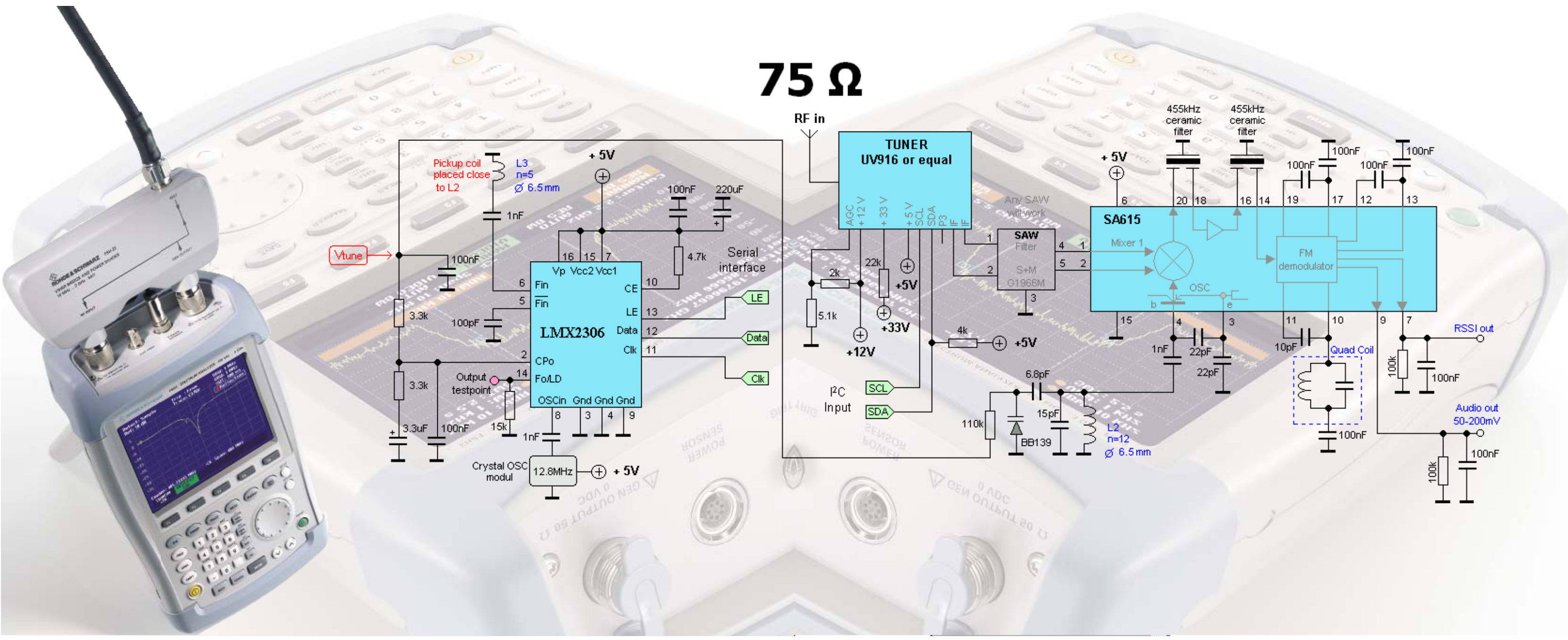

Products: R&S®FSH3-TV TV Analyzer

VSWR Measurement in 75 Ω Systems Using the R&S®FSH3-TV TV Analyzer

Application Note

The voltage standing wave ratio (VSWR) is one of the parameters in RF systems that measures the impedance mismatch. Under ideal conditions, when the load is perfectly matched to the source, the VSWR will be 1. A mismatch in the system causes reflections that will increase the VSWR and lead to losses in transmission. Although most RF components are typically designed and specified with a characteristic impedance of 50 Ω, applications and system components for cable television are designed and specified with a characteristic impedance of 75 Ω. This application note describes the measurement procedure for VSWR measurements in 75 Ω systems using the R&S®FSH3-TV handheld TV analyzer.

ROHDE&SCHWARZ

Subject to change – Ankita Pande 03.2008 – 7BM72_0E

Contents

1 Overview

Voltage standing wave ratio (VSWR) is one of the important RF parameters that characterize a cable TV system or any transmitting system. This document describes how to measure the VSWR in 75 Ω systems using the R&S®FSH3-TV with a 50 Ω impedance at its measurement ports. The basics of VSWR and the correction factor for the measurement are also discussed in the document.

