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New Miniature Dual Mode Rat-race Coupler Design for Autonomous Vehicles

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Abstract — *With the foundations of dynamic transportation and a growing prevalence, self-driving cars are the driving experience of the future. The challenging study is obstacle avoidance in most electric vehicle systems, which paved the responsibility of performing advanced objective control points to non-collision constraints. The issue with existing implementations of autonomous vehicles is obstacle avoidance, which enables vehicles to reach desired areas while avoiding barriers. Researchers recommend several methods for realizing obstacle detection and collision avoidance. However, most current solutions demonstrated low precision during the tracking process, leading the system to be offensive during bad weather conditions. Therefore, an evolutionary model has been proposed in work presented, having the capability to optimize the performance in terms of crucial parameters towards the bad weather conditions. Hybrid rat-race couplers have been introduced to operate in a dual-band operation, acting as a braking and non-braking function, permitting self-driving automobiles to emerge in a simulated environment. The dual-mode process is simulated using ANSYS resonates at 2.5Ghz. The results indicate a high degree of integration, commonly employed in MIMO research. It also results in reduced echo power in the RADAR direction; it acts as a disputer for electro-magnetic incident waves away from the receiver. The proposed work outperformed two modes and exhibits further enhancements to increase channel capacity with reduced SNR.*

Keywords — *Self- Driving Cars, Hybrid Rat-Race coupler, Retrodirective array, LIDAR, Computer Vision Method.*

I. INTRODUCTION

With the advancement of robotics and artificial intelligence approaches in recent years, autonomous technology has developed into a fascinating research subject. A self-driving car, also called a driverless vehicle, can sense its surroundings then control without human intervention [1]. Enriching the commute experience by engaging in work or entertainment instead of driving and reducing travel time when the traffic pattern is planned or performing the parking task is autonomous [2]. Using sensors such as GPS, Radar, camera, and LIDAR to feel its environments and essential decisions taken to identify path planning and obstacle detection [3]. These self-driving cars are used primarily to increase road safety by reducing traffic collisions caused by driver delay reactions. The potential user assistance is the heart of any particular vehicular system. The need for assistance is a must if the driver encounters an activity of medication, is too tired, or is due to diseased muscles.

Fully automated driving offers a tremendous capability to drive up new opportunities for individual mobility [4]. The study on obstacle detection and tracking are concerned with computer vision and LIDAR approaches. Multiple movement monitoring and detection systems are known as a model-based methods. With a model-based approach, objects are recognized using previously modeled data. An approach for tracking vehicles is manifested in [5]. In [6], Spinello proposed a system that divides a human figure into multiple layers, and then values are modeled. Another method is proposed in [7], where they do not recognize different category models. The drawback has been overwhelmed by using model-free methods. The segmentation model-free method has been practiced in [8] based on local projection, where the Kalman filter method is applied for managing tracks for detecting objects. It is determined by shape information, not by the mechanism of motion. Although the computer vision system was built utilizing deep learning, it is extremely light-sensitive, resulting in poor identification in low-light conditions.

A model-free technique for detection in two dimensions [9] LIDAR is designed to detect the state of dynamic objects using a local static map. It uses a velocity motion method; however, it can only preserve static data. RANSAC is a generative system that uses a Bayesian approach for segmentation and monitoring several objects to detect barriers in real-time. The speed and efficiency of the method are very high compared to other model-free methods. The 3D LiDAR method is employed to get the shape, distance, and position of the obstacle [10]. However, affects the precision during the tracking process and results in unsatisfactory results during bad weather conditions.

II. RESEARCH METHOD

The challenging analysis is obstacle avoidance in the more significant part of electric vehicle systems. The difficulty with recent autonomous vehicle technologies is barrier avoidance, allowing automobiles to reach desired places while avoiding obstacles [11]. The researchers offer numerous approaches for establishing obstacle detection and avoidance. However, most current systems revealed a lack of precision throughout the tracking process, making the system offensive in inclement weather. As an outcome, the technique presented here introduces an evolutionary model capable of increasing performance in terms of essential factors in response to adverse weather circumstances. Hybrid rat-race couplers [12] have been introduced to operate in a dual-band mode, providing braking (retro directive) and non-braking (non-retro directive) functionality, allowing self-driving vehicles to evolve in a virtual environment. When target resolution is insufficient, and a barrier is discovered, ports 4 concluded with 50Ω and 3 ended with 0Ω operating in retrodictive mode, a braking operation is performed. Port 3 is excited upon no barrier is detection, facilitating reliable driving operation.ANSYS is used to simulate the dual-mode process, which resonates at 2.5GHz. The passive coupler overcomes the inability to scan numerous angles with sufficient power. Figure 1 illustrates the conceptual design. At the resonant frequency, a microstrip patch with a length and width of 40mm and 60mm is simulated. Portability is limited in microstrip design, considering the importance of the ground plane. Line losses occur when the microstrip line wanders in seek of compactness [13]. Rat-race couplers are designed with a width of70.7Ω transmission lines of 1.1mm and 50Ω transmission lines of 3mm. The antenna array achieves retro-directivity by the use of a 180-degree hybrid, which reverses the phase difference between the array's components. These results demonstrated that the direct connection of both elements results in a high degree of integration and low fabrication loss. Retrodirectivity provides higher operating flexibility when compared to other smart antenna systems since it is achieved in one primary plane (the E- or H-plane); this section illustrates retrodictive [14]in both planes. It is especially advantageous when the sensor's location and orientation are unclear, as it is retrodictive in both of these planes, and it can detect the sensor from a wider range of directions.

