Photonics-based coherent dual-band 2x4 MIMO radar system

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In this paper the first coherent dual-band 2x4 MIMO radar experiment is presented. Range/cross-range maps demonstrate the higher cross-range resolution due to the coherence and the enhanced performance introduced by dual-band operation.

Keywords: micro-wave photonics, radar

Multiband and distributed radars are essential for accurate and reliable 2/3D imaging of targets. (i) Multiband radars, working at different radio frequencies (RF) improve the system detection capability and reliability. Coherent data fusion among multiband detections allows to avoid the loss of data and to optimize the system precision. Unfortunately, conventional RF electronics are intrinsically narrow band and lack in flexibility. Therefore, multiband radars can be obtained only by using several independent and non-coherent single-band apparatuses. In these cases, coherence among data is digitally reconstructed in the radar processing through heavy synchronization algorithms with high computational complexity. (ii) Moreover, distributed multiple input-multiple output (MIMO) radars are systems employing multiple transmit waveforms that have the ability to jointly process signals received by multiple antennas. They allow the scene observation from different viewpoints, improving the capability to detect targets characterized by high angular radar cross section variability (e.g. complex or stealth targets). MIMO radars allow to increase the cross-range (i.e. angular) resolution. In fact, in a monostatic radar the range resolution is determined by the bandwidth of the transmitted signal, whereas the cross-range resolution depends on the antenna beam aperture and the target distance. On the other hand, MIMO radars exploit spatially distributed information to achieve an excellent cross-range resolution independent of antenna features. Finally, the coherence of the data collected from different positions can increase the detection system performance. Unfortunately, the development of MIMO radars with widely separated antennas is nowadays accompanied by two main issues: they need high capacity data links to send raw data from the multiple antennas to the central processor; and they require extremely high phase coherence among all the radar signals, i.e. among all the components of the distributed system. Finding an RF solution to these problems is challenging. Recently, the use of photonics has been demonstrated both for radar signal generation and elaboration, and radar signal distribution providing distributed coherent multiband operation [1]-[2]. Recently the authors presented preliminary results on photonics-based coherent MIMO radar systems exploiting two transmitters and two receivers (2x2 configuration) [7]. Here, the first coherent dual-band 2x4 MIMO radar experiment is presented. The used RFs are 8 & 9GHz. Antennas are placed on 1D 3m-long baseline thus enabling 2D imaging. 400MHz frequency-modulated continuous-wave signals are used.

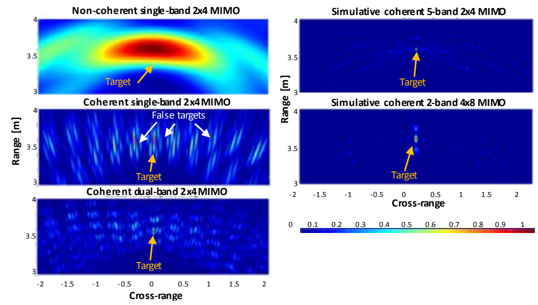

Fig. 1 Experimental range/cross-range ambiguity map using a 2x4 configuration and single-band operation with non-coherent (a) or coherent (b) MIMO processing, and with dual-band operation and coherent processing (c). Simulative range/cross range map using a 2x4 configuration and 5-band operation with coherent MIMO processing (d), and using a 4x8. configuration and dual-band operation with coherent MIMO processing (e).

Non-coherent and coherent MIMO radar processing tools have been developed as reported in [3]. Fig. 1(A) reports the experimental range/cross-range ambiguity map using a 2x4 configuration and single-band operation (8GHz) with non-coherent MIMO processing. The cross-range resolution is larger than 1 meter, while applying a coherent MIMO processing the cross-range resolution improves down to 3 cm. Unfortunately, due to the sparsity of the MIMO array configuration the coherent processing introduces not negligible sides lobes which may lead to false detections. A multi-band operation can help in decreasing these side lobes. as reported in Fig. 1(c.). By simulation we also demonstrated that the number of used bands (Fig.1d) and of used sensors (Fig.1e) further reduces the side lobes obtaining an extinction ratio >10dB. The range resolution is also improved due to the mult-band operation, while a total band equal to the sum of the used bands is synthesized.

References

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