Robert Adler’s Touchscreen Inventions

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Abstract—We honor the memory of our late IEEE colleague Robert Adler. Adler’s accomplishments include an impressive body of scientific work and major inventions. The SAW touchscreen is his last innovation having a major impact on our daily lives. The authors, who worked with Robert Adler on touchscreen research, share their perspectives on his SAW touchscreen inventions.

In addition to highlighting Robert Adler’s most recent creative output, this paper identifies themes from his SAW touchscreen inventions and makes connections to earlier career accomplishments. This retrospective of his career also provides an opportunity to share some of the personal story of the life of Robert Adler [1].

Keywords – Robert Adler; SAW touchscreen; biography

I. INTRODUCTION

This paper honors the memory of our late IEEE colleague and friend Robert Adler; see Fig. 1. The first [3] of the two photos of Fig. 2 shows him at roughly the time he published his first paper in 1929 at age sixteen in Austria [4]. The second photo shows him at the Montreal 2004 IEEE UFFC Conference in the midst of an informal discussion during which he contributed ideas now published in a recent patent application [5]. A long period of creative output indeed!

As is well documented elsewhere [6], Robert Adler’s accomplishments include an impressive body of scientific results and major inventions. His last innovation having a major impact on our daily lives is the surface-acoustic-wave (SAW) touchscreen. Fig. 3 shows a photo of a SAW touchscreen as well as an airline check-in kiosk and an interactive museum exhibit containing SAW touchscreens. The authors had the privilege to work with Adler on IEEE papers, patents and product development related to this invention. From this vantage point, the authors share their perspectives on his remarkable career.
During our collaboration with Robert Adler on SAW touchscreen technology, we knew him to be a brilliant scientist and an engineer with a great sense of practicality. Furthermore, we knew him as a humble and very kind-hearted man who effectively used these personality traits to facilitate teamwork and encourage creativity. Comparing notes with colleagues and reviewing the historical record, we conclude that this description applies to the entirety of Robert Adler’s career.

In this paper, themes from Robert Adler’s SAW touchscreen inventions are traced back to earlier career accomplishments. This also provides an opportunity to share a bit of his personal history. But first, his basic SAW touchscreen invention is briefly reviewed.

II. SAW TOUCHSCREENS & SAW FILTERS

Fig. 4 shows a SAW touchscreen as illustrated in one of Robert Adler’s patents [7]. First, consider measurement of the X coordinate of a touch. Transmit transducer T1 on a glass plate launches a surface acoustic wave along the axis of a grating of 45° reflectors G1 and is scattered at 90° illuminating the entire touch sensitive area. A touch at, for example, the location of circle A1 attenuates the surface acoustic waves propagating on a vertical path Pv through the touch. Surface acoustic waves traversing the glass plate are redirected by grating G2 towards the receive transducer R1. The vertical paths Pv with larger X coordinate values correspond to longer signal delay times. The delay time of an attenuated signal component provides a measure of the X coordinate of the touch. Sequentially in time, and in the same fashion, additional transducers and gratings provide for a Y coordinate measurement. The touch sensitive area of a SAW touchscreen is simply a blank piece of glass; for this reason, relative to competing touch technologies of more complex layered constructions, SAW touchscreens are known to provide high transparency and a robust touch surface.

Upon first hearing the term “SAW touchscreen”, many engineers falsely guess a reflection detection mechanism analogous to SONAR. In fact, this was Robert Adler’s initial concept. However, in the research lab it proved difficult to get any sort of detectable SAW reflection off a finger touch. To make sure he was not fooled by a dead transmit transducer, Adler added a second receive transducer as a beam dump at the end of the transmit beam path. The transmit transducer was in fact very much alive … and when he again touched in front of the transmit transducer looking for an echo signal, he noticed a dramatic drop in signal amplitude of the beam-dump receive transducer. SAW absorption, not SAW reflection, is the way to detect finger touches. This was the key “Eureka!” moment in Adler’s invention of the SAW touchscreen [8].

Guided by his great sense of engineering practicality, Adler did not stop at the obvious design solution of lining the perimeter of the touchscreen with numerous opposing transmit/receive transducer pairs, but rather introduced gratings to keep the transducer count low. By avoiding the cost of many transducers, this made the SAW touchscreen commercially viable. During the patent application process, Adler was surprised to find that a SAW touchscreen had already been invented [9] more than a decade earlier! However, this earlier SAW touchscreen design had numerous transducers and was not commercially viable.

When touchscreens attracted Robert Adler’s attention, resistive, capacitive, and infrared touchscreens were already on the market. It would have been natural to incrementally improve one of the existing touchscreen technologies, and in fact one of his patents does just that [10]. However, he took the bold and creative leap to a very different touchscreen technology. Undoubtedly, Adler’s pioneering work on SAW intermediate-frequency (IF) filters prepared him for the invention of the SAW touchscreen.
SAW filters are now commonly used in cell phones. Whole sessions of IEEE Ultrasonic symposia are devoted to this topic. Historically, the first major commercial use of SAW filters was as IF filters for television reception. Prior to this, the study of surface acoustic waves was largely an academic discipline. After the invention of the interdigital transducer (by others [11]), at a time when he worked for Zenith Radio Corporation, a leading innovator of television technology, Robert Adler promptly realized the potential of SAW filters as television IF filters. Fig. 5 shows one example of Adler’s SAW filter inventions [12] in which a series pair of receive transducers with oppositely offset center frequencies provides a band pass filter with a acceptance region of approximately constant attenuation. Why was Robert Adler so quick to recognize the commercial potential for SAW filters? Surely an important factor was Robert Adler’s earlier pioneering role in electro-mechanical filters.

