IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society
-UFFC, Touching the World -

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Abstract: Some 56 years ago, in 1953, the need for a distinct forum for ultrasonic engineering technology prompted a group of concerned engineers and scientists to petition the Institute of Radio Engineers (IRE) for the formation of the Professional Group on Ultrasonic Engineering (PGUE). Within the first year the newly formed group grew in membership to several hundred, sponsored technical sessions at the National Electronic Conference, Acoustical Society Symposium, and IRE National Convention, and had published the first issue of the *Transactions*. The IRE Group chose as its focus, ultrasonic measurements, communications, and processing, with emphasis on applications, devices, techniques, and associated circuitry. In 1985 we became the IEEE Ultrasonics, Ferroelectrics, and Frequency Control (UFFC) Society to reflect the expanded interests of the membership. The UFFC Society sponsors three annual Symposia; the International Ultrasonics Symposium (IUS), the International Symposium on the Application of Ferroelectrics (ISAF) and the International Frequency Control Symposium (IFCS). In the past 56 years our Society has grown and flourished as a top technical IEEE society through its symposia, publications, member sponsorship and awards, and its cooperative activities with other technical societies. We presently have 2000 members in 68 countries. The society has remained strong through the foresight and wisdom of its outstanding volunteer leadership and the strong support of its members.

IEEE UFFC Society Overview

The name UFFC, Ultrasonics, Ferroelectrics, and Frequency Control, was given in 1985 because of the addition of ferroelectrics and frequency control technical communities to the original ultrasonics group. In 1953, it became the Professional Group on Ultrasonic Engineering (PGUE), the 19th Society of the IEEE. Present membership of the UFFC is approximately 2000 with 50% in North America, and 50% in Europe and Asia. A total of 8% are Fellows of the IEEE. The Transactions on UFFC and a Newsletter are published twelve and two to three times a year, respectively. Each of the three technical groups comprising the UFFC hosts an annual international Symposium. The three conferences rotate through North America, Europe, and Asia with the following attendance; Ultrasonics~1000, Ferroelectrics~250, Frequency Control~300. Visit our Website www.ieee-uffc.org for more information.

The UFFC enhances the following disciplines; (a) Science – elastic wave interactions, (b) Industry – non-destructive testing, (c) Electronics – communications, signal processing, (d) Medicine– diagnostic, therapeutic, surgical, (e) Environment – sensors, (f) Aerospace – safety and security, (g) Consumer – convenience, time

Piezoelectricity - The Unifying Element

Piezoelectricity enables technology for our security, health, and welfare: calls dogs or chases mice, creates fog or disperses it, cleans auto parts or liquifies fat, images blood flow or blasts kidney stones, detects burglars or opens garage doors, checks weld joints or bone joints**,** explores inner or outer space**,** cleans electronic parts or teeth, listens to nature or the screams of flaws, cuts square holes or seals blood vessels: all these things and more are enabled by piezoelectricity.

Piezoelectricity extends our senses; Seeing – from our 20/20 sight capabilities to visualizing the interior of solids and the body, Hearing – from 0.06-20 KHz capabilities to > 20 KHz sounds of nature and detection of failures, Touch – from detecting a surface item 0.1mm to gently soothing an inner hurt or a healing touch, Taste – from one part in a million to sampling food products for consistency/quality control, Smell – from over 1000 different odors to detecting toxins at parts per billion levels. Piezoelectricity does a lot of crucial jobs for us.

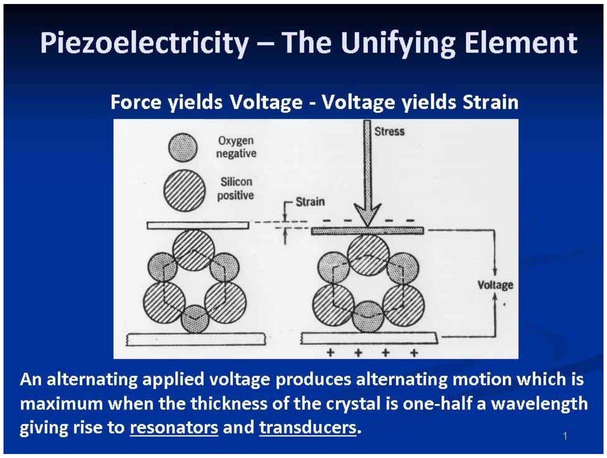

Fig 1. Piezoelectricity – The Unifying Element

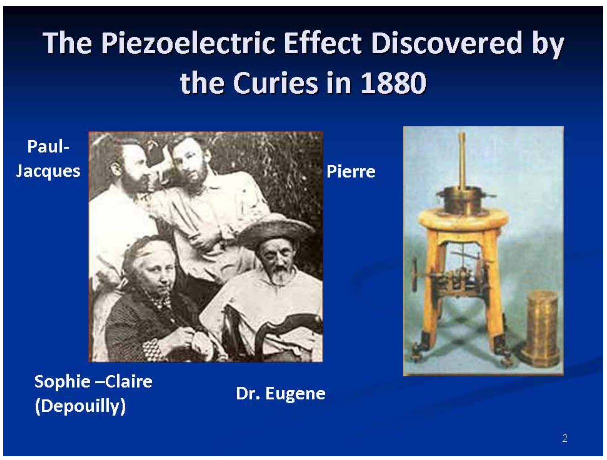

Fig. 2. The Piezoelectric Effect (Curie Family)

In 1880 the piezoelectric direct effect (force yields voltage) was discovered by the Curie brothers, Paul Jacques and Pierre. In 1882 the indirect effect (voltage yields strain) was discovered by the Curie brothers. The direct and indirect effects are shown in Fig. 1. A photo of the Curie family is shown in Fig. 2. The seismograph was developed in 1880 by British Geologist John Milne as shown in Fig, 3. He identified the basic longitudinal (P-waves), shear waves (S-waves), and surface waves or Rayleigh waves as they were later called when Lord Rayleigh in 1885 developed the mathematics surrounding them.

