Monopole Antenna Array for Femtocell LTE

Fitri Yuli Zulkifli [1], Sarah Karimah [2], Basari[3], Eko Tjipto Rahardjo[4]
[1,2,3,4]Antenna Propagation and Microwave Research Group (AMRG)
Department of Electrical Engineering, Faculty of Engineering, Universitas Indonesia
Kampus Baru UI Depok, Indonesia
Tel: 021-7270078, Fax: 021-7270077
Email: yuli@eng.ui.ac.id, sarah.karimah@ui.ac.id, basyarie@eng.ui.ac.id, eko@eng.ui.ac.id

***Abstract*—In this paper, a four element coplanar waveguide fed monopole antenna which is arrayed as volume array antenna to obtain omnidirectional pattern is presented. This femtocell antenna is designed to work at frequency 2.3-2.5 GHz for VSWR <2 and have at least 100 MHz impedance bandwidth. This array antenna has low mutual coupling, 460 MHz bandwidth at frequency 2.05-2.51 GHz and gain 6.3 dBi.**

***Keywords*— array antenna, Femtocell, LTE, microstrip, monopole antenna.**

I. Introduction

Cellular network is growing so rapidly this day. Internet connection usage is increasing makes the usage of channel higher too. Hence, the cellular service provider has to improve channel capacity to provide the good connection to all users. The key to increase the channel capacity is to improve reception [1]. One way to improve reception is by minimizing the attenuation of noise that occurs in the channel. However, it is quite difficult to do this because the channel is very complex and a lot of things cause attenuation. Another way to improve reception is to minimize the distance between the sender and the receiver such as femtocell.

Femtocell or small Base Station is cellular network access points that connect standard mobile devices to a mobile operator's network using residential Digital Subscriber Line (DSL), cable broadband connections, optical fiber or wireless last-mile technologies [2].

The key advantages of femtocell are that there is very little upfront cost to the services provider [1]. With femtocell, consumer installed wireless data access point inside homes, which backhauls data through a broadband gateway (DSL/cable/Ethernet/WiMAX) over the Internet to the cellular operator network.

For Femtocell, antenna also has an important role as transmitter and receiver. To achieve good performance for femtocell, therefore an antenna with good radiation characteristics is needed.

Many researches are ongoing in the LTE base station antenna design, however not many for femtocell antenna design. In [3], an aperture coupled elements antenna with 4x1 linear array, has 6-7.5 dBi gain at 2.3 GHz, and has unidirectional radiation pattern. Paper [4] discusses a 2x2 spiral array antenna for LTE which has 4.2-9.7 dBi gain varied at 1.6-3.3 GHz band. This antenna has bidirectional radiation pattern. While [5] is a two bent dipole antennas for LTE 700 MHz and 1600 MHz. The antenna has omnidirectional pattern with 2.35 dBi gain.

From researches which discuss about LTE, the Authors find that antenna requirement for femtocell should have omnidirectional pattern, gain more than 3 dBi, and 100 MHz bandwidth. Therefore, this paper proposes an array of four element coplanar waveguide fed monopole antenna.

In, addition, it is important for an array antenna to consider the mutual coupling between each element. The distance of each element in array antenna must be designed in such a way to reduce its mutual coupling below -20 dB [6].

II. Antenna Design

To obtain the aforementioned antenna requirement for femtocell, therefore the Authors must choose a certain antenna design. The Authors chose a coplanar waveguide (cpw) fed horse shoe-like monopole antenna design because cpw fed monopole antenna has omnidirectional pattern and horse shoe shape can reduce the dimension of the antenna. The antenna design proposed in this paper can be seen in Fig. 1.

The horse shoe-like antenna consists of a stub to tune the resonant frequency at 2.3-2.4 GHz. The horse shoe-like antenna consists of a curve patch and stub printed on a FR-4 substrate with ε_r = 4.6 and 1.6 mm thickness. The dimensions of this antenna are listed in Table 1.

