PATENTED ELECTRIC GUITAR PICKUPS AND THE CREATION OF MODERN MUSIC GENRES

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INTRODUCTION

The electric guitar is iconic for rock and roll music. And yet, it also played a defining role in the development of many other twentieth-century musical genres. Jump bands, electric blues and country, rockabilly, pop, and, later, soul, funk, rhythm and blues ("R&B"), and fusion, all were centered in many ways around the distinctive, constantly evolving sound of the electric guitar. Add in the electric bass, which operated with an amplification model similar to that of the electric guitar, and these two new instruments created the tonal and stylistic backbone of the vast majority of twentieth-century popular music.[1]

At the heart of why the electric guitar sounds so different from an acoustic guitar (even when amplified by a microphone) is the "pickup": a curious bit of very early twentieth-century electromagnetic technology.[2] Rather than relying on mechanical vibrations in a wire coil to create an analogous ("analog") electrical energy wave as employed by the microphone, "pickups" used nonmechanical "induction" of fluctuating current in a wire coil resulting from the vibration of a metallic object in the coil's magnetized field.[3] This faint, induced electrical signal could then be sent to an amplifier that would turn it into a much more powerful signal: one that could, for example, drive a loudspeaker. For readers unfamiliar with electromagnetic principles, these concepts will be explained further in Part I below.

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1 *See, e.g.*, THE WRECKING CREW! (Magnolia Pictures 2015).

2 *Invention of the Electric Guitar*, LEMELSON CTR. SMITHSONIAN NAT'L MUSEUM AM. HIST., http://invention.si.edu/invention-electric-guitar/p/35-invention (last visited May 28, 2016).

3 Kurt Prange, *How Guitar Pickups Work*, GUITAR PLANET MAG. (Sept.1, 2011), http://www.guitarplanet.eu/how-guitar-pickups-work.html.

Amplifiers of the early twentieth century were exclusively vacuum-tube circuits because the transistor—and hence "solid state" circuits—had not yet been invented.[4] Tube amplifiers have many virtues as "warm" and "natural" sounding systems, but they also have serious drawbacks.[5] Most notably, they often "clip" the signal—that is, cut off some of the amplitude peaks—resulting in a distorted sound even at fairly low volumes.[6] As tubes are "overdriven" when pushed too hard in a circuit, they also add extra harmonics to musical tones.[7] This played a role in what often sounds like the "honky" and fuzzy tone of early recordings from the 1920s and '30s.[8]

Combined, the electric guitar pickup and tube amplification generated what was originally viewed as a flawed and even unpleasant tone for some, until it became the signature sound of musicians pushing the boundaries of existing musical genres. But as much as the pickup was a solution to a problem posed by a small niche of musicians, it was equally an off-shoot of the explosion in sound-amplification inventive activity unleashed by Alexander Graham Bell's and others' pioneering work in harnessing "galvanic" forces to transmit sound. Thus, the "transducer"—a thin flexible diaphragm attached to a wire coil within a magnetic field that vibrated in response to sound waves striking the diaphragm to induce a faint electric signal—soon became but one way of transforming acoustic sound waves into electrical ones.[9] The pickup was one of these experimental methods and hardly the most successful at its outset. This made it more of a technician's solution in search of a problem. The volume limitations of the otherwise popular acoustic guitar, together with the relative ineffectiveness of early microphones to amplify it, made the guitar a perfect candidate for this fringe "electromagnetic pickup" approach.[10]

Once the unconventional tonal palette of an "electric guitar" (as well as other electric stringed instruments) became accepted in some quarters of the music world, a major invention race took off—first amongst upstart, electric instrument music companies and then soon involving major, established instrument manufacturers such as Gibson. While this race involved fascinating series of inventions in instrument bodies, strings, amplifiers, electric instrument cables, and ultimately "pedal" or "outboard" signal processing devices such as wah-wah pedals, distortion boxes, and time shifting

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4 Michael Riordan et al., *The Invention of the Transistor*, 71 REV. MOD. PHYSICS 336 (1999) (noting that the invention of the "point-contact" transistor—the first transistor—occurred in 1947).

5 Eric Barbour, *The Cool Sound of Tubes*, IEEE SPECTRUM (Jan. 4, 1999), http://spectrum.ieee.org/consumer-electronics/audiovideo/the-cool-sound-of-tubes.

6 *Id.*

7 *Id.*

8 Microphones of the time were run through tube pre-amplifiers to provide enough signal to drive acetate and later tape recording devices.

9 TEEMU KYTTÄLÄ, SOLID-STATE GUITAR AMPLIFIERS 242 (2008), http://www.jeanpierrepoulin.com/PDF/transistor.pdf.

10 *Invention of the Electric Guitar*, *supra* note 2.

circuits (reverb, delay, flange, and chorus), the patent competition for new and improved pickups was at the heart of the electric guitar revolution. With significant revenues at stake as the new electric music genres exploded, the patent system provided the basis upon which inventors, manufacturers, and investors could commit significant resources to intense, and often quite high tech, research and development ("R&D"). But equally important to the R&D race was the fact that these new devices required professional manufacturers to put them into scaled-up commercial production as only a very few musicians could—or would—hand wire their own pickups, build their own amps or guitars, etc. While not rocket science, by today's standards the new electric instruments and amplification were very much futuristic technology of the time, advancing along the leading edge of electrical engineering.

This Essay provides an overview of how patents thus played a core role in developing world-changing musical genres. This may be surprising, as normally copyright law is associated with incentivizing advances in the creative arts.[11] But as this Conference's theme and presentations emphasize, the whole range of intellectual property ("IP"), especially when viewed as a platform, supports innovation across the spectrum of human ingenuity and creativity.[12] This Essay is also intended to be read in conjunction with a viewing of the live-music demonstration of how pickups transformed popular music, delivered at the Conference and available at the Center for Protection of Intellectual Property's YouTube channel.[13]

Part I of this Essay explores how the electric guitar pickup emerged out of the turn-of-the-century invention gold rush in sound amplification and reproduction by electromagnetic means. Part II then explains how limitations of this new technology, combined with limits of the tube amplification of the time, created the unusual tonal aspects of the electric guitar. It also considers how patents were crucial to creating incentives for professional manufacturers to enter into commercial production of sophisticated gear that most guitar players could not—or would rather not—build at home for themselves. Part III argues that this new sonic palette inspired not only rock and rollers, but also a wide range of musicians and artists to modify existing genres of music, as well as to create entirely new ones. In this way, the "bugs" or limitations of this new sonic technology turned into

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11 Shyamkrishna Balganesh, *Foreseeability and Copyright Incentives*, 122 HARV. L. REV. 1569, 1572 (2009).

12 Content from this Fall 2015 Conference—produced by the Center for the Protection of Intellectual Property (CPIP) at the George Mason University School of Law—is available at *The IP Platform: Supporting Invention & Inspiration*, CTR. PROTECTION INTELL. PROP., http://cpip.gmu.edu/conferences/2015-fall-conference/ (last visited May 28, 2016).

13 *CPIP 2015 Fall Conference – Clip 6: Prof. Sean O'Connor*, YOUTUBE (Apr. 12, 2016), https://www.youtube.com/watch?v=8m7LKQPCHS0&feature=youtu.be [hereinafter *Guitar Demonstration*].

"features" that inspired and defined new musical genres.[14] Part IV reveals a surprising twist: even as far more accurate and "natural" sounding amplification systems were developed for acoustic guitars in the late twentieth century, the electric guitar sound was so well entrenched as its own kind of instrument that today's acoustic and electric guitars simply sit side by side as related-but-different instruments.

Finally, the Conclusion sums up the role of the patent system in incentivizing the musical and technical geniuses who conceived and reduced to practice what would become not only a major new family of musical instruments, but which also led to important new musical genres. It also points out the happy, historical happenstance that the development of the electric guitar represents: if better—meaning more accurate—guitar amplification systems had been possible in the 1930s-50s, the distinctive growl and vocal tone of the electric guitar, as well as so many of the most popular new music genres of the twentieth century, may not have been created.

I. THE EXPLOSION OF ELECTRICAL SOUND INVENTIONS FROM THE MID-1800S TO EARLY 1900S

Beginning with Samuel F.B. Morse's development of the telegraph in the early 1800s, scientists, inventors, and creators sought ways of using the newly harnessed forces of electricity and magnetism to communicate information and sounds.[15] Morse himself was a graphic artist and not a scientist or engineer, although he did invent other mechanical devices before the telegraph.[16] But the greater integration of arts and sciences in the late Enlightenment formed an intellectual milieu that carried into the nineteenth century, as "Renaissance" individuals kept up on the latest developments in a number of fields and used those to advance their own new idea and creations.[17] This Part first briefly explores the invention race to capture, transmit over distances, and then reproduce sound using the rapidly progressing science of electromagnetism.

A. *The Invention-Based Race to Translate Sound Vibrations into Electromechanical Signals Capable of Reproduction over a Distance*

Morse's telegraph relied on making and breaking an electrical circuit. The tap-tap-tap of Morse Code, the language created to correspond to the

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14 *Invention of the Electric Guitar*, *supra* note 2.

15 Christopher Beauchamp, *Who Invented the Telephone?: Lawyers, Patents, and the Judgments of History*, 51 TECH. & CULTURE 854, 860-61 (2010).

16 *See, e.g.*, PAUL J. STAITI, SAMUEL F.B. MORSE (1989).

17 Beauchamp, *supra* note 15, at 860-61.

clicking sound created by opening and closing an electromagnetic circuit, was necessitated because of the conception of the telegraph as a binary system.[18] There were only two states: current flowing, current stopped. In some ways, this was essentially a digital system in its use of binary states that can be conceived of as an early version of the modern "0s" and "1s" of digital, information-processing systems.[19]

By the mid-1800s, scientists and inventors were trying to harness this telegraphy system to transmit modulated sounds, such as voices, rather than simply clicks. Johann Philip Reis worked from the insight that make-and-break circuits could be made to click rapidly enough that they could be perceived as tones and not just clicks. For example, using the later-arising measure of *hertz*—sound or electromagnetic wave cycles per second—an electromagnetic armature opening and closing at the rate of 440 hertz would produce something that sounded like an "A" musical tone. The problem was that natural sound waves are *continuous* undulations represented by forms like the sine wave. While the *amplitude* of the wave—the total variation between its low state and its high state—might stay the same, *pitch* or *tone* results from the *frequency* by which the wave oscillates from low to high state. In natural sound, the wave smoothly and continuously increases and decreases between high and low states, similar to *crescendo* and *diminuendo* in musical passages. In Reis's system, the tone produced was harsher and cruder sounding because the oscillations were instantaneous.

The core of Alexander Graham Bell's invention for his telephone patent was the insight and application of a continuously varying electrical signal that he called "undulatory."[20] Such an electrical signal could be, in theory, perfectly *analogous* to the original sound waves transmitted acoustically through air. This, then, is the origin of the modern distinction between *analog* and *digital* sound reproduction: Bell wanted the electrical signal to continuously and smoothly vary in both intensity and frequency to track fully the frequency and amplitude of sound waves; Reis sought to approximate the effect of the waves by using binary clicks that varied instantaneously and discretely only as to frequency. In the famous consolidated patent litigation over inventorship of the telephone, *The Telephone Cases*,[21] the U.S. Supreme Court found that this difference in the fundamental operative principle both distinguished the two inventions and enabled Bell's

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18 Morse Code itself is conceived as having three states: long click, short click, and silent. But these are generated by binary electrical states of current or no current. Holding the current open caused the armature to keep clicking quickly, allowing the receiving operator to perceive it as a long sound.

