Multiband MIMO Antenna by Mutually Coupling Non radiating Edges for 4G

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Multiband MIMOAntenna by Mutually Coupling Non-radiating Edges for 4G

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Abstract

Wirelesslocalareanetwork (WLAN) technologies havebeenunifiedbymeansofmultiband antenna.The challengeis to optimizethe size of the multiband antennaforitsinclusioninasmallhandheld terminal,whilemaintaining itsperformance characteristics.The challenge is further intensified as the multiple element antenna(MEA) are considered for compactdiversityand multipleinput multipleoutput (MIMO)terminaldevices. MIMOisconsidered asa solution toovercome theproblems oflowdataratesand maximizethechannelbandwidth. Moreover,italso addresses theproblemsofmultipath fading. Unfortunately,inrealandrobustenvironmentsthereis atrade-off between number ofMEAandMIMO performance. Thisisprimarilyduetothemutual couplingbetween theantennas.Theproposed structure coversthe 3G/4Grangeof2.1GHzand 2.5GHz.The threeconfigurationshavemultibandbandswithVSWR≤2areintherangeof950-2100MHz and2.4-3.7GHz. Thesimulated andthemeasured resultsareinagood agreement.

Keywords:Multiband;rectangularmicrostripantenna;gapcoupledrectangular microstripantenna, multiple resonators;parasiticresonator;, multibandMIMO antenna..

1.Introduction

MIMO(MultipleInputMultipleOutput)systemsare provedtoachievehigherdataratesbydeployingmultiple antennasatboththetransmitterandreceiverinsteadofa single antenna at the respective locations without using additionalbandwidthoran increasein therespectivepower. MIMOsystemsareverymuchsuitableforthepresentand emergingcommunicationsystemslikeWi-Fi,3Gand4G etc.However,whenmultipleantennasareinvolvedatcloser spacing the technical challenges are more pronounced comparedtoaSISO(SingleInputSingleOutput)system. Hence, the basic aim of MIMO antenna design is to minimizethecorrelationbetweenthemultiplesignals.The parameter that describes the correlation between the received signals in highly diversified environments is mutualcoupling,whichdeterioratestheperformanceofthe communicationsystem.Bycalculatingthemutualcoupling, onecananalyzetheelectromagneticfieldinteractionsthat exist between the elements of a MIMO system. Highermutualcouplingreducesthe antennaefficiencyandthus minimizesthesystem channelcapacity.Theimpactof mutualcouplingonthecapacity ofMIMOsystemsis studied.Themutualcouplingmainlydependsonthedistance betweentheelementsofanantennaarray. Byincreasing the distancebetween theelements oftheantennas,themutual couplingcanbe reduced.However,the distance betweenthe antennas cannotbemaintained toolarge,sinceMIMO systemshavetheirmajorapplications inMobileterminals, laptops, andWLANAccess Points Wireless communications. Patchantennasareverymuchcompatible withMIMOsystemsbecausetheyareeasiertofabricateand inexpensive, low in weight, planar or conformal layout. Patchantennascanbedesignedinanydesiredshapeand thisflexibilityinpatchantennadesignmakesitpreferable formodernwirelesscommunications. However,thepatch antennas sufferfromnarrow bandwidth,whichlimitstheir applicationinmoderncommunication systemslikeMIMO systems[1].

Multiple-inputmultiple-output (MIMO)technology, which is the key technology for the fourth generation mobilecommunication system(4G),haspotentiality of increasing capacitywithoutsacrificing additionalspectrum.

