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TESTING OF ELECTROMAGNETIC RADIATION RESONATOR-CONVERTER PROTOTYPE

Phase I Report

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Contents

1. INTRODUCTION

All remotely-operating devices/equipment, which use a wireless method for receiving/transmitting of information, are sources of electromagnetic radiation (EMR) (for users of these specific signals) or sources of electromagnetic smog (for other people). The permissible EMR power density (10 μW/cm^2) set forth by the Lithuanian Hygiene Standard (HN 80:2015) is created by household appliances used on a daily basis: Personal computers (50 – 1000 MHz frequency band), mobile-/smartphones iPhone/iPad (900 – 2100 MHz), smart TV sets (54 – 1600 MHz), microwave ovens (300 MHz – 3 GHz), wireless routers (2,4 – 5 GHz), etc. Due to constantly increasing demand for such devices, their reliable operation at maximum distance and increasing the flux and volume of data transmitted by such devices, the EMR power of devices manufactured by competing companies will inevitably grow. Thus, naturally, the measures protecting against or partially suppressing the electromagnetic smog (e.g. the metal threads/fibres integrated into smart clothing or smart building structures) are becoming more and more relevant. Our test subject is the prototype of electromagnetic radiation resonator-converter (R-C) developed by AIRES TECHNOLOGIES. R-C is designed to partially suppress the excessive electromagnetic smog without interfering with the information receiving/transmitting devices' ability to remotely exchange information.

The aim of the work is to conduct the tests of EMR R-C prototype: to measure the electric/magnetic field strength, EMR flux density in the far-field zone (distance > 10 λ, where λ is the central wavelength of the wide-frequency-band electromagnetic wave incident onto device) and near-field zone (distance < 10 λ); to test the efficiency of the prototype in the 0 – 8 GHz frequency band and make recommendations to the manufacturer for development and optimization of R-C prototypes for specific EMR wavelength/frequency ranges.

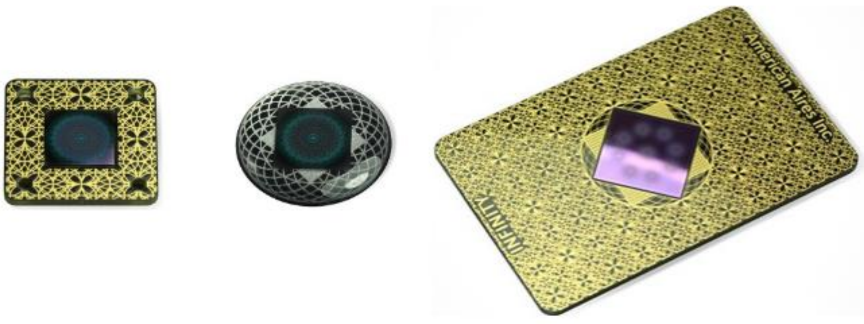
Objective of the Phase:

- To determine the flux density, residual electric/magnetic field strength, frequency of radiation and variation in frequency bandwidth due to EMR interaction with three different types of R-Cs (Aires Black Crystal, Aires Shield and Aires Defender) as well as the efficiency of the R-Cs in far-field and near-field zones relative to EMR source in the 0 – 8 GHz frequency band, compare their efficiencies and the characteristic parameters (according to the customer demand);

- In accordance with our established criteria, to select, to recommend and to manufacture R-Cs of specific characteristics, necessary for further tests foreseen in the project.

2. TESTING OBJECT

Three types of Aires EMR R-Cs (Fig. 1), which consist of Aires chip and resonator antenna.



a) b) c)

Fig. 1 Aires electromagnetic radiation resonators-converters: a) Aires Black Crystal; b) Aires Shield; c) Aires Defender.

Aires chip is a monocrystalline silicon panel covered in matrix, a two-piece circular EMR wave diffraction cell of special construction, creating maximums and minimums of amplitude of reflected EMR, which interact with the external variable electromagnetic (EM) field, resulting in EMR power redistribution along the frequency band of an incident EMR. The resonator antenna, made of electric conductor, covers the circular base of the matrix (Fig. 2).