19 CHRISTOPHER COLEMAN, AN INTRODUCTION TO RADIO FREQUENCY ENGINEERING 19 (2004).

20 U.S. Patent No. 174,465 (issued Mar. 7, 1876). This was contrasted both with what he called "intermittent" (make-and-break circuits like that of Reis) and "pulsatory" (which did not break the circuit, but were still based on near-instantaneous alternations between high and low states). *Id.*

21 126 U.S. 1 (1888).

design to reproduce articulable speech, whereas Reis's (at least as demonstrated in court) would never be able to do so.[22]

A further invention was required to create this perfectly analogous electrical wave: the transducer. Bell's patent disclosed an ingenious system of mirror image metal armatures attached to flexible membranes in proximity to electromagnetic wire coils. On the speaking side, the acoustic sound waves produced by the human voice vibrated the diaphragm, to which the armature was attached. As the armature then vibrated, it induced a variable current in the coil. This variation occurred both in terms of amplitude and frequency. The resultant signal was continuous, analogous to the original sound wave forms, and was just powerful enough to carry over a wire to the receiver device. At this other end, the process worked in mirror image. Now the electromagnetic coil induced movement of the armature, which, being attached to a flexible membrane, caused that membrane to vibrate quite similarly to how the transmitter membrane vibrated in response to acoustic sound waves. The receiver membrane then reproduced the acoustic sound waves in the earpiece. Granted, this was a low-level signal, which was why the original telephones had a horn-shaped earpiece—to get the most out of the weak sound waves created by the electromagnetic signal.

While Bell disclosed only the electroacoustic transducer described here, in practice he had initially used a "water transmitter" that may have been invented by Elisha Gray.[23] That device used water with added acid that changed the conductivity of the water, such that its electrical resistance (usually measured in ohms) could vary measurably in response to a rod or lever that was placed in it. By having the rod move in response to external vibrations, while an electrical charge was applied to the water, an undulating or varying electrical signal could be generated by the transmitter. Bell apparently used the water transmitter when he made his famous statement to his assistant Watson: "Mr. Watson—come here—I want to see you."[24] But in all public demonstrations he used other electroacoustic transducers.

Meanwhile, Gray and others were equally interested in creating electroacoustic musical tones. And even Bell disclosed some of the attributes of his telephone in terms of musical tones and intervals, such as a major third (and its frequency ratio). In fact, even Reis's "telephone" worked reasonably well to transmit sung, musical tones. However, it simply could not pro-

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22 *Id.* at 545 ("[Reis] failed to transmit speech telegraphically . . . . To follow Reis is to fail, but to follow Bell is to succeed.").

23 Gray was another challenger to Bell's patent. The extensive litigation over the telephone patent will not be detailed here, as there are excellent studies of it in the literature already. *See, e.g.*, Beauchamp, *supra* note 15, at 854-55.

24 JEAN-GUY RENS, THE INVISIBLE EMPIRE: A HISTORY OF THE TELECOMMUNICATIONS INDUSTRY IN CANADA, 1846-1956, at 48-49 (2001); Beauchamp, *supra* note 15, at 854 (noting that Bell's famous expression is often misquoted).

vide the dynamic articulation needed for audible speech, which is more complicated than pure frequency tones. Gray was actually awarded a patent seven months earlier than Bell's telephone patent for an *Electrical Telegraph for Transmitting Musical Tones*.[25] Gray's invention used make-and-break circuits, each set to oscillate at a particular frequency, and each attached to a key to trigger it on and off. In this way, the device could be played like a musical instrument, with the sound being reproduced at the other end of the line through an acoustic, metal, amplifier cone. In many ways, this was the first synthesizer or electrical music instrument and introduced the concept of "oscillators" to generate tones without naturally resonant bodies.[26]

B. *Vacuum Tube Amplification and Loudspeakers*

While there quickly followed many advances in telephony, invention in electrical music instruments was hampered by the lack of signal amplification and loudspeakers. Thus, even though advances in electromagnetic oscillators continued, their signals were of limited value, as they could not be reproduced very loudly. The best method was still the earpiece, so that the weak signals could be concentrated while the listener's ear was shielded from other sounds. Gray allegedly created a primitive loudspeaker for his music synthesizer, but it seems to have been nothing more than an acoustic enhancer, similar to putting a glass to a wall to listen to conversations in the next room.[27] Likewise, the early phonographs—typified by the Victrola—relied on acoustic horns to give some amplification to the otherwise faint sounds coming off the wax rolls and records.[28]

What was needed was a means of boosting the faint electrical signals of the telephone and electric oscillators. While passing through myriad twists and turns on the way, the major breakthrough came with vacuum tube technology. Developed in the first decade of the 1900s, the vacuum tube originated as a diode invented by John Ambrose Fleming to covert alternating current to direct current or to detect radio signals. By the end of the decade, Lee De Forest had invented the triode form that could amplify electrical signals.[29]

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25 U.S. Patent No. 166,095 (issued July 27, 1875).

26 Stefano Fasciani, *History of Digital Musical Instruments*, STEFANO FASCIANI (Aug. 16, 2014), http://stefanofasciani.com/?p=919.

27 In Gray's case, the effect was louder because he used a larger concave device resembling a washbasin. *The 'Musical Telegraph' or 'Electro-Harmonic Telegraph', Elisha Gray. USA 1874*, 120 YEARS OF ELECTRONIC MUSIC, http://120years.net/the-musical-telegraphelisha-greyusa1876/ (last visited June 6, 2016).

28 *History and Types of Loudspeakers*, EDISON TECH CTR., http://www.edisontechcenter.org/speakers.html (last visited June 6, 2016).

29 U.S. Patent No. 879,532 (issued Feb. 18, 1908).

Vacuum tube amplifiers were first used to boost telephone signals for long distance transmission, resulting in the ability to place transcontinental calls. It was then used to convert the turn-of-the-century radio experiments of Guglielmo Marconi and others into commercially feasible devices, as amplification was a necessity for both propagation of the waves in space and audible reproduction of them by receivers. This developed most significantly during World War I.

By the 1920s, microphones had improved from the original carbon models pioneered independently by David Edward Hughes, Emile Berliner,[30] and Thomas Edison[31] in the 1870s to early condenser and moving-coil versions. Following the principle of the water transmitters that Bell and Gray had first used for the telephone, inventors looked to other substances that could create variable currents in response to acoustic sound waves. The carbon microphone became the first commercially successful of these and dominated telephony and the newly emerging radio into the first decades of the twentieth century.[32] While successful, the carbon microphone had clear sonic limitations. In 1916, Bell Labs invented the condenser microphone, which acted as a large capacitor (often also called condensers), and had better fidelity and a fuller range than that exhibited by the carbon microphone.[33] Then, in the 1920s, the dynamic or moving coil microphone was invented, which in some ways was simply a mirror image of the recently developed, dynamic moving coil loudspeaker discussed below.[34]

Loudspeakers had themselves undergone significant changes since the early acoustic-mechanical, low-volume versions pioneered by Reis, Gray, and Bell. Edison experimented with a system using compressed air to drive a membrane, but ultimately gave it up for the passive acoustic horn used on the phonograph. Experiments with dynamic moving coil speakers began as early as the 1870s, but the first practical models were not developed until

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30 U.S. Patent No. 463,569 (issued Nov. 17, 1877).

31 U.S. Patent No. 474,230 (issued Apr. 27, 1877).

32 The carbon microphone used loose carbon granules enclosed between two thin conductive metal plates that formed a kind of pod around them. One plate was a flexible diaphragm that would move in response to air pressure on it. As it compressed the pod space in response to, say, sound waves from a human voice, the carbon granules would cluster together, decreasing resistance as a charge was passed through them. As it released, the granules would move back apart, increasing the resistance of the circuit.

33 A capacitor works by having two conducting plates separated by a thin nonconductive barrier such as paper. A charge applied to one plate can induce a charge in the other, with the level of induction proportional to the proximity of the plates. Thus, the condenser (capacitor) microphone worked by having one plate be flexible and exposed to the sounds waves to be reproduced. As those waves impacted the plate, it would move closer to the other plate, and then return to its original distance as the sound pressure subsided. In this way, an analogously varying electrical signal was created.

34 The dynamic microphone works by attaching an electromagnetic wire coil to a flexible membrane, where the coil is then slid over a permanent magnet. As the coil moves in tandem with the membrane, as the latter is moved by sound wave pressure, it passes back and forth across the permanent magnet, inducing a variable current in the coil.

the 1920s.[35] The dynamic speakers worked on the principle that a varying current sent into an electromagnetic coil, which itself encircled a permanent magnet, would make the coil move reciprocally along the length of the magnet. Attached to a simple membrane, sound would result, but not at particularly high volumes. But shaping the membrane into a cone resulted in higher volumes, somewhat analogous to how an acoustic horn amplifies sound waves. Thus, the new dynamic speakers adopted a paper cone as the membrane. This basic design is still used in most loudspeakers today. In some ways, the mirror-image relationship of today's dynamic microphones and loudspeakers is similar to how Bell's electromagnetic, vibrating armatures and membranes for capturing and then recreating acoustic sound waves were themselves mirror images of each other.

As all of these different technologies—microphones, amplifiers, and loudspeakers—came to commercial feasibility in the 1920s, they created a whole new industry of public address, sound reinforcement, and sound projection systems. This radically transformed the fields of news, politics, music, and theater, as it not only enabled the trained orator, singer, or musician to project sounds much farther—and to a larger audience than ever before possible—but also especially empowered the quieter speaker or crooner and softer instruments to be heard by large audiences. These larger audiences could be measured both in terms of those assembled in a single location and those distributed in different locations, but still within the reach of the new radio transmissions.

II. AMPLIFYING THE GUITAR

One of those quieter instruments that could benefit from electrical amplification was the guitar. Originally a chamber instrument in the same broad category as the ancient lyre and lute, it traditionally was strung with gut strings that produced a warm, rounded, but fairly soft sound.[36] As a versatile instrument that could be played polyphonically (i.e., producing multiple notes from a single instrument)[37] and with a greater dynamic range than other early polyphonic instruments such as the harpsichord and organ, the guitar expanded far beyond its medieval Spanish origins to a wide range of musical settings across Europe and into the New World by the 1800s.[38] This Part first sets out the limitations of—yet interest in—using the guitar in

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35 *History and Types of Loudspeakers*, *supra* note 28; *Loudspeaker History*, AUDIO ENGINEERING SOC'Y, http://www.aes.org/aeshc/docs/recording.technology.history/loudspeaker.html (last visited June 6, 2016).

36 Paul Guy, *A Brief History of the Guitar*, GUITAR HANDBOOK, http://www.guyguitars.com/eng/handbook/BriefHistory.html (last visited June 6, 2016).

37 *Polyphony and Monophony in Instruments*, WIKIPEDIA, https://en.wikipedia.org/wiki/Polyphony_and_monophony_in_instruments (last updated Mar. 13, 2016).

38 *Id.*

large venues, as well as the historical happenstance that made it an ideal candidate for an alternate form of amplification.

A. *Limitations of Existing Acoustic Guitars for Mid-to-Large or Noisy Performance Venues*

The multiple forms of guitar that developed in medieval Spain were themselves descendants of an ancient tradition of chordophone[39] instruments that could play not only musical intervals (i.e., two notes in harmonic relation), but also full chords (i.e., three or more notes in harmonic relation).[40] Most other categories of classical instruments are monophonic, such as horns, or limited to intervals, such as the bowed string instruments in the violin or viola family. The only major, equivalent polyphonic instrument in Western music is the family of keyboard instruments. Of those, the organ is by far the oldest.[41]

Built on very different principles, but still using a keyboard, the harpsichord arose in the late Middle Ages, likely the 1400s.[42] Relying on mechanisms that plucked its strings, the major drawback of the harpsichord was that it had little to no volume dynamics: the strings were plucked with uniform force regardless of how hard or soft the player activated the keys. By the late 1700s, the pianoforte (literally the "soft-loud" instrument) was rapidly displacing the harpsichord because the newer instrument used hammers to strike its strings, which allowed for musical dynamics commanded by how hard (or soft) the player actuated the keys.[43] But despite the overall power and volume of the keyboard chordophones, they still did not allow the kind of tonal and rhythmic nuances and dynamics that could be generated by direct manual contact with strings, especially on the plucking hand.[44] Accordingly, before and then alongside the keyboard chordophones devel-

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[39] Chordophones are instruments based on a vibrating string. *Chordophones*, OXFORD DICTIONARY OF MUSIC (6th ed. 2013); *see also Instruments, Classification of,* OXFORD DICTIONARY OF MUSIC (6th ed. 2013).

[40] Guy, *supra* note 36.

