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To the memory of antenna science Atlantes
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PYRAMIDAL DESIGN OF NANOANTENNA ARRAYS

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Abstract

Vertical designs of nanoantenna arrays as a part of multilayered nanonodes for realisation of wireless networks on the chip (WiNoC) on the basis of technologies MIMO and MultiUser MIMO are presented.

Keywords: wireless networks on the chip (WiNoC), system on crystal (SoC), MIMO, MultiUser MIMO, nanoantenna arrays.

I. Introduction

Known variants of use in the key elements of wireless networks on chip (WiNoC) nanosize MIMO-arrays are based on the use of nanoantennas of placing of nanochips and having the directivity characteristics of antenna's, squeezed from the substrate of a crystal [1]. More advanced solution [2] is based on the multilayered realization of stack (as a rectangular tower) designs of microassemblages (nanocircuits) in which each level contains the dipole antennas intended for communication in a tower-chip and between several analogous microassemblages (fig. 1). However in [2] for a wireless communication between "microtowers" only single dipole antennas whereas for the creation WiNoC is expedient to pass to application vertically oriented nanoantennas arrays. The possible variants of such antennas constructions are presented in the report, which application will increase the speed of data transmission in WiNoC.

II. The main part

One of the possible ways of increasing the capacity of wireless communication channels between WiNoC nanochip is perfection of tower technology [2] by combining the individual antennas face stacking structure (Fig. 1) into a single antenna array.

At multi-layered technology of nanotowers levels making in each levels can be located not line of emitters, but a flat digital antenna array (two-row, three-row, etc.). Besides, on some layers tower nanochip can be installed one common nanoantenna array. As a working range of frequencies for wireless transmission of data is advisable to choose terahertz.

The selective calculation of corresponding lengths of waves is simple to use known relations, and for the frequency 1 THz = 10^{12} Hz, we obtain λ = 300 microns. Similarly, for the 100 THz wavelength λ = 3 microns. Thus, when the antenna elements in an antenna array are located with a step in the half of wave-length at the carrier frequency signal 100 THz interelement distance between emitters will be equal 1.5 microns. To have a representation about scales of the corresponding geometry as an example, it is necessary to indicate that at such a step of array along the wall of corps of microelectronic chip with 1,5 mm can be placed in 1000 nanovibrators elements. Besides, if the size of the corps of system on a crystal, for example, 30 mm, at the same frequency of 100 THz it is simple to receive that within the microchips corps is placed about 10000 lengths of waves. It allows to operate an the analysis parameters of nanoantennas arrays in WiNoC structure with concept of a far-zone of the antenna.

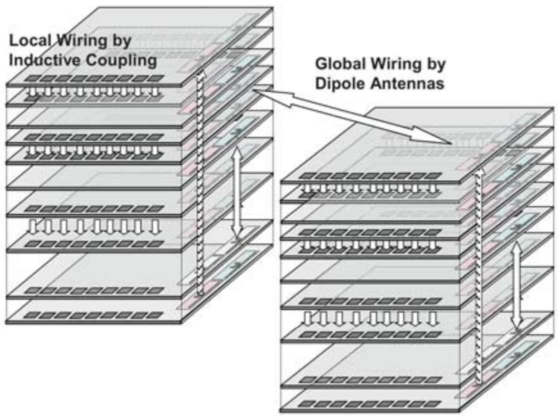

Fig. 1. Stacked constructions of microassemblies of tower type in composition of WiNoC [2].

Usually in the literature indicates that the far zone of antenna lies in the distance more than 100 lengths of waves. In this case, even if the distance between nanochips more than 300 microns can be applied electrodynamics model of the far zone antenna, which greatly simplifies signal processing.

For narrowing the directivity characteristics of partial-emitters array antenna space between nanochips can be filled with a metamaterial with a negative index of refraction (Fig. 2).

Such the waveguide channel will allow substantially to decrease the level of radiation penetrating outside the corps of microchip. Besides, the use of metamaterials will shorten the wavelength of radiation that will provide an opportunity to increase the density of configuration the nanochip in the crystal.

