Measurements on DVB-S2 Transmitters
Application Note

Products:

R&S®FSQ	R&S®FSMR
R&S®FSG	R&S®FSQ-K70
R&S®FSU	R&S®FSQ-B72
R&S®FSUP	R&S®FSU-B73

This application note provides information about measurements on DVB-S2 transmitters, including Amplitude Phase Shift Keying (APSK) signals. Specifically, this note will discuss how to import APSK mapping files in order to make modulation quality measurements.

ROHDE&SCHWARZ

Application Notes

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1 Overview

The Digital Video Broadcasting (DVB) suite of standards provides methods of broadcasting video signals for various applications, such as cable, terrestrial, mobile, and satellite transmissions. The DVB-S standard was adopted in 1994, using QPSK as a modulation method, for satellite transmission of video signals.

In 2003, new satellite transmission methods were defined in a new specification, known as DVB-S2. For RF engineers designing a transmitter for the DVB-S2 standard, it is necessary to develop and test devices that can perform more complicated modulation methods than what is used for DVB-S (i.e. QPSK). These modulation methods include 8PSK, 16-Amplitude Phase Shift Keying (APSK), and 32APSK.

The latter two modulation schemes described above require mapping files to be imported into Rohde & Schwarz's signal and spectrum analyzers FSQ, FSG, FSUP, FSMR, or FSU (all instruments hereafter referred as "Vector Signal Analyzer"). The mapping files allow these instruments to perform modulation quality measurements, such as Error Vector Magnitude (EVM) and Modulation Error Ratio (MER).

2 DVB-S2 Physical Layer Signal

2.1 16APSK Constellation

Figure 1 shows the bit mapping for data into the 16APSK constellation according to DVB-S2. As shown by the figure, the 16APSK modulation features constellation points arranged on two concentric circles.

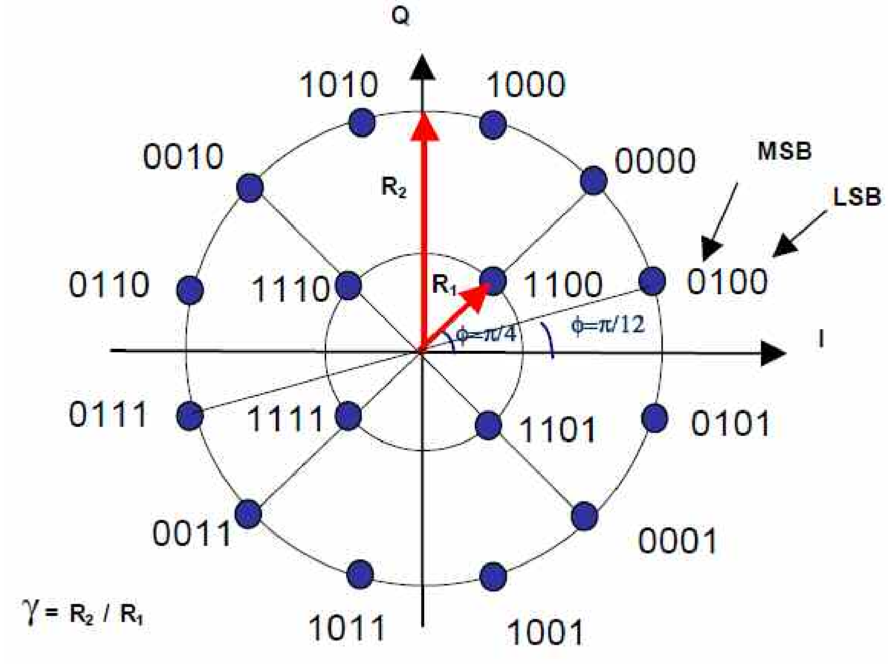


Figure 1: 16APSK Constellation Bit Mapping

An important parameter for this constellation is the Constellation Radius Ratio parameter (γ). This defines the ratio of the radius of the outer circle to that of the inner circle of constellation points. The DVB-S2 standard defines different values of γ according to which coding rate is used. Table 1 shows the possible values of γ for the defined coding rates.

Table 1

Constellation Radius Ratio values for 16 APSK

Code Rate	Constellation Radius Ratio (γ)
2/3	3.15
3/4	2.85
4/5	2.75
5/6	2.70
8/9	2.60
9/10	2.57

According to the DVB-S2 standard, 1 of 2 values is permissible for the radius of the outer circle (R2). R2 can be set in order to satisfy the following $[R_1]^2 + 3[R_2]^2 = 4$, or R2 can be simply set to 1. The channel characteristics typically determine which of these R2 values to choose.

2.2 32APSK Constellation

Figure 2 shows the bit mapping for data into the 32APSK constellation according to DVB-S2. As shown by the figure, the 32APSK modulation features constellation points arranged on three concentric circles.

