Journal of Systems Engineering and Electronics
Vol. 19, No. 6, 2008, pp.1133–1138

Co-aperture arrangement of dual antennas for orientation and telemetry in a conformal cavity

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(Received August 11, 2007)

Abstract: The feasibility of making two antennas work within a shared aperture conformal to a platform like an aircraft or a missile is investigated. The shared aperture is enclosed by a deep cavity, which is covered by a columniform dielectric radome. A modified quadrifilar helix antenna (QHA) with extended volute arms and a vertical monopole with a ring shaped ground are arranged in this co-aperture for global position system (GPS) orientation and telemetry, respectively. The effects of the cavity on these two antennas and the mutual coupling between these two antennas are studied through large numbers of experiments. The results show that the QHA has a strong influence on the monopole; however, these two antennas of the overall arrangement can perform simultaneously well within the aperture. The QHA has a right hand circular polarization (RHCP) and a broad beam normal to the radome topside, meanwhile the monopole can be used to produce a main lobe in the grazing direction above the aperture in some certain cases of the vertical location of the QHA in the cavity.

Keywords: antennas, co-aperture, cavity, radome.

1. Introduction

In some special environments for example on aircrafts or missiles, certain antennas have to be placed into a deep cavity, which is embedded below the platform surface and covered by an electrically thick dielectric radome. The cavity along with the radome forms an aperture. Although the cavity depth may be large enough, in general, the dimension of the cavity cross section is greatly restricted. For the purpose of integration and maintenance, the demands of arranging two or more antennas in the same aperture, i.e. a shared aperture or a co-aperture, have been further put forward. For example, two antennas can be required to work simultaneously in the shared aperture for RF orientation and telemetry, respectively. The orientation antenna should have a right hand circular polarization (RHCP) and a wide beamwidth for global position system (GPS) applications, while the main lobe of the telemetry antenna is expected to be in the grazing direction of the aperture. The aperture here is conformal to the surface of a platform like a plane nose, which indicates that the aperture topside is flush with the outer surface of the nose. The center frequencies of these two antennas are f_{01} and f_{02}, respectively.

The co-aperture arrangement of these two antennas makes the design challenging: the transverse dimension of the aperture is greatly restricted; the radome is electrically thick; the mutual shielding and coupling between these two antennas are very severe; it is very difficult to enlarge the beamwidth of the orientation antenna and make the main lobe of the telemetry antenna graze along the aperture topside simultaneously; etc. Few studies can be found in the published literatures. Although the cavity can be seen as a cylindrical waveguide, according to the waveguide theory, the electrical dimensions of the cavity determine that the operating frequency of the orientation antenna is in the cutoff region of the waveguide. Hence, the cavity cannot radiate energy directly by itself. Several telemetry antennas were introduced in Refs. [1–3], whereas they are not appropriate for the co-aperture purpose owing to their dimension restrictions or radiation characteristics. For the shielding by their ground planes, patch antennas are also not good candidates having the expected advantages to be arranged with another antenna in the cavity. The quadrifilar helix antenna (QHA)[4–6] has been widely used in GPS applications. However, the published studies mainly focused on the turn number[4] or size reduction of the helixes, and no application in deep cavities has been reported despite some designs having back reflectors[5]. In this article, a combined structure of thin wires is proposed to achieve the above goals: a 1/4 turn QHA was adopted and modified to suit a cavity for the proposed platform orientation, and a satisfactory trial was done by placing a vertical monopole near the inner wall of the cavity, which produced a lobe in the grazing direction of the aperture owing to the scattering in the cavity, the diffracting around the aperture edge, and the mutual coupling between these two antennas.

2. Structure and design

The actual electrical size of the platform and the surface curvature radius near the aperture can be very large, and the two antennas buried in the deep cavity and covered by the thick radome, which is conformal to the platform, can be affected slightly by the far end of the platform, therefore, a relatively small region surrounding the aperture can be intercepted from the platform surface to modeling the real environment, which is adequate for analysis. Here, a $1.57\lambda_{01}\times1.57\lambda_{01}$ sized sheet copper is utilized to simulate the platform surface. The proposed conformal cavity with a radome and the truncated platform are shown in Fig. 1 and Fig. 2(a), respectively. The $+z$ axis is in the normal direction of the aperture and the expected grazing direction is in the xoz plane.

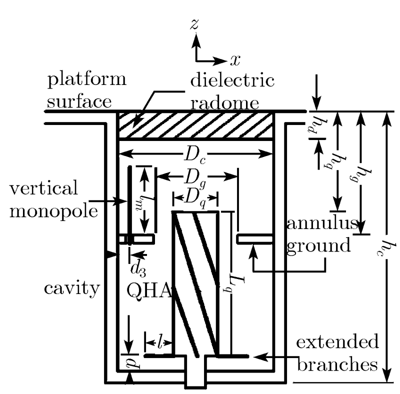
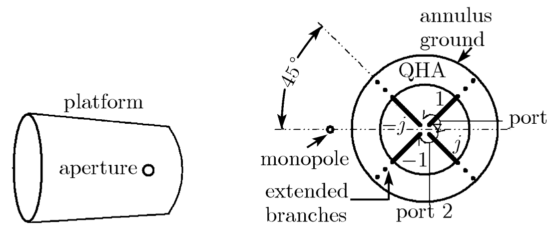


Fig. 1 Cutaway view of the structure

The traditional QHA has several advantages for orientation application including pattern symmetry, broad beamwidth, and excellent axial ratio. Another advantage is that owing to its large ratio of length to diameter, significant space in the cavity can be saved for installing the telemetry antenna. Various designs of traditional QHA are described in Refs. [4–6]. Our experimental studies show that these conventional designs do not yield good impedance match in the above cavity. As an improvement in this article, four horizontal branches are extended out from the distant ends of the four radials (see Fig. 1). It can improve the impedance match of the antenna to a transmission line to tune the capacitors formed by the branches and the cavity bottom. The key of the method to tune these capacitors is to change the length l and the height d of the four branches.

In Fig. 1, all the physical dimensions of the aperture are expressed using the center wavelength of the QHA. The inner diameter of the cylindrical cavity D_c is $0.41\lambda_{01}$, and the cavity depth is h_c, which varies with the QHA length L_q and the distance between the QHA topside and the platform surface h_q. With a relative permittivity of ε_r=2.2, the columniform dielectric radome also has a diameter of D_c.

For telemetry, a vertical monopole with a ring ground is proposed, and the center hole of the ring is used for threading through the QHA. Owing to symmetry, the ring ground slightly affects the balance between the two feeding ports of the QHA (see Fig. 2(b), where the two poles numbered "1" and "−1" form the first port while the two poles numbered "$-j$" and "j" form the other one). For tuning the monopole in the cavity, the ground should have a relatively large area and contact the inner wall of the



(a) A truncated platform with a conformal cavity embedded below its surface

(b) Top view of the two antennas in the cavity

Fig. 2 Model under consideration