On the concept of MIMO radar

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On the Concept of MIMO Radar

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***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 has led to serious errors.**

INTRODUCTION

In the last years MIMO Radars have become very popular. Many papers are published in journals, magazines and conference proceedings (e.g., [1-10]). As is well known, the term "MIMO" ("Multiple Input – Multiple Output") has been borrowed from communications. "MIMO" approach turns out to be very effective in communications, first of all, 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. Processes of radar signal propagation from a transmitter to targets, reflection from targets and back propagation to a receiver are considered as propagation through a communication channel. Target position, velocity and other target features determine characteristics of the channel. They describe them usually by the "channel matrix". The ultimate goal of a radar reduces to this matrix estimation.

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.

Known MIMO radars may be divided into two classes (Fig. 1): 1) MIMO radars with colocated antennas and coded signals and 2) radars with widely separated antennas, the so-called "Statistical MIMO radars"[*)]. Let us consider briefly both classes of MIMO radars.

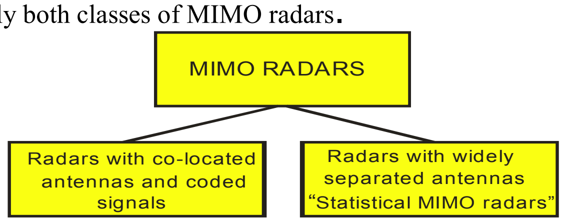


Fig.1. Two classes of MIMO radars

[*)] This term itself is hardly meaningful because all radars are "statistical" (target detection and localization are *statistical* decisions and *statistical* estimations)

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. Although the latter radars provide maximum target illuminating power, they have serious disadvantages when used for surveillance in a wide sector. Firstly, much time is required to scan a wide sector with a narrow transmitting beam, so that revisit time period is long. It is not good for close-in, especially fast targets. Secondly, for a fixed sector and a given time for surveillance over this sector, "the pulse hunger" takes place. It means that only few pulses from each target may be received within the given surveillance time, which is often insufficient for clutter rejection. Besides, sequential space scanning with a narrow beam does not allow performing all necessary functions during a dwell time.

A. The RIAS and surveillance MIMO radars

Evidently, the first MIMO radar with colocated antennas and coded signals was the French radar RIAS. In English RIAS is: "Synthetic Impulse and Aperture Radar, SIAR". The first paper on RIAS was published in 1984 [11]. The radar works at metric wavelengths. Its antenna system consists of receiving and transmitting sparse circular arrays, one inside the other. All elements of the transmitting array simultaneously radiate mutually orthogonal signals shifted in frequency. At a target we have the sum of all radiated signals with their specific phase shifts depending on the target position and velocity as well as on the frequency and position of the transmitting array elements. Because of orthogonality, these signals do not interfere. Each element of the receiving array receives reflected signals of all frequencies. They are separated and then processed properly. Target coordinates and radial velocity are determined by phase shifts of received signals. Here we have the super fast surveillance of the sector (during each transmitted pulse) and compression of multifrequency signals.

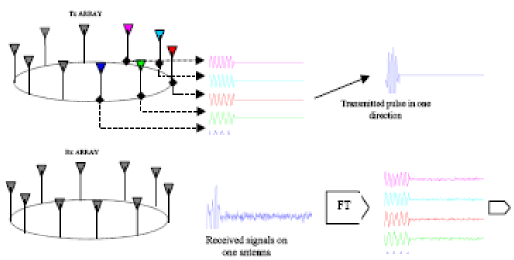


Fig. 2. Principles of RIAS (SIAR) [12]

Using proper processing of received signals, RIAS can combine surveillance in a wide sector with target tracking. Digital processing is used on transmit and receive sides.

Probably, the first detailed consideration of the first class of MIMO radars was published in [1]. The authors stressed that fully digital antenna arrays on both transmit and receive sides allow great deal of flexibility in how transmit energy is spatially distributed and then collected on receive, optimizing the "time-energy management".

It is well known that SNR at a radar receiver input in a search mode approximately does not depend on the transmitting beamwidth (that is, on the transmitting antenna gain) if the surveillance sector and the time for surveillance are fixed. The increase of target observation time approximately compensates for the decrease of illuminating power caused by broadening the transmit beamwidth.

All M elements of a MIMO radar transmitting array radiate M mutually orthogonal signals in a wide sector. Each element of an N-element receiving array 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.

