VAMOS
Technology Introduction
Application Note

R&S®SMU200A	R&S®FSQ
R&S®SMBV100A	R&S®FSG
R&S®AMU200A	R&S®FSV
R&S®CMW500	R&S®FSVR

Existing GSM mobile communication systems have the potential to double voice capacity by adding the “Voice services over Adaptive Multi-user channels on One Slot” (VAMOS) feature as specified in the 3rd Generation Partnership Project (3GPP) GSM/EDGE Radio Access Network (GERAN) Release 9 specifications. This application note describes the VAMOS feature from an air interface perspective in detail and specifically illustrates the VAMOS testing solution offered by Rohde & Schwarz test equipment.

VAMOS

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ROHDE&SCHWARZ

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1 Introduction

In the late 80s the GSM technology was originally designed to efficiently support voice services. In 1992 the first networks were launched. Meanwhile close to 500 commercial networks in 190 countries around the globe are in operation, i.e. GSM has become a globally adopted technology. Advancement throughout 20 years of operations have been manifold, e.g. enhancing GSM with GPRS/EDGE to support data services like e-mailing and web browsing. The latest remarkable improvement is called VAMOS (Voice services over Adaptive Multi-user channels on One Slot) and was recently added to 3GPP GERAN Release 9 specifications. It essentially enables to double transceiver peak capacity, since a single radio resource now supports two independent voice users. This greatly serves GSM network operator targets to improve competitiveness and profitability having in mind both, aggressive network expansions in emerging markets and the advent of new wireless services such as machine-to-machine (M2M) communication. The solution introduces an Adaptive QPSK (AQPSK) modulation scheme, new orthogonal training sequences and a VAMOS subchannel power control feature which is fully backward compatible, i.e. it can be introduced without impact on existing end user devices.

This application note describes the technology enhancements introduced in 3GPP specifications to improve speech capacity as described above. Both physical layer and higher layer impact is described in section 2 with focus on radio protocols. Additionally section 3 illustrates how to verify the new functionality for both base stations and user devices using test equipment from Rohde & Schwarz. Chapters 4, 5 and 6 provide additional information including literature references and ordering information.

This application note assumes basic knowledge of GSM radio protocols.

2 General

VAMOS enables multiplexing of two users simultaneously on the same physical resource in the circuit switched mode both in downlink and in uplink, using the same timeslot, the same frequency (Absolute Radio Frequency Carrier Number - ARFCN) and the same TDMA frame number (Figure 1).

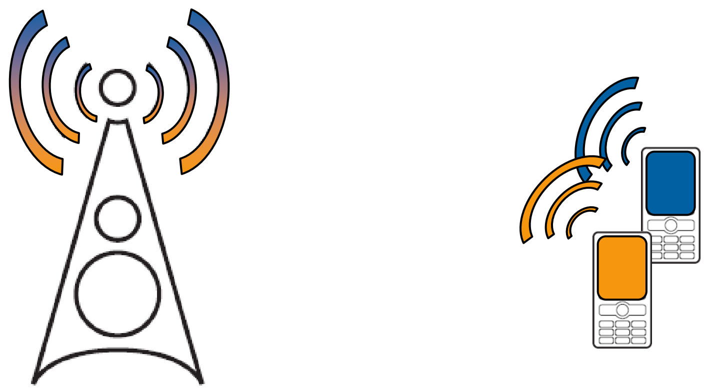

Figure 1: VAMOS air interface

Hence, a basic physical channel capable of VAMOS supports up to four traffic channels (TCH) along with their associated control channels (FACCH and SACCH) if both the VAMOS feature and the half rate feature are applied. VAMOS does not require new voice channels to be defined. It is an extension of the currently defined full and half rate channels, including Adaptive Multi Rate (AMR). Figure 2 illustrates the different possibilities to schedule full rate (FR), half rate (HR), VAMOS full rate (VFR) and VAMOS half rate (VHR) users in the time domain. A pair of traffic channels along with their associated control channels sharing the same time and frequency resource are referred to as a *VAMOS pair*. Note that the network may allocate legacy, i.e. non VAMOS capable users onto a VAMOS pair provided that none of the new orthogonal training sequences are allocated to the legacy user device.

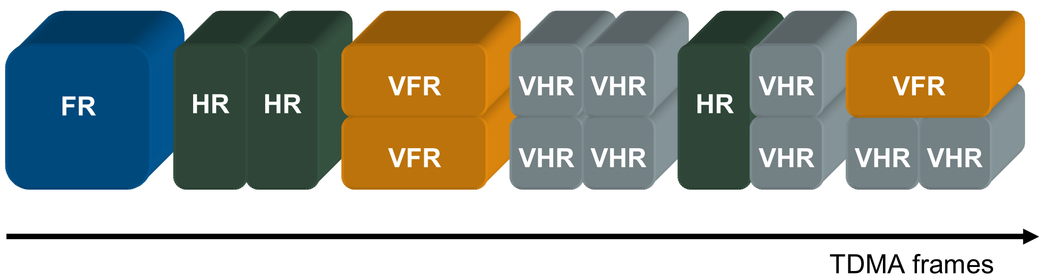

Figure 2: Possible allocations of FR, HR, VFR and VHR users on time slots

Details of the downlink and uplink operation are described in the following sections. Common to both transmission directions is the introduction of a new set of training sequences, that allow to distinguish between the two VAMOS users representing a VAMOS pair. The new set of training sequences has been found based on computational simulation work in order to obtain the best possible result with respect to cross correlation properties between existing and new training sequences.

On each side (base station and user device) the receiver uses its assigned training sequence for channel estimation and de-correlation processes, thus eliminating the data from the paired VAMOS user allocated to the same resource. As cross-correlation properties of the training sequences are not ideal, this leads to additional interference experienced by the user device. Table 1 and Table 2 below present both the existing set (TSC Set 1) and the new set (TSC Set 2) of training sequences.

Training Sequence Code (TSC)	Training sequence bits
0	(0,0,1,0,0,1,0,1,1,1,0,0,0,0,1,0,0,0,1,0,0,1,0,1,1,1)
1	(0,0,1,0,1,1,0,1,1,1,0,1,1,1,1,0,0,0,1,0,1,1,0,1,1,1)
2	(0,1,0,0,0,0,1,1,1,0,1,1,1,0,1,0,0,1,0,0,0,0,1,1,1,0)
3	(0,1,0,0,0,1,1,1,1,0,1,1,0,1,0,0,0,1,0,0,0,1,1,1,1,0)
4	(0,0,0,1,1,0,1,0,1,1,1,0,0,1,0,0,0,0,0,1,1,0,1,0,1,1)
5	(0,1,0,0,1,1,1,0,1,0,1,1,0,0,0,0,0,1,0,0,1,1,1,0,1,0)
6	(1,0,1,0,0,1,1,1,1,1,0,1,1,0,0,0,1,0,1,0,0,1,1,1,1,1)
7	(1,1,1,0,1,1,1,1,0,0,0,1,0,0,1,0,1,1,1,0,1,1,1,1,0,0)

Table 1: TSC Set 1

Training Sequence Code (TSC)	Training sequence bits
0	(0,1,1,0,0,0,1,0,0,0,1,0,0,1,0,0,1,1,1,1,0,1,0,1,1,1)
1	(0,1,0,1,1,1,1,0,1,0,0,1,1,0,1,1,1,0,1,1,1,0,0,0,0,1)
2	(0,1,0,0,0,0,0,1,0,1,1,0,0,0,1,1,1,0,1,1,1,0,1,1,0,0)
3	(0,0,1,0,1,1,0,1,1,1,0,1,1,1,0,0,1,1,1,1,0,1,0,0,0,0)
4	(0,1,1,1,0,1,0,0,1,1,1,1,0,1,0,0,1,1,1,0,1,1,1,1,1,0)
5	(0,1,0,0,0,0,0,1,0,0,1,1,0,1,0,1,0,0,1,1,1,1,0,0,1,1)
6	(0,0,0,1,0,0,0,0,1,1,0,1,0,0,0,0,1,1,0,1,1,1,0,1,0,1)
7	(0,1,0,0,0,1,0,1,1,1,0,0,1,1,1,1,1,1,0,0,1,0,1,0,0,1)

Table 2: TSC Set 2

If at least one user device assigned to a *VAMOS pair* indicates explicit support for VAMOS, then the network uses a training sequence chosen from TSC Set 1 for one of the VAMOS subchannels in the *VAMOS pair* and the training sequence with the same training sequence code selected from TSC Set 2 for the other *VAMOS subchannel* in the *VAMOS pair.*

2.1 Downlink operation

In downlink direction the key enhancement is the introduction of an Adaptive QPSK (AQPSK) modulation scheme in contrast to GMSK modulation as used before. This enables to schedule two users on in-phase (I) (subchannel 1) and quadrature-phase (Q) (subchannel 2). In addition, allocation of different power levels for each subchannel is possible, as shown in Figure 3.

