Double Lens Antennas in Millimeter-Wave Automotive Radar Sensors

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Abstract **─** In the near future, all newly introduced cars will be equipped with radar based systems enabling safer and more convenient driving. The performance of such systems is directly related with the performance of the antenna front end. Recently, double lens focusing system is proposed. With its high broadside directivity and low scan loss over a wide angular range, it can be considered as a good candidate for future long range radars. In this paper, effects of materials on beam scanning performance of double lens antennas are investigated for millimeter wave radars.

Index Terms **─** Automotive radar, double lens, millimeter-wave antennas, millimeter-wave radar, multiple-lens antennas.

I. INTRODUCTION

The majority of road accidents occur due to human errors. To reduce the human responsibility in accidents driver assistance systems are introduced. In automotive radar systems, the radar antennas placed to the front and/ or sides of the vehicle detects the objects surrounding the vehicle and decision on motion of the vehicle is activated. Automotive radar applications such as adaptive cruise control (ACC) and collision avoidance require highly directional antennas capable of distinguishing targets in the field of view. The choice of the radar antenna is determined by the requirements such as high gain and low loss combined with compact size and low cost. With lens antennas, radar sensors with different field of views can be easily build by simply changing the lens of the sensor. Lens antennas are well suited for automotive radar sensors and have been using as automotive radar antennas for over 10 years. The main advantage of this type of antenna is that they typically exhibit very low feed loss, thus yielding a high amount of gain for a given surface area [1]. The volume of this lens antenna is the major disadvantage since they require a non-negligible depth of few centimeters.

Recently, for automotive radars millimeter-wave range is forced by the regulatory agencies to eliminate the problem of the world-wide frequency allocation. The 77/79 GHz frequency band is the future choice for long-, mid- and short-range automotive radar [2-3]. Since almost all long or mid-range antennas will operate in the 76-81 GHz range in the near future, lens and reflector antennas are the first choice at millimeter-waves [4].

At millimeter waves, the most advanced antenna solutions available today are for ACC applications at 77 GHz. Some solutions are based on standard dielectric lens antennas (Bosch Gmbh and TRW/Autocruise) with a detection range up to 250 m and a field of view up to 30° [5]. With increasing requirements towards a much more detailed observation of the scenery in front or around the vehicle, the design of novel antenna concepts in combination with modified overall sensor arrangements became more important. These include multibeam antennas, scanning antennas, switched antenna concepts, and beam forming approaches with multiple transmit and receive antennas [6-11]. In practice, the standard lens antenna solutions proposed to scan the antenna beam use a unique lens illuminated by offset feeds. The feed offset dictates the beam pointing direction, as in optics. Nevertheless, large offset values lead to very poor antenna performance with increased scan loss and beam deterioration which is not acceptable for automotive sensors. In one of recent preliminary studies, the usage of double lens configuration to circumvent these limitations is demonstrated [12]. In literature, multiple lenses are mostly used in physics (e.g., microscope, telescope and camera). In [13], a double lens configuration operating at 30 GHz is proposed for single beam applications, whereas it was constructed and studied for the purpose of irradiation of biological objects in the range of 75-110 GHz in [14]. Compared with a single substrate lens antenna, the two lens antenna system can achieve up to 75% reduction of the lens material while maintaining about the same length and on-axis characteristics. In [12], it is proved that an integrated lens antenna with a double lens focusing system consisting of a hemispherical substrate lens and a plano-convex objective lens can provide simultaneously a high broadside directivity and low scan loss over a wide angular range. In the lens system, a material with low relative permittivity (ultem, $\varepsilon_r = 3.01$) is used in

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both lenses. The lens material has a strong impact on the radiation properties of the lens antennas. As the lens material changes, illumination angle provided by the primary feed would change and stronger impacts of internal reflections would be observed for the lens with high index of refraction. To minimize deteriorating effect of internal reflections, anti-reflective coatings are offered for dense lenses [15-16]. Dielectric lens antennas fabricated with a dense dielectric material allow good power transfer efficiency through the lens and enable fabrication of low-cost and compact-size lens antennas. Although, this is an important subject to be investigated, there is no work in literature that observes the effects of materials on radiation properties of double lenses.

