Design Narrow Slot Antenna for Dual Frequency

C. Chulvanich[1,2], **J. Nakasuwan**[1], **N. Songthanapitak**[1]
N. Anantrasirichai[3] **and T. Wakabayashi**[4]

[1]Department of Electronic and Telecommunication Engineering, Faculty of Engineering
Rajamangala University of Technology Thanyaburi (RMUTT) Klong 6
Thanyaburi, Pathumthanee, Thailand
[2]Department of Electronic and Telecommunication Engineering, Faculty of Engineering
Rajamangala University of Technology Phra Nakhon (RMUTP) North Bangkok
Bangkok 10800, Thailand
[3]ReCCIT, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang
Bangkok 10520, Thailand
[4]School of Information Science and Technology, Tokai University
Hirasuka, Kanagawa 259-1292, Japan

Abstract— The narrow slot loop antenna and linear slot antenna fed by microstrip line are designed for dual frequency at 2.44 GHz and 5.25 GHz on the standard of IEEE 802.11b/g (2.4–2.4835 GHz), IEEE 802.11j/a (5.15–5.35 GHz), and IEEE 802.16d (5.7–5.9 GHz). These structures are easy to adjust the length of slot antenna for dual frequency band. It can control the higher frequency band around 4.9 GHz to 5.8 GHz by linear slot antenna. Adjusting some parameters of narrow slot loop antenna will influence on the resonance frequency and bandwidth. By using IE3D software [1], the characteristics of antenna are investigated and analyzed, including instance input impedance, return loss and far field radiation patterns.

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1. CONCEPT OF LINEAR NARROW SLOT ANTENNA

The slot antennas in this paper are designed on FR4 (dielectric constant $\varepsilon_r = 4.5$) with thickness of 1.6 mm. The simple slot antenna is linear narrow slot antenna which is easy to control the resonance frequency by adjusting the length of slot antenna. The simple structure of single linear slot antenna is shown in Figure 1.

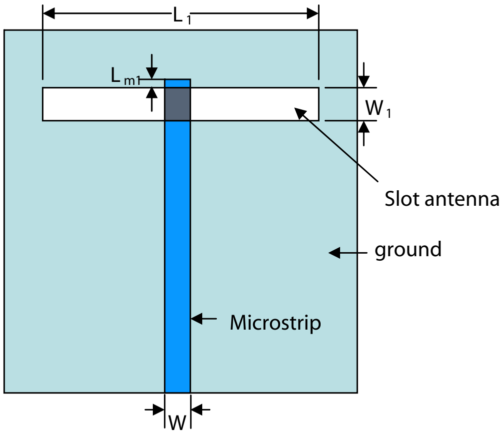


Figure 1: Simple structure of linear slot antenna.

The length of linear slot antenna L_1 is designed for 2.44 GHz which referred with wavelength in the substrate λ_g that can be calculated by following:

$$\lambda_0 = \frac{c}{f} \tag{1}$$

$$\lambda_g = \frac{\lambda_0}{\sqrt{\varepsilon_{eff}}} \tag{2}$$

where $\varepsilon_{\mathit{eff}}$ is the effective dielectric constant

$$\varepsilon_{\mathit{eff}} = \frac{\varepsilon_r + 1}{2} + \frac{\varepsilon_r - 1}{2}\left[1 + 12\frac{h}{w}\right]^{-1/2} \tag{3}$$

In this case, $\lambda_g = 74.14\,\mathrm{mm}$ at frequency 2.44 GHz.

The width of microstrip line is designed for match impedance with the characteristic impedance of transmission line 50 ohms which can be calculated by following:

$$\frac{w}{h} = \frac{2}{\pi}\left\{B - 1 - \ln(2B-1) + \frac{\varepsilon_r - 1}{2\varepsilon_r}[\ln(B-1)] + 0.39 - \frac{0.61}{\varepsilon_r}\right\} \tag{4}$$

where $B = \frac{60\pi^2}{Z_0\sqrt{\varepsilon_r}}$ and Z_0 is characteristic impedance.

