

# Novel beamforming network solution for single layer printed circuit board implementation

September 27 2021

### Novel Beamforming Network Solution for Single Layer Printed Circuit Board Implementation

Multibeam antennas use beamforming networks (BFNs) to direct output beams

Input signals → BFN (Butler and Nolen matrices) → Directed output beams

#### Novel matrix topology to reduce the number of layers

**Nolen matrix**: 13 layers, 8 input ports, 8 directed beams

**Proposed matrix**: 8 layers, 8 input ports, 8 directed beams

Directional coupler, Phase shifter, Cross over, Antenna

Cascaded directional couplers and phase shifters

38% reduction in number of layers for 8 beams

**Enables designing low-cost single layer matrices for multibeam antennas for next-generation wireless technology like 5G**

Generalized One-Dimensional Parallel Switching Matrices With an Arbitrary Number of Beams  
Hirokawa et al. (2021) | 10.1109/JMW.2021.3106871 | IEEE Journal of Microwaves



Credit: Tokyo Tech

Wireless technology enables radio and satellite communication. Central to these systems are antennas that can transmit and receive signals. As the scope of wireless technology continues to grow, the next generation of wireless systems requires multibeam antennas that are capable of efficiently handling multiple beams. To maintain stable and reliable connections between transmitters and receivers, these multibeam antennas use beamforming networks (BFNs) like the Butler and Nolen matrices. These BFNs control and direct output signals using a combination of electrical components including phase shifters and directional couplers. The type of BFNs used determines the structure of the circuit and the number of layers the circuit would need to generate a certain number of beams.

BFNs are key for implementing 5G technology in the millimeter-wave range, as these waves are much more prone to interference. This has led researchers to look into BFNs and improve them to provide low cost-solutions for single-layer printed circuit board (PCB) implementation. In other words, the goal is to produce a configuration with the maximum number of beams and the lowest number of layers.

Now, in a study published in *IEEE Journal of Microwaves*, scientists from Tokyo Tech, Japan, and the European Space Agency, The Netherlands, have introduced a novel one-dimensional switching matrix that achieves a reduction in the number of layers when compared to conventional matrices. Elaborating their approach, Prof. Jiro Hirokawa from Tokyo Tech explains, "We have numerically found the parameters of the directional couplers (including crossovers) and phase shifters that

determine the structure of the circuit for an arbitrary number of beams in the generalized configuration of the orthogonal matrix forming multiple antenna beams. The discovery improves over previously known solutions addressing the specific challenges of planar implementation."

The novel matrix topology overcomes the limitations of conventional beamforming matrices. While Butler matrices are limited in the number of beams they can generate to integer powers of two, the proposed solution can generate an arbitrary number of beams. Unlike Nolen matrices, an even distribution of the signals between the phase shifters and directional couplers is possible, resulting in more uniform output signals.

Compared to the conventional Butler and Nolen matrices, the novel matrix topology also achieves a reduction in the number of layers when the number of beams is five and above, reaching a reduction ratio of 38 percent with eight beams. "This reduction ratio is very useful for passive [antenna](#) orthogonal beamforming matrices. It is expected to benefit the design of next-generation wireless mobile systems and satellite communication microwave payloads," explains Prof. Hirokawa.

The improvements to the output signal and the compaction in the [number](#) of layers allows the proposed BFN to be implemented in low-cost printed circuit boards, making the manufacture of multibeam antennas for the next-generation wireless systems viable and cost-effective.

**More information:** Generalized One-Dimensional Parallel Switching Matrices With an Arbitrary Number of Beams. *IEEE Journal of Microwaves*, [DOI: 10.1109/JMW.2021.310687](https://doi.org/10.1109/JMW.2021.310687)

Provided by Tokyo Institute of Technology

Citation: Novel beamforming network solution for single layer printed circuit board implementation (2021, September 27) retrieved 14 June 2024 from <https://techxplore.com/news/2021-09-beamforming-network-solution-layer-circuit.html>

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