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Tolerance analysis of indoor test system for base station antenna*

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Abstract: This paper analyzes the potential error sources in the indoor test system for base station antenna and proves theoretically that the absorber chamber has an important influence on the measuring results (Voltage Standing Wave Ratio - VSWR, Isolation). According to the data analyses on the measuring results of different antennas in different absorber chambers, some conclusions are drawn on influences from absorber chambers. Finally, a new analysis method is proposed.

Key words: antenna; tolerance; network analyzer; absorber chamber; VSWR; isolation
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0 Introduction

Measurement of antenna parameters is an indispensable step in antenna production. Field measuring is impractical for production process and using gymnasium size absorber chamber will occupy a large space. Normally, the producers use a small size of absorber chamber to test the antenna to check whether it meets the specification or not. Due to environment differences between measuring and practical use, the measuring results are to deviate from their true values. How much is the deviation and where the deviation comes from are tasks of this topic.

1 Error sources in the antenna indoor test system

The antenna indoor test system is composed of the network analyzer[1,2], different kinds of switch and an absorber chamber, which are connected by connecting cables or measuring cables. The antenna under test is placed in the absorber chamber.

Error sources here can be divided into three categories: system errors, random errors and drift errors. Among them, system errors come from the reflectivity and insertion loss of every component in the measuring path; they are predictable and can be removed by calibration except the error from the absorber chamber, which

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will be derived next. Random errors like instrument noise and those resulting from repeatability of switches and connectors are unpredictable. Drift errors are caused by the temperature variation; they can be removed by frequent calibrations.

2 Theoretical analysis of the main sources of system errors

The following diagrams are simplified models for calibration and measurement. Here it is safe for us to equalize the intermediate components (switches, connecting cables, measuring cables) between network analyzer and device under test (calibration standard or antenna) to be a black box with certain transmission coefficient and reflection coefficient[3] indicated as *Te* and *Re*. *Rcal* denotes the reflection coefficient of calibration standard, *Rna* denotes that of network analyzer. *Tdut* and *Rdut* denote the transmission coefficient and reflection coefficient of the antenna respectively. *Rak* represents the reflection coefficient of the absorber chamber.

For one port calibration, the received reflection is composed of Ref_1 and Ref_2. See Fig.1, we can get

$Ref_1 = Re$

$Ref_2 = Te^2 \cdot Rcal$

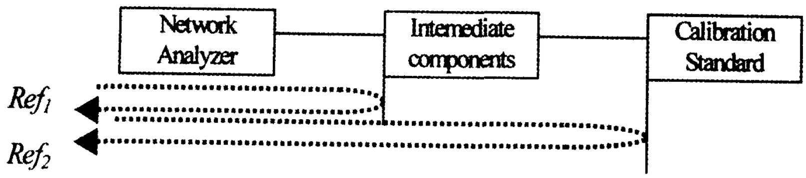

Fig.1 One port calibration

Then the whole reflection for one port calibration Ref_cal is represented as

$$Ref\_cal = Ref_1 + Ref_2 = Re + Te^2 \cdot Rcal$$

When the open calibration standard is applied, it means $Rcal = +1$. When it is the case of the short one, it means $Rcal = -1$. Thus the following two equations hold and *Te* and *Re* can be calculated from them.

$$Ref\_cal\_open = Re + Te^2 \tag{2.1}$$

$$Ref\_cal\_short = Re - Te^2 \tag{2.2}$$

For reflectivity measurement, the received reflection is composed of Ref_1, Ref_2 and Ref_3. See Fig.2,

$Ref_1 = Re$

$Ref_2 = Te^2 \cdot Rdut$

$Ref_3 = Te^2 \cdot Tdut^2 \cdot Rak$

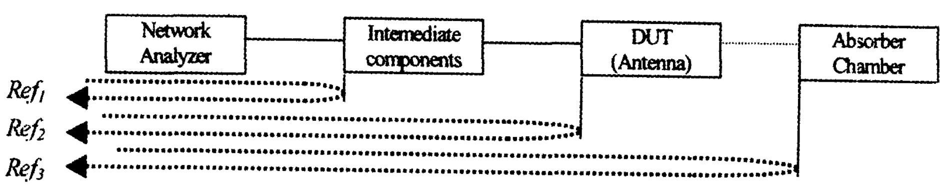

Fig.2 Reflectivity measurement(S11 or S22)

Then the whole reflection *Ref* is as

$$Ref = Ref_1 + Ref_2 + Ref_3 = Re + Te^2(Rdut + Tdut^2 \cdot Rak)$$

After calibration (Te, Re are known) the reflection of measurement Ref_meas is as

$$Ref\_meas = Rdut + Tdut^2 \cdot Rak \tag{2.3}$$

For isolation measurement and calibration, two ports are needed. Here no more than one time reflection is considered. See Fig. 3 and Fig. 4.