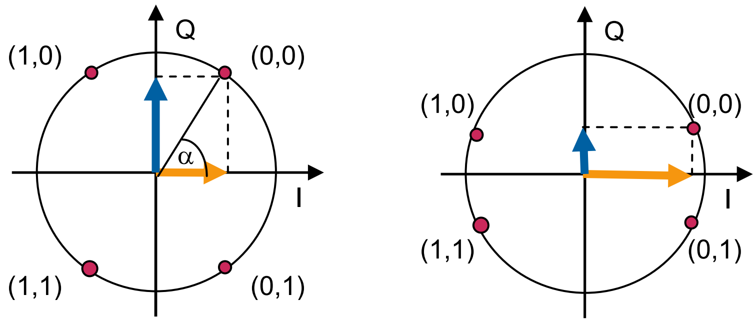

Figure 3: AQPSK constellation examples

The ratio of power between the Q and I channels is defined as the Subchannel Power Imbalance Ratio (SCPIR). The value of the SCPIR is given by

$$SCPIR = 20 \times \log_{10}\left(\tan(\alpha)\right) dB = \frac{Power_{Subchannel2}}{Power_{Subchannel1}},$$

where α shall be chosen such that $|SCPIR| \leq 10\,dB$.

Consequently, extra power can be assigned to one subchannel at the expense of the paired subchannel within the above stated limit. This is essentially the mechanism that allows legacy, non-VAMOS and VAMOS-capable devices to share the same frequency and time slot. The non-VAMOS devices will require higher power to compensate for the interference arising due to the cross-correlation process on the I and Q channels. The same mechanism can be used to allocate different power levels to users experiencing different radio conditions on the same resource. The VAMOS subchannel power control feature is symmetric, i.e. if one of the paired users has a SCPIR of 6dB, the other will have a SCPIR of -6dB.

As with existing modulation schemes (8PSK, QPSK, 16QAM and 32QAM) the symbols are continuously rotated with φ radians per symbol before pulse shaping. Table 3 shows φ depending on the modulation highlighting the new value for AQPSK modulation.

Modulation	8PSK	QPSK	16QAM	32QAM	AQPSK
φ	3π/8	3π/4	π/4	– π/4	π/2

Table 3: Symbol rotation φ depending on modulation

Note that AQPSK modulation is only used if both users have bursts scheduled for transmission. If one of the paired VAMOS users is in DTX state, i.e. voice transmission is interrupted because of speech pauses, the base station will use traditional GMSK modulation instead of AQPSK.

2.2 Uplink operation

For uplink operation the impact on the user device complexity has been kept to a minimum as the GMSK modulation scheme is maintained. The new training sequence set (TSC Set 2) needs to be implemented for VAMOS capable user devices, however apart from this no other modification is required (see also chapter 2.3 on different user device implementations). From a user device perspective uplink operation is fully backward compatible as modulation time and frequency structure are all preserved which allows legacy user devices to be paired with VAMOS capable devices. The base station receiver side will require an update, since uplink operation relies on the base station receiver's capability to distinguish and demodulate two simultaneous GMSK signals by applying a multi-user detection algorithm. However, as basic hardware decisive parameters such as carrier bandwidth and time slots remain unchanged, this is likely to only require software updates to existing base stations.

2.3 VAMOS UE categories

As with any improvement feature impacting the device, overall network capacity gain depends on VAMOS capable user device penetration in the network. In order to accelerate adoption of the feature, different support levels for VAMOS are foreseen. VAMOS I capable user devices need to fulfill less stringent performance requirements than VAMOS II capable user devices. VAMOS I user devices are anticipated having the same receiver performance as existing SAIC (Single Antenna Interference Cancellation) devices, i.e. those that fulfill Downlink Advanced Receiver Performance (DARP) Phase 1 requirements in [2]. The requirements under various propagation conditions are not fully specified yet, however it is expected that SAIC user devices will fulfill VAMOS I requirements by implementing TSC Set 2 only, i.e. without the need to modify the receiver structure. Note that all VAMOS user devices are required to satisfy all DARP phase I performance requirements. Consequently, it is expected that VAMOS I user devices will quickly arrive on the market.
VAMOS II user devices must cope with strong negative SCIPR values, which will likely require implementation of joint detection techniques in the receiver. Therefore VAMOS I and II requirements will differ by verifying voice performance at different SCPIR proof points. VAMOS I user devices will be tested at SCPIR = -4dB, 0dB and 4dB, whereas VAMOS II user devices will need to fulfill reference performance additionally at SCPIR = -8dB and SCPIR = -10dB.

2.3.1 Shifted SACCH for VAMOS II user devices

Speech data is typically not present at all times for transmission on a link, so the link can enter discontinuous transmission (DTX) mode. The speech activity period is expected to be in the region of 50%. When a speech link is in DTX, the transmitting side (either base station or end user device) only needs transmit slots containing SACCH data and silence descriptor (SID) data. In this case, the other user link on a given VAMOS channel becomes a GMSK transmission on other TDMA frames, which leads to significant performance gains for the speech channel from DTX. The SACCH channel, however, is always transmitted for both VAMOS channels, irrespective of their DTX state. Thus the SACCH channel performance will on average be relatively worse compared to its accompanying speech channel data. The 3GPP GERAN standardization defined a scheme as illustrated in Tables 4 and 5 for the so-called shifted SACCH concept, which improves the performance by shifting SACCH slots to a different position (T: Traffic slots, S: SACCH slots, I: Idle slots). This improvement has been specified for VAMOS II user devices only.

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
U_1	T	T	T	T	T	T	T	T	T	T	T	T	S	T	T	T	T	T	T	T	T	T	T	T	T	I
U_2	T	T	T	T	T	T	T	T	T	T	T	T	T	S	T	T	T	T	T	T	T	T	T	T	T	I

Table 4: Multi frame structure with two full rate TCHs applying the shifted SACCH concept

	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
U_1	T		T		T		T		T		T		S	T		T		T		T		T		T		
U_2		T		T		T		T		T		T			T		T		T		T		T		T	S
U_3	T		T		T		T		T		T		T	S		T		T		T		T		T		
U_4		T		T		T		T		T		T			T		T		T		T		T		S	T

Table 5: Multi frame structure with four half rate TCHs applying the shifted SACCH concept

2.4 VAMOS performance requirements

The VAMOS performance requirements are specified in [2] for both the UE and the base station including traffic and control channels. Generally a certain Frame Error Rate (FER) and Residual Bit Error Rate (RBER1b / RBER2) limit needs to be achieved the same way as for non VAMOS voice transmissions. Additionally C/I performance has to be verified, i.e. a certain reference performance has to be achieved while co-channel or adjacent carrier interfering signals are present. As mentioned above VAMOS I mobiles have specified performance limits at downlink SCPIR of +4dB, 0dB and -4dB whereas VAMOS II mobiles have additional proof points at SCPIR of -8dB and -10dB. All base station receivers need to fulfill performance requirements at uplink SCPIR of 0dB and -10dB. Note that for uplink in VAMOS mode, both interference and sensitivity limited cases, VAMOS subchannel 1 is offset in time and frequency with respect to VAMOS subchannel 2 [Annex Q5 in [2]]. Annex Q.6 in [2] specifies four different test scenarios for C/I testing covering synchronous single co-channel interferer, synchronous multiple interferer, asynchronous single co-channel interferer and asynchronous multiple interferer scenarios.

2.5 Higher layer modifications

VAMOS capable user devices need to inform the network about their capability in the uplink direction in order to make use of the feature. Signalling User devices indicate their VAMOS capability in uplink using two bits as part of the classmark 3 information as defined in the specification [1] and shown in Table 6.

Bits	**2**	**1**	
	0	0	VAMOS not supported
	0	1	VAMOS I supported
	1	0	VAMOS II supported
	1	1	Shall not be used, If the value '11' is received by the network, it shall be interpreted as '10'

Table 6: Mobile station classmark 3 information element

In downlink the necessity to signal that VAMOS is used during a connection is less obvious on first glance, because a VAMOS capable device has to be able to work in VAMOS mode and in non-VAMOS mode. However, whilst VAMOS I mobiles are expected to be based on a legacy DARP Phase 1 receiver, VAMOS II mobiles will be based on architectures which can better make use of the presence of an other synchronous subchannel signal. In particular, VAMOS II devices are expected to have good performance in VAMOS when receiving VAMOS signals at strong negative SCPIR.
Simulation results in the GERAN standardization showed that for VAMOS II architectures based on joint detection receivers, there would be a non-negligible loss in performance when these VAMOS level II devices operate in non-VAMOS mode, if VAMOS mode is not signaled in advance.
In consequence a downlink signalling method is introduced which allows VAMOS use to be signalled to an end user device within the following commands:

- Assignment Command
- Channel Mode Modify
- Handover Command

The respective information element modified in [3] are Channel Mode and Channel Mode 2 according to Table 7 and 8 below.

