CRLH Leaky-Wave Beam-Forming Antenna with Enhanced Gain for the V2X Communication

S. Kahng[1], J. Jeon[1], M. K. Khattak[1], K. Jang[1], H. Kim[1], H. Oh[2], and J. Kim[3]
[1]Dept. of Info. & Telecomm. Eng., Incheon national university, Incheon, Korea
[2]R&D Center, Innertron Inc., Incheon, Korea
[3]Electronics Research and Business Development Center, LG Innotek, Gyong-gi-do, Korea

***Abstract* - In this paper, a CRLH Leaky-wave two-dimensional array antenna for hemispherical beam-forming aimed at V2X communication is proposed. This antenna is composed of 4×4 feed-network and 4 rows of CRLH leaky-wave radiating structures that adopt the capacitive inter-element coupled mushrooms. Every single capacitive coupling uses 0.75 pF. We will show beam-forming and enhanced gain performances.**

***Index Terms* — Array antennas, Metamaterial, CRLH, Beam-forming, Leaky-wave antennas.**

I. INTRODUCTION

Lately, vehicles are reckoned as being more electronic and expected to have functions to guarantee higher probability of safety and adaptiveness to the changing environment. They are called smart cars to signal the drivers useful information on the traffic condition, detect the potential problems and assist the users to avoid accidents. This is what intelligent vehicles are demanded to do, and V2X communication is suggested to help the cars to be put in a network of ITS for the acquisition and sharing of traffic information interactively.

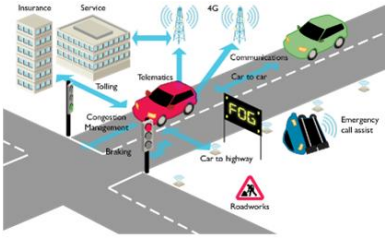
To make cars smart, more electronics should be involved from sensing physical phenomena inside and outside a car, transducing them to signals and data, through processing and storing them, and to informing the driver[1]. Getting the gist of the sensing for a car electronics, radars and V2X communication devices are the one and they explain the vital importance of RF engineering and antennas. Common in both the radar and the V2X function, beam-forming and steering is necessary to send a signal to a potential target and receive the reflected wave to check the distance and angle in the scanning range. This is enabled by phased array antennas.

A phased array antenna can form a beam and move it, and is found to be very useful. However, it winds up with a relatively large area to meet the specifications on a high gain and narrow beamwidth. It will become worse in size and cost, when it should be fed by active phase-shifters. But, this can be hammered out by the use of metamaterial radiating elements, and the operational scenario of fixed beam-tilting directions and broader beamwidth[2-4]. When a metamaterial leaky-wave antenna is adopted, it can scan the beam from backward to forward regions over a relatively wide band in the form of a low-profile passive structure[5]. This antenna turns out to emit fan-type beams with low gain.

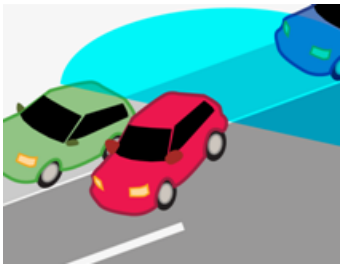
In this paper, the above-mentioned antenna is changed to have higher gain for the better V2X communication thruput and three-dimensional beam-steering function, while keeping the profile low and no use of active phase shifters. This antenna is composed of 4×4 feed-network and 4 rows of CRLH leaky-wave radiating structures that adopt the capacitive inter-element coupled mushrooms. Every single capacitive coupling uses 0.75 pF. In the later section, beam-forming and enhanced gain performances will be presented.

II. DESIGN OF THE METAMATERIAL LEAKY-WAVE 3D BEAM-SCANNING ANTENNA FOR V2X COMMUNICATION

The following figure illustrates the working scenario for V2X communication to make transportation and roads safer and in order[1].



(a)



(b)

Fig. 1. Pictures of V2X communication (a) A variety of nodes on the street are wirelessly linked for vehicles to other vehicles, nomadics, infra, etc (b) Alarming neighboring cars on the road to safe lane-changing.

One expected application of the V2X communication is the wireless link between two cars in the same lane to alarm the car behind to avoid collision.

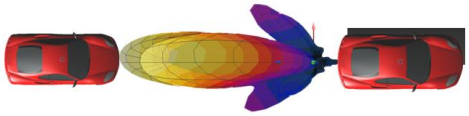
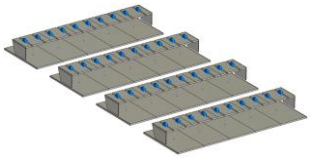
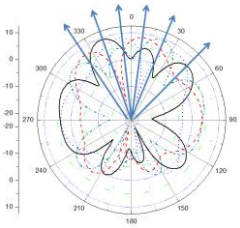


Fig 2. Link between two back-to-back cars:Simulated by SEMCAD X[6].

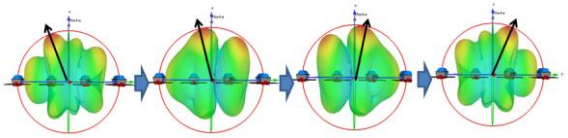
As is presented above, the radiated electromagnetic wave steming from the rear side of the preceding car should reach the front of the following vehicle. The antenna should have the beam-scanning function to keep the adaptive wireless linkage between the moving nodes and another frequency of operation to evade the potential interference from the car radar. So we have designed a beam-scanning array antenna with a wider angular coverage as follows.



(a)



(b)



(c)

Fig. 3. Beam-scannable function of the proposed antenna (a) 4 rows of the CRLH leaky-wave antenna structure (b) beam-scanning function(plotted in 2D) (c) beam-scanning function(plotted in 3D).

As the antenna is placed at both the front and rear sides of the car, it can transmit and receive the signals of alarming or emergency link on the road. According to our design using the metamaterial array antenna[2-4] which is instrumental in significant size-reduction, the beam from the proposed geometry covers the angular range of approximately 40 degrees at the rear of a car for the V2X communication with the antenna efficiency and the gain greater than 50% and 4 dBi, respectively. When the antenna structure is attached on the front and rear parts, the beam will be able to cover almost the entire azimuth plane.

III. CONCLUSIONS

This paper suggested a leaky-wave beam-scanning array antenna adoptable to V2X using the metamaterial structures. The far-field pattern from the proposed antenna covers the angular range of roughly 40 degrees at the rear of a car for the V2X communication with the antenna efficiency and the gain greater than 50% and 4 dBi, respectively.

ACKNOWLEDGEMENT

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