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A Novel Circular Microstrip Antenna with Reconfigurable Frequency Capability

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***Abstract**: A novelsingle-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 mm^3 and it is printed on a substrate with a thickness of 1.5 mm, and relative permittivity ε_r= 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 newreconfigurableantenna designwith a gaininterestas a patchantenna.Thisantenna is printedonasubstratelengthL=80 mm andwidth W= 80mm,relative permittivityε_r= 3and thickness h=1.5mm.The radiating partof the antennaconsists of ametallic disc radius R_3=18.5mm, surrounded by a metal ringinner radius ofR_2= 19mm and an externalradiusR_1=20.6mm.The diskand the ringare centeredon thesame center.Within thegeometry of the antennawas insertedsixPIN diodeswhichwill playthereafterthe role ofsixswitchesthat allowif necessaryconnection betweenthe various partsof the radiating element.

The discis attached totwo rodsconnected bya PIN diode, andtherightstemthere is aslotwhereDP1hasadiodePIN1. The ringis linked to thesetwo rodsbytwodiodesPIN3leftandrightPIN4diodetoshort-circuiting caseofneed. And the whole isfed bya microstripfeed lineconnecting the twostems to excitationport.PIN diodeshave been insertedintheslotsuchthatthePIN1diodeis inserted into theDP1slot,thePIN3diodeis inserted into theDP3slot,thePIN4diodeis inserted into theDP4slot,andPIN2diodeisinserted between the tworodsatDP2. Thegeometryof the antenna isshown in figure1. The antennadimensions areshown in table1.Whena diode isin its on mode(ONstate), it togglestheRFsignal,againstwhen inmodeblocked(OFF state) prevents thesignal to passfrom one side tothe other.To simplifythe implementation, we will model thediodeinthe(ONstate) by avery thinwiredimension1.60x1.90mm^2, however inoff modewill bemodeled by aperfectgap.The studyof the proposedreconfigurableantenna isperformed usingCSTsimulator.Thereafter, we will deal withsixconfigurationsof the antennaaccording to themodesofPINdiodes. Table2presents thesesix configurationswhich arecombinations of themodes (passing orblocking) of the six switches.

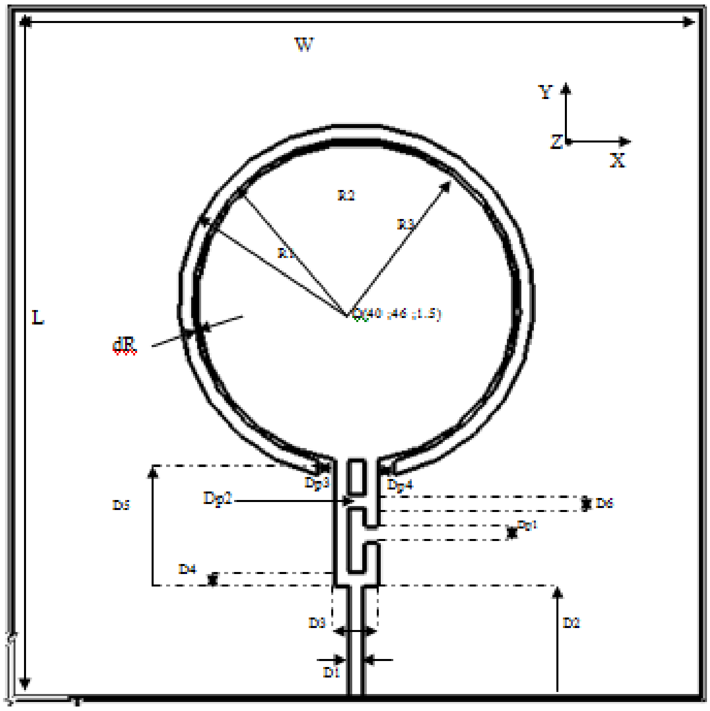

Figure 1: Geometryof the reconfigurable circularpatch antenna

Distance	W	L	D1	D2	D3	D4	D5	D6	Dp1	Dp2	Dp3	Dp4
Greatness(mm)	80	80	1.6	13	5.1	1.6	14.5	1.6	1.9	1.9	1.9	1.9

Table1: Dimensions of the reconfigurable circular patch antenna

Configurations	**PIN1**	**PIN2**	**PIN3**	**PIN4**
Configuration 1	ON	ON	ON	ON
Configuration 2	ON	OFF	ON	ON
Configuration 3	ON	ON	OFF	OFF
Configuration 4	ON	OFF	OFF	OFF
Configuration 5	OFF	ON	OFF	OFF
Configuration 6	OFF	OFF	OFF	OFF

