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TESTING OF ELECTROMAGNETIC RADIATION RESONATOR-CONVERTER PROTOTYPE

Phase III Report

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1. INTRODUCTION

Studies of the optical properties of prototypes of resonators-converters (R-C) of electromagnetic radiation were carried out in three stages.

The optical transmission and reflection of three types of R-Cs (Aires Black Crystal, Aires Shield and Aires Defender) were studied in **the first stage**. It was found that when R-C interacts with electromagnetic radiation (EMR), some of the energy of an incident electromagnetic wave is reflected. The reflection was recorded by a sensor with a bandwidth of 8 GHz. As has been confirmed by the results of numeric (digital) modeling performed by project partners, the incident wave and the wave reflected from the R-C surface interfere with each other. The result of the interference is an electromagnetic wave localized in a zone close to the R-C, whose frequency and phase differ from the corresponding characteristics of the incident and reflected electromagnetic waves.

It was found that the power of electromagnetic waves with a frequency of 0.9 GHz turns on the R-C, which we will call $E_{\min}$ is greater or equal to 2 W (*i.e.* detector of radiation registers the change in power of the wave interacting with the R-C). In the case of higher frequency radiation (*i.e.* given high-energy photons $h\nu$) and greater intensity, $E_{\min} = f(h\nu, E^2)$, where E^2 quantity is the squared magnitude of the electric field vector of the incident electromagnetic radiation which is proportional to a magnitude of the wave's Poynting vector or wave's intensity.

To measure the power of electromagnetic pollution damping efficiency by means of individual R-C, we built a setup allowing as to measure a resulting power of the electromagnetic radiation (EMR) in the case of the R-C located at a distances of $2-10\lambda$ (where λ is the central wavelength of an incident wave producing the maximum power in the signal receiving antenna) from the detector (*i.e.* the receiver) being located in an optical transmission or optical reflection mode. At a fixed distance between the receiver and the R-C, and also moving both together in respect to the source of EMR, we obtained that if receiver is being located in the optical transmission mode, the result of the interaction of the R-C with electromagnetic waves of the frequency range 0.9-2.5 GHz looks equivalent to electromagnetic shielding of incident radiation by means of regular metallic plate of dimensions equal to dimensions of the R-C. In optical reflection mode, due to a reflected wave interference with an incident wave, the electric field amplitude of resultant electromagnetic wave of frequency ranging between 0.9 and 2.5 GHz decreases by 20 % on average. The

maximum damping efficiency of electromagnetic waves of above mentioned range of frequencies is achieved in optical reflection mode when the R-C is located at distance shorter or equal to 3λ in respect to the signals receiver.

The second stage of our investigation has been devoted to studies of optical properties of individual R-C and sets of R-Cs in various frequency range from 0 to 8 GHz of an incident radiation. We performed studies of the optical reflection of EMR, the threshold power of the electromagnetic pollution for turning on the R-C, the threshold power and dimensions of the R-C dependence on frequency on incident wave, as well as studies of damping electromagnetic pollution efficiency by means of set of R-Cs, when the radiation source is located in near-field and far-field zones in respect to the testing R-C.

It was found that when an R-C is located in near-field zone, an incident electric field amplitude of the electromagnetic wave greater or equal to $E_{\min}$ can initiate the electrical micro spark between rings of a front or/and rear antennas of the R-C, resulting generation and emission of ultra-wide band frequency signals from the R-C. The frequency of the R-C's emitted wave depends on the characteristics of an incident radiation onto the R-C, on chemical composition of the substance (medium) in which the electrical discharge occurs, and on a type, size and geometry of an individual R-C.

The coefficient of effective EMR damping by the R-C, which is given in terms of a characteristic distance at which electric field amplitude of incident radiation decreased by $e = 2.718$ times), varies with the R-C location when the R-C is being located in the near-field zone in respect to the radiation source and being operated in an optical transmission or reflection modes. The coefficient of effective EMR damping by a group of R-Cs essentially looks very similar for both optical transmission and reflection modes. However, in the case of individual R-C for above mentioned modes of operation this parameter is larger in optical transmission mode, *i.e.* when the R-C is located in between the radiation source and the signals receiver that detects the signals of radiation source.

According to our earlier estimations, the minimal power density of $P^{0.9\text{ GHz}}_{\min} \geq 490\text{ mW/A}$ is required to turn on the secondary radiation of then R-C (where A stands for a R-C surface area interacting with the incident wave). When turned on, the R-C could emit electromagnetic waves of an ultra-wide frequency band whose central frequency will depend on the characteristics of the wave incident onto the R-C, the R-C's fractal sequence, the electrical

conductivity of the material of the silicon microprocessor, and the depth and width of plasma etched groves formed on the surface of the silicon wafer (microprocessor).

In the third stage, were studied the EMR interaction with a two-dimensional (2D) and three-dimensional (3D, spatial) prototype R-C.

Research objectives

- To build a theoretical 2D model of a set of R-Cs (hereinafter called a "group"), consisting of individual R-Cs, with optimally oriented surface normal in with respect to the direction of the Poynting vector of the wave emitted by the point source and far from each other at the optimal distance on the same plane a) from a group of 4 R-Cs arranged in the shape of a square, b) from a group of 4 R-Cs arranged in the shape of a cross, c) from a group of 5 R-Cs arranged in the shape of a square, with a R-C placed in the center, and d) from a group of 5 R-Cs arranged in the shape of a cross, with an R-C placed in the center.
- To build a 3D model of a group R-Cs, consisting of individual R-Cs, whose normal oriented at the optimal angle in respect to the direction of the Poynting vector of the electromagnetic (EM) wave emitted by the point source and spatially spaced at some optimal distance from one another.

2. METHODS

The experiments were carried out using two types of Aires Defender R-Cs: Infinity and Pro (Figure. 1).