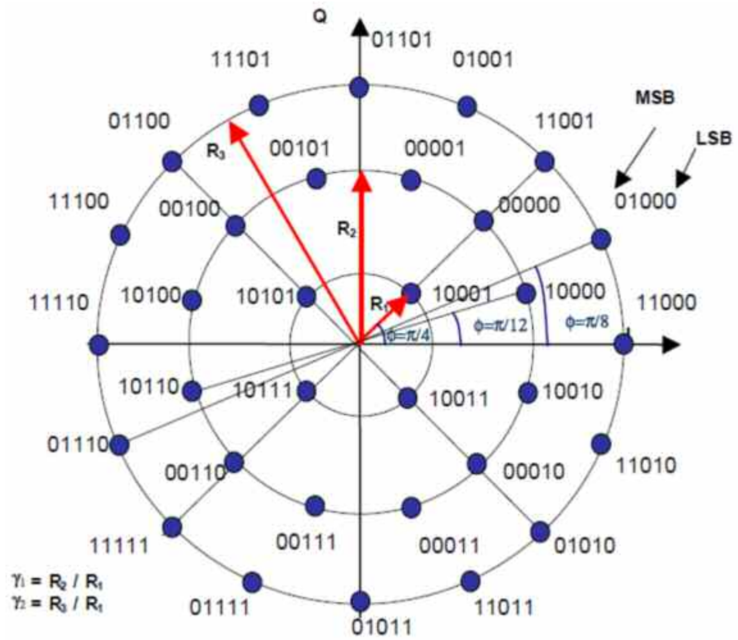


Figure 2: 32APSK Constellation Bit Mapping

Similar to the 16APSK modulation, the important parameters when making measurements are the Constellation Radius Ratios γ_1 and γ_2. These ratios define, respectively, the radius of the middle circle to that of the innermost circle, and the radius of the outermost circle to that of the innermost circle. The DVB-S2 standard defines different values of γ_1 and γ_2 according to which coding rate is used. Table 2 shows the possible values of γ_1 and γ_2 for the defined coding rates.

Table 2		
Constellation Radius Ratio values for 32 APSK		
Code Rate	γ_1	γ_2
3/4	2.84	5.27
4/5	2.72	4.87
5/6	2.64	4.64
8/9	2.54	4.33
9/10	2.53	4.30

According to the DVB-S2 standard, 1 of 2 values is permissible for the radius of the outermost circle (R3). R3 can be set in order to satisfy the equation $[R_1]^2 + 3[R_2]^2 + 4[R_3]^2 = 8$, or R3 can be simply set to 1. The channel characteristics typically determine which of these R3 values to choose.

2.3 DVB-S2 Frame Structure

The frame structure of the DVB-S2 signal is shown below in Figure 3. The first slot in the DVB-S2 frame is known as the PLHEADER. This header provides information such as a synchronization sequence, pilot signals, and information on the current frame such as modulation and coding rate.

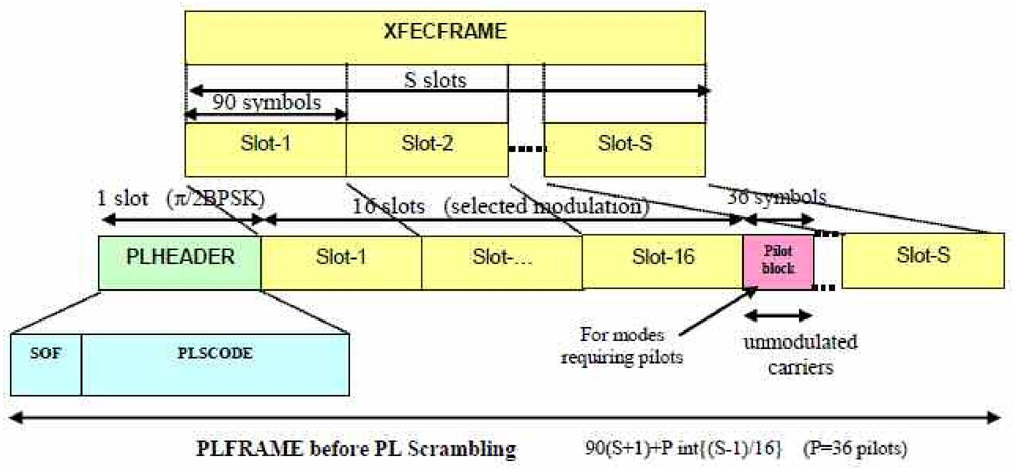


Figure 3: DVB-S2 Frame Structure

Note that the symbols included in the PLHEADER are pi/2 BPSK modulated. The standard defines these symbols to have a constellation radius of 1. It is necessary to consider these symbols when making modulation quality measurements, such as EVM and MER. These preamble symbols will overlap the APSK constellations when R2 (for 16APSK) and R3 (for 32APSK) are 1. However, when R2 and R3 are not set to 1, the pi/2 BPSK symbols do not overlap the APSK constellation points, requiring 4 additional symbols to be measured.

3 Configuring APSK Measurements

3.1 Custom Mappings for the Vector Signal Analyzer

The FSQ-K70 option for Rohde & Schwarz signal analyzers provides the possibility for the user to create custom mappings and modulations. The Vector Signal Analyzer mapping file (*.vam) can be imported into the signal analyzer and recalled during vector signal demodulation measurements.

Rohde & Schwarz provides a mapping editor called MAPWIZ that can be used to generate any arbitrary mapping. For more details on mapping files and the MAPWIZ tool, please view the MAPWIZ manual and FSQ-K70 operating manual listed in Section 4 of this document.

3.2 Mapping File Creation for APSK

Note: this section is optional for the reader. It is only provided to be instructive as to how the APSK mapping files were created. All necessary files have already been created and attached to this application note. Also, note that Matlab is required for this section and this section only, and it is also recommended to have a spreadsheet program such as Microsoft Excel.

Using the custom mapping feature described in section 3.1, files for all of the APSK modes in DVB-S2 were created and attached to this application note for convenience. To provide the user with an understanding of how these files were generated and what is involved, it may be instructive to provide an example. What follows is an example for the 16APSK coding rate 3/4 case.

Before creating the mapping file, it is first necessary to calculate the I and Q values based on the constellation radius ratios (see Table 1). A tool such as Microsoft Excel can simplify this process. If using Microsoft Excel, begin by listing the radiuses and angles of the constellation.

