MULTIBAND ANTENNA MADE OF FLEXIBLE POLYMER SUBSTRATE PRINTED WITH SILVER NANOPARTICLES USING INKJET PRINT TECHNOLOGY – A FEASIBILITY STUDY

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Abstract

This research paper describes a feasibility study regarding the use of inkjet printing for designing a flexible microstrip antenna. Our prototype antenna is printed, using a specially prepared ink based on silver nanoparticles with diameter ranging from 50 to 200 nm, on a plastic substrate PET (Polyethylene terephthalate). Nanoparticles and flexible PET substrate are used to achieve very advanced parameters in four frequency bands of 1.4 GHz, 3.1 GHz, 5.1 GHz and 6 GHz. These properties could be confirmed in our measurements.

Multiband antennas of this type may find use in many portable devices like cell phones, where it would be possible to implement the antenna on the cover in the form of printing, thus yielding important benefits with respect to size and weight. The inkjet printing technology onto flexible polymer substrates serves another wide range of applications, namely those with high demands on flexibility, like for instance wearable technologies.

Keywords: antenna, inkjet print, PET substrate, nanoparticles

1. INTRODUCTION

Virtually all contemporary portable electronic devices communicate with their environment using passive antennas.

This communication may be directed to a user or to exchange information among devices, in case of M2M (Machine to Machine) communication. As a consequence, these so-called passive antennas are widely used and we encounter them in mobile phones, tablets, radios, laptops, GPS devices, and even inside wireless sensors.

In principle, passive antennas can be made from a variety of materials. Obviously, a key requirement on the material is good electrical conductivity. Traditionally rigid materials were used for antennas, but recently flexible materials have attracted much attention, as these have several practical advantages. Currently so-called micro-strip antennas are used, built from metallic materials like copper foils, or copper and silver sheets; atop various substrates such as FR-4 or ceramic [1-5]. Different types of antenna, such as those using a meander stainless steel construction combined with plastic cover, may be found as well. Clearly, the choice of the conductive material has a decisive influence on the electrical antenna parameters. Currently used materials achieve very useful parameters in this respect, but antennas pre-fabricated from these materials are very complicated to embed into a polymer substrate [6].

The aim of the research presented in this paper is to explore novel ways of manufacturing antennas that better lend themselves for integration on a flexible carrier.

2. EXPERIMENTAL STUDY

Our approach was to create an antenna by means of an inkjet printer, specifically we chose a Dimatix DMP 2800, using a specially prepared conductive ink based on concentrated stabilized silver nanoparicles. The dispersion was synthesized using a solvothermal precipitation method. In order to remove any organic residuals from the synthesis process, the silver nanoparticles were washed by ethanol and stored in a stable dispersion solution. Micrographs using scanning electron microscopy (FEI Nova NanoSEM 450) showed spherical or polyhedral particles with and diameter span of 20-200 nm (Fig. 1.). The next step was the preparation of the silver nanoparticles layer. Nanoparticles were dispersed in deionized water using ultrasound homogenizer UZ Sonoplus HD 2070. To achieve good dispersion of the nanoparticles, 0.1 ml of a dispersion stabilizer solution was added to 10 ml of dispersion fluid, and then 25 % of nanoparticles were added to the prepared dispersion solution. A cartridge type DMP 2800 was filled using the prepared ink. After the printing process the antenna was dried in a vacuum oven at 120 °C for 20 minutes. In this way an antenna was successfully produced on the PET substrate.

3. RESULTS AND DISCUSSION

The silver printed part of the antenna was connected by means of electrically conductive silver paste with a semi-rigid coaxial cable with an impedance of 50 Ω. This semi-rigid coaxial cable has a gold-plated micro SMA connector. The joint in the layer of silver nanoparticles is connected by means of the electrically conductive silver paste. Primarily, the main task of the silver paste is to minimize signal loss during transmission between the coaxial line and the actual microstrip antenna. This method of jointing was chosen because PET substrates do not allow tin soldering; the method proved to be efficient, quick and perfectly acceptable for experimental measurements.

The measurements of the antenna were performed using the R&S spectrum analyzer in anechoic chamber (Fig. 2.) capable of measuring within a bandwidth of 9 kHz to 7 GHz. For our experimental measurements this range is sufficient. The following graph depicts the performance of the measured antenna. The graph in (Fig. 4.) represents the S11 parameter. The impedance of the printed antenna had been matched for frequencies of 1.4 GHz, (-3.55 dB), 3.1 GHz, (-6.89 dB), 5.1 GHz, (-21.2 dB) and 6 GHz, (-6.94 dB). The measured parameters show that the antenna indeed operates in multiple frequency bands so that it is justifiably called a multi-band antenna. Due to the involved tolerances the performance of the antenna could not be predicted prior to the printing; the precise values were determined during the actual testing phase. There are many parameters that can greatly affect the efficiency of the antenna. For example, the homogeneity of the printed layer has a great impact on the quality of the resulting microstrip antenna [7]. On average, achieving a very compact thin layer by means of inkjet printing is rather difficult. This issue can be reduced by thorough preparation of the electrically conductive ink so that the particles used create the best possible homogeneous structure as can be seen in microscopic images by SEM (Fig. 1.). The size of the PET substrate is 5 x 4 cm (Fig. 3.), while the total weight of the antenna is 0.52475 g.

