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EFFICIENT MICROSTRIP PATCH ANTENNAS FOR 5G SENSOR APPLICATIONS

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Abstract

It is strongly recommended that 5G mobile devices adopt a revolutionary new design for a microstrip patch antenna that is able to function at two different frequencies simultaneously. Because of the complexity of the radiation mechanisms that must be present for dual-band operation, this step is essential. The suggested antenna makes use of two patches in order to generate the electromagnetic coupling that is necessary for its operation. The primary source of low-frequency radiation is the first patch, which receives its power supply straight from a microstrip line. This particular patch is unique in that it is the only one of its kind. Because the first patch is coupled to the second patch by capacitive and inductive coupling, the second patch is the one that gets fed, and as a direct result of this, it is the one that is primarily responsible for radiating at higher frequencies. The precise same method as before was utilized, with the exception that this time, two sensor nodes were set up in the scenario of short grass field at the exact same height above the ground as the first time. In spite of the fact that the radio link that was being evaluated was not in its optimal state, unexpected findings emerged from an examination of the Quality-of-Service in terms of the theoretical bit error rate obtained by a variety of digital modulations.

Keywords:

Microstrip Patch Antenna, 5g Sensors, Dual Band Operation, Lower Band

1. INTRODUCTION

It is necessary to make the transition to higher frequencies (in the mmWaves) because it is necessary to provide the required gigabit data rate service [1], and increasing bandwidth is likely to be the most effective way to meet some of the requirements for 5G cellular services, which are scheduled to become commercially available in the year 2020. In addition, the transition to higher frequencies is necessary because it is necessary to provide the required gigabit data rate service [2]. At mmWave frequencies, however, even little diffractions can produce a large rise in path loss, which will ultimately result in a connection that is weak. These challenges can be conquered by employing beamforming strategies, as well as making use of high gain antennas and highly directed antenna arrays that are constructed out of a number of individual components. Because of this, it will be possible to send the signal in the desired direction. Microstrip patch antennas are an ideal option for use in sensors or in larger antenna arrays because they include a variety of positive properties that make them an outstanding choice [3].

The structure of microstrip patch antennas makes them simple to recognize, which contributes to their widespread application. These antennas are constructed out of a driven dipole, a reflector element, and a number of programmable directors, each of which contributes a separate component to the final product. Beamforming requires there to be an end-fire beam in order to function, which is something that can be consistently made with this method [4]. These structures have, in the past, been the focus of a significant amount of research and usage due to the fact that they offer a reasonable bandwidth and rather large returns for relatively low investment costs [5]. This is because of the fact that they provide a reasonable bandwidth and rather large returns for relatively low investment costs. Several Microstrip patch-like antennas have been introduced as a result of the development of printed circuits. These antennas are able to operate at a variety of frequencies and can be used for a number of different purposes [6]. These antennas have a wide range of applications that they can serve.

In order to ensure communication between sensors that are positioned on widely dispersed equipment and humans, use cases for the Internet of Things (IoT) require antennas to be included into every handheld or wearable device. Due to the fact that antennas are utilized in such a wide variety of contexts, it is strongly advised that they be as small and compact as is physically possible [7].

Finding options for shrinking antennas that preserve or even improve upon the antenna's essential properties while simultaneously reducing its total footprint is a field that has gained some research and development attention. One such solution is the use of microstrip antennas. In the research that has been done [8] many approaches are discussed. Some of these methodologies include fractals, metamaterials, high dielectric constant substrates, slow wave structures, and artificial ground planes. Different categories have been established for each of these research approaches. Reactive impedance substrates (RIS) [9] have been characterized as a method of downsizing that is frequently utilized and which also makes it possible to acquire broadband characteristics in the study that has been done so far. This has been done as part of the work that has been done. Both [10] and [11] exhibit two patches that have the potential to operate as ultra-wideband (UWB) antennas. These patches were generated on a RIS, which is also where their description can be found. The bandwidth of [10] is raised by a factor that is over 100 times greater than that of a normal patch antenna, whilst the bandwidth of [11] is increased by a factor that is 16 times more. On the other hand, RIS-based systems are notoriously difficult to design for millimeter waves. Furthermore, they are frequently implemented in antenna topologies that require the usage of ground planes in order to function properly.

