Reduced Sidelobe Multibeam Antenna Array with Broadside Beam Fed by 4x8 Butler Matrix

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***Abstract*— A concept of sidelobe level reduction in multibeam antennas fed by 4 x *N* Butler matrices has been extended on multibeam antennas with broadside beam. It has been shown that by adding in-phase power dividers at the output of a Butler matrix ensuring ±90°, 0° and 180° differential phases and by increasing the number of radiating elements a significant sidelobe reduction can be achieved, similarly as in case of known multibeam antennas fed by modified Butler matrices. The presented concept has been confirmed by measurements of a multibeam antenna array consisting of eight radiating elements fed by 4 x 8 modified Butler matrix in which the achieved sidelobe level is as low as -22 dB.**

Keywords*— *Antenna arrays; multibeam antennas; reduced sidelobe level; Butler matrices; feeding networks.

I. Introduction

Multibeam antennas are well-known solutions allowing for generating independent beams from the same aperture. One of the possible solutions for achieving *N* orthogonal beams is the utilization of *N* x *N* Butler matrices as feeding networks of *N*-element linear antenna arrays [1]. In literature, two types of Butler matrices are known, a classic solution which allows for achieving *N* beams symmetrically located along the normal to the antenna aperture and the modified one which produces broadside beam, endfire beam and intermediate beams distributed evenly [2]. In general, having electronically scanned beam such antennas suffer from relatively high sidelobe level and high grating lobe level which in classic solutions approaches -8 dB when standard microstrip patches are utilized as radiating elements. On the other hand it is known that the sidelobe level can be controlled by tapered excitation across the antenna array. Since Butler matrices offer equal power split at their outputs, modified Butler matrices have to be used to ensure unequal power distribution, and consequently, to ensure sidelobe level reduction. One of the possible solutions is the utilization of lossy networks which ensure an appropriate tapered excitation [3]-[4]. In [5]-[6] it has been shown, that it is possible to realize multibeam antennas fed by lossless feeding networks with reduced sidelobe level when an increased number of radiating elements is used. Moreover, in such antennas tapered excitation across the antenna arrays can be achieved when additional out-of-phase power dividers having appropriately chosen power division ratios are added at the outputs of classic Butler matrices, which further decreases the achievable sidelobe level [7]-[8]. As it is shown in [8] the achievable sidelobe level depends on the number of utilized radiating elements and for the case of eight-element linear antenna array fed by a 4 x 8 Butler matrix can approach -22 dB.

In this paper we extend the idea proposed in [8], and present a three-beam antenna array featuring a broadside beam and reduced sidelobe level. The presented antenna array is composed of eight radiating elements fed by a 4 x 4 Butler matrix ensuring ±90°, 0° and 180° differential phases at the outputs of which four unequal-split in-phase power divider are applied constituting a 4 x 8 modified Butler matrix. The proposed concept has been verified by measurements of a reduced sidelobe three-beam antenna array composed of standard microstrip patches operating at the center frequency of 2.45 GHz.

II. Concept of Reduced Sidelobe Multibeam Antenna Array with Broadside Beam

A concept of an eight element multibeam antenna array featuring broadside beam and reduced sidelobe level is shown schematically in Fig. 1. As it is seen the feeding network of the proposed antenna array consist of a 4 x 4 Butler matrix ensuring equal power split and ±90°, 0° and 180° differential phases and four additional in-phase power dividers connected at the outputs of the Butler matrix. By proper controlling the power split in additional power dividers it is possible to achieve a tapered excitation across the antenna array, and therefore, the sidelobe level reduction. It has to be underlined that since the Butler matrix ensures ±90°, 0° and 180° differential phases the additional power dividers have to ensure in-phase signals, in contrary to the concepts with classic Butler matrices presented in [7], and [8] where out-of-phase power dividers are required. Therefore, in the presented solution standard reactive power dividers can be utilized instead of rat-race couplers utilized in [7] or power dividers together with appropriate rotation of radiating elements as in [8]. Moreover, it has to be noted in the presented concept a similar limitation on the achievable power distribution exists as in the concept presented in [8]. The summarized power delivered to the appropriate pairs of radiating elements has to be identical since the Butler matrix offers equal power split at its outputs. However, in this solution the same limitation allows for achieving lower sidelobe level comparing to the antenna arrays with classic Butler matrices, since the maximum scanning angle is in this case lower (the endfire beam in this case is not considered since it has two main lobes pointing in opposite direction). Fig. 2 presents the electromagnetically calculated radiation patterns of a multibeam antenna array consisting of eight standard microstrip patches fed by an ideal 4 x 8 Butler