Low weight (0.52475 g) of the flexible silver antenna is a very important factor for the portable devices and also for wearable electronics. However, this inkjet print method can be applied for price tags on the RFID base as well, since similar antennas are in use there. Currently, the main limitation for a large-scale application of our method is the quite high price of the silver inkjet, as described above.

In the future the technology of inkjet printing of the antenna will be applied to integrate antennas in flexible portable displays. On the back side of the display (in this case the display will also serve as the substrate) there will be enough space to print, with the inkjet print technology using silver nanoparticles, more than one antenna for the next generation mobile networks. This may turn out very useful, as more antennas will be required in future communication technologies such as MIMO 4x4. In these cases it will be extremely advantageous if the weight of the antennas can be reduced merely to the weight of the silver ink.

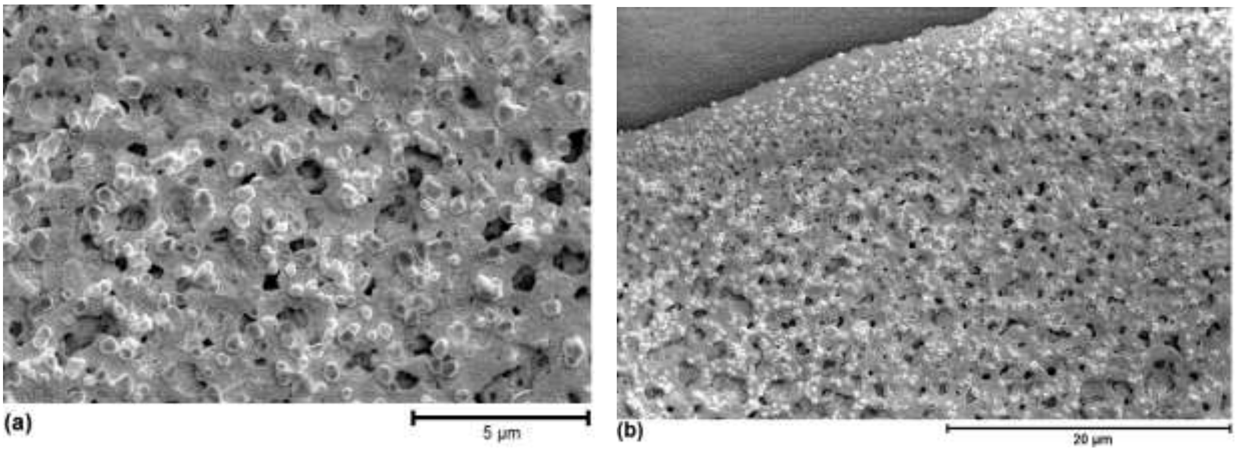


Fig. 1 SEM microscopy of the silver ink structure on the PET substrate. (a) detail (scale of 5 µm) (b) overview (scale of 20 µm).

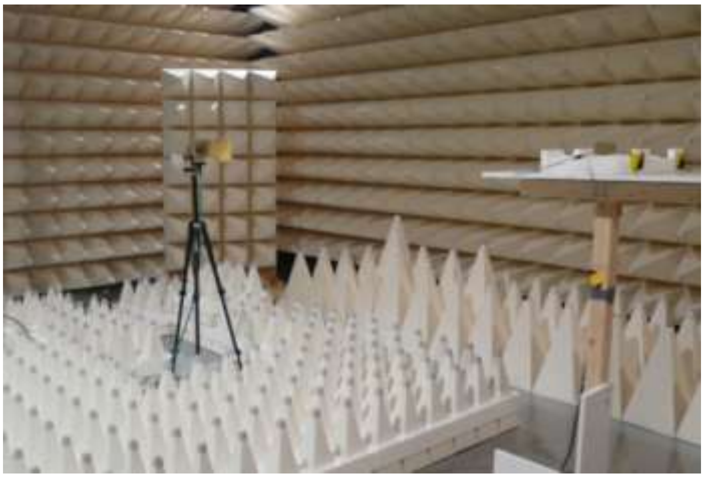
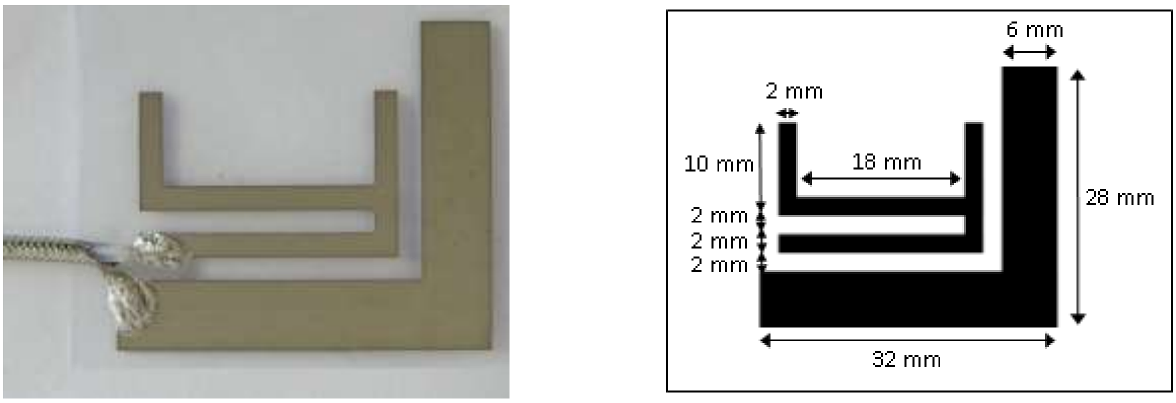