[41] Originating in an early incarnation as the water or hydraulic organ of Classical Antiquity, the organ began assuming its modern form in the early pipe organs of the 1300s. Over the next few centuries, the pipe organ took on—quite literally—monumental proportions in cathedrals across Europe, with some using pipes of up to sixty-four feet in length and up to 20,000 pipes across a range of sizes. *Organ*, OXFORD DICTIONARY OF MUSIC (6th ed. 2013).

[42] *Harpsichord*, OXFORD DICTIONARY OF MUSIC (6th ed. 2013).

[43] *Pianoforte*, OXFORD DICTIONARY OF MUSIC (6th ed. 2013).

[44] For purposes of this Essay, "hand-plucked" is used to signify both finger-style playing, where the musician activates the strings directly with the skin or nails of the hand, and plectrum playing, where the musician uses a small, flat piece of hard-yet-flexible material (wood, bone, plastic, or metal) to activate the strings. In both, the player has far more control of the timbre of the strings vibration, as well as the ability produce harmonic overtones, varied muting, and other sonic effects.

oped an equally wide array of hand-plucked chordophones, including the guitar.[45]

Hand-plucked chordophones were primarily chamber or solo instruments because of their low-volume output.[46] They were especially well suited to songwriting bards for whom the low volume allowed them more easily to sing above the instrument, with the latter providing accompaniment. Guitars proliferated in many kinds of folk music across Europe and the New World, although they were also used for classical pieces.[47]

Around the turn of the twentieth century, a major advance in the guitar's sound and role came about with the advent of steel strings. These were significantly louder than the traditional catgut strings. But they put much more pressure or tension on the instrument.[48] Serendipitously, the German immigrant Christian Friedrich Martin had already established a cost-saving X-brace structure for the top of acoustic guitars in the mid-1800s that turned out also to be much stronger and, thus, could withstand the high tension of the new steel strings.[49] Advances in mass production of steel and wire in the later 1800s likely also played a role in making steel strings affordable, dependable, and predictably conforming to the narrow width specifications and tolerances needed for a set of guitar strings.[50] Strings that are too far off will not have the right tension for the intended tuning pitch. Also, players have to be able to depend on the relative feel of the different strings on the guitar.

Of relevance for the coming development of both electric guitars and new genres of playing, Hawaiian musicians adopted and adapted the guitar in the 1800s for their own purposes.[51] The narrative is that Spanish and Portuguese sailors and cowboys came to the islands in the 19th Century and brought the Spanish guitar with them. But they left before teaching the native Hawaiians how to play the instruments, even as they left some of the instruments behind. The Hawaiians took their own intuitive approach to the

45 Guy, *supra* note 36.

46 *Id*.

47 Darryl Martin, *Innovation and the Development of the Modern Six-String Guitar*, 51 GALPIN SOC'Y J. 86, 87 (1998).

48 *Id.*

49 *Id.* at 89-91.

50 Conventional "medium" steel guitar strings have the following diameters from high to low E strings: .013", .017", .026", .035", .045", and .056". *See, e.g.*, C.F. Martin & Co., *Acoustic Strings*, MARTINGUITAR.COM, https://www.martinguitar.com/strings/ (last visited May 29, 2016) (listing diameters of Martin SP Acoustic, 80/20 Bronze, Medium Gauge).

51 *See, e.g.*, LORENE RUYMAR, THE HAWAIIAN STEEL GUITAR AND ITS GREAT HAWAIIAN MUSICIANS (1996); Andrew Durkota Augustine Bozanic, The Acoustic Guitar in American Culture: 1880-1980, at 132-82 (Spring 2015) (unpublished Ph.D. dissertation) (ProQuest No. 3718319); *A Short History of Hawaiian Slack Key Guitar (Ki Ho'alu)*, DANCING CAT RECORDS, http://www.dancingcat.com/shorthist.php (last visited May 29, 2016); *History of Hawaiian Steel Guitar*, HAWAIIAN STEEL GUITAR ASS'N, http://www.hsga.org/history.htm (last visited May 29, 2016).

instrument and tuned it so that the open strings formed a chord. Standard Spanish guitar tuning is E-A-D-G-B-E, which does not make a (useful) chord, but does allow for versatile and efficient playing in a range of keys. However, it takes significant training to figure out how to play in standard tuning. An open tuning allows the player to play major chords simply by placing one finger across all the strings. But this set-up also would allow for use of a bar that could be slid along the strings to make a beautiful singing vocal tone. Joseph Kekeku is credited with coming up with the use of a bar in 1885—reportedly a bolt he found by a railroad track. Soon many players in the islands adopted the style and then took it to the mainland.[52]

As blues and jazz emerged in America, the guitar was a central instrument, albeit used in novel ways. The new turn-of-the-century steel string acoustic guitars drove innovative styles of playing that emphasized the unique possibilities of steel strings and became synonymous with these new genres.[53] Perhaps following Hawaiian slack key playing or independently inventing it themselves, Delta bluesmen used bottlenecks, knives, and other hard objects to play slide guitar, using the blues scales that formed the basis of their music.[54] This not only allowed the guitar to have more of a fluid singing tone like fretless stringed instruments (such as the violin family whose instruments allow pitch to be varied continuously as opposed to the guitar's fret-by-fret, discrete pitch steps), but also resulted in a whole new kind of tone. The technique emphasized the lead instrument potential of the guitar and went hand-in-hand with a range of alternate tunings, again quite possibly based on the Hawaiian tunings.[55]

At the same time, blues and jazz players began using a dramatic form of vibrato that went far beyond what classical guitar players used and even further than what other string players such as violinists employed.[56] Moreo-

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52 *History of Hawaiian Steel Guitar*, *supra* note 51. The most common open tunings, especially for slide playing, are D-G-D-G-B-D ("Open G" or originally "Taro Patch" tuning) and D-A-D-F#-A-D ("Open D"). These alternate tunings are also referred to as "slack key" because the strings are generally "slacked," or loosened, from their normal tuning tensions. *Id.* It is unclear whether these earliest slide players were using traditional gut strings or the newer steel strings. However, the date of Kekeku's development of the style seems to have preceded the availability of steel strings.

53 Bozanic, *supra* note 51, at 1-6, 202-12.

54 *Id.* at 182-90.

55 *Id.* In fact, two of the most popular blues slide guitar tunings are the same as the Hawaiian Open G and Open D tunings.

56 Classical vibrato is a technique most easily accomplished on fretless instruments such as the violin, in which the player moves or vibrates her finger back and forth in parallel fashion on the string at the fingerboard, resulting in an tremulous, oscillating pitch reminiscent of the human voice when it is intentionally wavered on a held note to add intensity and emotion. The effect is generated on the violin because any movement of a finger holding down a string will change its pitch. But the vibrato effect is supposed to embellish the original note only, not add new notes to the passage. Fretted instruments cannot readily accommodate this traditional vibrato because the fret is what stops the string for the desired pitch, not the finger. Thus, vibrating a finger parallel to the string on a guitar will not change the pitch much, if at all—unless it slides so far that it crosses a fret, at which point there are clearly two

ver, it seems that the slacking of normal string tension used for open tunings also allowed blues players to bend strings—and hence vary pitch—much further than on traditional set-ups. Whatever the origin, blues and then jazz players not only engaged in sometimes wildly gyrating-sounding vibrato, but also began using string bends to actually settle on a higher microtonal, half-step, or even full-step note above the fretted position.[57]

As riveting as many of these new sounds were, they still could only be heard in relatively small or quiet settings. Even loud talking in a room could drown out much of the guitar's sound. Certainly, other instruments like the rapidly evolving piano, horns, and drums could easily overpower the guitar as well.[58] But the steel-strung guitar was unsurpassed as a bridge between the rhythmic and melodic/harmonic aspects of a musical passage. This is because the percussive and muted sounds possible—the "chicka chicka" kind of staccato strums—allowed for sounds that could loosely approximate snare drum brush rhythms. In fact, country legend Johnny Cash would later popularize a folk technique of placing a piece of paper, sometimes even a dollar bill, underneath the strings of his acoustic guitar to mimic a snare drum sound because his original group, the Tennessee Two, had only bass and lead electric guitar with no drummer. This hybrid kind of playing expanded quickly with the new forms of beat-and-rhythm-based music genres, such as blues, folk, ragtime, dixie, jazz, and country.

As dance and jazz bands grew into the early big bands of the 1920s, the guitar was an essential part of the rhythm section, but played an odd sort of role. It could not compete with the brass horns, booming new trap drum "kits," or even strings like violins to project enough from the bandstand to be heard by the crowd.[59] This was especially true as the swing dance craze took off with the jitterbug and other highly athletic dance forms. Audiences were dancing, talking, drinking, and making noise in ways that would have drowned out an unamplified acoustic guitar, even if the other instruments were not doing so.

But this near chaos, on the bandstand and off, meant that the musicians on stage really needed reference tones and rock-solid rhythms behind them. The new big-bodied acoustic guitars of the early decades of the twentieth century filled this role quite well.[60] Playing full chords with tight percussive

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tones that are discontinuous. But a wavering sound does result from vibrating the finger firmly behind one fret. This may be more of a *tremolo* effect, however, in which the note *amplitude* is wavering—not its pitch. However, vibrating a fretting finger *crosswise* or perpendicular to a string can create true vibrato on a fretted instrument. The ability to engage in this effect is limited by string tension, though.

57 The effects of the peculiar guitar vibrato and string bends used in blues, jazz, and then later rock and other kinds of popular music are demonstrated in the video of the Author's Conference presentation. *See, e.g.*, *Guitar Demonstration*, *supra* note 13, at 11:05 minute mark.

58 Martin, *supra* note 47, at 96, 101-02; Bozanic, *supra* note 51, at 202-12.

59 Martin, *supra* note 47, at 96, 101-02; Bozanic, *supra* note 51, at 202-12; *see also* DAVE HUNTER, THE GUITAR PICKUP HANDBOOK: THE START OF YOUR SOUND 11 (2008).

60 Martin, *supra* note 47, at 96, 101-02; Bozanic, *supra* note 51, at 202-12.

rhythmic technique and synching closely with the upright bass player and drummer, the guitarist became an anchor of the big band, audible largely only to the other performers on stage.[61] The only times the guitar could be heard clearly by the crowd were when there would be a feature of the rhythm section, usually representing a break and quieter passage to build dynamics.

Guitar players in many popular genres desired more volume from their instrument. Hawaiian and blues slide playing produced such a compelling vocal and emotional tone that it begged to be used as a lead instrument, including in larger ensembles and venues. Even jazz players, who did not rely on slide or wide bending of notes, sought to amplify their instruments so they could play single note solos.

B. *Vibrating Steel Strings as Electromagnetic Oscillators*

Given all of these developments by the turn of the century, and the "Yankee ingenuity" of American inventors, it is no wonder that various instrument makers sought to address the volume problem of the guitar. The first step had been steel strings and the required sturdier bracing to accommodate them. But this was still not enough to get the volume needed. In the 1920s, the National String Instrument Corporation, founded by George D. Beauchamp, a vaudeville violin and lap steel guitar performer and promoter, and luthier John Dopyera, developed "resonator" guitars that had a metal cone, emulating the sympathetic acoustic amplifiers that Gray had used in his protoelectric music instrument.[62] This gave a much brighter, punchier, albeit more metallic and less "natural," sound to the guitar, which came to be called a "National guitar."[63] The original version was a tricone model invented by John Dopyera and assigned directly to Beauchamp for National,[64] but it was relatively expensive for the average player.

Dissatisfied with the performance and cost of National's models and perhaps also due to a personality conflict with Beauchamp, Dopyera left to found his own company with his brothers Emil and Rudolph. Named the Dobro Company (from *Do*pyera *Bro*thers, and also meaning "good" in Slavic languages),[65] it would produce iconic resonator or resophonic guitars that came to be known generically as "dobros."[66] But Beauchamp and National initially beat the Dopyera brothers to the punch by inventing and pa-

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61 *See Guitar Demonstration*, *supra* note 13, at 1:10 minute mark.

62 Bozanic, *supra* note 51, at 213-30.

63 Al Handa, *The National Steel Guitar Part One: An Introduction*, NATIONAL RESO-PHONIC GUITARS, http://www.duolian.net/admin/history.html (last visited May 29, 2016).