It wasn't until 1912 with the sinking of the Titanic, that serious work on the use of the piezoelectric effect was initiated as a solution for detecting underwater objects. This prompted the patent of L. F. Richardson (1913) for submerged body echolocation. World War I brought urgency for the development of detecting underwater objects like submarines. The submarine sinking of the Lusitania (7 May 1915) spurred the efforts on. This led to the experiments of Langevin and Chilowsky. In 1917-18, Paul Langevin and Constantin Chilowsky, a young Russian immigrant to France, demonstrated the detection of underwater objects using quartz crystals bonded between two steel plates at f = 50 KHz. From this work in 1918 and later quartz (Fig. 4) and the piezoelectric effect was brought to the forefront. This led to SONAR, depth finders, and fish locators in the 1920's. Also in 1920 ferroelectricity was discovered in Rochelle salt by J. Valasek. Although the prefix ferro implies iron, most ferroelectric materials do not have iron in their lattice.

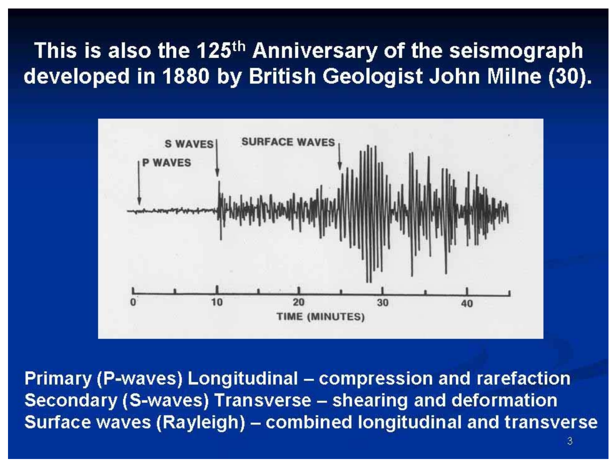

Fig. 3. The Seismograph (Milne)

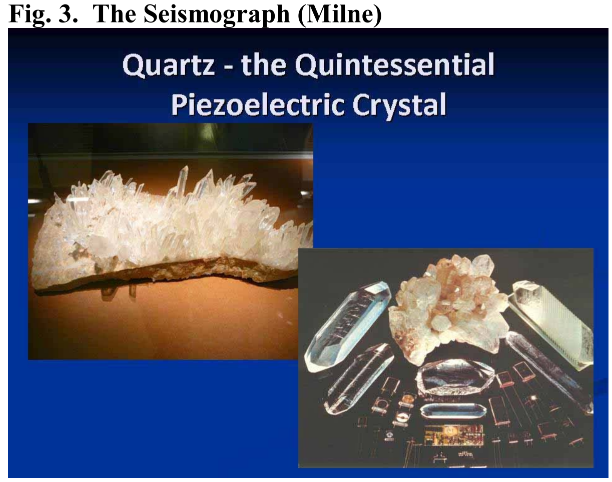

Fig. 4. Quartz – the Quintessential Piezoelectric Crystal

By then the WWI was over, quartz rested until 1922 when a patent was given to W.G. Cady for resonators. It was the era of radio and hams which were active in transmitting and receiving the world over. Amateur radio operators built quartz resonators and initiated the crystal industry in the 20s & 30s. A major area for quartz development was Carlisle, PA and Dickinson College in the early 30s. In 1935 the first quartz crystal company was formed in Carlisle – Standard Piezo. Major applications for quartz crystals are shown in Figure 5.

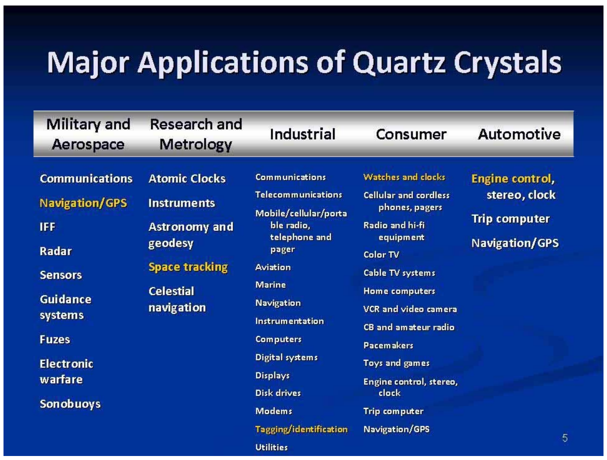

Fig. 5. Major Application of Quartz Crystals

In 1929 Mulhauser & Sokolov, were involved in material evaluation. In 1932 Debye and Sears patented their optical diffraction of ultrasonic waves. 1939 S. Sokolov, received a U. S. patent for the ultrasonic microscope.

With the advent of World War II, the quartz resonator again came to the forefront in communications. The production of quartz crystals for communications was second only to the development of the atomic bomb during the war years. In WWII Carlisle companies produced over 7 million quartz resonators for the production of hand-held walkie-talkies. Galvin Mfg. (Motorola) coordinated the effort. In 1946 Fort Monmouth, a government facility, continued to have classified conferences for several years and eventually became a part of the UFFC in 1985. Similarly the Ferroelectrics part of UFFC joined in 1985. The early history of the piezoelectric effect and the UFFC is contained in publications which may be found on the UFFC website [www.ieee-uffc.org.](www.ieee-uffc.org)

Ultrasonics, Ferroelectrics, and Frequency Control Society

The transition to the Ultrasonics, Ferroelectrics, and Frequency Control Society (UFFC-S) took place under the leadership of Dr. Herman van de Vaart who was the G-SU president in 1984. Ferroelectrics had been an integral part of the society since the late 1960's. The committee had co-sponsored a Symposium on the Application of Ferroelectrics held at Catholic University in October of 1968. In 1971, the Subcommittee on Ferroelectrics held a second Symposium on the Applications of Ferroelectrics organized and held in June, 1971, in Yorktown Heights, jointly sponsored with IBM and the Army Research office in Durham, NC. There had been 10 International Symposia on the Application of Ferroelectrics (ISAF) listed before joining the IEEE UFFC, which does not include the one in 1968. With the establishment of the UFFC-S, and the revised by-laws accepted in October, 1985, a Ferroelectrics Standing Committee was added and the Chair became a voting member of the UFFC Administrative Committee (AdCom).

