

Using the Equalizer Filter in the VSA Application Firmware for R&S Signal and Spectrum Analyzer Application Note

Products:

R&S®FSQ	R&S®FSU
R&S®FSG	R&S®FSUP
R&S®FMU	R&S®FSMR

The R&S spectrum analyzers and signal analyzers offer an additional equalizer filter in the Vector Signal Analysis Application Firmware R&S FSQ-K70/FSx-B73, which is a powerful tool for measurement and analysis of vector-modulated signals. This application note describes the functionality of the equalizer filter and how to set the filter parameter manually in an accurate and fast way.

Table of Contents

1 Overview	4
2 Adjustment of Filter Length and Step Size	4
2.1 Equalizer Length	5
2.2 Step Size	6
2.3 Summary	6
3 FAQs	6
4 References	8
5 Additional Information	8
6 Ordering Information	8

1 Overview

The option R&S FSQ-K70/FSx-B73 for vector signal analysis, which is available for the R&S FSQ, FMU, FSU, and FSMR, enables the analysis of analog and digital modulations. A possible source of high modulation errors of the device under test (DUT) is a non-flat frequency response or ripple in frequency response within the modulation bandwidth. An adaptive equalizer filter is able to identify and compensate the distorted frequency response or in general linear distortions from IQ modulated signals (figure 1), which also include group delay distortion and reflections or multipath distortion. This kind of filter is included in the option R&S FSQ-K70/FSx-B73.

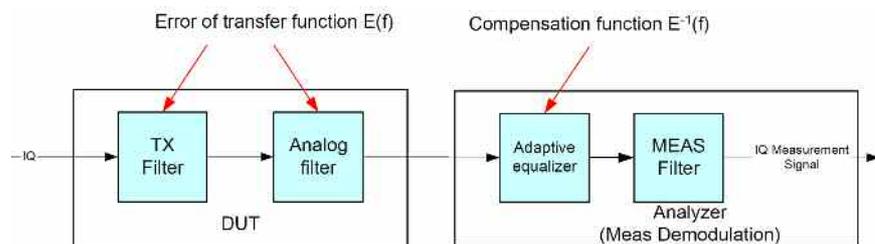


Figure 1: Baseband schematic: compensation of the transfer function's error (caused e.g. by the DUT's analog or digital filter sections) by inserting an adaptive equalizer in the receive path [K70].

The filter coefficients are adapted in such a way that the mean square value of the error vector magnitude (EVM) is minimized. Thus the equalizer filter is limited to PSK and QAM modulation schemes and it cannot be used for MSK, FSK, and VSB schemes [K70, 1].

The main purpose of the adaptive equalizer filter in the VSA is to find out if there is a non neglectable frequency response in the DUT. In case of such a frequency response the EVM will improve significantly with the use of the equalizer filter. Additionally nonlinear distortions or spurious errors can be identified more easily if linear distortions are compensated.

2 Adjustment of Filter Length and Step Size

Within the vector signal analysis option two parameters need to be set: Adaptive FIR filter length (softkey 'Equalizer Length') and step size of the implemented algorithm (softkey 'Equalizer Step'). The filter coefficients are calculated automatically according to this algorithm.

If the parameters are set correctly, the linear correction will lead to a low EVM very fast. If the parameters are set in a wrong way, it will take a long time to see improvements and the final value will not be very good. The following sections describe how to adjust the filter length and step size required to train the adaptive equalizer.

2.1 Equalizer Length

The equalizer's length L is always given in symbols. The number of taps can be calculated as follows: $L \cdot \text{OversamplingFactor} + 1$. If the length of the filter is chosen too low the filter will never be able to represent the system (under-modeling situation). If the length of the filter is chosen too high you will always be able to represent the system, however the converge properties will be poor (due to over-modeling) [2]. The aim is to find the one in between.

A good starting length is 10 symbols. To get a first and fast impression of the channel you can also start with 5 symbols. Then the equalizer can be trained (softkey 'Train') while looking at the impulse response of the filter (softkey 'Magnitude (log)'). If the impulse response on the left and right border of the display are almost zero the length can be reduced, otherwise it has to be increased (see figure 2). During training process always watch the EVM or constellation diagram to control the range of improvements.