64 U.S. Patent No. 1,762,617 (issued June 10, 1930).

65 BOB BROZMAN, THE HISTORY & ARTISTRY OF NATIONAL RESONATOR INSTRUMENTS (1998).

66 *Id.*

tenting a less expensive single-cone resonator.[67] Adolph Rickenbacker, then a tool, die, and metal stamping manufacturer, worked with both National and Dobro to produce the metal resonators and other parts. Rudolph Dopyera subsequently inverted the cone to design around Beauchamp's patent at National—as well as to improve the sound and affordability—and patented this new version that became known as the "Dobro."[68] By the early 1930s, conflicts and management issues fractured National, and Beauchamp seems to have departed as the Dopyera brothers gained control over National and merged the two companies.

Nationals and Dobros, as well as banjos, performed fairly well for higher volume applications. Their midrange-focused, metallic tones cut through noisy environments better than traditional gut or steel-string guitars. But they still could not really compete with larger ensembles such as big bands and the noisy crowds attending the shows. And their tone—while becoming closely linked with some styles of blues and country—was not to everyone's tastes, especially those who wanted a smoother, rounder tone for jazz.

But, in any event, Beauchamp had moved on to develop electric stringed instruments, forming the Ro-Pat-In Company (Elect*Ro Pat*ent *In*strument Company) with Rickenbacker. They seem to have become aware of the lineage of patents and inventions stemming from Gray, Bell, and others that showed how to use vibrating metal to induce signals in electromagnetic coils. At the same time, the contemporaneous developments in vacuum tube amplifier systems and loudspeakers meant that these inductive analog electrical currents could now be put to practical use in making guitars profoundly louder. The trick was how exactly to do it.

While, today, one might wonder why guitar players did not simply put a microphone in front of the guitar, the answer to this lies in the technology and practicalities of the era. First, the carbon microphones of the time were not particularly efficient or pleasant sounding. They worked well enough for the telephone and basic public address systems. They were also being used for radio, which did not have especially high fidelity in this era anyway. But, equally important, carbon microphones were omnidirectional and would have picked up all the other instruments in proximity to the guitarist.

The problem posed by the omnidirectional microphone was exacerbated by the low and diffused tone of the guitar. Whereas a vocalist could produce direct and sufficiently focused sound waves to adequately drive a microphone of the time, such that the volume could be kept low enough to minimally pick up other nearby instruments, the guitar could not (although the National and Dobro were better candidates). Further, the vocalist could

67 U.S. Patent No. 1,808,756 (issued June 9, 1931). One source states that Dopyera claimed to be the inventor of this model as well, but that it was patented by Beauchamp after Dopyera left National. *See* BROZMAN, *supra* note 65.

68 U.S. Patent No. 1,896,484 (issued Feb. 7, 1933).

stand out in front of the band, adding extra distance and isolation (including from her own body) of the microphone from other band instruments. This was not possible for the guitarist who had to be seated deep in the band with the other rhythm section players—keep in mind, the guitarist's main role then was to play the rhythm and chord structure for the other players.

At the same time, parallel, ongoing R&D into improved phonograph pickups, new vacuum tube circuit amplification, and purely electrical music instruments was yielding important interrelated developments. Perhaps most intriguing from a "paths-not-taken" perspective was the introduction of piezoelectric crystals for the phonograph pickup apparatus.[69] The crystal directly converts mechanical vibration—picked up from the needle of a stylus—into analog electrical waves. As described in Part IV, piezoelectric transducers would ultimately be one of the major avenues forward for reproduction of the natural acoustic tone of acoustic guitars in the 1970s. However, this approach was apparently not practical in the 1920s and '30s.[70]

Meanwhile, tube amplification was being used to amplify the signals produced by new kinds of microphones to drive the recently developed, dynamic loudspeakers, or "sound reproducers,"[71] to create rough but effective public address systems, as well as to transmit radio waves. On the receiving end of these radio waves, consumers could now purchase receivers that used antennas and capacitor/condenser circuits to sufficiently focus the waves to drive a tube amplifier, which in turn produced enough signal to drive small loudspeakers. In a different vein, inventors such as Leo Theremin of Russia,[72] Frank Miller of the United States,[73] and Maurice Martenot of France,[74] were continuing the legacy of Gray and others to develop pure-tone electric music instruments that could now become practical for use outside the lab with the advent of tube amplification and loudspeakers.

Theremin's eponymous instrument in fact became the sound of science fiction movies, with its eerie, wildly wavering tone, reminiscent of playing the saw, and then took on a cheerier cast in the much later "Good Vibra-

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69 U.S. Pat. No. 1,761,831 (issued June 3, 1930).

70 One source claims that the output signal of piezoelectric crystals was too low to drive the primitive tube amplifier circuits of the 1920s and '30s. Wallace Marx, Jr., *The Pickup Story Part I: The 1920s*, PREMIER GUITAR (Sep. 18, 2009), http://www.premierguitar.com/articles/The_Pickup_Story_Part_I_the_1920s. But, if that were true, then the crystals should not have worked for phonographs either, unless the vibration from the stylus was that much more powerful than the vibration of a guitar body and thus resulted in a strong enough electrical signal for existing tube amp circuits.

71 Andy Coules, *The History of PA, Part 1*, PROSOUNDWEB (Dec. 9, 2014), http://www.prosoundweb.com/article/the_history_of_pa_part_1/P1/.

72 U.S. Patent No. 1,661,058 (issued Feb. 28, 1928).

73 U.S. Patent No. 1,791,319 (issued Feb. 3, 1931).

74 U.S. Patent No. 1,824,402 (issued Sept. 22, 1931).

tions" song by The Beach Boys.[75] But outside of novelty applications, synthesized sounds would not really take off until the introduction of instruments like the Moog keyboard synthesizers of the 1960s. Finally, a major enabler for the dissemination and adoption of so many of these electricity-based radio, public address, and sound reproduction and amplification devices was the simple fact that electricity itself was becoming more widely available in businesses and residences across the country.

All of this electroacoustic innovation provided fertile ground for the development of electrical amplification systems for the guitar. As discussed above, microphones were not well adapted to the task. And piezoelectric transducers appear not to have been practical.[76] Notwithstanding, Arthur Stimson, an inventor at National-Dobro, patented two versions of a resonator guitar that included a transducer of "paramagnetic material."[77] This transducer picked up mechanical vibrations of the guitar, which were communicated through connectors from the bridge and top to a pickup inside the resonant body. Then, the pickup used an electromagnetic coil, mounted within a permanent horseshoe magnet to induce an analogous electrical current, which could then be sent to an amplifier.[78]

But inventors who had been designing pure-tone musical instruments had been working on both mechanical and electronic oscillators to generate the signal tone. Based on the glockenspiel and tuning forks, it was already well known that metal bars could be manufactured to vibrate at exact musical pitches when struck with hammers. Used as the armature in proximity to an electromagnetic coil, similar to Bell's original telephone mechanism, a tuned metal bar could induce an electrical wave analogous to the bar's acoustic sound waves produced when struck with a mallet or hammer.

In 1934, Carroll Kentner patented an "Electrical Pick-up Apparatus," assigned to the Radio Corporation of America (better known as RCA), which could accommodate a range of vibratory metal elements and translate their vibrations into analogous electrical signals.[79] This signal could then be sent to an amplifier and loudspeaker. Kentner specifically addressed the invention to "electric carillons, chimes, pianos, and the like."[80] In this device the vibrating bar was mechanically inserted into the pickup, which comprised a large, permanent horseshoe magnet perpendicularly surround-

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75 Alexander Stewart, *"Been Caught Stealing": A Musicologist's Perspective on Unlicensed Sampling Disputes*, 83 UMKC L. REV. 339, 352 & n.40 (2014).

76 Marx, *supra* note 70.

77 Electrophonic Stringed Musical Instrument, U.S. Patent No. 1,962,919 col. 1 ls. 105-08 (issued June 12, 1934) (assigned to Dobro Corp.).

78 *Id.* col. 1 l. 108 to col. 2 l. 49; Electrophonic Stringed Instrument, U.S. Patent No. 2,078,350 col. 1 ls. 1-6 (issued Apr. 27, 1937) (assigned to Rudolph Dopyera).

79 U.S. Pat. No. 1,978,583 (issued Oct. 10, 1934).

80 *Id.* col. 1 ls. 1-5. Kentner likely meant glockenspiels, in the English language sense of the small, high register instrument consisting of tuned metal bars and mallets, and not the English use of carillon that means a large instrument made of bells that are activated by keys or levers.

ing an electromagnetic coil, through which the vibrating bar passed—without touching—and then terminated in a metal housing positioned within the horseshoe magnet.[81] This configuration seems to have been the basis for George Beauchamp's landmark 1937 patent for an "Electrical Stringed Musical Instrument"[82]—what many consider to be the first (successful) electric guitar pickup patent.[83]

Beauchamp's stringed instrument pickup worked because of the availability of metal strings for instruments like the flat top and arch top guitars. While Beauchamp did not limit his invention to "metal" or "steel" strings per se, he did limit the strings to those that "are formed wholly or in part of conducting material or magnetic material having a different degree of magnetic permeability than the surrounding air."[84] But, importantly, Beauchamp emphasized that no acoustic or resonant body was needed for his "electrical" instrument, as all one needed were vibrating conductive strings.[85] Just like Bell's vibrating metal armature or Kentner's vibrating metal tone bars, vibrating metal strings could also induce an analogous electrical current in a proximate electromagnetic coil. However, to create a sufficiently strong magnetic field in which the vibrating string could induce enough of a signal to drive existing tube amplifiers, Beauchamp relied, as did Kentner, on a powerful, permanent horseshoe magnet encasing the vibrating string and

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81 *See id.* figs. 1-3.

82 U.S. Patent No. 2,089,171 (issued Aug. 10, 1937). Beauchamp's patent application was filed in 1934 but was a continuation of an earlier 1932 application. Kentner's application for the "Electrical Pick-up Apparatus" was filed in 1931 and thus precedes Beauchamp by either filing or issuance date.

83 Matthew Hill, *A Re-examination of the Rickenbacker "Frying Pan", the First Electric Guitar*, ORGANOLOGY.ORG, http://www.organology.org/rick%20re-exam.htm (last visited May 29, 2016). There is one peculiar "electrified guitar" patent that far predates that of Beauchamp. In 1890, George Breed patented a "Method of and Apparatus for Producing Musical Sounds by Electricity." U.S. Patent No. 435,679 (issued Sept. 2, 1890). Breed's invention was not for guitars alone, but also for pianos and telegraphic signaling. The major distinction from Beauchamp's and other later inventors' pickup systems is that Breed was harnessing the Lorentz Force (electrically charged particle moving through a magnetic field will experience a force perpendicular to the north-south axis of that field) to create a indefinitely self-vibrating string that would then sound acoustically. Matthew Hill, *George Breed and His Electrified Guitar of 1890*, 61 GALPIN SOC'Y J. 193 (2008). Thus, rather than providing for electric amplification of an mechanically activated string, Breed's design activated the string electrically, with the player simply pressing the strings at the desired place on the fingerboard (which used metal frets attached the circuit to activated electric vibration of the string). *Id.* at 195-200. The result was probably not any louder—and quite possibly softer—than conventional acoustic guitars of the time. *Id.* at 203. As Hill notes, Breed's suggestion for two-handed playing on the fretboard, as greatly facilitated by his self-actuating string vibration circuit, anticipated the popular innovative development of the same by legendary electric guitarists Eddie Van Halen and Stanley Jordan by nearly a century. *Id.* at 200. As a separate note, astute readers may be wondering why the famed inventor-guitarist Les Paul does not appear in this Essay: unfortunately, for all his contributions to other parts of the electric guitar, Paul does not appear to have invented anything directly pertaining to the pick-up.

84 '171 Patent col. 2a ls. 64-68.

