Navin Khaneja
Systems and Control Engineering
IIT Bombay - Powai, India
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Personal: Born, 5 December, 1972, Hansi, India. Overseas Citizen of India. Citizen of USA.

Professional Preparation:

Indian Institute of Technology, Kanpur	Electrical Engineering	B.Tech	1994
Washington University, St. Louis	Mathematics	M.A.	1996
Washington University, St. Louis	Electrical Engineering	M.S.	1996
Harvard University	Applied Mathematics	M.A.	1999
Harvard University	Applied Mathematics	Ph.d.	2000

Experience:

Professor of Systems and Control IIT Bombay	July 2017-present
Distinguished Visiting Faculty, Electrical Engineering IIT Bombay	July 2014-June 2017
Gordon Mckay Professor of Electrical Engineering Harvard University	July 2008-June 2015
Associate Professor of Electrical Engineering Harvard University	July 2005-June 2008
Assistant Professor of Electrical Engineering Harvard University	July 2001-June 2005
Assistant Professor of Mathematics Dartmouth College	July 2000-June 2001

Research Interest:

control theory, NMR spectroscopy, quantum information and control.

Research Plan:

Research in control theory with applications to NMR and quantum information, computing and control.

Awards: Bessel Prize, Humboldt Foundation, 2005.

Alfred P. Sloan Fellow, 2003.

National Science Foundation Career Award, 2001.

Jury award for outstanding thesis in the area of control theory, Harvard University, 2000.

National talent search scholarship, awarded by National Council of Education, Research and Training (NCERT), India, 1988-1994.

Teaching Graduate Clases taught at Harvard include " decision theory", "control and estimation of dynamic systems", "stochastic control" and "nonlinear control". Undergraduate classes

include, "probability with applications to electrical engineering" and "introduction to operations research". Graduate Clases taught at IIT Bombay include "estimation and identification", "physics and control", "quantum control" and "solid state systems and control".

Graduate Students

Advised following Phd Students. Van Mai Do, Philip Owrutsky, James Lin, Jamin Sheriff, Jr. Shin Li, Haidong Yuan, Dionisis Stefanatos, Brent Pryor, Paul Coote, Tejas Shetty, Sreya Das, Justin Jacob, Sambeda Sarkar.

Post-docs Robert Zeier, Mark Byrd and Randy Scott.

Journal Publications

1. S. Sarkar, P. Paruchuri, N. Khaneja, " Nonlinear Chirp Sequence for Broadband Rotation Using Hyperbolic Secant Pulse" Applied Magnetic Resonance, 1-18 (2023).
2. Justin Jacob, Navin Khaneja, "MODE: Multiply modulated frame technique, excitation and coherence transfer " Journal of Magnetic Resonance, 353, 107500 (2023).
3. Tejas Shetty, Navin Khaneja, "Design of NMR pulses by interative optimization of phases " Applied Magnetic Resonance, 54(3):1-8, (2023).
4. Sambeda Sarkar, Navin Khaneja, "Band selective excitation and pi/2 rotation using Fourier synthesis" Applied Magnetic Resonance, DOI:10.1007/s00723-023-01547-6, (2023).
5. Sreya Das, Navin Khaneja, "Composite pulse combinations for chirp excitation" Journal of Magnetic Resonance , 347, 107359, (2022).
6. Sreya Das, Justin Jacob, Navin Khaneja, "Mechanism of chirp excitation" Journal of Magnetic Resonance Open, Volumes 10-11, 100026, (2022).
7. S. Sarkar, R. Purusottam, A. Kumar and N. Khaneja, "Chirp pulse sequences for broadband π rotation" Joural of Magnetic Resonance 328, 107002 (2021)
8. N. Khaneja, "Time Optimal Control of Coupled Spin Dynamics: A global analysis" Automatica 111, 108639 (2020).
9. N. Khaneja, "Double swept band selective excitation" Global Journal of researches in Engineering: F Vol 19, Issue 2, Version 1.0 (2019).
10. N. Khaneja, "Magnetic resonance with number states vs coherent states" International Journal of modern Physics B (2018).
11. N. Khaneja, "Conservation of Energy, Density of States and Spin Lattice relaxation" Concepts in Magnetic Resonance: Part A (2018); 46A:e21457.
12. N. Khaneja, "Chirp Mixing" Chemical Physics Letters 704, 62-67 (2018)
13. N. Khaneja, "Electron dynamics in solid state via time varying wavevectors" Physica B 539, 29-34 (2018).
14. N. Khaneja, "Chirp excitation" Journal of Magnetic Resonance 282, 32-36 (2017).
15. N. Khaneja and A. Kumar, "Two Pulse Recoupling" Journal of Magnetic Resonance 281, 162-171 (2017).
16. N. Khaneja and A. Kumar, "Broadband excitation by method of double sweep", Applied Magnetic Resonance 48(8), 771-782 (2017).
17. N. Khaneja, "Rf-inhomogeneity compensation using method of Fourier synthesis", J. Magn. Res, **277**, 113-116 (2017).