In this work, double lens approach has been applied to millimeter-wave automotive radar antennas and its radiation characteristics are observed for antennas with low/high permittivity lenses. The scanning characteristics are observed. The structures are analyzed by means of a full wave simulator (Computer Simulation Technology (CST) software) based on finite integration technique. Due to ray principles of lenses, with a double lens antenna designed for the automotive radar antennas, better field of view (about 60^o) is observed.

This paper is organized as follows: The configuration of the double lens antenna with its feed and circular corrugation is explained in Section II. The radiation characteristics and performance comparison results are reported in Section III. Conclusions are drawn in the last section.

II. CONFIGURATION OF THE ANTENNA

The motivation to use double lens systems is to combine the pattern characteristics of hemispherical and planospherical lenses. The planospherical lens alone can scan a beam with low loss, however it has a limit due to its high scanning loss. Hemispherical lens antennas show higher scanning capability, but lower gain characteristics. In the double lens configuration, the radiation characteristics of the hemispherical lens compensate for the losses of the planospherical lens. When a hemispherical lens is placed on the feed antenna and a planospherical lens is used at some distance, much better scanning and gain can be obtained. This is the basic motivation for double lens configurations. By using the double lens system, 30^o scanning, resulting as 60^o field of view is achieved with lower than 3 dB loss in gain.

A. Double lens geometry

The considered double lens antenna geometry can be seen in Fig. 1. It consists of an extended hemispherical lens as the immersion lens and a planospherical lens as the objective lens. E is the thickness of the objective lens, F is the distance between the antenna feeding plane and objective lens, ϕ_1 and ϕ_2 are the radii of the hemispherical and objective lens, respectively. In some cases, an additional cylindrical dielectric extension is added to obtain elliptical lens profile which enhances the antenna pattern. L is the extension length of the hemispherical lens. ε_{r1} and ε_{r2} are the relative permittivity of the immersion and objective lens, respectively. The effects of these design parameters on the radiation characteristics are investigated with the full-wave simulator. Thus, all multiple internal reflection are accounted for dense materials.

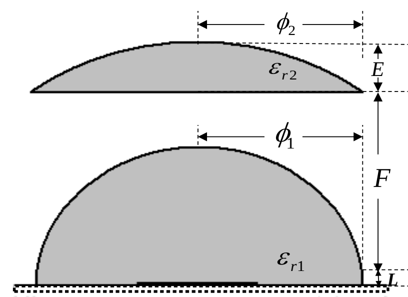


Fig. 1. Cut view of the double lens antenna geometry.

As the thickness of the planospherical lens (E) becomes larger, the focus distance, F gets smaller. Equations for obtaining the focus distance of a lens are available in literature; however these equations, which are functions of ϕ_2, ε_{r2} and E, don't give exact values, especially for thick lenses. To determine the exact location of the double lens focus, ray tracing code written in receiving mode is utilized. The path of the waves is calculated considering the varying propagation velocity, absorption characteristics, and reflecting surfaces. The point where all collimated rays are focused is found as the focus of the lens system. This is validated by the plane wave analysis of double lenses in receiving mode in CST. The plane of the focus point horizontal to the planar feed antenna is set as the feeding plane. Then, the radiation properties of the lens system illuminated by on- and off-axis feedings are investigated. As it is well-known, the lens system should be fed from the focus if the lens is aimed to radiate only to broadside direction. If it would be used for scanning purposes, it should scan the desired field of view with minimum scanning loss. In order to analyze the scanning performance, the feed antenna is shifted to a distance in x-axis. With the movement of the feed from on-axis to off-axis, the direction of the main beam rotates from 0° to larger scan angles. The decrease in maximum level of the pattern gives the scanning loss at that scan angle.

B. Feeding of the double lens antenna

Beam scanning performance of the proposed antennas is demonstrated by shifting a single feed antenna on x-axis and comparing the radiation performance with that of on-axis feed. The primary source is an aperture coupled microstrip patch antenna printed on a RT/Duroid 5880 substrate ($\varepsilon_{r,subs} = 2.23$) given in Fig. 2. It gives almost symmetric radiation patterns in E- and H-planes and is well suited to be realized in integrated or printed circuit board (PCB) technology. Two primary feeds have been designed at 77 GHz. First is designed to radiate into low permittivity material, namely ultem ($\varepsilon_r = 3.01, \tan\delta = 3\times10^{-3}$ at 77 GHz) [12], second is designed to radiate into high permittivity material, alumina ($\varepsilon_r = 9, \tan\delta = 1\times10^{-3}$ at 77 GHz). The patch whose dimensions are given in Table 1 has a nearly-symmetrical radiation pattern with a half power beam width (HPBW) of about 60°. The feed displacement with respect to the lens axis is denoted as *x*.

