International Journal of Engineering Research and Application www.ijera.com ISSN : 2248-9622, Vol. 6, Issue 10, (Part -5) October 2016, pp.63-68

RESEARCH ARTICLE OPEN ACCESS

An Omnidirectional Circularly Polarized Antenna with Dual-Band and Dual-Sense type

Dr. Pravat Kumar Subudhi [1], Ipsita Samal [2]

[1] *Professor, Department of Electronics and Communication Engineering, Gandhi Institute For Technology (GIFT), Bhubaneswar*

[2] *Assistant Professor, Department of Electronics and Communication Engineering, Gandhi Engineering College, Bhubaneswar*

ABSTRACT—A circularly polarized (CP) dielectric resonator an- tenna (DRA) loadedwithamodified circularpatchis proposed for dual-band applications. The antenna is centrally fed by a probe, giving omnidirectional patterns with different senses of circular polarization in two bands. It is observed that the lower and upper bands are controlled by the patch and dielectric resonator (DR), respectively, making design of the dual-band antenna very easy. Fordemonstration,aprototypehasbeendesigned,fabricated,and measured. The antenna features 10-dB impedance bandwidths of 2.64%and18.03%and3-dBaxial-ratio(AR)bandwidthsof3.16% and 5.06% in lower and upper frequency bands,respectively.

Index Terms—Circularly polarized antenna, cylindrical dielec- tric resonator antenna, dual-band antenna, omnidirectional an- tenna, patch antenna.

I. INTRODUCTION

CIRCULARLYpolarized(CP)antennasare desirableincertainapplicationsduetotheirimprovedimmunitytomultipath distortion and polarization mismatchlosses.Today,the rapid development of wirelesscommunicationssystemshas increased the demand for compact dual-bandormulti-band antennas. Therefore, various dual-band CPantennashavebeen studied extensively in recent years [1]–[6].Forexample,single-layerorstacked-patchdualbandCPantennashavebeendemonstratedin [1]and[2].Aringslotandacrossslotwereutilizedtodesignadualband CPslotantenna[3].AdualbandCPzonalslot/dielectricresonator(DR)hybridantennawasobtainedby placing a rectangular dielectric resonatorantenna(DRA)ontopofanLprobefedslotted cavity[4].However,alltheaboveantennas have unidirectionalCPradiationpatterns.Recently,adual-band omnidirectional CP antenna was firstdevelopedbyusingacircularmushroomstructure[7].Thedesignutilizesthezeroth- and thefirst-order resonancemodesofepsilonnegativetransmissionlines,exhibitinggoodomnidirectionalpatternand

ManuscriptreceivedFebruary26,2014;acceptedMarch26,2014.Dateof publicationApril02,2014;dateofcurrentversionApril21,2014.ThisworkwassupportedbytheNationalNaturalScienceFoundationofChinaunderGrant No. 61302001, the Research Fund for the Doctoral Program of Higher Edu-cationofChinaunderGrantNo.20130172120046,andtheFundamentalResearchFundsfortheCentralUniversitiesunderGrantNo.2013ZM0077.(Cor- responding author: Y. M.Pan.)axial ratio (AR) performance. However, the impedanceband-widthsareverynarrow,0.5% only.Anotherbacktobackmicrostrippatchantennahasbeenshowntoprovideomnidirectional CPwaveovertwofrequencybands[8].Slotswithlumped capacitor loaded were introduced into the patches, enabling the use of $\mathrm{TM}_{200}$and TM_{020}modes, which are responsible for the two bands operation. The impedance bandwidths of both bands are relatively wider, given by 1.5%. However, due to the asymmetry of the structure, the omnidirectionality is unsatisfying, and an AR fluctuation of 4.1 dB is obtained in the -plane. Moreover, since two modes of a single radiating element were used, the frequencies of two bands cannot be controlled independently for both designs in [7] and[8].