In this case, width of microstrip line: $W = 3.0\,\mathrm{mm}$.

At designed frequency of 2.44 GHz, the length of slot antenna $L_1 = 35.8\,\mathrm{mm}$ $(0.48\lambda_g)$. The width of linear slot antenna W_1 is varied in five values beginning from 2.5 mm to 5 mm by step up 0.5 mm, and L_{m1} is adjusted for match impedance. The simulation results of return loss S_{11}, resonance frequency, frequency range and bandwidth are tabulated in Table 1. It shows that the changing in width of slot antenna will affect on the resonance frequency. When the width of slot is increased, the resonance frequency will decrease and bandwidth is wider. Therefore, if we increase the width of slot, the length of slot should be decreased in order to achieve the same resonance frequency and wider bandwidth.

Table 1: The simulation results of slot antenna by adjusting W_1.

W_1 (mm.)	Resonance Freq. (GHz)	Freq. Range (GHz)	Bandwith (MHz)	Return Loss S_{11} (dB)
2.5	2.52	2.46–2.58	120	−20.9
3.0	2.49	2.425–2.56	135	−27.9
3.5	2.46	2.39–2.54	150	−41.5
4.0	2.43	2.355–2.51	155	−27.1
5.0	2.40	2.325–2.48	155	−21.7

2. ANTENNA STRUCTURE OF NEW DESIGN

The new design for low frequency is done by developing linear slot antenna as refer in Figure 1 to narrow slot loop antenna, as shown in Figure 2. There are six parameters in this structure used to control frequency and match impedance, namely L_1, L_3, W, W_1, s, and Lm_1. In this research, we fixed the value of L_1, W, W_1, s, and Lm_1 to 35.8 mm, 3.0 mm, 2.5 mm, 0.5 mm and 0.5 mm,

Table 2: The simulation results of single narrow slot loop antenna by vary L_3.

L_3 (mm.)	Resonance Freq. (GHz)	Freq. Range (GHz)	Bandwith (kHz)	Return Loss S_{11} (dB)
0.25	2.48	2.42–2.54	125	−32.9
0.5	2.475	2.415–2.54	125	−31.9
1.0	2.465	2.405–2.525	120	−30.4
3.0	2.44	2.385–2.5	115	−29.6
3.9	2.435	2.38–2.495	115	−29.1
5.0	2.425	2.37–2.485	115	−25.9
6.0	2.425	2.37–2.48	110	−27.4
10.0	2.425	2.37–2.48	110	−25.9

respectively. When varying the value of L_3 from 0.25 mm to 10.0 mm, it will affect on the range of bandwidth. Therefore, some value of L_3 can achieve the frequency band in the standard of IEEE 802.11 b/g; 2.4–2.4835 GHz, as shown in Table 2. This table shows that the adjusting of L_3 will affect on the frequency band, so the parameter L_3 is sub-control and W_1 is the main control for finding the required frequency bandwidth.

Table 2 shows various lengths of L_3 between 0.25 mm–10.0 mm. The length of L_3 will affect on resonance frequency, bandwidth and return loss. It can be seen that the resonance frequency, bandwidth and return loss will decrease when L_3 is increased.

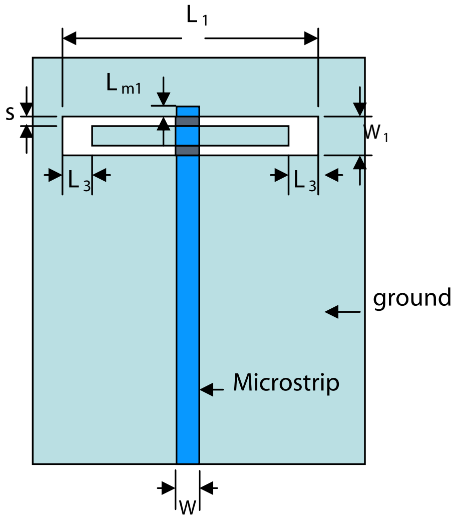


Figure 2: Structure of slot loop antenna for single low frequency.