Table 1: Dimensions of the primary feed designed to radiate into ultem and alumina (all units are in mm)

	L_{patch}	L_{slot}	L_{stub}	W_{line}	W_{slot}	$h_{substrate}$
Ultem	0.9	0.58	0.5	0.3	0.26	0.127
Alumina	0.6	0.58	0.45	0.3	0.26	0.1

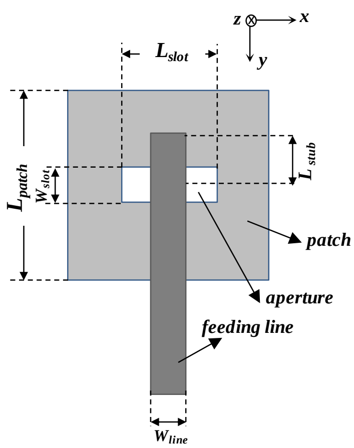


Fig. 2. Geometry of the primary feed (bottom view).

C. Matching layers for lenses with dense materials

Lens antennas made with high dielectric materials are desirable to favor power transfer from the feed to the lens. However, the impedance and radiation characteristics of such lenses are significantly distorted due to the excitation of multiple internal reflections [15]. These limitations can be moderately overcome by reducing the dielectric contrasts at the lens interface, using either conventional matching layers [15-16] or optimized ones [17-18]. Solution of adding a matching layer is difficult to realize since there may remain a gap of air between two layers. The existence of an air gap can expand the main lobe and raise the sidelobes. In automotive radar antenna design, low side lobe levels are crucial as high side lobes may lead to a false alarm in a collision avoidance system. An alternative solution is proposed in [19] by replacing an anti-reflection layer with the corrugated layer. This solution is realized by rectangular corrugations of alumina and was manufactured by stereolithography technique. Stereolithography is an additive layer-by-layer process that allows forming locally solid parts by selectively illuminating polymer photoresists or photoreactive ceramic suspensions. Consequently it becomes possible to construct all-dielectric 3-D devices with arbitrary complex geometries and/or adjustable refractive index by controlling the volumetric proportions of the composite materials. These concepts have been applied to design non-homogeneous monolithic lens antennas in Ka-band [20-21]. The corrugations are integrated directly on the surface of the lens. However, the weak point of using rectangular corrugations is that the results for the TE and TM modes are not identical which means it cannot be used for applications requiring bi-polarization or circular polarization. Thus, circular corrugation is proposed as the anti-reflective coating of the dense material lenses as shown in Fig. 3. The dimensions of each corrugation are calculated so that the relative permittivity is equal to that of the anti-reflection layer. *P* is the width and length of each unit cell. *D* is the diameter of each circular corrugation and is set to 0.8 mm. The thickness of the corrugations has no impact on the calculation of relative permittivity. Thus, it is set as the thickness of the quarter-wave transformer (0.56 mm at 77 GHz).

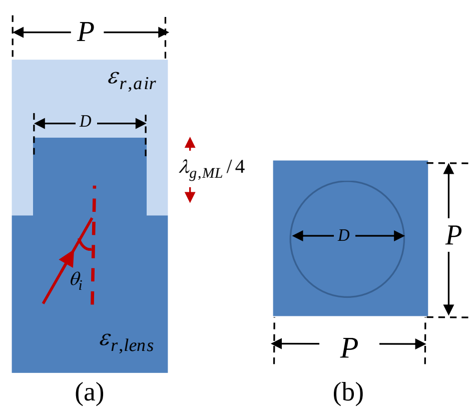


Fig. 3. Unit cell of a circular corrugation designed at 77 GHz: (a) cross-section view and (b) top view.

