A Test Record for Evaluating Stereophonic Systems

B. B. BAUER, G. SIOLES, A. SCHWARTZ, AND A. GUST*

A sweep-frequency test reveals resonances and other faults not necessarily uncovered by spot frequencies.

At the last Convention of the Audio Engineering Society in New York an interested crowd of engineers and audio specialists gathered daily to watch an operator place a pickup on a record and an automatic recorder draw a curve on graph paper—in just over one minute. This seemingly insignificant event was fully appreciated by the technical audience: here was a test record which could be used to automatically record phonograph characteristics. Significantly, although aimed mainly at the requirements of pickup designers and audio professionals, the new record answers several important needs of the high fidelity enthusiasts.

* *CBS Laboratories, Stamford, Conn.*

Conventional test records contain 25–30 spot frequency tones per channel. To evaluate a pickup or a phonograph system, the user plays the record and reads the output in db on a VTVM. Then a correction for the record calibration is added (by careful users). This provides the pickup response data which is then transferred manually to semi-logarithmic graph paper. With two channels and two sets of crosstalk (separation) points the complete procedure takes the better part of an hour.

A cartridge under test.

The CBS Laboratories STR-100 has a full set of spot frequency tones, with voice announcements preceding each tone, and it also includes two precisely cut sweep-frequency bands, one each for the left and right channels. These bands are synchronized to operate with a General Radio Type 1521-A recorder at a chart speed of 7½ ipm. The first band starts with a 1000-cps left channel "keying" tone, which may be used to set level. As soon as this tone ceases the frequency drops to 40 cps and starts rising immediately and continuously at a logarithmic time-rate of 1 decade in 24 seconds. Thus the sweep from 40 to 20,000 cps requires 24 log (20,000/40) = 64.8 seconds. After a brief pause (which is sufficiently long to allow the operator to reset the recorder) a 1000-cps right-channel tone is heard and this is similarly followed by a sweep from 40 to 20,000 cps. If one channel of a stereophonic pickup is connected to the automatic recorder the response and separation curves for the particular channel will be obtained in a fraction of the time formerly required. A typical set is shown in *Fig.* 1.

Another significance of the sweep test is that spot frequencies tell only about the performance at specific points of the spectrum and the sweep test provides information about performance at every frequency. Users may be surprised to discover that a pickup which appears to be "flat" with a spot frequency test may be found to have a peak or dip between the frequency spots!

A circuit for starting the recorder automatically when the keying tone ceases is shown in *Fig.* 2.

The 1000-cps keying tone preceding the sweep initiates the cycle. All relays are initially de-energized as shown in the schematic diagram. Left and right channel inputs are combined in the cathode of V_1 insuring that the keying tone will be present for either direct or crosstalk measurements. The cathode follower output is fed to the high gain amplifier, V_2, through a high-Q, LC, 1000-cps filter allowing only 1000 cps to feed through. Following this usage is a cathode follower, V_3, employed as a power amplifier to drive a sensitive relay, K_1 (Elgin Advance) after rectification by the two IN2482 diodes. A Zener diode and clipping-range control prevent high-signal levels from overheating the sensitive relay.

With K_1 energized, relay K_2 is energized and locks itself across the power supply through contact 1. At the cessation of the keying tone, K_1 is de-energized—thereby actuating K_3 which starts

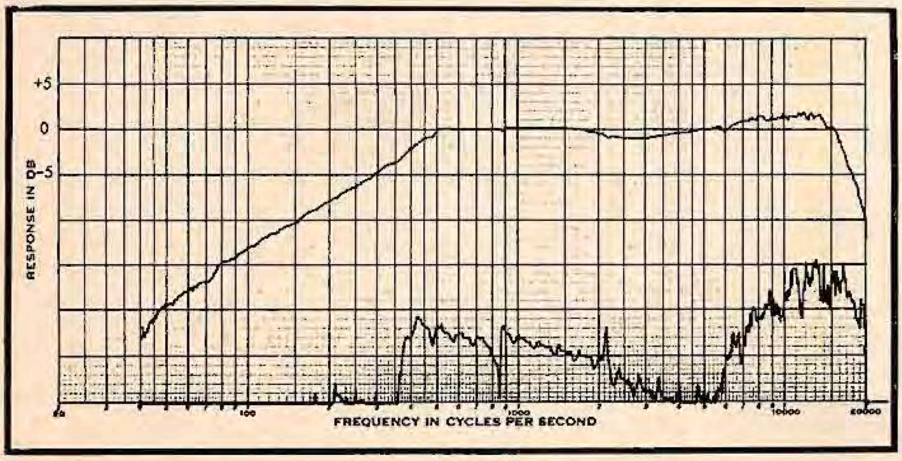

Fig. 1. Automatically plotted response and cross-talk curves of typical high-grade magnetic pickup.

