

All About The Beam, Baby!



The Apocalypse Now Sessions

After attending a Grateful Dead concert, director Francis Ford Coppola asked Mickey Hart and Bill Kreutzmann to record drum music for his film [Apocalypse Now](#). They improvised the music at the same time a rough cut of the movie was being screened. Some of that music ended up being used on the final soundtrack. The recording sessions took place over a period of ten days. Following that, selections from the sessions were remixed and assembled into the final album.

An unusual percussion instrument built for the sessions, variants of which have been built and later used in Grateful Dead concerts and Mickey Hart's solo touring bands, was "The Beam". This is a large (8 foot in length) aluminum I-beam (actually a "C" shaped beam facing down with the strings across the flat outside-top surface) strung with 13 bass piano strings all tuned to the note of D (a Pythagorean mono-chord at various octaves). The Beam has a heavy-duty bridge and string anchor at one end and a nut with tuning hardware at the other end. It has a movable magnetic pickup block to facilitate capture and transmission of various tonal qualities. The pickup block feeds a volume pedal and various audio effects units, which route the signals through an amplifier or sound system. The Beam generates a large variety of low frequency primary tones and harmonic overtones, and is played by hitting the strings with a percussion mallet, plucking the strings by hand or with a plectrum, scraping them with various implements (fingernails, plectrums, metal bars), or by pounding on The Beam frame itself to induce a bell-like resonance of all the strings simultaneously. [1]



Figure 1. Mickey Hart and the Apocalypse Now Beam (1979)

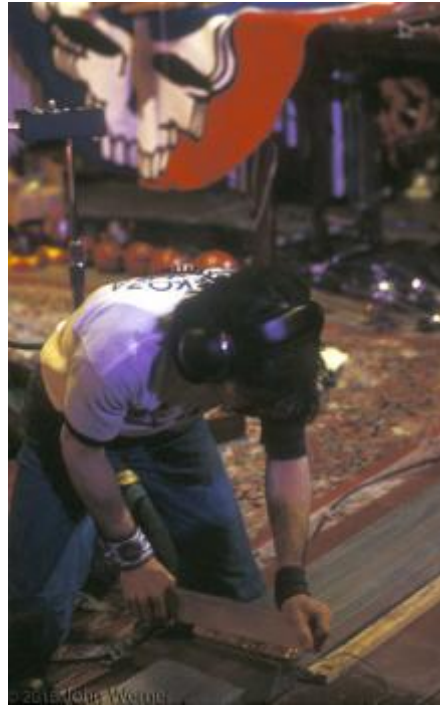


Figure 2. Mickey Hart playing the Apocalypse Now Beam

Alembic

The Beam sound track for *Apocalypse Now* initially contained a loud buzz on the recorded tracks. Mickey declared "The Beam system needs a major overhaul." This would be the first of many sonic updates over the next 36 years. Tom Paddock of [Sound Research®](#), recording engineer working on the *Apocalypse Now* sessions, was tasked with a re-design of The Beam pickup system. Tom Paddock machined Bakelite to create a new pickup enclosure for the

Alembic[2] single-coil pickup. The new case was laminated with soft nickel Mu-metal sheeting[3] to shield the sensitive single-coil pickup from noisy electrical and stray magnetic fields. The Alembic pickup, now encased and shielded, was 10dB quieter when compared with the earlier, exposed single-coil pickup. An MA332[4] op-amp provided 20dB of gain. Beam pickup DC offset and output gain was adjustable through small access holes in the top of the case cover.



Figure 3. Early Mu-metal shielded Apocalypse Now Beam pickup, mid 1980s

The Apocalypse Now Beam pickup was damaged during a subsequent tour and a new, more robust pickup design was required. This time, the pickup case was machined from DuPont Delrin®[5]. In addition, a discrete 24 volt bipolar Deane Jensen discrete JE-990 op-amp[6] was added and the output inductively-coupled through a Jensen JE 11-DM microphone transformer to "quietly" drive a low impedance cable 20 feet to the instrument's volume pedal.



Figure 4. Single-coil Beam pickup design with early discrete component electronics, late 1980s

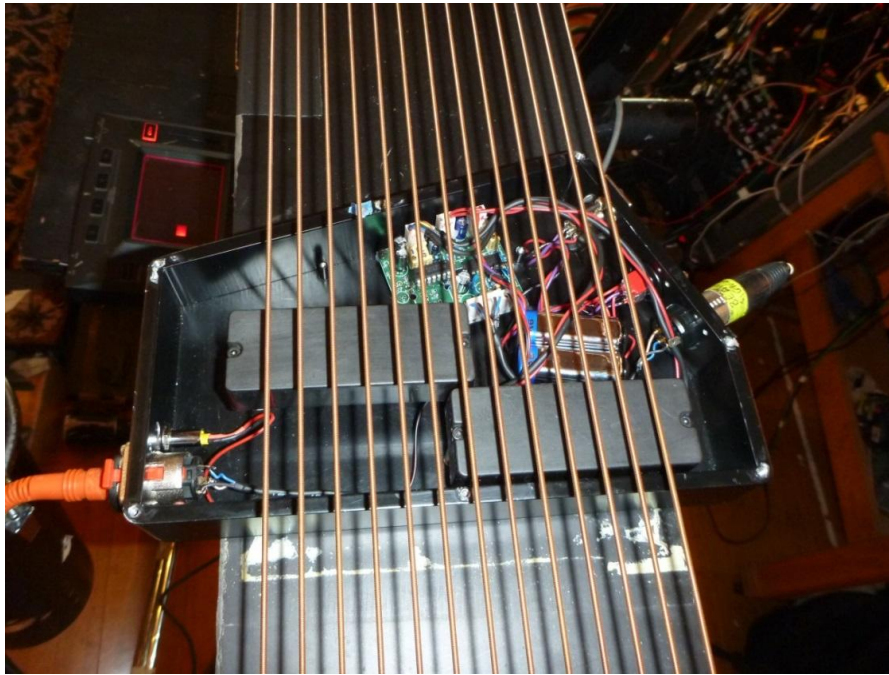


Figure 6. Battery-powered, electronically-balanced hum-bucking Beam pickup

A Klark-Teknik parametric equalizer[9] was added to enhance the treble frequencies which were rolled-off due to the "out of polarity"[10] hum-bucking pickup design. The two new dual-coil pickups were mono-summed and gain-matched to hand-wired electronics to ensure the best possible noise rejection and frequency response. Another Jensen JE-990 discrete amplifier with 18V bipolar power supply rails was selected for lower heat generation and was inductively coupled to the Jensen JE 11-DMCF low impedance output transformer for low bass distortion.

