Stacked Rectangular Microstrip Antenna Loading a Helical Pin for Triple Band Operation

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1. Introduction

Recently, antennas for multi band operation have received much attention and many single feed Microstrip antennas (MSAs) for dual band operation have been proposed [1][2]. The authors have proposed stacked MSAs with a shorting plate or pin for dual band operation in ITS (Intelligent Transport Systems) [3] and in wireless LAN [4]. In the lower frequency band, the electric current on the shorting plate (pin) is the strongest and the peak of the radiation field is at the low elevation angles (shorting plate mode). In the higher frequency band, the antenna operates as a conventional half-wavelength stacked MSA with the parasitic patch above the fed patch conductor (patch mode). Therefore, the bandwidth at the higher frequency band is wide.

The authors, moreover, have proposed a stacked rectangular microstrip antenna with a shorting plate and a helical pin for triple band operation [5]. The proposed antenna has an additional resonant mode by loading a helical pin (helical pin mode). In [5], the antenna characteristics at the helical pin mode were compared with those at the shorting plate mode. In this paper, the relations between the helical pin mode and the other resonant modes, the shorting plate and the patch modes, are clarified numerically. Moreover, an antenna for PHS/VICS/ETC operation in ITS is designed.

In the calculation in this paper, the simulation software package IE3D 10.2, based on the method of moments in the spectral domain is used [6].

2. Antenna Design

Figure 1(a) and (b) show a stacked rectangular MSA with a shorting plate and a helical pin. The antenna consists of a dielectric substrate and an air layer with a rectangular patch. The upper and lower patches are the same size and their widths are W and L. The upper patch is shorted to the lower patch at the apex of the rectangular patch by a conducting plate. The width of the shorting plates is d_S. The relative dielectric constant and the thickness of the upper and lower layers are ε_{r1}=1.0, h_1 and ε_{r2}=2.6, h_2=2.4mm, respectively. The antenna is excited at the lower patch by a coaxial feed through the lower dielectric substrate at point x_0, y_0 which lays around the diagonal.

3. Resonant modes

Figure 2 shows input impedance. The antenna has three resonant modes.

3.1 Resonant mode by patch (Patch mode)

Figure 3(a) shows the intensity of the time averaged electric current distribution and figures 3(b) and (c) show the radiation patterns on x-z and y-z planes at the highest resonant frequency, respectively. The antenna operates as a conventional half-wavelength stacked rectangular MSA. The lower patch conductor also operates as a rectangular patch conductor with a perturbation segments [3]. Therefore, the resonant frequency is designed by the patch widths L and W and the axial ratio of the circular polarization is designed by the ratio between L and W.

3.2 Resonant mode by shorting plate (Shorting plate mode)

Figures 4(a), (b) and (c) shows the electric current distribution and the radiation patterns at the lowest resonant frequency, respectively. The antenna resonates when the sum of the lengths of the diagonal of the upper and lower patches and the shorting plate becomes a half wavelength. The resonant frequency can be designed by the width d_S and height h_2 of the shorting plate [3].

3.3 Resonant mode by helical pin (Helical pin mode)

Figures 5(a), (b) and (c) shows the electric current distribution and the radiation patterns at the middle resonant frequency, respectively. The antenna resonates by a helical pin (a new resonant mode) at this mode [5]. The antenna operates as the normal mode in a conventional helical antenna with ground plane.

4. Results and Discussion

Figure 6(a) shows the difference between the frequency giving the lowest return loss and the frequency with C_H=3.0mm at the shorting plate and helical pin modes for change of C_H. Figure 6(a) also shows the difference between the frequency giving the best axial ratio and the frequency with C_H=3.0mm at the patch mode for changes of C_H. Figures 6(b) and (c) show the cases for change of the number of turns of a helical pin N and for change of the height of helical pin h_3, respectively. In figures 6(b) and (c), the based frequencies are the ones with N=2.5 and h_3=3.0mm, respectively. Although the radius of helical pin C_H influences the frequencies at the shorting plate mode, it dose not affect the frequency at the patch mode. The influence on the shorting plate mode becomes strong as the radius C_H increases. Although, similarly, the number of turns of a helical pin N influences the frequency in the short plate mode, it dose not affect the frequency the patch mode. The shorting plate mode is strongly influenced within from N =3.0 to 3.5. However, the influence of the height of helical pin h_3 on the shorting plate mode is small. The parameters of the antenna geometry which influences only one resonant frequency are important for the multi band antennas because the parameters make the designing of the antenna easier [3]. Although the geometrical parameters, C_H, N and h_3, of the helical pin influence the resonant frequency at the shorting plate mode, h_3 is a relatively effective parameter.

Figures 7 and 8 show the return loss and axial ratio of the antenna designed for PHS/VICS/ETC applications. The specifications of the VICS, PHS and ETC are shown in table 1. The bandwidths in the PHS, VICS and ETC bands are 2.95%, 2.12% and 4.71%, respectively. The bandwidths and the center frequencies of the antenna satisfy the specifications of all applications.