978-1-4799-5191-8/14/$31.00 ©2014 IEEE

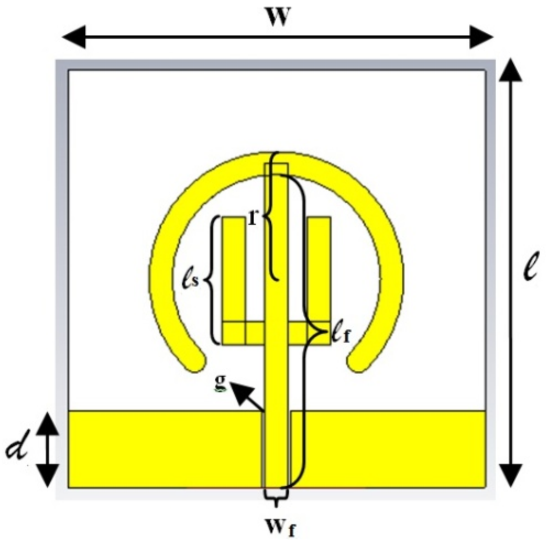


Fig. 1 Antenna Design

Table 1 Dimensions of proposed antenna

Parameters	Length (mm)
W	54
L	54
R	15
Ls	7
Lf	42
Wf	3
G	0.35
D	10

This single element antenna is arrayed as seen in Fig. 2 to obtain higher gain. Four antennas are attached to a 5 mm thick acrylic prism so each antenna elements position and spacing is fixed. This volume array design makes the antenna to have omnidiretional–like pattern.

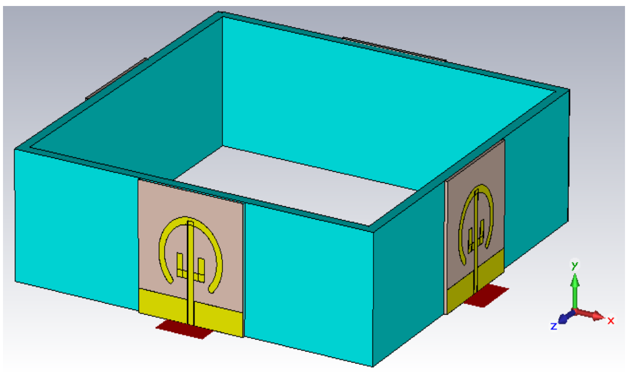


Fig. 2 Proposed array antenna design

The antenna is arrayed with spacing between each element antenna as seen in the Fig. 3. The parameter ***d*** is varied to get good mutual coupling suppression between elements.

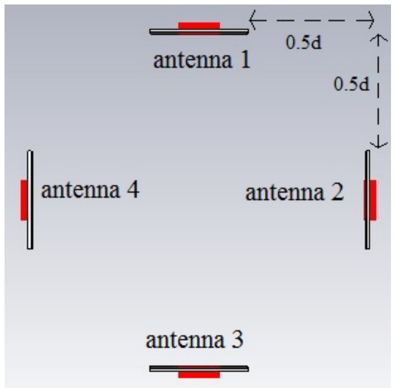


Fig. 3 Array antenna spacing

From Table 2, we can see that to get mutual coupling value between elements below -20 dB, the parameter ***d*** must be the same or farther than 0.5λ . And since the antenna gain shows similar result at ***d*** 0.5λ and 0.75λ, therefore at ***d*** = 0.5λ is chosen for the antenna design.

Table 2. Parametric study of distance ***d*** towards gain

	0.25λ	0.5λ	0.75λ
$S_{1,2}$	-15.59 dB	-20.5 dB	-22.33 dB
$S_{1,3}$	-18.4 dB	-20.97 dB	-23.56 dB
$S_{1,4}$	-15.59 dB	-20.5 dB	-22.33 dB
Gain	4.1 dBi	6.7 dBi	6.7 dBi

Fig. 4 shows reflection coefficient magnitudes in dB for this array antenna. The antenna has resonant frequency from 2.22 to 2.77 GHz with 550 MHz bandwidth at reflection coefficient magnitudes less than -10 dB.

