Analysis high gain waveguide slot antenna 2.3 GHz for Long Term Evolution-Time Division Duplex (LTE-TDD)

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Abstract. Waveguide slot antenna has many benefits in term of high gain, simple design and stable performance that can be applied to telecommunications systems. This paper will discuss about the design and analysis of waveguide slot antenna for LTE (Long Term Evolution) at a frequency of 2.3 to 2.4 GHz. The results obtained will be used for reference whether the antenna can be used for LTE-TDD frequencies. This research was conducted in two steps. The first step involved simulation of antenna design and optimization using 3D Electromagnetic Simulator software. Data simulation results showed that the working frequency of the antenna between 2.30 to 2.41 GHz. While in the second step, fabrication and measurement were carried out using a spectrum analyser and network analyser. The results obtained from measurements show that the antenna has a frequency between 2.28 to 2.41 GHz with bandwidth 130 MHz. The antenna has a directional radiation pattern with a gain at a frequency of 2.3 MHz of 15.68 dBi. From the simulation results and measurement, it can be concluded that the design of these antennas can be used for LTE-TDD applications.

1. Introduction

The demand for wireless communication services is constantly increasing, therefore the speed of data access should also increase. Multimedia Online Gaming (MMOG), Mobile TV, Web 2.0, and DSL contribute greatly to network traffic [1]. This is a challenge for the development of wireless communication systems providing wide frequency bands with better costs and performance.

The 4G technology, also known as Long Term Evolution (LTE), is designed to support wireless communication. LTE is a technology that provides many changes in wireless communication systems that are able to provide downlink data speeds of more than 100 megabits per second (Mbps), with low latency, and very efficient spectrum use. There are LTE cellular networks that use TDD (Time Division Duplex) and FDD (Frequency Division Duplex) technology. LTE-TDD uses the same frequency spectrum for uplink and downlink, while LTE-FDD for uplink and downlink uses a different frequency spectrum.

There has been a lot of development of LTE technology devices that aim to meet telecommunications needs [1-3]. One such device is an antenna, which acts as a transmitter and receiver. Research on the 2.3 GHz antenna frequency has been done a lot, but more is in the form of planar with low gain [2-5].
To get an antenna with a high gain, one of them is by making an antenna array. One antenna that is easy to create is an antenna waveguide slot. This antenna has advantages in simple design, wideband and high gain [6-8]. So that this type of antenna can be applied to 2.3 GHz LTE-TDD technology. This paper discusses the design of antenna waveguide slots that have a directional radiation pattern and gain greater than 14 dB at frequencies 2.3 to 2.4 GHz in accordance with LTE-TDD technology.

2. Antenna design
Design of the waveguide slot antenna is using monopole antenna feeder. This antenna has an impedance of 50 Ω to match it with the SMA connector. The antenna design and simulation is carried out using 3D Electromagnetic Simulator software. This software can display antenna performance parameters such as return loss, VSWR, impedance, gain, and radiation patterns. The design and dimensions of each parameter antenna is shown in Figure 1 and Table 1.

![Waveguide slot antenna design](image)

**Figure 1.** Waveguide slot antenna design (a) front (b) back side (c) right side.

| Parameter | Size (mm) | Parameter | Size (mm) |
|-----------|-----------|-----------|-----------|
| t1        | 37.70     | ps        | 55.20     |
| t2        | 20        | j         | 78.54     |
| t3        | 158.33    | x         | 20.43     |
| Ls        | 7.85      | W(width)  | 58.67     |
| L (length)| 113       | H (height)| 628       |

3. Simulation results
Return loss of the antenna is on the frequency 2.30 – 2.41 GHz. Figure 2 shows the return loss and bandwidth from the simulation results. Bandwidth from simulation is 108.89 MHz. The lowest return loss is at 2.33 GHz, which is -37.82 dB. Figure 3 shows VSWR simulation result. The antenna design has a directional radiation patterns. Figure 4 shows the radiation pattern of the antenna.
Figure 2. Return loss simulation result.

Figure 3. VSWR simulation result.

Figure 4. Radiation pattern waveguide slot antenna.
4. Fabrication results and analysis

After obtaining the simulation results, the next step is antenna realization. The material used for creating the antennas is a brass plate with a thickness 0.8 mm. The number of antenna slots is 6 pieces. Figure 5 shows the antenna realization. The purpose of antenna realization is to compare the results of simulations that have been carried out. The comparison of return loss simulation and fabrication is shown in Figure 6.

![Waveguide slot antenna](image)

**Figure 5.** Waveguide slot antenna.

![Comparison of return loss results between simulation and fabrication](image)

**Figure 6.** Comparison of return loss results between simulation and fabrication.

Based on Figure 6, it can be seen that there is a shift in the bandwidth and frequency of the antenna. For return loss the simulation results are obtained at -37.82 dB at a frequency of 2.33 GHz, while the fabrication results have a smaller value of -18.7 dB. Return loss of work frequency shifts to the left, but still in accordance with the desired specifications, which is < -10 dB in the frequency range 2.3 - 2.4 GHz. The bandwidth result from the simulation is 108.89 MHz, while the measurement is 130 MHz with a frequency range of 2.28 - 2.41 GHz. This difference can be caused by loss or bending on the connector cable.