Table2: The different configurationsof thereconfigurableantenna

III. Study Of Analog Configurations

The antennawas simulatedusingCST simulator insixconfigurations.According tothe simulation resultswere foundfortheanalogresultsstate1 with state2, the state3with state4.That is tosay, thesimulation resultsof return lossin the configuration1are the same inconfiguration 2.It has alsoled tosimilar resultsfor both configurations3 and 4. Thisanalogyat thereturn lossisrelated to thesymmetrybetweenthese antennaconfigurationscouplesexceptthe PIN diode2 whichshows the difference.That is tosay, whentwo stateshavegeometric symmetryand the onlydifference between them isthe PIN2mode(ONmode for state and OFF mode for the other), then these twostateswillachieve the sameresultslevelofthe resonant frequency.For example, ifwe compare theconfiguration1 withconfiguration 2, we note that the antennato the first configurationisthat of the secondconfigurationexcept that inthefirstconfigurationthe PIN diode2 isclosed (ON state) whileis blocked(OFFstate) in the secondconfiguration.Alsothese two configurationsacceptan axis of symmetryas shownin figure2. Thereforethe two configurationsgeneratethe samemetallic patterntothe RF signal, byfollowingthe same impedanceandthe sameresonance frequencies.The sameanalogycan explain theresultsofreturn lossforconfigurations3 and4 shownin figure3.Thenlaterwe willpresent the results ofS_{11}foronlyfourconfigurations, which is thefirst, 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. Whileinother configurations, the ring is not in contactwith the disc,as a resultithas only aparasitic elementtothe radiating partof the antenna.

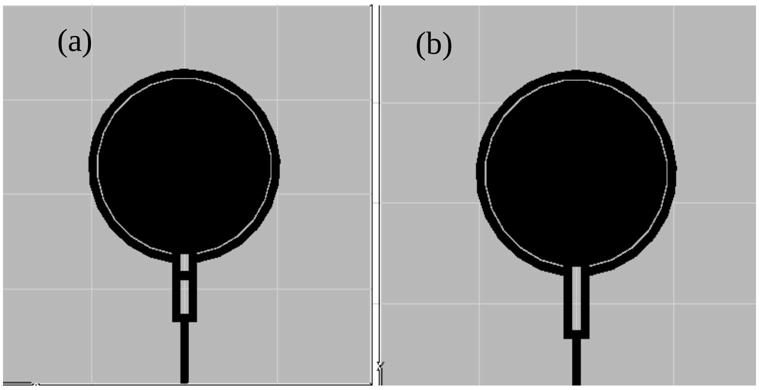

Figure 2: Antenna geometry (a) Configuration 1 (b) Configuration 2

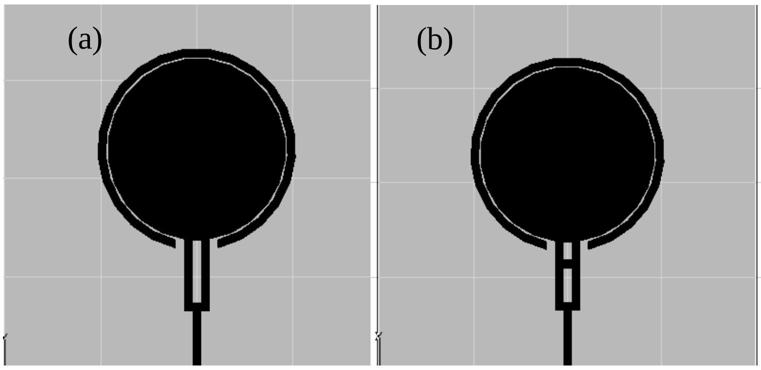

Figure 3: Antenna geometry (a) Configuration 3 (b) Configuration 4

IV. ResultsAnd Interpretations

For configuration1,according tonotessimulation resultsshown in figure4, thereconfigurableantennaprovides areturn loss of-40 dBin the frequencyband centered around5.18GHz.Thisresonance frequencyis includedin the band(5150-5825MHz) related to the standardIEEE 802.11a. The radiation patterninthreedimensions corresponding tothis resonance frequencyisshown in figure5. We deduce thatthe antennain this configurationpresents a considerablegain value10.45dB.These resultsare identicalwith those of theconfiguration2, from what wehave already mentioned.

