



Products: Signal Analyzer R&S FSQ, R&S FSQ-K70

EVM measurements for ZIGBEE signals in the 2.4 GHz band

Application Note

IEEE 802.15.4 (ZIGBEE) uses OQPSK with a half-sine pulse shaping filter as modulation. This application note describes how to import the correct pulse shaping filter into the Signal Analyzer R&S FSQ with R&S FSQ-K70 and set it up for modulation quality measurements, especially EVM for ZIGBEE.



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1 Overview

IEEE 802.15.4, which is also known as ZIGBEE, is a standard for low-data rate, low duty cycle applications. ZIGBEE devices will be designed for extremely long battery life (years). The standard defines different modulation types depending on the frequency band:

Band	Frequency (MHz)	Chip rate (kchip/s)	Modulation type	Pulse shaping filter
868/915	868 – 868.6	300	BPSK	RRC (Root raised Cosine)
	902 - 928	600	BPSK	RRC
2450	2400 – 2483.5	2000	OQPSK	Half-sine

BPSK with RRC-filtering can be demodulated and measured with most standard vector signal analyzers. But OQPSK with half-sine pulse shaping is often not available as the appropriate transmit filter.

This application note describes how to use the Signal Analyzer R&S FSQ with Vector Signal Analyzer option R&S FSQ-K70, how to import the correct ZIGBEE filter and how to set up the R&S FSQ for best EVM (Error Vector Magnitude) performance.

2 A Brief Description of the 802.15.4 Air Interface for the 2.4 GHz Band

Modulation type OQPSK

OQPSK (Offset Quadrature Phase Shift Keying) is similar to QPSK except for the timing of the I and Q transitions. In QPSK, I and Q transitions to the next symbol occur at the same time. This leads to trajectories passing through the origin of the vector diagram, which introduces amplitude modulation and requires linear amplifiers.

In OQPSK the transitions for I and Q are offset by half the symbol time. Since one OQPSK symbol consists of 2 bits, the time offset corresponds to the bit period. This bit period is referred to as chip period in ZIGBEE.

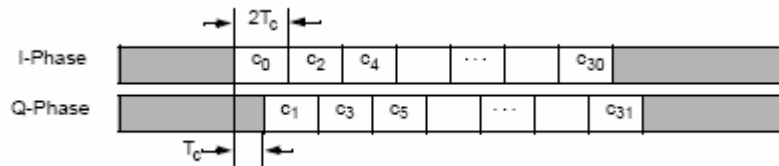


Fig. 1: Timing offset as defined in IEEE std 802.15.4

The chip rate is 2 MChip/s. Vector signal analyzers set the modulation rate usually in terms of symbol rate. For OQPSK this is half the bit rate (or chiprate for ZIGBEE). So the symbol rate has to be set to 1 MSymbol/s.

Since I and Q are decoupled, only one can change at a given time. This limits phase changes to a maximum of 90° . With QPSK the maximum would be 180° , causing a zero crossing.

This reduces the envelope variations significantly and allows more efficient RF amplification.

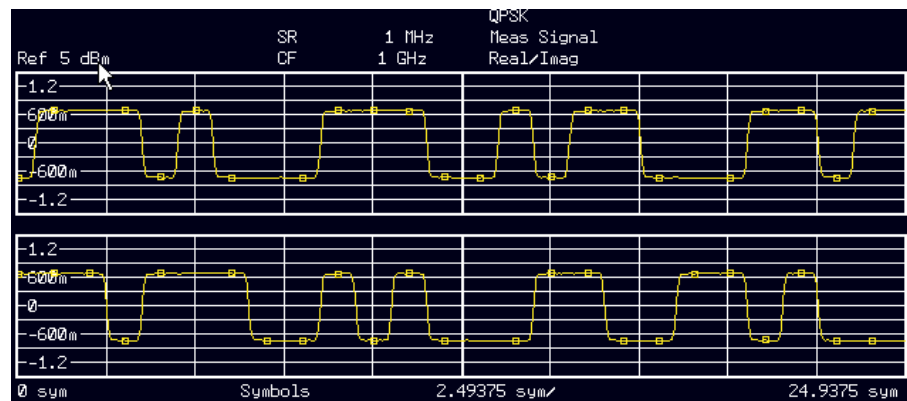


Fig.2: For QPSK, I and Q transitions occur at the same time instance. A simultaneous change is equivalent to a 180° phase shift.