Similarly, a Frequency Control Standing Committee was added and its Chair also became a voting member of AdCom. The Frequency Control part of the UFFC-S brought with it a long history of technical contributions which were highlighted by the annual Frequency Control Symposium (FCS) started in 1947. The first symposium, sponsored by the U. S. Army at Fort Monmouth, NJ, was held in a conference room in the Squier Laboratory. The purpose of the meeting, which was attended by personnel from the three armed services, contractors, and members of a sub-panel on frequency control, was to review progress with the contractors and assist the military in future program planning. During subsequent meetings it was expanded to include others and subsequently moved outside the Ft. Monmouth facility. In 1982, the G-SU assumed financial responsibility and technical co-sponsorship with the U. S. Army. The 50th International FCS was held in Hawaii in 1996. It was an IEEE symposium with participation of the personnel of the Army Research Laboratory in Ft. Monmouth, New Jersey.

With the addition of ferroelectrics and frequency control components to ultrasonics and their respective symposia, the participation in UFFC-S activities increased. The three symposia draw an average total attendance of approximately 1500. With recent changes in the constitution and by-laws the UFFC-S has restructured to better serve its members and the technical community.

Honors and Awards

The UFFC-Society has been honored, as its members have received many awards and honors. Society members have been honored by Presidents, knighted by Royalty, medaled by an Emperor, received international awards, and have been elected to prestigious Academies of Engineering and Science. The Society has over 130 IEEE Fellows, 8% of its membership.

Each of the three technical groups within the UFFC has major awards for technical contributions and service to the respective groups. The UFFC Society has honored its membership with Achievement Awards, Distinguished Lecturer Awards, Distinguished Service Awards and its publication community with Best Transactions Paper Awards. The Ultrasonics community has the Rayleigh award. Frequency Control has honored its community with the W. G. Cady Award, I. I. Rabi Award, and C. B. Sawyer Award. Ferroelectrics has honored its community with the Ferroelectric Recognition Award and the Ferroelectrics Young Investigator Award. Award winners in past years may be found at our website.

Publications and Conferences

The society has three major areas of publications, *Transactions*, Symposia *Proceedings*, and the *Newsletter*. The first *Transactions* was published in 1954 and is now published on a monthly basis.

The *Proceedings* of the three major symposia, Ultrasonics, Ferroelectrics, and Frequency Control, are regular publications received by attendees after the symposia now on an annual basis. Each conference rotates between Europe, Asia, and North America. The first mostly complete collection of ultrasonics symposia papers was in 1972 although programs from the symposia date from 1962. The proceedings of the Frequency Control Symposia predate (1956) the ultrasonics proceedings and for the first several years were classified. The ferroelectric proceedings of symposia were originally published by an independent publisher but since 1990 have become a part of the UFFC Society publications.

The venue for future society symposia reflects the recognition of the international nature of our membership. All three IEEE International Symposia will be held outside the United States in 2009. The International Ultrasonic Symposium was held in Rome, Italy, in September, the International Frequency Control Symposium was held in Besancon, France in May, and the International Symposium on the Application of Ferroelectrics was held in Xi'an China in August.

The first newsletter was published in 1953. The *Newsletter*, was originally published aperiodically with the chairman of the society as the editor. The newsletters have traditionally reported the minutes of AdCom meetings, reports of the most recent UFFC-S symposia, committee reports, new society Fellows, a report from the president, chapter's reports, financial report, upcoming symposia information, awards, distinguished lecturer, new AdCom members, and other items of interest. The purpose of the *Newsletter* is to inform and build a spirit of community. To this end, photographs have been used extensively over the past several years to give life to the written page. Members are always welcome to submit information and photos of interest to our society membership, to the newsletter editor. The *Newsletter* is published twice a year with plenty of photographs by the present editor Dr. Jan Brown.

Membership

As indicated there was a rapid growth of membership in the early years of the society. In the beginning, the members outside the United States represented a small fraction of the total membership. By 1966, when there were 1181 members in the society, 21 percent were from outside the United States with Japan having the largest membership (65). In 2007, with a total membership of 2000, 50 percent of the membership was outside North America. From Australia to Zimbabwe there are UFFC-S members in 68 countries of the world.

To arrive at the return on investment for a member today, the various working segments of the society were polled to determine the total number of volunteer hours which accrue during the period of one year. The conservative estimate was 17,000 hours. Translating those hours into dollars per member, assuming the U. S. minimum wage of $7.25, and adding in the individual cost benefits for publications, newsletter, paper review, savings on symposia registration, and administrative costs, approximately $486 in benefits accrue to each member. That's quite a bargain.

Ultrasonics

Ultrasonics for a long time was the backbone of the society. The word ultrasonics implies frequencies above what the ear can hear or 20,000 cycles. Bats and dog whistles do well above 20 KHz. Ultrasonics began in the water, progressed to the land with numerous applications, and moved to the air and to outer space. It remains in the water with early applications in SONAR (Sound Navigation and Ranging Systems), depth finders, sunken ship locators, and fish locators. On the surface of the earth it is invaluable in oil exploration, cleaning parts, finding flaws, recording blood flow, baby's first photos, and communications. In the air it controls planes and in space it communicates back to earth via satellites and deep space probes. Thus like its sister technologies of the UFFC it remains a mainstream technology in our society.

Transducers convert/detect ultrasound. Its velocity is 5 orders of magnitude or greater below electromagnetic (EM) waves. Thus it has shorter wavelengths than EM waves for the same frequency. Ultrasonic waves are readily directed, guided, focused, and detected.

Reflection and transmission capabilities at discontinuities form the basis for imaging and measurement at low power levels. At high power levels they clean, mix, seal, cut, drill, pulverize, and can help heal the body. Figures 6 and 7 illustrate some of the uses of ultrasound.