Exxon's Global Seismology Project

In 1988, Sound Research received a call from [Deane Jensen](#) of Jensen Transformers, who asked the technical team to participate in a joint electronics effort for a global seismology project for Exxon Production Research Corporation@[11]. Sound Research's job was to design and fabricate several instrumentation amplifiers that could accurately reproduce Extremely Low Frequency (ELF) signals by Exxon's precision data recorders.

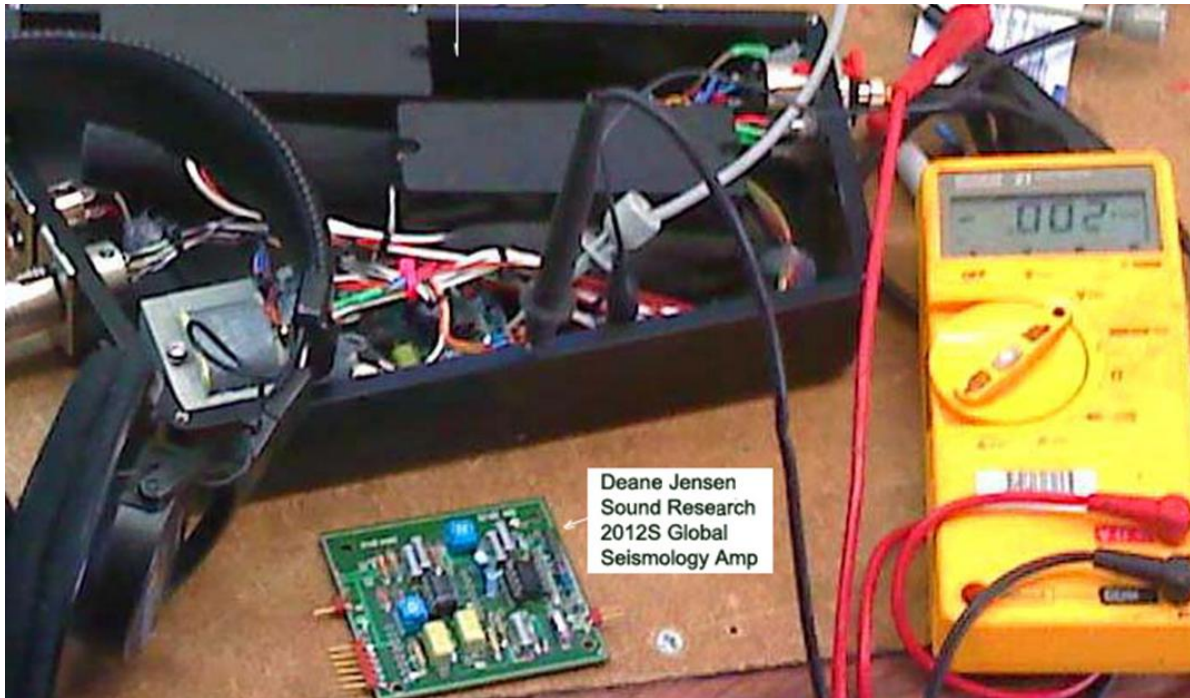


Figure 7. Beam pickup re-design with Deane Jensen and Sound Research ELF Global Seismology Amp

Deane Jensen ELF and The Reality Amplifier

Deane Jensen and Sound Research designed a JT-155K-E[13] transformer-coupled, servo-controlled ELF amplifier system that was linear[14] from 2.5Hz to over 90kHz (@-3dB). The dc-coupled instrumentation amplifier, tested to be superior to eight alternative design submissions, was used by scientists during global seismology surveys to accurately reproduce and capture ELF components of explosion-generated geophysical signals traveling through the Earth's crust. After some modifications, these amplifiers proved to be excellent for full spectrum audio reproduction, a fact further attested to by Jerry Garcia following initial listening tests.

