

A Review on Microstrip Patch Antenna Performance Improvement Techniques on Various Applications

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Abstract

Antennas are metallic structure elements developed for transmitting signals through radio waves. Nowadays, antennas are available in different shape depending upon their application and signal strength. The antennas which are employed for space and large signal communication utilizes a bowl shape structure for focusing the signals on a single point. Certain antennas are designed to move on both horizontal and vertical directions for their signal transmission. The microstrip patch antennas are very small in size and it comes under the type of printed antennas. The microstrip patch antennas are widely employed on mobile phone communications and medical applications. The performances of the microstrip patch antennas are increased in recent years and the motive of the review work is to analyse the methodology followed behind it. In the same way, the work analyses the merits and limitations of the recent techniques developed for the performance improvement of the microstrip patch antennas.

Keywords: Microstrip patch antenna, antenna design, feeding techniques, wireless communication

1. Introduction

The antenna is a transducer element developed for the transmission of electromagnetic waves from the source station to the destination. An antenna generates the electromagnetic

waves from the supply given to the antenna. The antenna converts the electrical supply into electromagnetic waves at the source station and in the destination station the receiver antenna amplifies the received electromagnetic waves by generating an electric supply from it. The movement of electrons involvement in an energy supply makes an invisible radio waves when it is connected with a metal antenna [1, 2]. The generated electromagnetic waves carries the informations available in the electrical signal given to the antenna. The electrical signals are meant here as converted speech and sound signals with the help of a mic. The transmission of signal takes place at the speed of light. The architectural view of a transmitter and receiver antennas are almost similar in nature [3]. Figure 1 indicates the classification of antennas based their nature.

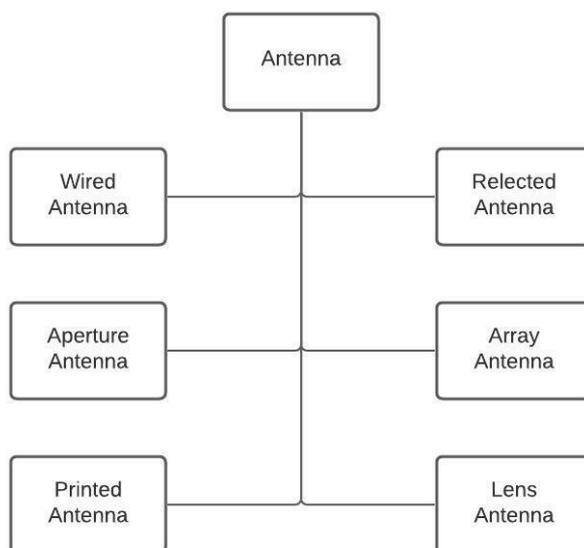


Figure 1. Primary classification of antennas

1.1 Classification of Antennas

The wired antennas are most commonly employed on the place the electrical energy is freely available. The important location where anyone can find the wired antennas are automobiles, aircrafts and buildings. The construction of the wired antennas are simple and there is no fixed shape or size is predetermined for this kind of antennas. The size and shape

may vary with respect to their application. The aperture antennas are general applied to the place where the transmission requires higher frequencies in the range of 3 to 30 GHz. The construction of the aperture antenna is made by making a slot or aperture over a metal plate. The slotted waveguide antenna and horn antenna are the kind of aperture antenna widely employed on the space craft and aircraft areas because of their convenience in the installation process. The slotted wave guide antennas are employed in the place where the transmission needs to be carried on microwave frequencies. The slotted antenna are designed to follow omnidirectional pattern on their transmission process [4-6].

The printed antennas are fabricated based on a standard photolithography technique. The most common fabricated antenna is made up of a metallic patch over a ground plane. The length and size of the fabricated antennas are predetermined with respect to their operation frequency. The printed antennas are widely used nowadays because of their cost efficiency and ease of implementation on the circuit boards. Due to the advancement in technologies the printed antennas are designed with the help of modern fabrication techniques. The ease of integration of printed antenna makes it to be applied on several critical space occupying places like mobile devices and missiles [7, 8].

The array antenna are developed with the help of various radiators segregated between each other for attaining desired frequency generations on different ranges. Generation of various frequency of signals are not possible when employing with a single radiator. The connected radiators are make a combination between each other when there is a requirement of higher range of frequency output. The individual kind of radiator antennas are also utilized on linear and planar grid models. The reflector antennas are designed to operate on signal transmission at larger distances. The reflector antennas are designed with a larger diameter size for obtaining a higher gain for longer transmission and communication. The reflector antenna utilizes a smaller size of antenna in additional as feed for enabling communications at space and very long distance. Certain antennas are employed with a lens setup for avoiding the energy divergent. The energy divergent may results in transmission of signal to undesired destinations.