Although microstrip patch antennas inherently present higher gains than microstrip patch antennas, the purpose of this work is to investigate the benefits of employing a microstrip patch antenna in a multilayer configuration in order to further improve its primary attributes. This will be done by comparing the gains of microstrip patch antennas with and without multilayer configurations. Gain is an additional concern for apps utilizing 5G and the Internet of Things.

Experimentation has been done with antennas that have numerous layers in the hopes of enhancing the gain of the device. The goal of the experiment is to increase the gain. [12] contain a diagram that shows a representation of a multilayer form with two microstrip patch antennas. An inexpensive approach that operates in the range of 3 GHz is suggested, in which the antenna is composed of two layered patches that are placed one on top of the other. In spite of the fact that the antenna has a bandwidth of 14%, its emission pattern and power have not been made public. On the other hand, a microstrip patch antenna is presented as an alternative option in a different work, which you can read. It is formed from three parasitic patches that serve as director elements and has a frequency range of around 10 GHz. Additionally, it functions at these frequencies. This antenna makes use of a ground plane in the shape of a V in addition to dielectric foam in order to maintain a consistent distance between its directors. As a result, the reflection coefficient of the antenna is improved. This antenna has a gain of 11.85 dB and a bandwidth of around 190 MHz; however, this comes at the expense of complexity, and there has not yet been a prototype produced. In addition, a Low Temperature Co-fired Ceramic (LTCC) structure for 10 gigahertz is described in [4]. This structure consists of the same eight layers. This particular antenna is constructed out of a microstrip patch and utilizes a proximity coupled feed. It has a gain of 3.43 dBi, an S11 of 11.52 dB, and a narrow bandwidth at 10 GHz. All of these measurements were taken at 10 GHz. In addition, the authors of the paper [5] propose the use of a multilayered antenna that operates at 4.2 GHz and is comparable to a slot Microstrip patch. This arrangement includes three patches that are placed vertically and include slots and slits for parasitic parts. The patches are arranged in a patchwork fashion. This prototype has a gain of roughly 12.20 dBi, and its bandwidth is close to 28%. On the other hand, the configuration of this skyscraper's floor plan is highly challenging and laborious. Additionally, another piece of research [16] recommends an array structure with a multilayer substrate integrated waveguide horn antenna. In order to broaden its frequency response, this antenna incorporates stacked cavities with progressively diminishing permittivity and progressively expanding aperture diameters above the slots. The array runs at frequencies ranging from 22.4 to 29.8 GHz, which is equivalent to approximately 28.4% of the total bandwidth; nonetheless, the level of complexity it possesses is exceptionally high. A gain of around 15 dBi is exhibited by the array.

The authors of [7] used microstrip patch antennas with air gaps in order to build a resonant antenna operating at 5.8 GHz with a bandwidth of 14% and a gain of 11 dBi. Using a microstrip patch antenna, this antenna was able to accomplish this goal successfully. This antenna has a complicated construction that makes it prone to deterioration with time, both in terms of its physical composition and the qualities it possesses. The presence of air gaps between the layers of this antenna is directly responsible for the significant amount of space that is present between the elements of the antenna. The frequency at which the antenna is operating causes these air gaps to shift, causing them to fluctuate over time.

