

## 2.45 GHz 에서 무선 통신 시스템을 위한 인셋 페드 마이크로스트립 패치 안테나

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### Inset Fed Microstrip Patch Antenna for Wireless Communication at 2.45 GHz

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#### 요 약

통신 시스템에서 다양한 종류의 마이크로스트립 안테나는 많은 어플리케이션에서 사용되고 있다. 본 논문에서는 무선통신을 위한 2.45 GHz의 인셋 페드 직사각형 마이크로스트립 패치 안테나를 HFSS를 활용하여 설계하였다. 안테나는 유전율 2.2, 두께 1.6 mm의 Teflon 기판을 사용하였으며 기판의 한쪽 면은 접지면을 갖는다. 시뮬레이션을 통하여 반사손실, VSWR, 이득, 방사패턴 등의 안테나 특성을 확인하였다.

#### ABSTRACT

In communication systems, there are various types of microstrip antenna that can be used for many applications. This paper mainly focuses on the simple design of inset fed rectangular microstrip patch antenna to operate at frequency of 2.45 GHz for wireless communication. The study involves using HFSS simulator to design the antenna dimensions and to determine its performance. This antenna is based on a thickness of 1.6mm Teflon substrate with a dielectric constant of approximately 2.2, on one side of the substrate and another side has a ground plane. After simulation, the antenna performance characteristics such as return loss, VSWR, gain, radiation pattern are obtained.

**키워드** : 마이크로스트립 패치 안테나, 인셋 페드 기술, 무선 통신

**Key word** : Microstrip Patch Antenna, Inset Fed Technique, Wireless Communication

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## I. Introduction

Wireless communication has a great impact on human life since it has been developed rapidly in the past decades. In the field of wireless communications, antenna plays a vital important role. During late 1970s, there was rapid development in the field of microstrip patch antenna technology. During early 1980s, antenna elements and arrays were developed in term of design and modeling. The antenna have been largely studied due to their advantages like light weight, reduced size, low cost, conformability and the ease of integration with active device. A microstrip patch antenna is the combination of a radiating patch on one side of the dielectric substrate and ground on the other side. The patch is generally made of conducting material like gold or copper. On the dielectric substrate, the radiation patch and the feed lines are usually photo etched. Microstrip patch antennas radiate primarily because of the fringing fields between the patch edge and the ground plane. Therefore, the antenna can be fed by the various methods. These methods can be classified into two categories one is contacting and another is non-contacting. In the contacting method, the radio frequency power is directly fed to the radiating patch by using a connecting element such as microstrip line or probe feed. Whereas, in case of the non-contracting method, electromagnetic field coupling is done to transfer power between the microstrip line and the radiating patch which includes proximity feeding and aperture feeding [1, 2].

Microstrip patch antenna is characterized by a large number of physical parameters. They are designed to have many geometrical shapes and dimensions but rectangular and circular microstrip patches have been used in many applications. In this paper, the design of inset fed rectangular microstrip patch antenna at 2.45 GHz for wireless communication is presented having length of the patch  $L_p$ , width of the patch  $W_p$ , length of ground plane  $L_g$ , width of the ground plane  $W_g$ , inset fed distance  $Y_o$ , transmission line length  $L_f$  and width  $W_f$

and  $W_{sf}$  is the width of the gap as shown in Figure 1. This antenna is designed on Teflon and its performance characteristic such as Return loss, VSWR, gain, radiation pattern are obtained from the simulation.

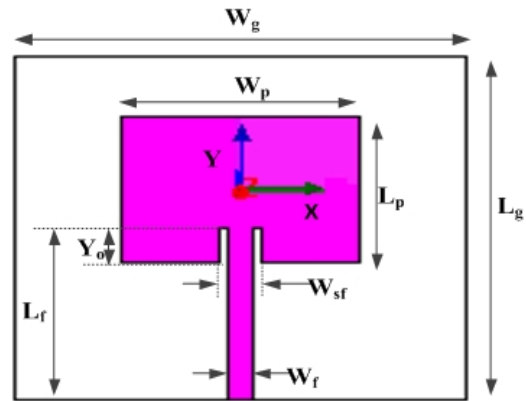


그림 1. 인셋 페드 사각형 마이크로스트립 패치 안테나  
Fig. 1 Inset Fed Rectangular Microstrip Patch Antenna

## II. Antenna Geometry and Its Design Requirement

For a rectangular patch, the length  $L$  of the patch is usually  $0.3333\lambda_0$  is the free space wavelength. The patch is selected to be very thin such that the height of substrate  $h \ll \lambda_0$ . Thus, a rectangular patch of dimension  $38.6 \text{ mm} \times 48 \text{ mm}$  is designed on one side of Teflon substrate of thickness  $1.6 \text{ mm}$  and the ground plane of  $90 \text{ mm} \times 90 \text{ mm}$  are located on the other side of the substrate.