Robert Adler’s personal library contains a copy of a reference book [13] on “Mechanical Filters in Electronics.” The following handwritten note is found on the inside cover: “To Dr. Robert Adler, who first showed the world that practical mechanical filters could be built, from Bob Johnson, the author, and one of your fans.” This book’s author refers to a breakthrough invention made during World War II. Fig. 6 reproduces representative drawings from the corresponding patent filed after the war. Events of world history motivated this invention.

When America entered World War II, Zenith Radio Corporation shifted its attention to the war effort. Radio communications of the Allied forces depended heavily on Brazilian quartz crystals and a potential disruption in their supply posed a serious threat [14]. Robert Adler, a newly hired research scientist at Zenith, was eager to respond and provide an alternate source of quality frequency control devices for radio communication. As a result, the first practical electro-mechanical filters were invented [15]. Although the supply of Brazilian quartz crystals was maintained and this invention was not used during World War II, electro-mechanical frequency references in the form of SAW filters are common today, for example, as components of cell phones.

Robert Adler’s adventures in the intersecting worlds of acoustics and electronics go back even further in time. In a 1940 UK patent application [16], he proposed methods that were later re-invented, modernized and commercialized as non-destructive ultrasonic testing via resonant analysis [17]. The problem was how to reliably check the quality of mass produced parts that were subject to difficult to see cracks and slight dimensional errors. The solution was to check for deviations in precisely measured characteristic frequencies of modes of vibration. This method is in use today to quality inspect, for example, grinding wheels for cracks and other defects [18]. This 1940 patent application is the earliest patent application [19] and as well as the first ultrasonics work of Adler known to the authors.

III. Grating Transducer & Acoustic Resonators

Robert Adler’s latest invention to be commercialized on a mass production scale is the SAW touchscreen grating transducer [20] illustrated in Fig. 7. Prior SAW touchscreen designs used wedge transducers. The protruding wedge posed little problem for the mechanical design of old CRT touch displays as there was plenty of room under the CRT bezel for the wedge. However, liquid crystal displays (LCDs) created a need for a flatter transducer design. Grating transducers met that need. A piezo bonded to the back side of the SAW touchscreen launches a pressure wave through the glass plate that is scattered at 90° and mode converted to SAW by a set of SAW-wavelength spaced gratings.
The SAW touchscreen grating transducer invention was inspired in large part by a much earlier 1980 theoretical paper [21] that proposed the grating transducer design shown in Fig. 8. Bulk pressure waves induce the thin strip gratings to bob up and down, and like logs bobbing up and down in a quiet pond, the gratings excite surface waves. With his keen sense for practical engineering, Adler quickly saw the manufacturing cost advantages of avoiding the grinding of a tilted glass surface to mount the piezo as in Fig. 8. Furthermore he had the insight that by choosing the glass thickness in Fig. 7 just right, transducer efficiency would be greatly enhanced via the excitation of a glass thickness-mode resonance. Later product development proved Adler to be absolutely right on both counts. Clearly he was no stranger to resonating mechanical structures; in addition to the electro-mechanical filter and non-destructive testing examples given above, Robert Adler’s invention of the first commercially successful wireless TV remote control made innovative use of acoustic resonators.

Today we are very accustomed to replacing batteries in handheld devices. However, at the time Robert Adler invented the TV remote control, his marketing colleagues insisted that any handheld device with a battery was unacceptable as users would assume that device was broken when the battery ran out [22]. With this in mind, he invented an entirely mechanical remote control device [23] shown in Fig. 9, an invention that became the first ultrasonic device to become a common household item [24]. A set of four narrow aluminum cylinders (blue), one of which is visible in the figure, resonate in the fundamental extensional (longitudinal) mode at frequencies of 38, 39, 40 and 41 kHz when excited by hammers (red) activated by push buttons (brown). Cylinders of initial research prototypes resonated around 20 kHz, but when a young woman in a nearby office complained of the irritating high pitched sounds emanating from the research lab, the frequencies were increased [25]. After decades of commercial success, such entirely mechanical devices were replaced by remotes based on infra-red beams. Nevertheless, even today the term “clicker” (from the audible clicks of the hammers hitting the aluminum cylinders) is used for remote controls, as in the 2006 movie “Click” starring Adam Sandler.

IV. RADIO RECEPTION & VACUUM TUBES

Early in the commercialization of SAW touchscreens, a number of SAW touchscreen systems were placed side-by-side for an eye-catching effect in a trade-show booth. All the touchscreen units functioned quite nicely in the factory. However, in the trade-show booth they malfunctioned. Before a poor shielding design was rectified, the sensitive SAW touchscreen receiver circuits received radio emissions from the excitation pulses of neighboring SAW touchscreen units. This illustrates the fact that the electronics of radio reception and SAW touchscreen signal reception do indeed have much in common [26]. Robert Adler was a great innovator of radio
reception electronics and perhaps this background also contributed to his invention of the SAW touchscreen.

When one of the authors asked Adler to name his most important invention, his answer was not the TV remote control, but rather work in the field of radio reception [27].