A good configuration of lens made with proper material will address these problems [9, 10]. The following Table 1 indicate the application and operating frequencies of the above discussed antennas.

Table 1. Application and operating range of antennas

S.No	Antenna	Frequency type	Application
1.	Wire Antenna	Medium to high frequency	Radio broadcasting, mid-sea and marine communications
2.	Aperture Antenna	Super high frequency	Satellite media and microwave communications
3.	Printed Antenna	Super high frequency to extremely high frequency	Satellite media, microwave and airborne radar communications
4.	Array Antenna	Medium to high frequency	Radio broadcasting, mid-sea and marine communications
5.	Reflector Antenna	Very high frequency to ultrahigh frequency	FM and television broadcasting, police navigations and surveillance, flight operation control
6.	Lens Antenna	Very high frequency to ultrahigh frequency	FM and television broadcasting, police navigations and surveillance, flight operation control

2. Related Work

The microstrip antenna are a common kind of printed antenna, which are widely used in recent days on mobile communications. The construction of the microstrip antenna follows the traditional fabrication technique. Radiating patches are fixed at one side of the dielectric substrate of a microstrip patch antenna with a ground plane connection [11, 12]. The geometrical view of a microstrip parch antenna is shown in Figure 2.

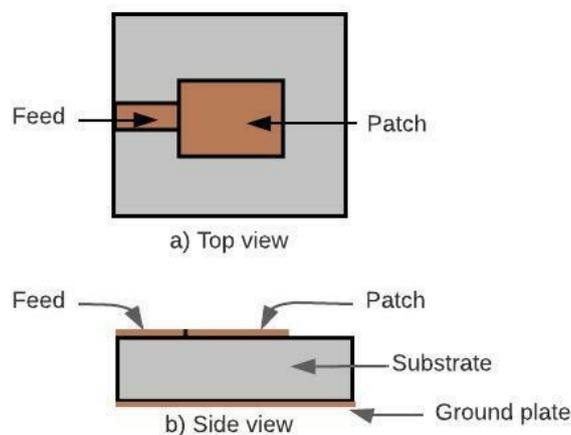


Figure 2. Geometrical view of microstrip patch antenna

The patch and feed lines of the microstrip antenna are etched over the surface of a substrate using very high conducting materials like gold and copper. The shape of the patch over substrate can be in any regular shape like circle, elliptical and rectangle. The change in patch shape are considered with respect to the application of the microstrip antenna. Due to the design size constraints, certain small size microstrip antenna generates fringing fields around the substrate and the patch edges. In order to avoid such fringing fields generation in a microstrip antenna, the dielectric substrate thickness must be increased with a better dielectric constant material. Therefore the efficiency and bandwidth will be improved in a microstrip antenna with lesser radiation. Though a better dielectric constant material for substrate will increase the size of the antenna to certain limit [13].

Excitation of microstrip patch antenna transmits the electromagnetic waves to the patch for creating negative charges over the feed lines and the positive charges will be generated around the other parts. The radiation from the microstrip antennas are generated because of the change in electric fields among the patch and the other areas of an antenna [14].

The shape and size of the microstrip antennas are modified with respect to the field and place of the application. A circular patch microstrip antenna is widely employed for the satellite

communications for generating a circularly polarized radiations. The circularly polarized antennas are also applied for the global positioning systems due to their compactness in size. However, it improves the cost of manufacturing. The microstrip patch antenna which are employed for healthcare applications are developed to transmit the radiation between 30 Hz and 5.8 GHz. The same frequency operated microstrip antennas are also employed for short range mobile communications [15].

Certain microstrip patch antennas are also employed in the wireless sensor network medium for transmitting the observed signals from the sensors. Such kind of antennas are also employed in healthcare field for telemedicine purposes. The operating frequency of such telemedicine antennas are around 2.4 GHz. The antennas employed in mobile devices are made up of semiconductor diodes for ensuring its cost efficiency and space occupancy [16, 17].

3. Literature Survey

The gain and bandwidth are the primary factors describing the efficiency of a microstrip patch antennas. There are several ways available for improving the gain and bandwidth of an antenna. The feeding method of a microstrip patch antenna is a primary one for attaining better gain and bandwidth. The basic feed methods are line feed and coaxial probe field. Aperture coupled feeding is a recent feeding technique developed for attaining larger gain with reduced space occupation. The below table explores the literature review of a microstrip patch antenna on various techniques.

