POS1-41

Development of Multiple Frequency Band Antenna for ITS

Seiji MORITA, Yoshinobu OKANO
Musashi Institute of Technology
1-28-1, Tamazutsumi, Setagaya-Ku, Tokyo, Japan 158-8557

1. Introduction

Recently, the number of wireless telecommunication equipments installed in the car increases rapidly because of the spread of ITS (Intelligent Transport Systems). Especially, GPS (Global Positioning System), VICS (Vehicle Information and Communication System), and ETC (Electronic Toll Collection System) are becoming indispensable telecommunication item. However, because space in the car is limited, it is impossible to set up the antenna for GPS, VICS, and ETC individually.

Accordingly, these antennas should be integrated. Actually, two or more antennas are electromagnetic coupled with MSL (Micro Strip Line). As the point that should be noted, VICS needs linear polarized antenna though GPS and ETC use circular polarized antenna. In circular polarized antenna, two point feeding method by power divider is adopted. In two point feeding method, when the phase difference between feed points is 90 degrees, the circular polarized radiation is caused. On the other hand, the linear polarized radiation is caused when there is no phase difference between feed points. Consequently, the circular polarized and the linear polarized radiation is divided only by the phase difference adjustment between feed points. In addition, because the use frequency for GPS, VICS, and ETC is 1.5GHz, 2.5GHz and 5.8GHz respectively, the antenna size can be gradually reduced. Hence, if each antenna is arranged in the nest, the integration of different polarized antennas becomes possible.

The requirement to the antenna for ITS has “Compact size”, “Coexistence of circular polarized wave and linear polarized wave”, and “Adaptability to multi band”, etc.. The most important technology for ITS antenna is method of radiating circular polarized wave. There are two methods that radiate circular polarized wave. The one point feeding method is advantage in simple feeding. On the other hand, two point feeding method is advantage in easier phase control. It is necessary to synthesize these methods so those circular polarized waves coexist with linear polarized wave.

Multi loop antenna is reported as the antenna, which obtains adaptability to multi band [1].
Therefore, the antenna which combined two point feeding method with multi loop antenna is designed. Fig. 1 shows the structure of that antenna. The antenna radiates circular polarized wave for the structure of Fig. 1 in the multi band.Accordingly, The requirement to the antenna for ITS can be achieved.

2. Antenna structure

At the first step, the antenna for GPS which uses a lower frequency band in ITS is designed.. Because the antenna for GPS is located the outside of multi loop antenna, this design decides the outline of the antenna.

The phase difference of $1/4\lambda o$=20mm (λo=equivalent wavelength) is given by using the MSL divider as shown in the Fig.2.

This antenna has some parameters to control input property.. Concretely, it is length for passage of feeding power line under the loop element “l”, width of loop element “d”, thickness of upper layer dielectric substance “h” etc. The impact of these parameters is shown in the following chapter.

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3. Parametric analysis

This chapter describes the impact, which each design parameter gives to the antenna performance. Those impacts are evaluated using numerical analysis by the finite-difference time-domain (FDTD) method [2]. The parameters of the FDTD calculation employed in this paper are as follows. The cell size is 0.5 mm uniformly. The time step of the FDTD calculation is 0.963 ps. Liao's method [3] is used for the absorbing boundary condition. The relative permittivity is set to 5 and the conductivity is assumed to 0 S/m in the dielectric substance.

3.1 Dependency of "*l*" for antenna property.

According to Fig.3, in the resonance frequency enclosed in the broken line, the characteristic into which only resistance changed by the "*l*" appeared.

3.2 Dependency of "*t*" for antenna property.

According to Fig.4, there is parallel resonance region in the lower frequency band, and the series resonance region exists in the higher frequency band in the impedance behaviour of this antenna. Circular polarized wave is radiated only with series resonance region, and it is not radiated in parallel resonance region.

The resistance in the series resonance frequency band can be controlled by "*l*", and the reactance of the series resonance frequency can be controlled by "*t*". Fortunately, the reactance adjustment by "*t*" does not influence resistance.