8	**7**	**6**	**5**	**4**	**3**	**2**	**1**
	Channel Mode IEI						
Mode							

Table 7: Channel Mode information element (2 octets)

The mode field is given as follows:
0 0 0 0 0 0 0 0 signalling only
0 0 0 0 0 0 0 1 speech full rate or half rate version 1
1 1 0 0 0 0 0 1 speech full rate or half rate version 1 in VAMOS mode (Note 3)
0 0 1 0 0 0 0 1 speech full rate or half rate version 2
1 1 0 0 0 0 1 0 speech full rate or half rate version 2 in VAMOS mode (Note 3)
0 1 0 0 0 0 0 1 speech full rate or half rate version 3

1 1 0 0 0 0 1 1	speech full rate or half rate version 3 in VAMOS mode (Note 3)
1 0 0 0 0 0 0 1	speech full rate or half rate version 4
1 0 0 0 0 0 1 0	speech full rate or half rate version 5
1 1 0 0 0 1 0 1	speech full rate or half rate version 5 in VAMOS mode (Note 3)
1 0 0 0 0 0 1 1	speech full rate or half rate version 6
0 1 1 0 0 0 0 1	data, 43.5 kbit/s (downlink)+14.5 kbps (uplink)
0 1 1 0 0 0 1 0	data, 29.0 kbit/s (downlink)+14.5 kbps (uplink)
0 1 1 0 0 1 0 0	data, 43.5 kbit/s (downlink)+29.0 kbps (uplink)
0 1 1 0 0 1 1 1	data, 14.5 kbit/s (downlink)+43.5 kbps (uplink)
0 1 1 0 0 1 0 1	data, 14.5 kbit/s (downlink)+29.0 kbps (uplink)
0 1 1 0 0 1 1 0	data, 29.0 kbit/s (downlink)+43.5 kbps (uplink)
0 0 1 0 0 1 1 1	data, 43.5 kbit/s radio interface rate
0 1 1 0 0 0 1 1	data, 32.0 kbit/s radio interface rate
0 1 0 0 0 0 1 1	data, 29.0 kbit/s radio interface rate
0 0 0 0 1 1 1 1	data, 14.5 kbit/s radio interface rate
0 0 0 0 0 0 1 1	data, 12.0 kbit/s radio interface rate
0 0 0 0 1 0 1 1	data, 6.0 kbit/s radio interface rate
0 0 0 1 0 0 1 1	data, 3.6 kbit/s radio interface rate
0 0 0 1 0 0 0 0	data, 64.0 kbit/s Transparent Data Bearer (Note 2)

Note 1: The speech versions are also referred to as follows (see 3GPP TS26.103):

full rate or half rate version 1:	GSM FR or GSM HR
full rate or half rate version 2:	GSM EFR
full rate or half rate version 3:	FR AMR or HR AMR
full rate or half rate version 4:	OFR AMR-WB or OHR AMR-WB
full rate or half rate version 5:	FR AMR-WB
full rate or half rate version 6:	OHR AMR

Note 2: This code point is only used for channel assignments made in GAN mode.
Note 3: This code point is only used for a mobile station that indicates support for VAMOS II.

8	7	6	5	4	3	2	1
	Channel Mode IEI						
Mode							

Table 8: Channel Mode2 information element (2 octets)

The mode field is enclosed as follows:

0 0 0 0 0 0 0 0	signaling only
0 0 0 0 0 1 0 1	speech half rate version 1
1 1 0 0 0 0 0 1	speech half rate version 1 in VAMOS mode (Note: 2)
0 0 1 0 0 1 0 1	speech half rate version 2
0 1 0 0 0 1 0 1	speech half rate version 3
1 1 0 0 0 0 1 1	speech half rate version 3 in VAMOS mode (Note: 2)
1 0 0 0 0 1 0 1	speech half rate version 4
0 1 0 0 0 1 1 0	speech half rate version 6
0 0 0 0 1 1 1 1	data, 6.0 kbit/s radio interface rate
0 0 0 1 0 1 1 1	data, 3.6 kbit/s radio interface rate

Note 1: The speech versions are also referred to as follows (see 3GPP TS26.103):

half rate version 1:	GSM HR
half rate version 2:	not defined in this version of the protocol

half rate version 3: HR AMR
half rate version 4: OHR AMR-WB
half rate version 6: OHR AMR
Note 2: This code point is only used for a mobile station that indicates support for VAMOS-II.

The above modification in the downlink signaling addresses the case of VAMOS II mobiles operating in non-VAMOS mode.

An additional modification addresses VAMOS (I and II) devices when operation in VAMOS mode is switched on, which is the possibility to signal the new training sequence set (TSC set 2). New coding is included to Channel Description and Channel Description2 information elements described in [3] in order to indicate which of the two TSC sets has to be used for the circuit switched channel. The TSC Set can be signaled using (see Table 9 and 10)

- Handover Command,
- Assignment Command or
- DTM Handover Command
  (and PACKET CS COMMAND which encapsulates RR messages).

<table>
<tr><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th></tr>
<tr><td></td><td colspan="7">Channel Description IEI</td></tr>
<tr><td colspan="5">Channel Type and TDMA offset</td><td colspan="3">TN</td></tr>
<tr><td colspan="3"></td><td>H=1-></td><td colspan="4">MAIO (high part)</td></tr>
<tr><td colspan="3">TSC</td><td>--- H ---</td><td colspan="4">---</td></tr>
<tr><td colspan="3"></td><td></td><td colspan="2"></td><td colspan="2">ARFCN</td></tr>
<tr><td colspan="3"></td><td></td><td colspan="2">0</td><td colspan="2"></td></tr>
<tr><td colspan="3"></td><td>H=0-></td><td colspan="2">spare</td><td colspan="2">(high part)</td></tr>
<tr><td colspan="2">MAIO (low part)</td><td colspan="6">HSN</td></tr>
<tr><td colspan="8">ARFCN (low part)</td></tr>
</table>

Table 9: Channel Description information element (4 octets)

Channel type and TDMA offset
S 0 0 0 1 TCH/F + ACCHs
S 0 0 1 T TCH/H + ACCHs
0 0 1 T T SDCCH/4 + SACCH/C4 or CBCH (SDCCH/4); TSC Set 1 shall be used
0 1 T T T SDCCH/8 + SACCH/C8 or CBCH (SDCCH/8); TSC Set 1 shall be used
The T bits indicate the subchannel number coded in binary.
S, TSC set
0 TSC Set 1 shall be used
1 TSC Set 2 shall be used
…

<table>
<tr><th>8</th><th>7</th><th>6</th><th>5</th><th>4</th><th>3</th><th>2</th><th>1</th></tr>
<tr><td></td><td colspan="7">Channel Description IEI</td></tr>
<tr><td colspan="5">Channel Type and TDMA offset</td><td colspan="3">TN</td></tr>
</table>

8	7	6	5	4	3	2	1
			H=1->	MAIO (high part)			
TSC			--- H ---	---			
						ARFCN	
				0			
			H=0->	spare		(high part)	
MAIO (low part)		HSN					
ARFCN (low part)							

Table 10: Channel Description 2 information element (4 octets)

Channel type and TDMA offset

0 0 0 0 0 TCH/F + FACCH/F and SACCH/M at the timeslot indicated by TN, and additional bidirectional or unidirectional TCH/Fs and SACCH/Ms according to the multislot allocation information element

0 0 0 0 1 TCH/F + FACCH/F and SACCH/F

0 0 0 1 T TCH/H + ACCHs

0 0 1 T T SDCCH/4 + SACCH/C4 or CBCH (SDCCH/4)

0 1 T T T SDCCH/8 + SACCH/C8 or CBCH (SDCCH/8)

1 1 0 0 0 TCH/F + ACCHs using TSC Set 2

1 1 1 0 T TCH/H + ACCHs using TSC Set 2

…

3 Rohde & Schwarz test solutions

Rohde & Schwarz provides comprehensive VAMOS testing capabilities spanning a variety of different test devices as illustrated in the subsequent sections.

3.1 Signal Generation

In general, a signal generator can be used for VAMOS to develop components within a transmitter chain, for example to provide a VAMOS signal as input to a power amplifier module, or to test receiver performance, e.g. using baseband or RF VAMOS signals as input for a user device receiver or for a base station receiver (see Figure 4).

Figure 4: Typical setup for base station or user device receiver testing

In all cases the test is characterized such that no signaling connection with the device under test exists The generator provides standard conform signals, but has limited possibilities to react on feedback. Figure 5 illustrates the configuration possibilities provided by the software option R&S®SMx-K41 on top of a Rohde & Schwarz signal generator, i.e. R&S®SMU200A or R&S®SMBV100A. Note that the VAMOS functionality as described in this section is currently available as beta Firmware upon request (customer support centre). Commercial release of the functionality is planned for Q1/2011.