B. Advantages caused by the increase of the number of degrees of freedom

Soon it became clear that such MIMO radars have many other important advantages caused by the increase of the number of "degrees of freedom" [2, 3]. It was shown that virtual ("phantom") antenna array elements appear additionally to physical antenna elements (Fig. 3).

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

Thanks to the significantly larger number of degrees of freedom, the number of targets whose positions can be independently determined increases. To characterize this feature, a notion of target "identifiability" has been introduced [4, 5]. It shows for how many targets the parameter estimation problem can be solved uniquely when either the signal to interference + noise ratio goes to infinity or the snapshot number goes to infinity.

In Fig. 4 the curves are shown for a linear receiving conventional phased array antenna consisting of 10 receiving elements with one transmitting element and for the same MIMO array with 10 transmitting/receiving elements. All arrays are with half-wavelength spacing between elements. K targets with equal radar cross sections are positioned at equal ranges and at the angles 0, ± 10°, ± 20° and so on.

The number of targets K is laid on the abscissa axis. The Cramer-Rao bound error for the target at 0 degrees is laid on vertical axis. It can be seen that Cramer-Rao minimal error of phased array grows rapidly as the number of targets increases from 1 to 6. The corresponding Cramer-Rao minimal error of MIMO radar is small and almost constant for the number of targets up to 12 and then becomes unbounded.

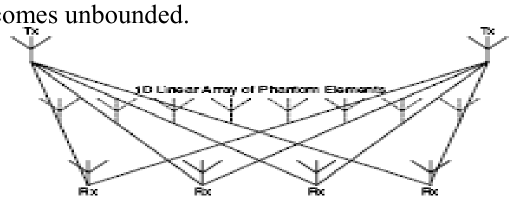


Fig. 3. An antenna array with physical 2 transmitting and 4 receiving elements and an equivalent array with 8 transmit/receive elements [2]

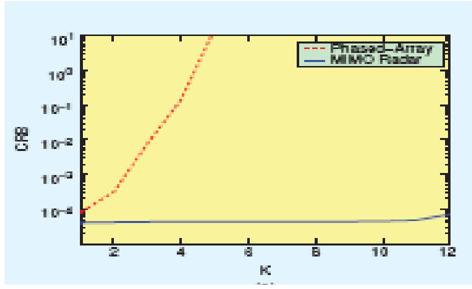


Fig. 4. Parameter identifiability of a conventional and MIMO arrays [5]

Another important feature of MIMO radars with colocated antennas is much better adaptation capability of antenna arrays. In MIMO radars each target is illuminated by a sum of M transmitted signals with certain phase shifts. These phase shifts differ for different targets. Therefore, the illuminated signals of different targets are mutually linearly independent, incoherent. This allows for direct applying effective adaptive algorithms.

Fig. 5 demonstrates target angle localization in a scenario with three targets and one intensive jammer [5]. A uniform linear MIMO array contains 10 transmit/receive antenna elements. On the left side is the result of the Capon algorithm. This spatial spectrum contains not only three targets but the jammer too. On the right side the result of the generalized likelihood ratio algorithm is presented. The peak caused by the jammer is rejected in the Capon spectrum but accuracy of target localization is worse. Combination of the two approaches provides only target localization with high accuracy.

C. Optimization of transmitting beampatterns

First works on MIMO radars with colocated antennas used orthogonal signals transmitted from each antenna element. However, it turned out that it was not necessary. One may control mutual correlation between transmitted signals from different antenna elements in order to create a desirable transmitting beampattern [6-8]. This is shown on Fig. 6 for a linear uniform array consisting of transmit/receive elements. The transmitted power in the certain direction is determined by the steering vector and cross-correlation matrix of transmitted signals. In the first extreme case, for a conventional phased array this cross-correlation matrix has rank 1 (full signal correlation), which provides the minimal possible beamwidth for the array considered and maximum power concentration in the selected direction. In the second extreme case, we have a multiple of the identity matrix (orthogonal fully uncorrelated signals). In this case, surveillance sector corresponds to the beam pattern of one antenna element. Choosing intermediate cases with partial correlation we may synthesize transmitting beampatterns of desired form and width.

