Multipath Spatiotemporal SIMO Wireless Systems

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I. Exercise 1

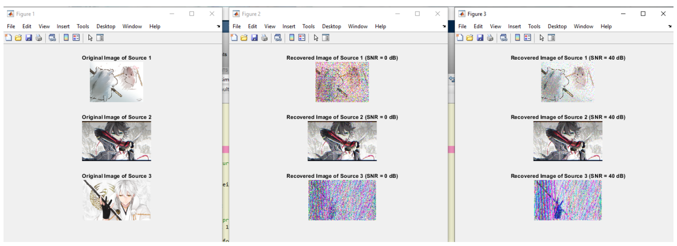

Fig. 1. Name 1: Original images (left), recovered images at 0 dB (middle), recovered images at 40 dB (right)

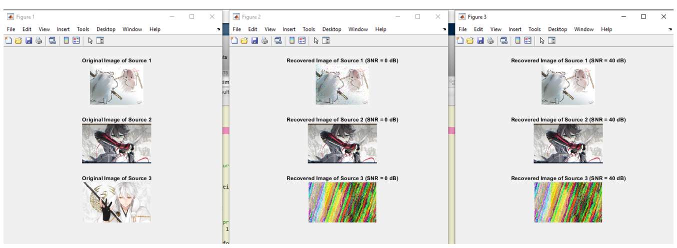

Fig. 2. Name 2: Original images (left), recovered images at 0 dB (middle), recovered images at 40 dB (right)

TABLE I
Task 1: Estimated delays and BER

	Variable	Exact	Name 1	Name 2
	Path 1	5	5	5
Delay	Path 2	7	7	7
	Path 3	12	0	5
BER	0 dB	N/A	0.21059	0.026432
	40 dB	N/A	0.15747	0

The gold sequence determined by name 1 cannot realise lossless encryption and decryption even if the delays are perfectly estimated and there is no noise. Moreover, the delay is estimated [1] by multiplying the shifted versions of the gold sequence with the output symbol stream then check the delay correspond with the maximum cost function. The result suggests that this method cannot detect the accurate delay for paths with a small fading coefficient (eg. 0.2 for path 3).

II. Exercise 2

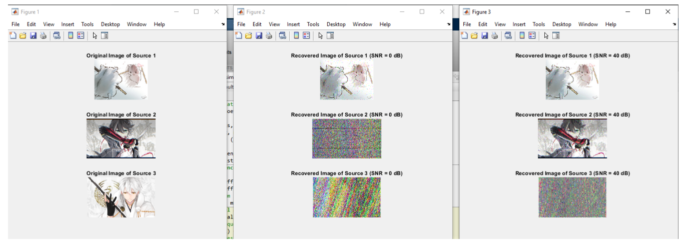

Fig. 3. Name 1: Original images (left), recovered images at 0 dB (middle), recovered images at 40 dB (right)

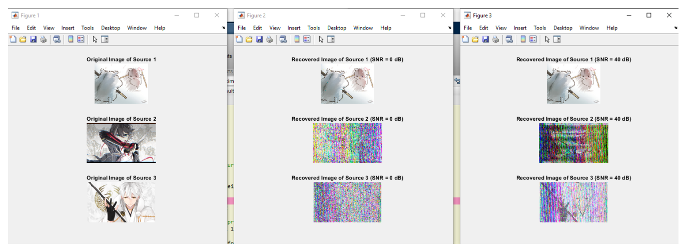

Fig. 4. Name 2: Original images (left), recovered images at 0 dB (middle), recovered images at 40 dB (right)

TABLE II
Task 2: Estimated delays and BER of name 1

	Variable	Exact	Estimated (0 dB)	Estimated (40 dB)
	Path 1	3	3	3
	Path 2	5	6	6
Delay	Path 3	12	12	12
	Path 4	8	9	8
	Path 5	13	0	1
BER	N/A	N/A	0.038251	0.026986

TABLE III
Task 2: Estimated delays and BER of name 2

	Variable	Exact	Estimated (0 dB)	Estimated (40 dB)
	Path 1	2	2	2
	Path 2	6	6	4
Delay	Path 3	13	13	13
	Path 4	8	13	7
	Path 5	13	3	3
BER	N/A	N/A	0.00086961	0

Multipath provides diversity which improves BER compared with single path case. The estimated delay of path 2 and 5 are not as accurate since the former has a relatively small fading coefficient with some phase shift and the latter is with an extremely small fading coefficient. Therefore, the approach of shifting gold sequence to obtain cost function requires optimisation for more accurate detection and thus we introduce multiple receivers in the following sections.