The authors of [8] built microstrip patch antennas, and these antennas did not have any air gaps in between the layers that they built them with. Gain of 11 dBi was successfully accomplished, and the antenna's measured bandwidth came in at roughly 20%, which is a respectable amount. On the other hand, the utilization of foam with a low permittivity in the areas in which the directors are located results in an increase in the volume of the antenna. Within the confines of the scope of this study, there will be no discussion of efficiency values. The resonance frequency of this antenna is 10 GHz, which, in comparison to the frequencies required for 5G and the enormous networks of the Internet of Things, is still considered to be relatively low. There is a description of a multilayer antenna that operates at 60 GHz in the reference (19). This particular antenna has a gain of 11 dBi and is noticeably more condensed in size compared to others of its kind. The fact that its bandwidth is only 4.2% is, unfortunately, a considerable limitation given the predicted high data rates of traffic. This is a major drawback to the situation.

2. FREQUENCY SWITCHING METHODS

Various FS methods are discussed below:

2.1 RECONFIGURABLE MATCHING NETWORK

The antenna, which is traditionally constructed for incorporation with liquid crystal polymer displays, has earned a stellar reputation due to the one-of-a-kind higher-frequency implementation that it employs (LCP). The architecture of the antenna incorporates a radiating patch in the form of a tuning fork, so that it may receive and transmit electromagnetic waves. In addition, there are two stubs that may be switched on and off in order to modify the radiation pattern of the antenna. This can be done by toggling a switch. The foundation of a reconfigurable antenna similar to the one that has been proposed could be something like a tuning fork with its prongs cut to various lengths. Switch 1 (SW1) is responsible for making the connection between the longer first prong (Lp1) and the shorter first stub (S1), and Switch 2 (SW2) is responsible for making the connection between the shorter second prong (Lp2) and the longer third stub. Both of these connections are made to the third stub, which is the longer of the two (3). (SW2). The patch antenna, which is made up of fork prongs and stubs, has the capability of having its radiating area and, consequently, its resonance frequency altered by the simple act of toggling a few switches. When both switches are set to the "on" position and both stubs are integrated into the radiating element, the proposed antenna has a bandwidth that covers an impedance range that extends from 20.7-33.2 GHz. This is the case when both switches are in the "on" position (Mode 1). It has been established that there will be a reorganization of the frequencies if there are any changes made to the configuration of the switches. When added together, all four modes have a combined bandwidth that falls anywhere between 20.7 and 36 GHz. Two PIN diodes can be set to correspond to any one of four unique frequency bands when they are used in a switch configuration. This is possible thanks to the diodes' ability to be changed. When switch 1 is in the forward biased (ON) position, the matching frequency is 32.3 GHz. When switch 2 is in the forward biased position, the matching frequency is 22.4 GHz (ON state). Both switches have to be in the forward biased position for the antenna to be matched at 31.7 GHz. This can only be done if the switches are in the "on" position (ON). In a similar vein, the recommended antenna has a satisfactory match at 28.8 GHz even with both switches in the off position, which is the reverse biased situation. This is because the antenna is designed to be polarized in the opposite direction. The suggested antenna is an excellent candidate for use in wearable communications systems and applications that center on the human body within 5G networks due to its compliance qualities, smaller weights, improved and enhanced efficiency, and configurable frequency. These characteristics make the antenna an excellent candidate for use.

2.2 CHANGING THE CURRENT FLOW

The findings of this experiment indicate that a microstrip line is the easiest technique of feeding, and that a notch and a circular patch are the only components that are required to carry out this task [28]. UWB, which stands for "ultra-wideband," is a term that describes a frequency range that extends from 3.1 GHz all the way up to 10.6 GHz. This frequency range was designed expressly for the purpose of carrying wireless communications, in addition to supporting other purposes. The notch of this circular patch antenna is fed by a microstrip thread, a single transmission stage, and a partial ground plane. The ground plane has only been constructed in part at this point. The frequency range for UWB applications that is defined by the Federal Communications Commission is 3.1-10.6 GHz. The antenna has a bandwidth of S11 10 dB, and the suggested voltage is 2.1. Together, these two specifications cover this frequency range (FCC). The suggested antenna has a frequency range that extends from 2.4 gigahertz all the way up to 11 gigahertz. This frequency range corresponds to the range in which the antenna is capable of achieving the targeted impedance bandwidth of 8.6 gigahertz. The return loss, radiation pattern, voltage standing wave ratio (VSWR), gain, and delay in the group, as well as the currently suggested antenna distribution, are all investigated in this study. The outcomes of the simulation, in addition to the recommended parameters for the antenna, are exhibited in the microwave studio that was developed by CST.

