Influence of Coupling between Probe and Antenna on Planar Near-field Measurement

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Abstract: In this paper, the influence of coupling between antenna and probe is discussed in antenna planar near-field measurement system. Using a standard gain horn with frequency 26.5GHz-40GHz as a AUT (antenna under test), amplitude and phase of sampling points in scan planes with measure distance 46mm and 245mm respectively is measured and showed in 3D Figure with matlab software. When the measurement distance is very short, the effect of coupling can't be ignored. After transformed using algorithm, a big error between the result of near-field measurement and antenna pattern in far field is found in closer distance. While in farther distance, the result of near-field measurement is accord with the antenna pattern result in far field because of few coupling affection.

1. Introduction

Antenna as a kind of transmitting and receiving signals equipment, widely used in many field such as radio astronomy, space exploration, rockets, radar, guidance, remote sensing and communications and so on. The radiation performance of a complex system depends on antenna radiation performance. Therefore antenna measurement is very important for estimating radiation characteristics of system. There are two methods in measuring antenna performance which are far field test method and near field test method. Using far field measurement, the distance between AUT (antenna under test) and the standard antenna is far enough that must meet the far field condition. As for a high frequency antenna with a big size, the distance for far field measurement is becoming very far. Attenuation of signal in space during transmission is frustrating to accurate antenna measurement because of causing the weak signal. In order to solve the problem, a near-field antenna measurement technology is gradually concerned and widely adopted by people [1].

Near field antenna measurement [2] is a way that using a probe scan and collect amplitude and phase information on a scanning surface in the near-field area of AUT, and then restore radiation pattern of AUT applying the FFT algorithm according to the theory of plane wave expansion. It is an indirect measurement method, which is affected by many factors. Measurement distance is one of the important factors. If the distance between AUT and the probe is too close, serious coupling effects can make a wrong result. Far distance scanning brings low efficiency. Generally speaking, the scope of measuring distance is 1-10 wavelengths. Choosing a suiTable distance for antenna measurement depends on the size of AUT, scanning range of scanner, type of probes and dynamic range of signal and so on. In this paper, the influence of coupling between probe and AUT on planar near-field measurement is discussed during experiments that can help to find a good way to choose a suiTable distance.

2. Planar Near-field Antenna Measurement System

Planar near-field antenna measurement system is shown in Figure 1. The system is composed of a vector network analyzer, an antenna scanner, scanning controller, antenna near-field scanning test software, AUT and scanning probe. The vector network analyzer is connected with AUT and probe. It injects signal to antenna feed port and at the same time receives signal from scanning probe in the process of measurement. The test scanner is used to scan following the desired trajectory. The scanning controller is used to control the scanner. The vector network analyzer and antenna scanner are controlled by the measurement software which can transform near-field information into direction pattern.

The scanning probe is fixed on the two-dimensional scanner frame which is installed on an optical platform. An AUT is fixed on the transmitting antenna holder. Test distance between the AUT and the scanning probe is adjusted through the guide rail on the optical platform. The model of scanning probe is 28EWGK with working frequency range 26.5GHz～40GHz. Model of the standard gain horn antenna is LB-28-25-C2-KF with the same working frequency range as the probe.

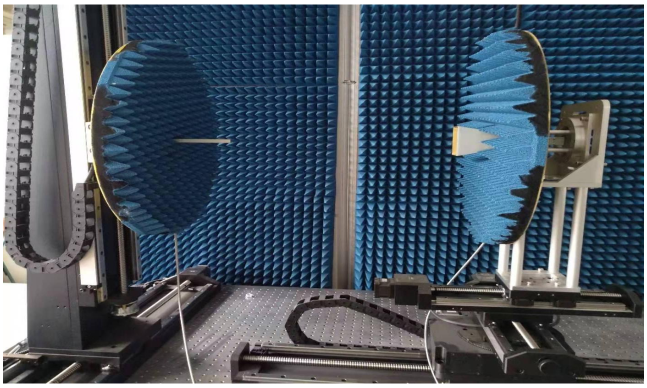


Figure 1: Planar near field antenna measurement system.

