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# Reduction of mutual couplings in 4-port ring antenna

***Abstract**. This paper deals with the mathematical model of the reduction of antenna's mutual coupling in antenna arrays. It is used a complex normalized scattering matrix for multiport network connection. The hybrid as uncoupler was proposed in article. Four-port uncoupler was model ling, build and researched. The parameters of 4-port ring antenna array with uncoupler was presented.*

***Streszczenie.** W artykule przedstawiono metodę redukcji sprzężeń pomiędzy elementami 4-elementowego układu antenowego. W modelu wykorzystano macierz rozproszenia normalizowaną do obciążeń zespolonych. Jako układ odprzęgający zastosowano hybrydę zbudowaną na liniach transmisyjnych. Układ został zbudowany i przebadany. (**Redukcja sprzężeń w 4-elementowym pierścieniowym układzie antenowym**)*

**Keywords:** Antenna array, mutual coupling, hybrid.
**Słowa kluczowe:** Układ antenowy, sprzężenia pomiędzy elementami anteny, hybryda.

### Introduction

One of the disadvantage of an antenna arrays are mutual coupling interactions between antenna elements. It depends from position of the elements in the array and the direction of the radiation. The strong couplings leads to degradation of structure's performances: impedance of the elements, shape of the main beam and sidelobe level. Some methods of the reduction couplings are exist. Simply method is increasing the spacing between elements, but it very often leads to degradation radiation characteristic [1-3]. Other methods are changing of the antenna array geometry (irregular antenna arrays) or using auxiliary elements for reducing couplings. The last method is especially good for circular antenna array.

### Model and scattering matrix for antenna array

Consider the 4-port antenna as a quadrate of identical broadband radiators (4-port ring antenna). Antenna array is situated on the car's top. Each antenna has 2.5m length and 20mm diameter. Distance between antennas is 1.6m. Dimensions of the car's roof is 2mx3m. The antenna array is connected to exciter and uncoupler (Fig.1.). The uncoupler is auxiliary element, used for reduction mutual couplings between elements of the antenna array.

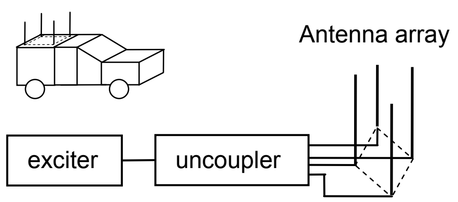


Fig.1. Four-port circular antenna array

Antenna array has circular symmetry and the scattering matrix of 4-port antenna $S_A$ is symmetric too. [1,2]

(1) $$\boldsymbol{S}_A = \begin{bmatrix} s_{11} & s_{12} & s_{13} & s_{12} \\ s_{12} & s_{11} & s_{12} & s_{13} \\ s_{13} & s_{12} & s_{11} & s_{12} \\ s_{12} & s_{13} & s_{12} & s_{11} \end{bmatrix}$$

The structure of the antenna array with exciter and uncoupler was modelling as cascade connection of multiports – exciter has modelled as real voltage sources, uncoupler – as $N$ multiport, antenna array as $A$ multiport (Fig.2).

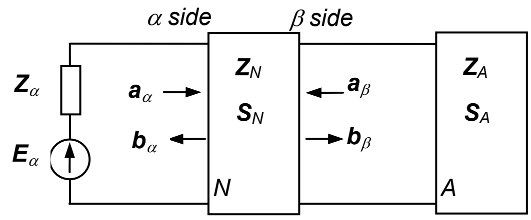


Fig.2. Cascade connections of multiports

The scattering matrix of $N$ multiport has form:

(2) $$\boldsymbol{S}_N = \begin{bmatrix} \boldsymbol{S}_{\alpha\alpha} & \boldsymbol{S}_{\alpha\beta} \\ \boldsymbol{S}_{\beta\alpha} & \boldsymbol{S}_{\beta\beta} \end{bmatrix},$$

where $\boldsymbol{S}_{\alpha\alpha}$, $\boldsymbol{S}_{\beta\beta}$ - matrices of transmission between ports of $\alpha$ side and $\beta$ side adequately, $\boldsymbol{S}_{\alpha\beta}$ and $\boldsymbol{S}_{\beta\alpha}$ - matrices of transmission from $\alpha$ side $\beta$ side and reversely.