There are three essential parameters for design of inset fed rectangular microstrip patch antenna. They are resonant frequency ( $f_r$ ), dielectric material of the substrate ( $\epsilon_r$ ) and the thickness of substrate. The resonant frequency chosen for this design is 2.45 GHz.

The dielectric material of the substrate chosen for this antenna design is Teflon having a dielectric constant of the 2.2 and the loss tangent equal to 0.0009. For design purpose, the dielectric constant of the substrate material is also an important parametric factor. Low dielectric constant of the substrate material is used in the design

because it gives better efficiency, higher bandwidth and the low quality factor Q. The low value of dielectric constant increases the radiated power. The designed has patch size independent of dielectric constant. So, the reduction of patch size is by using higher dielectric constant and Teflon is good in this agreement. In the simulation, the small loss tangent was neglected.

Thickness of substrate is another important in design parameter. Since thick value of substrate increases the fringing field of the patch periphery like low dielectric constant and also increases the radiated power. The dielectric substrate height of the inset fed microstrip patch antenna is  $h = 1.6$  mm.

### III. Mathematical Calculation of The Antenna Parameters

The parameters of the antenna can be calculated by the transmission line method [1, 3].

#### 3.1. Width of the Patch

The width of the antenna can be determined by

$$W_p = \frac{\lambda_0}{2} \left( \frac{\epsilon_r + 1}{2} \right)^{-\frac{1}{2}} \quad (1)$$

Where,  $\lambda_0 = c/f_r$

c = velocity of light

$f_r$  = resonance frequency

$\epsilon_r$  = dielectric constant of substrate

WP = Width of the patch

#### 3.2. Length of the patch

The effective dielectric constant can be determined by

$$\epsilon_{eff} = \left( \frac{\epsilon_r + 1}{2} \right) + \left( \frac{\epsilon_r - 1}{2} \right) \left( 1 + 12 \frac{h}{W} \right)^{-\frac{1}{2}} \quad (2)$$

Where,  $\epsilon_{eff}$  = effective dielectric constant

$\epsilon_r$  = dielectric material of substrate

h = height of dielectric substrate

Wp = width of the patch

The dimensions of the patch along its length have been extended on each end by distance, the extension length is given by

$$\Delta L = 0.412h \frac{(\epsilon_{eff} + 0.3) \left( \frac{W_p}{h} + 0.264 \right)}{(\epsilon_{eff} - 0.258) \left( \frac{W_p}{h} + 0.8 \right)} \quad (3)$$

The actual length L of the patch is given by

$$L = \frac{1}{2f_r \sqrt{\epsilon_{eff}}} - 2\Delta L \quad (4)$$

Where,  $f_r$  is the resonance frequency[4]

#### 3.3. Inset fed of the patch antenna

A physical notch is introduced by the inset feed, which in turn introduces a junction capacitance. The physical notch and its corresponding junction capacitance influence the resonance frequency. As the inset feed-point moves from the edge toward the centre of the patch the resonant input impedance decreases monotonically and reaches zero at the centre. When the value of the inset feed point approaches the centre of the patch, the  $\cos^2 \frac{\pi}{L} y_0$  where  $y_0$  is inset distance, which varies very rapidly; therefore the input resistance also changes rapidly with the position of the feed point. For maintaining very accurate values, a close tolerance has to be preserved [5-10]. In this paper, the value of inset fed distance  $y_0$  is 9.3 mm and the length and width of transmission line at 50  $\Omega$  is 45 mm and 5 mm respectively. The following Table 1 gives the detail design parameter specification of microstrip patch antenna[11].

