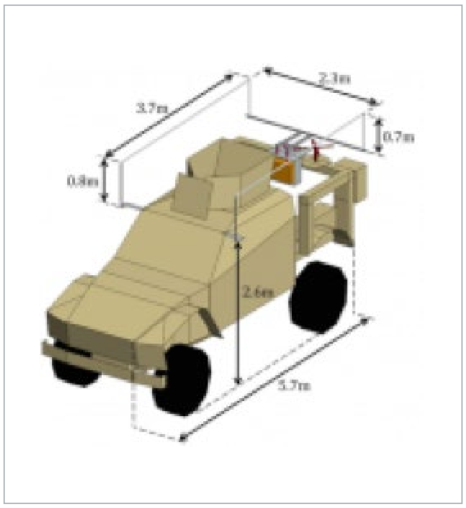
Altair

Developing Efficient Design Procedures for Wideband, Low-profile Antennas Using Altair FEKO Electromagnetic Simulation Technology



CADFEKO model of the vehicle to the right

Key Highlights

Industry
University/Research

Challenge
Evaluate the bottom side of a vehicle as an alternative to more conventional antenna placement positions for mounting high-frequency VHF antenna systems.

Altair Solution
Apply FEKO electromagnetic field simulation methods to assess bottom placement antenna performance.

Benefits
FEKO-based computational studies can be applied to accurately and efficiently assess antenna system mounting location in terms of omni-directionality, efficiency, and propagation loss.

Customer Profile

The Antenna Research Group (ARG) at the University of Colorado-Boulder is a leading research center housed in the Department of Electrical, Computer, and Energy Engineering. ARG is committed to research directed toward antenna theory and design with emphasis on applications of electrically small antennas, simultaneous transmit and receive techniques, and wideband microwave and millimeter wave antennas for electronic attack, electronic support and communications. Under the direction of Dr. Dejan Filipovic, the ARG team has designed and delivered many wideband and narrowband antenna systems operating as low as 2 MHz and as high as 220 THz.

The ARG at the University of Colorado Boulder has a 15-year history of dedication to antenna research and design. The research group has 8 post-doctoral research associates, 14 doctoral students, 2 undergraduate research students, and 2 research administrators. To date, the group has published over 225 peer reviewed journal publications, conference papers, short courses, and tutorials. Numerous best paper awards and citations for research excellence have been received by the group

Develop a Procedure for Evaluating the Feasibility of Bottom Placement of HF-VHF Antennas on Military Vehicles

Low profile concealed antennas are frequently desired for diverse applications across many military and commercial vehicle platforms. In HF-VHF bands, the commercial off-the-shelf vehicular antennas often resemble whips with heights exceeding 1 or even 2 m. These tall antennas increase vehicles' vertical clearance and constitute an easy to identify visual signature, which is undesirable. A vehicle underside can be considered as a viable alternative place for concealment, since it provides enough space to avoid extreme antenna miniaturization. The price is, higher signal propagation losses due to proximity to the ground. Thus, there is a need to assess and compare propagation losses for antennas at various vehicle positions.

Since antennas mounted close to ground have decreased efficiency, potential antenna applications need to benefit from the coupling to the ground and/or rely on short distance communication. More specifically, antenna propagation losses need to be computed and

Keywords: FEKO, antenna placement, mobile antennas, electromagnetic simulation

Antenna Research Group Success Story

"FEKO simulation capability allows our research team at the ARG to continue to develop efficient design procedures for diverse applications of wideband low-profile antennas"

Prof. Dejan S. Filipovic
Director, Antenna Research Group (ARG)
University of Colorado-Boulder

compared for frequencies from 20 to 200 MHz and distances less than 50 m. For example, these conditions are relevant for the communication with ground sensors.

Existing purely analytical propagation models are not applicable to short distance near ground signal propagation, so numerical modeling is required. Utilization of full wave computational tools as FEKO is very attractive due to superior capability and easy to use. Former numerical studies for near ground propagation neglected mutual coupling between receiving and transmitting antennas. In contrast, FEKO electromagnetic modeling capability accounts for all of these needed effects.

