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Metasurface in Antenna Design

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ABSTRACT—

Metasurfaces (MS) are two-dimensional structures made up of a single layer of periodic-patterned subwavelength elements, like dielectric or metallic antennas. In order to improve system performance in wireless communication, metasurfaces are essential. The goal of this study is to present a brief overview of the design of gain-improved metasurface-based antennas for contemporary wireless communication systems. The study examines a number of academic works that have improved gains through the use of metasurfaces in various configurations. It also provides a succinct summary of design concerns and possible uses for metasurfaces. The readers of this paper will learn about the latest developments in metasurface-based antenna design for effective communication. Microstrip patch antennas are becoming more and more common because of their inexpensive, lightweight, and simple to produce design.

Keywords—Antennas array, beamforming, coating metasurfaces, Huygens metasurfaces (HMSs), metasurfaces.Introduction

I. INTRODUCTION

The ubiquitous use of distinct metasurfaces in microwave-based wireless communication has drawn the attention of researchers, engineers, and academics. One kind of metamaterial is called a metasurface, where two-dimensional dielectric substrates with a metal backing are covered in metallic unit cells. These configurations have certain advantageous characteristics that do not arise normally, and they can affect electromagnetic manipulation in addition to the structures' distinct size, form, and geometry. Among the advantages is the capacity to block, absorb, and bend electromagnetic waves within a specific frequency range—a feat that is not achievable with conventional materials. Metasurface functions include artificial magnetic conductors (AMC), high impedance surfaces (HIS), and electromagnetic band gaps (EBG). The manipulation. To summarize the application of metasurfaces and their evolution for performance improvement, researchers have presented a metasurface-based solution. The improvement of bandwidth, gain, size, additional band generation, transmission between two antennas, SAR reductions, and the design and simulation of a metasurface. In addition to the aforementioned performance gain, there is a need for a review of developments in polarization conversions and RCS reductions.Metasurfaces have the potential to change a wide range of photonic and electronic device technologies. Metasurfaces that can concurrently and independently regulate all electromagnetic (EM) wave properties, including amplitude, phase, frequency, polarization, and momentum, while also being highly integrable and programmable, are difficult to develop and have yet to be attempted. We propose and demonstrate a microwave universal metasurface antenna.

(UMA) that can precisely, independently, dynamically, and simultaneously modify every aspect of electromagnetic waves in a software-defined manner. Our UMA improves the time- and space-varying wave properties, enabling beamforming, direct information processing, and the creation of more complex waveforms. For instance, the architecture of information transmitter systems can be greatly simplified by the UMA's ability to produce modulated waveforms that directly transfer digital information. One kind of artificial sheet material with a thickness less than a wavelength is called an electromagnetic metasurface. Metasurfaces with subwavelength-scaled patterns in the horizontal direction might be ordered or unorganized. In electromagnetic theory, metasurfaces—as opposed to constitutive qualities, which are typically employed in natural materials and metamaterials—control the behavior of electromagnetic waves in three-dimensional (3D) space by means of certain boundary conditions. The two-dimensional equivalents of metamaterials are also referred to as metasurfaces. Additionally, there are 2.5D metasurfaces, which employ the third dimension as an additional degree of freedom to modify how they operate.

On the other hand, one- and two-dimensional (1D and 2D) plasmonic arrays with subwavelength periodicity, which are also known as metasurfaces, have gained increasing interest lately. Because of their thinness in relation to the operating wavelength, metasurfaces (near resonances of unit cell constituents) can be viewed as an interface of discontinuity imposing an abrupt change in both the amplitude and phase of the impinging light. One of the most important applications of metasurfaces is the control of an electromagnetic wave front through the introduction of local, gradient phase changes to the incoming waves, which leads to a generalization of the well-known laws of reflection and refraction. In this way, a metasurface can be used as a planar hologram, illumination lens, or lens.