### IV. Simulation Result

The antenna was simulated in HFSS (High Frequency Structure Simulation) which is a high performance full-wave electromagnetic (EM) field simulator for arbitrary 3D volumetric passive device, having Microsoft windows graphical user interface. The designed antenna in HFSS simulator is shown in Figure 2.

표 1. 마이크로스트립 패치 안테나의 설계 파라미터  
Table. 1 Design parameter of microstrip patch antenna

Type of the antenna	Rectangular Patch Antenna
Dielectric constant of the substrate ( $\epsilon_r$ )	2.2
Dielectric substrate material used	Teflon
Height of the dielectric substrate (h)	1.6 mm
Operating frequency ( $f_r$ )	2.45 GHz
Feeding method	Microstrip inset line feed
Polarization	Linear
Dielectric loss tangent ( $\tan\delta$ )	0.0009
Length of the patch ( $L_p$ )	38.6 mm
Width of the patch ( $W_p$ )	48 mm
Length of the feed line ( $L_f$ )	45 mm
Width of the feed line ( $W_f$ )	5 mm
Length of the ground plane ( $L_g$ )	90 mm
Width of the ground plane ( $W_g$ )	90 mm
Width of the gap ( $W_{st}$ )	8.5mm
Inset feed distance ( $Y_o$ )	9.3 mm
Impedance Matching ( $Z_o$ )	50 $\Omega$

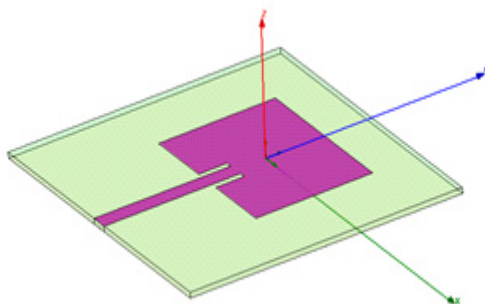


그림 2. HFSS로 설계된 안테나  
Fig. 2 Design Antenna in HFSS

The simulation result of return loss of the inset fed antenna is -33.66 dB at center frequency of 2.45 GHz as shown in Figure 3.

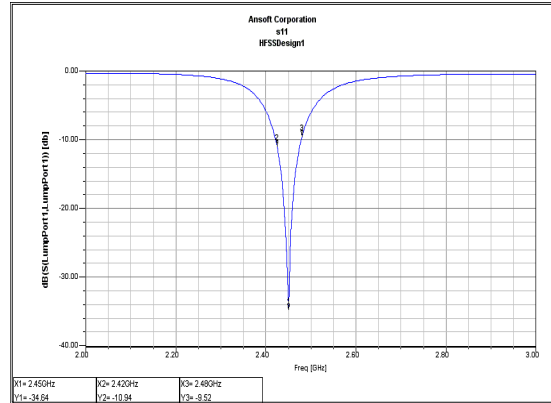


그림 3. 반사손실 vs. 주파수  
Fig. 3 Return Loss vs. Frequency

The bandwidth of the antenna in term of percentage is defined by

$$BW(\%) = \frac{f_{max} - f_{min}}{f_r} \times 100\% \quad (5)$$

Where,  $f_{max}$  and  $f_{min}$  are determined at -10 dB.  $f_r$  is the resonance frequency. The simulated value at -10 dB,  $f_{max} = 2.48$  GHz,  $f_{min} = 2.42$  GHz,  $BW = 60$  MHz and the bandwidth percentage is 2.44%.

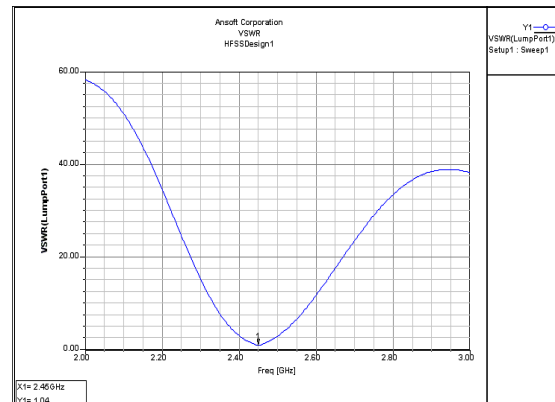


그림 4. VSWR vs. 주파수  
Fig. 4 VSWR vs. Frequency

The VSWR characteristic of the antenna should falls in between 1 to 2. From simulation its value is 1.04 at 2.45 GHz as depicted in Figure 4.