A single-band probe-fed omnidirectional CP DRA that has a modified Alford loop loaded on its top was investigated in [9]. The DRA is excited in its TM_{011}mode, radiating like a vertically polarized electric monopole. The modified Alford loopthatcomprisesacentralcircularpatchandcurvedbranches provides an equivalent horizontally polarized magnetic dipole mode. Omnidirectional CP fields are obtainedwhenthetwoorthogonallypolarizedfieldsareequalinamplitudewithphasequadrature.Sincethepatchwithproperdimensionscanalsoact well as a good radiating element, it has been frequently used together with DRA to design wideband or dual-band broadside linearlypolarized(LP)antennas[10].Inthisletter,adual-band hybrid DRA/patch omnidirectional CP antenna is proposed for the first time. It has been found that the patch and the DRA are responsible for the lower and upper bands, respectively. The two bands radiate CP fields with different senses. To demon- strate the idea, a dual-band (1.9/2.4-GHz) omnidirectional cylindrical DRA was designed. Its reflection coefficient, AR, radiation pattern, and antenna gain were simulated by ANSYS HFSS and verified bymeasurements.

I. ANTENNACONFIGURATION

Fig. 1 shows configuration of the proposed dual-band dual- sense omnidirectional CP antenna. The cylindrical DRA has a radius of a, a height of h, and a relative permittivityof ε_r. It is centrally fed by a coaxial probeoflengthandradius. Amodifiedcircularpatchisl oadedontopoftheDRA.Thecentralpatchhasaradiusof Therearefouridenticalcurvedbranches extended from the circular patch. The width, radial length, and arclengthofeachbrancharegivenby w, l_1, and l_2 ,respectively. The patch not only functions as a polarizer that converts the omnidirectional LP fields of DRA mode into CP fields, but it also provides another resonance mode torealizeadualbandoperation.WithreferencetoFig.1,t hesearcshapedbranchesareorientedinacounterclock wisedirectiontogenerateright- hand circularly polarized (RHCP) fields for lower (patch) band and left-hand CP (LHCP) fields for upper (DRA) band. Fields with reversed polarizations will be obtained when the branches are oriented in a clockwise direction.

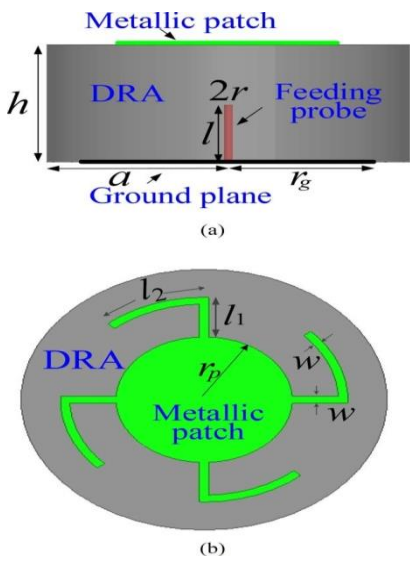

Fig. 1. Configuration of the dual-band dual-sense omnidirectional CP DRA/ patch hybrid antenna. (a) Front view. (b) Top view.

II. PARAMETRIC STUDY AND DISCUSSION

To characterize the proposed dual-bandomnidirectionalCP antenna, a parametric study of various design parameters was carried out using HFSS. The effect of DRA dimensions on the antenna performance is studied first. Fig. 2 shows the simulatedreflectioncoefficients[Fig.2(a)]andARs[Fig.2(b)] as a function of frequency for different DRA radii. It can be seen from the figure that when a varies from 28 to 32 mm, the impedance and AR change only slightly in the lower band, but they change significantly in the upper band. The results show that the upper band is mainly caused by the DRA, whereas the lower band is mainly caused by the patch. With reference to the figure, both upper impedance and AR passbands shift downward as increases, which is reasonable since a larger DR always has a lower resonance frequency. The effects of using different height are similar as that for , the results are thus not shown here forbrevity. Fig. 3 shows the simulated reflection coefficients[Fig. 3(a)]and ARs [Fig. 3(b)] for different patchradii.Asexpected,bothimpedanceand ARaremoresensitivetothevariationofin the lower frequency $< w < 2$) rangethanfortheupperfrequencyrange.Also,itwasfo undthatlargerpatchhasalowerresonancefrequency.T heeffectsofradialandarclengthsoftheextendedbranch esontheantennaperformancearequitesimilartothat coefficient. (b) AR. of the patch radii, again verifying that the lower mode is pri- marily associated with the patch. The effects of width of the branches have also been studied. It was found that affects bothlowerandupperbandssignificantly,andathinbran chwith small w (1mm mm is preferable for the genera- tion of CP fields. These results are, however, not shown here forbrevity.

