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PREVENTING "HOLLOW" SOUND WITH MIC TECHNIQUES
How to prevent acoustic phase cancellation

by Bruce Bartlett

Suppose you're reinforcing a singer/guitarist in mono. There’s one mic on the singer and one on the acoustic guitar.

The vocal sounds funny -- sort of hollow or filtered. What's happening? There are two vocal signals in the mix that interfere with each other. One signal is direct from the vocal mic. The other is delayed from the guitar mic. The vocal mic's signal is delayed because the vocal sound travels a longer path to the guitar mic (Fig. 1).

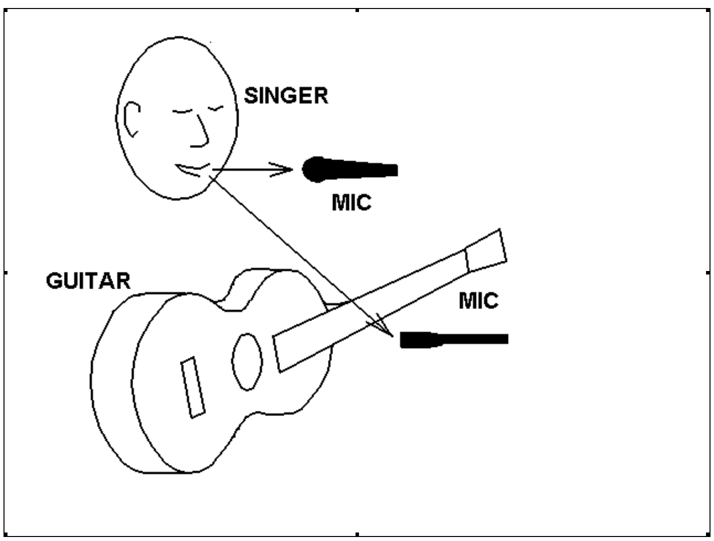

Figure 1. Vocal leakage into the guitar mic of a singing guitarist.

When you combine a signal with its delayed replica at equal levels, certain frequencies cancel out, depending on the delay. There appears a row of notches in the frequency response where the sounds cancel. This is called a comb filter effect, because the frequency response looks like the teeth of an inverted comb (Fig. 2).

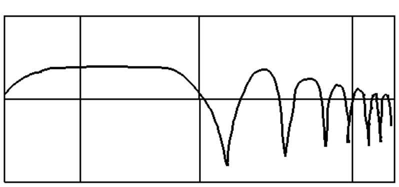

Figure 2. Frequency response of a comb filter.

In general, if two mics pick up the same sound source at different distances, and their signals are fed to the same channel, this might cause phase cancellations. These are peaks and dips in the frequency response caused by sound waves at certain frequencies combining out of phase. The result is a colored, filtered tone quality. It sounds like mild flanging.

In fact, that's how a flanger works. Using a digital delay that sweeps between 0 and 20 msec, a flanger creates a comb filter whose notches slide up and down the audio spectrum.

THE 3 TO 1 RULE
To reduce phase cancellations between two mics, follow the 3 to 1 rule: The distance between mics should be at least three times the mic-to-source distance. For example, if two mics are each 1 foot from their sound sources, the mics should be at least 3 feet apart to prevent phase cancellations (Fig. 3).

