ROHDE&SCHWARZ

BROADCASTING DIVISION

Application Note

Phase Jitter in DTV Signals

Products:

TV Test Transmitter	***R&S SFQ***
TV Test Receiver	***R&S EFA***

7BM30_0E

Contents

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1 Introduction

Today's state-of-the-art TV test transmitters for digital TV provide signals fully complying with the European DVB (digital video broadcasting) standard and the U.S. ATSC (advanced television systems committee) standard. Featuring calibrated settings for each of these standards, the transmitters cover all parameters stipulated by the respective specifications.
TV test transmitters must not only be capable of generating signals in conformance with international standards, but also of simulating unfavourable receive conditions to determine the limits of performance of DVB and ATSC receivers and demodulators. The ETSI Technical Report ETR290 specifies all parameters that may degrade DVB signal quality during modulation and transmission.
Main parameters include:

I/Q amplitude error (amplitude imbalance),
I/Q phase error (quadrature offset),
carrier suppression,
C/I ratio,
S/N ratio

and, last but not least,

phase jitter.

These parameters and in addition fading, which occurs during transmission, affect signal quality and therefore the values of

MER (modulation error ratio),
BER (bit error ratio) and
END (equivalent noise degradation)

at the receiver input. High-grade TV test transmitters allow the setting and variation of these parameters individually and as a group. In this way, reproducible measurements can be performed to determine the limits up to which adequate reception quality is ensured in digital TV transmission.

2 Measurement Capabilities of TV Test Transmitter R&S SFQ

TV Test Transmitter R&S SFQ meets the requirements of DVB and ATSC. Multistandard test capability is provided through options. The three DVB substandards – DVB-C (cable), DVB-S (satellite) and DVB-T (terrestrial) – are also implemented by means of options. Another option is available for fading simulation.
Configured in this way, the test transmitter is capable of setting and varying all of the above signal parameters except for phase jitter.

This application note, therefore, presents a simple method of setting defined phase jitter.

2.1 Phase Jitter Generation and Test Setup

What equipment is needed to generate defined phase jitter with high accuracy? The test setup is shown in Fig. 1:

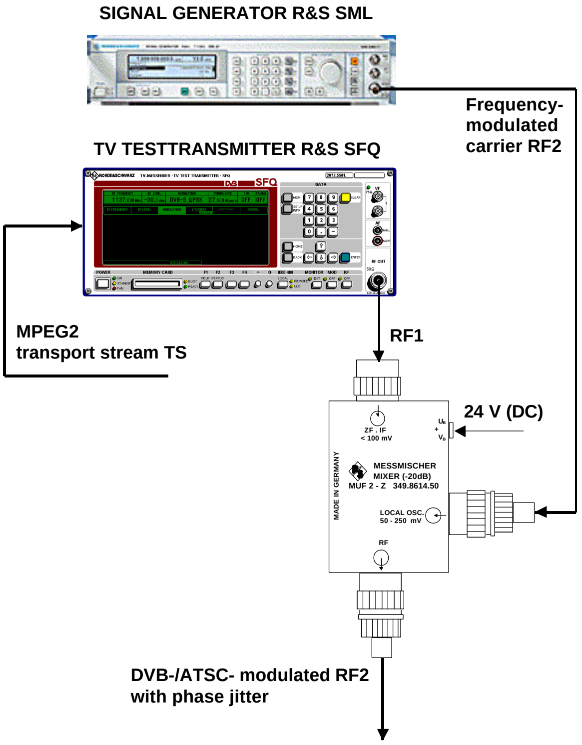


Fig. 1 Test setup for phase jitter generation

R&S SFQ generates a jitter-free DVB- or ATSC-modulated RF signal with a high carrier frequency (RF1), for example 1.0 GHz. This signal is applied to the IF input of a mixer (e.g. R&S MUF2-Z). Alternatively, any commercial passive mixer can be used that meets the specifications listed in the Appendix (page 7). A frequency-modulated RF signal from a signal generator, e.g. R&S SML, is used as a local oscillator (LO) signal. R&S SML is capable of internal sinewave modulation. The frequency-modulated signal is used to convert the R&S SFQ signal to another frequency via the mixer. As a result, an output signal with a carrier in the medium TV range (300 MHz to 700 MHz) with sinusoidal frequency modulation is obtained.

The defined phase jitter $\Delta\varphi$ introduced into the LO frequency by frequency modulation is also present in the output signal. This is because the characteristics of the external LO signal are transferred to the DTV signals generated by TV Transmitter R&S SFQ, so that these carry also the jitter superimposed on the LO signal. Both DVB signals and ATSC 8VSB signals with adjustable phase jitter can be generated in this way.