Table 2. Literature table on microstrip patch antenna and its attainments

S.No	First author & year	Technique & References	Design parameters	Output attainments
1.	Shamim (2021)	Graphene-based microstrip patch antenna [12]	Substrate material = Arlon AD 1000 Relative permittivity = 10.2 SL= 120 μm	Resonant frequency = 0.72 THz; Bandwidth range = 0.53 – 0.84 THz;

			SW = 120 μ m SH = 45 μ m PL = 60 μ m PW = 70 μ m FW = 14 μ m	Return loss (dB) = -59.67
2.	Liu (2021)	High quality factor cold sintered LiF ceramics [13]	Substrate material = LiF ceramic SL= 30 mm SW = 30 mm SH = 1.1 mm PL = 11.9 mm PW = 8.5 mm FW = 1.2 mm	Resonant frequency = 6.81 GHz; Bandwidth = 102 MHz; Gain (dB) = 4.25 Return loss (dB) = -20.3
3.	Ma (2021)	5G microstrip patch antenna with cold sintered LiWVO6–K2MoO4 composite [14]	Substrate material = cold sintered 30 wt% LWVO - 70 wt% KMO composite Ceramic SL= 17 mm SW = 17 mm SH = 1.2 mm PL = 12 mm PW = 9 mm FW = 3.25 mm	Resonant frequency = 6.58 GHz; Bandwidth = 170 MHz Gain (dB) = 5.59
4.	Mohammed (2021)	Microstrip patch antenna using air substrate for 5G application [15]	Substrate material = air substrate SL= 9.08 mm SW = 10.68 mm SH = 0.5 mm PL = 4.54 mm PW = 5.34 mm FW = 2.45 mm	Resonant frequency = 28 GHz; Bandwidth = 1.72 GHz Gain (dB) = 9.55
5.	Chinnathampy (2021)	Spectrum underlay finite element line	Substrate material = FR4 SL= 60 mm SW = 40 mm	Resonant frequency = 3.546 GHz; Bandwidth range = 2.41-4.45 GHz;

		feeding technique [16]	SH = 2 mm CPR = 9 mm FL = 20 mm FW = 2 mm	Gain (dB) = 4.21
6.	Matias (2021)	Cavity method with the nanocomposite as substrate [17]	Substrate material = Sillenite-cobaltite nanocomposites SDia = 13 mm SH = 1.9 mm CPR = 3.6 mm FL = 1.5 mm FW = 1.5 mm	Resonant frequency = 8.04 GHz; Bandwidth = 500 MHz;
7.	Singh (2020)	Moth–Flame Optimization Algorithm [18]	Substrate material = liquid crystal polymer SL = 50 mm SW = 50 mm SH = 2 mm PL = 12.72 mm PW = 17.22 mm FW = 8 mm	Resonant frequency = 20.3 GHz; Bandwidth = 3.1 GHz Gain (dB) = 8.9
8.	Srivastava (2020)	Slotted Array Technique [19]	Substrate material = RT Roger/duroid 5880 material SH = 2mm PL = 16 mm PW = 18 mm	Resonant frequency =9 GHz; Bandwidth = 920 GHz Gain (dB) =19.88
9.	Chandrashekar (2020)	Metal-ring superstrate [20]	Substrate material = Low loss Rogers RT duroid material SL = 32 mm SW = 30 mm PL = 9 mm PW = 11.85 mm FL = 11.5 mm FW = 2 mm	Resonant frequency = 14.85 GHz; Gain (dB) =10

			Metal ring inner radius = 1.8 mm Metal ring outer radius = 4.5 mm Metal ring height = 0.8 mm	
10.	Elluru (2019)	Air Substrate Microstrip Patch Antenna for the UHF Spaced Antenna Wind Profiler Radar [21]	Substrate material = air substrate SL = 45.2 cm SW = 48.7 cm SH = 2.5 cm PL = 30.2 cm Feed location (x, y) cm = 6.5, 0	Resonant frequency = 445 MHz; Bandwidth = 19.4 MHz Gain (dB) = 8.7
11.	Krishna (2019)	Symmetrical U shaped slots [22]	Substrate material = RT duroid 5880 SL = 6 mm SW = 6 mm SH = 1 mm PL = 2.89 mm PW = 4.23 mm	Resonant frequency = 25 GHz; Directivity (dB) = 3.129
12.	Reddy (2020)	Fractal Defected Ground Structure [23]	Substrate material = FR4 SL = 51.2 mm SW = 51.2 mm SH = 1.6 mm PL = 32 mm PW = 32 mm	Bandwidth = 120 MHz Gain (dB) = 0.02 Directivity (dB) = 2.46
13.	Prakasam (2020)	Right Hand Circularly Polarized [24]	Substrate material = FR4 epoxy SH = 1.6 mm PL = 14 mm PW = 18.83 mm FL = 8.3 mm FW = 3.1 mm	Resonant frequency = 4.85 GHz; Bandwidth = 71.4 MHz Gain (dB) = 6.59

