RM6 Standard Performance

September 2008

- **STANAG 4539 (QAM)**
- **MIL-STD-188-110B (QAM)**
- **STANAG 4285 (PSK)**
- **STANAG 4529 (NB PSK)**
- **STANAG 4415 (PSK NATO robust)**
- **MIL-STD-188-110A (PSK)**
- **MIL-STD-188-110B Appendix F (QAM, ISB)**

STANAG 4539

STANAG 4539 standard provides a family of coded data rates from 75 to 9600 bps and an uncoded data rate of 12k8 bps. In addition, these waveforms incorporate AUTOBAUD. STANAG 4539 is an attractive choice for Automatic-Repeat-Request (ARQ) systems.

For this waveform the *RM6* modem supports the DTE modes Standard Async, High-speed and synchronous.

Table 1 presents the complete STANAG 4539 suite of waveforms. Included in the table are the modulation, code rate and interleaver settings for each data rate. The lower rates include Tone Excision (TEX) (see TEX column Table 1 below). Cancellation of up to 4 tones is possible.

Data Rate (bps)	Modulation	Coding	Interleaver Settings	TEX Capability
75	*Walsh*	$^1/_2$	Z, S, L	*YES*
150	*BPSK*	$^1/_8$	Z, S, L	*YES*
300	*BPSK*	$^1/_4$	Z, S, L	*YES*
600	*BPSK*	$^1/_2$	Z, S, L	*YES*
1200	*QPSK*	$^1/_2$	Z, S, L	*YES*
2400 DATA	*8-PSK*	$^1/_2$	Z, S, L	*YES*
2400 VOICE	*8-PSK*	$^1/_2$	Z, S, L	*YES*
3200	*QPSK*	$^3/_4$	US, VS, S, M, L, VL	*NO*
4800	*8-PSK*	$^3/_4$	US, VS, S, M, L, VL	*NO*
6400	*16-QAM*	$^3/_4$	US, VS, S, M, L, VL	*NO*
8000	*32-QAM*	$^3/_4$	US, VS, S, M, L, VL	*NO*
9600	*64-QAM*	$^3/_4$	US, VS, S, M, L, VL	*NO*
12800	*64-QAM*	*None*	None	*NO*

Table 1: S 4539 waveform suite

The tables below present the different interleaver sizes.

Setting	Display	Length [s]
Zero	Z	none
Short	S	0.6
Long	L	4.8

Table 2: S 4539 Interleaver settings for 75 to 2400 bps

Setting	Display	Length [s]
Ultra Short	US	0.11958333
Very Short	VS	0.35875
Short	S	1.07625
Medium	M	2.1525
Long	L	4.305
Very Long	VL	8.61

Table 3: S 4539 Interleaver Settings for 3200-9600 bps

The following tables give performance results for the *RM6* unit for various data rates. The results were measured using an HF Channel Simulator.

An AWGN channel is representative of ground wave propagation while the POOR channel represents skywave conditions. A RICEAN channel has a steady (specular) component and a fading component, thus representing a mixture of the ground and skywave propagation scenarios.

STANAG 4539				
AWGN Channel (STANAG 4203 Filters included)				
Data Rate [bps]	**IB**	**SNR for BER = 10^{-5} [dB in 3 kHz]**		
		Mandatory Requirement	**Design Objective**	**RM6 Measured**
12800	N/A	**28**	*-*	**25.7**
9600	VL	**22**	*20*	**19.5**
8000	VL	**19**	*17*	**16.4**
6400	VL	**16**	*14*	**13.7**
4800	VL	**14**	*12*	**11.2**
3200	VL	**9**	*7*	**6.6**
RICEAN Channel (STANAG 4203 Filters included)				
Data Rate [bps]	**IB**	**SNR for BER = 10^{-5} [dB in 3 kHz]**		
		Mandatory Requirement	**Design Objective**	**RM6 Measured**
9600	VL	**32**	*29*	**24.2**
8000	VL	**26**	*23*	**20.6**
6400	VL	**22**	*19*	**17.0**
4800	VL	**18**	*15*	**14.0**
3200	VL	**13**	*-*	**9.4**
POOR Channel (STANAG 4203 Filters included)				
Data Rate [bps]	**IB**	**SNR for BER = 10^{-5} [dB in 3 kHz]**		
		Mandatory Requirement	**Design Objective**	**RM6 Measured**
9600	VL	**32**	*29*	**27.6**
8000	VL	**28**	*25*	**23.5**
6400	VL	**24**	*-*	**20.8**
4800	VL	**21**	*18*	**17.0**
3200	VL	**15**	*-*	**12.6**

Table 4: Performance: STANAG 4539

MIL-STD-188-110B

The MIL-STD 188-110B serial tone waveform comprises of the same family of data rates, coding and interleavers as STANAG 4539. Each setting is fully interoperable with its STANAG 4539 equivalent. In addition, an uncoded data rate of 4800 bps is supported.