In 1964, when American teenagers of the time first watched the Beatles perform on the Ed Sullivan TV show, Robert Adler’s innovations helped them clearly view their favorite Beatle despite contamination of the broadcast TV signal by sharp noise spikes from ignition switches and electronic motors, etc. To briefly hint at an Adler invention, large amplitude noise spikes of short duration may be clipped or gated out with the aid of fast non-linear electronics [28].

The middle of Fig. 10 shows a vacuum tube [29] invented by Robert Adler that was a key component in the electronic circuits for both the TV reception and the TV remote control inventions mentioned above. This is the 6BN6 gated-beam limiter that was a major commercial success in its day. Even today it continues to be traded on eBay. On the left of Fig. 10 is a high gain amplifier tube [30], the topic of Adler’s first patent granted in 1947 (filed 1944). The high gain is achieved through the regenerative effects, that is, controlled levels of positive feedback. The theme of regenerative or positive-feedback effects was developed by Robert Adler to a very high level of sophistication in a series of patents dealing with traveling-wave electron beam devices. The right of Fig. 10 relates to what became know as the “Adler Tube.” With an equivalent thermal noise temperature of only 30°K (despite using electron beams from heated tungsten filaments!) the Adler Tube set a new standard for sensitive radio wave reception.

Readers who attended the 2000 IEEE Ultrasonics Symposium may recall a plenary session talk and a tour of the Arecibo Radio Telescope. Our plenary speaker and tour guide notes that when the Arecibo Observatory was brought online in 1963, an Adler Tube was procured and tested for use [31]. However, about that time solid-state amplifiers appeared on the scene and displaced the Adler Tube. Earlier, in 1959, the Adler Tube was indeed a key to the successful bringing on line of the Illinois 400-foot Radio Telescope [32].

Robert Adler had the intellectual honesty and generosity of spirit to champion great ideas of others [33]. The Adler Tube [34] illustrates this. While the design of Adler Tube does indeed incorporate inventions of Adler [35], the key amplification mechanism of the Adler Tube is in fact the “quadrupole amplifier” invention of his colleague Glen Wade [36]. The following story [37] from Glen Wade illustrates how great it was to have Alder champion your ideas. After the invention of the quadrupole amplifier, while Adler led the commercialization effort, Glen Wade shifted his full attention to the development of an engineering research staff at Cornell University. Years later, after Cornell successfully led the construction of the Arecibo Radio Telescope, Glen Wade represented Cornell at the commissioning ceremony. While touring the facility, he asked what signal amplifier received the extraterrestrial signals. To his surprise and delight, the answer was “an Adler Tube”.

When asked how he was able to so thoroughly master to such different engineering disciplines as electron beam devices and ultrasonics, Adler answered that the two fields were just different variations of the same underlying principles of physics [38]. One of the most interesting achievements of Robert Adler in the field of ultrasonics is the demonstration of a rough SAW analogue of laser amplification [39]. Fig. 11 shows such a device where an input electronic signal from the left is converted to SAW by an interdigital transducer and the ultrasonic SAW wave itself is amplified on the way to a receive transducer and electrical output. The patent’s title “Solid-state Traveling-Wave Amplification System” reflects an analogy in Adler’s mind to traveling wave amplification of electron beam devices.
Robert Adler’s interest in electronics and electron beam devices dates back to his youth in Vienna.

V. ROBERT ADLER’S YOUTH IN VIENNA

Robert Adler was born in Vienna in 1913 [40]. He picked up an interest in science from his mother, who practiced medicine. As a teenager, Robert Adler developed an avid interest in radio technology [41], leading to his first publication at age sixteen [4]. His interests led him to pursue graduate studies in physics at the University of Vienna [42].

Fig. 12 is copied from Robert Adler’s grade book at the University of Vienna. In addition to a course on quantum theory as shown in Fig. 12, Adler also studied mechanics, electromagnetism, optics and thermodynamics with Professor Hans Thirring. Thirring was one of the first theoretical physicists to understand and extend Albert Einstein’s General Theory of Relativity [43]. This resulted in a lifelong friendship between Thirring and Einstein. It is possible that Robert Adler attended a lecture at the University of Vienna by Einstein on Relativity [44]. While his degree was in physics, Robert Adler’s doctoral research contributed electronic measurement methods to the research of a chemistry professor [45]. This chemist was Hermann Mark who is generally regarded as the father of polymer science [46]; Hermann Mark also introduced Linus Pauling to X-ray crystallography. Robert Adler took full advantage of the rich intellectual environment at the University of Vienna [47] to develop a truly profound understanding of science.

Fig. 13 shows photos of Robert Adler’s parents Jenny Herschmann Adler and Max Adler. Both were social idealists. Jenny Adler received a medical degree in 1905 and devoted herself to the cause of worker safety [52]. Max Adler was a sociologist and political theorist and achieved fame as one of the founders of a Vienna school of Marxism [53]. In addition to being politically active, both parents were of Jewish ancestry, if not practicing Jews. Let us put aside philosophical questions on differences between Max Adler’s Marxist ideals and the application of Marxism by later governments. As a practical matter, having a Jewish background and a famous Marxist as a father, the Nazi occupation (“Anschluss”) of Austria in 1938 put Robert Adler’s life was at risk [54]. In 1939 Robert Adler managed to escape Austria, ironically enough, with the aid of a Nazi passport. Many years later, archives of this dark period of human history were made easily accessible to the general public at the U.S. Memorial Holocaust Museum in Washington D.C. via interactive exhibits [55] based on Robert Adler’s SAW touchscreens as shown in the right photo of Fig. 3.

