Development of a Triple-Layered Patch Antenna Capable of Three Frequency Operations

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1. Introduction

Now, the Intelligent Transportation Systems (ITS) supports services in the 5.8GHz band (Electronic Toll Collection Systems -ETC), 2.5GHz band (Vehicle Information and Communication System -VICS) and the 1.5GHz band (Global Position System -GPS). In this situation, multimode terminals are requested [1]. A spiral antenna that can support 1.5 GHz, 2.6 GHz and 5.8 GHz was proposed [2]. In all frequencies, circular polarizations were used. Fundamental antenna characteristics were studied.

This paper investigates a thin and compact antenna. In this case, composite combinations of circular and liner polarizations are requested. A triple-layered patch antenna configuration is selected. The adequate antenna shapes and arrangements are determined through computer simulations. In order to simplify a feed structure, a through hole feed is employed and effectiveness is examined through experiments. Moreover, antenna radiation characteristics are ensured through experiments.

2. Antenna structure

Antenna design objectives are shown in Table1. Circular polarizations are requested at 1.5 GHz and 5.8 GHz bands. A single feed structure is preferred.

The proposed antenna structure is shown in Figure 1. Triple layers were employed in order to support three frequency operations. At 1.5 GHz and 5.8 GHz patches, opposite corners have trimmings that are made to support circular polarizations. Dielectric spacers have the same thickness (t). Figure 2 shows the cross-section of the antenna. The antenna is fed by a coaxial cable that passes through the ground plane, and is connected to the 5.8GHz patch. For 1.5GHz and 2.6GHz patches, through hole feed structures are employed [3]. A SMA connector whose inner and outer conductor sizes are 1.27 mmϕ and 4 mmϕ is used. Diameters of through holes are set 3.27 mmϕ. Those feed methods employing capacitive couplings are commonly used [4]. However, through hole feed method is not so common. Effectiveness of this method should be ensured experimentally.

3. Design of three frequency operations

In order to calculate antenna performances, A EM simulator of IE3D based on the Moment Method was used. The size of ground plane was 80mm, L3 was 59.36mm, L2 was 37.75mm and L1 was 16.34mm. Trimming sizes for 1.5 GHz and 5.8 GHz antennas were 3mm and 1.6mm, respectively [5]. The height of dielectric substrate was 0.33mm and the dielectric constant (εr) was 2.5. Very thin substrate was selected so as to suppress unwanted mode in lower frequency patches. Patch positions were very important to achieve satisfactory VSWR characteristics. Calculated VSWR characteristics are shown in Fig.3. At 1.5 GHz, 2.5 GHz and 5.8 GHz, VSWR values of less than 1.5 are achieved. At 5 GHz and 5.6 GHz, additional low VSWR levels are happened.

Calculated results of radiation patterns are shown in Figs. 4 to 6. At 1.5 GHz, right hand circular polarization characteristics are achieved. Excellent axisymmetric radiation patterns are also obtained. Levels of opposite circular components become -7 dB. The trimming size was not ideal. At 2.5 GHz, excellent linear polarization characteristics are achieved. Cross polarization levels less than –24 dB are achieved. At 5.8 GHz, right hand circular polarization characteristics are achieved. Excellent axisymmetric radiation patterns are also obtained. Levels of opposite circular components become -12 dB. The trimming size was rather suitable. Induce currents on patches are shown in Figs. 7 to 9. Very strong induced currents are achieved on individual patches of 1.5 GHz, 2.5 GHz and 5.8 GHz. Unwanted currents on individual patches are suppressed very well.

4. Measured results

Measured VSWR characteristics are shown in Fig.10. Minimum VSWR values are achieved at 1.563 GHz for the 1.5 GHz band, at 2.475 GHz for the 2.5 GHz band and at 5.97 GHz for the 5.8 GHz band. Reasons of these frequency shifts are supposed that differences of dielectric constants between actual and calculated antennas are occurred. Impedance matching frequencies of 4.946 GHz and 5.549 GHz are corresponds to calculated frequencies. However, frequencies of 3.152 GHz and 3.551 GHz are unexpected.

