Compact Multilayer Equal Size Printed Rectangular Antenna

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Abstract--**Microstrip antennas are printed circuits operating in the microwave range. They are based on the low cost technology and thus should be potentially suited for low cost consumers. This paper presents the design of a multilayer rectangular microstrip patch antenna operating at three different frequencies. The frequencies choosen are 1.227 GHz and 1.575 GHz for Global Positioning System (GPS) satellite receiver and 2.45 GHz for Wireless Local Area Network (LAN) application. The size of the patch element is determined mathematically using the mathematical software Mathcad 2000. Numerical simulations were carried out using Micropatch v.2 electromagnetic software.**

Index Terms-- **multiband antenna, feed, wireless LAN, GPS, simulation.**

I. INTRODUCTION

Microstrip antennas are getting increased attention due to their advantages such as low profile, light weight, ease of fabrication and integration with RF devices [1]. This paper proposes a compact multilayer equal size rectangular patch antenna operating at three different frequencies. The chosen frequencies are 1.227 GHz and 1.575 GHz for Global Positioning System (GPS) satellite receiver and 2.45 GHz for wireless LAN application. The design can be easily placed onto an equipment. The design can have only one feed to be used with a single multiband duplexer, or they may have multiple feed to be used with multiple single band duplexers. The derivation of the equal size radiating patches is presented in this paper. The designed antenna is simulated using the numerical software, Micropatch v.2 [2].

II. DESIGN SYNTHESIS USING MATHCAD 2000

The rectangular patch antenna is shown in figure 1. L is the length and W is the width. L and W are also known as the non-radiating and radiating edges, respectively. The size of the radiating element, $L \times W$, is inversely proportional to the operating frequency. However, equal size radiating elements can be designed as discussed next.

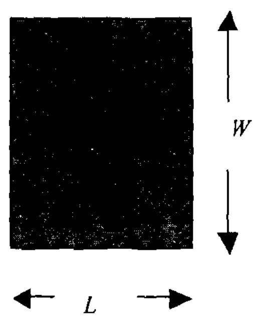

Fig. 1: Structure of the radiating element

Firstly, set the highest value of the operating frequency as the first frequency, f_1. Hence, a relatively small size of radiating patch can be set as reference. W can be determined using [3]

$$W = \frac{\lambda_1}{2} \times \left[\frac{\varepsilon r_1 + 1}{2}\right]^{-0.5} \quad (1)$$

where ε_r ≡ relative dielectric constant and λ_1 ≡ first operating wavelength $= c/f_1$. c is the speed of light. With this value of W, f_2 and f_3 can be written as

$$f_2 = f_1\left(\frac{\varepsilon r_1 + 1}{\varepsilon r_2 + 1}\right) \quad (2)$$

and

$$f_3 = f_2\left(\frac{\varepsilon r_2 + 1}{\varepsilon r_3 + 1}\right). \quad (3)$$

Hence, the relationship of ε_r and W can be plotted as in figure 2 using Mathcad 2000 [4]. The most suitable W and ε_r can be determined for the three frequencies.

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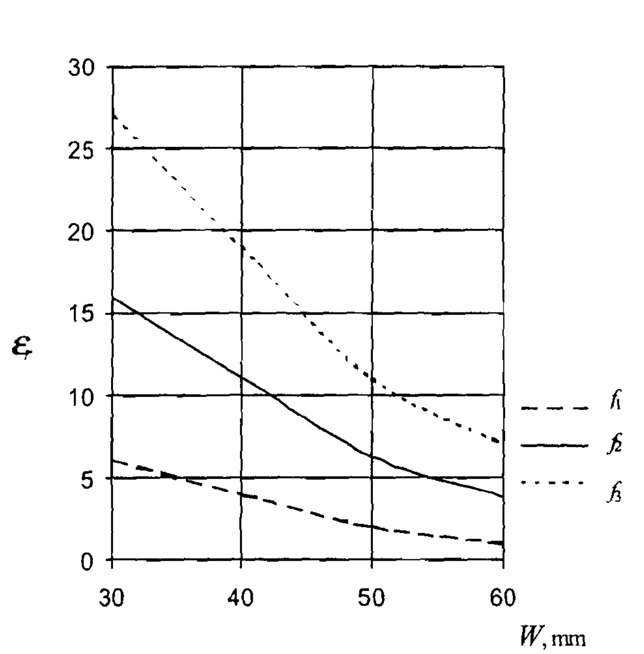

Fig. 2: ε_r versus W

Secondly, determine the corresponding value of L [3] versus substrate height, h, for $2 \le \varepsilon_r \le 11$ and $0.003\lambda_1 < h < 0.05\lambda_1$ [3]. L can be written as in Appendix 1, and can be solved using Mathcad 2000. Hence, the most suitable h for f_1, f_2 and f_3 can be determined. The relationship is plotted as in figure 3, generated using Mathcad 2000.

