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Research Paper

Design and Analysis of Air Gap Microstrip Slot Antenna Using Aperture Coupling

Engineering

KEYWORDS : Aperture coupled, H-slot, microstrip antenna, bandwidth, return loss

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ABSTRACT

A new air gap aperture coupled design is proposed for microstrip slot antennas to improve their bandwidth. The proposed design is based on a new aperture coupling technique in which slot is fed by microstrip line and coupled to patch radiators etched on the opposite side from the slot. The coupling slot is H-shaped slot. This paper presents design and simulation results of air gap aperture coupled microstrip antenna. The -10dB return loss bandwidth of the air gap aperture coupled antenna is 920MHz which is about 15.86% (from 5.42GHz to 6.34GHz)of the center frequency at 5.8GHz.This band is used in wireless LANs, cordless phones and HIPERLAN applications. The peak gain at the center frequency is about 8.03dB.The antenna is modelled using Ansoft HFSS (high frequency structure simulator) software.

I.INTRODUCTION

During recent year, microstrip antenna is widely used due to its many advantages, such as a low profile, light weight, and low cost, etc [1]-[2].Because of this advantages, it is widely used in many communication systems, such as a mobile satellite communications, personal communication systems, wireless local area networks etc. The main disadvantage of microstrip antenna is their narrow bandwidth characteristics, typically 1-5%,which is major limiting factor for the widespread application of these antennas.

Compared with other classical edge or probe fed microstrip antennas, the aperture coupled microstrip antenna, first proposed by D M Pozar in 1985 [3],has a number of advantages, such as isolation between the antenna and feed circuit, many possible variations in patch shape, aperture shape, feed line type, radomes, easy integration of arrays and active circuits [3].In the aperture coupled microstrip antenna configuration, the field is coupled from the microstrip line feed to the radiating patch through an electrically small aperture or slot cut in the ground plane. Two different dielectric substrates could be chosen, one for the patch and the other for the feed line to optimize the individual performances. The coupling aperture is usually centered under the patch, leading to lower cross-polarization due to symmetry of the configuration [7]. The shape, size, and location of the aperture decide the amount of coupling from the feed line to the patch. The coupling to the patch from the feed line can be maximized by choosing the optimum shape of the aperture. Since then, various shapes have been used to obtain large coupling with smaller aperture area [9]. Compared to the circular aperture, a thin rectangular aperture gives much stronger coupling. The coupling increases if instead of using rectangular aperture, an ''H''-shaped aperture is used. For a simple rectangular slot, the transverse electric field must vanish at the end of the aperture. By adding a slot at the end of the rectangular aperture (i.e., the ''H''-shaped aperture), the field becomes nearly uniform along the aperture and hence the coupling increases [8]-[9].

The simulations were carried out using software Ansoft "High Frequency Structure Simulator" HFSS which uses finite element method (FEM) as a solving method.

II.ANTENNA DESIGN AND STRUCTURE

The proposed top view and side view of the air gap aperture coupled microstrip antenna is shown in Fig. 1. In this design, the field is coupled from the microstrip feed line to the rectangular patch through small H-shape aperture cut in the ground plane. The substrate parameters of the radiating patch and microstrip feed line have a significant effect on the input impedance of aperture coupled microstrip antenna. The two substrate materials are used in this design, FR4 with dielectric constant εr=4.4 and height h2=0.8mm is used for feed substrate, Teflon with dielectric constant εr=2.5 and height h1=2.45mm used for patch substrate. There is air gap of height 2.43 mm between ground plane and radiating patch to increase bandwidth of antenna [7]. 3*3 mm Teflon material supporters are used for air gap. Design of this antenna by using Ansoft HFSS software is shown in Fig. 2.