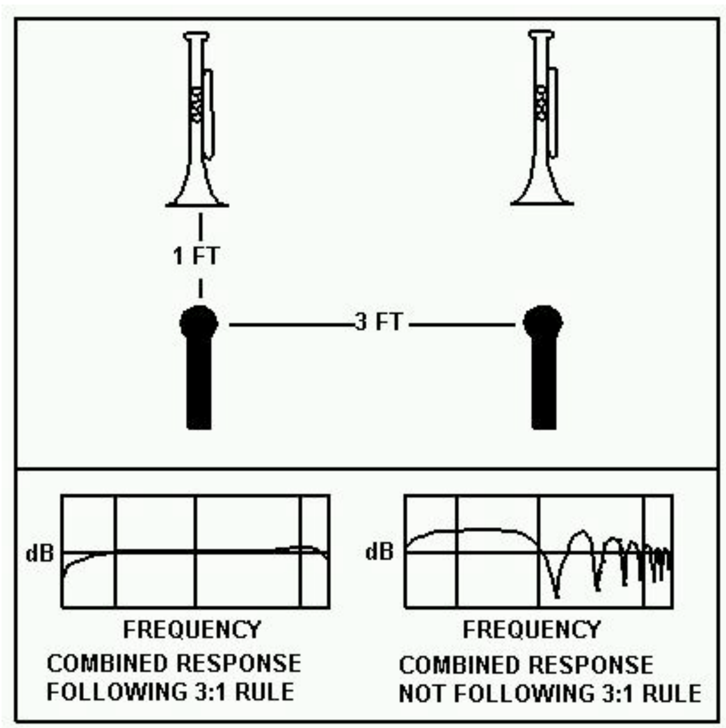

Figure 3. Following the 3:1 rule prevents acoustic comb filtering.

How was the 3:1 rule determined? It started with the following fact:

When you add a signal to its delayed replica at equal levels, you get severe comb filtering with deep notches. But when you mix direct and delayed signals at different levels, you get less deep notches.

Specifically, if the delayed signal is 9 dB less than the direct signal, the comb-filter notches are only +/- 1 dB, so for all practical purposes they are inaudible.

How do we make sure that the delayed signal, picked up by a distant mic, is at least 9 dB below the direct signal picked up by the closer mic? Put the distant mic at least 3 times farther from the source than the close mic is. Due to the inverse square law, the level drops 9.54 dB when the distance to the source is increased 3 times.

So the 3:1 rule ensures that the level at the distant mic will be down at least 9 dB, so the mixed signals will have comb filtering of +/- 1 dB or less. A ratio of 4:1 or more is even better. The 3:1 ratio is the minimum to avoid audible comb-filter effects.

The 3:1 rule applies to two mics of any polar pattern if they are both aimed at the same sound source. If both mics are parallel, the 3:1 rule applies to omni mics. But suppose that the mics have a directional polar pattern (cardioid, supercardioid, hypercardioid or bidirectional). If two mics are parallel and directional, they can be a little closer together than 3:1 and still achieve 9 dB of separation. It's simplest just to stick with a 3:1 ratio in any case.

If two cardioids are aiming in opposite directions, they can be very close (or even coincident) without causing comb filtering because the acoustic separation between mics is so high (due to the mics' rear rejection of sound).

In an anechoic setting such as outdoors, the 3:1 rule applies to a sound source at any distance from the mics. In a reverberant room, if the sound source is beyond the critical distance (where the direct sound level equals the reverberant sound level), then both mics are picking up mostly reverb from all directions. So the source's signal delay time from one mic to the other varies randomly with time. This "averages out" the comb filtering, making it inaudible. In other words, comb filtering is not audible in reverberant signals caused by a source being far away from two mics in a live room.

Back to our singing guitarist. Suppose the close mic is picking up a loud voice, and the distant mic is picking up a quiet acoustic guitar. You've placed the mics following the 3:1 rule. But you have to turn up the guitar-mic gain a lot because the guitar is so quiet. If so, you might negate the 9 dB separation. That is, the vocal signal in the guitar mic might be less than 9 dB below the vocal signal in the vocal mic, because the guitar-mic's gain is so high.

So there's more to it than just the 3:1 placement. The idea is to get at least 9 dB difference between track levels for the same instrument. You want at least 9 dB of separation, not exactly 9 dB of separation.

TIPS

Here are some ways to prevent phase cancellations between mics that are fed to the same channel:

- Mike close.
- Spread instruments farther apart..
- Use a pickup on the guitar instead of a mic.
- Use directional mics, and aim the null of each mic's polar pattern at the unwanted source.
- Delay the vocal mic signal by about 1 msec. Then it will align in time with the vocal signal picked up by the guitar mic.

Another tip to prevent phase cancellations: Don't use two mics when one will do the job. For example, use just one mic on a lectern. If you must use two mics mixed to the same channel, place them so their grilles touch, one above the other. That way, there is no delay between their signals, and no comb filtering. Consider using one mic (or one stereo mic) on a singing guitarist. Vary the balance between the vocal and guitar by changing the mic height.

EXCEPTIONS

How does this theory fit when you want to double-mic a snare drum, say with one mic on the top and one on the bottom to get more of the snare sound? Should one mic still be mixed at least 9 dB below the other?