2.3 META SURFACE CONFIGURATION

Analyses for mobile and Macintosh software applications are performed on antennas that are mechanically reconfigurable and have a better gain. The metallic jacket is a perfectly rotating unit, but it only covers the collection of radiating frames in a limited capacity. This guarantees that the scanning range in the azimuth position is optimized to its full capacity and that its full potential is realized. For a frequency range that is centered on 27.3 GHz, this method produces a net gain of 17.41 dBi and a beam width of 37 degrees on the azimuth axis. Additionally, the beam width is 37 degrees. This approach not only eliminates the difficulties that are associated with the traditional phase array, such as scanning loss, SLL deterioration, beam extension, and so on, but it also has a number of advantages over that design. Some of these advantages can be found in the following areas: It is likely that the element array and antenna's numerical results and array will be able to function well in 5G cellular networks based on the results of the experiments involving those two components.

2.4 VARYING THE SLOT LENGTH

The slot is often the location where the turning of the resonant frequency that is induced by a varactor switch may be observed. Because microstrip antennas provide users with access to a greater number of turning frequencies than patch antennas do, it's possible that frequency reconfigurable microstrip antennas are the superior choice. This is because microstrip antennas are capable of providing more turning frequencies than other types of antennas. By adopting PIN diodes, we are able to exercise unrestricted control over the aperture size of the antenna slot and its associated width. Four PIN diodes, each of which is capable of constructing a frequency band in one of five potential ranges, are positioned such that they run parallel to the slotted lines that make up the antenna. The following describes each range in detail: Uh, Fig. 10. The following diagram provides an illustration of the ground plane structure of the recommended antenna, which possesses a selectable frequency. This diagram may be found below. Because of the ON/OFF operation of the PIN diode, the slot has to be constructed with a size and shape that is completely different from anything else out there. Therefore, the frequency might be anywhere from 2.11 gigahertz all the way up to 10.92 gigahertz (GHz).

2.5 VARYING THE LUMPED ELEMENTS

The MMW is able to effectively demonstrate its usefulness in practice when combined with an antenna that can be tuned to a certain frequency. 5G networks are currently in the process of being constructed in order to take use of the enormous bandwidth given by the many types of waves that are already available. This can be accomplished by applying the method (CPW). This proposed type of antenna has a resonating changeable frequency that falls anywhere between 26 and 29 gigahertz, and it makes use of two primary variable resistors in order to achieve a return loss of 10 dB. When the resistance changes, the gain, directional efficiency, and effectiveness of the radiation pattern are contrasted and compared. The dB efficiency of the S11 signal is improved and amplified as a consequence of the fact that this fed-CPW technique is also sympathetic to the GCPW-grounded CPW.

Table.1. Parametric Comparison at different resistive values.

Frequency (GHz)	**Return Loss (dB)**	**Bandwidth (GHz)**	**Gain (dBi)**	**Directivity (dBi)**	**VSWR (dB)**
59.94	-41.60	8	5.76	9.83	1.02
59.86	-39.11	7.76	5.43	9.35	1.02
59.86	-27.16	12.63	7.17	8.8	1.09
60	-26.46	14.92	5.2	6.29	1.09
60.08	-38.62	8.35	5.74	9.82	1.02
60.02	-49.59	7.81	5.38	9.41	1.00
60.14	-24.92	12.63	7.04	8.73	1.12
61	-26.46	14.92	5.2	6.29	1.09

The next stage in selecting the modeling strategy that would produce the most accurate predictions is to determine the general pattern of path loss. It was demonstrated that the pattern of the route loss changes at two places, which are referred to as "crucial points," in each of the curves: first, close to the transmitter (dC0), and then not too long after that. The first place is close to the transmitter, while the second place is not too long after that (dCf). The obstruction brought on by the first Fresnel ellipsoid and the ground plane serve as the foundation for the three separate zones that are brought into existence at these points within the propagation distance.

