REVISITING THE GENERALIZED 3-PARAMETER APERTURE DISTRIBUTION AND HANSEN'S 1-PARAMETER DISTRIBUTION

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It is a privilege presenting an invited paper in this special session of the IEEE AP-S/USNC-URSI 2019 Symposium dedicated to the scientific life of late Dr. R. C. Hansen (1926-2017) or better known as "Bob". I had many fruitful discussions with him on all kinds of antennas including, arrays, reflectors, meta-materials, etc. What I vividly remember is his depth of knowledge in both the subjects of engineering electromagnetics and the practical implementation aspects of antennas in real life applications. Additionally we have shared some similar experiences, graduated from the University of Illinois Urbana-Champaign, served as the President of IEEE AP-S, received IEEE AP-S Distinguished Achievement Award, The IEEE Electromagnetics Field Award, inducted to the US National Academy of Engineering, etc. These common experiences allowed us to talk on variety of subjects. When I served as the president of IEEE AP-S, he always attended the AdCom meeting as the life member of the AdCom and brought much wisdom and historical insights to the conduct of those meetings. He was very straightforward and direct in his interaction with people and one could say he had the "no nonsense" approach and for sure did not mind to pose tough questions to the presenters no matter how young or old!

Apart from many useful engineering papers that he wrote, he also authored and edited many classical books on all aspects of array antennas. He was fund of developing simple equations and generating many design curves by hand! One of his seminal contributions was on the subject of 1-parameter circular aperture distribution. In one of his earlier reports he writes [1], "Circular aperture distributions used in texts and papers are almost always chosen because they can be readily integrated. For example, the $(1-\rho^2)^n$ on a pedestal is common. The Gaussian is of use only for very heavily tapered apertures where the truncation is not serious, but represents a very inefficient distribution. All of these distributions suffer two major disadvantages. First, there is no simple way of choosing optimum parameters, e.g. maximum efficiency for a given sidelobe level. And second, there is no simple way of finding the parameters to yield a given sidelobe level. Both these limitations are removed in a new circular distribution, the Modified $\mathbf{J_1(\pi u)/\pi u}$. This is related to the modified $\mathbf{\sin\pi u/\pi u}$ line source developed by Taylor."

Duan and Rahmat-Samii [2] developed a generalized 3-parameter elliptical aperture distribution, namely,

$$Q_{D-R}(t) = c + (1-c)(1-t^2)^{\alpha}\,\frac{\Lambda_{\alpha}(j\beta\sqrt{1-t^2})}{\Lambda_{\alpha}(j\beta)} \qquad (1)$$

where α, β and c are the three parameters and Λ function is related to the Gamma and the Bessel functions. Setting c=α=0, one recovers Hansen's 1-parameter circular aperture distribution as:

$$Q_H(t) = \frac{I_0(\beta\sqrt{1-t^2})}{I_0(\beta)} \qquad (2)$$

where I_0 is the modified Bessel function. This paper revisits the 3-parameter aperture distributions and the selection of the parameters using modern natured inspired optimization techniques. Additionally some unique features of Hansen's 1-parameter aperture distribution will be highlighted using the above generalized distribution.

[1] R. C. Hansen, "Design tradeoff study for reflector antenna systems for the shuttle imaging microwave system", Final Report 636-1 on Contract 954026, JPL, Aug., 1974.
[2] D. W. Duan and Y. Rahmat-Samii, "A generalized three-Parameter (3-P) Aperture distribution for antenna applications," IEEE Trans. Antennas and Propagation June, 1992.