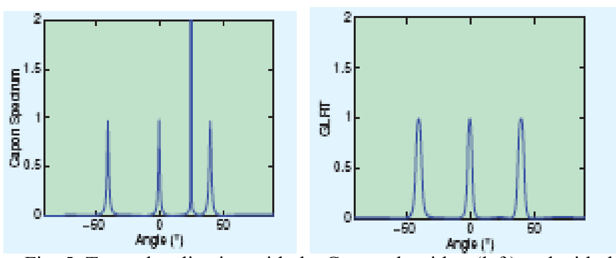


Fig. 5. Target localization with the Capon algorithm (left) and with the generalized maximum likelihood algorithm (right) [5]

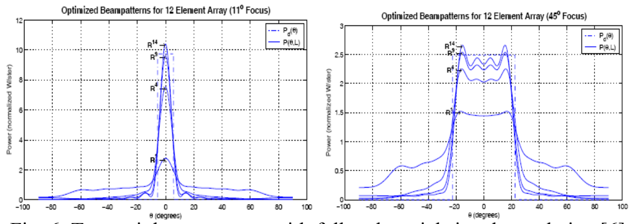


Fig. 6. Transmit beampatterns with full and partial signal correlation [6]

Thus, MIMO radars with colocated antennas and coded signals are really a new and promising concept in radar theory and technology. It may be successfully applied to wide range of radars. It was shown, for example, by interesting works on such MIMO technique application in Sky-wave Over-the-Horizon radar systems [13].

III. MIMO RADARS WITH WIDELY SEPARATED ANTENNAS: "STATISTICAL MIMO RADARS"

Perhaps, the first publication with a very pretentious title was [9]. The essence of the "idea" is eliminating signal fluctuations at the input of radar receivers like signal fading elimination in communications [14].

It is well known that if a target is much greater than the wavelength of an illuminated signal, the received signal is random at the input of a radar receiver and fluctuates in time. Signal fluctuations worsen detection performance. The authors of that "idea" propose to use multiple widely separated transmitting and/or receiving antennas. If distances between antennas are large enough, signal fluctuations at the receiver inputs become mutually uncorrelated. Joint incoherent processing of such signals can smooth signal fluctuations and reduce energy loss.

Let us consider the results presented by the authors of "Statistical MIMO radars" in more detail. First of all,

A. Novelty of "Statistical MIMO radars"

The problem of energy loss decrease by signal fluctuation smoothing was studied and solved in radar theory and practice many years ago. The essence of the problem is illustrated by the "classic" detection characteristics for two types of signals (Fig. 7). Curve 1 is for a signal with constant amplitudes. Curve 2 is for a signal with fluctuating amplitudes (according to Rayleigh probability distribution). It can be seen that energy loss caused by amplitude fluctuations takes place only at high detection probabilities and grows sharply with the increase of the required detection probability.

It is well known that incoherent joint processing of signals with uncorrelated fluctuations received from the same target provides fluctuation smoothing. One way is to employ frequency diversity of illuminating signals. Another way is to use spatial diversity of transmitting and/or receiving antennas, so as to look at the target from different directions. This method is realized in Multisite radar systems (MSRSs), which are also called Multistatic radars, Multiradar or Netted radar systems. Fundamentals of MSRSs are presented in the book [15] published in Russian in 1993 and in English in 1998.

A MSRS is defined in [15] as "*a radar system including several spatially separated transmitting, receiving and (or) transmitting-receiving facilities where information of each target from all sensors are fused and jointly processed*". According to this definition "Statistical MIMO Radar" is simply a particular case of MSRSs.

The effect of different signal correlation at the inputs of

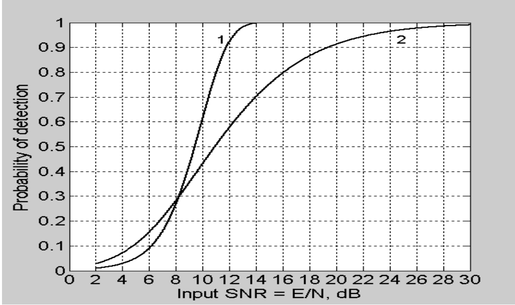


Fig. 7. Detection characteristics of nonfluctuating (1) and fluctuating (2) signals

receivers was investigated in detail including, of course, energy gain by joint incoherent processing of signals with uncorrelated fluctuations.

Thus, there is nothing new in the concept of "Statistical MIMO radar" excepting the acronym MIMO. This "idea" came to the authors with a large delay of many years.

