A Novel Circular Microstrip Antenna with Reconfigurable Frequency Capability

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Abstract: A novel single-feed circular microstrip antenna with reconfigurable frequency capability is proposed. This antenna consists of radiating circular patch surrounded by a ring, six switches, and two rods. Its dimensions are 80 x 80 x 1.5 mm² and it is printed on a substrate with a thickness of 1.5 mm, and relative permittivity εr= 3. The proposed antenna is designed for IEEE 802.11a standard, the S band, and C band. Keywords: Reconfigurable antenna, circular patch, frequency diversity.

I. Introduction

The term reconfigurable antenna has a relatively new concept in the telecommunication. This term was introduced for the first time in 1998[1]. Reconfigurable antennas have attracted much interest and play a key role in modern telecommunication systems [2]. Because with this type of antennas it was possible to achieve good performances with a small size, low cost, especially since they can operate at more than just one frequency while maintaining a small size [3] and make the operation of multiple antennas at both. Hence many efforts have been carried out making antennas reconfigurable to improve performance and flexibility of wireless systems for applications such as high-capacity dynamic mobile communications, smart tracking systems and reconfigurable sensor networks [4]. As for reconfigurability, a very large number of solutions have been proposed for achieving multiple frequencies [2], and different types of switching techniques have been used including GaAS field effect transistor (FET) switches, PIN diodes, and RF MEMS switches [5]. The switches have been simulated by transmission lines for the “closed” state and for the “open” state the switches are simply removed [5].

II. Design And Geometry Of The Antenna

In this paper, we will propose a new reconfigurable antenna designwith a gaininterestas a patchantenna. This antenna is printedon a substrate length L=80 mm and width W=80mm, relative permittivity εr= 3 and thickness h=1.5mm. The radiating part of the antenna consists of ametallic disc radius R₁=18.5mm, surrounded by a metal ring inner radius of R₂=19mm and an external radius R₃=20.6mm. The disk and the ring are centered on the same center. Within the geometry of the antenna, six PIN diodes which will play thereafter the role of switches that allow if necessary connection between the various parts of the radiating element.

The disk is attached to two rods connected bya PIN diode, and the right stemthere is a slot where DP1 has a diode PIN1. The ring is linked to these two rods by two diodes PIN3 left and right PIN4 diode short-circuiting case of need. And the whole is fed by a microstrip feedline connecting the two stems to excitation port. PIN diodes have been inserted in the slots such that PIN1 diodes inserted into the DP1 slot, the PIN3 diodes inserted into the DP3 slot, the PIN4 diodes inserted into the DP4 slot, and PIN2 diodes inserted between the two rods at DP2. The geometry of the antenna is shown in figure 1. The antennadimensions are shown in Table 1. Whena diode is on mode (ON state), it blocksthe RF signal, against when in mode off (OFF state) prevents the signal to pass from one side to the other. To simplify the implementation, we will model the diode in the (ON state) by a very thinwire dimension 1.60 x 1.90 mm², however in mode off will be modeled by a perfect gap. The study of the proposed reconfigurable antenna is performed using CST simulator. Thereafter, we will deal with six configurations of the antenna according to the modes of PIN diodes. Table 2 presents the six configurations which are combinations of the modes (passing or blocking) of the six switches.
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Figure 1: Geometry of the reconfigurable circular patch antenna

Table 1: Dimensions of the reconfigurable circular patch antenna

<table>
<thead>
<tr>
<th>Distance</th>
<th>W</th>
<th>L</th>
<th>D1</th>
<th>D2</th>
<th>D3</th>
<th>D4</th>
<th>D5</th>
<th>D6</th>
<th>Dp1</th>
<th>Dp2</th>
<th>Dp3</th>
<th>Dp4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Greatness (mm)</td>
<td>80</td>
<td>80</td>
<td>1.6</td>
<td>13</td>
<td>5.1</td>
<td>1.6</td>
<td>14.5</td>
<td>1.6</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
<td>1.9</td>
</tr>
</tbody>
</table>

Table 2: The different configurations of the reconfigurable antenna

<table>
<thead>
<tr>
<th>Configurations</th>
<th>PIN1</th>
<th>PIN2</th>
<th>PIN3</th>
<th>PIN4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Configuration 1</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>Configuration 2</td>
<td>ON</td>
<td>OFF</td>
<td>ON</td>
<td>ON</td>
</tr>
<tr>
<td>Configuration 3</td>
<td>ON</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Configuration 4</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Configuration 5</td>
<td>OFF</td>
<td>ON</td>
<td>OFF</td>
<td>OFF</td>
</tr>
<tr>
<td>Configuration 6</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
<td>OFF</td>
</tr>
</tbody>
</table>