2.1. Choice of a SuiTable Measurement Distance

The radiation characteristics changes gradually with the increase of propagation distance when the electromagnetic wave is emitted from antenna and then transmits in space .The radiation regions can be divided into three areas. The first one is reactive region and its outside boundary is about a wavelength away. In the region, energy is inversely proportional to the high power of the distance, and decreases rapidly with the increase of the distance from the antenna. The adjacent region is radiation near field region that is also called Fresnel region. In the region, the angular distribution of the field is relevant to distance, amplitude and phase of electromagnetic wave emitted from antenna are all functions of distance. In the process of near-field antenna measurement, amplitude and phase of electromagnetic wave is collected in the region. The outermost zone is the far radiation field, which is also known as the Fraunhofer region. The angular distribution of the field in this area isn’t relevant to distance. Strictly speaking, the far field area is infinity far away from the transmitting antenna. However, the region is started from a certain distance in which the attenuation of radiation energy is inversely proportional to the square of the distance, and the angular distribution of the field is relatively sTable. The recognized boundary distance of the near and far radiation field is,

$$d = \frac{2D^2}{\lambda} \quad (1)$$

Where D is antenna diameter and λ is working wavelength.

The characteristic comparison between near field and far field is shown in Table 1. The distance between a scanning probe and an AUT in near field antenna measurement should be 3λ<d<2D2/λ. For a standard gain horn antenna with model LB-28-25-C2-KF, its aperture D is 90mm, so the near field boundary range is 11.3mm ～ 1433.6mm.

Table 1: Comparison between near field and far field.

Boundary	Reactive Region	Near Field Region	Fraunhofer Region
Near Boundary	0	3λ	2D2/λ
Far Boundary	3λ	2D2/λ	∞

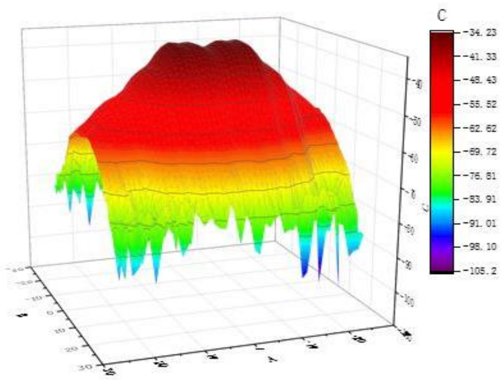
2.2. Results of Planar Near-field Antenna Measurement

We have conducted 2 experiments comparing the effects of distance between probe and AUT in planar near-field antenna measurement. Conditions of the two experiments are shown in Table 2. The size of the scanning plane is determined according to the signal amplitude of the sampling point. Generally, the amplitude value of the sampling point on the side of the scanning plane is at least 40dB lower than that of the central sampling point. The sampling step is less than 1/2 of the test wavelength.

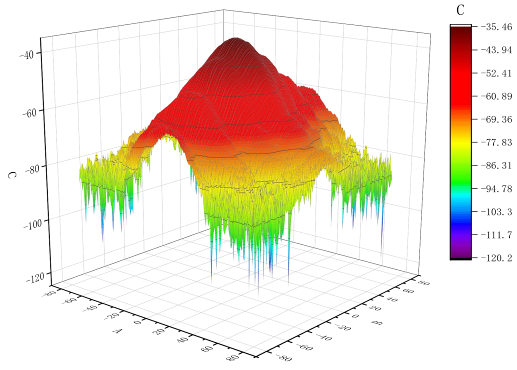
Table 2: Conditions of two experiments.