5. Conclusion

A stacked rectangular MSA for triple band operation and an antenna for PHS/VICS/ETC applications in ITS has been designed. The three resonant modes have been achieved by shorting the upper patch to the lower patch of the stacked rectangular MSA and by loading a helical pin on the lower patch conductor. The relations between three resonant frequencies for the geometry of the helical pin have been investigated. The proposed antenna is useful as the antenna for triple band operation.

References

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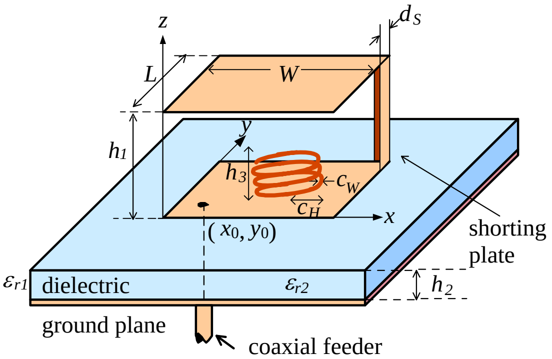
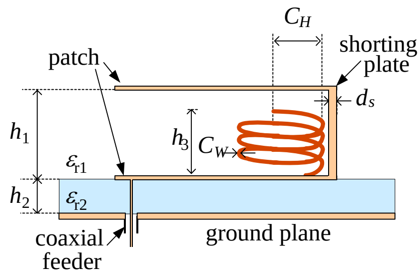


(a) Perspective view



(b) Side view

Figure 1: Geometry of a stacked rectangular MSA with a shorting plate and helical pin

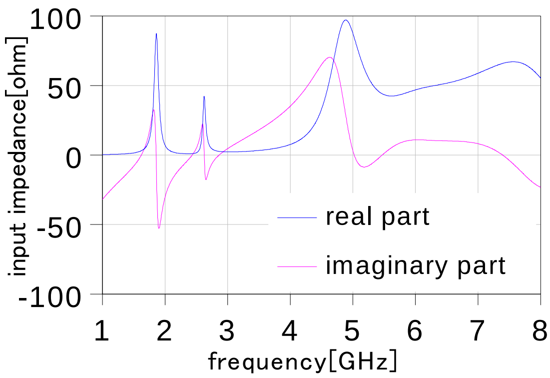
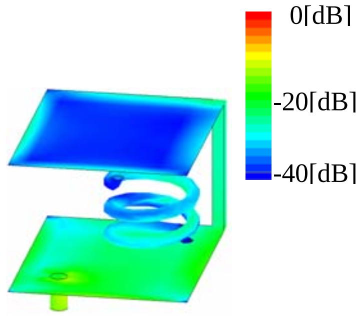
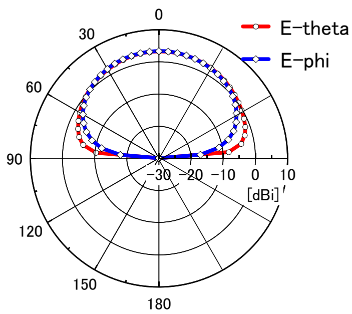


Figure 2: Input impedance

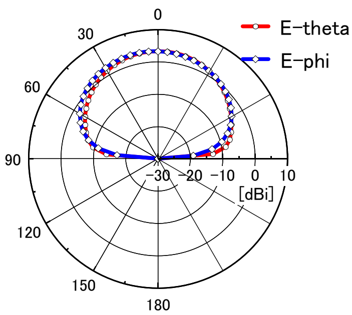
(W=12.8mm, L=16.1mm, h_1=8.6mm, d_S=1.0mm, h_3=6.0mm, C_H=2.5mm, C_W=0.5mm, N=2.5)



