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Research Note

Hexagonal configuration of cross-correlation interferometers

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Abstract. New configurations of interferometers ensuring practically equal resolution in all beam cross-sections are suggested. The suggestion is based on the arrangement of elements along the hexagon perimeter (or partly inside it) due to which a complete equidistant (regular) coverage of a hexagonal domain in the U, V-plane in the cross-correlation regime is obtained. A comparison of the systems proposed with a number of other ones showed that one can obtain the prescribed resolution and field of view using a smaller number of elements (antennas).

Key words. instrumentation: interferometers

1. Introduction

The most wide-spread configurations of multi-element interferometers capable of registering immediately the brightness distribution of the receiving radiation (snapshot regime) are T systems or their equivalent, Π systems (Bracewell 1961). Such systems ensure a complete coverage of a square spatial-frequency (U, V) domain, however the resolution in the diagonal cross-sections is found excessive, which suggests on a surplus quantity of the interferometer elements. In view of this, a search for configurations with fewer elements is of interest. At this point, the conditions of maximum constancy of the resolution in all directions (i.e. of constancy of the width of the beam synthesized, in all its cross-sections) is to be fulfilled.

An interesting analysis of the problem of the optimum synthesis of the interferometer as well as of the method of its solution has been made by Keto (1997). He suggested arranging the elements along the perimeter of the Reuleaux triangle (which ensures practically equal resolution in all cross-sections), and then to perturb them slightly from the equidistant locations in order to provide more uniform coverage of a circular domain in the spatial-frequency plane (U, V-plane). However, as it appears to us, Keto's method has certain disadvantages.

1. Owing to the irregular arrangement of the elements, some spacings in the circular U, V-plane covered are very close to each other, thus giving no new information, while others are spaced far apart; because of this, the synthesized beam has an enhanced sidelobe level which is noncontrolled with the usual method of weighting the correlation products;
2. The interferometer requires a large number of correlators equal, in a general case, to $0.5k(k-1)$ where k is the number of elements;
3. A search of optimum coordinates of the elements is to be carried out for each concrete interferometer from the start, with using methods of numerical optimization.

The disadvantages mentioned can be removed, if one succeeds in finding configurations with a regular element arrangement satisfying the requirements previously pointed out. For this purpose, we suggest hexagonal configurations (Sodin & Kopilovich 2000). Note that it is the nature of regular element arrangements to form beams with large diffractional lobes (in the non-equidistant configurations lobes are split into a large number of smaller ones); but one can suppress such lobes owing to the finite diameter of an individual-element aperture if the latter is close to the distance between the elements, or one can remove them from the borders of the field of view.

2. Hexagonal interferometers

Consider, as in our paper (Sodin & Kopilovich 2000), a rectilinear hexagon with elements arranged equidistantly in five sides of $r+1$ each. One can see that a collection of vector distances between the elements (bases) covers completely a hexagonal domain in the U, V-plane. Particularly, it is illustrated in Fig. 1 for $r = 4$ where an arrangement of elements (on the left) and their coverage of the U, V-plane (on the right) is shown (in view of symmetry, only a half of the U, V-plane is drawn), and this is true for any r.

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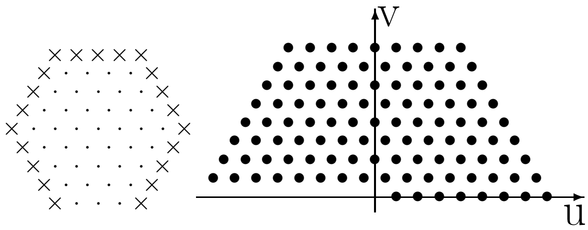

Fig. 1. The element arrangement on five sides of a hexagon (on the left), and the location of the spacings in the U, V-plane (on the right), for $r = 4$

The number of elements (k) of such interferometer and the total number of bases (N) are

$$k = 5r + 1, \; N = 3r(2r + 1). \tag{1}$$

The maximum and minimum diameters of the U, V-domain which determine the resolution are

$$D_{\max} = 4rd, \; D_{\min} = 2\sqrt{3}rd, \tag{2}$$

where d is the distance between the neighbouring elements.