18. N. Khaneja, "Cone separation, quadratic control systems and control of spin dynamics in presence of decoherence", Phil. Tran. R. Soc. A, **375**, (2017).
19. N. Khaneja, A. Kumar, "Four Pulse Recoupling", J. Magn. Res, **272**, 158-165 (2016).
20. N. Khaneja, A. Kumar, "Recoupling pulse sequences with constant phase increments", J. Magn. Res, **271**, 75-82 (2016).
21. N. Khaneja, A. Dubey and H.S. Atreya, " Ultra broadband NMR spectroscopy with multiple rotating frame technique", J. Magn. Res, **265**, 117-28 (2016).
22. J. Lin, R.G Griffin, N. C. Nielsen and N. Khaneja, "Three pulse recoupling and phase jump matching", J. Magn. Res, **263**, 172-183 (2016).
23. H. Yuan, R. Zeier, N. Pomplun, S.J. Glaser, and N. Khaneja, "Time-optimal polarization transfer from an electron spin to a nuclear spin" Phys. Rev. A 92, 053414 (2015).
24. Van D. M. Koroleva and Navin Khaneja, "Homonuclear decoupling for liquid-state NMR" , J. Chem. Phys. 137, 094103 (2012).
25. P. Owrutsky and N. Khaneja, "Control of inhomogeneous ensembles on the Bloch sphere," Phys. Rev. A 86, 022315 (2012).
26. J.M. Vinther, A.B. Nielsen, M. Bjerring, E. van Eck, A. Kentgens, N. Khaneja, N.C. Nielsen, " Refocused continuous-wave decoupling: A new approach to heteronuclear dipolar decoupling in solid-state NMR spectroscopy", J. Chem. Phys. 137, 214202-214202 (2012).
27. J. Lin, R.G. Griffin and N. Khaneja, " Recoupling in solid state NMR using gamma prepared states and phase matching." J Magn Reson. 2011 Oct; 212(2):402-11.
28. J.M. Vinther, N. Khaneja, and N.C. Nielsen, J. Magn. Reson. 226, 88-92 (2013).
29. Paul Coote, Haribabu Arthanari, Tsyr-Yan Yu, Amarnath Natarajan, Gerhard Wagner, Navin Khaneja , "Pulse design for broadband correlation NMR spectroscopy by multi-rotating frames." J. of Biomolecular NMR, 02/2013.
30. Optimal Control for Generating Quantum Gates in Open Dissipative Systems (149) T. Schulte-Herbrüggen, A. Spörl, N. Khaneja, S. J. Glaser, Phys. Rev. B 44, 154013 (2011).
31. N. Khaneja, "Problems in Control of Quantum Systems", Book Chapter, B. Shapiro J. Gorman, Eds., Springer, (2011).
32. H. Arthanari, G. Wagner and N. Khaneja "Heteronuclear Decoupling by Multiple Rotating Frame Technique", J. of Magn. Reson, 2011 Mar;209(1):8-18.
33. H. Yuan and N. Khaneja, "Efficient synthesis of quantum gates on a three-spin system with triangle topology" , 062301 (2011) Phys. Rev. A.
34. Optimal Control Methods in NMR Spectroscopy , N. C. Nielsen, C. Kehlet, S. J. Glaser, N. Khaneja, Encyclopedia of Nuclear Magnetic Resonance (2010).
35. J. Lin, M. Bayro, R. G. Griffin, N. Khaneja, "Dipolar Recoupling in Solid State NMR by Phase Alternating Pulse Sequences", Journal of Magnetic Resonance, (2009).
36. N. Khaneja, "On some model problems in quantum control", Communications in Information and Systems, Vol. 9, No. 1, pp. 1-40 (2009).
37. J. Neves, B. Heitmann, N. Khaneja and S.J. Glaser, "Heteronuclear decoupling by optimal tracking", J. Magn. Reson., 201(1), (2009).
38. L Strasso, M. Bjerring, N. Khaneja, N. C. Nielsen, "Multiple oscillating field technique for accurate measurement of internuclear distances", 130(22) , J. Chem. Phys, (2009).
39. H. Yuan, R. Zeier, N. Khaneja, S. Lloyd, "Constructing two qubit gates with minimal couplings", Physical Review A, 79, 042309 (2009).