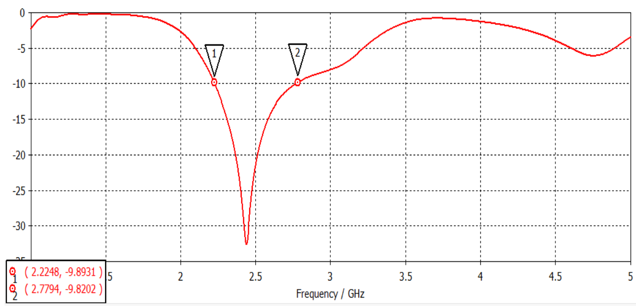


Fig. 4 Reflection coefficient magnitudes (dB) of proposed antenna array

The antenna radiation pattern depicted in Fig. 5 shows that this antenna has omnidirectional–like pattern because at phi=90 it has omnidirectional characteristic, however at phi=0 it is not perfectly omnidirectional characteristic. Although at phi=0, the radiation pattern show several sidelobes, but it can cover almost all directions. The gain of this array antenna is 6.7 dBi.

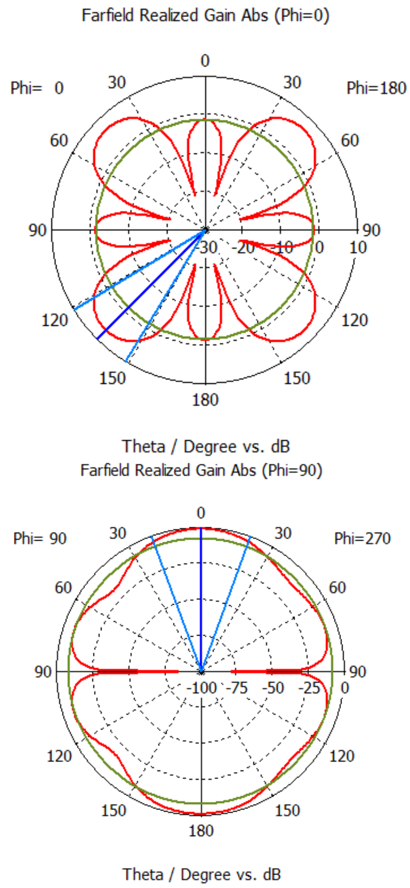


Fig. 5 Antenna radiation pattern

III. MEASUREMENT AND ANALYSIS

Measurement of the proposed antenna is conducted inside an anechoic chamber at Electrical Engineering Department, Universitas Indonesia. The Fabricated antenna can be seen in Fig. 6. Four element antennas are attached to a 5 mm thick acrylic. The antenna dimension is 120 mm x 120 mm x 55 mm. Each port of the antenna is connected to a power splitter COM SP-TX-4B using 0.5 m semi rigid cable.

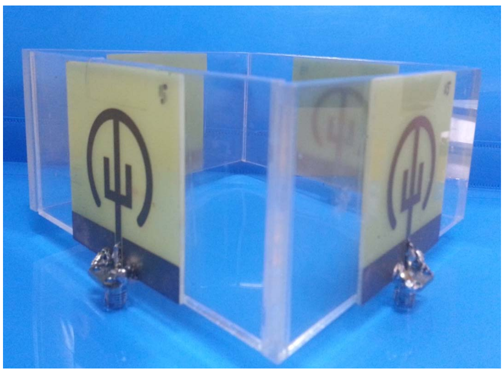
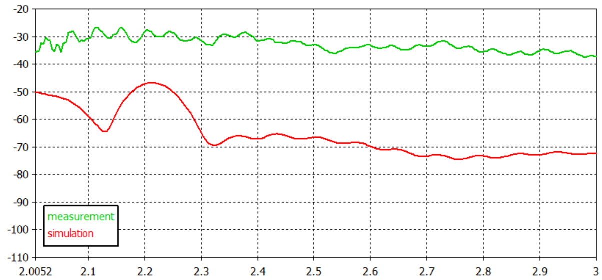
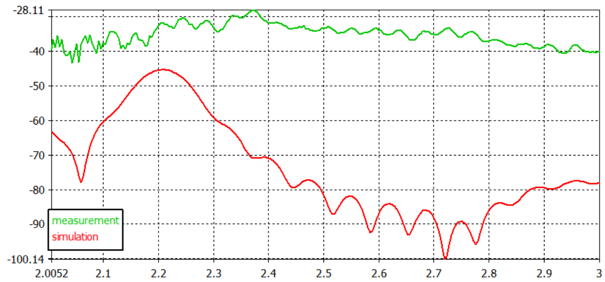


