Graphene antenna on a biodegradable substrate for frequency range of cellular operators

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***Abstract* – Computer model and manufacturing technology of the dipole graphene "green" antenna as an element of the Internet of things, for the frequency range of cellular operators has been developed. Its experimental layout is presented.**

***Index Terms* – graphene, antenna, green electronics, eco-friendly electronics, multilayer graphene, screen-printing.**

I. Introduction

NOWADAYS INTERNET of things (IoT) market is developing intensively. According to preliminary forecasts, by 2021 the distribution of IoT devices in the total number of devices connected to the Internet will be about 60% (16 billion out of 28 billion). Figure 1 represents the forecasts of big companies by the number of connected IoT devices. This figure shows that the exponential growth in the number of connected "smart" devices will continue.

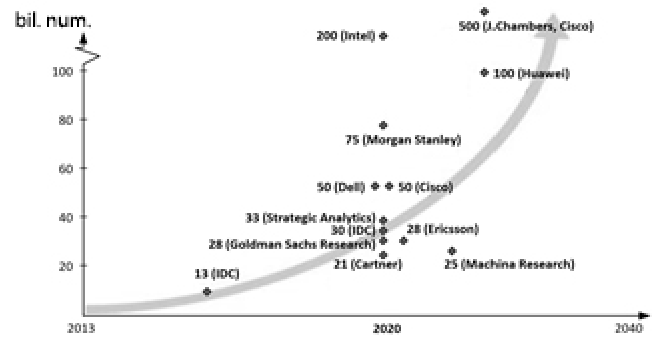

Fig. 1. Forecasts of the number of connected Internet of things devices.

The above forecast justifies the need for the development of environmentally friendly ("green") electronics in order to preserve the environment: for example, the use of graphene instead of metal and biodegradable materials as a substrate.

II. Problem Definition

Eco-friendly graphene inks used for printing antennas have a number of advantages over metallic ones: less weight, less curing temperature and a lower price [1]. These advantages allow the development of technologies for printing antennas on textiles of various types [2, 3] (Figure 2), in particular on clothing. This increases the distance of data transfer by mobile phones (up to 2 times), the speed of downloading and uploading files, the battery lifetime due to the decrease in the required power of the transceiver.

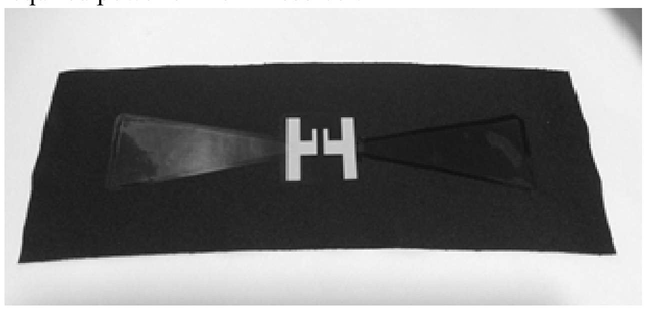

Fig. 2. A photograph of a graphene antenna applied to clothing [2].

Another acceptable biodegradable material suitable for the substrate is paper. It is distinguished by good flexibility, cheapness, and eco-friendliness, which allows the printing of IoT devices with high resistance to bending, low weight, and low price. At the moment, the development of graphene antennas on paper substrates is rather active [4-7].

III. Theory

Development of printing techniques for the production of electronic and photonic devices based on graphene, graphene derivative materials, and other 2D crystals is considered to very important and promising research field [8,9]. The rapid progress in flexible, stretchable and wearable electronics, smart textile, Internet of Things etc, also causes the strong actuality in printing techniques [10]. Therefore, development and production of RF antennas obtained from carbon materials on paper are important and relevant research direction. The opportunity of graphene using for producing antennas on flexible substrates had been demonstrated in [6].

One of the main criteria for creating IoT devices is their cost. To optimize the cost, it is advisable to include computer modeling in the development process and in the releasing device support during the technological cycle. Therefore, it is necessary to have a good correspondence between the computer model and the experimental sample created by the developed technology.

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IV. EXPERIMENTAL RESULTS

Antenna studied in the present work was produced by screen printing technique using graphene inks. Graphene inks are based on graphene suspension composed of few-layer graphene flakes with thickness 3-5 nm and lateral sizes about 1-5 µm. Graphene suspension was obtained from natural graphite using laboratory disperser IKA Ultra-Turrax T18 digital in the water-ethanol mixture at 20000 rpm. Graphene suspension production method was described in more detail in [11,12]. Water-based solution of poly(3,4-ethylene dioxythiophene) polystyrene sulfonate (PEDOT:PSS) 1.1 % was added to graphene suspension to obtain graphene inks. PEDOT:PSS is one of the best organic conductive polymers and it is often used as a binder in graphene suspensions. In our case, it was added with the aim to obtain more uniform films in term of thickness.

Then, mask for screen-printing from silicone compound Pentelast 750 was produced by forming method. Obtained silicone mask was deposited onto the substrate. Photo paper Kodak was used as a substrate, like in [13]. Graphene inks were uniformly deposited on the substrate through windows in the mask. After deposition, a substrate with the mask was dried at 90^{o}C for 5 min in drying oven. After that mask was pilled off from the substrate, the sample was dried for more 10 min. Since printed film after drying is loose, it is required rolling compression to obtain better electrical properties. Silicone roll was used to compress our printed pattern.

The sheet resistance of samples was measured by 4-point probe station JANDEL and HM21 Test Unit. Electrical contacts were made from copper wires. They were fixed on a printed pattern by silver pasta. SMA connector was used for connection to measurement devices.

The measured sheet resistance of the graphene layer with the use of four probe heads averaged 4 Ω/sq. Measurements in different regions of the sample structure showed good reproducibility of the resistance along the antenna strips.

