APPLICATION TIPS

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A Guide to Molex Application Specification Documents for Antennas

To help users understand the properties of Molex antennas and their applications, Molex provides an application specification (AS) document of each product. This guide introduces the basic parameters of the antennas, giving the users a quick overview of the properties of Molex antennas and enabling them to better apply the antennas in their devices.

1. **General information about antennas**
   a. **What is an antenna**
      According to the IEEE, an antenna is a device used for radiating or receiving radio waves. A transmitting antenna converts the traveling waves in the circuit's transmission line into radio waves in space, whereas a receiving antenna receives radio waves and converts them into traveling waves of the transmission line
   b. **Common parameters of an antenna**
      i. **Return loss**
         When there is an impedance mismatch (i.e., the antenna impedance is not equal to the characteristic impedance of the transmission line, which is often 50 Ohms), the incident wave and reflected wave coexist on the transmission line, causing return loss. The ratio of reflected wave voltage to incident wave voltage is known as reflectance, denoted as Γ. Lower reflectance results in lesser energy reflection from a radio frequency module or more energy delivered to the antenna.

Return loss (RL) =-20log|Γ| (In general, RL ≤ -6dB indicates good performance)

ii. **VSWR**

VSWR is the initialism for voltage standing wave ratio. VSWR = (1+Γ) / (1-Γ). The closer it is between terminal antenna impedance (Z_L) and transmission line characteristic impedance (Z_0), the smaller reflectance Γ is, and the closer VSWR is to 1, the better the impedance match.
In general, VSWR ≤ 3, or RL ≤ -6dB, indicates good performance.

iii. **Directivity**

The directivity is the ratio of the radiation intensity in a given direction to the radiation intensity averaged over all directions. The antenna pattern is a radiation pattern composed by values of electric fields at different locations in space. Common 2D and 3D patterns indicate the radiation conditions of an antenna.

iv. **Gain**

The gain of an antenna is defined as the ratio of the intensity in a given direction to the radiation intensity of an isotropic antenna (an antenna that radiates equally in all directions). The gain quantitatively describes the extent to which an antenna concentrates input power. Gain is closely related to directivity and is simply the directivity multiplied by the antenna efficiency. Gain is also closely related to the antenna pattern; for example, the combination of a narrower main lobe and a smaller side lobe translates into a higher gain. The unit of measure for the gain is dBd if the half-wavelength dipole is treated as the object of reference, and dBi if the reference is an ideal point source. The gain for an ideal half-wavelength dipole is 2.15dBi.

v. **Polarization**

The antenna polarization describes the time-varying direction and relative magnitude of the electric field vector. If the vector of the electric field as a function of time is directed along a line, it is called linear polarization. If it is directed along a circular path, it is called circular polarization.

vi. **Efficiency**

The ratio of the radiated power of an antenna to the input power is called antenna efficiency. An efficiency greater than 40% is considered good for an antenna operating synchronously at multiple frequency bands.

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2. Introduction to characteristics of Molex antennas

The product description section in AS documents provides an application scenario with the operating frequency, dimension, material, placement location, mounting method (cable, SMT, etc.), matching circuit and other relevant information.

It also describes the overall performance of the antennas in free space, including antenna operating frequency, return loss, maximum gain, average efficiency, polarization and impedance. Customers can use this information to make a preliminary judgment about whether a certain antenna meets their requirements.

Let’s use **AS 1461530100** to demonstrate how users can use Molex AS documents to design their antenna system for the best performance.

In this AS document, Figure 1.1 shows the antenna on a 1.50mm thick PC/ABS board that simulates a free space environment. The return loss is measured using VNA E5071C. The efficiency, gain and antenna pattern are measured using an over-the-air (OTA) chamber (Figure 1.2).

Figures 2.1 and 2.2 shows return losses. The x-axis indicates the antenna frequency and the y-axis indicates the corresponding return loss. For this antenna, both are below -10dB. Smaller return loss indicates better impedance matching.