40. J.S. Li and N. Khaneja, "Ensemble control of Bloch Equations", IEEE transactions on Automatic Control, 54(3), 528-536 (2009).

41. R. Zeier, H. Yuan and N. Khaneja, "Time Optimal Synthesis of Unitary Transformations in Fast and Slow Qubit System ", Physical Review A , 77, 032332 (2008).

42. H. Yuan, R. Zeier and N. Khaneja, "Elliptic fuctions and time-optimal control in linear spin topologies with unequal couplings", Physical Review A , 77, 032340 (2008).

43. N. Khaneja, N. C. Nielsen, "Triple oscillating field technique for accurate distance measurements by solid-state NMR", Journal of Chemical Physics 128, 015103 (2008).

44. K. Kobzar, T. Skinner, N. Khaneja, S. J. Glaser, B. Luy, "Exploring the limits of broadband excitation and inversion: II. Rf-power optimized pulses", Journal of Magnetic Resonance 194, 58-66 (2008).

45. H. Arthanari; D. Frueh; G. Wagner; B. Pryor; N. Khaneja, "Fourier synthesis techniques for NMR spectroscopy in inhomogeneous fields", Journal of Chemical Physics 128, 214503 (2008).

46. N. Gershenzon; T. Skinner; B. Brutscher; N. Khaneja; M. Nimbalkar; B. Luy; S. J. Glaser "Linear phase slope in pulse design: application to coherence transfer", Journal of Magnetic Resonance 192, 235-43 (2008).

47. N. Khaneja, "Switched control of electron nuclear spin systems " Phys. Rev. A , 76, 032326 (2007).

48. L. Jiang, J. Taylor, N. Khaneja and M. D. Lukin, "Optimal approach to quantum communication by dynamic programming", Proceedings of National Academy of Sciences, 104, 17291 (2007).

49. J. Hansen, C. Kehlet, M. Bjerring, T. Vosegaard, S. J. Glaser, N. Khaneja, and N. C. Nielsen, " Optimal control based design of composite dipolar recoupling experiments by analogy to single-spin inversion pulses" , Chem. Phys. Lett., 447, 154-161 (2007).

50. H. Yuan, S.J. Glaser and N. Khaneja, "Geodesics for efficient creation and propagation of order along Ising spin chains" Phys. Rev. A , 76, 012316 (2007).

51. N. Khaneja, B. Heitmann, A. Spoerl, H. Yuan, T. Herbrueggen and S.J. Glaser, "Shortest paths for efficient control of indirectly coupled qubits", Phys. Rev. A, 75, 012322(2007).

52. C. Kehlet, M. Bjerring, A.C. Sivertsen, T. Kristensen, J.J. Enghild, S.J. Glaser, N. Khaneja, N.C. Nielsen , "Optimal control based NCO and NCA experiments for spectral assignment in biological solid-state NMR spectroscopy", J. Magn. Reson. 188, 216-230 (2007).

53. B. Pryor and N. Khaneja, "Fourier decompositions and pulse design algorithms for NMR in inhomogeneous fields", J. Chem. Phys., **125**, 194111 (2006).

54. N. Khaneja, "Sensitivity enhanced recoupling experiments in solid state NMR by gamma preparation", Journal of Magnetic Resonance **183**, 261 (2006).

