

Cook Binaural Archiving Project

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Abstract: In recognition of Emory Cook being first, in 1952, to commercialize successfully stereophonic recordings on phonograph disks, four of 49 extant were restored using described techniques, with good quality of both the spatial stereo effect and the eclectic location-recorded music.

Background & purpose...

From his innovation in 1952 until realization in 1958 of the 45\45° stereo groove, audio engineer Emory Cook produced and distributed stereo on vinyl LP disks using a separate mono groove for each channel. Some 49 albums were released on the Cook label, the Livingston label (also manufacturer of a twin-head tonearm for their replay), and Atlantic Records. Having pioneered commercial stereo, his work has historic significance worthy of archiving. Not only by restoring one channel as for prior monophonic records, but of both channels in stereo form. Cook recorded seldom in a studio, but mainly on location, and was intent on capturing faithfully both the *sources* of sound and the *acoustic contributions* of their environs, which can account for the greater portion of sound energy. Three audio engineers collaborated on an experiment to come closer to Cook's intent.

Prior stereo on disk were Bell Labs \ Philadelphia Orchestra 1931 dual groove experiments (by Keller & Stokowski) and Decca's vertical/lateral "monogroove." The higher distortion of vertical modulation caused a mismatch that, with a cleaner lateral channel for comparison, caused it to fade in acceptance.

Cook was likely familiar with Blumlein's 1933 patent for a single 45\45° stereo groove, whereby inter-channel phase could be "perfect." Prior work by Keller & Fletcher at Bell Labs was not publicized or Patented until later as being "of no value."¹ Phase invariance of Decca's lateral\vertical *monogroove* would also allow natural-sounding, partly correlated stereo recordings with phantom images spread between speakers. Ultimately, recordings adopted the head-related transfer function (HRTF), a surrogate for human hearing.ⁱⁱ Realization of the stereo groove obviated timing concerns in 1958.² However, Cook's (and others') wide-spaced A-B recordings contain little by way of highly correlated signals, and no inter-channel timing issues were subjectively audible using the methods described next.

The archiving methodology...

Research continued while studio preparations were made. In addition to the angular time relationship of the L & R bands, design of the experiment was concerned with dynamic speed variations of the platter muddying spatial perception by the wandering localization of reproduced sounds using offset pickups. Others have transferred the channels in sequential plays using one tonearm that, after attempting synchronization, introduces time-variant speed errors. The simultaneous pickup method using two offset arms to minimize dynamic stereo phase errors was suggested by Cook himself in his liner notes.

¹ Unknown is whether either knew Keller's prior work at Bell Labs on a 45\45° groove for motion picture sound that, with radio, used 16in transcription disks.

² Timing errors between channels could also be affected by the offset mono heads of Cook's Magnecord PT-6 during both tape recording and playback.

For the experiment, Cook "Binaural" (actually "loudspeaker stereo"³ made using two microphones widely-spaced rather than head-spaced) were ultrasonically cleaned, then reproduced with bespoke 12in (305mm) transcription tonearms, aligned on a Technics SP15 direct drive turntable. Transducers were Stanton 680 with D6800SL Stereohedron line-contact styli, popular among archivists for their fine reproduction, reliable tracking ability, and low wearing of both stylus and groove when tracking at 2³/₄g. These styli & long arms, requiring minimal and non-critical anti-skating force, are known to have never produced a groove "skip" prior to this experiment. Yet two of the eight sides archived could not be tracked straight through, due to severe groove crossover damage, likely caused by previous playings with the dimensionally unforgiving Cook-Livingston twin-head arm. Needed then as now, two pickups trace Cook's grooves separated 1-11/16in (43mm) radially.



At the end of simultaneous replay of separate grooves by two transcription-length (305mm tip-to-pivot) tonearms to minimize dynamic speed variations. The ~136ms offset was lined up digitally. The pickups are Stanton 681\D6800SL Stereohedron.