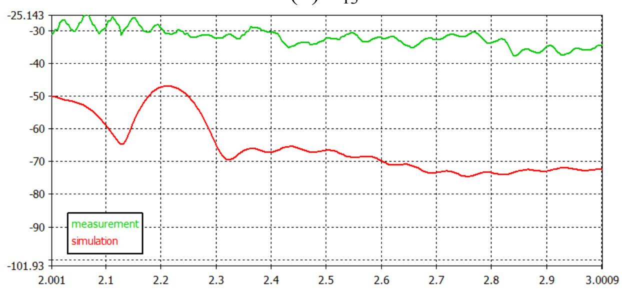
Fig. 6 Fabricated array antenna



(a) S_{12}



(b) S_{13}



(c) S_{14}

Fig. 7 Mutual Coupling (a) S_{12} (b) S_{13} (c) S_{14} of the array antenna

The mutual coupling between each element can be seen in Fig. 7. It shows that each element has mutual coupling below -20 dB.

The power splitter is measured to obtain the insertion loss of the splitter. The measurement result is shown in Fig. 8. The splitter with 4 port output has average insertion loss below 10 dB losses at frequency 2.3 GHz. Therefore, with considering the power splitter loss, the resonant frequency of the array antenna is 2.05 to 2.51 GHz as depicted in Fig. 9.

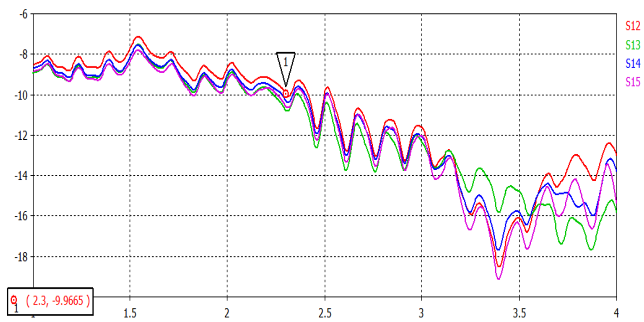


Fig. 8 Insertion loss of splitter COM SP-TX-4B

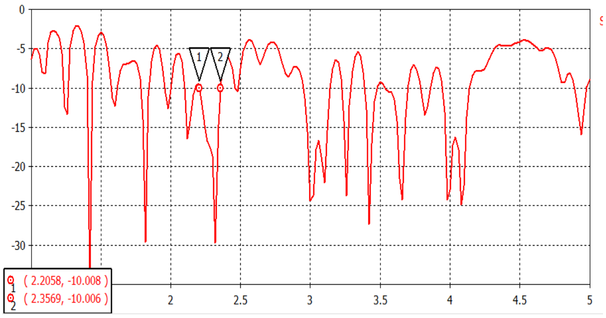


Fig. 9 Measurement result of Reflection coefficient magnitudes (dB) proposed microstrip array antenna

The radiation pattern of the fabricated array antenna can be seen from Fig. 10 and Fig. 11. By comparing the simulation result with the measurement result, it shows similar radiation pattern with maximum gain of 6.3 dBi.

IV. CONCLUSION

In this paper, simulation and measurement result of Femtocell LTE Base Station antenna design is presented. Four printed monopole coplanar waveguide is arrayed to obtain omnidirectional radiation pattern. It was shown that the measurement result agree well with the simulation result. This antenna has 460 MHz impedance bandwidth at 2.05-2.51 GHz with gain of 6.3 dBi. This design can be further improved by adding active element to increase gain and adding MIMO system to meet LTE system requirement.