III. RESULTS

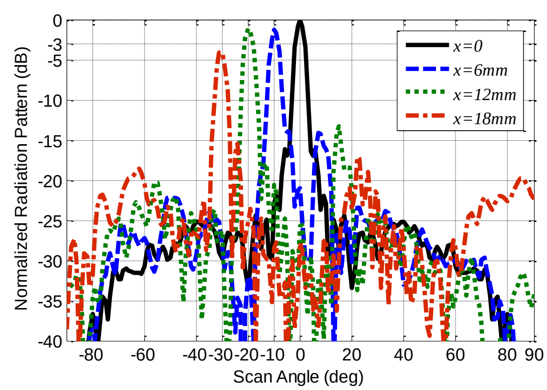
A. Analysis results

First attempt for the double lens antenna design is with a low permittivity, low cost dielectric, ultem. With the relative permittivity of $\varepsilon_r = 3.01$ and tangent loss $\tan\delta = 3\times10^{-3}$ at 77 GHz, this material can be considered as a good candidate for automotive radar applications. The diameter of the lenses is set to 64 mm (16.4 λ_o) in order to obtain approximately 30 dB gain at 77 GHz. The scanning performance of the system is observed for thick and thin planospherical lenses. Numerical analysis based on double lens dimensions (skipped for brevity) gives the lowest beam scanning loss when its parameters are set to L=0, E=10 mm, F=54 mm. The overall volume of the double lens is 64 mm x 64 mm x 64 mm (width x length x height) without boxing. Normalized E-plane radiation patterns of double lens with aperture coupled microstrip feed are given in Fig. 4 (a). Only E-plane patterns are demonstrated due to nearly-symmetrical radiation pattern of the feed antenna. The family of the curves refers to different feed positions. The directivity is obtained as 30.8 dB when fed by on-axis feed. It scans 30^o with approximately 3 dB loss. 30^o scanning is achieved by feeding the double lens 18 mm away from the focus point. When the size for the patch of the feed antenna (0.9 mm x 0.9 mm) and the distance between the feedings are considered, it is clear that more feed antennas can be added to the array to have better resolution. The scanning loss gets higher when the double lens is fed further than 18 mm, thus patterns up to 30^o main beam direction are plotted.

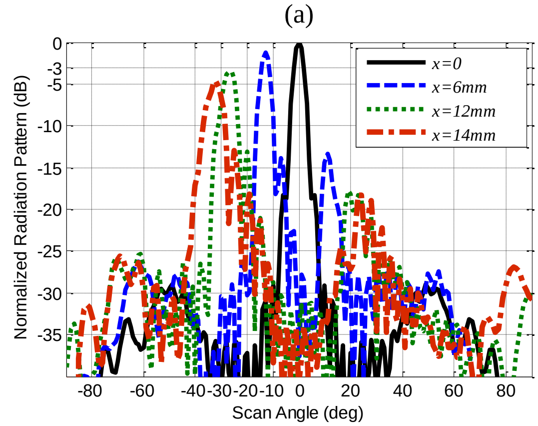
Lens with a dense dielectric material allow good power transfer efficiency through the lens and enable fabrication of low-cost and compact-size lens antenna. Thus, effects of using high permittivity material on double lens antenna radiation are investigated. Firstly, only the material of the objective lens is changed. Alumina with relative permittivity $\varepsilon_{r2} = 9$ is used in the objective lens. Using dense dielectric material causes strong multiple internal reflection behavior inside the lens. These multiple reflections deteriorate not only the return loss but also the radiation characteristics. Wide angle scanning performance is limited due to off-axis aberrations. To avoid the reflections that occur between air-alumina and alumina-air interface, the anti-reflective coating, namely circular corrugation described in the previous section is added to the upper and lower sides of the planospherical lens. After numerical analysis of the double lens, the results with highest directivity and lowest scanning loss is obtained with dimensions L=0, E=5 mm, F=39 mm. The directivity of the double lens fed by on-axis feed is 32.4 dB and the size of the structure is 64 mm x 64 mm x 44 mm (width x length x height) without boxing. Although the height of the double lens is reduced by 20 mm with this design, its beam scanning performance is not as good as the previous case. This can be observed with the normalized E-plane patterns shown in Fig. 4 (b).