(a) Current distribution

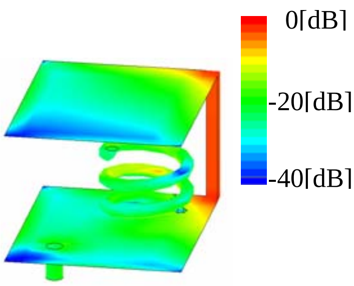


(b) x-z plane radiation pattern

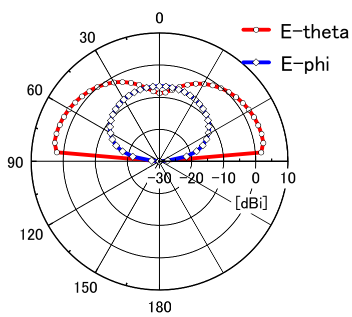


(c) y-z plane radiation pattern

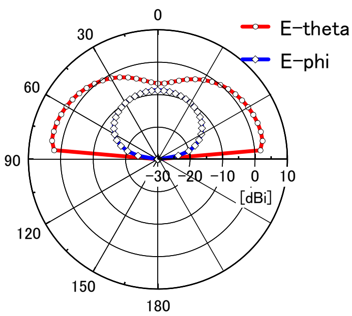
Figure 3 : Resonant mode by patch



(a) Current distribution

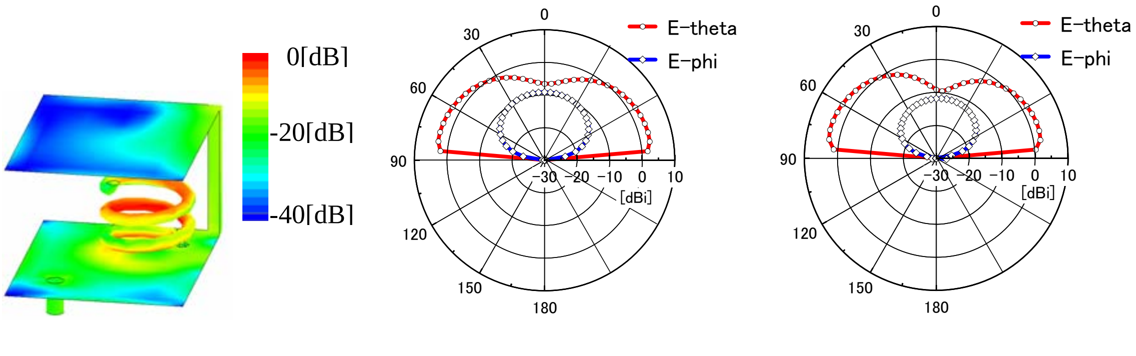


(b) x-z plane radiation pattern



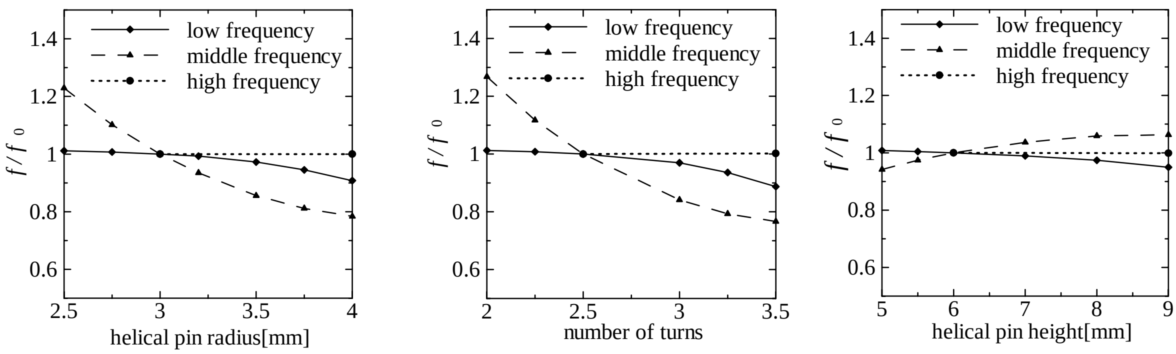
(c) y-z plane radiation pattern

Figure 4: Resonant mode by shorting plate



(a) Current distribution (b) x-z plane radiation pattern (c) y-z plane radiation pattern

Figure 5: Resonant mode by helical pin

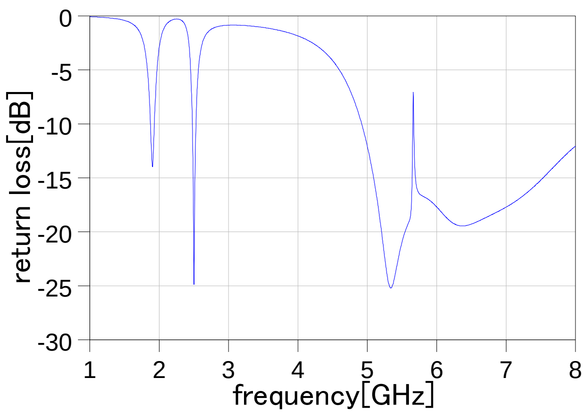


(a) for changes of C_H (b) for changes of N (c) for changes of h_3

Figure 6: Rate of changes in the resonant frequencies

Table 1 : Specification of PHS, VICS and ETC

	PHS	VICS	ETC
frequency[GHz]	1.9	2.5	5.8
bandwidth[MHz]	50	50	100
bandwidth[%]	2.63	2	1.73
polarization	linear	linear	circular



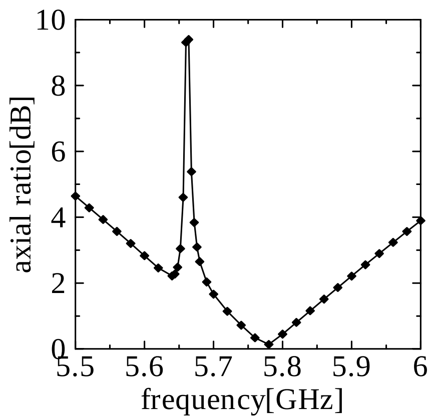


Figure 7: Return loss Figure 8: Axial ratio

(W=12.8mm, L=16.1mm, h_1=8.6mm, d_S=1.3mm, h_3=6.5mm, C_H=3.2mm, C_W=0.5mm, N=2.5)