March 25, 2015

Is Heyser Still Relevant?

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Introduction and Background

Writing about Dick Heyser presents some interesting challenges. To those who knew him, my comments will likely not do him justice. For those who did not have the privilege of knowing Dick or are unfamiliar with his work, my comments will likely be taken as hyperbole.

Richard C Heyser was born in the Chicago area in 1931. He earned a BSEE from Arizona State in 1953 and a MSEE from CAL TECH in 1954. Heyser then joined Jet Propulsion Laboratory (JPL) where he worked on a variety of projects in the space program until his untimely death after a brief battle with cancer in 1987.

At JPL, Heyser was a very brilliant man working alongside very brilliant men. One of his colleagues at JPL wrote in memory of Heyser "On a personal note, Dick was a Renaissance man in my eyes. He was a boy genius until the day he died. He questioned everything, had to understand everything, and knew so much about everything. He delighted all who surrounded him with his ingeniousness, his ingenuity, his kindness, and his modesty….Richard Heyser questioned everything and answered many of the questions that we mere mortals didn't have the sense to ask in the first place."[1]

The space program was his vocation. You might say that at JPL Heyser was a good sized fish in a large pond. When you are working at that level it is hard to rise above the mean. Heyser's *passion* however, was audio, and it was in audio that Heyser demonstrated his true genius and rose way above the mean. As is so often the case, when passion is the motivating force, true genius emerges. From what we can tell, Heyser's original impetus came from the work of Noble Laureate Dennis Gabor the inventor of Holography. Dick studied carefully Gabor's 1945 paper "The Theory of Communication" and a subsequent paper entitled "Communication Theory and Physics " published in 1953. In this paper Gabor pointed out that that vision, was one of the most important paths of communication, and is based essentially on quantum affects. Heyser often remarked that he was trying to bring audio into the

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[1] JAES Vol 35, #5 Heyser's' Obituary A quote from Manny Tward a physicist at JPL 1987

quantum age.[2] Heyser was fascinated with the discrepancy between the subjective and objective parts of audio. He loved to point out that we measure what we measure because we know how to - not necessarily because it is important. For Heyser, the ultimate goal was to be able to correlate measurement with listening, to be able to measure what we hear and hear what we measure. The first step then was to invent a completely new and revolutionary measurement platform. In 1967 Heyser submitted a paper to the Audio Engineering Society entitled Acoustical Measurements by Time Delay Spectrometry[3]

In his own words,

> " I was led to the development of time delay spectrometry (TDS) through my personal interest in the listening experience. Quite simply, I could hear distortion in audio amplifiers which I could not measure. My measuring apparatus for audio amplifiers was, at that time much bette than any that could be found in the better laboratories; yet I could find no unique relation between the distortion that I measured and that which I heard coming from these same devices. Since I was listening to the distortion through a loudspeaker in a room, I needed to understand what the loudspeaker was doing to the signal. I wanted to measure the free field response of the loudspeaker while that loudspeaker was in an otherwise reverberant environment.
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> The FFT had yet to be invented, and when one spoke of the "frequency response" of a loudspeaker it was understood to be the amount of amplitude of sound pressure produced by a signal drive voltage. Phase was not even considered a parameter in loudspeaker response.
>
> With no access to a reflection free measuring environment, I turned to my own expertise in signal processing. Since I wanted to measure the direct sound and reject later sounds which came from boundary reflections in the room, I chose to drive the loudspeaker with a test signal, that in effect, placed a time tag on each frequency component. Routing the microphone signal through filters which passed only those sounds having the desired time delay (from loudspeaker to measuring microphone) I felt that I should be able to measure both the frequency domain and the time domain spectra of sounds having the chosen time delay. Because of this characterization, I called this process time delay spectrometry..."[4]

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[2] From Don Davis, private correspondence with author
Don Davis along with his wife Carolyn founded Synergetic Audio Concepts, (Syn-AuD-Con) a continuing education organization which has had an enormous impact on professional sound. Syn-Aud-Con was largely responsible for introducing Dick Heyser to the professional audio community

[3] JAES 1967

[4] The Richard C. Heyser Collection, Box 3, Folder 14, Columbia College Archives, Chicago Il 60605

