Material meets millimeter wave (mmW)

Andreas Reil
Product Manager Microwave Imaging
1 MIP

Prepared for
Overview

mmW Imaging

Applications in Plastics
mmW Imaging

Frequency

0Hz  1 kHz  1MHz  1GHz  1THz  1PHz  1EHz

Cellphones  Radar  infrared  ultra-violet  visible light  X-Ray

Audio  AM Radio  FM Radio

Audio

77 GHz automotive radar
mmW Imaging
mmW Imaging

Honda CBR

BMW i3 - side

BMW i3 - front
QAR
Automotive Radome Testing

PCB sample with copper structure.

Find hidden structures in design radomes

COMPANY RESTRICTED
Reasons for blindspots within the radome
Why spatially resolved reflectivity images are important
NEW REQUIREMENTS FOR BODY PANELS
Radar compatibility - Influence factors for attenuation

- RAW MATERIAL
  - Type of material

Common exterior parts are produced out of PP, PC and ABS.
Radar compatibility - Influence factors for attenuation

- RAW MATERIAL
  - Wall thickness

\[ t_{\text{raw opt}} = n\frac{\lambda}{2} \]

A common wall thickness is in the range from 2.6 mm up to 3.5 mm

\[ \lambda = \text{Wave length of the radar} \]
\[ (76 \text{Ghz} = 3.9 \text{mm}) \]
Radar compatibility - Influence factors for attenuation

- PART
  - Raw material
  - Primer
  - Base coat
  - Clear coat

Important: an optimized $t_{part}$ is different for each color and not the same as $t_{raw}$
Radar angular measurement technology

Estimate azimuth / elevation angles from phase differences / amplitudes at the receive antennas of the phased array.

\[ \alpha = \sin^{-1}\left(\frac{\lambda \cdot \Delta\varphi}{2\pi d}\right) \]

- \( d \): Physical distance between antennas
- \( \Delta\varphi \): Phase difference
- \( \alpha \): Angle of arrival
- \( \lambda \): Wavelength

Sampling points

\( \varphi_5 \), \( \varphi_4 \), \( \varphi_3 \), \( \varphi_2 \), \( \varphi_1 \)
Phase fronts traveling towards the radar.

\[ \alpha = \sin^{-1} \left( \frac{\lambda \cdot \Delta \varphi}{2\pi d} \right) \]

- \( d \): Physical distance between antennas
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- \( \alpha \): Angle of arrival
- \( \lambda \): Wavelength

\[ \Delta \varphi_1 \neq \Delta \varphi_2 \neq \Delta \varphi_3 \neq \Delta \varphi_4 \neq \Delta \varphi_5 \]

Phase estimation is wrong
Radar angular measurement technology

Phase fronts traveling towards the radar.

Measuring the angle error does not lead to useful results, if:
- The radar is slightly moved.
- The distance between the antennas is changed.
- Another algorithm is used for angle of arrival estimation during post processing.

Or, more general, if:
- Another radar / radome combination is used.

An alternative method has to be used.
Angular inaccuracies are caused by inhomogeneity.

Inhomogeneity of the radome is measured by the QAR.

A threshold can be defined for either each car, or the whole fleet. Every radar is then measured using the same technique.
Comparison of measurement methods

<table>
<thead>
<tr>
<th>Method</th>
<th>Corner reflectors</th>
<th>Network Analyzer</th>
<th>R&amp;S®QAR</th>
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<tbody>
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| #1   | 1.2dB  | 0.2°   |
| #2   | 1.4dB  | 0.1°   |
| #3   | 1.6dB  | 0.3°   |

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## Comparison of measurement methods

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### Corner reflectors
- **Cheap & Quick**
- **Estimation & selective, Radar dependent**

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Comparison of measurement methods

Method

Corner reflectors

Network Analyzer

R&S®QAR

Descr.

Corner reflector

Radome

Radar

Result

Corner reflector

Radome

Radar

Meas. 2way Azimuth Point att. Error

| #1 | 1.2dB | 0.2° |
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Precise measurement

Slow and selective

Calibration required

Experts for operation

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**Spatially resolved**

- Easy to operate
- Time saving

**Equipment necessary**
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Material meets millimeter wave
The R&S QAR radome tester

In the marked area:

Mean value: -8.1 dB  35 %
Standard deviation: -17.2 dB  14 %

Mean value: 0.06 dB  for 76 GHz to 77 GHz
Mean value: 1.20 dB  for 76 GHz to 81 GHz

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Summary

Your benefits

Increase quality
Due to the possibility of 100% testing in production

Reduce measurement time
Measurement cycle of the instrument is ~ 7s

Reduced costs
Much easier to operate as a vector network analyzer
Thank You