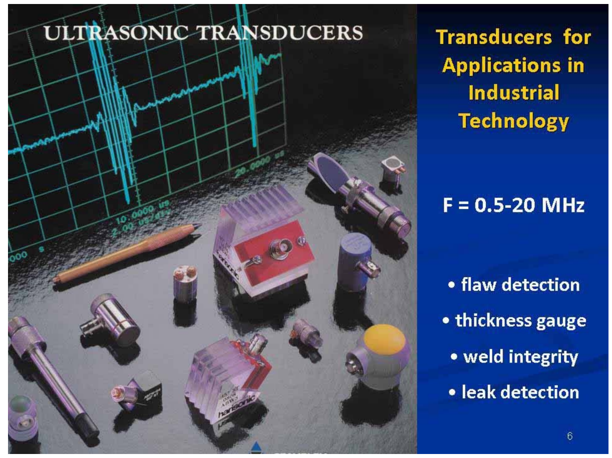

Fig. 6. Transducers for Applications in Industrial Technology

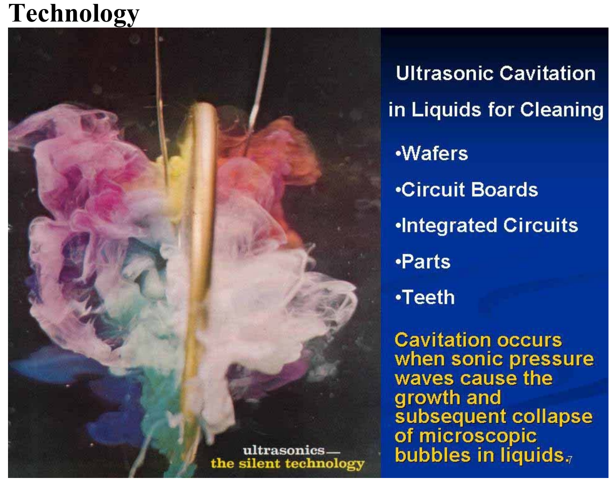

Fig.7. Ultrasonic Cavitation in Liquids for Cleaning

Medical ultrasound has made enormous progress since the first fuzzy 2D pictures of baby came to light. Medical ultrasound, normally operating in the 1-20 MHz regime, is diagnostic, (1-50 mW/cm2), therapeutic (1-5W/cm2), and surgical (5-300W/cm2). It now takes 3D pictures of baby. Several other applications have been used in ultrasonic imaging and in high intensity ultrasound treatment in medicine. Ultrasound is widely used in kidney – and gallstone treatment, tissue ablation, hyperthermia production. Applications of high-intensity ultrasound include enhanced gene delivery, ablation of cancer tissue, coagulation of bleeding tissue, revascularization of occluded blood vessels, increased drug delivery, ultrasound-activated drug delivery. Ultrasound has the potential to be a suitable tool for tumor treatment due to its qualities such as non-invasiveness, deep penetration in tissue, and being able to focus in a defined tumor volume. Figures 8 through 13 illustrate the equipment and uses of ultrasound in medicine.

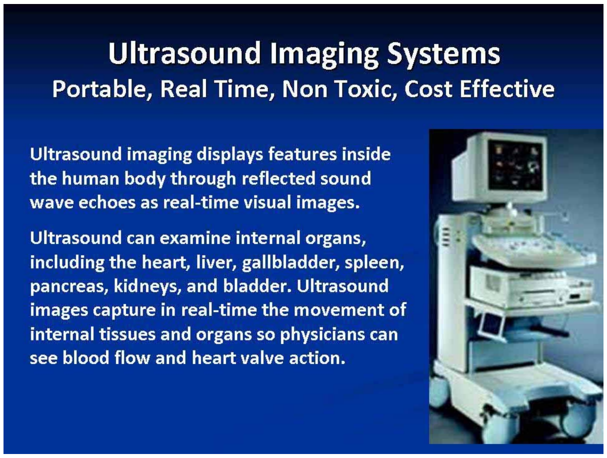

Fig. 8. Ultrasound Imaging Systems

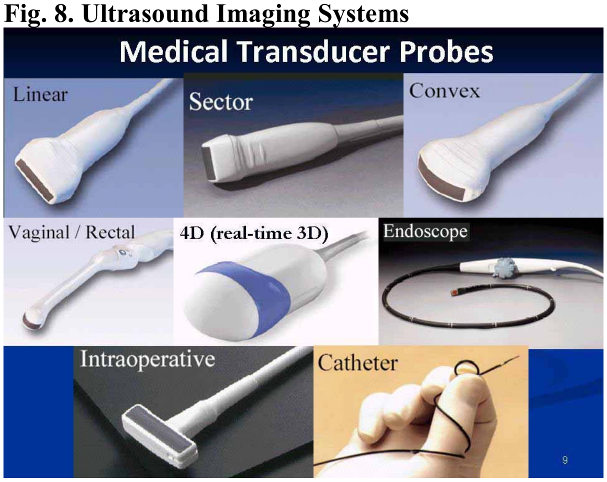

Fig. 9. Medical Transducer Probes

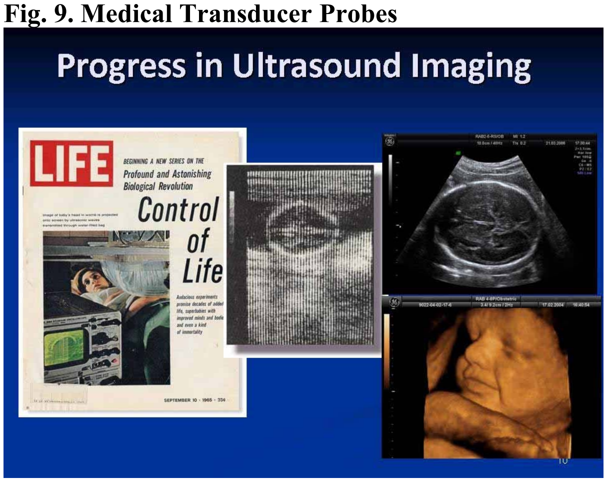

Fig. 10. Progress in Ultrasound Imaging (Baby)

