# THE THREE TO ONE RULE & PHASE CANCELLATION FULLY EXPLAINED

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## The Three To One Rule

The 3 to 1 Rule is a multiple microphone placement rule that generally prevents the pickup of one microphone from interfering with the pickup of another. The rule is:

> ***"Two microphones, intended to pick up two sound sources must be placed apart at least three times the distance that either microphone is from it's intended sound source."***

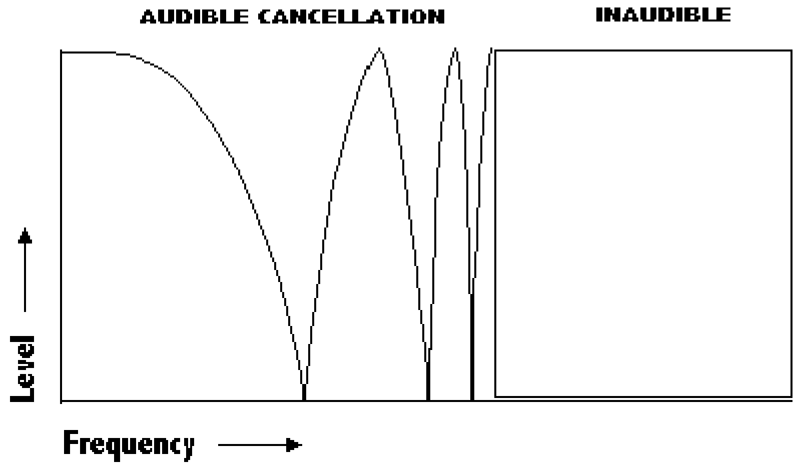
It is a rule that almost all professional recording engineers follow.

## Multiple Microphone Interference

Multiple Microphone Interference comes from the phase cancellation and addition that happens for frequencies that have a wavelength relationship with the distance between two microphones.

For frequencies where the distance between microphones represents a 1/2, 1 1/2 or 2 1/2 wavelengths, there is severe phase cancellation, These frequencies literally "disappear" and are no longer present in the signal. For frequencies where the distance between microphones represents an even 1, 2 or 3 wavelengths, there is complete phase addition. These frequencies are twice as loud as they should be.

The result is that the frequency response of the pickup by the two microphones becomes a Comb Filter that is shown in figure 2. The graph shows that there are three deep and wide cancellation nulls of the sound at three harmonically related frequencies. The frequencies in between the nulls have an increase in output. There are additional frequencies cancelled beyond the first three shown; however, these are inaudible because




the nulls are very narrow.

FIGURE 2 - COMB FILTER

The result to the ears is a very thin and unnatural, hollow, sound. The sound can be anywhere from mildly annoying to very objectionable, depending on which frequencies fall in the null. Since the frequencies canceled are harmonically related, it can be a very objectionable alteration of the sound.

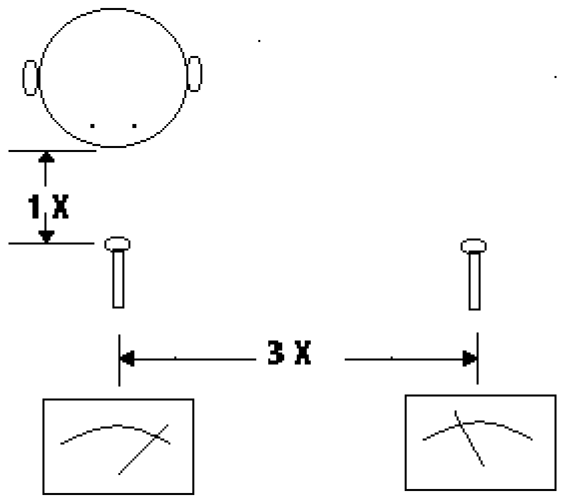
**Its All About "Phase"**

Phase is the time difference between to similar waveforms. When two signals are close in frequency and amplitude (level) but out of time with each other, there is a phase difference. One cycle of sound is considered to have 360 degrees. When a second signal starts a half-cycle later, it is called 180 degrees "out-of-phase" with the first signal. When two signals are 180 degrees out-of-phase, the peaks of one signal are in time with the dips of the second signal and the result is a cancellation of the signals' energy. Its sort of like someone pushing on a door as another person pulls on the same door - it doesn't move.