Serials	Frequency	Distance	Step	Scranning plane	Scranning points
1	26.5GHz-40GHz	46mm	3mm	150mm×150mm	51*51
2	26.5GHz-40GHz	245mm	3mm	450mm×450mm	151*151

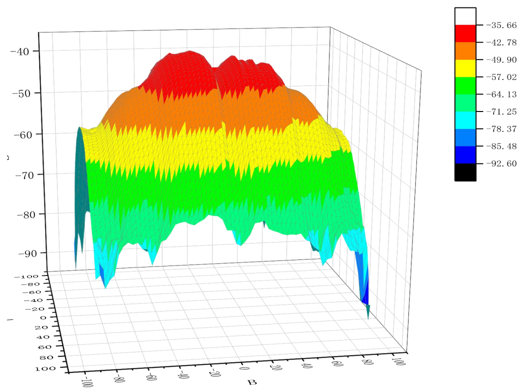
The measurement results of near-field scanning are displayed in three-dimensional by MATLAB program, as shown in below,



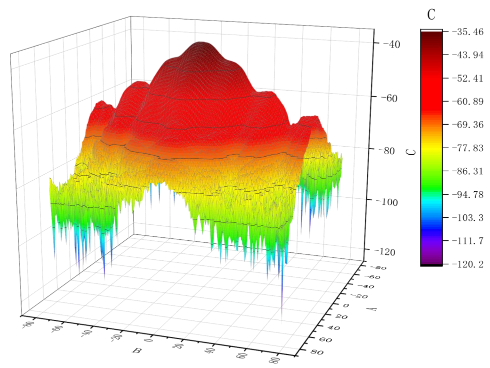
(a) Amplitude distribution cloud map of scanning plane with distance 46mm.



(b) Amplitude distribution cloud map of scanning plane with distance 245mm.
Figure 2: The field intensity amplitude distribution of the near-field scanning surface with frequency 27GHz.



(a) Amplitude distribution cloud map of scanning plane with distance 46mm.

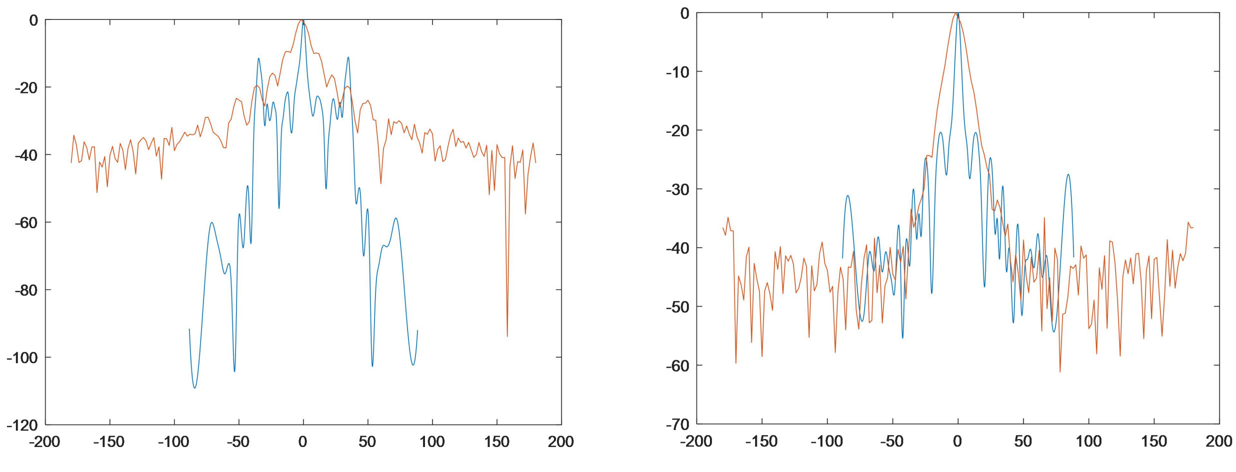


(b) Amplitude distribution cloud map of scanning plane with distance 46mm.
Figure 3: The field intensity amplitude distribution of the near-field scanning surface with frequency 35GHz.