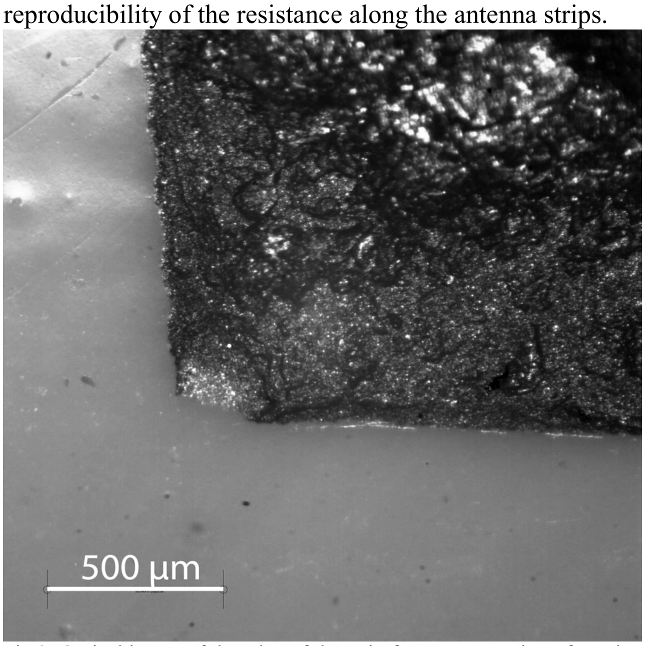

Fig.3. Optical image of the edge of the strip from a suspension of graphene, applied by screen printing on photographic paper by Kodak.

Figure 3 shows the optical image of the antenna angle, which demonstrates that the edge does not exceed 50 µm.
Figure 4 shows a photograph of a manufactured graphene dipole antenna.

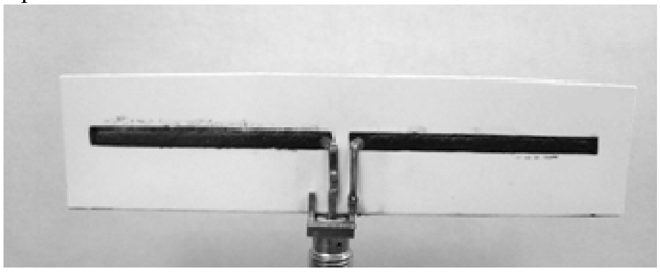

Fig. 4. Photograph of the experimental sample of a graphene dipole antenna on a paper substrate

The computer model was developed according to the experimental model of the antenna (Fig. 4). This model reflects all its design details and parameters. The standing wave voltage ratio (VSWR) of the model was calculated. A comparison of the measured and calculated VSWR showed (Figure 5) that the agreement between them is satisfactory, especially in the range 1600-1900 MHz. These frequencies cover the range in which the antenna transmits more than 90% of the power (1670 - 1920 MHz) in the GSM-1800 frequency band (1710 - 1880 MHz). The greatest discrepancy (~ 15%) is observed outside the operating range at a frequency of 2100 MHz. The minimum of the VSWR corresponds to the frequency of 1750 MHz and is 1.4.

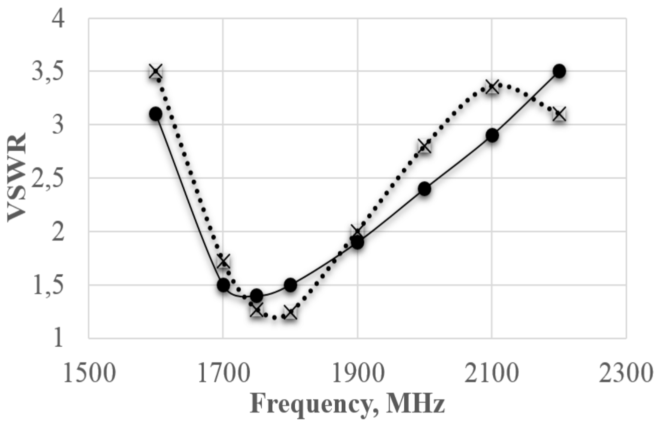

Fig. 5. Measured (dashed line) and calculated (solid line) VSWR graphene dipole antenna on a paper substrate.

A comparison of our results with [6] indicates a higher performance of our antenna compared to the graphene dipole antenna described in [6]: VSWR ≈ 1.7; frequency range 890 - 1020 MHz, Unfortunately, the authors of [6] did not give data on computer modeling

V. CONCLUSION

A computer model of a dipole graphene antenna for the Internet of things and a technology for its production on a biodegradable paper substrate for the 1600-2200 MHz range has been developed. The measurements of the VSWR showed a satisfactory agreement between the measured and calculated data. This confirms the advisability of including computer modeling in the technological cycle. Comparison with the literature indicates a satisfactory level of technology.

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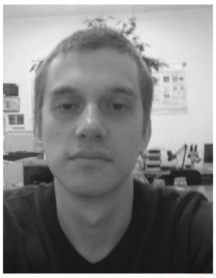

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Prof. Dr Irina V. Antonova graduated from the Novosibirsk State Technical University (Department of Physics and Engineering) in 1979. Since 1981 she has been working at the Institute of Semiconductor Physics, Siberian Branch of the Russian Academy of Science. Presently, I.V. Antonova occupies a leading researcher position ISP SB RAS. The scope of current research and professional activities of Prof. Dr I.V. Antonova includes chemical functionalization of graphene, fabrication of graphene / fluorographene heterostructures and arrays of graphene quantum dots embedded in a fluorographene matrix, 2D printed technologies with graphene based materials. Presently, Prof. Dr Irina V. Antonova has above 280 papers. Sum of the times cited is above 1000, h-index is equal to 14.