III. Study Of Analog Configurations

The antenna was simulated using CST simulator in six configurations. According to the simulation results, the return losses for the analog results state 1 and state 2, the state 3 with state 4. That is to say, the simulation results of return loss in the configuration 1 are the same in configuration 2. It has also led to similar results for both configurations 3 and 4. This analogy between the return loss is related to the symmetry between these antenna configurations except the PIN diode 2 which shows the difference. That is to say, when the two states have geometric symmetry and the only difference between them is the PIN diode mode (ON mode for state and OFF mode for the other), then these two states will achieve the same results level of the resonant frequency. For example, if we compare the configuration 1 with configuration 2, we note that the antenna to the first configuration is that of the second configuration except that the first configuration is the PIN diode 2 closed (ON state) while the second configuration is the PIN diode 2 open (OFF state) in the second configuration. Also, these two configurations accept an axis of symmetry as shown in figure 2. Therefore, the two configurations generate the same metallic pattern to the RF signal, by following the same impedance and the same resonant frequencies. The same analogy can explain the return losses for configurations 3 and 4 shown in figure 3. Then later, we will present the results of S11 for only four configurations, which is the first, third, fifth, and sixth. PIN 3 and 4, being in on mode for configurations 1 and 2 and knowing that both PIN linking the ring disk, ring in this case contributes to radiating elements of the antenna. While in other configurations, the ring is not in contact with the disc, as a result, it has only parasitic elements to the radiating part of the antenna.
IV. Results And Interpretations

For configuration 1, according to the simulation results shown in Figure 4, the reconfigurable antenna provides a return loss of -40 dB in the frequency band centered around 5.18 GHz. This resonance frequency is included in the band (5150-5825 MHz) related to the standard IEEE 802.11a. The radiation pattern in three dimensions corresponding to this resonance frequency is shown in Figure 5. We deduce that the antenna in this configuration presents a considerable gain value of 10.45 dB. These results are identical with those of configuration 2, from what we have already mentioned.

Figure 4: Return loss of the antenna for configuration 1
Figure 5: The gain of the antenna at the frequency 5.18 GHz for configuration 1.

The simulation results for the configuration 3, which is shown in Figure 6, shows that it is a dual-band operation, respectively centered around the frequency $f_1 = 3.4$ GHz and frequency $f_2 = 5.167$ GHz. The frequency $f_1$ is useful for the S-band (ranging from 2 to 4 GHz) of telecommunications, and the frequency $f_2$ is dedicated to the IEEE 802.11 standard (5150-5825 MHz). Figures 7 and 8 show the radiation patterns for the frequency $f_1$ and the frequency $f_2$, respectively. It is seen that the antenna has a gain of 8.68 dB at the resonance frequency $f_1 = 3.4$ GHz, and a gain of 9.7 dB at the frequency $f_2 = 5.167$ GHz. These results are also similar to those of the configuration 4, thanks to the symmetry mentioned above.

Figure 6: Return loss of the antenna for configuration 3.

Figure 7: The gain of the antenna at the frequency $f_2 = 5.18$ GHz for configuration 3.
Figure 8: The gain of the antenna at the frequency $f_2 = 5.167$ GHz for configuration 3.

For the configuration 5, the shape of the antenna will be as illustrated in figure 9 and simulated return loss results are presented in figure 10. Note that the antenna is also in this case a dual frequency spectrum around the two frequencies $f'_1 = 3.39$ GHz and $f'_2 = 5.06$ GHz. About figures 11 and 12, the antenna has a gain which is $10.51$ dB at $f'_1 = 3.39$ GHz and $11.54$ dB at $f'_2 = 5.06$ GHz.

Figure 9: Antenna geometry for configuration 5

Figure 10: Return loss of the antenna for configuration 5
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Figure 11: The gain of the antenna at the frequency $f_1 = 3.39$ GHz for configuration 5.

Figure 12: The gain of the antenna at the frequency $f_2 = 5.06$ GHz for configuration 5.

As regards the configuration 6, the antenna takes the form shown in figure 13, and the simulations results of return loss are illustrated in figure 14. The antenna in this case is operating in a 90 MHz bandwidth with two peaks: $f''_1 = 4.11$ GHz and $f''_2 = 4.16$ GHz. These two frequencies are dedicated to C-band. Concerning the corresponding gains in these two resonant frequencies, they are shown respectively by the figures 15 and 16. The gain of the antenna at the frequency $f''_1$ equal to 10.28 dB, and at $f''_2$ frequency equal to 10.21 dB.

Figure 13: Antenna geometry for configuration 6
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Figure 14: Return loss of the antenna for configuration 6

Figure 15: The gain of the antenna at the frequency $f_1 = 4.11$ GHz for configuration 6.

Figure 16: The gain of the antenna at the frequency $f_2 = 4.16$ GHz for configuration 6.
V. Conclusion

The design and simulation of a reconfigurable antenna frequency is presented. This antenna has a considerably large gain compared to printed patch antennas. The simulated results of return loss are illustrated and interpreted. The proposed antenna presents importance on IEEE 802.11 standard, the S band (which is mostly used by weather radar and some satellites communications) and C band (which is useful for weather radar).

References


[5]. Jessica A. Designor 1 and Jayanti Venkataraman, “Reconfigurable Dual Frequency Microstrip Patch Antenna Using RF MEMS Switches”, Department of Electrical Engineering Rochester Institute of Technology, Rochester, NY 14623, USA