40-years Anniversary Book of the Finnish Society for Medical Physics and Biomedical Engineering

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TAMPERE – GROWTH OF BIOMEDICAL ENGINEERING EDUCATION AND RESEARCH

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Beginning of Biomedical Engineering at Tampere University of Technology

Tampere University of Technology (TUT) started as a subsidiary to Helsinki University of Technology in 1965. Due to his interest in Biomedical Engineering, Rector *Pekka Ahonen* was active in establishing the chair of Associate Professor of Bioelectronics (Bioelektroniikka) for the Department of Electrical Engineering, Institute of Electronics. *Jaakko Malmivuo* was appointed to this post in August 1976. At that time his research group formed the Laboratory of Biomedical Engineering.

The position of Associate Professor in Bioelectronics was upgraded to full Professor in 1985. The Laboratory of Biomedical Engineering reached its independent position in 1987 when the Institute of Biomedical Engineering was established.

Establishing the Research Centers Hermia and BERC

Hermia
The essential part of the activities of a university of technology is research co-operation with industry and other research partners. During the 1970's when Tampere University of Technology was a young university, these research co-operation activities were, of course, not well developed.

To activate the relationships with industry and, especially, to take an active role in creating new high technology industry in the Tampere region, in 1980 *Jaakko Malmivuo* made an initiative to Rector *Osmo Hassi* for establishing a research center for this purpose. This initiative did not yet lead to a concrete resolution.

The Society of Students of Technology of Tampere University of Technology and Students of Economics of University of Tampere, called EKODI, organized in 28.1.1981 a seminar at TUT on research and development. In this seminar *Jaakko Malmivuo* introduced this initiative publicly. This led to establishing a committee to plan the founding of a research center. As an outcome of this work came a detailed plan to build Hermia research center. The idea of Hermia was to start research in co-operation with industry in high technology, especially in electronics and computer science.

Now the Science Park Hermia includes 11 research buildings and there are located 160 enterprises which employ 4000 persons. Biomedical Engineering research at TUT led to many spin-off companies which started their operation at Hermia. For instance the companies which developed and manufactured biodegradable implants like screws and nails for fixing broken bones. These implants slowly disappear by diluting thus making the second surgical operation for their removal unnecessary.

Biomedical Engineering Research Center, BERC
Biomedical engineering research is made in close co-operation between universities of technology and medical faculties and hospitals. Tampere University of Technology is located some 7 km distance from Tampere University Hospital and the Faculty of Medicine. However, this distance, taking less than a quarter of an hour by car, was a barrier that created difficulties in the practical co-operation between the partners: The medical doctors had to change their working clothes before traveling to the University of Technology and the engineers did not have an office in the hospital area to facilitate their work there.

Therefore in the early 1980's *Jaakko Malmivuo* initiated the discussion on establishing a research center on biomedical engineering in connection with the Tampere University Hospital. One of the first discussions on this issue was made during a lunch in the Tampere City Hall hosted by the Lord Mayor, *Pekka Paavola* on 14.2.1984. This discussion was, in addition to the aforementioned, participated by the director of Tampere University Hospital, Docent *Heimo Holli* and Professor of neurophysiology *Harry Frey*. This project proceeded under the name MEDITEK and it was first discussed at the council of the Tampere University Hospital on 13.10.1989. A detailed

plan of this project was finished on 15.5.1991. In this it was planned that a research building including the 5 storey complex Finn-Medi should be built in connection with the Tampere University Hospital. The building should include medical laboratories for the hospital and a research area which should be shared by the Institute of Biomedical Engineering of TUT, Medical Engineering Laboratory of the State Technical Research Centre VTT and Tampere University Hospital. It was also planned that biomedical engineering industry shall be located in the building.

Thereafter followed the economic recession in Finland which seriously hindered the realization of the project. During this time the Foundation of Health Care Technology, which was close to the VTT, was discontinued. The Faculty of Medicine of University of Tampere was under the threat of discontinuation, but it finally survived. All these unfortunate occasions postponed the Finn-Medi project and finally when it was realized, it was decreased in size. The corner stone of the building was laid in 29.3.1993 and the topping-out-party was held on 1.2.1994. Part of the Ragnar Granit Institute moved into the building in 1995 and had the opening party in 10.2.1995. Now biomedical engineering has about 500 m^2 research space in the building, and that is about the same size as the Institute's premises in the main campus in Hervanta. This research space in the Finn-Medi building is called Biomedical Engineering Research Center, BERC.