The next step in the replay process was to synchronize offset audio channels in time to zero the angular difference between the twin pickups. The reference is Cook's far from well-defined line-up impulses, stereo of an acoustic ticking clock. Over the duration on his test disk, the offset between channels drifted by ~450 samples, or approx. 10ms. Listening after synchronization, these ticks seem randomly coming from left or right depending on which is spontaneously earlier (Haas precedence effect). Although human hearing is capable of discerning micro-second timing difference, Cook's music and environmental sound recordings are largely uncorrelated, and thus are audibly immune to greater fixed or varying channel timing differences. His widely spaced "A-B" microphones, separated [quote] "at least 6ft, but up to 100~150ft for a pipe organ," might have mimicked varied stereo speaker placement, and it was the popular technique at the time [used by the author early on]. But Cook may have depended on it to hide sonic timing (phase) issues by capturing uncorrelated signals.⁴

All electronics were solid-state and of professional quality. Two custom preamplifiers provided +4dBu line level signals to the recorder, calibrated by the setup tones on the Cook Binaural Test disk. Affecting signals above 1kHz, Cook Binaural disks use different recording characteristics for each track: the outer

³ Later Cook himself preferred the more accepted term "stereophonic."

⁴ Blauert established that correlated auditory events of less than 14ms are fused into a single perceived sound (used for doubling lead pop vocal tracks.)

(L) channel was played with standard RIAA curve of 1953 and corrected to AES in the Digital Audio Workstation (DAW); the inner (R) channel was played with an archiving preamp with variable HF "rolloff" set to zero dB at 10kHz as Cook specified. Both channels *turnover* <500Hz affecting signals <1kHz.ⁱⁱⁱ

Pickup cartridges for the experiment were 2-channel stereo, so their unequal sensitivities, inherent to some degree in any stereo cartridge, were balanced by gain controls in each preamp before combining signals to mono in order to cancel vertical artifact distortions (which lateral monophonic cartridges ignore physically). Audio wiring was balanced, both from cartridge to preamp and from preamp to the remote-controlled DAW, ~20m to another studio. Replay was conducted with the turntable fixed solidly on a concrete floor, and with the levels of monitor speakers set low during transfer to avoid acoustic feedback.

Prior to ingestion, preamp gains were set using one of the Cook 1kHz tone tracks so that sensitivities to groove signals matched. This revealed the grooves were cut with a disparity in levels favoring the R channel by about ½dB, likely within the precision typical of Cook's day, and deemed not to need correction. Compared to the 1950s, noise of the modern solid-state phono preamps was insignificant; hum, usually caused by ground loops, was nil by the balanced wiring used throughout. Also because the pickups use two coils per channel for induced hum-bucking. Startup in corresponding grooves required each arm to be positioned, then both back-cued from start of audio.

Analog signals were converted to digital by a RME model UFX. The Cook Binaural Test Disk's 1kHz reference tones, with preamp outputs set to +4dBu, corresponded to -13.3dB digital full scale (FS). This allowed for a maximum 12dB peaks ("headroom"), ultimately a mark of fine LPs.⁵ The playback apparatus measured flat ±¼dB to 15kHz. Although the Cook 3-B Lateral Recording System claimed in its marketing a frequency response to 20kHz, signals vanished above 12.5kHz on the spectrographs of any of the disks.⁶ Therefore, and anticipating no more demanding audio than a CD, transfers were sampled at 44.1kHz, but at a 24bit depth (32 bit floating point in the DAW) to allow for artifact-free EQ correction and other digital processing, described next.

Following ingesting, raw audio files were processed using Adobe Audition CS6. A correction of 1.7dB at 10kHz raised the L channel rolloff of -13.7dB of RIAA replay to -12dB of the AES curve specified by Cook. Cuts were high-pass filtered (HPF) at $f_3=30\text{Hz}$ to reduce subsonic rumble. The recordings exhibited maxima of 6dB below digital full scale (FS), i.e. 7dB above reference tones.⁷ No change in level was imposed except the hard-limiting by Cook in mastering, or by 1950s era tape saturation. No level compression, limiting, or FS "normalizing," so that the restorations would reflect accurately the groove mastered by Cook. No EQ was applied to boost bass, which is "weak" despite Cook's use of non-directional mics. For the AES and other public demonstrations, Cook's friend Rudy Bozak provided speakers, known for accentuating bass, possibly causing Cook to err in reducing LF in mastering.

⁵ 12dB matches historically a master tape's highest headroom before saturation (3% 3rd HD), although in Cook's time it was 6-8dB.

⁶ Advertised "frequency range" usually means extremes are -10dB.

⁷ The original headroom for CD product was 16dB, today crushed to as little as 3dB (measured) in the Volume Wars of radio & pop music.

