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An Extensive Review on Printed Antenna Technology and Its Applications

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ABSTRACT

Despite the way that the Microstrip antenna has been broadly well thought-out for huge numeral of applications in most recent couple of decades still it has a colossal potential for further progressions. As the era is passing new modification in the style of conventional Microstrip Printed antenna is growing. The changes in substrate material, in design and shape of patch and ground, feeding techniques makes the Microstrip Printed antenna forever capable for novel applications. This article will be accommodating for researches working in field of Microstrip antenna. Great surveys of quite a bit of this Microstrip Printed antenna, descriptive prototypes, and plan strategies for Microstrip printed antenna is reviewed in this article. It is accomplished that as it is think that Microstrip antenna has reach their maturity, is not truthful in current scenario where wireless technology is achieving its ever time boom .

Keywords: Microstrip antenna, Substrate material, Gain and impedance bandwidth.

INTRODUCTION

The swift innovations in the wireless communication systems gives attraction to scientists and researchers due to its high data transfer rate with more reliability and this can be accomplished by wireless antennas with enriched performance. These antennas must be capable of fulfilling the requirement of currently used wireless communication system includes 2.4 GHz, 5 GHz communication systems (802.11a, 802.11b and 802.11g) for WLAN and WIMAX applications [1]. These prototype designs are anticipated to include forthcoming 5th generation wireless systems as well. Improved 5G systems that were developed lately and later may operate using current 4G or newly identified 5G frequency channels. Demands for mobile communication arise as a result of the rapid growth in mobile users. Mobile users require more features on their phones, such as a higher date rate, effective communication, less traffic, the ability to comfortably use various programmes, and so forth. Specialized businesses struggle to meet the demands of mobile clients, which should be achieved with the help of 5G technology. To deliver unlimited inclusion and support all use cases, 5G requires spectrum range within three important frequencies. Sub-1 GHz, 1-6 GHz, and greater than 6 GHz band are the three frequency bands. Ultra-high broadband rates intended for 5G are anticipated to be achieved at frequencies around 6 GHz [2-3].

Due to the fringing fields that surround its surface, a Microstrip patch antenna emits electromagnetic waves. As a result, the current value is low at the feed end and high in the middle of the half-wave patch. This large impedance at the feed side is explained by the low current value.

The utilization of Microstrip patch antennas has built radical development in the scenario of modern communication systems. It is an extremely good candidate to fulfil all these requirements due to its profound merits like [4]:

- Microstrip printed antenna are of low profile and very light in weight.
- Microstrip printed antennas can efficiently be combined with other circuit elements such as filters and oscillators.
- It is also simple to achieve the desired polarisation and reconfigurable properties with Microstrip printed antenna.
- These can be made using scraping and photolithography processes, which explains why they are affordable and structurally strong.

- The radiation pattern of a hemispherical form is sufficient for MA's directivity, which can be further improved by array design.

Few disadvantages also exist with Microstrip printed antenna like:

- Different types of losses can occur in printed antenna like for thinner substrates, conductor losses turn out to be severe, whereas for thicker substrates with dielectric constants other than foam/air, surface-wave losses can occur.
- MA is only operational at microwave frequencies and above (at lower frequencies, the volume of substrate becomes much big). It cannot handle extremely high power levels due to dielectric breakdown.

Due to the fringing fields that surround its surface, a microstrip patch antenna emits electromagnetic waves. As a result, the current value is low at the feed end and high in the middle of the half-wave patch. This large impedance at the feed side is explained by the low current value. The following key points are those that must be considered when designing an MPA and have an impact on how a patch antenna behaves: the substrate determination is unquestionably necessary, as well as the patch's shape and dimensions. A significant amount of planning went into selecting the best substrate material for the patch antenna. For designing MPA, a variety of substrate materials are available. An electrical insulator known as a dielectric substance can be divided by electrical fields. The dielectric constant, which is $2.2 \leq \varepsilon_r \leq 16$ in radio frequency or microwave bands, and loss tangent, which is $0.0001 \leq \tan\delta \leq 0.06$, are the two fundamental features of substrate materials. Increases in loss tangent generally degrade the appearance of that antenna for MPA [5].

