

## Obituary: Nirmal K. Bose (1940–2009)

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Nirmal K. Bose, the founding editor-in-chief of the journal, passed away on November 22, 2009 in Cologne, Germany. He was visiting the University of Wuppertal as an alumni senior scientist of the Alexander von Humboldt Foundation.

Born in Calcutta (presently Kolkata), India on August 19, 1940, Nirmal Bose received a B.Tech degree from IIT Kharagpur, India in 1961. Thereafter he travelled to Cornell University, Ithaca, New York for graduate education, where he received a Master's degree in Electrical Engineering in 1963. Although his later career was steeped in the tradition of circuits and systems theory, at Cornell his education was tilted more towards microwaves. However, it was at Cornell that he came in contact with Frank Rosenblatt (of the well known Rosenblatt perceptron), and took classes with him—something that manifested much later in Bose's work on neural networks in the late 1980s. Well-known circuit theorist Sanjit Mitra was a good friend as a young assistant professor at Cornell during these years.

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Bose moved to Syracuse University for more focused work on circuits for his doctoral dissertation with F. M. Reza, who later served as an Iranian ambassador to Canada under the Shah of Iran. Reza had come to Syracuse after a career at MIT and taught both circuits and information theory. At MIT, Reza belonged to the circuit theory group surrounding Ernst Guillemin, who had travelled to Germany in the 1920s to study with one of the most famous mathematical physicists of the century. Guillemin's PhD advisor in Munich was theoretical physicist Arnold Sommerfeld. In this sense, Bose's academic lineage can be traced back to the German science of that time.

At Syracuse he came in contact with many noted circuit theorists. Norman Balabanian, Sundaram Seshu and Theodore Bickart were among the most prominent ones. Classic books by these three still shine on the shelves of serious circuit theory students. Among fellow graduate students at Syracuse, he mentioned discussing and dissecting circuit theoretic concepts such as reciprocity and passivity with Alan Willson from papers by the celebrated control theorist Rudy Kalman. Control theory was an up-and-coming field in those years, and there was a vigorous exchange of ideas between circuit theory and system theory—a phenomenon that apparently influenced Bose's thinking all along.

Bose completed his PhD dissertation entitled "*Some new results and applications of realizability theory*" at Syracuse University in 1967. After a short stint at Princeton he then went to the University of Pittsburgh as an assistant professor and rose to full professor of Electrical Engineering and later held a joint appointment with the department of Mathematics and Statistics. At Pittsburgh he first wrote papers that showed his interests outside the traditional domain of circuit theory and in broader areas of system theory and mathematics. His initial collaborators at Pittsburgh were Ching-Chung Li, William Vogt, Mike Strintzis, and Chong-Yun Chao of the Mathematics Department. He taught courses on linear system theory, and network analysis and synthesis. During the year 1971 he spend about 8 months at the American University of Beirut as a visiting faculty under an exchange program with the University of Pittsburgh sponsored by the Gulf Oil Corporation.

It is during this period that ideas for multidimensional systems slowly began to germinate. While earlier work on lumped distributed networks by Dan Youla at Brooklyn Polytechnic, New York arising from considerations of microwave circuits had already paved the way for this development, interest in two-dimensional digital filters from the signal processing community provided much impetus as well. Although they never published together, Dan Youla remained a much admired colleague, with whom Bose consulted from time to time. In 1973 Bose took a sabbatical leave and spent approximately a year at University of California, Berkeley.

During this time he had some interest in discrete mathematics, graph theory and related routing and layout problems of large scale integrated circuits, and at Berkeley he discussed these interests extensively with his host Ernest Kuh. However, this is also the period when the work on two-dimensional systems started to take hold, and Bose's sojourn in Berkeley marked the beginning of lifelong collaboration and friendship with E. I. Jury. Other than multidimensional systems and signal processing research with E. I. Jury, he also worked with several others at Berkeley including Brian Anderson, who was visiting from Australia. He also collaborated with colleagues at UC Davis (Sanjit Mitra's group) during this period. It is fair to say that Tom Kailath's group at Stanford had much interest in his thinking at the time, as is obvious from several papers (authored by Tom Kailath, Bernard C. Levy, S. Y. Kung et al.) from that Stanford group giving rise to longstanding investigations on different versions of multidimensional matrix factorization problems that would engage many researchers including Bose himself for several decades to come. During the intervening period Bose also

collaborated with Bob Newcomb at the University of Maryland on a sequence of papers on multivariable circuit theory.