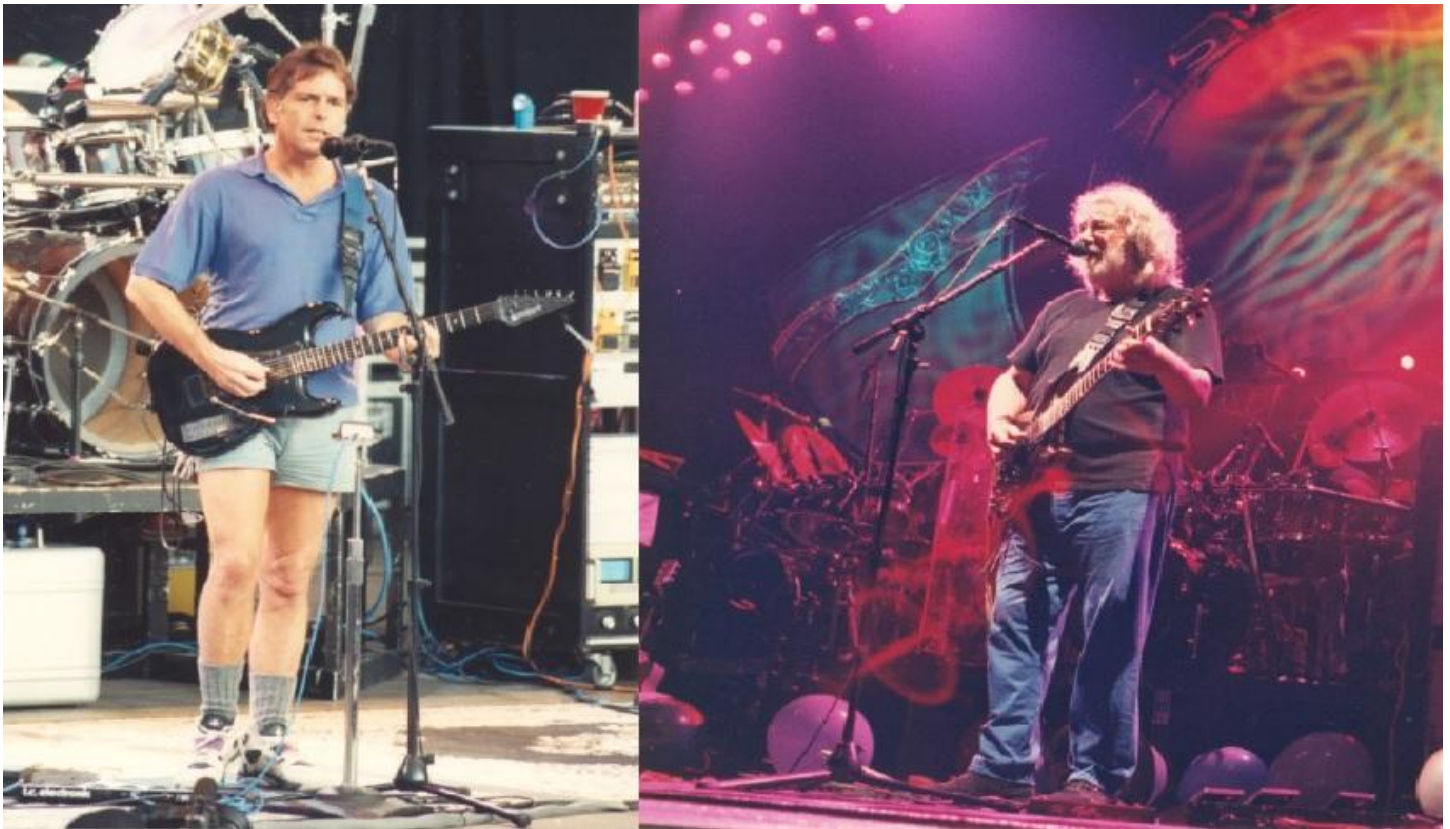


Figure 8. Bob Weir and Jerry Garcia stage systems were powered by ELF and The Reality Amplifier (dead.net photos, 1993 & 1994)

In '93, '94 and '95, Sound Research combined ELF signal generation with another of its newly developed technologies, called the "[Reality Amplifier](#)", into Bob Weir's and Jerry Garcia's stage systems. The Reality Amplifier is a digital processing technology that extends the peak dynamic range of acoustic transducers and enables acoustic products to reproduce the original performance characteristics.[16]

Early versions of the Reality Amplifier, prototyped by Tom Paddock and Morton Lave (CTO of [TC Electronics](#)), were embedded within a special Grateful Dead audio operating system for the legendary TC Electronics M5000 DSP mainframe.[17]

After a successful Grateful Dead tour using ELF signal generation technology and the Reality Amplifier, "[Big](#)" [Steve Parish](#) (Jerry Garcia's manager) ordered a backup system. This system was scheduled to be delivered in late 1995 for the Jerry Garcia Band and for Grateful Dead's winter 1995 tour. The new system was never completed due to Garcia's death in August 1995.



Figure 9. Grateful Dead crewmember [Ramrod](#) standing in front of the Beam

In 2010, for a Rhythm Devils tour, Mickey Hart and Tom Paddock re-designed The Beam system once again, using dual Jerry Garcia modified-ELF amplifiers. At the time, this system was considered to be state of the art, although monaural, with a spectrum of 36.7081Hz to 20kHz (See Figure 10).

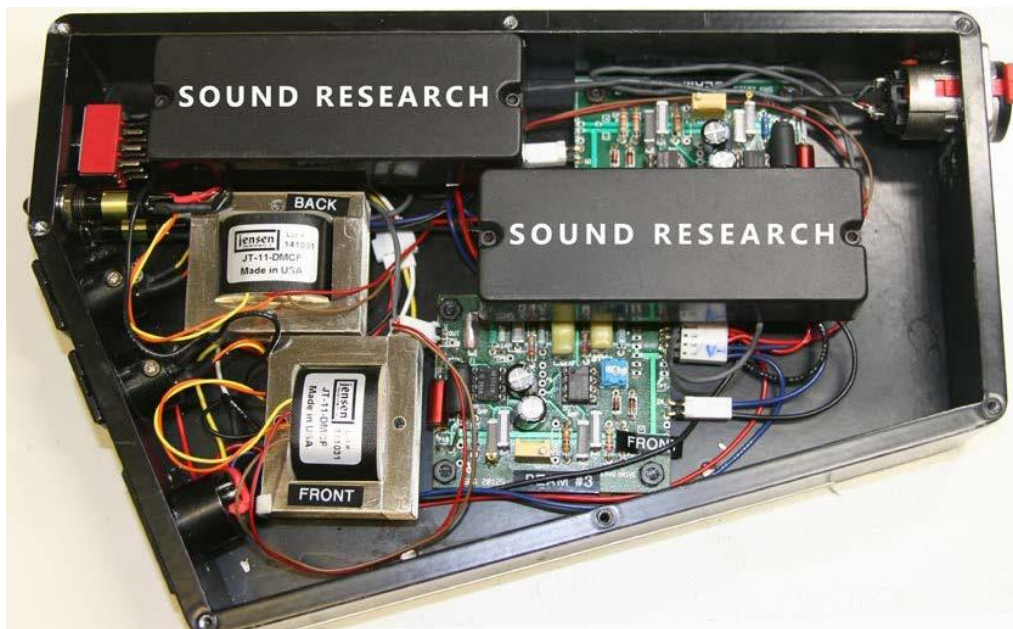


Figure 10. Rhythm Devils Beam pickup design with dual Jerry Garcia modified-ELF Amplifiers

Fare Thee Well: "Celebrating 50 Years of The Grateful Dead" Tour

In January, 2015 Mickey Hart contacted Sound Research and Meyer Sound and asked The Beam team to make ready a surround Beam system for inclusion in the "Fare Thee Well: Celebrating 50 Years of Grateful Dead" tour. Sound Research included the latest Reality Amplifier processing system, shipping today inside millions of PC and consumer products and licensed to [Hewlett Packard®](#) and [Intel Corporation®](#)[18], for unequalled Beam audio bandwidth and dynamic range.