Afterwards, the case with immersion lens having high permittivity material (alumina) and objective lens having low permittivity material (ultem) is analyzed. The best configuration with 30.1 dB directivity and 1.5 dB loss in 20^o scanning has dimensions: L=4 mm, E=10 mm, F=42 mm. Its normalized radiation patterns are given in Fig. 4 (c). It is found that 4 mm extension to the hemispherical lens enhances the beam scanning performance of the double lens. The aperture coupled microstrip antenna radiating to alumina is used as the feed antenna. The corrugations are added to half-sphere of the extended hemispherical lens. The antireflective coating is not added to the extension part due to the lack of radiation from that region. For scanning up to 30^o, the feed patch should be placed 8 mm away from the focus, however the patterns are deteriorated after 5 mm displacement of the feed. This is due to smaller critical angle for alumina ($\theta_i \cong 19.5^o$) compared to the critical angle of ultem ($\theta_i \cong 35^o$); total internal reflection occurs. Besides, when the size of the feed patch (0.6 mm x 0.6 mm) is considered, it is clear that it would be a challenging task to design feed array for this double lens antenna. Besides, the scanning losses of the antenna are greater compared to previous two designs.

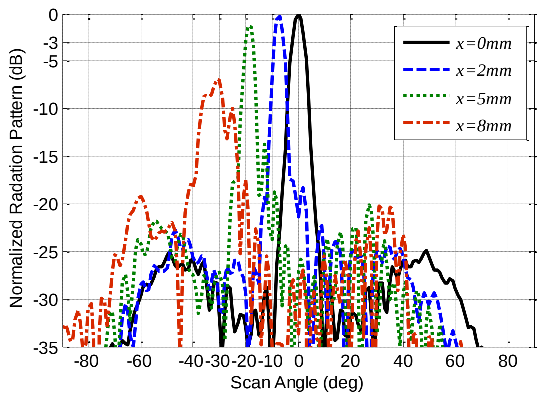
The last numerical analysis is performed for both immersion and objective lenses having dense material, alumina. With L=2 mm, E=4 mm, F=43 mm, this double lens has 49 cm total height. The matching is applied to both sides of planospherical lens and to the upper half-sphere of the extended hemispherical lens. The usage of matching layers has reduced the sidelobes; however they are still significant, especially for off-axis feedings (Fig. 4 (d)).



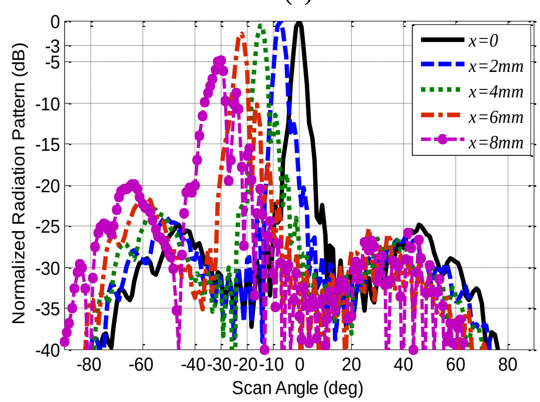
(a)



(b)

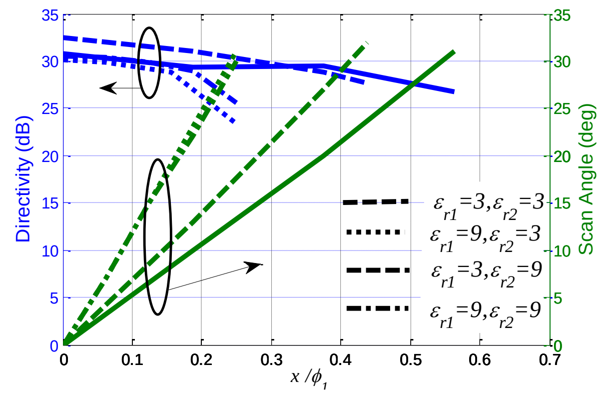


(c)

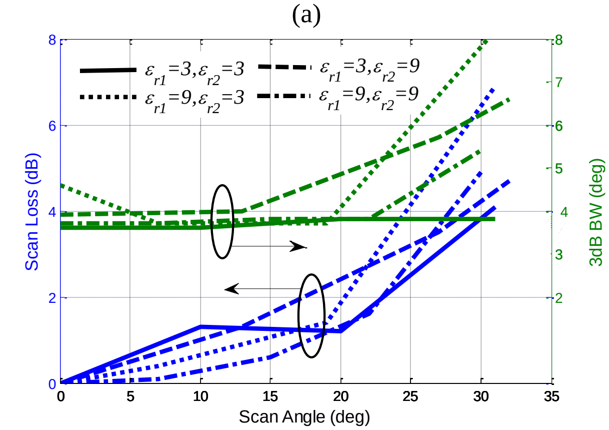


(d)