55. J.S. Li and N. Khaneja, "Control of inhomogeneous quantum ensembles", Phys. Rev. A, **73**, 030302 (2006).

56. N. Khaneja, C. Kehlet, S.J. Glaser, N. Nielsen, "Composite dipolar recoupling: anisotropy compensated coherence transfer in solid state NMR", J. Chem. Phys., **124**, 114503 (2006).

57. H. Yuan and N. Khaneja, "Reachable sets of bilinear control system with time varying drift", System and Control Letters, **55**, 501 (2006).

58. S. J. Glaser, T. Schulte-Herbrggen, N. Khaneja, "Non-Computing Applications of Quantum Information in NMR", Informatik Forsch. Entw. 21, 65-71 (2006).

59. J. L. Neves, B. Heitmann, T. O. Reiss, H. H. R. Schor, N. Khaneja, S. J. Glaser, "Exploring the limits of polarization transfer efficiency in homonuclear three spin systems", J. Magn. Reson. 181, 126-134 (2006).

60. T. E. Skinner, K. Kobzar, B. Luy, R. Bendall, W. Bermel, N. Khaneja, S. J. Glaser, "Optimal control design of constant amplitude phase-modulated pulses: application to calibration-free broadband excitation", J. Magn. Reson. 179, 241-249 (2006).

61. Z. Tosner, S. J. Glaser, N. Khaneja, and N. C. Nielsen, "Effective Hamiltonians by optimal control: solid-state NMR double-quantum and isotropic dipolar recoupling", J. Chem. Phys. 125, 184502-1-184502-10 (2006).

62. H. Yuan and N. Khaneja, " Time optimal control of coupled qubits under non-stationary interactions", Phys. Rev. A **72** 040301(R) (2005).

63. D. Stefanatos, N. Khaneja, S.J. Glaser, "Relaxation optimized transfer of spin order in Ising chains", Phys. Rev. A **72**, 062320 (2005).

64. H. Mabuchi and N. Khaneja, " Principles and applications of control in quantum systems", International Journal of Robust and Nonlinear Control **15** 647-667 (2005).

65. T. Vosegard, C. Kehlet, N. Khaneja, S.J. Glaser, N. C. Nielsen, " Improved excitation schemes for multiple-quantum magic-angle spinning experiments for quadrupolar nuclei designed using optimal control theory", J. Am. Chem. Soc. **127** 13768 (2005).

66. C. Kehlet, T. Vosegard, N. Khaneja, S.J. Glaser, N.C. Nielsen, "Low power homonuclear dipolar recoupling in solid state NMR developed using optimal control theory", Chem. Phys. Lett. **414** 204 (2005).

67. B. Luy, K. Kobzar, T.E. Skinner, N. Khaneja, S.J. Glaser, "Construction of universal rotations from point to point transformations", J. Magn. Reson. **176**, 179-186 (2005).

68. K. Kobzar, B. Luy, N. Khaneja, S. J. Glaser, "Pattern Pulses: design of arbitrary excitation profiles as a function of pulse amplitude and offset", J. Magn. Reson. **173**, 229-235 (2005).

69. D. P. Frueh, T. Ito, Jr-Shin Li, G. Wagner, S.J. Glaser, N. Khaneja, "Sensitivity enhancement in NMR of macromolecules by application of optimal control theory", J. Biomol. NMR **32**, 23-30 (2005).

70. N. Khaneja, F. Kramer, S.J. Glaser, "Optimal experiments for maximizing coherence transfer between coupled spins", J. Magn. Reson. **173**, 116-124 (2005).

71. N. Khaneja, T. Reiss, C. Kehlet, T.S. Herbrüggen, S.J. Glaser, "Optimal control of coupled spin dynamics: design of NMR pulse sequences by gradient ascent algorithms", J. Magn. Reson. **172**, 296-305 (2005).

72. T. Schulte-Herbrueggen, A.K. Spoerl, N. Khaneja, S.J. Glaser, " Optimal control-based efficient synthesis of building blocks of quantum algorithms seen in perspective from network complexity towards time complexity", *Phys. Rev. A*, **72**, 042331 (2005).

73. T. E. Skinner, T. O. Reiss, B. Luy, N. Khaneja, S. J. Glaser, "Tailoring the optimal control cost function to a desired output: application to minimizing phase errors in short broadband excitation pulses", J. Magn. Reson. **172**, 17-23 (2005).

