MIMO radars. What are they?

V.S. Chernyak
Moscow Aviation Institute (State Technical University)
chernyak@kmail.ru

***Abstract*– Two classes of MIMO radars are briefly considered. MIMO radars with colocated antennas and coded signals represent a new and prospective concept. MIMO Radars with widely separated antennas ("Statistical MIMO radars") are a particular case of well-known Multisite (Multistatic) radar systems. Most results presented by the authors of "Statistical MIMO radars" were obtained under much more general conditions and published many years ago. Besides, ignoring some specific features of radar by the authors of "Statistical MIMO radars" has led to serious errors.**

Key words: Radar, MIMO systems.

I. Introduction

In the last years MIMO Radars have become very popular (e.g., [1-10]). The term "MIMO" ("Multiple Input – Multiple Output") has been borrowed from communications. "MIMO" approach turns out to be very effective in communications because it permits significant increasing the throughput of physical communication channels.

Having borrowed the term "MIMO", many authors apply traditional notions from communications to radar. On one hand, such approach is fruitful because permits using certain results from communications theory and practice. On the other hand, it does not take into account specific features or radar and, therefore, may lead to serious errors.

Now it is clear that known MIMO radars may be divided into two classes. The first class contains MIMO radars with colocated antennas and coded signals. The second class includes radars with widely separated antennas, the so-called "Statistical MIMO radars".

II. MIMO Radars with Colocated Antennas and Coded Signals

They were suggested as an alternative to conventional surveillance radars with narrow transmitting antenna beams and sequential space scanning.

A. The RIAS and Surveillance MIMO Radars

Although the term MIMO was suggested for radars in 2003- 2004, the first MIMO radar was the French radar RIAS [11]. The radar worked at metric wavelengths. Its antenna system consisted of receiving and transmitting sparse circular arrays, one inside the other. All elements of the transmitting array simultaneously radiated mutually orthogonal signals shifted in frequency.

Probably, the first detailed consideration of the MIMO radar was published in [1] (Fig. 1). All M elements of a transmitting array (Tx) radiate M mutually orthogonal signals in a wide sector. Each element of an N-element receiving array (Rx) receives all these coded signals and separates them. Matched processing of all the M by N signals is performed. Thus, we have narrow receive beams and surveillance in a wide sector without beam scanning. The increase of target observation time may compensate for the decrease of illuminating power caused by broadening the transmit beamwidth.

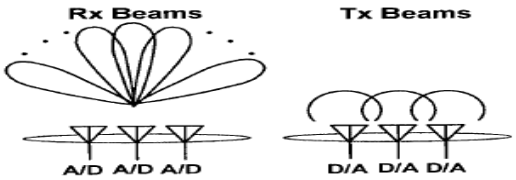

Fig. 1. Transmitting array with broad overlapping beams and orthogonal signals, receiving array with narrow beams receives all radiated signals [1]

B. Advantages Caused by the Increase of the Number of Degrees of Freedom

Many important advantages are caused by the increase of the number of "degrees of freedom" [2, 3]. Virtual antenna array elements appear additionally to physical antenna elements (Fig. 2).

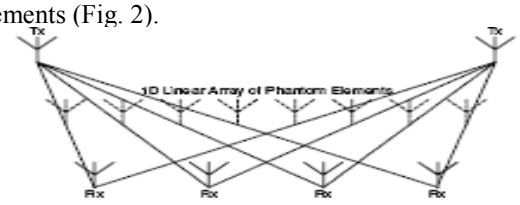

Fig. 2. An antenna array with physical 2 transmitting and 4 receiving elements and an equivalent array with 8 transmit/receive elements [2]

Sparse antenna arrays may be effectively filled in, and the total antenna aperture may be extended. It reduces sidelobes and leads to higher angle resolution.

For many unresolved targets, greater number of independent equations may be set up to determine their coordinates. This increases target "identifiability" [4,5].

Another important feature is better adaptation capability. Illuminated signals of different targets are linearly independent. This allows for direct applying effective adaptive algorithms with high resolution (for example, the Capon algorithm) [5].

A very interesting and important feature of MIMO radars with colocated antennas is the ability of transmitting beampattern adaptive optimisation. First works on MIMO radars used mutually orthogonal signals transmitted from antenna elements. However, it turned out that one may control cross-correlation between transmitted signals in order to create a desirable transmitting beampattern [6-8]. This is

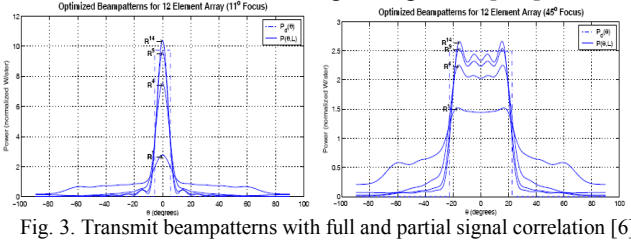

Fig. 3. Transmit beampatterns with full and partial signal correlation [6]