1 Abstract

Radome is an expression built from **Rad**ar D**ome**. It is a cover or enclosure in order to protect radar antennas from environmental influences. This application note explains how to select material and thickness of radar covers.

Every cover has some influence on the shape of detection field and the achievable maximum distance. Radar can „view“ through plastic and glass of any color. This allows a high degree of design freedom. Nevertheless, some rules should be considered.

2 Introduction

The cover of a radar sensor builds a very important part of the sensor and can have an important influence on sensitivity, radiated antenna pattern and immunity to vibrations. Radome design means minimizing microwave reflection at the surface of the cover. Poor radome layout can even cause unwanted sensitivity on the backside of the sensor. The cover material can act as a lens and focus or disperse the radar waves. This is why it should have a constant thickness within the area used for transmission.

3 Radome design

3.1 General rule

A radome should be designed in order to minimize its influence on sensor sensitivity as well as on the field pattern of the radar antenna. Any reflection caused by the radome leads to a degradation of the sensor characteristics. For FMCW radars, proper radome design is even more important than for simple Doppler radars because reflections near the antenna cause strong feed through of the FM signal to the IF output.

> The patch antenna must under no circumstances be painted or covered with a plastic film. This changes the resonance frequency of the antenna and leads to a changed radiation.

3.2 Radome thickness

In order to get the optimal radome thickness, wavelength λ_m in the radome material plays a key role. Wavelength becomes shorter in a material than in free air, depending on the permittivity ε_r (also called dielectric constant). Our goal is to get a wavelength in the material of n*λ_m/2, so that the radome becomes nearly “transparent" for the microwave.

If you can use a material with ε_r of app. 1.0, the thickness doesn't matter. Materials such as polystyrene and polyurethane foam have this property. They can also be placed directly on the antenna. Polyurethane foam can be sprayed very smoothly and thanks to the closed cells comes close to a plastic cover.

$$\lambda_0 = \frac{c_0}{f_c} \qquad (1)$$

- f_c *Transmitting frequency*
- c_0 *Speed of light (299’792’458 m/s)*
- λ_0 *Wavelength in free air*

$$\lambda_m = \frac{\lambda_0}{\sqrt{\varepsilon_r}} \qquad (2)$$

- λ_m *Wavelength in material*
- ε_r *Relative permittivity of the material*

$$T_m = \frac{\lambda_0}{2 \cdot \sqrt{\varepsilon_r}} \qquad (3)$$

- T_m *Optimal radome thickness*

> Thickness of radome needs to be T_m or a multiple of T_m. Determine and manufacture the thickness of the cover with an accuracy of 0.1 mm.

3.2.1 Suitable radome materials

Radome material must be dry and electrically isolating. Do not use coatings or paints containing metallic or carbon particles. Permittivity ε_r (dielectric constant) should be known in order to define optimal thickness according to formula (3). Low dissipation factor *tanδ* is important for low attenuation of the microwaves.

> The cover must not be metallic and must not use plastic coatings that contain metal or carbon particles.

Permittivity ε_r and *tanδ* are mostly specified only up to 100MHz. At higher frequencies, ε_r values usually become slightly lower. Large tolerances apply to many materials. Try to get ε_r values from your supplier.

Table 1: Most used and recommended radome materials

Material	Permittivity ε_r	Diss. factor *tanδ*
Polycarbonate	2.9	0.012
ABS	2.0 - 3.5	0.00500 - 0.0190
PEEK	3.23	0.0048
Teflon® (PTFE)	2.0	<0.0002
Plexiglass®	2.6	0.009
Glass (Corning 7059)	5.75	0.003
Ceramics (Alumina 98%)	9.8	0.0005
PE	2.3	0.0003

All values in this table are indicative only.

3.2.2 Example polycarbonate

Table 2: Optimal thickness for different frequency bands

Frequency f_c	Permittivity ε_r	Wavelength λ_0	Wavelength λ_m	Thickness T_m	Thickness $2*T_m$
24.125 GHz	2.9	12.4 mm	7.3 mm	3.6 mm	7.2 mm
62.000 GHz	2.9	4.8 mm	2.8 mm	1.4 mm	2.8 mm
76.500 GHz	2.9	3.9 mm	2.3 mm	1.15 mm	2.3 mm

3.3 Distance antenna - radome

Optimal distance between antenna and radome allows minimizing the effects of reflections and antenna detuning caused by the radome. The following formula can be used as a rule of thumb for a patch antenna:

$$d_m = \frac{\lambda_0}{2} \quad (4)$$

d_m *Minimal distance between antenna and radome*

Distances below d_m should be avoided while distances above d_m are not as critical.

If the thickness of the radome has been selected correctly, the distance between the antenna and the radome can be smaller as d_m, but the influences on the antenna diagram and the oscillator must be checked.

Table 3: Minimal distance for different frequency bands

Frequency f_c	Wavelength λ_0	Distance d_m
24.125 GHz	12.4 mm	6.2 mm
62.000 GHz	4.8 mm	2.4 mm
76.500 GHz	3.9 mm	1.95 mm

3.4 Vibration immunity

An imperfect radome reflects parts of the transmitted waves. As a radome can never be perfect, relative movements (vibrations) between antenna and radome will lead to large signal levels at the radar transceiver. These signals mostly look like normal Doppler signals caused by moving targets and can lead to malfunction of the sensor system.

Mechanical construction must prevent or at least damp relative movement between antenna and radome.

4 Conclusion

The patch antenna must under no circumstances be painted or covered with a plastic film. This changes the resonance frequency of the antenna and leads to a changed radiation.

The cover must not be metallic and must not use plastic coatings that contain metal or carbon particles.

Thickness of radome needs to be T_m or a multiple of T_m. Determine and manufacture the thickness of the cover with an accuracy of 0.1 mm.

Distances below d_m should be avoided while distances above d_m are not as critical.

Mechanical construction must prevent or at least damp relative movement between antenna and radome.

5 Links and Literature

Find here more information on different materials:
http://www.rfcafe.com/references/electrical/dielectric-constants-strengths.htm
http://users.tm.net/lapointe/Plastics.htm
http://www.professionalplastics.com/professionalplastics/ElectricalPropertiesofPlastics.pdf
https://www.kern.de/de/technische-datenblaetter-kunststoffe

6 Version History

Version	Date	Changes
1.0	11th of April 2013	• Initial release
1.1	13th of July 2020	• change of conclusion • removed best cover thickness • added calculation for different frequency bands
1.2	23th of May 2023	• updated to new design