Progress In Electromagnetics Research M, Vol. 113, 11–22, 2022

Focusing of the Electromagnetic Field in Several Given Areas of Space

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Abstract—The article describes the problem of spatial separation of devices operating in the same frequency range. The possibility of focusing electromagnetic fields in several specified regions of space is considered. The proposed method for focusing the electromagnetic field can be an additional method for separation devices that operate in the same frequency range. The system under consideration, consisting of space, radiating antennas, and focusing points, is represented as an abstract multipole with the number of inputs equal to the number of radiating antennas and with a set of outputs equal to the number of focusing points. A coordinate system has been introduced that makes it possible to calculate the distances between radiation and focusing points. A method for calculating complex transmission coefficients between emission points and reception points is described. An analytical expression is obtained, a system of linear algebraic equations, which makes it possible to calculate the necessary amplitudes and phases of signals supplied to radiating antennas. A model in a computer-aided design system containing 56 radiating antennas is presented. 9 focus points were set, and 4 of them should have maxima of the electromagnetic field. The simulation confirmed the theoretical calculations. A method for optimizing the calculations of the initial amplitudes and phases by eliminating the elements of the characteristic matrix is considered. This made it possible to reduce the number of elements in the characteristic matrix.

1. INTRODUCTION

In the modern world with a growing economy, digitalization of many spheres of public life is taking place. The number of subscribers of wireless telecommunications networks is large and growing rapidly. These include smartphones, TVs, personal computers, IoT devices, etc. The number of such subscribers will grow steadily. Thus, a dense environment with a large number of competing devices is formed. The consequence of this is an increase in the density of networks of data transmission systems. Devices operating in the same frequency range interfere with each other. Interference reduces the throughput of the data transmission channel [1]. The possibilities for frequency and time separation, their separation by data transmission channels are currently close to exhaustion [2]. At the same time, subscriber devices of wireless networks are, as a rule, spatially separated. This opens up additional ways for their spatial separation. In the simplest case, by forming the maximum radiation pattern of the base station antenna in the direction of the subscriber, it is possible to significantly increase the signal level and channel capacity without interfering with surrounding devices. However, in this case, a high level of the useful signal is formed in a certain direction. Selection of several subscriber devices located within the main lobe of the access point antenna pattern is not possible.

At the same time, methods for focusing antenna arrays to a finite distance are known [3–9]. In this case, as a rule, one focusing point is considered, in which the antenna radiation pattern is preserved, and the task of forming a given distribution of the electromagnetic field strength in space is not set.

Received 7 July 2022, Accepted 19 August 2022, Scheduled 31 August 2022

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The purpose of this work is to substantiate the possibility of forming a given distribution of the electric field strength in space for wireless data transmission networks.

2. MATHEMATICAL MODEL

Consider a rectangular room with radiating antennas on the walls. Figure 1 shows an example of the considered room with antennas, top view. In the room shown in Figure 1, there are N — transmission points (radiating antennas) located equidistantly along the perimeter of the room, M — reception points (receiving antennas of subscriber devices of the wireless data transmission network) located within the premises. The origin of the Cartesian rectangular coordinate system is located in the center of the room. We orient the coordinate axes oX and oY parallel to the walls of the room. The oZ axis is directed upwards.

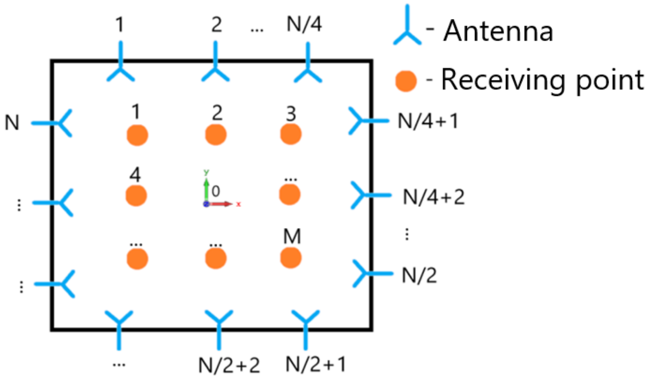

Figure 1. Antenna configuration.