the recorder motor at the instant the sweep begins. At the termination of the sweep band, the reset switch is manually set at RESET momentarily to de-energize K_2 and the circuit is then ready for the next sweep.

The Three Minute Test

The sweep tone bands, 1A and 2A, originally were intended for audio engineers and pickup designers with access to an automatic curve recorder. Even without a recorder, however, these bands provide a rapid and convenient qualitative appraisal of the reproducing system. They will help to answer a number of questions. Are the left and right channels correctly connected? (A surprising number of sets are reversed.) Do the left and right sounds appear to originate at the appropriate loudspeakers throughout the glide tone duration (which indicates good channel separation) or do they wander in between or beyond the loudspeakers (which would indicate poor channel separation)?

Are there any buzzes or rattles in the loudspeakers or the cabinet? (This might indicate poorly tracking pickup, dirt in the voice coil, loose panels in the cabinet, and so forth.) Is the glide tone relatively steady in loudness or does it go through a series of up-and-down gyrations? (Small variations are normal; large variations might indicate that the pickup or the loudspeakers are inadequate or that the room needs additional sound absorbtion in the form of carpet, drapes, or similar materials.)

In this manner, just by playing bands 1A and 2A, a listener can quickly spot trouble or reassure himself that everything is all right—in less than three minutes.

The technical user who does not have a recorder available but must employ spot frequency bands for calibrations work will still find that the sweep-tone bands have an added value. Unexpected peaks, dips, buzzes or rattles are revealed which otherwise might remain undetected with the spot frequency test alone.

Using the Spot Frequency Test

Two bands are provided (3A and 3B) each of which contain 30 spot frequency test tones for the left and right channels, respectively, *with voice announcements preceding each tone*. Since this record has been primarily designed to serve the needs of the scientific worker, these bands have been placed on the opposite sides of the record in exact spatial relationship so that the respective tones are at the same distance from the center of the record. This arrangement improves the accuracy of record calibration.

With magnetic pickups, an auxiliary plug and jack arrangement may be used to allow the pickup to be "bridged" with the VTVM, and simultaneously connected to a preamplifier with correct termination impedance, as recommended by the pickup manufacturer. The voice announcements are then heard directly over the loudspeakers. (See *Fig.* 3.) Start with the left channel and play band 3A. Note the meter reading and call this "0" db for the 1000-cps tone. As the voice announcements in the loudspeaker identify the frequencies being reproduced make a note of the db readings. With an ideal pickup performance, they should be as shown in Table I.

TABLE I

Frequency	*Relative Output (db)*
1000	0
20,000 to 500	0
400	− 2
300	− 4.4
200	− 3
100	−14
80	−16
60	−18.4
50	−20
40	−22
30	−24.4
25	−26
20	−28

Next, without changing connections, turn the record over and play band 3B. A similar set of readings will be obtained, except this time they will indicate crosstalk. Plot relative output in db vs. frequency, which should provide a curve similar to *Fig.* 1, except, of course, on a point-by-point basis. Repeat for the other channel, and the task is done. Corrections for deviation from ideal response are not needed.

Similar measurements can be performed on ceramic pickups. To this end, the left and right channels should be terminated with 10,000-ohm resistors. An ideal ceramic pickup terminated in this manner will have a response as in Table I and it will work satisfactorily if connected to the input terminals normally intended for magnetic pickups.

