Keynote Speech I

Number of Beams Extension for Butler Matrix Linear Array and Compact Two-Dimensional Planar

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ABSTRACT

The Butler matrix as a beamforming network for linear array and two-dimensional array. On the first subject, a scheme to extend the beam number of Butler matrices by utilizing reconfigurable couplers is presented and illustrated with experimental verification. The beam number of a traditional 2N × 2N Butler matrix is increased to 3·2N by substituting reconfigurable couplers for all hybrids while maintaining the structure and other components as the original. Moreover, only N sets of different parameters are required for these couplers. The principle, properties, and the generalized expressions for the N sets of parameters are discussed and exhibited. The properties of the extended beams are illustrated in terms of beams directions and crossover levels. As an example, a switchable 12 beam forming network extended from a 4 × 4 Butler matrix for 2.4 GHz applications is fabricated and tested. Over a 30% relative bandwidth is achieved with phase errors less than ±12°, amplitude unbalances lower than ±1.7 dB, isolations better than -15.5 dB, and a return loss better than 11.5 dB.[Kijia Ding, and Ahmed Kishk," Wideband Electrically Switchable 12-Beam Forming Network Based on 4×4 Butler Matrix Configuration" Accepted *IEEE Transactions on Microwave Theory and Technology*, February 2019].

The second subject presents the principals and design methods of twonovel devices, two-dimensional Butler matrix (2D-BM) and phase-shifter group, are presented. The 2D-BM has 2M+N × 2M+Nconfigurations that can be built based on the traditional 2M× 2M and a 2N× 2N BMs, and all the output ports can be arranged into a parallelogram configuration to fit the planar array. The major merits from traditional BMs, such as perfect matching, lossless transmission, spatially orthogonal beams, and equal power division can entirely be retained in the 2D-BMs. As an integral component of 2D-BMs, the phase-shifter groups are employed to offer more than two distinct values of phase delay on various paths without reference lines. The design procedure of the 2D-BM and the analytical solution of the phase-shifter group are discussed and illustrated. As experimental verification, a 2D-BM with 16 × 16 configurations feeding to a 4 × 4 square array for 2.4 GHz applications are fabricated and tested. Satisfying performances at matching, isolation, equal power division and progressive phase differences among all ports can be observed covering a 17% relative bandwidth [Kijia Ding, and Ahmed Kishk,"Two-Dimensional Butler Matrix and Phase-Shifter Group" *IEEE Transactions on Microwave Theory and Techniques*, Vol. 66 (12), 5554-5562, December 2018].