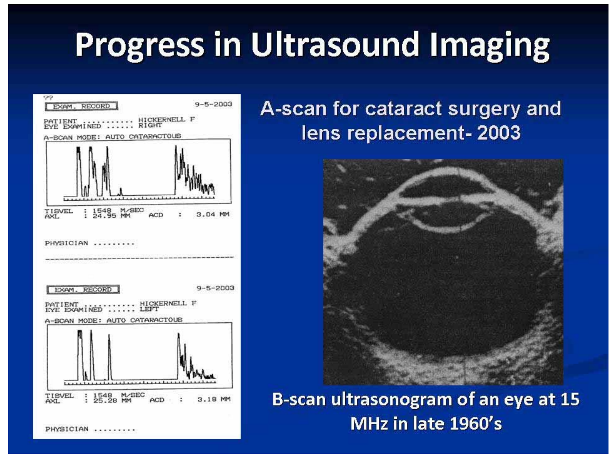

Fig. 11. A-scan for cataract surgery and lens replacement- 2003

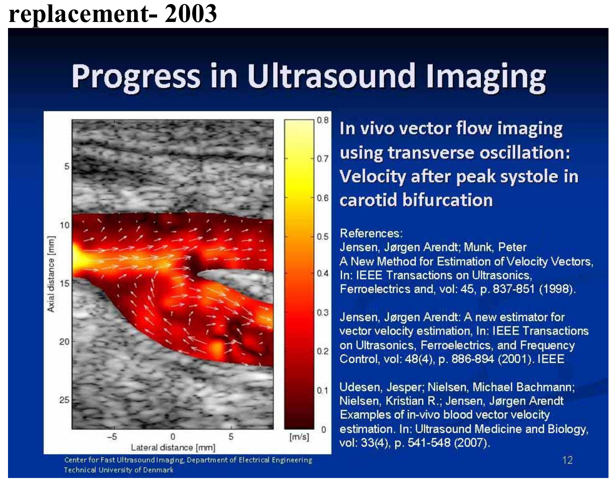

Fig. 12. Progress in Ultrasound Imaging (Blood Flow)

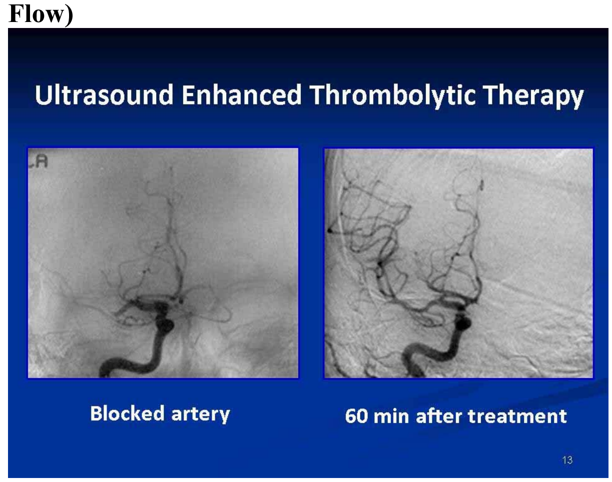

Fig. 13. Ultrasound Enhanced Thrombolytic Therapy

Surface Acoustic Waves, SAW devices, got their start with the early experiments of Dr. Richard White in 1965 at the University of California, Berkeley. The field grew rapidly, replaced large cumbersome tube filters in television sets, and went on as filters in cellular phones, touch screen technology and a host of other earthly applications. In space they were on several earth orbital satellites and the Voyager 1 and 2 launches into outer space that gave us our first look at the planets in our solar system. By 2000 they were sending information beyond our solar system. SAW devices are currently emerging as wireless, passive sensors, and RFID (Radio Frequency Identification) sensors for a wealth of demanding applications. Figures 14 through 17 illustrate the contributions of SAW.

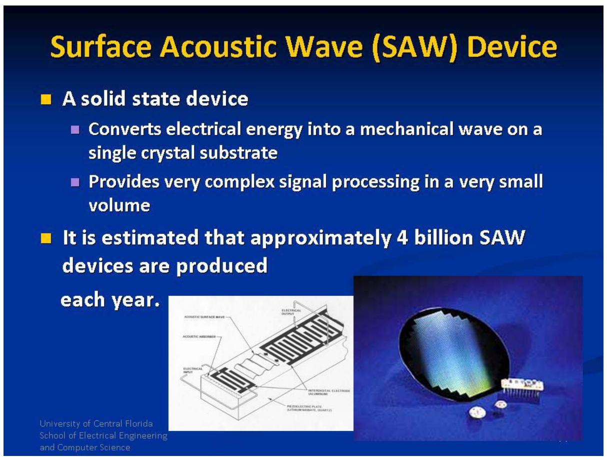

Fig. 14 Surface Acoustic Wave (SAW) Devices

Fig. 15 SAW Applications

Acoustic Micro Imaging or acoustic microscopy has long been a technology which has revealed flaws or defects hidden from sight. There have been numerous applications extending in frequency to the GHz. range. Figure 18 illustrates this useful quality.

