

Gain Enhancement of Dipole Antenna by Incorporating Partially Reflective Metasurface Layer and Director


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Abstract

This paper presents the design and performance analysis of a high-gain dipole antenna using a partially reflective metasurface (PRMS) layer and a parasitic director element operating at 3.2 GHz in the S-band. Conventional dipole antennas exhibit low gain and bidirectional radiation, which limits their efficiency in modern communication systems. The existing work on high-gain broadband dipole antennas using PRMS layers demonstrates gain improvement through Fabry–Perot cavity formation. However, further enhancement in directivity and gain is required for advanced applications. In the proposed design, a planar reflector, PRMS layer implemented using a frequency selective surface (FSS), and a rod-shaped director are integrated with the dipole antenna. The PRMS layer enables partial reflection and forms a resonant cavity, while the director focuses radiation in the forward direction. The antenna is simulated using ANSYS HFSS, and the results show a return loss of approximately -17 dB, VSWR close to unity, and gain around $7-8$ dB. The proposed design achieves improved directional radiation and enhanced gain compared to the existing model, making it suitable for S-band wireless and satellite applications.

Introduction:

The rapid advancement in wireless and satellite communication systems has increased the demand for antennas with omnidirectional or bidirectional radiation patterns, which reduce its effectiveness in long-distance communication systems. To overcome these limitations, several techniques have been proposed, including the use of reflectors, parasitic elements, and metasurfaces.

Among these, partially reflective metasurfaces (PRMS) have gained significant attention due to their ability to enhance antenna performance through controlled reflection and transmission of electromagnetic waves. PRMS structures, typically implemented using frequency selective surfaces (FSS), enable the formation of Fabry–Perot cavities that increase the effective aperture of the antenna, thereby improving gain. However, existing PRMS-based dipole antennas primarily focus on broadband characteristics, with limited improvement in directivity. Therefore, there is a need to further enhance gain and radiation directionality.

In this work, a gain enhancement technique is proposed by integrating a PRMS layer and a parasitic director with a dipole antenna. The combined effect of these elements results in constructive interference and controlled wave propagation, leading to improved gain and directional radiation. The antenna is designed and analyzed using ANSYS HFSS, and its performance is evaluated in terms of S_{11} , VSWR, gain, and radiation pattern.

high gain, improved directivity, and efficient **SO**

SOTWARE PROTOCOL:

radiation characteristics. The dipole antenna is one of the most fundamental radiating structures due to its simple geometry and ease of implementation. However, a conventional dipole antenna suffers from inherent limitations such

as low gain andThe design and analysis of the proposed antenna are carried out using ANSYS HFSS (High Frequency Structure Simulator), a widely used electromagnetic simulation software.

ANSYS HFSS:

ANSYS HFSS is a 3D full-wave electromagnetic field simulation tool based on the finite element method (FEM). It is extensively used for the design and analysis of high-frequency components such as antennas, microwave circuits, and RF systems.

Key Features

- Accurate 3D electromagnetic modeling
- Adaptive meshing for enhanced precision
- S-parameter analysis (S11)
- Radiation pattern and gain visualization
- Frequency sweep capability
- Support for various materials and boundary conditions
- Role in the Proposed Work

HFSS is utilized to model the antenna geometry, assign material properties, and simulate electromagnetic behavior. It enables the evaluation of critical performance parameters and assists in optimizing the antenna design to meet the desired

Specification

METHODOLOGY:

Step 1: Create a Reflector

A reflector is placed behind the antenna to bounce back waves, helping improve forward radiation and gain.

Step 2: Design PRMS Layer

The partially reflective meta surface is designed using periodic elements to reflect part of the waves and enhance constructive interference.

Step 3: Design Dipole Antenna above PRMS Layer

A dipole antenna is placed at an optimized height above the PRMS so that reflected waves combine effectively with radiated waves.

Step 4: Add a Director above of the Antenna

The director is positioned above to guide electromagnetic waves forward, increasing directivity and gain.

Step 5: Assign Boundaries

Radiation boundaries are applied to simulate open space conditions and avoid unwanted reflections from simulation edges.

Step 6: Assign Excitation

A wave port or lumped port is given to feed the antenna with an input signal for proper operation.

Step 7: Validate and Analyze All

Run simulations to observe antenna parameters like gain, radiation pattern, directivity, and return loss (S11).

Step 8: Check for Required Parameters

Verify if the results meet desired values such as high gain, directivity, good matching (low S11), and proper directional radiation.

LITERATURE SURVEY:

Recent research in antenna design has focused on improving gain and bandwidth using advanced electromagnetic structures. High-gain broadband dipole antennas using PRMS layers have been widely studied, where a partially reflective surface is placed above the radiator to form a resonant cavity. These designs utilize the Fabry–Perot cavity principle, where multiple reflections between the reflector and PRMS layer result in constructive interference, thereby enhancing gain.