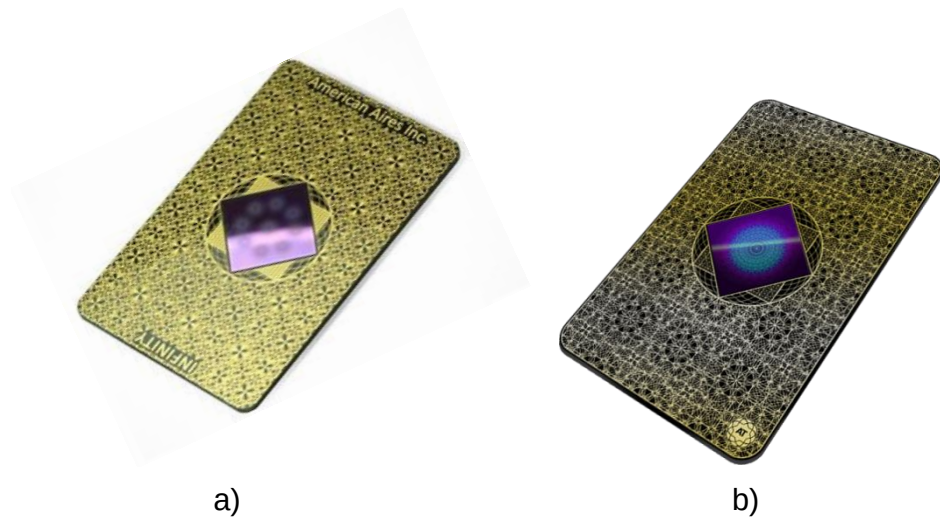


Fig. 1 Resonator-converters of electromagnetic radiation whose dimensions are $121 \times 65 \times 2 \text{ mm}^3$: a) Aires Defender Infinity, which consists of nine annular diffraction gratings; b) Aires Defender Pro with one annular diffraction grating

An R-C consists of an Aires "microprocessor" and a resonator antenna. An Aires "Microprocessor" is a single-crystal silicon wafer whose surface has an annular (circular) diffraction grating formed by means of plasma etching of micrometers narrow and micrometers shallow groves. The diffraction grating plays a dual role: it reflects electromagnetic waves, causing the phenomenon of wave interference, and creates favorable conditions for the redistribution of the surface concentration of charge carriers, which are predetermined by the number of diffraction gratings and the individual geometry of each of them. When the R-C interacts with an electromagnetic wave, both phenomena, that is, the phenomenon of interference of the reflected/incident waves and the phenomenon of redistribution of the concentration of charge carriers on the surface of the microprocessor, can simultaneously lead to the cancellation of the electromagnetic pollution created by the EMR source.

Both analyzed R-Cs are different: the microprocessor of the Aires Defender Infinity (Fig. 1, on the left) consists of 9 annular (circular) diffraction gratings, while the Defender Pro (Fig. 1, right) – has one diffraction grating whose area is twice as large as the total area of the gratings of the Aires Defender Infinity. The nine diffraction gratings, which are created by the

Aires Defender Infinity and separated from each other by a distance of 5 mm relative to the centers, can effectively reflect/emit waves with central frequency of $f = 7.5$ GHz.

The microprocessors, in the studied R-Cs, are glued onto the top antenna (an equivalent circuit of the Aires Defender Pro is shown in Fig. 2), which is separated from the rear antenna by a dielectric plate (with relative permittivity $\epsilon \sim 4$ and the tangent of the dielectric loss angle of 0.0027 at 10 GHz). Both antennas form an electric capacitor, whose electrical capacitance along with the parasitic inductance of both antennas determine the impedance of the R-C matching the impedance of free space (375Ω).

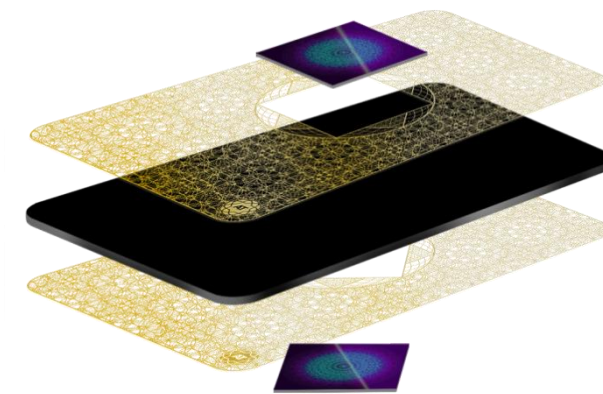


Fig. 2 A scheme of a resonator-converter of electromagnetic radiation: Aires Defender Pro, with a single circular diffraction grating

Experimental studies were carried out using a DFG 4060 electromagnetic wave generator (hereinafter referred to as a "transmitter"). The EMR amplitude and the change in the frequency band were detected using a Signal Hound Spectrum Analyzer (hereinafter referred to as a "receiver") at a frequency of 2.4 GHz. The accuracy of measuring the intensity of the electrical/magnetic component of EMR in the frequency range from 1.9-35 GHz is no less than 2.4 dB. The bands of EMR frequencies incident on the R-C were analyzed using the Fast Fourier Transform (FFT) of the received signal.

The 2D R-C group consists of five R-Cs (with a central R-C) or four R-Cs (without a central R-C) of type of the Defender Infinity, at the same distance $n \lambda$ (where λ is a central wavelength of the wide frequency band signal, n is an integer number, and $n\lambda$ product

expresses the distance (given in wavelengths) measured between the centers of the microprocessors of individual R-Cs of a single group of R-Cs) from the center of the incident EMR transparent dielectric wafer (a rectangular parallelepiped) to whose surface the group of R-Cs is attached. A detailed diagram of the R-Cs' layout is shown in Fig. 3.