Therefore, the control of VSWR is easy according to the adjustment of "*l*" and "*t*".

3.3 Dependency of "*d*" for antenna property.

According to Fig.5, the resonance frequency of the loop antenna depends on the average circumference of the loop element. The antenna resonates in the frequency that the average circumference of the loop element corresponds to one wave length. Input property is deteriorated though the antenna gain increases when "*d*" increases. When "*d*" becomes 9mm or more, input reactance does not approach 0 in Fig.5.

3.4 Dependency of "*h*" for antenna property.

According to Fig.6, the effect which upper layer dielectric substance thickness "*h*" gives antenna property looks like "*d*". In a word, input property is deteriorated though the antenna gain increases when "*h*" increases. However, "*h*" has a deeper impact for input property.

Hence, "*d*" and "*h*" are used as a parameter of the gain improvement. On the other hand, the input property deterioration because of the change in "*d*" and "*h*" is cancelled by "*l*" and "*t*". It is thought that the optimisation of the antenna can be achieved by those operations.

The antenna characteristic at *l*=2mm, *d*=6.5mm, *t*=11mm, *w*=2mm, and *h*=2mm is shown below.

Fig.7 shows antenna input property. The bandwidth of VSWR<2 satisfies the requirement for GPS. Additionally, the gain in a center frequency of GPS obtains about 2dBi (see Fig.8).

In this report, the design concept and the parameter analysis result of the multi band loop antenna for ITS were described. It has been understood that each design parameter is in the relation of the trade-off according to the result of the parameter analysis. The optimisation of each design parameter was carried out, and achieving the antenna that satisfied the requirement for GPS became possible at the present stage. At the next stage, the multi band loop antenna for ITS will be completed.

5. Technology for antenna integration

In this section, the actual accumulation technique of the L1(1.5GHz) band and L2(1.2GHz) band antenna of GPS is shown. Because the correlation of the L1 band and the L2 band is strong, the design is complex a little.Therefore, the L1 and L2 antenna are located in separate hierarchy as a correlation control technique of the antenna as shown in Fig. 9. The L1 and the L2 band are integrated as shown in Figure 10 though the gain adjustment is imperfect.

6. Conclusion

In this report, the design concept and the parameter analysis result of the multi band loop antenna for ITS were described. It has been understood that each design parameter is in the relation of the trade-off according to the result of the parameter analysis. The optimisation of each design parameter was carried out, and achieving the antenna that satisfied the requirement for GPS became possible at the present stage. However, because the adjustment of the gain of each antenna is imperfect, a further parameter analysis is needed.

References

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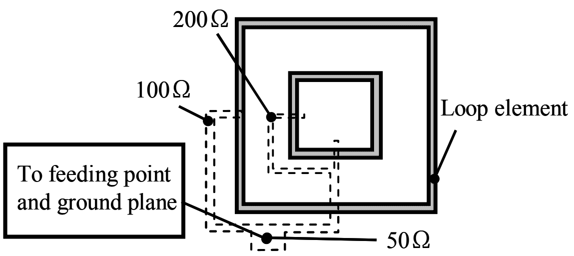