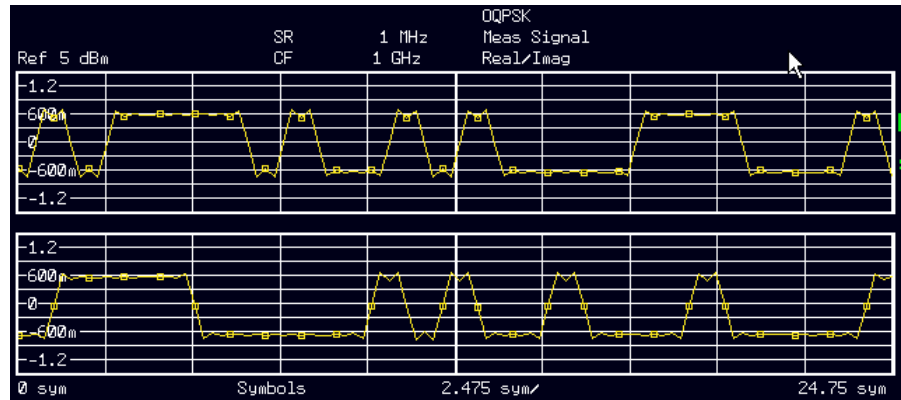


Fig. 2: For OQPSK I and Q transitions never occur at the same time instance. This limits the maximum phase change to 90° and reduces amplitude variations.

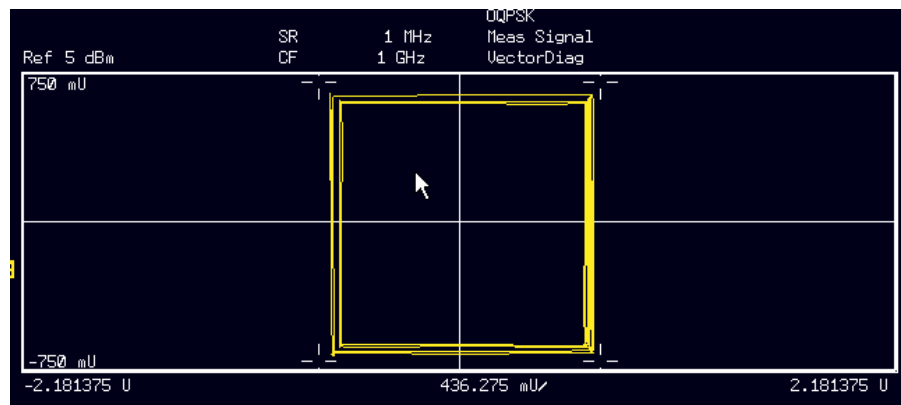


Fig. 3: The vector diagram for unfiltered OQPSK shows no transitions through the origin of the vector diagramm

Half-Sine Pulse Shaping Filter

Instead of rectangular or a RRC-filtered baseband pulses, ZIGBEE uses half-sinusoidal pulses, see equation below.

$$p(t) = \begin{cases} \sin\left(\pi\frac{t}{2T_c}\right), & 0 \leq t \leq 2T_c \\ 0, & \text{otherwise} \end{cases}$$

The half-sine pulse shaping filter changes the vector diagram of the OQPSK from a square to a circle. So it eliminates any amplitude variations and turns the OQPSK into a constant envelope modulation. The OQPSK now resembles a MSK. Actually some text books consider MSK as a special version of OQPSK [2]

