An Analytical Spectral Formulation to Determine the Antenna Phase Center

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The phase center of an antenna is a virtual point that can be associated to a generic antenna, that allows to treat it as a point source from which the electromagnetic (EM) field spreads out as a spherical wave (D. Carter, IRE Trans. Antennas Propag., 4, 4, 597–600, 1956). The exact position of the antenna phase center can be considered of primary importance in the design of reflector antennas, where the illuminating field of the primary feed antenna has to radiate from the reflector focus (Y. Y. Hu, Journ. Franklin Inst., 271, 31–39, 1961; I. Ohtera and H. Ujiie, IEEE Trans. Antennas Propag., 23, 6, 858–859, 1975). Indeed a misalignment between the phase center of the feed and the reflector focus implies a degradation of the reflector system radiation properties. In addition, the antenna phase center localization finds application also in EMC tests, antenna measurements, or in high-precision GNSS ranging. To the authors' best knowledge, although the phase center can be considered a very basic concept in antenna theory, a systematic general formulation for its explicit calculation is not yet provided. Some recent attempts have tried to address this issue analytically and experimentally (S. Perna, C. Esposito, A. Pauciullo and A. Gifuni, Intern. Conf. Electromagn. Adv. Appl., ICEAA, 1433–1435, 2017).

In this paper, we propose explicit formulas for the calculation of the (local) phase center of an arbitrary antenna. Such formulas allow to describe the dependence of the phase center both from observation and frequency. In general, an antenna can be represented by a radiation integral, which can be either a surface integral of surface current densities or a volume integral of volumetric current density, that in turn can be expressed in its plane-wave spectral form at a large but finite distance from the antenna. The asymptotic evaluation of such an integral provides the radiated field at a given point in its Geometrical Optics (GO) format, from which the local direction of propagation and wavefront curvatures are explicitly obtained. Such parameters permit the derivation of the antenna phase center associated to the given direction of observation.

The general formulas we present here can be easily linked to well-known concepts of basic classical mechanics; indeed, the first order momentum of the electric and magnetic current distributions can be associated to the barycenter in mechanics, whereas the second order momentum of the distributions to the equivalent momentum of inertia. The local phase center is simply written in terms of these parameters, alternatively to the standard definition in terms of radiation pattern phase derivatives. Moreover, as an example to prove the effectiveness of the proposed approach, the derived formulas can be applied to the very simple case of a pyramidal horn, thus simply providing closed-form formulas for the phase center. Finally, such formulas appear to be robust and can be applied to the general case of arbitrary current distribution provided by a numerical method or to near-field measurements.