For this waveform the *RM6* modem supports the DTE modes Standard Async, High-speed and synchronous.

The lower rates include Tone Excision (TEX) (see TEX column table below). Cancellation of up to 4 tones is possible.

Data Rate (bps)	Constellation	Coding	Interleaver Settings	TEX Capability
75	*Walsh*	$^1/_2$	Z, S, L	*YES*
150	*BPSK*	$^1/_2$	Z, S, L	*YES*
300	*BPSK*	$^1/_2$	Z, S, L	*YES*
600	*BPSK*	$^1/_2$	Z, S, L	*YES*
1200	*QPSK*	$^1/_2$	Z, S, L	*YES*
2400 DATA	*8-PSK*	$^1/_2$	Z, S, L	*YES*
2400 VOICE	*8-PSK*	$^1/_2$	Z, S, L	*YES*
3200	*QPSK*	$^3/_4$	US, VS, S, M, L, VL	*NO*
4800	*8-PSK*	*None*	None	*YES*
4800	*8-PSK*	$^3/_4$	US, VS, S, M, L, VL	*NO*
6400	*16-QAM*	$^3/_4$	US, VS, S, M, L, VL	*NO*
8000	*32-QAM*	$^3/_4$	US, VS, S, M, L, VL	*NO*
9600	*64-QAM*	$^3/_4$	US, VS, S, M, L, VL	*NO*
12800	*64-QAM*	*None*	None	*NO*

Table 5: MS 110B Waveform Suite

The MIL-STD 188-110B is functionally the same as STANAG 4539.
The Performance specification differs insofar as:

- **The performance requirements for a Ricean channel are omitted.**
- **Design objectives are omitted.**
- **The STANAG 4203 filters are omitted from the HFCS for this test.**

The following table gives performance results for the *RM6* unit (measured using HF Channel Simulator).

MS 110B				
AWGN Channel (STANAG 4203 Filters Excluded)				
Data Rate [bps]	**IB**	**SNR for BER = 10^{-5} [dB in 3 kHz]**		
		Mandatory Requirement	**Design Objective**	**RM6 Measured**
12800	N/A	**28**	-	**25.3**
9600	VL	**22**	-	**19.0**
8000	VL	**19**	-	**16.9**
6400	VL	**16**	-	**13.8**
4800	VL	**14**	-	**11.1**
3200	VL	**9**	-	**6.6**
POOR Channel (STANAG 4203 Filters Excluded)				
Data Rate [bps]	**IB**	**SNR for BER = 10^{-5} [dB in 3 kHz]**		
		Mandatory Requirement	**Design Objective**	**RM6 Measured**
9600	VL	**32**	-	**26.4**
8000	VL	**28**	-	**23.6**
6400	VL	**24**	-	**20.5**
4800	VL	**21**	-	**16.9**
3200	VL	**15**	-	**12.4**

Table 6: Performance: MS 110B

STANAG 4285

The STANAG 4285 waveform does not have embedded AUTOBAUD fields. Thus the transmitter and receiver need to be set up to the desired data rate and interleaver at both ends of the link. The setting used in one direction of the link by no means need to be the same as in the reverse direction.

For this waveform the *RM6* modem supports the DTE modes Standard Async, High-speed and synchronous.

The STANAG 4285 waveform includes TEX capability. Cancellation of up to 4 tones is possible. Table 7 and Table 8 below summarize the waveform OTA settings.

