TELKOMNIKA, Vol.16, No.3, June 2018, pp. 1120~1125
ISSN: 1693-6930, accredited **A** by DIKTI, Decree No: 58/DIKTI/Kep/2013
DOI: 10.12928/TELKOMNIKA.v16i3.9037

Design of Dual Band Stacked RDRA for 5G Applications

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Abstract

This paper focuses on the investigation and discussion of three different designs of stacked Rectangular Dielectric Resonator Antenna (RDRA) at dual bands of 25 GHz and 32 GHz for 5G applications. First, basic stacked RDRA. Second, basic stacked RDRA with a single notch. Third, basic stacked RDRA with double notches. All the proposed structure consists of two stacked DRA of dielectric permittivity of 10 which mounted on a Duriod dielectric substrate of dielectric permittivity of 2.2 and feed by Microstrip aperture slot feeding technique (MSA) for 50 Ω characteristic impedance. Authentication of all the proposed designs comparison is completed using 3D simulation tool by observing the performance of reflection coefficient, bandwidth, and gain. All the proposed RDRA are demonstrated simulated reflection coefficient lower than 20 dB for both bands and simulated gain more than 6 dBi. Meanwhile, for simulated bandwidth, only the proposed basic stacked RDRA with single and double notches are demonstrated simulated bandwidth more than 1 GHz, which fulfill the requirement for 5G applications.

Keywords: *5g applications, dielectric resonator antenna, microstrip aperture slot.*

1. Introduction

Over the years, evolution of mobile and wireless communication from first generation (1G) launched 1979 in Japan to the latest fourth generation Long Term Evolution standard (LTE) or 4G launched since 2009 in Norway and Sweden has been experience [1]. Similarly, such experience can be seen in crucial services such as e-learning, e-health, e-banking, infotainment services, e-industry, security and military applications, TV broadcasting, satellite remote sensing application, GPS etc. However, the need for enhanced high-speed data rates that can support multiple gigabits per second, spectral efficiency that can provide more bandwidth, support a large number of users and improved coverage triggered the research and development of the next generation mobile network (5G) [2].

In this recent years, Dielectric Resonator Antenna (DRA) has been rapidly used in RF designs due to small size, light weight, high radiation efficiency, small conductive loss, and ease of excitation and fabrication which is suitable to fulfill current needs in RF design, especially for 5G applications. Several DRA designs have been reported [3-9]. In [3], a Rectangular Dielectric Resonator Antenna (RDRA) is proposed at 28 GHz for 5G applications. The proposed RDRA using three different feeding networks in order to investigate the best feeding network for the proposed RDRA. As a result, Microstrip slot aperture feeding network is demonstrated better performance with a return loss of -38.5 dB and bandwidth of 8.9 % compared other feeds. In [4], a reflect array DRA is presented for Ka band applications at 30 GHz. From the measured results, a broadside radiation pattern is observed from the fabricated antenna with gain more than 28 dBi at 31 GHz, which suitable to use for high frequency device. Then, a wideband cylindrical DRA is proposed for mm-wave applications in [5]. The proposed antenna is targeted at two bands which are 25 GHz and 28 GHz. The measured antenna gives bandwidth more than 25 % and gains more than 8 dBi at both frequencies design. Most of the proposed RDRAs are focusing on the development of feeding networks, array, and use of different shapes to enhance the performance. However, the use of stacked RDRA with different approaches still not widely study yet.

Therefore, this paper mainly focused on the design of the three-different rectangular stacked DRAs with Microstrip slot aperture coupling in order to study the reflection coefficients, bandwidths, and gains of the proposed designs. The first design is a basic stacked RDRA. The

Received October 15, 2017; Revised March 20, 2018; Accepted April 3, 2018

second design is a basic stacked RDRA with a single notch. Then, the third design is a basic stacked RDRA with double notches. All the proposed designs basically stacked with two elements of Rectangular Dielectric Resonator (RDR) with permittivity of 10, mounted on RT Duroid 5880 with permittivity of 2.2, then feed by microstrip slot aperture coupling. The proposed DRAs are designed and simulated using 3D simulation tool for design comparisons.

