Dual Band Microstrip Patch Array Antenna for LTE Applications in Malaysia

A. Salisu[1,2], A. S. Hussaini[2,3,4], I.T.E. Elfergani[4], B. A. Mohammed[2], Wisdom Anuhu[3], R.A. Abd-Alhameed[2], J. Rodriguez[4,5]

[1]Department of Electrical Engineering, Modibbo Adama University of Technology, Yola
abubakarsalisu06@mautech.edu.ng

[2]University of Bradford, Bradford, BD7 1DP, UK,
{r.a.a.abd, a.s.hussaini7}@bradford.ac.uk

[3]School of Engineering, American University of Nigeria, Yola
{wisdom.anuhu, ash.hussaini}@aun.edu.ng

[4]Instituto de Telecomunicações – Aveiro, Portugal
{i.t.e.elfergani, ash, jonathan}@av.it.pt

[5]University of South Wales, Pontypridd CF37 1DL, UK
jonathan.rodriguez@southwales.ac.uk

Abstract. LTE is the latest step in the telecommunication development. The expansion of LTE is largely due to the success of the high-speed packet access and the overgrowing need for capacity. A dual band microstrip patch array antenna for LTE applications in Malaysia has been proposed. Firstly, a single element antenna is designed to resonate at 1.8GHz and 2.6GHz, and the dimensions were calculated using transmission line model. Then, to achieve higher directivity, antenna arrays with two and four number of elements have been applied. A microstrip feed line with 3dB divider is used to feed each of the elements. Simulations are been carried out using CST Microwave Studio. Subsequently, simulation results are compared and analyzed. From the results, the 4 x 1 array antenna configuration has shown the best results with directivity of 11.2dB and 12.9dB at 1.8GHz and 2.6GHz respectively.

Keywords: LTE: Long Term Evolution, CST: Computer Simulation Technology..

1 Introduction

Two different planar antennas operate with similar features, in terms of impedance matching and radiation, at two different frequencies. To obtain these, by using planar technologies is not straight forward, more especially when intrinsic structural and technological simplicity typical of patch antennas is to be considered [16]. In addition, dual frequency antennas may provide an alternative solution for high speed data application such as

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LTE application. In the following, one of the ways to improve overall gain of the dual band antenna is to use antenna array configuration. By increasing the array elements, the antenna directivity can be improved.

Microstrip patch antenna has broad practical application in wireless communication because it offers ease, lesser cost of fabrication and integration with feeding network. In microstrip antenna, rectangular, square and triangle shapes exist. For microstrip configuration, the conducting material (patch) is attached on one end of the dielectric substrate with ground plane on the backside. It can be feed by either series or corporate feeding arrangement [2].

However, the main drawback of microstrip patch antenna is that, it has very narrow bandwidth. This effects can be reduced by employing different feeding method, array configuration, ground plane, and dielectric materials [3].

Array antenna element is a collection of similar radiating element. The word 'similar radiators' means the element possess the same element, regular spacing, with the similar feeding arrangement oriented in the same direction in three dimensional space. Antenna array is generally used to direct the radiated power to the targeted angular sector [3]. Moreover, array antenna has the ability to scan antenna beam, improve its directivity and numerous important functions which could not be attained by single element. Array antenna performance can be raised by increasing the array elements. However, size, cost and complexity rise as the number of the element increased [4].

Table 1 LTE bands with their frequency allocation [8]

LTE Band Number	Allocation (MHz)
8	880 – 915
11	1427.9 - 1452.9
22	3410 – 3500
34	2010 – 2025
36	1930 – 1990
38	2570 – 2620
39	1880 – 1920

This paper initially presents an optimised rectangular microstrip patch antenna operating at a single frequency of 1.8GHz, and then obtained the second frequency 2.6GHz by introducing a slot or cut in U-shaped to one radiating edge, thereby producing an antenna operating at two different frequencies (1.8GHz and 2.6GH) respectively. This antenna is then optimised into 2x1 and 4x1 array antenna to improve the gain.