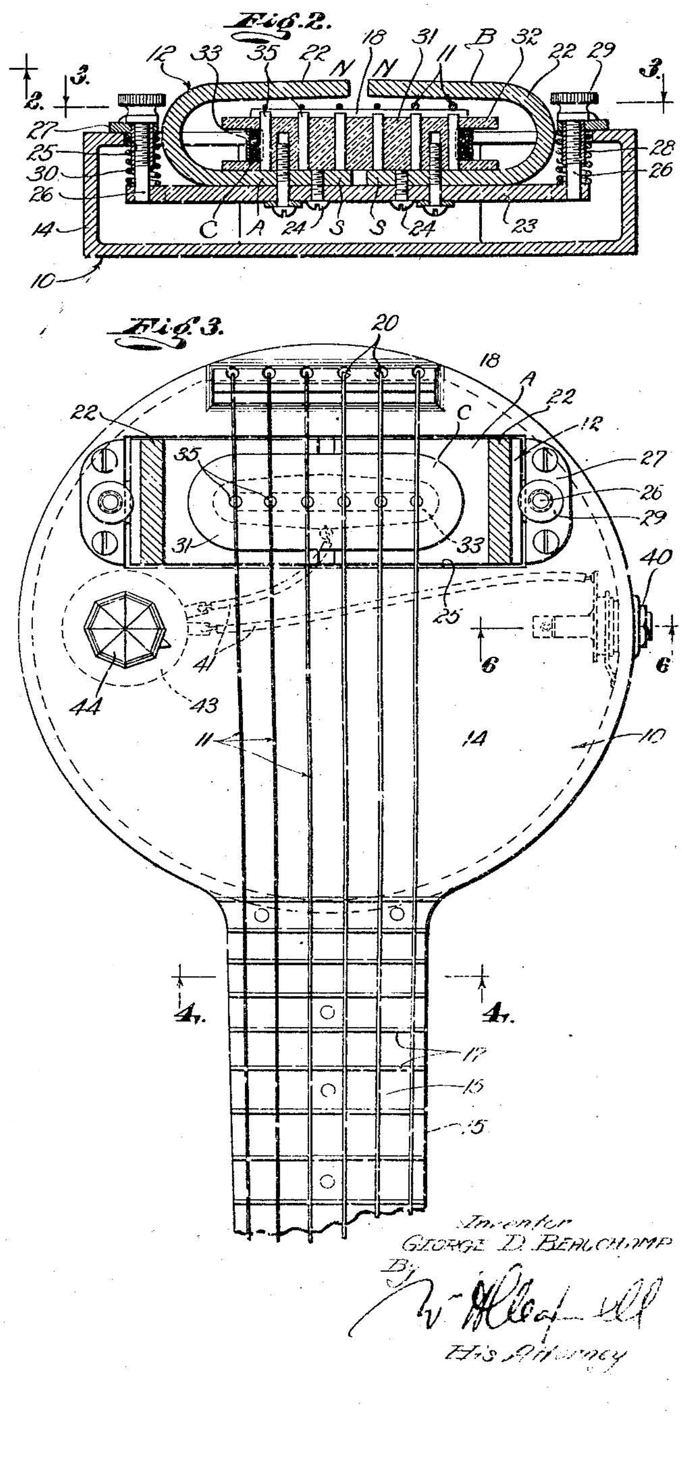
85 *See id.* col. 1a ls. 45-49.

stationary coil.[86] Beauchamp also introduced the use of pole pieces to "focus" or concentrate the magnetic field for each string.[87] With the exception of the big horseshoe magnet, this basic configuration has remained the core of electric guitar pickups to this day.

Figure 2 of Beauchamp's patent, shown below, reveals the horseshoe magnet enclosing the coil, the pole pieces, and the six strings—while looking at the pickup longitudinally. Figure 3, also shown below, indicates the position of the pickup on the guitar using a cutaway view of the pickup from the top of the guitar.

86 *See id*. fig.2, fig.7, fig.9.
87 *See id*. fig.2, fig.3, fig.9.

Figures 2 & 3 of Beauchamp's Patent No. 2,089,171



C. *Patents as Incentives for Professional Commercial Manufacture of Electric Guitars*

By the time electric guitars were developed, acoustic guitars had been around for a long time. There was certainly new innovation in acoustics—like Martin's X-bracing that would make steel strings practical—but there was also plenty of room for traditional luthiers who could make guitars locally for their clients and need not rely on patents as an incentive to do so. So the question naturally arises as to whether patents were actually needed to develop the electric guitar. This Section explains why patents were so critical for this transformation in the guitar.

Innovation in many fields can be accomplished by "users," or regular practitioners within a particular field. Starting largely with the work of Eric von Hippel,[88] a literature arose questioning whether patents play any constructive role in such fields. If users create the innovations themselves—and choose not to patent them—then why should a professional manufacturer be able to obtain patents and force users to pay more for commercially manufactured versions of what the users could have built for themselves? This proposition is reasonable enough.

If the user-generated invention is indeed all that the manufacturer is producing—and assuming that none of the user inventors patented the invention and transferred the rights to the manufacturer—then this prior art should invalidate the manufacturer's patent. It is possible that the users neither used the invention in public, nor gave any enabling public disclosure of it, and, thus, the manufacturer or another party was able to secure a patent, assuming they invented independently. Accordingly, for the manufacturer's patent to be valid and enforceable, the patent must either cover such an independent invention or, as is more likely the case, cover something beyond what the users had actually invented.

While a detailed consideration of this literature and its arguments is well beyond the scope of this short Essay, the particulars of the early days of electric guitar pickups are illuminating as to the value of patents in at least one user-innovation field. Beauchamp was himself a professional guitarist, and hence a user-innovator. But both the acoustic resonator guitars of National and Dobro, and then the electromagnetic pickup, were not things that ordinary players could practically produce on their own. In fact, Beauchamp had to work with others to develop these various inventions. The resonator guitars could have been made by skilled luthiers, once they saw the invention. But, even there, the luthiers would have needed a good metal shop to produce reliable and acoustically desirable cones.

Pickups presented a whole other level of production issues in that hand winding coils is quite an art—not to mention producing the bobbins, custom

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88 ERIC VON HIPPEL, THE SOURCES OF INNOVATION (1988).

pole and magnet pieces, and assembling the final product. In fact, one account of the early RoPatIn R&D discusses how they needed to convert washing machines into coil winding machines just to get scale and consistency.[89] And anyone who has ever wound their own wire coil for an amateur electronics project, such as a rudimentary radio receiver or motor, knows both how hard it can be and how tiny variances can lead to dramatically different results, or even outright failure. In the case of the electric guitar pickup, such tiny variances make the difference between incredible or awful amplified guitar tone, hum cancelling, or power output. These factors drove the success (or failure) of the many manufacturers in both the original equipment manufacturer and later-arising, after-market industry segments.[90]

Considering that most guitarists do not have the electronics knowledge or production facilities to produce their own pickups from scratch,[91] it should be clear that affordable, professionally produced gear is essential to create music that relies on these inventions. Beauchamp had decided to go into the instrument and equipment business, partly because of this problem of not being able to obtain or build the high-volume music instruments he needed as a player without commercial R&D and manufacturing resources. So, for him and his new business, it made sense to delve deeply into the electronics to both invent a new kind of amplification device and to figure out how to manufacture it at scale. The patents gave him and his partners the confidence that they could protect and receive a return on their investment of significant time and money in developing the inventions and their scalable, reliable manufacture.

It is safe to say that electric guitars would not have taken off the way they did (with teenagers across America from all walks of life picking up guitars to play) if every aspiring electric guitarist had to build and maintain his own rig. To be clear, in some segments of the guitar playing demographic (the Author's included), players customize or even build their own

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89 *The Earliest Days of the Electric Guitar*, RICKENBACKER, http://www.rickenbacker.com/history_early.asp (last visited May 29, 2016).

90 Anecdotally, the Author taught himself electronics before becoming a guitar player. While he designed and built signal effects pedals, variable power supplies, amps, radios, and swapped pickups in and out of many guitars (including completely rewiring a few of those instruments), he never tried to wind and build his own pickups from scratch. With enough free time and practice, he could probably build one. But would this be the best use of a guitarist's time (absent doing it for the love of it)?

91 To the extent electronics savvy guitarists "build" their own pickups, they generally still rely on commercial supply sources for manufactured pickup components—such as plastic bobbins, metal plates and covers, magnets, and pole pieces—to assemble them from. From the Author's experience, only a tiny percentage of guitarists do this, with some subset winding their own coils. At the same time, there are a handful of very small artisanal pickup shops producing custom pickups, but even these tend to be commercial, albeit small business, outfits.

guitars, pedals, or amps.[92] But rarely does this get to the level of manufacturing one's own bobbins, magnets, pole pieces, etc., or personally winding the coil on a purchased bobbin. The ability to go down to the local music store, or even pawn store, to get an inexpensive yet minimally viable electric guitar and amp and learn to how to play it with no real music background—forget electronics knowledge—is the iconic tale of not only American and British rock and roll, but also that of electric Chicago blues, Jamaican reggae, and a host of other influential genres that emerged based in large part off of the electric guitar in the twentieth century.[93]

III. THE DISTINCTIVE VOICE AND POWER OF ELECTRIC GUITARS DROVE THE CREATION OF MANY MODERN MUSIC GENRES

This new electric guitar amplification system was soon deployed in at least two very different directions. Most immediately successful was its use in the "frying pan" embodiment Beauchamp disclosed in his patent.[94] This instrument was manufactured by what had been renamed the Electro String Instrument Corporation (formerly Ro-Pat-In) as the A-25 Hawaiian Guitar, and known as the Bakelite B guitar.[95] This naming convention supports the accounts that place the development of slide guitar with the Hawaiian slack key players.

The A-25's configuration was perfectly well suited for Hawaiian, blues, and country slide players who then collectively developed the "electric lap steel" guitar: a stringed instrument designed around a guitar-type neck, metal strings, and an electric pickup, which could be placed on the player's lap, or even a table, and connected to an amplifier and loudspeaker.[96] For these players, volume was especially important because they played many monophonic lines—melodies—and thus could not obtain the volume associated with strumming full chords. Further, as described below, the warm, often muddy, sound of the early pickups and amplifiers actually enhanced the vocal quality of these vibrato-heavy melodic lines.

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92 *See, e.g.*, Steve Waksman, *Tinkering with Hardcore and Heavy Metal in Southern California*, 34 SOC. STUD. SCI. 675, 675-76 (2004).

93 *Cf.* Charles McGovern, *The Music: The Electric Guitar in the American Century*, *in* THE ELECTRIC GUITAR: A HISTORY OF AN AMERICAN ICON 17, 17 (André Millard ed., 2004) (commenting on the importance of the electric guitar to American popular music).

94 HUNTER, *supra* note 59, at 16; U.S. Patent No. 2,089,171 fig.1, fig.3 (issued Aug. 10, 1937).

95 Initially, the guitar was made of all aluminum, but this caused tuning problems as the body expanded and contracted too much in response to ambient temperature changes. It was then manufactured using the new Bakelite material of the time.

96 Over time the "pedal steel" would develop from this, using knee or foot levers or pedals to change tuning and to adjust volume (especially for "volume swell" effects) and other amplification parameters.

But many guitar players were wedded to the acoustic sound and the physical contours of their instruments and therefore had no interest in an instrument without a resonant sound body. Thus, to the degree they began experimenting with pickups, they did so with another of Beauchamp's embodiments: the standalone pickup that could be inserted into the body of most existing acoustic guitars.[97] The serious downsides to this approach were: (1) that a major cutout had to be made in the body of what might be an expensive guitar that could not be reversed; (2) this cutout, and the addition of the heavy pickup apparatus, significantly changed the acoustic tone of the instrument; and (3) the weight and balance of the instrument—especially important if one was holding the guitar while standing—was changed dramatically.

In the mid-1930s, the Gibson guitar company entered the electric market with its popular Electric Spanish 150 ("ES-150").[98] It sported a visually smaller pickup positioned up near the neck. This was made possible by removing the horseshoe magnet and replacing it with a heavy magnet positioned underneath the pickup within the body of the guitar, while inserting a metal bar or blade within the coil that was perpendicular and directly under the strings. The magnets underneath directly contacted the metal bar, magnetizing it, and allowing it to replace the horseshoe magnet. This change both allowed palm muting[99] and obtained a warmer, richer tone by picking up the string vibrations towards the middle of the string length, where vibration is fuller than at the extremities of the string. The inventor behind this seems to have been Guy Hart.[100]

The ES-150 was adopted and made famous by jazz guitarist Charlie Christian.[101] Before his standout use of the instrument to play memorable solos in the Benny Goodman Orchestra, electric guitars were primarily seen in the lap steel form.[102] While quite popular, they were largely limited to Hawaiian, country, Western swing, and some blues, and remained a niche instrument. But Christian showed how a more or less conventionally played

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97 *See* '171 Patent fig.8.