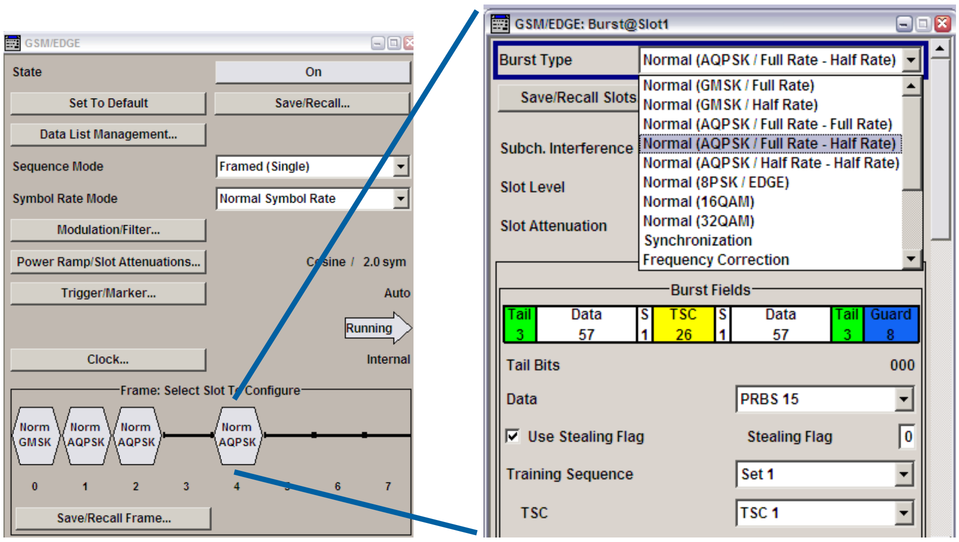

Figure 5: Burst configuration possibilities including new AQPSK modulation

Note that Rohde & Schwarz signal generators provide the flexibility to configure double framed signals as illustrated in Figure 6. Each slot within each frame can individually be configured according to Figure 5. Additionally the repetition rate per frame can be adjusted to individual testing needs. Following a trigger the first frame is repeated the specified number of times, and then the second frame. The frame structures are repeated cyclically, but the useful data is continuously generated. Consequently the frame configuration menu provides maximum flexibility.

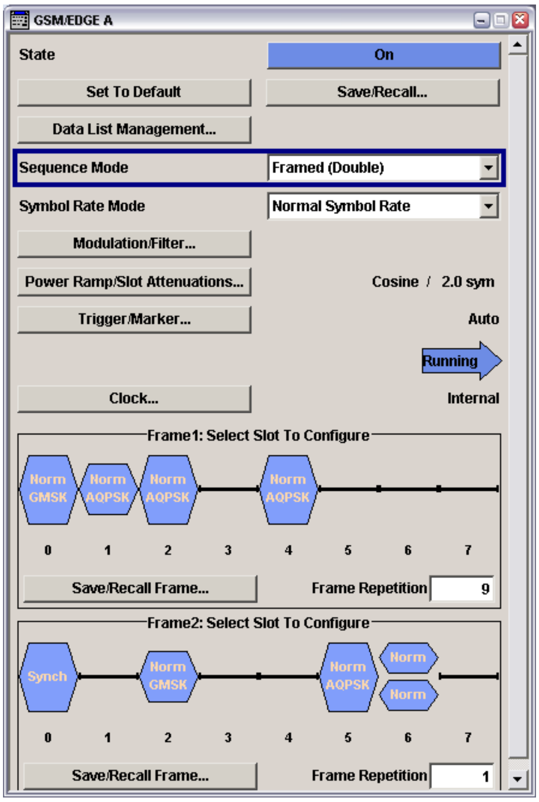

Figure 6: Example of a flexible frame configuration using the "Framed (Double)" feature

Within a frame existing bursts (GMSK, 8PSK, 16QAM and 32QAM) and new AQPSK bursts can be configured. By choosing AQPSK modulation all specified combinations can be selected, i.e. combining FR/FR or FR/HR or HR/HR users on the same time slot. Figure 7 illustrates the case of combining two half rate speech users on each AQPSK subchannel, i.e. providing four voice signals on the same time slot and frequency.

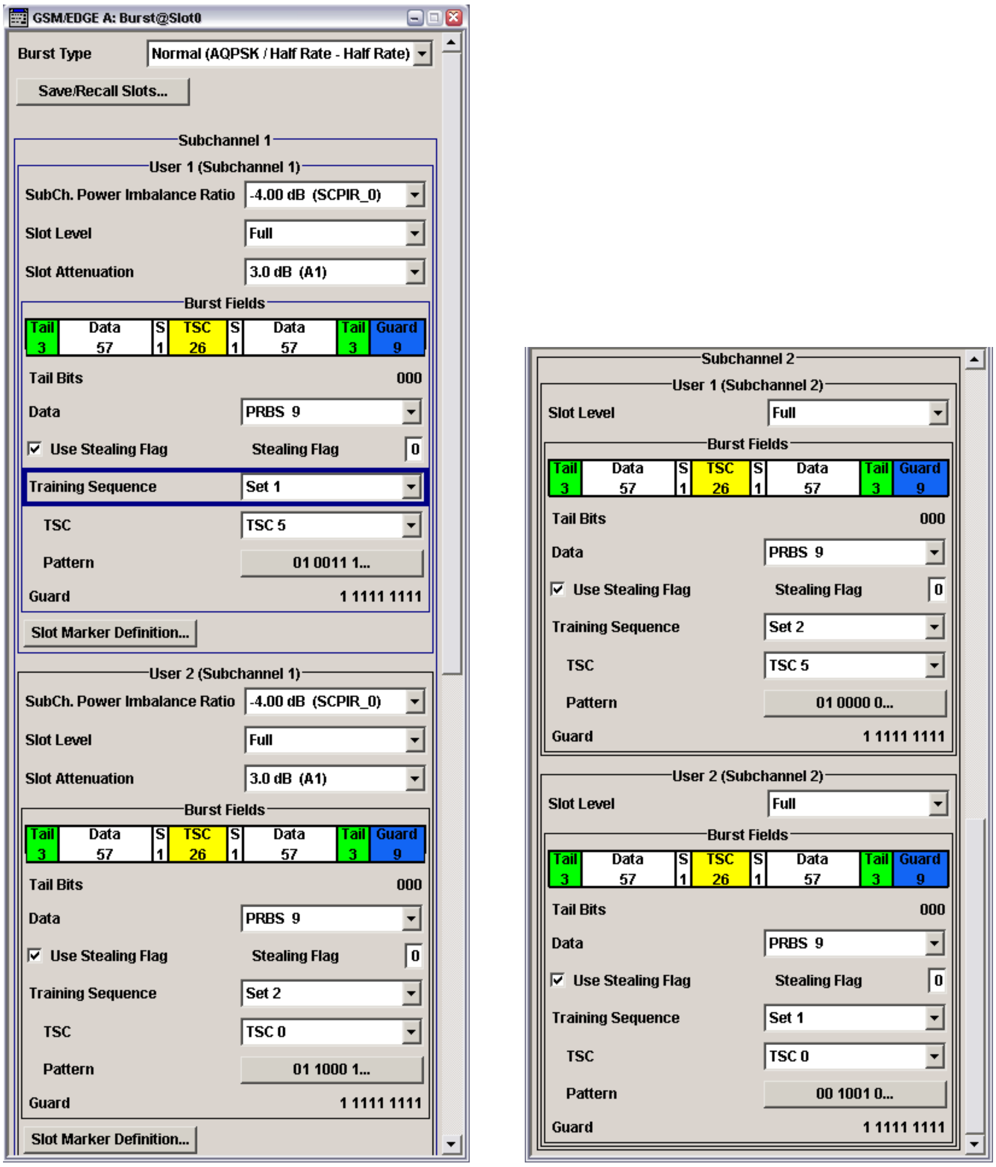

Figure 7: User interface of R&S signal generator to configure a VAMOS signal supporting four voice users on a single time slot and carrier frequency

If AQPSK modulation is chosen, the software options allows an arbitrary setting of the SCPIR (SubChannel Power Imbalance Ratio). Note that this power ratio can only be selected for subchannel1, since a power advantage on one subchannel always requires an equal power disadvantage on the corresponding subchannel.

The generator conveniently calculates the resulting power for subchannel 2 if SCPIR is set for subchannel 1. The generator user interface also provides an easy method to preset SCPIR ratios. Selecting Modulation/Filter in the frame configuration menu (see Figure 8) allows to set different SCPIR values. These values will automatically be translated into the corresponding angular values or vice versa; angular values can be set, which will be translated into the corresponding SCPIR values. Afterwards the SCPIR pull down menu within the burst settings provides all defined SCIPR values as specified previously (see Figure 9). Additionally for each subchannel the different Training Sequence Sets (TSC Set 1 or TSC Set 2) can be selected as well as one of the specified training sequences within each set (TSC0 – TSC7) or a user defined training sequence (see Figure 9).