The activities of biomedical engineering are divided between Hervanta and BERC so that the personnel is shared about equally between these premises. All the education takes place in Hervanta, where the TUT students are. Research is made in both premises. The BERC has greatly facilitated and developed the co-operation between TUT and Tampere University Hospital and Medical Faculty. Locating in the hospital building makes it easy for the physicians to come to BERC in research meetings and the biomedical engineering personnel to visit the hospital. A disadvantage in the use of BERC is that the personnel are situated in two separate places, but this problem is greatly improved by modern electronic communication technology. At present in the Science Park Finn-Medi the sixth research building is under construction and these will house 50 enterprises employing some 1000 persons.

Finn-Medi building adjoining Tampere University Hospital. Biomedical Engineering Research Center is in the fourth floor.

Ragnar Granit Institute and Ragnar Granit Foundation

Ragnar Granit Institute

Professor *Ragnar Granit* was born in Helsinki on October 30th, 1900. He received his education in medicine at the University of Helsinki and an MD degree from there in 1926. He served as Professor of Physiology at University of Helsinki 1937 1940. In 1940 he was invited to the Nobelinstitute for Neurophysiology, Karolinska Institute, Stockholm, Sweden. There he served as Professor of Physiology from 1945 to 1967 when he retired. On the same year he received the Nobel Prize in Physiology or Medicine together with *Haldan K. Hartline* and *George Wald* for this work at the Institute of Physiology, University of Helsinki before moving to Sweden. He could not receive the Nobel Prize earlier because, when in office, he was member of the Nobel Committee.

Professor *Ragnar Granit* died on March 12th 1991. After Granit's death notice Malmivuo was sad to note that he could have drawn attention to him as a Finnish Nobelist already during his life time but didn't. Therefore it came to his mind that we could honor the memory of Granit by appointing the research group on bioelectromagnetism at Tampere University of Technology as the Ragnar Granit Institute.

The name Ragnar Granit Institute was adopted in 1992 for the Bioelectromagnetism Research Group. The purpose for using the name of Ragnar Granit Institute was to inform the international scientific community as well as the general audience that Professor *Ragnar Granit* was Finnish Nobel Laureate. This information has steadily increased the knowledge that there are two Nobel Laureates in science in Finland instead of one, *A. I. Virtanen* and *Ragnar Granit*. For instance the dictionaries and other sources of information of notable persons nowadays list Granit as a Finnish or at least as a Finnish-born Nobelist. This was not the case before the name of Ragnar Granit Institute.

Ragnar Granit Foundation

In 1994 *Jaakko Malmivuo* established the Ragnar Granit Foundation to financially support the research and education at the Ragnar Granit Institute. Those institutions that were central in the life work of Granit were invited to be founder members of the Foundation. These were: the Academy of Finland, which awarded him the honorary degree Academician in 1985, the University of Helsinki, where he studied medicine, served as professor and where he made the research leading to the Nobel Prize, the Karolinska Institute, Stockholm, where he served as researcher and thereafter professor and Director of the Nobelinstitute for Neurophysiology 1945-1967, the University of Oxford, where he visited in 1928 and in 1932-1933 as well as the University of Pennsylvania, Philadelphia, where he visited in 1929-1932.

The Ragnar Granit Foundation supports the Ragnar Granit Institute and its scientists financially in several ways, eg.

- financial support for purchasing scientific instruments
- research grants for the scientists

- publication grants from scientific publications and patents
- financial support for organizing scientific congresses and symposia.

The Foundation has also organized jointly with the Institute the International Ragnar Granit Symposia, international scientific congresses and Studia Generalia lecture series. In addition the Foundation awards the Ragnar Granit Prize to significant scientists.

Institute Personnel

The scientific personnel of the Institute were strengthened in 1994 when the Institute received the post of Associate Professor in Medical Electronics. *Hannu Eskola* was appointed to this position for a period of 5 years 1995-1999. His main interest in education and research was medical physics. In 2000 Eskola moved to the position of Director of Digital Media Institute of Tampere University of Technology. After termination of Digital Media Institute Eskola returned to the Institute's professor.