“The Beam will be reproduced by the latest [Meyer Sound](#)® loudspeakers and some new Meyer subwoofers”[19], said Hart. “The stadiums will have surround towers where we will have the ability to reproduce the full audio spectrum.”

The Ultimate Surround Beam Project

Sound Research re-purposed four more of the archived Garcia global seismology ELF amp circuit boards and, along with four new hum-bucking Beam pickups, installed the tech into two water-jet cut, aluminum mono-block Beam pickup housings. The pickup enclosures would be positioned on the top of The Beam in sonically strategic positions (see [Figure 13](#)) for the Ultimate Surround Beam sound field. Mickey and the audience would have the capability of hearing The Beam accurately transmitted by the Meyer Sound quad-surround loudspeakers and subwoofers[19]. The new system was capable of eight discrete outputs.

The overall system frequency response was still limited by the lowest fundamental frequency of The Beam’s drone string. In order to achieve this result at equivalent string tension, The Beam’s low drone string, and The Beam itself, would have had to be [twice its present length](#) (16 feet!).

Sue Swanson and Tom Paddock met with Danny Rifkin, former Grateful Dead manager, in Vienna, Austria, in part, to research the low frequency potential of early Gothic cathedral pipe organs.



Figure 11. Danny Rifkin, outside of [St. Stephen's Cathedral](#) in Vienna, Austria, 2015, poses a thoughtful question to Mickey Hart and The Beam team...“30 foot pipes?”

Like Evan Griffith in “[The Mathematics of Pipe Organ Sound Production](#)”, Tom Paddock reflected on Rifkin’s questioning the need to double The Beam’s actual length in order to achieve the required ultra-low bass characteristics that Mickey had required for the 2015 Grateful Dead Reunion tour.

After abandoning plans for constructing a 16 foot long Beam, the team decided to design a unique resampling, pitch-shifting sub-harmonic synthesizer into The Beam Reality Amplifier that would add the extra ultra-low octave of “Beam” energy, simulating a double-length Beam. The Beam’s lowest notes are sampled, re-sampled, buffered, and then frequency shifted exactly one octave down, time-synced and remixed with original Beam signals. This process

used proprietary, patented virtual reality signal processing techniques[20]. The Beam Reality Amplifier engine allowed the existing 8 foot long Beam to "generate" the required ultra-low bass frequencies, eliminating the need for an extended 16 foot Beam (See Figure 15).

For the 2015 tour stadium shows, Mickey Hart will re-tune The Beam to the following keys:

Levi's Stadium 6-27: A

Levi's Stadium 6-28: E

Soldier Field 7-3: D

Soldier Field 7-4: E

Soldier Field 7-5: E

For "A" tuning, The Beam's fundamental low string has a frequency of 55.0000Hz. The Reality Amplifier will create another octave down to 27.5000Hz.

For "E" tuning, The Beam's fundamental low string has a frequency of 41.2034Hz. The Reality Amplifier will create another octave down to 20.6017Hz.

For "D" tuning, The Beam's fundamental low string has a frequency of 36.7081Hz. The Reality Amplifier will create another octave down to 18.3541Hz.