![Comparison of VSWR values from simulation and fabrication](image)

Figure 7 showing a comparison of VSWR values from simulation and fabrication. The VSWR that obtained from the simulation is 1.03 at the frequency of 2.33 GHz, while the measurement results obtained 1.26 at the frequency of 2.33 GHz. The emergence of value differences is caused by several factors, one of them is interference of wave in the air and losses in the connector.
In measuring the radiation pattern, the antenna is rotated every 10°. The data obtained will be normalized to the maximum average value so that the antenna radiation pattern is formed. Comparison of the radiation pattern result between simulation and fabrication can be seen in Figure 8.

Measurement of gain is done by comparing the waveguide slot antenna with the horn antenna, which has a 12 dBi gain as a reference antenna. Table 2 is showing the gain values of each 10 MHz starting from 2.3 GHz to 2.4 GHz. This is done so that the antenna measurement becomes more precise. Graph of gain comparison from simulation results and fabrication of antenna waveguide slot can be seen in Figure 9.
Table 2. Comparison gain between simulation and fabrication.

| Frequency (GHz) | Simulation (dBi) | Fabrication (dBi) |
|-----------------|------------------|-------------------|
| 2.30            | 14.26            | 15.68             |
| 2.31            | 14.26            | 15.31             |
| 2.32            | 14.26            | 15.28             |
| 2.33            | 14.26            | 15.24             |
| 2.34            | 14.25            | 15.15             |
| 2.35            | 14.24            | 15.43             |
| 2.36            | 14.22            | 15.42             |
| 2.37            | 14.2             | 15.13             |
| 2.38            | 14.16            | 15.39             |
| 2.39            | 14.11            | 15.39             |
| 2.40            | 14.05            | 14.89             |

Formatting the title, authors and affiliations Figure 9 shows that the results of the gain obtained from the simulation and fabrication are slightly different. The fabricated gain is greater than the simulation. The gain in the simulation ranges from 14 dBi, while the fabrication ranges from 15 dBi. The cause of this difference is due to the existence of free space loss and loss on the connector cable. In addition, the presence of objects around the measurement area causes the measurement results obtained to be different from the simulation results.

Figure 9. Comparison of gain values between simulation results and fabrication.

5. Conclusion
Waveguide slot antenna resulted in this research worked on the frequencies of 2.3 - 2.4 GHz with VSWR ≤ 2, therefore can be implemented on LTE (Long Term Evolution) technology. Antenna fabrication results from the simulation carried out have several differences, but still in accordance with the initial specifications. Antenna simulation return loss value < -10 dB in the frequency range of 2.30 GHz to 2.41 GHz or equivalent to VSWR ≤ 2. The measurement results obtained frequency range of
2.28 - 2.41 GHz with 130 MHz bandwidth. The average gain of an antenna is around 15 dBi with a directional radiation pattern.

References

[1] Chadchan S M and Akki C B 2010 3GPP LTE/SAE: An Overview International Journal of Computer and Electrical Engineering 2(5) 806-14

[2] Hariyadi, T, Huda Y T and Mulyanti B 2010 A Small Ultra-Wideband Unidirectional Microstrip Antenna for Through-Wall Radar Application Journal of Telecommunication, Electronic and Computer Engineering 8(1) 25-28

[3] Ratasuk R, Tolli D and Ghosh A 2010 Carrier Aggregation in LTE-Advanced Vehicular Technology Conference 1-5

[4] Chagharvarnd S, Hamid M R, Kamarudin M R and Khalily M 2014 Wideband Slot Antenna for 4G Applications IEEE Asia-Pacific Conference on Applied Electromagnetics (APACE) 2014 279–281

[5] Karimah S, Zulkifli F Y and Rahardjo E T 2014 Antenna design for femtocell LTE at frequency 2.3–2.4 GHz 2014 Makassar International Conference on Electrical Engineering and Informatics (MICIEEE) 50-53

[6] Ban Y-L, Chen J-H and Ying L-J 2012 Ultrawideband Antenna for LTE/GSM/UMTS Wireless USB Dongle Applications Antennas and Wireless Propagation Letters 11 403-406

[7] Al-Husseini M, El-Hajj A and Kabalan Y K 2013 High-gain S-band Slotted Waveguide Antenna Arrays with Elliptical Slots and Low Sidelobe Levels Progress in Electromagnetics Research Symposium Proceedings 12-15

[8] Shi L, Zhao G and Sun H 2013 Research on high-precision waveguide slot array 2013 IEEE International Conference on Microwave Technology & Computational Electromagnetics 39-42