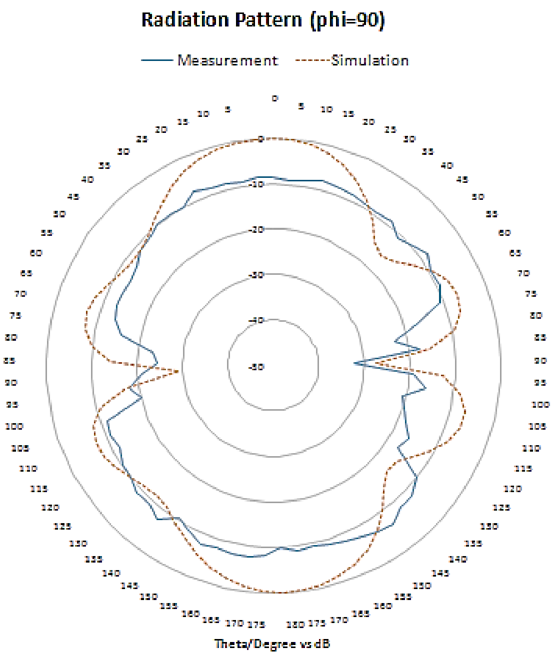


Fig 10. Comparison of simulation and measurement of radiation pattern at phi=90

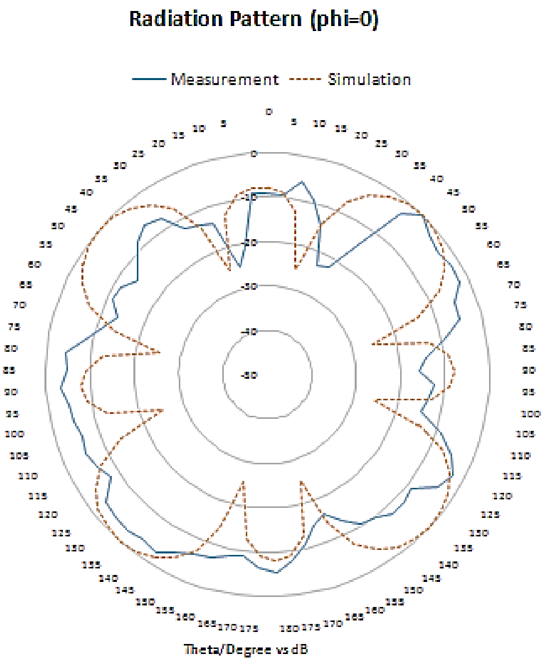


Fig 11. Comparison of simulation and measurement of radiation pattern at phi=0

ACKNOWLEDGEMENT

This work is partially supported by research grant: "Program lanjutan Dukungan penelitian dan Pengembangan Produk Telekomunikasi", Ministry of Communication and Information Technology, Republic of Indonesia

REFERENCES

[1] Chandrasekhar, Vikram; G. A., Jeffrey. "Femtocell Networks: A Survey". *IEEE Communications Magazine*. Sept. 2008.

[2] Zhang, Jie; De la Roche, Guillaume. "Femtocells : technologies and deployment". John Willey and Sons. 2010.

[3] Fernandes, Millind; Bhandare, Aniket; Dessai, Chetan; Virani, Hassanali. "A Wideband Switched Beam Patch Antenna Array for LTE and Wi-Fi" *IEEE India Conference* (INDICON), 2013.

[4] Sharma, Satish; Shanmugam Balamurugan. "Radiation Pattern Characteristic of a Wideband Modified Archimedean Spiral Antenna Array Covering DCS/PCS/WLAN and LTE Wireless Communication Bands". *IEEE ANTENNAS AND WIRELESS PROPAGATION LETTERS*, vol. 10, 2011.

[5] C.-M. Peng; I.-F. Chen; S.-M. Shen; D.-B. Lin. "Dual-band printed asymmetric dipole antenna array for LTE Applications" IEEE Antennas and Propagation Society International Symposium (APSURSI), 2013.

[6] Patron, Damiano; Dandekar, Kapil. "A Reconfigurable Antenna with Omnidirectional and Directional Patterns for MIMO System". *IEEE Antennas and Propagation Society International Symposium* (APSURSI). July. 2013.