Estimation of Coupling Between Mobile Vehicular Radars and Satellite Radiometers

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***Abstract* - Coupling of emissions from wideband vehicular collision avoidance radars into passive microwave satellites can impart significant interference to earth remote sensing applications. One of the most physically obvious coupling mechanisms is reflection of the main lobe of the radar by another vehicle toward the main lobe of the radiometer. Since vehicular radars will commonly illuminate another close-in leading vehicle it is suspected that such scattering scenarios will be commonplace. In order to estimate the interference from a collection of such vehicular radars to a passive microwave satellite we performed numerical simulations to determine the system coupling coefficient C_{sm},. The only reflection taken into account is that from the rear window of the leading vehicle. We considered three typical styles of automobiles having rear window angles of 25E, 35E, and 45E. It is shown that reflection of radiation from vehicular radars from the rear windows of automobiles can alone easily cause a significant amount of coupling (-10 to -20 dB) with space-borne radiometers. Additional scattering can be expected from other metallic parts of the leading automobile and by other nearby objects such as trees, railings, barriers, and the tilted roofs of buildings.**

I. Introduction

It has been recently suggested that proposed automotive radar systems can impart significant interference to passive microwave earth remote sensing applications in the bands between 22 and 27 GHz [1]. One of the most physically obvious coupling mechanisms between mobile vehicular radar and a satellite radiometer is a reflection of the main lobe of the radar by another directly-illuminated vehicle toward the main lobe of the radiometer (see Fig. 1). Since the primary reflecting target of a vehicular radar is often another close-ahead vehicle it is believed that such scattered energy would be commonplace, particularly in heavily trafficked urban areas.

To assess the potential impact on satellite radiometers we performed numerical simulations to determine the coupling coefficient C_{sm} defined as ratio of the power density at angle ∃ at the radiometer location for the reflected beam to the main lobe power density on the axis of the vehicular radar measured at the same distance. The only scattering taken into account here is a direct reflection from the rear window

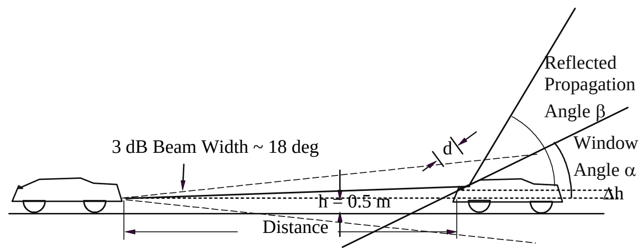

Figure 1. Reflection geometry

of the leading automobile since only this element is suspected to provide strong specular-reflected coupling to the radiometer antenna. We considered three typical styles of autos which we conditionally term "new sedan," "old sedan," and "station wagon," each having specified rear window tilt angles ∀. Geometrical parameters needed for further calculations are shown in Table 1 (*b* is the width of the window). The transmitter beamwidth is assumed to be 18E - consistent with industry prototype models.

TABLE I
VEHICLE GEOMETRIC PARAMETERS

Auto Style	*h* (m)	*d* (m)	*b* (m)	∀ (deg)
New Sedan	0.6	0.7	1.2	25
Old Sedan	0.6	0.7	1.2	35
Station Wagon	0.45	0.5	1.2	45

For different window angles and for different separation distances *h* the reflected propagation angles ∃ range from 30E to 90E (Fig. 2). This range covers practically all viewing angles used for passive earth remote sensing from space.

II. Coupling Model

Since the electrical sizes of automobile windows are large it is reasonable to use geometrical optics. Assuming further that the distance *D* between the two vehicles is much smaller than the distance to the radiometer antenna the coupling coefficient can be expressed as:

$$C_{sm}(D) = \left|R_{v,h}\right|^2 \cdot F \cdot S \cdot W, \qquad (1)$$

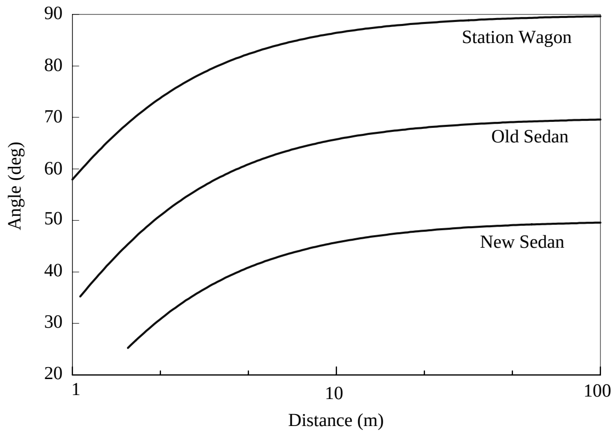

Figure 2. Reflected propagation angle ∃ measured relative to horizontal.