Fig.1 Multi band antenna by electromagnetic coupling with MSL

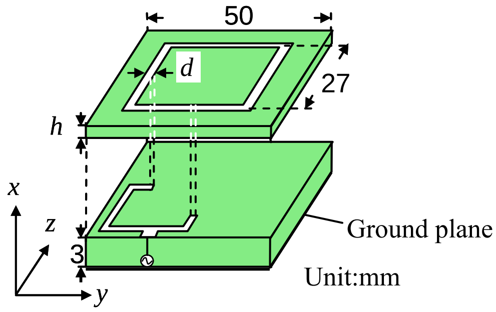


Fig.2-a Basic antenna model

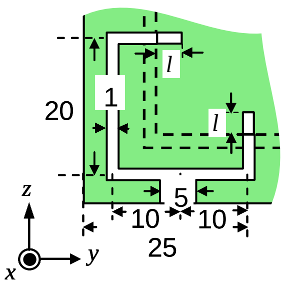


Fig.2-b Underlayer model

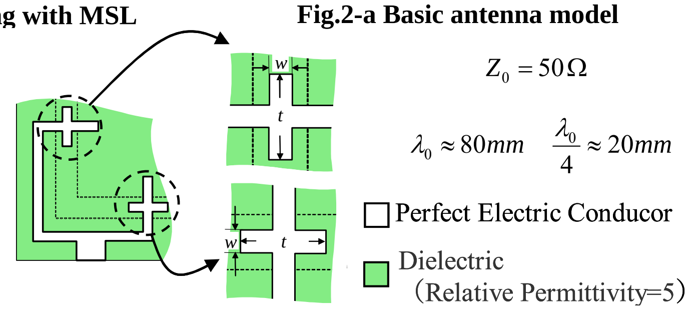


Fig.2-c Details on feeding power line

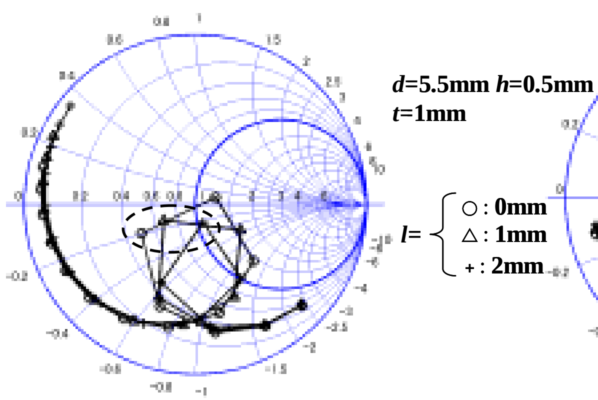


Fig.3 Impedance characteristic by "l"

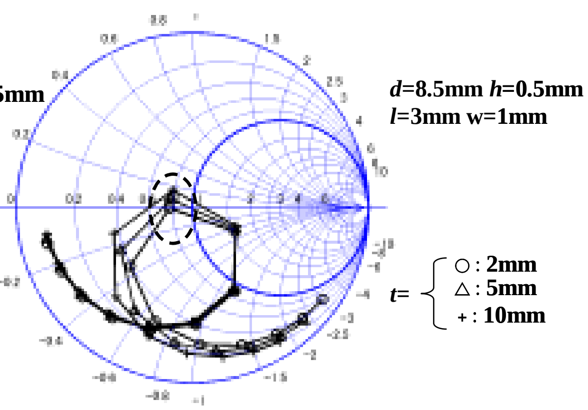


Fig.4 Impedance characteristic by "t"

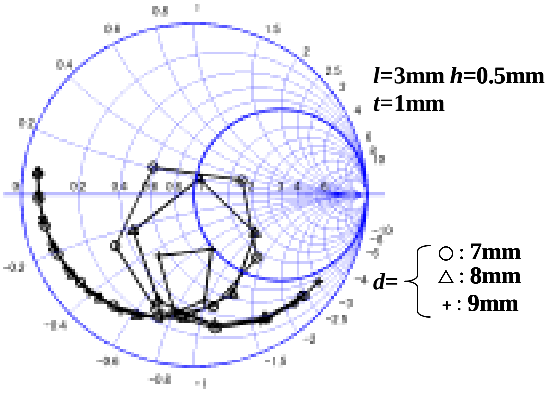


Fig.5 Impedance characteristic by "d"

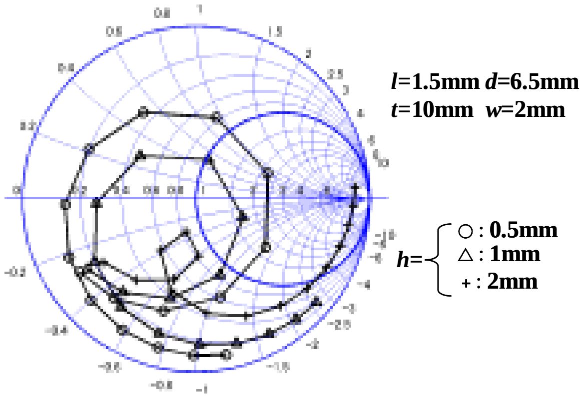
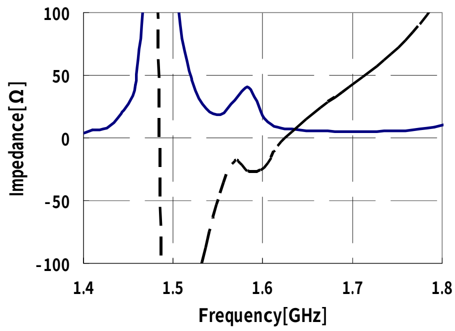