2 Requirements

The measurement described in this application note requires a 50 Ω VSWR bridge. Recommendation: the *R&S®FSH-Z2/Z3 VSWR bridge and power divider*, an *R&S®RAM 50/75 Ω matching pad* and the *R&S®FSH-K2 vector transmission and reflection measurements* option.

3 Basics of VSWR

The VSWR is a figure of merit for the match between a load and a source. Under ideal conditions, when a load is perfectly matched to a source, maximum power available from that source is transferred to the load. There are no reflections, the reflection coefficient is zero and the VSWR is 1. Any value higher than 1 represents a mismatch from the ideal match.

The reflection coefficient ρ can be expressed in terms of the load impedance Z_{load} and the characteristic impedance Z_0 as follows:

$$\rho = (Z_{load} - Z_0) / (Z_{load} + Z_0) \qquad (1)$$

The reflection coefficient can also be expressed in terms of the reflected voltage $U_{reflected}$ to the forward voltage $U_{forward}$ as follows:

$$\rho = U_{reflected} / U_{forward} \qquad (2)$$

The VSWR can then be expressed in terms of the load and characteristic impedances as follows:

$$VSWR = (1 + |\rho|) / (1 - |\rho|) \qquad (3)$$

Under ideal conditions, there are no reflections, the reflection coefficient is $\rho = 0$ and $VSWR = 1$. When the termination is open or short, there will be total reflection, $|\rho| = 1$, and therefore $VSWR = \infty$.

4 Measurement Procedure

A VSWR measurement in a 75 Ω system with a 50 Ω measuring instrument can be performed in the following two ways:

Using a 50 Ω calibration kit (see section 4.1)

Using an R&S®ZCAN 75 Ω calibration kit (see section 4.2).

The 50 Ω calibration kit comes with the R&S®FSH-Z2 VSWR bridge. Both methods require the R&S®RAM resistive 50/75 Ω matching pad. The R&S®RAM is recommended due to its internal diagram, which provides matching in forward as well as in reverse direction (for details, please refer to appendix A.2).

Using a 50 Ω calibration kit requires a correction of the measured value, applying a correction factor to the reading. Using a 75 Ω calibration kit requires no further correction.

4.1 Procedure with 50 Ω Calibration Kit

For reflection measurements the R&S®FSH-Z2 VSWR bridge is screw-connected to the RF input connector and the generator's output of the R&S®FSH3-TV. The test setup must be calibrated before any measurements are made. To perform the calibration, the following steps have to be carried out:

a. Connect the R&S®FSH-Z2 or R&S®FSH-Z3 to the R&S®FSH3-TV (the R&S®FSH-Z2 will be detected automatically if accessory auto detection is set in the setup menu of the instrument).

b. Select Tracking Generator in the MEAS menu.

c. Select VECTOR measurement mode if available in order to achieve higher measurement accuracy (R&S®FSH-K2 vector measurement option is required).

d. Set the desired frequency range.

e. Execute a reflection calibration (MEAS menu).

f. Connect the R&S®RAM matching pad to the test port.

g. Set a trace offset of 11.5 dB in the AMPT menu in order to compensate the attenuation of the R&S®RAM resistive matching pad. Please refer to appendix A.1 for the calculation of this correction factor.

h. Execute the reflection/VSWR measurement.

Note: Connecting a 50 Ω male connector to the 75 Ω female connector of the R&S RAM will damage the 75 Ω female connector.

4.2 Procedure with 75 Ω Calibration Kit

After connecting the R&S®RAM 50/75 Ω matching pad to the VSWR bridge, calibrate the 75 Ω port of the matching pad with the R&S®ZCAN 75 Ω calibration kit. After calibration, connect the load (in our example 220 Ω; see appendix A.1). Now the R&S®FSH3-TV reading will be the same as the calculated reading and corresponds to the actual measured value, without applying the trace offset mentioned in section 4.1. (See Fig. 1.)

