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Numerical Analysis of Small Parabolic Antennas using the Method of Current and Change Integral Equations

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Abstract—The method of current and charge integral equations [1] is applied to numerical electrodynamic analysis of radiation and impedance matching characteristics of parabolic antennas with reflector diameter from 0.5 to 10λ. As a result as opposed to the current method relying on physical optics approximation the influence of feed on reflector's radiation pattern, the influence of reflector on feed's impedance matching and the contribution of feed's rear radiation into reflector's radiation pattern are all accounted for. A new model of representing a parabolic surface in the form of its square approximation is suggested, which provides almost uniform partitioning grid and has at least 2.5 times less boundary elements that the common revolution surface representation while having the same sampling coefficient. Dependences of antenna's directivity on reflector dimensions (0.5–10λ) are calculated for six different focus distance to reflector's diameter ratios using the developed by the authors crystal_U software package. The calculated results are confirmed by good matching with well-known experimental results.

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INTRODUCTION

The on-going mass transition to terrestrial high-definition television (HDTV) broadcasting excites interest of consumers who live far from transmitting sites in wideband UHF directional antennas. One solution that would allow receiving the HDTV broadcast expects using small reflector parabolic antenna.

It is well-known that parabolic antenna's directivity is mainly determined by electric dimensions of its aperture which, in the case of 470–862 MHz frequency range, may turn out to be rather bulk considering inefficient use of reflector's surface. The mentioned problem facilitates the need for precise calculation and optimization of radiation and impedance matching characteristics of small parabolic antennas (with reflector's diameter starting at 0.5λ, where λ is wavelength in the free space) in order to achieve maximum efficiency of using reflector's surface.

It is well-known that in case of aperture antennas precision of approximate mathematical methods based on optical properties of radio waves is directly proportional to electrical dimensions of radiating structure. Specifically, for a parabolic antenna the long wave applicability boundary of physical optics approximation with current-based calculation method demands reflector's diameter to equal several λ [2] with a more precise value of 3λ provided in [3]. Thus, calculation results of electrically small parabolic antennas using the current method, which does not account for reflector-feed interaction, would require experimental verification and adjustment of the calculated values, especially when dealing with reflector's diameters well below 3λ. Such approach cannot be considered optimal in view of available processing power of modern computers. Hence the authors conduct electrodynamic analysis of small parabolic antenna by defining and solving the corresponding boundary problem.

An efficient method of numerically solving electrodynamic problems for arbitrary conducting surfaces based on current and charge integral equations was suggested by the authors in [1] and successfully applied to analysis of vibrator and combined complex structures [1, 4–5], whose dimensions are less than 2λ. Hence this method was chosen by the authors when facing a need to analyze aperture mirror-type antennas on example of studying radiation and impedance matching characteristics of parabolic antenna to be used for HDTV reception.

This paper presents results of applying method [1] to electrodynamic analysis of parabolic antennas with reflector's diameter from 0.5 to 10λ. As a result in contrast to the current method with physical optics approximation we account for influence of feed on reflector's radiation pattern (RP), influence of reflector on feed's impedance matching and contribution of feed's rear radiation into reflector's RP. A new model of