Let's assume that by controlling the amplitudes and phases of the signals supplied to the antennas located along the perimeter of the room, it is possible to set the zones of maxima and minima of the electromagnetic field. Let us denote the complex amplitudes of the emitted signals:

$$A_n = a_n \cdot e^{j \cdot \phi_n}, \tag{1}$$

where: a_n — the amplitude of the signal emitted from the n-th point; ϕ_n — the initial phase of the signal emitted from the n-th point; j — the imaginary unit.

Complex signal amplitude at the receiving points:

$$B_m = b_m \cdot e^{j \cdot \psi_m}, \tag{2}$$

where: b_m — signal amplitude at the m-th point; ψ_m — the phase of the signal at the m-th point.

The set of complex amplitudes emitted and received at the focusing points form a vector of emitted signals $[A]$ and a vector of received signals $[B]$, respectively.

The room shown in Figure 1 can be represented as an abstract microwave multipole with $N + M$ inputs. At the same time, the points from which electromagnetic waves are emitted (antennas along the perimeter of the room in Figure 1) correspond to the inputs of the multipole with numbers 1 to N. The receiving points correspond to the inputs of the multipole with numbers from $N + 1$ to $N + M$. A schematic representation of the system in the form of an abstract multipole is shown in Figure 2. In fact, the introduced abstract multipole characterizes the propagation medium of electromagnetic waves in the considered room.

This approach makes it possible to consider the problem of determining the parameters of emitted signals that provide focusing of the radiation of wireless data transmission networks at given points in the room as the problem of determining the input signals of a multiport network (microwave multipole) for given output signals. Taking into account the linearity of the propagation medium, we write the characteristic equation of a multipole based on the scattering matrix [10, 11]:

$$[Y] = [S] \cdot [X], \tag{3}$$

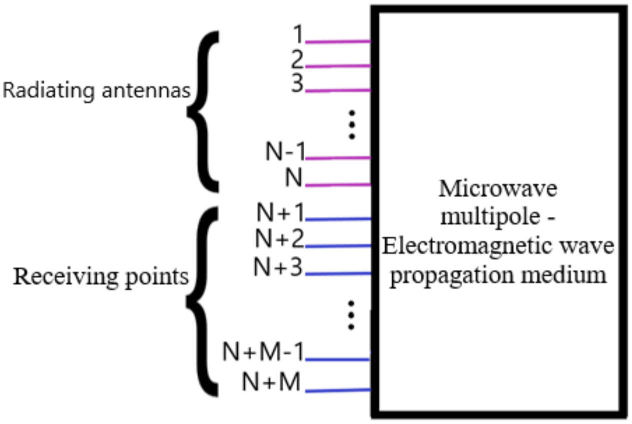

Figure 2. Schematic representation of the antenna system in the form of an abstract multipole.

where: $[Y]$ — a column vector composed of the complex amplitudes of the output electromagnetic waves of the multipole (the vector of reflected (scattered) electromagnetic waves) with the dimension $[N + M$ rows; 1 columns]; $[X]$ — a column vector composed of complex amplitudes of input (radiated) electromagnetic waves (the vector of incident electromagnetic waves) with dimension $[N + M$ rows; 1 columns]; $[S]$ — the characteristic matrix of a multiport network (scattering matrix) with dimensions of $[N + M$ rows; $N + M$ columns].

Consider the characteristic matrix and vectors of incident and scattered waves.

The vector of complex output signals $[Y]$ determines the resulting strength of the electromagnetic field at each of the considered points shown in Figure 1. The first N elements of the vector $[Y]$ characterize the resulting field strength at the points of location of the emitters. Since it is required to focus the radiation inside the room and not on its walls (see Figure 1), it is possible to impose the condition that the scattered waves are equal to zero at these points. The next M elements are the complex amplitudes of the electric field strength at the points of reception. Their values are determined by the required amplitudes and phases of the field strength at each of the M receiving points (B_m). With this in mind, the column vector of the output electromagnetic waves will have the following form:

$$[Y] = [\ y_1 = 0;\ \ \ldots;\ \ y_N = 0;\ \ y_{N+1} = B_1;\ \ \ldots;\ \ y_{N+M} = B_M\ ]^T . \tag{4}$$