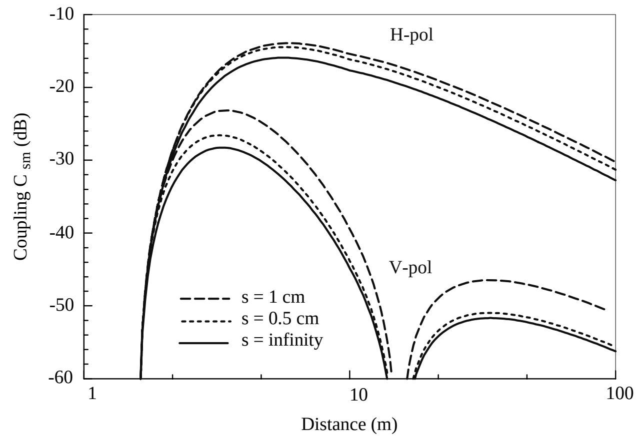

Figure 4. Coupling (dB) relative to M-M alignment: effect of window glass thickness for R_c = 10 m and new sedan geometry.

where $R_{v,h}$ is the polarization dependent Fresnel reflection coefficient of the window glass, *F* is the radar antenna gain pattern, *S* is a factor accounting for the portion of the power intercepted by the window, and *W* is the divergence factor due to the curvature of the window. Both cases of vertical and horizontal emitted radiation are assumed, although it is expected that mobile vehicular radars will preferentially use horizontal polarization to minimize ambiguous signals from roadway backscattering. We take into account the possibility that both interfaces of the glass reflect microwaves, therefore, the glass thickness is a parameter of the function $R_{v,h}$. The relative dielectric constant for glass at 24 GHz is assumed to be $\varepsilon_r = 6$. For simplicity we characterize the curvature of glass by a single effective radius of curvature.

We first present calculations for the coupling C_{sm} for the case of the flat conducting surface to compare with those of the curved glass surface. Fig. 3 shows C_{sm} as a function of distance between cars for the three styles. These differences are not significant in power but result in significant differences in the angles of the reflected rays. The coupling reaches a maximum of -5 dB for separation distances between 5 and 10 m. We also calculated a coupling coefficient taking into account the effect of curvature for the conducting surface. Accounting for the surface curvature leads to a reduction in peak coupling of ~10-15 dB, with much faster decrease at larger separation distances.

We considered further more realistic cases of curved glass windows. First (Figs. 4-6) we study the effect of window glass thickness *s* for two linear polarizations and three types of cars. The curvature radius, R_c, is taken to be 10 m. All curves for V-polarization are significantly lower then for H-polarization, showing typical notches at quasi-Brewster angles. The H-polarization coupling reaches a maximum of approximately -15 dB at about 5 m-distance for all three types of cars. Accounting for the finite thickness of glass yields ~2-3 dB more coupling than disregarding it.

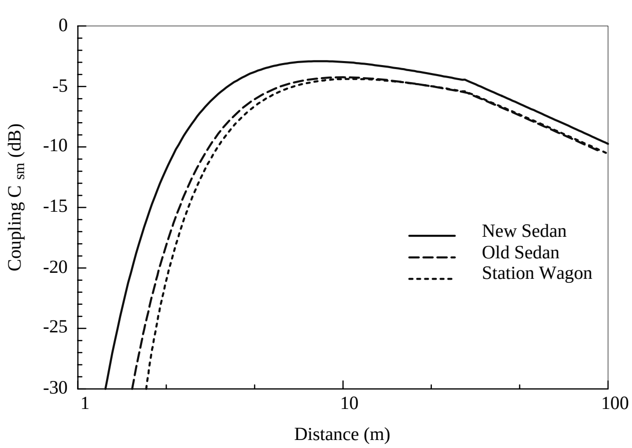

Figure 3. Coupling (dB) relative to M-M alignment: flat conducting surface.

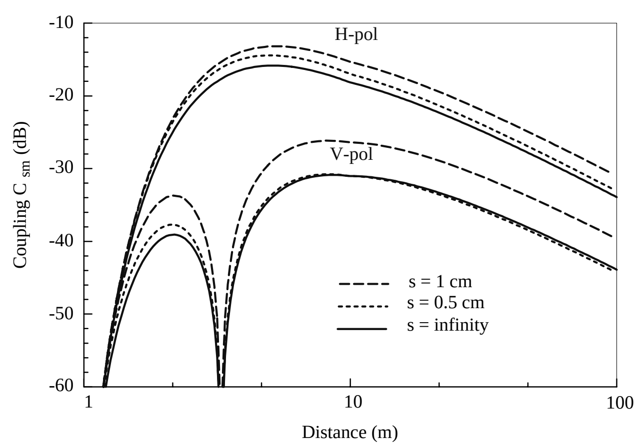

Figure 5. Coupling (dB) relative to M-M alignment: effect of window glass thickness *s* for R_c = 10 m and old sedan geometry.