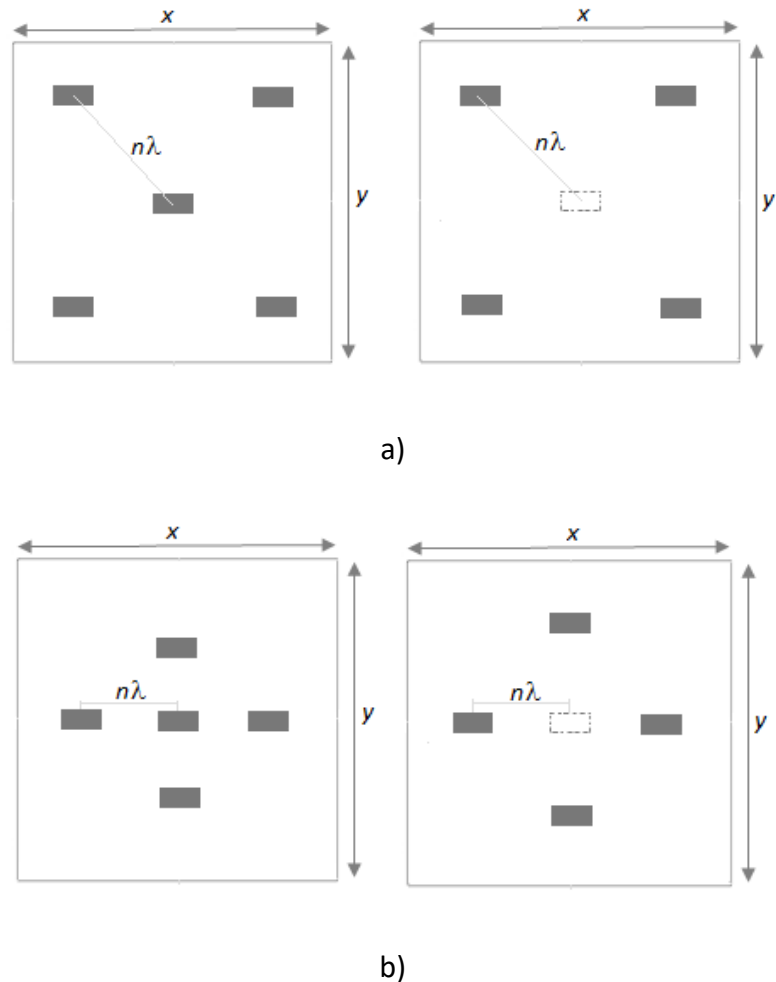


Fig. 3 Layouts of the resonator-converters: a) "rectangular parallelepiped" with and without a central R-C;
b) "cross " with and without the central R-C

The damping efficiency of EMR by means of R-Cs group being operated in the optical transmission and reflection mode was studied by measuring the power of electromagnetic waves with a change in the distance between the R-C and the receiver in the interval from 1λ up to 4λ while the R-C operates in optical transmission and optical reflection modes. The transmitter and receiver are spaced at distance of 5λ from each other (Fig. 4).



Fig. 4 Experimental layout for investigation of the damping efficiency of EMR by means of two-dimensional R-C

Changing the distance from the R-C to the transmitter, the power of the dBm signal received by the receiver was recorded at fixed points and subsequently converted to values of electric field strength of the component wave of electromagnetic radiation

$$E = \frac{\sqrt{30 \cdot P_t \cdot G_t}}{d}, \quad (1)$$

here E is the electric field strength, $[E] = \text{V/m}$; P_t is the power of the measured signal, $[P_t] = \text{W}$; G_t is the antenna gain, $[G_t] = \text{dBi}$. Asserting that the source of EMR is an ideal electric dipole, $G_t = 2.15 \text{ dBi}$ was used as the value of antenna gain.

For the study of the 3D group, an Aires Defender Pro R-C was used. The R-Cs were arranged in a circle, at equal distances from each other. The electromagnetic wave receiver was placed at the center of the circle. The electric field strength was measured with a change in the distance from the R-C group to the receiver in the interval from 0.5λ to 2λ . The transmitter moves away from the receiver at a step of $n\lambda$, with $n = 1; 1.5; 2; 2.5; 3; 3.5; 4; 4.5$ and 5 (Fig. 5).

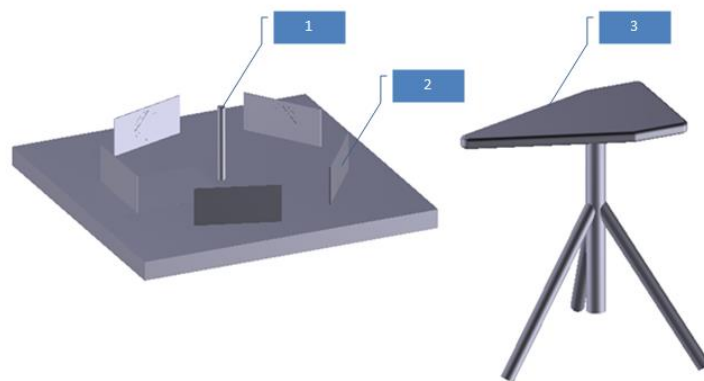


Fig. 5 Experimental layout of the study of the R-C 3D group. Here: 1 – receiver (antenna); 2 – R-Cs arranged in a circle; 3 – generator (transmitter)

The frequency of the electromagnetic waves generated by the generator is 2.4 GHz, and the wavelength is $\lambda = 0.0125$ m. The amplitude of the reflected signal of the medium surrounding the radiation source, group of R-Cs, and receiver of signals did not exceed the sensitivity limit of the receiver or was subtracted when calculating the damping efficiency of an electromagnetic pollution.

3. RESULTS AND DISCUSSION

The experiments were carried out with the transmitter operating at a frequency of 2.4 GHz. **In the first stage**, we performed the study of the arrangement of R-Cs in the plane, shown in Fig. 3a: a) with a R-C located in the center of a rectangular parallelepiped and b) without one. The R-Cs were removed relative to the center of the square: at a distance of 0.5λ , 1λ , 1.5λ and 2λ (i.e. 0.0063, 0.0125, 0.0188 and 0.025 m). The distance between the R-C group and the receiver changed within a step of λ . The strength of the component of the electric field of the wave was estimated when the R-C group located between the transmitter and the receiver (i.e. in optical transmission mode) and with it moved into the receiver's shadow region (in optical reflection mode) (Fig. 6-9). Here: $\Delta E = E_0 - E_{R-C}$ is the difference in the amplitudes of the electrical component of the electromagnetic wave, calculated at a fixed point in space. The red line indicates the position of the receiver (antenna).

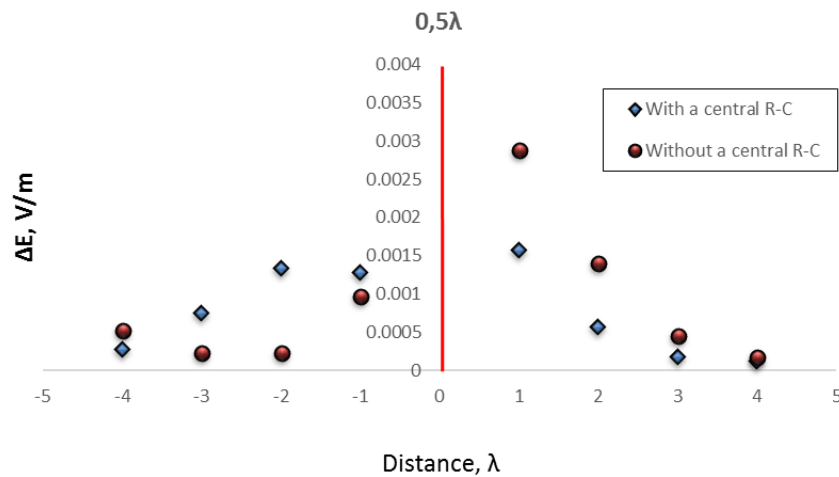


Fig. 6 Dependence of the amplitude of the electrical component of the electromagnetic wave on the distance to the receiver (antenna) for the R-C group in the shape of a rectangular parallelepiped, when all R-Cs are removed by a distance of 0.5λ with respect to the central R-C, with the group located in the optical transmission and optical reflection modes