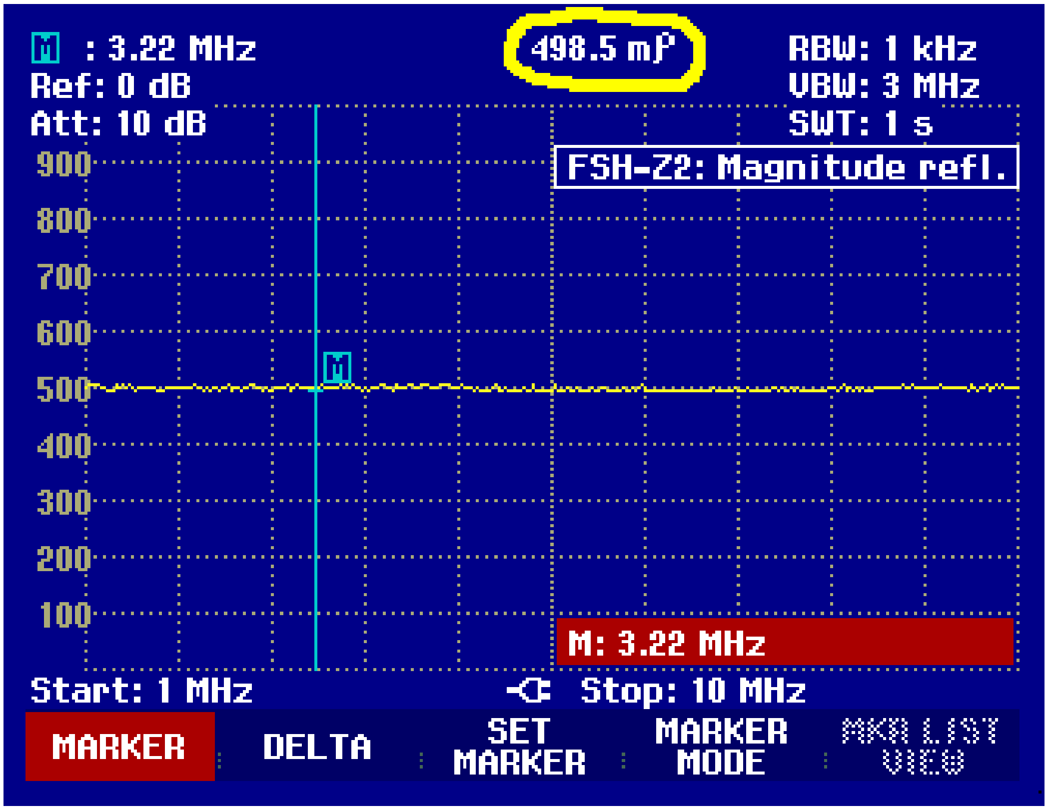

Fig. 1: Reflection coefficient of a 220 Ω load measured using the R&S®FSH3-TV when calibration was performed at the 75 Ω port. The calculated reflection coefficient
ρ_{calc} = (220 Ω − 75 Ω) / (220 Ω + 75 Ω) = 0.49.

5 Smith Chart Measurement

Impedance matching/mismatching can further be seen on the Smith chart that comes with the R&S®FSH-K2 *vector transmission and reflection measurements* option. To see the results for 75 Ω systems, the following steps have to be performed:

a. Select Mode: Vector: Smith Chart.

b. Press Marker button.

c. Select Marker Mode: Impedance: Z_0: 75 Ω.

Step c. is used to set the characteristic impedance for the system to 75 Ω so that the relation in equation 1 will be satisfied.

