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ENGINEERING AND SUBJECTIVE ASPECTS OF THE BINAURAL MEDIUM

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In about 1924 somebody started practising what was then engineering witchcraft involving two channels. We can well imagine that in his mind at that moment was the image of the two-eared mammal. They were two ears with a fixed spacing, -- fixed because of course he was not interested in producing binauralism for mice or for elephants, but for himself. Nobody had invented a decent loudspeaker. Everybody wore earphones in those days and the original premise was right. But it was also premature by nearly 30 years.

Today we are not operating a precious, easy and discreet system of 6" microphones into 6" earphones. Does this mean that the whole two-channel system is false? False because nobody can find a name for it? Perhaps we should go to three channels to appease the dissenters and extremists, but then we shall put dimensional sound out of reach of the pocketbook. Today, in the light of long-playing records, multiplex broadcasting, tape and mass-produced low-priced equipment, everybody can afford binaural, -- from the cost standpoint. No indeed. Having once learned about and understood a simple two-channel system based on earphones, we must now move on to practical and useful binaural systems, even though the premises on which they operate are all together different in conception.

In every new engineering development, it seems we have to guard against making of it a form of religion. Binaural is a potentially useful and wonderful medium, and we must now reject the binaural dogma of 20 and 30 years ago because it no longer applies today. But these days the entertainment market is well supplied with alternatives. If you don't like TV, there are 3-D pictures. If you don't care for radio, there are phonograph records. And if the binaural medium is to serve its function in exciting listeners and growing into a mass medium, -- perhaps even into an art form, -- it cannot afford to learn by experience alone, it cannot blunder, for in this way it will have lost its market. Its listeners will have rejected it in favor of one of the many alternatives.

In binaural today as reproduced through loudspeakers let us see what it is that we can do or want to do. What premises can we act upon? Right away it becomes a transporting medium, a number one magic carpet. If, for instance, we want to wave the cloak and make to appear in the living room a quartet or small ensemble, or a dialogue of voices, we will place the microphones 6 - 15' apart in an acoustically dead originating studio, and work fairly close to the microphones.

The violins will be on the right, viola and cello on the left. They will be right in the room, with the listener the moment he closes his eyes, because there are no acoustics in the originating studio, no reverberation pattern except that of the playback room. The close microphone technic in a two-channel system brings the artists to the living room in the flesh. It is a simple and easily executed premise -- premise # 1.

Premise # 2, the second magic carpet is not so easy to climb onto and ride, but it is more interesting, more exciting. It transports the listener out of the living room (the moment he closes his eyes) transports him into a new acoustical medium, that of the concert hall. Papers will be given, articles written, building up the basis for premise # 2. Here, due to lack of space in these programs, I will simply try to outline the basic hypothesis as follows.

In a living room of ordinary dimensions, where acoustics are not too stoney or hard, with two loud speakers we can rather accurately enlarge the acoustics to those of any bigger room, such as a concert hall. Somewhat in the same sense as enlarging a photograph, or projecting a motion picture, we "blow up" the dimension of the acoustics. Direction and depth-perception appear. The beauty of speaker reproduction is that it liberates the binaural listener. A system properly installed lets him wander around at will within the room and still be experiencing the full effect of binaural. Let us talk about the living room for a moment. There are wide misconceptions about the criteria for two-channel reproduction of dimensional sound through loud speakers placed in a room. What are the criteria?

Speaker spacing is not a criterion at all, just so long as it is not less than about 3 feet (as we shall see later on). We have a solid geometry of variable parameters. Let us name the parameters. Acoustical reverberation time of the living room is one. The deader it is acoustically the farther we may get away from the sound sources and still be satisfied binaurally. Speaker spacing is another parameter, and average listening distance is another. But the farther away we want to get in a deadish room the farther apart the speakers must be. Therefore, speaker spacing is not a criterion; the angle subtended between loud speakers at the average listening area must be the real criterion. Experience has shown that this angle must not be less than 45 degrees for a moderately well acousticized room with drapes, rugs and upholstered furniture. More angle is all right less angle is a binaural compromise.

In order to talk about this subject we have to introduce and define new terms such as acoustical dispersions in the concert hall, reverberative distribution or reverberation pattern, and reverberation-to-signal ratio, -- something akin to signal-to-noise ratio, except that it is a function of frequency. We sample two discreet points in an acoustic medium where artists are performing. The sampling is defined in terms of reverberation-to-signal ratio and in terms of time differentials.

What new information do we have binaurally that we did not have before? We are able to produce information in the form of comparisons, basically, which is all the six inch binaural ears ever did. Comparisons of what? Not phase. Phase comparisons are impractical and unnecessary; and earphones are uncommercial. Comparisons between signal to reverberation ratios at two discreet points, (which are reproduced in the living room in two new discreet points) -- and comparisons of time, i.e. time differential.

The comparison based on time reduces to zero unless the microphones are spaced at least 6 feet apart, and this is a minimum. The reason for this 6 feet as a limit is very basic, harking back to the original physiological design. Too bad our Darwinian derivation didn't produce a head, say twice as wide. Ugly of course, but at least the audio enthusiast would find himself hearing lower frequencies.