The column vector of emitted electromagnetic waves $[X]$ is also composed of two parts. Elements 1 to N represent the complex amplitudes of electromagnetic waves incident on the corresponding inputs of the abstract multipole. In fact, these are the complex amplitudes of electromagnetic waves radiated into the room. Elements from $N + 1$ to $N + M$ are complex amplitudes of electromagnetic waves radiated from receiving points. Obviously, they are zero. With this in mind, the column vector of complex amplitudes of radiated electromagnetic waves has the form:

$$[X] = [\ x_1 = A_1;\ \ \ldots;\ \ x_N = A_N;\ \ x_{N+1} = 0;\ \ \ldots;\ \ x_{N+M} = 0\ ]^T . \tag{5}$$

Consider the characteristic matrix $[S]$ of an abstract multipole, the scattering matrix. In general terms, for a multipole with inputs $N + M$, it can be written:

$$[S] = \begin{bmatrix} s_{1,1} & .. & s_{1,N} & s_{1,N+1} & .. & s_{1,N+M} \\ .. & .. & .. & .. & .. & .. \\ s_{N,1} & .. & s_{N,N} & s_{N,N+1} & .. & s_{N,N+M} \\ s_{N+1,1} & .. & s_{N+1,N} & s_{N+1,N+1} & .. & s_{N+1,N+M} \\ .. & .. & .. & .. & .. & .. \\ s_{N+M,1} & .. & s_{N+M,N} & s_{N+M,N+1} & .. & s_{N+M,N+M} \end{bmatrix} . \tag{6}$$

For a scattering matrix, its diagonal elements determine the reflection coefficients from each of the inputs. With regard to the considered problem of radiation focusing at given points, the diagonal elements of the characteristic matrix will be determined by the quality of matching of the antenna located at the radiation point corresponding to the element number with the feed path.

The off-diagonal elements of the characteristic matrix are the complex transmission coefficients between the respective multipole inputs. Taking into account the fact that an abstract multipole is a medium for the propagation of electromagnetic waves between all points of the considered in Figure 1 configuration, it is possible to write an expression that determines the off-diagonal elements of the characteristic matrix (without taking into account the re-reflections of electromagnetic waves inside the room):

$$s_{i,k} = g_{i,k} \cdot g_{k,i} \cdot r_{i,k}^{-q} \cdot \exp\left(-j \cdot \beta \cdot r_{i,k}\right), \tag{7}$$

where $r_{i,k}$ — the distance from the point corresponding to the i-th input of the multipole to the point corresponding to the k-th input of the multipole; $\beta = \frac{2 \cdot \pi}{\lambda}$ — phase factor; $g_{i,k}$ — elements of the matrix containing the field gains of the antenna installed at the point corresponding to the input k in the direction of the point corresponding to the input i; the factor $r_{i,k}^{-q}$ determines the decrease in the amplitude of the electromagnetic wave during propagation from the point corresponding to the input of the multipole i to the point corresponding to the input of the multipole k. When focusing the electromagnetic field in the near zone $q = 2$, in the far zone — $q = 1$.

Taking into account the introduced coordinate system in Figure 1, the distance between the considered points can be determined:

$$r_{i,k} = \sqrt{\left(x_i - x_k\right)^2 + \left(y_i - y_k\right)^2 + \left(z_i - z_k\right)^2}, \tag{8}$$

where (x_i, y_i, z_i) are the Cartesian coordinates of the i-th point.

Thus, in expression (3), which relates the input and output actions, the vector of complex amplitudes of the output electromagnetic waves $[Y]$ and the characteristic scattering matrix $[S]$ are determined. The desired vector is the complex amplitudes of the emitted electromagnetic waves $[X]$, at which the required distribution of the electric field strength within the room is provided. Expression (3) is a matrix form of the system of linear equations. By solving it in any known way, one can determine the vector $[X]$.

3. OPTIMIZATION OF THE CALCULATION OF THE INITIAL AMPLITUDES AND PHASES

When operating with matrices of a large number of elements, one may encounter the fact that the system will not be able to change the distribution of the electromagnetic field in real time, or the requirements for its computing resources will be enormous.