Did Robert Adler absorb, modify and successfully apply in his own unique fashion the humanistic ideals of his parents when, years later, he headed the impressive R&D organization at Zenith? At Zenith, he was known for an executive style that downplayed organizational rank and was much more of an anticipation of informal and creative Silicon Valley corporate cultures than a carry-over of the aristocratic culture of the Hapsburg Empire into which Robert Adler was born [56]. Colleagues at many levels of the organization knew him not as “Vice President Adler”, but simply as “Bob” [57] [58] [59].

After escaping to England, Robert Adler found gainful employment and was satisfied living and working in England. However, in anticipation of war with Germany, kind-hearted English friends urged him to flee to America to avoid the risk of misdirected anger directed toward anyone with a German (or Austrian) accent [60]. Thus he came to America and soon found employment with Zenith Radio Corporation. When the United States entered the war, Zenith directed its resources to the development of RADAR technology. Given Adler’s radio and electronics background, and the importance of RADAR to the war effort, Zenith logically would have put him to work on
Robert Adler became a leader in the field of ultrasonics.

In addition to the invention of electro-mechanical filters, which later evolved into the SAW filters, modern cell phone technology benefits from a second seminal breakthrough from Robert Adler’s research during World War II. Highly integrated wireless and wire line transceivers are vulnerable to undesired oscillator pulling and locking effects. These effects are analogous to Huygens’ 17th century observation of phase locking of a pair of pendulum clocks. Quantitative analysis of such effects, for example in cell phone transceivers, are greatly aided by what has become known as “Adler’s Equation” [61] [62].

VI. EPILOGUE

It is too soon to count the total number of Robert Adler’s patents or compile a list of his commercialized inventions. This paper concludes with a look at two recent touchscreen inventions that are likely to become future additions of Adler’s list of over 190 granted US patents [63] and many corresponding patents in other countries.

Love waves are an interesting alternative to Rayleigh waves [64] in SAW touchscreen design. Rayleigh waves of current SAW touchscreen products are susceptible to false touch signals from water drops landing on the touch sensitive surface. Water drops absorb Rayleigh-wave power via the same radiation damping mechanism used to sense finger touches. In contrast Love-wave absorption is by viscous damping, which is much stronger for a finger tip than a low viscosity liquid like water. With proper thresholds, Love-wave touchscreens promise to ignore water while responding to finger touches. Unfortunately, for the time-delay based touchscreen design of Fig. 4 it is important that the touch sensing wave have a well defined group velocity within the bandwidth of the electronics, which is typically not the case for Love waves. However, with the aid of Robert Adler’s laboratory skill and a large measure of serendipity, this obstacle was overcome with the Love-wave substrate design [65] shown in Fig. 14.

One of the authors had the pleasure to guide a productive collaboration between a team of material scientists who prepared samples and Robert Adler who experimentally tested their acoustic properties. For this effort, Adler set up a small one-man lab near his home in Northbrook, Illinois. The skill and pleasure he took in this solo lab work may well provide a glimpse of what teenage Robert Adler was like in his home experiments with radio technology seventy years earlier. In this fashion, Adler single handedly generated the essential laboratory data for three IEEE symposium papers [66].

This research on Love-wave touchscreens started with a very different purpose. The initial goal was a low-cost all-plastic SAW touchscreen in which gratings shown in Figs. 4 and 7 are included in the mold design of an injection molded substrate. Numerous polymer materials were evaluated and rejected as being too acoustically absorptive for use as a SAW touchscreen substrate. Certain polystyrene materials performed the best, but were still not good enough and a decision was made to admit defeat and end the project. Then it occurred to us that if the polystyrene material were used as a thin slow-velocity top layer of a two layer polymer/glass Love-wave substrate, only a small fraction of the Love-wave power would actually propagate in the polymer. The allowed rate of power absorption in the polymer would be increased by an order of magnitude. As a practical engineering matter, the exposed polymer layer was worrisome. At the risk of ruining the desired Love-wave, some samples were made with a three layer construction using a thin glass layer on top for scratch and chemical resistance.

Testing for Love-wave propagation in substrate samples was no easy matter. Experiments required a transducer that could easily be moved around the surface of a sample and further required no a priori knowledge of the Love-wave velocity. Many common transducer designs such as interdigital, wedge and grating transducers do require a priori knowledge of the excited wave’s phase velocity. Furthermore, the shear coupling needed to excite a Love wave cannot be provided by a liquid coupling. These challenges did not stop Robert Adler. He proceeded to invent [67] and successfully use the transducer design shown in Fig. 15. The ultrasonics design of this transducer is quite clever and involved [68]; for ultrasonics experts, here is a sketchy explanation. A standard pressure mode piezoelectric element is bonded at the top of a cleverly shaped piece of steel. Pressure waves reflect off a surface and are mode converted into shear waves. A conically curved surface reflects and focuses the shear wave power to a thin knife edge that makes contact with the surface of the sample under test.
Of the candidate samples prepared by the material scientists, the one corresponding to Fig. 14 provided by far the best Love-wave signal. Robert Adler measured group velocity as a function of frequency and found no measurable frequency dependence whatsoever. This seemed too good to be true, so Adler carefully repeated his measurements. Subsequent theoretical analysis showed that with careful tuning of parameters a nearly constant group velocity over a range of frequencies is indeed possible in a three-layer substrate. Fig. 16 shows plots of theoretically computed group velocity vs. frequency for several values of a key design parameter. Curve E is essentially constant from 4.5MHz to 6.5MHz, nicely covering the entire bandwidth of a SAW touchscreen controller with a nominal operating frequency of 5.5MHz. Serendipitously, Curve E also corresponds to the layered construction of Fig. 14. With the aid of Adler’s data, a fully functional Love-wave touchscreen was built and demonstrated to respond well to finger touches even when the entire touch surface is totally submersed underwater [69]. The future will determine whether or not Love-wave variants of SAW touchscreens will find sufficiently compelling market applications to justify commercialization.