For this example, the value of R2 will be chosen according to the equation $[R_1]^2 + 3[R_2]^2 = 4$, and for the coding rate of 3/4, the radius ratio for R2/R1 = 2.85. The angles (Theta) can be determined by inspection from Figure 1. The I and Q values can thus be calculated by: I = R * cos(theta) and Q = R* sin(theta). Figure 4 shows an example of the I and Q calculations in MS Excel for the 16APSK coding rate 3/4 case.

Coding Rate 3/4, Gamma = 2.85			
Theta (deg)	**I**	**Q**	**R1**
45	0.28079	0.28079	0.39709
135	-0.28079	0.28079	0.39709
225	-0.28079	-0.28079	0.39709
315	0.28079	-0.28079	0.39709
Theta (deg)	**I**	**Q**	**R2**
15	1.09315	0.29291	1.13171
45	0.80024	0.80024	1.13171
75	0.29291	1.09315	1.13171
105	-0.29291	1.09315	1.13171
135	-0.80024	0.80024	1.13171
165	-1.09315	0.29291	1.13171
195	-1.09315	-0.29291	1.13171
225	-0.80024	-0.80024	1.13171
255	-0.29291	-1.09315	1.13171
285	0.29291	-1.09315	1.13171
315	0.80024	-0.80024	1.13171
345	1.09315	-0.29291	1.13171

Figure 4: I and Q calculation for 16APSK coding rate3/4

The next step is to create a list of the I and Q pairs in ascending order of the symbol bit values. These can be determined by using Figure 1 as a reference. Remember that there will also be pi/2 BPSK modulated symbols contained within the PLHEADER. These symbols are defined to be located at: I = +/-(1/ √2) and Q = +/-(1/ √2). Since these symbols do not overlap with any of the symbols from Figure 4, it is necessary to add new I and Q values to those calculated for the 16APSK constellation. 16 additional symbols are created for the PLHEADER, with reasoning described below.

The type of modulation that will be used for APSK is User-QAM (see MAPWIZ documentation). The allowable degrees of modulation for User-QAM are 2, 4, 8, 16, 32, 64, 128, and 256. Since there are 20 symbols to define, User 32QAM is the modulation type that is chosen. The first 16 symbols will be the 16APSK symbols according to Figure 1. The last 16 symbols will be the PLHEADER pi/2 BPSK symbols, which will have 4 overlapping symbols at each pi/2 BPSK constellation point (in order to fill out the table of 32 mandatory symbols). Figure 5 shows a listing of the I and Q pairs by symbol number for 16APSK coding rate 3/4.

Symbol (dec)	Symbol (bin)	I	Q
0	0000	0.80024	0.80024
1	0001	0.80024	-0.80024
2	0010	-0.80024	0.80024
3	0011	-0.80024	-0.80024
4	0100	1.09315	0.29291
5	0101	1.09315	-0.29291
6	0110	-1.09315	0.29291
7	0111	-1.09315	-0.29291
8	1000	0.29291	1.09315
9	1001	0.29291	-1.09315
10	1010	-0.29291	1.09315
11	1011	-0.29291	-1.09315
12	1100	0.28079	0.28079
13	1101	0.28079	-0.28079
14	1110	-0.28079	0.28079
15	1111	-0.28079	-0.28079
16	10000	0.70701	0.70701
17	10001	0.70701	-0.70701
18	10010	-0.70701	0.70701
19	10011	-0.70701	-0.70701
20	10100	0.70701	0.70701
21	10101	0.70701	-0.70701
22	10110	-0.70701	0.70701
23	10111	-0.70701	-0.70701
24	11000	0.70701	0.70701
25	11001	0.70701	-0.70701
26	11010	-0.70701	0.70701
27	11011	-0.70701	-0.70701
28	11100	0.70701	0.70701
29	11101	0.70701	-0.70701
30	11110	-0.70701	0.70701
31	11111	-0.70701	-0.70701

Figure 5: I and Q pairs listed in symbol order for 16APSK coding rate 3/4.

Finally, in order to import into the MAPWIZ tool, create a new file in MS Excel and then cut and paste only the I and Q columns from above, listed in the order shown. Do not include any column headers and remove all formatting (tip: use Edit → Paste Special → Values in Excel). Save the file as a “Text Tab Delimited (*.txt)” file in Excel. Do not save as an Excel file because it will be unreadable by the MAPWIZ tool. The file is now ready for importing into MAPWIZ.

Start Matlab and activate the MAPWIZ tool by typing “mapwiz” at the command line. After the tool has started, select “User-QAM” as the modulation type. Go to “Import const”, choose “ASCII” as the data type, and select the file that was created from Excel (hint: be sure to change the File Type to *.txt files). The I and Q values will be imported into the tool. To complete the process, provide information in the “Descriptions” fields. The “Mapping Name” is the constellation name that will appear in the Signal Analyzer once the mapping file is imported. Go to “Save As…” and save as a *.vam file to complete the process.

See Figure 6 for the text file that was imported into MAPWIZ for the 16APSK coding rate 3/4 example.