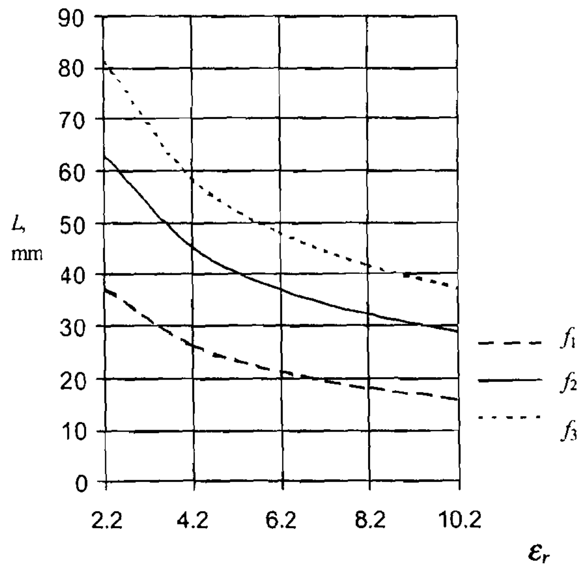

Fig. 3: L versus ε_r with specific h

III. NUMERICAL SIMULATION MICROPATCH V.2

The Micropatch v.2 software enables the user to design and analyse rectangular, circular and square microstrip patch antennas based on multiport network modelling approach. Micropatch consists of six main programmes. The command RPDesign is used for the optimisation process.

The input parameters required by the software are relative dielectric constant, loss tangent, height of substrate, thickness of conductor, t, conductivity of conductor and surface roughness.

The chosen microwave laminate has the specification regarding to dimensions determined using Mathcad. The width of the microstrip feed line, w, is obtained using mathematical formulations available in the literature [3, 5-7]. This was later verified using TLDesign command from Micropatch v.2 software. The length l is the quarter wavelength impedance transformer. The feeding at radiating and non-radiating edges were simulated using the software. Three sets of antennas having the two different side feeds are optimised using RPDesign. The results obtained are tabulated in Table 1.

Table 1: Optimisation of antennas using Micropatch v.2.
R - rectangular, s - side feed,
n - nonradiating edge, r - radiating edge

	Rsn1	Rsn2	Rsn3	Rsr1	Rsr2	Rsr3
W, mm	48.4	48.4	48.4	48.4	48.4	48.4
L, mm	38.3	38.1	38.2	37.9	38.06	38.19
w, mm				3.33	0.2713	0.123
l, mm				22.95	24.32	25.46
ε_r	2.2	6.15	10.2	2.2	6.15	10.2
loss tan	9×10^{-4}	0.002	0.002	9×10^{-4}	0.002	0.002
h, mm	3.58	1.08	1	3.58	1.08	1
t, mm	0.035	0.035	0.035	0.035	0.035	0.035

The simulation results obtained using the command RPanalyze are reflection coefficient (S_{11}), input impedance (Z_{in}), voltage standing wave ratio (VSWR), efficiency (η), directivity (D) and far field radiation pattern.

IV. RESULTS AND DISCUSSION

The antennas with the microstrip side feed at the radiating edge need matching network in the form of a quarter wave impedance transformer. From the simulation results of Micropatch, all the antennas exhibit low return loss at their corresponding frequency of operation. This indicates very well matched antennas at the input. The results are plotted in figures 4 and 5.

$|S_{11}|$, dB

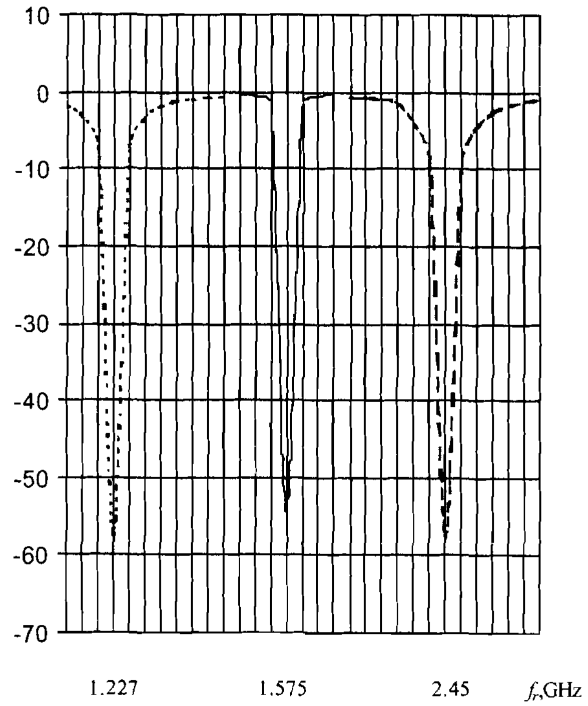

Fig. 4. Return loss of Rsn antennas versus frequency.

