Design of polymeric nanocomposite multilayers for efficient EMI shielding

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Design of polymeric nanocomposite multilayers for efficient EMI shielding

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PROBLEM DEFINITION

Challenge

Electronic devices emit electromagnetic (EM) radiation which may influence the functionality of neighbouring electronic equipment. In addition, with the rise of the internet-of-things (IoT) paradigm, there is an increasing need to locally control the power (P) density of the EM network connecting the individual devices.

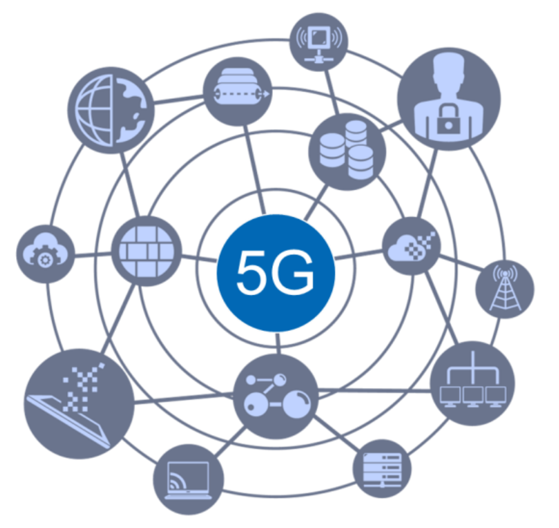


Fig. 1 - Illustration of the IoT principle. Devices are connected via a 5G network. The 5G EM waves have a wavelength λ on the order of a millimetre.

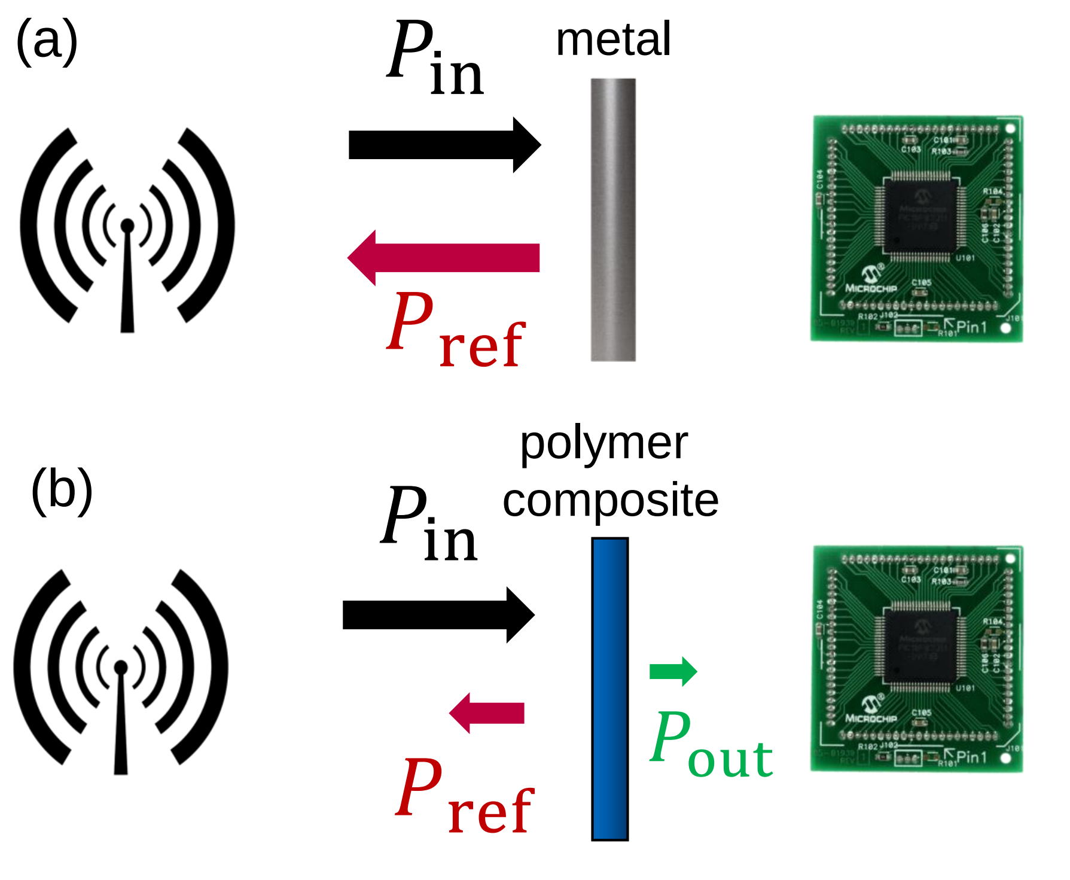


Fig. 2 – EMI shielding by (a) a metallic layer and (b) a composite layer comprising a polymer matrix and conductive particles.