Limits of Response

In a less formal fashion, the spot frequency bands may be used to "estimate" the frequency limits of your equipment —or of your own sense of hearing or that of your friends. This is because of the convenience afforded by the voice announcements. Starting at the beginning of band 3A, adjust the 1000-cps tone for a moderately loud signal and then observe the announcement following which you can just perceive a high frequency tone. The succeeding tones will become louder as the frequency is decreased, and then weaker again as the low-frequency end is approached. Observe in the low-frequency end which frequency just can be heard. Repeat for the right channel band 3B. Here are the

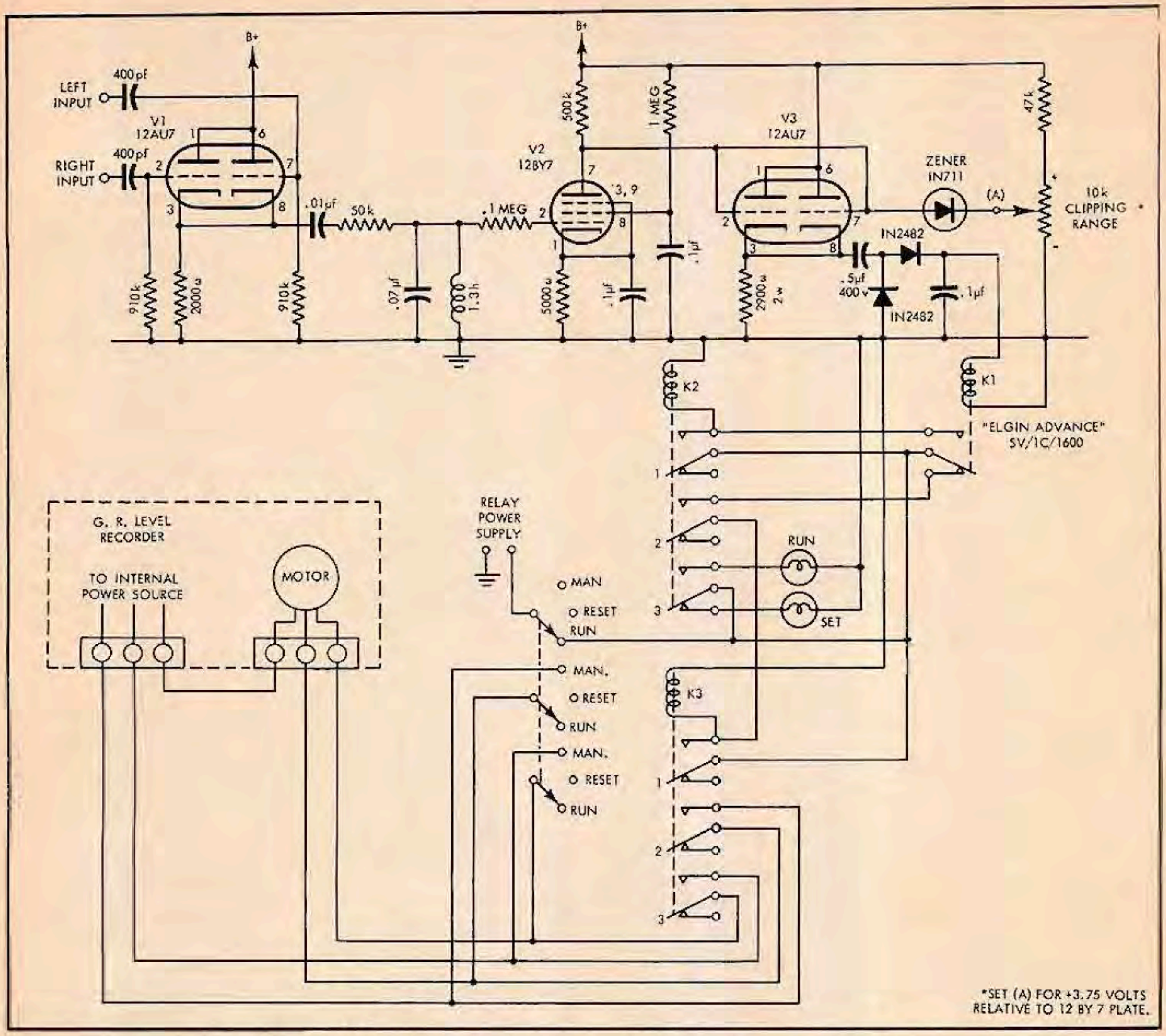

Fig. 2. Synchronizing circuit for automatically starting curve recorder.

facts about the approximate frequency range of your system!