Review a bit. The 1,000 cycle wave length is 1 foot. The half wave length is 6 inches. The region of maximum phase detecting sensitivity of two human ears corresponds to this region in the spectrum. It is also no coincidence that maximum sensitivity comes in here, too. The same is true for any mammal, -- all depending on the ear spacing. Bats and mice have the same thing happen at 12 - 15 kc. No wonder elephants trumpet. So far so good. At a frequency 1/10th of this amount, -- namely 100 cycles, the directional phase detecting ability of humans disappears for all practical purposes. Why, -- because they cannot determine the difference in time.

In reproducing binaural through loud speakers, therefore, two concrete deductions may be drawn. The speakers should not be closer than 6 feet before some potential binaural information is lost, because 6 feet is a half wave length at 80 cycles. The microphones must not be closer than 6 feet unless the acoustical environment (premise # 2) of making binaural-pickups is of no importance, -- because in so doing, time differential information will be largely lost. It will be lost not at 100 cycles alone but everywhere on up the scale. We don't have the time to go into it here in mathematical detail but it follows very well if we sit down and think it through.

In order to exercise to the full a full binaural potential, we have to analyze again the effect of reverberation psychologically on the listener. For the mathematicians as a basic hypothesis, we propose to treat this effect of reverberation as an integral function. It appears that the psychological effect on the listener of reverberation may be expressed somewhat as follows:

$$\text{Reverberation effect - } R_c = k \int_0^{20,000} \phi(f)\, df \quad \ldots\ldots\ldots (1)$$

For any given spot (of microphone placement) in the room, the function of frequency may be the 1/eth reverberation time for each incremental frequency, a complex function in itself. Phase may be ignored electrically at all but the lower frequencies, but not ignored acoustically at all.

It is easy to see from the direction of this approach that the effect of reverberation is very parallel to white thermal noise, -- on a per-cycle basis, rather than a per-octave basis. The practice of acousticizing studios so that reverberation is as constant as possible with frequency is basically all wrong, always was wrong. The distinction here lies in the method of assaying the value, -- the effect of reverberaton on the mind of the listener. The listener's ear and mind does not hear the flatness or peakedness of a reverberation vs frequency curve. The right kind of music may well point his mind's eye to curves of a different sort.

Reverberation of high frequencies, therefore, pulls the teeth out of the speech, ruins the intelligibility, because the reverberation of the sibilant (so to speak) interferes, reiterates in the wrong syllable at a later time. The reverberated transient hinders, -- it does not help.

In music it is the same. The transients are the only things that give meaning to music. Without them we could replace the orchestra with a vastly cheaper array of theremins. Perhaps even engineers could play them. Timing is of the essence for musical transients. Interference by reverberated transients makes music sound confused, strained and strangely unpleasant, as many discriminating listeners have testified in listening to originations of orchestras from "flat" studios.

What has all this to do with binaural? When we listen with two ears in a concert hall to music, we hear a basic proportion of reverberated musical vowels to direct musical vowels depending upon where we sit. This gives us an idea of the dimension and acoustical character of the hall, compatible with the visual impression. Direction is imparted by triangulation mainly through the workings of the unreverberated transients, for the ear is most directionally sensitive at 1,000 cycles and above. (The point where ear spacing is $\frac{1}{2}$ wavelength.) For this purpose we may define transients as

unrepetitive signals with substantial components lying in a frequency range above that where the aspect of musical pitch is apparent. Rather than try to define a specific geometry for justifying binaural technics in a wide variety of unspecific concert halls, let the main direction be as follows:

(1) Assume loud speakers at least 6 feet apart for the potential playback condition (although if they are only 3 feet apart we still have 80% effectiveness) Assume a minimum listener subtended angle of 45 degrees.

(2) Place the talent in the room or studio in a way that would not be unnatural for them were an audience there. If the room is not one which would be natural for audience listening, beware of making a binaural recording there.

(3) Distribute the microphones in pairs on the "audience" side of the talent at such a distance as to produce the direct vs reverberated ratio desired for the effect to be produced.

(4) Space the microphones in such a way as to receive in proper time-phase relationship the transient outputs of the various instruments, so that a maximum of directional intelligence is imparted to the recording.

(5) Use microphones that are capable of recording transients in the first place.

I would like at this point with the permission of our honored chairman to bring you a bit of audio folk lore. The field of audio is getting so far away from the basic unimpassioned engineering approach that I can see signs of the building of a tradition, perhaps ethnologically there may yet be hope for us. Let us wind up this session, then, with a binaural parable.

Binaural by Parable

Once upon a time there was a great dungeon deep under Dannemora castle. It often had been used for the medieval purpose of corrective politics, but now it was populated only with mice, -- many, many mice. The dungeon was pitch black, with not a single gleam of light, and in order to survive, the mice had to perceive binaurally the direction of approach of the castle cats. Wherever the cats would go in the inky pit, the prey would have just departed, leaving the <u>smell</u> of mice, but no <u>edible</u> mice.