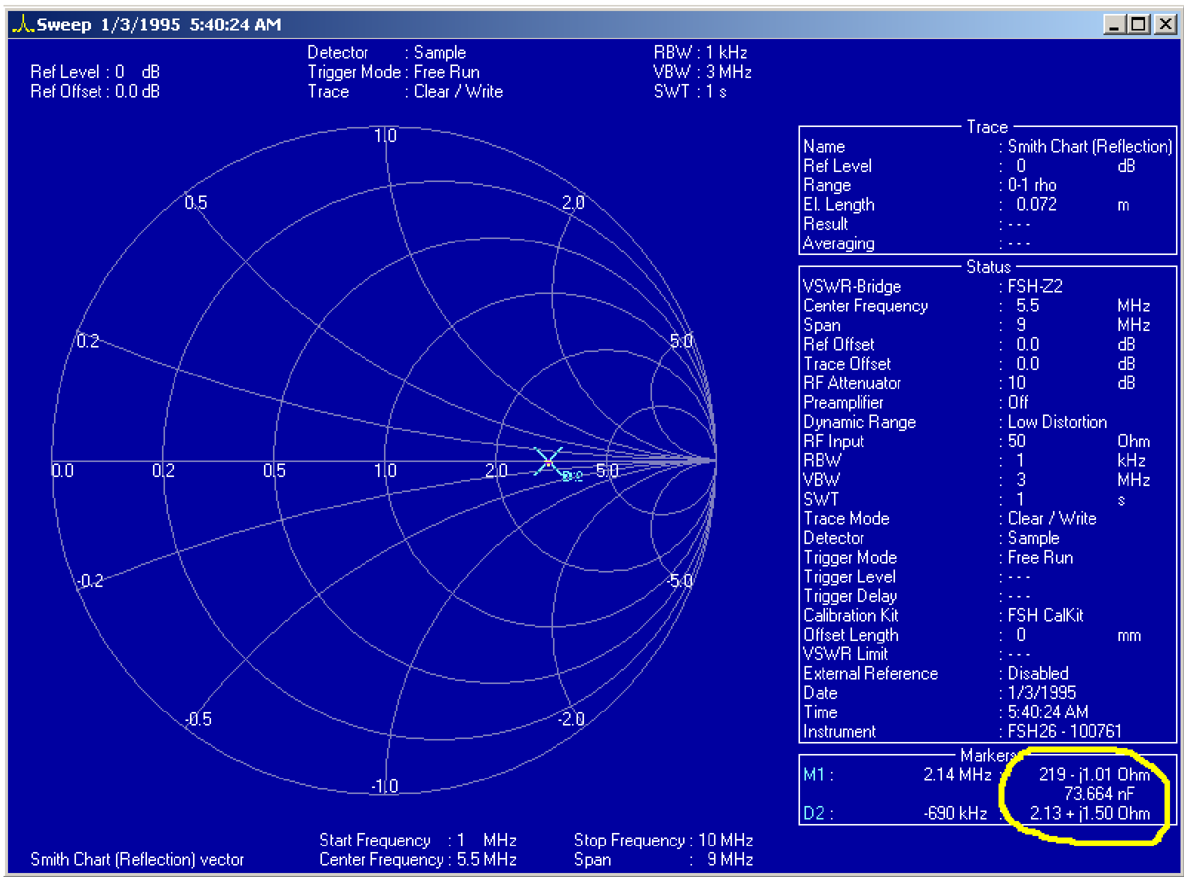

Fig. 2: Smith chart showing the load impedance of 220 Ω measured using the R&S®FSH3-TV

6 Appendix

A.1: Reflection coefficient correction factor TRACE OFFSET
Calibration is performed with 50 Ω calibration kit at P1.

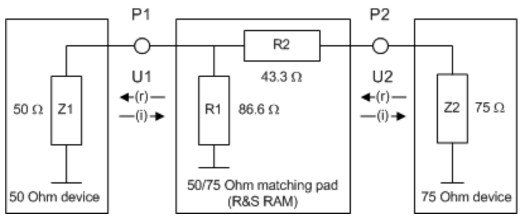

Fig. 3

$$\frac{U_{2(i)}}{U_{1(i)}} = \frac{Z_2}{Z_2 + R_2} \qquad \text{(1a)}$$

$$\frac{U_{1(r)}}{U_{2(r)}} = \frac{Z_1 \cdot R_1}{Z_1 \cdot R_1 + R_1 \cdot R_2 + Z_1 \cdot R_2} \qquad \text{(1b)}$$