Data Rate (bps)	Constellation	Coding	Interleaver Settings	TEX Capability
75	*BPSK*	$^1/_{16}$	S, L	*YES*
150	*BPSK*	$^1/_8$	S, L	*YES*
300	*BPSK*	$^1/_4$	S, L	*YES*
600	*BPSK*	$^1/_2$	S, L	*YES*
1200	*QPSK*	$^1/_2$	S, L	*YES*
2400	*8-PSK*	$^2/_3$	S, L	*YES*
1200	*BPSK*	*None*	None	*YES*
2400	*QPSK*	*None*	None	*YES*
3600	*8-PSK*	*None*	None	*YES*

Table 7: S 4285 Waveform Suite

Setting	Display	Length [s]
Short	S	0.8533333333
Long	L	10.240

Table 8: S 4285 Interleaver Settings

The following table gives performance results for the *RM6* unit (measured using HF Channel Simulator).

The STANAG 4285 standard does not specify any performance requirements. The requirements and measurement conditions given below are based on MS 110A. Please note that the SNR is measured in 3 kHz to alleviate comparisons.

STANAG 4285							
STANAG 4203 Filters excluded, Test based on MIL-STD-188-110A requirements							
Data Rate [bps]	IB	HF Channel Conditions			Design Objective		RM6 SNR Measured [dB]
		Doppler Spread [Hz]	Amplitude Path 2 [dB]	Multi-Path Spread [ms]	BER	SNR [dB]	
3600	-	0	Off	-	$<10^{-3}$	17	14.2
3600	-	0.5	0	2	$<10^{-3}$	27	21.4
2400	L	0	Off	-	$<10^{-5}$	10	9.8
2400	L	1	0	2	$<10^{-5}$	18	14.9
2400	L	5	0	2	$<10^{-3}$	30	13.3
2400	L	1	0	5	$<10^{-5}$	30	14.8
1200	L	1	0	2	$<10^{-5}$	11	7.9
600	L	1	0	2	$<10^{-5}$	7	4.5
300	L	5	0	5	$<10^{-5}$	7	0.5
150	L	5	0	5	$<10^{-5}$	5	-2.2
75	L	5	0	5	$<10^{-5}$	2	-4.8

Table 9: Performance: STANAG 4285 (STANAG 4203 filters excluded)

STANAG 4529

This waveform is suitable for shore-to-ship use in 1240 Hz channels.

The narrower occupied bandwidth is achieved by using a symbol rate of 1200 symbols per second. The transmitter and receiver need to be set up to the desired data rate and interleaver at both ends of the link.

For this waveform the *RM6* modem supports the DTE modes Standard Async, High-speed and synchronous.

The STANAG 4529 waveform includes TEX capability. Cancellation of up to 4 tones is possible. Table 10 and Table 11 below summarize the waveform OTA settings.

Data Rate (bps)	Constellation	Coding	Interleaver Settings	TEX Capability
75	*BPSK*	$^1/_8$	S, L	*YES*
150	*BPSK*	$^1/_4$	S, L	*YES*
300	*BPSK*	$^1/_2$	S, L	*YES*
600	*QPSK*	$^1/_2$	S, L	*YES*
1200	*8-PSK*	$^2/_3$	S, L	*YES*
600	*BPSK*	*None*	None	*YES*
1200	*QPSK*	*None*	None	*YES*
1800	*8-PSK*	*None*	None	*YES*

Table 10: S 4529 Waveform Suite

Setting	Display	Length [s]
Short	S	1.7066666666
Long	L	20.280

Table 11: S 4529 Interleaver Settings

The following table gives performance results for the *RM6* unit (measured using HF Channel Simulator).

The STANAG 4529 standard does not specify any performance requirements. The requirements and measurement conditions given below are based on MS 110A. Please note that the SNR is measured in 3 kHz to alleviate comparisons.

STANAG 4529								
STANAG 4203 Filters excluded, Test based on MIL-STD-188-110A requirements SNR units: **[dB] in 3 kHz**								
Data Rate [bps]	**IB**	**HF Channel Conditions**			**Design Objective**		**RM6 SNR Measured [dB]**	**Test Result**
		Doppler Spread [Hz]	**Amplitude Path 2 [dB]**	**Multi-Path Spread [ms]**	**BER**	**SNR [dB]**		
1800	-	0	Off	-	$<10^{-3}$	**17**	**12.0**	OK
1800	-	0.5	0	2	$<10^{-3}$	**27**	**25.8**	OK
1200	L	0	Off	-	**$<10^{-5}$**	**10**	**7.8**	OK
1200	L	1	0	2	**$<10^{-5}$**	**18**	**14.6**	OK
1200	L	5	0	2	$<10^{-3}$	**30**	**21.9**	OK
1200	L	1	0	5	**$<10^{-5}$**	**30**	**13.1**	OK
600	L	1	0	2	**$<10^{-5}$**	**11**	**6.5**	OK
300	L	1	0	2	**$<10^{-5}$**	**7**	**1.8**	OK
150	L	5	0	5	**$<10^{-5}$**	**7**	**-1.5**	OK
75	L	5	0	5	**$<10^{-5}$**	**5**	**-5.1**	OK