Shortly after Robert Adler’s 90th birthday, an informal lunch time conversation during the 2003 Ultrasonics Symposium in Honolulu triggered what may in the future prove to be Adler’s last major invention. The topic of conversation was the ever decreasing border widths of flat panel displays. In the early days of SAW touchscreens, CRT monitors of the time had relatively wide bezels around the display that gave plenty of room to hide and protect the relatively wide grating arrays of Fig. 4. However, over the last two decades, the trend has been to ever sleeker monitor designs and a corresponding decrease of border area available for the grating arrays. Every expectation is that this trend will continue. This leads to a basic problem for the SAW touchscreen design of Fig. 4. Making transducers and grating arrays less than ten wavelengths wide rapidly causes a loss of signal from beam spreading effects. One option to control such beam spreading effects is to somehow make use of acoustic wave guides. However, acoustic wave guide modes are generally dispersive and furthermore, the presence of more than one wave guide mode would lead to detrimental interference effects in received touchscreen signals.

While enjoying the pleasant Honolulu breeze, the conversation turned to edge waves such as shown in Fig. 17. This figure is copied from a 1979 Robert Adler research paper [70] and shows a snap shot of surface distortions for a simulated edge wave propagating along an edge at the intersection of horizontal and vertical surfaces. Edge waves are transverse waves in the sense that an atom on the edge is displaced perpendicular to the wave propagation direction and at a 45° angle with respect to the vertical and horizontal surfaces. Edge waves are trapped at or guided by an edge much like Rayleigh waves are trapped at or guided by a surface. Remarkably, edge waves, like Rayleigh waves, are non-dispersive. Furthermore, engineering numbers worked out beautifully for an operating frequency of 5.5MHz and a glass thickness of 3mm typical of SAW touchscreens.
The mean transverse dimension of edge wave power distribution is about 300 microns, a comfortable order of magnitude smaller than the glass thickness. An edge wave propagating along a clean 90° top edge is unaffected by the presence of a lower glass edge typically about 3mm below the top edge. This leads to a new concept for a very narrow border SAW touchscreen [71] [72] in which transducers emit and receive edge waves. Rayleigh waves traverse the touch sensitive area. Grating structures along the edges mode convert and scatter by 90 degrees the acoustic waves.

Such an edge-SAW-edge touchscreen requires edge-wave transducers. For example, Fig. 18 illustrates an edge-wave transducer design that has been proven in the lab to have high acoustic efficiency. The shear-mode piezoelectric element has an unusual electrode geometry that results in excitation amplitudes that decreases from the corner in approximately the same way the edge-wave amplitude itself does. In receive mode, this transducer design presents an electrical impedance problem. As the effective acoustical and electrically active area of the transducer matches the effective 0.1 square millimeter cross-section of the edge wave, the transducer impedance is very high, in the kΩ range. This high-impedance signal source tends to be heavily loaded by the capacitance of the cable run from the transducer to the controller electronics. For example, at 5.5 MHz, 100pF of cable capacitance is a reactive load of about only 300Ω. This suggests adding a local pre-amplifier at the transducer, but unfortunately that would add undesired cost and complication to the touchscreen design.

To solve this practical engineering problem posed by the edge-wave touchscreen invention of Robert Adler at age 90, let us seek inspiration from his first publication [4] on “Body capacity of headphone leads – a method to suppress its influence by means of a special push-pull choke.” At age 16, Robert Adler understood that undesired loading effects of a weak high-impedance signal source by cable capacitance could be reduced with appropriate use of inductance. Following his lead, we propose the circuit modification of Fig. 19. The edge-wave receive transducer signal VS has a source resistance RS in the kΩ range. By itself, the cable capacitance C would greatly decrease the signal voltage on the load resistance RL. However, the effects of cable capacitance C can be cancelled by an inductance L of an appropriate value added to the input of the controller electronics.

For everything you have done throughout your life from your teenage years to your 90s, we thank you Robert Adler!

VII. ACKNOWLEDGEMENTS

The breadth of Robert Adler’s accomplishments are so broad that it would have been impossible to write this paper without the expertise of numerous colleagues including James Aroyan, Joe Babb, Tom Dickinson, Paulo Gomes, Jon Hagen, Fred Hickernell, Samuel Hurst, John Larson, Bruce Maxfield, John Pederson, Behzad Razavi, Erwin Roschke, Jeff Sharp, Alan Sobel, George Swenson, Glen Wade, Richard “Dick” White and Geoff Wilson.

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Ingrid Adler is gratefully acknowledged for granting us access to historical documents from Robert Adler’s home office as well as her review of drafts. But most of all we thank Ingrid Adler for being a loving wife to Robert Adler.