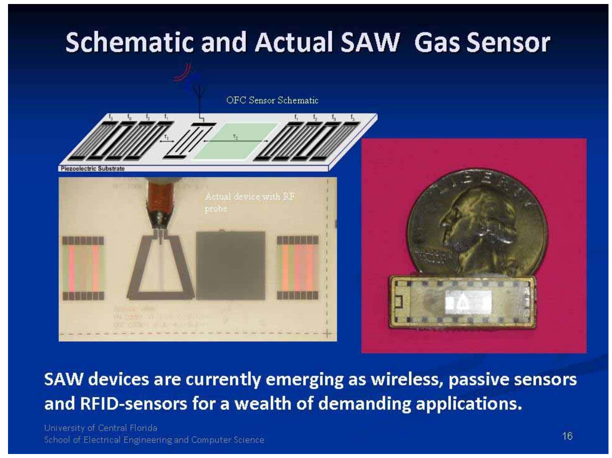

Fig. 16 Schematic and Actual SAW Gas Sensor

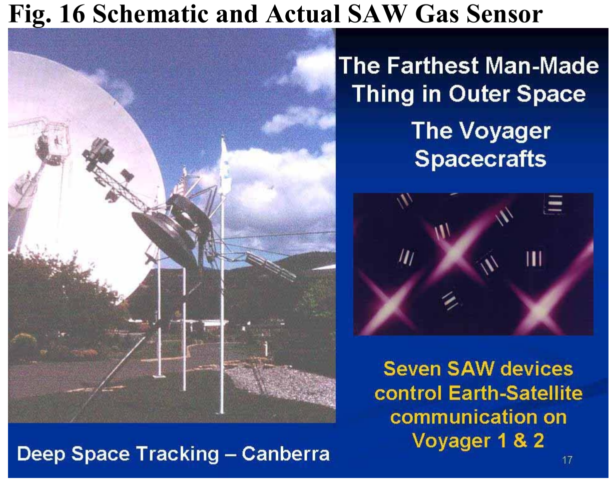

Fig. 17. The Farthest Man-Made Thing in Outer Space

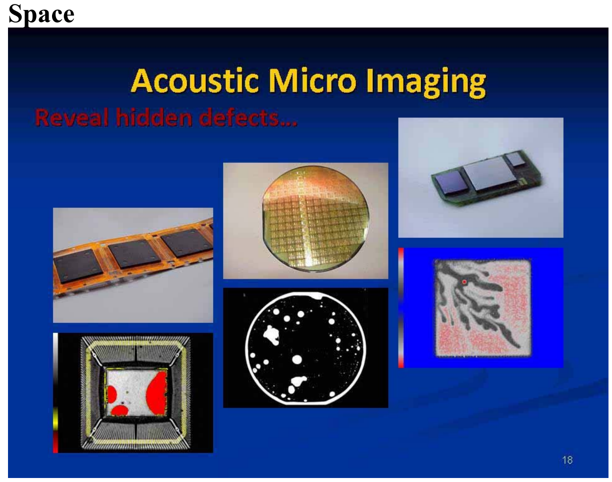

Fig. 18 Acoustic Micro Imaging

Ferroelectrics

Ferroelectrics are piezoelectric (Fig. 19). The ferroelectric state was discovered in 1920 by Valasek in Rochelle Salt. All ferroelectrics are required by symmetry conditions to be piezoelectric and pyroelectric. Typically ferroelectric materials only have this property below a certain phase transition temperature called the Curie temperature, Tc. The applications of ferroelectrics in the early years were with ceramic compounds with various dopings. Usually the transition from the ferroelectric state occurs around 300 degrees Celsius so the applications are for temperatures below 300 degrees.

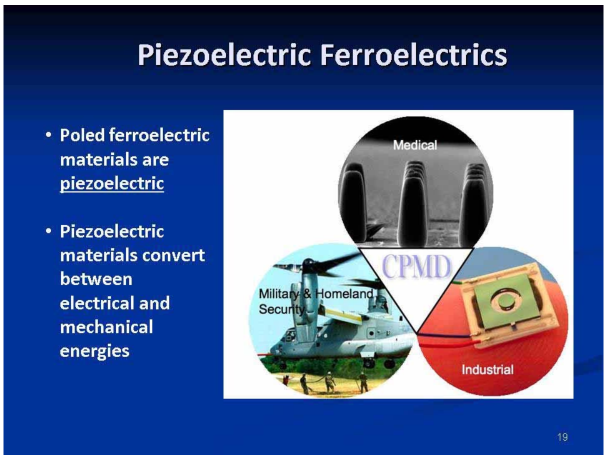

Fig. 19. Piezoelectric Ferroelectrics

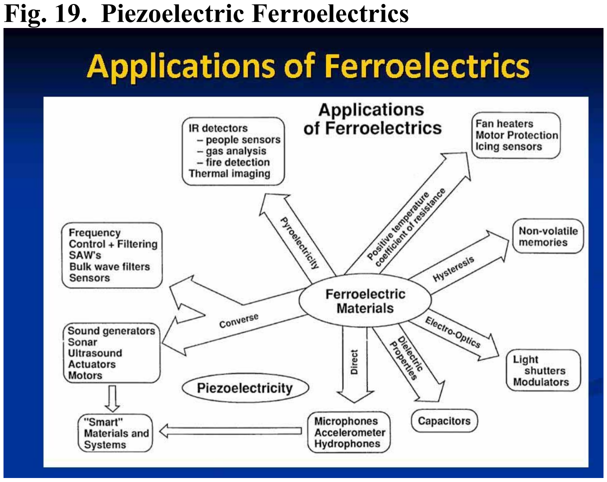

Fig. 20 Applications of Ferroelectrics

Ferroelectric materials are used in a variety of applications as shown in figures 20 and 21. In the automobile alone there are some 18 possibilities for ferroelectric devices (Figure 22). Thin film ferroelectrics also play a role as FBAR resonators, high frequency filters, high sensitivity accelerometers, actuators and transducers (Figure 23). In figure 24, four packaged and "bumped" FBAR filters are shown on a grain of rice. The performance in the Hubble telescope, where the original mirror was ground improperly, was improved by six electrostrictive actuators on the secondary mirror for precise positioning (Figures 25 and 26).

