8 Error Module of Vector Network Analyzer and Calibrating Theory

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Abstract It gives the 8-error module of S-parameter measurement of vector network analyzer and investigates the calibrating theory. The calibrating method of network analyzer is designed by making use of a set of devices with standard parameters by the theory. The simplified calibrating calculation is got.

Key words Network analyzer S-parameters Calibrating 8-error module

矢量网络分析仪8项误差模型和校正理论

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摘要 对矢量网络分析仪S-参量误差模型的建立及校正理论进行了研究。给出了八项误差模型建立的基本理论。并根据此理论设计了一套利用标准元件对矢量网络分析仪S-参量测量进行校正的方法。简化了校正计算。

关键词 网络分析仪 S-参量 校 正 8项误差模型

1 Introduction

When we measure the 2-port network parameters of radio frequency, we usually use the vector network analyzer. The analyzer has an RF signal source that produces an incident signal, which is used as a stimulus to the devices under test. The signal will be transmitted to the DUTs. The output signal will be transmitted to the network analyzer. See fig. 1[1].

Referred to Fig. 1, the forward transmission signal (routed to input B) and the reflected signal (input A) are measured by comparing with the incident signal. The reversed transmission signal (routed to input A) and the reflected signal (input B) are also measured by comparing with the incident signal. The analyzer couples off a small portion of the incident signal and uses it as a reference signal (routed to input R). Sweeping the source frequencies, the analyzer measures and displays the response of the testing device. The S-parameters need to be in ratios. The forward transmission S_{21} is B/R. The reverse transmission S_{12} is A/R. The reflection S_{11} of port 1 is A/R. And the reflection S_{22} of port is B/R.

We need the ratios of the two signals from the two ports of DUTs. One is input, and the other is output. But the ratios will be different from the values measured by network analyzer. Because the standard input and output tie-ins are type N negative tie-ins, we must use the cables for DUTs to connect them to the network analyzer. Further more the DUTs usually have many different input and output tie-ins. We can only connect the DUTs to the measurement system through certain transitions. There is some reflection at the tie-in transition, and there is also some wastage in the cables. The values measured by network analyzer are the S-parameters of the DUTs and the reflection and wastage of transmission system. So there are some errors in the measurement system. We must proofread the measurement system before we measure the S-parameters of DUTs.