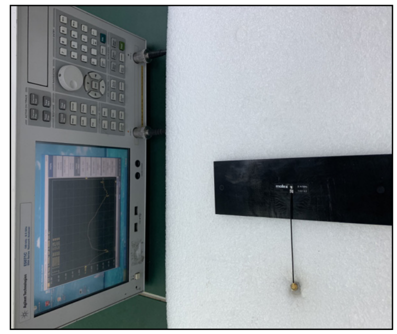

Figure 1.1

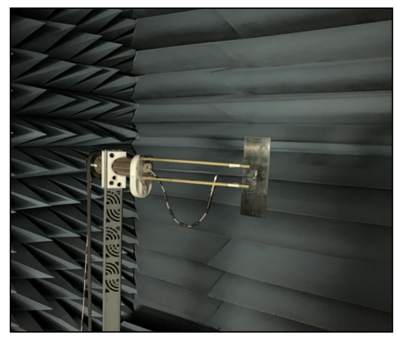

Figure 1.2

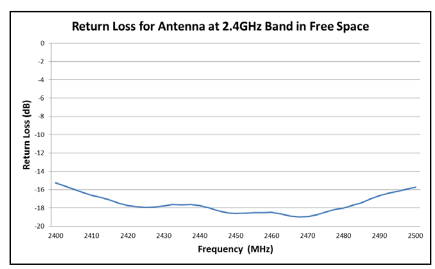

Figure 2.1

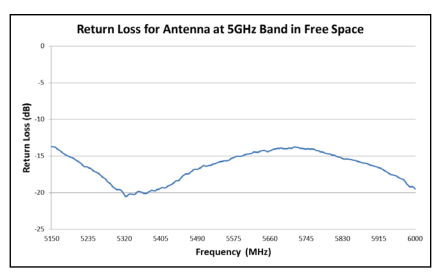

Figure 2.2

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Figures 3.1 and 3.2 show antenna efficiencies corresponding to the return losses in Figures 2.1 and 2.2, respectively. The x-axis indicates antenna frequency and the y-axis indicates efficiency. In both figures, the efficiency is higher than 60%. Higher antenna efficiency means lower losses and better energy radiation and antenna performance.

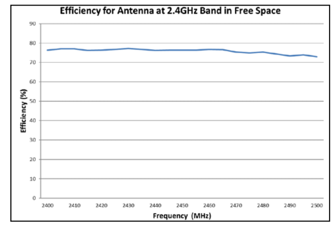

Figure 3.1

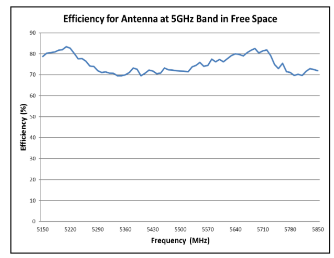

Figure 3.2

Figures 4.1 and 4.2 show the 2D antenna radiation patterns of the antenna at a specified frequency. The x, y and z axis are defined relative to the position of the antenna during testing. The portion of the figure labeled XY-2450MHz depicts the far-field radiation pattern in the XY plane. 0, 30, 60 … 330 refers to the angles at which the antenna rotates in one revolution, and -20, -15, -10, -5, 0 and 5 denotes the scale for the gain. The blue curve shows the gain pattern. The farther a point on the curve is from the center, the higher the gain at that angle. The round curve indicates good omni-directional directivity. Similarly, YZ and XZ plane diagrams can be read.

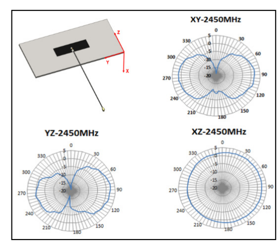

Figure 4.1

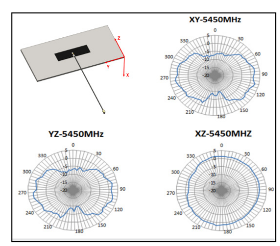

Figure 4.2

Figures 5.1 and 5.2 show the 3D patterns of the antenna. The x, y and z axis are defined relative to the position of the antenna during testing. The shape of the radiation pattern indicates the intensity of antenna radiation. A darker color indicates more intense radiation.

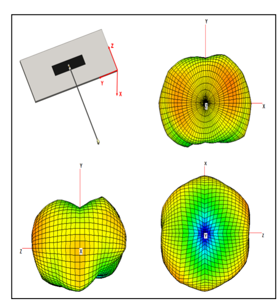

Figure 5.1

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3. Comparison of antenna performance by Application Scenario

The antenna performance described above is based on free space testing, which does not take into consideration the impact of the surrounding environment on antenna performance. Antennas are sensitive to the surrounding environment, especially to metal structures and PCB components. Molex AS documents also include performance comparisons for different environments where an antenna might be deployed.

Scenario 1: Metal grounding is parallel to the main radiating surface of the antenna

In Figure 6, a 90*90mm^2 metal sheet is used to simulate the surrounding environment of the antenna. Antenna performance comparison is measured with various gaps between the antenna and the metal.

Figures 7.1 and 7.2 show the return loss for the antenna for two frequency ranges. Figures 7.3 and 7.4 show efficiencies for the antenna. When the antenna is closer to the metal plane, the return loss reduces and the efficiency degrades compared to free space efficiency. When the gap is 15.00mm, the return loss is less than -6dB and the efficiency is more than 45%. Based on the figures, users can determine the minimum gap that would achieve the desired performance.