The first recording for commercial distribution in stereo was made September 1952 of trombonist Wilbur DeParis' Rampart Street Ramblers (New Orleans Jazz). Still experimenting with microphone placement, for some cuts, Cook spaced the two mics ~23cm, more separated than head-spaced binaural (~17cm with dummy head, Jecklin Disc omnis, ORTF cardioids). But closer than the 6~10ft of subsequent A-B positioning, used by many others for early stereo, although less common since. However as pictured (unless posed?) the mic pair was too close to the instruments for spatial pickup of the theater's ambience. Other cuts seem spaced at Cook's SOP of 10ft. The left-right orientation on the recording reverses the session photo (which judging by the instruments is correct, again unless posed).



The first recording for commercial stereo-on-disk distribution, Sept 1952, by trombonist Wilbur DeParis' Rampart Street Ramblers (New Orleans Jazz).



Emory Cook (1913-2002, BSEE Cornell, graduate study MIT) mastering twin groove "binaural" strapping two monophonic cutters. In addition to microphone placement, mastering, and replay quality, Cook also sought to perfect record pressing with his low noise Microfusion process, used for his later binaural and 45\45° disks through 1966.

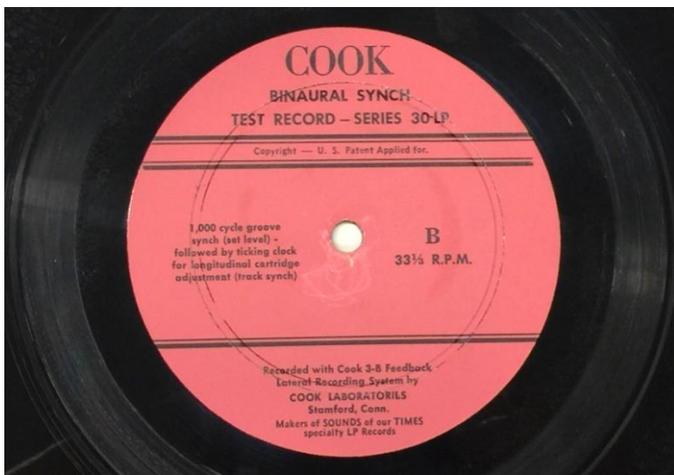
The team also considered mounting two pickups on a linear straight-tracking arm, however alignment would have been as complicated and prone to damaging grooves as the Livingston "double-header." Also the greatly increased tonearm mass

(actually angular momentum) may have adversely affected resonances with the cantilevers, so that notion was dismissed.^{iv}

Before burning a project CD, the mix files heads & tails were faded, de-clicked (non-aggressive inaudible process) to rid ground-in crud that ultrasonic cleaning did not free, and dithered to 16bit. The resulting recordings and metadata are:

1. Rampart Street Ramblers Dixieland A (partial) *Sensation*
Artist name: Wilbur De Paris and his Rampart Street Ramblers
Track title: Sensation 4:16
Album title: Cook Binaural-Atlantic Records 1208BIN
Track number: Side A1 (partial due to disk damage)
Year: ~1955 Emory Cook
Genre: Dixieland jazz
Comments: Archived 2018 by Robin Miller, Filmmaker Technology
2. " side A2 (complete) *Shreeveport Stomp, Tres Montarde* 6:16
3. " B (complete) *Hindustan, When the Saints Go Marchin' In* 10:28
4. Barbara Carroll Trio side A Livingston 1081BN (complete)
The Gentleman Is a Dope, Easy Livin', Alone Together 11:10
5. Barbara Carroll Trio side B (complete) *Making Whoopee, I Can't Get Started, St Louis Blues* 11:00
6. Mozart - *Symph #40 Gm 'Part I'* side A Cook Laboratories 2065BN (partial) - Orchestral Society of Boston \ Willis Page 2:53
7. " B (complete) Mozart - *#40 'Part II'* 6:50
8. Test Disk side B Binaural Synch Test Record - series 30LP (complete) *setup tone, clicks for syncng L/R channels* 3:18

Knowledge gained during the experiment can serve as a basis for further archiving of Cook Binaural records. The images that follow show the covers & labels of the four (4) disks involved in the project, along with photos of the disk cleaning, ingesting, and audio processing described above.



The Cook Binaural Synch Test Record, series 30-LP: A) "1,000 cycle spirals for adjusting 1-11/16" cartridge spacing; B) 1,000 cycle groove synch (set level) – followed by ticking clock for longitudinal cartridge adjustment (track synch)." Physical synchronization with the Livingston arm required adjusting one stylus point fore & aft relative to the other. Also the nominal 1-11/16in between the L & R cuts and styli.