Fig. 4. The normalized E-plane radiation pattern of the double lens antenna with: (a) $\varepsilon_{r1}=\varepsilon_{r2}=3.01$; (b) $\varepsilon_{r1}=3.01$, $\varepsilon_{r2}=9$; (c) $\varepsilon_{r1}=9$, $\varepsilon_{r2}=3.01$; (d) $\varepsilon_{r1}=\varepsilon_{r2}=9$.



(a)



(b)

Fig. 5. Performance comparison of double lenses: (a) directivity and scan angle vs. feed position; (b) scan loss and 3 dB beamwidth vs. scan angle.

B. Comparison

In the previous section, radiation patterns of four final designs are demonstrated. They are all fed by the same feed which is aperture coupled microstrip antenna designed to radiate into the dielectric material of the immersion lens. Comparison of the results is summarized in Fig. 5. In Fig. 5 (a), left axis belongs to simulated directivity as the function of the feed position for the double lens antenna in E-plane. The main beam direction is shown at the right axis. The scan angle is the same for both planes. It can be observed that when the immersion lens is made of dense dielectric material its feed has to be closer to the focus point to scan the same angle. The directivity of the configurations with low permittivity immersion lens is more stable compared to ones with immersion lens having high permittivity. In Fig. 5 (b), scan loss and 3 dB beamwidth vs. scan angle is given. When these figures are investigated, the double configurations having low permittivity material in immersion lens is found to have the most promising results for the millimeter-wave long-range radar.

IV. CONCLUSIONS

Lens antennas are well suited for automotive radar sensors. Automotive radars consisting of planospherical lenses are in use to detect complex traffic scenarios. As an alternative to this lens, double lens that combines the pattern characteristics of a planospherical and hemispherical lens is proposed in [12] which is manufactured with a low permittivity material. However, it is well-known that the lens material has a strong impact on the radiation characteristics of the antenna. Thus, in this paper, the effects of materials on scanning performance of double lens antennas are investigated. The performance of the double lens system has been successfully verified via full-wave analysis. The results obtained with a double lens system consisting of extended hemispherical lens made of low-permittivity material demonstrate the excellent scanning performance that could be achieved with such systems. The presented analysis results of the double lens demonstrate its good performance in terms of beam scanning performance and gain. With its wider field of view and high directivity, double lenses can be a strong candidate for millimeter-wave automotive radar sensors.

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REFERENCES

[1] W. Menzel, *Antennas in Automobile Radar*, *in Handbook of Antenna Technologies*. Springer Sci. Business Med., pp. 2475-2500, 2016.

[2] H. L. Blöecher, M. Andres, C. Fischer, A. Sailer, M. Goppelt, and J. Dickmann, "Impact of system parameter selection on radar sensor performance in automotive applications,"*Adv. Radio Sci.*, vol. 10, pp. 33-37, 2012.

[3] C. Sturm, G. Li, G. Heinrich, and U. Lübbert, "79 GHz wideband fast chirp automotive radar sensor with agile bandwidth," *IEEE MTT-S Int. Conf. on Microwaves for Int. Mobility (ICMIM)*, San Diego, CA, pp. 1-3, May 2016.

[4] W. Menzel and A. Moebius, "Antenna concepts for millimeter-wave automotive radar sensors," *Proc. of the IEEE*, vol. 100, no. 7, pp. 2372-2379, July 2012.

[5] J. Hasch, E. Topak, R. Schnabel, T. Zwick, R. Weigel, and C. Waldschmidt, "Millimeter-wave technology for automotive radar sensors in the 77 GHz frequency band," *IEEE Trans. on Microwave Theory and Tech.*, vol. 60, no. 3, pp. 845-860, Mar. 2012.

[6] T. Binzer, M. Klar, and V. Gross, "Development of 77 GHz radar lens antennas for automotive applications based on given requirements," *Proc. Int. Conf. Antennas*, Munich, Germany, pp. 205-209, Mar. 2007.