74. N. Khaneja, Jr. Shin Li, C. Kehlet, B. Luy, S.J. Glaser, "Broadband relaxation optimized polarization transfer in magnetic resonance", Proceedings of National Academy of Sciences, USA. **101**, 14742-47 (2004).

75. S. Dionisis, N. Khaneja, S.J. Glaser, "Optimal control of spin dynamics in the presence of longitudinal and transverse relaxation", Phys. Rev. A **69**, 022319, (2004).

76. C.T. Kehlet, A.C. Sivertsen, M. Bjerring, T.O. Reiss, N. Khaneja, S.J. Glaser, N.C. Nielsen, "Improving solid-state NMR dipolar recoupling by optimal control", J. Am. Chem. Soc. **126**, 10202-03 (2004).

77. K. Kobzar, T. E. Skinner, N. Khaneja, S. J. Glaser, B. Luy, "Exploring the limits of broadband excitation and inversion pulses", J. Magn. Reson. **170**, 236-243 (2004).
78. T. E. Skinner, T. O. Reiss, B. Luy, N. Khaneja, S. J. Glaser, "Reducing the duration of broadband excitation pulses using optimal control with limited RF amplitude", J. Magn. Reson. **167**, 68-74 (2004).
79. S.E. Sklarz, D.J. Tannor and N. Khaneja, "Optimal control of quantum dissipative dynamics: analytic solution for cooling a three level Lambda system", Phys. Rev. A **69**, 053408 (2004).
80. N. Khaneja, B. Luy, and S.J. Glaser, "Boundary of quantum evolution under decoherence", Proceedings of National Academy of Sciences **100**, no. 23, 13162-66 (2003).
81. N. Khaneja, T. Reiss, B. Luy, S. J. Glaser, "Optimal control of spin dynamics in the presence of relaxation", J. Magn. Reson. **162**, 311-319 (2003).
82. T. Reiss, N. Khaneja, S.J. Glaser, "Broadband geodesic pulses for three spin systems: Time-optimal realization of effective trilinear coupling terms and swap gates", J. Magn. Reson. **165**, 95-101 (2003).
83. T.E. Skinner, T. Reiss, B. Luy, N. Khaneja, S.J. Glaser, "Application of optimal control theory to the design of broadband excitation pulses for high resolution NMR.", J. Magn. Reson. **163**, 8-15 (2003).
84. M.S. Byrd and N. Khaneja, " Characterization of the positivity of the density matrix in terms of the coherence vector representation", Phys, Rev. A 062322 (2003).
85. "Increasing the size of NMR quantum computers", S. J. Glaser, R. Marx, T. Reiss, T. Schulte-Herbrggen, N. Khaneja, J. M. Myers, A. F. Fahmy in: Quantum Information Processing, pp. 53-65, Eds.: G. Leuchs, T. Beth (Wiley-VCH) (2003).
86. N. Khaneja, S.J. Glaser and R.W. Brockett, "Sub-Riemannian geometry and optimal control of three spin systems ", Phys. Rev. A **65**, 032301 (2002).
87. N. Khaneja, S. J. Glaser, "Efficient transfer of coherence through Ising Spin chains", Phys. Rev. A **66**, 060301(R) (2002).
88. T. Reiss, N. Khaneja and S.J. Glaser, "Time-Optimal coherence-order-selective transfer of in-phase coherence in Heteronuclear IS spin systems", J. Magn. Reson. **154**, 192-195 (2002).
89. N. Khaneja and S.J. Glaser, "Cartan decomposition of $SU(2^n)$ and control of spin systems", Chemical Physics **267**, 11-23, (2001).
90. N. Khaneja, R.W. Brockett and S.J. Glaser, "Time optimal control of spin systems", Phys. Rev. A **63**, 032308 (2001).
91. R.W. Brockett and N. Khaneja, "On the stochastic control of quantum ensembles", Chapter in System Theory: Modeling, Analysis and Control, Kluwer Academic Publishers (1999).
92. N. Khaneja, M. I. Miller and U. Grenander, "Dynamic programming generation of curves on brain surfaces", IEEE transactions on Pattern Analysis and Machine Intelligence **20**, No 11 (1998).
93. M. Bakircioglu, U. Grenander, N. Khaneja and M.I. Miller, "Curve matching on brain surfaces using frenet distances", in Special Issue of Human Brain Mapping, 6:329-333 (1998).
94. F. Yamaguchi, T.D. Ladd, C. Master, Y. Yamamoto, N. Khaneja, "Efficient decoupling and recoupling in solid state NMR quantum computing", quant-ph/0411099.