Measured radiation patterns are shown in Figs. 11 and 12. At 1.5 GHz band, agreement of radiation patterns between Fig.4 and Fig.11 seems very well. Measured gain of about 5dBd was obtained. Judging from the calculated gain of 6.67 dBi, feeding loss was very small. At 2.5 GHz band, agreement of radiation patterns between Fig.5 and Fig.12 is very well. Measured gain of about 4dBd was obtained. Judging from the calculated gain of 7.45 dBi, feeding loss was estimated 1.3 dB. By these small feeding losses, the through hall feed is ensured useful. Measured results of 5.8GHz band are to be studied.

5. Conclusions

A triple layered patch antenna of three-frequency operation was designed. Patch antenna positions were important in order to achieve good VSWR characteristics. Antenna spacing was also important so as not to introduce unwanted modes. An important trial of this antenna was through hole feed. Through comparing measured and calculated gains, feeding loss was shown to be rather small. Usefulness of the through hole feed was ensured. Radiation characteristics of circular and linear polarizations are successfully achieved. As a result, realization of a low profile antenna was shown.

References

[1] M.Umemoto et al, “Development of a Multimode Wireless Communication Terminal in ITS”, 7th World Congress on Intelligent Transport Systems, Oct. 2000 [2] A.Sagisaka, ”A study on ITS multi-band antenna for vehicles”, Technical Report of IEICE, AP 2001-167, pp.49-54, Jan. 2002 [3] T.Seki and T.Hori, “Pin-Fed Microstrip Antenna Array using Multi-Layer Teflon Substrate Constructing Method for Integrated Antenna”, Proceedings of the 2001 Communications society Conference of IEICE, B-1-131, 2001 [4] K.Hirasawa and M.Haneishi, “Analysis, Design and Measurement of Small and Low-Profile Antennas”, Artech House, pp.136-137,1992 [5] K.Hirasawa and M.Haneishi, “Analysis, Design and Measurement of Small and Low-Profile Antennas”, Artech House, pp.68-71,1992

Table1. Design objectives of an antenna

	GPS	VICS	ETC
Frequency	1.575G±30MHz	2.4997G±30MHz	5.8GH±50MHz
Gain	≧2dBi	≧0dBi	≧6dBi
VSWR	≦2	≦2	≦2
Polarization	RH Circular	Linear	RH Circular
Structure	patch antenna with single feed		

