Title: Smart Array for Intelligent Transportation Systems (ITS)
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Project Period: November 1, 2011-September 30, 2015

Radio communication between road installations and moving vehicles is an essential component of intelligent transportation service (ITS) infrastructure. This communication must be reliable and least vulnerable to radio interference. Although the intelligent antenna approaches under investigation in the proposed research are general and can be applied to a wide class of scenarios, of specific interest in the present research is the antenna system beam-forming adapted to the identification and location of the car approaching or passing a road installation. In several applications, such as electronic pricing or electronic toll collection, minimum detection error and locating of the moving vehicle with high accuracy even at high speeds is of paramount importance.

Many current installations are single-lane (toll plaza) type, which guide the vehicles into narrow paths between booths. Such configurations significantly slow down the traffic. Multi-lane free-flow systems have much faster traffic throughput because the vehicles do not need to decrease their passing speed. However these systems require the ability to identify and track any individual high speed vehicle which enters the interaction zone and to distinguish it from other moving nearby vehicles, including while vehicles are changing lanes. To meet the needs of accurate vehicle identification and toll collection operation this must be performed almost free of error.

The interrogating radio and the antenna system in the road installation must have sufficient intelligence to track and identify the approaching vehicles within certain distance, almost without error. The integrated antenna and the radio system should have the capability to: 1) direct the radiation pattern towards the vehicle which is being interrogated, and 2) minimize emission in the other directions to suppress interference and enhance detection efficiency given a certain level of radiated power. This will help increase the accuracy of location finding as well.

In a static environment (transmitter and receiver locations are fixed and known and the propagation environment is predictable and time invariant as well), to maximize radiation in a particular direction and suppress emission in unwanted directions, the radiation side-lobes (SL) should be decreased as much as possible. Low SL, high efficiency/gain antenna array design is a challenging task because of cost and complexity constraints. The problem becomes more difficult if the radio-wave propagation environment is not free space. A typical road-side-to-car radio communication link is surrounded by vehicle body, road, and road installation i.e. gantry. In such complex physical environments, in addition to direct ray of electromagnetic waves that link the transmitter to the receiver, there exist a multitude of other electromagnetic wave ray paths (namely multi-path effect) which make the wave propagation scenario very different from a simple free space model. The antenna pattern and the radio front-end circuit should be optimized to take these additional effects into consideration.

In a realistic environment, which is of interest to us in the research proposed here, the vehicle is moving and the propagation environment is varying rapidly with time. In this case, meeting the aforementioned requirements becomes much more challenging. The radiation pattern of the radio system should adapt to the changing environment and optimize the performance of the system under any multi-path condition.

The main objective of the proposed research is to explore novel adaptive antenna/radio architectures that can provide a reliable radio link between the road installation and a fast moving vehicle in a fast time- varying multi-path environment. A test-bed will be developed for the most promising approach and the proposed design concept(s) will be experimentally verified.