Fig. 2 Equivalent circuit of electromagnetic resonator-converter.

Thus, the equivalent circuit of the device is a capacitor comprising two conductive electrodes separated by an insulating layer. The interaction of the capacitor with incident EM wave results in charging up of the capacitor. More details on structure and a way of operation of the device are available on the Aires Technologies website: http://www.aireslita.com/en/.

3. METHODS

Experimental part of the work conducted in the Photovoltaic Technology Research Laboratory of Vilnius Gediminas Technical University (VGTU) and in field-conditions imitating EM waves emitted by radiation sources of household appliances and measuring the change of their amplitude and bandwidth using Signal Hound Spectrum analyzer in the frequency band 100 Hz – 8 GHz (the “receiver”) at room temperature (in the laboratory) or similar to it (at field-conditions). Absolute error of relative EMR power measurement does not exceed 1.0 dB, the measuring accuracy of the electric/magnetic EMR component strength is not more than 1.0 dB (in the frequency range between 50 MHz and 1.9 GHz) and 2.4 dB (in the frequency band between 1.9 GHz and 35 GHz) and isotropic deviation is not more than 1.0 dB. EMR bandwidths that fell on R-C and interacted with R-C were analyzed by Signal Hound Spectrum analyzer using the FFT method (Fast Fourier Transformation of pulsed signal).

In each individual measurement, it was attempted to move away from other EMR sources or to make sure that the power of EM waves emitted by other sources (*i.e*. noise) would not affect the test results of our selected source (the “transmitter”) radiation.

Changing the distance between the receiver and the transmitter, the power of incident signals (in dBm) was recorded at freely chosen distances and then converted into electric field strength values of EM field strength values, presuming that all EMR sources are ideal electric dipoles with antenna gain of 2.15 dBi. Introducing the R-C into our experimental setup (see Fig. 3) the experimental measurements were repeated holding approximately the same distances between source (transmitter) and receiver.

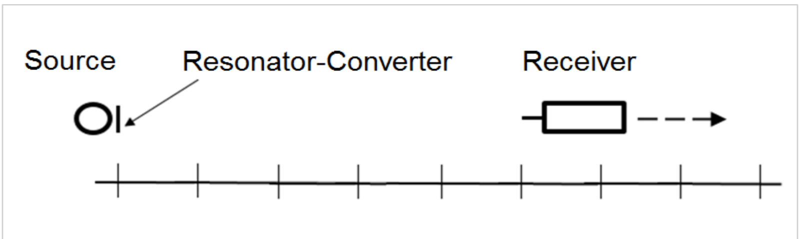


Fig. 3 Resonator-converter efficiency measurement setup.

To test the efficiency of R-C in the regime of optical transmission and optical reflection, the source of EM radiation together with the R-C has been fixed at a distance of 2 – 10 λ from the signals receiver: a) in an optical transmission regime (the R-C is located between the transmitter and the receiver); and b) optical reflectance regime (the R-C is one side faced to the receiver and the transmitter). At fixed distances between the receiver and the R-C, the R-Cs were gradually moved away from the transmitter (Fig. 4).