Finally, the effects of the probe length on the reflection co- efficient and AR are investigated in Fig. 4. With reference to Fig. 4(a), asincreases from 10.1 to 14.1 mm, the input imped-ancesofbothbandschangesignificantly,butthecorrespondingresonancefrequenciesremainthesame,showingthatthemodes arenotprovidedbytheprobe.Also,itwasfoundthatthe ARis insensitive to the probe length. Therefore, the matching can be done by adjusting after the AR isoptimized.

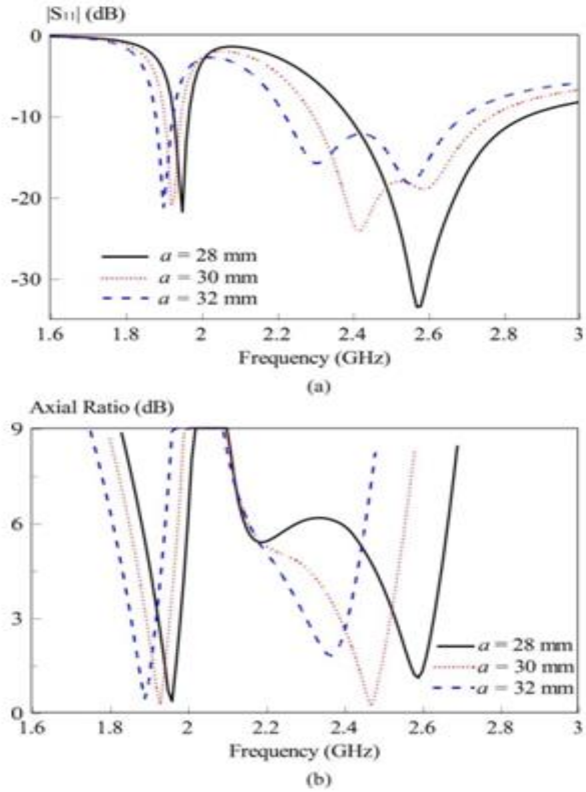

Fig.2.SimulatedreflectioncoefficientandARofthedualbanddualsenseomnidirectionalCPDRA/patchhybridantenna asafunctionoffrequencyfordifferent DRAradiiof, 30, and 32 mm. Other parametersarechosenas mm, , mm, mm, mm,mm, mm, mm,and mm. (a)Reflection

III. SIMULATED AND MEASURED RESULTS

To verify the design, a CP DRA/Patchhybridantennacovering the 1.9/2.4-GHz bands was fabricatedandtested.Theparametersoftheprototypearegivenby mm, mm,,mm,mm,

