BPSK Modulation Using Programmable Metasurfaces

Aditya S. Shekhawat, Aaron Grace, and Georgios C. Trichopoulos
Arizona State University, Tempe, AZ 85281, USA
(aditya.shekhawat, aaron.grace, gtrichop)@asu.edu

Programmable metasurfaces (PMs) have attracted great interest recently for their versatile possibilities for manipulating electromagnetic (EM) waves either in the form of reconfigurable intelligent surfaces (RISs) or as high-gain, electronic beamforming antennas. PMs are typically low-profile, low-complexity beamformers that can extend operation beyond the sub-6GHz bands. They consist of several sub-wavelength radiating elements integrated with tunable devices, such as positive-intrinsic-negative (PIN) diodes and varactors, enabling reconfiguration of the PM's functions in real-time and providing new avenues to tailor EM waves dynamically. On the one hand, PMs are used to reconfigure the wireless propagation environments to improve network coverage; on the other hand, they can provide temporal modulations of phase and/or amplitude and enable signal encoding. This provides a unique spatio-temporal modulation of signals that could enhance wireless communications or enable new applications in RF imaging and sensing.

This study presents a novel approach for controlling the phase of the reflected signal to implement binary phase shift keying modulation. We achieve this by periodically switching the reflection coefficient of a metasurface between two states, allowing us to shift the phase of the primary signal between 0^o and 180^o, as needed for binary shift keying modulation (BPSK). As proof of concept, we designed a prototype operating at sub-6GHz and conducted tests in an indoor communication setting. The proposed PM utilizes a simple 1-bit quantization scheme. To accomplish the quantization, we incorporate PIN diodes onto the individual unit cells of the designed metasurface. The surface is a 160-element tile (16 ×10) operating at 5.8GHz. In our wireless communication system, we positioned a transmitter and receiver in the PM's far-field (7.5 meters). We performed signal processing on a software-defined radio platform (Ettus USRP B205mini-i) for both the transmit (Tx) single-tone and the received modulated signals.

For the beam-steering in the desired direction, the phase of each unit cell is controlled by switching the states (ON (bit 1) and OFF (bit 0)) of the PIN diodes. However, by employing a conjugate coding sequence (switching bit 1 with bit 0 and vice versa), we can achieve a binary phase modulation without perturbing the signal amplitude or the main beam direction. This allows us to directly synthesize desired signal constellations at the operational frequency by loading different coding sequences onto the metasurface, eliminating the need for a complex RF chain. This approach offers the advantages of simplicity, cost-effectiveness, and energy efficiency in the system. Such an approach can be extended to future wireless communication systems operating in the millimeter-wave (mmWave) and terahertz (THz) bands. During the conference, the design aspects and limitations of metasurface will be presented, along with the results of the conducted experiments.