Miking the snare top and bottom does not cause significant combing because the two heads have such different timbres. In other words, the two mixed signals are not identical, so you don't get much combing. However, the heads move out-of-phase: one goes out when the other goes in. So you need to invert the polarity on the snare-head mic.

What if two mics pick up the same instrument at different distances and they are NOT mixed to the same channel? You don't get phase cancellations. Instead, you get stereo imaging. The location of the instrument's image between your house speakers depends on the delay between mics, the levels at those mics, and where you panned them.

Suppose one mic is panned hard left and the other is panned hard right. If the delay between mic signals is 0 msec, and the level is the same at both mics, the image will appear in the center between your speakers. If the delay is 0.5 msec, the image will be about halfway off-center. If the delay is 1.5 msec or more, the image will be at one speaker.

What distances do those delays correspond to? Coincident mics, with grilles touching, have no delay between their signals. If one mic is 6.8 inches farther than the other, the delay is 0.5 msec. If one mic is 20 inches farther than the other, the delay is 1.5 msec.

This brings up the issue of mono compatibility. Some stereo mic techniques are not mono compatible. That is, the frequency response is not the same in stereo and mono, due to phase cancellations in mono. Coincident stereo techniques, where the mic grilles are mounted one above the other, are mono compatible. That's because there is no delay between the mic signals. Near-coincident and spaced-pair methods may or may not be mono compatible -- you have to listen. As you monitor, occasionally switch between stereo and mono to see if the sound changes drastically.

PHASEY SOUND FROM REFLECTIONS

You can get phase cancellations even with a single mic in use, if the mic is near a hard reflective surface. Here's why.

Sometimes you are forced to place a mic near a surface. A cymbal mic might be near a wall or ceiling. You might be reinforcing a stage play with a mic near the stage floor. Or you're reinforcing a piano with a mic near the open lid.

In these situations, sound travels to the mic by two paths: (1) directly from the source to the mic, and (2) reflected off the surface. Note that the reflected sound travels a longer path than the direct sound. So the reflected sound is delayed relative to the direct sound. The direct and delayed sounds combine at the mic diaphragm.

All frequencies in the reflected sound are delayed by the same time. Having the same *time* delay (actually signal delay) for all frequencies creates different *phase* delays for each frequency, because different frequencies have different wavelengths.

For example, a signal delay of 1 msec causes a 360-degree phase shift for a 1000 Hz wave, but only a 180-degree phase shift for a 500 Hz wave. Fig.4 shows this point.