When Heyser submitted his manuscript to the Audio Engineering society it was met with a fair amount of skepticism. The professional and academic Audio community of the time was still trying to come to grips with the Fourier transform and Heyser's ideas were seen to be " too esoteric" and of little practical value. Years later Heyser was to discover that there was one anonymous peer reviewer who championed the original TDS paper and the two that followed it. Without the support of this anonymous reviewer it is likely that the papers would not have been published. The anonymous reviewer was the late Dr. Harry F. Olson of RCA fame. Heyser talks about this in an introduction to a paper on TDS written in the 1980s shortly after Olson's death.

> "At the very outset, I want to express my personal debt of gratitude to a great man and to dedicate this work to his memory. I discovered, many years after the fact, that my first paper on TDS might never have been published had not an anonymous reviewer interceded and recommend it be published without any alterations. This same person also requested to be the reviewer on any subsequent manuscripts which I might submit on this subject. My original version of the second TDS paper, on phase and time delay distortion, had three appendices. The anonymous reviewer again recommended publication, but requested that I expand my Appendix C into a full length paper, and that the set be published as the first—ever two part Journal paper. (This is the reason for the cryptic comment in Reference 26 of the first part of the 1969 paper). That anonymous reviewer was Dr. Harry F. Olson."[5]

Years later Heyser confided in Don Davis that he had learned that Dr. Olson had retrieved Heyser's paper form the wastebasket at the New York Audio Engineering Society Headquarters ![6] Heyser held Dr. Olson in such high esteem that he wrote the following:

" A Recommendation on Intensity Units

If we go back through all the literature on energy flow, back to the single pioneer who started it all, we discover that this pioneer, Dr. Harry F. Olson was contemplating a dynamic sound measurement. I can think of no better way to honor this pioneer, the person without whom the first paper on TDS, and subsequent publications which uncovered the new paradigm might otherwise not exist, than to recommend that the units of sound intensity be expressed in Olsons."

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[5] The Richard C. Heyser Collection, Box 3, Folder 14, Columbia College Archives, Chicago Il 60605

[6] From Don Davis, private correspondence with the Author

Heyser then goes on to describe the technical definition of the Olson. He closes this brief paper by saying " We can thus honor the man who started it all"[7]

Heyser's papers were published and received some attention but it wasn't until the mid 1970s when Cecil Cable a Canadian acoustical consultant read the original 1969 paper and decided to try to build a functional time delay spectrometer. At the time, Cable was loosely affiliated with Don Davis and the newly formed Synergetic Audio Concepts, an organization dedicated to providing training in the fundamentals of sound reinforcement. With Heyser's help, Cable assembled an analyzer and began making measurements of loudspeakers in rooms. Davis saw the value in disseminating this technology to a wider audience and in 1978 Davis convened the first TDS workshop. The 20 attendees were given training in the theory of TDS by Heyser, and were granted a license from Caltech[8] to build and operate a time delay spectrometer. A good number of the original 20 scraped together the $30,000 or so to assemble the off the shelf components connected together with a custom built "Heyser box" to perform TDS. The result was exactly what Davis wanted, a powerful analyzer in the hands of folks who were out in the industry doing things rather then in the ivory tower of Academe. In the early 1980s Caltech signed an agreement with Crown to build a purpose built TDS analyzer. The TEF 10 was introduced at around $12,000. Now the technology was available to even more users. By now Heyser was a minor celebrity in the audio circles because of TDS and because of his writing for the popular Audio Magazine. He continued to publish articles in the journal of the AES and in other refereed journals publishing over 30 papers by the time of his death in 1987. He was elected President of the AES in 1986. He died as President Elect before he could assume office. In 1988 The Audio Engineering Society published an anthology of Heyser's work, which to date is the only AES anthology comprised of the work of a single individual. Heyser was very popular in circles where Syn-Aud-Con had influence, but less so in the traditional academic circles. It is beyond the scope of this paper to explore the reasons for his chilly reception but it is insightful to read the letters to the editor and Heyser's replies through the 1980s which are all published in the Anthology.

