However, far from the sound source, when $r \to \infty \ (kr \gg 1)$, then $|i/kr| = 1/kr \ll 1$ and $\tilde{u}_{\rm r}(r,t)$ is predominantly real, and also ***in-phase*** with the complex over-pressure $\tilde{p}(r,t)$, and hence far from the point sound source, both the ***frequency-domain*** complex radial specific acoustic impedance $\tilde{z}_{a_{\rm r}}(r,\omega) = \tilde{p}(r,\omega)/\tilde{u}_{\rm r}(r,\omega)$ and ***frequency-domain*** radial acoustic intensity $\tilde{I}_{a_{\rm r}}(r,\omega) = \frac{1}{2}\tilde{p}(r,\omega)\cdot\tilde{u}_{\rm r}^*(r,\omega)$ will be largely ***real*** quantities associated with ***active/propagating*** sound radiation originating from the {distant} point sound source.

The "***near-field***" $(kr \ll 1)$ and the "***far-field***" $(kr \gg 1)$ behavior of the complex sound field $\tilde{S}(\vec{r},t)$ associated with an isotropic point sound source emitting monochromatic spherical outgoing waves can be easily understood from a physically-intuitive perspective:

Far from the point sound source $(r \to \infty)$, the spherical waves are to an increasing degree nearly perfect ***plane waves*** – the ***curvature*** of the spherical ***wavefronts*** becomes increasingly neglectable as *r* increases far from the point sound source. As we have seen in the previous P406 Lecture Notes 12, for a monochromatic plane/traveling wave propagating in "***free air***", the complex over-pressure $\tilde{p}(r,t)$ and {longitudinal} particle velocity $\tilde{u}^{\parallel}(r,t)$ are perfectly ***in-phase*** with each other; hence {here} both the frequency domain complex radial specific acoustic impedance $\tilde{z}_{a_{\rm r}}(r,\omega) = \tilde{p}(r,\omega)/\tilde{u}_{\rm r}(r,\omega)$ $\left(= \rho_o c \equiv z_o^{\parallel}\right)$ and the frequency domain radial acoustic intensity $\tilde{I}_{a_{\rm r}}(r,\omega) = \frac{1}{2}\tilde{p}(r,\omega)\cdot\tilde{u}_{\rm r}^*(r,\omega)$ will be ***purely real*** quantities associated with ***active/propagating*** sound radiation in the form of these monochromatic plane waves.

However, in proximity to the point sound source $(r \approx 0)$, the ***curvature*** of the spherical ***wavefronts*** becomes increasingly important as $r \to 0$, one consequence of which is that the radial particle velocity $\tilde{u}_{\rm r}(r,t)$ becomes increasingly more and more ***imaginary/out-of-phase*** with the complex over-pressure $\tilde{p}(r,t)$ as the ***curvature*** of the spherical ***wavefronts*** becomes more and more significant as $r \to 0$.

In the "intermediate field" region associated with an isotropic point sound source, this is where $kr \sim 1$, and the complex particle velocity $\tilde{u}_{\rm r}(r,t)$ has ~ equal real and imaginary components, and hence is ~ 45° out of phase with the complex over-pressure $\tilde{p}(r,t)$.

Thus, for a complex sound field $\tilde{S}(\vec{r},t)$ associated with an ***arbitrary*** sound source, if the wavefronts are non-planar (such as would be expected in proximity to the sound source), the particle velocity $\tilde{u}(r,t)$ will acquire an increasingly large imaginary component as the wavefronts become increasingly non-planar, $\tilde{u}(r,t)$ will become increasingly disparate in phase with respect to the complex over-pressure $\tilde{p}(r,t)$. Consequently, the complex specific acoustic impedance $\tilde{z}_{a_{\rm r}}(\vec{r},\omega)$ and complex acoustic intensity $\tilde{I}_{a_{\rm r}}(r,\omega)$ will acquire increasingly reactive/non-propagating/imaginary components as the wavefronts become increasingly non-planar, in proximity to the sound source…

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