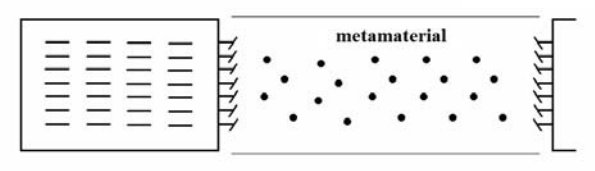

Fig. 2. The vertical configuration of electrically small nanovibrator antennas is in multilayered three - dimensional nanochip (side view).

Frequency-division or time-division multiplexing of signals can be added polarization-division multiplexing. For this purpose have to apply nanoantennas of double polarization, for example, turnstile vibrators (fig. 3).

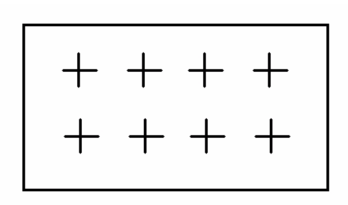

Fig. 3. Polarization-division multiplexing of channels.

The optimal placing of the nodes stations of WiNoC (nanonodes) on a chip can be carried out in accordance with methodology of Ermolaev S.Y. [3], supposing the use of ant algorithms for topology optimization of the base stations and adapted taking into account the model of distribution of signals into the corps of the system on a crystal.

At the multilayered topology of nanochips for the increase of efficiency of dispersion of radio waves in interests of technology of MIMO is worthy the using of pyramidal structures nanostations. In this case, circular, rectangular or multi-faceted pyramid forms, which nanovibrators are located on vertical walls can be used (fig. 4).

Such placing of elements of antennas on a nanochip allows to decrease the shading of nanostations each other and improves the conditions of refraction of radio waves into the corps of SoC. With the same purpose the pyramidal nanochips inside WiNoC can have different height. For example, in the center of crystal is a minimum height, on periphery is a maximum. Perhaps the opposite decision when the nanochip of maximum height takes place in a center, and the decrease of their levels goes to periphery. Nanopyramids of equal height in principle can be alternated taking into account configuration of subnet on a crystal.

On the top of pyramid for connection with a macrolevel are offered to place dielectric resonator antenna (DRA) (fig. 5) or other types of by volume electric small emitters, and also the printed microstrip antennas.

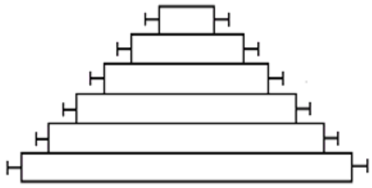

Fig. 4. The pyramidal configuration of electrically small nanovibrator antennas in a multilayer three-dimensional nanochip (side view).

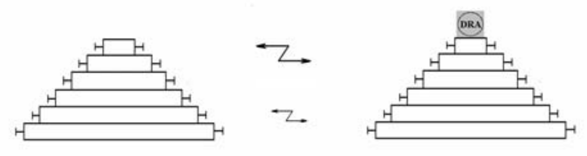

Fig. 5. The nanosystem MIMO with the DRA in the top layer of one of nanopyramids for realization of radiosluice with a macrolevel.

It should be noted that for realization of high-speed transmission of the system MIMO is sufficient to form 4 - 8 levels of nanopyramid, although, if speed of transmission is not critical, it is possible to be limited by the pair of levels.

To improve the manufacturability of the pyramidal arrays is preferred to use the horizontally located single vibrators or small element Uda-Yagi nanoantennas (fig. 6) on the pedestals of pyramid [4].

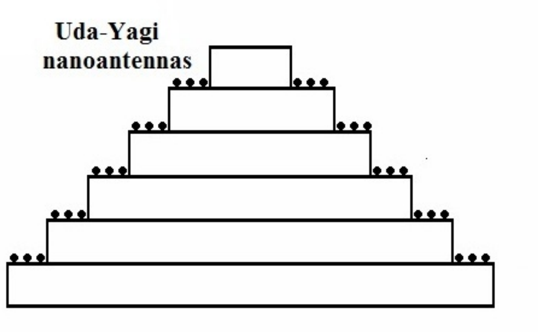

Fig. 6. Horizontally located Uda-Yagi nanoantennas in composition the vertical arrays of nanoemitters.

The length of the step pyramid to accommodate Uda-Yagi nanoantenna depends on the wavelength, interelement distance of vibrators in the antenna and their quantities. So, at half-wave step elements and the carrier frequency signal 100 THz for placing of 4 vibrators in structure the Uda-Yagi nanoantenna, in this case is necessary to provide the length of the pedestal in the horizontal plane not less than 8 microns.

