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Why Multiple Subs?

I want to start my posts with a lengthy discussion on the use of multiple subs, first why they should be used, and then how they are setup.

First I think it a good idea to go over some history behind the concepts. I will start by going all the way back to my PhD thesis (30 years ago), which was on this precise topic. At that time I was studying the LF (low frequency) sampling statistics in small rooms and how these were affected by the rooms shape. This is important question in sound measurement because it tells us how many points (samples) we need in a reverberant room to find the true source sound power given that each point has variations of the desired quantity due to the non-diffuse nature of the sound field at LFs in small rooms. There were several key results that came out of this study and I will highlight them here:

1) All rooms of equivalent volume, regardless of shape will have the exact same first mode. This is true as long as no one dimension prevails (no one dimension is more than twice any other dimension). If one dimension is excessive then the problem is no longer three dimensional and the dimension along this direction will prevail like a tube.

2) The modal distribution tends towards uniformity in all rooms as the bandwidth under consideration is widened. This simply means that no shape yields any more or less modes than any other shape of the same total volume. There will be small variations over small bandwidths but this will all meld together to be the same as this bandwidth increase. (This effect is enhanced with more and more damping.)

3) Modal degeneracy – when there are two mode shapes with the same frequency, such as happens in a square space – cause large increases in statistical variances. (That’s not a good thing). In any space where the dimensions are well separated from one another the modal distribution quickly becomes uniform for any room shape.

4) Damping in the room is key to its statistics, but here the rooms shape, or more precisely how the damping is distributed does play a crucial role. If the damping is placed such that all modes see a consistent damping then the effect on the variance for a given amount of damping is maximized. On the other hand, if, for example, only one wall of a rectangular enclosure has damping then the enhancement from a given amount of absorptive material is minimized.

5) Canting the walls does very little to affect the modes and modal distributions for small angles – less than say 30 degrees – but this same level of canting does have a major effect when damping is present on any wall because there are then no modes that do not see all of the walls (assuming the wall is canted in two dimensions).

6) In this study the most relevant statistic were found to be the spatial averaged, multiple source location statistics. This measure was by far the most sensitive to room variations and showed differences between rooms that other measures could miss. (This point is crucial to the concept behind multiple subs and was precisely how I came upon the idea).

The take-away importance of these points are :

a) Point 1 implies that there are basically two significant regions at LFs in a small room. The first is what I will call the "first mode" region. Basically nothing is going to affect this mode except for damping, and its darn hard to get any damping in the room at these frequencies. This region also contains the oft mis-understood "pressure mode" (more on that later) and will go up to about the second or sometimes the third mode. From my experience no amount of source moving or numbers of source will have any effect on these (1,2 or maybe 3) modes. EQ is always required to tame these modes if in fact your system goes low enough to excite them (but they are very easy to excite). These modes are also the reason that a sub can excite a room well below its actual free field LF cutoff point and why I don't pay a whole lot of attention to how low a sub goes in free space.

b) Above the "first mode" region lays the "modal region". Here is where multiple subs are more than desirable, they are basically essential. Above the modal region lies the "statistical region" where all rooms, regardless of size or shape, act exactly the same. It is in this region that we can begin to talk about things like wall reflections and transients. These features simply do not exist in the modal region and below. The wavelengths are such that the sound has typically bounced around the room dozens of times before a single period has elapsed and the ear can even begin to recognize anything remotely connected to a pitch. For this reason all that we can ever talk about in the LF region of a room is its steady state response. Nothing else even makes sense.

c) Points 2 & 3 imply that room shape, as far as modal distribution goes is not a big factor as long as no two dimensions are close or identical. This later aspect would be a pretty big problem if it occurs (been there seen that). For rooms that are not plagued by this "high symmetry" problems, they all seem to appear quite similar. So basically if your room isn't bad, then it's the same as any other room.

d) Point 4 is crucial to understand. Damping should be distributed about the room if the surfaces are all parallel (which is almost ubiquitous) or at least one side of any two opposing walls must be damped. Why just one side? Because it can be shown that one side that is damped is indistinguishable from a situation where both walls have half of the same amount of absorption. Believe me it's much easier to do high damping on one wall that anything on two walls. (Don't forget floor and ceiling!)

e) Point 5 was the basic conclusion of the study; that the shape of the room doesn't matter if there is sufficient damping. There is a small gain to be by certain shapes if the room was a reverberation chamber with almost no damping, but that's an entirely different case study.

f) Point 6 implies that the use of multiple source locations in the modal region will globally yield a response curve that is closer to the natural power response of the sources and the room. Said another way, if we use multiple source locations that the frequency response at any given location in the room will become closer to the true power response (read smoother) the more sources that are used. Basically if I have one source has a variance, V, of the frequency response (the variation of the response from the average or smooth response) of say 6 dBs, that by adding a second source we will reduce this variance by half to 3 dB. Adding a third source reduces this to 2 dB, etc. Basically the variance goes as V/N where N is the number of "independent" sources. A key requirement here is "independent". If the added sources are close to the first source then they are not independent. And two sources in opposite corners or symmetrical locations are not as independent as two sources placed non-symmetrical locations. It is impossible to have two sources that are completely independent at LFs in a small room, so the effect is never as good as the formula suggest.

   To augment point a) above, at the first mode all locations in the room are completely correlated (not statistically independent) so the 1/N variance reduction simply does not work in the "first mode" region. As stated above, nothing affects this region acoustically, not even multiple subs. This later aspect is why I use a single sub that goes very low and then multiple subs up to where the mains come in. There is nothing to be gained – statistically speaking - from more subs at very LF. (More power headroom can sometimes be advantageous.)

Point f) above is the crux of the story, but the other points are factors as well. To get the best possible LF response one needs to use multiple subs placed about the room in such a way as to maximize their independence from one another. There is little point in having all of these subs go as low as the First mode region since more sources has no effect. But there does not appear to be any solid rational that any one room location is any better than any other room location. There are a couple of factors that should be considered in choice of sub locations.

1) If there are corners, then one sub should probably go in a corner. Corners have the unique characteristic of see all of the modes. But using two corners is not an effective use of two subs because the symmetrical situation makes these two sources less statistically independent. A less symmetrical location for the second sub would be better.
2) One of the subs should be relatively close to the mains, but not too close. Ideal here might be to locate the first sub close to the mains, but back in a corner, if in fact the mains are pulled out slightly from the wall behind them, as they should be.
3) The rest of the subs locations become far less important if the first two points above are adhered to.

Once the subs have been located, the next step is to set them up properly. This will be the discussion point of another thread.

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