You may wish to repeat these tests with the treble, bass, and rumble controls in different positions and note what difference they make in the frequency response of your system.

Response Characteristics

In designing a test record there is always the question as to which response characteristic to provide. In the STR-100 a *constant displacement* characteristic is provided below 500 cps and a *constant velocity* characteristic above 500 cps. This means that the response of a perfect velocity-responsive (magnetic or dynamic) pickup will rise at 6 db per octave below 500 cps and will be "flat" above 500 cps, as indicated by Table I. In this manner, the pickup performance is evaluated by comparing it with two straight lines, which simplifies the task.

Some test records in the past have been recorded with constant-velocity characteristic at all frequencies. This introduces a problem in that amplitudes at low frequencies become unmanageably large; therefore the response must be broken into two separate bands, one recorded at a level 20 db below the other. This approach does not lend itself to a good graphical presentation on a curve recorder, and, therefore, it was not considered.

Why not use the RIAA characteristic? There is an argument in favor of this approach, which runs as follows (see *Fig.* 4): Let a test record be recorded with the RIAA characteristic, (A) of *Fig.* 4, then an ideal velocity-responsive pickup will reproduce this characteristic on a velocity basis, (B) of *Fig.* 4. The preamplifier is designed to provide an inverse characteristic (C), of *Fig.* 4; therefore the output of the amplifier into the loudspeaker voice coil or dummy load will be constant as a function of frequency, (D) of *Fig.* 4. If this event takes place, then the over-all system is satisfactory.

This argument is fine with two exceptions: First, in the event the over-all response of the system is *not* flat, then the user has no convenient means of determining whether the problem is with the amplifier on the pickup. Of course, one could measure the pickup by itself and compare the resulting curve with the published RIAA characteristic, on a point-by-point basis. This is far less convenient than simply matching response against two straight lines. Second, because of the rise of the RIAA curve above 2120 cps, cutters and recording styli cannot handle the output on a steady-state basis at standard recording level, and it becomes necessary to produce the record at considerably below the standard level. This would introduce the possibility of error because of noise and rumble.

A test record with RIAA characteristic would be useful for over-all checks of packaged equipment. But it would not be convenient for testing high-fidelity components, where each component must meet specific performance standards.

RIAA Function Generator

For the designer who wishes to assure himself of the performance of a preamplifier for magnetic pickups, an RIAA function generator has been devised. This circuit is composed of R and C elements, and it may easily be constructed by any technical person (*Fig.* 5). The design of this generator follows the theory previously employed to calculate an ideal compensation network for ceramic phonograph reproducers.[1] When connected to a low impedance amplifier (30 ohms or less), and driven by a constant voltage oscillator, the circuit will develop an ideal RIAA shaped curve across a 10-ohm resistor. With an input voltage of 8 volts, the output at 1000 cps is about 10 millivolts. With constant voltage input to the RIAA generator network, the output of the magnetic pickup preamplifier should be "flat" for all audio frequencies. Then, a pickup whose response follows the two straight lines of the STR-100 test record, will produce an ideal response with an RIAA-cut record and a particular amplifier.

The STR-100 also may be used to test the over-all system performance. In that case, the response in db will be the difference between the RIAA response and the STR-100 response. This is given in Table II.

Low-Frequency Sweep

In the STR-100 record, low-frequency sweep bands are available for the left and right channels, from 200 down to 10 cps. These sweep frequency bands, 4A and 5A, are recorded at a level + 3 db above the standard recording level to provide a rather severe tracking test at low frequency, which is convenient for testing arm and speaker resonance. Each band starts with a keying tone of approximately 1000 cps. The cessation of this tone indicates that the sweep is starting. This low frequency sweep is also synchronized to the General Radio Type 1521-A recorder.

Because the chart paper of the recorder does not go down to 10 cps, bands 4A and 5A have been recorded in a descending mode. In this manner, if the 200-cps point is placed correctly on the chart, all the other frequencies will properly be in place. The motor drive of the recorder should be set in the "reverse" mode of operation, the pen

[1] B. B. Bauer, "Compensation networks for ceramic phonograph reproducers," I.R.E. Transactions on Audio; Jan.-Feb., 1957.

