SLOTTED HIGHER-ORDER-MODE MICROSTRIP ANTENNAS FOR ROAD VEHICLE COMMUNICATIONS

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1. Introduction

Car antennas for road vehicle communications systems are desirable to have receiving power level characteristics as uniform as possible from just beneath the beacon antenna erected by the roadside to a long distance along the road. The antennas used for this purpose have been mostly the usual dominant mode microstrip antennas (MSA). One reason is that they are small-sized, light, and cheep, and another reason is that they work anyhow setting aside the communication quality. However, the dominant mode MSA does not have good antenna characteristics when viewed from the receiving power level uniform in the direction along the road and small in the direction perpendicular to the road. Thus, we investigated in detail the relation between the radiation patterns and the shapes of MSA, defining and using a measure called “effective directivity”, which can evaluate the effective receiving power level by taking into account the distance and mutual inclination between car antenna and beacon antenna. Thus, we proposed three types of higher-order-mode MSA as car antennas suitable for use in road vehicle communications systems [1].

This paper shows that another type of MSA, i.e., slotted higher-order-mode MSA is similarly suitable for the same purpose. To show clearly its receiving power level in the directions along the road and perpendicular to the road, the radiation patterns in the horizontal plane are given, together with those for the π type higher-order-mode MSA previously proposed and those for the dominant mode MSA.

2. Modeling of the problem

Figure 1 shows a simplified model of the positioning of the beacon antenna and car antennas for the road vehicle communications systems. The beacon antenna is of a dipole type and erected by the roadside at a height of h with an inclination angle of θ'. A car lane is drawn at a distance d from the roadside. In the VICS (Vehicle Information and Communications System) in Japan, the inclination angle θ' is usually 45 degrees, the height h is 5 m, and frequency f is 2.5 GHz. It is assumed that beacon antennas are placed at intervals of several kilometers and therefore that mutual interference between beacon antennas need not be considered. We suppose that car antennas are placed on a wide flat conducting plane like a car roof. Then, we idealize the problem so that the car antennas are on an infinitely wide conducting plane. This model does not give accurate radiation patterns for practical antennas of finite sized ground plane, particularly near horizontal direction. We think, however, that it would be allowed to make, by this idealized model, comparative evaluation of difference of radiated power level for various antennas as is written in Refs. [1] and [2].

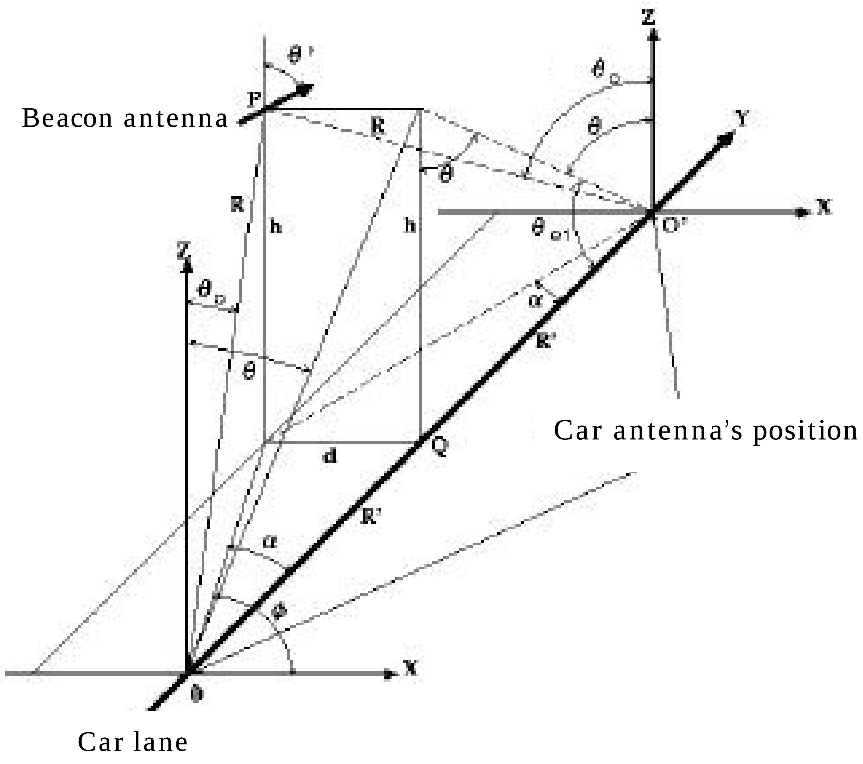

Fig. 1. Positioning of transmitting and receiving antennas.

