Rd Series Module Radome Design Guide

Version V1.1.0

Documentation resume

Version	Date	Formulate/modify content	Formulate	Approve
V1.1.0	2023.06.30	First time formulated	Shifeng Hu	Fangke Huang

Content

1. The impact of radome on modules

- Signal attenuation: The material and structure of the radome will attenuate the propagation of radar signals. Depending on the materials and media of the radome, the propagation energy loss of radar waves is different, which will affect the detection range and accuracy of the radar to some extent.
- Scattering: The surface of the radome will produce scattering, which will cause reflection and interference of the radar signal, affecting the radar detection effect.
- Multipath effect: The existence of the radome will cause the radar signal to produce a multipath effect, that is, the signal reaches the receiver after being reflected multiple times inside the radome, which will affect the measurement accuracy of the radar.
- Blind zone: The design and installation location of the radome will affect the radar's blind zone, which is the area that cannot be detected by the radar.
- Therefore, during the radar design and installation process, it is necessary to consider the influence of the radome, select appropriate materials and structures, and reasonably design and install the location to ensure the detection effect and accuracy of the radar.

2. Radome design considerations

- As an important part of radar, the performance of radome directly affects key indicators such as radar measurement distance, accuracy and anti-interference ability. The radome is installed in front of the antenna. Its main function is to protect the antenna from harsh environmental factors such as airflow, rain, snow, sand and salt spray, and to provide a stable working environment for the antenna, thereby improving the reliability of the radar.
- In order to ensure the performance of the radome, it needs to have excellent wave transmission performance, that is, it cannot strongly block the electromagnetic waves radiated by the antenna or destroy the required beam shape. At the same time, the impact of the radome on the antenna's gain, beam width and other performance indicators should be as small as possible. Therefore, when designing a radome, factors such as material selection, structural form, and wall thickness need to be comprehensively considered to ensure that the radome not only has good telecommunications performance, but also has good structural performance.
- To sum up, the importance of radome in radar system cannot be ignored. By optimizing the design and choosing the right materials,

It can effectively protect the antenna from harsh environments and improve the reliability and performance of the radar system.

- Here are some factors to consider in radar module radome design:
  - ✓ Material selection: The material of the radome should have good weather resistance, corrosion resistance and high temperature resistance. Commonly used materials include plastics and composite materials. It is worth noting that when designing, try to avoid the use of metal fixtures and coatings, especially metal materials that can significantly reduce signal strength.
  - ✓ Shape design: The shape of the radome should match the shape of the radar module to ensure that the radome does not negatively affect the performance of the radar module. At the same time, the shape of the radome should also take into account the convenience of installation and maintenance.
  - ✓ Dimensional design: The size of the radome should match the size of the radar antenna to ensure that the radome fully covers the radar antenna and does not negatively affect the performance of the radar antenna.
  - ✓ Transparency design: The transparency of the radome should be high enough to ensure that the radar signal can pass through the radome smoothly, and does not negatively affect the strength and accuracy of the radar signal.
  - ✓ Waterproof design: The radome should have good waterproof performance to ensure that the radar module can still work normally under severe weather conditions.
  - ✓ Dust-proof design: The radome should have good dust-proof performance to ensure that the radar module can still work normally in a dusty environment.
  - ✓ Anti-corrosion design: The radome should have good anti-corrosion properties to ensure that the radar module can still work normally in a corrosive environment.
  - ✓ Installation method design: The installation method of the radome needs to take into account its connection method and installation position with the radar module. Generally speaking, the radome can be fixed on the radar module through threaded connection, pasting, etc., and it is necessary to ensure that it fits well with the interface of the radar module.

- In short, the design of the radar module radome should comprehensively consider factors such as material, shape, size, transparency, waterproof, dustproof and anti-corrosion to ensure that the radome can fully protect the radar antenna and will not have a negative impact on the performance of the radar module.

- Other radome performance factors:

✓ Protect the antenna: The radome should be able to protect the radar antenna from the external environment, such as wind, rain, snow, dust, etc., while also preventing mechanical damage and electromagnetic interference.

✓ Ensure antenna performance: The structural shape of the radome should minimize the impact on radar antenna performance, such as reducing reflection, scattering, diffraction, etc.

✓ Adapt to the working frequency: The structural shape of the radome should adapt to the working frequency of the radar antenna to ensure the working performance of the radar antenna.

✓ Lightweight: The radome should be as lightweight as possible to reduce the impact on the weight and volume of the entire system.

✓ Aesthetics: The appearance of the radome should be beautiful, the surface must be smooth and flat, and the materials used should be uniform in nature, consistent in thickness, and consistent with the design style and requirements of the entire system.

- If the structural shape of the radome does not meet these requirements, it may affect the performance and use of the radar antenna. Therefore, when designing and manufacturing radomes, these requirements need to be strictly followed to ensure the normal operation of the radar antenna.