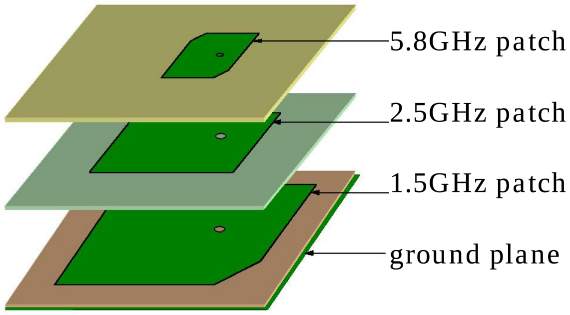

Fig.1 Triple-layered patch antenna

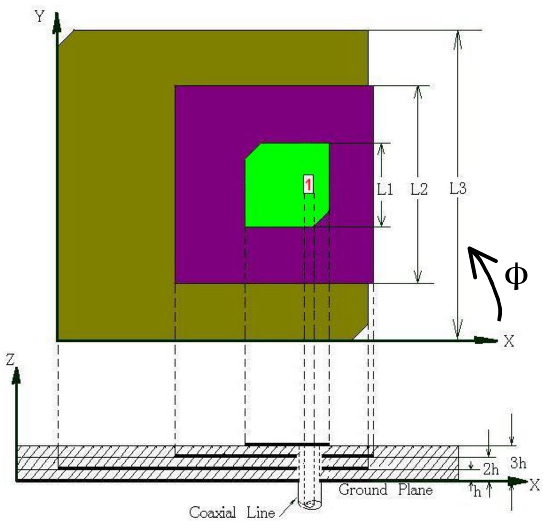

Fig.2 Layout of patch antennas

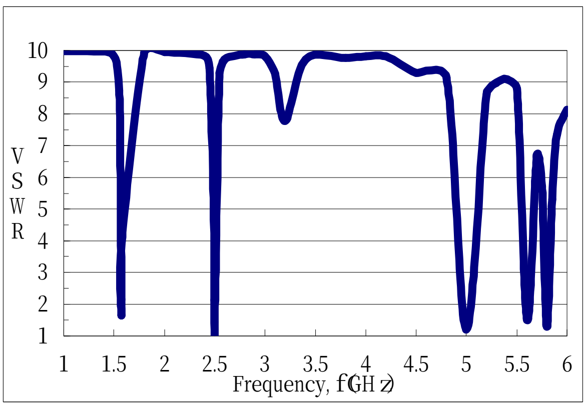

Fig.3 Calculated VSWR characteristics

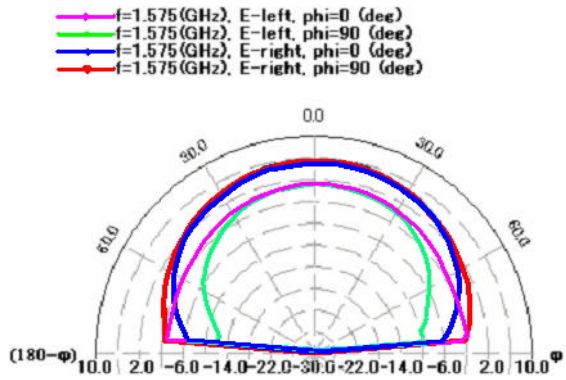

Fig.4 Radiation patterns at 1.5 GHz

(Circular polarization)

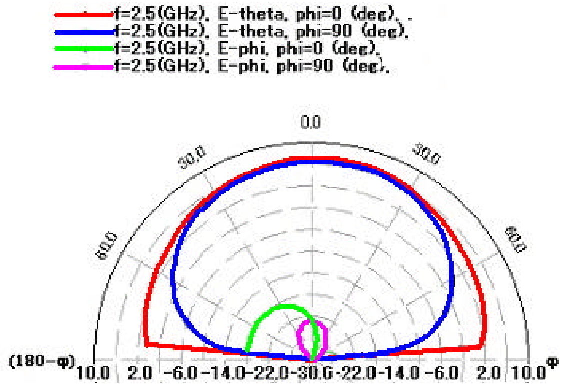

Fig.5 Radiation patterns at 2.5 GHz

(Linear polarization)

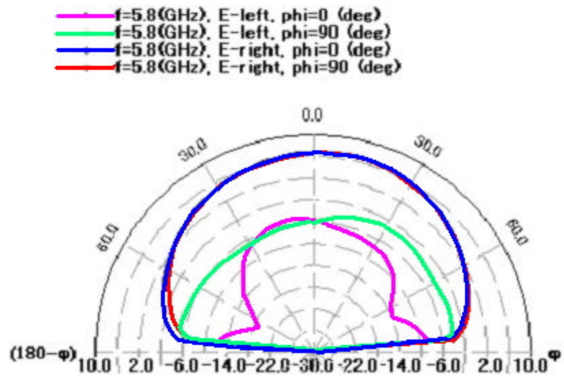

Fig.6 Radiation patterns at 5.8 GHz

(Circular polarization)

