THE APPLICATION OF NUMERICAL METHODS TO VEHICLE ANTENNAS

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1. Introduction

It is well-known that diversity and adaptive antenna systems are valid for reducing the effects of multipath fading in VHF band vehicle radio receiving. These systems consist of multiple antennas installed on a vehicle body and a control unit which switches or synthesizes these antennas. To obtain optimum control in systhesizing, it is necessary to know the actual radiation patterns of these antennas. However, these are difficult to predict because they fluctuate greatly according to the effects of reflection and diffraction on the metal body of the vehicle. For solving this problem, wire-grid modeling [1] and moment-method solution was applied to compute vehicle antenna properties in reference [2], where the numerical results were obtained by specially adjusted distribution of piece-wise sinusoidal currents (PSC) on the wire structure [3]. However, the algorithm of this adjustments was not clear. In other words, it is difficult to apply this method to general cases. This paper shows that another wire-grid solution, which doesn't need any special adjustments, is valid for analysis of vehicle antennas. Under a variety of conditions, the results of this method agree with the measurement results on a scale model with highly accurate measurement system. Finally, the example of synthesized antennas analysis is shown as the application of this numerical method.

2. Calculation method and measurement

The model used in the calculation procedure is shown in Fig.1. It is similar to actual vehicle model with partitions between passenger room and engine compartment, and between the passenger room and trunk. The antennas which are calculated here are typical ones: front pillar, front glass, and two whip antennas. (The antennas are numbered in the figure.) Each antenna is given a mount angle and length similar to actual vehicle antennas in selected vehicles. Wire-grid model shown in Fig.2 is automatically generated by computer program from the structural data of the vehicle model, and then the distribution of PSC is

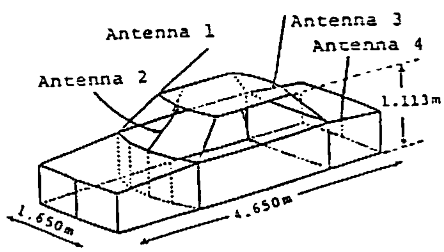


Fig.1. Vehicle model

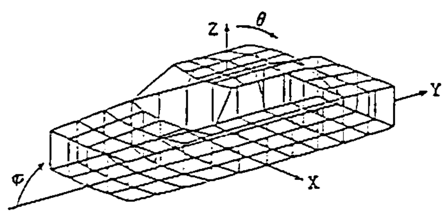


Fig.2. Wire-grid model

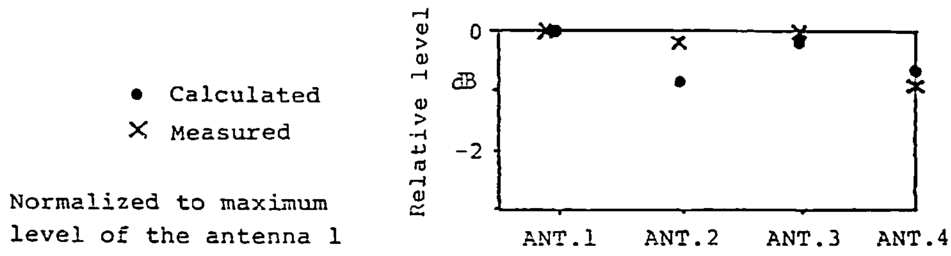


Fig.4. Comparison of calculated and measured levels.

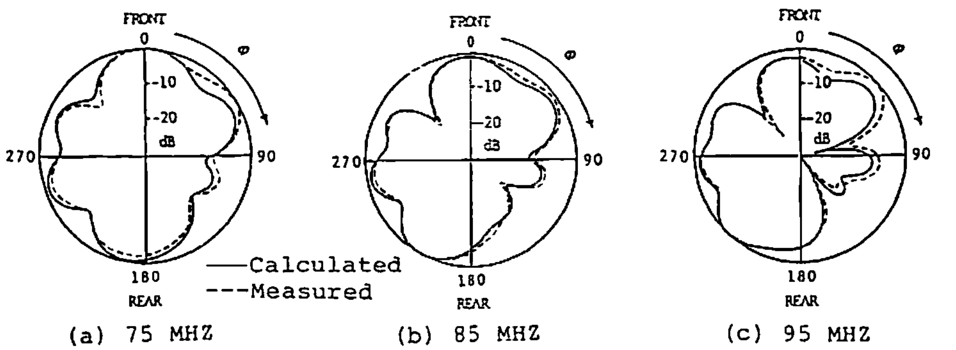


Fig.5. Radiation patterns of antenna 4 at different frequencies in the xy plane with φ polarization.