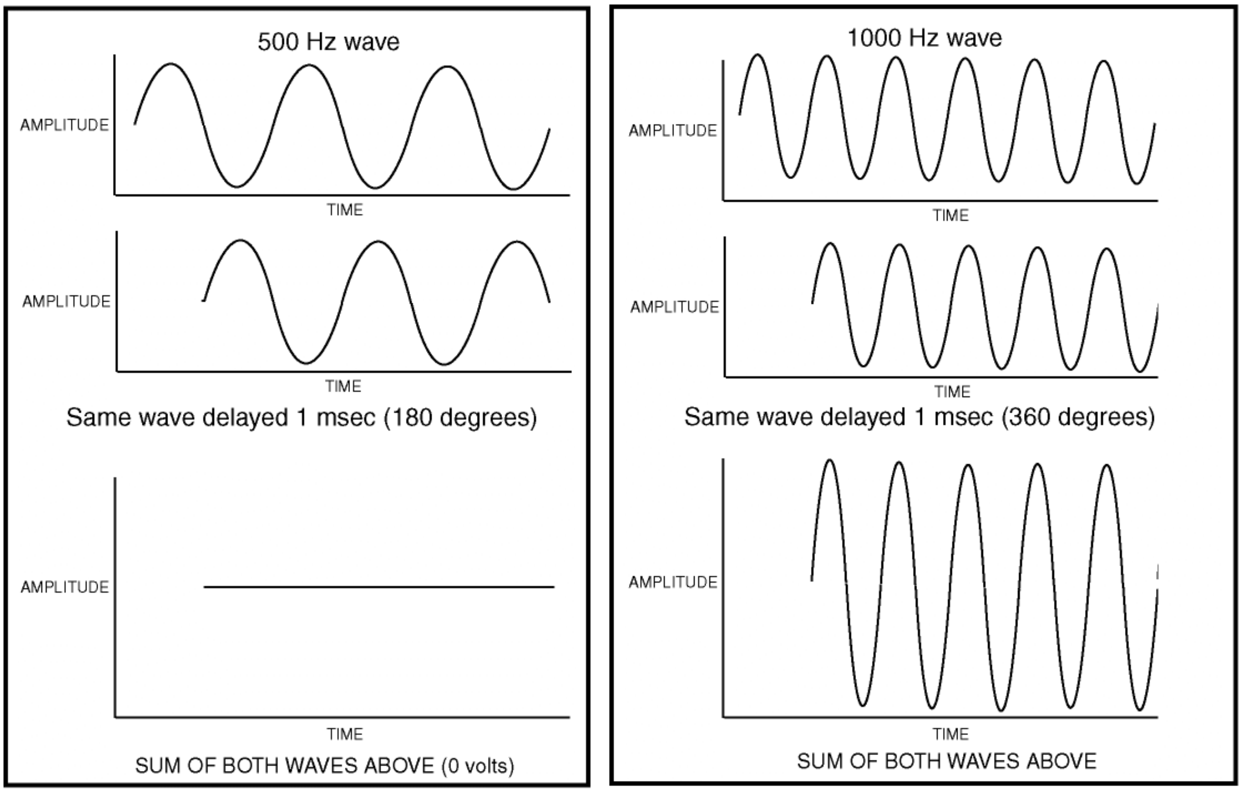

Figure 4. Two 500-Hz waves with a 1 msec delay in one wave cancel out when summed.
Two 1000-Hz waves with a 1 msec delay in one wave add when summed.

At frequencies where the direct and delayed sounds are in-phase (coherent), the signals add together. This doubles the sound pressure and boosts the level 6 dB. At frequencies where the direct and delayed signals are out-of-phase (opposite polarity), the signals cancel each other, creating a dip or notch in the response.

There results a series of peaks and dips in the net frequency response called a comb-filter effect. (It's the same effect you get with multi-miking a single instrument. This bumpy frequency response colors the tone quality, giving an unnatural sound.

Sometimes you can prevent this problem by angling the surface away from the mic. Figure 5 (top) shows a mic picking up a singer who is using a music stand. Sound reflections off the music stand bounce into the mic, causing a colored tone quality. In Fig. 5 (bottom), the music stand is angled so that sound reflections bounce away from the mic. Result: no coloration.

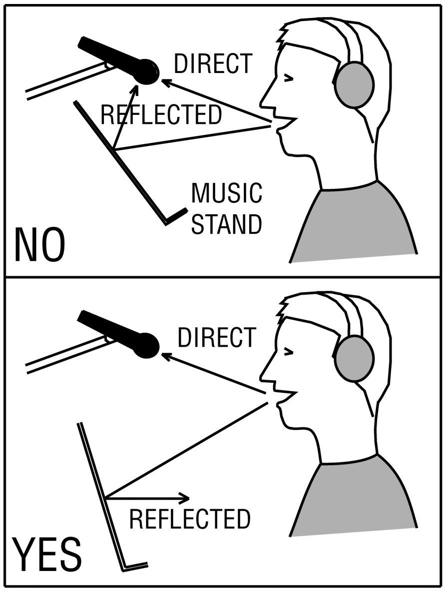

Figure 5. Top: Sound reflects off the music stand into the mic, causing acoustic comb filtering.
Bottom: Sound reflects off the music stand away from the mic, preventing acoustic comb filtering.

What's another way to prevent phasing near surfaces? Shorten the delay of the reflected sound so that it arrives at the mic when the direct sound does. You do this by putting the mic on the surface. This is the principle used in the Electro-Voice "Mike Mouse," which was a foam housing for mounting a mic just above a floor.

If you place the mic on the surface (as in Fig. 6), the direct and reflected paths become nearly equal. There is still a short delay in the reflected sound because the center of the mic diaphragm (where the two sound paths combine) is slightly above the surface. So the high frequencies may cancel, giving a dull sound.