The first commercial release in Cook Binaural [aka Duplex] stereo, recorded 9/1952. The first cut is overly reverberant, with mics wide-spaced, and where Instruments seem separated at each mic, giving a dual-monophonic impression, not spatial stereo. The 2nd in the same theater reveals little ambience due to close-spaced and close-in mic'ing. The performance is wonderfully energetic!



Barbara Carroll Trio, Livingston 1081BN: Livingston also manufactured the twin-head tonearm. The sound is acoustically "dry," and so is intimate in feel, capturing a small club in which it was likely recorded. A gifted improviser, the pianist herself had gained well deserved recognition.

Mozart Symphony No.40 G minor, Cook Binaural 2065: Part I; Part II, Orchestral Society of Boston, Willis Page conductor. The only release of the set donated by the Cooks to the Ralph Rinzler Folklife Archives & Collections of the Smithsonian Institution. The sound is well played, nicely spatial, including the ambient contributed by a large church or concert hall.



60+ years of crud ground into the disks was ultrasonically cleaned. While dirt clicks and pops were removed, scratch removal was applied in the digital workstation, justifiable because Cook did not intend them!



Custom preamps, not shown for being pretty. Top for the left (outer) band, an RIAA preamp; bottom for the right (inner) band has 10kHz rolloff set to zero as Cook prescribed. Capacitive loading of each of four Stanton 680/681 channels measured ~286pF for flat response of less than $\pm 1/4$ dB to 15kHz from the groove to the preamp outputs. Channel sensitivities were matched before mixing pairs to mono for vertical distortion cancellation.



Two custom 305mm transcription tonearms cued to begin ingesting to digital using a Technics SP15 direct drive turntable having good speed stability. Matched replay called for identical tonearms, pickups, and line-contact styli.

microphones by CAPPS

CONDENSER

CAPPS CONDENSER MICROPHONES are designed and produced for those who can afford or must have the best.

Gracefully styled in soft metallic colors and grey finishes CAPPS CONDENSER MICROPHONES are sensitive and odd quiet distinction to any setting.

- 30-15,000 cps ± 3 db
- Omnidirectional
- Acoustically faithful
- Free from angular discrimination
- Blast proof
- Unaffected by moist atmospheres

Three models to choose from, supplied COMPLETE with preamp, power supply and cables.

Dimensions: $1\frac{1}{2}$ " dia. x 6" long.

CAPPS stretched diaphragm CONDENSER MICROPHONES are the product of many years of engineering and development. They are acoustically faithful, distortion free, omnidirectional, blast proof, and have a smooth frequency response from 30 to 15,000 cps. The excellent transient response in addition to the above mentioned characteristics make them ideal for those who must have the ultimate in acoustical transmission.

Studio models CM 2001 (20 Ohms) and CM 2250 (250 Ohms) also "Professional" model CM 2001—High Impedance.

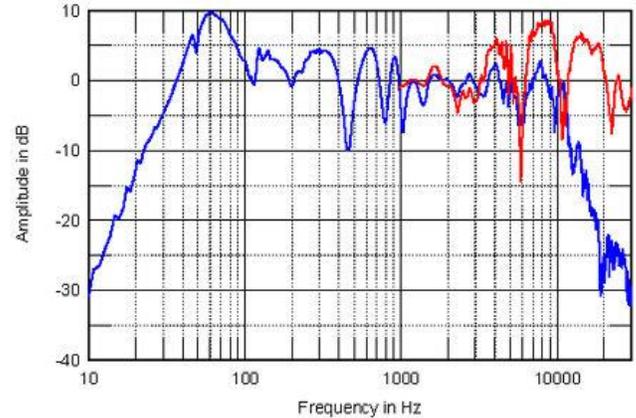
POWER SUPPLY, Model CM 3003
Designed for rugged and continuous operation, the CAPPS Model CM 3003 preamplifier power supply, used with the CAPPS Model CM 2030 or CM 2250 microphones assures the quality performance and dependability which is built into each CAPPS microphone.

CABLE No. 51 (not shown)
Cable connects microphone to power supply, 25 ft. long, equipped with Cannon connector No. P-6-CG-11 and P-6-CG-12.

CM 2001 "PROFESSIONAL" "STUDIO" CM 2030—30 Ohm CM 2250—250 Ohm

the Ultimate in acoustical transmission!

Capps microphone catalog entry for the CM-2250 Cook used, at right above, with specified frequency response " ± 3 dB 30~15,000 cps." Omnidirectional (pressure) microphones are capable of flat LF response and spatial sound.