2. Research Method

In this section, 3D geometry and physical dimension values for the basic stacked RDRA, basic stacked RDRA with a single notch, and basic single RDRA with double notches are presented. Note that, all the dimension values obtained in this section are calculated by using equations taken from [10-13].

2.1. Basic stacked rectangular dielectric resonator antenna

Figure 1 shows a Dual-band two element RDRA stacked with slot aperture couple feed and dielectric constant (ε_r) of 10. The RDRA is placed on RT 5880 substrate with a dielectric constant (ε_r) of 2.2 and thickness of 0.25 mm. The dimension of the substrate is 7×7 mm (W×L). The ground plane covered the rear side of the substrate with a dimension of 7×7 mm (W×L). The RDRA is having resonators of square shaped with a dimension of 4.4×4.4×3.0 mm (W×D×H) where W is the length of the DRA, D is the width of the DRA and H is the height of the DRA. The slot aperture with microstrip feeding technique is used with Width (W) of 1.25 mm, length (S) of 1.86 mm and 50 Ω line for impedance matching. Then, Table 1 summarizes all the calculated parameters values.

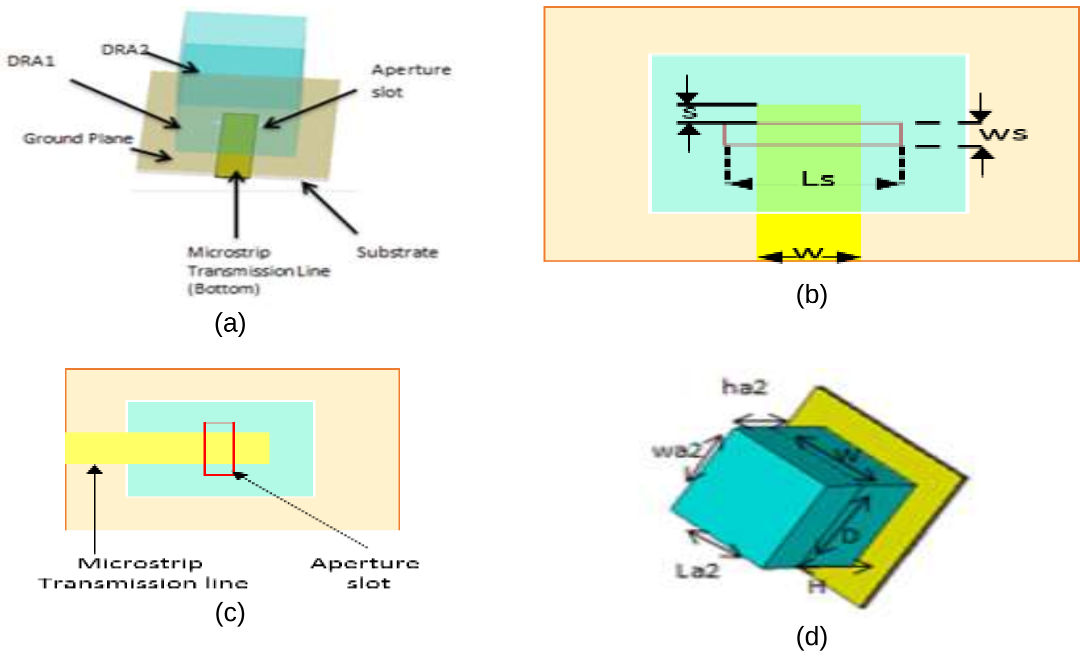

Figure 1. 3D geometry of basic stacked Rectangular Dielectric Resonator Antenna (RDRA) (a) 3D view, (b) Top view, (c) Bottom view, and (d) Cross sectional view.

