Influence of a Metallic Turntable on Automotive Antenna Pattern Measurements

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Abstract

This article investigates the influence of finite ground planes surrounding the turntable in automotive antenna measurement ranges. The orientation of the non-symmetrical ground plane in relation to the vehicle has a severe effect on the measured radiation patterns that cannot be avoided. In order to develop possible methods of error correction the strength of the effect is determined. The influence of position errors in measurements is also investigated and shown to be comparatively small.

1. Introduction

Antenna measurement ranges for automotive applications feature a turntable that can bear the weight of a car and an antenna that is situated far enough from the turntable to achieve far field conditions as shown in Figure 1. The ground plane surrounding the turntable is often rectangular for design reasons. During measurements the car is rotated on the turntable while the antenna pattern is recorded.

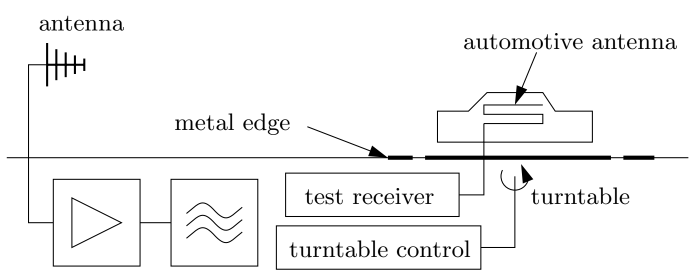


Figure 1: Schematic of an automotive antenna test site

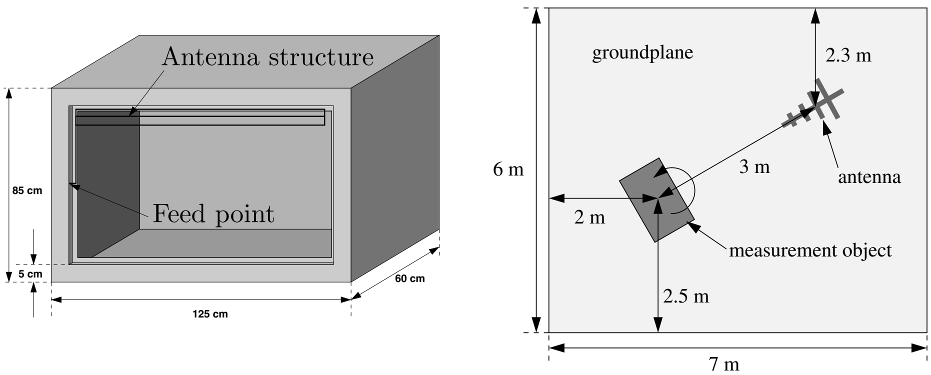
The effect of finite ground plane size on antenna impedance has been studied extensively for simple geometries [1]. However, in an automotive measurement the car body forms the antenna ground and therefore the influence of the measurement range ground plane has so far been neglected. In automotive antenna simulations the ground plane is usually assumed to be perfectly conducting and of infinite extent (PEC ground plane) [2]. This work shows that this assumption is not justified, especially in the case of a non-symmetrical ground plane.

2. Model for evaluating orientation effect

In order to suppress other possible errors that might occur in the measurement of a complex system as a conformal automotive antenna first a simple antenna model has been created for this investigation. The model is shown in Fig. 2.(a) and represents a window antenna mounted in the rear window. The box is a simplification of the car body and the opening similar in size to that of a rear window of a modern car.

The model contained a wire antenna in the aperture that was fed against the left edge of the aperture. The antenna consists of three parallel wires at the upper edge of the aperture that are connected to the feed point via a vertical wire resembling an automotive antenna integrated in the top of the rear window.

Measurements were done on a ground plane of size $6\,\mathrm{m} \times 7\,\mathrm{m}$ completely covered with $0.8\,\mathrm{mm}$ copper foil. To minimize the effects of the conductivity of the earth surrounding the copper, the ground plane was raised $0.2\,\mathrm{m}$ from the ground on a wooden pedestal. The measurement model and antenna were positioned



