High-Resolution J-Band Radar with Continuous 360^o Imaging Capability for Autonomous Vehicle Applications

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Millimeter-wave (MMW) radars, especially those operating at 77 GHz, have been used successfully by car manufacturers in several driver-assistive applications, such as adaptive cruise control, forward collision warning, and lane-change assistance systems. Further development of these automotive radars is currently underway to enable their use in more demanding safety-critical applications, such as road condition assessment and collision mitigation. Furthermore, it is expected that MMW radars will continue to play an important role in the forthcoming autonomous vehicles. The absence of human-drivers in autonomous vehicles expands the role of the automotive sensors from only detecting objects in front of the vehicle to detecting all objects surrounding the vehicle (near and far) and in all directions. Several developers of autonomous vehicle technologies are already utilizing optical, laser, and other sensing modules to continuously scan the surroundings of the vehicle while on the move. These sensors are mounted atop the vehicle to maximize the scanning range and minimize blind regions to maximize the view of complicated road scene environment. Through continuous azimuthal rotation of the sensors, 2-D images of the surroundings are generated and updated while the vehicle is on the move. The performance of these sensors is severely hampered by inclement weather conditions, such as rain, snow, fog, and dust storms. To the contrary, MMW radars can perform the desired azimuthal scanning of the environment surrounding the vehicle, unhampered by weather conditions, provided that high resolution images can be generated. In order for a 77-GHz radar to produce the desirable 1^o in azimuth resolution, its aperture width needs to be at least 22 cm. This large aperture is difficult to place and rotate above the vehicle. However, a high-resolution and compact radar can be still attained if the radar's frequency is increased three folds to 231 GHz (J-band) resulting in a size reduction of the aperture by a factor of three to 7.5 cm.

In this paper, a newly developed prototype 360^o scanning radar system, that can be used to continuously monitor the environment around a moving vehicle with fast update rates (even at highway speeds), will be presented. The system consists of a J-band radar, mounted in the up-right position and illuminating a 45^o-tilted flat plate that is continuously-rotating around the vertical axis. This arrangement ensures that the radar beam is rotated in azimuth over the entire 360^o. The J-band radar is a compact extremely fast fully-polarimetric FMCW instrumentation radar operating 225-GHz and has 1^o in effective radar beamwidth (A.Y. Nashashibi, B. Alazem, and K. Sarabandi, 2017 IEEE AP-S International Symposium and USNC/URSI Radio Science Meeting, pp. 35-36). Details of the system design and fabrication will be presented, along with an analysis of signal processing requirements for different range resolutions, vehicle speeds, and image update rates. Examples of outdoor generated images of different road scenes will be presented and phenomenological observations, including the presence of ghost targets, will be discussed.