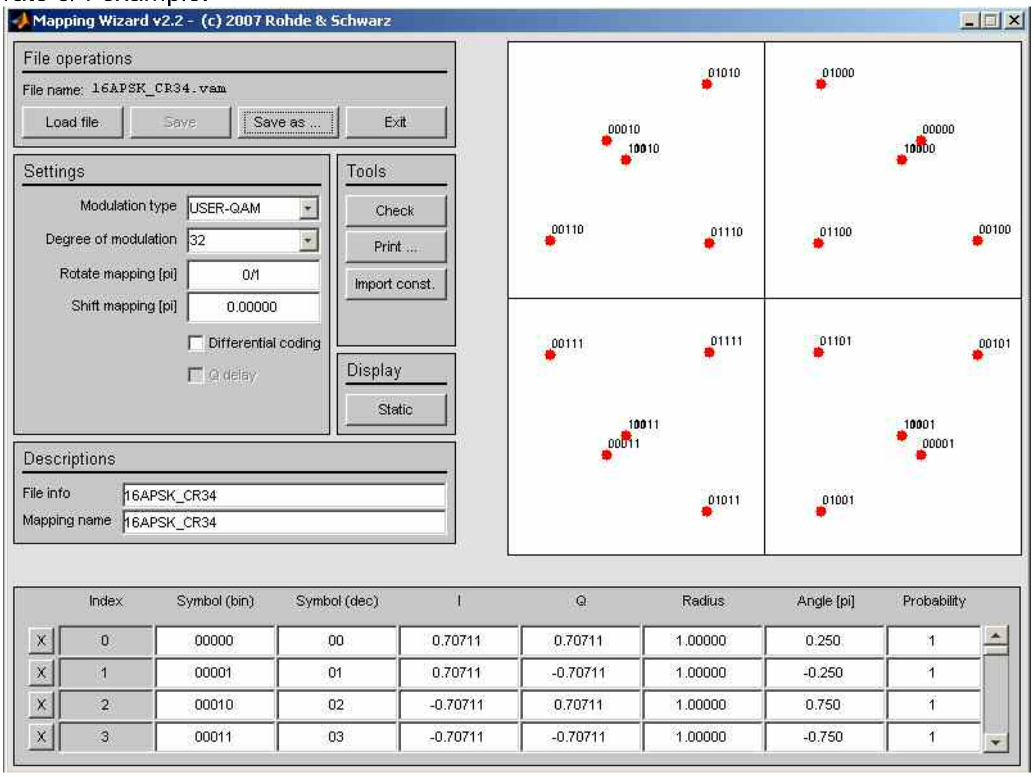


Figure 6: Import of 16APSK Coding Rate 3/4 File into MAPWIZ

3.3 Importing the Mapping Files into the Signal Analyzer

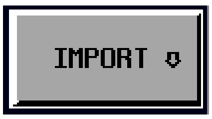
Included with this application note are a total of 24 mapping files. There are 6 different coding rates for 16APSK and 5 different coding rates for 32APSK. For each of the 16APSK coding rates a file was generated for the two permissible values of R2. For each of the 32APSK coding rates a file was generated for the two permissible values of R3. Finally, for completeness, a file for each of the QPSK and 8PSK symbol mappings for DVB-S2 was included.

Start with the Preset key in the upper left corner of the instrument.

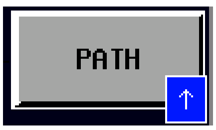
Press the VSA softkey towards the bottom of the display.

Press the NEXT key towards the bottom right of the display.

Press the IMPORT softkey.

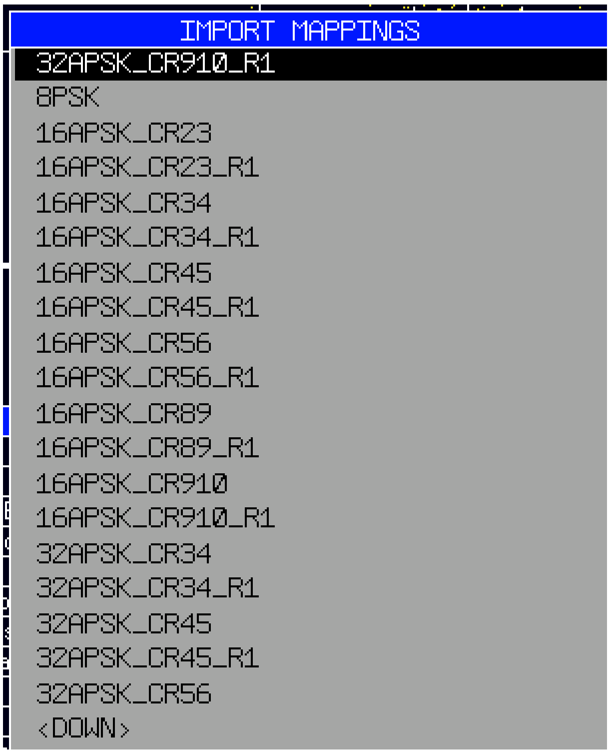


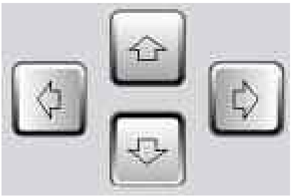
Press the PATH softkey. A Windows Explorer window will appear. Browse to the directory in which the files are stored and press ‘Open’. Tip: Place all the DVB-S2 files on a USB memory stick and select the USB stick (or subdirectory) as the location where the files desired to be imported are stored.

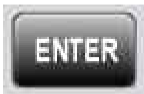


Press the MAPPINGS softkey.

A window will appear which shows all mapping files that are available to be imported. For each file, use the arrow keys and press enter to import the file. It is necessary to repeat this for each file to be imported.

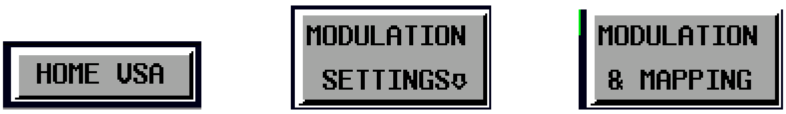






3.4 Organization of Imported Mappings

In order to locate and select the imported mappings, begin by going to HOME VSA → MODULATION SETTINGS → MODULATION & MAPPING.



When selecting the Modulation & Mapping setting, it is helpful to understand how these files are organized within the instrument's user interface. The QPSK and 8PSK files will appear under the Modulation category 'PSK'. All of the APSK files will appear under the Modulation category 'USER-QAM'. As described in section 3.2, 'USER-QAM' is the modulation type that was defined for the APSK files when the mappings were created.