Solution

Reflective metallic layers can be used to shield devices. To reduce pollution via reflected waves, one can make use of a polymeric composite layer which absorbs (part of) the incoming power. The shielding efficiency (SE_{tot}) of a polymer composite layer is dictated by the (distribution of) electromagnetic properties: the complex relative permittivity ε(f) and the complex relative permeability μ(f), where f is the frequency of the EM wave. A tailored distribution of ε(f) and μ(f) can be achieved via multilayer design, these multilayers may also exhibit enhanced ductility and toughness compared to mono-layers made of identical polymer composite material.

Approach

The aim is to design polymer composite-based multi-layer shields of high shielding effectiveness where shielding is dominated by absorption instead of reflection. Theoretical predictions are combined with measurements to reveal how the distribution electromagnetic properties and multilayer geometry dictate shielding properties.

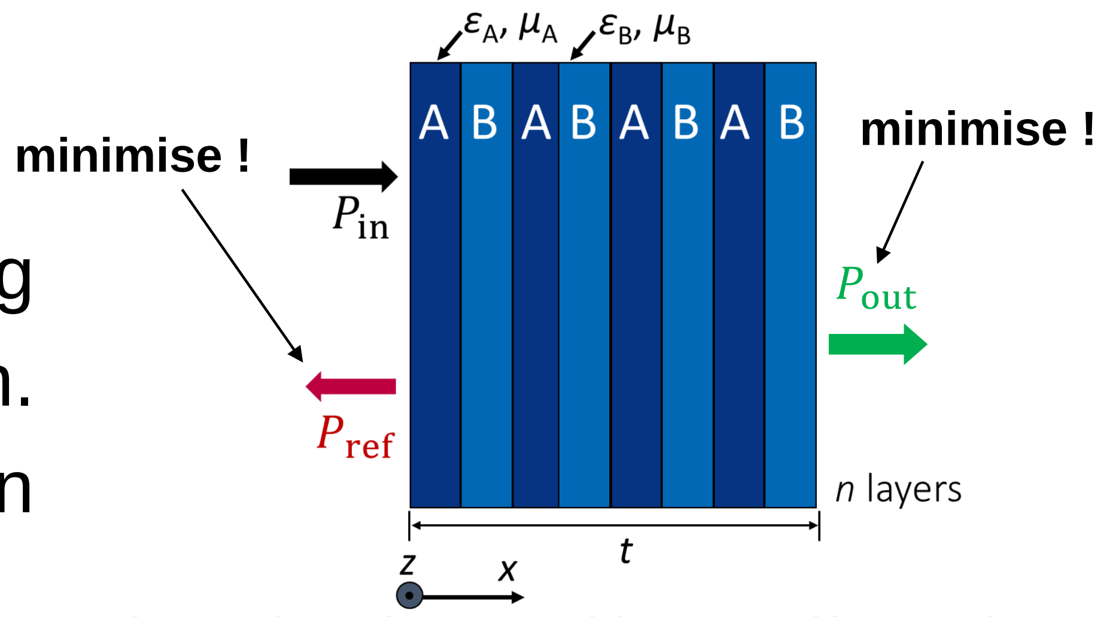
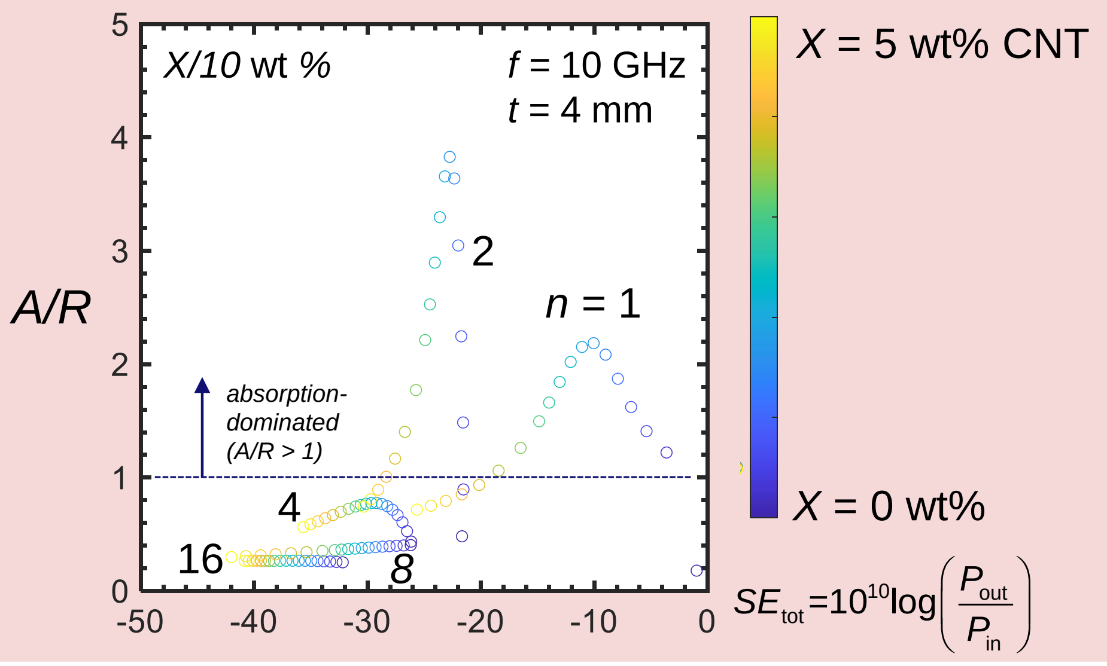


