Adaptive Compensation of Disturbances Formed as Sums of Sinusoidal Signals with Application to an Active Vibration Control Benchmark

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I. Simulation Results when is known the number of frequencies

TABLE I
Simulation Results - Simple Step Test

LEVEL 1							
Frequency (Hz)	**GA (dB)**	**DA (dB)**	**MA (dB@Hz)**	**N^2T ($\times 10^{-3}$)**	**N^2R ($\times 10^{-3}$)**	**MV ($\times 10^{-3}$)**	**TD (ratio)**
50	33.8	46.9	6.0@54.7	45.7	3.9	35.2	1.143
55	32.6	46.0	6.7@78.1	20.6	4.5	27.6	1.049
60	33.3	47.8	7.3@68.8	20.2	4.2	32.8	1.096
65	33.6	50.2	8.5@51.6	16.5	4.1	34.8	1.063
70	32.8	48.7	8.2@53.1	15.7	4.6	31.8	1.047
75	33.6	52.0	9.6@53.1	23.9	4.2	42.8	1.086
80	33.9	49.6	7.4@54.7	33.7	4.0	51.8	1.094
85	33.0	48.0	9.1@51.6	42.6	4.3	55.9	1.055
90	31.0	42.9	10.6@53.1	45.3	4.5	52.9	1.086
95	23.3	36.9	8.9@87.5	56.3	4.9	67.9	1.119
LEVEL 2							
Frequency (Hz)	**GA (dB)**	**DA (dB)-(dB)**	**MA (dB@Hz)**	**N^2T ($\times 10^{-3}$)**	**N^2R ($\times 10^{-3}$)**	**MV ($\times 10^{-3}$)**	**TD (ratio)**
50-70	33.9	42.9 - 38.6	13.2@92.2	103.6	7.8	69.6	1.122
55-75	36.3	46.3 - 45.9	9.9@84.4	80.8	6.0	68.7	1.005
60-80	39.2	48.3 - 49.6	7.7@87.5	82.9	4.3	81.3	1.125
65-85	38.7	50.7 - 48.1	9.7@51.6	101.5	4.5	89.6	1.059
70-90	36.9	50.2 - 42.6	13.2@53.1	137.6	5.1	104.4	1.012
75-95	33.6	46.1 - 38.2	17.0@53.1	207.8	5.7	128.7	1.111
LEVEL 3							
Frequency (Hz)	**GA (dB)**	**DA (dB)-(dB)-(dB)**	**MA (dB@Hz)**	**N^2T ($\times 10^{-3}$)**	**N^2R ($\times 10^{-3}$)**	**MV ($\times 10^{-3}$)**	**TD (ratio)**
50-65-80	38.8	44.8 - 41.8 - 40.8	14.6@93.8	255.3	6.7	111.3	1.104
55-70-85	41.5	46.7 - 53.2 - 46.2	8.0@60.9	251.6	4.9	134.5	1.072
60-75-90	40.8	45.3 - 52.9 - 42.4	8.7@51.6	320.4	5.0	159.5	1.065
65-80-95	38.0	46.8 - 46.3 - 41.4	13.5@51.6	451.9	5.8	191.9	0.999

TABLE II
Simulation Results - Chirp Test

	Mean Square $\times 10^{-6}$		**Maximum $\times 10^{-3}$**	
Profile	↗	↘	↗	↘
Level 1	31.3	15.3	16.7	14.4
Level 2	49.4	18.0	20.8	15.7
Level 3	35.7	11.7	21.0	10.6

TABLE III
SIMULATION RESULTS - STEP FREQUENCY CHANGES TEST

	Frequency (Hz)	**N^2T** ($\times 10^{-3}$)	**MV** ($\times 10^{-3}$)
Level 1	**Sequence - 1**		
	60→70	15.2	21.3
	70→60	15.4	21.1
	60→50	31.6	20.2
	50→60	81.8	22.2
	Sequence - 2		
	75→85	15.5	22.0
	85→75	15.4	22.5
	75→65	14.3	20.2
	65→75	15.3	22.0
	Sequence - 3		
	85→95	17.8	22.5
	95→85	29.3	28.8
	85→75	15.9	23.6
	75→85	14.8	21.8
Level 2	**Sequence - 1**		
	[55-75]→[60-80]	22.2	31.1
	[60-80]→[55-75]	22.0	30.0
	[55-75]→[50-70]	46.8	29.4
	[50-70]→[55-75]	129.1	32.3
	Sequence - 2		
	[70-90]→[75-95]	23.2	24.9
	[75-95]→[70-90]	42.4	29.8
	[70-90]→[65-85]	71.3	53.4
	[65-85]→[70-90]	18.4	29.3
Level 3	**Sequence - 1**		
	[55-70-85]→[60-75-90]	41.0	50.1
	[60-75-90]→[55-70-85]	42.0	52.1
	[55-70-85]→[50-65-80]	71.3	53.4
	[50-65-80]→[55-70-85]	102.2	55.7
	Sequence - 2		
	[60-75-90]→[65-80-95]	39.7	49.4
	[65-80-95]→[60-75-90]	50.7	55.6
	[60-75-90]→[55-70-85]	42.2	55.0
	[55-70-85]→[60-75-90]	40.2	51.4