Fig. 2 Measurement of the antenna's parameters in an anechoic chamber.



(a) **(b)**

Fig. 3 (a) A picture of the antenna made using the inkjet print technology (b) dimensions of the produced antenna in mm.

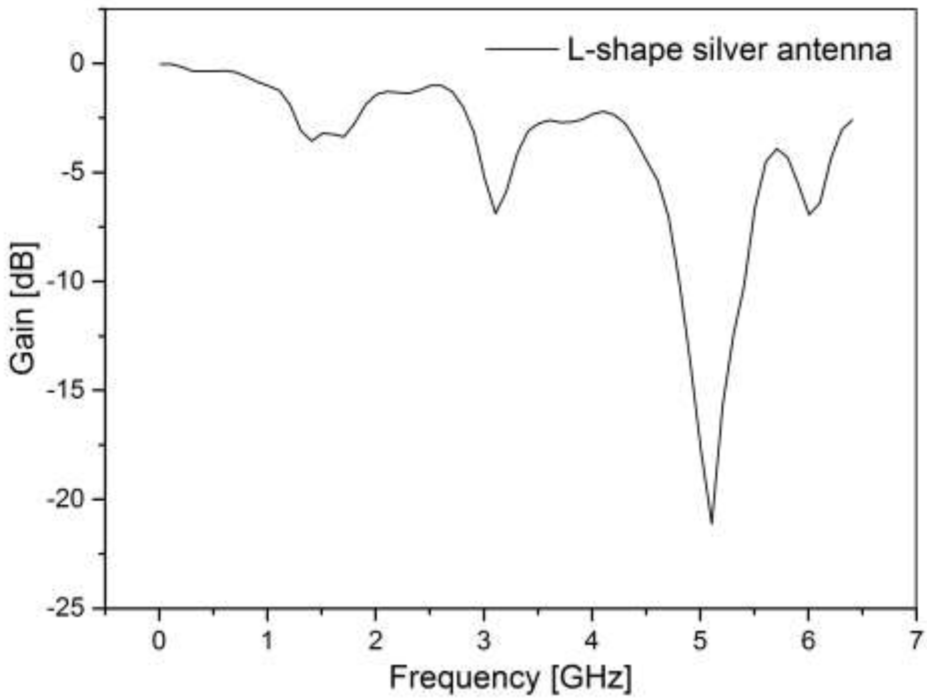


Fig. 4 S11 impedance of the proposed printed flexible multiband antenna.

4. CONCLUSION

The aim of this research was to test the functionality of silver ink based on silver nanoparticles for the construction of a passive microstrip antenna. The measurements on our experimental prototype of such an antenna proved that this technology can indeed be used for the preparation of a multiband antenna operating in the bandwidth of frequencies 1.4 GHz, 3.1 GHz, 5.1 GHz and 6 GHz. Such antennas excel in low weight, high flexibility and easy integration, and therefore suggest themselves for many embedded applications. One of these is wearable electronics where antennas need to be integrated into flexible textile materials. Portable telecommunication devices, such as mobile phones, on the other hand, may benefit from the ability to print the antenna directly on polymer substrate, where the PET covers belong to, as well. Replacing the currently used antennas based on copper foils or metallic strips will save space and reduce weight.

Moreover, the required distance between the antennas would be maintained, for instance in MIMO systems where the distance of λ/2 for end users of communication devices must be observed. The requirement of the distance of λ/2 among individual antennas puts high demands on the mechanical design of the antenna and its miniaturization in order to optimize the use of the limited physical space of the device for which the antenna is to be implemented.

The majority of widespread technologies, e.g. UMTS or LTE, operate at frequencies for which we have shown the feasibility of producing a customized antenna made of silver nanoparticles.

The next step of our research will be the optimization of the design of the antenna shape to reach the required frequencies.

ACKNOWLEDGEMENTS

The work behind the article was supported by the Operational Programme 'Research and Development for Innovations' co-funded by the European Regional Development Fund (ERDF) and the national budget of the Czech Republic, within the project 'Centre of Polymer Systems' (reg. number: CZ.1.05/2.1.00/03.0111). We also acknowledge the support of the Ministry of Education, Youth and Sports of the Czech Republic - Program NPU I (LO1504).

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