3.1. Splitting the Characteristic Matrix into Submatrices

As it was said in the first section of the article, the space of the room is represented as an abstract multipole, and its characteristic matrix is determined by expression (6). The characteristic matrix of an abstract multipole can be divided into four submatrices:

$$[S] = \begin{bmatrix} [S_{TT}] & [S_{TR}] \\ [S_{RT}] & [S_{RR}] \end{bmatrix}, \tag{9}$$

where $[S_{TT}]$ — submatrix that determines the transmission coefficients from one radiation point to another radiation point (submatrix of mutual transmission coefficients), dimension [N rows; N columns]; $[S_{TR}]$ — submatrix that determines the transfer coefficients from the receiving point to the emission point (submatrix of inverse transfer coefficients), dimension [N rows; M columns]; $[S_{RT}]$ — submatrix that determines transfer coefficients from the emission point to the receiving point (submatrix of direct transfer coefficients), dimension [M rows; N columns]; $[S_{RR}]$ — submatrix that determines the transfer coefficients from the receiving point to another receiving point (submatrix of mutual transfer coefficients), dimension [M rows; M columns]. An illustration of the division into submatrices is shown in Figure 3.

A schematic representation of the role of submatrices is shown in Figure 4.

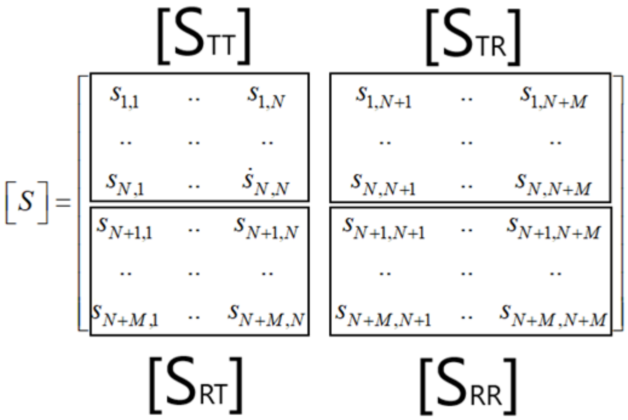

Figure 3. Splitting the characteristic matrix into submatrices.

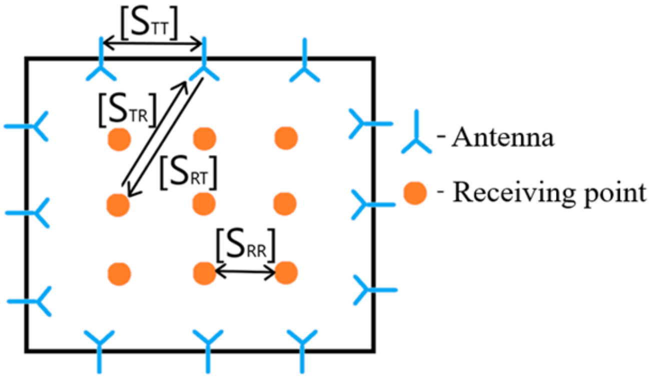

Figure 4. Schematic representation of the role of submatrices.

Consider submatrices. For submatrix $[S_{TT}]$, the diagonal elements are the reflection coefficients from the input of the emitting antenna. The off-diagonal elements are the complex gains between the respective multipole transmit inputs (radiating antennas):

$$[S_{TT}] = \begin{bmatrix} s_{1,1} & \cdots & s_{1,N} \\ \vdots & \ddots & \vdots \\ s_{N,1} & \cdots & s_{N,N} \end{bmatrix}, \tag{10}$$

The elements of submatrix $[S_{TR}]$ are the complex transmission coefficients from the receiving points to the emitting point:

$$[S_{TR}] = \begin{bmatrix} s_{1,N+1} & \cdots & s_{1,N+M} \\ \vdots & \ddots & \vdots \\ s_{N,N+1} & \cdots & s_{N,N+M} \end{bmatrix}, \tag{11}$$

where $s_{N,N+M}$ — the transfer coefficient from the receiving point with the number $N + M$ to the emitting point with the number N. The submatrix $[S_{TR}]$ consists only of the transfer coefficients.

All elements of the submatrix $[S_{RT}]$ are the transfer coefficients from the transmission point to the reception point:

$$[S_{RT}] = \begin{bmatrix} s_{N+1,1} & \cdots & s_{N+1,N} \\ \vdots & \ddots & \vdots \\ s_{N+M,1} & \cdots & s_{N+M,N} \end{bmatrix}, \tag{12}$$

where $s_{N+M,N}$ — the transmission coefficient from the transmission point N to the reception point

$N + M$. Submatrix $[S_{RT}]$ consists only of the transfer coefficients from the transmission point to the reception point.