II. Simulation Results when is unknown the number of frequencies

TABLE IV
SIMULATION RESULTS - SIMPLE STEP TEST

LEVEL 1							
Frequency (Hz)	**GA (dB)**	**DA (dB)**	**MA (dB@Hz)**	**N^2T ($\times 10^{-3}$)**	**N^2R ($\times 10^{-3}$)**	**MV ($\times 10^{-3}$)**	**TD (ratio)**
50	34.0	43.5	5.9@54.7	58.7	3.9	32.6	1.09
55	33.4	43.6	7.4@50.0	32.4	4.2	35.9	1.05
60	33.7	43.4	7.1@53.1	27.1	4.0	37.8	1.12
65	33.5	50.1	8.9@73.4	19.3	4.2	36.1	1.07
70	33.3	47.0	7.7@76.6	20.2	4.3	33.0	1.09
75	33.6	46.0	8.2@67.2	28.9	4.3	44.7	1.06
80	33.6	42.6	8.1@53.1	39.0	4.2	52.0	1.07
85	33.2	41.5	6.6@75.0	55.4	4.3	60.4	1.09
90	32.1	39.5	6.7@53.1	69.6	4.0	73.7	1.05
95	24.5	40.8	6.3@115.6	84.8	4.2	90.9	1.06
LEVEL 2							
Frequency (Hz)	**GA (dB)**	**DA (dB)-(dB)**	**MA (dB@Hz)**	**N^2T ($\times 10^{-3}$)**	**N^2R ($\times 10^{-3}$)**	**MV ($\times 10^{-3}$)**	**TD (ratio)**
50-70	39.2	46.6 - 47.8	8.5@76.6	128.8	4.3	67.6	1.11
55-75	38.5	46.2 - 46.4	8.8@50.0	86.4	4.7	72.4	1.02
60-80	39.2	46.3 - 45.0	8.9@68.8	86.6	4.3	82.6	1.14
65-85	38.7	50.5 - 46.9	9.6@73.4	112.8	4.5	88.3	1.07
70-90	37.9	47.9 - 41.4	8.1@53.1	152.8	4.5	101.3	1.07
75-95	35.0	49.3 - 41.6	8.5@67.2	222.8	4.8	125.4	1.06

TABLE V
SIMULATION RESULTS - CHIRP TEST

	Mean Square $\times 10^{-6}$		**Maximum** $\times 10^{-3}$	
Profile	↗	↘	↗	↘
Level 1	11.6	11.8	15.1	19.8
Level 2	18.9	16.7	19.7	14.9

TABLE VI
SIMULATION RESULTS - STEP FREQUENCY CHANGES TEST

	Frequency (Hz)	**N^2T** ($\times 10^{-3}$)	**MV** ($\times 10^{-3}$)
Level 1	**Sequence - 1**		
	60→70	29.2	42.8
	70→60	20.0	25.6
	60→50	64.0	39.0
	50→60	43.6	44.7
	Sequence - 2		
	75→85	20.9	26.0
	85→75	20.0	33.6
	75→65	15.6	26.5
	65→75	22.9	43.8
	Sequence - 3		
	85→95	20.4	24.6
	95→85	24.4	27.3
	85→75	22.6	28.7
	75→85	23.9	31.8
Level 2	**Sequence - 1**		
	[55-75]→[60-80]	27.0	32.1
	[60-80]→[55-75]	33.0	42.3
	[55-75]→[50-70]	59.6	35.2
	[50-70]→[55-75]	54.6	35.8
	Sequence - 2		
	[70-90]→[75-95]	27.4	38.1
	[75-95]→[70-90]	31.0	31.3
	[70-90]→[65-85]	26.5	39.2
	[65-85]→[70-90]	46.5	48.8

