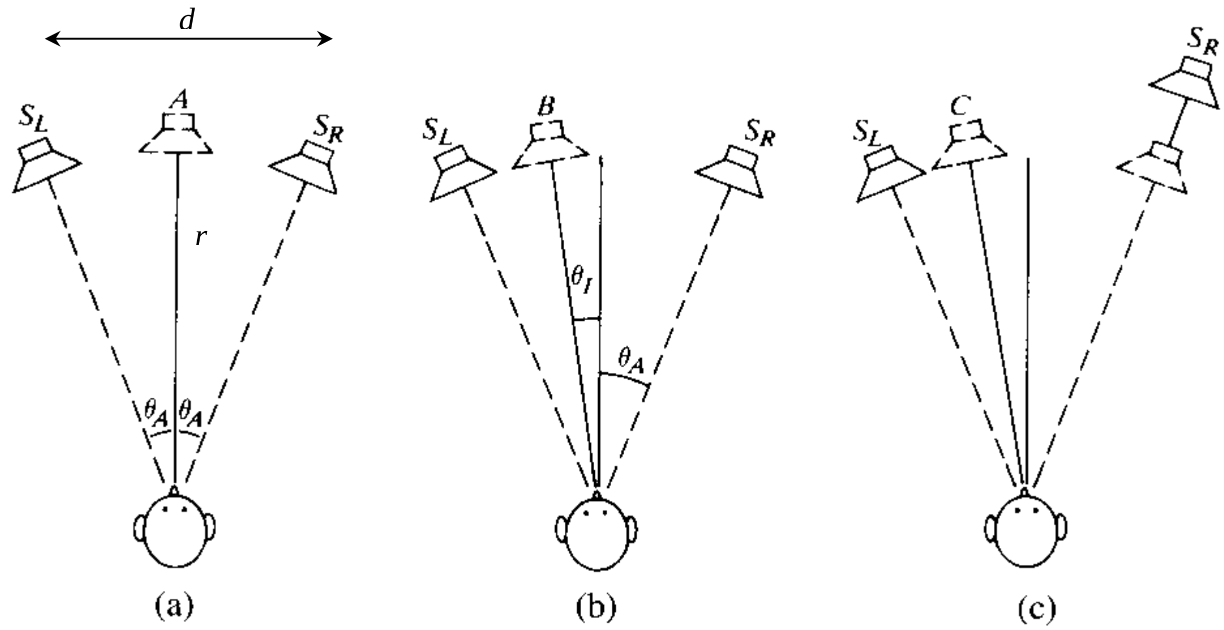
As discussed in previous P406 lecture notes on human hearing, at low frequencies ($100 < f < 1500$ *Hz*) our main clue to the direction/location of a sound source is the inter-aural time difference – *i.e.* the difference in arrival times/phase information at our two ears, whereas at higher frequencies, the inter-aural intensity difference (*IID*) dominates our ability to localize high-frequency sounds. Below $f \sim 100$ *Hz*, we have increasing difficulty in localizing sounds {a consequence of which *e.g.* is that only a single sub-woofer is needed in the 5.1 surround sound scheme for low frequencies}.

Before launching into a discussion of high-fidelity stereo and/or 5.1 surround sound systems, we first discuss some aspects of how humans, with their binaural hearing and neural sound-processing networks perceive sounds from two or more sound sources…

<u>Human Perception of Sound From Two Loudspeakers, Fed by a Monophonic Signal:</u>

A listener located at a distance *r* on the median plane equidistant from two identical loudspeakers separated a transverse distance *d* apart from each other, and fed by a common {monophonic} signal, perceives a sound "image" located on the median plane, at location *A*, as shown in diagram (a) of the figure below:



If instead the signal strengths of the two speakers are <u>not</u> equal – *e.g* the left speaker's signal is louder than that from the right speaker, the sound "image" in the mind of the listener will shift towards the louder (left) speaker, *e.g.* to location *B* as shown above in diagram (b). The angle θ_I of the sound "image" shift with respect to the median plane can be calculated from the equation:

$$\sin\theta_I = \left(\frac{p_L(\vec{r}) - p_R(\vec{r})}{p_L(\vec{r}) + p_R(\vec{r})}\right)\sin\theta_A = \left(\frac{p_L(\vec{r}) - p_R(\vec{r})}{p_L(\vec{r}) + p_R(\vec{r})}\right)\frac{d/2}{\sqrt{r^2 + (d/2)^2}}$$

where $p_L(\vec{r})\left(p_R(\vec{r})\right)$ are the over-pressure amplitudes associated with the sounds coming from the left (right) loudspeakers, respectively, evaluated at the listener's position $\vec{r}$.