> The sensation of sound is a thing _sui generis_, not comparable with any of our other sensations. No one can express the relation between a sound and a colour or a smell. Directly or indirectly, all questions connected with this subject must come for decision to the ear, as the organ of hearing: and from it there can be no appeal. But we are not therefore to infer that all acoustical investigations are conducted with the unassisted ear. When once we have discovered the physical phenomena which constitute the foundation of sound, our explorations are in great measure transferred to another field lying within the dominion of the principles of Mechanics. Important laws are in this way arrived at, to which the sensations of the ear cannot but conform.
>
> Lord Rayleigh, _The Theory of Sound_ 1877

These words were written almost a hundred years ago, just before the dawn of what has been called euphemistically The New Physics, and at a time when nothing was believed completely understood until it had been reduced to the level of a mechanism. This was the first paragraph in what was to become the greatest single work in acoustics. It is still a basic reference.

Today much of audio is still mechanism oriented in its thinking. Our blueprints to understanding this mechanism are composed of meters, oscilloscopes, graphs, mathematics, and inferences based on the way physical objects react. The mechanistic view is so deeply engrained that there are many who never question the accuracy of the pieces of the blueprint for evaluating how well the complete audio system does its job.

I am one of those who has been placing a burr under the saddle of complacency by questing the primacy of the simple measurements we are now making to evaluate audio systems. My role is not that of a spoiler, however. I believe that we can best improve audio by first understanding what it is.

I would like to share with you some results of one aspect of recent

research into understanding audio. Some of it is pretty far out, while some of it is so obvious when stated that the normal reaction is, "of course, what else could it be". The technical jargon is covered in the Journal of the Audio Engineering Society. In this summary of some of that work I will use a much more colloquial vehicle because I am trying to describe audio in the same terms as we usually think of it.

One precaution before we start. This work is not the result of ex cathedra dictum. It is a look at research in progress and the final chapter will never be written. Its timeliness to understanding subjective sound can be stated simply as: it's where it's at today.

" The sensation of sound is a thing sui generis, not comparable with any other sensations. No one can express the relation between a sound and a colour or a smell. Directly or indirectly, all questions connected with this subject must come for decision to the ear, as the organ of hearing; and from it there can be no appeal" LORD RAYLEIGH, THE THEORY OF SOUND, 1877

SOUND AS SHE ARE HEARD

As aperson who listens with ~~his~~ your ears have you ever wondered about the value of measurements when describing the sound of audio systems? If so, you are not alone. The plain fact is that what we measure doesn't always correlate well with what we hear. Very few subjects in audio have caused more arguments than that observation.

Unfortunately that's usually what it boils down to - an argument. No matter which end you go after it, either from the mathematics of sound or from listening jury tests, coming to grips with explaining this fact is like trying to grab a greased pig and hold on. Add to this the fact that personal emotions become involved and you can understand the reluctance of professional audio people opening their mouth about the merits of either view. This has resulted in a situation similar to a standoff between armies who have fought each other so often to a draw that they go their separate ways ignoring the presence of each other. However, woe be to him who enters the battleground without knowledge of either army and makes flat unequivocal statements. Both are then liable to jump him and tear him to shreds. In other words, there is a high professional RISK OF LOOKING FOOLISH ~~foolishness factor risk~~ associated with entering the fray.

What I would like to describe is some high points of MY OWN recent research into this subject of measuring and listening. I believe the person who listens to sound with his ears will find points of value in such a discussion.

Both armies are poised ready to strike. OK, which one will I champion. Surprise, they're both correct.

No, this isn't a cop out, but a result of analysis which has been published. An overall statement is that the measurement is correct but it isn't measuring what people hear (Jeers and boos and cries of," go home, we know that!" from both armies). Wait fellas, hear me out. This isn't opinion, but comes from an analytical look at audio processing.

MONA LISA ON A STRING

In order to try to illustrate what I am saying, let me use an analogy in the form of a "gedanken" "THOUGHT" experiment. Mathematically it is possible to take a two dimensional object, like a painting, and cleverly transform it into a one dimensional form. Suppose I had found a way to code the Mona Lisa and have it presented on a string. It's all there, and you can transform this string back into the original painting with absolutely no loss of detail.