Jari Hyttinen served as acting Professor of Medical Electronics. In 2001 he was appointed to this position for the period of 5 years. In 2006 he received a tenure. The research group of Professor *Kari Mäkelä* at the Seinäjoki unit of TUT was organizationally connected to the Digital Media Institute. In the same connection when DMI was discontinued Mäkelä and his group were organizationally moved to the Ragnar Granit Institute.

Many of the scientists, who were educated at the Ragnar Granit Institute, served shorter or longer periods of time as senior scientists at the Institute. *Juha Nousiainen* was appointed to permanent position of Lecturer in 1999. In addition to research on biomagnetism and Internet education he is responsible for the administration of education at the Institute. In 2001 *Jari Viik* was appointed Assistant Professor (yliassistentti). In addition to his responsibility in the administration of education, he is making research in electrocardiology. *Pasi Kauppinen* was appointed to the permanent position of Researcher/Laboratory Engineer in 2003. His research interest being in bioimpedance and EEG. Docent *Ville Jäntti*, MD, was appointed as part time

Senior Researcher in 2003. Part of the time he served as neurophysiologist in Tampere University Hospital being an important link to the hospital.

Ragnar Granit Institute personnel visiting Karolinska Institutet in August 2006. In the first row second from right our host Dr. Heikki Teriö.

Biomedical Engineering Education

The Biomedical Engineering (BME) education given by the Institute is offered for 3rd and 4th years of studies. Because the Institute was in the Department of Electrical Engineering, the education concentrated on Bioelectromagnetism and Medical Electronics. But it covers all the main aspects biomedical engineering, including Medical Physics and Medical Informatics.

The first introductory course, Human Anatomy and Physiology is lectured by physicians from Tampere University Hospital. It raises wide interest throughout TUT and is taken by 150-200 students annually. The number of students in other courses varies from 20-80. This indicates that about 20

students annually take BME as their main subject and about 40 as a subsidiary subject.

Education in English

In 1992 all the education at the Ragnar Granit Institute was overnight turned to be given in English. The all important motivation for this was to educate the Finnish students to become more international. Accepting international students to the program further strengthened this target.

Ragnar Granit Institute was the first to replace education in Finnish with education in English also for the Finnish students. There had been some university courses in Finland in English but they were intended only for the international students.

The education in English raised considerable interest among the students and the size of the BME classes almost doubled after this decision. Also the teachers were very willing and motivated to use the English language though it needed a lot of additional work in preparing all the educational material in English. Fortunately the textbooks were usually in English, which helped the workload. Ph.D. *Simon Walker* from Imperial College, London, worked at the Institute during 1993-1998. He helped very much in teaching in English and in making English the working language of the Institute.

The first international student to complete the Master of Science degree in English was *Chenguo Zheng* from China. His thesis under the title "Measurement of Triglycerides in Human Serum using the Optimate Automated Fluorometer and Photometer" was completed in 1994.

In 2005, 13 years since the Ragnar Granit Institute started the education in English, the Ministry of Education in Finland launched a call for International Master's Degree Programs in Finnish universities. From TUT altogether six applications were made and four programs were accepted by the Ministry of Education. One was Biomedical Engineering.

The number of international students in Biomedical Engineering increased steadily. For instance, in 2004 we had 2 international students in PhD program, 9 in M.Sc. Program, 11 in non-degree International program and

26 exchange students in shorter visits. The total number of international students in 2004 was 50.

Academic Degrees

The number of M.Sc. degrees completed at the Institute is about 300. Because all the education was given in English from the beginning of 1990's, from 1993 almost all M.Sc. theses were written in English. To date altogether 17 doctoral degrees have been completed by the students of the Institute. From them 16 were Dr. Tech. and one Ph.D. In addition, three M.D. degrees have been completed in University of Tampere, Faculty of Medicine, where the research work has been done in projects directed by the Ragnar Granit Institute.

From the doctors educated at the Institute, four have been appointed professors, *Hannu Eskola*, *Jari Hyttinen*, *Jukka Lekkala* and *Kari Mäkelä*.

