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AUDIO

STEREO EQUIPMENT & RECORD REVIEWS

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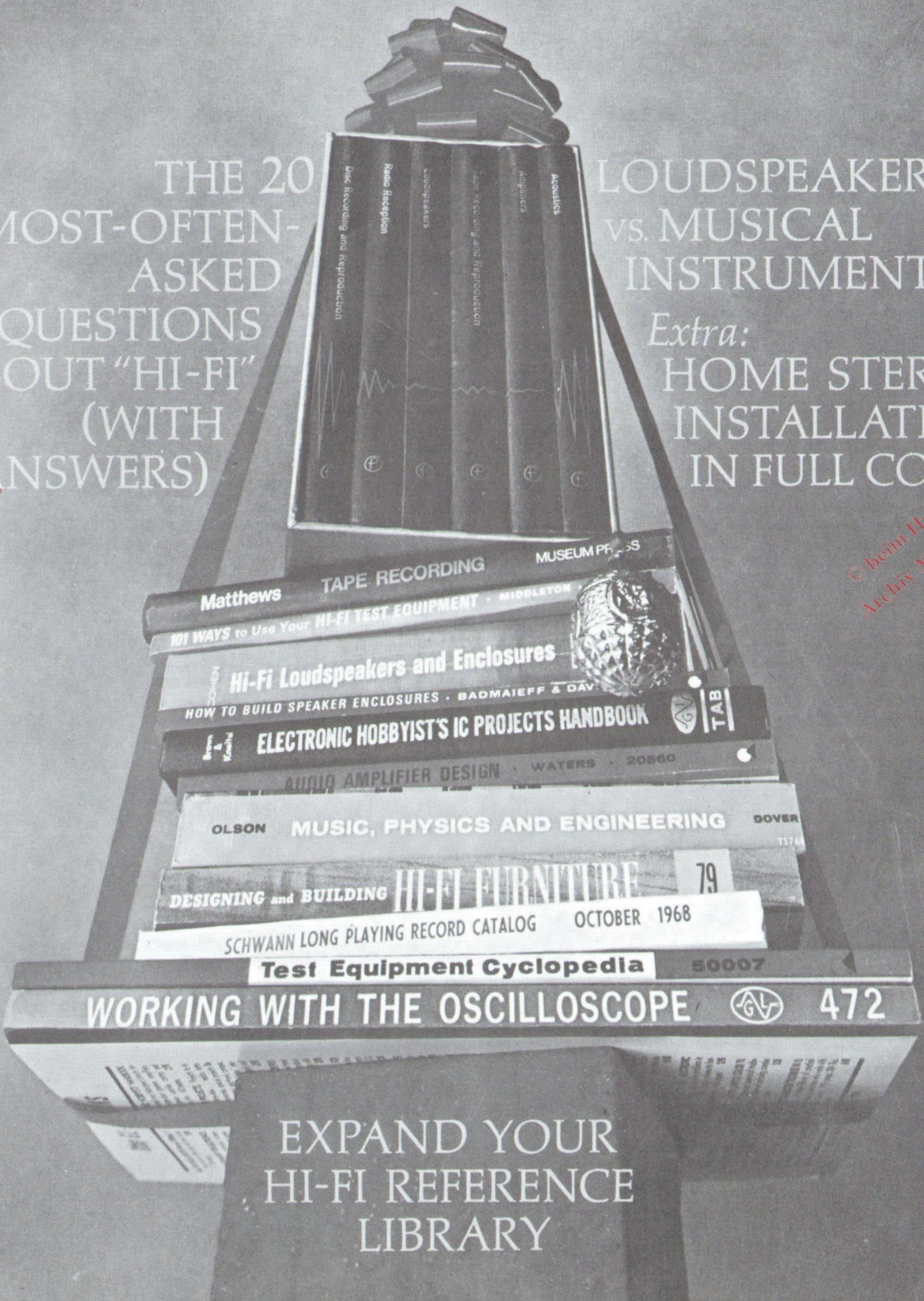
THE 20 MOST-OFTEN-ASKED QUESTIONS ABOUT "HI-FI" (WITH ANSWERS)

