# On the Use of Multi-Turn Loop Antennas for Vehicle-Based Communications in High Frequency (HF) Band

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The HF communications may be accomplished via three propagation modes including ground wave, long-range skywave and near vertical incidence skywave (NVIS). These modes are different in polarization, frequency range, and takeoff angles, just to mention a few. Considering large wavelength and proximity to the ground, the vehicular antenna designers truly face a tremendous difficulty. Particularly challenging is the lowest portion of the HF band (say 2-10MHz) in which all three modes may be desired. At this frequency range, the achievable bandwidth limited by the fundamental limitations associated with electrically small antennas, besides the radiation efficiency is very small. For a typical vehicular platform, the product of the wavenumber and the radius of enclosing sphere is $ka < 0.2$ at the lowest portion of the band. Since the wavelength comparable antennas in this range are very large, their placement on a vehicle is not feasible. This paper evaluates the use of an HF multi-turn loop as a practically feasible, low-cost and profile, electrically small antenna for vehicle-based platforms. Note that the single turn loop antennas have been used for many years by both, military and radio amateurs for NVIS, and methods for rapid tuning thereof are well developed. The radiation resistance of a multi-turn loop increases with the square of the number turns while its characteristic modes and resistive losses scale with the unwrapped length. Smart loading with the ferromagnetic materials may also help increase the radiation resistance, though one has to cognizant of the rapidly increased weight associated with excessive use of these. This paper also looks at the impact of the chosen vehicular platform (Assault Amphibious Vehicle – AAV) on both, ground effects, and antenna performance. It is seen that even though the vehicle is electrically small, it may still help antenna improve its radiation efficiency if proper placement and means of interaction with antenna are selected. The various parametric studies are used to achieve the highest radiation efficiency, widest bandwidth, desired polarization and gain pattern of a multi-turn loop. Impacts of material and proximity losses, as well as wire shaping and loading are also considered. Antenna performance on and its interaction with AAV is also studied in details. It is seen that the desired radiation patterns may be achieved by proper antenna placing. Also, the ground loss, while it cannot be fully avoided it may be utilized to achieve desired bandwidths in 10s of kHz. Conducted method of moments computational studies are validated by simplified analytical models and other computational approaches.