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 modeled 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 obciążenia zespołowego. Jako układ odpregulujący zastosowano hybrydy zbudowane na liniach transmisyjnych. Układ został zbudowany i przebadany. (Redukcja sprzężeń w 4-elementowym pierścieniowym układzie antenowym)

Keywords: Antenna array, mutual coupling, hybrid.

Stoiwa 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.

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

\[
S_A = \begin{bmatrix}
11 & 12 & 13 & 12 \\
12 & 11 & 12 & 13 \\
13 & 12 & 11 & 12 \\
12 & 13 & 12 & 11 \\
\end{bmatrix}
\]

The scattering matrix of 4-port ring antenna array with uncoupler is auxiliary element, used for reduction mutual couplings between elements of the antenna array.

\[
S = \frac{1}{\sqrt{2}} \begin{bmatrix}
0 & 0 & 1 & 1 \\
0 & 0 & 1 & -1 \\
1 & 1 & 0 & 0 \\
1 & -1 & 0 & 0 \\
\end{bmatrix} = \begin{bmatrix}
0 & T^T \\
T & 0 \\
\end{bmatrix}
\]

The scattering matrix of \( N \)-multiport has form:

\[
S_N = \begin{bmatrix}
S_{aa} & S_{ab} \\
S_{ba} & S_{bb} \\
\end{bmatrix}
\]

where \( S_{aa} \) and \( S_{bb} \) - matrices of transmission between ports of \( \alpha \) side and \( \beta \) side adequately, \( S_{ab} \) and \( S_{ba} \) - matrices of transmission from \( \alpha \) side to \( \beta \) side and reversely. If occurs dependence:

\[
S_{aa} = S_{bb} = 0
\]

The scattering matrix of 4-port ring antenna array with uncoupler is auxiliary element, used for reduction mutual couplings between elements of the antenna array.

Fig.2. Cascade connections of multiports

Hybrid as uncoupler

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

\[
S = \begin{bmatrix}
0 & 0 & 1 & 1 \\
0 & 0 & 1 & -1 \\
1 & 1 & 0 & 0 \\
1 & -1 & 0 & 0 \\
\end{bmatrix} = \begin{bmatrix}
0 & T^T \\
T & 0 \\
\end{bmatrix}
\]

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where $T$ 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.

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).

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 $|s_{ii}|$ 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.

**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 uncoupler 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.

**REFERENCES**


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