I hand you this string which I state is the Mona Lisa. Before you can react, I hand you another string which I say is Gainsborough's Blue Boy and ask your opinion on the genius of ~~Michelangelo~~ DA VINCI versus Gainsborough and which was a better master of color and detail.

As far as you are concerned these are NOTHING MORE THAN two weird looking pieces of string. Even if you accept on face value that I wasn't a candidate for

the funny farm, you couldn't possibly even identify what these were, let alone pass judgement on nuances of detail. All the information is there, but it is not in a form you can recognize. It isn't until I transform these one dimensional strings into two dimensional ~~forms~~ PAINTINGS that you suddenly identify what they are.

CONTINUING, If I were now to transform this two dimensional form which you recognize into a three dimensional blob, you would again find it meaningless. THE ONLY THING THAT MAKES SENSE AS A PAINTING IS AN OBJECT WITH THE PROPER NUMBER OF DIMENSIONS

OK, now suppose I hand you a plot of the ACOUSTIC impulse response of Carnegie Hall from stage center to some selected seat and ask you to look at it. I then hand you a plot of the impulse response taken in Lincoln Center and ask you which hall has better acoustics for a vocalist standing at that spot on each stage. I don't think you could tell me. I could have used the steady state frequency response rather than the impulse response, but the results would be the same because this is <u>one dimensional data</u>. It is sound pressure as a function of position on the time axis (or on the frequency axis) of the piece of paper. It is Carnegie Hall presented to you on a string and, just as in the case of the Mona Lisa, doesn't have any meaning to you even though all the data is there. → (B)

You see, what we are talking about here is the form of the presentation. I'm asking you to think in terms of a type of geometry of sound.

Now, let's go back and see how we arrived at this wild way of thinking about sound.

Imagine, if you will, that there are two viewpoints on the analysis of audio. This is symbolized in figure 1. One viewpoint is the subjective approach (don't bother me with numbers, how does it sound?). The second viewpoint is the objective approach (If you "golden ears" are hearing something, it doesn't belong to the laws of physics). The Assumption was made that somehow both had merit but that it just doesn't work trying to force one viewpoint into the other. Instead, another approach was taken. The objective viewpoint was temporarily set aside and a closer look was taken of the subjective way of life.

This required doing something that is so repugnant to the objective person who uses mathematics that it hadn't apparently been tried before. However, it demands a mathematical look at the subjective view which appears quite contrary to what is under trial. The assumption is made that if two or more people can "hear" something and independently describe it to someone else, then what they hear exists even if objective mathematics of the type we normally use doesn't show anything.

Taking that assumption further the question was asked, " how does a subjective person describe what he hears - what words does he use?". The reason for this is that if what he is describing is real (at least to the way we hear and perceive), then if he can meaningfully communicate these impressions to others he has a useful language. Just possibly we can use this language to come up with a (horrors!) objective description of what he hears. And that's exactly what was done.

The details are in the JAES, but quite simply what was found was that when we describe a sound, or a distortion to a sound, we use more then

LISTENING INVOLVES MULTIPLE DIMENSIONS

one coordinate of description. The words we use are descriptions involving certain independent types of things. How loud a sound is doesn't imply the direction it comes from. The loudness and direction are separate attributes which we must independently specify when we describe a sound. If we are going to talk about the pitch of a natural sound we don't have to use words relating to direction.

That seems pretty obvious. The next step in this procedure, after sifting out a number of coordinates, was to thumb back through some of the pages of mathematics and see if there is some type of analysis that could be applied to the subjective view. The present mathematics clearly didn't work because the descriptions are one dimensional and we want to describe sounds in many dimensions. A topology of processing offered the solution. This meant we could conceptualize the experience of subjective sound as a type of geometry where the form of things is what we describe.

That's well and good, but what about the objective viewpoint with its mathematics which we left out in center field when we began this analysis. Must it always remain a thing to itself? The answer, surprisingly, is no. Because when we look at the present objective analysis through the eyes of our topology we find that the objective analysis is actually a part of what we came up with. Now we can look at the impulse and steady state frequency response of objective analysis and say that this is like our presentation of Mona Lisa on a string. All the information is there and it is correct but it is simply not in a form which has any meaning to the subjective listener.