

Modified Direct Adaptive Regulation of Unknown Time-varying Narrow Band Disturbances applied to a Benchmark Problem

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I. SIMULATION RESULTS

TABLE I
SIMULATION RESULTS - SIMPLE STEP TEST

LEVEL 1							
Frequency (Hz)	GA (dB)	DA (dB)	MA (dB@Hz)	N ² T ($\times 10^{-3}$)	N ² R ($\times 10^{-3}$)	MV ($\times 10^{-3}$)	TD %
50	35.8	40.5	6.2@57.8	76.4	3.6	24.1	100
55	35.4	44.8	4.6@48.5	55.5	3.7	35.2	100
60	35.3	45.2	4.8@51.6	45.3	3.6	34.3	100
65	34.9	49.7	5.4@54.7	40.7	3.7	33.8	100
70	34.8	51.9	5.2@64.1	31.0	3.8	25.4	100
75	34.8	48.5	7.0@68.8	21.4	3.8	21.9	100
80	35.0	46.5	5.0@71.9	15.9	3.7	22.3	100
85	34.5	44.4	3.9@75.0	15.9	3.7	22.3	100
90	33.3	42.7	4.1@79.7	19.1	3.8	25.9	100
95	29.5	38.4	5.4@85.9	21.9	4.2	32.9	100
LEVEL 2							
Frequency (Hz)	GA (dB)	DA (dB)-(dB)	MA (dB@Hz)	N ² T ($\times 10^{-3}$)	N ² R ($\times 10^{-3}$)	MV ($\times 10^{-3}$)	TD %
50-70	41.2	43.5 - 50.3	7.2@59.4	71.7	3.7	31.3	100
55-75	40.9	47.6 - 49.5	6.1@67.2	51.6	3.8	31.9	100
60-80	41.1	44.1 - 45.3	6.0@71.9	33.3	3.7	35.8	100
65-85	40.6	45.8 - 44.2	5.9@75.0	28.9	3.8	38.2	100
70-90	39.6	50.6 - 40.7	5.5@78.1	41.1	4.0	41.7	100
75-95	37.9	50.0 - 43.0	6.0@87.5	50.4	4.2	45.8	100
LEVEL 3							
Frequency (Hz)	GA (dB)	DA (dB)-(dB)-(dB)	MA (dB@Hz)	N ² T ($\times 10^{-3}$)	N ² R ($\times 10^{-3}$)	MV ($\times 10^{-3}$)	TD %
50-65-80	44.5	42.2 - 42.3 - 45.3	8.2@54.7	167.7	3.8	60.0	100
55-70-85	43.7	45.5 - 45.4 - 43.4	6.6@64.1	138.6	4.0	71.4	100
60-75-90	43.0	45.4 - 47.2 - 40.7	6.2@82.8	127.5	4.1	54.1	100
65-80-95	42.5	45.7 - 42.3 - 43.4	6.4@89.1	125.8	4.0	61.4	70.8

TABLE II
SIMULATION RESULTS - CHIRP TEST

Profile	Mean Square $\times 10^{-6}$		Maximum $\times 10^{-3}$	
	↗	↘	↗	↘
Level 1	6.0	8.0	8.8	12.0
Level 2	29.1	49.6	17.4	25.0
Level 3	37.9	58.2	20.0	32.3

