ACOUSTICS

Redesigning the guitar

Applying the laws of physics to musical craftsmanship has improved sound and power

by Alan Perlmeter

Over the years physicists and acoustical engineers have bemusedly studied the world's great stringed instruments, trying to discover the reasons why one violin sounds better than another. Sometimes they go beyond investigation and try to construct new instruments based on acoustic principles. One such effort (SN: 3/4/67, p. 212) produced a whole new family of stringed instruments.

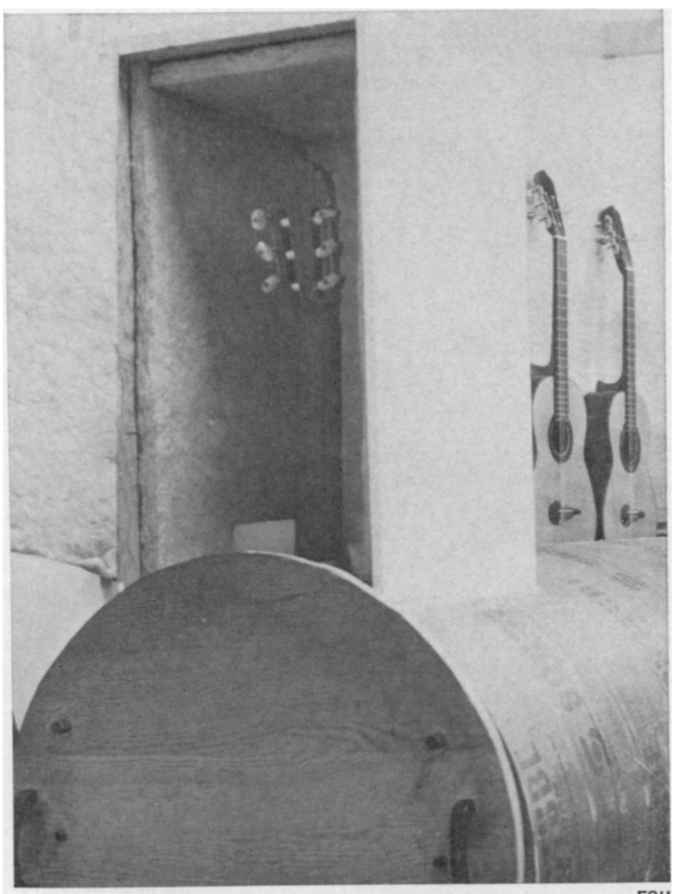
The revival of classic guitar playing has led to interest in improving that subtle but low-powered instrument, and at least one experiment in that direction has produced guitars of superior sound and power. But as with other stringed instruments from Stradivari-built violins onward, the question is whether the guitars are good because of their design or because of the skill of their craftsman-builder.

"The minute I looked inside a guitar I knew something was wrong," says Dr. Michael Kasha, Director of the Institute of Molecular Biophysics at Florida State University and inventor of the Kasha guitar. Dr. Kasha looked inside after his son asked for help with his guitar lessons five years ago. He says he saw an engineering defect in the traditional structure of the resonating top or soundboard of the guitar body. The defect, he claims, inhibits the power and tonal quality of the instrument.

Dr. Kasha developed a mathematical model of the soundboard, based on the mechanics of wave functions, circular plate harmonics and the theory of coupled oscillators. He then used this model to design and test some 20 custom-made instruments, with the assistance of eminent guitar builders, musicians and a sound tunnel.

The new design is still somewhat controversial and Dr. Kasha admits that it is not yet fully perfected. The natural resistance to innovation in the traditional music world is also a reason for the wait-and-see attitude toward the Kasha Model expressed by some guitar experts and aficionados. Others, including the guitarist Andres Segovia and Vladimir Bobri, President of the Society of the Classical Guitar, are more enthusiastic about the quality and potential of the design.