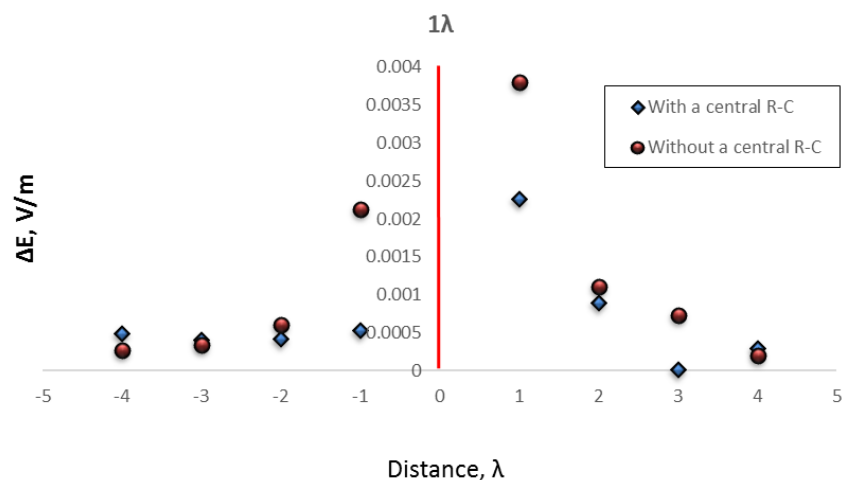


Fig. 7 Dependence of the amplitude of the electrical component of the electromagnetic wave on the distance to the receiver (antenna) for the R-C group in the shape of a rectangular parallelepiped, when all R-Cs are removed by a distance of λ in all directions with respect to the central R-C, with the group located in the optical transmission and optical reflection modes

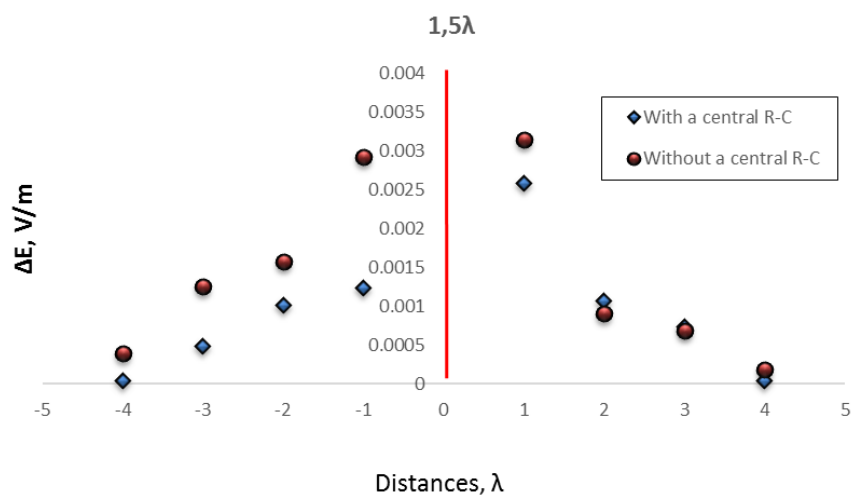


Fig. 8 Dependence of the amplitude of the electrical component of the electromagnetic wave on the distance to the receiver (antenna) for the R-C group in the shape of a rectangular parallelepiped, when all R-Cs are removed by a distance of 1.5λ in all directions with respect to the central R-C, with the group located in the optical transmission and optical reflection modes

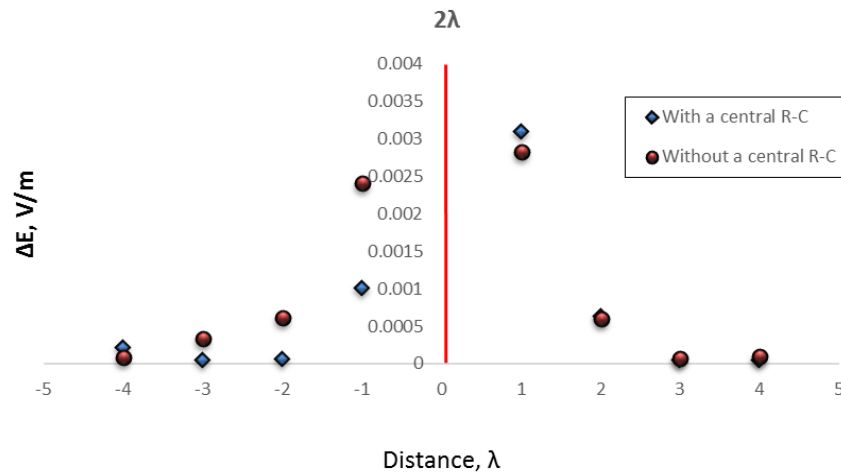


Fig. 9 Dependence of the amplitude of the electrical component of the electromagnetic wave on the distance to the receiver (antenna) for the R-C group in the shape of a rectangular parallelepiped, when all R-Cs are removed by a distance of 2λ in all directions with respect to the central R-C, with the group located in the optical transmission and optical reflection modes

During interactions with the R-C group, the maximum change in the amplitude of the electrical component of the wave $\Delta E = E_0 - E_{R-C}$ was measured with the R-C group located at a distance of 1λ from the receiver. However, when the receiver is moved away from the transmitter, ΔE consistently decreases. In previous stages of the project, it was established that in the case of optical reflection of electromagnetic radiation by an R-C, some of the energy of the incident electromagnetic wave is reflected. The result of mutual interference of the EMR incident on and reflected from the surface of the R-C is a wave whose frequency and phase is different from the frequency and phase of incident and reflected waves. Results of our investigation showed that the maximum damping of 2.4 GHz electromagnetic pollution by means of R-C is achieved when the R-C group is located at distance as close as 1λ in respect to the surface of the signals receiver (*i.e.* the antenna) when the receiver operates in the optical reflection mode. In the near field zone, the damping efficiency of the electromagnetic pollution by means of R-C group, being operated in the optical reflection mode, is of 27 % more efficient than that one operated in the optical transmission mode.

The R-C arrangement in the shape of a rectangular parallelepiped, without a central R-C (see Fig. 3a on the right) is more effective than the arrangement with a central R-C (see Fig. 3a on the left) by 35 % and 26 % respectively, in optical transmission and reflection modes.

For the 'rectangular parallelepiped' relative to the center, all the R-Cs are located at the

same distance: a) 0.5λ , b) 1λ , c) 1.5λ and d) 2λ . The most effective suppressor of electromagnetic waves, in the case of the R-C group in the shape of a rectangular parallelepiped, was designed by placing a R-C at a distance 0.5λ and 1.5λ from the parallelepiped relative to the geometric center.