The problem here is to design car antennas such that receiving signal levels are as uniform as possible from just beneath the beacon antenna to a long distance along the road (desirably, more than several tens meters in the case of VICS), with radiation in the directions vertical to the road being small. The important point is that we try to find such desirable antennas by only small change in shape from the dominant mode MSA. Theoretical analysis is done by using the FD-TD method. Radiated fields are calculated by a surface integration of fields on a closed surface enclosing the antenna where the fields obtained by means of the image theory are used in place of those on the ground conductor.

3. Effective directivity

We use as a measure of receiving power level of car antennas, the following quantity, the effective directivity E_{eff}:

$$E_{eff} = \frac{1}{R} | D_x \sin\theta' + D_z \cos\theta' | \tag{1}$$

where θ' is the inclination angle of the beacon antenna, and R is the distance between the beacon antenna and the car antennas; long distance approximation is used for this R. The D_x and D_z are given as

$$D_x = D_\theta \cos\theta_0 \cos\varphi - D_\varphi \sin\varphi \tag{2}$$

$$D_z = -D_\theta \sin\theta_0 \tag{3}$$

where D_θ and D_φ are the θ and φ components, respectively, of the directivity of car antenna in the direction of beacon antenna with the car antenna position being the coordinate origin. The angles θ_0 and φ are shown in Fig. 1.

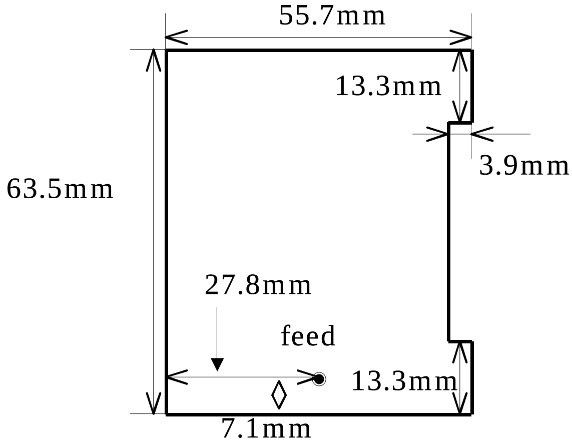

Fig. 2. π type microstrip antenna.

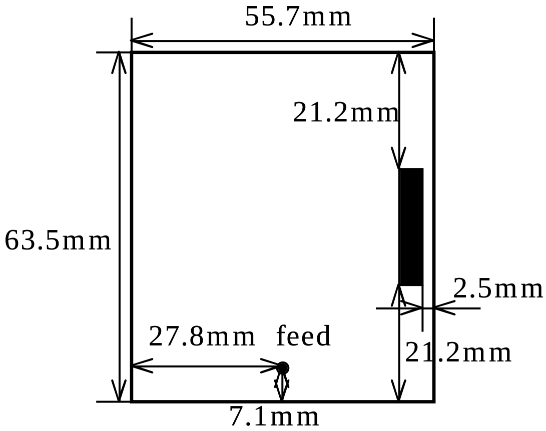

Fig. 3. slotted microstrip antenna.

4. Characteristics of slotted antennas

In Ref. [1], the MSA with various shapes were investigated in detail under the condition that the antennas are used in VICS. As a result, three types of higher-order-mode MSA were proposed which have better characteristics than those of the dominant mode MSA. Among these three, the π type one shown in Fig. 2 looks to be the best on the whole. This paper presents another type of simple higher-order-mode MSA, i.e., slotted MSA which has similar or slightly better characteristics than those given in Ref. [1]. The shape is shown in Fig. 3. The relative dielectric constant is chosen as 3.4. Figures 4 and 5

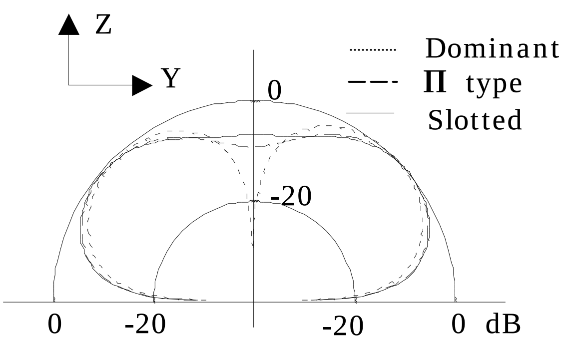

Fig. 4. Effective directivity (d = 1m).

