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COMMENT

Further remarks on the non-existence of linear non-reciprocal bi-isotropic media

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Abstract. This communication follows four manuscripts published in this journal; in particular, it is motivated by the most recent comments made by Raab and Sihvola. Here we show that these comments of Raab and Sihvola affirming the recognizable existence of linear non-reciprocal bi-isotropic (NRBI) media are based on (i) a factually incorrect statement, and (ii) a confusion between static fields and fields with slow temporal variations.

1. Linear NRBI media

The frequency-domain constitutive relations of a linear, homogeneous, bi-isotropic medium were stated by Weiglhofer [1] as

$$\mathbf{D}(\mathbf{x}, \omega) = \epsilon(\omega)\mathbf{E}(\mathbf{x}, \omega) + (\alpha(\omega) + \beta(\omega))\mathbf{B}(\mathbf{x}, \omega) \quad (1)$$

$$\mathbf{H}(\mathbf{x}, \omega) = (-\alpha(\omega) + \beta(\omega))\mathbf{E}(\mathbf{x}, \omega) + \mathbf{B}(\mathbf{x}, \omega)/\mu(\omega). \quad (2)$$

A non-reciprocal bi-isotropic (NRBI) medium is characterized by $\alpha(\omega) \neq 0$. The Post constraint (PC) requires that $\alpha(\omega) \equiv 0$ [1], and thereby negates the recognizable existence of NRBI media. Our discussion is confined to *material* media, and we restate unequivocally that material media with purely instantaneous response are non-casual and cannot recognizably exist [3].

All four constitutive scalars— $\epsilon(\omega)$, $\mu(\omega)$, $\alpha(\omega)$ and $\beta(\omega)$ —are commonly understood to be complex valued in general [2, 5]. The real parts of both $\alpha(\omega)$ and $\beta(\omega)$ are time odd, and the imaginary parts of both are time even. Whereas the so-called proof of Van Vleck [2] *may* apply to the real parts of both—a doubt on the applicability having been raised in [4]—it certainly does not apply to the imaginary parts. On the other hand, the PC applies equally to both the real and the imaginary parts of $\alpha(\omega)$. Thus, whether ‘the Van Vleck proof is inapplicable at the level of laboratory-made ‘macroscopic molecules’ ’ [4] or not, it is certainly *irrelevant* to the Post constraint.

With [5] as the backdrop, Weiglhofer never wrote in [1] that $\alpha(\omega)$ is real valued and $\beta(\omega)$ is purely imaginary. Yet, Raab and Sihvola made that *incorrect assertion* on page 1338 of [2], and even more transparently in [4][†]. All conclusions drawn in Raab and Sihvola on

[†] In addition, Weiglhofer never asserted in [1] or elsewhere that (1) and (2) apply only for ‘plane monochromatic waves[s]’, as claimed by Raab and Sihvola [4]. Instead, both equations are supposed to apply for all monochromatic fields, plane waves or otherwise.

NRBI media (including Tellegen media), after assuming that incorrect assertion to be valid, are incorrect. In particular, the conclusions drawn in *Reply 1* and *Reply 2* of [4] are not meritorious.

2. Time-independent fields

A time-dependent field cannot be spatially uniform, but a time-independent (i.e. temporally uniform or static) field can be. Raab and Sihvola [4] are correct that a time-independent field can be spatially non-uniform. However, a time-independent field cannot have a *casual* effect on any material because any effect it could have must remain unchanged for all time, $-\infty < t < \infty$.

The so-called *static field effects* mentioned by Raab and Sihvola have nothing to do with static fields. Instead, they are due to *fields with very slow temporal variations*, which are certainly time dependent. Raab and Sihvola, as well as some other authors they must have in their minds when writing [4], confuse between *time-independent* and *slowly-varying* fields. Sometimes this confusion is inconsequential, sometimes not. This confusion probably led them to ask rhetorical questions in *Reply 3* of [4].

The recognizable existence of Tellegen media—whose production ‘in principle’ has been stated in *Reply 4* of [4]—is ruled out by the PC. As shown in section 2 here, the principle behind this assertion of Raab and Sihvola remains unconfirmed. We have urged them earlier (e.g., [3]) to actually implement Tellegen’s recipe and correctly verify the recognizable existence of Tellegen (and other NRBI) media experimentally.

Honorary Editor’s note: This correspondence is now closed.

References

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