Through experimentation, we evaluated (Fig. 10-11) the percentage change in optical reflection / transmission modes of the amplitude of the wave's electric field ΔE with varying distance of all R-Cs relative to the central R-C, from 0 to 0.5λ , from 0.5λ to 1λ , from 1λ to 1.5λ , and from 1.5λ to 2λ .

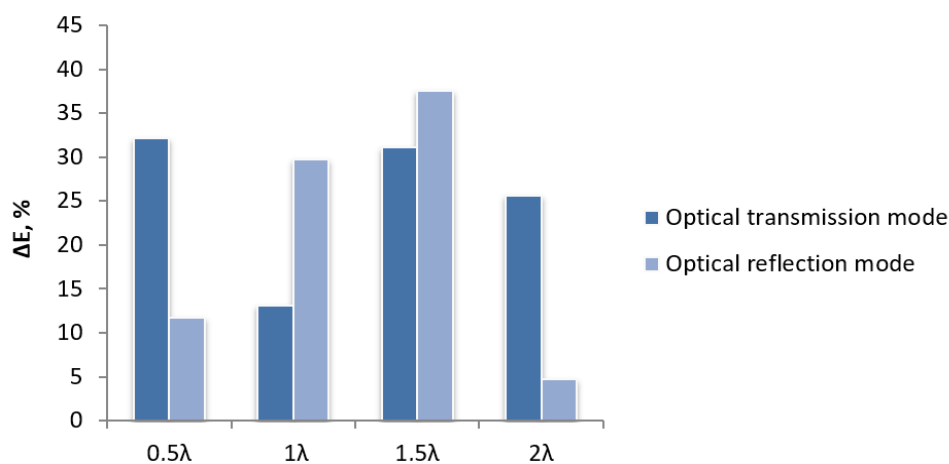


Fig. 10 Change in the amplitude of the electrical component of the electromagnetic wave given a change in the distance of all R-Cs relative to the central R-C, from 0 to 0.5λ , from 0.5λ to 1λ , from 1λ to 1.5λ , and from 1.5λ to 2λ , in the group in the shape of a rectangular parallelepiped with a central R-C

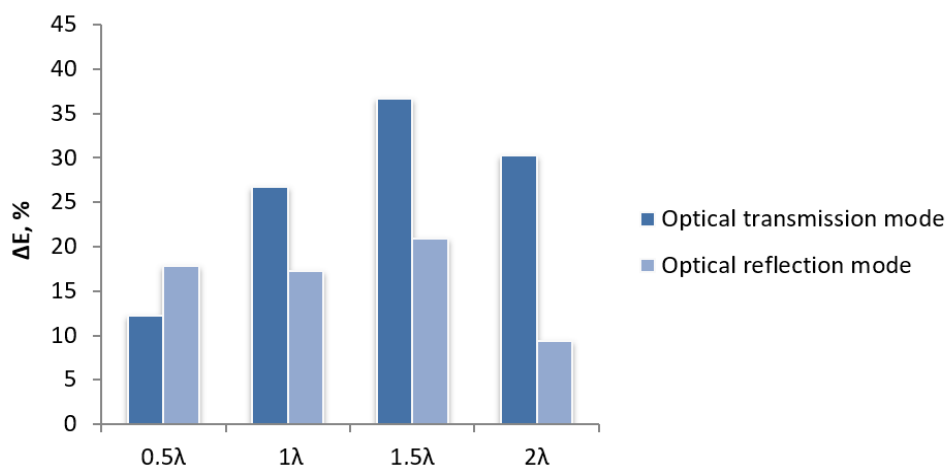


Fig. 11 Change in the amplitude of the electrical component of the electromagnetic wave given a change in the distance of all R-Cs relative to the central R-C, from 0 to 0.5λ , from 0.5λ to 1λ , from 1λ to 1.5λ , and from 1.5λ to 2λ , in the group in the shape of a rectangular parallelepiped without a central R-C

Fig. 10 shows that for the R-C group in the shape of a rectangular parallelepiped with a R-C located at the center, the change in signal amplitude given a change in the distance of all R-Cs relative to the central R-C, from 1λ to 1.5λ is 31 % and 37 % respectively in optical transmission and reflection modes. Similarly, without a central R-C (Fig. 11), the change is 37% and 21 % in optical transmission and reflection modes, respectively. It was established that in both experiments the R-C group located at a distance of 1.5λ most effectively suppresses electromagnetic pollution at a frequency of 2.4 GHz.

In the second stage, we studied the R-C group in the shape of a cross (see Fig. 3b): with a central R-C (on the left) and without a central R-C (on the right). The efficiency of the electromagnetic pollution damping by the R-C group in the shape of a cross was analyzed with all R-Cs at a distance of 0.5λ , 1λ , 1.5λ and 2λ ($\lambda = 0.0125$ m) relative to the central R-C and with a change in the distance from the R-C group to the electromagnetic wave receiver by a step λ . We evaluated the amplitude of the electrical component of the wave with the R-C group located between the transmitter and the receiver (in optical transmission mode) and with its being relocated to the receiver's shadow region (in optical reflection mode) (Fig. 12-15).

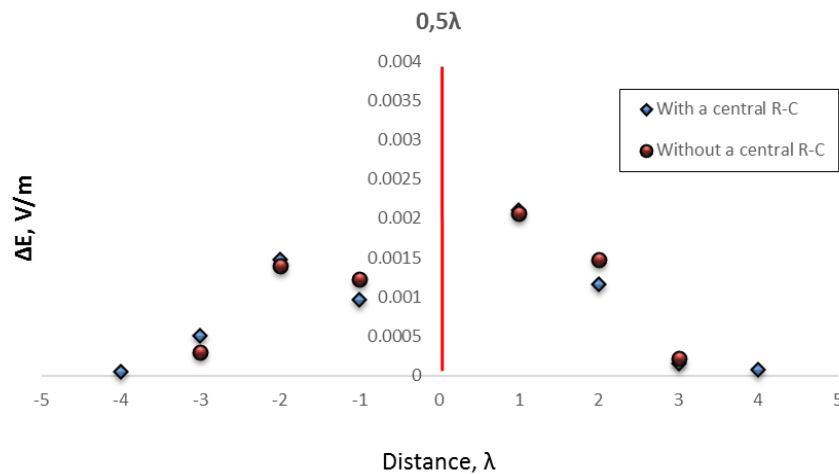


Fig. 12 Dependence of the amplitude of the electrical component of the electromagnetic wave on the distance of the R-C group in the shape of a cross to the receiver (antenna), when all R-Cs are removed by a distance of 0.5λ with respect to the central R-C, with the group located in the optical transmission and optical reflection modes