Survey on the Education

In 1998 *Jari Viik* made a survey on the education given by the Institute. A questionnaire was sent to those persons who had studied at the Institute and who were already working. During the 20 years, 275 students had studied biomedical engineering courses at the Institute. Part of them had received the M.Sc. degree from the Ragnar Granit Institute, part of them from other institutes at the university. It was important that the target of the questionnaire was to those persons who were already working, because they know better than the students how well the education meets the requirements of the industry, hospitals, research institutes, trade, etc. This also gave a possibility to get information on the placement of the persons in the working life and their career development. In our understanding this was the first survey of its kind in Finland, at least in the universities of technology.

According to the survey results, nine out of ten have found a job within three months of their graduation. About half of the persons had their job in the Tampere region and of the rest, most were located in Helsinki region. About half of the persons had a job, which was related to biomedical

engineering. Also the correspondence between the capabilities provided by our M.Sc. education and the skills they required at work were studied. In this comparison it was notable, that although all our education was given in English, the language skills were apparently needed still more. The results also indicated that the persons, in general, received more skills in research and less skills in marketing than they need in their working life. These results were not surprising, because the Institute is research oriented academic department.

International Graduate School in Biomedical Engineering and Medical Physics

Because there was an apparent need for a joint graduate school in biomedical engineering for the Finnish universities giving BME education, discussions were initiated by the Finnish Society for Medical Physics and Medical Engineering in 2005. The representatives participated in these discussions were from Tampere University of Technology, Helsinki University of Technology, University of Turku, University of Kuopio and University of Oulu. It was accepted that the application to the call of Ministry of Education and Academy of Finland shall be made by the Ragnar Granit Institute under the direction of *Jaakko Malmivuo*. It was decided that the name of the school will be: International Graduate School in Biomedical Engineering and Medical Physics, iBioMEP (www.tut.fi/ibiomep.htm). Internationality shall be a characteristic feature of the school.

The Ministry of Education decided that the Graduate School shall be established for the period of 1.1.2007 - 31.12. 2011 and that eight Ph.D. student positions will be funded. Though this number is considerable smaller than our application, it is, however, very satisfactory in the beginning of the school. The later enlargement of the school will then be based on its future success.

Research Activities

Theory of Bioelectromagnetism

The research at the Ragnar Granit Institute has mainly concentrated on Bioelectromagnetism, i.e., the theory and applications of bioelectric and biomagnetic phenomena. In principle, there are two opposing methods to approach these problems: In the direct method the electric and magnetic fields of the bioelectric sources are calculated. In the reciprocal method, it is virtually fed a unit current to the detector and distribution of the field it generates in the source region is calculated. This latter method is based on the principle of reciprocity introduced by *Hermann von Helmholtz* in 1853. This principle is based the lead field theory formulated by *Richard McFee* and *F. D. Johnston* hundred years later.

Almost all groups working in the area of bioelectric and biomagnetic fields have used the direct method. The only group (in addition to McFee, who discontinued his activities in the 1970s'), which had the principle of reciprocity and the lead field theory as the dominating method, has been the Ragnar Granit Institute. Because many of the fundamental problems of bioelectromagnetism can be solved only, or at least much easier, with the reciprocal method, we have been able to be the first to achieve several fundamental results in bioelectromagnetic research.

Jaakko Malmivuo authored with *Robert Plonsey* the book on Bioelectromagnetism. It is the first and only one which consistently uses the principle of reciprocity and lead field theory throughout the book. It was transferred to the Internet in February 2002 (www.tut.fi/~malmivuo/bem/bembook). It was the first scientific book completely available on the Internet free of charge. The illustrations in the Internet version are improved and most of them are in full color. Because they may be copied free of charge, they are frequently used in other publications and conference presentations by other colleagues working in the field.

The research on modeling the bioelectric and biomagnetic fields started when *Jari Hyttinen* in 1990 spent one year in University of Tasmania, Hobart, Australia funded by the Rotary Grant. In 1994 he defended his

thesis “Development of Regional Aimed ECG Leads Especially for Myocardial Ischemia Diagnosis”. In 1999 *Pasi Kauppinen* published his thesis on impedance cardiography under the title “Application of Lead Field Theory in the Analysis and Development of Impedance Cardiography”. *Päivi Laarne* defended in 2000 her thesis “Implementation of Realistic Conductivity Model for the Head”.

