some personal reminiscences: communication theory and a nobel prize

DAVID MIDDLETON, FELLOW, IEEE

Dr. David Middleton kindly consented to write these reminiscences at the request of your Editor. A brief biographical sketch of Dr. Middleton follows the article.

On October 11, 1977, Prof. J. H. Van Vleck, Professor of Physics Emeritus at Harvard, along with Sir Neville Mott of Cambridge University and Dr. Philip Anderson of the Bell Laboratories, was awarded the Nobel Prize in Physics for fundamental theoretical investigations of the electronic structure of magnetic and disordered systems and, more generally, for his lifetime work in the theory of magnetic phenomena. Not only did his Nobel citation call him "the father of modern magnetism," it also noted that "Van Vleck's ideas have played a central rôle in the development of the laser." Born in 1899, Van Vleck was educated at the University of Wisconsin and at Harvard. He taught at the Universities of Minnesota and Wisconsin, and joined the Harvard faculty in 1935, becoming Hollis Professor of Natural Philosophy in 1951, which chair he held until his retirement in 1969.

On the morning of October 12, 1977, I was on my way to present a paper at an International Symposium on Information Theory, at Cornell, when the morning newspapers announced this exciting and welcome Nobel news. For me, the excitement and pleasure were particularly highlighted for personal reasons as well: during the three years (1942–1945) of the war (World War II), I had the privilege of being Prof. Van Vleck's research assistant at the Radio Research Laboratory of Harvard, and after that, of being one of his doctoral students (1946–1947). What is perhaps not too well known now but is of relevant interest to the information and communication theory communities here, and elsewhere, is the important basic work (among others) done by Van Vleck during this period in (electronic) noise and signal detection problems. I mention, in particular, the studies on the spectrum of "clipped" noise [1], and on the performance of radar receivers [2]. The former had important applications in our wartime effort in electronic countermeasures, then a just-beginning discipline, and the latter was a major early step in analyzing the optimum performance of radar (and later, communication) systems in Gaussian noise. In fact, the fundamental concept of the so-called "matched filter" [2], [3] was discovered and developed during this period (and simultaneously and independently, also, by Dr. D.O. North (RCA), using a different approach). Still other noise studies [4] came directly from this wartime work, which was also significantly aided by the then very new and powerful approaches [5] introduced by S. O. Rice of Bell Laboratories. Not only did much of this work of the wartime years lead to many further important results, but also their descendants have continued to provide fertile areas of investigation and application in such now familiar domains as random processes, signal processing, system performance, and optimization, to mention a few of the principal ones.

Professor John H. Van Vleck, Nobel Laureate.

But, to return to Harvard (1942–1945): at that time Van (as he is familiarly known to his friends and colleagues), I (as his assistant), and a few others, some my age, some more senior, constituted the "Theoretical Group" at the Radio Research Laboratory (R.R.L.), directed by Prof. Frederick Terman, of Stanford, where a variety of problems were under consideration, almost all concerned with radar counter-measures, such as "chaff" and active noise sources. An important exception here, however, was Van Vleck's concurrent work on K-band absorption by the oxygen molecules in the atmosphere (later published in the *Physical Review*), which had critical system implications for the then very new K-band microwave radars. In any case, our blackboards got thoroughly encrusted with chalk, our electromechanical hand calculators were kept busy overtime (except for one unforgettable period when a mouse—no doubt an enemy agent—died in the partitions, a very small mouse with a very large olfactory effect!) and time was often measured as an interval between progress reports. It was an exciting time, and Van was a stimulating teacher to learn from and to work for. His formidable applied mathematical abilities never got in the way of direct and intuitive approaches to the physical kernel of a problem. (I can recall many back-of-the-envelope calculations which later blossomed into important technical results.) For me, it was a privileged and memorable opportunity, made richer by Van's often outré sense of humor and his awesomely encyclopedic, and up-to-date, command of railroad timetables, for every railroad in the USA!

Prof. Van Vleck lecturing at a Symposium March 21, 1978 at Bell Laboratories in honor of the 1977 recipients of the Nobel Prize in Physics.