- Zone #1: The initial critical distance, also referred to as dC0, is calculated using the transmitter as the point of measurement. However, the power combination at the receiver continues to create a route loss rate that is comparable to that of free space for H2 and less restrictive for H1. This occurs despite the fact that the 2-ray mode of propagation begins to take the lead at this stage.

- Zone #2: The second zone, which is located midway between the two important sites, is where the majority of the action in the near-ground scenario takes place. Because route loss occurs in this zone, it is also substantially faster than the first zone.
- Zone #3: As a result of the mixing of diffracted and scattered rays from zone 2 in the receiving antenna, a larger destructive path loss rate is observed in zone 3 once the second critical point has been passed. This is because the reception antenna is located in zone 3. This transpires as a direct result of the fact that zone 3 is situated past the second critical point in the system. This persistent path loss will still be present after the finish of this final section.

A log-distance fitting was performed on each and every one of the three zones so that we could identify the overall pattern of path loss. This was done in order to find out how the path loss was distributed throughout the three zones. The equation that is described may be shown to be consistent with the model that was generated as a result of this. In this equation, the power attenuation is expressed in decibels (dB), and it decreases in a logarithmic fashion in proportion to both the distance and the number of critical sites.

$$PL(d)=10\cdot n_1\cdot \log10(d), \text{ if } d\le d_{C0} \quad (1)$$

$$PL(d)=10\cdot n_2\cdot \log10(d), \text{ if } d_{C0}\le d\le d_{Cf} \quad (2)$$

$$PL(d)=10\cdot n_3\cdot \log10(d), \text{ if } d\ge d_{Cf} \quad (3)$$

The variables n_1, n_2 and n_3 each represent an attenuation factor that is measured in dB/m in the expression. It is presumable that the occurrence in issue conforms to the free-space paradigm when the attenuation value is equal to 2.

The critical points d_{C0} and d_{Cf} are obtained as per:

$$d_{C0} = H_{1,22}p\cdot\lambda,\ d_{Cf} = 2\cdot d_{C0} \quad (4)$$

where

$H_{1,2}$ - transmitter and receiver antenna height,

λ - transmitted wavelength, and

p - ratio $H_{1,2}/r_1$.

We are able to compute the free-space route loss L_{fs} in dB as follows:

$$L_{fs} = 32.44 + 20\log10(f\times10^{-6}) + 20\log10(d\times10^{-3}) \quad (5)$$

where

f - transmitted signal frequency in Hz and

d - distance between the transmitter and the receiver in meters.

When compared to the outcomes of the three-slope log-distance model that was suggested, the outcomes of the measurements displayed an eerie resemblance to the theoretical expectations. The estimated power loss in transmission based on the free-space model is shown to be based on irrational assumptions, and the proposed path loss model provides more data to support the argument that this is the case.

Table.2. Attenuation Factors for the Path Loss Model

Modes	Freq (GHz)	F1=868 MHZ		
		n_1	n_2	n_3
Soil	60	3	3.5	3.5
	61	1.8	2.75	2.75
Short grass	60	3.1	2.75	3.5
	61	1.75	2.75	2.75
Tall grass	60	3	2.75	2.75
	61	2.3	2.75	2.75

Modes	Freq (GHz)	F2=2.4 GHZ		
		n_1	n_2	n_3
Soil	60	1.5	3.75	3.5
	61	0.5	1.75	2.75
Short grass	60	1.0	3.75	3.5
	61	1.25	1.75	2.75
Tall grass	60	3	3.75	2.25
	61	1.5	2.5	3.5