Fundamental Problem of Biomagnetism

In the beginning of biomagnetic research in the 1970's there was a controversy on the independence on the bioelectric and biomagnetic signals. *Robert Plonsey* claimed that they are fully independent but *Stanley Rush* claimed that they are fully interdependent.

This fundamental problem was solved by Jaakko Malmivuo as follows: The bioelectric and biomagnetic signals both originate from the bioelectric activity of the source, from the flux and vortex sources, respectively. Though, on the basis of the Helmholtz theorem, the distributions of flux and vortex sources are independent, the signals generated by them are only partially independent. This result was verified with clinical recordings in the doctoral theses of *Juha Nousiainen* in 1991 and *Sakari Oja* in 1993.

Electrocardiography

In the early 1980's we started a project jointly with Tampere University Hospital to improve the diagnosis of ischemic heart disease with ECG. This was based on the analysis of the ST-segment changes as a function of heart rate (HR). At the Institute there were prepared two doctoral theses on this subject. The first one was the thesis of *Harri Sievänen*, “Development and Evaluation of the Multivariate ST/HR Analysis for the Assessment of Myocardial Ischemia” in 1991. It was followed in 1997 by the thesis of *Rami Lehtinen*, “Improved Detection of Coronary Artery Disease by Computerized ST Segment Depression/Heart Rate Analysis of the Exercise Electrocardiogram”.

The properties of ECG leads were studied with statistical analysis and modeling methods in several doctoral studies, e.g., in the aforementioned thesis of *Jari Hyttinen*. In 2000 *Jari Viik* defended his thesis “Diagnostic

Properties of Exercise Electrocardiographic Leads in the Detection of Coronary Artery Disease". In 2002 *Noriyuki Takano* from Tokyo, Japan defended his thesis "Reduction of ECG Leads and Equivalent Sources Using Orthogonalization and Clustering Techniques".

Magnetocardiography

Because *Jaakko Malmivuo* entered into the research on magnetocardiography already in the early 1970s' and continued this research at Stanford University during 1974-1976, biomagnetism was the main topic of research in the beginning of the Laboratory of Biomedical Engineering.

The bioelectric activity of the heart is associated with magnetic field, which detects the bioelectric activity in a different aspect. Due to the basic laws of electromagnetism, this signal is very weak, about a millionth of the earth's static magnetic field. Therefore the measurement of magnetocardiogram (MCG) has to be made with extremely sensitive instruments in a magnetically shielded room. To the Laboratory on Biomedical Engineering it was in 1979 constructed the first magnetically shielded room in the Nordic Countries. It was a cube with dimension 2 m and thickness of 5 cm made from pure aluminium.

Hannu Eskola made in 1983 the first doctoral thesis in the Institute. It was in the area of biomagnetism and entitled "On the Properties of Vector Magnetocardiographic Leads". *Jukka Lekkala* published in 1984 his thesis "On the Design and Properties of a Magnetocardiographic Instrumentation".

MCG was recorded in the shielded room from a total of more than 1000 persons, consisting both normal healthy persons and patients with different cardiac disorders. One interesting group was policemen from the Tampere Police Department. We had a personal contact with the Chief Police Officer of Tampere and asked him whether the policemen would like to serve as volunteers. This was successful proposal because it gave a very good source of middle-aged, healthy volunteers for our reference base in magnetocardiography. *Juha Nousiainen* defended his Doctoral Thesis on

"Behavior of the Vector Magnetocardiogram in Normal Subjects and in some Abnormal Cases" in 1991.

We also made a clinical study of 313 persons including normal healthy subjects, patients with inferior myocardial infarction (IMI) and patients with anterior myocardial infarction (AMI). When differentiating normals and IMI the ECG gave about 90% correct classification. Similarly, the MCG alone gave about the same 90% correct classification. But when combining these methods, i.e., when measuring the dipolar electric and magnetic components of the cardiac source, the classification rate was 95%. This improvement was statistically significant. These results were included in the MD Thesis of *Sakari Oja*, "Vector Magnetocardiogram in Myocardial Disorders" in 1993.