A. Length and Width of the Patch

The length of the patch determines the resonant frequency of the antenna. The width of the patch affects the resonant resistance of the antenna, with wider patch gives the lower resistance. Equations (1) - (4) are used to find the length (Lp) and width (Wp) of the antenna [7],

$$Wp = \frac{c}{2.f_r}\left[\left(\frac{\varepsilon_{r1}+1}{2}\right)\right]^{-\frac{1}{2}}$$

Where c =velocity of light
Wp =width of the antenna
fr =resonant frequency,5.8GHz
εr1=dielectric constant of patch substrate

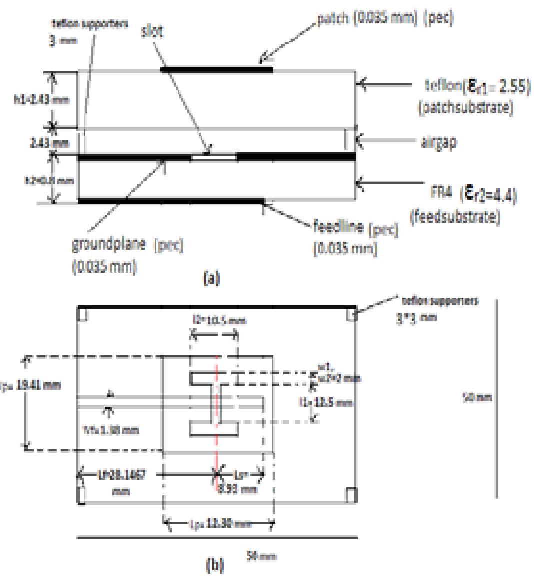

Fig.1 Air gap aperture coupled microstrip antenna (a) side view (b) top view

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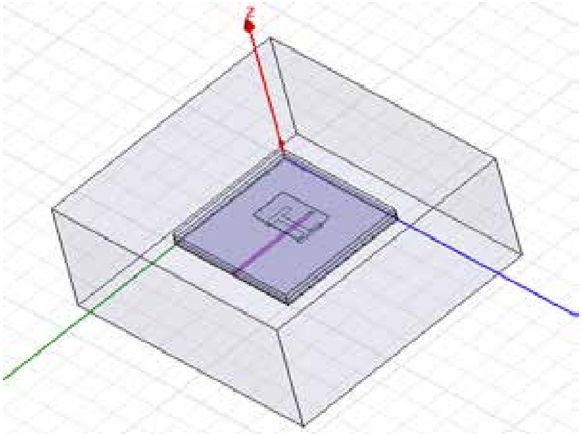

Fig.2 Model of air gap aperture coupled microstrip antenna using Ansoft HFSS software

effective length is given by

$$L_{eff} = \frac{c}{2 f_r \sqrt{\varepsilon_{eff}}} - 2\Delta l$$

Where Leff=effective length
εeff =effective dielectric constant of the substrate
Δl=line extension

εeff and Δl can be calculated by using following equations

$$\varepsilon_{eff} = \left(\frac{\varepsilon_{r1}+1}{2}\right) + \left(\frac{\varepsilon_{r1}-1}{2}\right)\left(1+\frac{10.h_1}{Wp}\right)^{-0.5} \quad (3)$$

$$\Delta l = 0.412 h_1 \left(\frac{0.262+\frac{Wp}{h_1}}{0.813+\frac{Wp}{h_1}}\right)\left(\frac{\varepsilon_{eff}+0.3}{\varepsilon_{eff}-0.258}\right) \quad (4)$$

where h1=height of the patch substrate

Finally the actual length is calculated as Lp=Leff–2Δl. The patch is designed to operate at resonant frequency fr =5.8GHz. Based on above equations we can calculate the width is Wp=19.41mm and length is Lp =12.30mm.

B. Length and Width of the Slot

The coupling level is primarily determined by the length of the slot, as well as back radiation level. In this antenna H-shape slot is used for better coupling. The dimensions of the slots are l1=12.5mm,l2=10.5mm,w1=w2=2mm.

