Design and Implementation of Planar Fourtear Microstrip Antenna for WLAN and WiMAX Applications

Perancangan dan Implementasi Antena Planar Mikrostrip *Fourtear* untuk Aplikasi WLAN dan WiMAX

Ken Paramayudha[*,a], Aprilia Puspita Sari[b], Heroe Wijanto[b], Yuyu Wahyu[a]

[a]Research Center for Electronics and Telecommunication, Indonesian Institute of Sciences (LIPI)
Komp. LIPI Gd 20, Jl. Sangkuriang 21/54D, Bandung 40135 Indonesia
[b]Department of Telecommunication Engineering Telkom University,
Bandung, Indonesia

Abstract

In this paper, the microstrip planar fourtear antenna that operate at frequency range 2300 – 2500 MHz was investigated, Some applications suitable to operate in this frequency are WiMAX at 2.3 and 2.5 GHz and WLAN at 2.4 GHz. Simulations performed with the aid of Finite Element Emthod (FEM) based software which can calculte and comply the appropriate design to be able to operate at the desired working frequency. The analyzed parameters include : SWR, impedance, return loss, radiation patterns, gain, and polarization. From the measurement, bandwidth obtained is equal to 7.69% in the frequency range of 2318,250-2500 MHz in VSWR < 2. Radiation pattern measurement was unidirectional and the polarization was elliptical.

Keywords : *fourtear, VSWR, unidirectional, elliptical.*

Abstrak

Pada tulisan ini, antena mikrostrip *planar fourtear* dirancang dengan frekuensi operasi pada rentang frekuensi 2300 – 2500 MHz dan memiliki beberapa aplikasi seperti WiMAX pada frekuensi 2,3 dan 2,5 GHz, dan WLAN pada frekuensi 2,4 GHz pada VSWR ≤ 2. Metode pencatuan yang digunakan yaitu pencatuan dengan *probe* koaksial. Simulasi dilakukan dengan bantuan *software* berbasis *Finite Element Method* (FEM) yang nantinya bisa didapatkan desain yang tepat agar bisa beroperasi pada daerah frekuensi kerja yang diinginkan. Parameter yang akan dianalisis meliputi : SWR, impedansi, *return loss*, pola radiasi, *gain*, dan polarisasi yang dilihat dari segi simulasi *software* maupun dengan pengukuran langsung setelah prototipenya dibuat. Dalam realisasinya, diperoleh *bandwidth* sebesar 7,69% pada range frekuensi 2318,250 – 2500 MHz dalam batasan VSWR < 2. Pola radiasi hasil pengukuran adalah unidireksional dan polarisasi berbentuk elips.

Kata kunci : *fourtear*, VSWR, unidireksional, elips

I. INTRODUCTION

Rapid development in communication technology especially in wireless communication plays important role in research of new and novel antennas. Recently, many type of antennas with different geometries have been developed such as fractal inspired antennas [1] – [3], slot microstrip [4] – [6], planar inverted [7] – [9], etc.

In the last decade, a new design of antenna called fourtear antenna had been developed as a generalized crossed dipole antenna [10] (Figure 1). Fourtear geometry was inspired by a teardrop antenna but with an assymetric shape and was implemented in a microstrip substrate. This antenna has a wideband characteristics and a similarity of geometry with a fourpoint and foursquare antenna.

In this paper, design and implementation of a planar fourtear microstrip antenna operated in 2.3 – 2.5 GHz was investigated. The analyzed parameters include : SWR, impedance, return loss, radiation patterns, gain, and polarization. Some applications that are suitable to operate in this frequency are WiMAX at 2.3 and 2.5 GHz and WLAN at 2.4 GHz.