2 Design, Simulation and Fabrication

The design, simulation and fabrication results for the single element, 2 x 1 and 4 x 1 microstrip array antennas is discussed. The proposed design antenna element is analysed using computer simulation technology (CST) microwave studio 2014 software. Effect of the reflection coefficient, bandwidth, directivity and other simulation parameters was clearly been observed. Additionally, comparison between the measured and simulated results were presented.

2.1 Dual Band Microstrip Antenna

This section is to design single element dual band microstrip patch antenna. The single element consists of radiating patch, inset feed line, substrate and ground plane. Width (W), length (L), of the patch was calculated[19]. SMA connector is used to connect the inset feed line. The use of slot or cut allows a frequency ratio of 1.3 to 3 [15]. Figure 1 shows a single element dual band microstrip patch antenna resonating at 1.8GHz and 2.6GHz respectively.

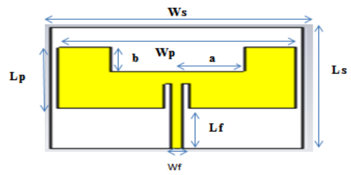

Figure 1. Single element dual band microstrip patch antenna

From Figure 1, it can be seen that U-shaped cut denoted by a and b dimensions gives the second frequency at 2.6GHz. The dimensions of the slot or cut a and b was first optimised to get a better result.

2.2 Proposed Array Antenna Structure

Dual band microstrip patch array antenna is designed in this work, starting with single element, 2 x 1 elements and finally to the 4 x 1 elements at 1.8GHz and 2.6GHz for LTE applications in Malaysia. Corporate feed with T-junction power divider is used to fed the microstrip patch array antenna. Figure 1.1, 1.2 and 1.3 show the optimized geometries of the single element, 2 x 1 elements, and 4 x 1 elements of the dual band microstrip patch array antennas respectively. Initially, single element was designed and simulated. Simulation results were then evaluated in terms of frequency of operation, radiation pattern, gain and impedance bandwidth. Then the single element was transformed to 2 x 1 dual band antenna array and finally to 4 x 1 linear arrays. After optimization, it has been observed that, the best result regarding to the element inter-spacing is found to be 72.77mm. The complete dimensions of the proposed single and 2 x1 elements dual band microstrip antenna are shown in Figure 2 and is tabulated in Table 2 and 3.

Table 2 : Design specifications and parameters of single element dual band antenna

Description	Parameter	Value (mm)
Patch width	Wp	59.28
Patch length	Lp	37.5
Substrate width	Ws	63
Substrate length	Ls	75
Feeding length	Lf	25
Feeding width	Wf	3.14

Gap width	Wg	1.7
Gap Length	Lg	15
Slot cut width	a	16.66
Slot cut horizontal	b	14.22

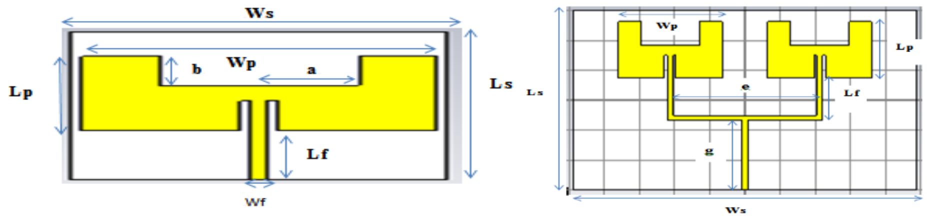

Figure 2 Geometry of single and 2 x 1 elements dual band microstrip array antenna

The single is then transformed into 2 x 1 dual band array antenna using a corporate T-junction feeding technique as shown in Figure 3. The dimensions is tabulated in Table 3.

Table 3 Design specification and parameters of 2 x 1 dual band microstrip array antenna

Description	Parameter	Value (mm)
Patch width	Wp	59
Patch length	Lp	37.5
Substrate width	Ws	195
Substrate length	Ls	120
Feeding length	Lf	25
Feeding width	Wf	3.137
Gap length	Lg	15
Slot width	a	16.66
Slot cut length	b	15.62
Element spacing	e	85
Vertical feed length	g	48
Horizontal feed length	f	3.137

The 2 x 1 dual band microstrip array antenna is then transformed into 4 x 1 dual band microstrip antenna. The new 4 x 1 array antenna configuration is shown in Figure 4 and it tabulated dimensions are presented in Table 4.

