Otto Schmitt: The Schmitt trigger and his many other major contributions to bioelectromagnetism

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Abstract—**When the name of Otto Schmitt is mentioned by engineers, comments are usually made about his invention of the Schmitt trigger, a threshold detecting circuit with hysteresis that is commonly used in digital circuits. In reality, he made significant contributions in a wide range of fields including submarine detection, ECG, and quality of life measures. He was also an early organizer of professional societies focusing on biomedical engineering and biophysics. Compared to many of his colleagues who tended to focus their research in a single field, Otto made significant contributions in many areas. Although very diverse, when answering a scientific question he was very thorough. He has said "Some people are in it for the money, others for pleasure, still other for power. Me, I'm into ideas". He talked frequently about doing mental jogging as an exercise. Although not into money or fame, he has over 60 patents and 200 publications. He did not patent the Schmitt trigger.**

Keywords—Schmittt; Schmitt trigger; vector ECG; electro-physiology history.

I. Early Years

Otto Schmitt was born in St. Louis, Missouri on April 6, 1913 and died in Minneapolis, Minnesota on January 6, 1998. He went to grade school and high school in St. Louis. He obtained his PhD from Washington University May 19, 1937 with a major in both physics and zoology and a minor in mathematics. His thesis topic was an electric circuit model of the nerve axon, which used a number of Schmitt trigger circuits to simulate the propagation of the nerve action potential. On his examination committee was his brother who was 10 years older and a faculty neurophysiologist. During his high school and college years he created many electronic measurement instruments for his brother, who was an outstanding neurophysiologist at MIT. One of these early designs was the differential amplifier. He did a postdoctoral study at University College in London under Nobel Prize winner A. V. Hill. His colleagues and research collaborators were Alan Hodgkin and Bernhard Katz, who later both won Nobel Prizes.

II. Professional Development

In 1939 he was recruited to the University of Minnesota by Maurice Visscher, a professor of physiology and John Tate, a prominent physicist and dean of the College of Science, Literature and the Arts to fill a new position for future developments in the border line field between biological and physical sciences. Later Tate left the University to work in the Office of Scientific Research and Development (OSRD) to help with USA's World War II effort. In 1942 he asked Otto to join his research team. He was quickly made a member of the top secret Airborne Instruments Laboratory (AIL) and was made supervising engineer in charge of the Special Devices Division. His outstanding contributions during the war included the development of the magnetic anomaly detector (MAD) which successfully detected submarines by measuring changes in the earth's magnetic field observed from an airplane. The MAD device was used long after the war. Other creations during the war included a flight simulator, degaussing techniques for ships to eliminate the activation of magnetically activated mines, and the development of a 3D display of radar information, which he later used to display his 3D vector ECG data.

In 1947 he returned to the University of Minnesota in the Department of Physics. Buchta, the department Head, looked forward to linking physics and medicine. In 1949 he was made full Professor. In 1965 he moved to the Department of Electrical Engineering and was given his own building, which was a Quonset hut style temporary wood frame structure built during World War II. He became Professor Emeritus in 1983.

III. The Higlight of Schmitt's Scientific Contributions

- The Schmitt trigger circuit which was part of his axon model used in his PhD thesis.
- The 3D vector ECG system to display a dipole representation of electrical activity of the heart during the cardiac cycle. The name he created was stereovectorelectrocardioghaph (SVEC). He used a fiberglass shell of his wife's body filled with saline to map out the surface fields and combine them to obtain XYZ projections of the potential. To display the results in 3D, he developed switched LCD

glasses, which are similar to what is used in some current 3D TVs.