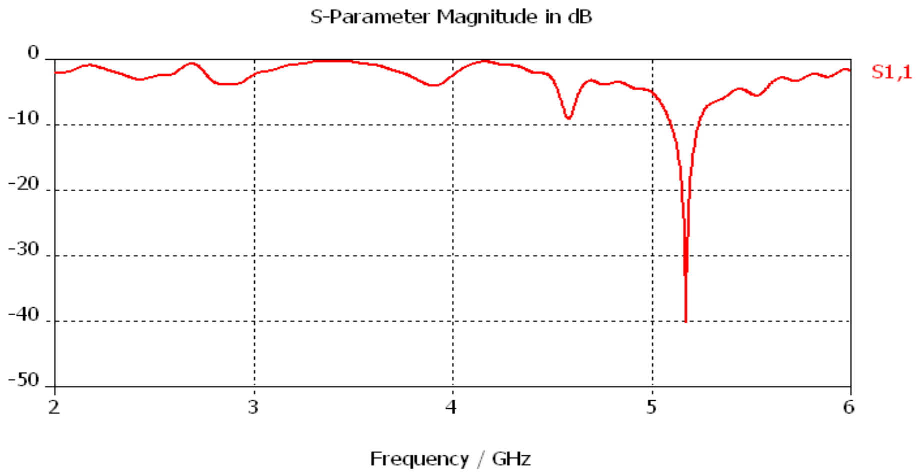

Figure 4: Return lossof theantenna for configuration 1

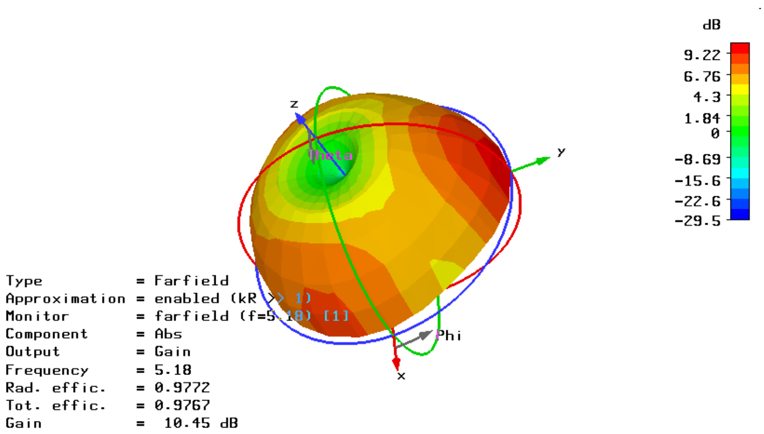

Figure 5: The gain of theantennaat the frequency5.18GHz for configuration 1.

The simulationresults fortheconfiguration3, which isshown in figure6shows that itis adualbandoperation,respectively centeredaround the frequencyf_1=3.4GHzand frequencyf_2=5.167GHz.The frequency f_1 is usefullfor S-band(ranging from 2 to 4 GHz) ofthetelecommunications, and thefrequency $f_2$is dedicated to theIEEE 802.11astandard(5150-5825 MHz).Thefigure7andfigure8show theradiation patterns forthe frequency $f_1$andthe frequency $f_2$respectively. It is seen thatthe antenna hasa gain of8.68dB atthe resonance frequencyf_1=3.4GHz, and a gain of9.7dB at thefrequencyf_2=5.167GHz.These resultsare also similarto those of theconfiguration4,thanks of the symmetrymentioned above.