LOUDSPEAKERS vs. MUSICAL INSTRUMENTS

Extra: HOME STEREO INSTALLATIONS IN FULL COLOR



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BEHIND THE SCENES

BERT WHYTE

WALK INTO the average hi-fi shop and what do you see? Walnut boxes. Dozens of them . . . most quite small, resembling breadboxes or whiskey cases. Some are even as big as *two* whiskey cases. These are loudspeakers . . . a ubiquitous breed, many imitative of each other's design. The claims for these speakers range from modest to monumental. No matter how clever their design, however, to *me* they have the common failing of sounding like a small point source. The music they reproduce sounds rather compressed and constricted, like it is being squeezed through a small window.

Am I prejudiced? You bet! For you see, I'm a "big speaker" man. Unabashed. Uncompromising.

You'll see the big ones in some of the better salons, interspersed among the walnut boxes, standing like some noble monoliths; speakers of massive proportion and imposing aspect. These are the sonic aristocrats . . . the "big speakers" . . . loathed by women and loved by men.

At the moment, this partiality is a bit of a problem since I find myself on a most uncomfortable spot. You see, I've been listening to a pair of small speakers that are reproducing music with a high-quality BIG speaker sound, something no small speakers have any right to do. This iconoclastic speaker is known as the Bose 901 . . . and thereby hangs a tale.

The 12-Year Quest

The speaker was designed by Dr. Amar G. Bose, a Professor of Electrical Engineering at the Massachusetts Institute of Technology. Among other things, Dr. Bose teaches acoustics, and for many years has been an avid music lover and hi-fi enthusiast. About 12 years ago, he began a research program to investigate loudspeakers, realizing the truth of the old axiom that the loudspeaker is the weakest link in the chain of music reproduction. A student of the violin in his younger days and a frequent visitor to concerts of the Boston Symphony Orchestra in nearby Symphony Hall, Dr. Bose could not equate what he heard in the concert hall with the reproduction of music through commercially available loudspeakers. This was especially true with his beloved strings, which the speakers reproduced as "interesting but far from realistic sounds." Preliminary investigations convinced him that a good part of the loudspeaker problems derived from the inadequacy of standard speaker measurement techniques, which relied mainly on anechoic chamber tests or free-field testing, and a lot of subjective listening.

Speaker design over the past thirty years has been part science, with anechoic chambers and chain-driven oscillators and oscilloscopes, and part art, which is "cut and try," "cone doping," "individual tuning," and still more subjective listening. There would seem to be little argument that empiricism plays a significant role in speaker development. It is also obvious that we don't listen to music in anechoic chambers, so that questions have been raised regarding the relevancy of chamber data to the home listening environment.

The task Dr. Bose set for himself was formidable indeed: to determine what kind of sound an ideally "perfect" speaker (theoretically a pulsating sphere) would make—if such a thing could be made; and to develop precise techniques of measuring this sound, all within the context of the home listening experience.

With the vast technical resources of MIT at hand, Dr. Bose's first consideration was the simulation of the ideal pulsating sphere, whose surface will emit pressure waves in all directions evenly over its entire circumference. It is important to note that a prime requirement was that the pulsating sphere be measured in a typical room, in the same fashion as a normally operating speaker. Thus the normal room nodes, standing waves, etc., would be included in the measurement. The ideal pulsating sphere turned out to be a high-voltage spark, which was discharged into a typical home-type room at a frequency rate of once per second. The sound of the spark discharge was picked up by a calibrated Western Electric 640-AA condenser microphone. The microphone reconverted the sound into an electrical signal which was fed into an accumulator in a special digital computer.