The RF1 frequency f_1 = 1.0 GHz from R&S SFQ and the RF2 frequency, e.g. f_2 = 700 MHz from the LO are widely spaced from each other, so that the image frequency spectrum at 1.7 GHz produced by mixing is of no importance. The useful signal for DVB-C is at 300 MHz.

The generation of defined phase jitter for DVB-S signals with QPSK modulation is based on the image spectrum. Taking the values of the above example, the second IF carrier of the satellite signal would be at 1700 MHz and thus also in the center of the IF frequency range.

2.2 What Phase Jitter is Produced at What Modulation Frequency f_{MOD}?

With sinusoidal frequency modulation, the phase is inversely proportional to the modulation frequency as long as the frequency deviation is constant. The phase jitter generated with the above test setup is, therefore, determined by the FM deviation and the modulation frequency as follows:

$$j_{RMS} / \mathrm{deg} = \left\{\left[\left(\frac{\Delta f}{f_{MOD}}\right) * \frac{1}{\sqrt{2}}\right]\right\} * \frac{180}{p} \quad \text{(Equation 1}$$

)

where

Δf = frequency deviation (Hz)
f_{MOD} = frequency of modulation signal (Hz)

To check the test setup, a series of phase jitter measurements was performed with TV Test Receiver R&S EFA model 60 for DVB-C. As mentioned above, the following statements apply analogously to ATSC 8VSB, DVB-S and DVB-T.

The following settings were made:

- On TV Test Transmitter R&S SFQ:
  DVB-C with 16QAM
  Symbol rate 6.9 Msymb/s
  Frequency f_1 = 1.0 GHz
  Level -12 dBm
- On Signal Generator R&S SML:
  FM deviation Δf = 1000 Hz
  Level of modulation signal = 1 V_{RMS}
  LO frequency f_2 = 700 MHz
  Level of LO signal -1 dBm
- On TV Test Receiver R&S EFA (DVB-C model):
  Loop bandwidth LOW and MEDium
  RF frequency 300 MHz

The theoretical values obtained with equation 1 and the measured values obtained with TV Test Receiver R&S EFA model 60 for DVB-C were compared with each other, see Table 1. With the above settings, equation 1 reads as follows:

$$\varphi_{RMS} / \mathrm{deg} = 40.51 \bullet 10^3 \bullet 1 / f_{MOD}$$

Frequency f_{MOD} /kHz	Phase jitter $\varphi 1_{RMS}$ /deg measured with LOOP BANDWIDTH		Calculated phase jitter $\varphi 2_{RMS}$ /deg	$\Delta\varphi_{rRMS}$ /deg = $\varphi 1_{RMS} - \varphi 2_{RMS}$	
	LOW	MEDIUM		LOW	MEDIUM
1	0.41	0.27	40.51	---	---
2	0.76	0.41	20.26	---	---
3	1.34	0.57	13.50	---	---
4	2.33	0.76	10.13	---	---
5	-----	0.98	8.10	---	---
6	6.46	1.25	6.75	-0.29	---
7	5.51	1.58	5.79	-0.18	---
8	4.84	1.99	5.06	-0.22	---
9	4.26	2.44	4.50	-0.24	---
10	3.78	2.75	4.05	-0.27	---
11	3.42	2.85	3.68	-0.26	---
12	3.15	2.80	3.38	-0.23	-0.58
13	2.93	2.70	3.12	-0.19	-0.42
14	2.75	2.60	2.89	-0.14	-0.29
15	2.58	2.48	2.70	-0.12	-0.22
20	2.02	2.00	2.03	-0.01	-0.03
30	1.41	1.42	1.35	+0.06	+0.07
40	1.11	1.13	1.01	+0.10	+0.12
50	0.92	0.95	0.81	+0.11	+0.14
60	0.80	0.82	0.68	+0.12	+0.16
70	0.70	0.73	0.58	+0.12	+0.15

Table 1 Measurement and calculation of phase jitter as a function of modulation frequency

For a clear illustration, the test series was performed for DVB-C with 16QAM. The decision fields in 16QAM are larger by a factor of 16 compared with 64QAM; for this reason, phase jitter up to φ_{pp} = 20 deg (corresponding to φ_{RMS} = 7 deg) is possible.