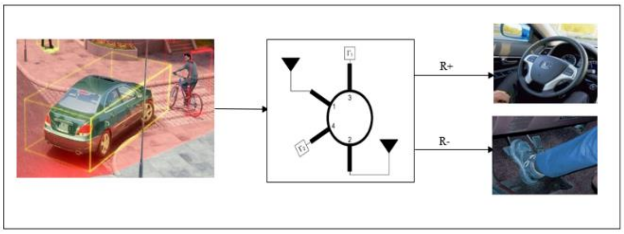

Fig. 1 Prospective Model

A. Rat-Race as Retrodirective

Rat-Race couplers are vital aspects of an extensive array of microwave systems, including beamforming networks, balanced mixers, amplifiers, and multiplexers [15]. The device is constructed using the semi-rigid coaxial cable that is widely available. Due to their ease of integration into printed circuit boards, microstrip components are essential in microwave applications (PCB) [16-17]. The antennas can operate as transmitters and receivers when ports 1 and 2 are connected to a patch antenna [18-19], and the rest are terminated with the same reflection coefficient. The desired characteristic impedance of the coupler design is Z0√2, whereas Z0 is the characteristic port impedance [20, 21]. All ports will be synchronized to the coupler line in this mode. The rat race couplers approach can be utilized to derive the retro-directivity conditions [22]. Below Eq (1) is the representation of the scattering matrix.

$$[s] = \frac{1}{\sqrt{2}}\begin{bmatrix} 0 & 0 & \ell^{\frac{-j\pi}{2}} & \ell^{\frac{-j\pi}{2}} \\ 0 & 0 & \ell^{\frac{-j3\pi}{2}} & \ell^{\frac{-j\pi}{2}} \\ \ell^{\frac{-j\pi}{2}} & \ell^{\frac{-j3\pi}{2}} & 0 & 0 \\ \ell^{\frac{-j\pi}{2}} & \ell^{\frac{-j\pi}{2}} & 0 & 0 \end{bmatrix} \quad (1)$$

The input waves are represented by Eqs. (4) and (5), whereas the output waves are by Eqs. (2) and (3). The input signals at ports 1 and 2 are indeed the output signals at ports 3 and 4.

$$b3 = \frac{1}{\sqrt{2}}\left(a_1 e^{-\frac{j\pi}{2}} + a_2\, e^{-\frac{j3\pi}{2}}\right) \quad (2)$$

$$b4 = \frac{1}{\sqrt{2}}\left(a_1 e^{-\frac{j\pi}{2}} + a_2\, e^{-\frac{j\pi}{2}}\right) \quad (3)$$

$$a1 = \Gamma 1\, b3 \quad (4)$$

$$a2 = \Gamma 2\, b4 \quad (5)$$

The condition Γ2 = -Γ1 sets comparing the phase difference by retro-directivity condition [23, 24] is where the output phase is negative concerning input. For the non-retro-directive mode of operation, ports 3 and 4 are fused with 50Ω impedance and 0Ω impedance. Figure 2 depicts the operation of the retrodictive coupler model.

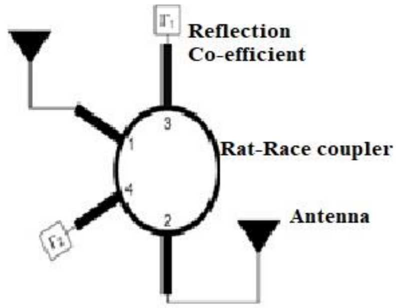

Fig. 2 Rat-race acts as retrodictive.

