DESIGN GUIDELINES FOR USING PLASTICS IN FRONT OF AUTOMOTIVE RADAR UNITS

This document is intended to assist designers of exterior plastic trim components in determining the thickness of SABIC materials while increasing transparency to automotive RADAR signals. Readers will learn the main aspects of interactions between dielectrics and Gigahertz (GHz) waves and the industry-recommended way to calculate the thickness of a plastic component to maximize its transparency to RADAR waves.

A new generation of vehicles incorporates advanced driver assistance systems (ADAS), which allow partial autonomy while driving and parking and will eventually be expanded to enable full self-driving capability. Ultrasound, RADAR, camera and LiDAR sensors are used in ADAS.

RADAR, which transmits high-frequency radio waves to obtain the range, direction and velocity of objects, is a particularly useful technology. The sensitivity of RADAR receivers is not degraded by fog, snow or rain, provided there is no ice build-up on the radome, which is the protective cover or trim component.

It is expected that as autonomous vehicle technology matures, the number of RADAR units per vehicle will increase from a single long-range RADAR (LRR) sensor at the front and two medium- and short-range RADAR units (MRR/SRR) in the rear corners, to eight units (two LRRs and six MRR/SRRs) offering 360-degree coverage (Fig. 1).

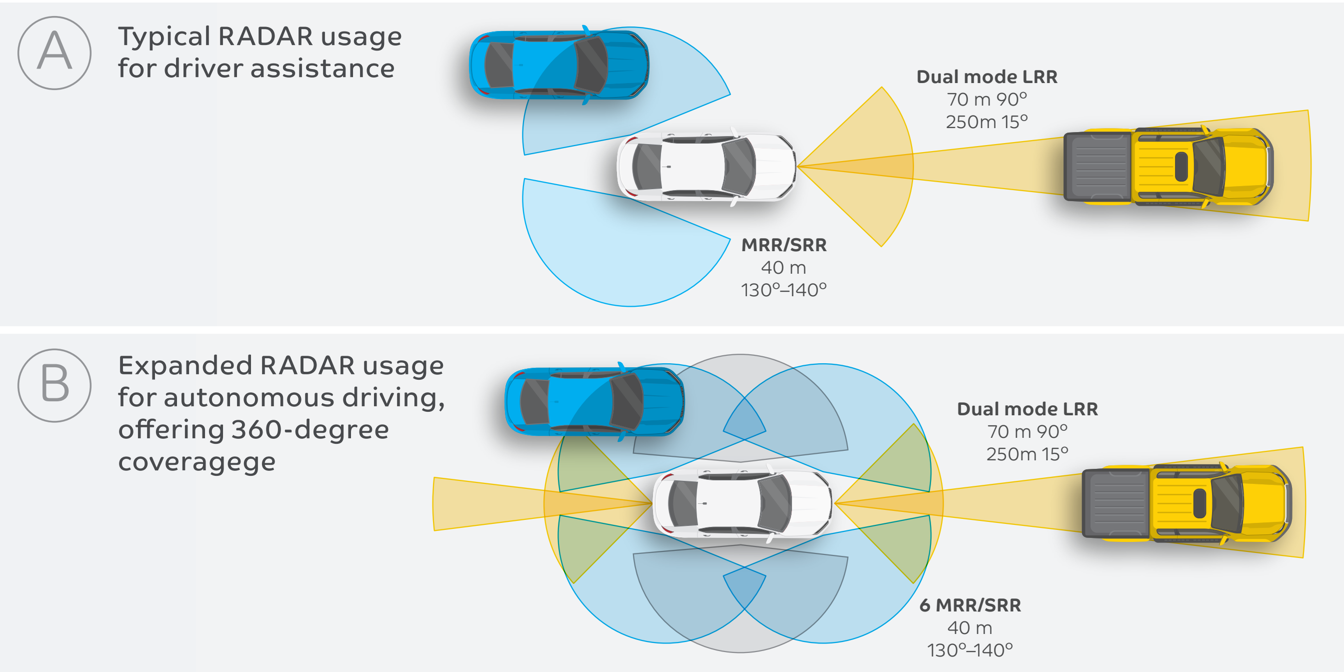


Figure 1. Projected automotive RADAR evolution

INTERACTION OF GIGAHERTZ WAVES WITH PLASTICS

Gigahertz waves are used in ADAS RADAR sensors and 5G vehicle-to-vehicle communication, among other applications. The designated frequencies and wavelengths are listed in Table 1.

