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Physical Bounds for Functional Surfaces and Materials

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A common approach to realizing functionality such as absorption, frequency or polarization selectivity, artificial magnetic conductivity etc, is to construct a periodic structure in the xy-plane with finite extent in the z-direction. With three-dimensional periodicity, we usually talk about metamaterials. The bulk properties of the structure, such as the reflection or transmission coefficient, can be controlled by the microstructural geometry or temporal dispersion of the component materials. For linear, passive, time invariant systems such properties can be associated with Herglotz functions, whose asymptotic values in the low and high frequency limit represent physical constraints such as the total thickness of the structure. In this tutorial, we demonstrate how to use the analytical properties of Herglotz functions to provide physical bounds restricting the desired functionality, typically in terms of the product of bandwidth and performance level being constrained by the total thickness of the structure in wavelengths. Similar bounds apply also to the temporal dispersion of metamaterials. Many of the bounds are tight, and hence provide a direct estimation of the best possible performance of the structure, regardless of geometry or material being used.