Multipleantennascloselyspacedwillcausesstrongmutualcouplingwhichdeterioratestheperformanceofthe MIMOsystem.Somevariousmethods havebeenpresented to increasetheisolationofMIMOantenna, such asslitsetched intothegroundplane[2],anLC-basedbranch-line hybrid coupler[3]andneutralizationline[4,5].Unfortunately,all ofthoseMIMOantennascould notcover the operationband ofmobilephoneforthethirdgeneration mobile communication system(3G).Inordertogettheoperation bandofmobile phonefor3Gandtakeadvantage ofthe MIMOtechnology,a multibandantenna,compactand a wideband MIMOantenna,ispresented, andthisantennais suitableformobilephone of3Gorfourthgenerationmobile phone (4G). A single RMSA is splitted into smaller elementsalongthewidth.Oneofthesmallerelementsisfed usingco-axial probewhileothersarecoupledtoit’snon-radiating edge[6,7].Thelengthsandthegapbetween the elementsisvariedtoincreasetheseparation between differentresonances toobtaindualandtriplefrequency operation.Configurations consisting amaximumtilltwelve stripshavebeeninvestigated. Frequency ratioincreases withincreaseinnumberofelementsinthesystem.When thedifference between thelengthsofthedifferentelements islargethentheseparationbetweentheresonancesismoreyieldinglargerfrequency ratio,butthebandwidths atthe individualfrequency bandsislessasmatchingisnot optimum. As the number of elements increase, the flexibilityformultifrequency operationalsoincreases,as therearemorenumberofelements thatarevariedtoobtain thedesiredperformance [8,9].Configuration from ten elements to twelve elements have been obtained which yieldsfourandfiveindividualfrequency bandswith sufficientseparation betweentheindividual bandshasbeen presentedinthispaper.Also,asbandwidth increaseswith increaseinnumberofelements,considerably wide bandwidth canbeobtainedatindividualresonance frequencies. However,asthewidthofindividualelement decreaseswith theincreaseinnumber ofelements, gainand efficiency alsodecrease[10].Sothesegapcoupled configurations suffer from poor gain and may not be suitableforapplicationswithhighgainrequirements. So, techniquescan be devised to improvethe gain of these configurations[11,12].

2. MultibandConfiguration

Withincreaseinnumberofelements, numberofgaps increase,andsotheiroptimizationbecomesquitetedious. Sodetailedobservations fortheeffectofgapsizeon frequency ratioaremade,whichmayserveasanaidfor effectivedesignofthesegapcoupledconfigurations. As regardstheeffectoffeedprobe diameter, ithasbeen observedthatwith increaseinfeedprobe diameter, the bandwidth increases butdoesnothavesignificanteffecton thefrequency ratio.Thisisbecausetheinductanceofprobe decreaseswithincreaseindiameter, therebyyielding higher bandwidth dueimprovedmatching.Also,ithasbeenfound that the bandwidthincreases withincreaseinlosstangent,at thecostofefficiency.Theradiation patternofthese configurations hasalsobeenstudiedindetail.Ithasbeen foundthatradiation patternofconfigurations withodd numberofelements ismoreregular,ascomparedtothe configurations withevennumberofelementsandremains moreorlessinbroadsidedirectionatallthefrequencies.

TheFourBandconfiguration isobtainedwithten elementswithfrequenciesaslistedinTableI.

TABLEI FOURFREQUENCY RESPONSEOF CONFIGURATIONWITHTEN STRIPS (Єr = 4.3 ,h=1.59mm ,tanδ=0.02 ,W=4.18mm)

Lengths L (mm)	***Gaps,S (mm)***	***x (mm)***	fr1(GHz)	2.072
			RL1(dB)	-17.8
L_1=31 L_2=33 L_3=34 L_4= 32 L_5(fed)=33 L_6= 36 L_7=34 L_8= 33 L_9= 31 L_{10}=32	S_1=0.575 S_2=0.425 S_3=0.575 S_4=0.2 S_5=0.2 S_6=0.45 S_7=0.45 S_8=0.475 S_9=0.475	8	BW1(MHz)	61
			fr2(GHz)	2.304
			RL2(dB)	-26.5
			BW2(MHz)	60
			fr3(GHz)	2.456
			RL3(dB)	-30.59
			BW3(MHz)	81
			fr4(GHz)	2.637
			RL4(dB)	-16.08
			BW4(MHz)	52

thefrequencies areabletobeintherangefor3Gand4G mobileapplications.Alsothemutualcoupling between the frequenciesisreducedasshowninFig.1.The bandwidths fortheindividualfrequency bandsisalmostsamewith considerable ioslationbetween theindividualfrequency bandsisachievedwiththisconfiguration. TheFirst frequency isat 2.072GHz and the fourth at 2.637GHz.