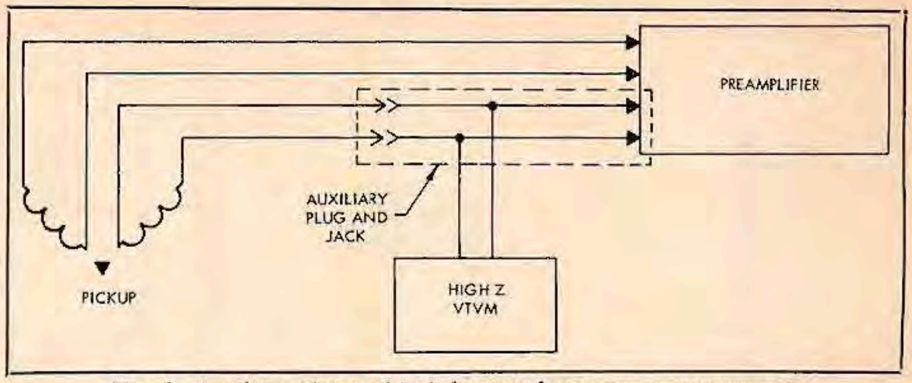

Fig. 3. Auxiliary plug and jack for spot-frequency measurements.

TABLE II

Frequency	*Relative Output (db)*	*Frequency*	*Relative Output (db)*
1000	0	800	+0.7
20,000	−19.5	600	+1.8
18,000	−18.8	500	+2.6
16,000	−17.7	400	−1.9
14,000	−16.6	300	+1.1
12,000	−15.3	200	+0.2
10,000	−13.7	150	−0.6
8000	−11.9	100	−0.9
6000	− 9.6	80	−1.3
5000	− 8.2	60	−2.3
4000	− 6.6	50	−3.0
3000	− 4.8		−4.2
2000	− 2.6		−5.8
1500	− 1.5		−7.0
1000	0		−8.6

being placed at 200 cps and the gear engaged as soon as the keying tone has ceased. The sweep will end off the chart. If desired, the recording may be started at the 2000-cps ordinate on the chart continuing down to 100 cps; remembering however for correct presentation to divide all frequencies by 10.

Arm Resonance Test

The low-frequency sweep is ideal for detecting and remedying any arm resonance that may be present. The principle is illustrated in *Fig.* 6, by the vector velocities acting on the stylus under three conditions of arm resonance. Symmetrical resonance is shown (A) of *Fig.* 6. Here the resonance generates a velocity, v_a, which is additive with say, the left modulation velocity, v_l; since no crosstalk velocity is generated, separation is unaffected: Symmetrical resonance shows up as a peak or dip in the main channels. In (B) of *Fig.* 6 a condition of vertical arm resonance is illustrated: Here the arm velocity, v_a, at resonance produced by the modulation velocity, v_l, introduces a component of crosstalk velocity, $-v_r$. This will result in a loss of channel separation. (C) of *Fig.* 6 shows the effect of horizontal or torsional arm resonance: Again the velocity v_a introduces a crosstalk velocity component, v_r. Torsional resonances, often have a high "Q" and the loss of separation may be in the form of sharp "peaks" in the crosstalk channel graph. These often go undetected by the spot-frequency test, but are clearly evident with the sweep-tone test.

Standard-Level Test

For some time there has been a need for accurately calibrated standard 1000-cps tones for specifying pickup sensitivity data. Standard lateral recording level is 5 cm per second rms velocity at 1000 cps, which corresponds to $5/\sqrt{2} = 3.54$ cm per second rms velocity for each of the two 45-45 deg. channels. Thus the voltage sensitivity of a pickup measured on the STR-100 record can be expressed

