100 Years of Phased Array Antenna Modeling and Design

From the Array Factor to Network Theory and Array Signal Processing

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A phased array is a collection of many antenna elements for which multiple signals are combined to synthesize a collective beam with high gain, low sidelobes, or other design goals. The old-school method for modeling array antennas is based on the array factor. In this approach, the radiation pattern of an array is approximated as the product of the element pattern and an array factor that depends on the locations of the elements. The array factor method has been used for decades in many application areas. It is intuitive, simple to apply, and works well.

In recent years, phased arrays have been developed for demanding applications such as radio astronomy, remote sensing, and satellite communications. For these applications, high antenna efficiency is critical. Effects like interactions between elements and mutual coupling must be accounted for in the design process. The array factor method does not directly model these effects. The infinite array approximation has been used for many years to incorporate mutual coupling, but elements at the edges of the array are not handled well by this approximation. For ultra-high sensitivity applications, we use numerical modeling, network theory, and array signal processing theory to include coupling effects from the ground up.

The presentation will use words, pictures, and a few equations to give a gentle introduction to phased array antennas and the traditional array factor and infinite array analysis method. We will then make a quick transition from "textbook" approaches to state-of-the-art design methodologies developed in the last decade. The talk will survey design requirements and open challenges for challenging new applications, numerical modeling, network theory, array signal processing, performance figures of merit for active phased arrays, and examples of modern phased array systems for applications like radio astronomy and satellite communications.

Karl F. Warnick received the B.S. degree and the Ph.D. degree from Brigham Young University (BYU), Provo, UT, in 1994 and 1997, respectively. From 1998 to 2000, he was a Postdoctoral Research Associate at the University of Illinois at Urbana-Champaign. Since 2000, he has been a faculty member in the Department of Electrical and Computer Engineering at BYU, where he is currently a Professor. Dr. Warnick has published many scientific articles and conference papers on electromagnetic theory, numerical methods, remote sensing, antenna applications, phased arrays, biomedical devices, and inverse scattering, and is the author of three books in these areas. Dr. Warnick is a Fellow of the IEEE for contributions to theoretical and numerical analysis of phased-array antennas and microwave systems and is a recipient of an Outstanding Faculty Member award for Electrical and Computer Engineering, the BYU Young Scholar Award, the Ira A. Fulton College of Engineering and Technology Excellence in Scholarship Award, and the BYU Karl G. Maeser Research and Creative Arts Award. He has served the Antennas and Propagation Society as a member and co-chair of the Education Committee and as Senior Associate Editor of the IEEE Transactions on

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