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# Subterahertz circularly polarized 1k-pixel reflective surface for 6G applications

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**Abstract.** Wireless communication is a hot topic of research and development at this moment. The need of increasing data transfer rates and connection stability within vast digitalization of people interactions sets new tasks for scientific community. One of them is the utilization of higher operating frequencies in range of 140–150 GHz. This is an obvious way to obtain bigger channel capacity. However, for line-of-sight wireless channels, it may potentially lead to severe propagation losses, including absorption in water-containing atmospheric environments and scattering off static or dynamic objects. In this work, we report on the development of a technologically robust reflective surface that can be used in the sixth-generation reflection-aided data links. The proposed reflective surface has 36×36 spiral metallic elements implemented on top of a thin back-metalized quartz plate. The fabricated prototype was designed for 50° deflections from specular propagation paths at angles of incidence within ±75° and successfully used for a non-distorting reflection of a 6є wide Gaussian beam at 145 GHz. It supports both linear and circular polarizations and exhibits cross-polarization level of approximately −25 dB.

**Keywords:** subterahertz, reflectarray antenna, wireless channel, 6G communication

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# Субтерагерцовая 1к-пиксельная отражающая поверхность с круговой поляризацией для технологий 6G

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**Аннотация.** Поиск новых решений в сфере беспроводных сетей является актуальной областью проблематики науки и техники. Потребность общества в повышении скорости и надежности беспроводной передачи данных ставит перед научно-техническим сообществом новые задачи, в частности разработки решений для работы в субтерагерцовом диапазоне частот. Для данного диапазона крайне актуальной является задача разработки устройств маршрутизации в каналах беспроводной связи. В данной работе мы представляем результаты разработки и экспериментального исследования антенной решетки отражательного типа 36×36 элементов на основе массива логарифмических спиральных антенн для диапазона частот 140–150 ГГц.

**Ключевые слова:** субтерагерцовый диапазон, отражательная антенная решетка, беспроводной канал, 6G связь

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## Introduction

New solutions in wireless communication technologies are of great interest in modern scientific and industrial considerations. Development of novel applications and services imposes high data rate and stability requirements on wireless networks [1]. The migration of operating frequencies into the subterahertz (sub-THz) band, on the way of increasing baud rates, is accompanied by the appearance of new signal attenuation factors leading to ultra-directional data links in the sixth generation (6G) wireless networks. Thus, line-of-sight communication channels are potentially exposed to the effects of dynamic blockages, micromobility and scattering off obstacles [2]. Reflection-aided data links with either static, semi-static or dynamically reconfigurable reflective surfaces [3] are among novel solutions to avoid this problem. In this work, we report on a static reflective surface (RS) that can be used for handling of few degrees wide Gaussian beams (GBs) during the first deployment stage of 6G wireless networks. It utilizes 36×36 spiral metallic elements [4] as antenna array implemented on top of a thin back-metalized quartz wafer and is designed for non-specular channels operating at 140–150 GHz.

## Materials and Methods

The development of the electromagnetic (EM) model is the first step in the workflow. The modeling is done via computer-aided system utilizing finite element method. The elementary cell of the RS is modeled using Floquet port analysis to obtain in-reflection phase shifts for different spiral arm lengths. As a result, we obtained the geometry-dependent data. From the calculations we select three length values conforming the following principle: phase shifts between two of three adjacent cells with corresponding phases $\varphi_1$, $\varphi_2$, $\varphi_3$ must be equal 120°, i.e. $\varphi_2 - \varphi_1 = \varphi_3 - \varphi_2 = \varphi_1 - \varphi_3 = 120°$.

After the determination of spiral arm lengths with corresponding phase shifts, we constructed the array of 36×36 cells within the multibeam interference theory by the array factor method [5]. The construction utilizes quartz as a substrate. A metallic screen is implemented on the bottom side to provide non-specular reflection of the incident beam. As shown in Fig. 1,*a* the normally incident GB is reflected by angle θ, which is equal to 50° in the RS under study (here $\vec{E_0}$ is the electric field strength vector, $\vec{k}$ is the wave vector). Spiral stop angle defines the arm length of spiral antenna in each elementary cell. The phase shifting is dependent on the spiral stop angle as shown in Fig. 1, *b*.