Plastics are frequently used in radio frequency and microwave bands due to their ease, simplicity of assembly, and strong exterior linkage, despite having higher thermal expansion coefficients, poorer dielectric properties, dimensional stability, and thermal conductivity contrast to other materials like ceramic and sapphire. The effect of the effective permittivity (dielectric constant) on the radiation characteristics should be taken into consideration while choosing the dielectric material. In general, low radiation is produced using a Microstrip patch antenna with a high dielectric constant [6].

The comprehensive review of literature suggests that researchers are working continuously and rigorously on MPA to persistent it fruitful for modern communication devices regardless of its shortcomings such as low bandwidth and gain. It is also realized that various kind of slots of appropriate dimension in ground and patch can enrich the performance of antenna. The types of feed and substrate material also play a crucial role in antenna performance. In view of these facts some of the novel prototype design antenna geometries are presented in this work.

MATERIAL AND METHODS

An examination of properties of different sort of extremely basic substrates material is displayed in Table - 1. It is perceived from the table that substrate must be select according to the necessity of utilization and cost. In [7], James and Hall introduced that there is trade-off between antenna parameters and substrate properties as shown Table - 2.

EFFECT OF SUBSTRATE PROPERTIES ON MPA

Fig. 1 shows the anticipated antenna's design geometry, which was created and tested using IE3D electromagnetic simulation software [8]. The overall size exterior dimension (substrate material) is 55.0 mm × 30.0 mm × 1.59 mm. Both the elliptical shape patch (blue colour) and the elliptical shape ground (light green colour) are given the same dimensions. Semi-major axis values were taken to be 10.0 mm and semi-minor axis values to be 15.0 mm. The antenna is built on FR4 with a dielectric constant value 4.4 and a loss tangent value 0.025. The right side ellipse serves as the ground plane and is printed on the lower surface of the dielectric substrate, while the left side ellipse serves as a patch and is placed on the upper surface. The X-axis contains the feeding point.

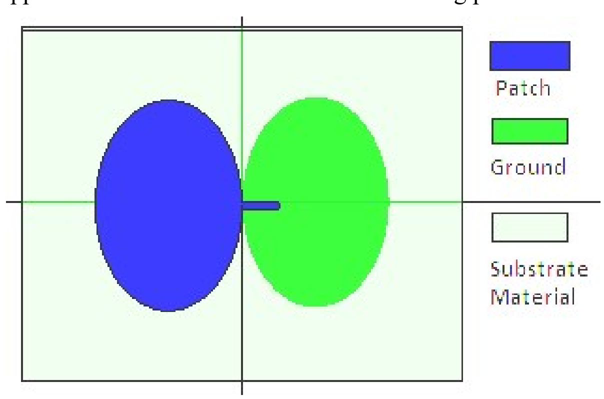

Fig.1 The geometry of the projected antenna with finite ground

Table -1 Properties of Diverse Substrates Material

Parameters	Bakelite	FR4 Glass Epoxy	RO 4003	Taconic TLC	RT Duroid
Dielectric constant	4.78	4.36	3.4	3.2	2.2
Loss tangent	0.03045	0.013	0.002	0.002	0.0004
Water absorption	0.5- 1.3%	-	0.06%	0.02%	-
Tensile strength	60 MPa	-	141 MPa	-	450 MPa
Surface resistivity	5×10^{10}	2×10^{5}	4.2×10^{9}	1×10^{7}	3×10^{7}
Application	Can be used as an electrical insulator for mechanical strength	Especially for low frequency region up to 6 GHz	excellent choice for high frequency application	Low cost specialty RF laminate	used for high gain antennas

Table 2 Approximate Performance Trades-Offs for a Rectangular Patch [7]

Requirement	Magnitude (High / Low)	Substrate relative Permittivity	Substrate height	Patch width
Radiation Efficiency	High	Thick	Low	Wide
Dielectric Loss	Low	Thin	Low	-
Conductor Loss	Low	Thick	-	-
Impedance bandwidth	Wide	Thick	Low	Wide
Surface Wave	Low	Thin	Low	-
Cross Polarisation	Low	-	Low	-
Weight	Low	Thin	Low	-
Strong	-	Thick	High	-
Sensitivity to tolerances	Low	Thick	Low	Wide

Effect of Substrate Permittivity (ε_r) on Impedance Bandwidth and Gain

Fig. 2 displays the variation in the reflection coefficient with frequency for various dielectric constant values. The observed enhanced bandwidth for low permittivity values is most likely caused by the fact that the stored energy diminishes with low values of dielectric constant. The highest BW is observed for dielectric constant 2.1, and a bump is seen above -10 dB as shown in Fig. 2, it is likely that proper matching was not performed and that the feed point was maintained at (4, 0).