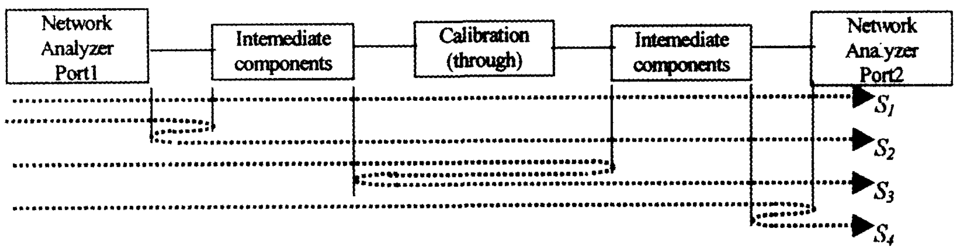

Fig. 3 Two_port calibration

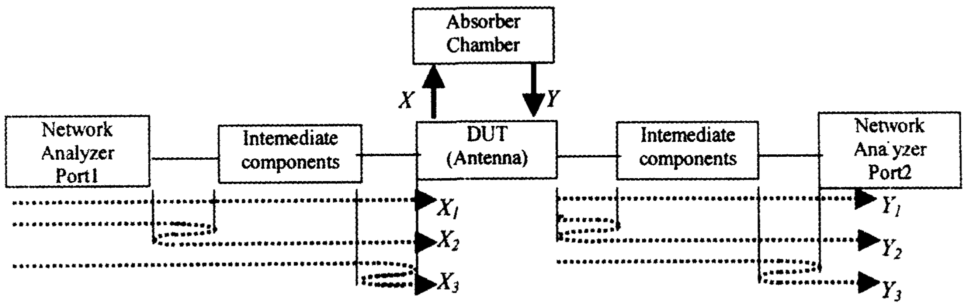

Fig. 4 Isolation measurement(S21 or S12)

For through calibration (assuming no reflection and no return loss for the through standard device)

$$\begin{aligned} S21\_cal &= S_1 + S_2 + S_3 + S_4 \\ &= Te^2 + Re \cdot Rna \cdot Te^2 + Te^2 \cdot Re^2 + Te^2 \cdot Re \cdot Rna \\ &= Te^2 \cdot (1 + 2 \cdot Re \cdot Rna + Re^2) \end{aligned}$$

Since we have known Te and Re from one port calibration, Rna becomes definite now.

For isolation($S21$) measurement, here X means the signal sent out by one antenna (e.g. $+45°$) and Y means the signal received by another one(e.g. $-45°$).

$$X = X_1 + X_2 + X_3 = Tdut \cdot Te(1 + Re \cdot Rna + S11 \cdot Re)$$

$$Y = X \cdot (Rak + S21)$$

The signal received at port 2 is denoted as $S21\_rec$, composed of Y_1, Y_2 and Y_3.

$$\begin{aligned} S21\_rec &= Y_1 + Y_2 + Y_3 = Y \cdot Te \cdot (1 + Re \cdot S22 + Re \cdot Rna) \\ &= (S21 + Rak) \cdot Tdut \cdot Te^2 \cdot (1 + Re \cdot Rna + S11 \cdot Re) \cdot (1 + Re \cdot S22 + Re \cdot Rna) \end{aligned}$$

Here $S11$ and $S22$ mean reflectivity coefficients from the two ports of antenna respectively, which can be approximated as Ref_meas from the VSWR measurement above. After calibration, we get the measurement value of $S21\_meas$,

$$S21\_meas = (S21 + Rak) \cdot Tdut \tag{2.4}$$

From (2.1) and (2.2), we can know that system errors (Te and Re) can be corrected by calibration. Assuming that $Tdut$ equals 1, the measurement values are the sum of the true values and the reflection from the absorber chamber, as in (2.3) and (2.4). Through the above derivatives, it is clear that the absorber chamber is a main influence on the measuring results after calibration. However the reflection from the absorber chamber is not constant; it depends not only on the size of the absorber chamber but also on the frequency and power of incident waves. Therefore the radiation pattern of the antenna itself will also be an influential factor on the measuring results.

3 Test results

The absorber is made from specially treated low-density polyurethane foam, shaped as conventional pyramids. The absorber chamber is one in which absorber pieces are installed. Measuring the S parameters of an antenna outdoor with no reflections around and those values in an absorber chamber respectively, we define the reflections from the absorber chamber as the corresponding differences between measurement results in two cases, which is derived in section 2. Some random errors such as those from temperature, moisture, operators, and equipments, etc. are excluded.