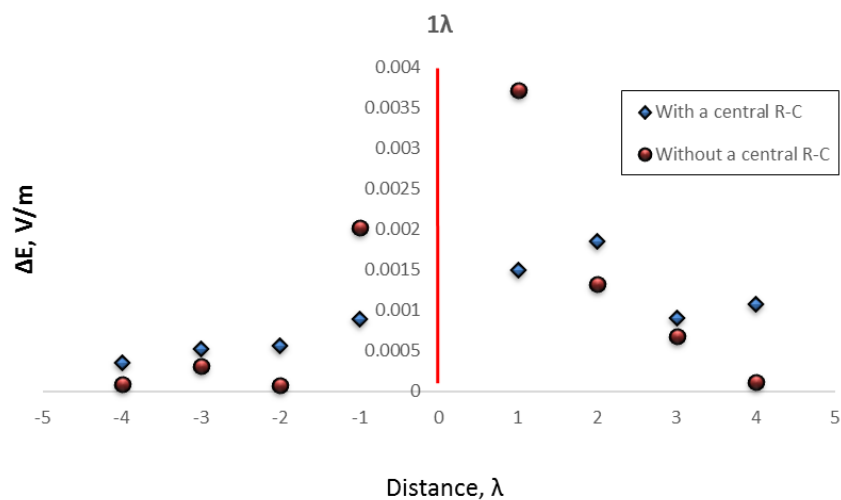


Fig. 13 Dependence of the amplitude of the electrical component of the electromagnetic wave on the distance of the R-C group in the shape of a cross to the receiver (antenna), when all R-Cs are removed by a distance of λ with respect to the central R-C, with the group located in the optical transmission and optical reflection modes

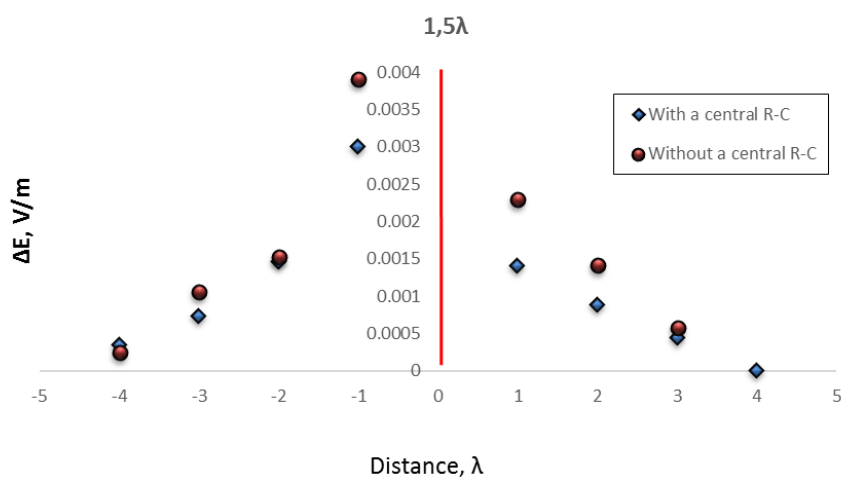


Fig. 14 Dependence of the amplitude of the electrical component of the electromagnetic wave on the distance of the R-C group in the shape of a cross to the receiver (antenna), when all R-Cs are removed by a distance of 1.5λ with respect to the central R-C, with the group located in the optical transmission and optical reflection modes

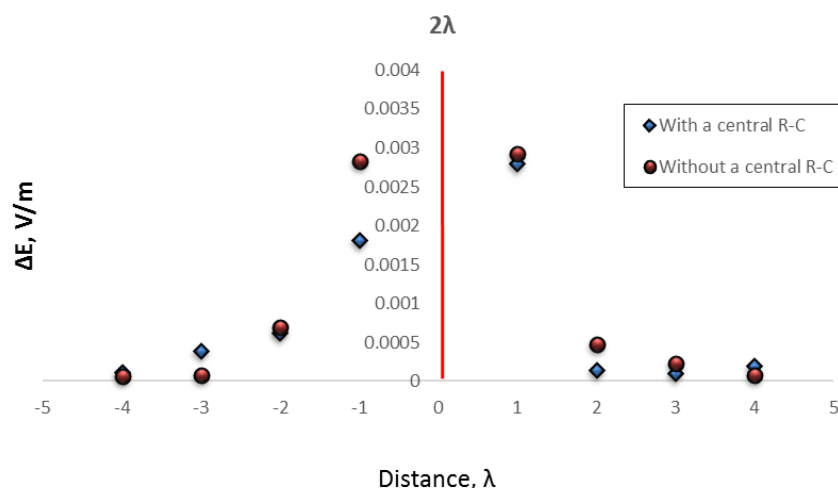


Fig. 15 Dependence of the amplitude of the electrical component of the electromagnetic wave on the distance of the R-C group in the shape of a cross to the receiver (antenna), when all R-Cs are removed by a distance of 2λ with respect to the central R-C, with the group located in the optical transmission and optical reflection modes

The maximum damping of electromagnetic pollution power at a frequency of 2.4 GHz by the R-C group arranged in the shape of a cross was achieved when the group was located at a distance of 1λ from the receiver. Moving the receiver away from the transmitter, the damping of electromagnetic power efficiency by the R-C consistently decreases. It is worth noting that (as in stage 1) being operated in optical reflection mode, in the near-field zone the R-C group in the shape of a cross is 9 % more efficient than in optical transmission mode.

In optical transmission mode and optical reflection mode, the R-C arrangement in the shape of a cross, without a central R-C, is more effective than with a central R-C. In the conditions mentioned above, ΔE is 13 % and 32 % respectively in optical transmission and reflection modes. The experimentally observed maximum cancellation of electromagnetic pollution at a frequency of 2.4 GHz by a R-C arranged in the shape of a cross was obtained by removing all R-Cs, relative to the central R-C, by a distance of $0.5-1.5\lambda$.

Comparing the damping efficiency of electromagnetic pollution by means of the rectangular parallelepiped group of R-Cs with cross-shape group of R-Cs, we found that the former is 6 % more efficient than the latter.

Through experimentation, we evaluated (Fig. 16-17) the percentage change in optical reflection/transmission modes of the amplitude of the wave's electric field ΔE with varying

distance of all R-Cs relative to the central R-C, in the group in the shape of a cross, from 0 to 0.5λ , from 0.5λ to 1λ , from 1λ to 1.5λ , and from 1.5λ to 2λ .