Frequency response of B-410 "Concert Grand" loudspeakers (with four 12in woofers) developed by Rudy Bozak for demonstrating to AES Cook's 1951 recording (Trains at Night) "to best effect." The large broad peak 40~100Hz averaging 6+dB cf. 400Hz illustrates how Cook may in error have attenuated LF while monitoring, mastering his Binaural disks. [data courtesy Stereophile]

Audio quality – critical observations...

Emory Cook was both ahead of his time and of his time. His legacy recordings are pioneering, but not primitive sounding in our view nearly 70yr later, after a lifetime of advances in the art-science of audio reproduction. He sought very good musicians to participate in his stereo experiments.

Then as now, transducers – microphones, cutterheads, pickups, and especially loudspeakers – had the toughest jobs in audio reproduction. We investigated why Cook's recordings sound "thin;" a subwoofer crossing over at 120Hz is mute for double bass viols in the Mozart and standup bass in the New Orleans Jazz and piano trio. Cook's condenser microphones were Capps CM2250 two omnidirectional made by his friends Frank Capps and Roy Ruth with response specified as " ± 3 dB 30Hz~15kHz, considered flat as condenser omni anomalies typically occur at HF, along with ruler flat LF. However Cook demonstrated using speakers likely developed for him by his friend Rudy Bozak. Known to be bass-heavy as shown above, Cook possibly attenuated LF -6dB to sound correct, as natural sound is believed to have been his intention. The author's ear calls for +6dB compensation <120Hz. Or possibly, before the advent of look-ahead variable pitch and heated stylus cutting, Cook feared overmodulating the groove and reduced the bass. ⁸

⁸ For 45/45° stereo, uncorrelated LF that vertically displaces the stylus are summed to mono (lateral displacement), avoiding hopping out of the groove.

A natural benefit is that Cook's dual mono records had no need for monauralizing bass, as became standard practice with 45\45° disk mastering, high-pass filtering below 150~250Hz [Krepps], so Cook's recordings are stereo over the full range. LF localization across the "soundstage" and "splicing" to subwoofers is more natural sounding than many 45\45° disks.

All restored recordings exhibit the unmistakable sonics of microphones wide-spaced 6~10ft apart. The ~23cm spacing in the posed image of the Jazz septet may have been among Cook's experiments, but there's no evidence of its use, as it would not have separated instruments as exclusively between left & right. Only preserving the left (outer) band would result in the right half the smaller ensembles to be largely unheard. This characteristic is quite obvious in playing only the left channel of the virtuoso septet recording of September 1952 that was Cook's first for commercial distribution in binaural.

The first cut of the New Orleans septet is overly ambient by microphones spaced too distantly from the instruments. While today listeners are habituated to ambience from the front along with direct sounds, one wonders if it was off-putting in 1952. The other cuts are the opposite, too close – reverberance of the theater where they were recorded is mostly inaudible. It may be in the same theater as in the reverberant first cut (and the image), as Cook rarely recorded in a studio.

The small ensemble recordings exhibit an exaggerated "ping-pong" effect practiced by early stereo recordists to make demos that wowed the buying public. Close-positioned, wide-spaced A-B mics cause this, and a characteristic hole in the middle. Instruments seem "assigned" to one side or the other, or jump in between. Centered (middle) sounds might have had randomly correlated signals, but these do not remain centered, somewhat unstable L-to-R with pitch, or are absent.

The piano trio selections are not too distant nor too close. With bass boosted per discussion above, there is good timbral balance among instruments, with the ambience of an intimate jazz club. Carroll's style is lovely, and innovative for the time.

The Mozart specimen exhibits a natural spatiality, mic'd most distantly, perceivably at about the hall's critical radius⁹. The relatively distant pickup contains good stereo ambience, so they do not seem captive inside the speakers.¹⁰ Distortion in the original tape and mastering, comb filtering, and groove damage cause this large ensemble to sound somewhat raspy. The complex signals of an orchestra produce distortions that are most obvious to listeners having live concert experience.

The three specimens suffered groove damage from prior use: clicks & pops from scratches, and so-called "sibilance" added to loudest high frequencies. Occurring more in the R inner groove, they result from the slower linear groove speed, and possibly by a lower compliance crystal cartridge used in the "side-car" head sloppily slamming into the groove walls at the equally shared tracking force as the main pickup. We only imagine the sound before "re-carving" caused this distortion.

⁹ Critical radius (CR) is the distance in acoustic spaces where direct sound and reverberant energies are equal, and beyond which the intensity becomes constant. While direct sound continues to attenuate by the inverse square law at the rate of -6dB/double-distance, it becomes overwhelmed by reverberance.