When two signals have their valleys start at the same time and their peaks start at the same time, the two signals are said to be "in-phase" and the energy of the two signals will double when the signals are combined. This is sort of like two people both pushing on the same door - it opens faster and/or further.

**How The Three To One Rule Works**

The Three To One Rule works on the basis of using distance to reduce the pickup of one sound source in the microphone intended for another source. Phase cancellation only occurs if the two signals are close to the same level. Looking at figure 3, singer #1 will get to his/her intended microphone at full level. The leakage signal into the other microphone is greatly reduced because of the distance singer #1 is from the other




METERS SHOWING PICKUP FROM SINGER #1

FIGURE 3

microphone.

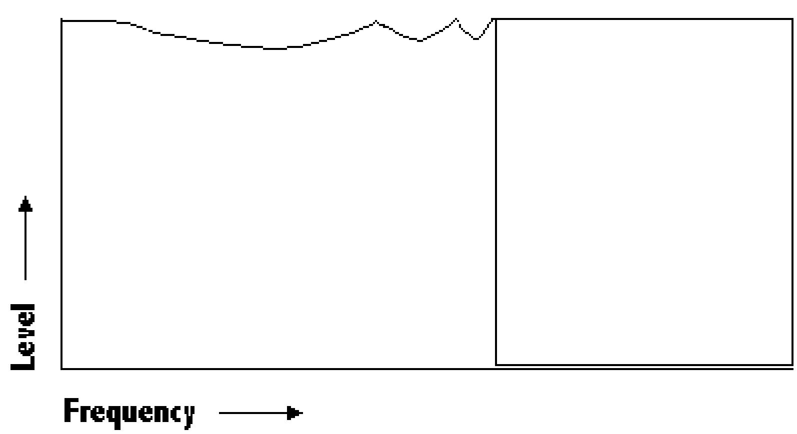



FIGURE 4 - INAUDIBLE PARTIAL CANCELLATION USING 3-1

The leakage signal into the second microphone is so weak that it cannot significantly cancel the signal in the first microphone. Only a very slight reduction in frequencies occurs as shown in figure 4.

**When The 3 To 1 Rule Doesn’t Work**

The three to one rule works well if the two singers (or other sound sources) have similar levels. When the singers have different levels, the 3 to 1 rule loses its effectiveness.