The authors have taken MIMO method from communications and merely apply it to radar without serious studying of previous achievements in radar theory and technology. This is a typical example of hasty publications without conscientious and thorough study of existing situation in the field.

Although "Statistical MIMO radar" is a particular case of MSRSs, its authors, may be, contribute significantly to the theory of MSRSs? Unfortunately, their approach has led to serious errors.

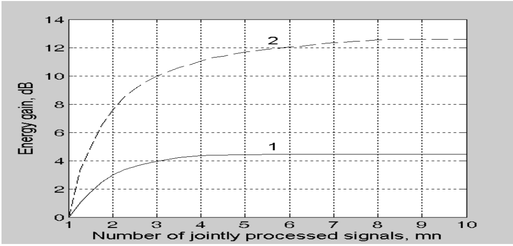
B. Detection characteristics

Using their experience in communications, the authors of "Statistical MIMO radar" try to reach maximal smoothing of signal fluctuations for better detection characteristics by using many diverse antennas [14]. This is a wrong way for radar systems.

In Fig. 8 energy gain is presented thanks to fluctuation smoothing versus the product *mn* of joint incoherently processed signals with uncorrelated fluctuations [15]. (Of course, gain values are meaningful only for integer values of *mn*). The total signal energy and the total antenna aperture are kept constant. It can be seen that even for very high detection probability, energy gain grows if *mn* is no more than 3...5. Further increase of *mn* leads to saturation.

This conclusion is illustrated by detection characteristics depicted in Fig. 9. Curves 1 and 2 repeat the curves from Fig. 7. Curves 3, 4, and 5 are for joint processing of different number *mn* of signals: 3, 10, and 30. It follows from these characteristics that joint processing leads to effective energy gain if no more than 3…4 such signals are jointly processed. Therefore, from the point of view of detection performance, MIMO radars with spatially diverse *transmitting antennas are not reasonable at all if we have already 3…4 spatially diverse receiving antennas.* Further increase of the number of summed signals provide a little additional energy gain only for very high detection probability and energy loss for lower detection probabilities which are typical for search mode. The point is that the probability density of the sum of signals with uncorrelated fluctuations does not tend to the probability density of nonfluctuating signals. Thus, "Statistical MIMO radars" *are even harmful in such cases.*

This error of the authors of "Statistical MIMO Radar" is, probably, a result of ignoring an important difference between radar and communications. Unlike the communications, the radar detection problem is *the problem of decision making.*



Fig,8. Energy gain versus the number of incoherently summed signals with uncorrelated fluctuations. 1: P_d=0.9, 2: P_d=0.99; $P_{fa} = 10^{-4}$

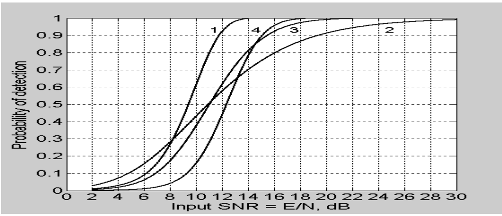


Fig. 9 Detection characteristics for different number of incoherently summed signals with uncorrelated fluctuations. 3, 4, and 5: for 3, 10, and 30 signals, respectively; 1 and 2: the same as in Fig. 7; $P_{fa} = 10^{-4}$

It is worth to remind that the problem of amplitude fluctuation smoothing is important for high required values of detection probability (curves 1 and 2 in Figs. 7, 9), which are typical for tracking mode when transmitted energy concentration in the target direction is highly desirable. For tracking mode, better results may be obtained if transmitting antennas are used as a coherent array (without spatial diversity) to increase incident energy on a target.

Detection characteristics in tracking mode are shown in Fig. 10 for three systems with 4 transmitting and 4 receiving antennas. Total transmit energy and total antenna aperture, as earlier, are kept constant. It is clear that the best system is the second one because it effectively combines the maximum incident energy on a target with sufficient fluctuation smoothing on the receiving side. The worst system is the MIMO radar with energy loss about 6 dB for $P_d = 0.9$!

C. Target model. Conditions of uncorrelated fluctuations

For both Multisite radar systems and their particular case "Statistical MIMO radars", it is important to reveal conditions under which signal fluctuations at the inputs of receiving antennas are uncorrelated. The authors of [14] suggested a target model and derived corresponding equations. They claim that they have generalized the classical Swerling signal fluctuation models to spatially diverse observation. Therefore, they consider this result as an important contribution to the radar theory. Their model is shown in Fig. 11. Each target is modeled as a rectangular two-dimensional collection of *random* scatterers.