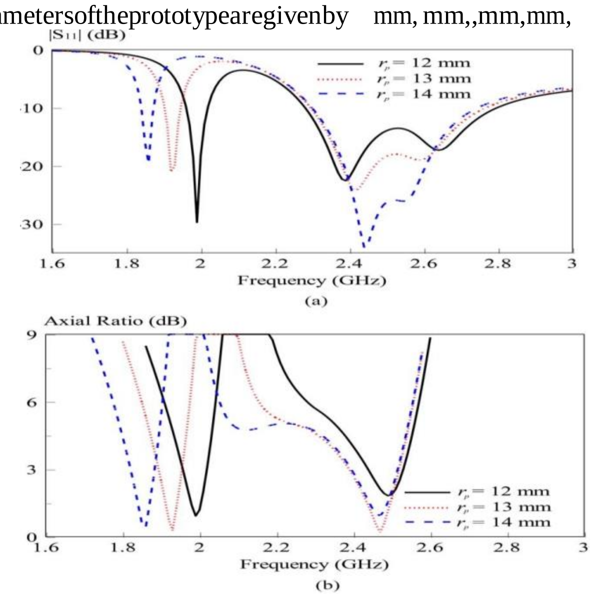

Fig. 3. Simulated reflection coefficient and AR of the dual-band dual-sense omnidirectional CP DRA/patch hybrid antenna as a function of frequency for different patchradiiof $r_p = 12$,13,and14mm.Otherparametersarethesame as inFig. 2. (a) Reflection coefficient. (b)AR.

$= 8.2$ mm, mm, $= 15.7$ mm, $l = 12.1$ mm and mm $r = 10.6$ In this letter, the reflection coefficient was measured using an HP8510C network analyzer, whereas other measuredresultswereobtainedusingaSatimoStartlab System.

Fig.5showsthesimulatedandmeasuredreflectioncoefficients of the prototype. Two passbandscan be observed $\theta = 90°$ at $= 0°$ 1.93 and2.5GHz,correspondingtothepatch(TM_{02}) andDRA(TM_{011})modes, respectively. With reference to the figure, the measured 10-dBimpedancebandwidths $(|S_{11}| < -10$ dB$)$ of the lower and upper bands are 2.64% (1.87–1.92 GHz) and 18.03% (2.22–2.66 GHz), agreeing reasonably well with the simulated values of 2.60% (1.90–1.95 GHz) and 18.18% (2.30–2.76GHz).Therelativelylargerdiscrepancyintheupper band is caused by the measurement error of DR permittivity. The bandwidth of patch mode is much narrower than that of the DRA mode, which is to beexpected.

Fig. 6 shows the simulated and measured ARs of the DRA/ patch hybridantennaat , ϕ. Again, reasonable agreement between the simulated and measured results is ob- tained, with the discrepancy caused by experiment tolerances and imperfections. The measured 3-dB AR bandwidths of the lower and upper bands are 3.16% (1.87–1.93 GHz) and 5.06%(2.312.43GHz),respectively.TheARwasalsosimulatedat

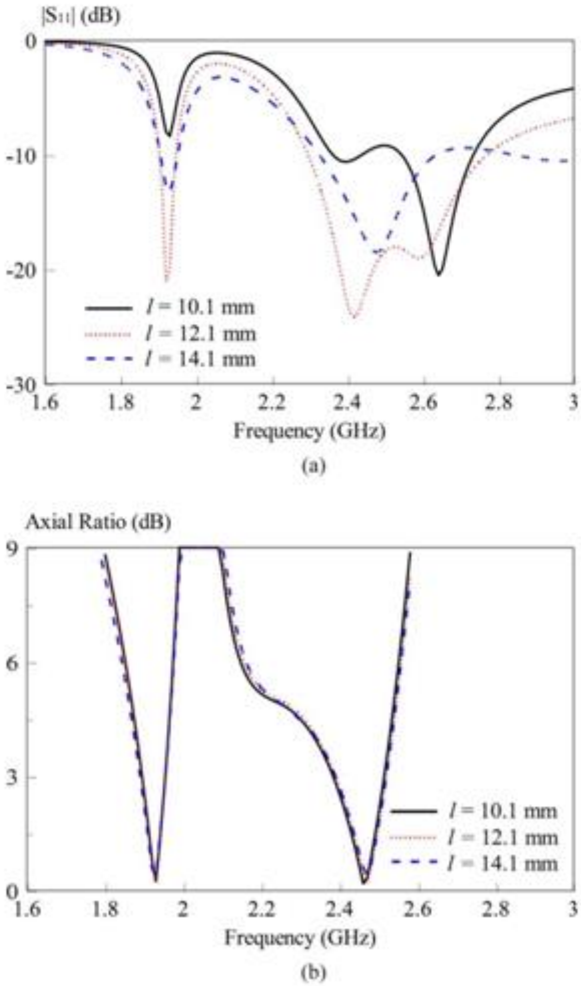

Fig**. 4.**Simulated reflection coefficient and AR of the dual-band dual-sense omnidirectional CP DRA/patch hybrid antenna as a function of frequency for different probelengthsof , 12.1, and 14.1 mm. Other parameters are the same as in Fig. 2. (a) Reflection coefficient. (b)AR.