Modes	Freq (GHz)	F3=5.8 GHZ		
		n_1	n_2	n_3
Soil	60	0.85	2.6	2.6
	61	2	2.25	2.6
Short grass	60	1.75	2.1	2.6
	61	2	2.25	2.6
Tall grass	60	2.75	4.25	2.6
	61	2	3.5	2.6

The following section provides a comparison of the four distinct types of reconfigurable antennas that are currently available. The following characteristics of the antennas are investigated and contrasted: return loss, gain, directivity, voltage standing wave ratio, and resonant frequency. In order to evaluate how the parameters react, the values of the resistors are changed by a factor of ten, both above and below the value at which they were first set. A resonance frequency of sixty gigahertz is assumed to exist within each of the four different variants before their production can begin. The decisive results for the parameters with values that are ten standard deviations above or below the mean are presented in the table that follows. According to the findings, the different performance characteristics of the model are influenced by the shape of the model itself. The following characteristics of the antennas are investigated and compared: return loss, gain, directivity, voltage standing wave ratio, and resonant frequency. In order to evaluate how the parameters react, the values of the resistors are changed by a factor of ten, both above and below the value at which they were first set. A resonance frequency of sixty gigahertz is assumed to exist within each of the four different variants before their production can begin.

The decisive results for the parameters with values that are ten standard deviations above or below the mean are presented in the table that follows. The findings indicate that the form of the model has an influence on the numerous performance qualities that it possesses. It is recommended that Model 1 be utilized for use as a highly directional antenna due to the fact that it is possible to concentrate more of the transmitted power in one direction than is possible with the other models and due to the fact that it has a low voltage standing wave ratio (VSWR). The findings of the research have led to the formulation of this recommendation. Model 2 has a poor radiation efficiency, whereas Model 3 has large gains, making it excellent for transmitting maximum power in the direction of peak radiation. Model 1 has a moderate radiation efficiency. The radiation efficiency of Model 2 is rather low. This type of antenna can be utilized for the quick transmission of radio waves despite the fact that it has poor performance in all other regards. Out of the four choices that are now accessible, it has the highest bandwidth, hence it is the best option for doing so.

To acquire a better comprehension of the findings, one may make use of a radio link that has a partially blocked line of sight (OLoS). The dB level at which the FFZ is considered to have made contact with the ground is characterized as follows:

$$dB \approx 4h_t xhrx/\lambda \quad (6)$$

where,

h_{tx} – transmitter height

h_{rx} - receiver heights, and

λ - wavelength.

Through the utilization of a three-slope log-distance model, we were able to ascertain that the path loss is directly proportional to the physical distance separating the radio links. Because of this, we were able to arrive at the correct conclusions. The model that has been suggested takes into account the fact that the characteristics of the near-ground radio channel can primarily be described in terms of the obstruction caused by Fresnel zones. This is one of the main considerations that the model takes into account. By illuminating that the distance between the transmitter and the receiver may be partitioned into three zones, which are limited by two important points and the breakover or cross-over point, this method truly constitutes its most significant contribution. The distance that separates the transmitter and the receiver determines which of these three zones are present.

3. CONCLUSION

When it comes to 5G, we investigate both the benefits and downsides of using a plain antenna as well as a reconfigurable antenna, and we compare the two types of antennas side by side. It can be observed that microstrip patch antennas exhibit behavior consistent with resonance. [Further citation is required] The relevant models are used for each of these processes, and their existence is acknowledged in the appropriate way. An experienced designer is able to modify the structure of the antenna and adapt its composition in a variety of various ways to achieve the desired outcomes. This allows the designer to obtain perfect reconfiguration properties. A resistor is currently used as a single parameter in the process of frequency reconfiguration; but, in the future, an inductor, a capacitor, or even a simple diode may be used instead.

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