Within the USER-QAM category, there will be subcategories entitled 16ary, 32ary, and 64ary. The 16APSK mappings can be found in both the 16ary and 32ary subcategories. If the preamble and payload symbols of the signal being measured are overlapping (when R2 = 1 as described in section 2.1 and 2.3), there will only be 16 symbols for the constellation and these mappings are found in the 16ary subcategory. Within the 16ary subcategory, mappings for the 6 coding rates of APSK will be found. If the preamble and payload symbols of the signal being measured are not overlapping (i.e. when $R2 \neq 1$ as described in section 2.1 and 2.3), there will be 20 symbols for the constellation and thus these mappings are found in the 32ary subcategory. Within the 32ary subcategory, there will be mappings for the 6 coding rates of 16APSK.

The 32APSK mappings are organized in a similar way as for the 16APSK. For signals where the preamble and payload symbols overlap, the mappings will be found in the 32ary subcategory since there are only 32 symbols in the constellation. For signals where the preamble and payload symbols don't overlap, the mappings will be found in the 64ary subcategory since there are 36 symbols in the constellation.

Table 3 below summarizes the organization of the imported mappings from this application note. The mapping names are as they appear in the Signal Analyzer user interface.

Table 3

Mapping Files Included with Application Note

Mapping Name	Modulation and Coding	Outer Constellation Radius	# of Constellation Points	Mapping Category / Subcategory
DVB-S2 QPSK	QPSK (All Coding Rates)	N/A	4	PSK / QPSK
DVB-S2 8PSK	8PSK (All Coding Rates)	N/A	8	PSK / 8PSK
16APSK_CR23	16APSK 2/3	R2 = 1.13578	20	USER-QAM / 32ary
16APSK_CR23_R1	16APSK 2/3	R2 = 1	16	USER-QAM / 16ary
16APSK_CR34	16APSK 3/4	R2 = 1.13171	20	USER-QAM / 32ary
16APSK_CR34_R1	16APSK 3/4	R2 = 1	16	USER-QAM / 16ary
16APSK_CR45	16APSK 4/5	R2 = 1.13006	20	USER-QAM / 32ary
16APSK_CR45_R1	16APSK 4/5	R2 = 1	16	USER-QAM / 16ary
16APSK_CR56	16APSK 5/6	R2 = 1.12917	20	USER-QAM / 32ary
16APSK_CR56_R1	16APSK 5/6	R2 = 1	16	USER-QAM / 16ary
16APSK_CR89	16APSK 8/9	R2 = 1.12724	20	USER-QAM / 32ary
16APSK_CR89_R1	16APSK 8/9	R2 = 1	16	USER-QAM / 16ary

Table 3				
Mapping Files Included with Application Note				
Mapping Name	**Modulation and Coding**	**Outer Constellation Radius**	**# of Constellation Points**	**Mapping Category / Subcategory**
16APSK_CR910	16APSK 9/10	R2 = 1.12662	20	USER-QAM / 32ary
16APSK_CR90_R1	16APSK 9/10	R2 = 1	16	USER-QAM / 16ary
32APSK_CR34	32APSK 3/4	R2 = 1.27681	36	USER-QAM / 64ary
32APSK_CR34_R1	32APSK 3/4	R2 = 1	32	USER-QAM / 32ary
32APSK_CR45	32APSK 3/4	R2 = 1.26770	36	USER-QAM / 64ary
32APSK_CR45_R1	32APSK 3/4	R2 = 1	32	USER-QAM / 32ary
32APSK_CR56	32APSK 3/4	R2 = 1.26269	36	USER-QAM / 64ary
32APSK_CR56_R1	32APSK 3/4	R2 = 1	32	USER-QAM / 32ary
32APSK_CR89	32APSK 3/4	R2 = 1.25421	36	USER-QAM / 64ary
32APSK_CR89_R1	32APSK 3/4	R2 = 1	32	USER-QAM / 32ary
32APSK_CR910	32APSK 3/4	R2 = 1.25335	36	USER-QAM / 64ary
32APSK_CR90_R1	32APSK 3/4	R2 = 1	32	USER-QAM / 32ary

Figure 7 below shows how to locate, in the user interface, the QPSK file that is imported. Figure 8 shows how to recall the 8PSK file that is imported. Figure 9 shows how to recall the 16 APSK files (with outer radius R2=1) that are imported. Figure 10 shows how to recall the 32 APSK files (with outer radius R3=1) and 16 APSK files (with outer radius R2>1) that are imported. Finally, Figure 11 shows how to recall the 32 APSK files (with outer radius R3>1) that are imported.