A Case for Relevancy

I believe that I could present a strong case supporting the notion that Heyser's work is still relevant. However it is far more compelling in my view to let his own words speak for themselves. I have decided to let Heyser make his own case by using excerpts from his writings all of which may be found and examined in the Heyser Archives at Columbia College Chicago.

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[7] The Richard C. Heyser Collection, Box 3, Folder 7a, Columbia College Archives, Chicago Il 60605

[8] California Institute of Technology operated Jet Propulsion Labs where Heyser worked, therefore Caltech owned the patent on TDS.

From a draft for the last paper he wrote, published posthumously:

> "Perhaps more than any other discipline, audio engineering involves not only purely objective characterization but also subjective interpretations. It is the listening experience, that personal and most private sensation, which is the intended result of our labors in audio engineering. No technical measurement, however glorified with mathematics, can escape that fact. But we must not assume, because our present mathematics may not seem to contain the essence of experience, that the sensation of sound must always lie beyond comprehension. We hear. We listen. We enjoy. But what do we hear?
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> Our industry is based on a commonly shared illusion. A magician's act in which the sound from two or more separated loudspeaker systems is fused into an illusion of continuous three dimensional reality; of being there. We all share this illusion to one extent or another. If we did not, then no audio mixer could ever hope to produce a product of economic value. But what is it that we hear? How do we measure an illusion? How do we put numbers on it and explain its properties in terms that others may know?"
>
> And, perhaps more important, how do we make it better?"[9]

From another draft of the same paper;

> "But we must never assume because our present mathematics may not seem to contain the essence of experience, that the sensation of sound may always lie beyond our comprehension. I contend that any discrepancy between subjective and objective descriptions lies with our present mathematics. It is not that the mathematics is wrong; the mathematics is right, but it is incomplete.This is a startling declaration which demands justification. I intend to demonstrate this fact by presenting a more complete development of the principles of time delay spectrometry, which requires that we go beyond present analysis structure. It is a new approach requiring new tools. The development of a mathematical structure, whether of audio engineering or of any science, is often guided by our perceived sensations. We tend to model in the manner we see, touch and hear the world about us. We use our personal frame of reference to model nature. Often, it is the best mathematical

[9]The Richard C. Heyser Collection, Box 3, Folder 14, Columbia College Archives, Chicago Il 60605

model is that which "makes sense", in the literal meaning of the term.[10]"

"Modern technologists usually avoid considering the philosophical basis of their own work; perhaps under the assumption that everything is all tidy in the basement and that one should "get on with it" to obtain results. Well, everything is not all tidy in the basement, as can be readily discerned in the conceptual arguments that still rage about fundamental science. Nor should we forget that much of our interpretation of the world about us is based on common human sense perceptions of that world, our "common sense" interpretations. An excursion into the basement can prove most illuminating to those of us who are principally oriented toward technology. Such an excursion is warranted in audio engineering; it is directly meaningful to the problem of delivering an end product which is the listening experience, and, as we will see, it is not only audio engineering, but all of science, which can benefit from such an excursion."[11]

From a hand written excerpt of a draft for a presentation:

"Lorentz freely admitted that although all the paraphernalia of the Theory of Relativity existed before Einstein (constancy of light, Lorentz Contraction, relativity of motion), Einstein is the true innovator because he challenged something that every one, including Lorentz, believed to be so perfectly obvious as not to be questioned at all. Einstein questioned the concept that events can be simultaneous… that was the spark of genius. The rest is history. Einstein was correct, 'common sense' was wrong. Do not draw theories from observations; draw observations from theories. If the theory is wrong, the observation will fail. It is failure to do this that has got audio tied up in conceptual knots; open the mind, question dogma."[12]

From a published paper entitled " A View Through Different Windows"

"There have been many science fiction stories with plots involving worlds of differing dimensionality. My favorite among these is a perennial science fiction

[10] The Richard C. Heyser Collection, Box 3, Folder 14, Columbia College Archives, Chicago Il 60605

[11] The Richard C. Heyser Collection, Box 3, Folder 14, Columbia College Archives, Chicago Il 60605