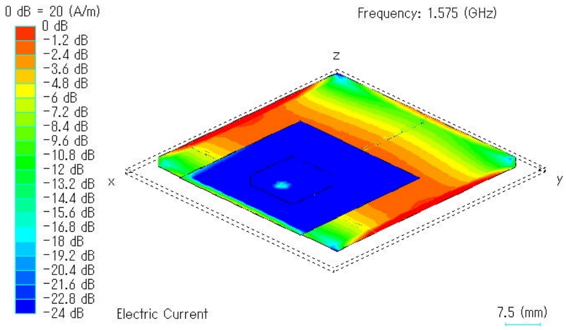

Fig.7 Induced currents at 1.5GHz

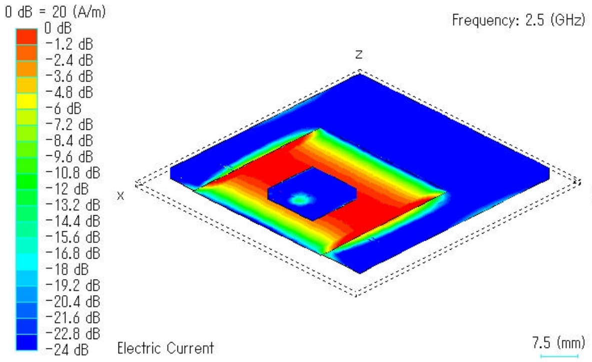

Fig.8 Induced currents at 2.5GHz

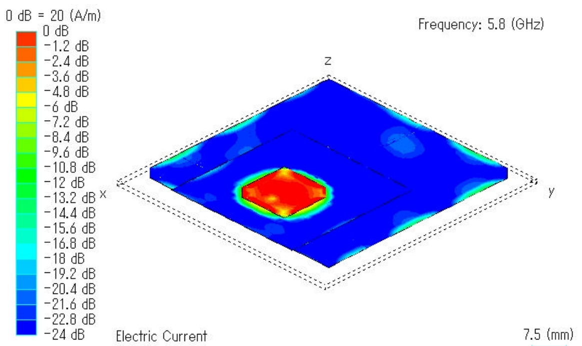

Fig.9 Induced currents at 5.8 GHz

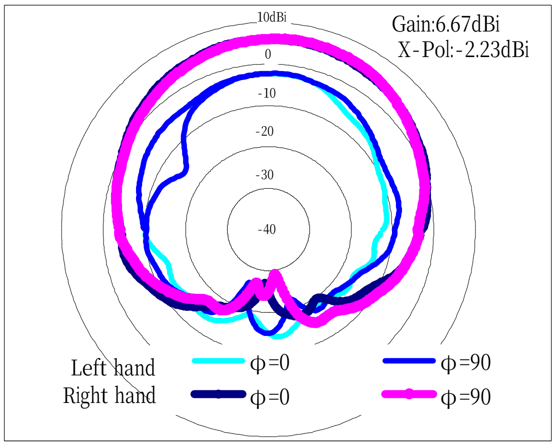

Fig.11 Measured radiation patterns at 1.563 GHz

(Circular polarization)

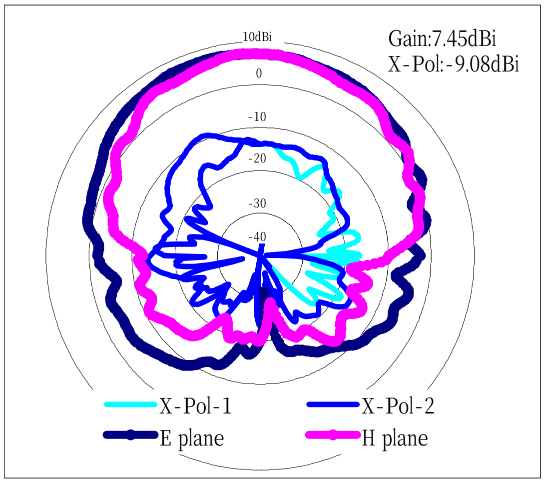

Fig.12 Measured radiation patterns at 2.475 GHz

(Linear polarization)

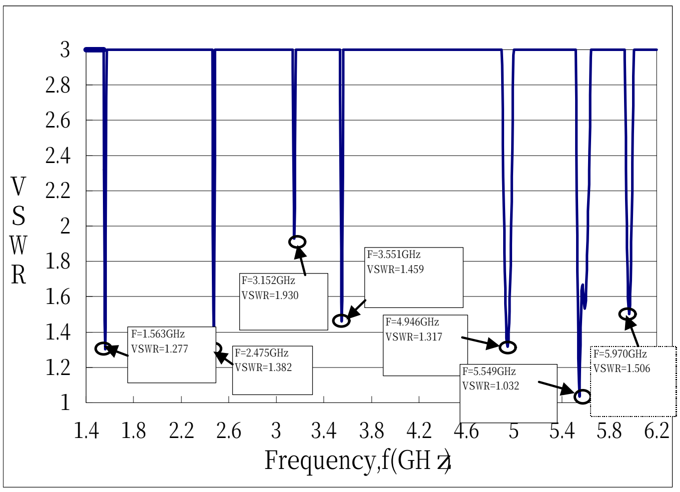

Fig.10 Measured VSWR characteristics