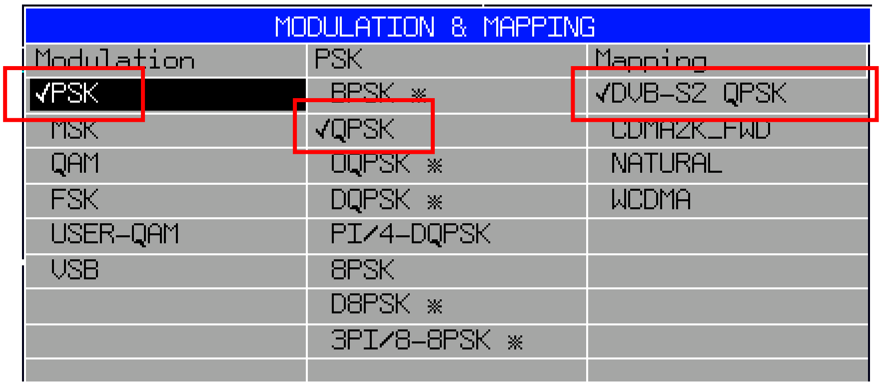


Figure 7: QPSK Imported Mapping

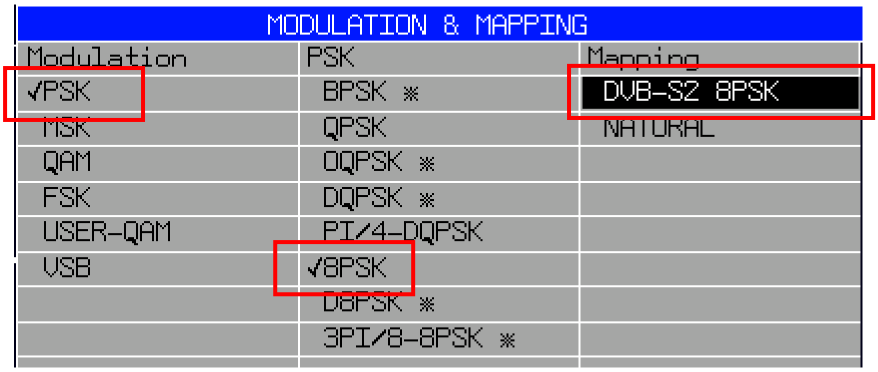


Figure 8: 8PSK Imported Mapping

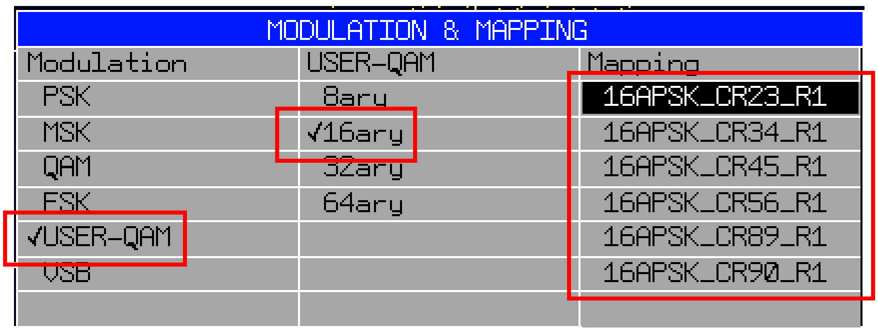


Figure 9: 16APSK w/ R2=1 Imported Mappings

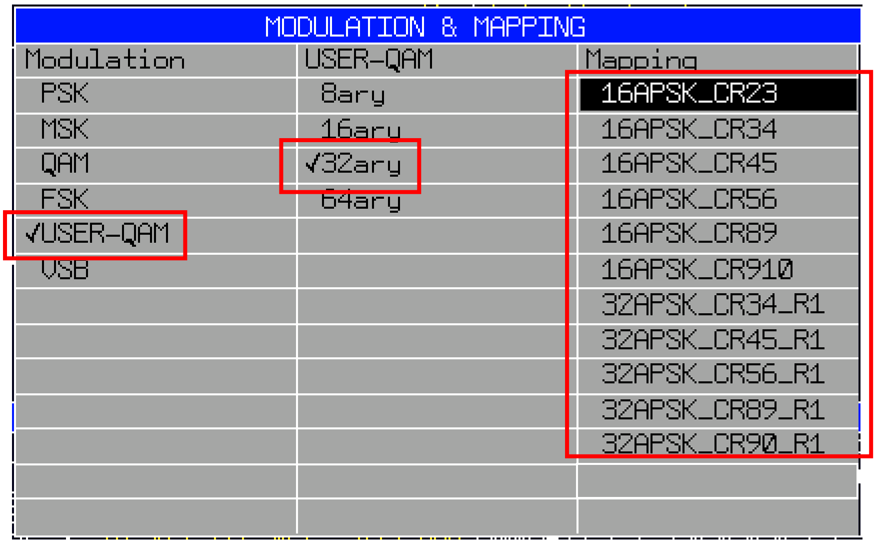


Figure 10: 16APSK w/ R2>1 and 32APSK w/ R3=1 Imported Mappings

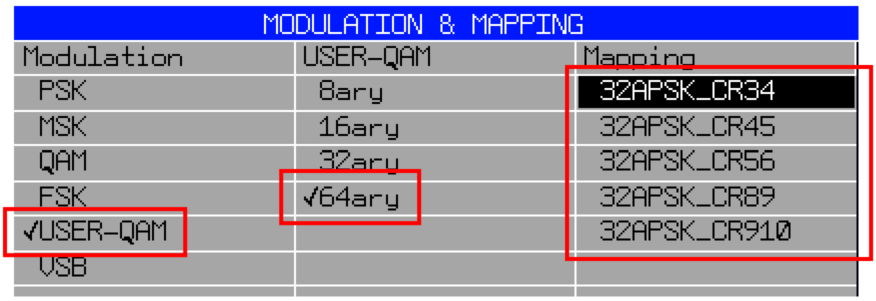
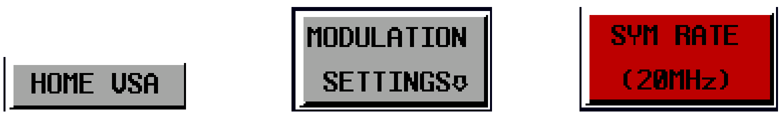


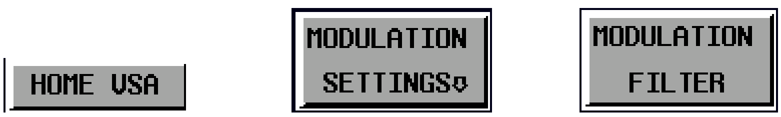
Figure 11: 32APSK w/R3=1 Imported Mappings