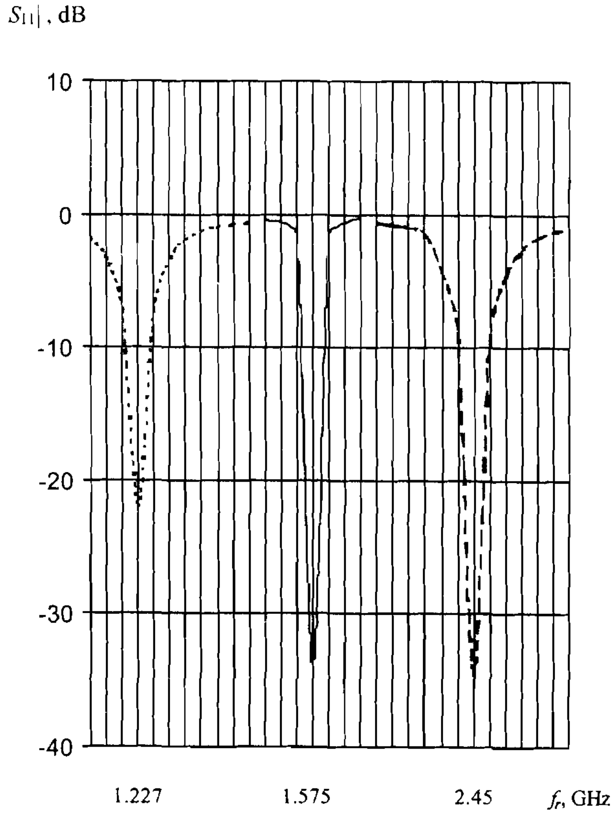

Fig. 5: Return loss of Rsr antennas versus frequency.

The –10 dB reflection bandwidth for Rsn1 is 100 MHz or 4.08 %. For Rsn2, reflection bandwidth from Micropatch is 2.961 %. The 0.815% reflection bandwidth has been obtained for Rsn3. Such narrow bandwidths may be a disadvantage to the microstrip antenna. Theoretically, the microstrip antenna has typically bandwidths from one to six percent [8]. The performance indices of the six antennas are tabulated in Table 2.

Table 2: Performance indices of Rsn and Rsr antennas.

	Rsn1	Rsn2	Rsn3	Rsr1	Rsr2	Rsr3
$\|S_{11}\|$, dB	-57.1	-54.47	-51.74	-21.59	-33.84	-34.6
VSWR	1.002	1.003	1.005	1.182	1.042	1.037
η, %	89.345	49.115	28.463	89.768	50.834	27.834
Z_{in}	50.03	50.074	50.241	50.13	50.555	50.883
D	6.849	5.645	5.309	6.848	5.646	5.296

V. CONCLUSION AND FUTURE WORK

Equal size radiating element of rectangular shapes operating at three different frequencies have been obtained using mathematical approach. The size of the structure is slightly different with that obtained using the simulation software. The constant size of the antenna is finally decided to be W = 48.4022 mm and L = 37.331 mm. The corresponding values of h and ε_r are as in Table 3.

Table 3: Values of h and ε_r for each corresponding antenna

Substrate / Operating frequency	f_1	f_2	f_3
ε_r	2.2	6.15	10.2
h, mm	3.58	1.084	1

From Table 3, high frequency corresponds to low dielectric constant and thick substrate, whilst low frequency corresponds to high dielectric constant and low substrate thickness. Simulation results showed that the antenna having the higher operating frequency possesses wider reflection bandwidth. Hardware implementation is currently under way.

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APPENDIX 1

$$L := \frac{\lambda o}{2\cdot\sqrt{\frac{\varepsilon r+1}{2}+\frac{\varepsilon r-1}{2}\cdot\left(1+\frac{12h}{w}\right)^{-0.5}}} - 2\cdot\left[\frac{h\cdot 0.412\left[\frac{\varepsilon r+1}{2}+\frac{\varepsilon r-1}{2}\cdot\left(1+\frac{12h}{w}\right)^{-0.5}+0.3\right]\cdot\left(\frac{w}{h}+0.264\right)}{\left[\frac{\varepsilon r+1}{2}+\frac{\varepsilon r-1}{2}\cdot\left(1+\frac{12h}{w}\right)^{-0.5}-0.258\right]\left(\frac{w}{h}+0.8\right)}\right]$$