RECORDING ELECTRIC GUITAR—
The Science and The Myth

By Alex Case

Electric guitar tone,
you know it's right when you hear it. How is it achieved?

The typical starting approach at the guitar amp: Shure SM57 microphone, slightly off center of one of the cones of a driver, up close and almost touching the grille cloth. Oh, and angle the microphone a little.

Ask veteran engineers why this microphone placement strategy is so common and a range of justifications follows, from seemingly scientific explanations, to vague guesses, to an honest, "I have no idea. I've always done it that way. Everyone does."

Sure, we change it up a little. It could be a different microphone, but moving coil dynamics at the affordable end of the price range are common choices. It's not always the thickness of a thin guitar pick away from the grille cloth; we might back the microphone away from the amp an inch, maybe even two. As for the angle? I've never worked in a studio with a protractor (until last night), so I could only guess the range of angles we use.

It's time to quantify the close microphone, electric guitar ritual. Let's measure the effect of these classic recording gestures one-by-one—off center, up close, and angled a little.

INTO THE LAB

A guitar amp is set-up—in this case it's a currently available open-back Fender tube amp with a single 10-inch driver. The single-driver amp keeps our tests simple, and any insights are easily applied to multidriver amps. On a 4-by 12-inch cabinet, for example, any one of the four cones is approached the way this single driver is.

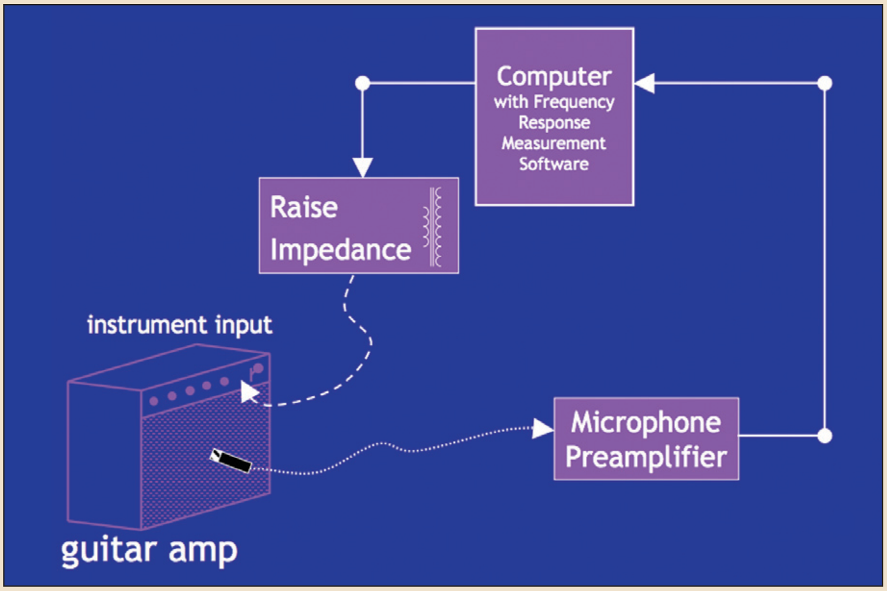

Fig. 1: Measurement setup

A tasty, clean tone that might be appropriate for any generic rock or pop rhythm part is dialed up. And then we do something rather rude, but edifying (Fig. 1). The guitar is unplugged, and a computer is hooked up. We boot up the same sort of software used to measure the frequency response of loudspeakers or microphones, and we measure the electric guitar amp, as miked. We aren't in search of a flat frequency response, of course. We want a spectral snapshot of this real-world guitar setup, as seen by the SM57, when the guitar sounds good.

If the guitar output is to be replaced by a test signal (a maximum length sequence or a swept sine wave, in this experiment), we must make sure the signal electrically looks like a guitar signal. We re-amp the test signal. The computer output is a balanced, line-level, low-impedance source. Raising it's impedance and unbalancing it, the signal may be fed at very low level to the electric guitar amp input on an instrument cable. This measurement apparatus now lets us document the tonal implications of placing that dynamic microphone off-center, up close, and angled. Three tests are run.

DISTANCE FROM CENTER

In the first test we measure the effect of having the microphone slightly off-center of the loudspeaker cone. Starting with the microphone up close, almost touching the grille cloth, aimed straight at the amp, we measure the frequency response dead center of the driver, and then work our way horizontally, left to right, from the center to the edge, in one-inch increments

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Fig. 2: Moving off center of driver

(Fig. 2). The distance from the amp is unchanged; it remains at the grill cloth. The angle of the microphone stays perfectly perpendicular to the amp. The only change is the horizontal distance from the center of the driver. The change in spectral content based on off-center placement is shown in Fig. 3.

