

**Maurer, D., Suter, H.: "Flat" vowel spectra revisited in vowel synthesis.  
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Details of the listening test and entire tables of the corresponding results (confusion matrices).

Vowel recognition was investigated by means of a listening test: five phonetic expert listeners assigned the synthesised sounds to Standard German vowel qualities or to "no vowel" (ns = not specified). Subtests corresponding to the single tables shown below were performed, separated with a pause of 10 min. in minimum. The results are presented below in terms of confusion matrices.

Experiment 1: Increasing the number of harmonics stepwise from H1 to H1-H20.														
Harmonics		Results of the listening test (5 listeners)										Frequency		
Numbers		Confusion matrix								Majority		kHz		
H(i)		u	o	ɔ	a	ɛ	ø	e	y	i	ns	4/5 and 5/5		
Extension of harmonic series	1-20					4		1				ε	Frequency in kHz	4
	1-19					3		2				ε		3.8
	1-18					4		1				ε		3.6
	1-17					4		1				ε		3.4
	1-16					4		1				ε		3.2
	1-15					4		1				ε		3
	1-14					3	1	1				ε		2.8
	1-13					5						ε		2.6
	1-12					3	2					ε		2.4
	1-11					4	1					ε		2.2
	1-10				1	2	2							2
	1-9			1	2		1				1			1.8
	1-8				5							a		1.6
	1-7				5							a		1.4
	1-6				1	4						a		1.2
	1-5				4	1						ɔ		1
	1-4			2	3							ɔ		0.9
	1-3	1	3	1								o		0.6
1-2	2	3									o	0.4		
1 (only)	5										u	0.2		

Experiment 2: Decreasing the number of harmonics stepwise from H1-H20 to H20 only.													
Harmonics		Results of the listening test (5 listeners)										Frequency	
Numbers		Confusion matrix								Majority		kHz	
H(i)		u	o	ɔ	a	ɛ	ø	e	y	i	ns		
Extension of harmonic series	20 (only)									4	1	Frequency in kHz	4
	19-20									5			3.8
	18-20								1	4			3.6
	17-20									5			3.4
	16-20							2		3			3.2
	15-20							2		3			3
	14-20							2	1	2			2.8
	13-20							3	1	1			2.6
	12-20							3	1	1			2.4
	11-20							2	1	1	1		2.2
	10-20					1	2		1	1			2
	9-20				1	1	1	1			1		1.8
	8-20				2	1		2					1.6
	7-20				4						1		1.4
	6-20				4						1		1.2
	5-20				2	3							1
	4-20			2	3								0.9
	3-30			2	1	2							0.6
2-20		1		1	1	2					0.4		
1-20			1	1	2					1	0.2		



Harmonics	Results of the listening test (5 listeners)										Frequency	
Numbers	Confusion matrix										Majority	kHz
H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns		
5-15					4		1				ɛ	
5-14					5						ɛ	2
5-13					5						ɛ	1.8
5-12					5						ɛ	1.6
5-11					5						ɛ	1.4
5-10				3	2						a	1.2
5-9				4						1	a	1
5-8				5							a	0.9
5-7				5							a	0.6
5-6			2	3							a	0.4
5 (only)	4	1									u	0.2

H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns		
6-16					2		3				e	2
6-15					4		1				ɛ	
6-14					3	1	1				ɛ	1.8
6-13				1	2		2					1.6
6-12					4		1				ɛ	1.4
6-11				3	1					1	a	1.2
6-10			1	2	1	1						1
6-9			1	3		1					a	0.9
6-8		1		3						1	a	0.6
6-7		1	1	3							a	0.4
6 (only)	2	2								1	u	0.2

H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns		
7-17					3		2				ɛ	
7-16					4		1				ɛ	2
7-15					3		2				ɛ	1.8
7-14				1	3		1				ɛ	1.6
7-13					4		1				ɛ	1.4
7-12				1	3		1				ɛ	1.2
7-11					2	2		1				1
7-10			1	3				1			a	0.9
7-9		1		3				1			a	0.6
7-8		1	1	2				1				0.4
7 (only)	2									3		0.2

H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns		
8-18					4		1				ɛ	
8-17					4		1				ɛ	2
8-16					4		1				ɛ	1.8
8-15				1	2		2					1.6
8-14					3		2				ɛ	1.4
8-13					3		2				ɛ	1.2
8-12				1	1	1	1			1		1
8-11				4				1			a	0.9
8-10				4				1			a	0.6
8-9			1	1	1			2				0.4
8 (only)	1			1				2		1		0.2