WAVE TYPE	RANGE	FREQUENCY (WAVELENGTH)
Long range RADAR	0.5 – 250 m	76-77 GHz (4 mm)
Medium range Short range RADAR Ultra-short range	0.25 – 60 m	77 GHz – 81 GHz (4 mm)
5G vehicle-to-vehicle communication		5.7 – 6.0 GHz (5 cm)
Global Positioning System (GPS)	0.30 m resolution	1.2 – 1.6 GHz

Table 1. Gigahertz wave usage in automotive RADAR

Plastics are dielectrics. The behavior of a dielectric material is characterized by two constants: dielectric permittivity (ε_r or Dk) is a measure of electric polarizability, while the dissipation factor, also known as loss tangent (tan δ or Df), measures the loss in amplitude (height) when the GHz wave passes through the plastic.

Under a charge, the plastic molecules' dipoles align with the electric field, demonstrating permittivity (Fig. 2).

As depicted in Figure 3, when a radio wave passes through a dielectric material, part of the energy (called S12, or forward reflection coefficient) is transmitted and exits on the other side. Another part of the energy (called S11, or reverse transmission coefficient) is reflected back with negligible absorption.

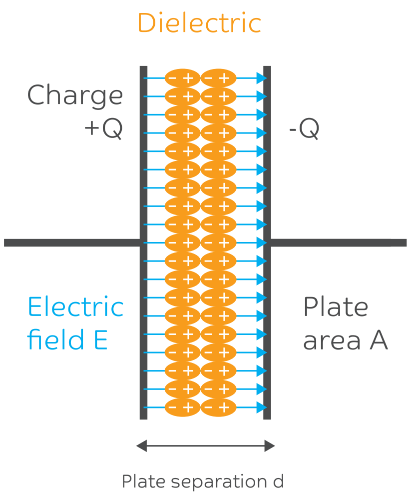
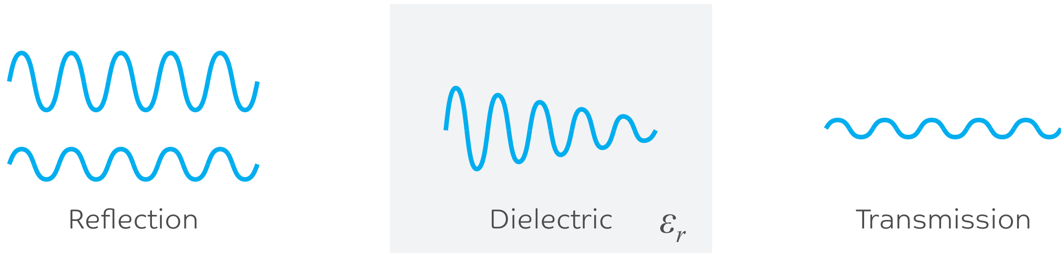


Figure 2. Dielectric behavior under an applied electric field



$$\lambda_d = \frac{\lambda_0}{\sqrt{\varepsilon_r}}$$

Figure 3. Effect of a dielectric material on a wave, showing s11 reflection and s12 transmission.

The goal of the RADAR sensor designer is to reduce reflection and therefore maximize transmission to improve resolution (speed and distance). This requires an understanding of the effect of plastic materials on speed and the amplitude of GHz waves. The wave is affected by the dielectric constants as follows: higher permittivity (Dk or ε_{rr}) results in a shorter wavelength (λ_d) while higher dissipation, Df or tan δ, affects its amplitude (a higher Df reduces amplitude).

The loss in power is proportional to Dk multiplied by Df and the thickness of the material (Dk x Df x thickness)

The properties of plastics at GHz frequencies are measured using a Vector Network Analyzer (VNA) and a waveguide that converts the output into a plane wave (Fig. 4). This set-up measures the reflection of the wave (S11 component) and transmission through the material (S12 component). Typical sample size is 50 x 50 mm with a thickness ranging from 2mm to 5mm.

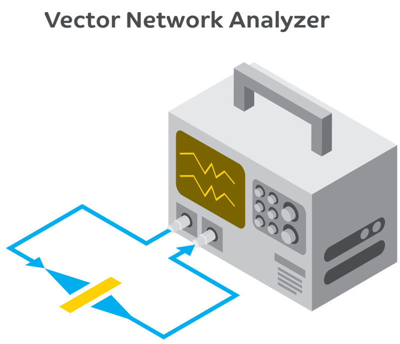


Figure 4. Measurement of Dk and Df

To increase wave transparency in RADAR design, the goal is to use a material with as low a dissipation factor as possible to preserve wave amplitude, and to minimize reflection by using an optimal thickness. The optimal thickness is expressed in multiples of the half wavelength of the material. This results in the waves' exiting the material at a maximum amplitude (Fig. 5).