Development of a Numerical Procedure for Assessing Antenna Signal Loss Associated with Near Ground Placement

The numerical study was conducted with the vehicle model illustrated in Fig. 1a. An all metallic structure was assumed to be a perfect electric conductor, whereas antenna sources were approximated as Hertzian electric diploes placed 0.05 m away from the vehicle surface for top and bottom positions. A rear source was shifted from the rear right corner by 0.1 m and placed 0.35 m above the trunk surface. These dipoles are omni-directional sources similar to whip antennas often used on vehicles.

Even though the dipoles represent infinitesimal sources, numerical validation studies performed on FEKO proved that this is a good approximation to regular quarter wavelength whips (Fig 1b).

FEKO accounts for the ground loss by means of Sommerfeld integrals implemented in the code. Three types of grounds including dry sand, asphalt and wet soil were considered. ARG project team, led by Dr. Maxim Ignatenko, heavily relied on FEKO results to validate their analytical procedure for the propagation loss calculations and then use the developed FEKO models to accurately determine impact ranges for various antenna/ platform systems.

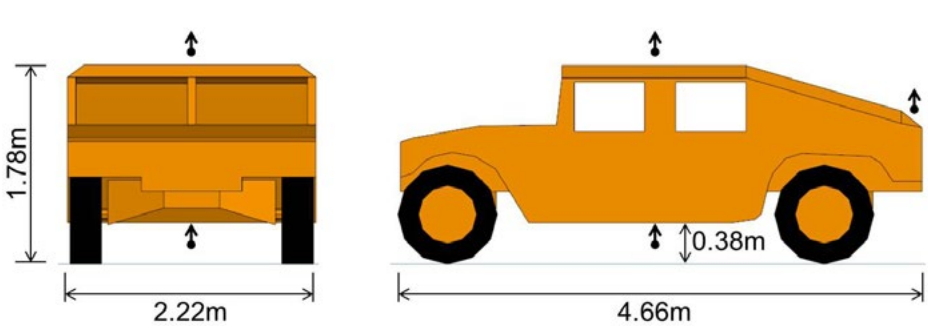


Fig. 1a Dimensions of the Utilized Vehicle Model

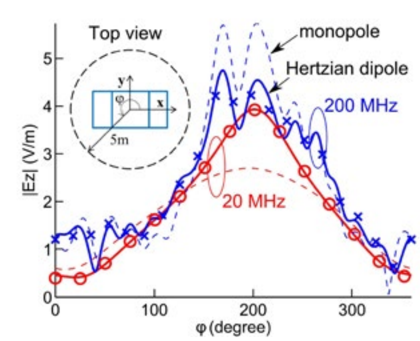


Fig. 1b Validation Results for Numerical Modeling Procedure

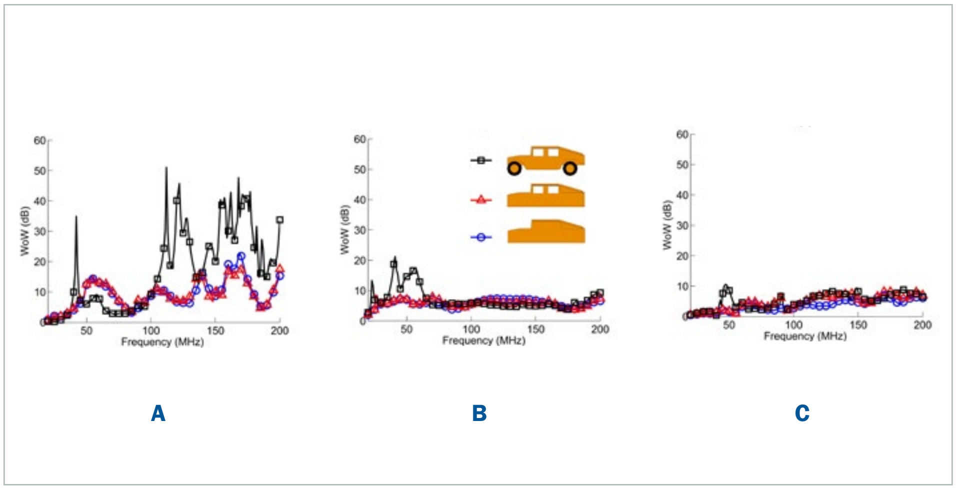


Fig. 2 Far Field WoW Modeling Results for (a) Bottom, (b) Rear End and (c) Top Antenna Placement