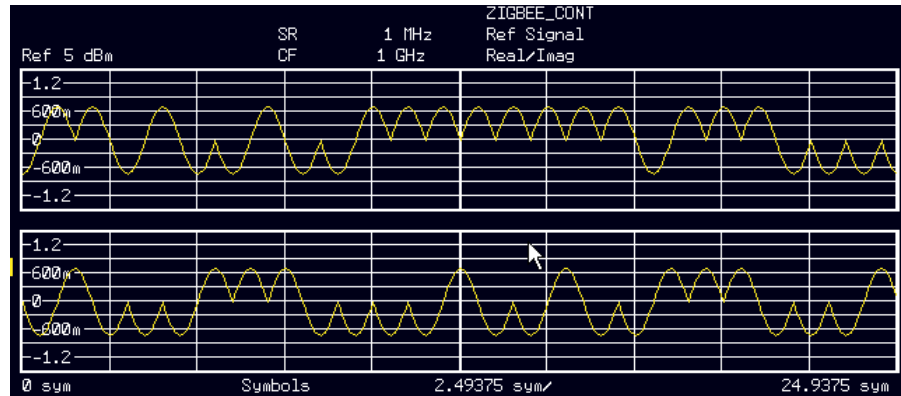


Fig. 5: I and Q display for OQPSK after pulse shaping

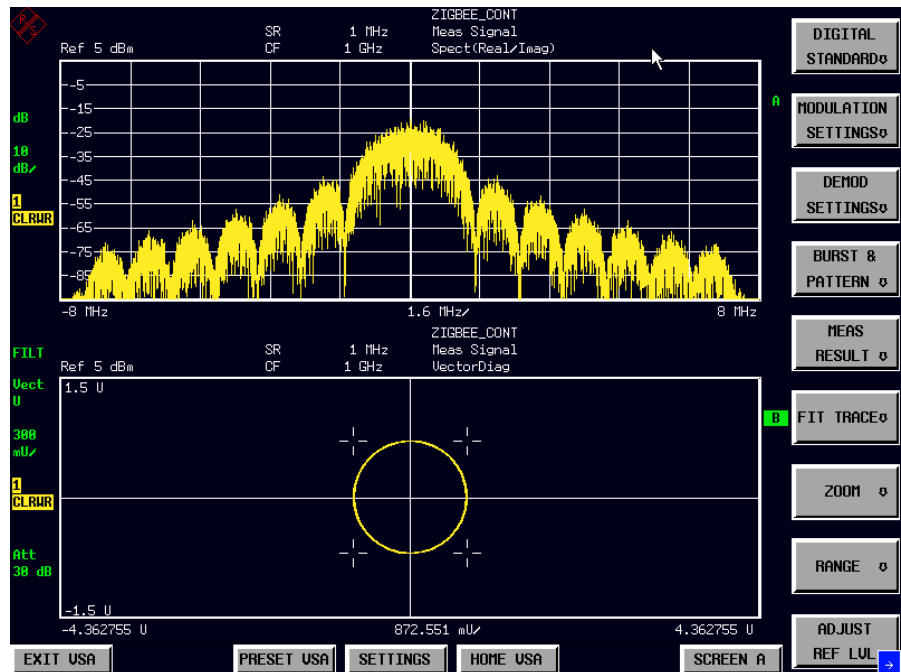


Fig 6: The vector diagram of the half-sine filtered OQPSK shows a constant envelope, just like MSK. The spectrum reveals the sidelobes of a unfiltered MSK

3 Preparing the Measurement

Importing the Half-Sinusoidal Pulse Shaping Filter

The Vector Signal Analyzer Option FSQ-K70 has the possibility to import user-defined filters. For example MatLab can be used to design the filters, and these can be converted into the FSQ-K70 format by the tool FILTWIZ. This tool can be downloaded from the R&S website and is an add-on for MatLab. An appropriate filter for ZIGBEE comes with this application note.

In order to import the half-sine pulse shaping filter for ZIGBEE, copy the attached file *zigbee.vaf* onto a 3.5" floppy disk and insert it into the floppy drive of the FSQ.

- Press HOME VSA
- Select the right supplementary menu by pressing the NEXT key
- Press IMPORT – FILTER
- A selection box appears, select ZIGBEE and press ENTER

Creating a User-defined Filter Set

Now the filters used as transmit, receive and measurement filter have to be defined in a filter set:

- Press PRESET VSA
- Press HOME VSA – MODULATION SETTINGS - NEXT – NEW USER SET
- Press ENTER – a selection box with available filters for the TX filter appears
- Select ZIGBEE and press ENTER, now the receive filter is highlighted
- Select in the same way the filter type NONE as receive and as meas filter
- Press SAVE USER SET, the new filter set is saved as USER(X). X is a number increased automatically with every new user filter set. So the first user filter set will be saved as USER1.

Setting up the R&S FSQ for ZIGBEE

Set modulation type, modulation rate and filtering:

- Press HOME VSA – MODULATION SETTINGS
- Set symbol rate to 1 MHz
- Select the filterset USER(X) in MODULATION FILTER
- Set the modulation to PSK – OQPSK in MODULATION & MAPPING
- Set POINTS/SYMB to 16

As mentioned above, OQPSK with half-sine pulse shaping filter is equivalent in the spectrum and vector diagram to an unfiltered MSK. Unfiltered MSK uses a rather wide spectrum, which requires a wide demodulation bandwidth in the signal analyzer. In the R&S FSQ-K70 the demodulation bandwidth is defined with the oversampling ratio in the POINTS/SYMBOL parameter. Setting points/symbol to 16 will increase the sampling rate to 16 MHz, which gives a demodulation bandwidth of 8 MHz.