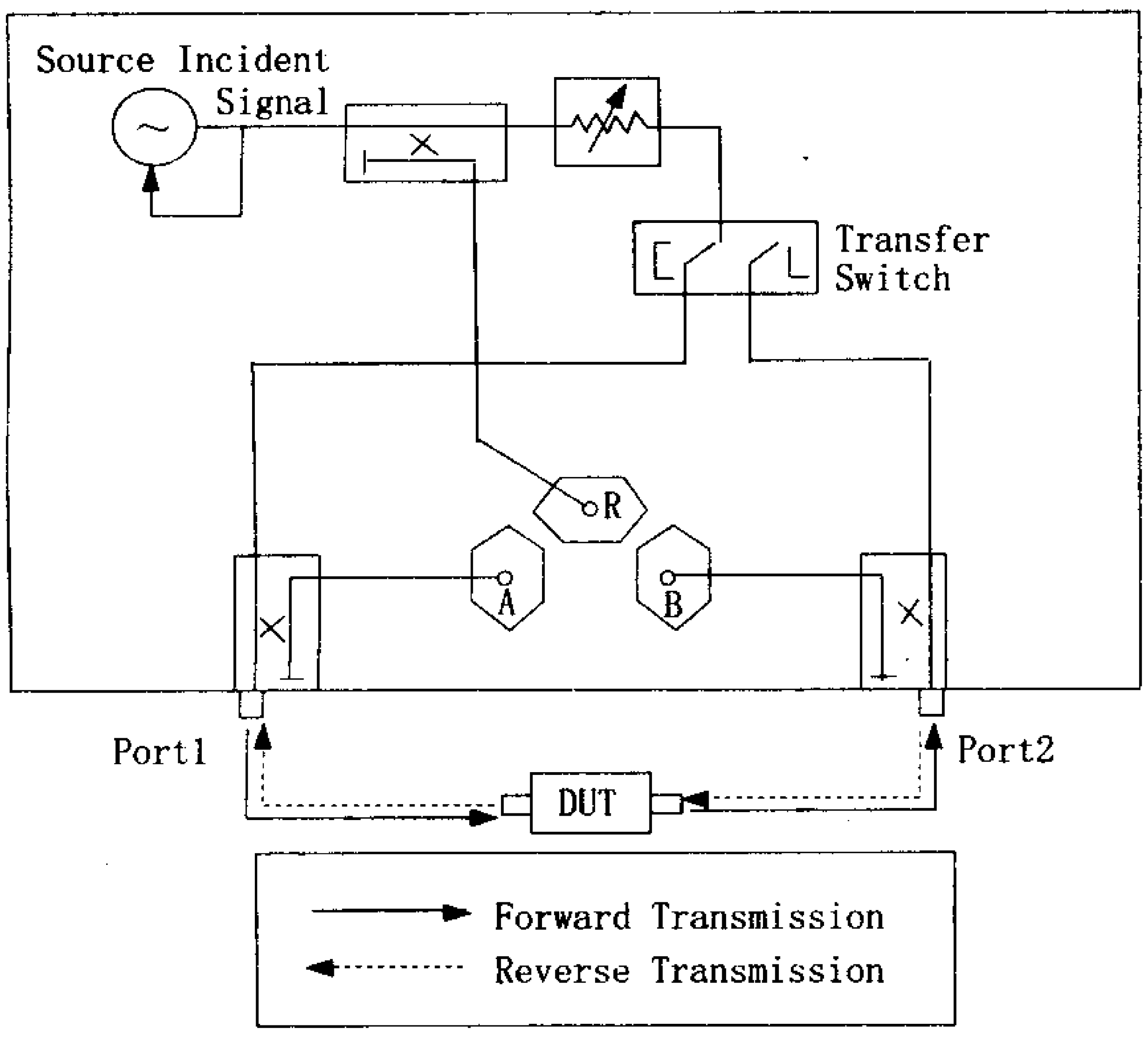

Fig. 1

2 8-Error Modeling

In the actual measurement system, we can look the parts out of network analyzer as three two port networks. The network A is the transmission system from first port of analyzer to first port of DUT. The network X is the device under test (DUT). The network B is the transmission system from second port of DUT to second port of the analyzer. See Fig. 2