The result is a complicated alteration—primarily a reduction—of high frequency content in the guitar tone. As the microphone moves from center toward the edge of the cone, the high end rolls-off and becomes choppy. To better highlight the changes caused by this change in microphone placement, the measurement data can be normalized to the center placement (Fig. 4). While placement of an SM57 dead center of the amp leads to a sound that is far from flat, Fig. 4 shows the spectral content of each placement off-center relative to this starting point.

The changes to spectral balance as the microphone migrates away from the center can be substantial. Just one inch off-center leads to pockets of attenuation that are a good 4 to 14 dB deep, beginning at frequencies as low as 2 kHz. Further off center, at 3 inches, the guitar tone is reshaped with some 20-dB alterations to spectral content. While the effect is shown to continue upwards in frequency, beyond 10kHz, it is important to note (Fig. 3) that there is little content in the guitar tone that high to begin with. The perceptually significant part of off-center placement is likely in the middle to upper-middle frequencies.

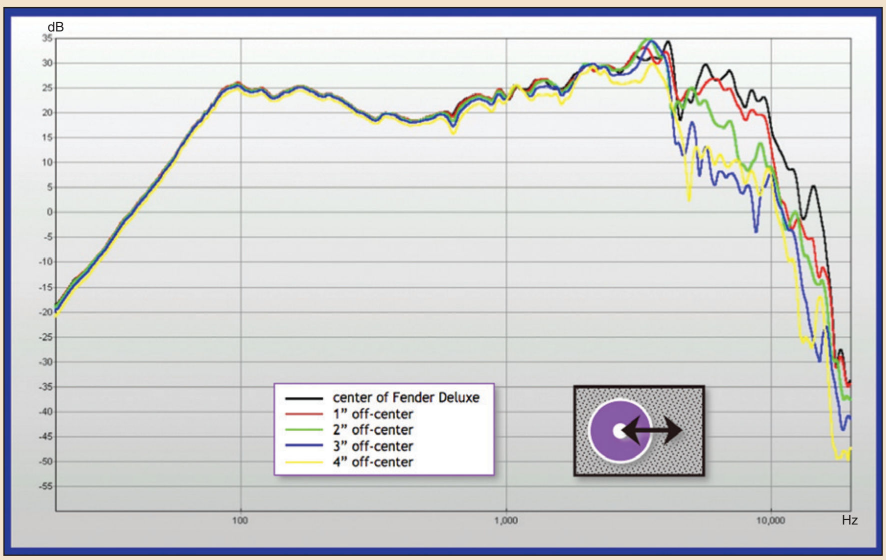

Fig. 3: Spectral effect of moving off center of driver

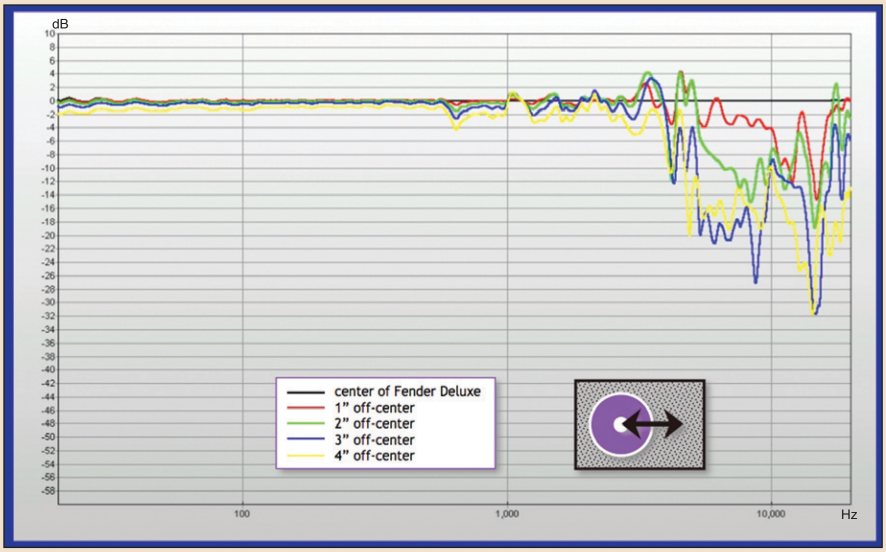

Fig. 4: Normalized to center

The familiar mental image of a cardioid pick-up pattern explains much of what is likely going on with the electric guitar amp. Think of the speaker as having a cardioid-like radiation pattern. There is a general trend in the radiation pattern of the loudspeaker driver that it becomes increasingly directional at higher frequencies. While it may approach omnidirectional behavior at low frequencies, it grows more cardioid (and even more focused still) at higher frequencies. To move the microphone off-center is to move it out of the more directional high-frequency beam. Meantime, there is relatively little change at low frequencies with off-center placement as the radiation pattern has less bias in any direction down at larger wavelengths.