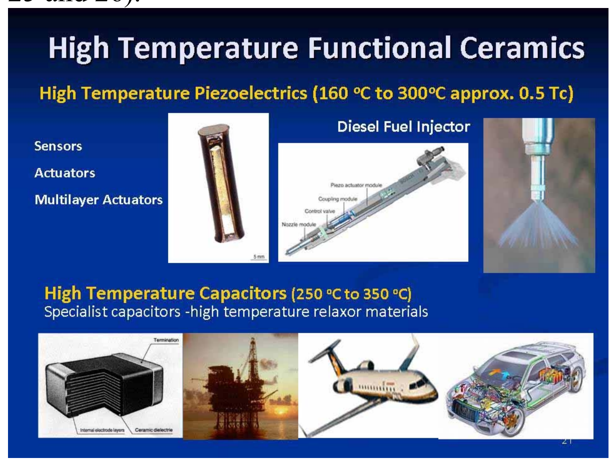

Fig. 21 High Temperature Functional Ceramics

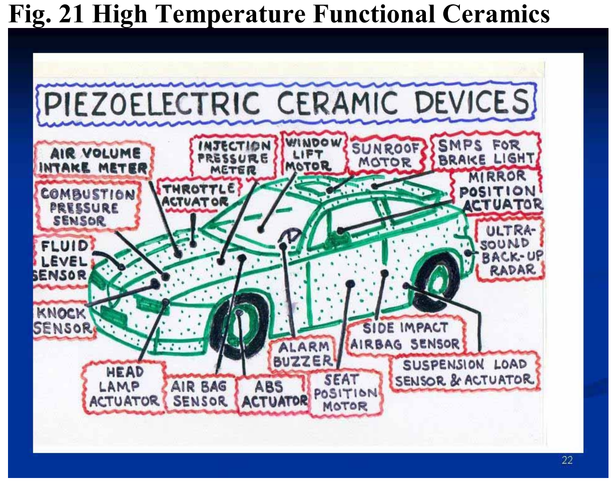

Fig. 22 Piezoelectric Ceramic Devices

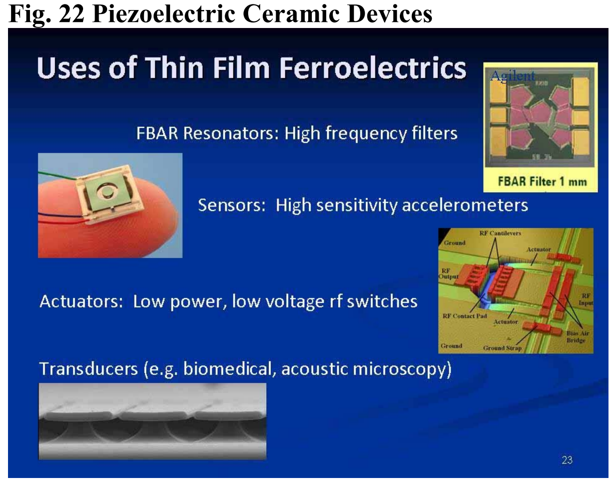

Fig. 23 Uses of Thin Film Ferroelectrics

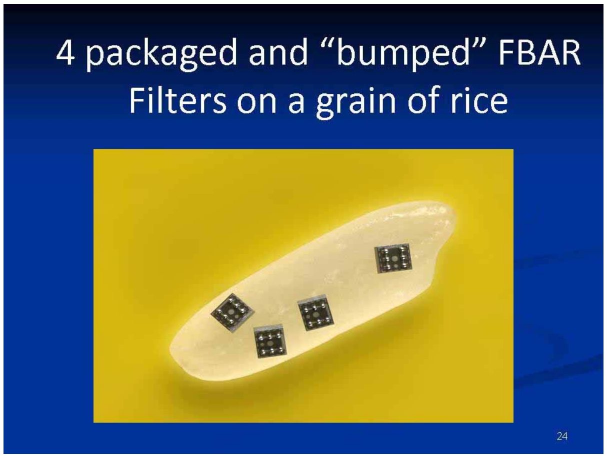

Fig. 24 Four Packaged and "Bumped" FBAR Filters on a Grain of Rice

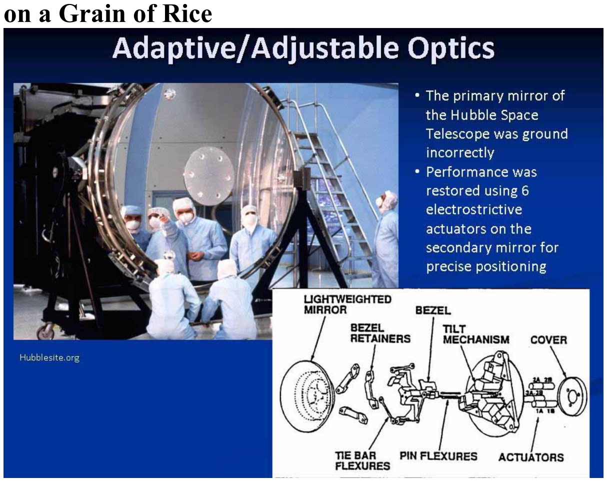

Fig. 25 Adaptive/Adjustable Optics

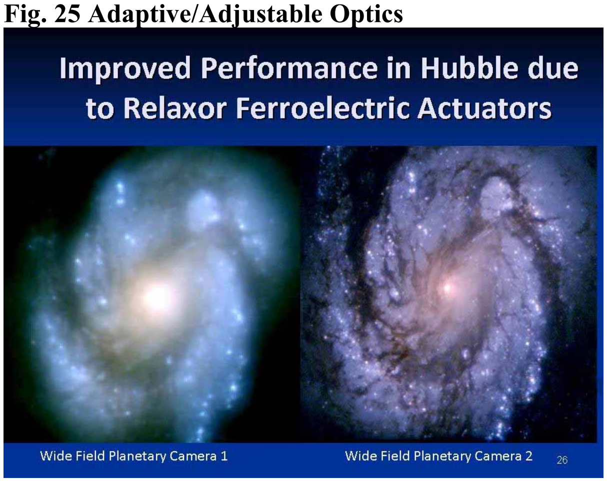

Fig. 26 Improved Performance in Hubble due to Relaxor Ferroelectric Actuators

Frequency Control

The heartbeat of frequency control is the quartz resonator. Frequency control is all about clocks, time, and the second. The earliest clock was probably a sun dial. The pendulum clock was developed in the 1600's and Harrison's famous chronometer in 1736. By the 1800's there were clocks in steeples in Europe. These early mechanical clocks were marvels of their day with several thousand mechanical parts (Figure 27).

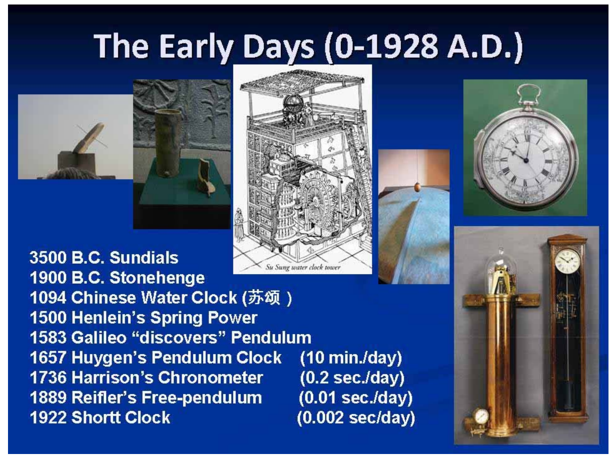

Fig. 27 The Early Days (B.C.-1930 A.D.)

Quartz resonator crystals became pervasive in time and frequency control. They can be found in watches, radios, television, pagers, video games, pacemakers, celestial navigation, and the list goes on and on. Major fields such as astronomy, radar, and geodesy benefited from their presence (Fig. 28).

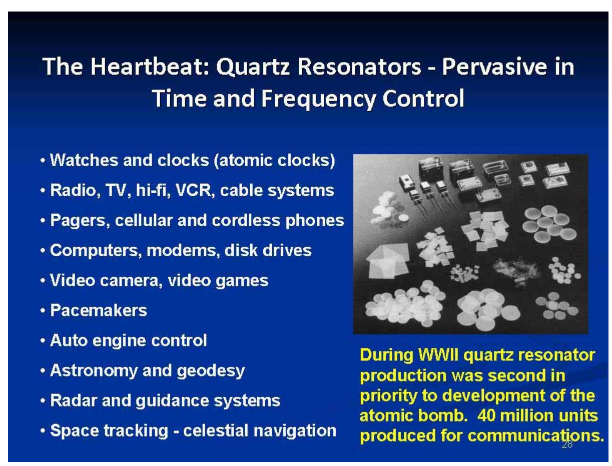

Fig. 28 The Heartbeat: Quartz Resonators - Pervasive in Time and Frequency Control.