The diagonal elements of the submatrix $[S_{RR}]$ are the reflection coefficients from the input of the receiving antenna, and the off-diagonal elements are the transmission coefficients from one reception point to another reception point:

$$[S_{RR}] = \begin{bmatrix} s_{N+1,N+1} & \cdots & s_{N+1,N+M} \\ \vdots & \ddots & \vdots \\ s_{N+M,N+1} & \cdots & s_{N+M,N+M} \end{bmatrix}, \tag{13}$$

where $s_{N+i,N+k}$ — the transfer coefficient from the reception point $N + k$ to the reception point $N + i$.

Let us write an expression for calculating the k-th element of the column vector of the output (at the receiving points) electromagnetic waves using the full characteristic matrix:

$$y_k = \overbrace{\underbrace{s_{k,1} \cdot x_1 + s_{k,2} \cdot x_2 + \ldots + s_{k,N} \cdot x_N}_{[S_{TR}],k>N}}^{[S_{TT}],k\leq N} + \overbrace{\underbrace{s_{k,N+1} \cdot x_{N+1} + s_{k,N+2} \cdot x_{N+2} + \ldots + s_{k,N+M} \cdot x_{N+M}}_{[S_{RR}],k>N}}^{[S_{RT}],k\leq N} \tag{14}$$

Let's remember:

1. Elements of the column vector of radiated electromagnetic waves $[X]$ from 1 to N determine the complex amplitudes of the signals supplied to the transmitting antennas. Elements from $N + 1$ to $N + M$ correspond to the complex amplitudes emitted from the receiving points. Obviously, the receiving points do not emit anything, and the elements from $N + 1$ to $N + M$ are equal to zero. $x_j = 0$, $k \in [N + 1; N + M]$.
2. Elements of the column vector of output electromagnetic waves $[Y]$ from 1 to N are equal to zero, because within the framework of the problem under consideration, it is required to focus the electromagnetic field inside the space of the room and not on the walls. Elements from $N + 1$ to $N + M$ take values from zero to one. Their value is determined by the required field distribution in the room.

Based on the above and expression (14), we write down the impact on the calculations of each of the four submatrices (9):

- Submatrix $[S_{RR}]$ containing the transfer coefficients from one receiving point to another receiving point does not affect the final amplitude-phase distribution. This is because the receiving points do not emit a signal. In expression (14) elements $x_1 \ldots x_N = 0$.
- Submatrix $[S_{TR}]$, containing the transmission coefficients from the receiving points to the transmission points, satisfies the conditions $[S_{TR}] = [S_{RT}]^T$. The elements of the column vector $[Y]$ from 1 to N are equal to zero, which means that the elements of submatrix $[S_{TR}]$ do not affect the final amplitude-phase distribution.
- Submatrix $[S_{TT}]$'s diagonal elements are the reflection coefficients from the input of the respective antennas, and whose off-diagonal elements are the transmission coefficients between the radiating antennas. It can be equated to zero if we provide high-quality matching with the supply path, and the radiation patterns will be of such a form that they will provide high isolation from neighboring antennas. In addition, the elements of the column vector $[Y]$ from 1 to N are equal to zero, so the elements of submatrix $[S_{TT}]$ do not affect the final amplitude-phase distribution.

Consequently, only the submatrix $[S_{RT}]$ of direct transfer coefficients will influence the magnitude of the intensity at the reception point. Then the expression for the multipole, in the form of which we represent the medium of wave propagation, can be written in the following form:

$$[B] = [S_{RT}] \cdot [A] \tag{15}$$

Expression (15) for convenience of perception can be written as a system of linear algebraic equations containing M equations and N unknowns (complex amplitudes of emitted signals A_n):

$$\begin{cases} B_1 = s_{RT_{1.1}} \cdot A_1 + s_{RT_{1.2}} \cdot A_2 + \ldots + s_{RT_{1.n}} \cdot A_n \\ B_2 = s_{RT_{2.1}} \cdot A_1 + s_{RT_{2.2}} \cdot A_2 + \ldots + s_{RT_{2.n}} \cdot A_n \\ \vdots \\ B_m = s_{RT_{m.1}} \cdot A_1 + s_{RT_{m.2}} \cdot A_2 + \ldots + s_{RT_{m.n}} \cdot A_n \end{cases} \tag{16}$$

The resulting system of linear algebraic equations can be solved by any known method, for example, Gauss, Cramer, etc.