$l = 10.1$

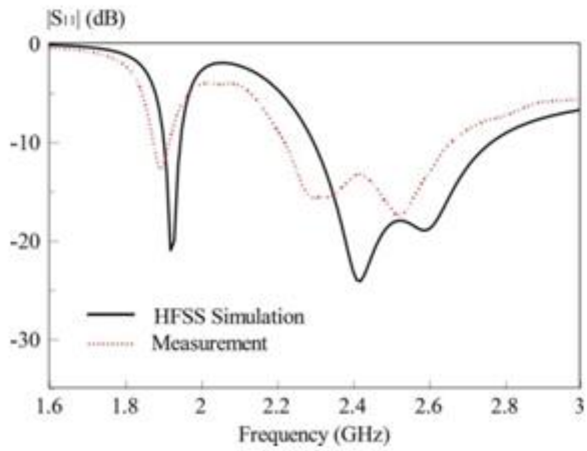

Fig. 5. Simulated and measured reflection coefficients ofthedual-banddual-sense omnidirectional CP DRA/patchhybridantenna: $a = 30$ mm, $l = 25$ mm, $l_p = 6.85$ mm, $r_p = 1.3$ mm, $w = 1.4$ mm, $l_1 = 8.2$ mm, $l_2 = 15.7$ mm, $l = 12.1$ mm, $r = 0.63$ mm, and $r_g = 27$ mm.

other values of ϕ with $\theta = 90°$, and a small AR variation of ~ 0.3 dB is obtained, showing that it is a good omnidirectional antenna.

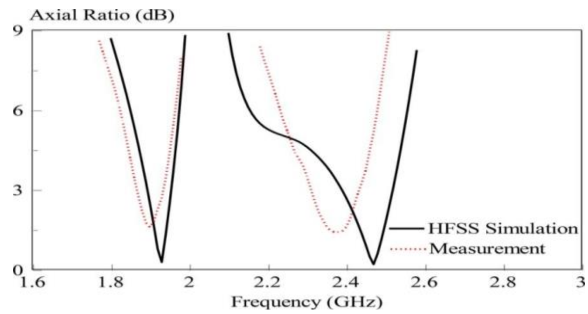

Fig. 6. Simulated and measured ARs of the dual-band dual-sense omnidirec- tional CP DRA/patch hybridantenna at $\phi = 90°$ and $\theta = 0$. The parameters are the same as in Fig.5.

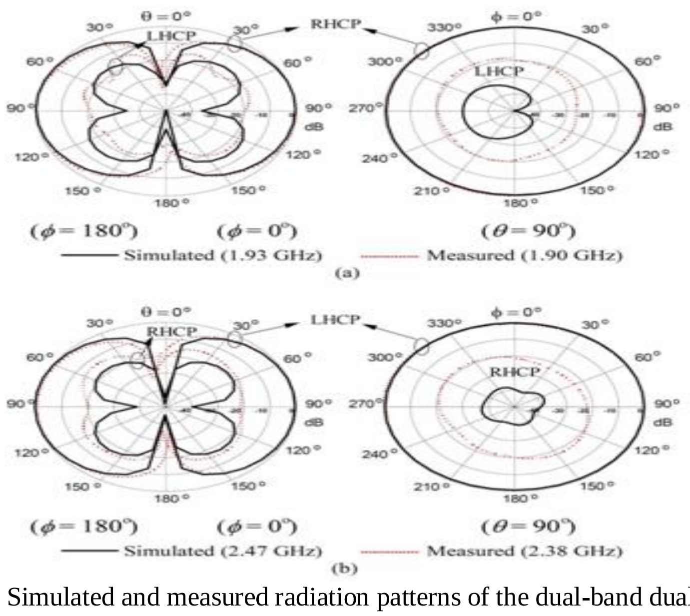

Fig. 7. Simulated and measured radiation patterns of the dual-band dual-sense omnidirectionalCPDRA/patchhybridantenna.Theparametersarethesameas in Fig.5.