¹⁰ Close-mic'ing can create an intimate "They are here" impression, but does not transport a listener from the listening room for the illusion "You are there."



Label for the archiving project CD, with cover design echoing Cook releases. Available for educational use via email and PayPal at enquire@filmmaker.com.

Conclusion...

Four of Emory Cook's Binaural records, representing the only stereo on disk widely available from 1952~58, were transcribed in a manner preserving content as original to the groove as possible, improving on known past attempts to recapture this content in stereo form. Not available was the twin-head arm manufactured by Livingston, nor the "side-car" adapter also available in the 1950s that clipped on a single tonearm. It was not the archiving team's choice to fashion a version of either. Two tonearms playing simultaneously for the separate bands minimized dynamic inter-channel timing (phase) anomalies due to instantaneous turntable speed variations, cf. errors from separate transfers using a single arm.

Although processing could have been employed for purposes other than accurately reflecting Cook's intentions, this experiment entailed: no change in level from Cook test disk reference tones; no level compression or digital full-scale "normalizing;" no limiting on top of any imposed by Cook during mastering. Also, no EQ to boost bass perceived as weak, although Cook used pressure microphones known for flat LF response. Cook auditioned with his friend Bozak's loudspeakers known to be bass-heavy, or attenuated the bass for other reasons prior to or during mastering. It is possible that attenuating LF was Cook's and others' practice for safety in cutting, leaving users to compensate with their tone controls or bassy speakers, a *de facto* rewriting of the RIAA standard.

2-channel stereo is often attributed to Blumlein's patent in the 1933, but put on hold through WW2, when Emory Cook was one of the first to rekindle and develop it. He recorded on location using state-of-the-art microphones and a Magnecord PT-6 tape machine with dual electronics and offset half-track heads.¹¹ A disk masterer and maker of monophonic cutter heads, he strapped two together to cut dual groove "Binaural" disks he later called stereo. As restored in this project, these recordings survive as proof also of Cook's prowess recording and pressing music and environmental sounds in stereo.

Knowledge gained from this experiment might serve further archiving, or even re-mastering and re-releasing to contemporary standards & tastes, of Cook Binaural records.

¹¹ Easy, after Magnecord PT-6 machines accommodated a 3rd head, allowing an inverted half-track head for the 2nd stereo channel record and playback.

Acknowledgements...

In the 60th anniversary year of introducing the 45\45° stereo groove that ended the Cook Binaural era of six years, the Cook Binaural Archiving Project 2018 team is R. A. Bruner, G. H. Aykroyd, and R. E. Miller. Mr Bruner was the prime mover of the experiment, contributing his knowledge of Cook's work and collection of Cook disks; Mr Aykroyd the analysis of the Cook twin-head arm alignment & alternatives; Mr Miller the audio work and this paper. The three 70-something audio & video engineers, with combined professional experience of a century and a half, reside in semi-retirement with their spouses in AL, AZ, and PA. Two have yet to meet the third in person!

Thanks to musician and engineer Howard Moscovitz for *lending his ears* and opinions re audio quality for this paper.

A posthumous credit, and the story of two audio pioneers and friends. On 11/11/17 just before the Audio Engineering Society (AES) he helped found in 1948 honored him with a Citation Award, Clair Dwight Krepps was interviewed for the 3rd time by the author for his Phonograph book. Krepps was an inventor, two-time Grammy award-winner, just turned 99, amazingly lucid about anything about disk-making, and Emory Cook's friend, one-time partner, and fellow disk mastering engineer. Regarding Cook's "binaural," Krepps said "I know all about it. We met at MGM\WMGM studios at 701 7th Ave, NYC, mastering radio ETs, like Mickey Rooney & Lionel Barrymore doing Anna Karenina." In 1951, Cook and Krepps lugged the Magnecord PT-6 recorder and mics to the NYC loft of Carroll Music Equipment Rentals' percussion instruments, and Cook told Krepps "Just go around and hit them." Later at a demonstration at the AES Convention in 1953, Krepps says of the response: "All that crashing sounded so good!" Playing the separate grooves was tricky, and "Cook had to try three times to start the demo." Yet new stereo enthusiasts accepted the inconvenience of aligning the twin-head tonearm that, when its settings didn't conform to the grooves, was prone to jumping and destroying them. "There were complaints getting the needles in the right time...it sounded like phase distortion. Cook said it could have been solved." But Krepps never found out what Cook had in mind. P. P. Kellogg of Cornell University, who wanted Krepps to succeed him as department

head, called Cook "One of audio's advanced thinkers." Of great help consulting for this project, unfortunately in the midst of it, Krepps, just begun his 100th year, passed 12/15/17.