TABLE III
SIMULATION RESULTS - STEP FREQUENCY CHANGES TEST

	Frequency (Hz)	N ² T ($\times 10^{-3}$)	MV ($\times 10^{-3}$)
Level 1	Sequence - 1		
	60→70	19.5	23.1
	70→60	17.8	22.8
	60→50	24.6	26.0
	50→60	39.5	33.5
	Sequence - 2		
	75→85	19.4	24.2
	85→75	24.3	27.8
	75→65	18.6	25.5
	65→75	20.1	24.5
	Sequence - 3		
	85→95	41.6	23.9
	95→85	61.3	28.9
	85→75	22.2	25.6
	75→85	21.1	24.4
	Level 2	Sequence - 1	
[55-75]→[60-80]		44.0	34.4
[60-80]→[55-75]		40.6	32.7
[55-75]→[50-70]		54.0	37.9
[50-70]→[55-75]		60.8	41.7
Sequence - 2			
[70-90]→[75-95]		68.1	35.4
[75-95]→[70-90]		86.1	37.9
[70-90]→[65-85]		56.9	37.0
[65-85]→[70-90]		50.0	34.9
Level 3	Sequence - 1		
	[55-70-85]→[60-75-90]	128.7	68.4
	[60-75-90]→[55-70-85]	164.5	66.8
	[55-70-85]→[50-65-80]	105.5	61.0
	[50-65-80]→[55-70-85]	152.6	69.0
	Sequence - 2		
	[60-75-90]→[65-80-95]	170.3	59.1
	[65-80-95]→[60-75-90]	233.1	59.3
[60-75-90]→[55-70-85]	123.7	63.7	
[55-70-85]→[60-75-90]	131.7	68.4	

II. REAL TIME RESULTS

TABLE IV
REAL TIME RESULTS - SIMPLE STEP TEST

LEVEL 1							
Frequency (Hz)	GA (dB)	DA (dB)	MA (dB@Hz)	N ² T ($\times 10^{-3}$)	N ² R ($\times 10^{-3}$)	MV ($\times 10^{-3}$)	TD %
50	34.5	40.3	9.3@62.5	111.3	6.8	30.7	92.2
55	33.1	45.4	8.2@50.0	47.6	5.8	29.4	100
60	33.3	45.6	6.8@125.0	27.5	5.1	20.9	100
65	31.8	45.4	9.1@56.3	15.2	5.2	19.6	100
70	29.9	45.6	8.1@131.3	13.6	5.6	20.8	100
75	30.3	47.9	8.6@70.3	19.8	5.0	18.4	100
80	29.5	48.6	7.7@6.3	13.4	5.3	20.9	100
85	29.5	43.6	6.3@117.2	21.3	5.2	23.3	100
90	29.1	43.7	7.5@117.2	18.1	5.0	23.4	100
95	27.1	39.0	6.8@375.0	20.9	4.8	28.1	100
LEVEL 2							
Frequency (Hz)	GA (dB)	DA (dB)-(dB)	MA (dB@Hz)	N ² T ($\times 10^{-3}$)	N ² R ($\times 10^{-3}$)	MV ($\times 10^{-3}$)	TD %
50-70	38.2	40.9 - 43.9	10.3@64.1	99.3	6.8	30.9	100
55-75	35.9	46.1 - 47.2	11.9@60.9	52.9	6.9	30.5	100
60-80	37.8	45.6 - 45.9	7.9@70.3	38.0	5.1	34.2	100
65-85	35.2	42.9 - 42.9	7.9@212.5	28.9	6.2	35.7	100
70-90	36.1	43.7 - 44.9	10.0@115.6	42.8	5.2	39.3	100
75-95	35.0	44.9 - 40.0	9.9@128.1	51.3	5.4	44.2	100
LEVEL 3							
Frequency (Hz)	GA (dB)	DA (dB)-(dB)-(dB)	MA (dB@Hz)	N ² T ($\times 10^{-3}$)	N ² R ($\times 10^{-3}$)	MV ($\times 10^{-3}$)	TD %
50-65-80	40.1	38.3 - 39.7 - 43.7	8.9@125.0	151.5	7.2	50.2	100
55-70-85	40.1	45.2 - 45.1 - 42.7	7.8@78.1	103.0	6.0	57.6	100
60-75-90	38.7	45.2 - 42.2 - 43.3	10.8@78.1	105.3	6.4	79.7	100
65-80-95	38.8	43.9 - 41.7 - 40.5	10.2@85.9	119.2	5.8	63.6	100