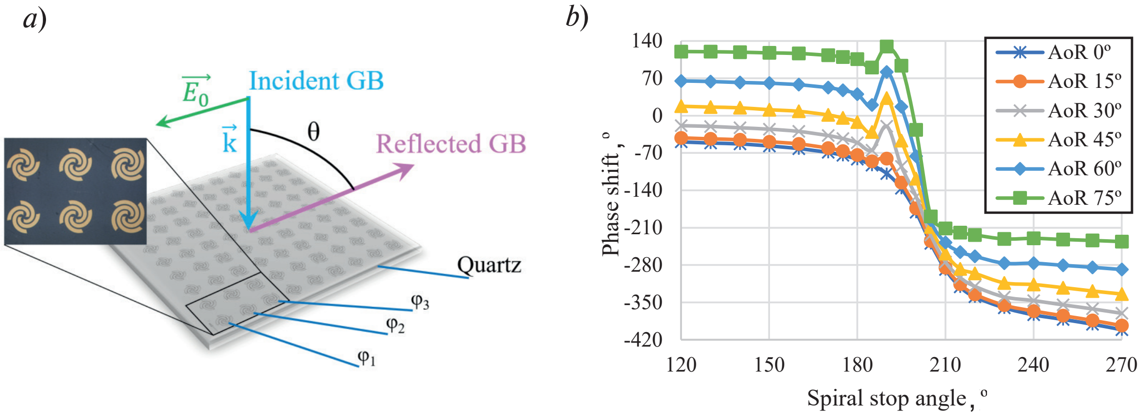


Fig.1. Scheme of the proposed reflective surface in action and (*a*), dependencies of phase shifts on spiral stop angle with different angles of reflection (AoR) (*b*)

The developed RS prototype is fabricated in a cleanroom process. The technological route includes forming a metallic spiral antenna array on a 140 μm thick quartz wafer using lift-off lithography process. The substrate is covered with AZ1512 photoresist using centrifuge, then exposed with maskless laser-beam aligner machine MLA150. The sample is developed in 0.7% KOH after the exposure and chemically hardened by chlorobenzene. To implement metallization of the array, 5 nm Ti and 400 nm Au layers are made via thermoresistive evaporation with VUP-5M machine. The titanium is used as a sorbent layer for improving adhesive characteristics. The lift-off removal of the unexposed regions is performed in heated acetone bath. The back-side metallization is implemented by attaching a 400 μm thick sapphire wafer entirely covered by Ti/Au (5/400 nm) evaporated thin film.

**Results and Discussion**

To measure beam profiles of the fabricated device, we developed experimental setup (Fig. 2, *a*). It includes a continuous wave microwave synthesizer, 12× frequency multiplier, voltage-controlled attenuator (VCA), horn antennas, envelope detector based on Schottky diode and lock-in amplifier. The carrier frequency is 145 GHz. The VCA is used for amplitude modulation and synchronized with lock-in amplifier. During the measurement, Rx is rotated around its axis with 1° step. The data is then acquired from the lock-in amplifier. Three types of experiments are conducted: measurements in E- and H-planes and cross-polarization measurement.

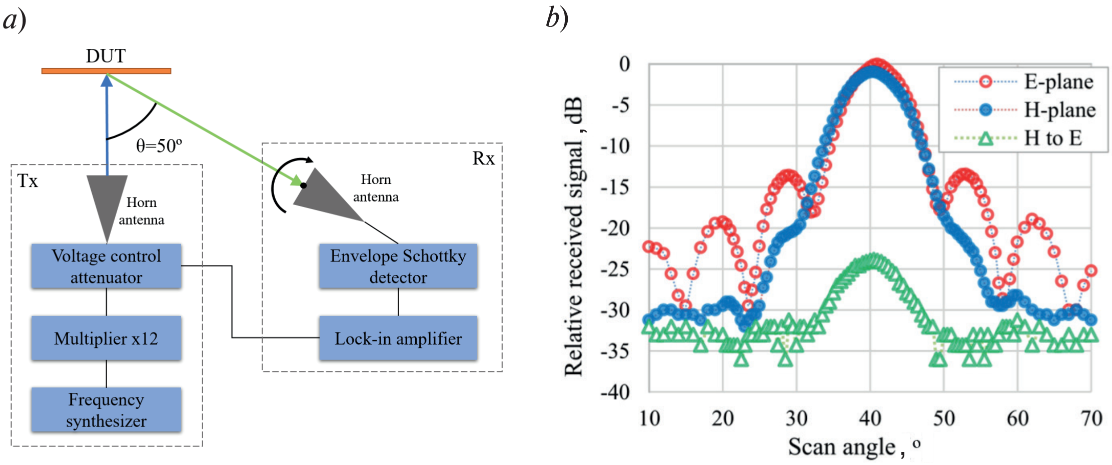


Fig. 2. Scheme of the measurement setup (*a*) and measured BP of the fabricated prototype (*b*)

Results of the RS prototype beam profiles (BP) measurements are presented in Fig. 2,*b*. The prototype is successfully used for a non-distorting reflection of a 6є wide GB at 145 GHz. It supports both linear and circular polarizations and exhibits cross-polarization level of approximately −25 dB.

## Conclusion

We presented development and fabrication process of the subterahertz circularly polarized 1k-pixel reflective surface for 6G applications and its characteristics, obtained experimentally. The prototype is represented by an array of scaled spiral antennas on the low loss quartz substrate. Spiral antennas have three variants of spiral arm length to provide 120° phase shift between adjacent elementary cell in row. The prototype was fabricated utilizing clean room processes that are necessary to provide accuracy of geometrical dimensions. The prototype under test shows the reflection of normally incident beam by the expected 50° angle. It is capable of static beamforming and disrupt geometrical optics law of reflection. It also demonstrates the support of both s- and p-polarizations. We believe that our findings should be interesting to developers of the next generation wireless systems operated at 140–150 GHz.

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