Personal notes...

The author has owned, maintained, and used professionally many audio tape machines (including two MagneCORDs) and turntables with multiple arms, cartridges, and styli. Also prior to single groove stereo in 1958, friends Gil Aykroyd & Robin Miller began recording in stereo on tape. In our pre-teens, our parents had given us each a consumer-grade monophonic tape recorder. Anticipating pre-recorded releases, Gil's Pentron had an inline 2-channel record-play head-stack. So naturally we connected the record circuit of Robin's Ampro to the Pentron's 2nd channel head to record environmental sounds and music in stereo. While in the author's memory it was spectacular, it surely was not, due to the wide disparity in tube electronics, microphones (one crystal, one variable reluctance), and single cone speakers. Scotch 111 with its limited overload capability was likely the same tape used by Emory Cook, about whom unfortunately we knew nothing.

At about age 10, I was introduced to Cook binaural at the home studio of a broadcaster, musician (organist at an uncle's church) and audio aficionado, but could only wonder about the strange two-headed tonearm on a huge gear-driven 16in Fairchild broadcast turntable. But owing to piano studies, I totally got the great sound, and was bit by the audio bug.

In grownup friendships with Clair Krepps and well-known mastering engineer Pete Helffrich, I got to observe cutting with a proper Scully or Neumann lathe (and middling Presto at my first radio station job). However I greatly admired those top artist-engineers who did. Somehow, within the seemingly insurmountable limits recording & reproducing "vinyl," they played while cutting their wax or Slacquer masters with heated chisels, variable advance-read depth, and at half-speed. But if at too high a level another percent or two distortion occurred, or they over-filled the side, or cut too low in level for a few dB more noise, or saw under the lathe's microscope a potential groove crossover, they rewound and recued the master tape, inserted a new blank, and started over. Striving for perfection.

Selected bibliography ...

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Cook, Emory - Binaural Disc Recording - JAES Vol1 Iss1 pp1-3 Jan 1953. A synopsis of major factors involved with the recording on disc of binaural sound. Notes are given on radial playback error, recording techniques, testing and alignment methods, and compatibility with existing standards. Placement of loudspeakers for best effect is discussed, as well as the influence of binaural reproduction on quality, loudness, and scope of records.

Cook, Emory - Audio Engineering Society live binaural demonstration ["crashing" referred to above] - JAES 10/14~17/1953

Cook, Emory – Cook Binaural album liner notes and inserts. *Hand-typed theory of stereophonic reproduction, and instructions for proper replay of his records.*

Smithsonian - Folkways listing of Cook titles - <https://www.coursehero.com/file/p26a4tb5/COOK-01-46-Printout-of-Smithsonian-Folkways-webpage-listing-Cook-titles-4-pages/>

Smithsonian collection EAD - <https://sirismm.si.edu/EADs/CFCH.COOK-ead.xml> Recordings (140) - <https://folkways.si.edu/search/?query=cook+records>, <http://sova.si.edu/record/CFCH.COOK>

2013 experiment - Audio & Music Bulletin Rudolf A. Bruil - <http://www.soundfountain.com/cook/cook-livingston-binaural.html>

Roger Russell memoir - <http://www.roger-russell.com/cook/cook.htm>

Pioneers of stereo on disk prior to Keller & Blumlein - https://en.wikipedia.org/wiki/United_Kingdom_patent_394325

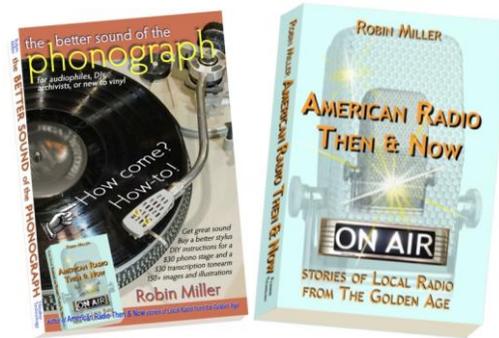
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Robin Miller, R A Bruner - *The Better Sound of the Phonograph: How come? How-to!* www.amazon.com/dp/B071VBY71D, book UPDATES at www.filmaker.com/papers.htm

Robin Miller has presented his work to the Audio Engineering Society, Society of Motion Picture & Television Engineers, Acoustical Society of America, Canadian Acoustical Assn, and German Tonmeisters VDT. His company, Filmmaker Technology, engages in applied research, systems design & integration, and has a Patent for a system of full-sphere 3D recording & reproduction. He has published White Papers and two books: a memoir "American Radio Then & Now," and for vinyl hobbyists to pro archivists "The Better Sound of the Phonograph."