Fig. 3 – A/B multilayer comprising layers with alternating electromagnetic properties to enhance absorption via multiple wave reflections between the layers.

CASE STUDY: PMMA-CNT A/B MULTILAYERS

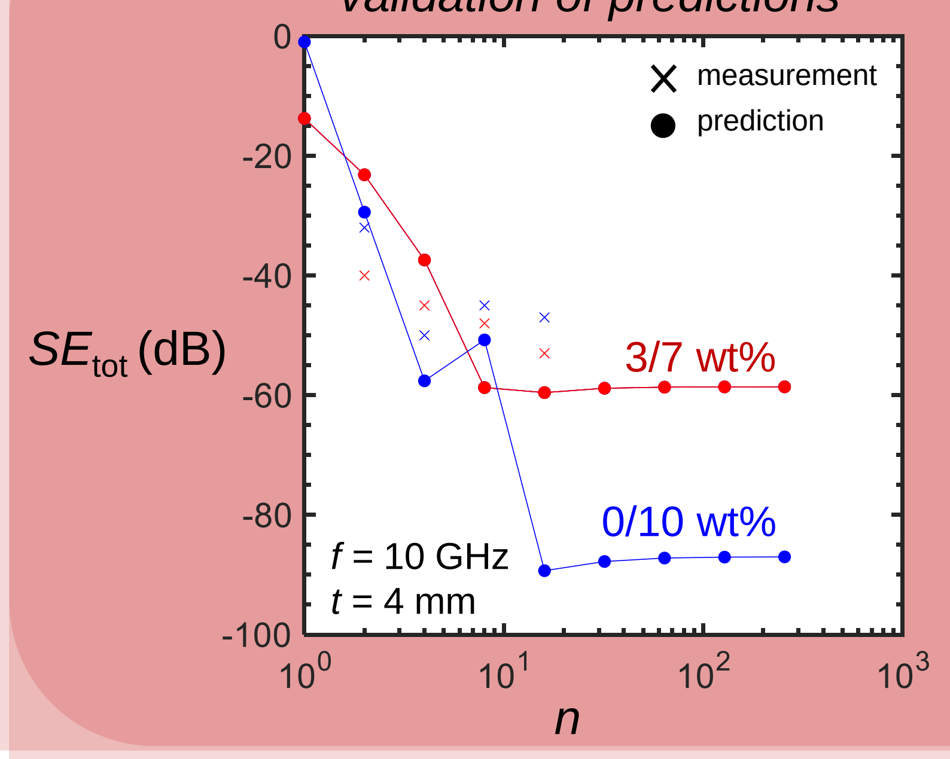
analytical theory

absorption vs. reflection-dominated shielding



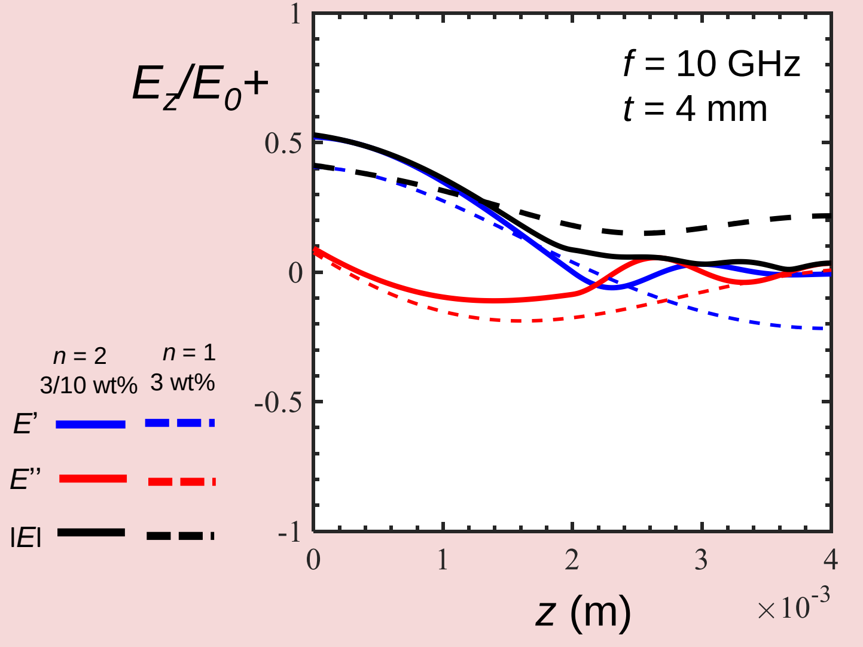
$SE_{\mathrm{tot}}=10^{10}\log\left(\frac{P_{\mathrm{out}}}{P_{\mathrm{in}}}\right)$