4. VERIFICATION OF THEORETICAL RESULTS BY MATHEMATICAL MODELING

To test the theoretical results in the CST Microwave Studio electrodynamic simulation environment, a model of a rectangular space with dimensions of 840 × 840 mm was built, containing 56 printed antennas, 14 antennas on each wall (see Figure 5). The space inside the simulated room is free space $\varepsilon_r = 1$, $\mu_r = 1$, including focus areas. The wall material is red brick and does not affect the efficiency of the system in any way, because there is a reflective shield behind the printed antennas. The antennas are designed for a center frequency of 2.5 GHz [11–18]. The substrate material for the antenna (Difmolen-2) has a relative permittivity $\varepsilon_r = 2.33$. The substrate thickness is 2.1 mm. The diameter of the radiating element is 46 mm. The directivity of the antenna is 7.09 dB. The plot of $S_{1.1}$ reflectance versus frequency for the antenna is shown in Figure 6 and shows that the antenna has a good match at 2.5 GHz.

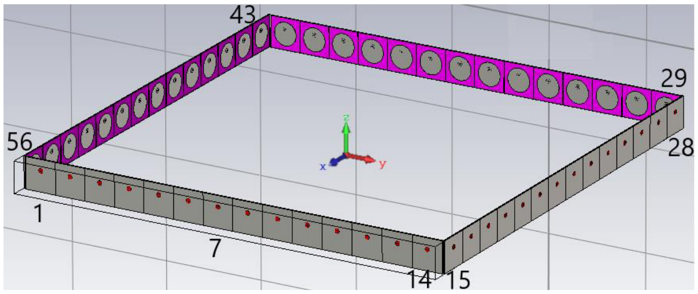

Figure 5. Space model with 56 antennas.

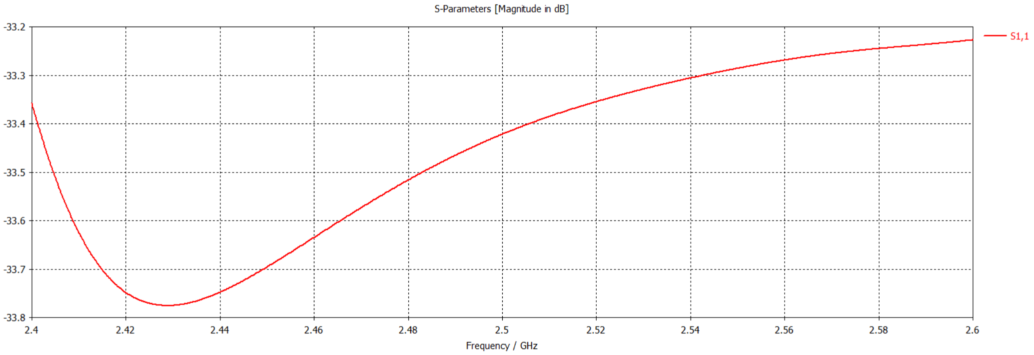

Figure 6. The reflection coefficient of the printed antenna used.

Let's set 9 reception points inside the space of the constructed model, with a step of 200 mm, equidistant from each other. Thus, the total number of emission and reception points is 65. Let's set two field configurations. It is expected to obtain the distribution of the electromagnetic field in space, with areas of maxima in the corners of the room (see Figure 7(a)) and field configuration resembling the letter "Y" (see Figure 7(b)).

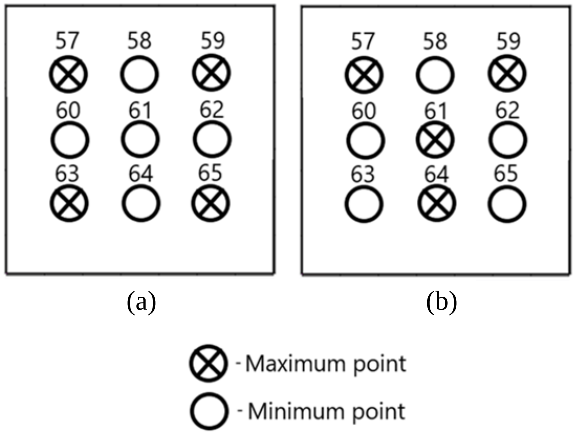

Figure 7. The desired distribution of the amplitude of the electric field strength in the room.