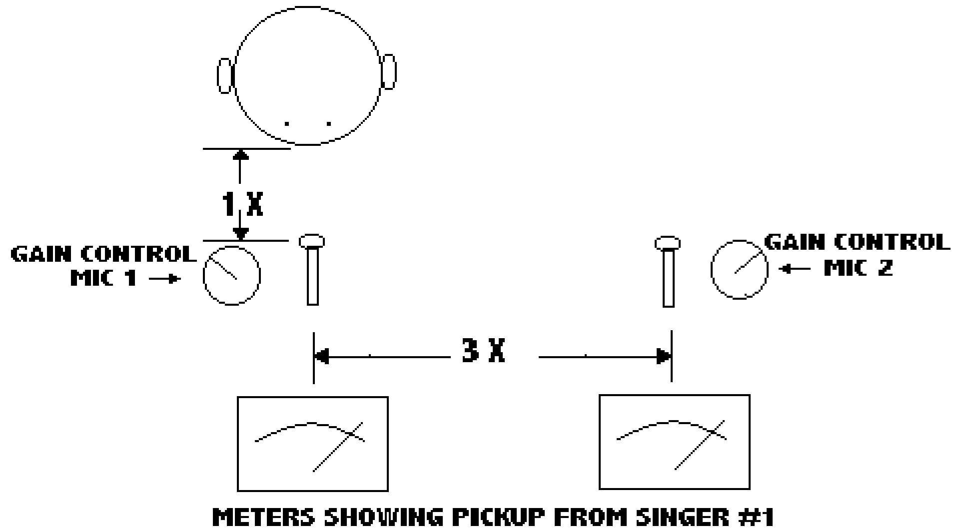



FIGURE 5 - STRONG & WEAK SINGER USING 3 TO 1 PLACEMENT

As an example, figure 5 shows the 3 to 1 microphone placement on a strong and weak singer. Microphone number 1, intended for the strong singer has the gain turned down, so the microphone input does not distort. Microphone number 2, used for the weak singer, has the gain turned up so that the weak singer sounds as loud as the strong singer. Because of the increased gain on microphone #2, singer 1's leakage signal is at a strong level. In an instance like this, every time singer #1 sings, there will be an objectionable phase cancellation of his/her voice. So here is an instance where the 3 to 1 rule was used but there is still multiple microphone interference.

**Ride The Faders**

If the 3-1 rule can't be followed, or it doesn't work because of level differences in the sound sources, riding the faders (level controls) can be a usable solution. This solution works when the singers (or speakers) are answering each other and not singing (or speaking) at the same time.

The sound person (or recording technician) would turn up the gain on the weak singer only when he or she sang (or spoke). In the example in figure 5, the technician would turn up mic two when the second singer sang, and would turn down the gain on mic 2 when singer #1 sang.

**Properly Place Directional Microphones**

If you were using direction microphones, with a "Cardioid" pickup pattern, [Also called a "Uni-directional" microphone.] you could change the angle of the microphones to violate the 3 to 1 rule or to reduce multiple microphone interference when two singers have

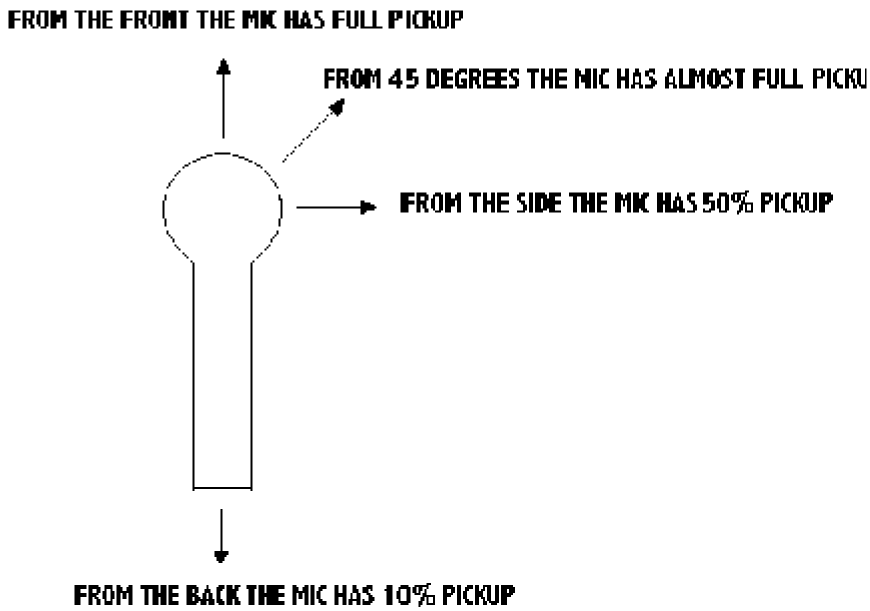



FIGURE 6 - CARDIOID PICKUP PATTERN

different vocal strengths.

The cardioid pickup pattern means that the microphone will pickup sounds to the side of the microphone at half level. Figure 6 shows the pickup of a cardioid microphone from different angles.