validation of predictions



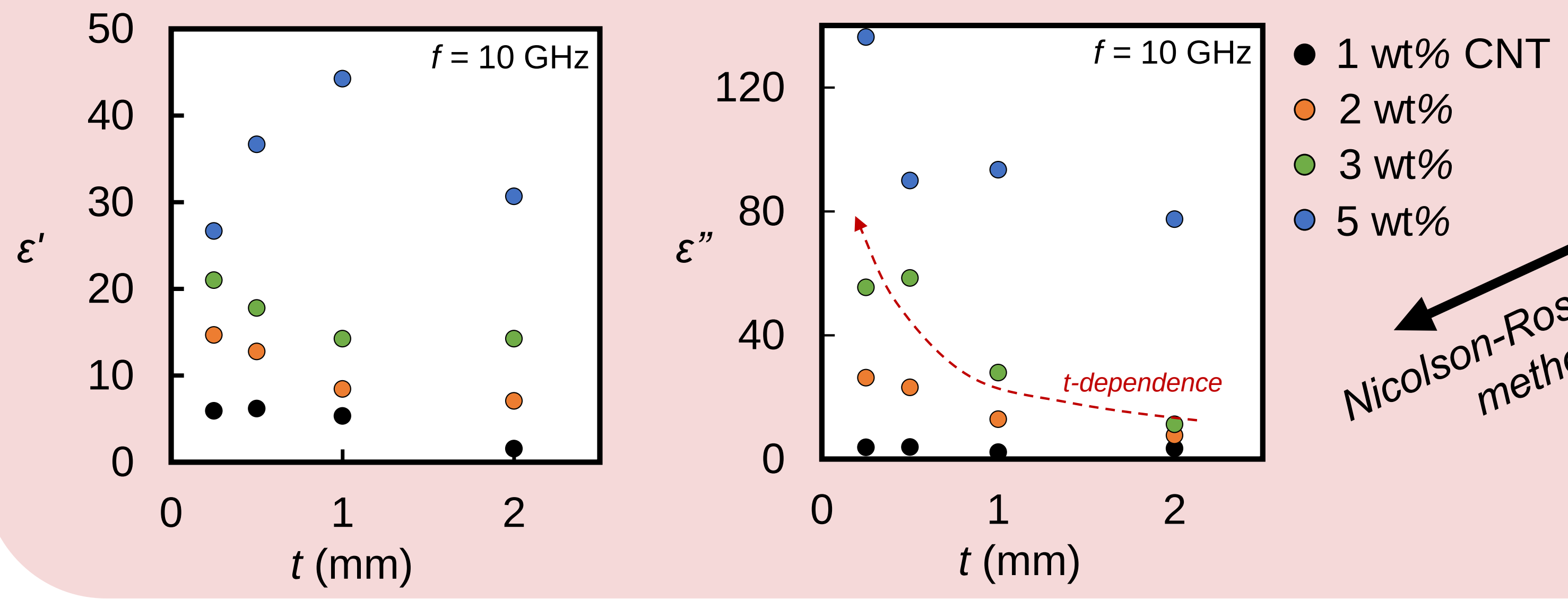
numerical calculations

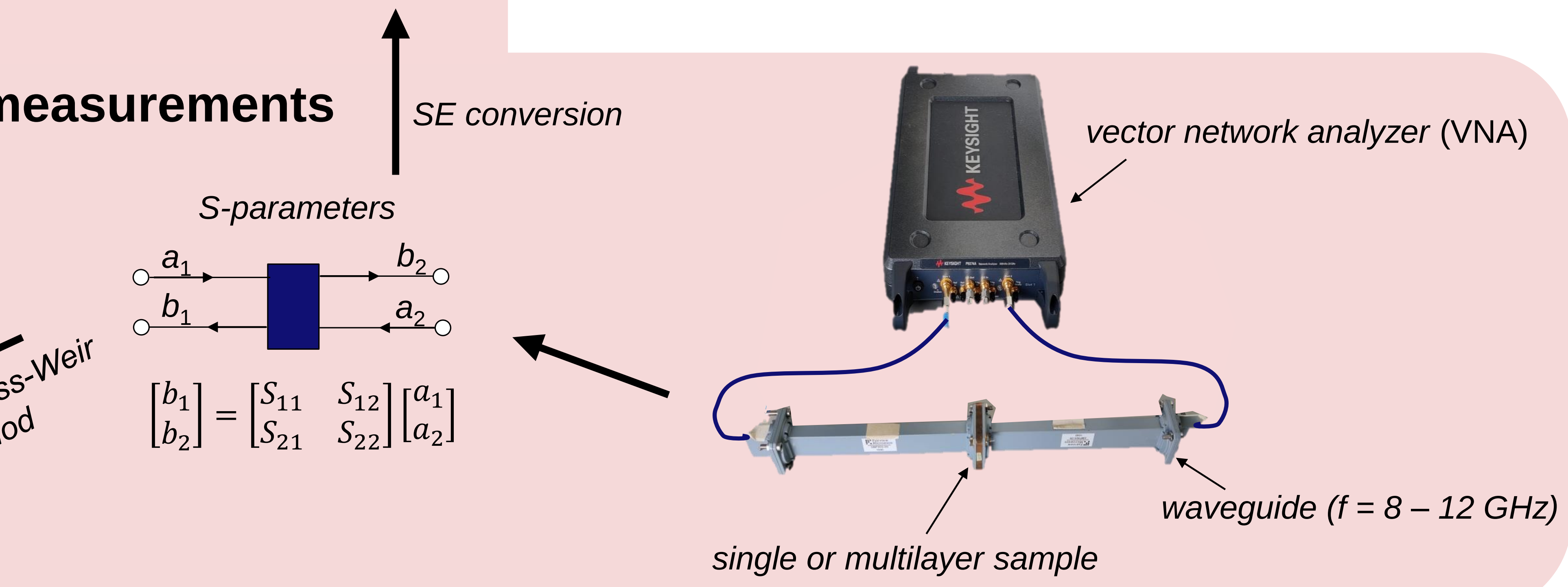
FE predictions give insight into distribution of complex E-field amplitude within multilayer



measurements

PMMA-CNT single layer permittivity measurements





$$\begin{bmatrix} b_1 \\ b_2 \end{bmatrix} = \begin{bmatrix} S_{11} & S_{12} \\ S_{21} & S_{22} \end{bmatrix} \begin{bmatrix} a_1 \\ a_2 \end{bmatrix}$$