14.	Arulaalan (2020)	Multiple-input-multiple-output technique [25]	Substrate material = FR4 SL = 68 mm SW = 26 mm SH = 1.6 mm	Resonant frequency = 5.1 & 5.8 GHz; Bandwidth = 128 & 205 MHz Gain (dB) = 8.23 & 8.1
15.	Vashi (2019)	Dual Band antenna using Graphene and FR4 [26]	Substrate material = FR4 SL = 38.5 mm SW = 33 mm SH = 1.45 mm Patch material = Graphene PL = 24 mm PW = 18 mm FL = 8 mm FW = 2 mm	Resonant frequency = 2.41 & 5.45 GHz; Gain (dB) = 1.39 & 2.59 Impedance Bandwidth % = 3.04 & 4.92

SL = Substrate length; SW = Substrate width; SH = Substrate height; PL = Patch length;
 PW = Patch width; FL = Feed length; FW = Feed width

4. Discussion

The design parameters of certain recently made microstrip patch antennas are reviewed in the paper with their performance metrics. Most of the substrate in recent microstrip antennas are in square or rectangle shape with a ground and patch particles covering them. The patches in most of the antennas are made as same link of the substrate shape with lesser in size of length and width. The resonant frequency observations of the recent modalities are ranges from 2.41GHz to 0.72THz. Figure 3 indicates the number of times the substrate materials are found in the literature survey.

FR4 and RT Roger substrates are very popular in recent years, which can be viewed clearly in Figure 3. However, the resonant frequency of FR4 substrates are ranges from 2.41 MHz to 5.6 MHz only. At the same time, the resonant frequency of RT Roger substrate ranges from 9 GHz to 25 GHz. Similarly, the resonant frequency of air substrate attains from 445 MHz

to 28 GHz. The higher most resonant frequency of 0.72THz is found on graphene substrate of Arlon AD 1000 with relative permittivity of 10.2. Apart from the material type, its size is also playing a major role in their achievements.

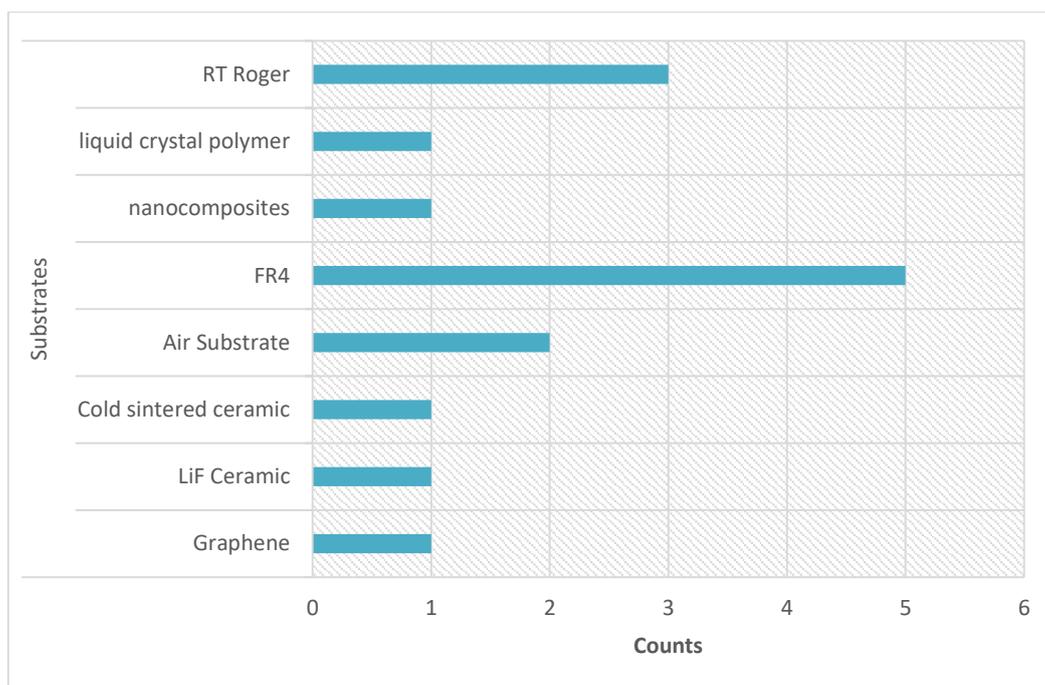


Figure 3. Analysis of substrate materials for microstrip patch antenna

5. Conclusion

The microstrip antennas are applied from medical applications to the missile and space applications due to its compactness in size and cost. The fabrication process of the microstrip antennas are also very simple and reliable. The recent researches are reviewed in the paper to understand the performance attainments of the present designs and it has been found that the resonant frequency up to 0.72THz is attained with graphene substrate on reduced antenna size of 120 μm on their length and width. The size constraint of the microstrip antennas are making it as the most expensive one when it produces larger frequencies. The recent research motives are about to maintain the cost efficiency with higher resonant frequency.

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