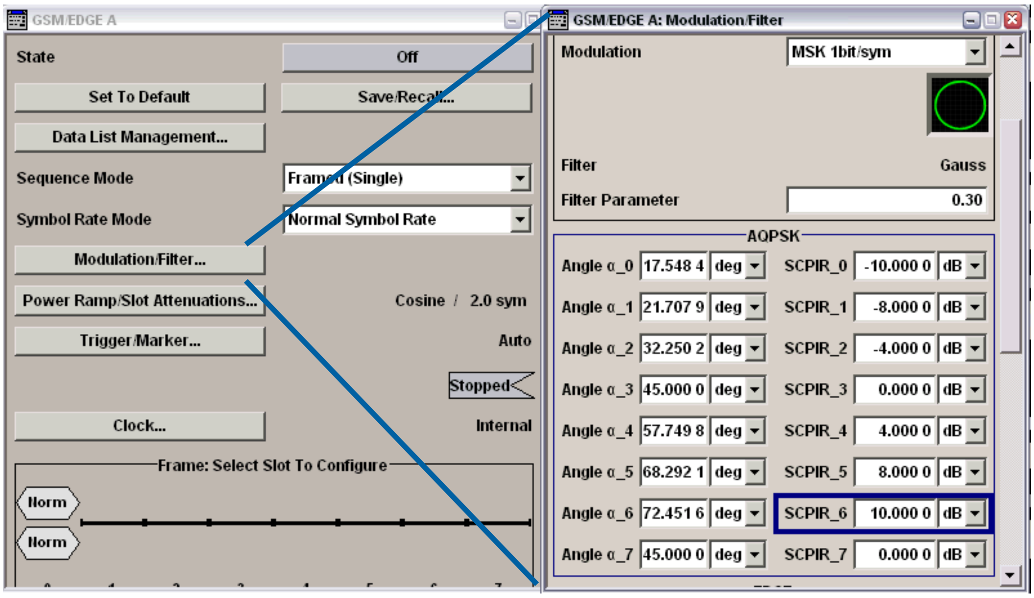

Figure 8: Configuration possibilities for easy SCPIR settings

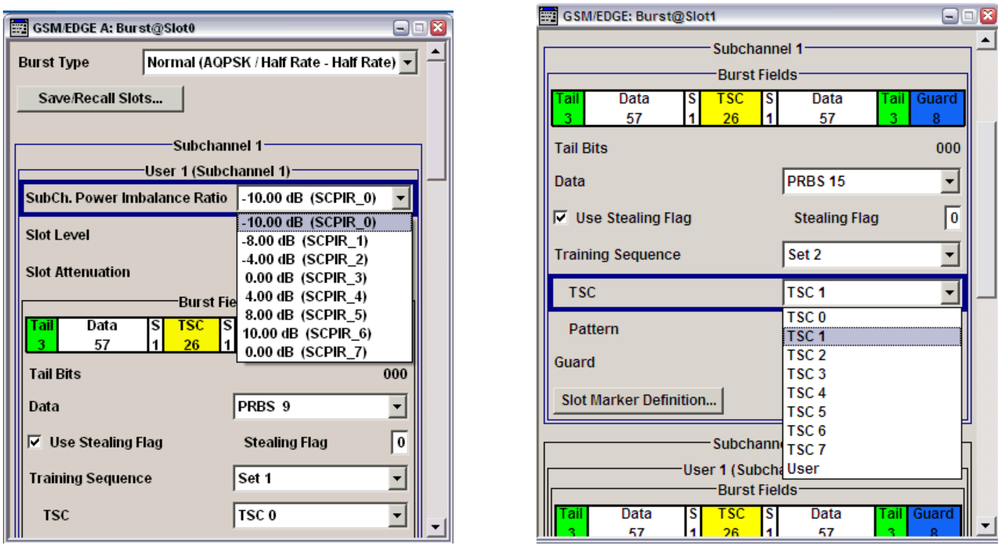

Figure 9: Configuration possibilities per subchannel

3.2 Signal Analysis

From a signal analyzer perspective the relevant VAMOS test case is measuring a base station that transmits a GSM signal using the newly specified AQPSK modulation or using GMSK modulation with a training sequence out of the new TSC Set 2. RF characteristics such as spectrum emission mask, spurious emissions and output power have to be verified while using the new modulation and specifically modulation accuracy, i.e. EVM needs to be measured. In a general setup the RF or baseband signal is connected to a signal analyzer device (see Figure 10).

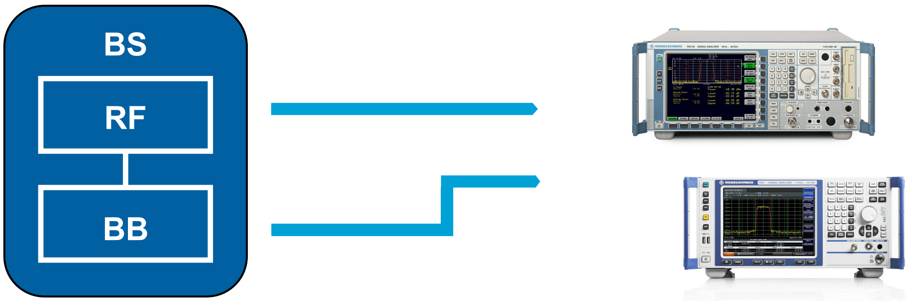

Figure 10: Typical setup for base station transmitter testing

The user interface of e.g. an R&S®FSV with software option K10 allows to measure AQPSK modulation as illustrated in Figure 11. Note that the VAMOS functionality for R&S®FSQ as described in this section is currently available as beta Firmware upon request (customer support centre). Commercial release of the functionality is planned for end 2010. General settings per frame are unchanged. Within "Modulation" of the burst settings AQPSK has to be selected and additionally the used SCPIR value needs to be set. Finally the appropriate training sequence set and its chosen training sequence has to be adjusted. As described in section 2 the TSC number would be the same out of the two different TSC sets applied on the two subchannels. As with other GSM configurations it is also possible to measure on user-specific training sequences by specifying the User TSC bits (see "Burst @ slot 4" in Figure 11).

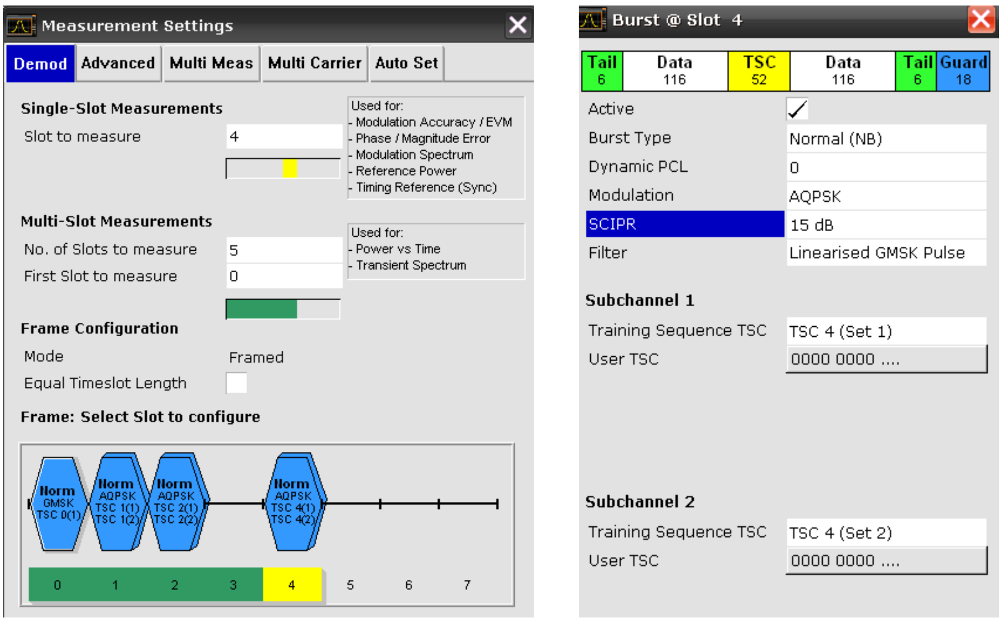

Figure 11: General and detailed settings for measuring an AQPSK base station signal

As an example the power versus time measurement of the frame configuration according to Figure 11 is shown in Figure 12. For three different AQPSK slots different SCPIR values were set, i.e. SCPIR = 1dB in slot 2, SCPIR = 3dB in slot 3 and SCPIR = 10dB in slot 5. As one would expect the power variation for absolute small SCPIR values is much higher than for absolute high SCPIR values since a SCPIR of 0dB would lead to a true QPSK modulation with zero-crossings in the I/Q plane. Figure 12 also illustrates that in comparison to AQPSK, a GMSK signal as configured in slot 0 has a constant amplitude with equal min, max and average power values.