II. METASURFACE TECHNOLOGY AND ITS TYPES

i. MICROSTRIP PATCH ANTENNA

A microstrip patch antenna is a type of antenna that operates in the microwave frequency range. They can be printed directly onto circuit boards and are low-profile. They consist of a radiating patch, usually made of conductive material, mounted on a dielectric substrate. It consists of a rectangular metal patch on a dielectric substrate and is excited by a voltage source across the metal patch and the bottom ground plane of the substrate. The microstrip antenna produces maximum radiation in the broadside direction (θ = 0), with ideally no radiation along the substrate edges (θ = 90°).

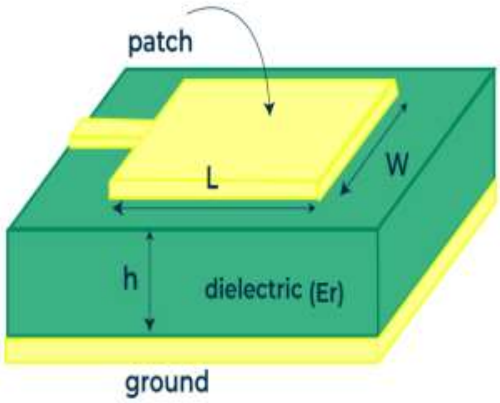

Fig 1: Microstrip patch antenna

ii CONSTRUCTION AND GEOMETRY OF MICROSTRIP PATCH ANTENNA

A thin metallic patch of any shape placed on a dielectric slab with one side grounded and the other side being open is called a microstrip patch antenna. The dielectric slab ranges in thickness from 0.03λ to 0.05λ. The slab's dielectric varies from 2.2 to 12, while the patch's dimensions fall between λ/3 and λ/2. The RF or microwave circuit associated with the antenna, which must be constructed on the same board, restricts the choice of substrate.Typically, photo-etching technology is used to etch the microwave circuit and antenna together.

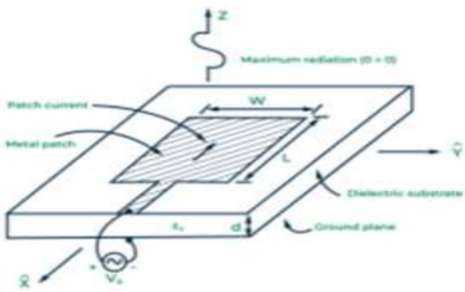

Fig 2: Geometry of Microstrip patch antenna

iii METHODOLOGY OF MICROSTRIP PATCH ANTENNA

A conducting patch on a dielectric slab with a grounded other side is present in the microstrip patch. Electromagnetic waves are produced when current flowing through a feed line enters the strip located on the antenna. As waves start to radiate from the patch's sides, they create a pattern of radiationThe thickness of the substrate determines the waves that are created; if the substrate is too thin, the waves are reflected off the edges.

It is crucial to remember that the radiation cannot be released due to the continuous construction of the strip. Following a specific discontinuity, radiation transmission from the patch's second side starts up again.Patch antennas are inefficient because they only radiate a part of energy. It functions less like a transmitter and more like a cavity.Its inefficient radiation prevents it from being widely utilized.

iv. CHARACTERS OF MICROSTRIP PATCH ANTENNA

There are various types of microstrip patch antenna:

• Square

• Rectangular

• Dipole

• Circular

• Ellipse

• Triangular

• Disc Sector

• Circular Ring SquareSquare type microstrip antennas are microstrip patch antennas with a radiating patch that is square in shape. Due in large part to its ease of design, this form of antenna is widely employed in many different devices and has a wide range of applications.

Rectangular: Rectangular type microstrip antennas are microstrip patch antennas with a radiating patch that is rectangular in shape. Due to its adjustable tuning capability, this kind of antenna finds extensive application in communication systems.

Dipole: The microstrip patch antenna is referred to as a dipole type microstrip antenna because its radiating patch resembles a dipole in construction. It is utilized in applications that require larger frequency coverage and is best known for providing broadband performance.

Circular: Circular type microstrip antennas are microstrip patch antennas with a circular radiating patch. This kind can be used to carry out circular polarization. Additionally, mobile and satellite communication use it.

Ellipse: Elliptical type microstrip antennas are microstrip patch antennas with an elliptical radiating patch. It can be employed precisely when a certain radiation pattern is needed because it provides a different radiation pattern than other varieties.

