Seminar

Institute for Plasma Research

Title:	Design, Development, and Experimental Validation of Reconfigurable Plasma-Based Array Antennas for Improved Gain and Wideband Performance
Speaker:	Mrs. Manisha Jha Institute for Plasma Research, Gandhinagar
Date:	06th February 2026 (Friday)
Time:	10:30 AM
Venue:	Seminar Hall, IPR

Abstract

Conventional metallic antennas are fundamental to modern telecommunications, their fixed physical properties limit adaptability and increase radar visibility. Plasma, being a conductive medium of charged particles, can be engineered to behave like conventional metallic conductors under certain conditions. This makes plasma a viable option for antenna applications in the VHF and UHF frequency ranges. This study explores the possibility of replacing metal antennas and reflectors with plasma in an antenna system. Plasma antennas offer unique advantages, including low Radar Cross-Section (RCS) when turned off, frequency reconfigurability, wide bandwidth. It is suitable for modern communication, radar, and defence applications.

The main objective of this study is the design, analysis, and fabrication of a wideband reconfigurable plasma antenna and surface wave coupler at UHF and VHF frequency range. Various methods are used for plasma discharge, such as DC discharge, RF discharge (ICP, CCP, Helicon), and surface wave discharge. In case of DC and RF discharges two electrodes are used to produce plasma which may affect the antenna characteristics. In contrast, plasma can be generated from a single end using surface wave discharge. This work explores the signal transmission capabilities of a plasma antenna excited at 13.56 MHz for the first time. A two-port Surface Wave Coupler (SWC) was designed and experimentally validated, achieving a coupling efficiency of 99%. The design utilizes a dual-isolation strategy: (i) spatial separation of the ports and (ii) frequency-orthogonality (13.56 MHz for power and 820 MHz for signal). Characterisation shows that while the inherent isolation (S_{21}) is -80 dB without a matching network, the application of an impedance matching network yields a resonant S_{11} of -20 dB and an operational isolation of approximately -47 dB, ensuring efficient forward power transmission without port interference. For the plasma antenna design, SWC integrated with plasma is modelled in CST Microwave Studio which resonates at 820 MHz with S_{11} of -25 dB. The plasma antenna excited by a surface wave has a broader bandwidth than its metallic counterpart. The experimental data shows that as input power varies from 2 W to 10 W, the resonant frequency shifts from 901 MHz to 661 MHz achieving a reconfigurability span of approximately 240 MHz for the system. Furthermore, the design achieves a maximum impedance bandwidth of 540 MHz, substantially exceeding the fixed bandwidth limitations of traditional metallic antennas. A peak gain of -5 dB was experimentally validated, confirming the efficiency of the surface wave excitation method. The plasma antenna's radiation is similar to metal monopole antenna.

This plasma antenna is further transformed into an array by surrounding the plasma antenna with plasma reflectors which is yet to be explored in forming an all plasma Reconfigurable Central Plasma Antenna Array (RCPAA)**.** The new design allows dual reconfigurability, including frequency and pattern, while significantly improving antenna gain, front-to-back (F/B) ratio, and minimizing cross-polarization. In RCPAA, the central monopole plasma antenna is the primary radiating element, and the plasma reflectors around it provide beam shaping and steering. The plasma windowing technique achieves beam steering across the full azimuthal angle at every 18°. The RCPAA is optimized for 820 MHz, demonstrating a significant improvement in gain from -5 dB to 0 dB, cross-polarization below 20 dB, an F/B ratio of 25 dB, and a wide bandwidth of 600 MHz. Radar Cross Section (RCS) measurements cover the L to X bands, ranging from 6 dBm^2 to -30 dBm^2. The RCPAA shows transparency in the X-band region.

While designing RCPAA, the radiation efficiency of the array decreases as the antenna is placed on the conducting ground. To address this, a gap coupling and deformed ground plane (DGP) is introduced in RCPAA to enhance the plasma antenna's radiation efficiency. A modified equivalent circuit model is proposed to systematically analyse this effect, incorporating additional lumped elements (C_g and L_g) to account for the coupling introduced by the gap. The gap also contributes to a 10% increase in radiation efficiency at resonant frequency, with a maximum efficiency of 25%. The study successfully designs a reconfigurable central plasma antenna array featuring plasma as both a radiator and a reflector in CST Microwave Studio and demonstrates its experimental performance for validation.

To add the property of circular polarisation and band reconfigurability in the plasma antenna, a plasma fed with helical antenna was designed and experimentally validated. The results show this antenna setup supports a wide range of frequencies up to C band. The structure also introduces circular polarization at C band along with both normal and axial mode radiation pattern.

The present study establishes a comprehensive framework for the development of all-plasma antenna systems, successfully demonstrating frequency and pattern reconfigurability with enhanced radiation efficiency. The integration of the RCPAA and the plasma-loaded helical structure confirms the potential of plasma-based radiators to meet the demands of modern, stealth-capable, and multi-band communication systems.

<u>References</u>:

I. "Wideband Frequency Reconfigurable Plasma Antenna Launched by Surface Wave Coupler", AEU-International Journal of Electronics and Communications, March 2024, DOI: 10.1016/j.aeue.2023.155113.

II. "Design and experimental validation of pattern and frequency reconfigurable central plasma antenna array" IET MAP, January 2026, Wiley, https://doi.org/10.1049/mia2.70065

III. "Enhancement of radiation efficiency of plasma antenna in a reconfigurable central plasma antenna array. Microwave and Optical Technology Letters, January 2026, 68, e70517. https://doi.org/10.1002/mop.70517"

IV. "Reconfigurable Plasma Antenna Array for Beam Steering Application at S-Band", IEEE MAPCON 2022, Bangalore, India, pp. 1403-1406, doi: 10.1109/MAPCON56011.2022.10047047.

V. "Pattern Reconfigurability using Plasma for Beam steering at S-band", IEEE MAPCON 2023, Ahmedabad, doi: 10.1109/MAPCON58678.2023.10463954.

VI. "Design and Performance Analysis of Reconfigurable Corner Reflector Antenna with Plasma", WAMS 2025.

VII "Design of a Plasma-Based Yagi–Uda Antenna Array for Beam Steering Applications", under review WAMS 2026