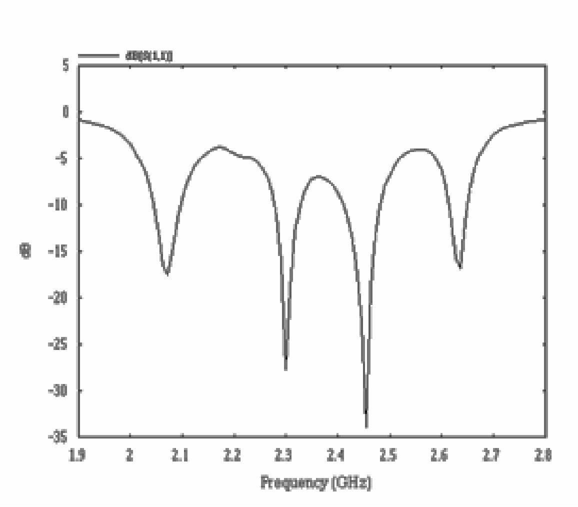

Figure 1.Four frequencyresponse of tenpatchconfigurationS11 plot

Now thesingleelementissplittedintoelevenelementsthe widthsoftheindividual elementisagainkeptconstantand thelength isvariedalongwiththegapcoupling. Theresults areillustratedinTableII.Thefirstresonantfrequency is sameasthatofthetenbandconfiguration butthefourth individualfrequencyhaschangedto2.645GHz. The bandwidths arealsoimprovedforthethirdfrequency band whereas it is same for the fourth frequencyband. This configuration hasbeenfabricated usingFR4substratewith parameters,h= 1.59mm,Єr= 4.3,andtanδ= 0.02.

TABLEII-FOURFREQUENCY RESPONSEOF CONFIGURATIONWITH ELEVENSTRIPS(Єr = 4.3,h= 1.59mm, tanδ=0.02,W=4.18mm)

Lengths L (mm)	***Gaps,S (mm)***	***X (mm)***	fr1(GHz)	2.027
			RL1(dB)	-18.62
L_1=30 L_2=34 L_3=36 L_4= 36 L_5=36 $L_{6(fed)}$=33 L_7=31 L_8= 30 L_9= 32 L_{10}=34 L_{11}=31	S_1=1.475 S_2=0.35 S_3=0.7 S_4=1.05 S_5=0.2 S_6=0.2 S_7=1.05 S_8=0.7 S_9=1.225 S_{10}=1	9	BW1(MHz)	49
			fr2(GHz)	2.227
			RL2(dB)	-12.87
			BW2(MHz)	64
			fr3(GHz)	2.364
			RL3(dB)	-16.47
			BW3(MHz)	112
			fr4(GHz)	2.473
			RL4(dB)	-24.74
			BW4(MHz)	73
			fr5(GHz)	2.645
			RL5(dB)	-17.21
			BW5(MHz)	52

Fig.2 showstheexperimentalandsimulatedresultsofreturn lossindBversesfrequencyinGHzforelevenelements that yieldfourindividualfrequency bandswithincreased isolationbetweentheindividualfrequencybands.

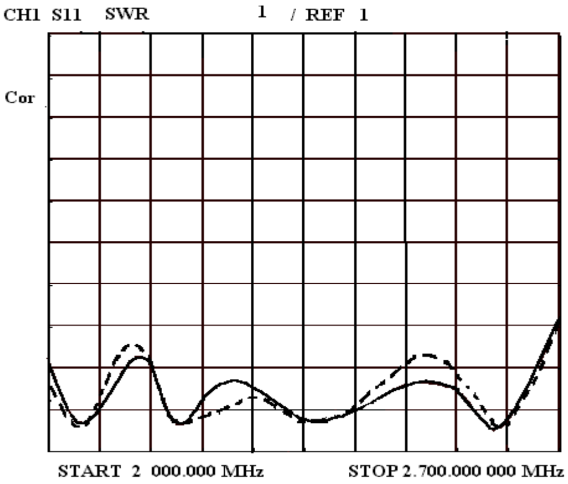

Figure2.Comparativeplotfor measured ()andsimulated(---------) VSWRforelevenpatch configuration.

Thefurtheraddition fortwelfthelementconsiderably increases the separation between individual frequency bands,Fig.3showsthecomparative plotofreturnlossfor elevenand twelvestrip configurationfor four frequency bandsoperation.Thefourthfrequency bandobtainedwith twelveelements is2.88GHz.Theeleven andtwelve patch configuration showsthefourfrequencybandoperationbut duetoincreaseinelementshowsthefrequency separation ratioforfirsttwofrequencies witheleven patches is1.07 whereasitis1.09fortwelvepatches.