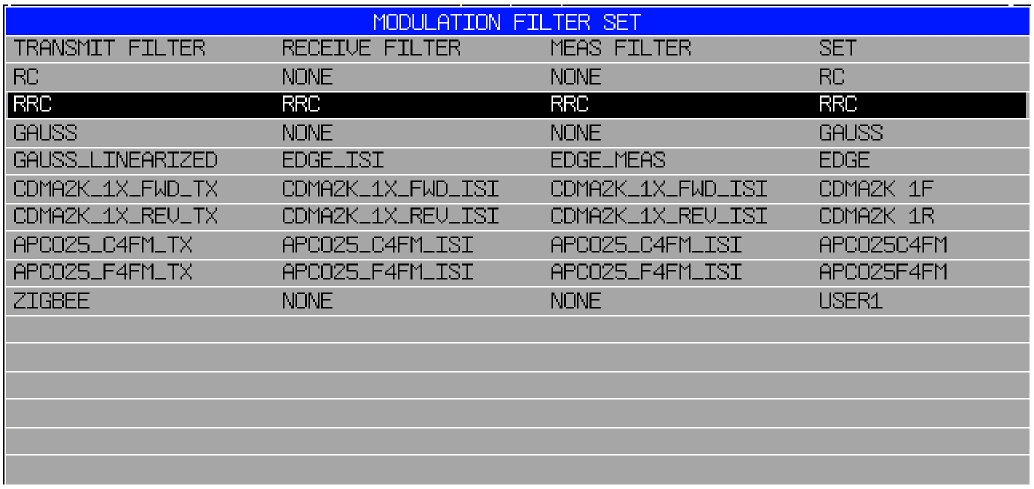
3.5 Configuring the Remaining Modulation Parameters

Set the symbol rate by going to HOME VSA → MODULATION SETTINGS → SYM RATE. The symbol rate for DVB-S2 can vary from 1 Msps to a maximum of 42 Msps, depending on the coding rate and constellation. Note: For a symbol rate > 25 Msps, it is necessary to have an FSQ configured with FSQ-B72 option (see Table 4).



Set the filter setting by going to HOME VSA → MODULATION SETTINGS → MODULATION FILTER. Select the RRC Filter Set.





MODULATION FILTER SET			
TRANSMIT FILTER	RECEIVE FILTER	MEAS FILTER	SET
RC	NONE	NONE	RC
RRC	RRC	RRC	RRC
GAUSS	NONE	NONE	GAUSS
GAUSS_LINEARIZED	EDGE_ISI	EDGE_MEAS	EDGE
CDMA2K_1X_FWD_TX	CDMA2K_1X_FWD_ISI	CDMA2K_1X_FWD_ISI	CDMA2K 1F
CDMA2K_1X_REV_TX	CDMA2K_1X_REV_ISI	CDMA2K_1X_REV_ISI	CDMA2K 1R
APCO25_C4FM_TX	APCO25_C4FM_ISI	APCO25_C4FM_ISI	APCO25C4FM
APCO25_F4FM_TX	APCO25_F4FM_ISI	APCO25_F4FM_ISI	APCO25F4FM
ZIGBEE	NONE	NONE	USER1

Set the Filter Rolloff by going to HOME VSA → MODULATION SETTINGS → ALFA/BT. DVB-S2 allows for values of either 0.2, 0.25, or 0.35 for this parameter.

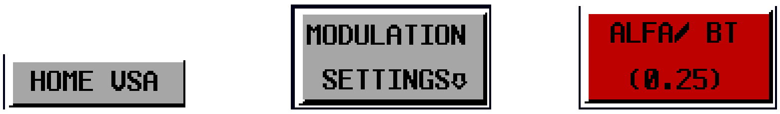
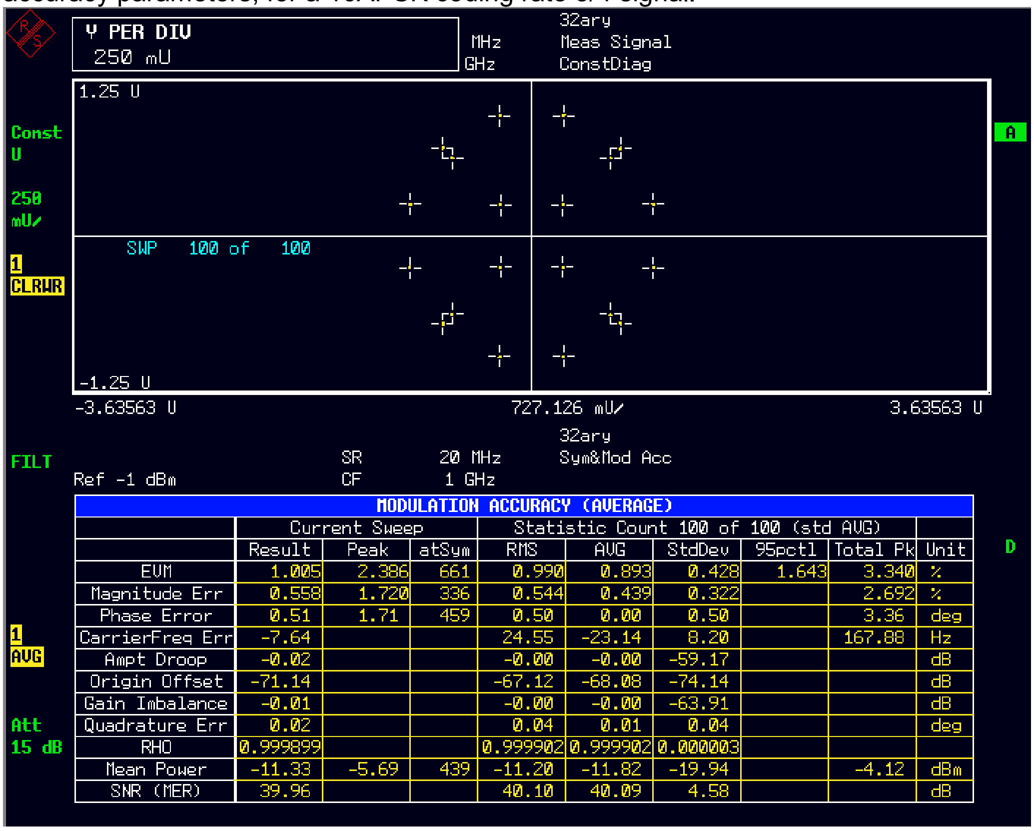