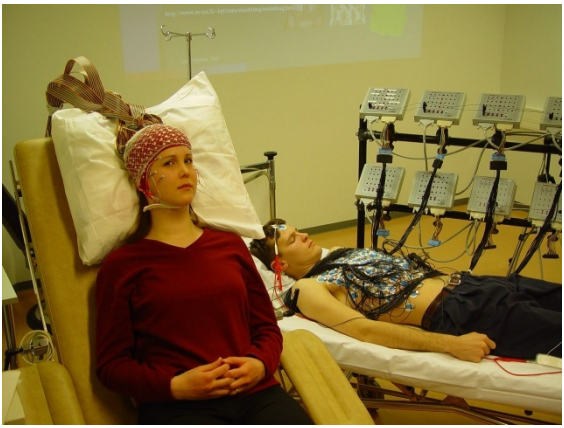
Recording fetal magnetocardiogram in the magnetically shielded room.

In brief, magnetocardiography is about as good in cardiac diagnosis as the electrocardiography. But when combining these methods, the number of incorrectly diagnosed patients may be decreased to one half.

Electro- and Magnetoencephalography

In the beginning of biomagnetic research it was also believed that because the skull has high electric resistivity and therefore impedes the measurement of the electroencephalogram (EEG) but on the contrary, it is "transparent " to magnetic field, the magnetoencephalogram (MEG) should measure the electric activity of the brain more accurately. We calculated the spatial resolution of EEG and MEG and also to our surprise, we found that despite of the high resistivity of the skull, the EEG is more accurate

than the MEG. In addition, *Outi Väisänen* in her theses "Multichannel EEG methods to improve the spatial resolution of cortical potential distribution and the signal quality of deep brain sources" in 2008 found out that with EEG it is possible to detect the sources located deep in the brain much better than believed earlier. Especially, the sensitivity of EEG to deep sources is dramatically better than that of MEG.



High resolution 256-channel EEG-recorder may be also used for ECG mapping.

In 2001 the Institute received the 256 channel EEG/ECG recording instrumentation. It represented the state of the art in its field. At that time such instruments existed only in two other sites in the world.

Neurology

Kari Mäkelä defended in 1996 his thesis "Quantification and Calibration of Clinical Neurophysiological Studies of the Visual System". His doctoral degree was Doctor of Philosophy. All other doctoral degrees awarded by the Institute have been Doctor of Technology. In 1999 *Tomi Heinonen* defended his thesis "Applications of Magnetic Resonance Image Segmentation in Neurology" which was based on modeling the anatomy of the body. *Ilpo Rimpiläinen* defended in 1994 in the Faculty of Medicine, University of Tampere his MD thesis "Magnetic Stimulation of Facial Nerve". The research work was done in and funded by the Ragnar Granit Institute.

European Projects

Ragnar Granit Institute has also actively participated in research in European projects. In 2002 *Jaakko Malmivuo* joined the European project

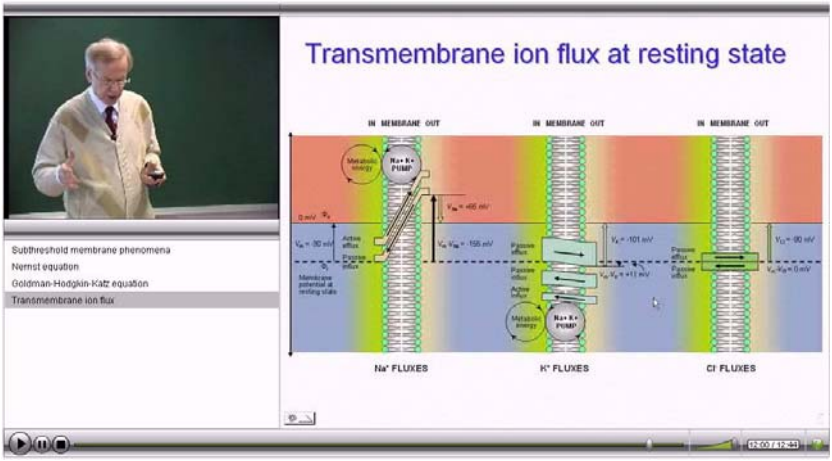
DASPTOOL, where new digital signal processing methods were applied to impedance measurement.