Conference Publications

1. Philip Owrutsky and Navin Khaneja, "Control of Inhomogeneous Ensembles in the Presence of a Random Periodic Drift 2012", ACC, Montral, Canada, June 27-June 29, 2012.
2. J.S. Li and N. Khaneja, "Ensemble control on Lie groups" IFAC Symposium on Nonlinear Control Systems, Pretoria, South Africa (2007).
3. B. Pryor and N. Khaneja, "Fourier synthesis technique for control of inhomogeneous quantum systems"IEEE Conference on Decision and Control, New-Orleans (2007).
4. J.S. Li and N. Khaneja, "Ensemble controllability of linear systems " IEEE Conference on Decision and Control, New-Orleans (2007).
5. J.S. Li and N. Khaneja, "Ensemble controllability of the Bloch equations" IEEE Conference on Decision and Control, San-Diego (2006).
6. B. Pryor and N. Khaneja, "Optimal control of homonuclear spin dynamics subject to relaxation"IEEE Conference on Decision and Control, San-Diego (2006).
7. H. Yuan and N. Khaneja, "Time optimal control of spin systems with unequal couplings" IEEE Conference on Decision and Control, San-Diego (2006).
8. H. Yuan and N. Khaneja, "Reachable set of bilinear control system with time varying drift", IEEE Conference on Decision and Control, Spain (2005).
9. D. Stefanatos and N. Khaneja "Semi-definite programming and reachable set of dissipative bilinear control system", IEEE Conference on Decision and Control, Spain (2005).
10. D. Yamins, S. Wydo and N. Khaneja "Group control and the 1D equigrouping problem", IEEE Conference on Decision and Control, Bahamas(2004).
11. N. Khaneja, S.J. Glaser, "Optimal control of coupled spins in presence of cross-correlated relaxation", IEEE Conference on Decision and Control (2003).
12. S. Dionisis, N. Khaneja, S.J. Glaser, "Optimal control of coupled spins in presence of longitudinal and transverse relaxation", IEEE Conference on Physics and Control, St. Petersburg, Russia (2003).
13. N. Khaneja, S.J. Glaser, " Constrained bilinear systems ", IEEE Conference on Decision and Control (2002).
14. N. Khaneja, S.J. Glaser, R.W. Brockett, "Subriemannian geodesics and time optimal control of spin systems", American Control Conference (2002).
15. R.W. Brockett, N. Khaneja, S.J. Glaser, "Optimal input design for NMR identification problem", IEEE Conference on Decision and Control (2001).
16. N. Khaneja and R. Brockett, "Dynamic feedback stabilization of nonholonomic systems,", IEEE Conference on Decision and Control (1999).

Professional Activities:

Reviewed publications for science, journal of magnetic resonance, IEEE transaction of automatic control, system and control letters, mathematics of signals and systems, physica D, SIAM journal on control and optimization, physical review, journal of chemical physics, quantum information processing, control and decision conference (CDC) and american control conference (ACC). Served on NSF review panels on quantum and biological inspired computing. Co-organized workshops on 'control of quantum systems" in the CDC conference 2002, 2004. Co-organized the first meeting on principles and applications of control in quantum systems (Pracqsys), Caltech 2004. Organizer of the second meeting on principles and applications of control in quantum systems, Harvard 2006. Served on

international program committees for Pracqsys 2004, 2005, 2006 and 2007. Served on the scientific committee for the first meeting on "control, constraints and quanta" in Poland (2007) and "Mathematical foundations of quantum information and control", in Madrid, Spain (2008). Co-organizer of the school on "Quantum Control of Light and Matter" held at Kavli-Institute of theoretical physics in Santa-Barbara in 2009.

Collaborators and References:

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Professor Niels Nielsen, University of Aarhus, Denmark. Email: ncn@chem.au.dk.

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