The port with zero impedance will be disconnected, while the other will behave as a circulator. The largest power transfer happens at port 2 as an emitter, and the rest of the power is transferred at the receiver (Port 1); this results in an in-phase pattern. Port 3 operates as an isolated zero, while port 4 is activated with a 50-ohm impedance; the maximum power then reaches port 1 (transmitter), with the rest at port two. The resultant phasor will therefore be 180 degrees out of phase [25,26], satisfying the retro-directivity condition

III. RESULTS AND DISCUSSION

A. The Geometry of Rat-race Hybrid Coupler

A 2.45 GHz patch antenna is designed with length and width dimensions of 40mm and 60mm, respectively, and a substrate thickness of 1.58mm. The ground plane is an inherent partin microstrip design, resulting in reduced portability. The line loss increases when the stripline is meandering for compactness. The geometry of the microstrip patch antenna connected to a rat-race coupler is shown in Figure3. Fabrication of the proposed coupler employs a ring with a circumference of one and a half wavelengths, which occupies less space. Rat-race coupler is simulated with 70.7Ω transmission line width as 1.1mm, substrate thickness as 1.58mm, and 50Ω transmission line width as 3mm. The model's geometry consists of the rat-race coupler combined with two microstrip patch antennas, and FR-4 substrate is manipulated in the design.

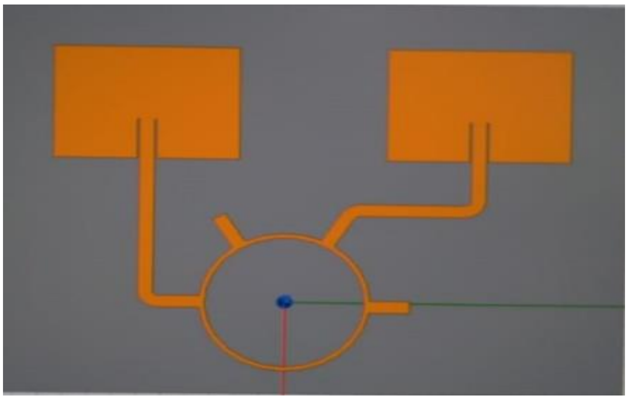

Fig. 3 Geometry of the rectangular microstrip antenna connected to a Rat-race hybrid coupler.

The pattern comprises two devices: a coupler and a microstrip line antenna. Straightening them throughout the fabrication would improve integration and minimize the connecting loss between the two discrete parts. The two segments are bonded to the same substrate and ground plane, resulting in a high degree of integration, as shown in Figure 3.

B. The magnitude of the S-Parameters

Figures 4 and 5, which show responses less than -10dB at roughly 2 GHz, do not conform to the specification. Both circumstances exhibit a modest variation in frequency from 2.25 GHz to 2.65 GHz. However, it does provide a peak resonance at 2.5 GHz with a magnitude of -15dB in the first and -18dB in the second. It exhibits much lower return losses than the numbers below and an input power of -3.6dB; this ensures that the maximum capacity is delivered to the communication terminal.

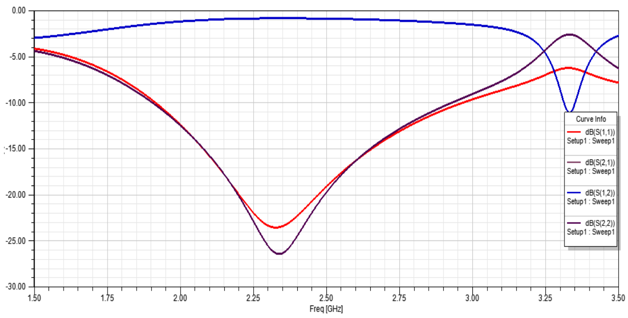

Fig. 4 Magnitude response of the coupler when port 3 opened and port 4 short-circuited.

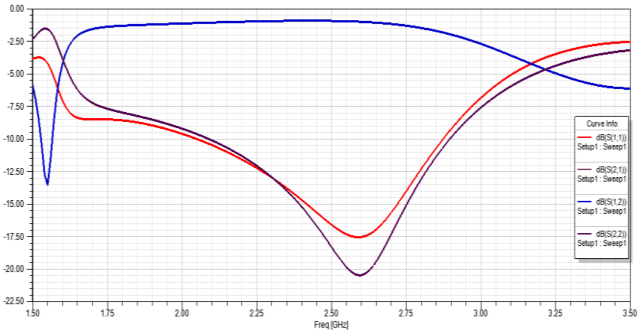

Fig. 5 Magnitude response of the coupler when porting 3 is short, and port 4 is open-circuited.