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matrix. For the purpose of comparison the same power division ratios of additional power dividers have been utilized as in the concept presented in [7], i.e. 5.9 dB for the power divider 'a' and 12 dB for the power divider 'b', respectively. As it is seen in Fig. 2 the achieved sidelobe level is as low as -27 dB, and is about 5 dB lower than in the case of the antenna presented in [7].

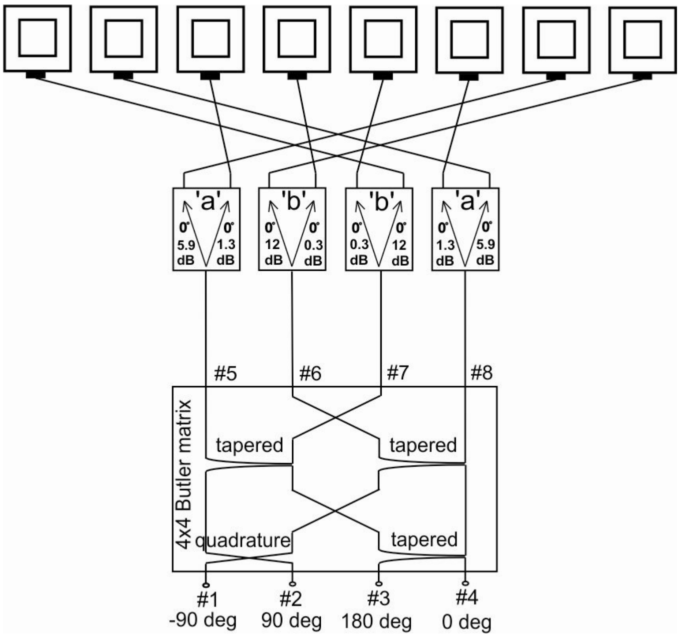

Fig. 1. Concept of a reduced sidelobe three-beam antenna array featuring a broadisde beam fed by a 4 x 8 modifed Butler matrix.

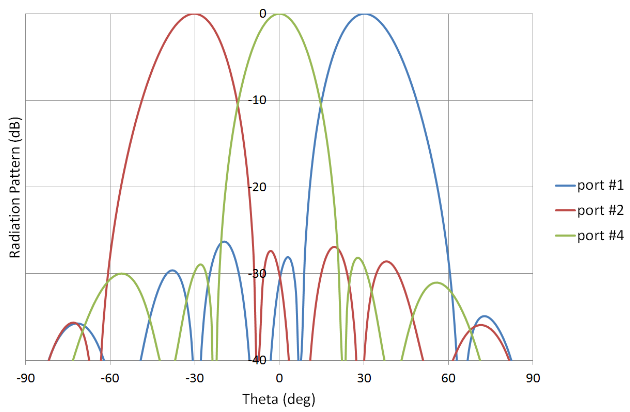

Fig. 2. Electromagnetically calculated radiation patterns of the reduced sidelobe three-beam antenna array consisitng of eigth standard microstrip patches and fed by an ideal 4 x 8 modified Butler matrix.