Harmonics	Results of the listening test (5 listeners)										Frequency	
Numbers	Confusion matrix										Majority	kHz
H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns		
9-19					<b>3</b>		<b>2</b>				<b>ɛ</b>	
9-18					<b>3</b>		<b>2</b>				<b>ɛ</b>	2
9-17					<b>2</b>		<b>3</b>				<b>e</b>	1.8
9-16					<b>2</b>		<b>2</b>	<b>1</b>				1.6
9-15					<b>2</b>	<b>1</b>	<b>2</b>					1.4
9-13					<b>3</b>	<b>1</b>	<b>1</b>				<b>ɛ</b>	1.2
9-13					<b>2</b>	<b>1</b>	<b>1</b>			<b>1</b>		1
9-12				<b>1</b>	<b>2</b>	<b>1</b>				<b>1</b>		0.9
9-11				<b>1</b>		<b>2</b>	<b>2</b>					0.6
9-10				<b>1</b>		<b>1</b>	<b>3</b>				<b>y</b>	0.4
9 (only)							<b>5</b>				<b>y</b>	0.2

H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns		
10-20					<b>3</b>		<b>2</b>				<b>ɛ</b>	
10-19					<b>3</b>		<b>2</b>				<b>ɛ</b>	2
10-18					<b>3</b>		<b>2</b>				<b>ɛ</b>	1.8
10-17					<b>1</b>		<b>4</b>				<b>e</b>	1.6
10-16					<b>2</b>		<b>3</b>				<b>e</b>	1.4
10-15					<b>2</b>		<b>3</b>				<b>e</b>	1.2
10-14					<b>1</b>	<b>1</b>	<b>1</b>	<b>1</b>		<b>1</b>		1
10-13					<b>1</b>	<b>2</b>		<b>1</b>		<b>1</b>		0.9
10-12								<b>5</b>			<b>y</b>	0.6
10-11				<b>1</b>		<b>1</b>	<b>3</b>				<b>y</b>	0.4
10 (only)							<b>3</b>	<b>2</b>			<b>y</b>	0.2

H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns		
11-20					<b>2</b>		<b>3</b>				<b>e</b>	2
11-19					<b>3</b>		<b>2</b>				<b>ɛ</b>	1.8
11-18					<b>2</b>		<b>3</b>				<b>e</b>	1.6
11-17							<b>5</b>				<b>e</b>	1.4
11-16					<b>1</b>		<b>4</b>				<b>e</b>	1.2
11-15					<b>1</b>		<b>3</b>			<b>1</b>	<b>e</b>	1
11-14						<b>2</b>	<b>1</b>		<b>1</b>	<b>1</b>		0.9
11-13						<b>3</b>		<b>1</b>	<b>1</b>		<b>ø</b>	0.6
11-12					<b>1</b>			<b>3</b>		<b>1</b>	<b>y</b>	0.4
11 (only)								<b>3</b>	<b>1</b>	<b>1</b>	<b>y</b>	0.2

H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns		
12-20					<b>2</b>		<b>3</b>				<b>e</b>	1.8
12-19					<b>1</b>		<b>3</b>			<b>1</b>	<b>e</b>	1.6
12-18							<b>3</b>		<b>1</b>	<b>1</b>	<b>e</b>	1.4
12-17							<b>4</b>		<b>1</b>		<b>e</b>	1.2
12-16							<b>2</b>	<b>1</b>	<b>1</b>	<b>1</b>		1
12-15						<b>1</b>	<b>3</b>		<b>1</b>		<b>e</b>	0.9
12-14							<b>1</b>	<b>3</b>	<b>1</b>		<b>y</b>	0.6
12-13								<b>4</b>	<b>1</b>		<b>y</b>	0.4
12 (only)								<b>3</b>	<b>2</b>		<b>y</b>	0.2

H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns		
13-20							<b>4</b>		<b>1</b>		<b>e</b>	1.6
13-19							<b>4</b>			<b>1</b>	<b>e</b>	1.4
13-18							<b>4</b>		<b>1</b>		<b>e</b>	1.2
13-17							<b>3</b>		<b>2</b>		<b>e</b>	1
13-16							<b>1</b>		<b>4</b>		<b>i</b>	0.9
13-15							<b>2</b>	<b>2</b>	<b>1</b>			0.6
13-14								<b>3</b>	<b>2</b>		<b>y</b>	0.4
13 (only)								<b>2</b>	<b>2</b>	<b>1</b>		0.2

Harmonics	Results of the listening test (5 listeners)											Frequency
Numbers	Confusion matrix										Majority	kHz
H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns		
14-20					1		3			1	<b>e</b>	1.4
14-19s							4		1		<b>e</b>	1.2
14-18							3		2		<b>e</b>	1
14-17							2		3		<b>i</b>	0.9
14-16									5		<b>i</b>	0.6
14-15								1	4		<b>i</b>	0.4
14 (only)								1	3	1	<b>i</b>	0.2

H(i)	u	o	ɔ	a	ɛ	ø	e	y	i	ns		
15-20							4		1		<b>e</b>	1.2
1-9							2		3		<b>i</b>	1
15-18							3		2		<b>e</b>	0.9
15-17									5		<b>i</b>	0.6
15-15							1		4		<b>i</b>	0.4
15 (only)								1	3	1	<b>i</b>	0.2