Table 1. Calculated parameters values of the basic stacked RDRA

Parameters	Values (mm)	Parameters	Values (mm)
Length of DRA (W)	4.4	Width of slot (ws)	0.37
Width of DRA (D)	4.4	Length of MLIN (S)	1
Height of DRA (H)	3.0	Width of MLIN (w)	1.25
Height of substrate (H1)	0.254	Height os second DRA (h2)	2
Thickness of copper	0.035	Width of second DRA (wa2)	4.4
Length of slot (Ls)	1.86	Length of second DRA (la2)	4.4

2.2. Basic stacked rectangular dielectric resonator antenna with single notch

Figure 2 shows a dual band two elements stacked RDRA with a single notched; slot aperture couple feed and dielectric constant (εr) of 10. The RDRA is placed on RT5880 substrate with a dielectric constant (εr) of 2.2 and thickness of 0.25 mm. The dimension of the substrate is 7 x 7 mm (W x L). The ground plane covered the rear side of the substrate with a dimension of 7 x 7 mm (W x L). The RDRA is having resonators of square shaped with a dimension of 4.6 x 4.8 x 5.9 mm (W x D x H) where W is the length of the DRA, D is the width of the DRA and H is the height of the DRA. The slot aperture with Microstrip feeding technique is used with Width (W) of 1.25mm, length (S) of 1.86 mm and 50 Ω lines for impedance matching. Then, Table 2 summarizes all the calculated parameters values.

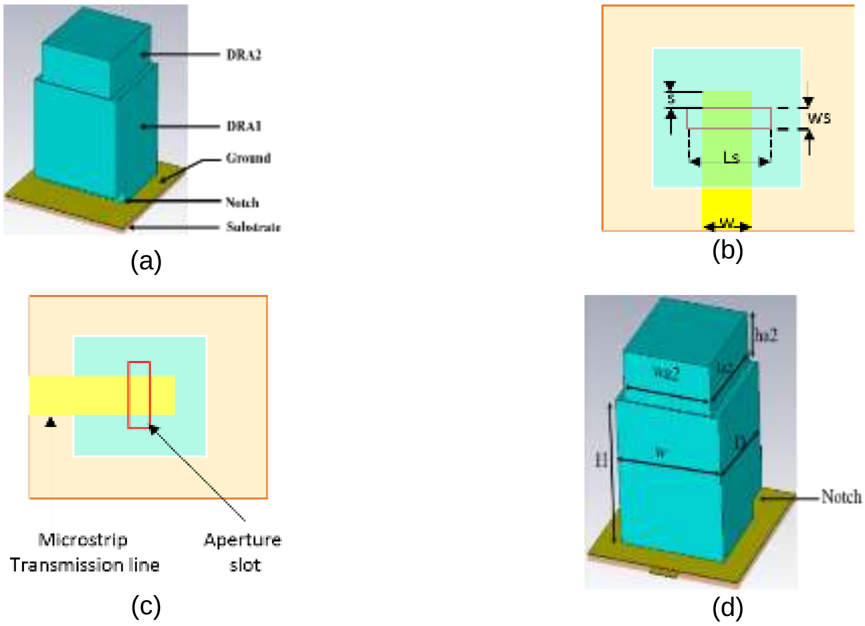

Figure 2. 3D geometry of basic stacked Rectangular Dielectric Resonator Antenna (RDRA) with single notch (a) 3D view, (b) Top view, (c) Bottom view, and (d) Cross sectional view.

Table 2. Calculated parameters values of the basic stacked RDRA with single notch

Parameters	Values/mm	Parameters	Values/mm
Length of DRA (W)	4.6	Width of slot (ws)	0.37
Width of DRA (D)	4.8	Length of MLIN (S)	1
Height of DRA (H)	5.9	Width of MLIN (w)	1.25
Height of substrate (H1)	0.254	Height os second DRA (h2)	2
Thickness of copper	0.035	Width of second DRA (wa2)	4
Length of slot (Ls)	1.86	Length of second DRA (la2)	4.4
Height of Notch (nh)	2.5	Length of Notch (nd)	1.2

2.3. Basic Stacked Rectangular Dielectric Resonator Antenna with Double Notches

Figure 3 shows a dual band two elements stacked RDRA with double notches; slot aperture couple feed and dielectric constant (εr) of 10. The RDRA is placed on RT5880 substrate with dielectric constant (εr) of 2.2 and thickness of 0.25 mm. The dimension of the substrate is 7x7 mm (WxL). The ground plane covered the rear side of the substrate with a dimension of 7x7 mm (WxL). The RDRA is having resonators of square shaped with a dimension of 4.6x4.8x5.9 mm (WxDxH) where W is the length of the DRA, D is the width of the DRA and H is the height of the DRA. The slot aperture with microstrip feeding technique is used with Width (W) of 1.25 mm, length (S) of 1.475 mm and 50Ω lines for impedance matching. Then, Table 3 summarizes all the calculated parameters values.