98 Michael Leonard, *A Guitar Geek's Guide to Gibson ES Models*, GIBSON (July 3, 2014), http://www.gibson.com/News-Lifestyle/Features/en-us/A-Guitar-Geek-s-Guide-to-Gibson-ES-Models.aspx (last visited May 29, 2016).

99 The Electro String Instrument Corporation's guitars had a metal shield over the horseshoe magnet, through which the strings had to pass, unfortunately located right at the place of the strings where a player would mute them with the palm of her right hand. *See Guitar Demonstration*, *supra* note 13, at 10:20, 19:20 minute marks.

100 Electrical Musical Instrument, U.S. Patent No. 2,087,106 (issued July 13, 1937) (assigned to Gibson, Inc.).

101 *See, e.g.*, Martin, *supra* note 47, at 102.

102 Gibson also made lap steel electrics, designating them "EH" for "electric Hawaiian, again underscoring the acknowledged role of the Hawaiian slack key players in the development of lap steel and slide guitar." GEORGE GRUHN & WALTER CARTER, GRUHN'S GUIDE TO VINTAGE GUITARS: AN IDENTIFICATION GUIDE FOR AMERICAN FRETTED GUITARS 150 (3d ed. 2010).

"Spanish" guitar could be electrified, such that it could finally take its place among the lead instruments of big bands and, indeed, any music format.[103] The sound was still a bit muddy, but this bassy sound became a signature jazz guitar tone.

By the late 1930s, Herb Sunshine invented a pickup for Gibson's smaller competitor, Epiphone, featuring adjustable poles. These poles enabled differences in the flux induction of each string (and hence its resulting volume) to be individually compensated.[104] Gibson soon followed with an early adjustable pole pickup that was no match for Sunshine's.[105] Meanwhile, the Electro String Instrument Corporation changed its name to the now well-known Rickenbacker.

In the 1940s, three major advances occurred. First, Gibson introduced its very successful P90 adjustable pole pickup that finally eclipsed Epiphone's. Second, Leo Fender entered the market with solid body electrics that were meant to be used in a similar way as the Electric Spanish models of Gibson and Epiphone, but which moved away from standard guitar shapes into the precursors of the legendary Telecaster and Stratocaster. Fender himself did not play music but was an avid and skilled inventor. In particular, he created a new kind of adjustable pole pickup that was much brighter and snappier than the existing ones.[106] Third, Harry De Armond introduced the "floating pickup" that could be attached to flat top or arch top acoustic guitars with little to no modification of the guitar itself.[107] This configuration also resulted in a warmer, more acoustic sound, as the instrument itself could freely resonate throughout its body as originally designed. Many jazz players adopted the new format, and it still is used extensively in that genre. But players in other genres were already coming to appreciate the brighter, more powerful, and edgier tone of the "inferior" (from a pure acoustic, sound-reproduction perspective) built-in pickups.

With the Gibson and Fender advances in electric guitar tone, and especially picking up with the energy and forward-looking sentiments of the immediate post-WWII late 1940s, new musical genres and subgenres emerged. Jump bands were high power, often stripped-down versions of earlier big bands. The electric guitar was essential to cementing a tight, loud, and driving rhythm section for them. Country bands were now adding not only electric lap and pedal steels, but also electric Spanish guitars, which likewise added more volume, rhythmic drive, and lead parts. Blues became electrified and legendary black blues players began cranking up and

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103 *See, e.g.*, Martin, *supra* note 47, at 102.

104 Magnetoelectric Pick-up Device for Stringed Musical Instruments, U.S. Patent No. 2,175,325 (filed Nov. 10, 1937).

105 Magnetic Pick-up for Musical Instruments, U.S. Patent No. 2,145,490 (filed Apr. 18, 1938) (assigned to Gibson, Inc.).

106 *See* Pickup Unit for Stringed Instruments, U.S. Patent No. 2,455,575 (issued Dec. 7, 1948).

107 Guitar Magnetic Microphone, U.S. Patent No. 2,455,046 (issued Nov. 30, 1948).

overdriving their amps, creating the precursor of the distorted rock guitar sound. Related to both jump and blues, R&B emerged around the same time as an "urbane, rocking, jazz-based music . . . [with] a heavy, insistent beat," marketed by record labels towards African-American radio stations and listeners—at a time when the music markets were still heavily segregated.[108] Finally, Cuban and other Latin music influences were being imported into the jump, R&B, jazz, and swing formats, creating further new directions. The central theme in all of these emerging forms was that the electric guitar enabled versatile, driving rhythms and clear lead tones with a full and amplified sound, allowing small groups of three to five players to rock even a large hall by themselves.

Core to the success of this sound was what sound engineers call "compression" and "clipping."[109] First, the nature of the electromagnetic pickup was that it had a limited bandwidth, such that it could not fully track the dynamic amplitude range of a natural acoustic instrument. But the use of amplification meant that even quiet playing could come out of the speakers quite loudly. However, once the electromagnet reached its top output, it would not produce any higher output—translating into volume—even as the strings were played harder.[110] Therefore, the total range of volume from quiet to loud playing was reduced. Second, the tube amps of the time imposed an even more dramatic compression of the signal. In fact, the louder the amp was turned up, the more compression that resulted. This was because quiet signals, even minor finger noises on the strings, were quite loud due to the heavy amplification. On the other hand, more aggressive playing hit the limits of the tubes quickly, and they began "clipping"—or cutting off the high amplitude peaks.[111]

At the same time, the precise way that vacuum tubes worked as both amplifiers and as the "rectifier" that converted the now standard alternating current ("AC")—as supplied by commercial and residential power outlets—into direct current ("DC") provided another "flaw" that quickly became a feature.[112] When a guitar player hit the strings harder, this momentarily stronger signal caused a voltage "sag" across the grids of the amplifier and rectifier tubes, somewhat paradoxically reducing the amount of power available to amplify that signal.[113] The musical effect of this was significant: electric guitarists could go from single note lines to full chord strumming without the dramatic volume change that one would expect from the vol-

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108 ROBERT PALMER, DEEP BLUES 146 (1981).

109 *See* Russell Myers, *Engineering Rock and Roll: A Casual Introduction to Signal Processing*, ILLUMIN (Feb. 1, 2002), http://illumin.usc.edu/20/engineering-rock-and-roll-a-casual-introduction-to-signal-processing/fullView/; *Guitar Demonstration*, *supra* note 13, at 10:15 minute mark.

110 *Guitar Demonstration*, *supra* note 13, at 11:26 minute mark.

111 *Id.* at 10:15 minute mark.

112 KYTTÄLÄ, *supra* note 9, at 171.

113 Dave Hunter, *All About Rectifiers*, GUITAR PLAYER (Oct. 29, 2008), http://www.guitarplayer.com/miscellaneous/1139/all-about-rectifiers/16429.

ume difference in an equivalent transition on an acoustic guitar.[114] For example, given the volume (in terms of sound pressure) of minor pick and finger sounds emanating from the loudspeaker, if a full chord strum were truly proportional in natural acoustic terms, it would be frighteningly deafening and likely unlistenable.

But another key electric guitar element was being added by the confluence of these limitations: harmonic overdrive and distortion. As the tubes were driven harder than they were designed to work, they added harmonic overtones, even as they were also clipping and compressing the signal. This further fattened the sound and added sustain to the notes.[115] Because the electromagnetic signal from the pickups was decaying, the power across the amplifier and rectifier tube grids was increasing back to normal states, boosting the output signal and resulting in a sound as if the natural tone was simply ringing out longer.[116] As both guitar pickups and amps became more powerful over the next decades, this interplay of input signal, tube response, and output signal could also be harnessed to create "musical feedback" in which a note actually begins *increasing* in volume, even as the player does nothing to activate the strings again.[117]

But the basic result, even in the late 1940s, was that the electric guitar was beginning to have a wild, emotional, sometimes almost screaming tone that a skilled player could ride to produce solos equal to those of the hottest saxophone, trumpet, or fiddle players. It also allowed the "Spanish" electric guitar player to nearly match the singing quality and sustain of Hawaiian or electric lap steel players (whose solid body instruments, especially when made fully of metal, or at least substantial amounts of metal hardware, had natural sustain to the vibrating string, even as they produced little to no resonant acoustic sound on their own without amplification).[118] Further, as blues players took their bottlenecks, knives, and other tools used to play slide guitar to the new electric Spanish guitars, the result could be almost indistinguishable.[119]

A further crucial aspect of all of these tonal and sustain elements was that the direct, fully electrical signal path of electric guitars and their amps meant that they *could* be overdriven in ways that would have sounded terri-

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114 *Guitar Demonstration*, *supra* note 13, at 10:15, 11:26 minute marks.

115 *Audio Guide to Guitar Effects*, CHI. MUSIC EXCHANGE (Mar. 23, 2015), http://www.chicagomusicexchange.com/blogs/soundboard/15817252-audio-guide-to-guitar-effects.

116 *Guitar Demonstration*, *supra* note 13, at 18:15 minute mark.

117 Ted Drozdowski, *Turn It Up: The Virtues of Playing Loud*, GIBSON (Dec. 3, 2013), http://www.gibson.com/news-lifestyle/features/en-us/turn-it-up-the-virtues-of-playing-loud.aspx.

118 *See supra* Section I.A.

119 However, the expansion of lap steel guitars to larger configurations of strings—8, 10, even multiple neck formats—allowed them to retain a distinctive sound to the attentive listener. This was especially true in the clean, reverb-heavy, "lonesome" tone used in country, Western swing, and bluegrass. Jason Borisoff, *How Pedal Steel Guitar Works*, MAKING MUSIC MAG. (Sept. 27, 2010), http://makingmusicmag.com/how-pedal-steel-guitar-works/.

ble with an acoustic sound wave and mechanical-vibration-originated signal, such as with microphones. While some degree of overdrive and clipping has been used over the years to great effect on vocals in blues, R&B, rock, soul, and funk, these instances were quite mild when compared to what has been used on the guitar.

Pushing the amplifier much further into overdrive on a microphone-based signal results in the kind of nonmusical screeching or howling feedback that everyone has unpleasantly experienced at some point when a microphone is being used. Even at overdrive points below feedback levels, the clipping and added harmonics render vocal articulation indecipherable—meaning that the listener cannot understand what words are being spoken or sung. While this eventually was intentionally used in the emerging blues, R&B, and rock genres to partially mask sexually suggestive and alcohol- or party-oriented lyrics—or simply because it sounded cool to some singers and their listeners—it was not always desirable.

At the same time, the difference between an electromagnetically generated signal and an electromechanically generated one further explained why placing microphones in front of guitars was not the path to guitar amplification in the early days. Microphones can produce feedback even at subclipping power levels. Because of their basis in acoustic-mechanical vibrations, when their amplified signal emerges from loudspeakers in the same room, the sound waves produced by those speakers can themselves trigger the vibratory mechanism of the microphone, producing more electrical signal (literally "feeding back") from the microphone to be amplified by the amp system. This sets up the feedback "loop" that results in that painful, screeching feedback that is so familiar. In an electric guitar, the player can hold or dampen the strings so they do not vibrate much or at all, which limits or breaks the feedback loop. Restricting this effect to one or two strings, especially ones that are fretted, and hence not ringing in uncontrolled fashion, means that the guitarist can play with, or shape, the feedback, harnessing and limiting it to musical sound and purpose.