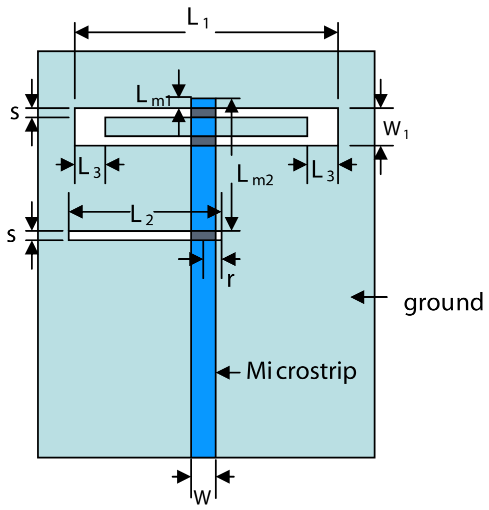


Figure 3: Structure of slot antennas for dual frequency.

Finally, a novel slot antenna for the dual frequency is proposed by inserting short linear narrow slot antenna below narrow slot loop antenna as illustrated in Figure 3. The new parameters of this structure are: L_2, Lm_2, and r. The parameter L_2 is the length of the linear narrow slot which use for achieving the higher resonance frequency in order to support the standard of IEEE 802.11j/a (4.90–5.091/5.15–5.35 GHz) or IEEE 802.16d (5.7–5.9 GHz). In this case, the length of linear narrow slot L_2 depends on the desired frequency. For the good results of S_{11}, we will set the parameter r to 2.0 mm and adjust L_{m2} for match impedance of 50 ohms.

3. RESULTS AND DISCUSSION

The simulation results in various different lengths L_2 and adjusts L_{m2} for matching impedance of 50 ohms at low frequency and high frequency are shown in Table 3.

Table 3: Simulation results by adjust L_2, L_{m2}.

Paramenter		Lower Frequency (GHz)			Upper Frequency (GHz)		
L_2 (mm)	L_{m2} (mm)	Resonance Freq.	Freq. Range	Return Loss S_{11} (dB)	Resonance Freq.	Freq. Range	Return Loss S_{11} (dB)
20.18	11.68	2.44	2.38–2.505	−38	4.945	4.84–5.11	−38
20.00	11.58	2.44	2.38–2.505	−38.9	4.995	4.86–5.155	−48.9
18.95	10.8	2.44	2.38–2.505	−43.6	5.25	5.125–5.39	−61.4
17.3	8.08	2.435	2.375–2.5	−40.5	5.8	5.53–5.965	−40.2

Table 3 shows the return loss, resonance frequency, and frequency range by fixing the L_3 to 3.9 mm, and adjusting the length L_2 and L_{m2} for dual frequency at lower resonance frequency 2.44 GHz and higher frequency from 4.945 GHz to 5.8 GHz. When the length of L_2 is decreased, the distance L_{m2} which is used for match impedance will be decreased, and the resonance frequency of the upper frequency will increase. However, the resonance frequency and frequency range of the lower frequency are slightly changed. The return loss of the lower frequency and the higher frequency are also shown in Table 3.

The simulation result of the return loss S_{11} of Figure 3 with different length of L_2 is shown in Figure 4.