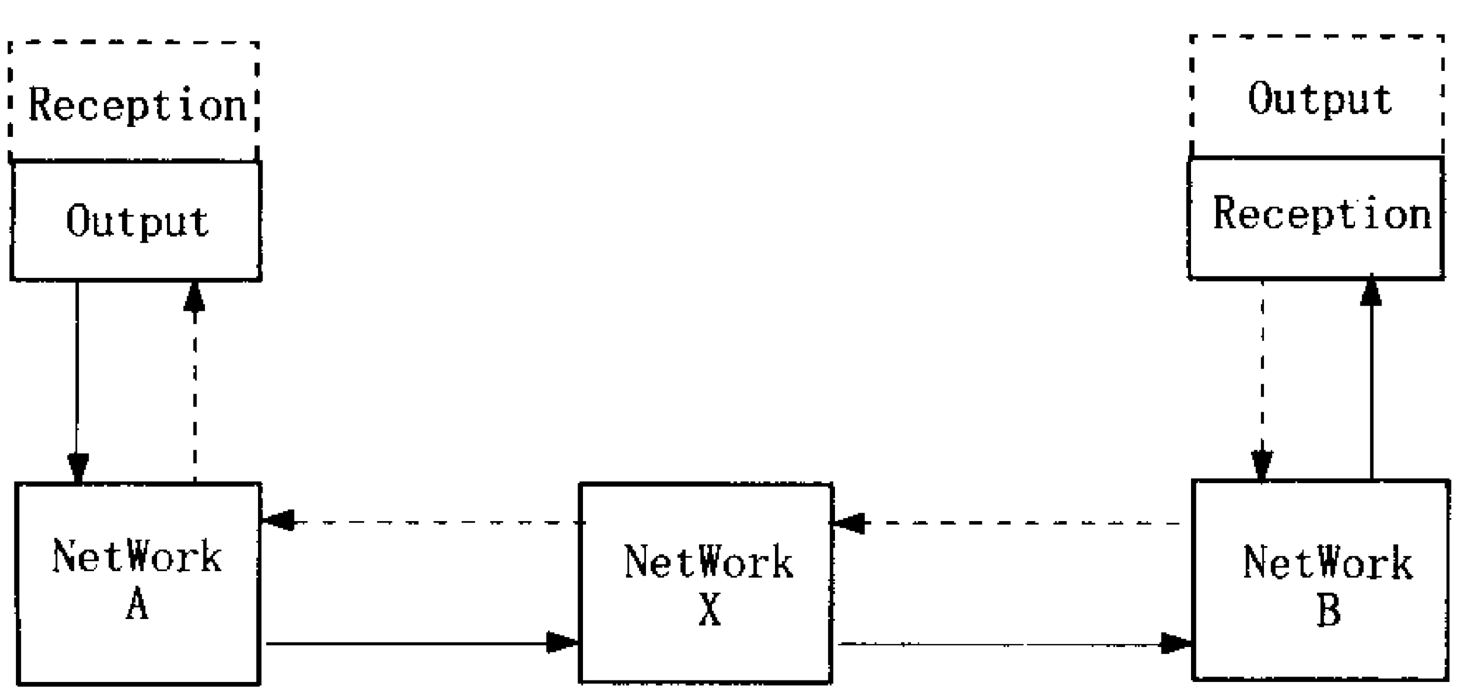

Fig. 2

We can use the signal diagram to express the two port networks. The models of signal figures of forward and reverse transmission system are showed as Fig. 3[2].

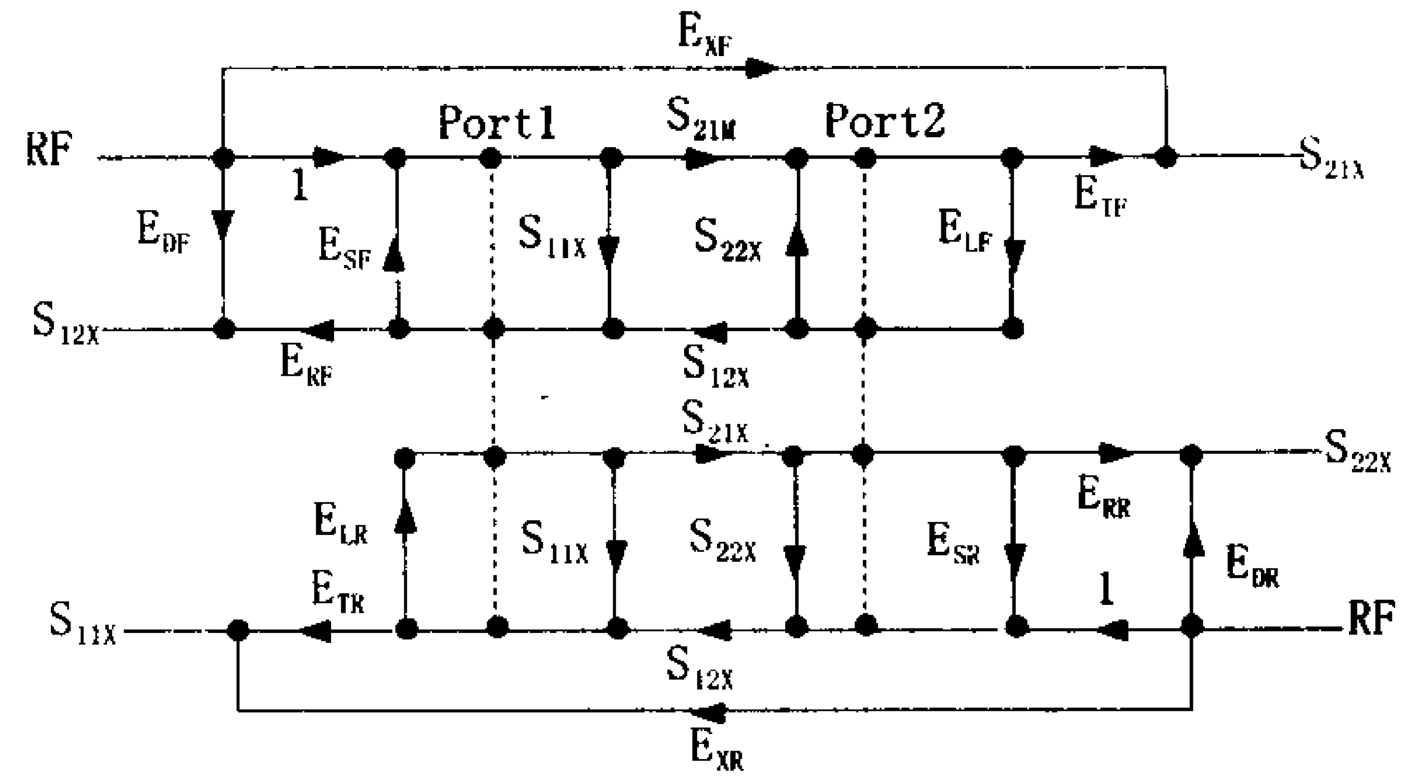

Fig. 3

This is the traditional 12 error model of S-parameter measurement using network analyzer. But in fact, we can see E_{DF}, E_{SF}, E_{RF}, E_{LR} and E_{TR} as the S-parameters of network A, and see E_{DR}, E_{SR}, E_{RR}, E_{TF} and E_{LF} as the S-parameters of network B. The S-parameters are ratios of outputs to inputs. Such as network A, whether the RF signals are in forward or reverse, the S-parameters of network A are aptotic. So we consider that E_{SF} is equal to E_{LR} and E_{RF} is equal to E_{TR}. The network B is the same to the network A. In this case, E_{LF} is equal to E_{SR} and E_{TF} is equal to E_{RR}. So we can predigest the 12 error model to 8 error model. The signal diagram of forward and reversed transmission system are showed as Fig. 4.