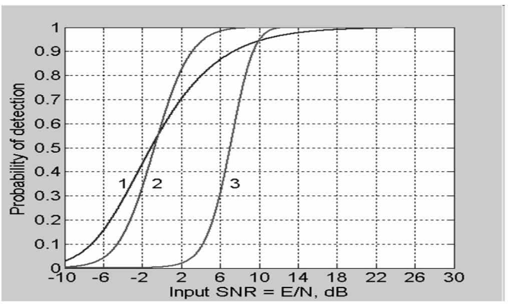
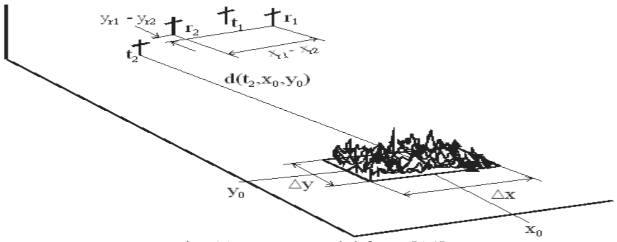


Fig. 10. Detection characteristics for tracking mode. 4 transmitting and 4 receiving antennas. 1: coherent transmitting and receiving arrays ("SISO"in terms of [14]; 2: coherent transmitting and diverse receiving arrays ("SIMO" in terms of [14]): 3: diverse transmitting and receiving arrays ("Statistical MIMO radar")



Fig, 11. Target model from [14]

However, firstly, this model is unduly simplified: real targets are usually three-dimensional objects of arbitrary form. Such model does not permit to reveal fully determining parameters affecting signal spatial correlation for a real target. Secondly, the suggested model conflicts with the real physical nature of signal fluctuations.

In reality, signal fluctuations at a radar receiver are caused not by random character of scatterers. Small *scatterers on a target are, as a rule, not random*. If a target size is much greater than the wavelength of an illuminating signal, differences of distances from scatterers to radar antennas significantly exceed the wavelength. Then phases of partial signals from different scatterers at the receiver input may have any values. The sum of all these partial signals turns out to be random. Even small random rotations of a real target about its center of mass lead to significant changes in distances *as compared with the wavelength*, and hence *to sharp phase variations of partial signals received from different scatterers*. Just this results in amplitude and phase fluctuations of the summed signal.

If the number of scatterers is large enough, and their signals are approximately of equal intensity, we have the well-known Swerling models one and two.

Of course, for formal considerations of the received signals, there is no difference why these signals are random, because of random scatterers or because of summation signals from different non-random scatterers with random phases. However, each model should be as close to physical nature of the modeled object as possible (without significant complication of a model). In particular, the model introduced in [14] fails to explain why there is no signal fluctuations if a target is motionless or if its size is smaller that the signal wavelength.

It is especially strange that such an imperfect model was suggested in the paper published in 2006. The correct and much more general *space-time correlation matrix* of signal fluctuations for a 3-dimensional moving target of arbitrary form was published in [15] in 1998.

Let us consider one transmitting and a pair of widely separated receiving stations (or antennas) in 3-dimensional space (Fig. 12). This is the same as one receiving and a pair of widely separated transmitting stations (or antennas). A target of a large size (as compared with the wavelength) is assumed to be perceived by all the stations as a system of N small scatterers. Each scatterer can be characterized by the radius-vector $\boldsymbol{\rho}_i$ (relative to the target center of mass) and complex amplitude b_{ik} of the scattered signal at the k-th receiving station. All scatterers are not random and not resolved. Then the complex amplitude of a signal received by each station can be written as follows:

$$A_k = \sum_{i=1}^{N} b_{ik}\, exp\left\{-j\left(2\pi/\lambda\right)\boldsymbol{\rho}_i\left(\mathbf{r}_0+\mathbf{r}_k\,)\right)\right\},\; k=1,2.$$

The spatial correlation function of these complex amplitudes is

$$B_{12} = 0.5\overline{A_1 A_2^*}$$

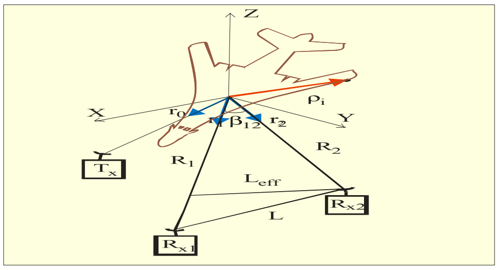


Fig. 12. 3D target model from [15]

Averaging should be made over the random target aspects relative to spatially diverse antennas.