Fig. 3 shows the gain fluctuation with frequency for various dielectric constant values. Owing to the lossy nature of the FR-4 substrate employed here, the gain value is rather modest, but it can be raised by using different substrate materials. When compared to FR-4 substrate having dielectric constant 4.4, the gain for low loss substrate dielectric constant 2.1 is approximately two times higher.

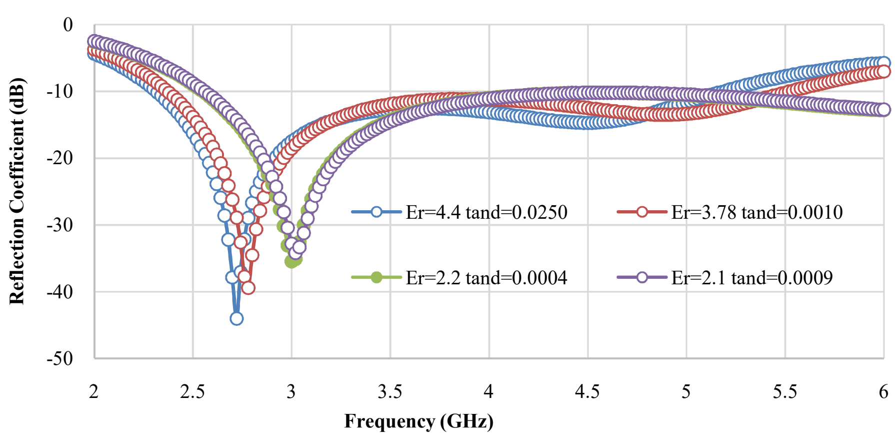

Fig. 2 Change in S_{11} value with frequency for various value of ε_r

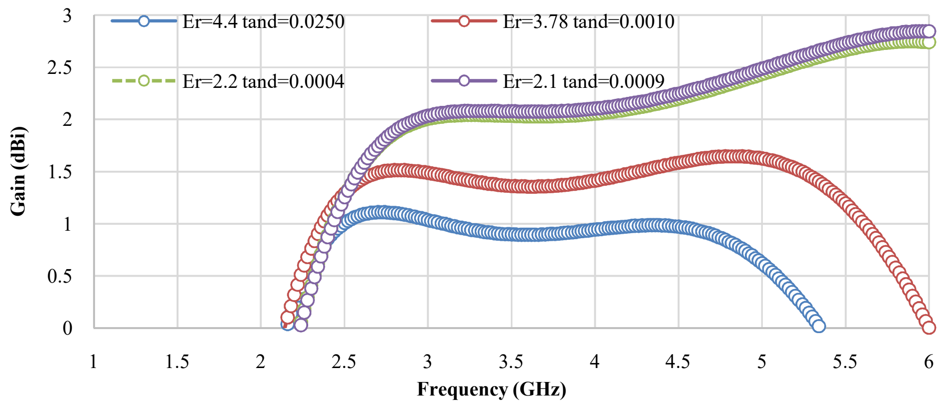

Fig. 3 Change in gain value with frequency for various value of ε_r

TECHNIQUES FOR INCREASING GAIN AND IMPEDANCE BANDWIDTH OF PRINTED ANTENNAS

A single layer direct fed printed Microstrip antenna's bandwidth can be increased using two inherent approaches. One involves thickening the substrate, and the other involves making the antenna substrate's dielectric constant smaller (relative permittivity of near to one). A direct fed single layer Microstrip patch's bandwidth trends relative to substrate height and permittivity are depicted in Fig. 4.