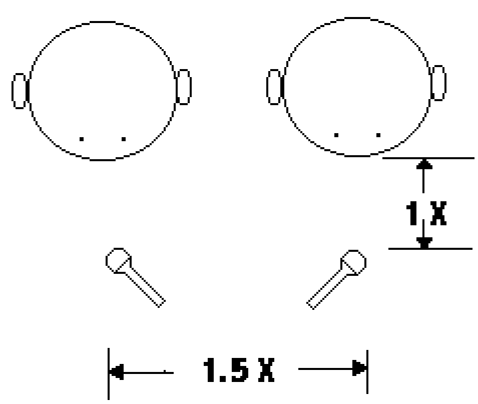



FIGURE 7 - USING CARDIOID MICROPHONES

Figure 7 shows the placement of the microphones to reduce multiple microphone interference. The two microphones are pointing at their intended singer, but the side of each microphone reduces the pickup of the unintended singer.

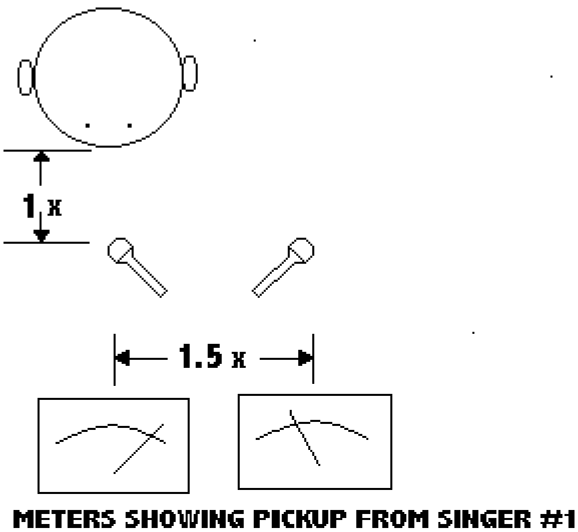



FIGURE 8 - USING CARDIOID MICS TO VOLATE 3 TO 1

Figure 8 shows the pickup of a singer in both mics with this placement.

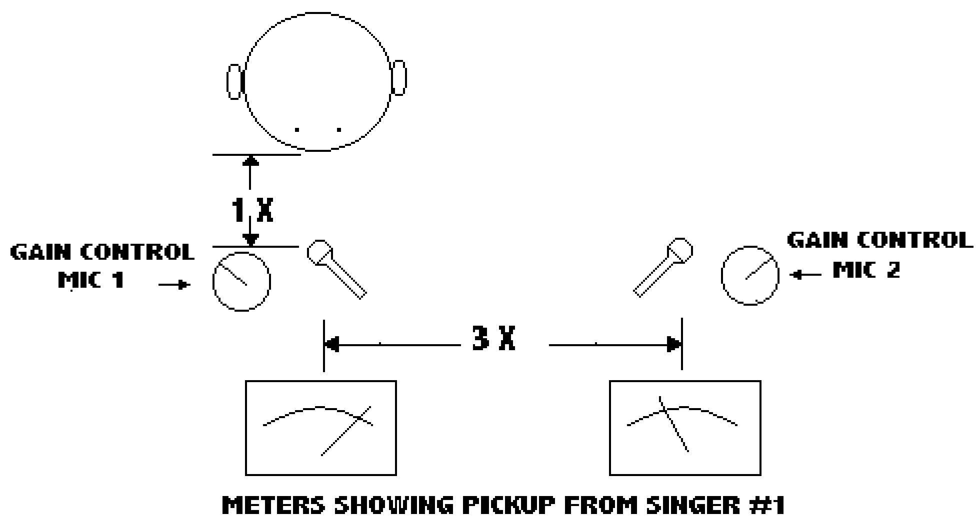



FIGURE 9 - STRONG & WEAK SINGER USING 3 TO 1 PLACEMENT AND CARDIOID MICS

Figure 9 shows the pickup when properly placed cardioid microphones are used to overcome the multiple microphone interference from different strength singers.