* Corresponding Author.
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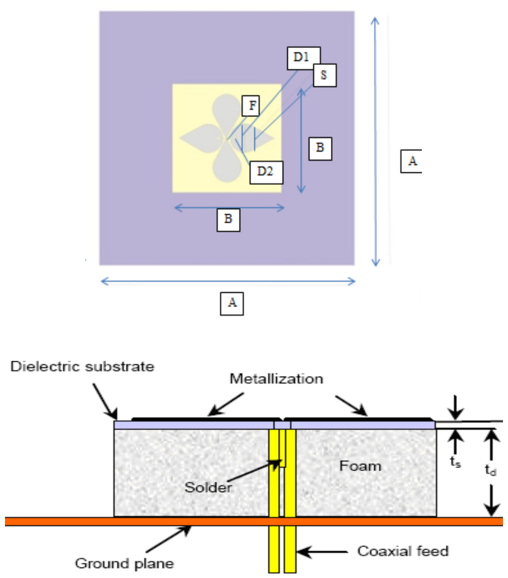

Figure 1. Fourtear Antenna (top) topview (bottom) sideview.

II. ANTENNA DESIGN

A. Antenna Specification

Complete requirements for the antenna are specified in the Table 1.

TABLE 1
ANTENNA SPECIFICATION

Working Frequency	2300 -2500 MHz
VSWR	< 2
Impedance	50 Ω
Gain	> 5 dBi
Polarization	Linear
Radiation Pattern	Unidirectional

Antenna consist of three layers: patch layer, dielectric substrates and groundplane. Materials that were used for these 3 layers are copper for the patch antenna, a FR4 and styrofoam for dielectric substrate and aluminium for groundplane. The FR4 that was used for dielectric substate has a relative permitivity of 4.4 and relative permeability of 1 with 3.2 mm thickness. Whereas, the styrofoam has a relative permitivity of 1 and relative permeability of 1 with 2.5 mm thickness.

B. Antenna Calculation

Fourtear antenna design consists of four patches that resemble the geometric shape of tears which is not asymmetrical. The tear shape has a mirrored geometry in the other side. Antenna calculation step start with calculating the dimensions of the circle in the teardrop element based from Equations 1, 2 and 3.

$$\mathcal{E}reff = \frac{\mathcal{E}r\mathcal{E}r1(h+h1)}{\mathcal{E}rh1+\mathcal{E}r1h} \quad (1)$$

With $\varepsilon r = 4{,}4$; $h = 3{,}2$ mm; $\varepsilon r_1 = 1{,}3$; $h_1 = 2{,}5$ mm

$$a = \frac{ae}{\left\{1+\left(2htot/\pi\varepsilon_{reff}\,(ae)\right)\left[\ln\left(\pi(ae)/2htot\right)+1.7726\right]\right\}^{0.5}} \quad (2)$$

$$ae = \frac{8.791\times 10^{9}}{fr\sqrt{\varepsilon_{reff}}} \quad (3)$$

with :

ae = effective patch radius
a = patch radius
ε_{reff} = dielectric effective permitivity
htot = total thicness of dielectric

By using the equations, the patch radius of 17.9 mm can be obtained. The calculated patch radius will be used for the parameter in the teardrop size in fourtear antenna design.

C. Groundplane Dimension

Ideally, a groundplane has an infinite width and length. However, as the infinite length is impossible to built in realization, in the antenna simulation groundplane dimension was determined by 280 × 280 mm. The size was sufficient to cover all area of patch antena and substrate in order to simplify the analysis

D. Antenna Feeder

The antenna has four teardrop radiator but only two feeders was connected. Thus, two other teardrops acted as parasitic elements for the other two. Generally an impedance of 50 ohm is located in one-six part of the patch radius that previously have been calculated, which was about 2.98 mm. However, to determine the optimal position of feeder in order to have the impedance requirement, the design must be simulated first. Parasitic element was used to improve the bandwidth of antenna and also to have an isolation in polarization or in other word to reduce the cross polarization between the tears elements.

E. Antenna Simulation

Finite Element Method (FEM) based software was used to comply the antenna calculation with the simulation results. Firstly, calculated parameter was inputed as a basis of antenna dimensions. Secondly, antenna was simulated, and the results were compared with the desired specification. Lastly, the parameter was optimized until the results have met the requirement.

