A liquid crystal switched passive Van Atta array for automobile radar target enhancement in heavy rainfall

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Severe weather poses a major challenge to safe driving. Sudden precipitation or heavy fog can reduce visibility and extend braking distances, increasing the risk of an accident. To combat this, modern cars are adopting a wide variety of driver aids such as braking-assist, lane detection and blind spot alerts (P. Green et al, US D.O.T., Int. Vehicle-Based Safety Sys., 2008). These require vehicle sensors, the most popular being radar and VANETs (Vehicular Ad-hoc NETworks), which allow inter-car data sharing. Both use radio frequencies, which are more resistant to weather and obstacles than older optical systems. However, radar range is still degraded by heavy rainfall (M. I. Skolnik, Introduction to Radar Systems, 442-449, 2001). Also, global regulatory bodies have moved from 24 GHz radars to 76-82 GHz radars, which are even more susceptible. Regulatory power limitations imposed upon radar have also limited the success of increasing range with more powerful transmitters.

This project proposes to increase the Radar Cross Section (RCS) of vehicles by using a Radar Target Enhancer (RTE) to boost radar range. The system absorbs the functionality of VANETs by rapidly switching on and off, modulating the target car's RCS and sending data to scanning radars while reducing bandwidth load and increasing the speed and range of data transmission.

The switchable RTE chosen is the Van Atta array, which uses spaced pairs of antennas to receive and retransmit a signal without signal processing, as the phase of the incoming wavefront is preserved. The array uses aperture-coupled patch antennas to minimize thickness. Amplifiers are not used, as they are somewhat expensive and limited in bandwidth and size at this frequency, so gain is obtained by a larger array size. Size problems were encountered using PIN diodes to switch the array, so a nematic liquid crystal layer of the type found in LCD monitors is put on the microstrip substrate. Biased properly, it can interrupt the coupling of microstrip to patch, switching the array off with one signal. Such materials have excellent performance at 76-82 GHz.

Initial simulations of this design in HFSS have proven its feasibility, with each patch producing 3.51 dBi broadside gain at a VSWR of 2.4 when biased "on," and -5.23 dBi broadside gain with a detuned VSWR of 10.9 when biased "off." Higher gain can also be obtained with a smaller detune. A scaled frequency prototype will be fabricated to test the switching and radar performance at 10 GHz. The primary contribution of this project is the creation of a new type of automotive radar safety device, and demonstrating that RTE systems can increase automobile radar range and transmit information in adverse weather.