3D Nolen Matrix Beamforming Phased Array

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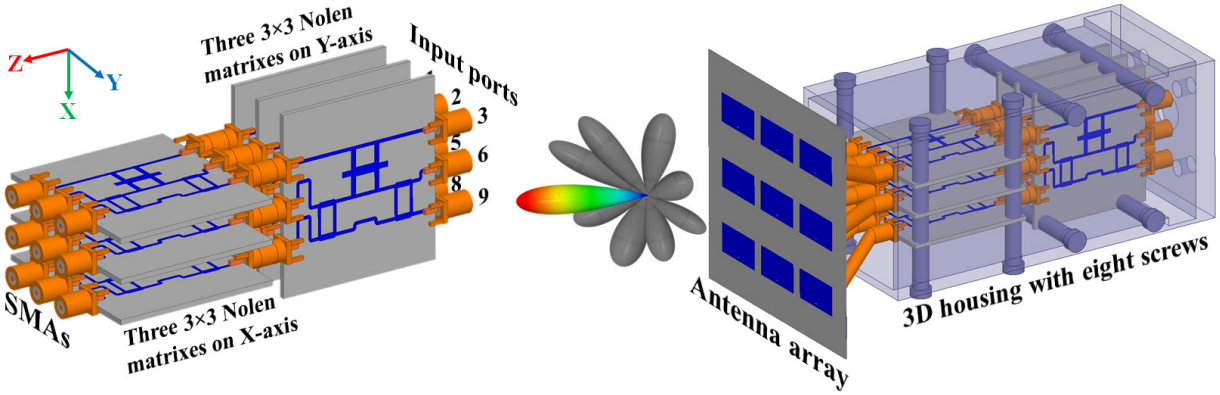
In the beamforming antenna array, feeding network is an important component to allocate desired magnitude and phase delay of signal to each array element, and the series-feed, parallel-feed, and matrix feed are three common topologies for the feeding network. Comparing to conventional series- and parallel-feed networks, the matrix feeding network is multiple input multiple output network supporting MIMO and consists of components such as coupler, phase shifter, crossover, power divider, and switch. Butler matrix, Blass matrix, and Nolen matrix are three major kinds of matrix network. As it is well-known, Butler matrix features a symmetrical and simple structure, but the number of input and output ports must follow power of two. Blass matrix is another type of matrix, where partial of the signal in this network flows into the terminated loads. As a result, the total efficiency is low comparing to Butler matrix. Nolen matrix is similar to Blass matrix, but it solves the power loss issue. Although Nolen matrix has great advantages, it is not explored extensively due to its complex design theory. In this work, a novel 3D beamforming phased array using 3×3 planar Nolen matrix is realized in Fig. 1. The proposed 3×3 Nolen matrix is composed of three couplers and three phase shifters. The major advantage of the proposed Nolen matrix is that couplers can feature arbitrary phase difference to generate flexible phase difference for antenna array. The closed-form equations are derived for designing proposed 3×3 Nolen matrix with flexible performance. Then, a two-dimensional phased array as shown in Fig. 1(a) is implemented by stacking and cascading six 3×3 Nolen matrixes and integrated with an antenna array as shown in Fig. 1(b). By switching the input ports, nine unique radiation beams will be generated to achieve a significant 3D beamforming function. The performance of the proposed design is verified in both simulation and measurement, and all the results match well with the theoretical prediction.



(a) (b)

Figure 1. Schematic diagram of (a) two-dimensional phased array consisting of three 3×3 Nolen matrixes on X- and Y- axis respectively; (b) 3D beamforming phased array including six 3×3 Nolen matrixes and a nine-element antenna array.