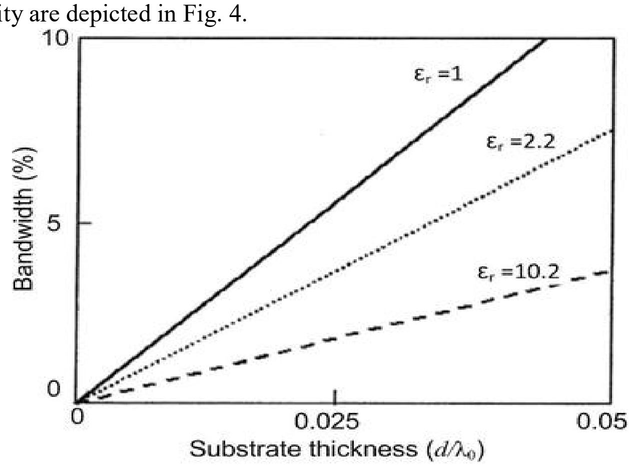

Fig. 4 Variation in % bandwidth with substrate thickness [9]

Recently, a number of techniques have been used to overcome the inherent gain and bandwidth problems with Microstrip antennas. An overview of some of these common techniques is provided below:

Co- Planer Parasitic Patch (es) and Stacked Parasitic Patch (es)

The bandwidth of Microstrip patch antennas are improved using the parasitic patch approach. In the parasitic patch approach, there are two different configurations that can be used: stacked and coplanar.

Co- Planer Parasitic Patch Method

Different patches are integrated on a single plane over a dielectric substrate in the coplanar approach. Here the main patch, which receives stimulation among the several patch radiators. In [10], two pairs of patches with distinct patch areas are positioned around an edge-truncated elliptical patch among the five patches taken into consideration in the current assembly. The other patches are parasitically gap linked to the centre patch, which is fed by an inset feed arrangement along its central edge (Fig. 5(a & b)). To get the maximum performance out of this assembly of patches, extensive refinements in slot width and position along major and minor axes of the standard elliptical patch antenna are made and it become possible to attain an improved impedance bandwidth of 2.45 GHz (or 36.2%) with respect to the centre frequency of 6.1 GHz..

Stacked Parasitic Patch (es) Method / Air Gap

When utilized as a dielectric substrate between a reflecting surface and a radiating patch the air's reduced permittivity as a direct result in an efficient radiation pattern with minimal return loss. These results demonstrate that electromagnetic waves are produced using the maximum amount of input power. In the stacked approach, a succeeding dielectric layer is placed in between each patch as it is used on top of another patch (Fig. 6(a & b)).. This enables two patches or more to share a similar aperture region [11-12]. Although the edge-truncated elliptical patch antenna with a single feed exhibits circular polarisation, its axial ratio bandwidth, impedance bandwidth, and gain are modest. As a result, this geometry is changed in this communication, and a two-layered stacked configuration with significantly better performance is suggested. The impedance bandwidth and antenna gain are greatly enhanced by taking into account the current arrangement. With the current setup, circular polarisation with increased axial ratio bandwidth is possible. In comparison to conventional or edge-truncated elliptical patch antenna architecture, the observed impedance bandwidth and axial ratio bandwidth are 27.9% and 3.33%, respectively.

By Employing Various Type of Slots/ Slits/ Cuts / Truncations

On the patch radiator, slots are inserted to enhance impedance matching, especially at higher frequencies. The current distribution is altered by the slots carved out of the radiator patch, which also alters the input point's impedance and current path length. A new resonance frequency is added when slots are added to the antenna's patch. Adding more slots results in the creation of two or more resonance areas, which, when properly optimized, increase bandwidth [13-14]. In [13], the intended elliptical Microstrip patch antenna (EMPA) has two sector slots that are orthogonal to each other and aligned along the main axes, as well as a third sector slot that is oriented along the minor axis (Fig. 7). These sector slots' location and size are chosen to maximise bandwidth, which is close to 10.96% and approximately four times higher than that of a standard EMPA tested under the same test conditions. Additionally, the antenna's gain has somewhat increased. Whereas in [14], a square patch is truncated to opposite corners along with Y shaped slot at the centre to attain large impedance bandwidth along with circular polarization and moderate gain value (Fig. 8).

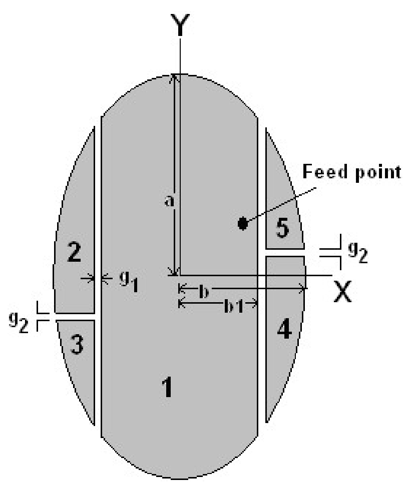

Fig. 5 (a) View of assembly of patches forming gap coupled elliptical patch antenna