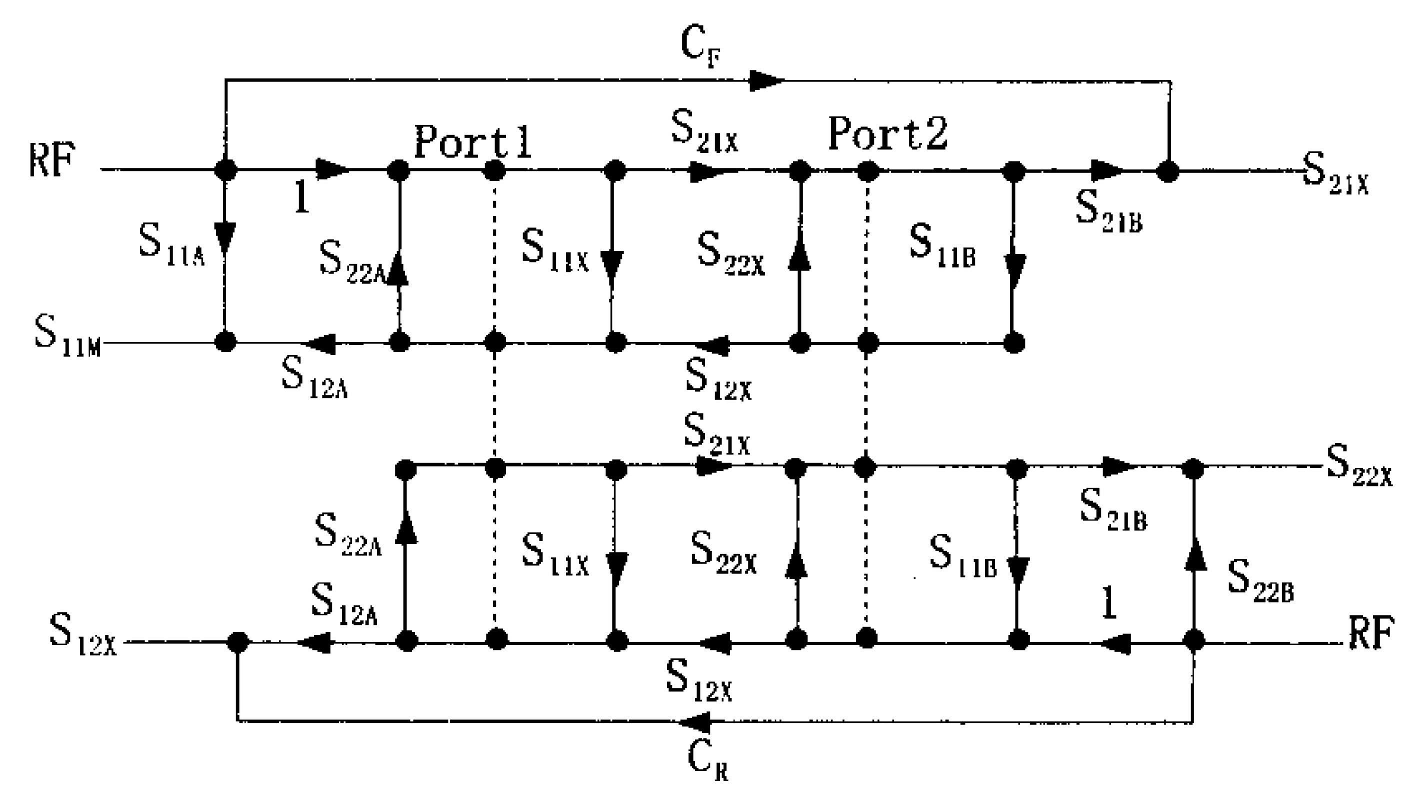

Fig. 4

According to Fig. 4, the models we got have 8 errors. They are S_{11A}, S_{22A}, S_{12A}, S_{11B}, S_{22B}, S_{21B} and C_F, C_R.