III. Real Time Results

A. Known number of frequencies

TABLE VII
Real Time Results - Simple Step Test

LEVEL 1							
Frequency (Hz)	**GA (dB)**	**DA (dB)**	**MA (dB@Hz)**	**N^2T ($\times 10^{-3}$)**	**N^2R ($\times 10^{-3}$)**	**MV ($\times 10^{-3}$)**	**TD (ratio)**
50	34.7	41.7	9.3@54.7	99.2	6.4	31.0	1.141
55	34.6	45.9	11.7@128.1	40.4	5.1	34.3	1.040
60	32.8	47.8	9.6@46.9	26.7	5.5	39.6	0.879
65	33.1	50.5	8.4@90.6	25.3	4.5	36.4	0.993
70	30.8	47.6	8.0@64.1	17.8	5.0	33.4	1.055
75	30.2	46.4	9.0@281.3	16.5	4.9	32.2	0.878
80	30.1	46.8	7.7@115.6	21.9	4.5	31.5	1.005
85	29.2	40.5	10.6@73.4	24.4	4.8	41.2	0.963
90	28.0	41.5	10.1@67.2	25.7	4.9	38.4	1.019
95	25.8	40.0	10.9@129.7	25.4	4.9	26.2	1.092
LEVEL 2							
Frequency (Hz)	**GA (dB)**	**DA (dB)-(dB)**	**MA (dB@Hz)**	**N^2T ($\times 10^{-3}$)**	**N^2R ($\times 10^{-3}$)**	**MV ($\times 10^{-3}$)**	**TD (ratio)**
50-70	33.1	39.4 - 35.6	15.6@90.6	179.4	12.7	77.7	0.946
55-75	35.1	45.0 - 45.4	11.4@92.2	90.0	7.9	56.8	1.008
60-80	37.7	49.0 - 47.6	9.6@70.3	52.5	5.1	63.0	1.019
65-85	34.5	49.0 - 39.9	10.5@106.3	63.5	6.6	70.6	0.961
70-90	33.8	51.4 - 40.6	12.2@59.4	64.4	6.4	58.3	0.955
75-95	31.7	44.9 - 42.1	14.1@103.1	68.2	7.4	49.1	0.981
LEVEL 3							
Frequency (Hz)	**GA (dB)**	**DA (dB)-(dB)-(dB)**	**MA (dB@Hz)**	**N^2T ($\times 10^{-3}$)**	**N^2R ($\times 10^{-3}$)**	**MV ($\times 10^{-3}$)**	**TD (ratio)**
50-65-80	38.0	39.4 - 42.8 - 39.5	14.3@93.8	302.6	9.6	116.8	0.977
55-70-85	36.8	45.7 - 51.4 - 42.9	10.8@40.6	294.0	9.1	140.5	0.947
60-75-90	37.1	45.6 - 48.7 - 44.4	12.8@68.8	312.8	7.8	146.2	1.107
65-80-95	34.7	44.4 - 44.6 - 42.5	13.9@51.6	105.1	9.1	62.9	0.970

TABLE VIII
Real Time Results - Chirp Test

	Mean Square $\times 10^{-6}$		**Maximum** $\times 10^{-3}$	
Profile	↗	↘	↗	↘
Level 1	42.8	18.6	17.6	20.4
Level 2	67.9	22.2	18.8	24.1
Level 3	50.8	15.4	14.3	24.9

TABLE IX
REAL TIME RESULTS - STEP FREQUENCY CHANGES TEST

	Frequency (Hz)	**N^2T** ($\times 10^{-3}$)	**MV** ($\times 10^{-3}$)
Level 1	**Sequence - 1**		
	60→70	17.9	24.1
	70→60	18.9	24.1
	60→50	66.7	24.1
	50→60	125.9	25.3
	Sequence - 2		
	75→85	14.7	17.9
	85→75	15.5	23.7
	75→65	16.8	23.7
	65→75	17.5	22.5
	Sequence - 3		
	85→95	18.8	16.7
	95→85	30.6	21.6
	85→75	16.0	23.7
	75→85	14.9	19.2
Level 2	**Sequence - 1**		
	[55-75]→[60-80]	27.9	32.6
	[60-80]→[55-75]	30.6	31.4
	[55-75]→[50-70]	93.0	32.6
	[50-70]→[55-75]	197.1	36.0
	Sequence - 2		
	[70-90]→[75-95]	26.0	25.3
	[75-95]→[70-90]	44.7	26.2
	[70-90]→[65-85]	21.3	28.6
	[65-85]→[70-90]	19.2	25.3
Level 3	**Sequence - 1**		
	[55-70-85]→[60-75-90]	48.2	55.5
	[60-75-90]→[55-70-85]	50.1	56.0
	[55-70-85]→[50-65-80]	126.7	58.0
	[50-65-80]→[55-70-85]	147.6	57.2
	Sequence - 2		
	[60-75-90]→[65-80-95]	46.7	45.8
	[65-80-95]→[60-75-90]	59.1	53.5
	[60-75-90]→[55-70-85]	52.6	59.3
	[55-70-85]→[60-75-90]	48.8	56.8