Fig.6 Impedance characteristic by "h"



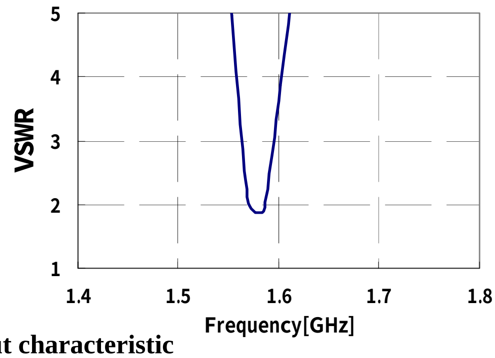
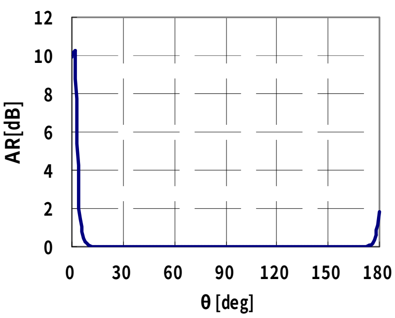
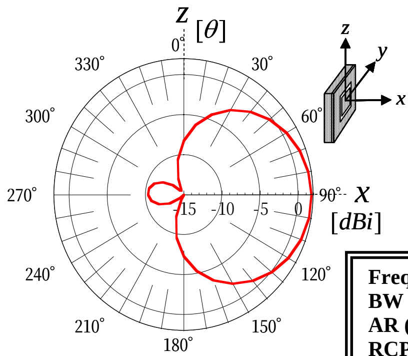


Fig.7 Input characteristic





Frequency : 1.575GHz
BW (VSWR≦2) : 24MHz
AR (Min) : 0dB
RCP Gain (Max) : 1.74dBi

Fig.8 Radiation pattern (Z-X plane)

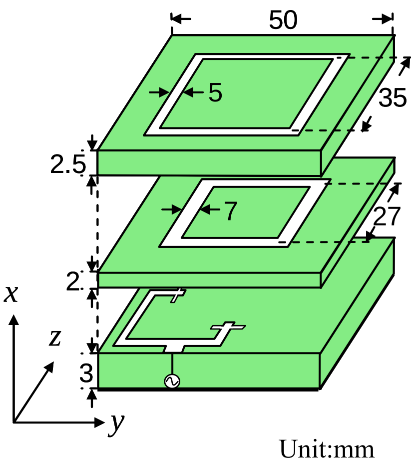


Fig.9 Antenna structure

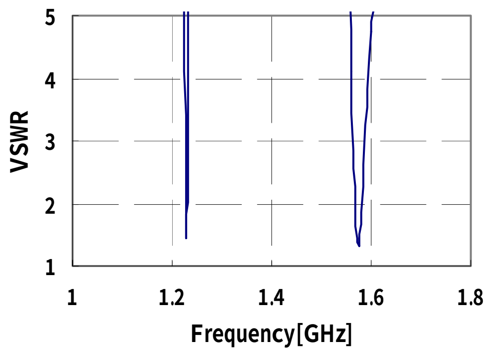


Fig.10 Input characteristics

Table 1 calculation result

	GPS(L2)	GPS(L1)
Frequency	1.227GHz	1.575GHz
BW (VSWR≦2)	8MHz	24MHz
AR (Min)	0dB	0dB
RCP Gain (Max)	-8.87dBi	1.46dBi