Then the column vector of the complex amplitudes of the output electromagnetic waves $[Y]$ has the form:

$$[Y] = [\ y_1 = 0;\quad \ldots;\quad y_N = 0;\quad y_{N+1} = 1;\quad \ldots;\quad y_{N+M} = 1]^T, \tag{17}$$

For field configuration shown in Figure 7(a), all elements are equal to zero, except for elements numbered 57, 59, 63, 65 — they are equal to one. For field configuration shown in Figure 7(b), all elements are equal to zero, except for elements numbered 57, 59, 61, 64 — they are equal to one.

Having calculated the elements of the characteristic matrix $[S]$ with dimension $[65 \times 65]$ according to expression (7), and having solved the systems of Equations (3) and (15) by the Gauss method [19], the distribution of amplitudes and phases of the emitted signals was obtained. The values for the field configuration shown in Figure 7(a) are shown in Table 1(a), and the values for the field configuration in Figure 7(b) are shown in Table 1(b). Calculation by both expressions gives the same results. The difference between expressions (3) and (15) lies in the fact that expression (15) uses a truncated version of the characteristic matrix of a multipole, thus, when calculating this expression, fewer mathematical operations are performed.

The obtained values of the amplitudes and phases are set for antennas with corresponding numbers in the model (see Figure 5). As a result of electrodynamic modeling, the distribution of the amplitude of the electric field strength in the space of the room was obtained (see Figure 8 and Figure 9).

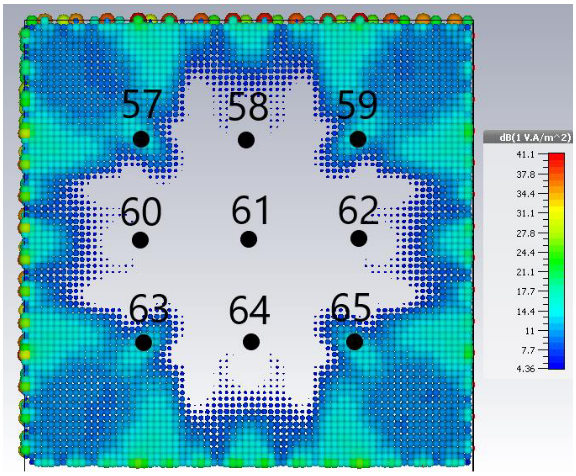

Figure 8. Distribution of the electromagnetic field.

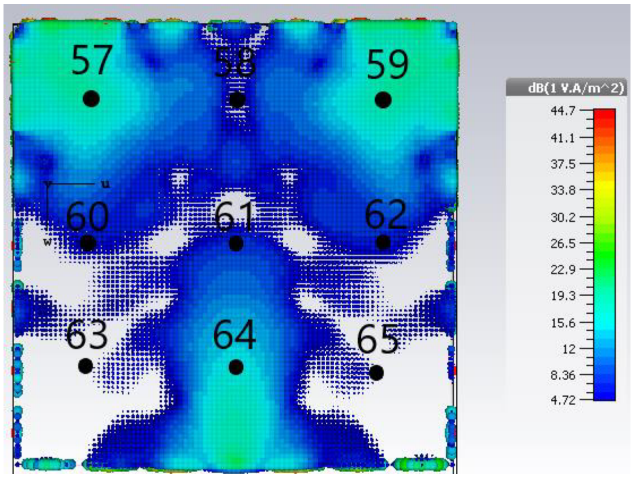

Figure 9. Distribution of the electromagnetic field.

The levels of the electric field strength at the considered points of space for the distribution of the electromagnetic field shown in Figure 8 are presented in Table 2(a).

The levels of the electric field strength at the considered points of space for the distribution of the electromagnetic field shown in Figure 9 are presented in Table 2(b).

Table 1. (a) Distribution of amplitudes and phases for the formation of a given field. (b) Distribution of amplitudes and phases for the formation of a given field.