If the signal is a continuous signal as in this example, the above settings are sufficient. If the signal is bursted, then burst search parameters can be additionally defined in BURST&PATTERN settings. Further details can be found in the R&S FSQ-K70 operating manual.

Creating a User-defined Standard for ZIGBEE

For convenience, the current settings can be stored as a user-defined standard so that they can be recalled immediately.

Press HOME VSA – DIGITAL STANDARDS – NEXT – SAVE AS STANDARD

In the table two entries have to be done: a name for this setting, for example ZIGBEE_CONT, and a name for the generic standard, for example ZIGBEE.

In that way different settings, which may differ for instance in the record length, result length or burst search parameters can be easily created for the same generic standard.

4 EVM Measurement and Results

Using a signal generated with the signal generator R&S SMIQ an EVM of appr 0.3% has been measured. This EVM is the residual EVM with contributions from both the signal generator and the signal analyzer.

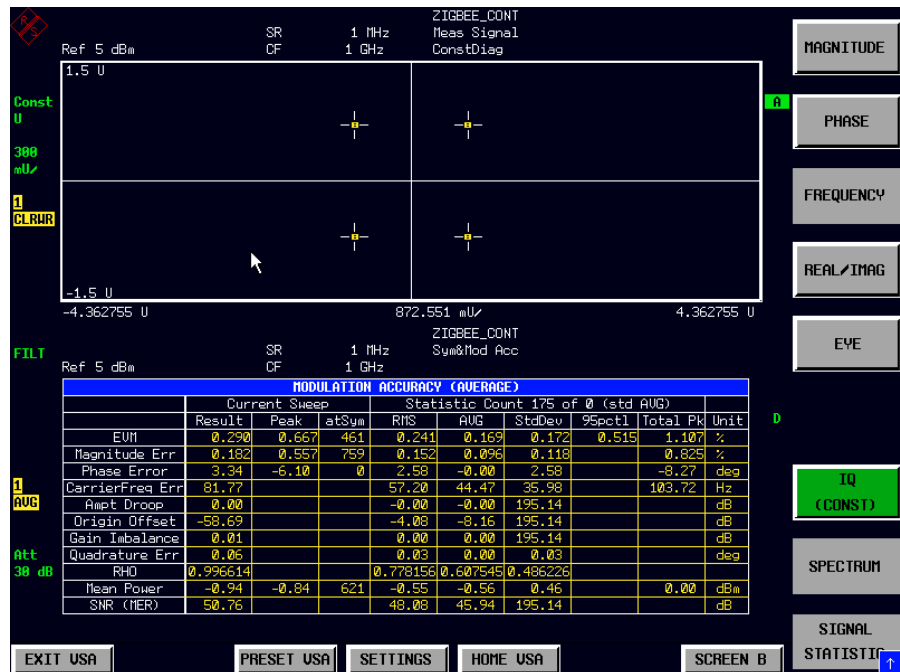


Fig. 7: The EVM measurement with the R&S FSQ shows a very low residual EVM of < 0,3%. This is a prerequisite for accurate EVM measurements.

5 Signal Used

The signal used has been generated by an R&S SMIQ with the following settings:

- Modulation type: GMSK
- Filtering: rectangular
- Symbol rate : 2 Msymbol /s

MSK has two modulation states and 1 bit per symbol. OQPSK has 4 modulation states and 2 bits per symbol. For MSK, bitrate and symbolrate are equal. For OQPSK they differ by a factor of 2. So, for the same bit rate, the symbol rate in MSK has to be set twice as high as for OQPSK.

6 Literature

1. IEEE std 802.15.4 – 2003
2. Rappaport, Theodore: Wireless communications, Prentice Hall,

7 Additional Information

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

8 Ordering information

Signal Analyzer

R&S FSQ3	20 Hz to 3.6 GHz	1155.5001.03
R&S FSQ8	20 Hz to 3.6 GHz	1155.5001.08
R&S FSQ26	20 Hz to 3.6 GHz	1155.5001.26

Vector Signal Analyzer for R&S FSQ

R&S FSQ-K70		1161.8038.02
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