In the more general case in different levels of a pyramid can be used different types of antennas (vibrators, Uda-Yagi etc.), interleaving flat and linear arrays with different quantity of radiators at various length of the stage of nanopyramid. It allows to involve different ranges of frequencies in levels for realization of frequency division of channels and improvement of electromagnetic compatibility of nanochips.

Let's consider the case of placing in the levels of pyramidal nanochips of different amount of Uda-Yagi nanoantennas, having in the composition a different amount of elements for providing of communication of data on a few frequencies.

As an example, Fig. 7 shows a top view of corresponding options of three-level pyramidal nanochips. On a pedestal of the first level in each side of a pyramid are located 4-element nanoantenna arrays on the basis of Uda-Yagi radiators for realization with co-operating nanonodes of the chip system multi-MIMO under scheme N×4×4, where N – number of nanonodes.

In the second tier of nanopyramid, having a smaller useful area, in each of verges it is placed for two Uda-Yagi nanoantennas, providing forming multi-MIMO of network size of N×2×2 in other frequency range, for example, the greater wave-length, due to released as a result transition to a two-element antenna array of useful area. DRA is located on the third tier of nanochip and it providing connection with a macrolevel.

For increase of distance of communication of a wireless network at a crystal (WiNoC) with external consumers it makes sense to use co-operative data transmission with the help of using clustering distributed the nanosystems of MIMO on a crystal.

Depending on distance of connection the size of cluster can be adaptive change by an association four and more than nanochips in one emitter. The example of four element cluster is presented on fig. 7. The similar decision by "a nested doll" principle is possibly too for simultaneous multifrequency communication, thus the upper level of nanochips is united in one cluster, more low lying - in others clusters. Thus, it is formed clusters, which enclosed each other and differing with a working range of frequencies, quantity of united nanochips.

Separate clusters, forming MIMO-system, can have a not-identical topology, to minimize regional effects, sidelobes of directivity characteristics of antenna's elements of antenna's array, to reduce the mutual coupling of the radiators. For each range can have its own configuration of clusters and their optimal topology.

As a result connection is provided in the different ranges of frequencies, in a few standards simultaneously, for the decision of different on the functional setting tasks, for example, in combinations of type "communication + GPS + rectenna" (for the feed of chip).

The configuration of the separately taken clusters of nanoantennas schemes can be optimised by means of genetic algorithm, by analogy to the printing antennas having the fragmented structure, protected by the patent of the USA № 6323809. Such decision allows to optimize the form of directivity characteristics, polarization characteristics, and at inphase radiation - to provide demanded level SWR in a wide band frequency response of the antenna at work on a radiation.

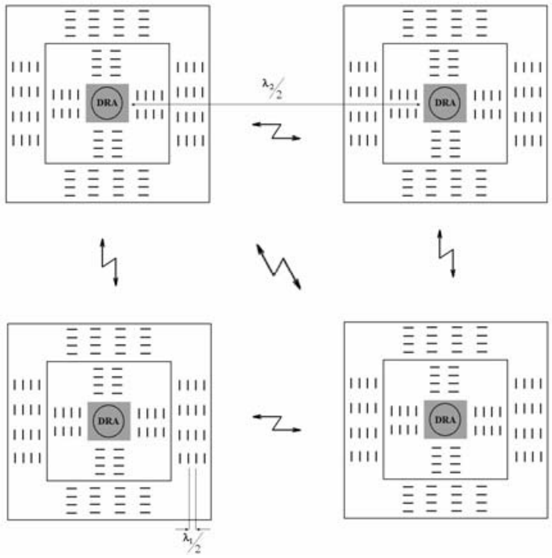

Fig. 7. Three-level pyramidal nanochips with Uda-Yagi antennas and DRA.

The considered cluster principle can be used and for connection inside of WiNoC. A cluster can form the identical levels of several pyramidal nanochips. It will allow to use comparatively a low-frequency radiation inside a crystal, to improve the energy of radio waves at communication of data between the remote peripheral areas of chip.

III. Conclusion

The offered variants of vertical configuration of MIMO-arrays of nanoantennas elements allows to raise the carrying capacity of communication of WiNoC channels by using of multiple elements antennas constructions. Perfection of their design and the analysis of electrodynamics by modeling are the purpose of the further researches.

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