The measured reflection coefficient at P1 is ρ_{meas};

$$\rho_{\text{meas}} = \frac{U_{1(r)}}{U_{1(i)}} \qquad \text{(2a)}$$

The actual reflection coefficient at P2 is ρ_{act};

$$\rho_{\text{act}} = \frac{U_{2(r)}}{U_{2(i)}} \qquad \text{(2b)}$$

Using the actual values from Fig. 3 in equations (1a) and (1b), we get:

$$\frac{U_{2(i)}}{U_{1(i)}} = \frac{75\,\Omega}{75\,\Omega + 43.3\,\Omega} \approx 0.6338\,; \quad U_{2(i)} \approx 0.6338\, U_{1(i)} \qquad \text{(3a)}$$

$$\frac{U_{1(r)}}{U_{2(r)}} = \frac{50\ \Omega \cdot 86.6\,\Omega}{50\,\Omega \cdot 86.6\,\Omega + 86.6\,\Omega \cdot 43.3\,\Omega + 50\,\Omega \cdot 43.3\,\Omega} \approx 0.4226;$$

$$U_{2(r)} \approx U_{1(r)} / 0.4226$$

(3b)

Using (2a) and (2b), we get:

$$\rho_{\text{act}} = \frac{U_{2(r)}}{U_{2(i)}} \approx \frac{U_{1(r)}/0.4226}{0.6338 \cdot U_{1(i)}} = \frac{1/0.4226}{0.6338} \cdot \frac{U_{1(r)}}{U_{1(i)}} = \frac{1/0.4226}{0.6338} \rho_{\text{meas}}$$

Correction factor $\rho_{\text{act}} / \rho_{\text{meas}} \approx 3.73$ (4a)

→ $TRACE\_OFFSET = 20 \cdot \lg(\rho_{act} / \rho_{meas}) = 20 \cdot \lg 3.73 = 11.43\ \text{dB}$

The formula for the VSWR is

$$VSWR = (1 + 3.73 \cdot \rho_{meas}) / (1 - 3.73 \cdot \rho_{meas}) \qquad \text{(4b)}$$

Example:

Measurement of a 220 Ω load at the 75 Ω port of the matching pad

The reading of the reflection coefficient ρ_{FSH} on the FSH3-TV will be (Fig. 4):

$$\rho_{FSH} = 0.1330$$

Using equation 1 with the values for the parameters Z_0 = 75 Ω and Z_{load} = 220 Ω, the reflection coefficient ρ_{calc} can be calculated as

$$\rho_{calc} = (220\ \Omega - 75\ \Omega) / (220\ \Omega + 75\ \Omega) = 0.49 \qquad (4)$$