TABLE V
REAL TIME RESULTS - CHIRP TEST

Profile	Mean Square $\times 10^{-6}$		Maximum $\times 10^{-3}$	
	↗	↘	↗	↘
Level 1	7.9	9.5	14.6	12.4
Level 2	26.2	50.3	17.4	25.2
Level 3	34.6	53.5	20.7	34.5

III. NEW PROTOCOL RESULTS

TABLE VI
REAL TIME RESULTS - STEP FREQUENCY CHANGES TEST

		Frequency (Hz)	N ² T ($\times 10^{-3}$)	MV ($\times 10^{-3}$)
Level 1	Sequence - 1			
		60→70	23.3	23.2
		70→60	22.2	25.7
		60→50	50.5	23.2
		50→60	48.0	36.8
	Sequence - 2			
		75→85	18.2	23.2
		85→75	21.3	23.4
		75→65	20.3	24.4
		65→75	19.8	22.0
	Sequence - 3			
		85→95	33.4	18.5
	95→85	57.7	26.8	
	85→75	21.1	24.4	
	75→85	19.3	20.1	
Level 2	Sequence - 1			
		[55-75]→[60-80]	47.6	37.9
		[60-80]→[55-75]	48.7	35.7
		[55-75]→[50-70]	65.0	37.9
		[50-70]→[55-75]	70.5	45.5
	Sequence - 2			
		[70-90]→[75-95]	66.6	40.6
		[75-95]→[70-90]	79.2	38.1
	[70-90]→[65-85]	59.3	35.4	
	[65-85]→[70-90]	49.5	33.2	
Level 3	Sequence - 1			
		[55-70-85]→[60-75-90]	102.3	66.0
		[60-75-90]→[55-70-85]	145.6	68.8
		[55-70-85]→[50-65-80]	168.8	63.5
		[50-65-80]→[55-70-85]	125.9	65.2
	Sequence - 2			
		[60-75-90]→[65-80-95]	167.8	59.0
		[65-80-95]→[60-75-90]	237.7	60.2
	[60-75-90]→[55-70-85]	146.1	67.6	
	[55-70-85]→[60-75-90]	143.5	66.0	

TABLE VII
REAL TIME RESULTS - SIMPLE STEP TEST - NEW PROTOCOL

Level		GA (dB)	DA (dB)	MA (dB@Hz)	N ² T ($\times 10^{-3}$)	N ² R ($\times 10^{-3}$)	MV ($\times 10^{-3}$)	TD %
2	Sim	40.7	43.8 - 47.1	3.9@54.7	90.2	3.8	43.6	100
	RT	37.0	41.0 - 40.4	8.0@135.9	59.9	5.7	31.7	100
3	Sim	43.8	40.7 - 40.8 - 42.7	5.8@76.6	459.9	4.0	111.4	100
	RT	39.2	36.9 - 35.4 - 41.2	5.6@65.6	214.6	6.2	66.1	100

TABLE VIII
REAL TIME RESULTS - STEP FREQUENCY CHANGES TEST - NEW PROTOCOL

Level	Frequency (Hz)	N ² T ($\times 10^{-3}$)		MV ($\times 10^{-3}$)	
		Sim	RT	Sim	RT
		2	[61.5, 71.5] → [66.5, 76.5]	55.8	47.5
[66.5, 76.5] → [61.5, 71.5]	53.0		64.3	41.3	40.5
[61.5, 71.5] → [56.5, 66.5]	52.9		62.1	38.9	41.6
[56.5, 66.5] → [61.5, 71.5]	57.0		54.1	40.3	41.6
3	[61.5, 71.5, 81.5] → [66.5, 76.5, 86.5]	170.0	158.9	66.7	62.5
	[66.5, 76.5, 86.5] → [61.5, 71.5, 81.5]	189.0	204.9	82.0	76.0
	[61.5, 71.5, 81.5] → [56.5, 66.5, 76.5]	162.6	199.8	62.2	62.5
	[56.5, 66.5, 76.5] → [61.5, 71.5, 81.5]	195.1	197.4	72.9	67.4