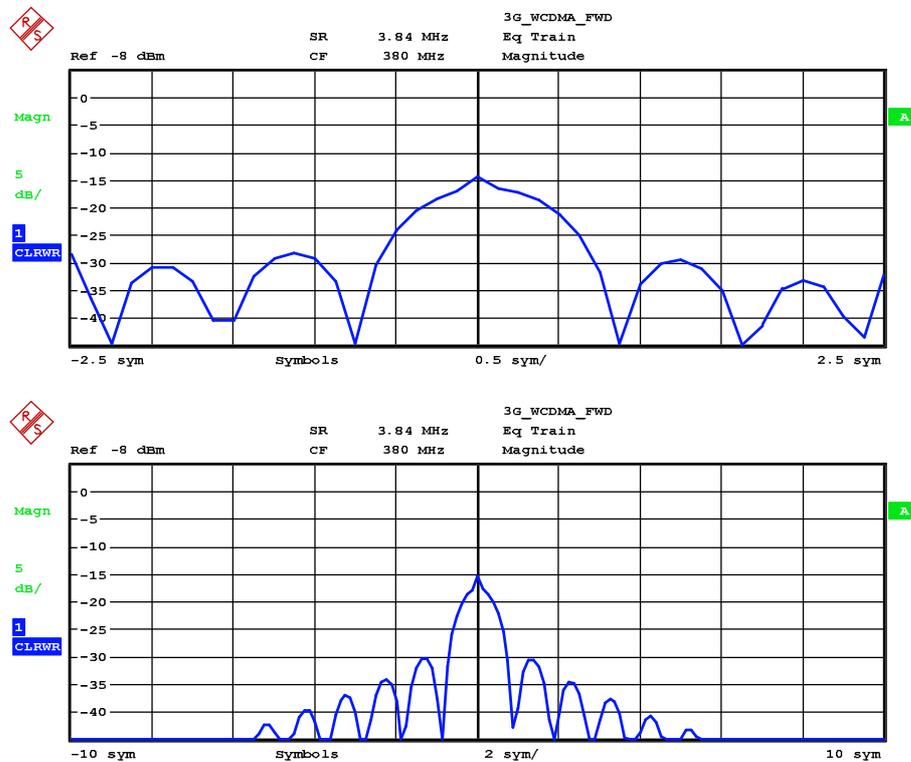


Figure 2: The impulse response of the equalizer filter with an equalizer length of 5 symbols (above) and 20 symbols (below). In this case the impulse response is approx. 12 symbols long and thus a filter length of 12 symbols is needed.

Changing the length during operation of the equalizer is possible in principle. However, it is recommended to preset the coefficients to a neutral filter (softkey 'Equalizer Reset') after changing the length followed by a new learning phase (softkey 'Equalizer Train'). So the equalizers learning process can restart with a defined setting.

2.2 Step Size

The softkey 'Equalizer Step' controls the equalizer's learning rate. At the beginning of the equalizer training a step size of 0.25 or 0.1 is favourable for quick improvements of the EVM display. If the EVM is somehow settled and only small improvements are noticeable, the step size can be reduced to 0.05 or less in order to get an even lower EVM. When lowering the step size the learning rate decreases but the accuracy of the compensation increases. At the end of the equalizer training a step size of 0.01 or less is recommended.

Opposed to the equalizer length the step size can be altered during operation. This does not reset the equalizer. Finally you can press 'Equalizer Freeze' to use the current settings for the filter, which will increase the measurement speed. For further information please refer to [K70].

2.3 Summary

1. Set Equalizer Length to 10 symbols and Equalizer Step Size to 0.25
2. Train Equalizer
3. Look at the impulse response of the filter and adjust Equalizer Length
4. Reset Equalizer and train it again
5. Look at the EVM and when EVM is somehow settled reduce Equalizer Step Size to 0.05
6. Wait again until EVM is settled and reduce Equalizer Step Size to 0.01
7. Freeze Equalizer

3 FAQs

Frequently asked questions about the VSA equalizer filter and hints regarding the practical use:

Q1: Which optimization algorithm does the equalizer-train-function of R&S FSQ-K70 use?

Answer: The equalizer uses block-based LMS (least mean square) optimization. For the equalizer to work in all cases the eye of the signal must already be open at the beginning, only a few wrong symbol decisions are allowed.

Q2: Which modulations does the equalizer in R&S FSQ-K70 support?

Answer: The equalizer in R&S FSQ-K70 is not applicable for MSK, VSB, FSK, and OQPSK modulation.

Q3: Where is the convergence time limit?

Answer: The time needed to train the equalizer depends on the chosen step size. The best way is to use a larger step size first (about 0.25), then after a while decrease it step by step (about 0.1 or lower, 0.01).

If step size is larger:

- rather fast convergence (typically after a few seconds)
- can follow changes in the channel transfer function faster
- but may not reach optimum state (minimum EVM)

If step size is small:

- slow convergence
- can not follow changes in the channel transfer function fast
- it can reach optimum state if channel stays constant (lowest EVM)

Q4: How do I know that the equalizer is unstable?

Answer: The equalizer is unstable, if...

- there is no decreasing trend in the EVM RMS value at a large step size (e.g. 0.25)
- the constellation diagram resembles a single big cloud or the clouds around the ideal constellation points do not get smaller.
- the equalizers frequency response does not look like a more or less flat low pass.

If once the eye of the signal is closed, it is not guaranteed that the equalizer gets better again. In this case it is recommended to reset it or to load an equalizer response that is known to match for the current channel.

Q5: How precise does the analyzer need to have the frequency set?

Answer: The lock range of the center frequency is about symbol rate / 10. Correct symbol rate is a prerequisite.

Q6: Is there a kind of built-in frequency-correction in the analyzer/demodulator?

Answer: Yes, the VSA application firmware has a coherent demodulator. It estimates the frequency error and corrects it before doing the RX filtering. However, if the R&S FSQ-K70 displays large frequency errors it is recommended to incorporate that effect into the set center frequency. This typically improves the performance of R&S FSQ-K70.