Table 4 Design specifications and parameters of 4 x 1 array antenna

Description	Parameter	Value (mm)
Patch width	Wp	59
Patch length	Lp	37.5
Substrate width	Ws	221
Substrate length	Ls	128
Feeding length	Lf	22.8
Feeding width	Wf	3.137
Gap length	Lg	15
Slot width	a	16.66
Slot cut length	b	15.62
Element spacing	e	83
Vertical feed length	g	44.3
Horizontal feed length	f	3.137

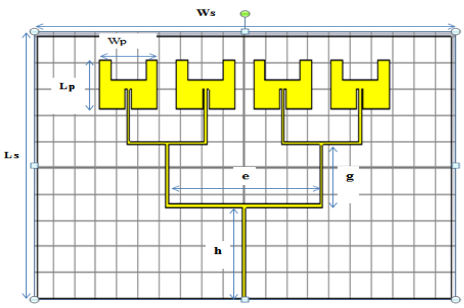

Figure 4 4x1 element dual band microstrip array antenna

2.3 Simulation Results

The simulation results of a dual band microstrip array antenna operate at 1.8GHz and 2.6GHz respectively are presented. In the following, the antenna performances are showed and discussed.

2.3.1 Reflection Coefficient and Impedance Bandwidth

Figure 5 shows reflection coefficient response (|S11 dB |) for simulation results of the dual band microstrip patch array antenna for single-element, 2 x 1 elements and 4 x 1 element array respectively. It can be seen that the antennas resonate at 1.8GHz and 2.6GHz, for single element with |S11| below -16.53dB and -27.18 dB. Meanwhile, for 2 x 1 elements, the refelection coeefficient response below -16.14dB and -31.11dB have been obtained at 1.8GHz and 2.6GHz respectively. For 4 x 1 elements array antenna, it can be noticed that the antenna resonates at 1.8GHz and 2.64GHz with the reflection coefficient |S11| below -23.47dB and -

24.37 dB. As for the -10dB impedance bandwidth,the simulation results show antenna bandwidth of 55MHz and 99MHz for single element, 32MHz and 59MHz for 2 x 1 elements and 38MHz and 51MHz for 4 x 1 elements at resonances.

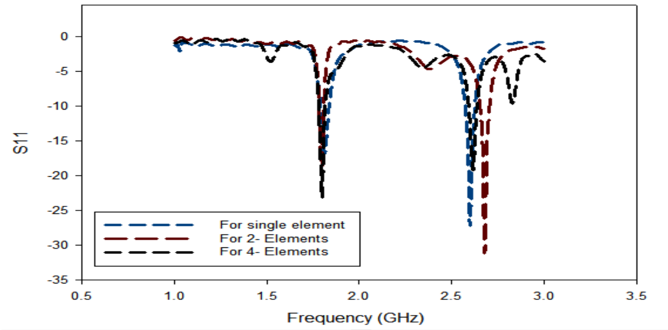

Figure 5 Results of a single element, 2 x 1 and 4 x 1array element reflection coefficient

It can be observed that only the single element antenna operate at the exact operating frequencies of 1.8GHz and 2.6GHz, while a litlle shift in the operating frequencies is observed for 2 x 1 and 4 x 1 array antenna respectively. This might be due to the fringing effect in the fields of the antenna. Moreover, reflection coefficient magnitude for all the antennas is found below -10dB at resonance frequencies.

2.3.2 Radiation Pattern

The radiation characteristics of the simulated dual band microstrip patch array antenna at both frequency of operation are shown in Figure 6. Figure 6 represents the simulated polar plot radiation pattern result at 1.8GHz and 2.6GHz. It can be clearly observed that single element and 2 x 1 elements array antennas have a main lobe that is broadside with small back lobe. Meanwhile, for the 4 x 1 elements antenna array, the radiation pattern is more directional with a narrower beamwidth in the main beam.