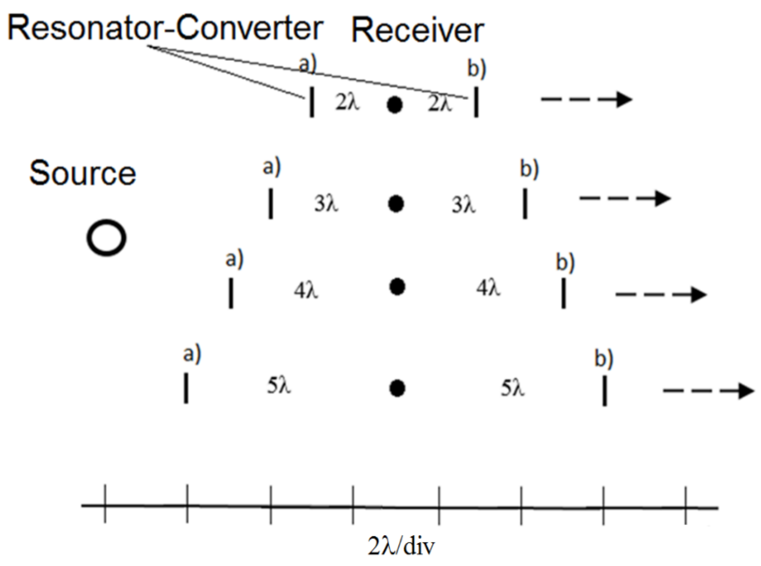


Fig. 4 The scheme explaining the experimental procedure of measurements of the transmitter signal power, where the resonator-converter is located at distance of 2 – 10 λ a) in the regime of optical transmission and b) in the regime of optical reflection.

The sources of EM waves transmitting power in range between 1 and 800 W were selected for our measurements, however to minimize errors of measurements we performed our measurements using the most powerful sources.

When measuring the values of electromagnetic fields, the Lithuanian Hygiene Standard HN 80:2011 “Electromagnetic field at the workplace and living environment. Values and measurement requirements with standardized parameters in 10 KHz ÷ 300 GHz radio frequency band” was observed.

Theoretical simulation of our experimental results will be carried out by prof. Gennadi Lukyanov, Professor of University of Information Technologies, Mechanics and Optics (ITMO), Saint Petersburg, Russia, partner of the Electromagnetic Radiation Resonator-Converter Prototype Testing project, and Aires Technologies, manufacturer of EMR resonator-converter.

4. RESULTS AND DISCUSSION

The efficiency of different types of R-C converters was tested experimentally using the 0.5 – 800 W power sources generating EMR in the 900 – 2.5 GHz frequency band and the residual signal power was measured by means of receiver which is constantly moving away from the transmitter. Electric field strength at fixed locations with R-C added the transmitter (in optical transmission mode) ($E_{R\text{-}C}$) and without it (E_0) (Fig. 4). Here: Transmitter 1 is 0.5 W, transmitter 2 – 2 W, transmitter 3 – 400 W, and transmitter 4 – 800 W. Fig. 5 ΔE – difference of electric field strength $E_0 – E_{R\text{-}C}$, calculated at a fixed point in space.

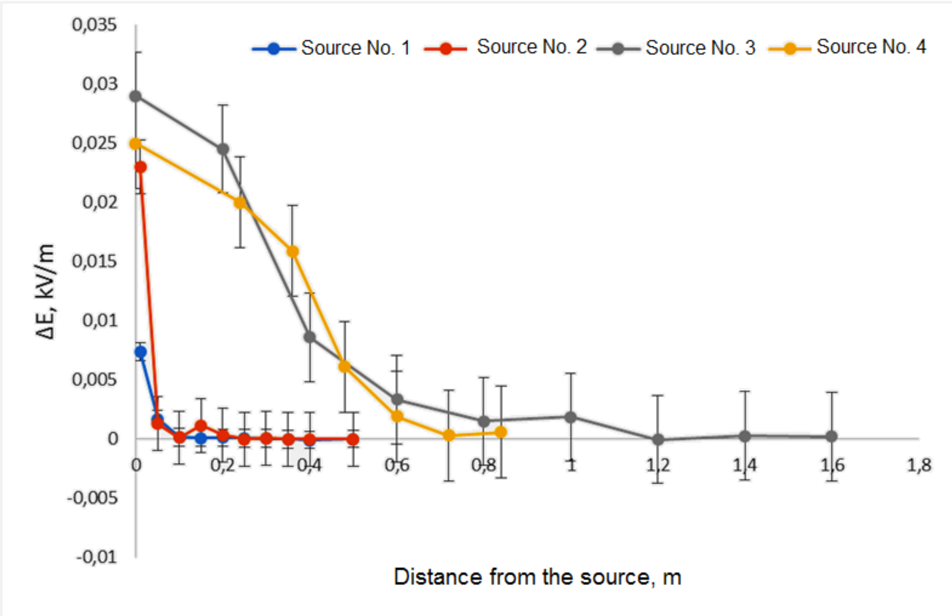


Fig. 5 The electric field strength of incident wave versus the distance from the source.