But the microphone works in almost the opposite way: placing one's hand over the mic or otherwise trying to cover it to stop the feedback—which is the understandable natural response of the inexperienced mic user—results in even worse feedback. The only way to control mic feedback is either by turning down the amplifier, unplugging the mic, or, ideally, simply angling the mic away from the speakers creating the feedback loop.[120] But the same principle behind why the mic howls when you put your hand over it explains why a mic will screech when you put it too close

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[120] Mic and speaker positioning is the key to feedback control. Mics should never be placed in front of the speakers if at all possible. Further, the closer the speakers are to the input side of a mic, the more likely the feedback—even at relatively low volumes. Reducing the treble tone control of the amplifier can reduce feedback, but this also muddies the sound, which is particularly problematic for vocal articulation.

to an enclosure like the resonant body of an acoustic guitar. Efforts to get adequate signal to drive the mic and provide enough difference between the desired guitar sound and that of other nearby instruments focus on placing the mic as close to the guitar's sound hole as possible. However, this both creates the equivalent of placing one's hand over the mic *and* results in a boxy and muddy tone. Guitars and other resonant body instruments are designed so that their desired tone develops some distance *away* from the sound hole, as that is where listeners will be. To accomplish this, the tone at the sound hole itself is quite odd.[121]

By contrast, the electromagnetically generated signal of the new electric guitar pickups was controllable against feedback, even at high clipping and overdrive levels. Further, with no need to clearly reproduce the subtle articulation of human speech—the problem that plagued Reis and Gray in the race to the telephone—the added harmonics and coloration of overdriven electric guitar amps again somewhat paradoxically made the guitar a highly vocal and "articulate" instrument in its own way.[122] With an expressive and sustained lead tone equal to that of saxophones, voice, and other lead instruments, but combined with full chord playing capacity *and* unique rhythm feels and sounds, the electric guitar quickly became incredibly versatile in most any musical format, but especially in smaller ensembles. It became in many ways the equivalent of a piano or organ, as a full-range lead and rhythm/accompaniment instrument. But it was better in that its percussive element—especially when played with a flat-pick—enabled a host of unique, syncopated, funky rhythms that arguably *created* the boundary pushing and pulling African- and Latin-derived, beat-oriented musical genres that defined the post-war period.

At the beginning of the 1950s, Fender further enhanced the tone and sustain of its electric guitars by integrating pickups and metal tailpieces that also increased sustain of the electric signal.[123] It also introduced its electric basses that revolutionized the way bassists approached both the instrument and its role in music groups. The Precision Bass, or "P-Bass," and the Jazz Bass were fretted just like a guitar and had pickups that enabled a powerful, punchy, highly articulate, and very precise tone.[124] This empowered bassists to engage in far more aggressive playing that could further drive the rhythm

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121 While off point here, it is worth mentioning that miking an acoustic guitar for recording purposes has traditionally been its own art form, with many wildly varying, and often conflicting, opinions about how best to do it. But almost none of the successful results, from a listening perspective, used a microphone placed very close to a sound hole. Instead, mics are generally placed some distance away from the sound hole, over the fretboard or closed parts of the body, or some combination of these.

122 *See supra* Section I.A.

123 Combination Bridge and Pickup Assembly for String Instruments, U.S. Patent No. 2,573,254 (issued Oct. 30, 1951).

124 *Pure and Powerful: Precision Bass—the Original Sound in Electric Bass*, FENDER, http://www.fender.com/basses/precision-bass/ (last visited May 29, 2016).

of a song. Now a drummer, bassist, and guitarist could be a loud, powerful, and extremely tight rhythm unit.

A major musical turning point for both the electric guitar and popular music came in 1951 when Jackie Brentson and his Delta Cats (really a young Ike Turner and his Kings of Rhythm band writing and playing behind Jackie as the singer for this particular recording) released "Rocket 88."[125] Whether or not it constitutes the "first" rock and roll record, its influence was profound. Besides being an ever rawer form of jump or R&B music, it featured an overdriven guitar and was played on white stations as well as black ones.[126] This introduced white audiences to the energetic, rhythm-heavy music forms proliferating on black stations, and the demand for more led Sam Phillips (the producer for "Rocket 88" at Sun Recording Studio in Memphis) and others to seek out white players who could duplicate the sounds and grooves.[127]

Located in the South, it was only natural that a lot of the white players Phillips found were country or folk oriented. Thus, this became one of the reasons why some postulate rock and roll to be the combination of blues, R&B, and country music. But gospel, also indigenous to the South, was clearly an element as well, especially for singers like Phillips's most famous discovery—Elvis Presley.[128] Bill Haley and the Saddlemen, originally a country band, recorded a cover of "Rocket 88" a few months later, presaging the group's transformation into the seminal Bill Haley and His Comets, most known for their 1954 hit "Rock Around the Clock."[129] For the guitar, the early '50s saw the introduction of popular new artists and bands in these beat-heavy formats that were fronted by singer-guitarists like Bill Haley, B.B. King, and John Lee Hooker.

In 1954, the Fender Stratocaster was released and dramatically increased the sonic palette for players by using three pickups—instead of two—that provided some new and surprising tones.[130] Played individually, the neck, middle, and bridge pickups sounded like existing bright and thin Fender pickups. But players soon discovered that they could balance the pickup switch between the neck and middle (and middle and bridge) positions, such that both neck and middle or middle and bridge pickups were activated simultaneously. Having two pickups activated was not new—most guitars with two pickups had this feature. But what was different about the "Strat" was that—because it was not designed to have two

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125 JACKIE BRENTSON AND HIS DELTA CATS, ROCKET 88 (Chess Records 1951).

126 HOLGER PETERSEN, TALKING MUSIC: BLUE RADIO AND ROOTS MUSIC 156 (2011).

127 *Id.* (recounting an interview with Ike Turner wherein Turner describes Sam Phillips's idea to find marketable, white musicians who could duplicate the "Rocket 88" sound).

128 PETER GURALNICK, LAST TRAIN TO MEMPHIS: THE RISE OF ELVIS PRESLEY 95-96, 132 (1994) (describing Phillips's work with Elvis and the singer's "confident exploitation of his gospel-learned technique").

129 BILL HALEY AND HIS COMETS, ROCK AROUND THE CLOCK (Decca Records 1954).

130 *Guitar Demonstration*, *supra* note 13, at 13:10 minute mark.

pickups on simultaneously—these pairs of pickups were out of phase with each other. Thus, when they were both on, the result was a hollow, funky sound that came to define both the Strat and certain kinds of groove music genres.[131] However, in many ways this was a feature waiting to be discovered, as the widespread use of these tones did not occur until the 1970s and ‘80s. This may also have been because, around this time, Fender started putting in full-function 5-way pickup toggle switches to make it easier for players to get these tones.[132]

In the ‘40s and early ‘50s, however, Fender solid bodies were being used mostly by country players who loved the "twang" of the bridge pickups. In fact, patented on some Telecaster models, and later as the standard configuration for the Strat, Fender had angled the bridge pickup so that the poles for the lower strings were towards the neck, while the poles for the higher strings were closer to the bridge. This was because the high strings could sound great close to the bridge, whereas the lower strings just sounded too thin and harsh.

In the mid-to-late 1950s, popular music underwent its foundational sea change as rock and roll emerged, squarely focused on bright sounding electric guitars. While some pioneers, such as Bill Haley and Chuck Berry, used arch top hollow or semihollow body electric guitars, others, such as Buddy Holly, relied on solid bodies like Fender's new Strat. Still others, like Bo Diddley, went their own way with idiosyncratic instruments they made themselves or had custom made for them.[133] Developing alongside, and equally based on, the bright and often reverb- and delay-soaked sounds of the new electric guitars and amps were rockabilly and surf music. Even doo-wop bands tended to have electric guitars and basses backing up the signature vocals.

With regard to sound effects like reverb, delay, and tremolo, the electric guitar excelled because its strong and direct electrical signal could be more easily "processed" with further electronic circuits.[134] In fact, electric guitars, amps, and off-board effects like spring reverb tanks (when not included in the amp itself) arguably constituted the original "signal processing." In other words, given a completely electrical signal, engineers could manipulate it to interesting effect.

Also in the 1950s, Gretsch entered the fray with its hollow body electrics, often outfitted with Bigsby Tremolo units. But for present purposes, it

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131 *Id.* at 14:40 minute mark.

132 Fender had known that players were "balancing" the switch between positions on the original 3-way toggles—and that this trick was not always dependable. *See 5-Way Switches Explained*, ALLOUTPUT.COM, http://alloutput.com/guitar/5-way-switches-explained/ (last visited May 29, 2016).

133 In addition, Bo Diddley introduced the seminal "shave and a hair cut" riff/rhythm that formed the basis for countless rock songs down to the present day.

134 *See* Gerlinda Grimes, *How Guitar Pedals Work*, HOWSTUFFWORKS, http://electronics.howstuffworks.com/gadgets/audio-music/guitar-pedal1.htm.

was its "FilterTron" (*filter*s out elec*tron*ic hum) pickups that gave Gibson and Fender a run for their money.[135] Voiced somewhere between a full and warm Gibson pickup, such as the P90, and the bright and twangy Fender pickups, the FilterTron was ideal for the new Rockabilly sound, and even much of country, jazz, and blues. It also introduced the use of two coils for one pickup that would be the basis of the coming revolution in guitar pickups. But Gretsch's double coil was mainly intended to produce a more powerful signal than single coil pickups could generate.

Released shorty afterwards, and as somewhat of a response to the FilterTron, the Gibson "PAF" ("patent applied for") instituted a seismic event that created the tone and power enabling the rock guitar revolution of the 1960s and on—rivaled only by continuing evolution of Fender's Strat.[136] The problem with all existing pickups was that they also picked up significant electrical and radio wave interference from devices in the same vicinity as the guitar player. This hum and buzz could be quite pronounced, especially as the amp was turned up. The compression that was so helpful for the new sound of the electric guitar also amplified the static and interference noise, so that it was distracting and in some cases unbearable. Manufacturers and players sought a way to reduce this noise. Seth Lover at Gibson hit on it with a new kind of dual coil in which the coils were wired to pass through and strengthen the strings' magnetic vibrations while cancelling out other extrinsic signals.[137] This "humbucker" pickup was released with the legend "patent applied for" on it, thus becoming known as the "PAF" pickup.[138]

With hum reduced, greater output, a warmer and fatter tone, and better articulation able to compete in that regard with the bright Fender single coils and Gretsch's FilterTron, PAF-equipped Gibsons of the late 1950s and early 1960s dominated the electric guitar market and created a golden period that produced instruments that are still highly coveted to this day. But, equally important, they produced a hotter signal that could then more easily overdrive the preamp tubes of the increasingly powerful and sophisticated tube amps of the period. This created a new kind of overdrive that complemented the power tube overdrive and the speaker overdrive that were being caused by connecting more powerful amps to loudspeakers of limited power-handling capability. The result was smoother overdrive that seemed more intentional on the player's part (and not just the result of bad equipment)

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135 HUNTER, *supra* note 59, at 105; U.S. Patent No. 2,892,371 (issued June 30, 1959).

136 *See PAF® 36th Anniversary*, DIMARZIO, http://www.dimarzio.com/pickups/humbuckers/paf-36th-anniversary (last visited May 29, 2016).

137 U.S. Patent No. 2,896,491 (issued July 28, 1959). Armand Knoblaugh at Baldwin Piano Company had actually patented a humbucking dual coil pickup much earlier—1938—but it was designed for pianos. U.S. Patent No. 2,119,584 (issued June 7, 1938). The patent is not expressly limited to pianos, but at the same time, neither Knoblaugh nor Baldwin seemed to consider adapting it for guitars. Also, it is unclear whether Lover or any other guitar pickup inventor knew of the Knoblaugh humbucker.