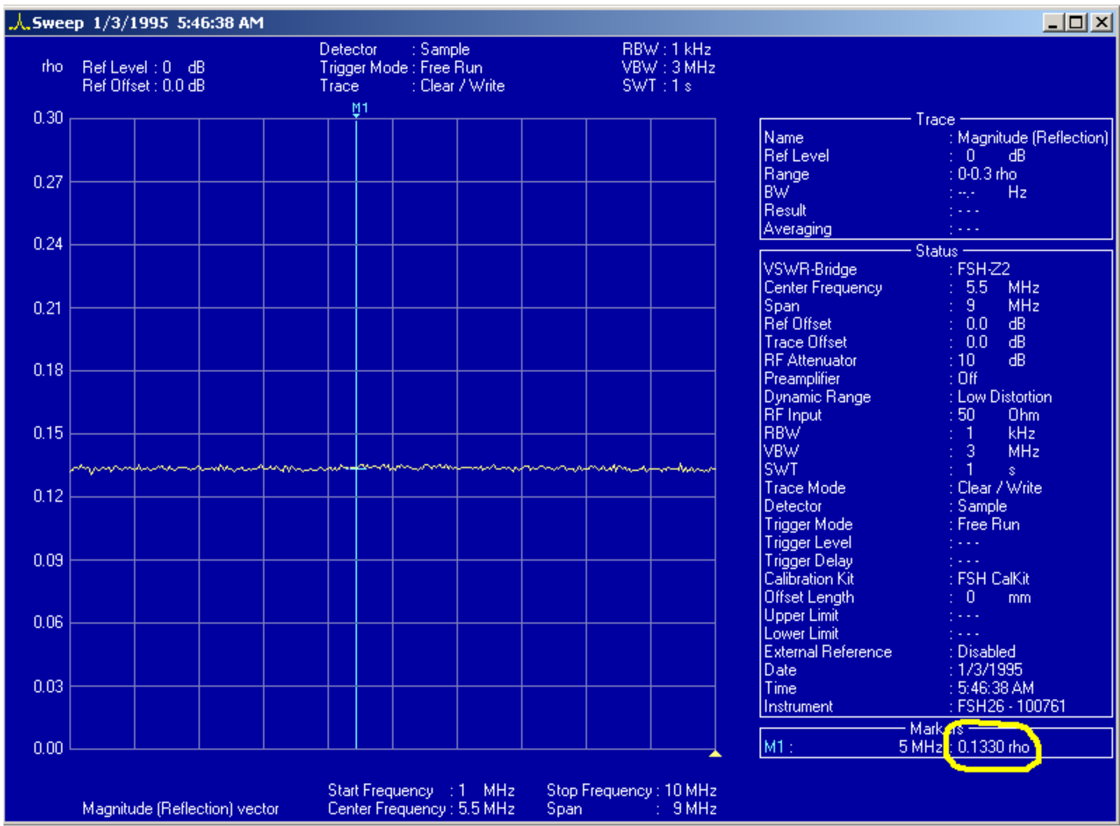

Fig. 4: Reflection coefficient of a 220 Ω load measured using FSH3-TV when calibration is performed at the 50 Ω port.

The actual reflection coefficient ρ_{act} is calculated from the measured reflection coefficient ρ_{FSH} with the following formula:

$$\rho_{act} = \rho_{FSH} \text{ X correction factor} \qquad (5)$$

The correction factor is 3.73 (please refer to appendix A.1 for the calculation of this correction factor).

$$\rho_{act} = 0.133 \text{ X } 3.73 = 0.49 = \rho_{calc}$$

To calculate the VSWR, equation 3 is used as follows:

$$VSWR = (1 + 3.73\ \rho_{FSH}) / (1 - 3.73\ \rho_{FSH})$$

$$= (1 + 3.73 \cdot 0.133) / (1 - 3.73 \cdot 0.133) = 2.97 \qquad (6)$$

A.2: Reason for using the R&S®RAM resistive matching pad:

The impedance for a signal moving in the forward direction at P1 ($U_{1(i)}$) will be 50 Ω. The signal moving in the reverse direction ($U_{2(r)}$) will also be matched, and the net impedance will be 75 Ω as shown below:

$$Z_{forward} = \left[\frac{1}{R_1} + \frac{1}{R_2 + Z_2}\right]^{-1} \approx \left[\frac{1}{86.6\ \Omega} + \frac{1}{43.3\ \Omega + 75\ \Omega}\right]^{-1} = 50.0\ \Omega$$

$$Z_{\text{backward}} = R_2 + \left[\frac{1}{R_1} + \frac{1}{Z_1}\right]^{-1} \approx 43.3\ \Omega + \left[\frac{1}{86.6\ \Omega} + \frac{1}{50\ \Omega}\right]^{-1} = 75.0\ \Omega$$

The R&S®RAM matching pad is bidirectional, i.e. it provides a match for both the forward and the reflected signals.

7 Summary

The *R&S®FSH3-TV TV analyzer* is configured for 50 Ω system impedances. With the *R&S®FSH-Z2 VSWR bridge and power divider* and the reflection coefficient of the R&S®RAM external matching pad, highly accurate VSWR and Smith chart measurements in 75 Ω systems are possible.

8 References

1. Operating manual of the R&S®FSH3-TV analyzer

2. 7BM60_0E: Distance-to-fault (DTF) measurement in 75 Ω systems with the R&S®FSH3-TV

9 Additional Information

Our Application Notes are regularly revised and updated. Check for any changes at http://www.rohde-schwarz.com.

Please send any comments or suggestions about this Application Note to Broadcasting-TM-Applications@rohde-schwarz.com.

10 Ordering Information

Designation		
TV Analyzer	R&S®FSH3-TV	2111.7005.63
VSWR Bridge and Power Divider, 10 MHz to 3 GHz (contains short, open and 50 Ω load for calibration)	R&S®FSH-Z2	1145.5767.02
VSWR Bridge with DC Bias and Bypass Connector for the R&S®FSH3-TV, 10 MHz to 6 GHz (incl. open, short, 50 Ω load ¸FSH-Z28)	R&S®FSH-Z3	1300.7756.02
50/75 Ω Matching Pad	R&S®RAM	0358.5414.02
75 Ω (type N) Calibration Kit	R&S®ZCAN	800.8515.72
Vector Transmission and Reflection Measurements	R&S®FSH-K2	1157.3387.02

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