During interaction with R-C, the electric field strength of incident 0.9 – 2.5 GHz EM wave decreases by 27 % on average (grey curve). The difference of electric field (given as $\Delta E = E_0 – E_{R\text{-}C}$) was measured using R-C placed directly in front of the transmitter. However, as the distance between the receiver and the transmitter was gradually increasing, the parameter ΔE gradually decreased due to EM wave interaction with R-C and in the case of 800 W source it eventually vanished for the distance larger than 1.2 m.

As it follows from our measurement results the minimum power necessary for the R-C excitation by means of an incident 0.9 – 2.5 GHz frequency band EM wave is $E_{min,0.8–1.8\ GHz}$ ~ 2 W (see red curve). However, the E_{min} is the function of frequency ν of an incident EM wave since the increase in wave's frequency affects increase in energy of incident photons hν. Our experimental results suggest that E_{min} is determined by the number of incident onto R-C photons and by the quantum energy of these photons.

The dependence of the transmitter's electric field strength amplitude on the distance to the receiver is shown in Figures 6 and 7. Figure 6 shows a case, where R-C in optical transmission mode is at a distance of 2 – 5 λ from the receiver (here λ is the wavelength of source emitted radiation: λ ~ 12 cm) and Figure 7 represents the R-C in an optical reflectance mode at a distance of 2 – 5 λ from the receiver. In both experimental cases, transmitter radiation power was of 800 W.

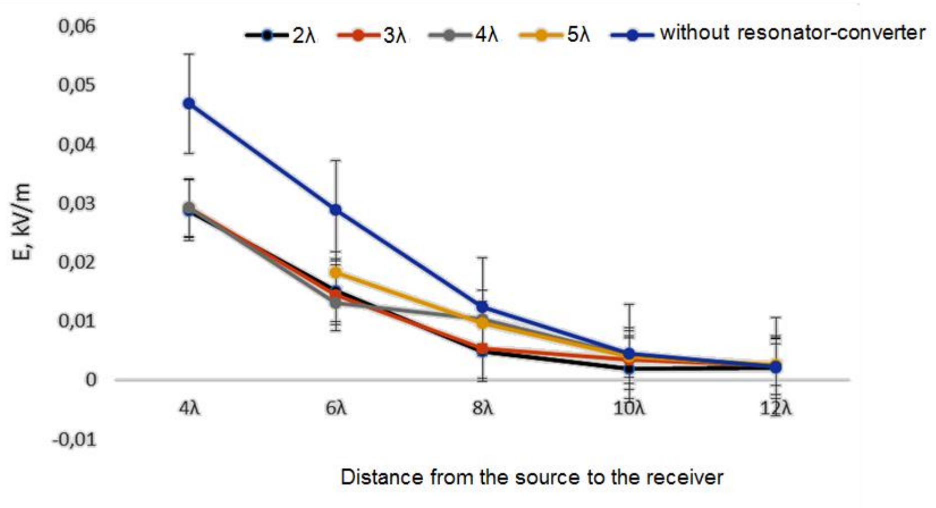


Fig. 6 The electric field strength recorded by the receiver versus the distance between the receiver and the transmitter dependence, where the resonator-converter was in the optical transmission regime at a distance of 2 – 5 λ away from the receiver.