Fig. 5 (b) Photograph of designed antenna [10]

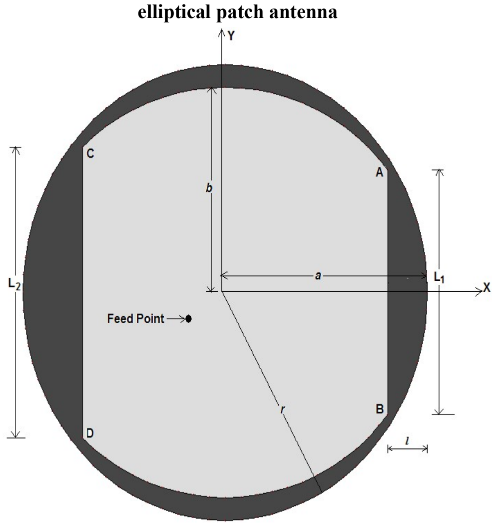

Fig. 6(a) Side view of designed stacked arrangement of patch antenna [11]

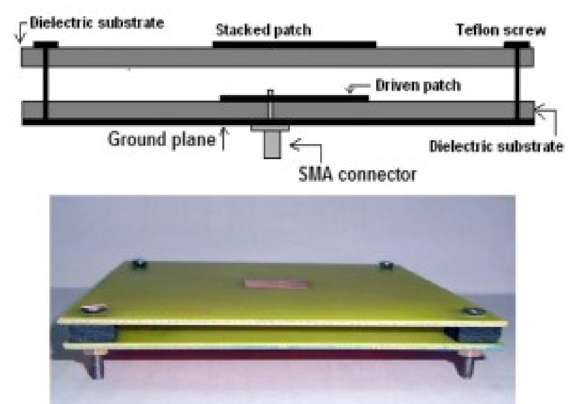

Fig. 6(b) Geometry of considered stacked arrangement of antenna [12]

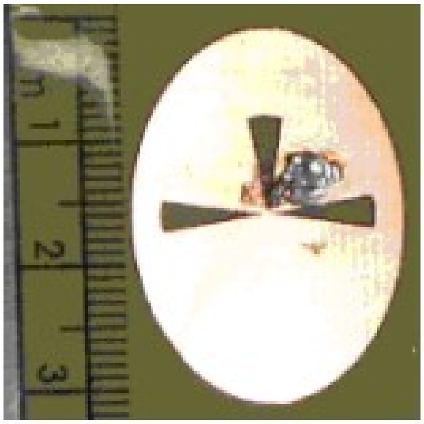

Fig. 7. Geometry of EMPA with sector slots [13]

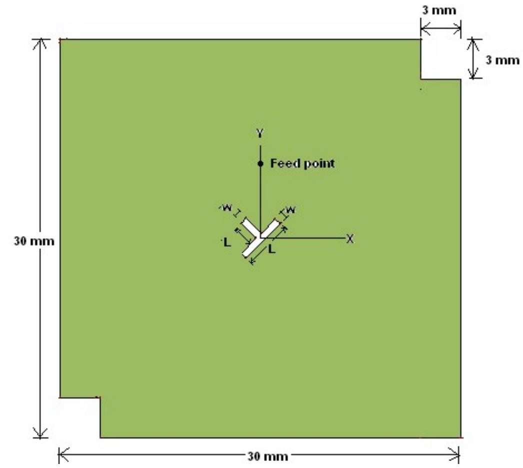

Fig .8 Corner truncated square shape slot antenna [14]

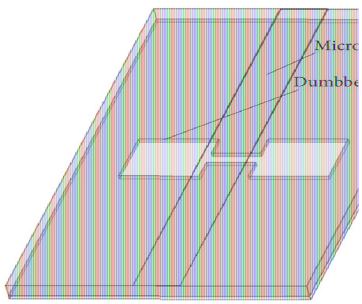

Fig. 9 The dumbbell DGS unit [15]

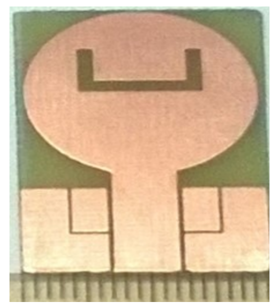

Fig.10 CPW fed prototype of circular patch antenna L shaped slits in ground [16]