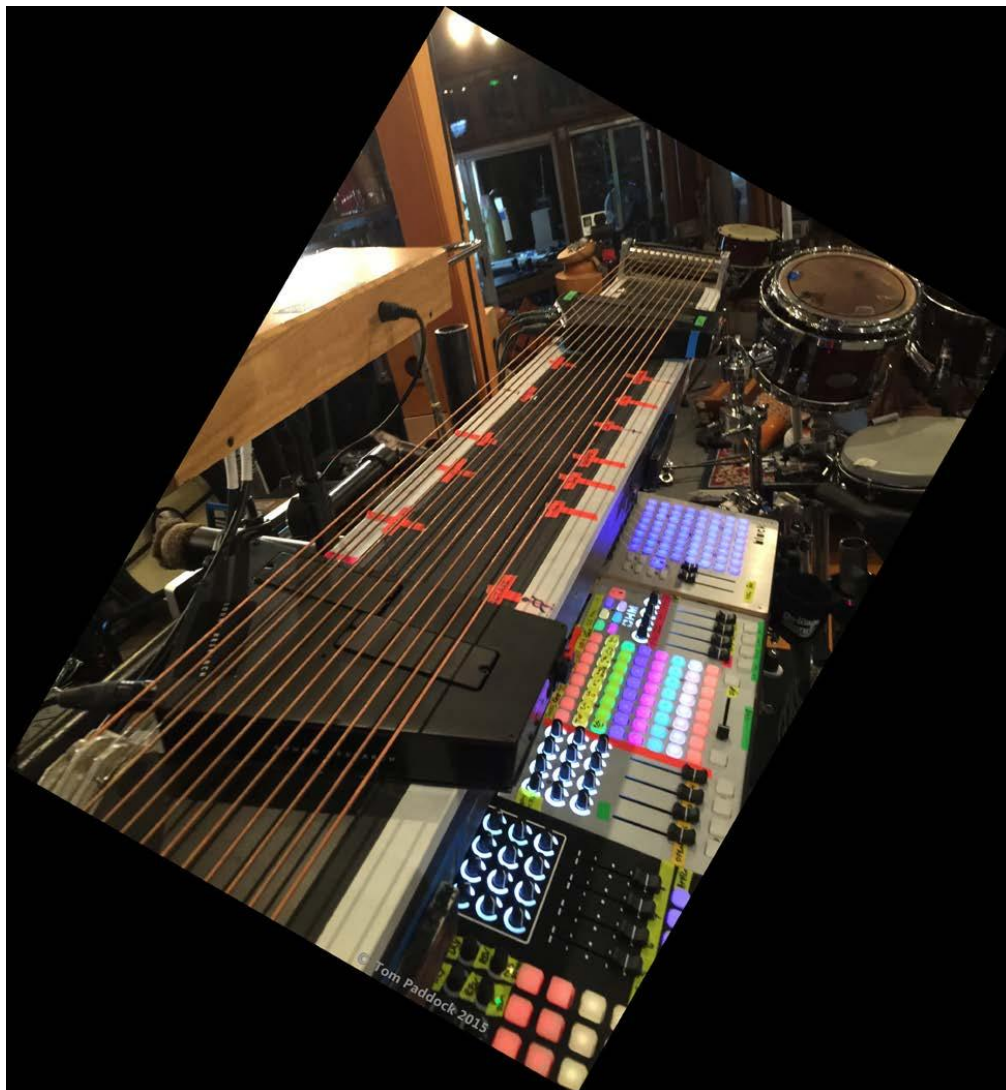


Figure 12. The Ultimate Surround Beam system for the 2015 Grateful Dead tour

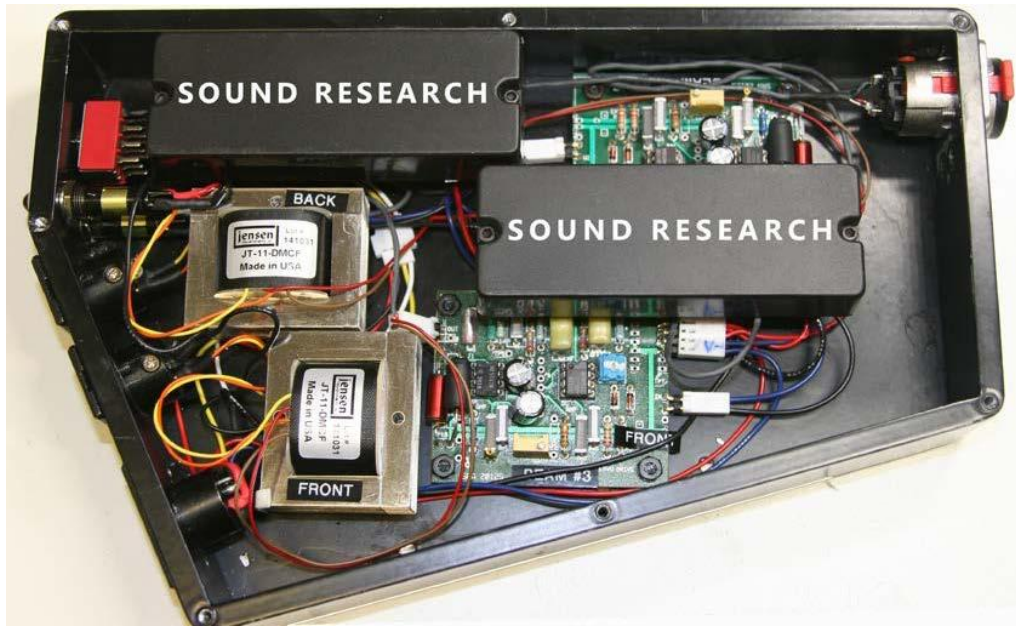


Figure 13. The Ultimate Surround Beam pickup design (1 of 2) with dual Jerry Garcia modified ELF Amplifiers



Figure 14. Reality Amplifier rack powers The Beam w/ ultra-low bass synthesizer

According to [Dennis "Wiz" Leonard](#), sound engineer for the 2015 Grateful Dead reunion tour, "If Billy and Mickey had a patch with [a low 'A'] 55Hz fundamental with elements added to produce an intermodulation beat frequency of both 27.5Hz and 13.75Hz this would produce an audible effect. I created a similar effect in Harry Potter 4 at approximately 19 Hz (I don't recall the exact frequency). This produced a very creepy effect which I refer to as 'Barometric Events'."