When 4000 discharges had been stored, the computer performed a computation known as digital convolution or superposition integration (which I assure you is quite beyond my ken) and the result was, in essence, a mathematical model of the ideal speaker. The signals on the computer tape are, of course, different from the original (reproduced by the ideal pulsating sphere/spark speaker) because of the characteristics of the "speaker" and the acoustical properties of the room. However, there is a mathematical relationship between the two signals. Once this is known it is possible to calculate how the "speaker" would reproduce any other recorded signals in that room, even something as complex as a symphony. The next step was to feed actual speech and music samples into the computer in the form of electrical signals. The computer produced a tape of this material as it would have been recorded in a living room if the samples were played through a hypothetical one-eighth of an ideal pulsating-sphere speaker placed in a corner. The same music and speech samples were also played in the same room through an approximation to the ideal sphere speaker, consisting of 22 four-inch speakers placed on an octant of a sphere of 20 inches radius, driven by a computer-derived electronic equalizing network.

The two tapes were subjectively compared. According to Dr. Bose, observers were unable (during an A-B test) to distinguish the computer-processed music and speech from the speaker-processed music and speech.

The mind boggles at the enormous computations necessary to produce these tapes. The need for a computer is obvious. Even so, when Dr. Bose started this experiment some years ago, it would have taken 20 *hours* of computer time to process 7 *seconds* of music! Today, this has been reduced to 3 to 6 minutes for the same 7-second processing.

The importance of the experiment was that it proved that with proper frequency equalization, the multiplicity of closely spaced small speakers on the spherical surface can produce music and speech signals in a *normal listening environment* that are *subjectively* indistinguishable from those that would be produced by an ideal pulsating sphere in the same environment having no resonances, phase shift, diffraction, or distortion of any kind. Thus Dr. Bose had a precise measurement technique, yet one that worked with the subjective factors in listening experience.

Another experiment was conducted to provide a measurement technique for speaker distortion. Distortion in speakers has usually been measured in an anechoic chamber, but this method of detecting distortion isn't meaningful to the listener in the environment in which the speaker normally operates—his living room. Most speakers exhibit various forms of distortion as their intensity of radiation increases, and have relatively negligible distortion at very small intensities. Dr. Bose's experiment made use of this fact to determine the level of intensity at which a speaker begins to generate audible distortion in music reproduction. Selections of music and speech were played a number of times through the speaker in a listening room at successively increasing intensity levels. Binaural recordings of each successive speaker playing were made at a constant, standard level. The various recordings were synchronized on parallel tracks of an eight-channel tape recorder. The listener subject was then given an A-B presentation of the sample that was recorded with the speaker playing at the lowest level and a sample representing a higher speaker output level. Naturally, both samples were presented at the same level to the listener, and he was asked only to try to detect a *difference*. The level of intensity produced by the loudspeaker for which a difference is first detected is then a measure of the performance of the loudspeaker. This measure is pertinent to the ultimate *subjective* evaluation, but it was obtained without introducing the problems of individual value judgment or prior notions of the sound of distortion. Essentially, this is a way of correlating objective measure with the subjective perception of sound. The subject was not asked whether he likes or dislikes a sound, but merely if he could detect a *difference* between sounds.

Armed with these unique measurement techniques, Dr. Bose continued his researches. As you can see from the foregoing, there has been considerable emphasis placed on the measurements as applied to the listening room environment. There have been many studies of concert halls made which show, conclusively, that an auditor at a concert, no matter where he may be seated, hears the orchestra at a certain ratio of direct-to-reflected sound. Dr. Bose expanded much of the original European data on concert hall measurement; his studies have shown that for virtually all seats in the average concert hall, the reverberant field is dominant. Even in a large hall such as Symphony Hall in Boston, the reverberant field equals the direct field only 19 ft. from the orchestra. It is important to note that in a reverberant field, sound energy arrives at any point via reflections from the surfaces of the room and that the angles of incidence of the arriving sound are widely distributed. This spatial property of the sound incident upon a listener, plus the frequency spectrum for the incident energy, are the important factors in the subjective appreciation of music.