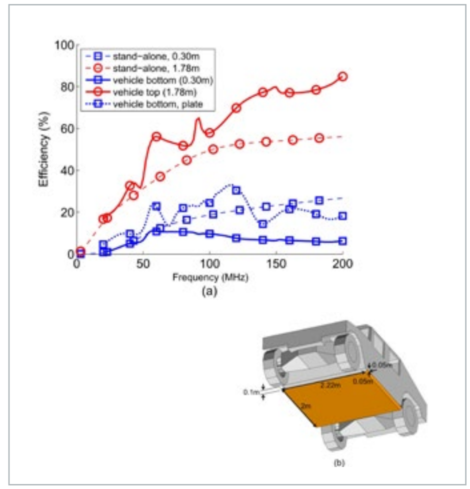


Fig. 3 (a) Efficiency of Top and Bottom Sources With (Solid Lines) and Without (Dashed Lines) Vehicle Above Ground (b) Installed Steel Plate (Efficiency Results Shown with Dotted Line)

Application of the Numeical Procedure for Performance Evaluation of Varied Vehicle Bottom Antenna Locations

Performance of the vehicle mounted antennas at various locations was evaluated in terms of omni-directionality, efficiency, and propagation loss.

OMNI-DIRECTIONALITY

A Wobble-of-the-Wave (WoW) parameter was used to characterize omni-directionality of the antenna far-field characteristics. For many applications (communications, jamming), WoW should be as close to 0 dB as possible. For omni-directional sources like the Hertzian dipole, deviation of WoW from zero is the result of complex interaction between the source, the vehicle, and the ground. To demonstrate the effect of the vehicle geometry on WoW, a simplified vehicle model employing a flat bottom, with and without windows, was used in the study. Far field omni-directional results for antenna placement are illustrated in Fig. 2 for bottom, rear, and top placement sources. The result clearly demonstrate that at frequencies below 80 MHz omni-directionality of the bottom source is comparable or better than that of the rear source often used in practical scenarios. Top mounting source behaves the best, as expected.

EFFICIENCY

Efficiency is defined as the ratio of far field radiated power to the power accepted by an antenna. In contrast to the typical definition of radiation efficiency, when only the loss in the antenna structure is taken into account, this study also accounts for ground loss, as the ground is an integral part of the radiator. When the height of the stand-alone antenna above the ground is much less than a wavelength, the source strongly couples to the ground and its efficiency is low. The efficiency increases together with electrical height as it is shown in Fig. 3a (dashed lines). The vehicle presence helps to improve the top mount efficiency, but significantly reduces the efficiency of the bottom-mounted source (Fig. 3a, solid lines). Since the vehicle redirects some radiated power down for the bottom source, one alternative to increase its efficiency is to screen the ground by installing a metallic plate (Fig. 3b). Using this approach, the FEKO-based modeling results showed that the effect of the vehicle is significantly reduced (Fig. 3a, dotted line).

PROPAGATION LOSS

Propagation loss is used to assess the overall impact of the antenna - platform interaction on communication channels. Contrary to WoW and efficiency parameters, propagation loss is a near-field parameter depending on distance along with angle. The dependence on angle leads to the range of losses for each given distance, where the upper bound corresponds to the worst case scenario. This study showed that propagation loss upper bound for bottom, top, and rear antenna source placements are comparable at most frequencies below 100 MHz and at distances less than 10 m. These distances are of vital significance for jamming, and antennas designed for these frequencies are the most challenging to conceal. Thus, bottom-side located antennas can be considered as an alternative to conventionally used positions.

In summary, FEKO-based electromagnetic field simulation capability formed the framework for estimating the propagation loss for low-height antennas mounted to a vehicle bottom side. Carefully validated numerical examples demonstrated very good accuracy for various communication scenarios. It was shown that even though bottom-mounted sources often cannot compete with conventionally-mounted antennas in terms of far-field omni-directionality and efficiency, near-field propagation loss was comparable for distances shorter than 10 m and frequencies ranging from 20 to 100 MHz.

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