Parameter that was inputed for the simulation of antenna in Figure 1 were:

A = groundplane width
B = substrate width
F = gap between patch
D1 = circle diameter
D2 = coaxial diameter
S = triangle length
Ts = fr4 substrate height
Td = styrofoam height

Complete dimension can be seen in Table 2 below:

TABLE 2
COMPLETE PARAMETER OF ANTENNA DIMENSION

Component	Antenna Dimension (mm)
A	280
B	120
F	21
D1	35.8
D2	2
S	13.5
Ts	3.2
Td	2.5

To investigate the effect of styrofoam in the substrate layer for bandwidth enhancement, a simulation was done and the result could be seen in Figure 2. From the graph, it can be concluded that styrofoam could enhance antenna bandwidth and also the VSWR. The calculated bandwidth for VSWR < 2 are 190 MHz in port 1, and 180 MHz in port 2 was obtained.

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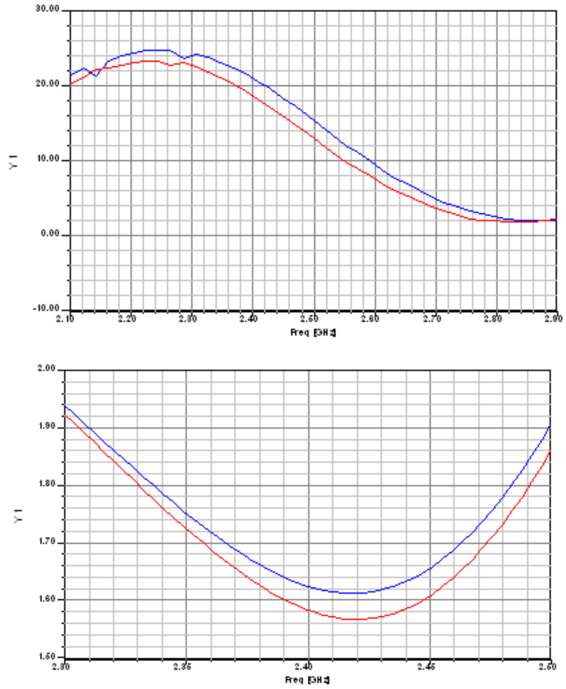

Figure 2. Styrofoam additon (top) before (bottom) after.

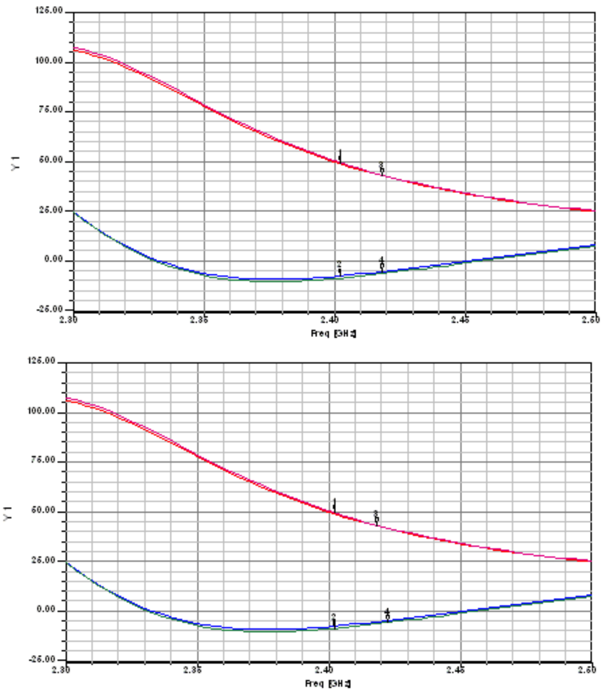

Figure 5. Antenna impedance (top) port 1 (bottom) port 2.

Simulation result for gain, radiation pattern, and impedance could be seen in Figure 3, 4 and 5. Gain in simulation was 5.317 dBi. Radiation pattern was unidirectional as can be seen in Figure 4. A ntenna impedance for 2.4 GHz in simulation result was 49.34 – j6.85 ohm for port 1 and 49.90-j7.97 ohm or port 2.