Figs. 3 and 4 also make clear that the high-frequency roll-off is quite irregular. This is likely due to the modal behavior of the cone at higher frequencies. While the designer might intend to build a loudspeaker in which the cone moves as a single, rigid piston of unchanging shape, the physics conspires against the guitar amp. Just as the soundboard of a piano or an acoustic guitar bends and moves in complicated patterns depending on the notes played, the cone of the loudspeaker flexes into unusual shapes, with small regions of resonance. For a microphone very close to the cone, localized pockets of spectral coloration occur, resulting in highly complicated plots of the frequency response.

Moreover, these alterations to spectral content along the radius of the loudspeaker cone are a function of level. The peaks and valleys in frequency response come and go and change frequency location as the speaker is forced into more or less modal break-up with increases and decreases in level settings of the amp and guitar, as well as the perfor- ➥

mance dynamics of the guitarist.

An engineer can not match the effect of off-center placement with a simple adjustment in EQ. It is not as simple as a shelf or roll-off. It would require many bands of parametric EQ to match, and the EQ would have to be automated into a constant state of fine adjustments to keep up with the dynamic level-dependence of the effect. Off-center placement is a way for the engineer to soften the brightness of the tone, while leaving pockets of strong spectral character.

Perhaps more interesting still, the mechanical overdriving of the loudspeaker cone is revealed as ever changing distortion, which a close microphone, offset from the center of the driver, is well-positioned to emphasize. Off-center placement reshapes the tone in ways that engineers find interesting, and perhaps easier to fit into a crowded mix.

DISTANCE FROM AMP

The next variable to quantify is the distance from the amp. Starting dead center of the driver, at the grille cloth, with no angle to the microphone, measurements are taken at 6-inch increments from the amp (Fig. 5).

As we might expect, moving the microphone straight back, away from the amp, leads to an overall reduction in level. The farther away the microphone is, the lower the amplitude of the signal. Fair enough.

Normalizing the measurements again to the starting point, when the microphone is at the closest location practical (Fig. 6), reveals a bit more information. The signal doesn't grow uniformly quieter with distance. The attenuation is more pronounced at low frequencies. As the microphone used is a cardioid, it possesses proximity effect. Backing-off the microphone not only reduces level, but also reduces proximity effect.

Engineers adjust the distance dimension, in part, to tune the low-end content of the signal—enough for the power and fullness desired, but not so much that it muddies the tone and makes it hard to hear any interesting elements of tone in the midrange due to overwhelming bass.