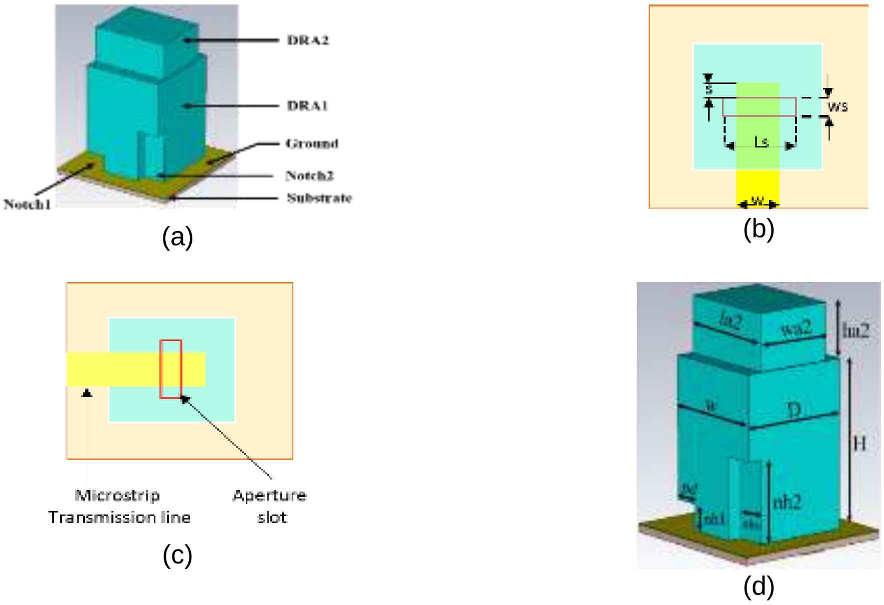

Figure 3. 3D geometry of basic stacked Rectangular Dielectric Resonator Antenna (RDRA) with double notches (a) 3D view, (b) Top view, (c) Bottom view, and (d) Cross sectional view.

Table 3. Calculated parameters values of the basic stacked RDRA with double notches.

Parameters	Values (mm)	Parameters	Values (mm)
Length of DRA (W)	4.6	Width of slot (ws)	0.37
Width of DRA (D)	4.8	Length of MLIN (S)	1
Height of DRA (H)	5.9	Width of MLIN (w)	1.25
Height of substrate (H1)	0.254	Height of second DRA (h2)	2
Thickness of copper	0.035	Width of second DRA (wa2)	3.4
Length of slot (Ls)	1.86	Length of second DRA (la2)	4.4
Height of Notch 1 (nh1)	5	Length of Notch 1 (nd)	1.2
Height of Notch 2 (nh2)	3	Length of Notch 2 (nhv)	1.72

3. Results and Analysis

This section discusses on the simulated reflection coefficient, bandwidth, and gain of the proposed three different stacked RDRAs. Figure 4 as shows the comparison of simulated reflection coefficients and bandwidth of the three-different stacked RDRAs within a range frequency studied from 22 GHz to 34 GHz. As can be seen, the simulated reflection coefficient for the basic stacked RDRA is demonstrated a value of 37 dB and 23 dB at 26.2 GHz and 32.5 GHz, respectively with 3.3 % of impedance bandwidth from 26.3 GHz to 27.2 GHz for first band and 2.5 % of impedance bandwidth from 31.8 GHz to 32.6 GHz for second band.