Figure 12 below shows an example constellation measurement, along with modulation accuracy parameters, for a 16APSK coding rate 3/4 signal.



MODULATION ACCURACY (AVERAGE)									
	Current Sweep			Statistic Count 100 of 100 (std AVG)					
	Result	Peak	atSym	RMS	AVG	StdDev	95pctl	Total Pk	Unit
EVM	1.005	2.386	661	0.990	0.893	0.428	1.643	3.340	%
Magnitude Err	0.558	1.720	336	0.544	0.439	0.322		2.692	%
Phase Error	0.51	1.71	459	0.50	0.00	0.50		3.36	deg
CarrierFreq Err	-7.64			24.55	-23.14	8.20		167.88	Hz
Ampt Droop	-0.02			-0.00	-0.00	-59.17			dB
Origin Offset	-71.14			-67.12	-68.08	-74.14			dB
Gain Imbalance	-0.01			-0.00	-0.00	-63.91			dB
Quadrature Err	0.02			0.04	0.01	0.04			deg
RHO	0.999899			0.999902	0.999902	0.000003			
Mean Power	-11.33	-5.69	439	-11.20	-11.82	-19.94		-4.12	dBm
SNR (MER)	39.96			40.10	40.09	4.58			dB

Figure 12: 16APSK Measurement

3.6 Instrument Configurations for DVB-S2 Measurements

Rohde & Schwarz provides several possible options for signal and spectrum analyzers that can analyze the DVB-S2 signals. Table 4 shows a chart listing all of the instruments available to use the signal mappings from this application note, along with the required options and maximum achievable DVB-S2 symbol rates. It is recommended to contact your local Rohde & Schwarz representative to determine the instrument and configuration that is best suited to your application.

Table 4

DVB-S2 Instrument Configurations

Instrument	Options	Maximum DVB-S2 Symbol Rate
FSQ3, FSQ8, FSQ26, FSQ40	FSQ-K70	25 Msps
FSQ3, FSQ8, FSQ26, FSQ40	FSQ-K70 and FSQ-B72	42 Msps (81.6 Msps generally)
FSG8, FSG13	FSQ-K70	25 Msps
FSMR3, FSMR26, FSMR50	FSQ-K70	25 Msps
FSUP8, FSUP26, FSUP50	FSQ-K70	6.4 Msps
FSU3, FSU8, FSU26, FSU46, FSU50, FSU67	FSU-B73	6.4 Msps

4 Literature

- DVB-S2 Standard ETSI EN 302 307 v1.2.1
- R&S FSQ-K70 Operating Manual
- Introduction to “Mapwiz” Manual
- Fischer, Walter (2008). *Digital Video and Audio Broadcasting Technology: A Practical Engineering Guide*. (Available from Rohde & Schwarz.)

5 Additional Information

6 Ordering Information

Ordering Information		
Signal Analyzer		
FSQ3	**3.6 GHz Signal Analyzer**	**1155.5001.03**
FSQ8	**8 GHz Signal Analyzer**	**1155.5001.08**
FSQ26	**26 GHz Signal Analyzer**	**1155.5001.26**
FSQ40	**40 GHz Signal Analyzer**	**1155.5001.40**
FSG8	**8 GHz Signal Analyzer**	**1309.0002.08**
FSG13	**13.6 GHz Signal Analyzer**	**1309.0002.13**
FSMR3	**3.6 GHz Measuring Receiver**	**1166.3311.03**
FSMR26	**26 GHz Measuring Receiver**	**1166.3311.26**
FSMR50	**50 GHz Measuring Receiver**	**1166.3311.50**
FSUP8	**8 GHz Signal Source Analyzer**	**1166.3505.09**
FSUP26	**26 GHz Signal Source Analyzer**	**1166.3505.27**
FSUP50	**50 GHz Signal Source Analyzer**	**1166.3505.51**
FSU3	**3.6 GHz Spectrum Analyzer**	**1166.1660.03**
FSU8	**8 GHz Spectrum Analyzer**	**1166.1660.08**
FSU26	**26 GHz Spectrum Analyzer**	**1166.1660.26**
FSU46	**46 GHz Spectrum Analyzer**	**1166.1660.46**
FSU50	**50 GHz Spectrum Analyzer**	**1166.1660.50**
FSU67	**67 GHz Spectrum Analyzer**	**1166.1660.67**
FSQ-K70	Firmware General Purpose Vector Signal Analyzer	1161.8038.02
FSQ-B72	I/Q Bandwidth Extension	1157.0336.02
FSU-B73	Vector Signal Analysis Hardware and Firmware	1169.5696.03

About Rohde & Schwarz
Rohde & Schwarz is an independent group of companies specializing in electronics. It is a leading supplier of solutions in the fields of test and measurement, broadcasting, radiomonitoring and radiolocation, as well as secure communications. Established 75 years ago, Rohde & Schwarz has a global presence and a dedicated service network in over 70 countries. Company headquarters are in Munich, Germany.

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