Although we felt at times that much of our own work had a rather academic flavor, compared with the exciting equipment and systems being developed in other parts of the Laboratory (R.R.L.), this work was nevertheless new and exciting in its own fashion. The fact that some of it never made it to the arenas of wartime applications, then so urgently before us, was at least partially mitigated by the hope that it would nevertheless someday prove technically interesting and possibly useful. Happily, this has indeed turned out to be the case, and what was so new and often untried then has been absorbed into today's mainstream of concept and method, as some of the references below indicate. At any rate, with the end of the war, Van returned to teaching and the other duties of a senior professor, and I, among others, returned to completing our Ph.D.'s, and in some cases, with the fortunate advent of the Office of Naval Research (1946–), to a further exploitation for peaceful use of the many new ideas and methods engendered in the wartime technical effort.

REFERENCES

[1] J. H. Van Vleck, "The spectrum of clipped noise," Rep. 51, July 21, 1943. For a full account, both historical and technical, see: J. H. Van Vleck and D. Middleton, "The spectrum of clipped noise," *Proc. IEEE*, vol. 54, pp. 2–19, Jan. 1966. This paper also cites much of the early, post-war work in the noise field, stemming from wartime efforts.

[2] J. H. Van Vleck and D. Middleton, "A theoretical comparison of the visual, aural, and meter reception of pulsed signals in the presence of noise," *J. Appl. Phys.*, vol. 17, pp. 940–971, Nov. 1946. See, in particular, Part I, Section II (and p. 944).

[3] D. Middleton, "The effect of a video filter on the detection of pulsed signals in noise," *J. Appl. Phys.*, vol. 21, pp. 734–740, Aug. 1950. See, also, ch. 12, 13 of D. Middleton, *Introduction to Statistical Communication Theory*, McGraw-Hill (1960), for many additional references.

[4] ——, "Some general results in the theory of noise through nonlinear devices," Doctoral dissertation (Physics Dep. Harvard Univ., 1947), under the supervision of Prof. J. H. Van Vleck. [See the paper, same title in *Quart. Appl. Math.*, vol. V, pp. 445–498, Jan. 1948.]

[5] S. O. Rice, "Mathematical analysis of random noise," *Bell Syst. Tech. J.*, vol. 23, p. 282, 1944; and vol. 24, p. 46, 1945.

David Middleton (S'42–A'44–M'45–SM'53–F'59) is a Physicist, Applied Mathematician, and Educator. He was born in New York City on April 19, 1920. He received the A.B. (scl), A.M., and Ph.D. degrees from Harvard College in 1942, and Harvard University in 1945 and 1947, respectively. He has been a Special Research Associate, Research Fellow, and Assistant Professor of Applied Physics at Harvard. He has also served as Adjunct Professor in Electrical Engineering and Applied Physics at Columbia University, Rensselaer Polytechnic Institute (Hartford Graduate Center), and currently, as well, as Professor at the University of Rhode Island; and has been a Visiting Professor at the University of Denver, Johns Hopkins, and the University of Texas.

Prof. Middleton's general areas of research, teaching, and applications are principally: 1) statistical communication theory—with particular attention to random processes and signal detection and extraction theory (since 1942); 2) statistical physics—propagation and scattering in random media with emphasis on the underwater acoustic environment (since 1960); and 3) electromagnetic compatibility—models and processing for the man-made and natural electromagnetic environment (since 1968). Other areas of current interest are physical oceanography, remote sensing, optimal system design, and various special applications in communications, radar, and signal processing.

Dr. Middleton has published over 100 technical papers and two books in the above areas. His *Introduction to Statistical Communication Theory* (McGraw-Hill, 1960) and *Topics in Communication Theory* (McGraw-Hill, 1965) have also been published in translation by *Soviet Radio* (Moscow), 1961 and 1966. He is a consulting physicist and contractor with universities, industry, and various agencies of the Federal Government, including the Departments of Defense, Commerce (Office of Telecommunications), and the Executive Office of the President (Office of Telecommunications Policy now, with the Office of Telecommunications, the National Telecommunication and Information Administration in the Department of Commerce). He has been a member of the Naval Research Advisory Committee, and is currently a member of other advisory boards and committees, such as CCIR (U.S. Study Group IE), and editorial advisory boards. He holds memberships and fellowships in many scientific and engineering societies, including Fellowship in the American Physical Society and the American Association for the Advancement of Science (AAAS).