Education and research are the two central areas of universities. At the Ragnar Granit Institute we have also made research on education. This includes the European project EVICAB - European Virtual Campus on Biomedical Engineering (www.evicab.eu). EVICAB is a platform which offers a high quality educational program on Biomedical Engineering for students in the European Union and worldwide.

EVICAB includes lecturing courses given by the best international scientific and pedagogical experts in this field. The courses are recognized by European universities. The courses include eg.,

- video lectures with a small video screen of the lecturer and a large screen of the slides
- simultaneous presentation of the textbook material
- additional lecture slides
- exercises
- Internet examination
- video files to be downloaded for iPod and may be also viewed by Cinemizer
- video files to be downloaded for Media Phones

All this is available free of charge.



Example of a video lecture on the Internet in the EVICAB portal.

International Congresses and Symposia

In 1990's The Nordic Congresses on Biomedical Engineering did not attract too many participants. Apparently, because the number of congresses in this field was quite large. The Baltic countries had regained their independence in the early 1990's and they had a great need for developing biomedical engineering and getting contacts to the colleagues and research groups all around the world. In this situation Malmivuo developed the idea of enlarging the Nordic Congress to Nordic-Baltic Congress.

The joint 10th Nordic Baltic Conference on Biomedical Engineering & 1st International Conference on Bioelectromagnetism was arranged in the new Tampere Hall in June 1996. *Jaakko Malmivuo* served as President and *Hannu Eskola* as chairman of the organizing committee. The congresses were attended by more than 400 active participants from 36 countries including Europe, North and South America, Asia and Australia. There were a total of 350 scientific contributions of which 236 were oral presentations given in eight parallel sessions. The number of organized sessions was 19 including 74 invited papers. Of the papers 113 originated from the Nordic Countries and 35 from the Baltic states. In addition to these the

Conferences included 13 high quality State of the Art lectures. Among them was a presentation given by the Nobel Laureate professor *Ivar Giaever*.

The conference was followed by a satellite symposium in Tallinn. This prepared the 11th NBC which was held in Tallinn in 1999. The strength of the idea of Nordic-Baltic Conference has been later proved with the continuation of this series.

Because Malmivuo had established the discipline of Bioelectromagnetism and it has been the main topic of research and education of the Ragnar Granit Institute, we got the idea to organize the First International Congress of Bioelectromagnetism in connection to the Nordic-Baltic Congress on Biomedical Engineering. The strength of the idea of International Conference of Bioelectromagnetism has been later proved with the continuation of this series. The 2nd ICBEM was arranged in Melbourne in February 1998 and the latest 6th in Aizu-Wakamatsu City in October 2007.

Electrocardiography has been important research field in over 20 decades. As the Council member of the International Society of Electrocardiology Malmivuo made the initiative in 2001 to arrange the Society's Congress in Helsinki. It was accepted that the XXX International Congress on Electrocardiology was organized by the Ragnar Granit Foundation jointly with the Ragnar Granit Institute, Finnish Cardiac Society, Finnish Society for Medical Physics and Medical Engineering, Ministry of Social Affairs and Health and the International Society for Bioelectromagnetism in Helsinki June 2003. *Jaakko Malmivuo* served as President of the Congress and *Jari Viik* as Chairman of the Organizing Committee. Doc., MD *Markku Mäkijärvi*,

Opening ceremony of the XXX International Congress on Electrocardiology in the Auditorium of University of Helsinki in June 2003.

represented the Finnish Cardiac Society in the Scientific Committee. The congress venue was the House of Estates in the heart of the monumental center of Helsinki. The congress was participated by more than 200 active participants from 30 countries from all over the world.

After the congress the Midnight Sun Symposium was organized in Saariselkä, Lapland. Its scientific program was arranged by Professor, MD *Heikki Huikuri* and Doc., MD *Pekka Raatikainen*. The Symposium was participated by about 60 participants. Finland is one of the very few places in the world where it is possible to arrange a scientific conference in the presence of the midnight sun. The accompanying persons had an opportunity to experience real gold panning.

Ragnar Granit Institute has arranged jointly with the Ragnar Granit Foundation nine international symposia under the name Ragnar Granit Symposium. The purpose of these symposia has been to support the education and research of the Institute. The first was arranged in 1992 in Tampere under the title “Electrical and Magnetic Stimulation of Motor Nervous System”. One of the symposia was arranged in 1997 in Chicago and two of them in Helsinki. The ninth symposium was the 30 years’ anniversary symposium arranged at Tampere in November 2006.