3. Radome height and thickness design

3.1. The height of the antenna to the inner surface of the radome: h

- The height h from the antenna to the inner surface of the radome generally depends on the specific antenna, radar and dome design. In practical applications, comprehensive considerations need to be made based on factors such as radar emission, antenna frequency, power, radiation direction, radome material, shape, and size to ensure the effectiveness and safety of the radome.

- The ideal height is an integer multiple of the radar half-wavelength (0/2) in the air. Maintaining an appropriate distance between the antenna and the inner surface of the radome can effectively reduce the reflection effect caused by the radome. When the reflected electromagnetic wave is different from the emitted electromagnetic wave When consistent, this effect will be minimized. The height h from the antenna to the inner surface of the radome can be calculated by the following formula.

$$h = \frac{n * \lambda_0}{2}$$

$$\lambda_0 = \frac{C}{f}$$

The meaning of each parameter in the formula: h is the height from the antenna to the inner surface of the radome; n is a positive integer; 0 is the wavelength of electromagnetic waves in the air; C is the speed of light in vacuum; f is the average carrier frequency used.

3.2. The distance between the outer and inner walls of the radome: d

- The distance d between the outer wall and the inner wall of the radome, usually called the "radome wall thickness", refers to the distance from the inner surface to the outer surface of the radome, which is the wall thickness of the radome.

- This value is usually determined by the designer based on factors such as radar emission, antenna operating frequency, radome material and manufacturing process. In practical applications, the radome is a shell used to protect millimeter-wave radar sensors and antennas from external interference and environmental influences. The wall thickness of the radome has a certain impact on the performance and operating frequency of the antenna and radar, so it needs to be carried out Reasonable design and selection. When designing a radome, it is necessary to comprehensively consider radar and antenna performance and actual application requirements, and select an appropriate thickness.

- The ideal wall thickness is an integer multiple of the radar half-wavelength (λ/2) in the medium. The performance of millimeter-wave radar sensors is closely related to the wall thickness of the radome. The key is to ensure that the wall thickness of the radome is an integer multiple of the radar half-wavelength (λ/2).
- In this way, the radome becomes "almost transparent" in the millimeter-wave frequency range. The wavelengths in the radome material become shorter relative to natural air, which

is inversely proportional to the dielectric constant of the material. The thickness of the radome can be calculated by the following formula.

$$d = \frac{n * \lambda}{2}$$

$$\lambda = \frac{C}{f\sqrt{\varepsilon_r}}$$

The meaning of each parameter in the formula: d is the thickness of the radome; n is a positive integer; λ is the wavelength of the electromagnetic wave in the material; C is the speed of light in vacuum; f is the average carrier frequency used; ε_r is the relative dielectric constant of the radome material.

4. Common material designs for radomes

- In order to minimize the impact on the radar antenna's emitted and reflected electromagnetic signals, it is crucial to select suitable materials for the radome. When selecting a radome material, one needs to mainly consider its electrical properties, mechanical properties and environmental resistance. According to relevant information, the relative dielectric constant ε_r (Dk) of wave-transparent materials in the frequency range from 0.3 to 300GHz.
- Usually it should be less than 10, the loss tangent value tan δ (Df) should be less than 0.01, and the electrical parameters should not change significantly with changes in temperature and frequency. In terms of mechanical properties, the radome material should have high strength to ensure that it is not easily damaged or destroyed when subjected to external forces, thereby providing a stable working environment for the antenna. In addition, the low thermal expansion coefficient and good thermal shock resistance also help to maintain stable performance of the antenna system.
- Broadly speaking, the material of the radome should have good electromagnetic transparency, that is, it should be able to allow radar signals to pass through the material without being excessively absorbed or reflected. This ensures that the performance of the radar system is not affected. The radome needs to have sufficient mechanical strength to protect the radar antenna from the external environment, such as wind, rain, snow, ice, etc. The material should have sufficient impact resistance, compression resistance, tensile resistance and other properties. Radomes usually need to be exposed to the outdoor environment for a long time, so the material should have good weather resistance and be able to resist the erosion of natural environments such as ultraviolet rays, high temperatures,

and low temperatures. Radomes usually need to withstand corrosive environments such as acid rain and salt spray, so the materials should have good anti-corrosion properties and be able to resist erosion by corrosive substances. When choosing a material, you also need to consider its weight and cost. Materials should be as lightweight as possible to reduce the impact on the overall weight of the radar system, and should be of low cost to reduce production costs. Therefore, when selecting materials, the above factors need to be considered to ensure that the radome can minimize the impact on the antenna signal and provide a reliable working environment.