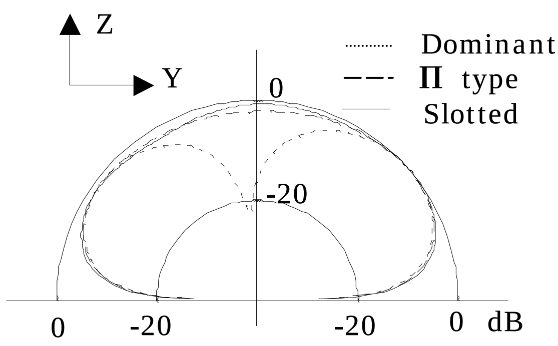

Fig. 5. Effective directivity (d = 3m).

show the E_{eff} patterns of this MSA, together with those of π type and dominant mode MSA; Fig. 4 is for d = 1 m and Fig. 5 is for d = 3 m. It is seen, from these figures, that slotted MSA has similar or a little better E_{eff} patterns than those of π type MSA, and far better E_{eff} patterns than those of dominant mode MSA.

The radiation patterns in the horizontal plane of slotted MSA, π type MSA, and dominant mode MSA are shown in Fig. 6. The magnitude itself of Fig. 6 is not practical since the ground conductor is assumed to be infinitely wide. However, Fig. 6 does have reliable meanings in the sense that comparison between the pattern of one antenna and that of other antenna is possible, because the effect of finiteness of the ground conductor width on the patterns should be almost the same to all antennas, as long as the antenna height is small and ground conductor width is sufficiently large. It is clear from Fig. 6 that slotted MSA has far better characteristics than dominant mode MSA as regards the receiving power level in the directions along the road as well as perpendicular to the road.

5. Conclusion

The properly slotted higher-order-mode microstrip antenna is presented for one of those MSAs which are more pertinent to car antennas for road vehicle communications systems than dominant mode MSAs. It seems not so easy to examine directly the E_{eff} patterns of various MSAs through experimental means. However, it would be necessary to do some experimental verification of the results obtained theoretically here, which is now under way.

References

1. Y. Kazama, N. Morita, and S. Tokumaru, “Mobile communications higher-order mode microstrip antennas for road vehicle communications”, IEICE Trans.Commun., Vol. J82-B, No.10, pp.1898-1904, Oct. 1999.
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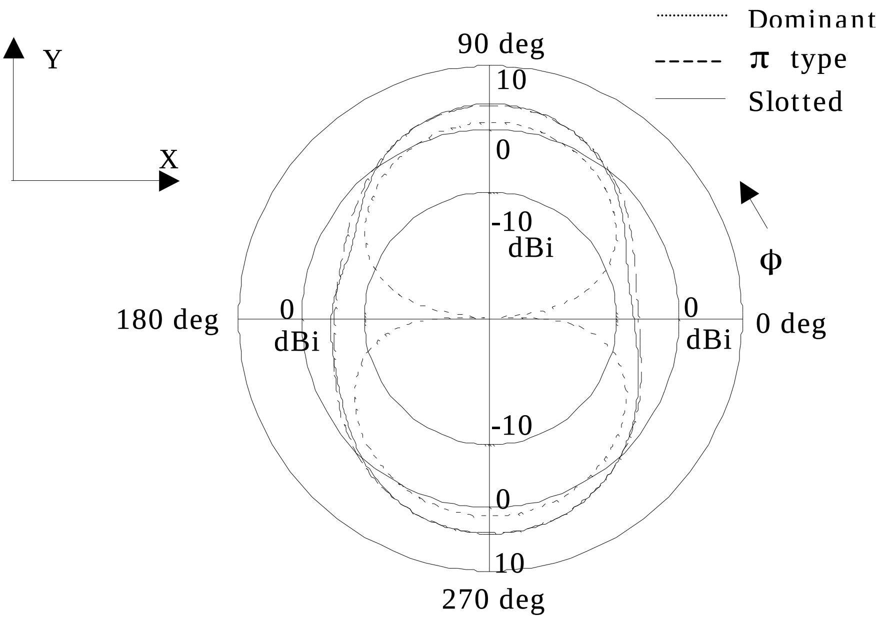

Fig. 6. Radiation patterns in the horizontal plane.