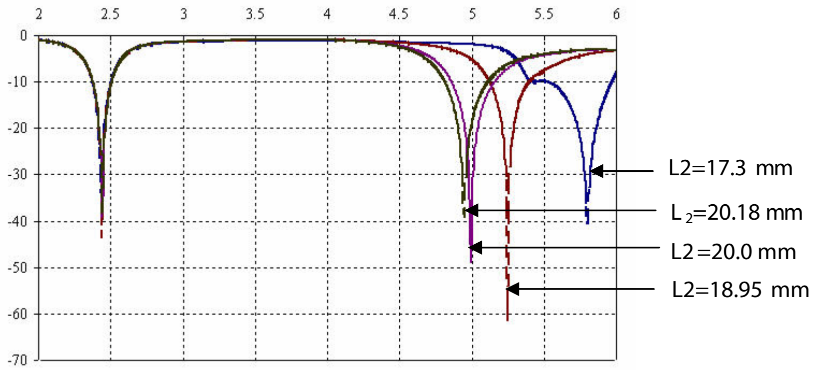
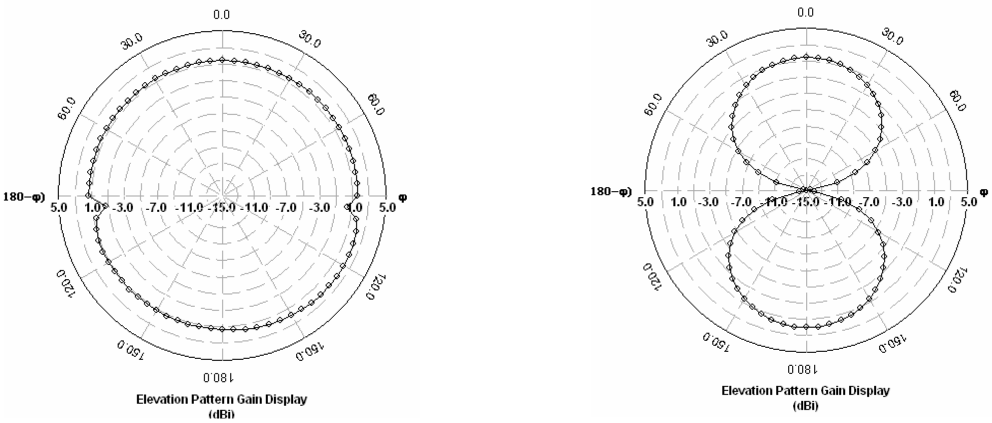


Figure 4: Return loss for dual resonance frequency of difference L_2.

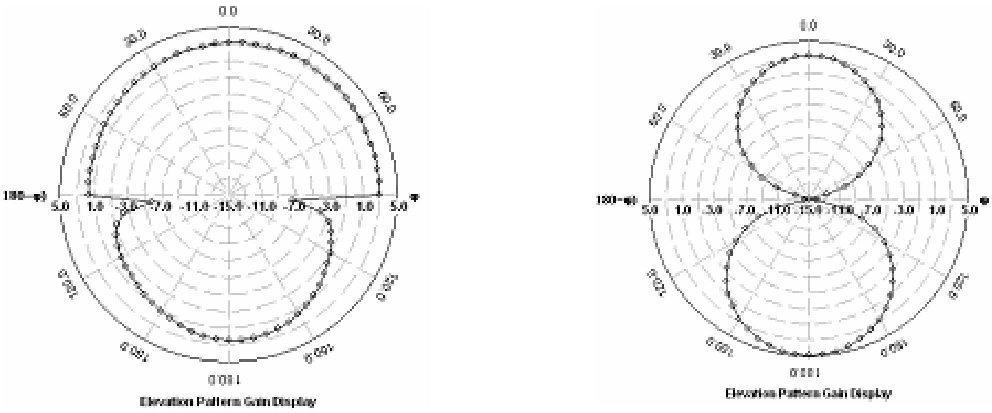
4. RADIATION PATTERN



(a)

(b)

Figure 5: Radiation pattern of E-total at 2.44 GHz, (a) yz plane ($\phi = 90°$), (b) xz plane ($\phi = 0°$).



(a)

(b)

Figure 6: Radiation pattern E-total at 5.25 GHz, (a) yz plane ($\phi = 90°$), (b) xz plane ($\phi = 0°$).

The radiation pattern on yz-plane and xz-plane at frequency 2.44 GHz and 5.25 GHz are shown in Figure 5 and Figure 6.

5. CONCLUSIONS

In this paper, a narrow slot loop antenna and linear slot antenna were designed for dual frequency. The former was accomplished at the lower frequency on standard frequency by IEEE 802.11b/g and the latter was done at the higher frequency on standard frequency by IEEE 802.11j/a and IEEE 802.16d. The new design of narrow slot loop antenna with using the technique of adjusting L_3 can achieve the good match impedance for lower and higher resonance frequency.

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