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Heat-Resistant Microstrip Antenna Array for Hypersonic Aircraft with Small Radar Visibility

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Abstract—Technical implementation of the microstrip antenna array of segmented design has been proposed. It is shown that at the expense of using heat-resistant materials the antenna array has stable parameters of radiation at high temperatures and can be used for radio engineering systems of hypersonic aircraft. The investigation results were also presented demonstrating a significant reduction of the scattering cross-section of such antenna as compared with the equivalent planar antenna array.

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The creation of effective multi-function aerospace system involves the need of developing reusable hypersonic aircraft and missiles having small dimensions and weight. The problem of minimization of the weight-size parameters of hypersonic aircraft (HAC) without any loss of the performance efficiency of its radio engineering systems involves the need of using the antennas of small weight and dimensions in relation to the wavelength of radiation. In addition, these antennas should maintain the performance ability in conditions of intensive heating to high temperatures [1].

Modern HAC should be able not only to fly with hypersonic speed over the ballistic trajectory, but also arbitrarily change the direction of motion. The flight over complex trajectory contributes to the possibility of overcoming the antimissile defense system, provided the appropriate measures are made to reduce the radar visibility. The presence of RF windows leads to strong reflection of radar signals from antennas that may significantly reduce the efficiency of measures taken for the reduction of aircraft visibility as a whole [2]. All this actualizes the problem of creating the on-board heat-resistant antennas with small scattering cross-section (SCS).

Microstrip antennas (MSA) are characterized by simple design, small dimensions and weight. That is why their use as on-board HAC antennas is of considerable interest. For example, MSA with ring-shaped radiating element are used for the transmission of telemetric information on American intercontinental ballistic rocket Minuteman I [3] that can travel at a speed of up to 7 M, where M is the Mach number. MSA with rectangular-shaped radiating element and the working frequency of 15 GHz are applied for data transmission at the transport space Shuttle [4].

Taking into account the potential of using MSA for HAC, the present paper considers the possibility of technical implementation of a heat-resistant antenna array (AA) for HAC with due regard for the requirements of reducing their radar visibility.

The problem of antenna operation in conditions of intensive thermal exposure arises in the case of hypersonic flight or during the ballistic descent in dense layers of atmosphere, when the HAC body is subjected to intensive aerodynamic heating. In this case the temperature at different sections of the HAC surface is not identical. It depends on the speed and the aspect angle of flight. This temperature may reach 2000 °C near the nose cone [5]. At flat sections of the surface remote from the nose compartment and from the place of location of the scramjet engine the values of temperature do not exceed 1100 °C [5]. That is why the temperature in sections of HAC depending on the place of location of antenna windows may change from 250 to 700 °C.

It should be noted that the maximum working temperature of MSA made of isotropic dielectrics with small losses and dielectric permittivity amounts to about 250 °C. That is why, the heating of on-board sections, where AA are located directly near the surface of heat-resistant coating (HRC) of antenna window, may reach 700 °C. This results in the need of using HRC on the surface of the antenna array proper. The use of such HRC under the specified conditions implies the need of reaching the (3–4)-fold reduction of thermal