The key and natural assumption is that *the random aspect of the target is a result of a rotation from the mean position through a small random angle* $\delta\theta$**.** Assuming further that all the three Cartesian projections of the rotation vector are statistically independent random variables with uniform distributions within certain limits ($\pm\Delta\theta_x/2$, $\pm\Delta\theta_y/2$, $\pm\Delta\theta_z/2$), one can obtain after averaging the expression for the spatial correlation function [15].

In practice, simple approximate expressions are convenient for conditions of high and low mutual correlation of signal fluctuations. For example, the condition of low correlation (see Fig. 12)[15]

$$\left(L_{eff}/R_1\right) \approx \beta_{12} > min\left[0.8\lambda/l_{12};3\lambda/\Delta\theta_y l_z;3\lambda/\Delta\theta_z l_y\right],$$

where $l_{12} = l_x$, l_y, and l_z are the target dimensions along X,Y and Z axes. X axis is parallel to the effective baseline.

This expression determines requirements to the relationship between the average width of target scattering pattern lobes and the angle between directions from a target to spatially diverse antennas. The determining parameter is "the effective baselength" L_{eff} – *the projection length of baseline L onto the plane perpendicular to the bisector of the angle β_{12} between directions from the target to diverse antennas.*

It is worth to notice that the analysis of a 3-dimensional target shows the possibility of low and zero spatial correlation even when the target dimension along the effective baseline (X axis) is small. This takes place when limits of target random rotations about perpendicular axes (Y and Z) are sufficiently large. Of course, this important feature of real 3-dimensional targets cannot be revealed from the 2-dimensional target model proposed in [14].

D. Range resolution of coherent MIMO radars with narrowband signal

One more "discovery" made by the authors of the "Statistical MIMO radars" is the high range resolution, which may be obtained with a narrowband signal in coherent MIMO radars with widely separated antennas, even higher than resolution with a wideband signal [16].

This idea is also very old. It is well known that the wave front from a point-like scatterer or a point-like signal source has a spherical form. It is clear that not too far from this scatterer or source where the incident wave within the antenna aperture preserves its curvature, it is

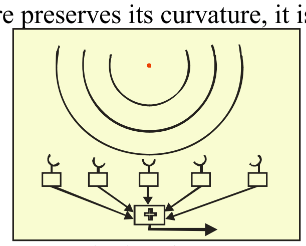


Fig. 13. Determination of a scatterer's position using the curvature of the signal wavefront

possible to determine coordinates of the scatterer or signal source by coherent processing of received signals (by measuring signal phase distribution on antenna aperture) without using wideband signals, even with sinusoidal signals. This problem was discussed in West and Russian literature as long ago as in the seventies (e.g., [17]). Even the book [18] devoted to this problem was published in Moscow, Russia in 1984. The possibility of using curvature of electromagnetic wave fronts was considered in this book in detail. In particular, it was shown (as it was expected) that using the wave front curvature one can obtain higher range resolution (as compared to range resolution of a wideband signal) only for a very large antenna. The required relationship between the length L of a linear antenna aperture, target range R, signal carrier frequency f_0, and signal bandwidth Δf is as follows [18]

$$L/R > 4\sqrt{\Delta f/f_0}\ .$$

For a sufficiently narrowband signal (the bandwidth is 1 MHz and the carrier frequency is 3 000 MHz) and target range of 100 km, the antenna length must be greater than 7 300 m! Even for a short range radar when target range is only 10 m, the antenna length must be greater than 12.6 m! Using several transmit antenna elements does not change the situation significantly.

High range resolution in [16] is obtained for an antenna with elements partly surrounding the scatterer. The angles between directions from the scatterer to transmit and receive antenna elements are of the order of 90°. It means that the length of a linear antenna aperture at the range 100 km from the scatterer should be 140 km!

It is clear that wideband signals with simple antennas of usual size are much more reasonable to use. This is the more so that unlike using the wave front curvature, range resolution of a wideband signal does not depend on a target range.