Several studies have demonstrated that the use of FSS-based PRMS layers significantly improves antenna performance by increasing directivity and radiation efficiency. However, these designs often exhibit limitations such as moderate gain improvement and insufficient control over radiation direction. To address these issues, researchers have explored the use of parasitic elements such as directors and reflectors, similar to Yagi-Uda antenna configurations, to further enhance radiation characteristics.

Recent advancements from 2020 onwards have shown the integration of metasurfaces, MIMO systems, and reconfigurable antennas to achieve higher performance. Despite these developments, achieving a compact, high-gain antenna with simple structure and efficient radiation remains a challenge. This motivates the proposed work, which combines PRMS and a director element to achieve improved gain and directivity.

EXISTING SYSTEM:

The existing system consists of a high-gain broadband dipole antenna integrated with a PRMS layer. In this configuration, a dipole antenna is placed above a planar reflector, and a partially reflective metasurface is positioned above the dipole. The PRMS layer, implemented using an FSS array, allows partial transmission and reflection of electromagnetic waves, forming a Fabry–Perot cavity between the reflector and the metasurface.

The gain enhancement in the existing system is achieved through constructive interference of multiple reflected waves within the cavity. The PRMS layer increases the effective aperture of the antenna and improves radiation efficiency. However, the radiation pattern remains relatively broad, and the gain improvement is limited due to the absence of additional focusing elements. The lack of a director results in less control over the radiation direction, leading to wider beamwidth and reduced directivity.

PROPOSED SYSTEM:

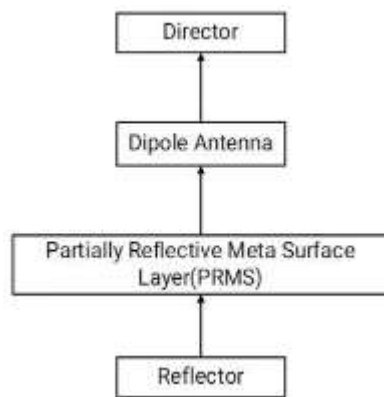
In the proposed system, a dipole antenna is integrated with a reflector, PRMS layer, and a parasitic director element to achieve enhanced gain and directivity. The reflector is placed at the bottom and acts as a perfect electric conductor, reflecting backward radiation toward the forward direction. Above the reflector, a PRMS layer is implemented using a 3×3 FSS array on an FR4 substrate, which introduces partial reflection and forms a Fabry–Perot cavity.

The dipole antenna is positioned at an optimized height above the PRMS layer to ensure constructive interference. A rod-shaped director is placed above the dipole at a specific distance to guide electromagnetic waves in the forward direction. The director introduces a phase shift that aligns the wavefront, resulting in a narrower beam and higher gain.

The design is based on wavelength calculations, where:

The spacing between elements is chosen as a fraction of λ to maintain phase alignment and resonance. The antenna is simulated using HFSS, and parameters are optimized to achieve improved performance

3.6 FLOW CHART:



OPERATING FREQUENCY AND TARGET SPECIFICATIONS:

Parameter	Target Value
Return Loss (S11)	< -17 dB
VSWR	< 2
Gain	< 8dBi
Frequency	2.4GHz

RESULTS AND DISCUSSION:

The simulated results demonstrate that the proposed antenna achieves significant improvement in performance compared to the existing system. The return loss (S11) is observed to be approximately -19 dB at the operating frequency of 3.2 GHz, indicating excellent impedance matching. The VSWR is close to unity, confirming efficient power transfer and minimal reflection.

The gain of the antenna is observed to be around 7–8 dB, which is higher than that of a conventional dipole antenna and improved compared to the existing PRMS-based design. This enhancement is achieved due to the combined effect of the reflector, PRMS layer, and director. The reflector redirects backward radiation, the PRMS layer enables constructive



interference through cavity resonance, and the director focuses radiation in the forward direction.

The radiation pattern shows a strong directional beam with reduced back lobes, indicating improved directivity. The gain is related to directivity and efficiency as:

The results confirm that the proposed design effectively enhances gain and radiation characteristic

CONCLUSION:

A high-gain dipole antenna using a PRMS layer and director has been successfully designed and analyzed. The proposed antenna overcomes the limitations of conventional dipole antennas and existing PRMS-based designs by improving gain and directivity. The integration of a reflector, PRMS layer, and director results in constructive interference and efficient wave propagation. The simulated results validate that the antenna achieves good impedance matching, high gain, and directional radiation. The proposed design is suitable for S-band applications such as wireless communication, radar, and satellite systems.

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