After returning from Berkeley his first extensive paper on multidimensional systems, “New Techniques and Results in Multidimensional Problems,” appeared in a special issue entitled “Recent Trends in Systems Theory” published by the *Journal of the Franklin Institute* jointly with the *Proceedings of the IEEE* in January 1976. Subsequently, he guest edited a special issue of *Proceedings of the IEEE* in June 1977 on Multidimensional Systems, edited an IEEE benchmark paper collection entitled: *Multidimensional Systems: Theory and Applications* in 1979, and his first authored book *Applied Multidimensional Systems Theory*, published by Van Nostrand Reinhold, appeared in 1982. This was followed by the publication of an edited volume, *Multidimensional Systems: Progress, Directions and Open Problems*, by D. Reidel Publishing Company, Dordrecht, Holland in 1985. The latter book contained the first exposition of Groebner basis techniques by Bruno Buchberger from Linz, Austria that became one of the most widely referenced articles in symbolic computation—an area in which Bose himself was to engage in later with Zhiping Lin in Singapore, Li Xu in Japan and several PhD students including Chalie Charoenlarnnoppapart (now in Thailand). The book was later revised, with the addition of new materials, and published as *Multidimensional Systems Theory and Applications*, by Kluwer Publishing Company, Dordrecht, Holland in 2003 with Bruno Buchberger and J. P. Guiver as co-authors.

During the second half of the 1970s Bose became interested in the multidimensional wave-digital filter work independently started by Alfred Fettweis in Bochum, Germany, whom he had already known from a previously held NATO Advanced Study Institute (ASI) on circuit theory. This started a longstanding discussion, exchange of ideas, and collaboration with German colleagues that lasted until the very end, first under the sponsorship of the Deutscher Akademischer Austausch Dienst (DAAD) and then the Alexander von Humboldt (AvH) Foundation. Anton Kummert—his host in Wuppertal Germany during his last days and one of the two current co-editors for this journal—had, in fact, written his PhD dissertation on two-dimensional circuit synthesis under the direction of Alfred Fettweis in Bochum.

Since the field of digital signal processing had come of age in the 1980s and faculty members at many universities, including Bose himself, were teaching courses on the topic, he consolidated his class notes in the undergraduate (senior) level textbook *Digital Filters: Theory and Applications*, published by North-Holland Elsevier, NY, 1985. An expanded version of this book was later reprinted by Krieger Publishing Company, Florida under the new title *Digital Filters* in 1993.

Around this point of time the field of multidimensional systems and signal processing began to become somewhat diverse, and it would be difficult to give a comprehensive coverage of all his activities. Among the many topics in which he published with students and colleagues are multidimensional approximation theory, model reduction and filter design. One of the better known developments of this period was the so-called Kharitonov type interval stability theorems on robust stability, which Bose discussed and provided circuit theoretic interpretations for based on properties of lossless impedance (Foster) functions. This interpretation not only provided further confirmation for the validity of the Kharitonov interval stability theorem from obscure Russian literature that was viewed with skepticism in the West at first, but later paved the way to further generalization in many directions including those for multidimensional systems. In April 1991, he guest edited a second special issue of the *Proceedings of the IEEE* on “Multidimensional Signal Processing” in order to assess the status of the field since publication of the first *Proceedings of the IEEE* special issue on the topic in 1977.

Meanwhile, in 1986 Bose had moved from the University of Pittsburgh to Pennsylvania State University, where over the years he served as Singer Professor of Signal Processing, the HRB Systems Professor, and later as university Endowed Fetter professor. Here, at first he devoted considerable time in developing laboratory and curriculum in digital signal processing in the EE department with the help of younger colleagues. He also turned his attention towards more practical areas at least for a while. An example of the latter is his interest in the burgeoning field of neural networks during this period. His interest in this topic can be traced back to his student days at Cornell where he had taken courses with Frank Rosenblatt, and was probably also aided by his early work on graph theory and algorithms arising from involvement in routing and layout of large scale integrated circuits. He taught courses, gave several plenary lectures in international conferences, and was the principal author of a book entitled *Neural Network Fundamentals with Graphs, Algorithms and Applications*, coauthored with P. Liang and published by McGraw-Hill Book Company, NY, in 1996.