**Phase Cancellation From Acoustic Reflections**

Another micing circumstance can have phase cancellation, an example of which is shown in figure 10. If a reflective surface is close to the sound source, the reflection can reach the microphone at almost the same strength as the direct sound. Since the reflection has a longer path, it will phase-cancel the direct sound giving the same type of thin, hollow Comb Filter frequency response of multiple microphone interference.

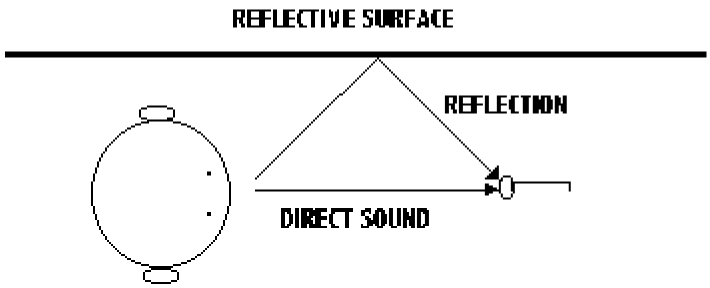



FIGURE 10 - REFLECTION CAUSING PHASE CANCELLATION

**Using The 3 to 1 Rule With Acoustic Reflections:**

You can apply the 3 to 1 rule to prevent phase cancellation due to sound reflections. Simply place the microphone at least three times the distance that the microphone is from it's intended sound source. This is shown in figure 11.

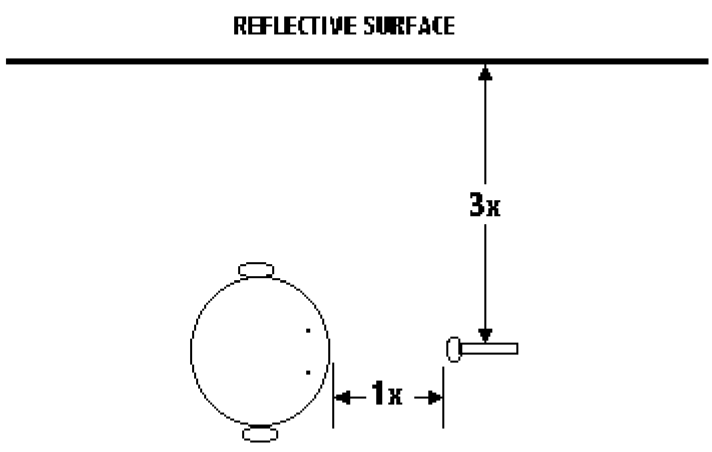



FIGURE 11- USING 3 TO 1 TO PREVENT
REFLCTIVE PHASE CANCELLATION

**Using Delay To Prevent Objectionable Phase Cancellation:**

The frequencies that are cancelled in the nulls of phase cancellation are defined by the time delay between the microphones. When two microphones are 33 inches apart, the frequencies of objectionable cancellation are 200 Hz, 600 Hz and 1 kHz as shown in figure 12. The 2.5 millisecond delay between the microphones causes these frequencies to be completely out-of-phase.