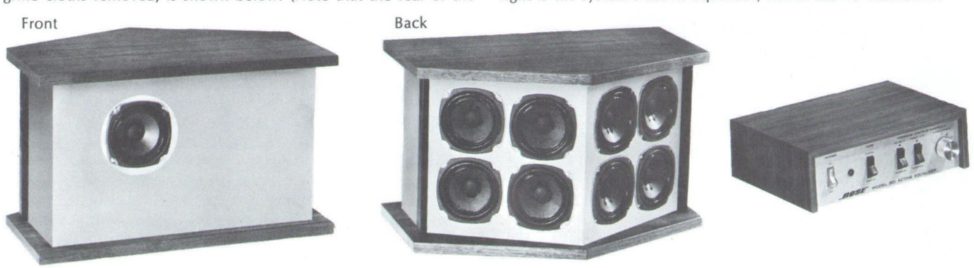
* * *

At first glance the Bose 901 is rather unprepossessing, but a closer look reveals that the unit is pentagonal in shape, with the two rear panels forming a "Vee" angled at about 30 degrees. As you can see from the illustration, four speakers are mounted on each of the rear panels (total of eight), while a single speaker is mounted on the front panel. All nine drivers are identical, specially designed, 4-in. units, with long-excursion voice coils. Each speaker has a power handling rating of 30 watts. Each is a full-range speaker, so there are no crossover networks. The sealed enclosure is densely packed with fiberglass. In this seemingly simple unit there are many sophisticated concepts derived from the research program.

The Bose Model 901 is sold as a stereophonic speaker *system*, with two of the units comprising the stereo channel, and both units controlled by a specially matched active equalizer. To function properly, the speakers must be placed in front of a wall with a minimum spacing from the wall of 6 inches, a maximum of 18 inches (optimum spacing is 12 inches).

Dr. Bose's concept, based on the concert hall measurements which showed the need for a dominant reverberant field, results in the 8 speakers on the two back panels radiating 89 per cent of the energy toward the wall, while the single speaker on the front panel radiates 11 per cent of the energy into the room. This is said to provide the necessary ratio of reverberant-to-direct sound. With the rear panels angled at 30 deg. to the wall, the wavefronts emerging from the first reflections from the back wall, together with the second reflections from the side walls, produce an effective source that is much larger than the actual enclosure; and that is well distributed across the wall in the

Fig. 1—A front and back view of the Bose 901 speaker system, with grille cloths removed, is shown below. (Note that the rear of the system has eight speakers, while the front panel has only one.) At right is the system's active equalizer, which has 10 transistors.



same sense that an orchestra is distributed across a stage. Since the reflected sound affords a virtual central image, considerable flexibility is possible in regard to the separation of the speakers. Naturally there is a certain optimum placement in any given room, but if circumstance dictates, the speakers may be placed further apart and closer together than other types of speakers, while maintaining the desired balance of stereo separation or center fill (judicious angling of the speakers inwards or outwards in relation to the walls is necessary, of course).

The nine speakers in each enclosure are full-range units and, as you can see in the photo, are closely spaced. The resultant acoustic coupling causes the resonant frequencies of each speaker to be different from every other speaker. In much the same manner as i.f. cans are staggered to get a broad response, the resonances become inaudible; thus the sound of the total array of speakers is very smooth. With no crossover network, each speaker receives the same audio signal. At low frequencies, the nine drivers, operating in phase, move a great deal of air, which is a well-known principle. At higher frequencies the relatively small cones behave like tweeters, with the highest frequencies propagated by the speakers' dustcaps. The pentagonal shape of the enclosure ensures there are no sides parallel to any of the panels on which any of the nine drivers are mounted, which eliminates the problem of standing-wave resonance.

The Bose active equalizer is a solid-state device which influences the acoustic output of the two speaker units. Precise equalization is necessary for flat frequency response of the radiated sound. This involves considerable boost. In the case of flat response for the lowest frequencies, as much as *18 dB* boost is needed. By manipulating the controls of the unit in the proper manner, a total of 20 different frequency contours are available to compensate for variations in room acoustics, phono pickups, program material, and so on. Some of the contours available are unique. For example, midrange frequencies can be reduced, but without a drastic roll-off of high frequencies. There is also a "below-40-hertz" switch that can reduce turntable rumble and other low-frequency disturbances without adversely affecting response above 50 hertz. The equalization of the signal comes before the power amplifier. The unit can be conveniently patched into a preamp/amplifier setup, or an integrated amplifier or a receiver. In fact, the unit is treated as if it were a tape machine, utilizing the tape-in/tape-out jacks of your particular rig. Auxiliary tape input and output jacks are provided on the rear panel of the equalizer.