Around 1990 he founded with Kluwer Academic Publishers the journal *Multidimensional Systems and Signal Processing* for which he served as the Editor-in-Chief until the end. In order to maintain technical balance of the journal in theoretical as well as applied areas such as geophysical signal processing and image processing, and at the same time to provide an international coverage, he sought assistance of two co-editors. Marwan Simaan from the US and Jan Biemond from Delft, Holland were the first two co-editors for the journal. While several others have held those two positions since then, Zhiping Lin was the first co-editor to be appointed from Asia in recognition of the increased activity in that region of the world. As the only journal in the area, it continues to be published by Springer today. The journal enjoys a truly distinguished editorial board appointed from all continents around the world. Dr. Bose religiously attended the biannual *Multidimensional Systems Workshop* that was initiated by European researchers (including Krzysztof Galkowski in Poland and Eric Rogers in the UK) in 1998, at several of which he gave opening plenary lectures.

His later years were more concerned with the development of multi-target tracking and super-resolution techniques for image processing. On this latter topic he made substantial contributions and collaborated with researchers in Hong Kong including Michael Ng. During the last couple of years he travelled more to collaborate with researchers abroad. He spent more than a year as an Alexander von Humboldt Awardee with Alfred Fettweis in Bochum, Germany, during which he coauthored papers on mathematical questions posed by Fettweis arising from issues of numerical integration of partial differential equations based on multidimensional wave-digital methods. He also spent extended periods on research visits to Tokyo Institute of Technology (host, Isao Yamada) and Akita Prefecture University (host, Li Xu) in Japan, and Nanyang Technological University in Singapore (host, Zhiping Lin).

Professor Bose authored, coauthored or edited 15 books, published special issues of several journals in engineering and mathematical disciplines, contributed about 25 chapters in edited books, and authored or coauthored more than 150 journal papers. He was an elected Fellow of the IEEE, served in various positions in IEEE Circuits and Systems Society including in its Board of Governors, served in the editorial board of the Transactions (including several other non IEEE journals), and served for a while as the chairperson for its education committee. He was the recipient of the IEEE 3rd Millennium award in 2000, and in 2007 the IEEE Circuits and Systems Society honored him with the society education award. A list of PhD dissertations supervised by him until 2006 shows that he had advised 30 PhD students in addition to many more Masters thesis students. He served in numerous advisory and visiting committees including serving as an education advisor to the government of India for the United Nations.

His most important contributions in signals and systems theory lie in unifying and presenting a broad range of problems from engineering to applied mathematics under the common umbrella of multidimensional signals and systems. His work in this area and even in applied mathematics can be largely traced back to classical circuit theoretic concepts. In this difficult and demanding field he was by far the most influential promoter worldwide as a researcher as well as an educator. Despite the fact that his approach to engineering problems was rather theoretical, he emphatically taught students that the degree of technical understanding can be measured by the ability to articulate results clearly and meaningfully without overtly resorting to mathematical justification. Professor Bose had a keen perspective on the problem of choosing what problems to work on. According to Y. Q. Shi—one of his PhD students now on the faculty at the New Jersey Institute of Technology—he often said to his students, “There are so many questions unsolved in this world ... we should choose to work on those whose solutions are meaningful.”

While many notes of condolence on the untimely loss of Dr. Bose were received from friends and colleagues all over the world, the common sentiment among all those is probably best expressed by Brian Anderson of the Australian National University in writing: “I found him to be a committed scholar, a complete gentleman, and a person of encyclopedic knowledge. ... we (with Eliahu Jury) collaborated on a problem known as output feedback stabilization, ... The problem had for some years been regarded as one of the significant unsolved problems, and it was Nirmal who identified the tools which subsequently turned out to be the ones that solved the problem ... and at the end we were all very proud of what we had achieved technically, while friendships had been reinforced in the process.”

Over the years, his research was supported by the National Science Foundation, Air Force Office of Scientific Research, and the Office of Naval Research in the US and by various overseas organizations such as the two German organizations AvH and DAAD mentioned earlier as well as the Japan Society for the Promotion of Science.

His dedication to this field and to his family will be missed by all who knew him well. He is survived by his wife, two daughters and two grandchildren.