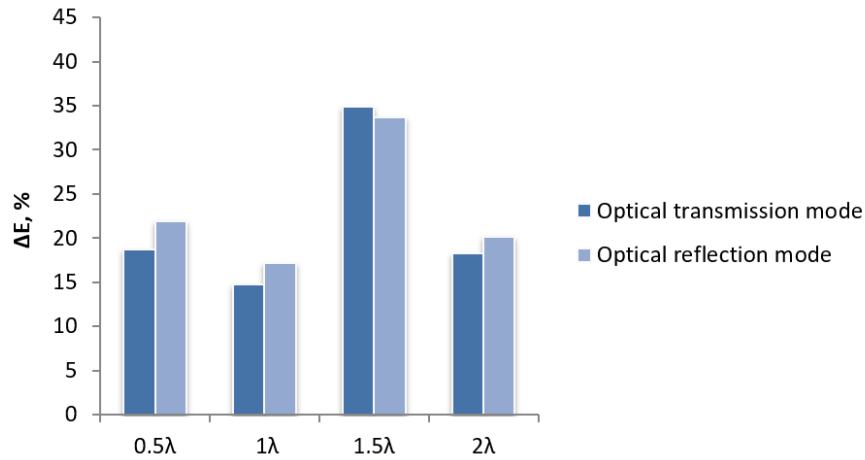


Fig. 16 Change in the amplitude of the electrical component of the electromagnetic wave given a change in the distance of all R-Cs relative to the central R-C, from 0 to 0.5λ , from 0.5λ to 1λ , from 1λ to 1.5λ , and from 1.5λ to 2λ , in the group in the shape of a cross with a central R-C

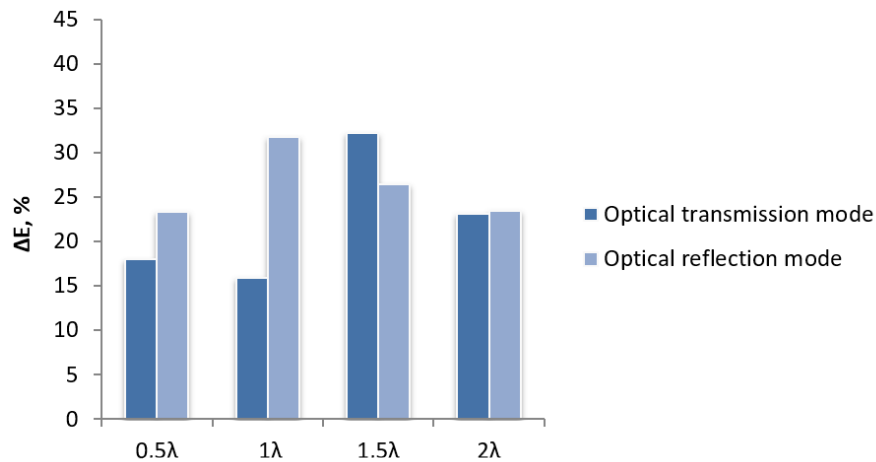


Fig. 17 Change in the amplitude of the electrical component of the electromagnetic wave given a change in the distance of all R-Cs relative to the central R-C, from 0 to 0.5λ , from 0.5λ to 1λ , from 1λ to 1.5λ , and from 1.5λ to 2λ , in the group in the shape of a cross without a central R-C

Fig. 16 shows that for the R-C group in the shape of a cross with a R-C located at the center, the change in the amplitude of the wave's electric component given a change in the distance of all R-Cs relative to the central R-C, from 1λ to 1.5λ is 35 % and 34 % in optical transmission and reflection modes, respectively. Similarly, without a central R-C (Fig. 17), the mentioned change is 32 % and 26 % in optical transmission and reflection modes,

respectively. The obtained results make it possible to assume that electromagnetic pollution at a frequency of 2.4 GHz is most effectively damped by a R-C group in the shape of a cross located at a distance of λ , without a central R-C, with the group located in optical reflection mode.

In the third stage, we studied a three-dimensional ("3D") group of R-Cs in the shape of a sphere, consisting of separate Aires Infinity II R-Cs, equidistant from one another. We measured the electrical component of the wave ΔE with a change in the distance between the R-C group and the receiver in the range from 0.5λ to 2λ . The distance between the transmitter and receiver is $n \lambda$, where $n = 1; 1.5; 2; 2.5; 3; 3.5; 4; 4.5$ and 5 (Fig. 5). The maximum ΔE of a wave with a frequency of 2.4 GHz (and simultaneously the cancellation of electromagnetic pollution) was achieved by moving the transmitter away from the receiver to a distance λ , and also when all the R-Cs are placed in the shape of a circular arc relative to the receiver's antenna located in the center are simultaneously separated from each other by a fixed distance of 0.5λ . When the transmitter is removed from the receiver and simultaneously from the 3D group of R-Cs, the suppression effectiveness of the whole group decreases (Fig.18).

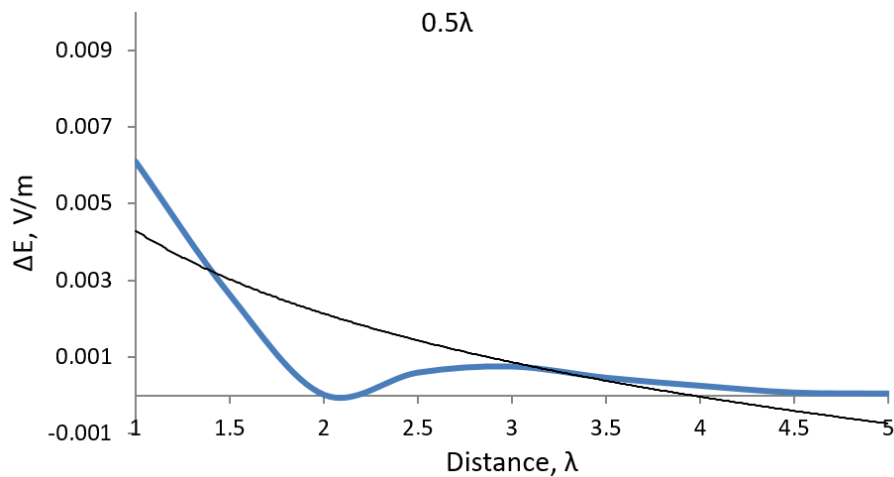


Fig. 18 Dependence of the change in the amplitude of the electrical component of the electromagnetic wave registered by the receiver, on the 3D R-C group's distance to the receiver (of the antenna) when all R-Cs, relative to the receiver's antenna, are removed by a distance of 0.5λ . In this case, the dashed line indicates the relationship $\lg(\Delta E) = f(\text{Distance})$. (ΔE is computed at a fixed point in space)

It was also experimentally established that when a three-dimensional group of R-Cs is moved away from the transmitter, the damping efficiency of electromagnetic pollution changes,

and the maximum cancellation is achieved only when the 3D-shape of the R-C group is located at a distance of 1λ from the transmitter (Fig. 19).