The behavior of the wave shown in Figure 5 is based on a plane wave incident at 0 degrees. Because the RADAR beam typically exhibits an angle inclination, this angle will affect the exact position of the maximum thickness. However, this is a good first approximation and a key starting point towards maximizing RADAR transparency.

Table 2 shows the measured dielectric constants for several SABIC material families and derived suggested thicknesses to optimize RADAR transparency for each grade.

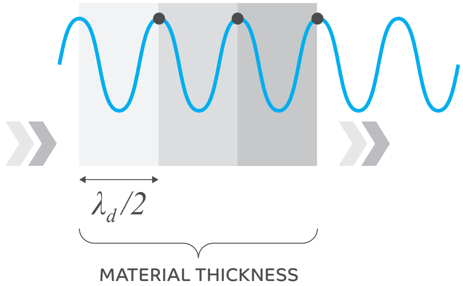


Figure 5. Effect of material thickness on GHz wave

PRODUCT FAMILY	GRADE	Dk	Optimum Thickness (mm)			Df
GELOY™	CR7500	3.06	1.11	2.23	3.34	0.020
	HRA170	2.65	1.20	2.39	3.59	0.010
	XP4034	3.07	1.11	2.22	3.34	0.017
SABIC® PPc	108MF10	2.20	1.31	2.63	3.94	0.001
	5405	2.24	1.30	2.61	3.91	0.001
	7451B	2.37	1.27	2.53	3.80	0.001
	8500	2.38	1.26	2.52	3.78	0.002
	8510E	2.45	1.24	2.49	3.73	0.002
	8536B	2.33	1.28	2.55	3.83	0.002
	8609U	2.61	1.21	2.41	3.62	0.002
	8650U	2.36	1.27	2.54	3.81	0.002
	8659U	2.35	1.27	2.54	3.82	0.002
	8710U	2.47	1.24	2.48	3.72	0.002
CYCOLOY™	C1200HF	2.68	1.19	2.38	3.57	0.009
	CM8622	2.89	1.15	2.29	3.44	0.011
	CM8823	2.99	1.13	2.25	3.38	0.013
	XCM830	2.78	1.17	2.34	3.50	0.009
	XCM840	2.86	1.15	2.30	3.46	0.008
	XCY620S	2.67	1.19	2.39	3.58	0.008
CYCOLAC™	MG37EPX	2.65	1.20	2.39	3.59	0.008
XENOY™	CL100	2.83	1.16	2.32	3.48	0.017
	CL100S	2.81	1.16	2.33	3.49	0.016
	HTX950	2.74	1.18	2.35	3.53	0.006
	X4850	2.92	1.14	2.28	3.42	0.014
	X5230	2.93	1.14	2.27	3.41	0.009
	X5630Q	3.05	1.12	2.23	3.35	0.016
LEXAN™	121R701	2.69	1.19	2.38	3.56	0.007
	143R	2.72	1.18	2.36	3.54	0.008
	161R	2.67	1.19	2.39	3.58	0.007
	LS_111H	2.66	1.19	2.39	3.58	0.007

DISCLAIMER: the above results were obtained using industry-recommended calculations, under lab-controlled conditions, and for SABIC's required purposes. Customer outcomes may vary under different conditions.

Table 2. SABIC grades and their measured dielectric values at 77 GHz

To show how to use this table, we can use an automotive bumper fascia as an example. If SABIC® PPc 108MF10 high-impact copolymer is used to manufacture this part, then the suggested optimal thickness requires variations in multiples of 1.31 mm. The ideal thickness for a fascia would be 2.63 mm. If, due to mechanical constraints, a thickness of 3.20 mm is preferred, then the designer should consider the feasibility of reducing the thickness to 2.63 mm in the RADAR window, the area transversed by RADAR beams. If this is not feasible, the designer should consider whether an increase from 3.20 to 3.94 mm in that area is possible. If a uniform thickness is required, then a fascia with a thickness closer to either 2.6 or 3.9 mm would be more transparent to radio waves than the intended thickness of 3.20 mm.

Figure 6 illustrates the relative positions of the SABIC products listed in Table 2 based on each product's dielectric performance. Lowest losses in radio wave transmission will be achieved by selecting SABIC® PPc or LEXAN® grades from the lower left corner.

