharper in the axial direction when teflon is loaded. It is also

concluded from the computational result that the value of the gain of antenna is increased from 8.35 dB to 11.5 dB when a helical antenna is loaded with teflon.

In the second part, we have investigated the complex mode EM wave dispersive characteristics of Dielectric Loaded Radially thick Helix (DLRTH), which shows leaky wave modes characteristics. The eigenmode equations are solved analytically, numerically, and computed using EM wave solver CST Microwave Studio to visualize HE and EH hybrid modes behavior separately. The two distinguish characteristics and applications of the proposed DLRTH structure are found. The first one is that it supports slow wave propagation having phase velocity ten times less than the velocity of light, which finds potential application in SW (phase delay) devices and phase filters. The second feature is that it supports a wide leaky mode region, which can be controlled by pitch angle, which finds application in beam steering-based leaky wave antennas system. Based on the theory, a leaky wave dielectric loaded helix is designed using CST Microwave Computational software. Compared with other Leaky wave antennas, the proposed antenna shows advantageous characteristics of simple structure, compact length of $4.33\lambda_0$, (λ_0 is the wavelength of free space at the center frequency, i.e., 6.5 GHz), wide functional beam scanning range (110°), omnidirectional radiation in azimuthal plane and high radiation efficiency (98%), which fulfills the growing demand for the miniaturization and integration of frequency-dependent devices.

In last part of the work, a wideband circularly polarized two-layer concentric cylindrical dielectric resonator antenna (CDRA) is designed and simulated for C-band applications. The helix excites the two orthogonal modes ($HE_{11\delta}$) in quadrature phase, which result in the circular polarization. The four different design cases are investigated and the best one is fabricated and measured. The simulated and measured bandwidth of the proposed antenna varies from 3.60 to 6.03 GHz with impedance bandwidth of 50.46% and 3.65 to 6 GHz (48.70% impedance bandwidth) respectively, while axial ratio impedance bandwidth are 43.13% (4.20–6.51 GHz) and 38.82% (4.40– 6.52 GHz) respectively. The proposed antenna attains 10.9 dBi measured peak gain at 4.5 GHz.

References:

1. Gerd Keiser, “Optical fiber communication”, McGraw-Hill, 2003.

2. Constantine A. Balanis , “Modern antenna handbook”, Wiley, 2008.

3. Barr, L.E., Ward, G.P., Hibbins, A.P. *et al.* Slow waves on long helices. *Sci Rep* **12,** 1902 (2022).