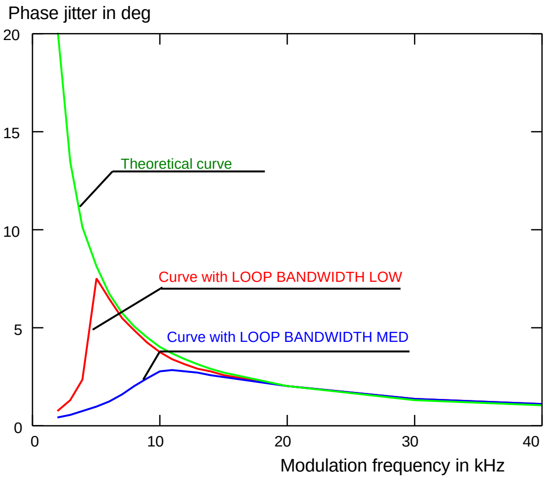


Fig. 2 Graphical representation of values listed in Table 1

It can be seen immediately that the PLL bandwidth of TV Test Receiver R&S EFA has a strong effect on the phase jitter characteristic. The theoretical sinusoidal phase jitter φ_{RMS} obtained for the above test setup is in practice suppressed at lower frequencies by the PLL loop filter. The frequency up to which phase jitter is suppressed is determined by the loop bandwidth. Measured values that agree with the theoretical values can be expected to be delivered by TV Test Receiver R&S EFA from about 6 kHz modulation frequency (with loop bandwidth set to LOW). At this frequency, measured values deviate from theoretical values by no more than $\Delta\varphi_{RMS}$ = -0.29 deg. Peak-to-peak phase jitter at this point is $\varphi_{SS} \approx$ 18 deg. This is sufficient for measuring degradation caused by phase jitter. Differences at higher frequencies result from the characteristic of the PLL loop filter, which has a minor but still measurable effect.

With the PLL loop bandwidth set to MEDium, usable results can be expected only from approx. 12 kHz. At this modulation frequency, deviation from theoretical values is still $\Delta\varphi_{RMS}$ = -0.58 deg. Fig. 2 shows that the MEDium setting is not suitable for measuring phase jitter because the curve is too flat in the range that can be evaluated.

Using the above test setup and equation

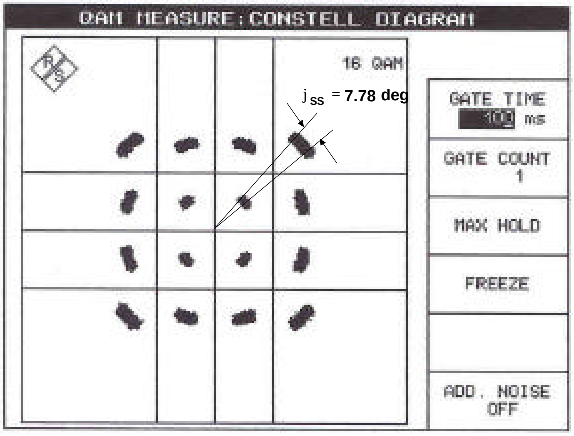
$$\varphi_{RMS} / \text{deg} = 40.51 * 10^3 * 1/ f_{MOD} ,$$

which describes the relationship between the phase jitter φ_{RMS} and the modulation frequency f_{MOD}, defined phase jitter can be set in the range

$$0.5 \text{ deg} \leq \varphi_{RMS} \leq 6 \text{ deg}$$

with the PLL loop bandwidth set to LOW.

2.3 Examples of Phase Jitter in a Constellation Diagram


QAM MEASURE:CONSTELL DIAGRAM

16 QAM

j_{ss} = 7.78 deg

GATE TIME 100 ms

GATE COUNT 1

ADD. NOISE OFF

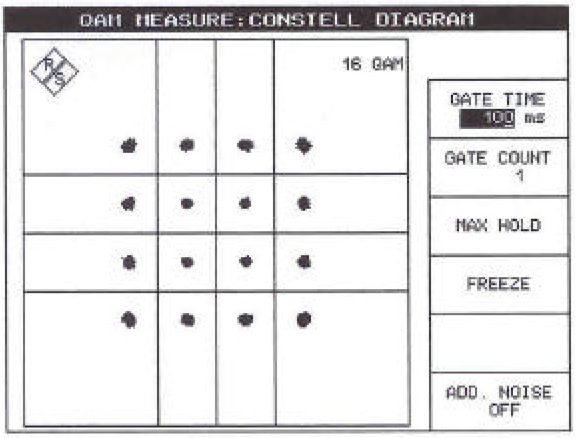
Fig. 3 φ_{RMS} = 2.75 deg with 1 kHz FM deviation and 14 kHz modulation frequency

Jitter is clearly discernible from the outer symbol clouds, which are distorted into circular segments. Converting the sinusoidal RMS phase jitter of

φ_{RMS} = 2.75 deg to the peak-to-peak value yields the phase angle:

$\varphi_{pp} = 2.75 * 2 * \sqrt{2} = 7.78$ deg.

