Abstract
Radome is an expression built from Radar Dome. 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.

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 radarwaves. This is why it should have a constant thickness within the area used for transmission.

Radome Design
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: reflexions near the antenna cause strong feed through of the FM signal to the IF output.

Radome Thickness
In order to get the optimal radome thickness, wavelength $\lambda_m$ in the radom material plays a key role. Wavelength becomes shorter in a material than in free air, depending on the permittivity $\varepsilon_r$ (also called dielectric constant). Explaining physical details on impedance transformation goes beyond the scope of this application note. But we can conclude:

Our goal is to get a wavelength in the material of $n \cdot \lambda_m/2$, so that the radome becomes nearly “transparent” for the microwave.

$$\lambda_0 = \frac{c_0}{f_c} = 12.4\,\text{mm}$$

(1)

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

(2)

$$T_m = \frac{\lambda_0}{2 \cdot \sqrt{\varepsilon_r}} = 6.2\,\text{mm} / \sqrt{\varepsilon_r}$$

(3)

$T_m$ Optimal radome thickness (@ $f_c = 24.125\,\text{GHz}$)

\[ f_c \quad 24.125\,\text{GHz} \]

\[ c_0 \quad \text{Speed of light} \quad (3 \times 10^8 \, \text{m/s}) \]

\[ \lambda_0 \quad \text{Wavelength} \quad @ \, 24\,\text{GHz} \, \text{in vacuum (free air)} \]

\[ \varepsilon_r \quad \text{Relative permittivity in the material} \]
Example Polycarbonate
This material has a typical $\varepsilon_r = 2.9$
With Formula (3) we get

$$T_m = \frac{6.2\text{mm}}{\sqrt{2.9}} = 3.6\text{mm}$$

Distance Antenna - Radome
Optimal distance between antenna and radome allows minimizing the effects of reflections caused by the radome, that never will be absolutely perfect. These effects become minimal if the waves returned at the antenna are in phase with the transmitted waves.

$$d_m = \frac{\lambda_0}{2} = 6.2\text{mm} \quad (4)$$  \hspace{1cm} d_m \quad \text{Optimal distance radome - antenna}$$ \quad \text{(@} f_c = 24.125\text{GHz})$$

Distances $< 6.2\text{mm}$ should be avoided while distances $> 6.2\text{mm}$ are not as critical.

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.**

Suitable Radome Materials
Radome material must be dry and electrically isolating. Do not use coatings or paints containing metallic or carbon particles.
Permittivity $\varepsilon_r$ (dielectric constant) should be known in order to define optimal thickness according to formula (3).
Low dissipation factor $\tan\delta$ is important for low attenuation of the microwaves.
Permittivity $\varepsilon_r$ and $\tan\delta$ are mostly specified only up to 100MHz. At higher frequencies, $\varepsilon_r$ values usually become slightly lower. Large tolerances apply to many materials. Try to get $\varepsilon_r$ values from your supplier.

**Most used and recommended radome materials:**

<table>
<thead>
<tr>
<th>Material</th>
<th>Permittivity $\varepsilon_r$</th>
<th>Diss. factor $\tan\delta$</th>
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<tbody>
<tr>
<td>Polycarbonate</td>
<td>2.9</td>
<td>0.012</td>
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<tr>
<td>ABS</td>
<td>2.0 - 3.5</td>
<td>0.00500 - 0.0190</td>
</tr>
<tr>
<td>PEEK</td>
<td>3.23</td>
<td>0.0048</td>
</tr>
<tr>
<td>Teflon® (PTFE)</td>
<td>2.0</td>
<td>&lt;0.0002</td>
</tr>
<tr>
<td>Plexiglass®</td>
<td>2.6</td>
<td>0.009</td>
</tr>
<tr>
<td>Glass (Corning 7059)</td>
<td>5.75</td>
<td>0.003</td>
</tr>
<tr>
<td>Ceramics (Alumina 98%)</td>
<td>9.8</td>
<td>0.0005</td>
</tr>
<tr>
<td>PE</td>
<td>2.3</td>
<td>0.0003</td>
</tr>
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</table>

All values in this table are indicative only.
Conclusion

• Cover must not be metallic.
• No plastic coating with colors containing metallic or carbon particles.
• Distance between cover and front of Radar sensor >= 6.2mm
• Best cover material is Polycarbonat or ABS
• Best cover thickness is 3-4mm
• Vibrations of the Radar antenna relatively to the cover should be avoided, because this generates signals that can trigger the output

Links and Literature

Find here more information on different materials:
http://www.rfcafe.com/references/electrical/dielectric-constants-strengths.htm
http://www.matweb.com/search/SpecificMaterial.asp
http://www.kayelaby.npl.co.uk/general_physics/2_6/2_6_5.html
http://users.tm.net/lapointe/Plastics.htm

Version History

<table>
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<th>Version</th>
<th>Date</th>
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<tr>
<td>1.0</td>
<td>11-April-2013</td>
<td>initial release</td>
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