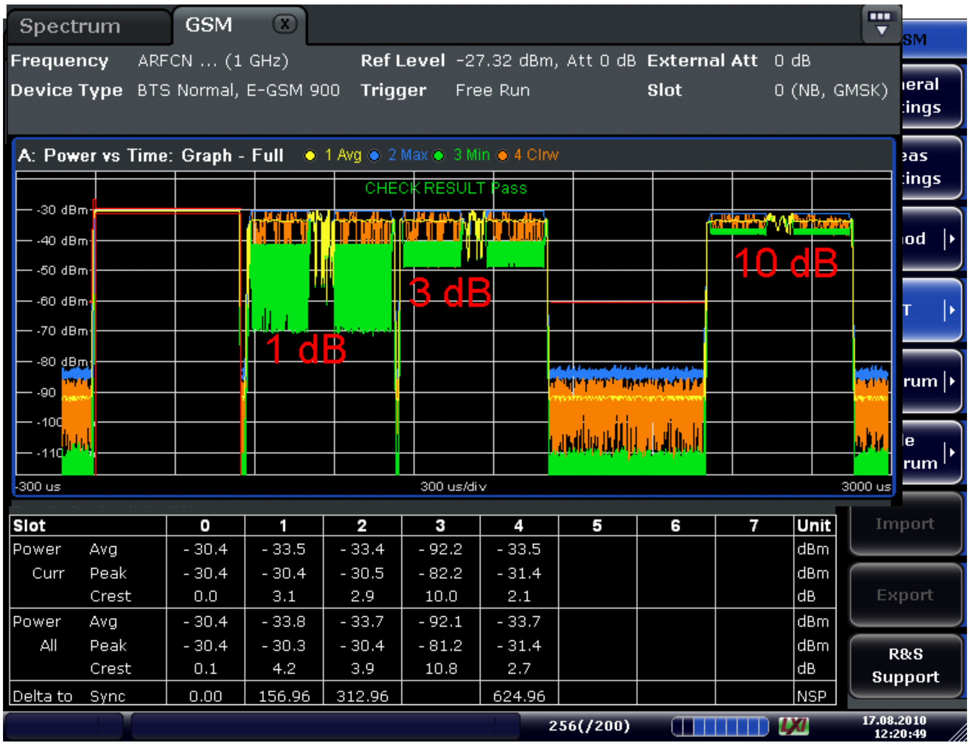

Figure 12: Power vs. time frame measurement including one GMSK burst and multiple AQPSK bursts

"Easy-to-add" marker settings effectively provide a power measurement possibility for each time slot as shown in Figure 13. Additionally power values are provided in a tabular form for each slot including average and peak values which result into a crest factor measurement.

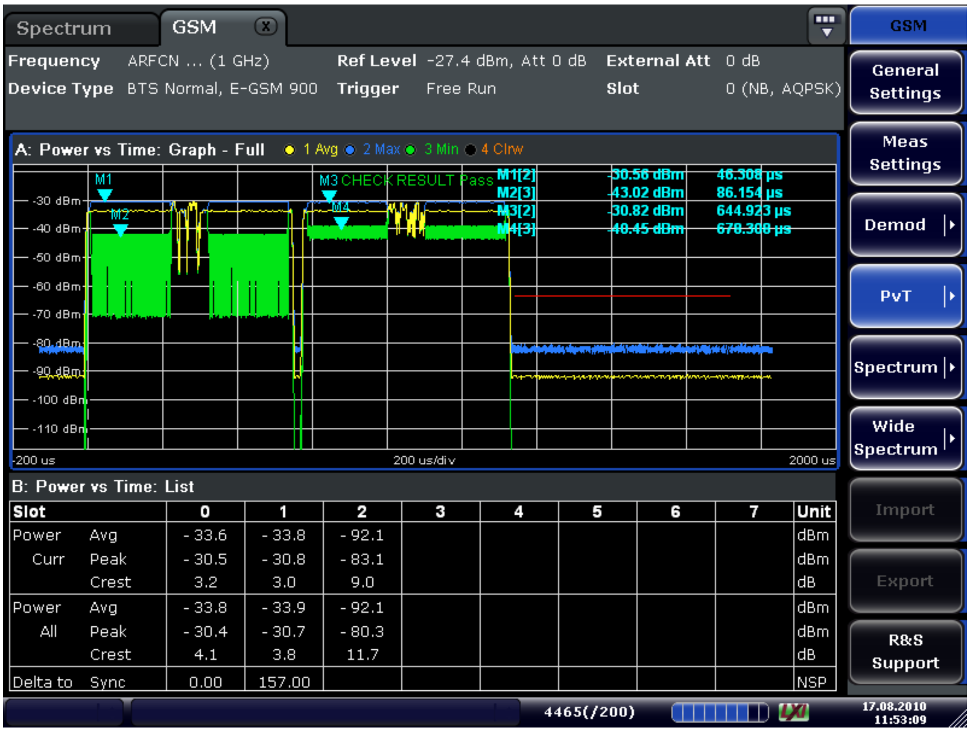

Figure 13: Power vs. time measurement for different time lost using multiple markers

As mentioned earlier it is essential to verify modulation accuracy when applying the new AQPSK modulation at the base station transmitter. Figure 14 exemplifies a EVM vs. time measurement and a table summarizing all relevant signal quality values at a glance including key I/Q-impairment figures and frequency error measurement values.

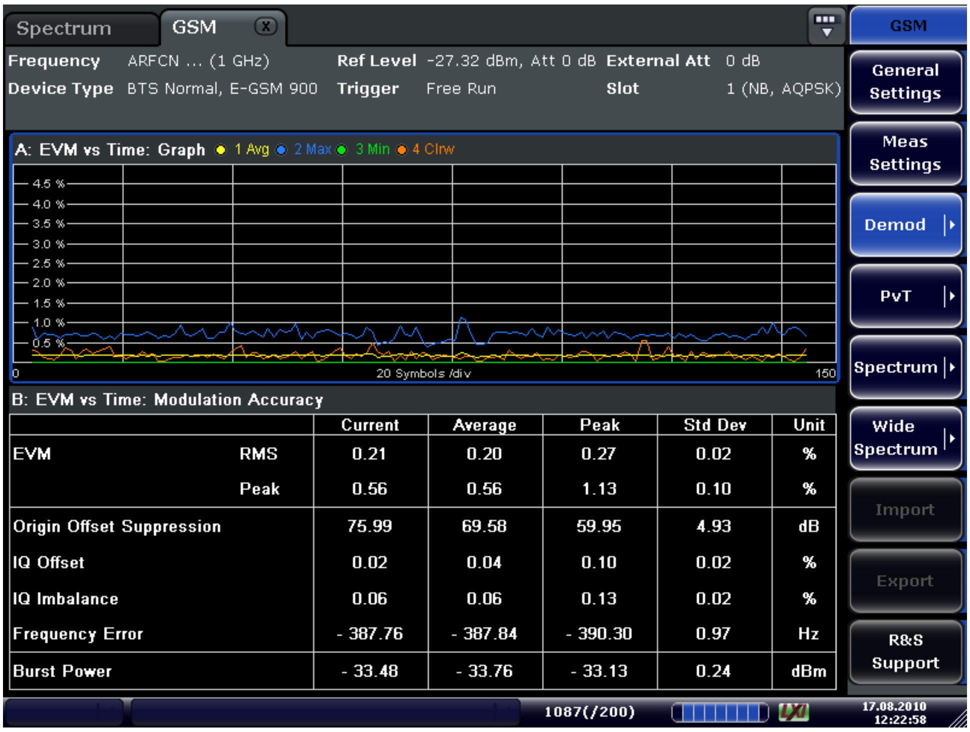

Figure 14: Example of a EVM measurement of a AQPSK transmitter signal

In a similar way the key EVM measurement results can also be displayed in combination with the constellation diagram (see Figure 15). This is an especially important view for AQPSK testing as it visualizes the different SCPIR values that may have been applied. Any EVM related measurement will need to take into account dedicated requirements for the AQPSK modulation to be included in [2]. These requirements are, however, not yet finalized in 3GPP standardization (GERAN).

Figure 15: Constellation diagram of a AQPSK signal and measured modulation accuracy values

In addition to modulation accuracy, testing a base station always requires measurement of the RF characteristics in terms of maximum output power, output power dynamics, modulation spectrum and time mask measurements. These measurements do not differ from traditional GMSK signal measurements. In particular requirements due to modulation and wideband noise are unchanged when using the new AQPSK modulation, i.e. the same limits as with QPSK, 8PSK, 16QAM and 32QAM modulation apply. Note that the time mask requirements will need to be adapted, because different SCPIR values result into varying power levels as illustrated in Figure 12. However, specifications of new limits in 3GPP GERAN standardization have not yet been finalized.
An example of a modulation spectrum mask measurement for an AQPSK modulated transmitter signal is shown in Figure 16.