Defective Ground Structure (DGS) Technique

Defected Ground Structure refers to slots or other faults embedded on the ground plane of microwave planar circuits. DGS is used as a new way to enhance the many characteristics of microwave circuits, such as their poor impedance bandwidth poor gain and other properties. A simple imperfection of any shape can be engraved on the ground plane to create the recently created idea of defective ground structures. These structures cause the ground plane current to be affected. The handling of excitation and radio wave propagation through the substrate layer are the end effects of this. Inductance and capacitance, two transmission line properties, can be changed with the use of DGS configuration. To accomplish the desired performance, the ground defect can be altered in accordance from a simple shape to a complex shape.

In [15], the details about the development of DGS are presented. The working principles and fundamental ideas of DGS units are offerd, along with corresponding circuit models of DGS units that can be found in the literature. Fig. 9 represents a dumbbell DGS unit. The following techniques can be used to extract the DGS equivalent circuit. (i) LC and RLC equivalent circuits (ii) shaped equivalent circuit (iii) Quasi-static equivalent circuit (iv) using ideal transformer.

In [16], a U shaped slot of suitable magnitude is set up in the circular patch as shown in Fig. 10 which gives a rejection band for WLAN system. L-shaped slits in the ground plane and a U-shaped slot in the patch are used to modify the coplanar waveguide fed circular patch antenna. With a peak gain close to 3.86 dBi, the redesigned structure offers a wide impedance bandwidth of 10.38 GHz (3.33 GHz–13.71 GHz) with rejected WLAN 5.5 GHz band (4.74 GHz–6.15 GHz). Defective ground structures in Microstrip antennas offer a number of benefits in the areas of power amplifiers, couplers, transmission lines, oscillators, dividers and combiners [17].

APPLICATIONS OF MICROSTRIP PRINTED ANTENNA

The utilization of Microstrip printed patch antennas satisfies a variety of industrial, domestic and commercial applications. The essential criteria require for satellite, wireless and mobile communication systems are met by these printed antennas. Due to their special features these antennas in form of single antenna and/or array form are best suited for use in airborne, orbital, satellite, and missile applications. Additionally, there are other official and commercial uses for this antenna in the fields of mobile radio and wireless communications.

Wireless communications: various applications of Microstrip printed antennas evolve in wireless communications include Near Field Communication (NFC) Tags, Wi-max, long term evolution (LTE) and RFID (Radio Frequency Identification) Tags etc.

Domestic communication devices, such as 4G/5G smart phone, Bluetooth, Wi-Fi devices, wireless webcam, and wireless microphones etc.

Massive MIMO technology, device-to-device communication (D2D) system etc

Wireless remote controls are available for security and medical equipment such automatic gates and doors and systems for industrial automation.

Military Applications: Microstrip printed antennas can be used for various military applications includes Radar, maritime navigation, GPS for instance, Satellite Navigation, maritime radio, air traffic control missiles, coast guard communication and Vehicular radar systems.

Energy Harvesting (Rectenna) Application: Rectenna is primarily a combination of a receiving antenna and a rectifier circuit and it is used to convert RF energy into usable DC electrical energy. For this kind of wireless power transfer, many defective ground structure (DGS)-based designs are put forth in order to provide a coupled system with a high efficiency.

Biomedical Applications: Microstrip printed antennas can be used for various Biomedical Applications includes Telemedicine application, Sensing directly using site-directed mutagenesis, Medicinal applications of the patch, for monitoring different pathological changes relating bones, muscle disorders, breast cancer etc.

Wearable Microstrip antenna is used for the Wireless Body Area Network.

CONCLUSION

This study demonstrates that researchers are investigating more and more methods that will make the Microstrip antenna the centre of the communication system as a new era of Microstrip antenna technology is beginning. Due to its unique qualities of low profile and stress-free fabrication, it is suitable for many applications; nevertheless, due to some of its drawbacks, which limit its usage for many other applications, researchers are exerting effort. The shortcomings of Microstrip antennas, such as their narrow impedance bandwidth and limited gain, are emphasized. There are numerous approaches, only a few of which are included in this article. It is projected that Microstrip antenna will solidify its position in contemporary communication systems and will continue to be a fascinating subject of study among scientists and researchers for some time. This investigation could be able to predict future changes.

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