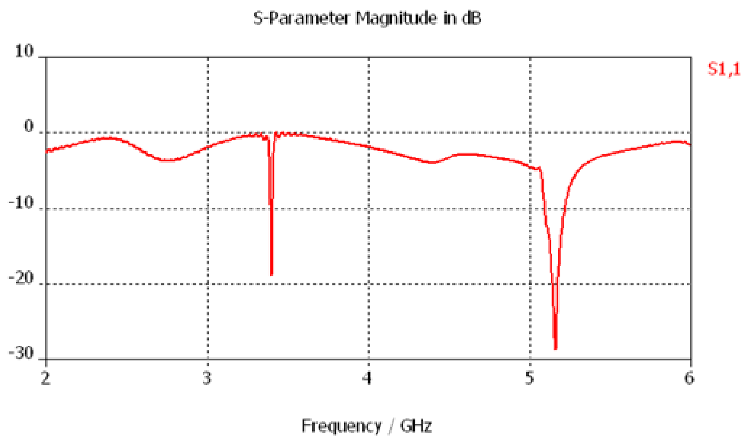

Figure 6: Return lossof theantenna for configuration 3

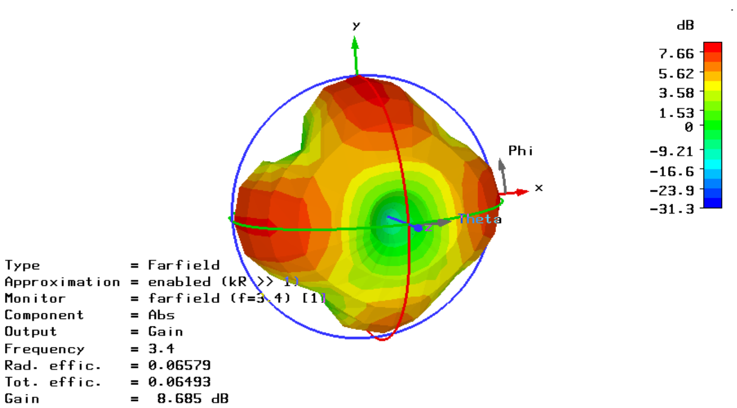

Figure 7: The gain of theantennaat the frequency f_1=5.18GHz for configuration 3

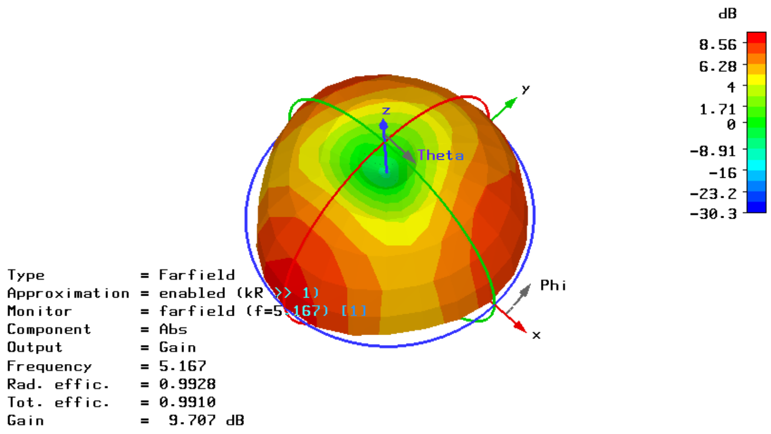

Figure 8: The gain of theantennaat the frequency f_2= 5.167GHz for configuration 3.

For the configuration5,theshape of the antennawill be as illustratedin figure9and simulatedreturn lossresultsare presentedin figure10.Note thatthe antennaisalso in this caseadualfrequency spectrumbandaround the twofrequenciesf'$_1$=3.39GHzandf'$_2$=5.06GHz.About figures11and12, theantenna has a gainwhichis10.51dB atf'$_1$=3.39GHz and11.54dB atf'$_2$=5.06GHz.

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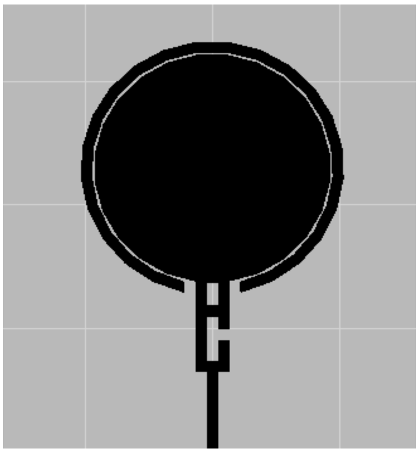