Also the radiation pattern of the antenna obtained is shown in Figure 5 at  $\phi = 90^\circ$  and  $\phi = 0^\circ$  at 2.45 GHz. The 3D polar plot of gain is shown in Figure 6 which shows the gain of 6.9 dB.

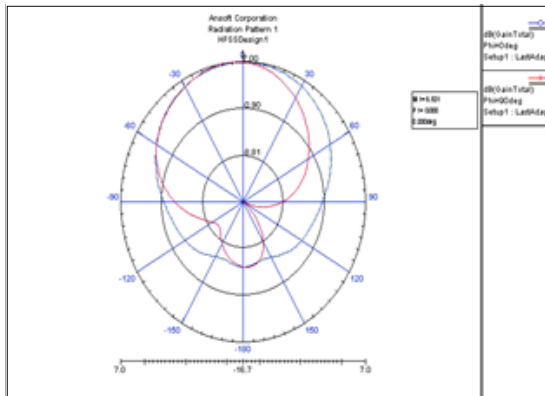


그림 5. 2.45 GHz 방사 패턴  
Fig. 5 Radiation Pattern at 2.45 GHz

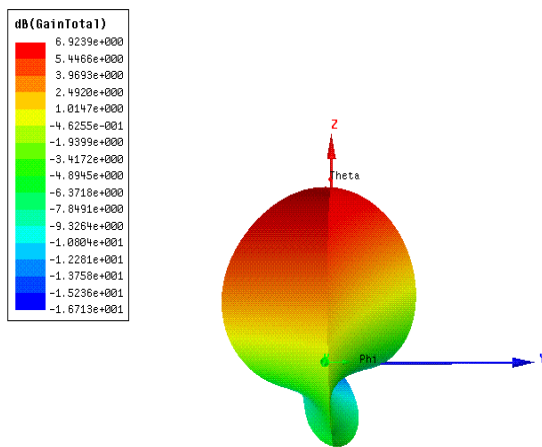


그림 6. 전체 이득의 3D Polar Plot  
Fig. 6 3D Polar Plot of total gain

The scattering parameter for the antenna design at 2.45 GHz on the smith chart is shown in Figure 7.

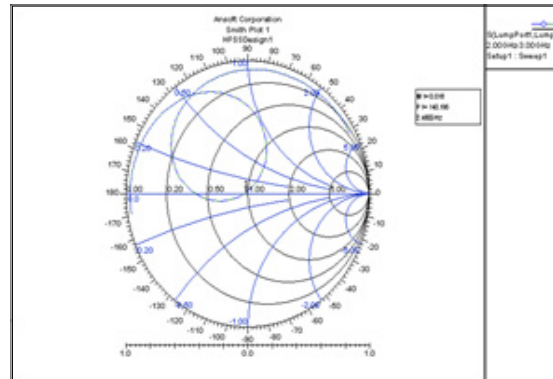


그림 7. 2.45 GHz 스미스 차트  
Fig. 7 Smith chart at 2.45 GHz

Table 2 summarizes the obtained simulation features of the antenna from high frequency simulation software.

표 2. 마이크로스트립 패치 안테나의 시뮬레이션 결과

Table. 2 Simulation results of microstrip patch antenna

Resonant frequency	2.45 GHz
Return loss	-34.64 dB
VSWR	1.04
Max U	0.39176 W/Sr
Peak Directivity	4.9126
Peak Gain	4.9249
Peak Realized Gain	4.9232
Radiated Power	1.0021 W
Accepted Power	0.99965 W
Incident Power	1 W
Radiation Efficiency	1.0025

## V. Conclusion

In this paper, the mathematical calculation for design of inset rectangular patch antenna at 2.45 GHz is presented. Simulation of inset fed microstrip patch antenna is done in HFSS. The antenna performance characteristics such as return loss, VSWR, gain, radiation pattern are obtained in simulation. Hence, from simulation, the return loss obtained is -34.64 dB at

2.45 GHz, VSWR is 1.04 and gain about 6 dB. In future, the simulated antenna can be fabricated in PCB Board.

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