From Figure 2 and 3, we can find the closer between antenna and probe, the more serious coupling influence on signal. The affection leads to that the amplitude of signal in the opposite direction is lower than it on the side. Therefore in Figure 2 and 3, picture a) the amplitude distribution cloud map in 3D (three-dimensional) is concave shape. When transmitting antenna holder on optical platform is controlled to move far away from the probe, the signal measured by a vector network analyzer become bigger and bigger in a certain distance range, and then the signal become small during the distance increase over the range. While in theory, the signal should be decrease all the time with the distance increase. Therefore we can judge that these abnormal phenomena are caused by coupling between antenna and probe. The distance equals to 245mm, which is far enough. There is almost no coupling existence, so amplitude distribution of electric field in near field scanning surface presents peak shape.

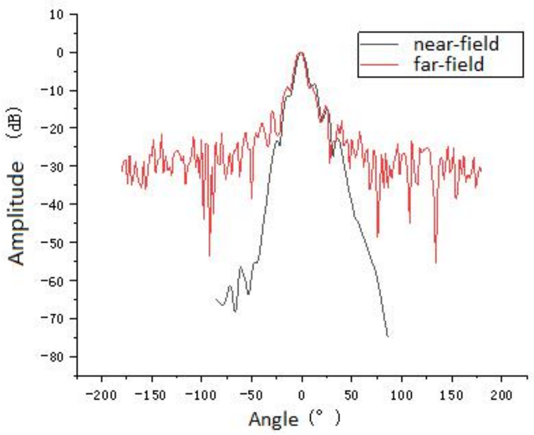
2.3. Processing Results of Near and Far Field Transformation Algorithm

The amplitudes and phases of sampling points in near-field scanning surface are transformed antenna direction pattern using near and far field transformation algorithm. The transformation result is compared with the antenna pattern which is measured in far-field way. As shown in Figure 4 and 5, red curve is an actual data of antenna direction pattern measured in far field way, while the blue curve is the data that obtained by transformation in near-field scanning measurement. In fig.4, the results of near field measurement is big different with it of far field measurement because of the coupling affection between probe and antenna. When the distance becomes 245mm, the coupling affection is very weak that can be ignored. Therefore the results in two measurement ways are very close. Near field measurement result can well reflect the antenna radiation characteristics. So in the process of near field measurement, we need choose a suiTable measurement distance that will help to deduce the coupling affection and improve the accuracy of test. The best way for choosing a suiTable distance is to move antenna far away from probe gradually and at the same time to monitor the S21 from vector network analyzer. When the S21 shows a downward trend with the increase of distance in whole working frequency band, then means the distance is suiTable. Otherwise, a large error is caused in near field measurement.

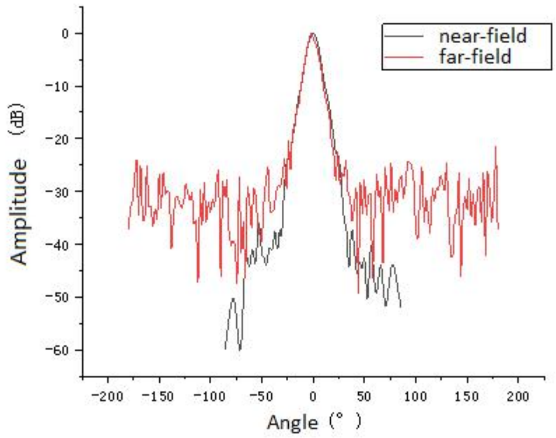


(a) Direction pattern of plane E (b) Direction pattern of plane H

Figure 4: Results comparison of near field measurement and far field measurement in 27GHz frequency at 46mm distance.



(a) Direction pattern of plane E



(b) Direction pattern of plane H

Figure 5: Results comparison of near field measurement and far field measurement in 27GHz frequency at 245mm distance.

3. Conclusions

In the process of planar near-field measurement, coupling between antenna and probe is relative with the measurement distance. The larger the measurement distance, the smaller the coupling between antenna and probe, and the converse is also true. The coupling affection exceeds a certain extent which will affect the accuracy of the measurement results. We can move the AUT far away of probe gradually and then observe the change rule of the S21 signal from the vector network analyzer. According to the S21 parameter variation trend, the suitable distance between antenna and probe in planar near-field measurement can be determined.

References

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