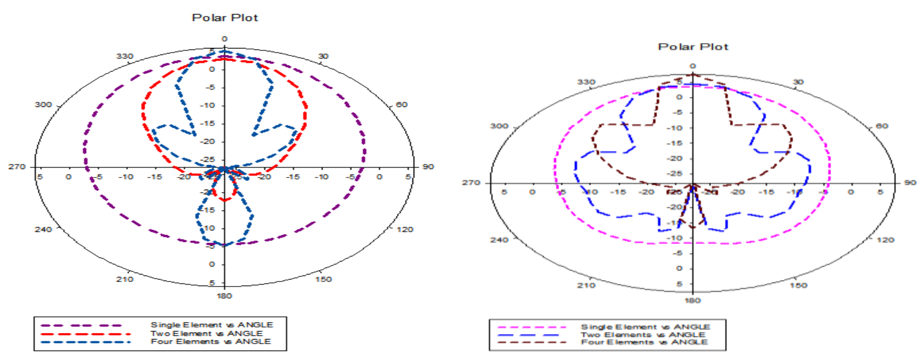

Figure 6 Simulated polar plot of the single element, 2 x 1 and 4 x 1 at 2.6GHz

2.3.3 Gain and Directivity

Table 5 summarised the gain and directivity of the dual band microstrip patch array antenna. The directivity achieved for the array antennas at 1.8GHz and 2.6GHz are 5.96dB and 6.46dB, 9.16dB and 8.91dB, 11.2dB and 12.9dB for single, 2 x 1 elements and 4 x 1 elements array antennas respectively. Due to improvement in directivity of the array antenna, it can be ascertained that antenna gain and directivity increase as the number of the elements increased. Hence, a good directivity higher than 10dB have been achieved for 4 x 1 elements array configuration and the antenna can be a very good candidate for LTE applications in Malaysia.

Table 5 Summarized results of the single element, 2 x 1 and 4 x 1 elements array antennas

Elements	Resonant Frequency (GHz)	Return Loss S11 (dB)	Magnitude of Reflection Coefficient |S11| (MHz)	Gain (dB)	Directivity (dBi)
1-Element	1.8	-16.53	55	3.71	5.96
	2.6	-27.19	59	3.72	6.46
2-Elements	1.8	-16.14	32	4.49	9.16
	2.68	-31.11	59	5.14	8.91
4-Elements	1.8	-23.47	38	7.32	11.2
	2.6	-24.37	51	7.77	12.9

It can be clearly observed that, the antenna gain and directivity for all configurations are always higher at 2.6GHz compared to 1.8 GHz. This may be due to the effect of the slot dimensions that affect the current distribution on the the patch antenna.

Conclusion

Dual band microstrip patch array antenna was designed and implemented. The antenna was fabricated on FR4 substrate of thickness of 1.6mm and dielectric constant of 4.6. The resonant frequencies of the single element, 2 x 1 elements and 4 x 1 elements antennas are 1.8GHz and 2.6GHz respectively. The maximum directivity achieved have been recorded as 5.96dB and 6.46dB (single), 9.16dB and 8.91dB (2 x 1 elements) and 11.2dB and 12.9dB (4 x 1 elements) at both frequencies. Meanwhile, the -10dB impedance bandwidth are obtained as 55MHz and 99MHz at 1.8GHz and 2.6GHz for the single element, 32MHz and 59MHz for 2 x 1 elements and 38MHz and 51MHz for 4 x 1 elements. The simulated and mesured results for single element and two elements are compared, and good agreement between the simulated and measured results was achieved. Hence, the antenna can be a good candidate for LTE applications. However in future work, other shapes can be employed to achieve higher gain and directivity. At the same time more antenna elements can be added so that higher gain can be obtained. There is also a need for the improvement of the bandwidth of the antenna. Many techniques could be employed to improve the antenna bandwidth such as using stacked patches, slot coupling and parasitic patches on the same plane. For future mobile communications, higher frequency of operation should be used to design the future dual band microstrip antenna, as the size of the antenna depends solely on the frequency of the antenna. The bigger the frequency of the dual band microstrip antenna , the smaller the size of the antenna.

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