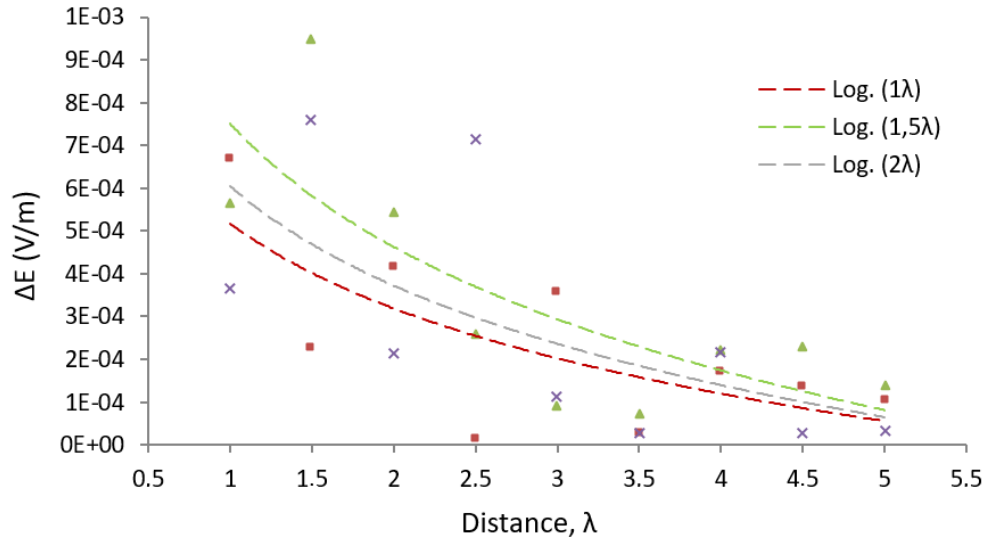


Fig. 19 Semi-log plot of dependence of the amplitude of the electrical component of the electromagnetic wave on the distance of the 3D R-C group to the receiver (of the antenna), when all the R-Cs, relative to the receiver's antenna, are removed by a distance of 1λ , 1.5λ and 2λ

It is believed that when using 2D or 3D groups of R-Cs, whose size is comparable (or greater than) with the wavelength of the incident EMR of 2.4 GHz ($\lambda = 12.5$ cm), measurements in the near zone of the field, where the amplitude of the electrical component of the wave detected by the receiver is very strong, are inaccurate due to the reflection of the signal from the receiver and its interference with the incident and reflected waves. The accuracy of the experimental quantitative measurements is also not large in the far-field zone (that is, at a distance $> 10\lambda$), because of the very small amplitude of the electrical component of the cumulative wave and measurement errors due to the reflection of waves off of walls and other objects in the research laboratory. The most accurate result of wave interference would be calculated using numerical modeling techniques. A theoretical model should include the contribution of the reflected signal of each separate R-C in the group and the contribution of the reflected signal of the whole combined 2D or 3D group of R-Cs to the amplitude and phase of the electromagnetic waves registered by the receiver. In both experimental and numerical modeling, there is great significance in the orientation of the resultant surface of the 2D and 3D group of R-Cs relative to the direction of the Poynting vector of the electromagnetic wave interacting with the group.

4. CONCLUSIONS

1. The set of Aires Defender resonator-converters, consisting of a group of resonators located in a plane (2D arrangement) does not show much higher cancellation of electromagnetic waves with a central frequency of 2.4 GHz (*i.e.* 2.4 GHz frequency electromagnetic pollution) when comparing the efficiency of a group of resonator-converters with the efficiency of a single resonator-converter. The main reason is the mutual interference of electromagnetic waves reflected from the resultant surface of the group of resonator-converters, which can cause both a decrease and/or an increase of amplitude and (or) the power of the incident wave of the electric field. The most effective damping of electromagnetic pollution take place when using a single resonator-converter located near-field zone in respect to the receiver of electromagnetic waves and being operated in an optical reflection mode.
2. In the case of sets of two-dimensional and three-dimensional resonator-converters, the amplitude and/or the power of the electromagnetic wave of the electric field should be measured in the far-field zone, at a distance at which the set of resonator-converters could be considered as a point source of secondary (*i.e.* reflected) electromagnetic waves. Thus, the optimal method of quantitative analysis of how effectively two-dimensional and three-dimensional resonator-converters can damp the 2.4 GHz electromagnetic pollution appears to be a numerical modeling of electromagnetic radiation interaction with a group of resonator-converters if a theoretical model includes the contribution of the signal simultaneously reflected by each individual resonator-converter and the entire group of two-dimensional and three-dimensional resonator-converters to the amplitude and phase of the electromagnetic waves registered by the receiver, as well as to the mutual interference of the incident and reflected waves.

In the fourth (final) stage, the following is planned:

Prepare a report on the scientific research, summarizing the results of the experimental studies and comparing them with the results of numerical (digital) modeling obtained by the project partners, in cases of electromagnetic pollution at a different frequency and amplitude of the electrical component of the electromagnetic wave.

Further plans:

1. To conduct an experimental study and use numerical (digital) methods to simulate the efficiency of Aires Crystal, Aires Shield Pro, Aires Defender Pro resonator-converters, and others, in cases of electromagnetic pollution in various ranges of frequencies ranging from 0.9 GHz to 300 GHz. Identify the optimal dimensions of the processor and the front and rear antennas that comprise the resonator-converter, as well as the period/pattern of the diffraction grating of the above-mentioned parts of the resonator in cases of monochromatic electromagnetic waves of different frequencies.
2. To determine how damping efficiency of electromagnetic pollution by means of the resonator-converter varies as a function of the change in the frequency of the electromagnetic wave incident on it. How does the magnitude of the threshold of electromagnetic energy necessary for excitation of the resonator-converter depend on the frequency of the electromagnetic pollution interacting with the resonator-converter?
3. To determine how the efficiency of a group of 2D and 3D resonator-converters interacting with electromagnetic pollution at a different frequency depend on a distance of the arrangement of the resonator-converters in the 2D/3D group, relative to the central resonator-converter and (or) to the signals detector antenna located in the center of the receiver's group.