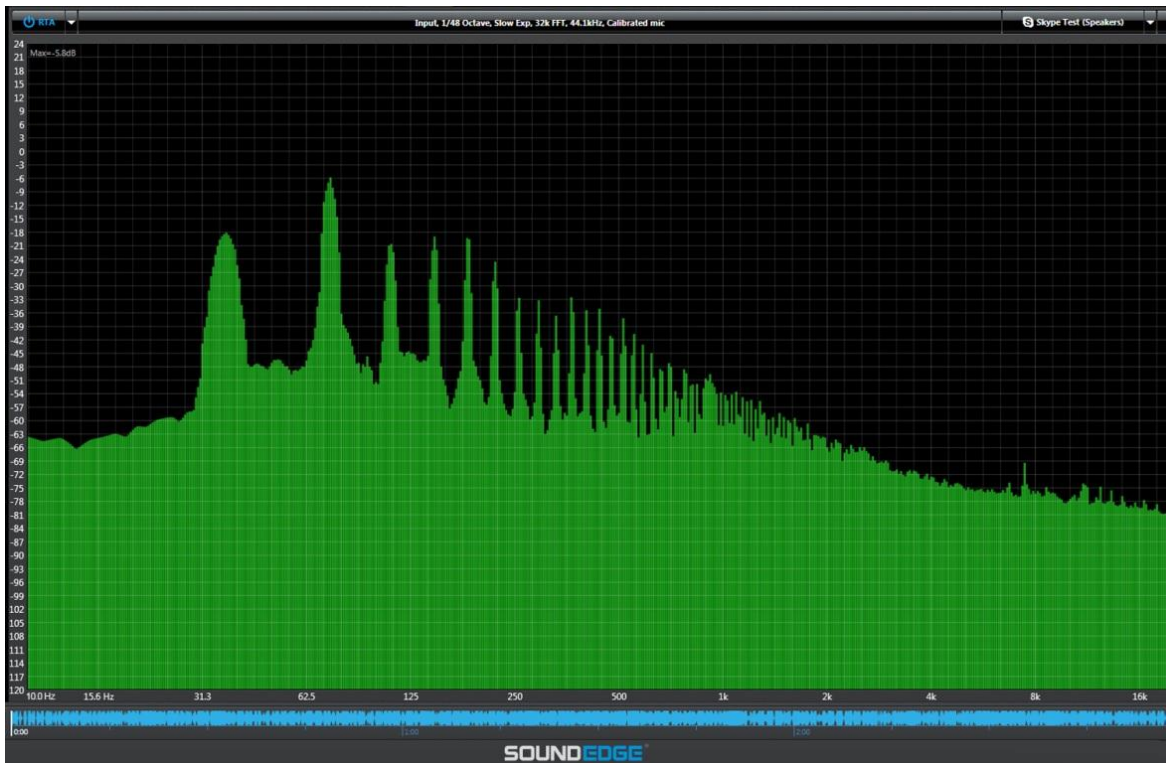


Figure 15. "D" tuning example: 36.7081Hz fundamental with overtones

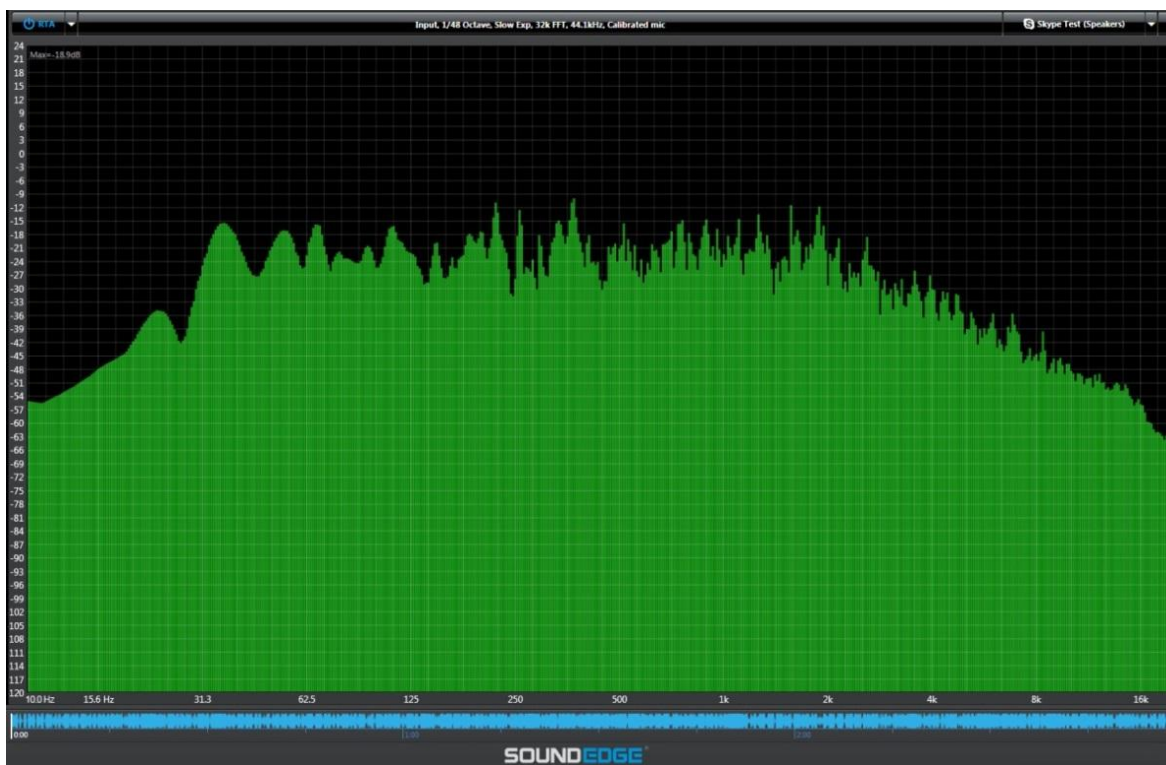


Figure 16. "D" tuning example with the Reality Amplifier: 18.3541Hz fundamental with overtones

Meyer Sound and The Beam

John Meyer and Mickey Hart first worked together on Apocalypse Now, followed by Coppola's 1982 musical film, One from the Heart. Meyer's decades-long association with the Grateful Dead began when the band's original

sound engineer, [Owsley "Bear" Stanley](#), tapped Meyer to create acoustic solutions for the legendary "Wall of Sound" system.

The Meyer Sound [1100LFC](#) subwoofer is the latest in a long line of linear and powerful subwoofers that date back to the late 1970s and Apocalypse Now and iconic early '80s Grateful Dead shows. The two proprietary 18" transducers have a custom-designed extremely high-power magnetic assembly that, when coupled with the Berkeley-designed class H amplifiers, create a subwoofer that is unique in its ability to reproduce sonically clean, extremely low frequencies that the new beam will produce. In addition to the 1100LFC, the subwoofer complement will include Meyer Sound's [700HP](#), which will also produce clean, linear low frequencies without adding any additional sonic coloration. Meyer Sound is continuing research in state-of-the-art transducer and amplifier design which will allow Meyer Sound to continue exploring the fascinating complexities of low frequency infrasonic sound and especially the emotional and bioacoustic effects on human behavior.