- Currently, the materials commonly used in radomes generally include inorganic non-metallic materials and organic wave-transmitting materials. Inorganic non-metallic materials refer to inorganic non-metallic ceramics, glass and other materials, which have high temperature resistance and corrosion resistance and are suitable for radomes in some special environments. Organic wave-transmitting materials refer to materials such as resin-based wave-transmitting composites, which have good transparency, wave-transmitting properties and electrical properties, and can better allow electromagnetic waves to pass through.

- Of course, the most important thing to note is the material's dielectric constantε_r (Dk) and loss tangent tan δ (Df). When the material'sε_r and tan δ values are small, this means that the material's ability to absorb working electromagnetic waves lower.Therefore, during the propagation process of electromagnetic waves, this dielectric material can transmit electromagnetic waves more effectively, thereby keeping the intensity of electromagnetic waves at a high level. This phenomenon can be explained by the fact that the material attenuates electromagnetic waves to a smaller extent, allowing electromagnetic waves to propagate more fully and maintain their original intensity. Such a property is very beneficial for many applications, as it can reduce energy loss and increase the efficiency of electromagnetic wave transmission. Therefore, choosing materials with smallerε_r and tan δ values can achieve better performance and effects during electromagnetic wave propagation.

- Generally speaking, materials with smaller Dk and Df are selected as the material for making radomes. The following are the dielectric constant Dk and loss tangent tan (Df) of some media and common media used in radar radomes.

Table 1 Parameters of some media and common media for radar radomes

Medium	Dielectric constant	Loss tangent tan
Air	≈1	≈0
vacuum	1	0
Polytetrafluoroethylene (PTFE)	2.1-2.3	0.0002-0.0003
Polyimide (PI)	3.4-3.5	0.003-0.005
Polystyrene (PS)	2.5-2.7	0.001-0.002
Polycarbonate (PC)	3.0-3.2	0.005-0.008

- It should be noted that these values are only typical values in the general range, and there may be certain differences in actual applications. In addition, radar systems in different frequency bands have different material requirements, so the specific selection of materials needs to be evaluated and tested based on actual needs.

Before designing, first understand the material and electrical characteristics of the radome. Refer to the figure below. The data is for reference only. Please confirm with the supplier for actual information.

Medium	ε_r **Typical value**	**Half wavelength （mm）**	**1/8 wavelength （mm）**	**1/10 wavelength （mm）**
Air	1.00	6.20	1.55	1.24
ABS1	1.50	5.06	1.27	1.01
ABS2	2.50	3.92	0.98	0.78
PC material	3.00	3.58	0.89	0.72
PMMA acrylic 1	2.00	4.38	1.10	0.88
PMMA acrylic 2	5.00	2.77	0.69	0.55
PVC hard	4.00	3.10	0.78	0.62
PVC soft	8.00	2.19	0.55	0.44
High density PE	2.40	4.00	1.00	0.80
Low density PE	2.30	4.09	1.02	0.82
Quartz glass	5	2.77	0.69	0.55

Figure 1 Common material properties (based on 24.125GHZ)

- Height from antenna to inner surface of radome: H

  - ✓ When space permits, 1x or 1.5x wavelength is preferred.
  - ✓ For example, 12.4 or 18.6mm is recommended for 24.125GHz
  - ✓ Error control: ±1.2mm

- Radome thickness: D
  - ✓ Recommended half wavelength, error control ±20
  - ✓ If the half-wavelength thickness requirement cannot be met
  - ✓ It is recommended to use low r materials;
  - ✓ Thickness recommended is 1/8 wavelength or thinner
- The impact of uneven materials or multi-layer composite materials on radar performance, it is recommended to make experimental adjustments during design.

5. Structural design of radome

5.1. Appearance structure

- Radar radomes have a variety of structures, generally divided into flat covers, spherical covers, and arched covers. The radome used for radar modules generally chooses the flat cover style, which has a simple structure and low cost, and makes the radome parallel to the radar module, which will fit better. It is worth mentioning that no matter which structure is chosen, the texture must be uniform and the surface smooth, so that the equivalent value of electromagnetic waves passing through each part of the radome at the same angle is consistent after being lost.

