# On Spatially Variant Apodization for Synthetic Aperture Radar

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***Abstract*—Angle:Angle: Dual-apodization, Spatially Variant Apodization, and Adaptive Sidelobe Reduction are all promising SAR imaging algorithms. Multi-apodization has often been suggested, but never tested. In particular, steered beampatterns have never been considered as candidates. In addition, all of the above mentioned adaptive beamforming methods from the SAR literature can be collectively addressed in the MPDR framework, making a comparison between them (with respect to e.g. expected performance, actual performance, robustness, and computational complexity) much easier.**

**Suggestion: Start with MPDR, point out robustness issues, coherence, etc. Relate to beamspace (SVA, ASR), suggest the LCA line-of-thought (with steered beampatterns from a family).**

***Index Terms*—Dual apodation, multi-apodization, spatially variant apodization, adaptive sidelobe reduction, SAR, adaptive beamforming**

## I. Introduction

- (Complex) Dual- and multi-apodization (CDA, DA, and MA) originally suggested in [1]. The title suggests "sidelobe control", i.e. micro-steering is not considered.
- "SVA" denotes an adaptive parametrized cosine-window, which corresponds to a symmetric 3-element beamspace/1 degree of freedom (I am not sure if all relevant points related to beamspace have been made, but it is acknowledged that SVA is a 3-point convolution in the image domain).
- No paper has demonstrated MA with a sampled window set from a parametrized window. The robustness of this approach as compared to SVA is one possible point...
- ...the use of micro-steered windows is another point.
- In addition; no one has related the importance of having several realizations from a family (such as cosine/Hamming/Hanning or alternatively Dolph-Chebyshev or Kaiser) to the variable White Noise Gain (WNG) in the windows.
- CDA is an aggressive thresholding phase-coherence-type algorithm that in addition nulls the individual I/Q components if their phases differ in sign between the two images. We could probably relate both this (and the ASR algorithm from [2]) to the coherence factor and write a CF/SWiP-type paper for SAR as well.

References on MA, DA, SVA, and related SAR algorithms (from the 90s):

1) [3]: Introduces DA, DCA, SVA. Shows "beampattern" (i.e. single-source steered response) for tri-apodization (uniform, Hamming, and Hanning). Only claims to preserve the resolution of uniform weighting while achieving the low sidelobes of non-uniform weighting. No claim about increasing resolution beyond uniform DAS. The importance of preserving clutter speckle patterns is mentioned.
2) [1]: The journal version of [3]. A lot of math on pahse transitions etc. No significant new points are made.
3) [2]: De Graafs "adaptive FIR filtering" approach can be related to the coherence factor. He also presents Adaptive Sidelobe Reduction (ASR), which is the same as Stankwitz' SVA, but generalized to more than 3 beams that can be asymmetrically weighted. It is basically ordinary MPDR beamspace processing.
4) [4]: Appendix D.3 describes SVA as an extension of CDA.
5) [5]: A recent summary of SVA/ASR-algorithms, which does not seem to have been picked up by anyone in particular.

Eq. (D.7) from Eq. (D.8) from [4]:

$$C(n) = 1 + 2w\cos\left(\frac{2\pi n}{N}\right) \tag{1}$$

Eq. (D.8) from [4]:

$$c(m) = \delta(m) + w\delta(m-1) + w\delta(m+1) \tag{2}$$

## II. Contribution

**Note:** I will use LCA to denote MA with steered beampatterns (something different from Stankwitz' contributions).

- Although SVA can be viewed as a generalization of DA/CDA/MA, it is advantageous to view SVA as something separate, i.e. a reduced dim./symmetric=robust beamspace (as compared to ASR = complete beamspace). The robustness of LCA is special and should be emphasized.
- LCA is independent of Fourier-domain sampling and array geometry.
- LCA set size can be limited by e.g. allowable WNG.

## References

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[3] H. Stankwitz, R. Dallaire, and J. Fienup, "Spatially variant apodization for sidelobe control in sar imagery," in *Radar Conference, 1994., Record of the 1994 IEEE National*, mar 1994, pp. 132 –137.

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