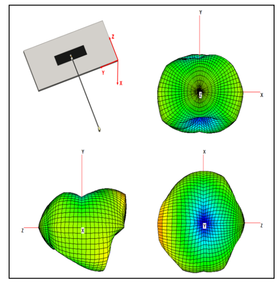

Figure 5.2

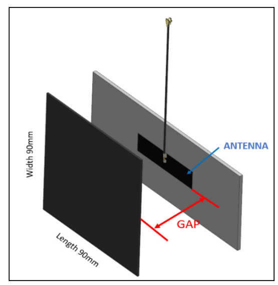

Figure 6.0

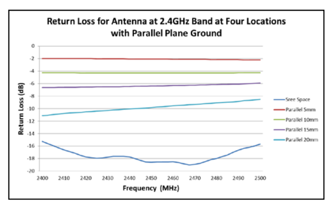

Figure 7.1

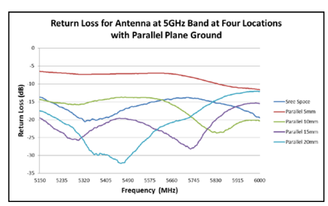

Figure 7.2

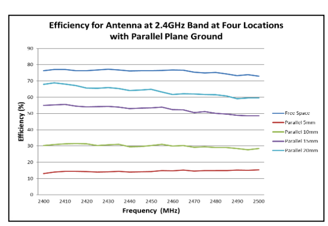

Figure 7.3

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Scenario 2: Metal grounding is vertical to the main radiating surface of the antenna

In Figure 8, a 90*90mm^2 metal sheet is used to simulate the surrounding environment of the antenna. Antenna performance comparison is measured with various gaps between the antenna and the metal.

Figures 9.1 and 9.2 show return losses for the antenna, while Figures 9.3 and 9.4 show efficiencies for the antenna. When the antenna is closer to the metal plane, the return loss reduces and the efficiency degrades from free space efficiency. When the gap is 5.00mm, the return loss is less than -6dB and the efficiency is more than 45%. Based on the figures, users can determine the minimum gap that would achieve the desired performance levels.

Scenario 3: Metal grounding is parallel to one side of the main radiating surface of the antenna

In Figure 10, a 90*90mm2 metal sheet is used to simulate the surrounding environment of the antenna. Antenna performance comparison is measured with various gaps between the antenna and the metal.

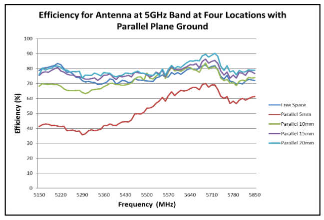

Figure 7.4

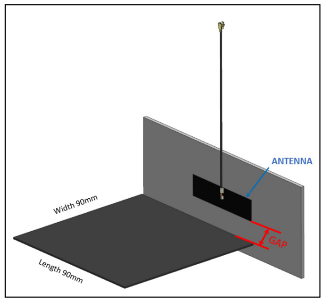

Figure 8.0

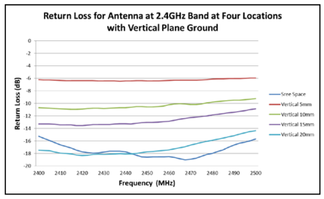

Figure 9.1

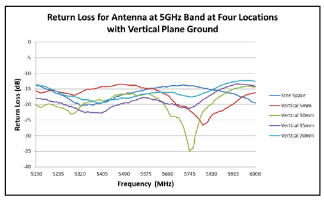

Figure 9.2

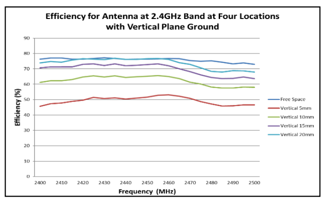

Figure 9.3

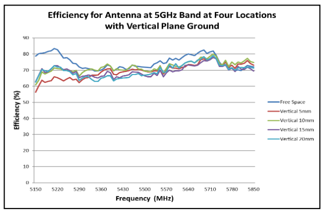

Figure 9.4

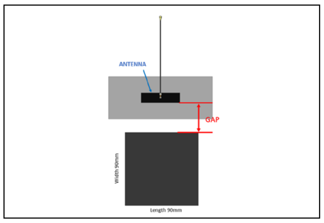

Figure 10

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Figures 11.1 and 11.2 show return losses for the antenna while Figures 11.3 and 11.4 show efficiencies of the antenna. When the antenna is closer to the metal plane, the return loss reduces and the efficiency degrades from free space efficiency. When the gap is 5.00mm, the return loss is less than -6dB and the efficiency is more than 45%. Based on the figures, users can determine the minimum gap that would achieve the desired performance levels.

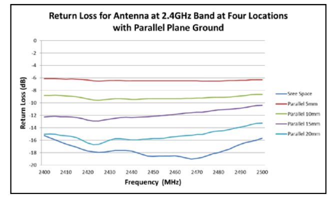

Figure 11.1

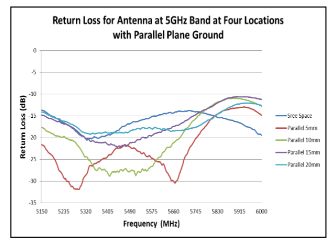

Figure 11.2

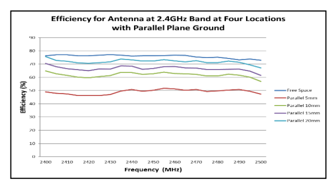

Figure 11.3

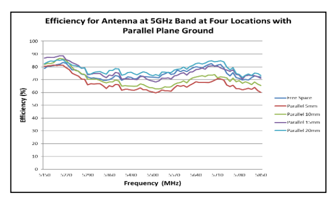

Figure 11.4

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