If occurre dependence:

(3) $$\boldsymbol{S}_{\alpha\alpha} = \boldsymbol{S}_{\beta\beta} = 0$$

then the multiport is uncoupled - matched network. It means that all ports are matched and mutually insulated and only transmission between input and output ports exists. That structure may be used for uncoupling antenna's inputs.

The scattering matrix $\mathbf{S}_N$ is connected with impedance matrix $\mathbf{Z}_N$ by equation:

(6) $$\boldsymbol{S}_N = \boldsymbol{R}_0^{-0.5}(\boldsymbol{Z}_N - \boldsymbol{Z}_0^*)(\boldsymbol{Z}_N + \boldsymbol{Z}_0)^{-1}\boldsymbol{R}_0^{0.5}$$

where $\boldsymbol{R}_0 = \mathrm{Re}\boldsymbol{Z}_0$, $\boldsymbol{Z}_0 = \{z_\alpha, z_\beta\}$ - diagonal matrix of impedance's (Fig.2). For one-side excitation ( $\boldsymbol{a}_\beta = \boldsymbol{0}$ ):

(7) $$\boldsymbol{b}_\alpha = \boldsymbol{S}_{\alpha\alpha}\boldsymbol{a}_\alpha \,, \boldsymbol{b}_\beta = \boldsymbol{S}_{\beta\alpha}\boldsymbol{a}_\alpha \,,\ \boldsymbol{a}_\alpha = 0.5\boldsymbol{R}_\alpha^{0.5}\boldsymbol{E}_\alpha$$

### Hybrid as uncoupler

Hybrid is four-port element, its scattering matrix has the form:

(8) $$\boldsymbol{S} = \frac{1}{\sqrt{2}} \cdot \begin{bmatrix} 0 & 0 & 1 & 1 \\ 0 & 0 & 1 & -1 \\ 1 & 1 & 0 & 0 \\ 1 & -1 & 0 & 0 \end{bmatrix} = \begin{bmatrix} \boldsymbol{0} & \boldsymbol{T}^T \\ \boldsymbol{T} & \boldsymbol{0} \end{bmatrix},$$

where $\boldsymbol{T}$ is normalized transmission matrix. This structure fulfilled criteria on equation (3) – it is uncoupler.

The construction of hybrid on transmission lines is presented on Fig.2.

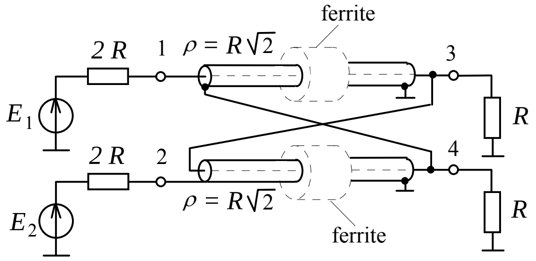


Fig.3. Construction hybrid on transmission lines

To balance the structure impedance generators should be set on value R, impedance loads on value 2R (or reversely) and characteristic impedance of the transmission line should be set on $\rho$. Ferrite core is used for reduction shunt effect of transmission line shield inductance's. More information about theory of hybrid was presented in [4].

### Realization of antenna uncoupler

How as noticed earlier 4-channel phase commutator could be used as antenna uncoupler. Its use gives decreasing of coupling between antenna array inputs. The hybrid and multiport phase commutators too, may be made in two way. The transmission line may be spooled on the ring of ferrite cores or put the cylindrical cores on transmission line .(Fig.4).