3 The Analysis and Elimination of Errors

According to Fig. 4, we can get the S-parameter measurement by network analyzer using Mason Law:

$$S_{21M} = C_F + \frac{S_{21B}S_{21X}}{D}$$

$$S_{12M} = C_R + \frac{S_{12A}S_{12X}}{D}$$

$$S_{11M}=S_{11A}+\frac{S_{12A}S_{11X}(1-S_{11B}S_{22X})+S_{12A}S_{11B}S_{21X}S_{12X}}{D}$$

$$S_{22M}=S_{22B}+\frac{S_{21B}S_{22X}(1-S_{22A}S_{11X})+S_{22A}S_{21B}S_{21X}S_{12X}}{D}$$

$$D=1-S_{22A}S_{11X}-S_{11B}S_{22X}-S_{22A}S_{11B}S_{21X}S_{12X}-S_{22A}S_{11B}S_{11X}S_{22X}$$

Based on equations above, we can get the actual S-parameters of DUTs:

$$S_{11X}=\frac{\left[\frac{S_{11M}-S_{11A}}{S_{12A}}\left(1+\frac{S_{22M}-S_{22B}}{S_{21B}}S_{11B}\right)-\left(\frac{S_{21M}-C_F}{S_{21B}}\right)\left(\frac{S_{12M}-C_R}{S_{12A}}\right)S_{11B}\right]}{B}$$

$$S_{22X}=\frac{\left[\frac{S_{22M}-S_{22B}}{S_{21B}}\left(1+\frac{S_{11M}-S_{11A}}{S_{12A}}S_{22A}\right)-\left(\frac{S_{21M}-C_F}{S_{21B}}\right)\left(\frac{S_{12M}-C_R}{S_{12A}}\right)S_{22A}\right]}{B}$$

$$S_{21X}=\frac{\left[\frac{S_{12M}-C_R}{S_{12A}}\right]}{B}$$

$$S_{12X}=\frac{\left[\frac{S_{21M}-C_F}{S_{21B}}\right]}{B}$$

$$B=\left(1+\frac{S_{11M}-S_{11A}}{S_{12A}}S_{22A}\right)\left(1+\frac{S_{22M}-S_{22B}}{S_{21B}}S_{11B}\right)-\left(\frac{S_{21M}-C_F}{S_{21B}}\right)\left(\frac{S_{12M}-C_R}{S_{12A}}\right)S_{11B}S_{22A}$$

We can eliminate the errors in the network A and B with a set of devices with standard parameters.

(1) Two ports connect through

$(S_{11X}=S_{22X}=0 \quad S_{21X}=S_{12X}=1)$

$$M_1=S_{21M}=C_F+\frac{S_{21B}}{1-S_{22A}S_{11B}}$$

$$M_2=S_{12M}=C_R+\frac{S_{12A}}{1-S_{22A}S_{11B}}$$

$$M_3=S_{11M}=S_{11A}+\frac{S_{12A}S_{11B}}{1-S_{22A}S_{11B}}$$

$$M_4=S_{22M}=S_{22B}+\frac{S_{22A}S_{21B}}{1-S_{22A}S_{11B}}$$

(2) Two ports connect to the Loads

$(S_{11X}=S_{22X}=S_{21X}=S_{12X}=0)$

$M_5=S_{21M}=C_F$

$M_6=S_{12M}=C_R$

$M_7=S_{11M}=S_{11A}$

$M_8=S_{22M}=S_{22B}$

According to the 8 equations, we can get the 8 errors:

$C_F=M_5$

$C_R=M_6$

$S_{11A}=M_7$

$S_{22B}=M_8$

$$S_{22A}=\frac{M_4-M_8}{M_1-M_5}$$

$$S_{11B}=\frac{M_3-M_7}{M_2-M_6}$$

$S_{21B}=(M_1-M_5)(1-S_{22A}S_{11B})$

$S_{12A}=(M_2-M_6)(1-S_{22A}S_{11B})$

4 Conclusion

We consider that the 8 error module of S-parameter measurement using vector network analyzer meet the actual requirements. The S-parameters of a two-port network are changeless. It cannot vary with the direction changes of the stimulating signals. Not only the DUTs but also the transmission network A and B has this character. So we consider that the S-parameters of forward transmission system is equal to the S-parameters of reversed transmission system. And we get 8 error module from 12 error module.

In the vector network analyzer, the S-parameters are complex numbers. We need calibrations in every frequency points for the S-parameter measurement in a frequency span. In one frequency span, we get hundreds of points to measure. In the measurement, there are great deals of complex calculations. Applying the 8 error module to the measurement, we can simplify the calculation of calibration and accelerate the measurement.

Reference

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2 Shixian Tang. Microwave measurement. China: Beijing Institute of Technology, 1991.

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