- An electrical stimulus isolation technique using RF electrical fields to eliminate the common coupling artifact.
- Otto undertook a very in depth study asking the question – "Can humans sense 60 Hz magnetic fields?" The field was randomly turned on and off and the subject answered by pushing a button whether the field was on or off. Even though a significant effort was made to isolate the experimenter from the subject, initial results indicated that the subject could detect the field. Only after many rounds of improved isolation, (which included in one case, washing the subject's ears to remove possible metal dust) he concluded the answer was no.
- A technique to synchronize respiration to the heart beat. A subject is given a tone or light to signal inspiration or expiration based on ECG. The signal synchronizes the respiration as sub-multiple of the heart rate. For example, for the first two beats the subject would be directed to inspire and then expire for the next three beats. Therefore, one breathe cycle for every five heartbeats. The technique can be used to synchronize the respiratory phasic physiological influence, which changes other parameters like the ECG and blood pressure. It could also be used to investigate how different phases of the respiratory cycle influence other cardiac parameters. He named this Voluntary Cardio-Respiratory Synchronization (VCRS).
- The cathode follower now used with transistors as a emitter follower.
- Otto coined the word Biomimetics, which is about solving problems and creating systems based on how nature does it. From his first use of the term in 1963, he strongly promoted the study of biomimetics.
- In the 70's Otto proposed the creation of a Personal Portable whole-Life Medical Report that would be carried by everyone in digital form.
- The Santosha Index, which is a quantitative index of the quality of life, which includes sex drive, fame, wealth, research goals, ethics, and shared consciousness.
- A Hierarchically Co-Optimized Plan for Enhanced Health Care.

IV. The Highlights of Schmitt's Professional Contributions

In 1947 Otto helped in creating one of the first professional organizations focused on biomedical engineering; the Joint Executive Committee for Engineering in Medicine and Biology (JCEMB). It was formed by the cooperation of the American Institute of Electrical Engineers (AIEE), the Institute of Radio Engineering (IRE) and the Instrumentation Society of American (ISA). JCEMB members held their first meeting in 1948. For the first 10 years the meetings were rather small with only about 25 papers. In 1958, Schmitt organized a meeting with a theme of "biology and computers", which was held in Coffman Union at the University of Minnesota. It had approximately 70 papers and 400 attendees.

The IRE formed the Professional Group on Medical Electronics (PGME). Otto was vice chair in 1953 and chair in 1962. In 1963, AIEE and IRE merged to form the IEEE. The IEEE formed the Engineering in Medical and Biology Society (EMBS), which in 1963 awarded Schmitt the William J Morlock Memorial Award for his past work. This award was renamed the EMBS Career Achievement Award, which Schmitt won again 1987.

Along with his good friend and colleague Herman Schwan from the University of Pennsylvania, he helped form the Biophysical Society in 1957 and served as its first vice president. In 1968, the Biomedical Engineering Society was formed, which was much easier for medical and biological trained researchers to join. Otto was the first president.

Before NASA was started, the National Academy of Sciences set up a Space Science Board. There were four committees dealing with biological, physiological and human challenges in space. Schmitt was on three of the four committees and chair of one.

Summary

Otto was a person, who would meet with anyone to talk about a very wide variety of subjects, including his strong interest in parapsychology. He even met with six graders once a month to talk about mental jogging.

He could clearly think "out of the box". During World War II, radar information was obtained from ground stations and radioed to the pilots. Schmitt was asked to develop a method to block the German pilots' communication with the ground. Schmitt went to the army's barracks and obtained the dirtiest stories he could find and had them recorded in German. He then transmitted the stories to the German pilots off the frequency they used to talk to their ground support. Since apparently many pilots like to listen to the stories, they missed the radar information from the ground. It was supposedly very effective.

Schmitt was greatly respected and recognized nationally and internationally. In 1979, he was voted into the National Academy of Engineering. Otto was seemingly less successful in obtaining his educational objectives of setting up educational programs at the University of Minnesota.

In my over 50 years at the University of Minnesota both as a student of Otto and then a faculty colleague, I can say I never met a more brilliant individual at the University and with such a diverse knowledge base. He was always open to listen to any ideas from any person without out regard to status.

Much of this information and more is available from the special issue of IEEE Engineering in Medicine and Biology 23(6), November/December 2004. Of particular interest is the article on the history of Otto's life by JH Harkness [1-2] along with technical articles on Schmitt's work by ME Valentinuzzi [3], JA Malmivuo [4], RP Patterson, A Belalcazar, Y Pu [5], D Stillings [6], LA Geddes [7], and OH Schmitt [8].

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