4. Application to synthesized antennas

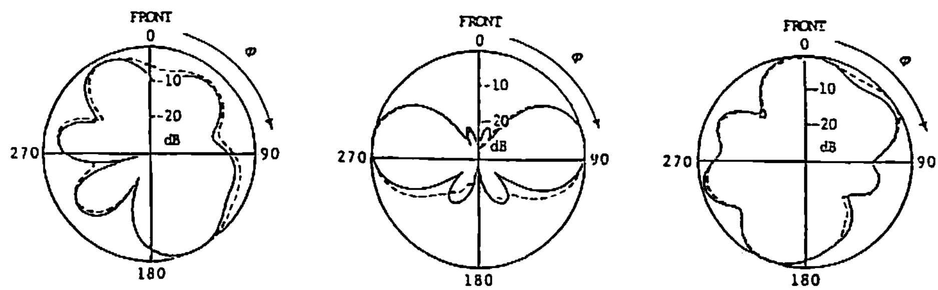
It was demonstrated in the preceding sections that it is possible to calculate radiation patterns of vehicle antennas accurately. Now, this section is devoted to reducing the effect of multipath fading in the VHF band vehicle antnnas under various field conditions. We developed the synthesized antenna analysis process shown in Fig.6 for this purpose, which uses the current distributions calculated by the moment-method. The first step in this process is to calculate the current distributions of each antenna. Obviously, the wire-grid model for calculating each antenna property should contain the source impedance of the other antenna elements. The phases and levels of current distrubutions should be appropriately controlled and synthesized in order to obtain the best adjusted lobes and nulls in the radiation patterns. An example of synthesized antennas is shown in Fig.7. This example assumes an antenna system on a moving vehicle in the field, which includes direct and indirect waves from various directions according to the position of the vehicle. It can be seen that this synthesized antenna analysis provides radiation patterns, including adjusted lobes and nulls, which are effectively formed to reduce the effect of multipath fading.

determined by a simple algorithm; that is, N-1 PSC are assigned for N wires which are connected together at each grid point. 360 PSC were employed for the models containing antennas 1, 2 and 3, respectively, and 361 PSC was used for the model containing antenna 4.

For comparison, on the other hand, a 4/25 scale model was measured in an anechoic chamber, taken special care to (1) avoid reflection waves by using a receiving antenna with narrow directivity beam, and (2) ensure the separation of horizontal and vertical polarization components of electric field by setting the scale model and receiving antenna in a precisely horizontal position.

3. Numerical results

Radiation patterns and the relative levels of each antenna have to be calculated accurately in order to employ them effectively in the analysis of sythesized antennas. So, to determine the degree of accuracy, the properties of the antennas shown in Fig.1 were calculated, and these calculations were compared with the experimental results on them at several frequencies. A comparison of measured and calculated horizontal radiation patterns at 80 MHz is shown in Fig.3. Agreement shown in the case of each antenna is very encouraging. Figure 4 shows calculated and measured maximum radiation levels for each antenna, which is normalized to the antenna 1 level for both the measurement and calculation. The difference in the levels between calculated and measured results are less than 1 dB. Radiation patterns for the antenna 3 at several frequencies are shown in Fig.5. Details in these patterns, such as lobes and nulls, change according to frequency fluctuations (75-95MHz). And at each frequency, agreement with the measured results is excellent. (An IBM 3081 computer was used, and it took about 20 minutes for each calculation.)



Frequency: 80MHZ
Wire radius: 0.005λ
Normalized to max level

—— Calculated
--- Measured

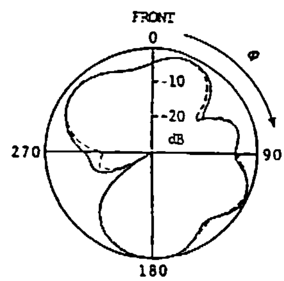


Fig.3. Radiation patterns of each antenna in the xy plane with φ polarization.

