Statement of Purpose
of Sasank Chilamkurthy (CMS applicant for Fall – 2015)

I am applying for Computational and Mathematical Sciences graduate program at California Institute of Technology because I would like to conduct corporate research and development after graduation. I'm finishing a Bachelor's degree in Electrical Engineering at Indian Institute of Technology, Bombay in Spring 2013 with minor in Mathematics.

Education: I had always been interested in mathematics because of relative ease with which it can model complex real world phenomenon. I chose Electrical Engineering as my major because of its strong mathematical flavour and because it is one of the most impactful fields of our times. As a freshman, I was strongly fascinated at the rigour with which mathematics is approached. This led me later to do several graduate level courses from mathematics department earning a minor degree in Mathematics.

The undergraduate program at IIT Bombay has exposed me to wide variety of topics in the vast field of Electrical Engineering. Signal processing and Communication systems particularly appealed to me as mathematics applied to solve the practical problems of processing and transmitting data generated from various sources. It surprised me that seemingly abstract techniques like Fourier transform, convolution and optimization can be used to model and solve an amazingly wide variety of problems ranging from image processing, speech recognition to communication systems. Mathematical foundations of communications as formalised in Information Theory excited me. For a course project, I implemented decoding of LDPC codes using sum product algorithm on factor graphs based on the research paper by Kschischang et al. This made me appreciate some of the algorithms used in modern communication systems. I attended an interesting winter school on information theory held at Institute of Network Coding, Chinese University of Hong Kong. This further cemented my interest in this field and prompted me to take graduate level electives like Information and Coding Theory, Digital Image processing and Stochastic Optimization.

Research: Coming to my research experience, I worked on Fractional Fourier Transform (FrFT) in the summer of my sophomore year. The problem was to estimate chirp signal parameters from very noisy samples using FrFT. This is of particular interest for sonar systems and acoustic communications. I surveyed available discretizations of the transform and chose one which is relevant to the problem and still as fast as FFT. When experimented with this transform on Matlab, an algorithm to determine the chirp parameters became clear. I proved this algorithm using a clever trick of seeing given samples as a rescaled signal sampled in a specific way for which we know that discrete FrFT is an approximation of continuous FrFT. I also looked at a generalized version of FrFT which can handle higher order chirps like quadratic chirps. I proved uncertainty principle for this transform and worked on proving a tighter bound for real valued signals. In a nutshell, I understood mathematical foundations of a novel signal processing technique and used them to solve the problem at hand. This project won me an Undergraduate Research Award.

In the summer of my junior year, I interned at Centre for Optics, Photonics and Lasers (COPL), Quebec under supervision of Prof. Leslie Rusch. I worked on Coded Modulation for Coherent Optical Communication systems. My primary assignment was to apply MLCM heuristics proposed by Ramtin et al[1] to various signal constellations. In particular, I had to compare, both by simulation and experiments, a constellation optimized for both high phase noise and limited effective number of bits (ENOB) of transmitter with other constellations proposed in the literature. I modelled limited ENOB effects of DAC at higher Baud rates and simulated the coherent modulation setup with MLCM for various line-width lasers and signal constellations. My simulations showed that

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[1] Ramtin Farhoudi and Leslie Ann Rusch, Multi-Level Coded Modulation for 16-ary Constellations in Presence of Phase Noise, Journal Of Lightwave Technology, Vol. 32, No. 6, March 15, 2014

ENOB optimized constellation was the best performing constellation for high phase noise regimes. At low phase noises, however, square 16 QAM is the best performer. Next step was to validate this experimentally by calculating post FEC BER from offline processed data. Three different lasers of line-widths 10 KHz, 100 KHz and 1 MHz laser were used. For the first two lasers, experimental results echoed my simulations. It turned out that data from 1 MHz line-width laser has phases noise too large for my offline DSP to handle. In this project, I got hands-on experience on end to end optical communication system including different signal processing algorithms for carrier phase recovery and advanced modulation techniques.

In my senior year, I worked on multiple projects. One of them is traffic sign recognition. I used Fisher's Linear Discriminant algorithm on Histogram of Oriented Gradient (HOG) features to achieve test set classification accuracy of about 97%. In another project, I reviewed a paper on theoretical aspects of deep learning[2]. For my B.Tech Project (senior thesis), I am working on water filling power allocation schemes for energy harvesting wireless networks. The problem is to find a water filling scheme which maximizes the expected average throughput in presence of both data arrival and energy recharge queues. I ran the simulations of the queues and they showed that average throughput is a quasi concave function of water level parameter of the water filling policy. I devised and implemented a stochastic approximation algorithm and results matched with that of simulations. To prove convergence of this algorithm, it is necessary to show quasi-concaveness of expected average throughput. I am working to prove this.

Teaching: Apart from research experience, I have also gained considerable teaching experience at IIT Bombay. I have been teaching assistant for introductory mathematics courses of Calculus, Linear Algebra and Differential Equations. My duties included conducting weekly tutorials to help students understand the material and solve the problems from tutorial sheets and grading of answer sheets and assignments. Thanks to the excellent feedback received from the students, my experience with teaching has built in me the confidence necessary to excel as a teacher.

Future Plans: As a graduate student, I plan to work on signal processing, in particular image processing. I would like to solve problems related to perception of images. One such problem which excites me is automated perceptive image quality assessment. Since humans are almost always the end users of image communications and compression, solving this problem will allow compression algorithms to directly optimise the perceptive quality of image rather than a proxy measure. I am also interested in exploring areas of computer vision and compressive sensing. My longterm career goal is to obtain a highly skilled professional position in industry and to contribute to the cutting edge of technology in the area of my choosing. I see excelling at graduate school as a natural and necessary intermediate step in this direction.

Why Caltech?: The Computation and Mathematical Sciences graduate program at Caltech is distinctly suited to my interests. Since my interests are at the intersection of Electrical Engineering, Applied Mathematics and Computer Science, the true interdisciplinary nature of this program allows me to work on wide variety of problems from various disciplines which have similar theoretical core. I believe that, at least in research, deeper understanding of theoretical foundations of techniques is necessary to apply them to practical problems. This fits nicely with the one of the tenets of the program. At Caltech, I'd love to work with Prof. Joel A. Tropp or with Prof. PP Vidyanathan's DSP group. I also find work done by Prof. Pietro Perona on computer vision very interesting.

In conclusion I would say that I am fully aware of kind of hard work, dedication and perseverance that is required for graduate research. Given my preparation and strong mathematical foundations, I am confident that I have what it takes to be successful at a graduate school both in terms of subject background and motivation. I, therefore look forward to have join Caltech as a graduate student.

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[2] Sanjeev Arora, Aditya Bhaskara, Rong Ge, and Tengyu Ma. Provable bounds for learning some deep representations. Proceedings of the 31st International Conference on Machine Learning, Beijing, China, 2014.