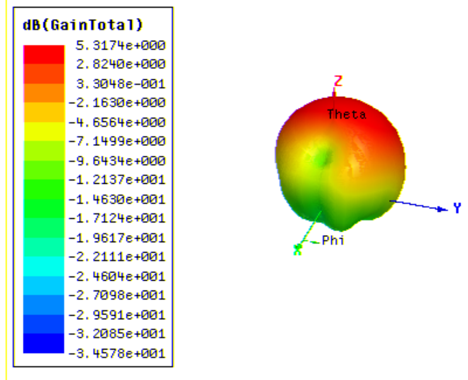

Figure 3. Antenna Gain

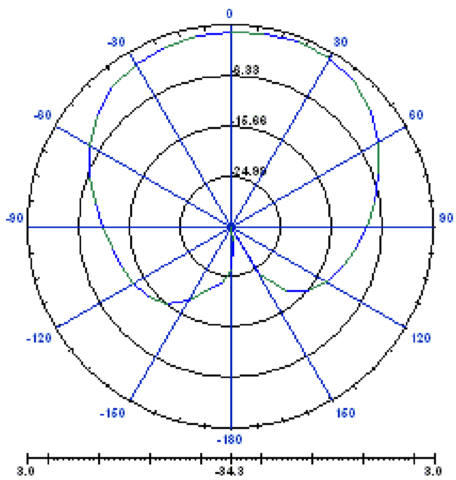

Figure 4. Radiation Pattern.

III. Measurement and Analysis

The designed antenna was fabricated in FR4 substrate. The topside view of fabricated antenna can be seen in Figure 6. Two connectors were attached in the radiator part through dielectric and groundplane layer. An aluminium was used as a groundplane in the bottom of the antenna.

Figure 6. Fabricated Antenna.

Measurement was carried out to search an agreement between simulation and fabrication. Parameters that were investigated in the measurement namely VSWR, bandwidth, impedance, radiation pattern, polarization and gain. Instruments that were used for antenna measurementare: Advantest Network analyzer, HP 8563E Spectrum Analyzer, HP 8350B Sweep Oscilator, and Nikon V-12B Profile Projector.

The objective of VSWR measurement was to analyze the standing wave value that occured due to the reflected signal. Value of V SWR is directly proportional with the amount of reflected signal which return to the transmitter. This means, if the VSWR are high (> 2), there was approximately one-third of signal returning to the transmitter. This condition will lead to inefficiency. Because of this reason, VSWR value that is below 2 was used to determine the bandwidth of antenna. Similar with the VSWR measurement, impedance was measured to investigate the unmatched condition between feeder and the antenna that will lead to a reflected wave.

Table 3 illustrates the VSWR measurement for port 1 and 2. F rom the table, bandwidth for VSWR < 2 could be calculated as equation 4 below:

$$BW = fu - fl \quad (4)$$

With BW = bandwidth, fu = upper frequency, fl = lower frequency. Thus, resulting bandwidth for port 1 and 2 were 184.75 and 170.125 MHz respectively. The ratio of bandwidth could be determine from equation (5):

$$BW\,(\%) = \frac{fu - fl}{fo} \times 100\% \quad (5)$$

Thus, fractional bandwidth for port 1 and 2 were 7.7 and 7.1 respectively. There was a slight shift in the resonant frequency for about 20 M Hz compares to the result in the simulation. This occured because of the inaccuracy in the fabricated antena dimension. The width of the substrate also affect the resulting bandwidth in the measurement. Styrofoam substrate used in the measurement was thicker than in the simulation. As a result, the bandwidth is wider in the measurement compared to the simulation.

TABLE 1
VSWR MEASUREMENT

Frequency (MHz)	VSWR port 1	VSWR port 2
2318.25	1.617	1.641
2329.875	1.596	1.634
2400	1.335	1.337
2420	1.328	1.330
2500	1.617	1.634

Result of impedance meeasurement could be seen in Table 4. For both port, impedance value that was near 50 ohm occured at 2.5 GHz. In the middle frequency at 2.4 GHz, impedance value was 38,674+6231j and 37,923+3,909j for port 1 and 2 respectively.