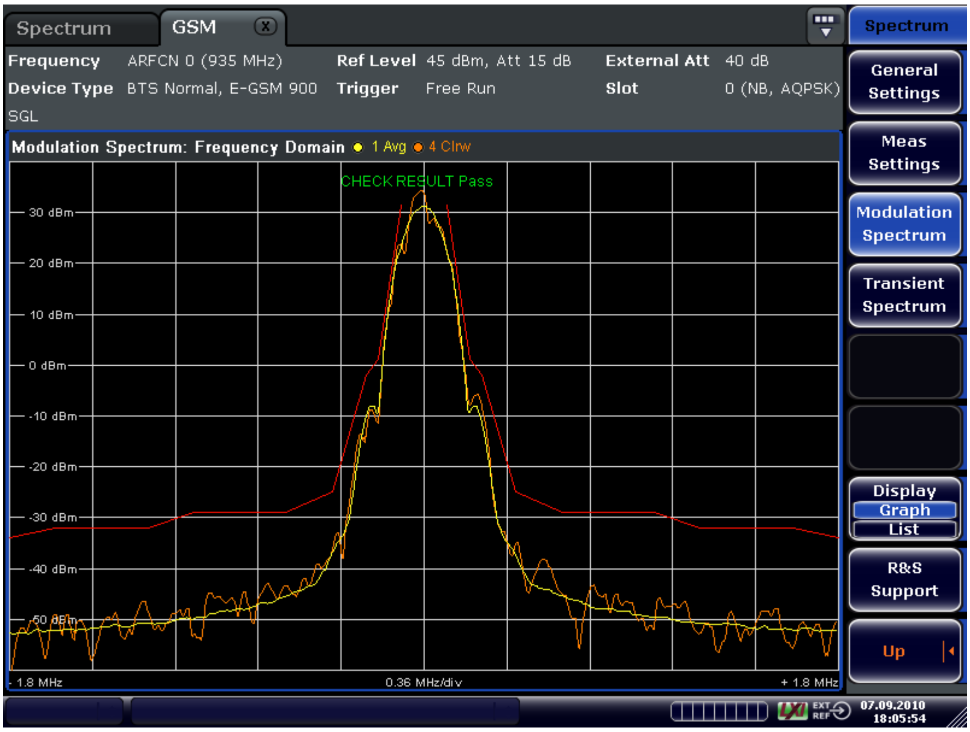

Figure 16: Spectrum mask measurement of an AQPSK modulated transmitter signal

3.3 Radio Communication Tester

During the development process of a VAMOS capable end user device it is essential to verify its functionality and performance, i.e. the ability to establish and maintain an active voice and signaling connection, when the new AQPSK modulation is used on the transmitter side. In an end user device test environment the connection is established with a base station emulator transmitting a standard conform AQPSK signal. Rohde & Schwarz provides VAMOS test capabilities with the R&S®CMW500 wideband radio communication tester. The basic set-up is shown in Figure 17.

Figure 17: Test set-up connecting the end user device with the R&S®CMW500

In order to set up a VAMOS call with the tester, appropriate parameter settings are necessary in the GSM signaling configuration. Figure 18 illustrates the main parameters. “Enable” has to be checked to use the VAMOS feature. Both mobile levels, i.e. VAMOS I and VAMOS II are supported and can be selected from the related pull down menu. Applying VAMOS II would cause the radio communication tester to use the shifted SACCH concept for scheduling (see section 2.3.1). The training sequence (TSC) and training sequence set (TSC Set) for the active user can be selected in accordance with 3GPP GERAN specifications. Selecting TSC set and TSC number for the active user subchannel will automatically allocate the same TSC number from the alternative TSC set for the paired VAMOS user to be transmitted. Additionally the SCPIR value may be set according to testing needs within the limits of -15dB up to +15dB. All settings become active by using the “Apply” button.

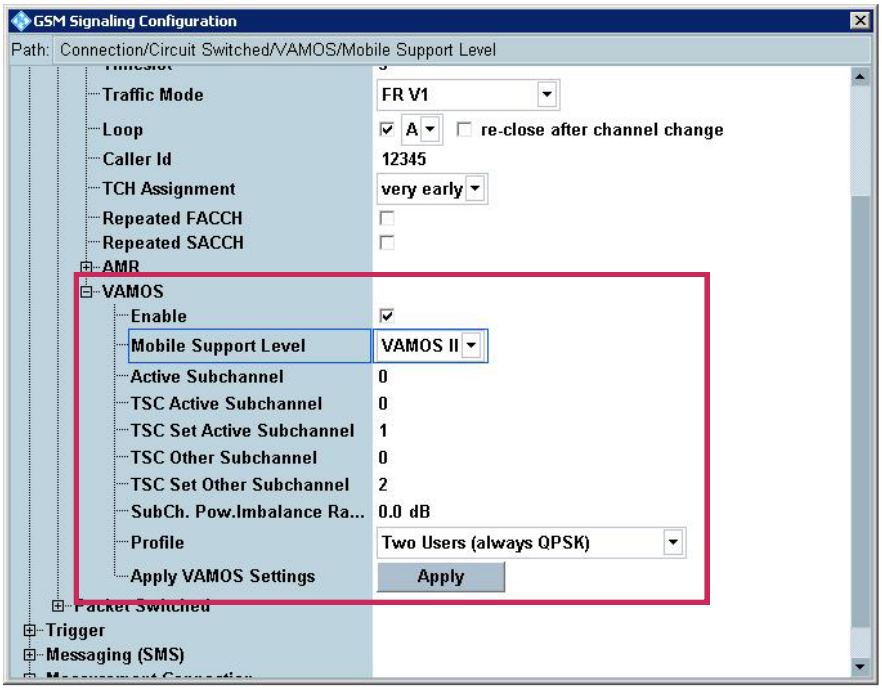

Figure 18: Configuration possibilities of a VAMOS voice connection using the R&S®CMW500

The "GSM Signaling" application allows to establish a CS VAMOS call for one mobile station. The second VAMOS user is only virtually present, i.e. there is only one DUT at a time. Other downlink properties depend on the selected profile. Three profiles are available:

- Single User: There is no second VAMOS user at all. The downlink signal contains speech frames and signaling data for the DUT only. GMSK modulation is used. The main difference to disabled VAMOS is that the VAMOS specific training sequences can be applied (TSC set 2).
- Two users, both active: The downlink signal contains speech frames and signaling data for both users. AQPSK modulation is applied. For the virtual user PRBS 2E9-1 is sent as data and no channel coding is applied. For the subchannel used by the DUT the same data source (e.g. Echo) as without VAMOS is selected. This applies to all profiles.

- Two users, only one active: The downlink signal contains speech frames for the DUT only. For the virtual user DTX is transmitted. Depending on the TDMA frame number either GMSK modulation (virtual user transmits nothing) or AQPSK modulation (virtual user transmits SID or SACCH) is applied.

Furthermore the signaling user interface allows setting the DL Reference Level (power) and the frequency to be used, i.e. selecting the appropriate Channel / Band value (see Figure 19). Applying the settings above will execute the VAMOS call on the base station emulator side and with a VAMOS capable end user device the call can be established. Within an established call basic quality parameters reported by the device are displayed, i.e. RX level and RX quality as illustrated in the left lower part of Figure 19.