(a) **(b)**

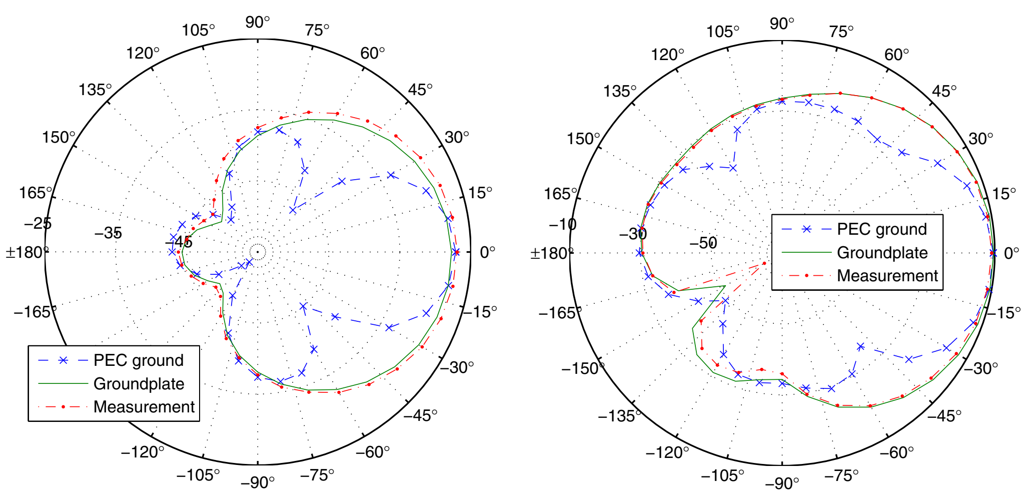
Figure 2: (a) Model used for measurement. (b) Geometry of measurement setup

on the ground plane as shown in Fig. 2.(b). The test object was set on a table of height 0.63 m made of dry wood that contained no metal parts.

The simulation model included the discretized ground plane. A field probe was set at a distance of 3 m from the center of the test object model where the receiving test antenna was positioned during measurements. For each measurement position, the test object was rotated in relation to the ground plane and the measurement antenna and a new simulation was made. For reasons of comparison a simulation including an infinite PEC ground was also done.

2.1 Comparison of Simuation and Measurement

Figures 3(a) and 3(b) show exemplary comparisons of the measured field strength and the electric field at the field probe position of the different simulation models. As can be seen, the exact simulation results agree almost perfectly with the measurements. However, if the simpler approach of the infinite PEC ground is taken, the results differ notably.



(a) **(b)**

Figure 3: Comparison of simulations and measurement at (a) 100 MHz and (b) 135 MHz

The antenna with PEC ground has nulls whereas the simulation with limited ground plane and the measurement do not show these nulls. The design goal for automotive antennas is an omnidirectional pattern so that radio reception is independent of the driving direction. This smearing up of the nulls due to the measurement site poses a severe problem as existing nulls of the antenna cannot be identified on the test range.

3. Field radiated by turntable ground plane

Though the ground plane has a severe influence on the radiation pattern it is questionable whether the presence of the ground plane will have an effect on current distribution on the test object. If the current distribution of the test object itself is not perturbed by the ground plane, the antenna impedance will be the same as that for the free space case. However, simulations have shown differences. Therefore the current distribution cannot be expected to be the same for both cases. In order to check whether the changed current distribution will also affect the radiation pattern significantly a simple test has been deviced.

The far field radiation from any object with a known current distribution is given by

$$\mathcal{E}(\mathcal{J}) = -j\omega\mu \int_V' G \wedge \mathcal{J} \tag{1}$$

in differential forms notation [3].

The current distribution $\mathcal{J}_{all}$ for a detailed simulation including turntable and vehicle can be extracted and separated into the current distribution on the car $\mathcal{J}_{car}$ and that on the turntable $\mathcal{J}_{table}$:

$$\mathcal{J}_{all} = \mathcal{J}_{car} + \mathcal{J}_{ground} \tag{2}$$

Then $\mathcal{E}(\mathcal{J}_{car})$ and $\mathcal{E}(\mathcal{J}_{ground})$ can be calculated with (1). If $\mathcal{E}(\mathcal{J}_{car})$ is the same as the field of only the vehicle in freespace $\mathcal{E}_{free}$ the assumption that the pertuberation of $\mathcal{J}_{car}$ by the ground plane is negligible.