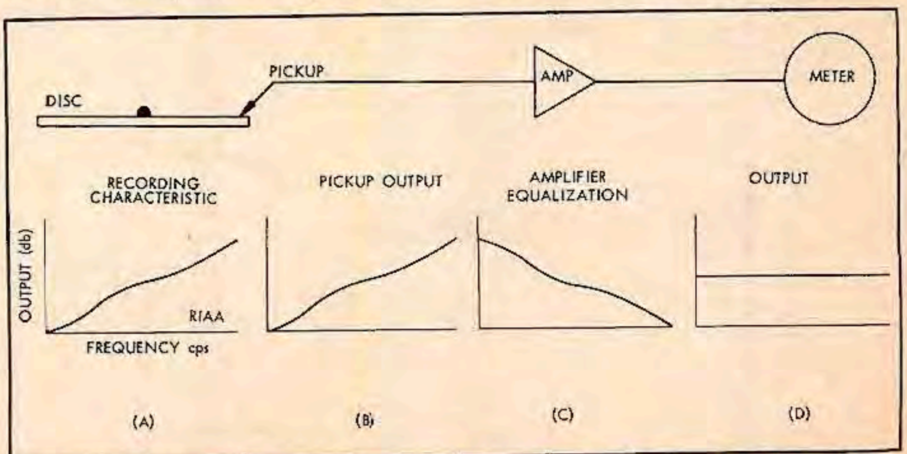

Fig. 4. Frequency-response relationships between record and amplifier output.

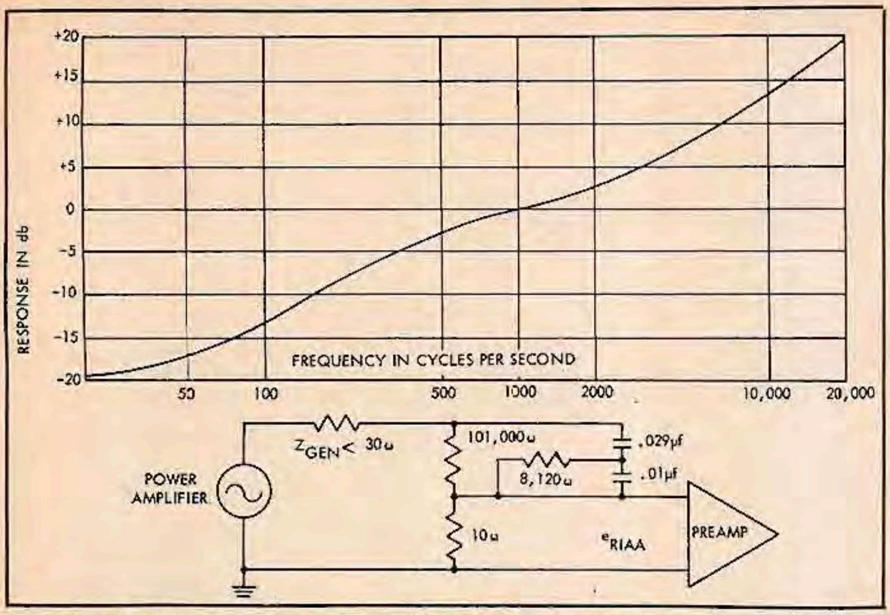

Fig. 5. RIAA function generator for testing magnetic pickup preamplifier.

in terms of volts per channel for 5 cm/sec rms lateral velocity.

Wavelength-Loss Test

The corresponding left and right high-frequency bands, 1B–6B and 2B–7B, at the outside and inside radii of side B are intended for research studies of high-frequency response as a function of stylus force and mass, radius, wear, and other pickup design factors. In this manner the engineer will be able to determine the effect that a particular pickup design may have on high frequency response and record life.

The wavelength-loss bands contain only the high frequencies—20,000, 18,000, 16,000, 14,000, 10,000, and 5000 cps, in addition to the 1000-cps reference level. The recording level of these bands has been purposely placed well below the standard 1000-cps reference level of bands 6A and 7A. To test the wear at the left channel side of the stylus, for example, turn the volume control to normal "loud" level, and the bass control to a minimum setting to attenuate any hum and rumble in the system. Start the pickup at the outside of band 1B. As the voice announcements are made, listen for the just perceptible highest frequency tone. Then repeat this test on band 6B, and again note the just perceptible highest frequency. If it is the same frequency and level as in 1B, then the stylus is probably a fine one and the stylus force is not unduly large. If the just perceptible tone in the inner bands is at a lower frequency, or is considerably less audible than the corresponding tone in the outer band, then the stylus needs replacement or the stylus force should be reduced.

The wavelength loss or the wear test for the right channel side of the stylus employs bands 2B and 7B.