- The schematic diagram of the flat cover is as follows:

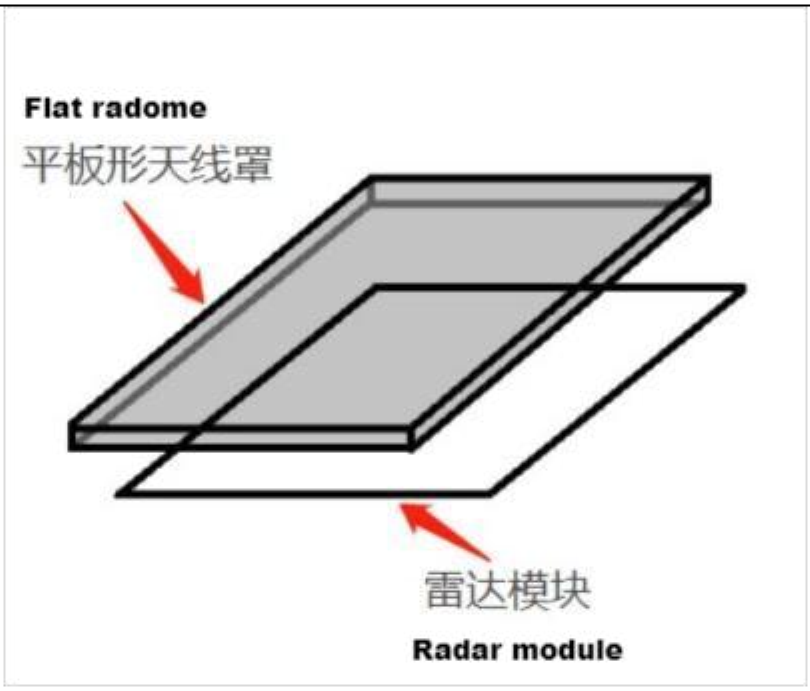

Figure 2 Flat radome

5.2. Cross-sectional structure

- Radomes can be divided into single layer, interlayer, and multi-layer according to the cross-sectional form of the radome wall. Generally, radomes will adopt solid wall (single layer), A-type sandwich and C-type sandwich structures. Radomes used for radar modules generally choose the form of solid walls. It is simple to make and is characterized by high incident angles. and has good electrical properties under both polarization conditions. The cross-sectional structure design of some radomes uses a sandwich structure of different materials, because the sandwich structure not only has better strength retention, but also has better wave transmission performance. The sandwich structure can utilize the mutual cancellation effect of electromagnetic wave reflection between the two surface layers to ensure its good wave transmittance. When electromagnetic waves enter the interlayer from the air, they are reflected in each dielectric layer. When the thickness of the core layer is optimal, the reflected waves of the inner and outer skins have equal amplitudes and opposite phases, canceling each other out, thus reducing the impact of reflected waves on radar performance. , improving the strength and bandwidth of the transmitted signal.

- Some cross-sectional forms of radomes are shown below:

  Solid wall construction (single layer)

Figure 3 Solid wall structure (single layer)

- ✓ A-type sandwich structure

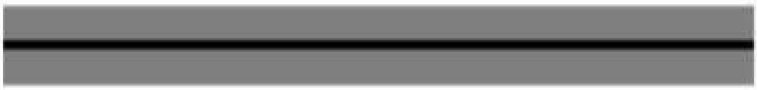

Figure 4A type sandwich structure

- ✓ C type sandwich structure

Figure 5C type sandwich structure

- The gray part in type A and C sandwich is the skin, and the black part is the core layer. The skin structure commonly used in sandwich structures is wave-transmissive composite laminates, such as glass fiber/resin matrix composites. The core layer of the radome is mainly made of honeycomb core material and foam core material, which can effectively offset the reflection of the skin.

6. Module design guidance

6.1. Radar installation precautions

- ✓ Regarding the installation position on the motherboard, the following methods are recommended:Try to ensure that the radar antenna is facing the area to be detected and that the surrounding area of the antenna is open and unobstructed.

- ✓ It is necessary to ensure that the installation position of the radar is firm and stable. The shaking of the radar itself will affect the detection effect.

- ✓ Make sure there is no movement or vibration of objects on the back of the radar. Due to the penetrating nature of radar waves, the antenna signal back lobe may detect moving objects behind the radar. A metal shield or metal back plate can be used to shield the radar back lobe and reduce the impact of objects on the back of the radar.

- ✓ Due to differences in target size, status, RCS, etc., the target distance accuracy will fluctuate; at the same time, the maximum distance will also fluctuate slightly.

- When there are multiple 24GHz band radars, please do not have beams facing each other and install them as far away as possible to avoid possible mutual interference.

- In order to meet the performance of the onboard antenna, it is prohibited to place metal parts around the antenna and keep away from high-frequency devices.

- The power input voltage range is 3.0V-3.6V, and the power supply ripple is required to have no obvious frequency peak within 100kHz. Users need to consider corresponding electromagnetic compatibility designs such as ESD and lightning surges.

6.2. Installation environment requirements

This product needs to be installed in a suitable environment. If used in the following environments, the detection results will be affected:

- There are non-human objects in continuous motion in the sensing area, such as animals, continuously swinging curtains, large green plants facing the air outlet, etc.
- There is a large area of strong reflectors in the sensing area, and the strong reflectors will cause interference to the radar antenna.
- When installing on the wall, you need to consider external interference factors such as air conditioners and electric fans at the top of the room.

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