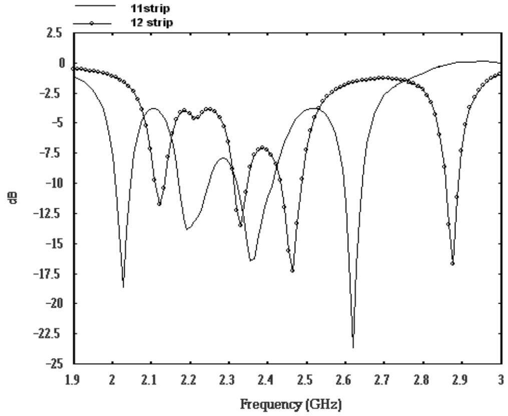

Figure3. Comparative plotofreturnlossforelevenand twelvestrip configurationfor four frequencybands operation.

Forseparation betweensecondandthirdfrequencybandsis sameforboththeconfigurations. Nowtheseparation betweenthethirdandfourthfrequency bandhasdrastically increased with twelve patches as compared to eleven patchesfrom1.10to 1.16.

The optimizationforfive frequencybandswithten and twelveelementswasunsuccessful. Thefiveindividual frequency bands wereachievedonlywithelevenelements configuration.Theoptimizationforfivefrequencybands didnotincreasedthefrequency ratio.Butthisconfiguration hasfivedistinctiveindividual frequencieswithreturnloss thatisacceptable. Withmanyevennumberofelements the optimization isnotpossibleasthedistributionofelements withrespecttothecentrefeedelementisunequal sothe resonantfrequencies arenotoptimizedwithconsiderable separation betweentheindividualfrequencies. Theresults forfivefrequencies withelevenelements isspecifiedin Table III. The optimization with further addition of elementsdonotshowimprovement intheincreaseof numberoffrequency bandsduetoincreaseofmutual coupling between theindividual elements. Mutualcoupling hasbeenreducedintheaboveconfiguration andthusthe multibandsweresuccessfullysimulatedandmeasured.

TABLEIII-FIVE FREQUENCY RESPONSEOF CONFIGURATIONWITH ELEVENSTRIPS(Єr = 4.3 ,h=1.59mm , tanδ=0.02,W=4.18mm)

Lengths L (mm)	***Gaps,S (mm)***	***x (mm)***	fr1(GHz)	2.027
			RL1(dB)	-18.62
L_1=30 L_2=34 L_3=36 L_4= 36 L_5=36 $L_{6(fed)}$=33 L_7=31 L_8= 30 L_9= 32 L_{10}=34 L_{11}=31	S_1=1.475 S_2=0.35 S_3=0.7 S_4=1.05 S_5=0.2 S_6=0.2 S_7=1.05 S_8=0.7 S_9=1.225 S_{10}=1	9	BW1(MHz)	49
			fr2(GHz)	2.227
			RL2(dB)	-12.87
			BW2(MHz)	64
			fr3(GHz)	2.364
			RL3(dB)	-16.47
			BW3(MHz)	112
			fr4(GHz)	2.473
			RL4(dB)	-24.74
			BW4(MHz)	73
			fr5(GHz)	2.645
			RL5(dB)	-17.21
			BW5(MHz)	52

3. Conclusion

Inthispapermultiplefrequencies uptofivebandsare obtainedbydividing asingleresonatoralongthewidthso thatwidthofeachelementisequal,thenthelengthsandgap between theindividual elements isvaried.Themutual couplingbetweentheelementsisreducedthat yield multiple frequencies. Butthereislimitation onthenumberof elementsasthemutualcouplingincreasesthatcombinesthe individualfrequency bands.Theconfigurationwithten, eleven and twelve structure covers the 3G/4G range of2.1GHzand2.5GHz.Theseparation between theindividual frequency Thethreeconfigurations havemultibandbands withVSWR≤2areintherangeof950-2100MHzand2.4-3.7GHz.Thesecharacteristicsare wellsuitedfor all 4G MIMOapplications.

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