[7] M. Kishida, K. Ohguchi, and M. Shono, "79 GHz band high resolution milimeter wave radar," *Fujitsu Sci. Tech.*, vol. 51, no. 4, pp. 55-59, Oct. 2015.

[8] M. Steinhauer, H. O. Ruo, H. Irion, and W. Menzel, "Millimeter-wave radar sensor based on a transceiver array for automotive applications," *IEEE Trans. Microw. Theory Tech.*, vol. 56, no. 2, pp. 261-269, Feb. 2008.

[9] C. Lievers, W. van Rossum, A. Maas, and A. Huizing, "Digital beam forming on transmit and receive with an AESA FMCW radar," *Proc. Eur. Radar Conf.*, Munich, Germany, pp. 47-50, Oct. 2007.

[10] I. Sarkas, M. Khanpour, A. Tomkins, P. Chevalier, P. Garcia, and S. Voinigescu, "W-band 65-nm CMOS and SiGeBiCMOS transmitter and receiver with lumped I-Q phase shifters," *Proc. IEEE Radio Freq. Integr. Circuits (RFIC) Symp.*, Boston, MA, pp. 441-444, June 2009.

[11] C. Wagner, M. Hartmann, A. Stelzer, and H. Jaeger, "A fully differential 77 GHz active IQ modulator in a silicon-germanium technology," *IEEE Microw. Wireless Compon. Lett.*, vol. 18, pp. 362-364, May 2008.

[12] N. T. Nguyen, A. Boriskin, L. Le Coq, and R. Sauleau, "Improvement of the scanning performance of the extended hemispherical integrated lens antenna using a double lens focusing system," *IEEE Trans. on Ant. Propag.*, vol. 64, pp. 3698-3702, May 2016.

[13] X. Wu and G. V. Eleftheriades, "Two-lens and lens-fed reflector antenna systems for mm-wave wireless communications," *Int. Symp. Ant. and Propag. Soc.*, Toronto, Canada, pp. 660-663, July 2000.

[14] K. Komoshvili, B. Kapilevich, B. Litvak, and Y. Nagar, "Two lens-antenna system for mm-wave biological experiments systems," *IEEE Int. Conf. on Microwaves, Comm., Ant. and Electronics Sys.*, Ariel, Israel, pp. 1-4, Dec. 2011.

[15] N. T. Sönmez and N. T. Tokan, "Effects of antireflective coatings on scanning performance of millimetre-wave lenses," *IET Microw. Antennas Propag.*, vol. 10, no. 14, pp. 1-7, Oct. 2016.

[16] Y. Tajima and Y. Yamada, "Simulations of a shaped dielectric lens antenna by FEKO," *Applied Computational Society Journal*, vol. 24, no. 4, pp. 419-426, Aug. 2009.

[17] J. R. Costa, C. A. Fernandes, G. Godi, R. Sauleau, L. Le Coq, and H. Legay, "Compact Ka-band lens antennas for LEO satellites," *IEEE Trans. Antennas Propag.*, vol. 56, no. 51, pp. 1251-1258, May 2008.

[18] F. Tokan, "Optimization-based matching layer design for broadband dielectric lens antennas," *Applied Computational Society Journal*, vol. 29, no. 6, pp. 499-507, 2014.

[19] N. T. Nguyen, N. Delhote, M. Ettorre, D. Baillargeat, L. Le Coq, and R. Sauleau, "Design and characterization of 60-GHz integrated lens antennas fabricated through ceramic stereolithography," *IEEE Trans. Antennas Propag.*, vol. 58, no. 8, pp. 2757- 2762, Aug. 2010.

[20] K. F. Brakora, J. Halloran, and K. Sarabandi, "Design of 3-D monolithic MMW antennas using ceramic stereolithography," *IEEE Trans. Antennas Propag.*, vol. 55, no. 3, pp. 790-797, Mar. 2007.

[21] J. S. Silva, M. G. Vigueras, T. Debogovic´, J. R. Costa, C. A. Fernandes, and J. R. Mosig, "Stereolithography based antennas for satellite communications in Ka-band," *Proceedings of the IEEE*, vol. 105, no. 4, Apr. 2017.

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