III. Experimental Results

The proposed concept of a three-beam antenna array featuring a broadside beam and reduced sidelobe level has been experimentally verified. As radiating elements standard aperture coupled microstrip radiating elements have been utilized having the center frequency of 2.45 GHz and the radiating elements have been spaced by 0.48 λ. As a feeding network the Butler matrix presented recently in [9] and composed of three tapered-line directional couplers and a 3-dB/90° five-section symmetrical directional coupler has been utilized. At the output of the Butler matrix four reactive power dividers with power division ratios equal respectively 5.9 dB and 12 dB have been added. A picture of the assembled model of the developed antenna array is shown in Fig. 3. The developed antenna array has been measured and the obtained results are presented in Fig. 4. As it is seen the obtained sidelobe level is slightly worse than the calculated one. This is caused by the performance of the utilized Butler matrix which features ±1 dB amplitude imbalance and ± 10° differential phase imbalance which limits the accuracy of signal distribution across the antenna array. Since the assumed sidelobe level is as low as -27 dB, the required amplitudes and phases of signal feeding respective radiation elements has to be ensured with high accuracy higher than the one provided by the applied Butler matrix. Nevertheless, the obtained sidelobe level is better than -22 dB which validates the presented concept of sidelobe level reduction in multibeam antennas with broadside beam.

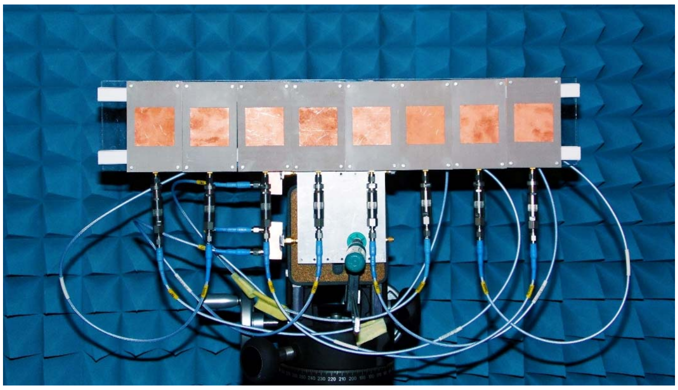

Fig. 3. Picture of the manufacured three-beam antenna array during measurements.

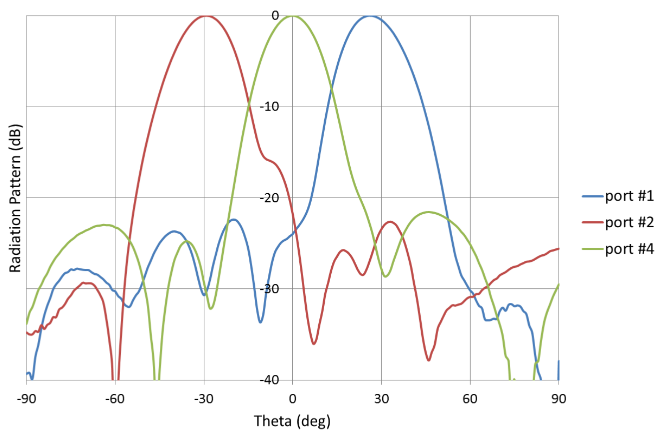

Fig. 4. Measured radiation patterns of the reduced sidelobe three-beam antenna array consisitng of eigth standard microstrip patches and fed by the 4 x 8 modified Butler matrix. Measurements performed at the center frequency of 2.45 GHz.

IV. Conclusion

The concept sidelobe level reduction in multibeam antenna arrays fed by classic Butler matrices has been extended on multibeam antenna arrays fed by Butler matrices featuring ±90°, 0° and 180° differential phases. It has been shown that a similar method can be applied for sidelobe level reduction of multibeam antenna arrays with broadside beam, however, comparing to the classic solutions in the presented case the additional power dividers have to ensure in-phase signals. Moreover, it has been shown that the same limitations on achievable power distribution allow for obtaining lower sidelobe level than in corresponding classic multibeam antennas. The theoretical analysis has been confirmed by measurements of an eight-element linear antenna array fed by the modified 4 x 8 Butler matrix and operating in 2.45 GHz frequency range. The obtained measurement results confirm the validity of the presented concept of sidelobe level reduction in multibeam antenna arrays with broadside beam.

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