Fig. 7 shows the simulated and measured radiation patterns intheelevation andazimuth $(\theta =$ planesat minimumARfrequenciesofthetwobands.Withreferencetothefigure,thelowerandupperbandsradiateRHCPandLHCP waves, respectively. Both elevation patterns have a null in the boresightdirection $(\theta = 0^\circ)$,whereastheazimuthalpatternsare omnidirectional. In each elevation plane, the copolarized fields at $\theta = 90^\circ$ are ~ 20 dB stronger than the corresponding cross- polarized counterpart. The former arealso ~ 20 dB stronger than the latter for whole azimuth planes. The antenna gain has also been studied, with the average valuesgivenby ~ 1.4 and 1dBicatthetwobands.Theresultsarealmostthesameas that for the design in[9].

IV. CONCLUSION

A dual-band omnidirectional CP DRA loaded with a patch on its top is investigated in this letter. The patch is used to convert the LP wave radiated by the DRA into a CP wave, also it provides another resonance mode to implement a dual-band operation. It is found that the two bands can almost be independently controlled by the dimensions of DR and patch, respectively, which is highly desirable. The overlapping 10-dB impedance and 3-dB AR bandwidths are 2.64% for the lower (RHCP) band and 5.06% for the upper (LHCP) band, respectively.

REFERENCES

[1] P. Nayeri, K. F. Lee, A. Z. Elsherbeni, and F. Yang, "Dual-band circularly polarized antenna using stacked patches with asymmetricUslots,"IEEEAntennasWirelessPropag.Lett.,vol.10,pp.492–495, 2011.

[2] K. L. Lau and K. M. Luk, "A wide-band circularly polarized L-probe coupledpatchantennafordual-bandoperation,"IEEETrans.Antennas Propag., vol. 53, no. 8, pp. 2636–2644, Aug.2005.

[3] Y.ShaoandZ.Y.Chen,"Adesignofdual-frequencydual-sensecircu- larly polarized slot antenna," IEEE Trans. Antennas Propag., vol. 60, no. 11, pp. 4992–4997, Nov.2012.

[4] Y. Ding, K. W. Leung, and K. M. Luk, "Compact circularly polar-izeddualbandzonal-slot/DRAhybridantennawithoutexternalground plane,"IEEETrans.AntennasPropag.,vol.59,no.6,pp.2404–2409, Jun.2011.

[5] C.H.ChenandE.K.N.Yung,"Dual-banddual-sensecircularlypolar- ized CPW-fed slot antenna with two spiral slots loaded," IEEE Trans. Antennas Propag., vol. 57, no. 6, pp. 1829–1833, Jun.2009.

[6] X. L. Bao and M. J. Ammann, "Dual-frequency dual-sense circularly polarized slot antenna fed by microstrip line," IEEE Trans. Antennas Propag., vol. 56, no. 3, pp. 645–649, Mar.2008.

[7] B. C. Park and J. H. Lee, "Dual-band omnidirectional circularly po- larized antenna using zeroth- and first-order modes," IEEE Antennas Wireless Propag. Lett., vol. 11, pp. 407–410,2012.

[8] A. Narbudowicz, X. L. Bao, and M. J. Ammann, "Dual-band omnidi-rectionalcircularlypolarizedantenna,"IEEETrans.AntennasPropag., vol. 61, no. 1, pp. 77–83, Jan.2013.

[9] W. W. Li and K. W. Leung, "Omnidirectional circularly polarized di-electric resonator antenna with Top-loaded Alford loop for pattern di- versity design," IEEE Trans. Antennas Propag., vol. 61, no. 2, pp. 563–570, Feb.2013.

[10] A. Petosa, Dielectric Resonator Antenna Handbook. Norwood, MA, USA: Artech House,2007.