* * *

Having described the Bose 901 system and its revolutionary concepts, the question, quite naturally, is how does it sound? At this point we'll have to bring up the matter of power amplification. [Because the equalization comes before the power amplifier] when you are trying to reproduce the very lowest frequencies at substantial levels, the 18-dB boost mentioned earlier can place really heavy demands on amplifier power. Let's put it this way: for 99 per cent of the program material played by most people at better than "apartment house" levels, a good 30 to 40 watts *continuous* power per channel should suffice. But when you want to play that other 1 per cent of program material — the great pipe organs, with the really low pedal and, most especially, a sustained low frequency at thunderous levels — that's when you need all the amplifier power you can afford.

The speakers can handle high power, of course (each speaker in the Bose enclosures is rated at 30 watts, for a total of 270 watts per channel). You can lower your power requirements by activating the "below 40 Hz" switch, however. You gain about 6 dB this way. It is true you lose the frequencies below 40 Hz, but if you desire to play the system at house-shaking levels, and don't have sufficient amplifier power, this is the way it can be accomplished.

I've had good results driving the Bose with medium- and high-power amplifiers. I tried it with a University receiver and with a CM 911, for example. Also with the McIntosh 2105, which has the advantage of a power level meter. If you monitor the output of the Mac amplifier during the heaviest fortes of some grandiose symphony, and set the gain so that you don't exceed +3 (105 watts per channel), you won't hear any distortion. (I didn't.) You will also find it's pretty loud!

Lucky lad that I am, there is very little program material that I can't cope with; not when I have a pair of McIntosh 3500 amplifiers, each capable of a mere 350 continuous watts per channel! These 120-pound (each) brutes are quite magnificent when working with the Bose speaker systems. I put on an organ recording containing plenty of "low C" pedal, and at a level of 108 dB (measured on a sound-level meter) the visual evidence of a scope across the speaker terminals and the audible evidence indicated that the Bose and the Mac had just barely reached a point of mutual distortion.

In evaluating the sound of the Bose 901 system, I was constantly aware that I was listening to an entirely *different* kind of loudspeaker. In some ways, comparison of this speaker with conventional types isn't quite valid. Even without its other virtues, the overwhelming superiority of the Bose in terms of *spatial presentation* and *stereo effect* was immediately apparent. There is no question in my mind about the desirability of the direct/reflecting principle for home listening. With a symphonic recording, the illusion of an orchestra spread across the wall is uncanny. With the virtual image in the center you can sit well away from the traditional "stereo axis" and enjoy a very good stereo presentation. It is the closest thing I have heard to a true three-channel stereo recording. The overall sound is outstanding for its clarity, transparency, wide range, crisp clean transients . . . and just plain naturalness. Equally astonishing is the bass response. To hear a thunderous "low C" organ pedal from these small (approx. 20 x 12 x 12) speakers, or a clean, weighty impact of a large bass drum is truly impressive. The speakers are mercilessly revealing of the faults in all manner of program material. It is a comparatively rare recording that could be played with the equalizer set in the flat position. (There is obviously more high-frequency distortion around than I realized.) The Bose really comes into its own with top-quality tapes. I have some symphonic masters and some one-to-one copies of masters, and they were reproduced with a naturalness that is quite compelling.

With only kudos for the Bose's performance, there *are* some minor drawbacks, some of which have already been mentioned: Fairly high-power amplifiers are needed to realize the 901's *full* potential; if you use headphones, the equalizer should be switched off; priced close to $500 for the entire system (two speaker systems and the solid-state equalizer), they cannot be considered to be truly inexpensive; placement requirements (6 to 18 inches from the wall) can be a problem to some persons since "bookshelf" location is excluded. But the above are trifles, in my estimation, when balanced against the astonishingly realistic sound achievable at home with the Bose speakers.

There is no doubt that the much-abused and overworked term, "breakthrough," applies to the Bose 901 system and its bold new concepts. Æ