REFERENCES

[1] The life of Robert Adler is reviewed in a video prepared by one of the authors (Greg Laux) for Adler’s memorial service of April 2007. This video, as well as this paper, will be presented in a special session in memory of Robert Adler at the 2007 International IEEE Ultrasonics Symposium.
Robert Adler, personal communication.

Typical SAW touchscreen receiver circuitry is like direct conversion AM radio. The antenna and tuning circuit in AM radio is analogous to a receive SAW piezo. In both AM radio and SAW touchscreen signal reception this is followed by RF amplification, detection via rectification and baseband amplification. Joe Babb, personal communication.

Unfortunately, the authors are unclear exactly which invention relating to radio reception Robert Adler cited as his “most important”.

For example, Robert Adler et al., US patent 2,814,671 (1957).

Robert Adler, US patent 2,511,143 (1950); Fig. 12.

R. Adler & J. Prentiss, US patent 2,426,681 (1947); Fig. 1.

Jon Hagen and Rolf Dyce, personal communication. Jon Hagen was our plenary session speaker for the 2000 IEEE Ultrasonics Symposium as well as our tour guide at the Arecibo Radio Telescope.

George W. Swenson, personal communication. Here is an excerpt of e-mailed notes from George W. Swenson: “Dr. Adler … inquired if we would like to use a Zenith traveling wave parametric amplifier in our new 400-foot radio telescope. Of course I jumped at the opportunity. … Zenith Radio manufactured two Adler Tubes (I never heard him use that term) to our frequency and bandwidth specifications, together with power supplies, and presented them to the university as a gift. We were delighted, of course. In those days transistors were not very useful in low-noise applications at our frequency of 600 MHz, and we had been planning to use the very latest vacuum triodes which were barely able to perform with the necessary gain, noise and bandwidth.”

Geoff Wilson, formerly a chief technology officer of Elo TouchSystems was well acquainted with Robert Adler’s intellectual honesty to champion the best idea regardless of who came up with the idea. In particular, Geoff Wilson comments “In the mid-nineties, in setting up an off-site brainstorming session with senior R&D people to address a particularly troublesome technical issue, I made a point of including Bob Adler as an active participant, to avail myself, not only of his wide experience in touch technology in general and the respect that he had engendered in my staff, but also of his innate ability to act as a fair and impartial technical sounding board for the many suggested approaches to resolving the problem.”

Robert Adler never used the term “Adler Tube.” Given his strong tendency to direct attention to contributions of others, the term “Adler Tube” may well have made him uncomfortable.

For example, the Adler tube used methods of Adler’s US patent 2,832,001 (1958) to remove thermal noise at a selected frequency from electron beam from the electron gun. To hint at this invention, note that if cyclotron oscillations the electron beam and oscillations of a resonant external circuit of the same frequency are coupled for half of a beat period, thermal noise from the electron beam will be transferred to the resonant external circuit.

G. Wade, US patent 3,449,678 (1969). The right of Fig. 10 is copied from Fig. 8 of this patent. Also see Robert Adler et al., “A Low-Noise Electron-Beam Parametric Amplifier”, Proceedings of the IRE, volume 46, No. 10 (1958). Here is a very brief explanation of the quadrupole amplification mechanism. First recall the basic operation of the cyclotron for which Ernst O. Lawrence was awarded the Nobel Prize in 1939. A charged particle circling in a uniform magnetic field receives a fixed accelerating impulse kick each orbit cycle from a oscillating dipole electric field. The result is an outwardly spiralling orbit whose radius, and particle energy, increases linearly with time. Now imagine replacing the dipole electric field with an oscillating quadrupole electric field. The quadrupole field strength, and hence delivered accelerating impulse kick, is proportional to radius. This results in an outwardly spiraling orbit whose radius increases exponentially with time. A weak signal amplitude in the form of small cyclotron orbit radii can be rapidly amplified in an exponential fashion with the aid of such a oscillating quadrupole accelerating field. In an Adler Tube, such outward spiraling...
motion transverse to the magnetic field is superposed with a constant electron velocity parallel to the magnetic field. Intended for use inside a solenoid electromagnet, an Adler Tube consists of an electron beam source, an input modulator in which a weak input signal excites small transverse cyclotron oscillations via deflection plates, a quadrupole amplifier stage as described above, and an output demodulator to convert large amplified cyclotron oscillations into strong output electronic signals.

[37] Glen Wade, personal communications. When Glen Wade inquired about the noise temperature achieved by that Adler tube, he was told that it could get down to 30º Kelvin. Wade knew that if a low-noise traveling wave tube had been used instead of the Adler tube, the input noise temperature at best would have been substantially above that of the cathode temperature of the tube. Thus the use of the Adler tube instead of the low-noise traveling wave tube - the next best signal amplifier available - increased the sensitivity of the Arecibo Radio Telescope by a factor of substantially more than 20 times. Wade was very happy to become aware of such an improvement.

[38] Robert Adler, personal communications.

[39] Robert Adler, US patent 3,678,401 (1972); Fig. 1.


[41] A little over a decade later, and in another part of the world, radio technology also played an essential inspirational role for a boy of humble beginnings in the Appalachian mountains of United States. This boy, by the name of Samuel Hurst, also went on to have an impressive career as a physicist and an inventor, including pioneering work in resistive touchscreen technology and founding the company that later commercialized Robert Adler’s SAW touchscreen. Samuel Hurst, personal communication.