The last major improvement in guitar design was made around the middle of the 19th century by Antonio de Torres of Spain, who introduced an expanded soundbox, longer strings and what are called resonance bars. These were originally simple cross-braces glued to the underside of the soundboard to give it strength. Torres placed them in a symmetrical fan-shape radiating from the soundhole down to the end of the soundboard and roughly parallel to the grain of the wood. The idea was to increase the transmission of vibrations



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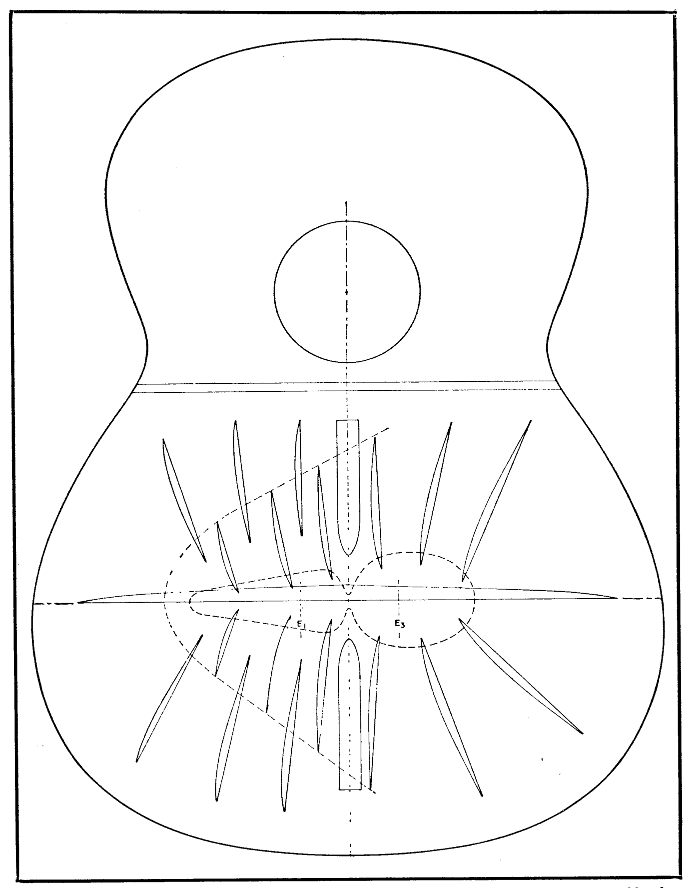
This sound tunnel was used to measure guitar intensity.



Kasha

Asymmetric bars on Kasha soundboard distribute sound.

across a larger area of the soundboard.

While the new bars effectively transmitted vibrations, they functioned, at the same time, to limit the amplitude of such vibrations. Guitar builders were forced to compromise between a heavier soundboard and bars, which would give greater tonal quality and depth but less power, and a lighter soundboard and bars, which would give greater power but less tonal quality and strength.

Dr. Kasha set out to increase the amplitude of vibration and the power of the guitar by having the resonance bars correspond to the harmonic properties of circular plates. If the soundboard is considered to be essentially a circular plate, it is possible to develop a mathematical model of its wave motions. The force of the vibrating strings causes it to vibrate at different frequencies. The vibrations travel in waves across the board from the bridge and are reflected back from its edges, superimposing their motion over the incoming waves. This results in a symmetrical pattern of nonvibrating nodal lines which separate the different vibrating segments of the plate.

The patterns of such Chladni figures, as they are known, revealed either by laser holography (SN: 1/6/68, p. 19) or more simply by sand or powder patterns, delineate the harmonic frequencies. Each segment vibrates at a given frequency, in opposite phase to the segment on the other side of the line. The different patterns represent the normal modes of vibration and correspond to characteristic notes or frequencies. The note itself is the sum of the partial tones produced by the separate segments, and the greater the number of such segments in a pattern the higher the frequency of the note.

Dr. Kasha's first test models had bars one-quarter inch high, tapered at the sides and ends. radiating from the underside of the bridge toward the edges of the soundboard. They were shaped and positioned to follow the nodal lines of the normal modes in order to transmit the impulses from the string bridge to the whole board, without interfering with the amplitude of the resonances as they developed into patterns.