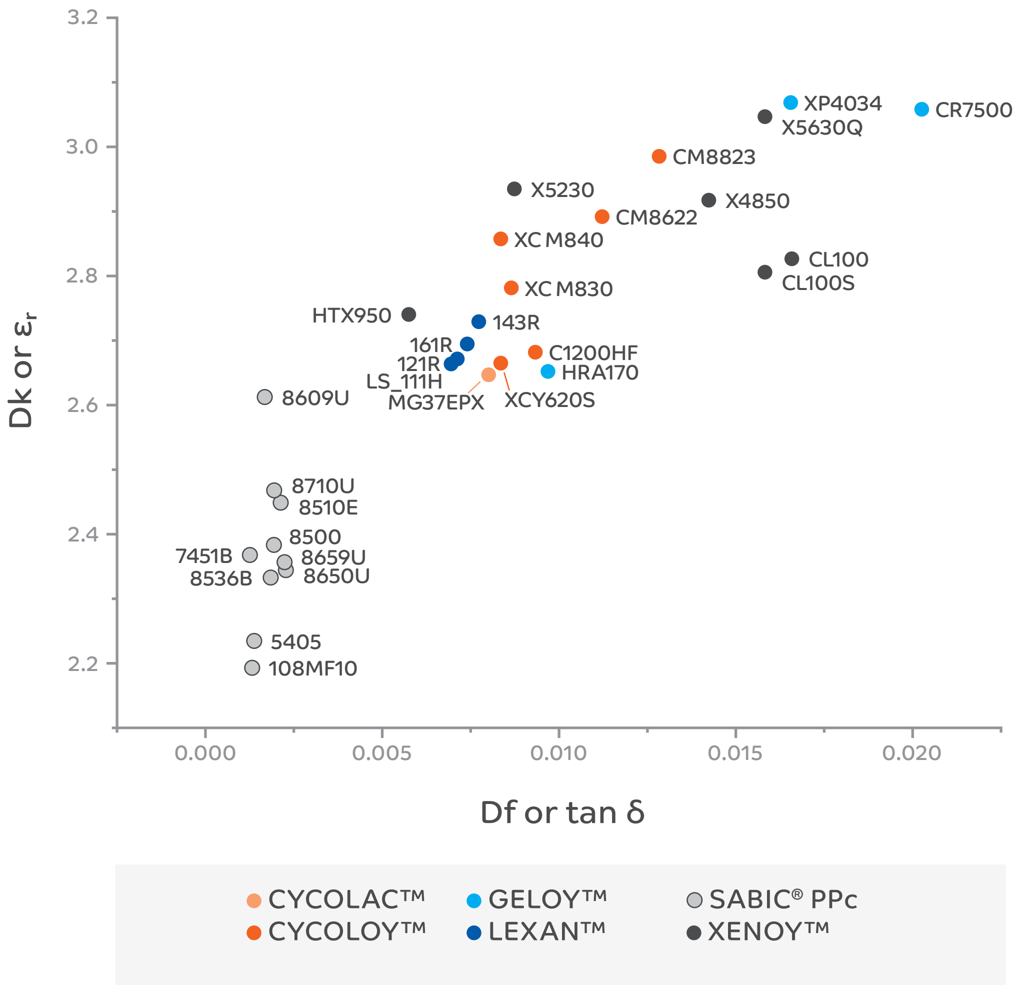


Figure 6. Dielectric constants for SABIC materials

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SABIC AUTOMOTIVE

SABIC HEADQUARTERS
PO Box 5101, Riyadh 11422,
Saudi Arabia
T: +966 (011) 225 8000
Fax: +966 (011) 225 9000
E: info@sabic.com

EUROPE
PO Box 5151, 6135 PD Sittard,
The Netherlands
T: +31 467 222 222
Fax: +31 467 220 000
E: info@sabic.com

GREATER CHINA
2550 Xiupu Road
Pudong, Shanghai 201319,
China
T: + 86 21 2037 8188
Fax: + 86 21 2037 8288
E: stcl-sha@sabic.com.cn

REST OF ASIA
One Temasek Avenue
06-01 Millenia Tower
Singapore 039192
T: +65 655 725 55
Fax: +65 653 181 01
E: sappl@sabic.com

UNITED STATES
SABIC Americas Head Office
Suite 650
2500 City West Boulevard
Houston TX 77042
USA
T: +1 713 532 4999
Fax: +1 713 532 4994
E: info@americas.sabic.com

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