In Fig. 4, by contrast, the phase jitter is hardly discernible. The settings in this case were φ_{RMS} = 0.92 deg with 1 kHz FM deviation and 50 kHz modulation frequency. The symbol clouds in the outer four corners are only faintly distorted.



GATE TIME 100 ms

GATE COUNT 1

ADD. NOISE OFF

Fig. 4 φ_{RMS} = 0.92 deg with 1 kHz FM deviation and 50 kHz modulation frequency

2.4 Phase Jitter as a Function of Modulation Frequency

The table below lists the generated phase jitter versus the modulation frequency. The selected phase jitter range is the range that can be evaluated with TV Test Receiver R&S EFA. The figures given are valid for the PLL loop bandwidth set to LOW.

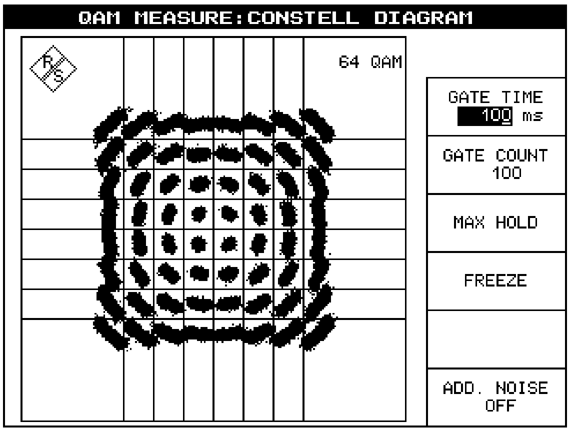
Phase jitter φ_{RMS} /deg	Modulation frequency f_{MOD} /kHz
0.5	81.03
1.0	40.51
1.5	27.01
2.0	20.26
2.5	16.21
3.0	13.50
3.5	11.58
4.0	10.13
4.5	9.00
5.0	8.10
5.5	7.37
6.0	6.75

Table 2 Modulation frequency as a function of phase jitter

2.5 Phase Jitter Limits for 16QAM and 64QAM

From Table 1 it can be seen that a 16QAM system tolerates phase jitter up to approx. φ_{RMS} = 6.5 deg. While the BER before RS FEC (Reed-Solomon forward error correction) is still < $2*10^{-4}$, PLL synchronization is no longer guaranteed from this limit.

For 64QAM, the phase jitter limit is φ_{RMS} = 3.9 deg, corresponding to a modulation frequency f_{MOD} ≈ 10 kHz. The constellation diagram shows that this value leads to near failure of the DVB-C system.



GATE TIME 100 ms

GATE COUNT 100

ADD. NOISE OFF

Fig. 5 Phase jitter φ_{RMS} = 3.9 deg with 64QAM

3 Summary

With only little extra equipment, TV Test Transmitter R&S SFQ is capable of setting defined sinusoidal phase jitter φ_{RMS} for DVB and ATSC signals in the range

$$0.50 \text{ deg} \le \varphi_{RMS} \le 6 \text{ deg}.$$

This requires in addition a mixer (e.g. R&S MUF2-Z) or any commercial passive mixer, and a signal generator capable of FM modulation, e.g. Signal Generator R&S SML. With this setup, peak-to-peak phase jitter φ_{SS} in the range

$$1.4 \text{ deg} \le \varphi_{SS} \le 18 \text{ deg}$$

can be generated, which is sufficient for phase jitter measurements.

Appendix

Technical Data of Mixer R&S MUF2-Z2

Frequency range	25 MHz to 1000 MHz
Amplitude frequency response	
Over 10 MHz	≤0.1 dB
25 MHz to 800 MHz	≤1.5 dB
800 MHz to 1000 MHz	≤3.0 dB
Conversion loss	20 dB ±1 dB
Return loss	
Input	≥20 dB
Output	≥10 dB
Mixer LO input level	100 mV to 250 mV
Mixer input level	≤100 mV
Intermodulation (dual-sound measurement, carrier level lowered by 6 dB in each case)	
100 mV	typ. 70 dB down
50 mV	≥70 dB down
Spurious (at 50 mV)	≥70 dB down (vision/sound = 0/-10 dB)
Crossmodulation (at 100 mV)	≥70 dB down (vision/sound/SB = -8/-10/-16 dB)
Supply voltage	15 V