The distinction between $D_{\max}$ and $D_{\min}$ is not essential, and in this case the beamwidth in the cross-sections for them is practically the same, as we shall see further.

Now let us estimate the "efficiency" of a hexagonal configuration which we shall characterize by a factor α equal to the ratio of the number of bases (N) to that of the "ideal" ($N_{\rm id}$) one:

$$N_{\rm id} = k(k-1)/2 = 2.5r(5r + 1). \tag{3}$$

Thus, for the construction given by Eq. (1)

$$\alpha = N/N_{\rm id} = 0.48[1 + 0.3/r + {\rm O}(r^{-2})]. \tag{4}$$

The factor α equals 0.545 with $r = 2$, 0.5 with $r = 7$, and 0.48 with $r \to \infty$.

It is also possible to construct hexagonal configurations with a number of elements smaller than $k = 5r + 1$ while still ensuring complete coverage of the corresponding hexagonal domain in the U, V-plane. An example of a configuration at $r = 2$ is presented in the paper of Golay (1971). Hexagonal configurations of any radii covering completely the U, V-plane have been suggested by Kopilovich (1999); these configurations at r from 2 to 7 are represented in Fig. 2. Their peculiarity is that $3(r+1)$ elements are arranged equidistantly on three non-adjacent sides of the hexagon while others are arranged inside it. The efficiency of such configurations is higher than of those shown in Fig. 1. For example, for $r = 2, \alpha = 0.6$, and for $r = 7, \alpha \simeq 0.561$.

3. Comparison of hexagonal and T configurations

A comparison of hexagonal and T systems is of interest, in view of the widespreadness of the latter. To provide the resolution and the field of view equal to those of the hexagonal system of the type shown in Fig. 1, the T system must have $s = 2r + 1$ elements on each of its three

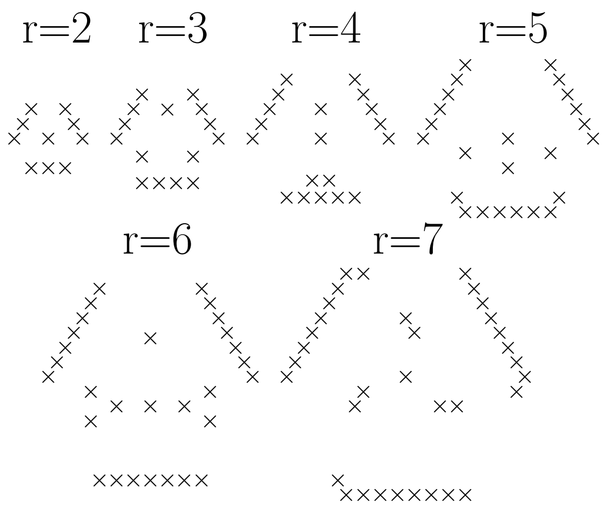

Fig. 2. Variants of hexagonal interferometers for $2 \leq r \leq 7$

"arms", with a distance $d\sqrt{3}/2$ between the neighbouring elements where d is the distance between the elements on the hexagon side. So, the total number of elements in the T system is

$$k = 3s - 2 = 6r + 1. \tag{5}$$

A comparison of Eqs. (5) and (1) shows that to obtain equal resolution, with an equal field of view free from diffractional beams, the hexagonal configuration requires approximately 20% fewer elements than the T one. When using configurations shown in Fig. 2, the economy would be still larger.

Also, note that in the case of the equality of all correlation products, the beam of a T-shaped (or of a Π-shaped) interferometer has the sidelobe level of magnitude 0.22 that is more than for the beam of an analogous hexagonal system.

4. Conclusion

Based on the analysis of interferometers with a hexagonal arrangement of elements, their advantages, compared to other configurations, are:

1. the economy of the element number while maintaining resolution and field of view;
2. the possibility of calculating all parameters without using complicated optimization procedures.

It seems that hexagonal configurations may be realized when creating new radio interferometers, particularly in the millimeter wave range (Chandler 1998).

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