[42] More details on Robert Adler’s education are given in the following e-mail from Dr. Wolfgang L. Reiter: “Adler attended the Bundesrealgymnasium Wien II, final exam (Matura) in June 1932. Adler studied at the University of Vienna between winter semester 1932/33 and summer semester 1936. His final exams (Rigorosen) in physics in connection with chemistry had been with H. Thirring, St. Meyer and H. Mark; in philosophy and psychology (Philosophikum) with R. Reinner and K. Bühler. Graduation (Promotion Dr. phil.) on May 14, 1937. At that time his address was: Josefstaedterstrasse 43/II, VIII district, Vienna, where he lived with his parents.”

[43] A test of Thirring’s prediction that the rotation of the earth warps space-time in a twisting sense (“frame dragging”) is a major scientific objective of NASA’s 2004 launch of Gravity Probe B. Results are expected in the near future. For more details, see the web site www.nasa.gov/mission_pages/gpb.

[44] “Einstein’s last visit in Vienna (before he fled from Europe) took place in October 1931. Einstein held a lecture on the 14th October 1931 at the Physics Institut of the University of Vienna. The lecture dealt with problems of the Theory of General Relativity. It is indeed very likely that Adler was present in the auditorium, since he was a student already at the time.” This quote is based on comments from Dr. Wolfgang L. Reiter of the University of Vienna, and translated to English by Moritz Hennerbliecher.

[45] More details on Robert Adler’s doctoral thesis are given in the following e-mail from Dr. Wolfgang L. Reiter: “Dissertation/PhD Thesis: Über ein hochempfindliches Differentialmanometer (On a high sensitivity differential manometer), 35 pages. The referees of his thesis had been (signed March 3, 1937): Prof. Stefan Meyer (director of the Institut für Radiumforschung, experimental physics) and Prof. Hans Thirring (theoretical physics). The work had been motivated by Prof. Hermann Mark and constantly supported by the chemist, Dozent Philipp Gross and had been performed at the I. Chemisches Laboratorium, University of Vienna, between summer 1935 and December 1936. Adler had the task to construct a differential manometer with a sensitivity higher than given in literature. With his device Adler reached a sensitivity of 210(exp-6) mm Hg (two orders of magnitude higher than figures in the literature). The method is based on measuring the capacity between the membrane of the manometer and a backplate electrode by comparing the frequency (f) of an oscillator circuit, with f variable due to the changes of the capacity caused by changes of the pressure, and a fixed frequency (f') of a second oscillator circuit by using a heterodyne beat method. f- f' had been chosen to be in the audible range of frequencies which allowed a convenient determination of the small pressure changes.”

[46] For example, “Introduction to Physical Polymer Science” by L.H.Sperling contains the following comment on page 241: “… For these and many other advances (see Section 3.8), and a life-long leadership in polymers (he died at age 96 in 1992), Herman Mark was called the Father of Polymer Science.” For more information, see the web sites http://center.acs.org/landmarks/landmarks/polymer/pol3.html and www.nap.edu/html/biomems/mark.html.

[47] More details on Robert Adler’s teachers are given in the following e-mail from Dr. Wolfgang L. Reiter: ‘Adler’s teachers at the University of Vienna had been outstanding. The introductory course in experimental physics he took with Felix Ehrenhaft, well known for his controversy with Robert A. Millikan on the measurement of the electric charge of the electron, his “discovery” of subelectrons and magnetic monopoles and other oddities; Hans Thirring was his teacher in theoretical physics together with Friedrich Kottler. Calculus he took with Karl Menger, who worked in topology, mathematical logic and economy and was mentor of Kurt Gödel; Philipp Furtwängler, a pupil of Felix Klein and one of the leading number theorists of his time, was another of his math teachers. In the humanities his teacher in psychology was the eminent Karl Bühler, and in philosophy Moritz Schlick, a leading member of the “Vienna Circle” of neo-positivism. His teacher in physical chemistry was Hermann Mark. The Nazis dismissed 53% of the professors named in the "Meldungsbuch", the grade book from which fig. 12 is copied: F. Ehrenhaft, E. Haschek, F. Kottler, H. Thirring, H. Mark, K. Menger, K. D. Konstantinovsky, F. Feigl, K. Bühler. This fact serves as a indicator that the rich intellectual and scientific life in Austria came to an end in March 1938.’


[49] Robert Adler’s efforts to promote a sense of international community with the IEEE included learning to speak Russian and Japanese in preparation for symposia in Russia and Japan.

[50] The authors have mixed feelings about including the story of Robert Adler as a refugee. Given his commitment to harmonious cooperation within the international technical community, we feel it would dishonor his memory to use his story in any way that might revive past animosities. On the other hand, history ignored is often history repeated; this is our motivation for including Robert Adler’s experiences as a refugee. Also see next footnote. During a dinner conversation at the 2001 IEEE Symposium in Atlanta, in the middle of which the military campaign against the Taliban in Afganistan began, Robert Adler was clearly troubled by a sense of history repeating itself.