Antenna number	Amplitude	Phase, deg.	Antenna number	Amplitude	Phase, deg.
1	0.2646	145.87	29	0.2646	145.87
2	0.2569	52.76	30	0.2569	52.76
3	0.3257	2.43	31	0.3257	2.43
4	0.5511	−44.58	32	0.5511	−44.58
5	0.3647	−54.36	33	0.3647	−54.36
6	0.3671	14.3	34	0.3671	14.3
7	0.4207	165.79	35	0.4207	165.79
8	0.4207	165.79	36	0.4207	165.79
9	0.3671	14.3	37	0.3671	14.3
10	0.3647	−54.36	38	0.3647	−54.36
11	0.5511	−44.58	39	0.5511	−44.58
12	0.3257	2.43	40	0.3257	2.43
13	0.2569	52.76	41	0.2569	52.76
14	0.2646	145.87	42	0.2646	145.87
15	0.2646	145.87	43	0.2646	145.87
16	0.2569	52.76	44	0.2569	52.76
17	0.3257	2.43	45	0.3257	2.43
18	0.5511	−44.58	46	0.5511	−44.58
19	0.3647	−54.36	47	0.3647	−54.36
20	0.3671	14.3	48	0.3671	14.3
21	0.4207	165.79	49	0.4207	165.79
22	0.4207	165.79	50	0.4207	165.79
23	0.3671	14.3	51	0.3671	14.3
24	0.3647	−54.36	52	0.3647	−54.36
25	0.5511	−44.58	53	0.5511	−44.58
26	0.3257	2.43	54	0.3257	2.43
27	0.2569	52.76	55	0.5269	52.76
28	0.2646	145.87	56	0.2646	145.87

(a)

Antenna number	Amplitude	Phase, deg.	Antenna number	Amplitude	Phase, deg.
1	0.14	−101.28	29	0.26	143.7
2	0.24	124.38	30	0.29	40.14
3	0.2	8.93	31	0.4	−12.81
4	0.12	−171.4	32	0.68	−55.66
5	0.28	66.58	33	0.39	−64.33
6	0.32	−19.13	34	0.49	19.22
7	0.37	−80.4	35	0.41	159.6
8	0.37	−80.4	36	0.41	159.6
9	0.32	−19.13	37	0.49	19.22
10	0.28	66.58	38	0.39	−64.33
11	0.12	−171.4	39	0.68	−55.66
12	0.2	8.93	40	0.4	−12.81
13	0.24	124.38	41	0.29	40.14
14	0.14	−101.28	42	0.26	143.7
15	0.13	−40.4	43	0.27	156.79
16	0.23	−122.5	44	0.35	67.87
17	0.20	−140.93	45	0.48	−0.81
18	0.11	−61.18	46	0.66	−47.62
19	0.28	−155.86	47	0.51	−56.87
20	0.17	−105.91	48	0.35	38.97
21	0.46	−133.82	49	0.38	121.58
22	0.38	121.58	50	0.46	−133.82
23	0.35	38.97	51	0.17	−105.91
24	0.51	−56.87	52	0.28	−155.86
25	0.66	−47.62	53	0.11	−61.18
26	0.48	−0.81	54	0.2	140.93
27	0.35	67.87	55	0.23	−122.5
28	0.27	156.79	56	0.13	−40.4

(b)

Table 2. (a) Electric field strength levels. (b) Electric field strength levels.

Point number	Field strength level, dB
57	20.7
58	−0.7
59	20.7
60	−3
61	−17
62	−4
63	20.7
64	2
65	20.7

(a)

Point number	Field strength level, dB
57	20.6
58	1
59	20.6
60	4
61	14.2
62	3.9
63	−3.8
64	20.9
65	−3.7

(b)

5. CONCLUSION

The article proposes a method for calculating the amplitudes and phases of emitted signals that provide focusing of the electromagnetic field in several specified areas of space. The method consists in representing the space in the form of an abstract multipole, whose inputs are radiating antennas, and the outputs are the receiving points. A way of reducing the calculations of amplitudes and initial phases of the signals supplied to the antennas is proposed and considered. It has been established that in order to calculate the initial amplitudes and phases, it is required to specify only the transmission coefficients from the emission points to the reception points. Solving the resulting system of equations, we obtain the values of the amplitudes and initial phases of the signals supplied to the antennas, which will provide the required distribution of the electromagnetic field in space. The practical implementation of such an antenna system can be achieved by using multiple phase shifters and tunable attenuators for each antenna. The results are confirmed by electrodynamic simulation.

ACKNOWLEDGMENT

The study was financially supported as part of the implementation of the NSTU development program, scientific project No. C22-25.

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