# Distributed BeamForming (DBF):

# Myths and Realities

by

Andreas Polydoros, Ph.D.

Professor of Physics (retired)

NKUA, Greece

## Abstract

BeamForming (BF) is well understood and widely used via co-located antennas, as in an array, particularly for forming narrow downlink beams in a grid-based system (e.g., massive MIMO in 5G). It can provide focused energy at a spatial position or a direction. The key enablers for BF are (i) simultaneous availability of a common message, i.e., of a user's baseband bitstream, across the antennas; (ii) controllable delay elements which translate to directional energy through carrier-phase adjustment; and (iii) a single oscillator crystal at the transmitter which provides a common phase reference to the array elements.

When addressing the distributed version of BF, namely DBF, particularly in the uplink towards a destination receiver, these enablers are not there. A set of spatially distributed radio units possess individual oscillators, they don't automatically share a common message, and their respective carrier phases are not easily streamlined to provide directional energy. As a result, the only popular and practical option has been spatial multiplexing, namely independent messages (one per each radio) being simultaneously emitted towards an array-enabled infrastructure receiver, a scheme also known as Space Division Multiple Access. DBF on the other hand has been researched for about two decades, mostly for range extension of sensor and *ad hoc* mobile networks (MANET); however, working systems have yet to emerge.

We will discuss recent progress that makes DBF appear on the cusp of deployment. The key is to replace closed-loop DBF with open-loop DBF, whereby the dispersed radios manage to synchronize amongst themselves without help from the destination. The underlying principles that make this possible will be explained, and practical algorithms for timing, frequency and phase adjustment will be explored, thus also revealing the ultimate limitations of such a system. Yet, the promised gains in signal enhancement are very significant (quadratic in coherent power instead of linear in incoherent), thus opening up the road to the eventual vision of distributed virtual MIMO.