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CHAPTER 5

INTRODUCTION

This discussion might be subtitled "A funny thing happened on the way to an answer". Because, in applying the formalism of this new paradigm, which was developed from considerations of subjective perception, it became apparent that the answer to another perception-based science was beginning to emergy. That science is quantum mechanics.

Put down your baseball bat and listen. Carefully reading the philosophical quandaries of quantum theory, with its Shroedinger's Cat and Wigner's Friend paradoxes to name only a few, it is not unreasonable to infer that the fuss concerns the distinction between reality and perceived reality. If you think that nontechnical subjective audio represents a never-never land, try to understand the Copenhagen Interpretation. All the fine math to the contrary, the physics seems based on magic, if you accept that magic is the intervention of some agent not included within your purview.

But perhaps we don't need to resort to magic for physics, any more than we need to resort to magic for subjective perception.

In the previous discussion, we saw that the new paradigm scores rather well in predicting the distinction between the procedures of map and operator; a distinction that is not foreseen in the contemporary paradigm. However, in my opinion, a more significant prediction of this new paradigm relates to the failure of certain types of operator to commute.

This failure to commute lies at the heart of modern physics, and, although the reason why such noncommutation should exist is extremely important for an understanding of the basis of such physics, no GENERAL answer has been discovered, although many people have really tried to solve the problem. In this discussion I'm going to defer a formal proof using the new paradigm, and present a thumbnail history of why this problem is so very important. We're going to be discussing something that, at first glance, may seem to have nothing to do with audio. Actually, it has a great deal to do with the raison d'etre of this whole subject:reconciling subjective perception with objective analysis.

A HISTORY

Classic physics, as a way of "explaining" nature, was dealt a death blow at the turn of this century when it was shown that a discontinuous, rather than continuous, description was a more accurate characterization of some aspects of nature. Tiny jumps, called quanta, could better explain nature than smooth flows, in many cases.

(Incidentally, one of my pet peeves, which was first pointed out to me by a colleague, Dr. James Rooney, is the ad writer who proudly announces his new product as representing a "quantum leap". Doesn't he know that what he just said was that his product represented the LEAST possible advance? Then again, maybe that's what he subconsciously meant to say.)

At first, there was an "old" quantum physics, which explained things in terms of quanta, but still held to certain classic concepts and, as yet unexplained, "rules" of why things did what they did. After the First World War this gave way to a "new" quantum physics, spearheaded by younger scientists eagerly unraveling the mysteries with new tools. No holds were barred and nothing was sacred.

It was soon discovered that a most remarkable relationship existed between two entities, whose classic counterparts were called "position" and "momentum". This relationship came out of the matrix mathematics which was developed by a young genius named Werner Heisenberg. It also was found in other approaches, such as that of a wave mechanics in which the entities, to be called "position" and "momentum" were represented as operators. The relationship was this: position and momentum did not commute.

The matrix math of Heisenberg is technically accurate in its ability to handle quantum mechanics. But it has one flaw. It's like a monster sausage machine: you know what you put in, and you know what comes out if you turn the crank properly, but you haven't the foggiest idea of what's going on inside. So in order to see what might be going on "inside", which gave this noncommutation, Heisenberg turned to the new wave mechanics of the Dirac-Jordan transformation theory.

Now, a most bizarre twist. The wave equation which Heisenberg used, and which has been the basis for most analysis ever since, is nothing more than our old friend, the Fourier transform.

At this point I'm going to ask you to think as audio people. When I use the word "position", you mentally replace it with the word "time". And when I use the word "momentum", you mentally replace it with the word "frequency". Also, I want you to do something else. Haul out the first AUDIO article in this series and open to page ( ) so that you have the multi-dimensional Fourier transform, equation 5, in front of you. Now, let's go back to the thumbnail history of quantum mechanics and the noncommutation relationship.

The equation that Heisenberg was confronted with looked like relation (19). The letter p stands for momentum, the letter q stands for position, and the letter h stands for a fixed number called Planck's constant. The purpose of h is to make the numbers and units come out right. Remember that position is expressed in units of length, whose unit value was established in classic physics. Similarly, momentum is expressed in units which are also derived from classic physics. If you look back at our first article, you will recognize that the "upstairs" part of the exponential that lies inside the integral is an "angle" that appears as a hyperplane. Therefore, since an angle is unitless, the term p times q divided by h must have no units of expression. There is an old classic physics relationship, known as Hamilton's equations, which tell us what the units of h need to be in order to make the "angle" unitless. Planck's constant must itself have the units of energy times time, or erg-sec.

(No, that's not the way the students of quantum theory is presented with Planck's constant. What I'm doing is showing you another interpretation which can be placed on Planck's constant. In my interpretation you never make the mistake of yearning for some way of causing the constant to be zero so that the uncertainty relation will go away and nature will be causal and predictable.)