Q7: How many % of frequency error can the demodulator still correct?

Answer: If the demodulator locks, it measures correctly.

Be aware: If you have a constant channel impulse response $h(t)$, that you want to equalize with the equalizer, and you train the equalizer 1 minute at the frequency $f_{ideal} + f1$ it might reach a good state.

But if you then suddenly switch the transmitter to e.g. the frequency $f_{ideal} - f1$, this causes a sudden change in the impulse response the equalizer sees. Shifting the frequency means frequency shifting the channel frequency response. In this case you should reset the equalizer.

Q8: What can one do if the symbol frequency is not really exactly known?

Answer: Symbol rate is not estimated and compensated in the VSA application firmware. But the correct symbol rate is important and should be entered as exactly as possible.

You can recognize an incorrect symbol rate in the "EVM vs symbols" measurement. The EVM is good in the middle and worse at both edges.

Hint 1: Very important for QAM with higher order: The "result range" of the VSA application firmware should be at least 8 times the modulation order, e.g. 8×128 symbols for 128QAM. Otherwise the demodulation may be unstable.

Hint 2: If the channel to equalize is always similar, you can save a good equalizer impulse response you once got and load this impulse response in the next measurement to use it as a starting point with a frozen equalizer.

Hint 3: The VSA application firmware can be used for a rough estimate of the symbol rate as follows (the same can be done by capturing IQ data and processing it with e.g. Matlab):

- Increase the capture length (but not longer than your signal burst).
- Go to "Capture Buffer, Magnitude" and switch on the FFT for this result.
- Trace average is recommended
- At the symbol rate a peak will show. Read its frequency with the marker.
- The initial symbol rate should be greater than or equal than the expected symbol rate.

4 References

[K70] Rohde & Schwarz, **Application Firmware R&S FSQ-K70, Software Manual**, R&S 2005

[1] Rohde & Schwarz, **Spectrum Analyzer R&S FSQ, Operating Manual**, R&S 2005

[2] Christoph Rauscher, **Fundamentals of Spectrum Analysis**, R&S 2004

5 Additional Information

This application note may be updated from time to time. Please visit the website 1EF61 in order to download new versions.

Please contact TM-Applications@rsd.rohde-schwarz.com for comments and further suggestions.

6 Ordering Information

Designation	Type	Order No.
Base Unit R&S FSQ		
Signal Analyzer 20 Hz to 3.6 GHz	R&S FSQ3	1155.5001.03
Signal Analyzer 20 Hz to 8 GHz	R&S FSQ8	1155.5001.08
Signal Analyzer 20 Hz to 26,5 GHz	R&S FSQ26	1155.5001.26
Signal Analyzer 20 Hz to 40 GHz	R&S FSQ40	1155.5001.40
VSA Option for R&S FSQ		
General Purpose Vector Signal Analysis	R&S FSQ-K70	1161.8038.02

Base Unit R&S FSG

Signal Analyzer 9 kHz to 8 GHz	R&S FSG8	1309.0002.08
Signal Analyzer 9 kHz to 13.6 GHz	R&S FSG13	1309.0002.13

VSA Option for R&S FSG

General Purpose Vector Signal Analysis	R&S FSQ-K70	1161.8038.02
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Base Unit R&S FMU

Baseband Analyzer DC to 36 MHz	R&S FMU36	1303.3500.02
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General Purpose Vector Signal Analysis included**Base Unit R&S FSU**

Spectrum Analyzer 20 Hz to 3.6 GHz	R&S FSU3	1166.1660.03
Spectrum Analyzer 20 Hz to 8 GHz	R&S FSU8	1166.1660.08
Spectrum Analyzer 20 Hz to 26,5 GHz	R&S FSU26	1166.1660.26
Spectrum Analyzer 20 Hz to 43 GHz	R&S FSU43	1166.1660.43
Spectrum Analyzer 20 Hz to 46 GHz	R&S FSU46	1166.1660.46
Spectrum Analyzer 20 Hz to 50 GHz	R&S FSU50	1166.1660.50

VSA Option for R&S FSU

General Purpose Vector Signal Analysis	R&S FSU-B73	1169.5696.03
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Base Unit R&S FSUP

Signal Source Analyzer 20 Hz to 8 GHz	R&S FSUP8	1166.3505.09
Signal Source Analyzer 20 Hz to 26.5 GHz	R&S FSUP26	1166.3505.27
Signal Source Analyzer 20 Hz to 50 GHz	R&S FSUP50	1166.3505.51

VSA Option for R&S FSUP

General Purpose Vector Signal Analysis	R&S FSQ-K70	1161.8038.02
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Base Unit R&S FSMR

Signal Source Analyzer 9 kHz to 3.6 GHz	R&S FSMR3	1166.3311.03
Signal Source Analyzer 9 k Hz to 26.5 GHz	R&S FSMR26	1166.3311.26
Signal Source Analyzer 9 k Hz to 50 GHz	R&S FSMR50	1166.3311.50

VSA Option for R&S FSMR

General Purpose Vector Signal Analysis	R&S FSMR-B73	1169.5696.02
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