[12] The Richard C. Heyser Collection, Box 6, Folder 29, Columbia College Archives, Chicago Il 60605

classic called,"Flatland, A Romance of Many Dimensions. Written in1884 by E. A. Abbott, a schoolmaster, it is still available, in its seventh edition in paperback. What does that have to do with audio? Well. if you know the story, and accept some of the concepts I am about to present, you might come to agree with me that we now live in an audio flatland."[13]

From an unpublished paper titled "The Great Pretender" written in 1979

One does not have to be a chemist in order to be a good cook. A simple book of recipes is sufficient. So too in the sciences there are those who depend upon cookbook recipes to get results. But the scientific recipes take the form of equations and methods of using rules to get answers. It is regrettable that in the haste to get rules which seem to work we often abandon any attempt to understand their inner meaning or to determine what limitations we should impose on their use. Before the days of large scale machine computers we could seldom extend our calculations beyond the simple domains where the rules worked. Our expanding technology has now given the cookbook scientist the opportunity to make large mistakes very rapidly….. The mistake I want to prevent audio people from making is tied to a concept which I personally think of as the Great Pretender….. The name of the Great Pretender is group delay. What it pretends to be is the value of time delay for each frequency component of a signal passing through any system which has a transfer characteristic that changes with frequency. [14]

Finally an excerpt from an unpublished work entitled " The Two Parts of Energy"

"…..Therefore, total energy density must always have at least two parts. One of these parts can be called kinetic energy density and the other part can be called potential energy density. These parts are not only uniquely related to each other, but when we add up all the components we will find that the magnitude of kinetic energy will be equal to the magnitude of potential energy. which means that, when summed up, total energy is split down the middle. In my opinion, this is a startling fact, because nowhere in this analysis did we impose any restriction on the frame of reference in which the energy is to be expressed. It is a relationship at the primal structural level and finds expression in any coordinate system we use to describe a signal.

This has several implications for audio analysis. First, since the time domain is an alternative to the frequency domain, the time domain response must

[13] Audio Magazine, Diamonds Communications 1988, A View Through Different Windows Richard C Heyser

[14] The Richard C. Heyser Collection, Box 5, Folder 31, Columbia College Archives, Chicago Il 60605 From "The Great Pretender"

be considered a complex quantity just as we talk about frequency domain response as a complex quantity with magnitude and phase."[15]

Conclusion

In letting Heyser speak for himself in these brief excerpts I have tried to show the depth and breadth of Heyser's interests and analytical abilities. I have purposely chosen comments from the Archives, both published and unpublished which should be at least intriguing and possibly down right shocking. Heyser had much more to share with us, some of which can be found by spending time with the archives at Columbia College Chicago. In the twenty seven years years since Heyser's untimely passing it seems to me that the audio community has become fixated with the world that digital audio has made possible. We can now store, transmit and process audio in ways which Heyser could scarcely have imagined. Yet with all of the advances since his passing, many of the questions he posed in his writings remain unanswered. What is more distressing, few seem to be following the lines of investigation that Heyser set forth. We still measure the things we measured 27 years ago. Heyser used to love to say that he could measure an unknown signal with every available analyzer made at the time, but could not tell whether it was speech, music or gibberish. But, he could play that signal over a two dollar loudspeaker and clearly identify what the signal was. We still do not have a good map between the objective and subjective. TDS has fallen out of favor, not because it is an inferior technology, but because it has no contemporary champion. When asked if Heyser's work is still relevant today, Don Davis replied, "The relevance of Dick's work is obvious to me in his statement 'it gives me a certain pain to give away in 10 minutes what took 10 years to put together'. Those of us who heard him say it came to realize that it took us 10 years to understand what he had said in 10 minutes! No one in the field of communication has ever wasted a moment studying the work of Heyser, Gabor, and Ville." [16]

It is my fervent wish that some young investigator equipped with the double edged sword of reason and curiosity will take up Heyser's work and move audio science out of the flatland that it currently inhabits. This is the reason that the Heyser Archives exists.

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[15] The Richard C. Heyser Collection, Box 5, Folder 32, Columbia College Archives, Chicago Il 60605 From "The Two Parts of Energy"

[16] Don Davis, Private Correspondence