Tutorial: Aperture Synthesis Radar Imaging applied to Ionospheric/Atmospheric radar

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Resolving space and time ambiguities in the directions transverse to the radar antenna pointing in some atmospheric and ionospheric applications are dealt with by means of imaging in different pointing directions. Modern systems using phased-arrays, can accomplish radar imaging by electronically steering the beam in different directions, but the number of pointing positions are limited by the integration time needed for each position. If the radar power or the radar cross-section of the target of interest permits, transmission can be done with a broad beam, and different pointing positions can be synthesized digitally on reception, allowing all pointing directions to be examined at the same time. Normally, the resulting resolution will be limited by the size of the receiving array, however by implementing numerical deconvolution, the resolution can be improved.

In this tutorial we review the mathematical formulation for the radar imaging problem as an extension of the simple 3 antenna radar interferometry formulation, as an analogy to the pin-hole optical camera, as well as its similarities with the well-known spectral (time-frequency) estimation problem. We expect that presenting the radar imaging problem from these three points of view, would help to understand not only how it works, but also what are the main considerations to design and use a system, as well as to interpret the data.

In addition, we discuss some of the non-parametric and parametric methods that have been successfully employed in atmospheric/ionospheric radars, as well as their advantages and disadvantages. Finally, examples will be presented for both (a) high-resolution imaging, where the brightness of interest is much narrower than conventional transmitting beams, as well as (b) examples where the brightness are usually much wider than typical transmitting beams, but their spectral information is not homogeneous in the illuminating beam. The latter is being used in Polar-Mesospheric Summer echoes (PMSE) to relax the assumption of a homogeneous wind field in +/-30 degrees region, by combining the use of wide beams, electronic beam steering, and aperture synthesis radar imaging.