In the early 1950's work began on the atomic clocks which today are with accuracies of 10^{-10} or better. Originally the second was defined as 1/86400 of the mean solar day. Then in 1967 CGPM - Conférence Générale des Poids et Mesures changed the definition to: “The second is the duration of 9,192,631,770 periods of the radiation corresponding to the transition between the two hyperfine levels of the ground state of the cesium 133 atom.” According to the 1997 CIPM - Comité International des Poids et Mesures, “This definition refers to a cesium atom at rest at a temperature of 0 degrees K.”

There are three types of noteworthy atomic clocks, rubidium vapor cell, cesium beam, and hydrogen maser. In the rubidium vapor cell the atoms are confined in a Pyrex envelope; and interrogated optically. It is of modest performance and of lowest cost. In the cesium beam the atoms are formed into a beam, and interrogated with microwaves. It is the best accuracy and of intermediate cost. In the hydrogen maser the atoms are prepared to support atomic oscillation in a microwave cavity. It has the best stability in short term, but is high in cost. A picture of these three commercially available clocks is shown in Figure 29.

Fig. 29 Commercially-Available Atomic Clocks

Navigation: the Global Navigation Satellite System (GNSS) known as GPS (Global Positioning Satellite) in the US has had wide publicity. (Figure 30) It was developed by the U.S. Department of Defense (Navy) in the mid 1970’s. Telephony (cell, data, voice) was also developed as well as metrology. The SI second is the most precisely defined unit of measure; the meter was redefined in 1983 using a fixed definition for the speed of light. In radio astronomy masers are used as a critical element in the low noise receivers. The uses for GPS are commercial navigation (e.g. Garmin, Magellan, others), safety of life: rescue, E911, surveying and agriculture (Where are we and where do we need fertilizer?) (Is the field flat so that irrigation is uniform?)

Fig. 30 Navigation

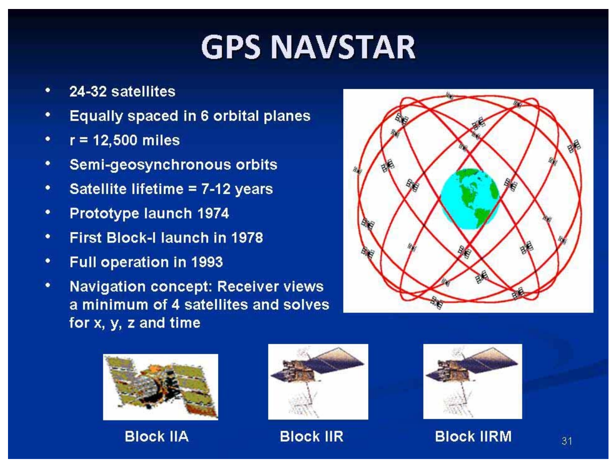

Fig. 31 GPS NAVSTAR

GPS NAVSTAR has had an exciting history with the details found in Figure 31. Rubidium vapor cell clocks are widely used in CDMA cellular telephony to support cell-to-cell handoff for people on the move. This application requires seven microsecond synchronization. For long haul digital data transfer it is necessary to remove accumulated timing noise by re-clocking the data with cesium beam clocks. In the defense area, shown in Figure 32, there have been considerable applications going into advanced fighter jets. Finally, the NIST F1, the newest U. S. National Time Standard, shown in Figure 33 is an atomic fountain clock.

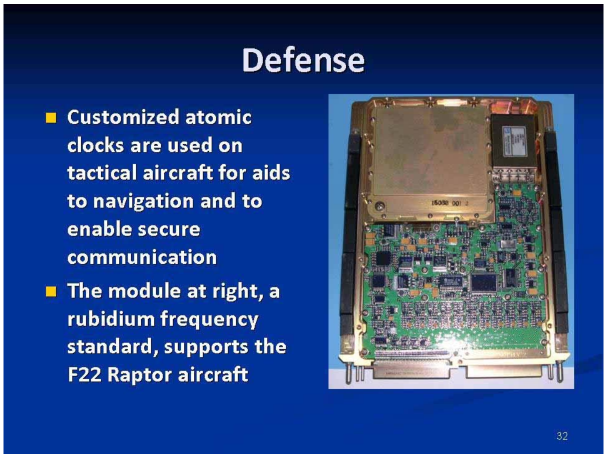

Fig. 32 Defense

Fig. 33 NIST F1 U.S. National Time Standard

Summary

The IEEE Ultrasonics, Ferroelectrics, and Frequency Control Society has a very exciting and rich technical and human heritage. The founders were zealous in their efforts to establish a place for ultrasonic technology, later joined by ferroelectrics and frequency control, among the engineering disciplines. Its technology has had a positive impact on the welfare of the world. Its international membership has been highly honored. The society organizes premier technical symposia and publishes valuable proceedings. The *Transactions on Ultrasonics, Ferroelectrics, and Frequency Control* rank high as a reference source among engineering and scientific journals.

The evolution of UFFC technology has been through the combined efforts of physicists, mechanical, electrical, chemical, and bio-medical engineers, computer technologists, researchers, medical professionals, clinicians, university and government administrators as well as adventurous and perceptive commercial entrepreneurs. It will continue to be so in the future

The UFFC society now brings together people from all over the world with valuable society and related technical information, through a website at **http://www.ieee.org/uffc**. The site has ultrasonics, ferroelectrics, frequency control, and sensor pages. Various aspects of the history of the UFFC-S and its related technologies appear in symposia proceedings and the *Transactions*. Articles which appear in the November, 1984 issue of the *Transactions*, commemorating the IEEE Centennial, capture much of the early society history. The 2004 conference in Montreal included all three components of the society and was the celebration of our 50th Anniversary.

Finally, the spirit of the IEEE UFFC needs to be recounted: the uniqueness of the technology, the anticipation of learning, the excitement of discovery, the opportunity for sharing, the responsibility for integrity, the development of relationships, the rich history with which to build on the past and the vision to inspire the future.

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