Then, for the basic stacked RDRA with a single notch, a simulated reflection coefficient at 24.8 GHz is obtained with a value of 29 dB with a simulated impedance bandwidth of 6.7 % from 24.5 GHz to 26.1 GHz for the first band. Meanwhile, a value of 30 dB at 31.6 GHz with a simulated impedance bandwidth of 8.0 % from 29.5 GHz to 32.0 GHz is observed for the second band. At the same time, simulated reflection coefficient for the basic stacked RDRA with double notches are 29 dB and 27 dB at 25 GHz and 31 GHz, respectively with simulated impedance bandwidth of 7.2 % from 25 GHz to 26.2 GHz for first band and bandwidth of 11.8 % from 29.9 GHz to 33.5 GHz for second band.

From these simulated results, although all the proposed RDRAs are demonstrated simulated reflection coefficients lower than 20 dB, however only the proposed design of the basic stacked RDRA with single and double notches are observed with a bandwidth more than 1 GHz. Therefore, it can be concluded that the proposed basic stacked RDRA with single and double notches are theoretically fulfilled the bandwidth requirement for 5G applications of up to 1 GHz [9]. The comparison data of simulated reflection coefficient, impedance bandwidth, and gain is summarized in Table 4.

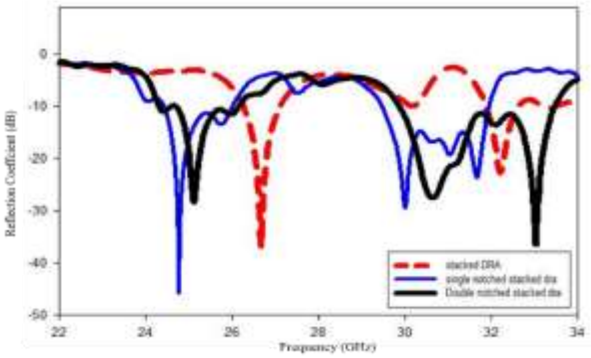

Figure 4. simulated reflection coefficients and bandwidth for three different stacked RDRAs.

The obtained simulated gains for all three different stacked RDRAs from CST software are also observed in order to have an idea on the performance of the antenna in terms of how much power the antenna can radiate or how far the antenna can radiate its power. The simulated gain for the basic stacked Rectangular DRA is 9 dBi at 26.2 GHz and 10.3 dBi at 32.5 GHz. The simulated gain for the basic stacked RDRA with a single notch is 6.5 dBi at 24.8 GHz and 8.0 dBi at 31.6 GHz. The simulated gain for the basic stacked RDRA with double notches are 7.5 dBi at 25 GHz and 9.8 dBi at 31 GHz. This shows that the basic stacked DRA with no notches has the highest gain due to its narrow bandwidth as compared to other designs.

Table 4. Comparison data of simulated reflection coefficient, impedance bandwidth, and gain.

Proposed design	Frequency (GHz)	Relection coefficient (dB)	Bandwidth (%, GHz)	Gain (dBi)	Comment
Basic stacked RDRA	26.2	37	3.3 % (26. 3 – 27.2)	9	Bandwidth does not meet the requirement for 5G applications (up to 1.0 GHz)
	32.5	23	2.5 % (31.8 – 32.6)	10.3	
Basic stacked RDRA with single notch	24.8	29	6.7 % (24.5 – 26.1)	6.5	Bandwidth has meet the requirement for 5G applications (up to 1.0 GHz)
	31.6	30	8.0 % (29.5 – 32.0)	8.3	
Basic stacked RDRA with double notches	25	29	7.2 % (25 – 26.2)	7.5	Bandwidth has meet the requirement for 5G applications (up to 1.0 GHz)
	31	27	11.8 % (29.9 – 33.5)	9.8	

4. Conclusion

Three different designs of stacked Rectangular Dielectric Resonator Antenna (RDRA) are successfully investigated at dual bands of 26 GHz and 32 GHz for 5G applications. The CST simulation showed that the basic stacked RDRA with single and double notches have a wider bandwidth more than 1 GHz at both bands. Meanwhile, the basic stacked RDRA with no notches have higher gain compared to other designs. At the same time, all the proposed RDRAs are demonstrated simulated reflection coefficients lower than 20 dB. However, only the basic stacked RDRA with single and double notches have met the requirement for 5G applications due to the bandwidth performance up to 1 GHz.

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