Figure 9: Antenna geometry for configuration 5

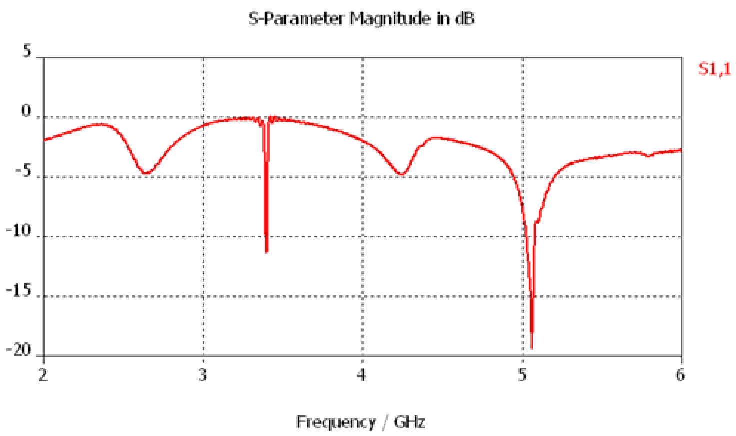

Figure 10: Return lossof theantenna for configuration 5

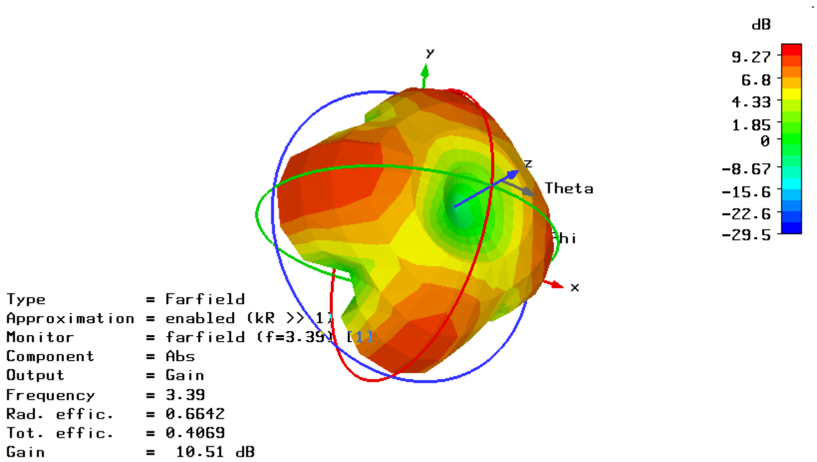

Figure 11: The gain of theantennaat the frequency f'$_1$= 3.39 GHz for configuration 5.

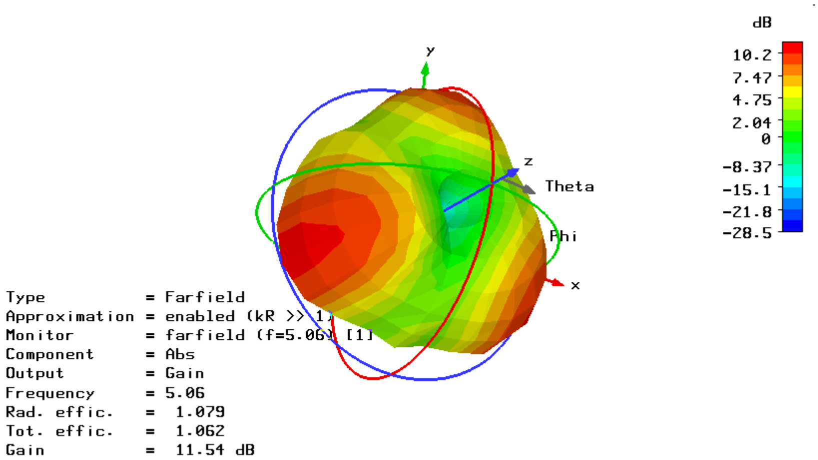

Figure 12: The gain of theantennaat the frequency f'$_2$= 5.06 GHz for configuration 5.

As regards the configuration6, the antenna takesthe form shownin figure13, and the simulations results ofreturn lossare illustratedin figure14. The antennain this case isoperatingin a90MHz bandwidthwith twopeaks:f"$_1$=4.11GHzandf"$_2$= 4.16GHz. Thesetwo frequenciesare dedicatedtoC-band.Concerningthe corresponding gainsinthesetwo resonant frequencies, theyare shownrespectivelybythefigures15and16.The gain of theantennaat the frequencyf"$_1$equal to10.28dB, and at f"$_2$frequency equal to10.21dB.