National and International Societies

The Finnish Society for Medical Physics and Biomedical Engineering was established in 1968. The personnel of the Ragnar Granit Institute have been in central role in the administration and operation of the Society:

President:	Jaakko Malmivuo	1987 - 1990
	Jari Hyttinen	2001 – 2003
Vice President:	Hannu Eskola	1999 - 2001
Secretary:	Juha Nousiainen	1984 - 1989
	Jari Hyttinen	1992 - 1997
	Jari Viik	2001 – 2006
Treasurer:	Hannu Eskola	1988 - 1993
Member of Board:	Jaakko Malmivuo	1979 - 1986, 1990 - 1995
	Jari Hyttinen	1998 - 2000, 2005 - 2008
	Hannu Eskola	2001 - 2005
	Jari Viik	2007 -

The Society has played an important role in developing the disciplines of Biomedical Engineering and Medical Physics in Finland. It has been active in introducing these disciplines to students and young scientists. It also had a central role in creating international contacts, for instance in organizing the World Congress in Espoo in 1985 and in starting the series of Nordic Congresses in 1970 in Espoo.

In connection to the First International Congress of Bioelectromagnetism in June 1996 Jaakko Malmivuo made the initiative to establish the International Society for Bioelectromagnetism (www.isbem.org). It is the purpose of the society to facilitate the dissemination of new knowledge in bioelectromagnetism, to encourage new research in bioelectromagnetism, to sponsor International Congresses on Bioelectromagnetism and to assist with satellite meetings related to bioelectromagnetism.

Ragnar Granit Institute has had a central role in the administration of the Society. *Jaakko Malmivuo* served as President of the Society for 1996 - 2000. As secretary have served *Hannu Eskola* 1996 - 2000, *Pasi Kauppinen* 2000 - 2006 and *Jari Hyttinen* 2006 - . Several persons from the Institute have also been members of the Council.

In connection to the 2nd ICBEM in Melbourne in February 1998 Malmivuo made the initiative for establishing the International Journal of Bioelectromagnetism (www.ijbem.org). The idea was that the journal should be primarily published on the Internet and be available free of charge. The first issue was published in May 1999 and included the presentations from the 6th Ragnar Granit Symposium: EEG Meets MRI.

Examples on Industrial Developments

The fundamental tasks of universities are education and research. Performing these tasks successfully the universities develop the society in their area. In addition to education and research it is nowadays assumed that it is not enough to educate competent engineers to work at industry and develop new products based on the new theoretical results obtained in the university research. It is expected, especially from universities of

technology, that the university research immediately also leads to new industrial products, in its most desirable form to new spin-off companies.

In late 1970's we started co-operation with Dr. Gerhard Baer of Tampere University Hospital and Prof. Harry Frey of University of Tampere in developing implantable nerve stimulators. *Pasi Talonen* made his diploma thesis on this topic in 1979. The main application area of the stimulators was the phrenic nerve of tetraplegic patients. The other application was a patient with paralysis in the foot rising muscle which considerably hindered his walking. Installing a nerve stimulator to stimulate the corresponding muscle and which was triggered with a switch under the heel considerably helped the patient's walking. On the basis of this research a company named Athrotech was established to Tampere.

As mentioned before, at the Institute we have developed the ST/HR analysis method for diagnosing the ischemic heart disease during the exercise ECG test. In this method the ST-segment deviation in the ECG during the exercise test is analyzed as a function of the heart rate. This program is added as an option to the GE Healthcare ECG recorder. Recently similar ST/HR methods have also been implemented by other manufacturers in their ECG analyzers.

The mission of the Ragnar Granit Institute: "To educate M.Sc. and Ph.D. to international tasks, to perform basic research on a high international level, to promote the health care and industry and to develop the information society in biomedical engineering and bioelectromagnetism" has been the guidelines of the Institute for 30 years. During this time Tampere University of Technology has developed into the leading university in Biomedical Engineering in Finland and the Nordic Countries and is one of the leading universities in this discipline in the world. From this situation it is good to develop biomedical engineering and bioelectromagnetism further.