Table 12: Performance: STANAG 4529 (STANAG 4203 filters excluded)

STANAG 4415

The STANAG 4415 is also known as the *very robust 75 bps* HF data waveform. It will operate effectively almost 11 dB below the noise floor in a noise dominated environment.

For this waveform the *RM6* modem supports the DTE modes Standard Async, High-speed and synchronous.

The STANAG 4415 waveform includes TEX capability. This waveform is also included as the 75 bps rate of STANAG 4539, MIL-STD-188-110B and MIL-STD-188-110A.

The waveform supports the interleaver sizes given in Table 2.

The following tables give performance results for the *RM6* unit (HF Channel Simulator).

STANAG 4415 / MIL-STD-188-110B, 75 bps (NATO Robust)							
STANAG 4203 Filters excluded							
Data Rate [bps]	**IB**	**STANAG 4415 Mandatory HF Channel Conditions**			**STANAG 4415 Mandatory Performance**		**RM6 SNR Measured [dB]**
		Doppler Spread [Hz]	**Amplitude Path 2 [dB]**	**Multi-Path Spread [ms]**	**BER**	**SNR [dB]**	
75	L	0.5	0	10	**$<10^{-4}$**	0	**-2.0**
75	L	1	0	10	**$<10^{-4}$**	-1	**-4.0**
75	L	2	0	10	**$<10^{-4}$**	-1	**-5.5**
75	L	5	0	10	**$<10^{-4}$**	-1	**-3.8**
75	L	10	0	10	**$<10^{-4}$**	-1	**-4.2**
75	L	20	0	10	**$<10^{-4}$**	-1	**-4.6**
75	L	30	0	10	**$<10^{-4}$**	-1	**-4.9**
75	L	40	0	10	**$<10^{-4}$**	-0.5	**-3.1**
75	L	50	0	10	**$<10^{-4}$**	0	**-3.6**
75	L	0	N/A	N/A	$<10^{-3}$	-9	**-11.6**
75	L	1	0	2	$<10^{-3}$	-9	**-5.8**
75	L	0.5	0	5	$<10^{-3}$	-9	**-4.6**
75	L	5	0	5	$<10^{-3}$	-9	**-6.6**

Table 13: Performance: STANAG 4415 / MIL-STD-188-110B, 75 bps (NATO Robust)

STANAG 4415 / MIL-STD-188-110B, 75 bps (NATO Robust)					
Data Rate [bps]	**IB**	**STANAG 4415 Mandatory Interference Conditions**	**Mandatory Performance**		**RM6 SNR Measured [dB]**
			BER	**SIR [dB]**	
75	L	Self interference (S 4415 waveform with independent data sequence)	**$<10^{-4}$**	-6	-9.3
75	L	Swept CW, 0 – 3000 150 Hz/s	**$<10^{-4}$**	-40	-59.7
75	L	NATO standard voice test tape	**$<10^{-4}$**	-25	Not tested
75	L	FSK, 75 bps, Mark: 1575 Hz, Space: 2425 Hz	**$<10^{-4}$**	-40	-51.2

Table 14: Performance: STANAG 4415 / MIL-STD-188-110B, 75 bps (NATO Robust)

MIL-STD-188-110A

This waveform provides a family of rates from 75 bps to 2400 bps with convolutional coding and 4800 bps in an uncoded form.

For this waveform the *RM6* modem supports the DTE modes Standard Async, High-speed and synchronous.

The MIL-STD 188-110A waveform suite includes TEX capability whereby suppression of up to 4 interfering tones is possible.

Table 15 summarizes the waveform OTA settings.