[51] As pointed out by Dr. Wolfgang L. Reiter, Robert Adler chose to tell his refugee story. In an e-mail, Dr. Reiter comments “Adler was participating in an international symposium on the exodus of scientists under Hitler in 1987 here in Vienna (I remember vividly his talk) and contributed a most interesting paper on his experiences as a child and student in Vienna, and as a refugee in England and his emigration to US. Here is the citation of his paper: Robert Adler. Zeitzeug. In: Vertriebene Vernunft II. Emigration und Exil österreichischer Wissenschaft. Intern. Symposium 19. bis 23. Oktober 1987 in Wien. Friedrich Stadler (Hrsg.) Wien – München: Jugend und Volk 1988. (Unveränderte Neuauflage: Teilband 2, Münster: LIT Verlag, 2004). pp. 740-743. At that symposium Reiter gave an overview on the emigration of scientists from Austria after 1938. An English translation is in:
Adler was best known for having tried to synthesize Marxism and Kantianism. What that meant was that he did not accept rigid determinism and "teleology" in Marxist doctrine, arguing instead that causality was independent of any grand design and that Marxists had to accept the principles of the scientific method, especially empiricism. His more practical contribution was in the area of pedagogy. He advocated what might be called a pedagogical social idea best represented by the institutions of "Red Vienna" — to effect a synthesis of improvement in social conditions — housing, schooling, health and welfare — with democratic electoral politics. Socialism could be anticipated and ingrained in the younger generation. His son's anti-authoritarianism came from that side of Adler's work and he was a staunch opponent of the Catholic anti-Semitism that marked the conservative opposition to the Socialist control of the municipality from 1918 to 1934. There is a rather unsympathetic psychological portrait of Max Adler in Mark E. Blum, The Austro-Marxists and a more positive one in my own The Crisis of Austrian Socialism: From Red Vienna to Civil War. Some of his writings have been published in English in Tom Bottomore, Austro-Marxism. During the 1970s there was a revival of interest in Max Adler and his colleagues because they were neither Bolsheviks or traditional Social Democrats, representing a kind of "third way." By the way, the anecdotes about the Austro-Marxists in Leon Trotsky's memoirs are devastating but also humorous. He recalled that their academic standing took precedence over their revolutionary ideology, and that they addressed each other as "Comrade Herr Doktor."

During the ugly McCarthy or "Red Scare" period of American politics during the 1950s, it also would have been troublesome if authorities made a connection between Robert Adler and his Marxist father. One can only imagine that it took much courage and a strong sense of justice for Robert Adler to write to the FBI during that period in defense of a colleague falsely accused of being a disloyal "communist". The U.S. Memorial Holocaust Museum continues to use state-of-the-art touchscreen-based interactive exhibits to remotely internet access.

A great sense of mutual respect between all levels of the organization was a hallmark of the R&D corporate culture under Robert Adler's leadership. Personal communication, John Pederson, former Zenith Director of Patents and former Zenith VP Consumer Affairs.

Alan Sobel, personal communication.

Adler chose to be known as "Bob" rather than "Rob" or "Robert" in part because his pronunciation with an Austrian accent of the letter "R" was often not understood by American ears. Robert Adler, personal communication.

Erwin M. Roschke, who worked both with and for Robert Adler in a management role, observes that “Even as a VP, Bob’s door was open to anyone with any problem, and people leaving his office were always happier when they left his office. I never had a boss that was more considerate.”

Robert Adler, personal communication.


Behzah Razavi, personal communications. An e-mail from him notes “An oscillator sensing an external stimulus can be pulled by or locked to the stimulus. Adler analyzed this effect for the first time and derived an equation that, despite the approximations made by Adler, has found widespread use even if Adler's assumptions do not quite hold. The problem of oscillator pulling has become more pronounced in highly-integrated wireless and wireline transceivers and hence Adler's equation has reappeared in the literature after decades.”

This paper does not cover the full breath of Robert Adler’s inventiveness. Outside the scope of this paper are Robert Adler’s inventions that made use of lasers, inventions (while working at Extel) related to printers, display related inventions, inventions related to video disk technology and inventions in other diverse fields.

For readers unfamiliar with the terms “Rayleigh waves” and “Love waves”, here is a brief description. Qualitatively, if not quantitatively, Rayleigh waves that detect touches in current commercial SAW touchscreens may be visualized as miniature ocean waves in glass rather than sea water and with a wavelength less than one millimeter. Like a seagull on the ocean, an atom of the touchscreen glass surface bobs up and down as well as moving horizontally back and forth in the direction of wave propagation. In contrast, for a Love wave (which only exists in layered structures), the glass surface remains completely flat and an atom at the glass surface moves horizontally back and forth perpendicular to the direction of wave propagation.


While technically more original than the subject matter of many patents, this invention was never patented. No mass market was identified to justify legal expenses.

Robert Adler et al., “Experiments with Love Waves on Layered Glass”, talk 3F-2 of the 2000 IEEE Ultrasonics Symposium (Puerto Rico). This was Robert Adler’s last IEEE Ultrasonics Symposium talk for which he was the presenting speaker.

Paulo Irulegui Gomes led the successful effort to built a Love-wave touchscreen and recalls his work with Robert Adler in the following comments: “Bob was always the youngest in spirit in the lab. Curious and unassuming, we could feel his pleasure in working on problems. Extremely sharp and quick, his intuition was always a step ahead of the equipment. It was always a pleasure to interact with him when he was around in the lab or at meetings.”


For an interesting alternate approach to narrow-border SAW touchscreen design, particularly for small handheld devices, see F. Katsumi et al., “A Compact and High Optical Transmission SAW Touch Screen with ZNO Thin-film Piezoelectric Transducers”, talk 5H-5 of the 2003 IEEE Ultrasonics Symposium (Honolulu).