Disc Sector: Disc sector type microstrip antennas are microstrip patch antennas with a radiating patch fashioned like a disc sector. Its primary benefit is that it emits directed radiation and can be utilized in situations where particular angles are needed.

Circular Ring: Circular ring type microstrip antennas are microstrip patch antennas with a radiating patch in the shape of a circle ring. It possesses the ability to vary the properties of radiation.

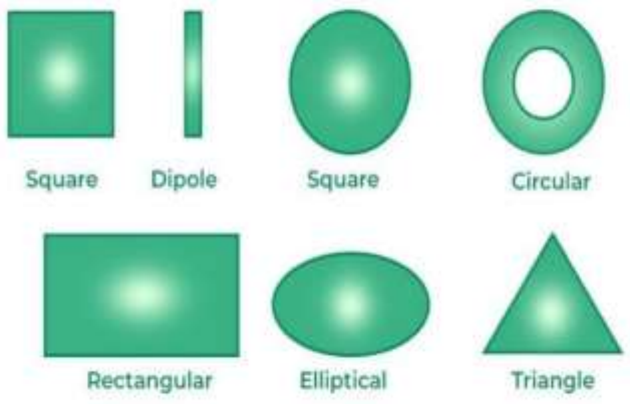

Fig 3: Types of Microstrip Patch antenna

v. RADIATION PATTERN OF MICROSTRIP PATCH ANTENNA

• Generally we represent a normalized radiation pattern, a normalized radiation pattern is scaled relative to some value.

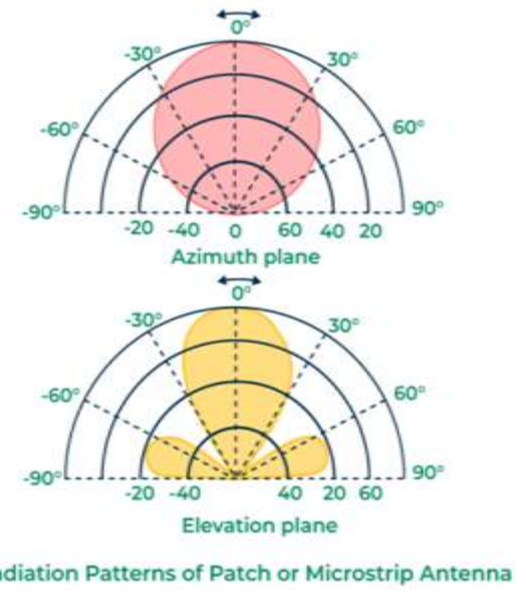

Fig 4: Radiation Pattern of Microstrip Patch Antenna

• A patch antenna at an angle of 30° to 180° provides hemispherical coverage, resulting in a rather broad radiation pattern. The radiation power is low due to the small frequency band. Its directivity is about 5-7 dB lower. By employing these patch antennas, an array can be built with a higher directivity.

vi CHARACTERISTICS OF MICROSTRIP PATCH ANTENNA

The radiating patch on the grounded substrate is the primary feature of microstrip. Its low profile design, ease of production, and light weight are its defining characteristics.

• The substrate's thickness ranges from 0.03 to 0.05 μ, and for optimal radiation efficiency, we typically favor thick substrates with low dielectric coefficients.

• Unlike microstrip dipole antennas, which only display linear polarization, it displays both linear and circular polarization.

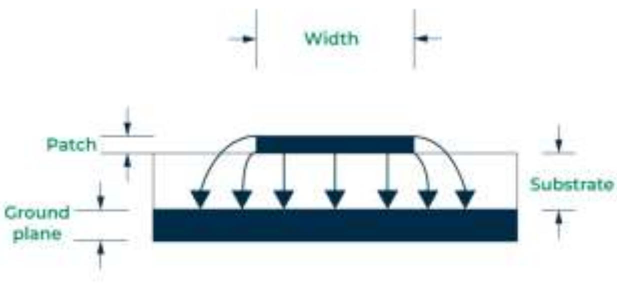

Fig 5: Fringing Effect

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