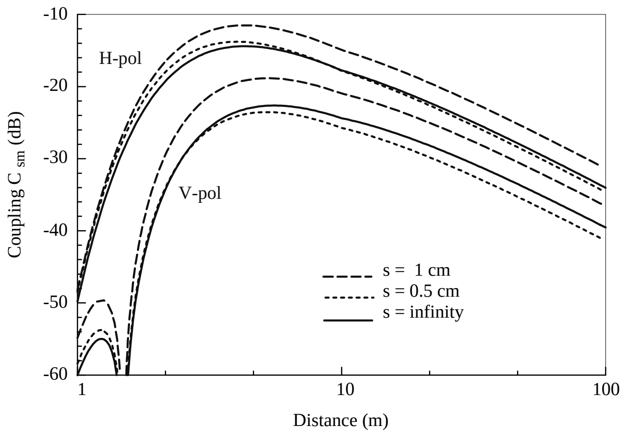

Figure 6. Coupling (dB) relative to M-M alignment: effect of window glass thickness for R_c = 10 m and station wagon geometry.

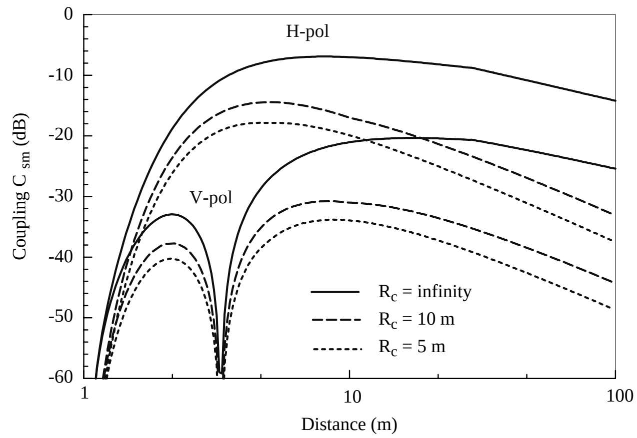

Figure 8. Coupling (dB) relative to M-M alignment: effect of window surface curvature for glass thickness *s* = 0.5 cm and for old sedan geometry.

Figs. 7-9 show how different curvatures of the window surface could affect our estimations for different styles of cars. The largest coupling is achieved for the "station wagon" (see Fig. 9). For realistic curvature radii of 5-10 m the peak coupling at the H-polarization reaches a level of -15 dB to -18 dB. For V-polarization the coupling peak is lower, at -25 dB to -28 dB.

III. Conclusion

The cases we considered show that reflection of the radiation of vehicular radars from rear windows of cars can easily cause a significant level of coupling (-10 to -20 dB) with space-borne radiometers. Moreover, while we have taken into account only scattering by one element of the car, namely, the rear window, additional scattering can be expected by other metal parts of the leading automobile and by other objects such as trees, railings, roadway barriers, and tilted roofs of buildings.

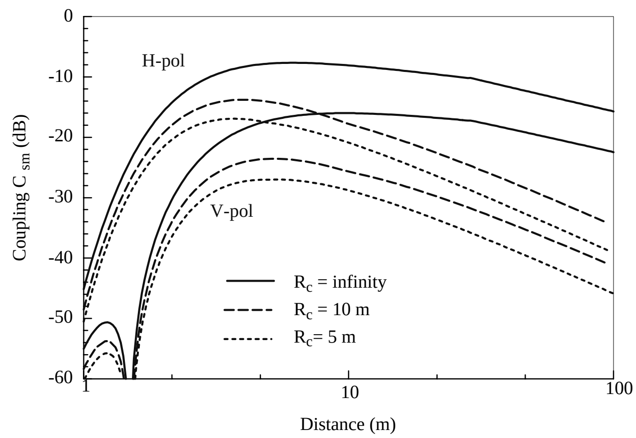

Figure 9. Coupling (dB) relative to M-M alignment: effect of window surface curvature for glass thickness *s* = 0.5 cm and for station wagon geometry.

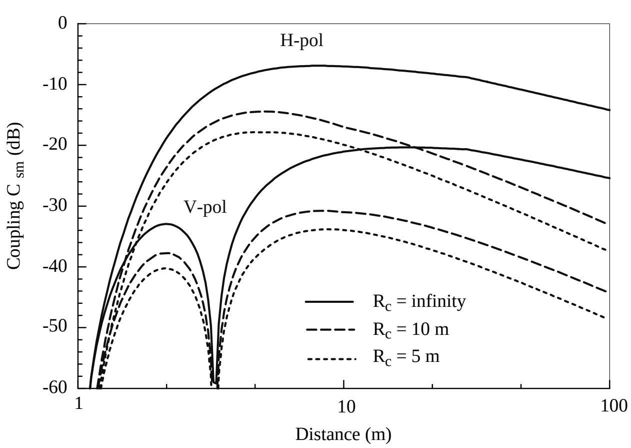

Figure 7. Coupling (dB) relative to M-M alignment: effect of window surface curvature for glass thickness *s* = 0.5 cm and for new sedan geometry.

References

[1] A. J. Gasiewski, W. Wiesbeck and C. S. Ruf, "Impact of mobile radar and telecommunications systems earth remote sensing in 22-27 GHz range," *Technical Assessment by the IEEE GRSS Technical Committee on Frequency Allocation in Remote Sensing (FARS)*, April, 2002.