III. Exercise 3

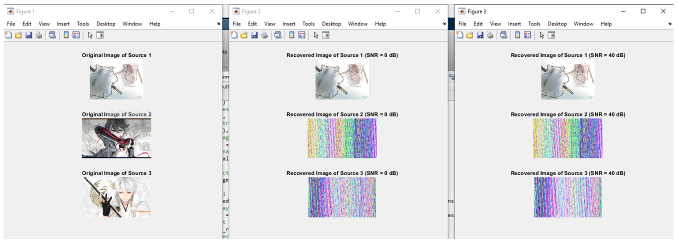

Fig. 5. Original images (left), recovered images at 0 dB (middle), recovered images at 40 dB (right)

TABLE IV
Task 3: Estimated delays, DOAs, and BER

	Variable	Exact	Estimated (0 dB)	Estimated (40 dB)
	Path 1	5	5	5
Delay	Path 2	7	7	7
	Path 3	12	12	12
	Path 1	30	30	30
DOA	Path 2	90	90	90
	Path 3	150	150	150
BER	N/A	N/A	0.00052548	0

It can be concluded that the receiver array can estimate the delays and DOAs [2] quite well when the signals are uncorrelated. Also, we employed a super-resolution beamformer to maximise SIR rather than Wiener-Hopf since the interference is the main source of error and the directions of interference can be estimated accurately. The BER is very low even if the SNR at the receiver end is 0 dB.

IV. Exercise 4

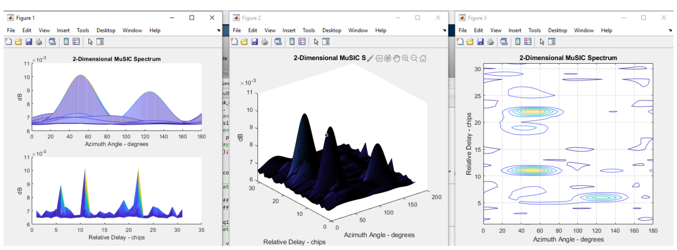

Fig. 6. Unsmoothed: 2-dimensional MuSIC spectrum

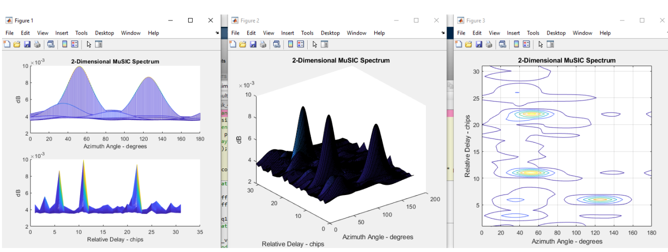

Fig. 7. Smoothed: 2-dimensional MuSIC spectrum

TABLE V
Task 4: Estimated delays and DOAs

	Variable	Estimated (Unsmoothed)	Estimated (Smoothed)
	Path 1	6	6
Delay	Path 2	11	11
	Path 3	22	22
	Path 1	125	125
DOA	Path 2	52	52
	Path 3	53	53

We investigated two estimation algorithms in this task. The unsmoothed version can be applied to estimate the delays and DOAs of uncorrelated paths while the smoothed one [3] [4] is suitable for coherent sources although it may need some optimisation. The detailed explanation of both algorithms is in code. A spatiotemporal beamformer is employed in this task. The recovered text is “Yang , excellent!!! You have completed the mission!!!!!!!!!!”. It can be concluded that the temporal smoothing algorithm provides sharper peaks of the cost function and is expected to present more accurate estimations.

V. Appendix: MATLAB code

The source code can be retrieved from https://github.com/SnowzTail/.

References

[1] A. Manikas, “Coursework: Multipath spatiotemporal simo wireless systems,” September 2018.
[2] ——, “Advanced communication theory,” September 2018.
[3] A. Manikas and M. Sethi, “A space-time channel estimator and single-user receiver for code-reuse ds-cdma systems,” *IEEE transactions on signal processing*, vol. 51, no. 1, pp. 39–51, 2003.
[4] A. Manikas and L. Huang, “Star channel estimation in ds-cdma communication systems,” *IEE Proceedings-Communications*, vol. 151, no. 4, pp. 387–393, 2004.