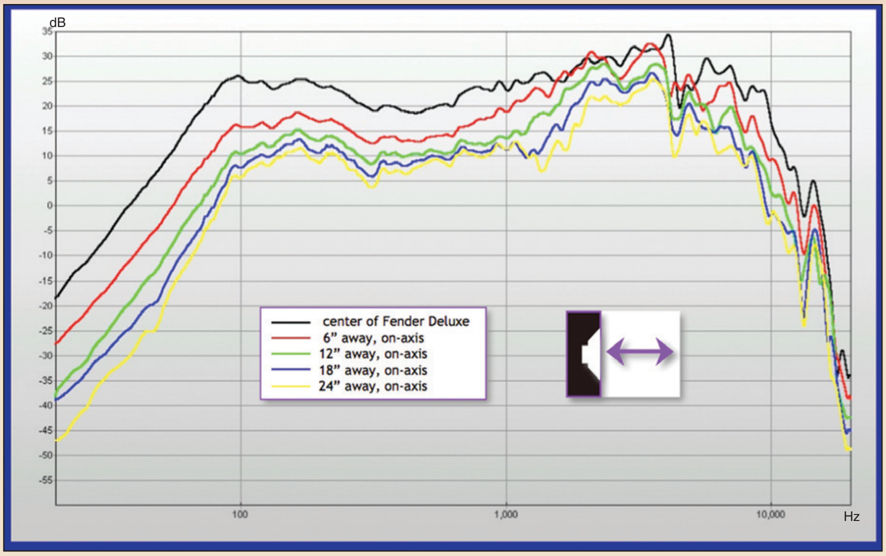

Fig. 5: Moving away from driver

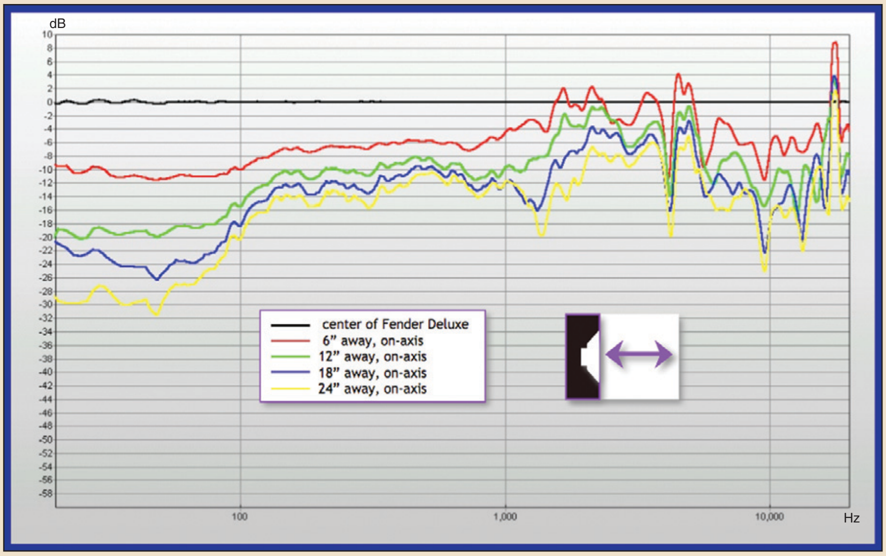

Fig. 6: Moving away from driver • normalized to 0"

At mid and higher frequencies, peaks and dips in the spectral content start to appear. One would expect the effects of the room to start to creep into the measurements as the microphone is placed farther and farther from the amp. Specifically, the floor bounce and other reflections eventually become a factor (Fig. 7). As the reflected sound travels farther than the direct sound, it arrives at the microphone delayed relative to the direct sound. If the level of the reflection is similar to the level of the direct sound, the inevitable result is some comb filtering. The strong boosts and cuts that appear with increasing distance

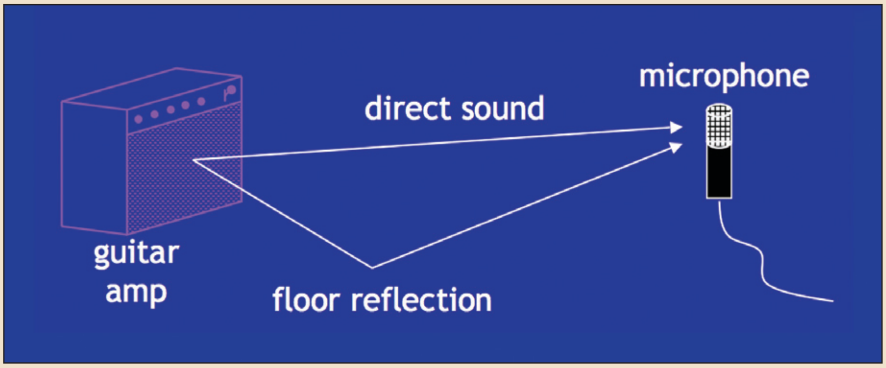

Fig. 7: Floor bounce introduces comb filtering

Fig. 8: Off axis orientation

are likely caused, in part, by the comb filtering of this first reflection.

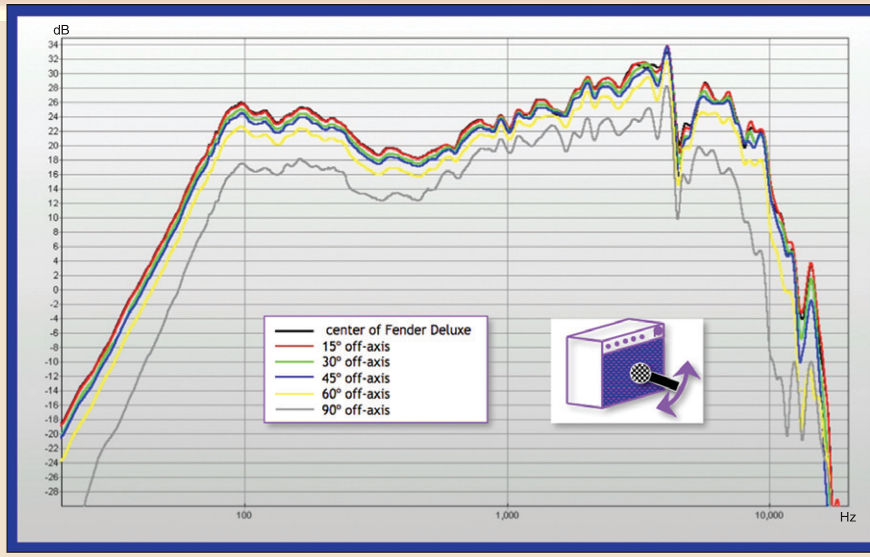

Fig. 9: Off axis microphone orientation

OFF-AXIS ANGLE

Then there is the famous tendency to angle the microphone, um, you know, "a little." Does this gesture have merit? Phase 3 of our test explores this question.