C. Width of the Feed Line

Usually 50Ω microstrip feed line is used to feed the radiating patch. Feed line width decides the characteristic impedance of the feed line, so chosen to get the required impedance. Also for maximum coupling, the feed line must be placed perpendicular to the center of the slot. By taking the feed substrate parameters h2=0.8mm and εr2=4.4, and computing by use of Equation (5) iteratively the proper feed line width to obtain a characteristic impedance of 50Ω.For value of wf=1.38mm, we get the Zc=49.9Ω.

$$Zc = \frac{1}{2\pi}\sqrt{\frac{\mu_o}{\varepsilon_o \varepsilon_{eff}}}\, ln\left(F1\frac{h_2}{w_f} + \sqrt{1+\left(2\frac{h_2}{w_f}\right)^2}\right) \quad (5)$$

$$F_1 = 6 + (2\pi - 6)exp\left[-\left(30.666\frac{h_2}{w_f}\right)^{0.7528}\right] \quad (6)$$

Where εo and μo are the free space permittivity and permeability

D. Length of the Feed Line

Length of the feed line is Lf=28.1467mm.The tuning stub is used to tune the excess reactance of the slot coupled antenna. The length of the tuning stub is LS=8.93mm.

E. Position of the Patch Relative to the Slot

For maximum coupling, the patch should be centered over the slot. Moving the patch in the H plane direction has little effect, while moving the in the E plane direction decrease the coupling level.

III.DESIGN PARAMETERS

For final designing of the air gap aperture coupled microstrip antenna, the values of the parameters are given in Table 1.

TABLE 1
DESIGN PARAMETERS

Antenna part	parameter	value
patch	Length Lp Width Wp	12.30 mm 19.41 mm
Patch substrate	Relative permittivity εr1 Height h1 Losses tanδp	2.5 2.45mm 0.001
Slot1 Slot2,slot3	Length l1 Width w1 Length w2 Width l2	12.5mm 2mm 2mm 10.5mm
Feed substrate	Relative permittivity εr2 Height h2 Losses tanδf	4.4 0.8 mm 0.02
Feed line	Length Lf Width Wf Stub length Ls	28.1467mm 1.38 mm 8.93mm
Air gap	-	2.43 mm

IV. SIMULATION RESULTS

A. The Plot of the Return Loss Against Frequency

Fig. 3 shows the simulation result of return loss of the air gap aperture coupled microstrip antenna by using Ansoft HFSS software. The resonance frequency of the antenna is 5.8GHz.The -10dB return loss bandwidth of the air gap aperture coupled antenna is 920MHz which is about 15.86% (from 5.42GHz to 6.34GHz) of the center frequency.

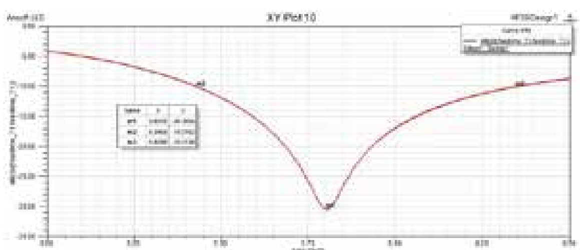

Fig.3 Return loss

B. Radiation Pattern

The simulated E-plane and H-plane radiation pattern of the antenna is presented in Fig. 4.The peak gain at the center frequency at 5.8 GHz is about 8.03dB.

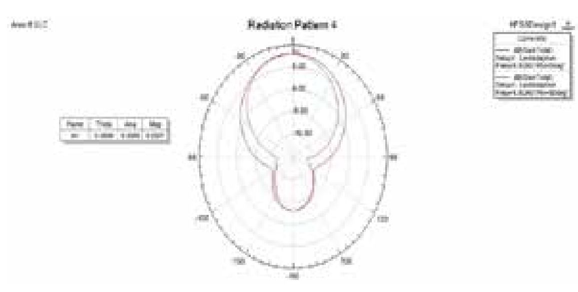

Fig.4 Radiation pattern

V. CONCLUSION

This paper present the air gap aperture coupled microstrip antenna using H-shape slot. By using the Ansoft HFSS software, the simulation result of return loss and radiation pattern can be achieved. The -10dB return loss bandwidth of the air gap aperture coupled antenna is 920MHz which is about 15.86% (from 5.42GHz to 6.34GHz) of the centre frequency at 5.8GHz. This band is used in wireless LANs, cordless phones and HIPERLAN applications. The peak gain at the centre frequency is about 8.03dB.

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