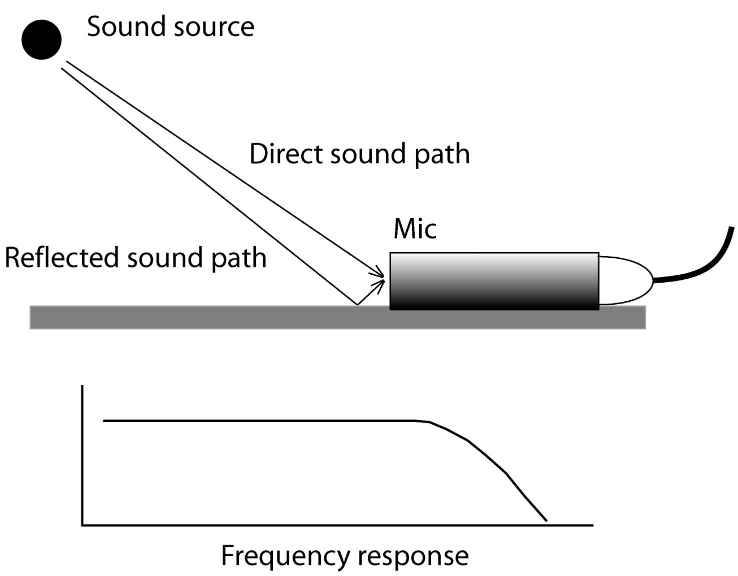

Figure 6. Direct and reflected waves cancel at high frequencies at the diaphragm center.

BOUNDARY MICS

The solution is to use a boundary mic. In an omnidirectional boundary mic, the diaphragm is face down about .020 inch above the surface (as in a Crown PZM-30D). Or the diaphragm is face up, flush mounted in the surface (as in a Neumann GLM 132).

In these mics, the direct and reflected waves arrive at the diaphragm at the same time. Any phase cancellations happen above 20 kHz, resulting in a smooth frequency response in the audible band (Fig. 7).

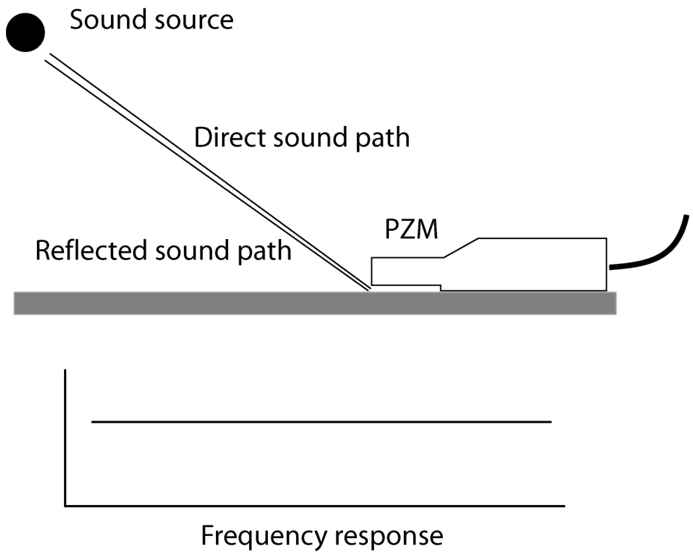

Figure 7. In a boundary mic such as a PZM, direct and reflected waves add in phase at all frequencies in the audible band.

Other benefits are these: 6 dB more sensitivity, 6 dB better signal-to-noise ratio, lack of off-axis coloration, and clear pickup of distant sounds.

A unidirectional boundary mic has a cardioid or supercardioid pickup pattern. In this microphone, the mic axis is parallel with the surface. That is, the mic aims along the surface. The mic is about 1 cm diameter -- small enough so that any phase cancellations are above 20 kHz. You get a wide, smooth frequency response.

In contrast, the mic capsules in conventional mics are relatively large. As a result, reflections are delayed enough to cancel high frequencies, so the sound is dull (Fig. 6).

Some examples of uni boundary mics are the Crown PCC-160 or PCC-170, Audio Technica AT847R, Shure SM-91A, and AKG C-547.

Uni boundary mics are a popular choice for miking drama or opera in a theater, or for picking up people at a conference table. Omni boundary mics are often used on the underside of a piano lid, or on the wall as ambience mics.

Boundary mics have a hard plate attached. The plate does not pick up sound vibrations, rather it acts as a predictable hard reflective surface.

A boundary mic should be mounted on a large surface, otherwise the low-frequency response shelves down 6 dB. Typical surfaces are floors, walls, goboes, piano lids, and clear plastic panels at least 2 feet square.

By using boundary mics, and by keeping separation high between mics, you will prevent the "hollow" sound that can plague your recordings.

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