Data Rate (bps)	Constellation	Coding	Interleaver Settings	TEX Capability
75	*Walsh*	$^1/_2$	Z, S, L	*YES*
150	*BPSK*	$^1/_8$	Z, S, L	*YES*
300	*BPSK*	$^1/_4$	Z, S, L	*YES*
600	*BPSK*	$^1/_2$	Z, S, L	*YES*
1200	*QPSK*	$^1/_2$	Z, S, L	*YES*
2400 DATA	*8-PSK*	$^1/_2$	Z, S, L	*YES*
2400 VOICE	*8-PSK*	$^1/_2$	Z, S, L	*YES*
4800	*8-PSK*	*None*	None	*YES*

Table 15: MS 110A Waveform Suite

The waveform supports the interleaver sizes given in Table 2.

The following table gives performance results for the *RM6* unit (HF Channel Simulator).

MIL-STD-188-110A (Serial mode)							
STANAG 4203 Filters excluded							
Data Rate [bps]	IB	110A Mandatory HF Channel Conditions			110A Mandatory Performance		RM6 SNR Measured [dB]
		Doppler Spread [Hz]	Amplitude Path 2 [dB]	Multi-Path Spread [ms]	BER	SNR [dB]	
4800	-	0	Off	-	$<10^{-3}$	17	14.4
4800	-	0.5	0	2	$<10^{-3}$	27	23.3
2400	L	0	Off	-	$<10^{-5}$	10	8.7
2400	L	1	0	2	$<10^{-5}$	18	14.5
2400	L	5	0	2	$<10^{-3}$	30	11.1
2400	L	1	0	5	$<10^{-5}$	30	13.8
1200	L	1	0	2	$<10^{-5}$	11	9.5
600	L	1	0	2	$<10^{-5}$	7	5.9
300	L	5	0	5	$<10^{-5}$	7	0.1
150	L	5	0	5	$<10^{-5}$	5	-2.9
75	L	5	0	5	$<10^{-5}$	2	-4.6

Table 16: Performance: MIL-STD-188-110A (Serial mode)

MIL-STD-188-110B Appendix F (ISB operation)

The rates specified in MIL-STD 188-110B Appendix F are for ISB operation and require a ISB capable radio. These rates of this waveform family include 9600, 12800, 16000 and 19200 bps (all coded). This waveform is suitable for very high data rate traffic under ground-wave or benign HF propagation conditions.

For this waveform the *RM6* modem supports the DTE modes Standard Async, High-speed and synchronous.

Table 17 represents the data rates and interleavers for MIL-STD 188-110B Appendix F.

Data Rate (bps)	Constellation	Coding	Interleaver Settings	TEX Capability
9600	*8-PSK*	$^3/_4$	US, VS, S, M, L, VL	*NO*
12800	*16-QAM*	$^3/_4$	US, VS, S, M, L, VL	*NO*
16000	*32-QAM*	$^3/_4$	US, VS, S, M, L, VL	*NO*
19200	*64-QAM*	$^3/_4$	US, VS, S, M, L, VL	*NO*

Table 17: MS 110B-F Waveform Suite

The following table gives performance results for the *RM6* unit (measured using HF Channel Simulator).

The MS 110B App. F standard does not specify any performance requirements. The requirements and measurement conditions given below are bases on STANAG 4539.

MIL-STD-188-110B App. F (ISB)				
RICEAN Channel (STANAG 4203 Filters included)				
Dual channel (ISB) HF Channel Simulator: LSB & USB HF Channel distortion is coupled LSB & USB noise is independent				
Data Rate [bps]	**IB**	**SNR for BER = 10^{-5} [dB in 3 kHz]**		
		Mandatory Requirement	**Design Objective**	**RM6 Measured**
19200	VL	**32**	***29***	**25.8**
16000	VL	**26**	***23***	**21.0**
12800	VL	**22**	***19***	**17.8**
9600	VL	**18**	***15***	**14.4**
POOR Channel (STANAG 4203 Filters included)				
Data Rate [bps]	**IB**	**SNR for BER = 10^{-5} [dB in 3 kHz]**		
		Mandatory Requirement	**Design Objective**	**RM6 Measured**
19200	VL	**32**	***29***	**28.5**
16000	VL	**28**	***25***	**24.0**
12800	VL	**24**	*-*	**20.9**
9600	VL	**21**	***18***	**17.6**

***Table 18: Performance:** MIL-STD-188-110B App. F (ISB)*