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Frames of multi-windowed exponentials on subsets of \mathbb{R}^d

Given discrete subsets $\Lambda_j \subset \mathbb{R}^d$, $j = 1, \dots, q$, consider the set of windowed exponentials $\bigcup_{j=1}^q \{g_j(x)e^{2\pi i\langle \lambda, x \rangle} : \lambda \in \Lambda_j\}$ on $L^2(\Omega)$. We show that a necessary and sufficient condition for the windows g_j to form a frame of windowed exponentials for $L^2(\Omega)$ with some Λ_j is that $m \leq \max_{j \in J} |g_j| \leq M$ almost everywhere on Ω for some subset J of $\{1, \dots, q\}$. If Ω is unbounded, we show that there is no frame of windowed exponentials if the Lebesgue measure of Ω is infinite. If Ω is unbounded but of finite measure, we give a sufficient condition for the existence of Fourier frames on $L^2(\Omega)$. At the same time, we also construct examples of unbounded sets with finite measure that have no tight exponential frame.