138 HUNTER, *supra* note 59, at 62; *see also PAF® 36th Anniversary*, *supra* note 136.

and which also played a central role in what became the sound of not just the early rockabilly, boogie rock, or surf rock that typified the early years of the overall rock genre, but set the stage for the harder and even more driving rock of the mid-1960s onwards.[139]

With music changing so rapidly, in tandem with the nonstop innovation in electric instruments and amps, new guitar and amp models could effectively inspire new subgenres of music around their tone. Players were becoming identified with particular guitar models, such as Buddy Holly, the first to popularize the Strat in rock music, and then Jimi Hendrix, arguably personifying the apex of Strat lead guitar sound and technique in the late '60s. Angus Young of AC/DC became closely associated with the Gibson SGs he uses. Other rock guitar gods switched brands and models over the years but were closely associated with certain instruments for different phases of their careers. In the reverse, manufacturers designed models and even components such as pickups to the specifications of famous players, sometimes on a singular basis, although other times on a limited or mass-produced basis.[140]

IV. THE LATE DEVELOPMENT OF FAITHFUL ACOUSTIC AMPLIFICATION

Despite the runaway success of the electric guitar—in its many formats—by the 1960s, some guitarists and inventors had not given up the quest for more faithful and accurate amplification of the natural acoustic tone of the guitar. While the piezoelectric pickup had been deployed for phonograph cartridges since the development of the first wire-coil, electromagnetic guitar pickups, for whatever reason, they were not practical for guitars until the late 1960s and really only widely commercially available in the 1970s. Even then, they often had a "pingy" tone, especially on the high strings, making them annoying or undesirable to many players (the Author included). But they certainly sounded more "acoustic" than the electric guitar pickup. This Part briefly considers both the development of more natural sounding acoustic guitar amplification in the 1970s and 1980s, as well as how electric guitar sounds that players and listeners had grown to love could not, for the most part, be replicated on these new acoustic amplification systems. The result was the cementing of the coexistence of two very different kinds of guitars: acoustic and electric.

The eventual harnessing of the piezoelectric crystal for guitar opened up the market for affordable acoustic guitar amplification, especially in noisy venues or for performance with loud instruments or bands, like those in the rock genre. Once microphones matured into high quality dynamic

139 *Guitar Demonstration*, *supra* note 13, at 18:00 minute mark.

140 *See, e.g.*, HUNTER, *supra* note 59, at 77 (noting Gibson's introduction of the "Angus Young Signature" humbucker).

and condenser versions in the mid-century, the most natural amplified sound for an acoustic guitar came through a microphone carefully placed either out in front of the sound hole (although not too close and often a bit off axis) or over the neck or body. But the sound waves being picked up were not strong and, thus, a lot of amplification had to be used. This greatly increased the risk for uncontrolled feedback.

Likewise, while there was some success with placing small microphones inside the body of the guitar, feedback was a constant threat. If the venue was too large, or the companion instruments too loud (such as the increasingly large and loud kits used by rock drummers and, of course, the electric guitar itself), it simply became impossible to turn up the acoustic guitar microphone loud enough to be heard without collapsing into a wall of feedback. By contrast, the piezoelectric transducer dramatically raised the threshold of volume before feedback because it took vibrations directly from the guitar. In the most common version, it did so from directly underneath the bridge saddle where it picked up mechanical vibrations directly from the strings via the saddle. This design resulted in a much more powerful signal, while also not being directly or significantly activated by any other sound source in the vicinity. Accordingly, the new piezoelectric pickups enabled the sonically unconventional experience of hearing an acoustic guitar to be nearly as high in volume as an electric guitar.

Other electromechanical transducers have also been developed. Generally pricier, they often also require special, and expensive, preamps and tone controls. Yet the best of these minimize any unnatural "pings" or other distortions to render what sounds very close to a natural acoustic guitar.[141] Further, by the late 1980s, hybrid "acoustic electric" guitars appeared with onboard preamps including volume and tone controls—sometimes even including three- to five-band EQ controls.[142] These could sound like an acoustic in one mode, but also sound a bit like an electric in other modes. Other advances were made to limit feedback problems at higher volumes.

However, all of this came too late to turn back the tide of the electric guitar. The warm, fuzzy, distorted, edgy, icy, singing, searing, grinding, and wailing tones of the classic electric guitar, through both clean and overdriven tube amps, had simply become its own instrument. The genie was out of the bottle, and certainly by the 1980s there were relatively few "old-timers" who would even want to put him back in. For most people, there was zero interest in abandoning the electric guitar simply because natural sounding acoustic amplification had finally become a reality.

And while there is continued high-tech tinkering both to make "acoustic" guitars played through effects pedals or "modeling" amps to sound like

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141 *See supra* Section II.B.

142 *See* Valerie Cruice, *From the Ratcheting of Helicopters to a Guitar's Hum*, N.Y. TIMES (Dec. 8, 1996), http://www.nytimes.com/1996/12/08/nyregion/from-the-ratcheting-of-helicopters-to-a-guitar-s-hum.html.

electrics and to make electrics, played through similar devices, sound like acoustics, ultimately the distinction still turns on how big and open the resonant body of the instrument is.[143] A deep, open hollow body acoustic guitar will never be able to produce the heavily overdriven, signature sound of the electric guitar without feeding back uncontrollably. In other words, the modern transducers allow for a *clean* guitar sound at relatively high volumes, but the hyperamplification of both the preamp and power amp stages of modern Marshall or Mesa-Boogie amps that produces that creamy, growling, and screaming tone of hard rock and heavy metal is still out of reach for the full hollow body, without nasty feedback.

In fact, even "hollow body" electrics generally cannot pull this off either. At best, "semihollow" body electrics—which are quite thin and have a solid block of wood running down the middle of the resonant cavity—can be used for these kinds of super overdrive or distortion tones. But more typically, it is only solid bodies that can do it. In the reverse, a solid body will never really sound like a natural, deep hollow body acoustic guitar. The strings will sustain too much due to both the solid body and the metal bridge and tailpiece, and, overall, the tone is just fundamentally different. It is, however, more likely that a solid body could eventually be run through a sophisticated, computer-modeling signal processor that could generate a "natural" acoustic tone, than it is for a hollow body to produce the fully overdriven sound of heavy metal. This is because, while signal processing can completely change the timbre of an electric guitar, the acoustic-feedback vulnerability of hollow bodies means that they can never be run through the kind of excessive amplification required to produce overdrive without painfully and uncontrollably feeding back.

The future almost shifted to completely digital tone production, starting in the 1980s with Roland's "hex" pickup.[144] The strings were now a different kind of oscillating trigger, so that the pickup was simply a conduit for the strings to control a digital synthesizer. But ultimately these kinds of digital pickups did not take off in the market, as the resultant instrument just did not sufficiently replicate the visceral experience of playing either an acoustic or electric guitar. However, such an approach may come around again, especially following the rise of GarageBand and other apps that let users create tracks by "playing" all instruments through a mouse and computer keyboard. In other words, as perhaps fewer artists than ever have to learn to play the "real" guitar, they may never experience its visceral feel and, thus, a guitar that simply acts as another kind of keyboard trigger to

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143 *See generally Acoustic Guitar Buying Guide*, MUSICIAN'S FRIEND (Nov. 11, 2013), http://thehub.musiciansfriend.com/guitar-buying-guides/budgets-bouts-and-body-styles-the-acoustic-guitar-buyer-s-guide.

144 *See* Wallace Marx, Jr., *Putting the Hex On: The Postmodern Pickups*, PREMIER GUITAR (Jan. 14, 2010), http://www.premierguitar.com/articles/Putting_the_Hex_On_the_Postmodern_Pickups.

such apps may be perfectly satisfactory. But that moment has not yet arrived.

CONCLUSION

This Essay only scratches the surface of invention and innovation in electric instruments that transformed music in the twentieth century. In fact, it presents only a small slice of innovation in *electric guitars*. It is not even comprehensive as to invention in guitar pickups. But it should give some sense of the continuity and influence from the earliest efforts of Bell and others to use newly harnessed electrical and magnetic forces to reproduce, or even create from scratch, vocal and musical sounds. In doing so, this Essay seeks to present the highlights and major transformations in electromagnetic guitar pickups.

Equally important, this Essay highlights serendipitous events occurring throughout both technological and cultural history. The limits of sound amplification technology, especially microphones, of the 1920s and '30s, created an impetus for inventors to look for other means of amplifying guitars. The one that worked best at the time, especially given the limits of the then-new vacuum tube amplifiers, did not produce a particularly natural acoustic tone. But the sound it did produce was compelling to certain forward-looking artists and audiences. Further, it represented a kind of melding of attempts to amplify a guitar and to create synthetic musical tones. The reasonably practical embodiment of these efforts in the guitar pickups available by the mid-to-late 1940s was then timed perfectly—albeit serendipitously—with the progressive and futuristic inclinations of the postwar period. This confluence of culture, attitudes, and musical instrument innovation only deepened in the 1950s and early '60s. Fender captured it well with the names and body designs of its solid body electrics: Broadcaster, Telecaster, and Stratocaster.

Ironically, by the later 1960s and accelerating in the 1970s and beyond, more natural means of reproducing and amplifying the sound of acoustic guitars with microphones or piezoelectric transducers only cemented the reality that there were now two kinds of guitars: electric and acoustic. The electric, especially when used in rock and many other forms of pop music, made no pretenses of being an amplified acoustic. Its signature sounds were the overdriven, crunchy, and singing rock tone, the funky, out-of-phase sound of some funk, soul, and R&B, and a host of unique tones produced by effects such as tremolo, reverb, wah-wah, chorus, flange, phase shifter, envelope follower/filter, delay, and golden throat voice box. By contrast, and equally popular in different contexts, the natural sounding, amplified acoustic was simply a different instrument with different playing styles. Clearly, the instruments are still quite similar with regards to basic playing techniques. But there are many excellent players who commit to one or the other and rarely, if ever, cross over. Further, playing one exactly like the other often does not work well.

Patents played a major role in the story of electric guitar pickups because inventors and their investors relied on them to facilitate professional quality commercial production. Individual musicians can, and sometimes do, make their own pickups. But the precision technique needed for winding the fine wire coils, the machining needed for bobbins, magnets, pole pieces, frames, and covers, and the basic electrical knowledge needed to wire everything up successfully puts this beyond most players' ability or interest. But many potential inventors and manufacturers were not willing to invest in bringing their new designs to commercial application without some protection for their R&D, tooling, and scale-up efforts. Thus, it is no accident that Beauchamp and Rickenbacker named one of their companies after the "elect*ro pat*ent *in*strument."[145] Patents were essential to these pioneers, as they would also be to Gibson, Fender, Gretsch, and many others.

In sum, patents played a key role in the development of entire new musical sounds and genres of the twentieth century. While copyright is often thought of as the primary IP right related to music, in fact, patents have played an equally if not more important role in the development of new sounds and genres.[146] This is especially true when one considers that style and genre are generally held not to fall within copyright.[147] Trade secrets and trademarks have also played major roles in music development,[148] but those are stories for a different day. As policymakers continue to debate the merits and scope of IP rights,[149] it is crucial that they see the full picture of the interplay of different IP rights—and the creative innovation they facilitate—in any particular area of innovation. Uncovering the complete picture can reduce the potential myopia or tunnel vision that can result from relying on common perceptions about IP rights and certain areas of creativity and innovation.

Music is a timeless, fundamental aspect of human culture and ingenuity. It seems to have undergone more dramatic and impressive changes over the past century than in any other period of its history. In at least one aspect of these changes—the development of the electric guitar and its place in driving new musical genres—patents played a central role in enabling invention to move into high quality commercial production. It would not be

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145 *See supra* Section II.B.

146 Catherine Jewell, *Creating Value from Music—The Rights that Make It Possible*, WORLD INTELL. PROP. ORG., http://www.wipo.int/ip-outreach/en/ipday/2015/creating_value_from_music.html (last visited May 29, 2016).

147 *See* NIGEL PARKER, MUSIC BUSINESS: INFRASTRUCTURE, PRACTICE AND LAW 303 (2004).

148 *See generally* Jeanne C. Fromer, *The Role of Creativity in Trademark Law*, 86 NOTRE DAME L. REV. 1885 (2011).

149 *See, e.g.*, Steve Lohr, *New Economy: The Intellectual Property Debate Takes a Page from 19th-Century America*, N.Y. TIMES (Oct. 14, 2002), http://www.nytimes.com/2002/10/14/business/new-economy-intellectual-property-debate-takes-page-19th-century-america.html?pagewanted=all.

surprising to find patents playing similar roles in other pivotal changes to musical instruments, amplification, signal processing, recording, distribution, and playback of the last century. This Essay sought to use this one example of guitar pickups to light a path for further similar inquiries, so that a fuller picture of innovation in music is available to policymakers and society at large.