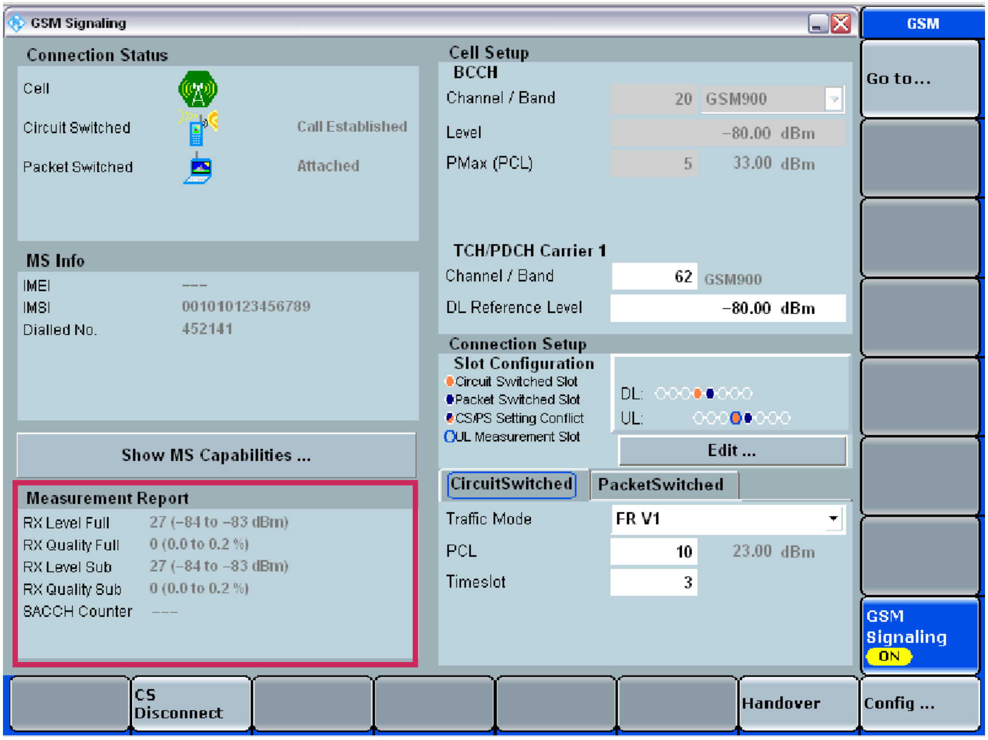

Figure 19: GSM signaling user interface on the R&S®CMW500 in an active VAMOS voice connection

The main test requirement on the VAMOS end user receiver side is to demonstrate fulfillment of performance requirements as specified in [2], i.e. to achieve a certain BER performance in an active VAMOS call. This measurement is offered with the BER measurement application on the R&S®CMW500. Figure 20 and 21 exemplify two measurement results at different downlink power levels. As one can expect the BER increases by decreasing the input power level at the VAMOS capable end user device. The performance can easily be assessed by changing the most dominating parameters SCPIR and power level during an ongoing VAMOS connection.

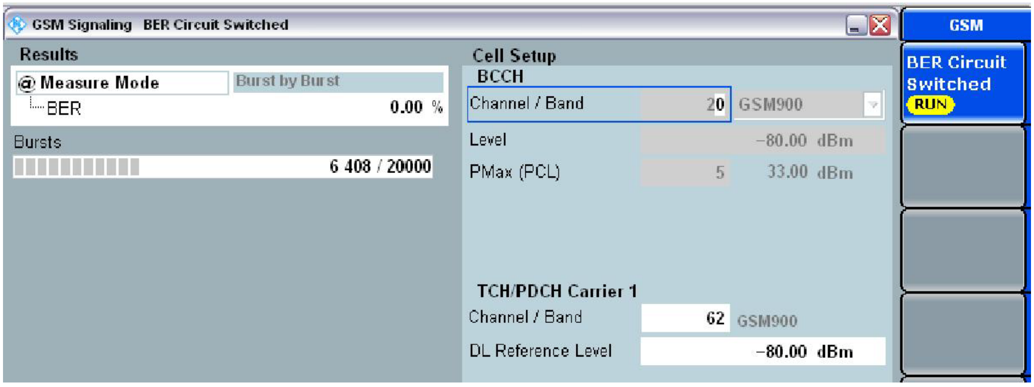

Figure 20: BER measurement example at high input level

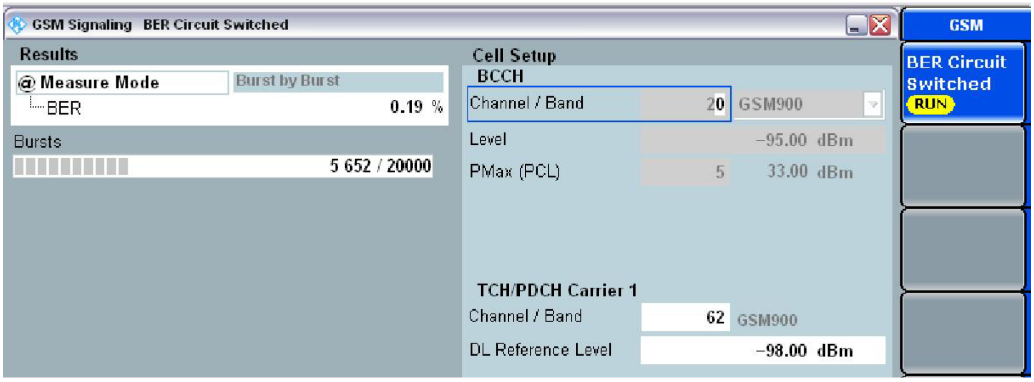

Figure 21: BER measurement example at low input level

As described in section 2, the uplink transmission of a VAMOS capable device is essentially the same as for a traditional GSM phone, since in uplink direction GMSK modulation is used. Applying a new training sequence out of TSC Set 2 will not change the main RF characteristics such as output power, output power dynamics or spectrum emission mask, which have to be verified during the development process. Consequently the UL measurement example of an end user device in an active VAMOS connection as shown in Figure 22 does not differ from the equivalent measurement example of a traditional GSM device.

Figure 22: Multi evaluation uplink measurement of a VAMOS capable end user device

4 Literature

[1] **3GPP TS 24.008 v9.7.0 (2011-06)** 3rd Generation Partnership Project; Technical Specification Group Core Network and Terminals; Mobile radio interface Layer 3 specification; Core network protocols; Stage 3 (Release 9)

[2] **3GPP TS 45.005 v9.7.0 (2011-05)** 3rd Generation Partnership Project; Technical Specification Group GSM/EDGE Radio Access Network; Radio transmission and reception (Release 9)

[3] **3GPP TS 44.018 v9.9.0 (2011-06)** 3rd Generation Partnership Project; Technical Specification Group GSM/EDGE Radio Access Network; Mobile radio interface Layer 3 specification; Radio Resource Control (RRC) protocol (Release 9)

5 Additional Information

This Application Note is subject to updates and extensions. Please visit our website in order to download new versions. Please send any comments or suggestions about this Application Note to

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6 Ordering Information

Ordering Information		
Vector Signal Generator		
SMU200A		**1141.2005.02**
SMU-B103	100kHz – 3GHz	1141.8603.02
SMU-B10	Baseband Generator with ARB (64 Msamples) and Digital Modulation (realtime)	1141.7007.02
SMU-B13	Baseband Main Module	1141.8003.04
SMU-K40	Digital Standard GSM / EDGE	1160.7609.02
SMU-K41	Digital Standard EDGE Evolution	1408.7810.02
SMBV100A		**1407.6004.02**
SMBV-B103	100kHz – 3.2GHz	1407.9603.02
SMBV-B10	Baseband Generator with Digital Modulation (realtime) and ARB (32 Msample), 120 MHz RF bandwidth	1407.8607.02
SMBV-K41	Digital Standard GSM/EDGE	1415.8031.02
SMBV-K41	Digital Standard EDGE Evolution	1415.8460.02
Baseband Signal Generator		
AMU200A		**1402.4090.02**
AMU-B10	Baseband Generator with ARB (64 Msample) and Digital Modulation (realtime)	1402.5300.02
AMU-B13	Baseband Main Module	1402.5500.02
AMU-K41	Digital Standard EDGE Evolution	1403.0253.02
Signal and Spectrum Analyzers		
FSQ	**Up to 3, 8, 26 or 40 GHz**	**1155.5001.xx**
FSG	**Up to 8 or 13 GHz**	**T000.0003.16**
FSV	**Up to 3, 7, 13, 30 or 40 GHz**	**1307.9002.xx**
FSQ-K10 FSG-K10	GSM/EDGE/EDGE Evolution Measurements	1309.9700.02
FSV-K10	GSM/EDGE Analysis	1310.8055.02
xx stands for the different frequency ranges (e.g. 1155.5001.26 up to 26 GHz)		
Wideband Radio Communication Tester		
CMW500	**Wideband Radio Communication Tester**	**1201.0002K50**
CMW-PS502	Mainframe	1202.5408.02
CMW-S550B (flexible link)	Baseband Interconnection Board	1202.4801.03

Wideband Radio Communication Tester (continued)		
CMW-S590A	RF Frontend Module	1202.5108.02
CMW-S600B	Front Panel with Display/Keypad	1201.0102.03
CMW-B200A	Linkhandler: Signaling Unit Universal	1202.6104.02
CMW-B210A	Linkhandler: 2G Extension Module	1202.6204.02
CMW-KM200	GSM/GRPS/EDGE Tx Measurements	1203.0551.02
CMW-KM201	EDGE evo Tx Measurements / 16 QAM	1204.8404.02
CMW-KS200	GSM/GPRS/EDGE Basic Signaling	1203.0600.02
CMW-KS210	GSM/GPRS/EDGE Adv. Signaling	1203.9759.02
CMW-KS201	EDGEevo Basic Signaling	1204.8504.02
CMW-KS211	EDGEevo Adv. Signaling	1207.3455.02
CMW-KS203	VAMOS Basic Signaling	1207.0759.02

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