Bob Bruner has worked in broadcasting and professional sound since age 15. He designed and built AM and FM radio facilities, TV production trucks and, before retiring, completed the conversion of WTTW in Chicago from analog to a fully integrated HD production and broadcast facility producing national music & documentary programs for PBS and others. He's restored turntables, and a 1950s era radio control room. He is the editor of the how-come, how-to reference textbook "The Better Sound of the Phonograph."

Gil Aykroyd has experience in audio recording and radio & TV broadcasting beginning at a proverbial "250-watt station in a small town." He served on several PBS technical committees, Philadelphia SMPTE and the Arizona chapter of the Society of Broadcast Engineers (SBE). As director of engineering for two public television stations including #9 market KAET-TV8 in Phoenix AZ, he converted both to digital transmission and high definition, including four times relocating their transmission frequencies in spectrum "repacking" by the FCC



ⁱ White Papers are brief educational, semi-technical surveys on practical topics. Scientific papers, updates, and books by the author are at <http://www.filmaker.com/papers.htm>.
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ⁱⁱ Stereo microphone techniques for capturing interaural level difference (ILD) include coincident XY (aka "Blumlein") and M-S pairs and related Ambisonics (4 mics). HRTF-related techniques for capturing also interaural timing (phase) difference (ITD) include head-spaced ORTF, pinna-less sphere [Theile], 2D surround OCT 5.1 (7 mics) [Theile, Wittek], (Pan-)Ambiophone [author]; and HSD-3D (8 mics) [author]. Spatial choral and movie music use 50cm-spaced omnis (2 omnis) and 100cm-spaced Decca Tree (3 large omnis), respectively.

ⁱⁱⁱ Electro-magnetic cutters & pickups are constant velocity-responding, so for grooved media it is necessary to convert audio signals to approximate constant amplitude to prevent HF amplitudes too small and lost in noise, and LF grooves becoming too wide and cutting into adjacent grooves. The result is groove wobbles approaching the waveform of an oscilloscope display. In 1953, the record industry standardized on the RIAA replay curve, cutting with its inverse. It has filter slopes of 6dB/octave (20dB/decade) except for a plateau an octave either side of 1kHz both to provide a stable reference area, and to limit the amplification range to 40dB instead of the 60dB needed to encompass the full 20~20kHz at that slope.

^{iv} Several tonearm implementations were analyzed before settling on the twin 305mm transcription ones used, having identical geometries, overhangs, mass (angular momentum) re resonance with identical stylus cantilevers. It was determined that they solve most problems in stereo replay of Cook recordings. (Using only ~\$30 in ordinary hardware each and moderate mechanical skills with a drill press, Maker instructions for these arms is in the Phonograph book above.)

The Cook-Livingston two-headed arm geometry is quite remarkable. **With the Right channel set at 12.4mm overhang, phase offset is zero at beginning and end, and less than 1ms at mid track! The downside is that the Left overhang is 33mm.** Instructions with the two-headed arm called for zero overhang and zero offset angle at the beginning of both tracks. However by their ends, the "under-hang" will mean a gradual loss of tangency between the cantilevers and their respective grooves, causing distortion due to mis-tracking to increase gradually from zero at the beginning to maximum by the end.

For the twin arms used, aftertime-aligning the tracks, offset drift from beginning to end of the 39mm tracks geometrically would be 1.97~2.25deg, Left channel lagging. This corresponds to 9.8~11.3ms offset, very close to the measured 10.2ms. Cook's uncorrelated audio is immune to audibility of this scale of phase offset. As mentioned, instantaneous turntable timing errors manifest as random instability of isolated transients between left & right in accord with the Haas precedence effect. For both these sources of phase error, steady state sounds in typical spatial music sounds may mask the timing of many transients.

If Cook's recordings were sensitive to phase offset, the offset/drift from beginning to end of the track could also cause bass cancellation (and comb filtering) to vary over the duration of the track. However we are reporting constant weak bass throughout, whether intentional or in error being misled by bassy monitoring, but that in either case was nicely compensated in the experiment's listening sessions using a constant boost between 40~120Hz to +6dB at 60Hz