Compliance and Tracking Test

Can your pickup properly track heavily modulated low-frequency tones such as common to organ music and the like? A partial answer to this question will have been provided already by the low-frequency sweep test. Any pickup which passes this test without perceptible distortion is apt to do well even on the heavily modulated passages. A more quantitative answer is given with the aid of band groups 4B and 5B. These consist of 100-cps laterally and vertically modulated grooves, respectively, with progressively increasing amplitudes of modulation.

Band groups 4B and 5B also are helpful in selecting the minimum proper tracking force for a pickup. If the pickup plays all the bands in these groups without evidence of distortion or rattle, then it probably has an adequate margin of safety. You can try to reduce the stylus force of this pickup. On the other hand, if only the first 1 or 2 bands of these groups will play without evidence of rattle or distortion, then probably a greater stylus force is indicated, or there is something wrong with the pickup.

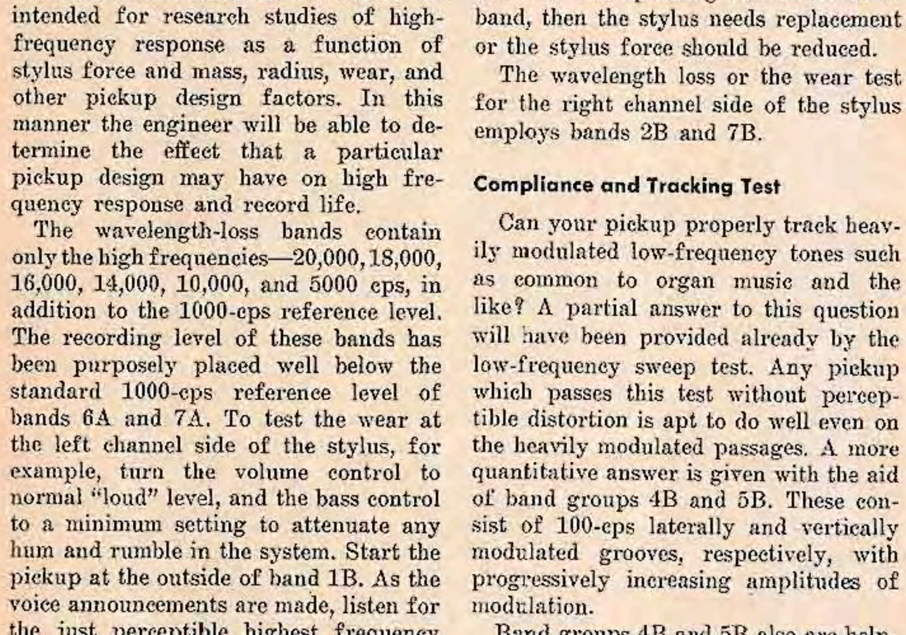

Fig. 6. Crosstalk conditions for different arm resonances.

Lateral and Vertical Compliance

Band groups 4B and 5B also are intended to provide an operational measurement of lateral and vertical compliances. Lateral compliance measurement by means of compliance meter[2] is well known, but a similar meter for vertical compliance has not been made available.

The bands are recorded with lateral (for 4B) and vertical (for 5B) modulation at peak amplitudes of .001, .002, .003, .004, and .005 cm respectively. To measure lateral or vertical compliance, adjust the stylus force, in grams, until the pickup just fails to track one of the respective bands in groups 4B or 5B. At this point the displacement divided by compliance just equals the tracking force. Compliance in cm per dyne is given by the equation:

$$C = \frac{\text{peak amplitude in cm}}{980 \times \text{stylus force in grams}}$$

The lateral compliance determined by use of the bands in group 4B may be at variance from the lateral compliance measured with a compliance meter. This is because the actual force on the groove-walls may vary from that determined with the gram gauge, as a result of the arm friction, side thrust, arm inertia, and so forth.

Conclusion

The STR-100 record brings to the audio specialist and the high-fidelity enthusiast a combination of tools which permit obtaining factual information in a rapid and convenient manner. In addition to the quantitative measurements which it affords, it provides the following important value: Any system capable of playing this record on both sides with correct left-right placement, smooth and extended frequency range, and absence of distortion or evidence of poor tracking will offer strong presumptive evidence of being in "top-notch" operating condition. Æ

Acknowledgement

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[2] B. B. Bauer. "Measurement of Mechanical Compliance and Damping of Phonograph Pickups," Journal of the Acoustical Society of America; 19:2:319, March 1947.