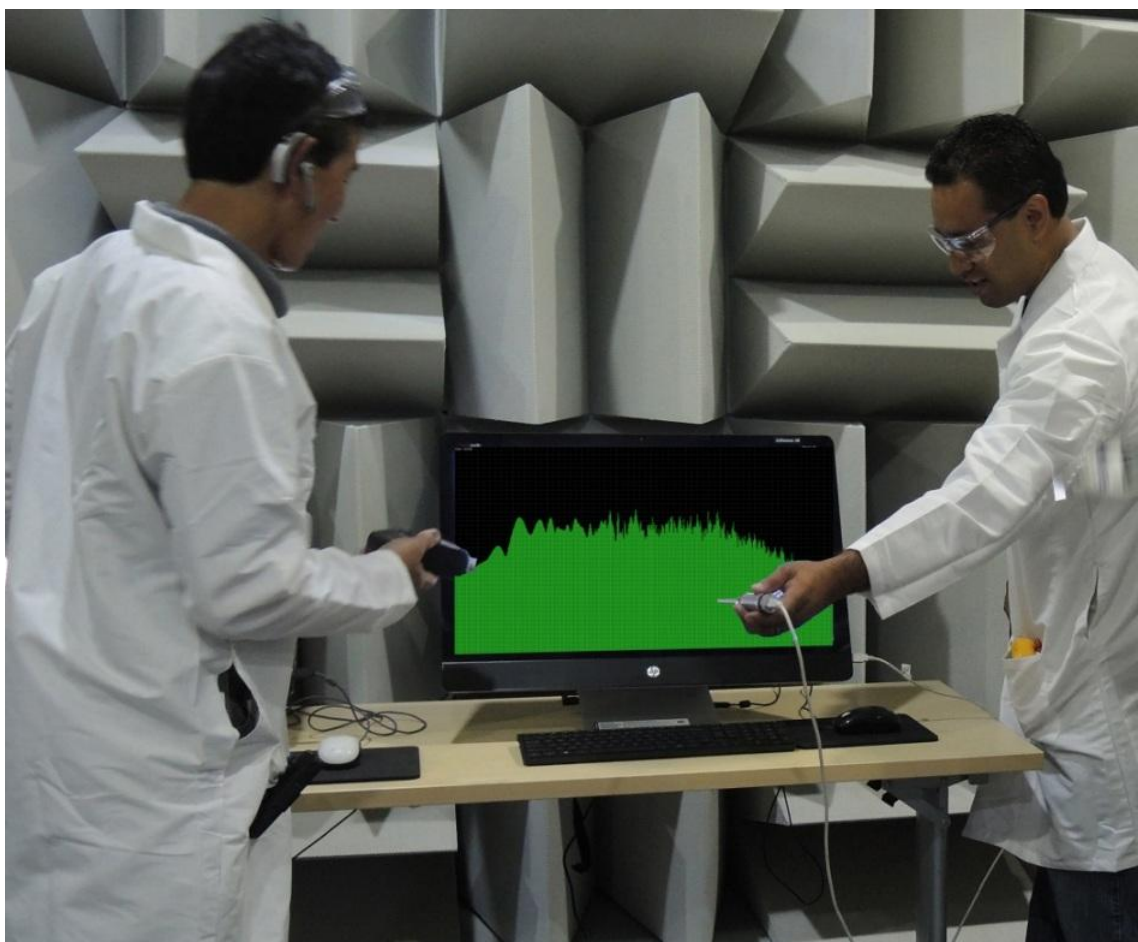


Figure 17. Moses Morales of Intel and Paul Kitano of Sound Research use Sound Edge software to calibrate The Beam at Intel Corporation's Folsom, CA anechoic chamber



Figure 18. The Ultimate Surround Beam is controlled by Hewlett Packard's Envy

A Hewlett Packard Envy TouchSmart™ [21] audio workstation running the Sound Edge™ [22] audio analysis and speaker calibration software from Sound Research includes the Reality Amplifier and manages The Ultimate Surround Beam system. The system's electronics package provides eight channels of +4dBV balanced outputs to drive surround-enabled stadium sound systems, such as the Meyer Sound system used at the "Fare Thee Well: Celebrating 50 Years of Grateful Dead" tour venues at Santa Clara, CA and Chicago, IL[23].



Figure 19. Mickey Hart plays the Beam at Red Rock, April 2015



Figure 20. Tom Paddock calibrates the Ultimate Surround Beam, Hart's Studio X, May 2015



Figure 21. Mickey Hart plays the Beam at Studio X in May, 2015

The Ultimate Surround Beam has a natural, wide sound field with dynamic impact and extended low frequency resolution below audibility, though, as "Wiz" says, it should be possible to hear the intermodulation effects of inaudible and audible Beam frequencies. The Beam sound field is stunning and distortion-free. Mickey Hart's Beam fills the entire audible spectrum and provides dramatic width, dynamic impact and range.



Figure 22. Bird's Eye View of The Ultimate Surround Beam (beneath the video screens) and other instruments at Hart's Studio X



Figure 23. Bill Kreutzmann and Mickey Hart rehearse for the Grateful Dead reunion tour



Figure 24. Mickey Hart and Bill Kreutzmann (with Fred Carlton, audio workstation engineer) rehearse for the Grateful Dead reunion tour



Figure 25. Mickey Hart's domain in Studio X



Figure 26. "The Beam is the only instrument capable of creating audio from 20Hz to 20kHz." ~Mickey Hart



Figure 27. Mickey Hart and Tom Paddock, 2015

Footnotes:

1. From Wikipedia, "The Apocalypse Now Sessions";
https://en.wikipedia.org/wiki/The_Apocalypse_Now_Sessions
2. "Alembic History"; <http://www.alembic.com/family/history.html>
3. "Mu-metal is a nickel–iron soft magnetic alloy with very high permeability suitable for sensitive electronic equipment shields."
 4. MA332 ultra-low noise op-amp from Linear Technology;
<http://www.datasheet.hk/search.php?part=ma332+ic&stype=part>
5. "Delrin® is a crystalline plastic that offers an excellent balance of properties that bridge the gap between metals and plastics" (Acetal Homopolymer); https://www.plasticsintl.com/datasheets/Delrin_150.pdf
6. Circuit design of the original JE-990 op-amp by Deane Jensen of Jensen Transformers. Deane was awarded U.S. patent #4,287,479 for aspects of this design. Later consolidated packaging and production design of the 990 was by John Hardy of the John Hardy Company.
 7. Rick Turner (luthier); https://en.wikipedia.org/wiki/Rick_Turner_%28luthier%29
 8. Rick Turner Guitar Company "The RENAISSANCE line of guitars and basses has never been 'for everybody'. Rick Turner has designed and built each model to fill a specific need.";
<http://www.rickturnerguitars.com>
 9. Klark-Teknik DN410 Analogue EQ; <http://www.klarktechnik.com/dn410.php>
 10. "How to make a Humbucking Pickup for a Guitar";
<http://behindthetone.com/johnfisher/buck/humbuck.htm>
<http://behindthetone.com/johnfisher/buck/humbuck.htm>
11. ExxonMobil Production Company;
<http://www.bloomberg.com/research/stocks/private/snapshot.asp?privcapId=8631784>
12. Ultra and Extremely Low Frequency Electromagnetic Fields;
<https://books.google.com/books?id=llX7AAQBAJ&pg=PR5&lpg=PR5&dq=elf+earth%27s+crust&source=bl&ots=KYOJi1rMu1&sig=190kmAcDCcob52sZoe8ovoCnd9g&hl=en&sa=X&ei=gM2CVYfFI87YggS73rzAAQ&ved=0CDcQ6AEwAw#v=onepage&q=elf%20earth%27s%20crust&f=false>
13. JT-115K-E60; Jensen Transformers Inc., 9304 Deering Ave. Chatsworth, CA 91311 P: (818) 374-5857 F: (818) 374-5856 info@jensen-transformers.com [jensen-transformers.com](http://www.jensen-transformers.com)
<http://www.jensen-transformers.com/wp-content/uploads/2014/08/jt-115k-e60.pdf>
14. "Linear; An amplifier (or speaker) which multiplies the amplitudes of all frequencies by the same factor is said to be linear." <http://hyperphysics.phy-astr.gsu.edu/hbase/audio/amp.htm>
15. "Seismic surveying with an impulse pattern consisting of positive and negative impulses"; US 3326320 A
16. "Reality Amplifier restores digital audio's dynamic impact without introducing unnatural, unpleasant, or fatiguing distortion and related sound field artifacts. Combined with the new audio transducer technologies, Sound Research's Reality Amplifier normalizing algorithms, along with the ability to rapidly prototype and customize those algorithms for challenging new sound module designs, provide truly innovative and game-changing improvements, not only for end users, but also for OEMs and ODMs." Devon Worrell, Audio Architect, Intel Corporation; <http://soundresearch.com/story>
17. "T.C. Electronic M5000 At a Glance"; <https://www.google.com/patents/US3326320>;
<http://www.sonicstate.com/digital/model.cfm?modelID=2344>
18. "Technology...that improves the sound quality of speakers in small, compact environments";
<http://www.pcworld.com/article/2605083/intels-itty-bitty-nuc-pc-prototypes-pack-broadwell-chips-touch-controls.html>;
19. Meyer Sound subwoofer speakers for "The Grateful Dead 2015 Reunion Tour": (14) LFC 1100 left in a column; (14) LFC 1100 right in a column; (22) 700HP center subs; (8) 700HP in the delay towers;
<http://www.meyersound.com>
20. "Acoustical virtual reality engine and advanced techniques for enhancing delivered sound"; Paddock-Barber; Patent#US8676361 B2; <http://www.google.com/patents/US8676361>
21. Hewlett Packard Corporation Envy TouchSmart;
<http://store.hp.com/us/en/pdp/desktops/hp-envy-recline-27xt-touch-all-in-one-PC>

22. "Sound Edge"; <http://soundedge.com>

23. "Grateful Dead Original Members Reunite to Celebrate 50th Anniversary tour";
<https://www.mickeyhart.net/news/grateful-dead-original-members-reunite-celebrate-50th-anniversary-2736>

Author: Tom Paddock; Editor: Dan Davis, Sound Research; Photographer: John Werner; Science advisor: Professor Elizabeth A. Cohen; Grateful Dead Historian: Sue Swanson

Special Thanks:

Mickey Hart, Caryl Hart, John, Helen and Perrin Meyer and Meyer Sound, Jerry Garcia, Bob Weir, Ramrod, "Big" Steve Parish, Rob Taylor, Kidd Candelario, Howard Cohen, Manager, 360 Degrees Productions; Rose Solomon, Administrator, 360 Degrees Productions; Jon Dory, Program Manager, Hewlett Packard; Victor Lee, Sr. Audio Engineer, Hewlett Packard; Maureen Lu, Sr. Audio Engineer, Hewlett Packard; Rose Freeman, Administrator, Sound Research; Moses Morales, Audio HW Enabling Engineer, Client Customer Engineering (CCE) Group, Intel; Devon Worrell, Audio Architect, Intel; Rick Turner, Luthier, Rick Turner Guitar Company; Dave Rittenhouse, Sr. Mechanical Engineer, Intel; Queena Zhou, Audio Engineer, Intel; Edward Gamsaragan, Principal Engineer, Intel; Tim Prince, VP Product Development, Sound Research; Jes Dory, Webmaster, Sound Research; Paul Kitano, Sr. R&D engineer, Sound Research, Kristin Kosak, Technical Administrator, Sound Research; Edward Abramian, Chief Scientist, Sound Research; Dr. Charles Chin, Senior Architect and Regional Manager, Sound Research; Srikanth Potluri, Program Manager, Intel; Peter Kowalczyk, DSP Engineer and Acoustics, Chuting Su, CTO, Realtek Corporation; Sound Research; Ty Kingsmore, Audio Engineer, Marketing Manager, Realtek Corporation David R. Schwind, Sr. Audio Systems & Acoustics Technical Advisor, Sound Research; Scott Bair, Audio Architect, Intel; Gayle Martin Sanders, Technical Acoustics Advisor, Sound Research; Ted Roby, Network Operation, Sound Research; David Lai, Network Operations, Sound Research; Edward Weller, Technical Writer and Patents, Sound Research; John McCabe, Acoustical Mechanical Consultant, Sound Research; Zeke Brown, Electrical Engineering Candidate, Sound Research; Mike McGinn, engineer, TRI Studios; Dr. Peter Brown, Voice Advisor, Sound Research; Maureen Dorney, Legal, Sound Research; Marilyn Blankenship, CPA, Sound Research; Feng Shengzhen, Acoustics and Audio software, Sound Research; Lars Risbo, Acoustics Advisor, Sound Research; Larry Telford, Legal, Sound Research; Mike Johnson, Facilities, Sound Research; Mike McGuire, digital consultant, Rachel Anne, digital consultant.

Sound Research has brought together a team of industry leaders in acoustics and advanced technologies with the goal of creating product excellence and disruptive innovation in the rapidly expanding field of sound.

©2015 [Sound Research Corporation](#) Press inquiries: dan@soundresearch.com