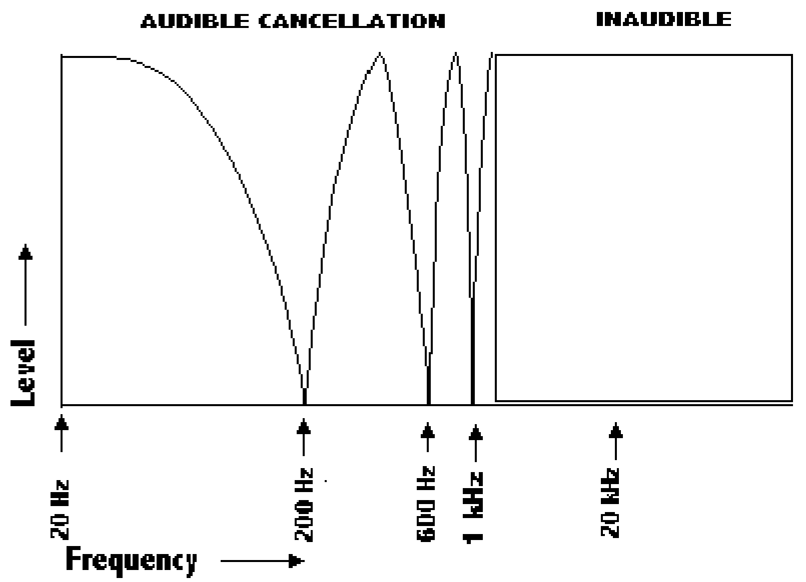



FIGURE 12 - FREQUENCIES CANCELING WITH 2.5 MS DELAY BETWEEN MICS

If the time delay between microphones was increased to 20 milliseconds, the frequencies of objectionable cancellation would shift to 25 Hz, 75 Hz and 125 Hz as shown in figure 13.

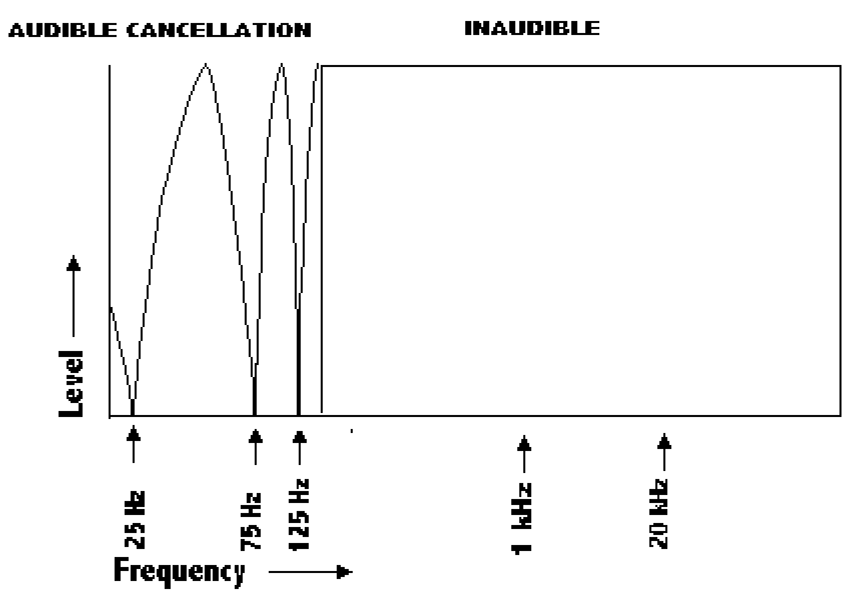



FIGURE 13 - FREQUENCIES CANCELING WITH 20 MS DELAY BETWEEN MICS

Since the majority of instruments put out energy starting at about 100 Hz, a 20 millisecond delay added to one of the microphones prevents audible phase cancellation and multiple microphone interference. When applying this delay to one of two multiple microphones, delay the microphone on the weaker voice (or other sound source).

Using a 20 ms- 30 ms delay will usually make a vocal, guitar or other non-percussive instrument sound fuller. The delay is not long enough to give two distinctive images. Delay of this amount on percussive instruments, however, will cause "double hits." As a result of this fact and the fact there are low-frequency nulls that are still audible, this 20 ms delay method will not work on drums and bass and piano, but will work for other instruments.

**The Universal Delay Method**

The nulls caused by phase cancellation, affect certain sets of frequencies. The frequencies of cancellation are determined by the delay time between microphones. Sometimes phase cancellation doesn’t greatly diminish the sound quality. You can violate the 3 to 1 rule and sometimes get away with it. In these instances the frequencies of cancellation are relatively unimportant to the sound of the instrument being picked up.

The engineer can always put a delay on a microphone and make small adjustments to the delay time to "tune" the nulls to an unobjectionable frequency. A handy rule is to start with about a 5 ms delay time and then carefully vary it up and down to get the best overall sound.

**Summary**

With the amount of tools at hand for the recording engineer or sound technician, it is easy to remedy the thin and hollow sound of multiple-microphone interference.