TABLE 2
IMPEDANCE MEASUREMENT

Frequency (MHz)	Impedansi port 1 (Ω)	Impedance port 2 (Ω)
2318.250	34.186-12.366j	32.869-12.172j
2329.875	33.986-12.154j	33.098-11.041j
2400	38.674+6.231j	37.923+3.909j
2420	40.059+8.013j	38.938+6.127j
2500	52.089+24.694j	51.937+25.213j

Measurement results for radiation pattern were depicted in Figure 7. In azimuth and elevation, radiation pattern were nearly unidirectional. This agree with the simulation but with a slightly more backlobe due to an non ideal environment that may lead to the reflected signal.

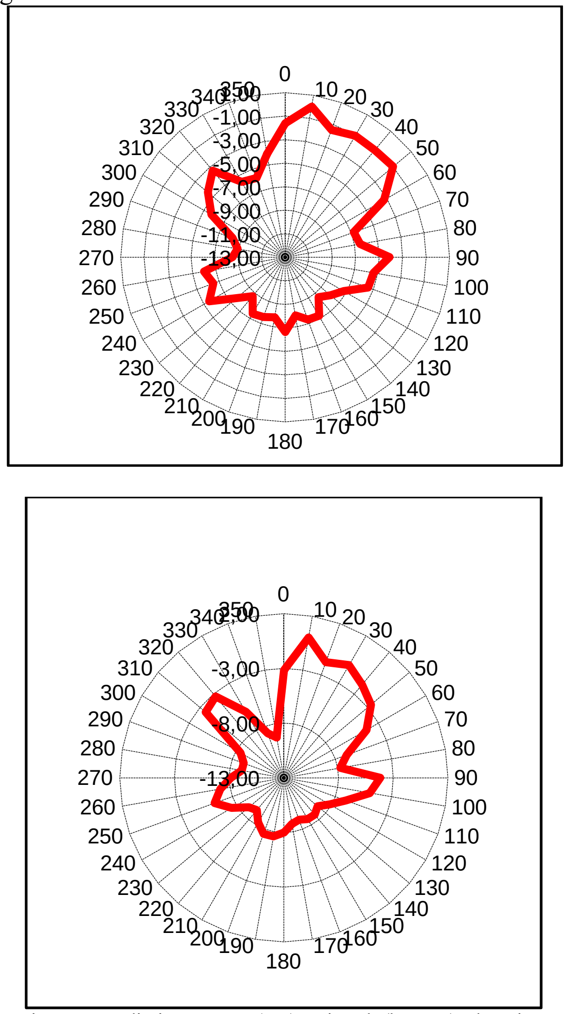

Figure 7. Radiation Pattern (top) Azimuth (bottom) Elevation.

An antenna that was used as a r eference in gain measurement is a sleeve dipole λ/2 with 2.14 dBi gain. From the measurement that had been carried out, gain was 5.5 dBi. This has met the gain requirement which was more than 5 dBi. As for the polarization, from the measurement it can be obtained that the type of polarizationwas elliptical which is different with the result from the simulation.

The profile projector was used to investigate the accuracy of dimension in fabricated antenna. There was a deviation of size in the fabricatied antenna up to 0.206 mm size. This occured due to inaccuracy in the fabrication process. As a result, there was a slight differency between simulation and measurement as had mentioned previously.

CONCLUSION

The fourtear antenna design that operate in 2.3 - 2.5 GHz frequncy had been investigated in this paper. Antenna consist of three layers : patch layer, dielectric substrates and groundplane. Materials that were used for these 3 layers are copper for patch antenna, FR4 and styrofoam for dielectric substrate and aluminium for groundplane. Resulting bandwidth for port 1 and 2 were

184.75 and 170.125 MHz respectively which are proportional to 7.7 and 7.1% of fractional bandwidth. The measured radiation pattern was nearly unidirectional which is suitable for WiMAX and WLAN applications. The polarization was elliptical. Overall, there was a fine agreement between simulation and measurement. A slight differency between the two results occured due to inaccuracy during the fabrication process as had been investigated by a p hysical measurement of fabricated antenna using a profile projector.

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