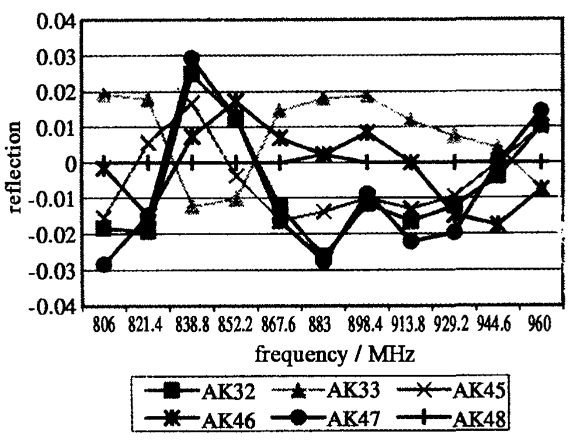

Fig.5 Reflections from different absorber chambers

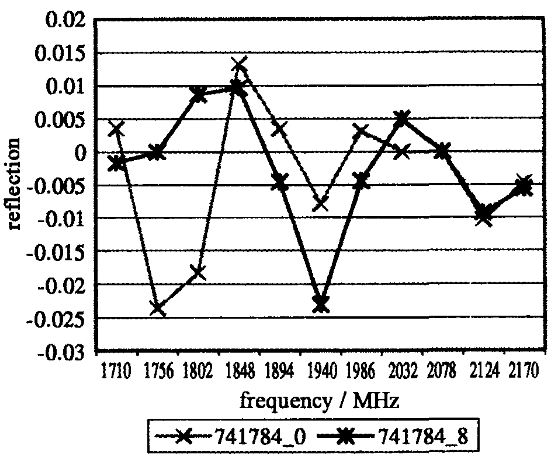

Fig.6 Reflections from absorber chamber AK32 in measuring $S11$ of antenna 741784 with 0° and 8° downtilt respectively

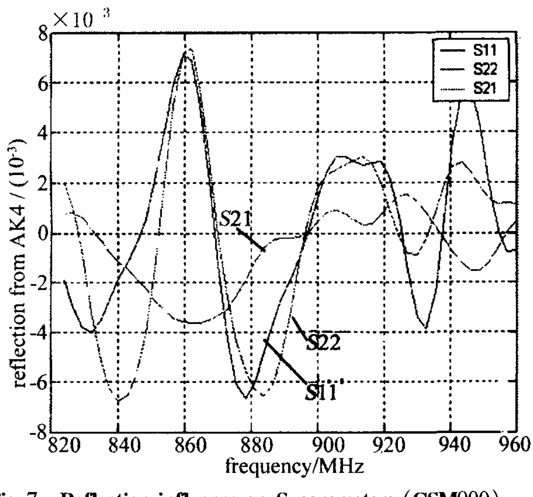

Fig.7 Reflection influence on S parameters (GSM900)

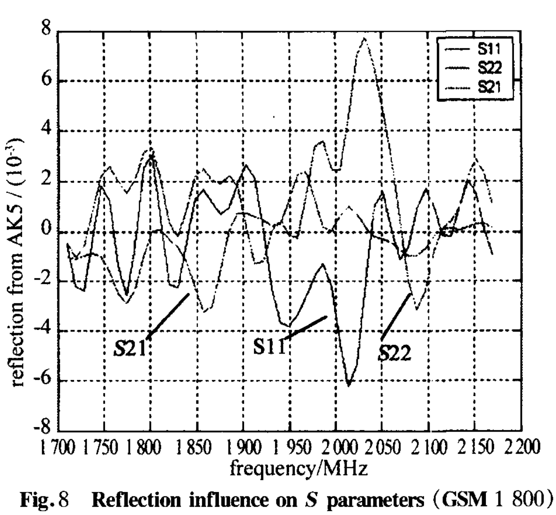

Fig.8 Reflection influence on S parameters (GSM 1 800)

Reflections from several absorber chambers in measuring $S11$ of antenna 739632[4] are shown in Fig. 5, in which AK32, …, AK48 represent different absorber chambers. Reflections of the same antenna with different down-tilt in the same absorber chamber are shown in Fig. 6.

For different S parameters, by performing FFT on reflections from the absorber chamber, the waveforms composed of the first ten important harmonics are shown in Fig. 7 and Fig. 8.

4 Conclusions and further work

At least, the following three conclusions can be drawn from the test results. (1) For the same antenna, measuring results are different in different absorber chambers, because there are always nuance among different absorber chambers although they are made based on the same specification. (2) One absorber chamber has different reflection influences on antennas with different radiation patterns; even it is the case of same antenna with different down-tilt. That is, reflection from the absorber chamber is relevant to the incident waves. (3) One absorber chamber has different influences on different S parameters of the same antenna because of the different reflection paths. However, all measuring results meet the specification of the corresponding antenna.

The above analysis is based on the scalar data or the amplitude alone; the phase differences are neglected, but phase differences are obvious. Thus in order to get accurate and quantitative results, it is a proposal to carry-out analyses using vector differences.

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基站天线室内测量系统的误差分析

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摘　要:分析了基站天线室内测量系统的误差源,理论证明微波暗室是影响测量结果(电压驻波比,隔离度)的重要因素.根据对测试结果的分析,得出了关于微波暗室对天线性能参数影响的几点结论.最后指出了所用方法的不足之处,提出了新的分析方法.

关键词:基站天线;误差;网络分析仪;微波暗室;电压驻波比;隔离度

(**Edited by**: ZHOU Jian-lan)

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