A New Pigdiam in Analogue Multibeam Antennas Employing Generalized Joined Coupler Matrix

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***Abstract*—In this talk, we present an overview on a new type of feed networks for multibeam antennas, known as the generalized joined coupler (GJC) matrix. A salient feature of the GJC matrix is that the same phase shifters can be used for tuning each beam, and different beams can be steered independently. Different configurations of the GJC matrix and the theories for designing the GJC matrix are discussed. The low cost and low energy features of the GJC matrix make it attractive for future wireless communications systems such as 6G.**

***Index Terms*—multibeam, feed network, beam steering, generalised joined coupler matrix**

Future wireless communications systems such as 6G are expected to be de-centralized and to support peer-to-peer networking. Consequently, each mobile communications node will be able to connect with a number of adjacent nodes simultaneously, thus forming an ad hoc network. For instance, an UAV is expected to be connected with both adjacent UAVs in a fleet and some ground-based, and even space borne nodes such as low earth orbit (LEO) satellites. Ground based mobile terminals will be able to communicate with other directly without necessarily going through any access point.

To achieve the above ambitious goals, it is necessary for the many, if not most, communications nodes to be equipped with multibeam antennas. Although digital beamforming is the most flexible technology in forming multiple beams, the hardware cost and power consumption may make it unsuitable for many applications where low cost and power consumptions are imperative [1]. In fact, cost and power consumption are two major metrics for the design of 6G. In contrast, analogue beamforming techniques do have the potential advantage of low cost and low energy consumption, especially for mobile platforms that move relatively slowly. In that case, the power consumption in tuning the phase shifters and switching certain part of the circuits would be negligible in comparison to that for digital beamforming.

Analogue multibeams can be formed by using either circuit-type feed networks or quasi-optical approaches. Widely known circuit-type multibeam feed networks include the Butler matrix, the Blass matrix and the Nolen matrix. These matrices are traditionally used for fixed beams.

Butler matrices typically produce equally spaced orthogonal beams, whereas Blass matrices and Nolen matrices can produce flexible multibeams which can be designed to point in arbitrary directions. Although Nolen and Blass matrices can in theory be used to support adaptive multibeams, these beams are inter-dependent and cannot be steered independently. As a result, it would be too costly and complicated for them to be employed for multibeam steering or adaptive beamforming.

In the talk, we provide an overview on a new type of multibeam feed networks, known as the generalised joined coupler (GJC) matrix. A salient feature of the GJC matrix is that individually controllable multibeams can be produced by optimizing the coupling coefficients of all the couplers once, and the directional steering of the individual beams can be achieved by tuning the phase shifters. This result in "phased" multibeams, in which the steering of each of the M multiple beams can be achieved by simply varying the phase shift values of M rows of the same phase shifters independently.

There are two types of GJC matrices that can be designed to obtain steerable multibeams, namely, the Blass-like GJC matrix and the Nolen-like GJC matrix. The former provides more flexibility in beamforming and the latter is lossless for transmitting. There are also two types of algorithms to design the GJC matrices based on optimization and direct solutions. The two algorithms have pros and cons, but both can produce excellent steering beam patterns with high directivity and low sidelobes.

The concept and theory mentioned above have been implemented at different frequencies using different circuit technologies, including the microstrip lines and striplines. Experimental results are in excellent agreement with theoretical predictions.

We hope that the topics presented will usher a new paradigm in circuit-type multibeam antennas, moving from fixed beams to phased multibeams.

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