The result was a continuous, graded asymmetrical pattern with long bars on the bass side of the bridge for low-frequency coupling and shorter high-frequency bars on the treble side.

The string bridge couples the two oscillators, string and soundboard, by means of its forward and backward rocking motions. The Kasha Model bridge was designed with a wide bass side in order to transmit more effectively the slow, high-amplitude motion of the bass strings. A narrow treble side, connected by a thin strip to the bass bridge, was used to give a separate low-amplitude high-frequency motion.

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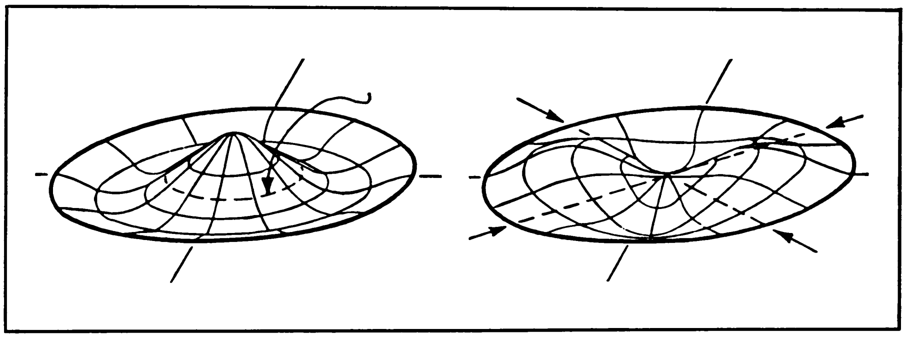
Dr. Kasha (right) watches guitarist Mario Abril try out a Kasha Model.



McGraw-Hill

Shapes of some normal modes of vibration of a clamped circular plate.

Altogether, 20 structural changes were introduced over a five year period. The latest Kasha Model includes half-pound weights embedded in the neck and bottom to cut out unwanted vibration, a more fully rounded redwood soundboard and spruce soundbox members for added resonance. The total effect of these changes, says Dr. Kasha, is that the full design has 10 times the amplitude and three times the detectable loudness of a traditionally designed guitar.

Measurements of the guitar's sound intensity were made in a sound tunnel constructed especially for the purpose at Florida State, under the direction of E. E. Watson, now at Pennsylvania State University's Acoustics Lab. Intended to duplicate the conditions of an anechoic chamber, it was built at one-tenth the cost. The guitar is placed in a chamber at one end of a tube 16 feet long and 24 inches wide, with a smaller concentric tube suspended inside of it. A special mechanical guitar plucker is used, and the sound is recorded at the other end of the tunnel.

"The aim of this project," Dr. Kasha says, "has been to make it easier for the craftsman to produce exceptional guitars by today's standards. The high consistency of the results shows the new design does have this function."

John Huber, technical consultant to the Martin Guitar Co., disagrees. He contends that the results are not conclusive and that the qualities of the Kasha Model are due largely to the craftsmanship of its builder, Richard Schneider of Grosse Point, Mich. Huber has made laser holograms of a vibrating soundboard and believes that guitar acoustics, as revealed by his own research, are more complex than the Kasha modification allow. Specific wood resonances, he points out, cannot be predicted or detected except by the tap tones used by an experienced builder to adjust for natural soundboard frequencies. While Huber credits Dr. Kasha with making an important challenge to the hallowed traditions of guitar building, he stresses the need for more basic research.

Bobri, who is editor of GUITAR REVIEW, thinks that the Kasha Model compares favorably with the greatest traditional makes such as Ramirez, Hauser or Kohno, and would sell in the same exclusive price range for upwards of $1,200 each. For this price, says Bobri, you would be getting a guitar with great power for the concert stage and excellent tone balance. "Ultimately Kasha will arrive at a model that will surpass the best handmade guitars," he predicts. □