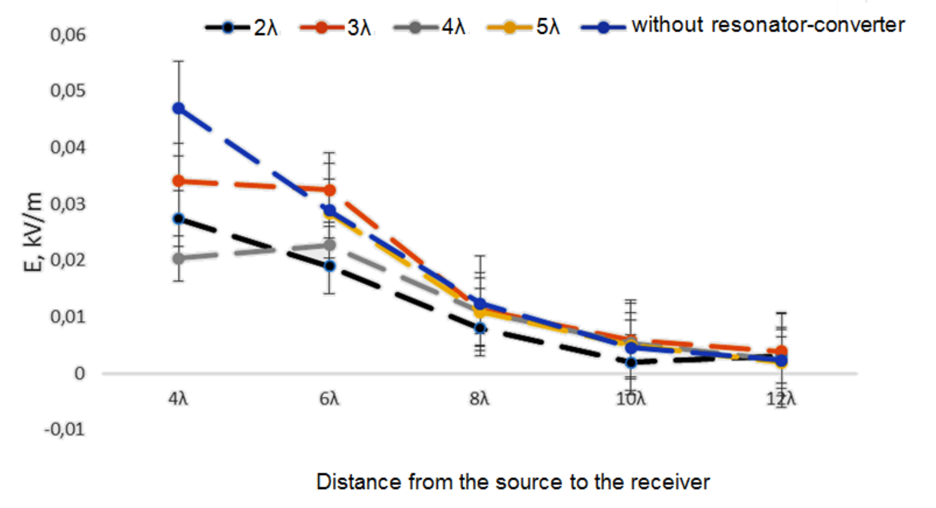


Fig. 7 The electric field strength recorded by the receiver versus the distance between the receiver and the transmitter dependence, where the resonator-converter was in the optical reflectance regime at a distance of 2 – 5 λ away from the receiver.

The amplitude of an incident EM wave decreases considerably as a result of wave's interaction with R-C in optical transmission mode; however, the parameter $\Delta E = E_0 - E_{R\text{-}C}$ does not depend on the distance between R-C and the receiver (Fig. 6). Similar results obtained when replacing the R-C by the conductive (metal) plate, screening the electric field component of an incident EM wave.

In optical reflectance mode, maximum R-C efficiency was observed at a distance between the receiver and the R-C of 2 – 3 λ or with the R-C mounted directly in front the receiver. Thus, R-C is more efficient in optical reflectance mode located in a near-field zone, because only in the near-field zone the electric field's amplitude of an incident EM wave surpasses the threshold E_{min} value necessary for the R-C excitation.

5. CONCLUSIONS

- Resonator-converter (R-C) suppresses power of an EM wave. Maximum efficiency can be achieved when the R-C is located directly in front of the transmitter (source of EM waves). The minimal power of 0.9 – 2.5 GHz frequency bandwidth of an incident EM wave necessary for excitation of the R-C is $E_{min,0.9–2.5\ GHz} \geq 2$ W. If the frequency of the EM wave ν increases or the bandwidth of the waves emitted by the transmitter is shifting towards the higher frequency region, the photon energy $h\nu$ should also affect the E_{min}. Our preliminary results suggest that two factors determining E_{min} are number of incident photons and their quantum energy.

- While in the optical transmission regime the EM wave interaction with the R-C looks very similar to that of a metal conductive plate (*i.e.* screening the electric field component of an incident EM wave), the same interaction in optical reflectance regime expresses itself in different way. The R-C damps the EM wave power demonstrating the maximal efficiency when it is located directly on the receiver or fixed at a distance shorter than 3λ from it.

- The R-C is more efficient in the regime of optical reflectance if located in a near-field zone. In the near-field zone the incident power is high enough for reaching the E_{min} threshold power value necessary for the R-C excitation.

Further plans:

We plan to test the electric properties of individual R-C of the same type and groups of R-Cs of the same type under incident EM waves in frequency range between 0 and 8 GHz. We are going to investigate the EMR distribution capacity, threshold EMR power for R-C excitation and power's dependence *versus* frequency of an incident EM waves and R-C dimensions, power suppression efficiency for individual R-C groups, where the EMR transmitter is located in the near-field and far-field zones with respect to R-C.

Placing an order with Aires Technologies for production of several Aires Black Crystal, Aires Shield and Aires Defender R-Cs with identical dimensions and antenna shapes. Having results of test we will be able to select devices with the most similar properties and dimensions for our further experiments.