A tunable detector for distributed targets when signal mismatch occurs

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Aiming at the problem of distributed target detection when there is signal mismatch, this paper proposes a tunable detector, which is characterised by a tunable parameter. The proposed detector can realise robust detection or selective rejection of the mismatch signal. A parametric adjustable detector suitable for mismatched signals of the homogeneous environment (HE). For this reason, this paper proposes homogeneous environment. However, this detector is not suitable for the characteristics to mismatched signals, but lack robustness. A parametric adaptive detector was not considered in [6]. In practice, a robust detector may be preferred for distributed targets [6]. However, the phenomenon of signal mismatch in [4] and a literature review was given by Liu et al. in [5].

Multichannel adaptive signal detection was edited by De Maio and Greco [1]. Based on Kelly's GLRT, denoted as Kelly's GLRT (KGLRT) [1]. Based on Kelly's research, a variety of detectors have been proposed e.g., adaptive matched filter (AMF) [2] and De Maio's Rao detector [3]. Recently, a book about multichannel adaptive signal detection was edited by De Maio and Greco in [4] and a literature review was given by Liu et al. in [5].

With the development of radar technology, radar resolution continues to improve. Hence, a single target may occupy multiple range resolution units. Conte et al. proposed several GLRT-based adaptive detectors for distributed targets [6]. However, the phenomenon of signal mismatch was not considered in [6]. In practice, a robust detector may be preferred if signal mismatch occur due to uncalibrated arrays, uncertainty of the target's direction of arrival (DOA), etc. In contrast, a selective detector may be needed if signal mismatch is due to sidelobe targets or jamming. A selective detector provides a probability of detection (PD), which diametrically reduces as the increase of amount of signal mismatch.

Two selective detectors were proposed in [7,8] for distributed target detection. However, these two detectors have only selectivity characteristics to mismatched signals, but lack robustness. A parametric adjustable detector for distributed target was proposed in [8] for partially homogeneous environment. However, this detector is not suitable for the homogeneous environment (HE). For this reason, this paper proposes a parametric adjustable detector suitable for mismatched signals of the distributed target in HE. By adjusting a parameter, the proposed detector can realise robust detection or selective rejection of the mismatch signal.

Detector Design: For an array radar containing N antennas, if a distributed target occupies K range bins, the data vector reflected by the tunable parameter, and hence the directivity (robustness or selectivity to mismatched signals) of the tunable detector can be smoothly adjusted. In addition, the tunable detector can obtain approximately the same detection performance as the corresponding generalised likelihood ratio test in the absence of signal mismatch. The proposed tunable detector also possesses the constant false alarm rate performance. Numerical examples illustrate the effectiveness of the proposed detector.

Introduction: Since its appearance, the functions of the radar have been continuously expanded and improved; however, target detection is always one of the most important functions. The problem of multichannel adaptive signal detection was first investigated by Kelly. Based on the generalised likelihood ratio test (GLRT) criterion, Kelly proposed his GLRT, denoted as Kelly's GLRT (KGLRT) [1]. Based on Kelly's research, a variety of detectors have been proposed e.g., adaptive matched filter (AMF) [2] and De Maio's Rao detector [3]. Recently, a book about multichannel adaptive signal detection was edited by De Maio and Greco in [4] and a literature review was given by Liu et al. in [5].

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cosine square of the angle between the actual signal steering vector $h_0$ and the presumed one $h$ in whitening space, defined as

$$\cos^2 \phi = \frac{|h_0^H R^{-1} h|^2}{(h_0^H R^{-1} h)(h^H R^{-1} h)} \quad (9)$$

The case of signal mismatch: Figures 1 and 2 show the detection performance of the detectors under different amounts of signal mismatches with the target expansion as a parameter. The results indicate that the T-GLRT-HE has the robust characteristics when $0.1 < \gamma < 1$, while the T-GLRT-HE has the selectivity characteristics when $\gamma > 1$. In particular, the T-GLRT-HE has the most robust characteristics when $\gamma = 0.5$, while the T-GLRT-HE has the best selectivity characteristics when $\gamma = 3$. We can conclude that the directivity (selectivity and robustness) of the T-GLRT-HE can be smoothly change by adjusting the value of the tunable parameter.

The case of no signal mismatch: Figures 3 and 4 show the detection performance of the detectors under different SNRs in the absence of signal mismatch. The results indicate that the T-GLRT-HE can achieve roughly the same detection performance with the GLRT-HE. Moreover, the PDs of the detectors all decrease when the SNR is fixed and the target expansion becomes higher. An explanation is that the higher the target expansion, the larger the unknown parameter space. This fact leads to a decrease in detection performance.

Figure 5 shows the detection performance of the T-GLRT-HE under different adjustable parameters without signal mismatch. It can be seen that as the adjustable parameter increases, the detection probability of the T-GLRT-HE first increases and then decreases. And the highest PD is equal to that of the GLRT-HE.

Conclusion: In this paper, we proposed the T-GLRT-HE for distributed target detection in the presence of signal mismatch. With a large value of tunable parameter, the T-GLRT-HE can achieve selective detection by rejecting mismatched signals. In contrast, the T-GLRT-HE with a moderately small tunable parameter can provide robust detection by maintaining high PD for mismatched signals. In addition, when there is no signal mismatch, the T-GLRT-HE, under reasonable parameter settings, can provide a comparative PD with the GLRT-HE. Moreover, the T-GLRT-HE also has the CFAR property.

Acknowledgments: This work was supported in part by National Natural Science Foundation of China (Nos. 62071482, 61871469, and...
and the Youth Innovation Promotion Association CAS (No. CX2100060053).

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Received: 11 March 2021  Accepted: 9 April 2021
doi: 10.1049/ell2.12196

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