Review of TUFFC-05673-2013: "Wiener Coherence Factor with Spatial-temporal Smothing Applied to Ultrasound Imaging"

I. Summary

The authors present a new variation on the adaptive imaging technique known as the Coherence Factor (CF). This variation, called the Wiener Coherence Factor, incorporates spatial and temporal averaging for improved performance.

All existing CF-type methods have stability issues to some extent, and the suggested method seems to improve on these. However, the paper suffers under the fact that the connection between the authors' motivating theoretical work and the final implementation feels somewhat contrived. It seems to me that the authors set out to do one thing, and ends up with a result that could have been motivated in a simpler manner resulting in much less confusion. I will try to motivate my opinion through the lists of concerns below.

II. Major concerns

1) The authors suggested method is identical to the coherence factor with spatial and temporal smoothing in both numerator and denominator. They state that the method is a result of "Wiener theory", hence the suggested name "Wiener Coherence Factor". This is a problematic statement because the introductions of both temporal and spatial averaging are alterations of the problem and solution (respectively) that are suggested by the authors which are ultimately unrelated to the "Wiener" derivation.

Temporal averaging is introduced somewhat vaguely between Eqs. (6) and (7). The only explanation I can find is that Eq. (6) should have been:

$$F_{wcf} = \arg\min_{F} \sum_{n=n_1}^{n_2} E\left\{ \left\| A[n] - F\vec{w}^H \vec{x}[n] \right\|_2^2 \right\}, \tag{1}$$

or that the expectation is somewhow both spatial and temporal. However, this does not satisfy the authors' motivation given immediately before (7), which is: that F_{wcf} is "obtained through minimizing the MSE estimate of the desired signal amplitude $A(t)$". If the motivation is to minimize the average MSE across the duration of a pulse, then this is a revision of the problem and should be clearly stated.

Spatial averaging is introduced to "decorrelate the signal and interference" in (7), but it is not clear why this decorrelation is warranted. Eqs. (6) and (7) are not based on any assumptions of signal and noise being uncorrelated, and the authors have earlier stated the importance of using an accurate signal model. Therefore, it stands to reason that if there is actual correlation between signal and interference, then it should not be removed from the estimate. If spatial averaging is meant as a general robustness technique for estimating $E\left\{\vec{w}^H\vec{x}\right\}$, it is not clear why the resulting reduction from M-element model in (6), (7), and (8) to an L-element model in (9) and the removal of model-accurate correlation is an acceptable price to pay for the increased robustness. The authors are quite clear on the point that model accuracy is important, which means that they should not introduce such drastic changes without proper justification.

2) Another problem is that the authors, to arrive at their final solution, introduce $E\left\{\vec{w}^H\vec{x}[n]\right\}$ into (7) as an "estimate" of $A[n]$. This is an unusual substitution, and it must be adressed since it is a vital step towards the final expression. Now, it is not quite clear whether the authors consider $A[n]$ to be deterministic or a random variable. At any rate, we are left with the following options:
a) If $A[n]$ is unknown and deterministic with $E\left\{\vec{w}^H\vec{x}[n]\right\} = A[n]$, then the authors have intentionally made Eq. (8) more uncertain than Eq. (7). A more suitable replacement for $A[n]$ would probably be $\vec{w}^H\vec{x}[n]$, wchich actually is a proper estimator of $A[n]$.
b) If $A[n]$ is a random variable that is equal to the random variable $\vec{w}^H\vec{x}$, then the numerator and denominator of Eq. (7) are identical and we get $F_{wcf} = 1$. In this case, substituting just one occurence of $\vec{w}^H\vec{x}$ in the equation to avoid this trivial solution seems rather arbitrary.
c) If $A[n]$ is a random variable (with an uncertain relationship to the random vector $\vec{x}[n]$), then the implications of the substitution are unclear.

3) At any rate, a coherence factor that includes spatial and temporal smoothing for increased robustness can just as easily be motivated directly from (1). As I reasoned in **1)**, the decision to average across a pulse length is (probably) simply a revision of the problem, and can just as easily be introduced directly as a revision of (1). The effects of spatial smoothing can be interpreted as broadening the numerator beam and making the denominator elements directive in CF. These modifications are just as reasonably applied directly to CF as they are through the “Wiener” derivation. In short, the “Wiener derivation” is not necessary to achieve the specific equation that the authors end up with, and it does not result in any new, general solution that can be adapted by the readers. It is redundant, and should probably be removed.

4) The authors mistakenly think that the Wiener postfilter derived in [15] is based solely on an assumption of spatially white noise, and that their derivation is the first attempt to correct this “incomplete model”. If they inspect [15] closer, they will find that the general solution given in [15]-(19) contains no such assumptions about the spatial noise distribution. The specific solution with the white noise-assumption is only given as an example that explains the CF in the context of the much more general Wiener postfilter. In fact, the invalidity of the spatially white noise assumption is repeatedly stated in [15]. Because [15]-(19) is completely general, the method suggested by the authors in (9) could actually just as easily be derived from this expression by introducing temporal and spatial smoothing (for robustness) when estimating the expressions in both numerator and denominator. In addition, the covariance matrix estimator given by [15]-(23) that is applied throughout the paper is based on a completely general, non-white noise model and contains both spatial and temporal averaging for increased robustness. Hence the authors must revise their summary of earlier work done on Wiener postfilters and also cite [15] as an application of both spatial and temporal averaging for robustness that pre-dates their suggested method.

5) The suggested name of “Wiener Coherence Factor” is poorly chosen seeing as how the final result is not a general expression with several realizations through user-defined estimators (unlike the ones given in [15]) but rather the very limited and specific variant of the coherence factor with spatial and temporal smoothing. “Smoothed Coherence Factor”, or something to that effect, is a much more descriptive and correct name for the method.

III. Minor concerns

1) “Spatio-temporal” is a better term than “Spatial-temporal” in the title.
2) in my opinion there is no need to include PCF in this paper, as it is significantly different from ordinary CF. PCF should be removed completely.

IV. Conclusions

I do think that a CF with spatial and temporal averaging is a good idea, but I would like to see it presented as such and not in this “Wiener Coherence Factor”-context. The authors confuse the readers by giving the impression that their solution and derivation are strongly linked, while the solution in reality could be derived from any number of existing solutions. There is nothing significantly new in the authors’ application of Wiener theory as compared to the general derivations in [15] (from which the authors have mistakenly chosen one specific realization to represent the entire Wiener postfilter framework), and the authors should refrain from giving the impression that there is. The only novel contribution is the application of spatial and temporal smoothing, which does not follow explicitly from the derivation, and this should be stated clearly. If the authors were to change the focus of their paper and change the somewhat ad-hoc-nature of the contribution, I would be happy to re-evaluate my decision.