It is well known that large coherent antenna arrays (including sparse arrays) are used for high resolution in cross-range directions (e.g.,[19]) but not in range direction!

Thus, using wave front curvature for range resolution and for target range measurement is senseless.

This approach may be useful in passive location where the moment of signal transmission is unknown, so that signal propagation time (and hence target range) cannot be measured. However, large coherent antenna systems are difficult to create and maintain. Therefore, even for passive systems, incoherent processing with hyperbolic method of target localization is used, as a rule.

D. Assumption of narrowband signals

The authors of [9, 10] and many other works on "Statistical MIMO radars" assume all signals to be narrowband which means that channel matrices contain only amplitude factors and phase shifts but not time delays of signal envelopes. Such assumption may, as a rule, be valid for MIMO radars with colocated antennas but is often not valid for "Statistical MIMO radars" where wide separation of antennas is used to provide uncorrelated signal fluctuations**.** The point is that antenna separation required for uncorrelated signal fluctuations often does not permit neglecting the differences in signal envelope delays.

Fig. 14 explains the corresponding relationships. The condition of uncorrelated fluctuations

$$d_{eff}/R = d\cos\beta/R > \lambda/l_{\perp}$$

or, for simplicity, $d/R > \lambda/l_{\perp}$.

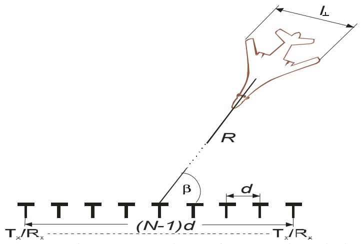


Fig. 14. To the assumption of narrowband signals

Signal delay differences at different antenna elements may be neglected if

$$L = (N-1)d << c/\Delta f \ .$$

Combining the last two inequalities yields

$$(N-1)\Delta f/f_0 << l_\perp/R$$

For example, when the cross-range size of a target is 10 m, and target range is 100 km, then for a uniform linear array consisting of 6 elements and carrier frequency 1000 MHz the signal bandwidth should be much less than 20 kHz. Obviously, such signals are seldom used in real radar systems.

On the other hand, one of the most important advantages of a radar system with widely separated antennas (a Multisite radar system) is its ability to determine all the three coordinates of a target with high accuracy using only range measurements without angle measurements with directional antennas [15]. Therefore, wideband signals should be employed in such systems.

Of course, taking into account differences in signal envelope delays makes the problem of detection optimization and other problems of signal processing optimization much more difficult.

The theory of Multisite radar systems faced this problem many years ago. It was especially difficult for signal detection in a background of spatially correlated jamming from several jammers distributed in space.

This problem was solved in the beginning of the seventies [20] for different real situations and different Multisite radar systems including systems that are referred now to as "Statistical MIMO radars" (see also [15]).

IV. CONCLUSION

1. The known MIMO radars may be divided into two classes: 1) with colocated antennas and coded signals and 2) with widely separated antennas ("Statistical MIMO radars").

2. MIMO radars with colocated antennas and coded signals represent a really new and prospective concept in radar theory and technology. The most important feature of such MIMO radars is the significantly larger number of degrees of freedom. This leads to many important advantages: increased angle resolution and reduced antenna sidelobes, increased target parameter identifiability, increased adaptation capability including adaptive transmitting beamforming. Besides, such radars can effectively search targets in a wide sector without scanning.

3. There is nothing new in the concept of MIMO radars with widely separated antennas ("Statistical MIMO radars"). These radars are a particular case of Multisite (multistatic) radar systems (MSRSs) – multichannel radar systems with spatially diverse channels. Most "new" results on "Statistical MIMO radars" were obtained under much more general conditions and published many years ago. If it is desirable to retain an attractive short acronym "MIMO", the term ***"Multisite (or Multistatic) MIMO radar"*** should be used instead of the meaningless term "*Statistical* MIMO radar".

5. Borrowing MIMO method from the communications, the authors of "Statistical MIMO radars" merely applied it to radar without studying the corresponding achievements in the radar theory and practice and without taking into account essential differences between communications and radar problems. Such an approach has led to serious errors.

6. It may be considered that theoretical fundamentals of MSRSs are, in principle, known. Of course, there are many problems to solve. MSRSs are an intensively developed branch of the radar (especially in the last years). New applications and new ideas appear. However, really new ideas must base on the state-of-the-art in this field.

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