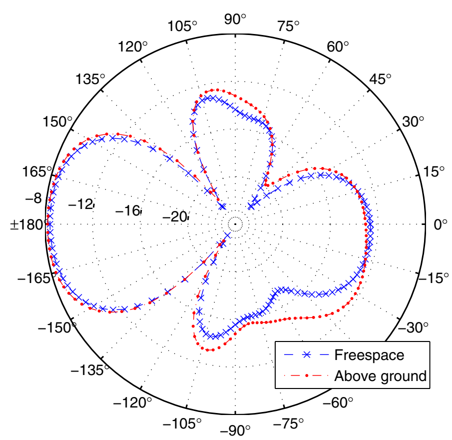
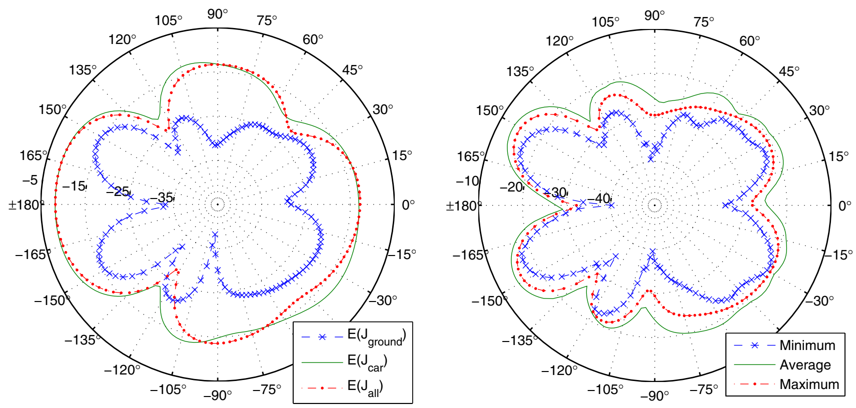


Figure 4: Comparison of far fields $\mathcal{E}_{car}$ and $\mathcal{E}_{free}$ in dB/V normalized to $r = 1\,\mathrm{m}$.

Simulations have been done with a detailed car model consisting of 37656 triangles positioned on a ground plane of $5.5\,\mathrm{m} \times 5.5\,\mathrm{m}$ and in free space. The vehicle was positioned only $0.2\,\mathrm{m}$ above the ground plane so the coupling should be stronger as in the simple model used above. The results in Fig. 4 illustrate that the far field radiated by the current distribution on the vehicle does not change significantly through the presence of the turntable. Therefore the assumption that $\mathcal{J}_{car}$ is not significantly perturbed by the presence of the turntable ground plane.

In a similar manner the field $\mathcal{E}(\mathcal{J}_{ground})$ radiated by only the currents on the turntable ground plane can be calculated. This radiation is somewhat unphysical as the current distribution $\mathcal{J}_{ground}$ probably never can be excited without the vehicle present on the turntable. Yet it gives an upper bound of the error that can be introduced by the ground plane. In Fig. 5(a) $\mathcal{E}(\mathcal{J}_{ground})$ is compared to the field by the vehicle alone $\mathcal{E}(\mathcal{J}_{car})$ and the entire field $\mathcal{E}(\mathcal{J}_{all})$. As can be seen, $\mathcal{E}(\mathcal{J}_{ground})$ is well below the $\mathcal{E}(\mathcal{J}_{car})$ for most angles and therefore has no influence on the entire field. For some angles however, the turntable field has a severe impact and thus has to be considered.



(a) **(b)**

Figure 5: (a) Far fields $\mathcal{E}(\mathcal{J}_{all})$, $\mathcal{E}(\mathcal{J}_{car})$, and $\mathcal{E}(\mathcal{J}_{ground})$, and (b) Minimum, maximum, and average of $\mathcal{E}(\mathcal{J}_{ground})$ for 9 different positions. Both in dBV/m normalized to $r = 1\,\mathrm{m}$.

4. Vehicle Positioning on Turntable

As was shown in the preceding section the turntable current distribution contributes perceivably to the entire field $\mathcal{E}(\mathcal{J}_{all})$. Therefore it is of strong interest whether the position of the vehicle is critical for $\mathcal{E}(\mathcal{J}_{ground})$. As the vehicle is driven on the turntable, it can only be positioned within a range of $\approx 0.15\,\mathrm{m}$ around the center position.

In order to evaluate the influcence of positioning the vehicle was moved $\pm 0.25\,\mathrm{m}$ in lateral x and y-direction to eight different positions. For all these cases $\mathcal{J}_{ground}$ was extracted from the simulation and the electric field has been calculated from these currents. Minimum, maximum and average field strength evaluated across all 9 positions are shown in Fig. 5(b). It can be seen that $\mathcal{E}(\mathcal{J}_{ground}$ does not change significantly with changes in position. The influence of the mere presence of the ground plane is much stronger. As the actual positioning error is likely to be even smaller the positioning error can be neglected.

5. Conclusion

It was shown that the orientation of a non-symmetrical turntable ground plane as it is widely used in automotive antenna measurement has a severe impact on the radiation patterns and therefore has to be considered during the design process of automotive antennas. It was also shown that this effect is due to the radiation from the currents excited on the ground plane and not by a change of the current distribution on the vehicle itself. Therefore the ground plane might be considered using more efficient techniques like the uniform theory of diffraction (UTD).

The positioning of the vehicle is not critical with respect to the current distribution on the ground plane. Therefore a small positioning error during measurement is negligible.

References

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