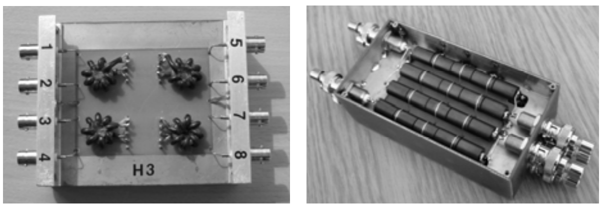


Fig.4. Practical realization of 4-port uncoupler

The hybrid with many cores put on transmission line was realized and researched. The device work in the 30-90 MHz frequency band. The uncoupling characteristic of hybrid was presented in Fig.5. In theory, the values of $|s_{ii}|$ parameters should be equal 0 or near 0. In really its strongly depends from magnetic permeability of cores. The finding proper cores with high permeability, working in work band is very difficult.

The $|s_{ji}|$ characteristics was measure for this antenna array (Fig.6). We can see that isolation between antenna ports has values near –15 to – 25 dB. The uncoupler was connected to the antenna array ports. Uncoupling characteristic were presents in Fig.7. We can see that coupling values are near -25 to -45dB – it grew less about 10-20dB. It means that our uncoupler can diminishes couplings between system elements and can assure improvement of work conditions base stations of radiocommunication systems, among this electromagnetic compatibility of base station.

### Conclusion

The paper presents one of the couplings reduction method for antenna array – using of especial device – hybrid as uncoupler. Parameters, and results of computer modeling and experimental researches of the 4-channel uncopuler was presented. Results of design and experimental researches of the radiocommunication complex with uncoupler may be used for EMC and EMD tests of radiocommunication systems.

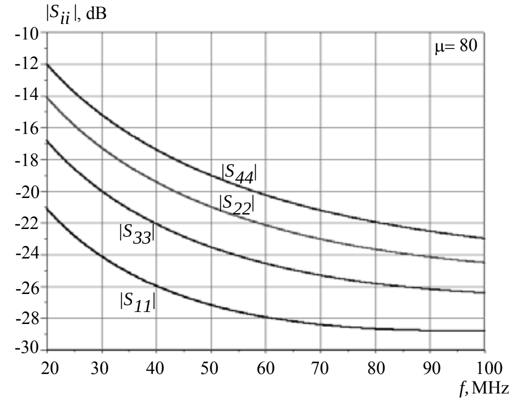


Fig.5. Characteristics of 4-channel hybrid as uncoupler

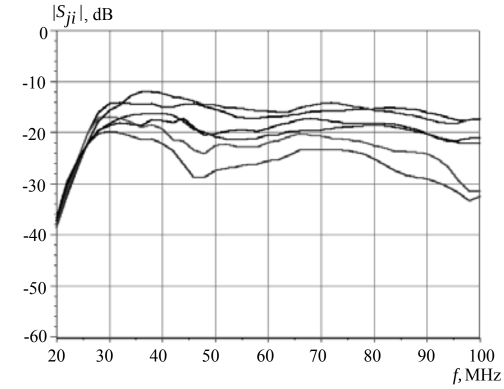


Fig.6. Inputs isolation characteristics for antenna array

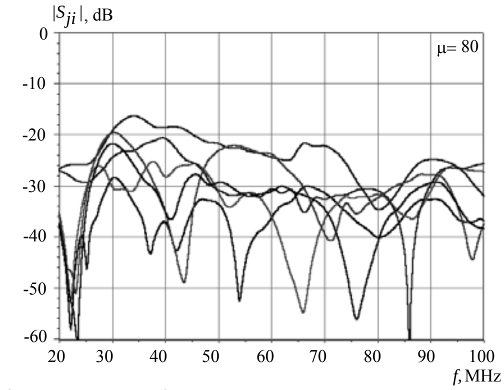


Fig.7. Characteristics of antenna array with uncoupler


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