Starting with the microphone dead center of the driver, almost touching and perfectly perpendicular to the grille cloth, the angle of the microphone is adjusted—15 degrees, 30 degrees, 45 degrees and beyond (Fig. 8). Yes, it happened: someone brought a protractor to the guitar session.

For each measurement, we keep the tip of the microphone perfectly on axis with the center of the driver, and always up close to the grill cloth. While engineers are unlikely to go beyond a 45 degree angle, the experiment continues on to 60, then 90 degrees, where the microphone is fully perpendicular to the firing axis of the guitar amp.

Fig. 9 shows the spectral result. For the most part, angling the microphone causes only very small changes to the frequency response. Fig. 10, which again normalizes the measurements to the starting placement (close, centered, and on-axis), reveals spectral alterations of generally less than plus or minus 2 dB from 20 Hz to above 12 kHz for angles as pronounced as 45 degrees. Keep in mind that the bulk of the energy for guitar tones generally lives above 80 Hertz and starts rolling off well before 8 kHz.

The most that can be said is that angling the microphone introduces some choppiness to the frequency content of the signal being recorded. There is also a general decrease in level as the angle of the microphone diverges from the axis of the loudspeaker. Lastly, we might also observe that, with increasing microphone angle, the complex alteration to frequency response includes an overall reduction in level that is slightly more pronounced at high frequencies than mid or low frequencies.

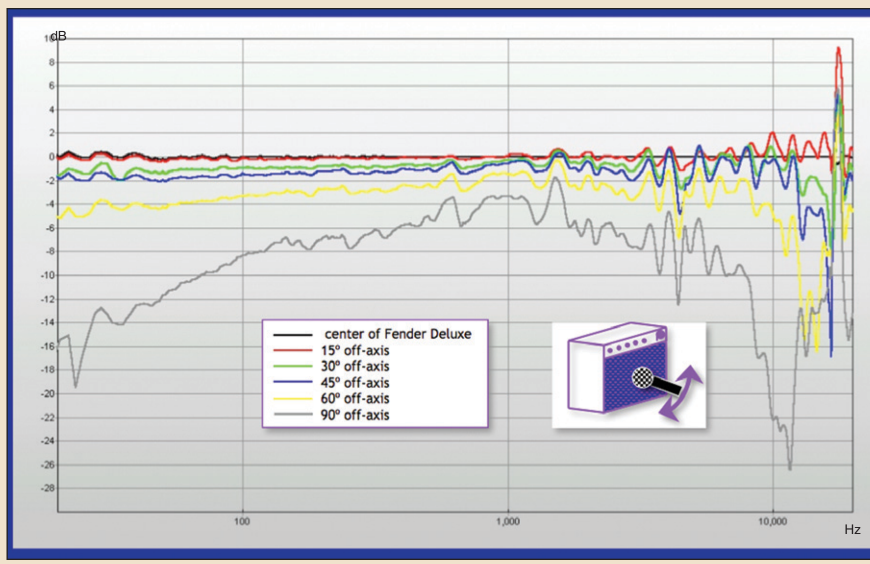

Fig. 10: Off axis microphone orientation • normalized to 0"

While many factors may explain these trends (off-axis coloration of the microphone, nearfield anomalies of the loudspeaker, asymmetric coupling to the front and back of the capsule, and more), the recording engineer need only assess the impact on their production.

For angles that might reasonably be used on a session (15, maybe as much as 30 degrees), the effect is minimal indeed, showing significant changes only at very high frequencies which, as Fig. 9 reminds us, contain very little energy in the guitar tone to begin with. Measurable, yes. Perceivable, less likely. We leave it for the reader to decide: angling the microphone, valid production technique or overstated urban myth?

BACK TO WORK

Time-consuming subjective testing to actually figure out what is perceptually meaningful with adjustments to each recording variable is the subject of further research. The first step of this work seeks only to share with you the data that was measured objectively. Let it influence what you listen for and modify your electric guitar recording traditions as much as you dare.