C. Phasor Measurement of the S-Parameters

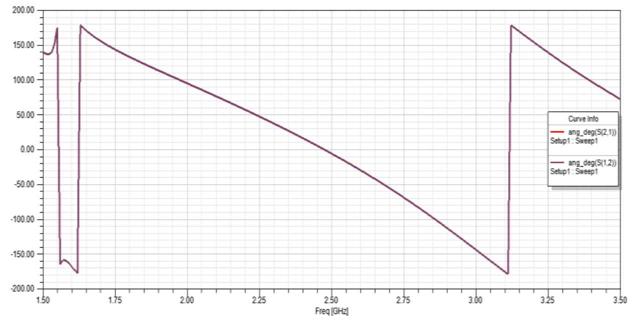

Fig.6 Phasor response of the coupler when porting 3 open and port 4 short-circuited.

In correlation, port 3 acts as an open circuit, whereas port 4 acts as a short circuit; the phase angle is -0.44 degrees, as illustrated in figure 6 and vice versa, the phase angle obtained when port 4 acts as an open circuit are 178.45 degrees in figure 7. The phase shift between the signals is used to characterize the retrodictive rat-race ring system's features. The computed phase angle is 178.45 - (-0.44) = 179 (almost 180). As a result, retrodictive characteristics are obtained by using hybrid couplers.

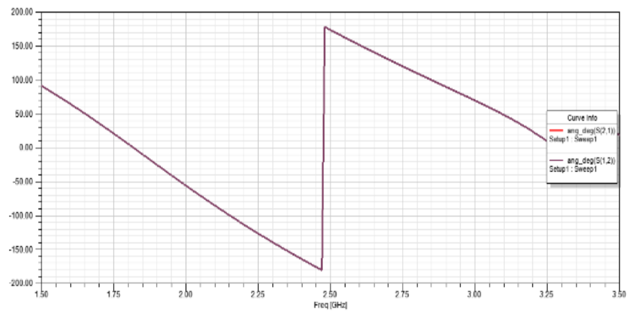

Fig.7 Phasor response of the coupler when porting 4 open and port 3 short-circuited.

D. Radiation Pattern

The radiation patterns for the two instances at 2.5GHz are depicted in Figures 8(a) and (b). The narrow beamwidth in retrodictive mode is displayed in Figure 8(a), and again of 2.12 dB is obtained. The beamwidths of Port 4 and Port 3's primary beams are nearly identical. The non - retrodictive radiation pattern with a maximum 0.96 dB gain is depicted in Figure 8(b). The radiation pattern becomes more precise and focused since the retrodictive arrays have the same beam width as a single antenna but offer significantly higher gain. Retrodirecitivity gain is enhanced by minimizing losses and correctly separating termination ports.

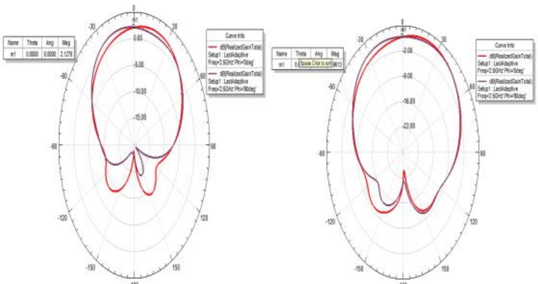

Fig. 8(a) and 8(b) Radiation pattern measurements of patch antenna in both retrodictive and non - retrodictive mode.

IV. CONCLUSIONS

This article discusses a method for identifying and tracking obstacles in inclement weather. The impact of climate based on radar data has been implemented to close the natural environment. Hybrid rat-race couplers-based retrodictive methods have been applied to detect static and movable obstacles in rainy conditions. The passive coupler solves the inability to scan numerous angles with sufficient power. The reliability of the work is demonstrated in two modes as in phase with -0.44◦and out phase with 178.45◦ degrees. Thus from the retrodirectivity conditions, the output is negative concerning input; the phase difference is around 178.45-(-0.44◦) =179◦ (nearly 180◦) is obtained. The results demonstrate maximum integration, which was commonly employed in MIMO research. The echo power is reduced in the direction of the radar; it acts as a disputer for electro-magnetic incident waves away from the receiver. Retrodirective arrays based on hybrids are simple to design, but inadequate isolation of the terminating ports will ultimately reduce the retrodirectivity response. When multiple retrodictive tags are employed for future enhancements and their outputs are encoded orthogonally, the channel's capacity will be increased where SNR is low. The number of retrodictive array elements is simulated to enhance reality and explore the 'most unfavorable case' situations for automated driving systems

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