In order to be completely analogous with our audio equations, if "position" corresponds to "time", then "momentum divided by h" must correspond to "frequency". Thus if "q" is in length, then "p/h" is in per-length, much as "t" is time and "f" is per-time. So now we've cast the quantum mechanics problem into conventional audio mathematics. Heisenberg wanted to solve this equation, using something whose form he could understand. It's no different than you or I approaching this audio equation and wanting to find something you could put into the right hand side an know what the answer was on the left hand side. So he used a Gaussian.

Now, the Gaussian has a very nice property. The Fourier transform of a Gaussian is also a Gaussian. That's not the only self-reciprocal function under the Fourier transform, but it is perhaps the easiest to handle. The Gaussian looks like a resonance, with most of the activity clustered symmetrically around one place, and things quickly falling off away from that place. Heisenberg wanted to cluster most of the activity around a single value of position, as a function of momentum, and determine what resulted.

He got a big surprise, that really should be no surprise. The equation maps an expression from a position frame of reference to a momentum frame of reference. Position and momentum, like time and frequency, are alternatives under the Fourier transform. The governing map uses a hyperplane, expressed in terms of the source and destination frames of reference. What Heisenberg found was that the narrower the spread of the Gaussian became in the position domain, the broader the spread of the alternative Gaussian in the momentum domain.

SOLVING A PROBLEM

This really bothered Heisenberg. It seemed to imply that just about the time you know where something was in position, it "fuzzed" out in terms of momentum, and vice versa. But, in classic physics, you could know exactly where something was in position and also know exactly what momentum it had at that place. Position and momentum were, what was called, canonically conjugate entities, and that's all you really needed to know about something in order to describe its dynamics properly (assuming the system which it described was conservative). Now, this newfangled science seemed to say that you couldn't know both of them with unlimited precision.

Does that sound a little familiar in audio, particularly if we use the terms "time" and "frequency"? Isn't there a subjective impression of a sound experience that consists of codeterminable attributes which we can call "pitch'' "moment of time". And doesn't it seem a little mysterious that when we try to pin down the instant at which a tone appears, we can say nothing about its frequency, and vice versa.

Heisenberg, at that time, was a younger scientist studying in Copenhagen under that grand old man of quantum theory, Neils Bohr. Prior to this, Bohr had become fascinated with a concept which he called complementarily. Things seemed to be related in twos such that both were required for completeness, and hence complemented each other, yet each seemed to stand alone in what it related to. I know that's a poor description, but it seems to be the essence of Bohr's concept. Young Heisenberg's discovery fit this concept quite well, and, in my opinion, because of this, caused a course of action to be taken which resulted in a modern tragedy of science.

SOLVING A DILEMMA

Heisenberg and Bohr became convinced that the reason why position and momentum could not be precisely codetermined was because the observer must ultimately disturb that which was under observation. In audio terms, the reason why you cannot know the precise value of frequency of a signal at a moment in time is because your instrument (or you) must disturb the signal in some inescapable way. Even in principle, you could not perform a disturbanceless experiment. There was a basic indeterminacy; a principle of uncertainty, as it came to be called.

Because of complementarily, from the moment that the Fourier transform was used, the results of that transform were carried forward in argumentative form. Nobody looked back to ask what the meaning was of the transform itself, or what you really were implying when you used the transform.

The heart of the matter seemed to be some sort of relationship between canonically conjugate variables that showed up as a noncommuting of the operators representing those variables, and which was manifest as an undeterminacy through the Fourier transform. For a long time, analysts tried to find out what underlying property dictated that operators should or should not commute. But only those limited properties of quantum mechanics seemed to yield any demonstratable results.

In my opinion there were two assumptions which eventually led to all the fuss. The first assumption was that the position and momentum of quantum mechanics were the same things as the position and momentum of classic physics; that, somehow, the microscopic examination of quantum phyics disclosed a strange behavior in the details of those classic entities. The second assumption was that the basic indeterminacy in a codescription of position and momentum was due to a law of nature that was called into being whenever you tried to observe (or even know) what was going on. In audio terms, we generally assume that time and frequency mean the same thing in objective analysis as moment and tonal basis in subjective perception. The inevitable consequence of these two assumptions is startling: there is no ultimate certainty, only probability. Not even the deterministic equations of relativity can reflect "reality".

You can imagine the furor which this caused. That other grand old man of science, Albert Einstein, was dragged into the argument, since it was felt by some that if there was something wrong with this theory, then Einstein could find the holes. Einstein couldn't find anything wrong. At first he tried to find counter examples to the indeterminacy. Then he tried to suggest that it was a result of some essential incompleteness in the theory; something must be left out. One by one, the challenges to uncertainty were turned aside.

Thus, what started out as a search to try and understand what it means when two procedures do not commute, led to a dilemma of devastating proportions. Einstein's famous statement that "God does not play dice" is an anguished response to that dilemma.

In the next article, we shall demonstrate the second prediction of the new paradigm, and discuss what it may mean when two operators fail to commute.

END OF CHAPTER 5