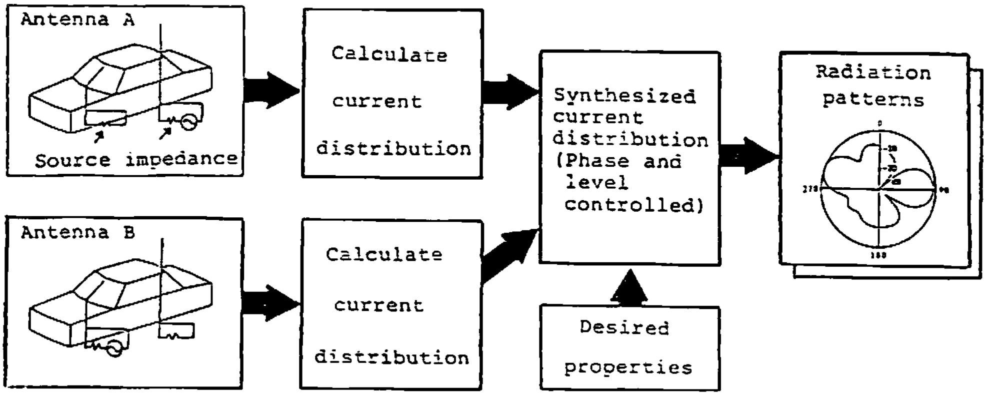


Fig.6. Process of synthesized antenna analysis

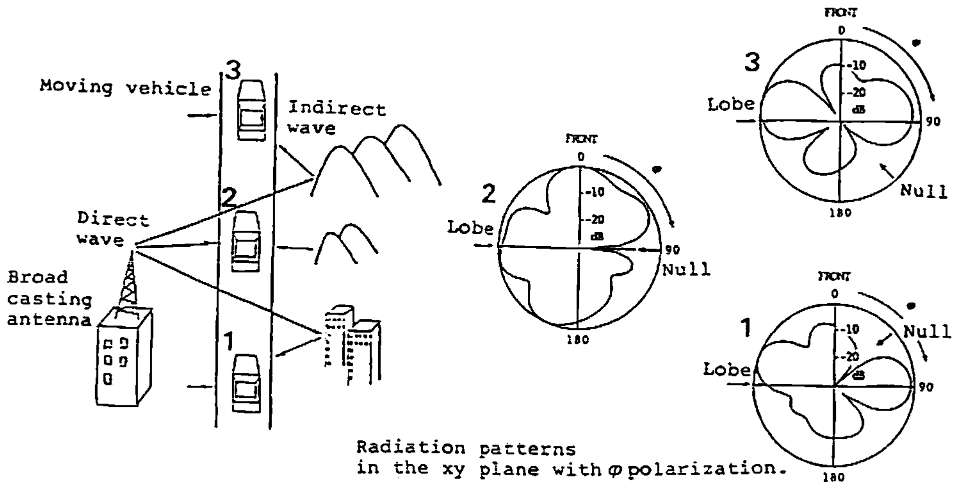


Fig.7. Example of synthesized antenna pattern analysis

5. Conclusion

A wire-grid modeling and moment-method solution is applied to analyze vehicle antenna properties. By comparing with the measured results on a scale model, the numerical results were found to be accurate enough under a variety of conditions for using in designing synthesized antennas. Furthermore, it is proposed that these numerical solutions can be used effectively in obtaining the desired properties of radiation pattern that lobes and nulls are adjusted to face in the desired direction. These methods are expected to be utilized to reduce the effects of multipath fading.

References

[1] Richmond, J.H.,"A wire-grid model for scattering by conducting bodies," IEEE Trans., Vol. AP-14, pp. 782 - 786, Nov. 1966.
[2] Nishikawa, K., "Analysis of a monopole antenna mounted on an automobile body by the wire-grid method," Trans. IECE Japan, Vol. J66-B, 7, pp.845 - 852, 1983.
[3] Private Communication.