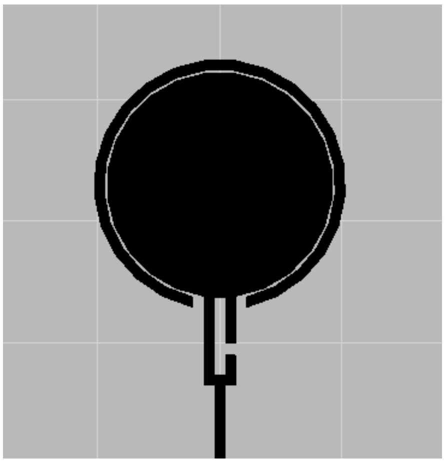

Figure 13: Antenna geometry for configuration 6

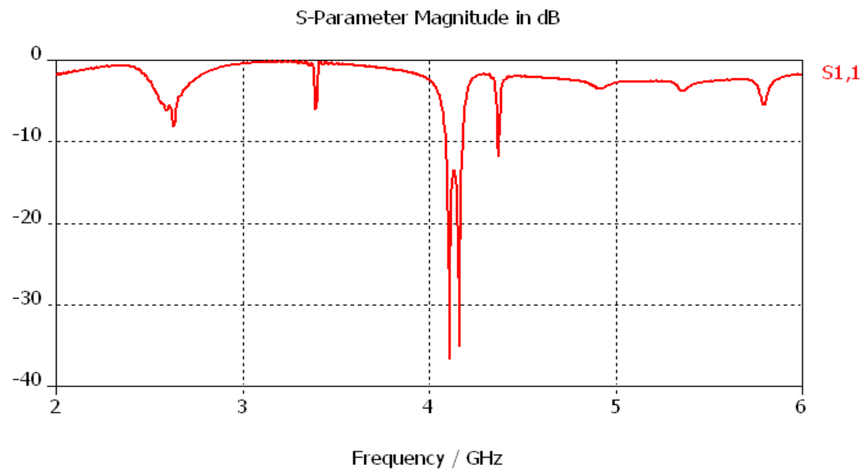

Figure 14:Return lossof theantenna for configuration 6

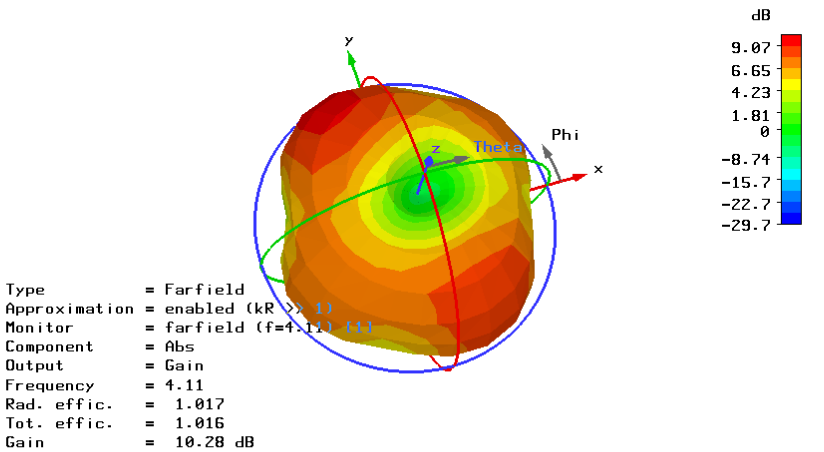

Figure 15:The gain of theantennaat the frequency f’’$_1$= 4.11 GHz for configuration 6.

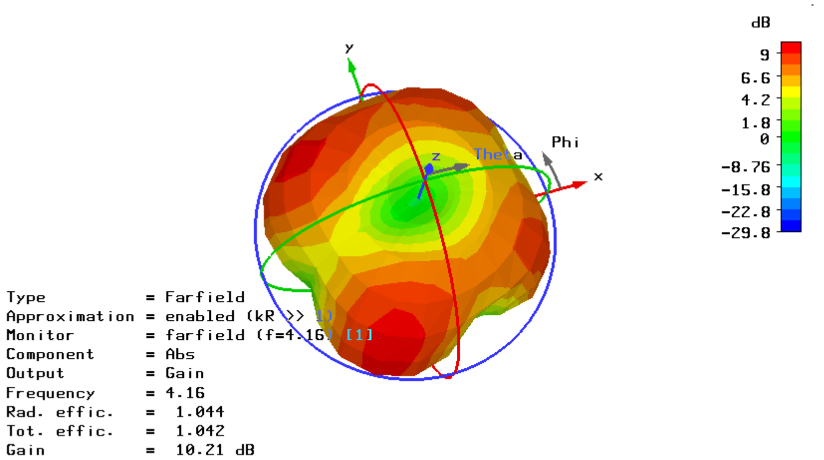

Figure 16: The gain of theantennaat the frequency f’’$_2$= 4.16 GHz for configuration 6.

V. Conclusion

The design andsimulation of are configurable antennafrequencyis presented.Thisantenna hasaconsiderablylarge gaincompared toprintedpatchantennas. The simulated results ofReturn lossare illustratedand interpreted.Theproposedantennapresentsimportance on IEEE 802.11astandard, the S band(which ismostly used byweather radarand somesatellites communications) andC band(which is useful for weather radar).

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