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Design of load-bearing antenna structures by embedding technology of microstrip antenna in composite sandwich structure

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Abstract

Electrically and structurally effective antenna structure is developed for the next generation of surface technology for communication, in which the structural surface itself becomes an antenna. The basic design concept is a sandwich structure composed of composite laminates and Nomex honeycomb, with which microstrip antenna is integrated. Composite materials with high electrical loss must not reduce antenna efficiency. Stacked-patch microstrip antenna is preferred for wideband performance. An open condition that defines a position of outer facesheet is exploited in order to allow an antenna into the sandwich structure without loss of antenna performances. Measured electrical performances of fabricated structure show that the gain is more improved than original antenna and the bandwidth is as wide as specified in our requirements. With the open condition, wideband antenna can be integrated with mechanical structures without reducing any electrical performances, as confirmed experimentally here.

Keywords: Smart structure; Composites; Honeycomb; Sandwich structure; Antenna

1. Introduction

In the past 10 years, researches have been performed on the embedding of antennas in load-bearing structural surfaces of aircraft in order to improve both structural efficiency and antenna performances [1–3]. The research program in [1] successfully designed, fabricated, and confirmed the structural integrity of a multifunction antenna component panel subjected to realistic aircraft flight load conditions. Use of a composite roof structure in a military truck with multiple antenna reception can allow the latest in communication and entertainment reception needs within a light-weight and durable self-contained structure [4]. Through the innovative integration of antenna elements, amplifiers and ground plane, the reception quality and manufacturability of vehicles is expected to be significantly improved. Even though the articles published to date indicate that the technology has had some spectacular success in its initial stages, little has been published about the problems that remain to be overcome for use in an operational vehicle. The most important outstanding problem is that structurally effective materials cannot be used without reducing antenna efficiency. Load-bearing antenna structures [5–7], designed through compromise between electrical and mechanical properties will not have great benefits because its each performance becomes worse by integration of two performances.

The present study aims to design electrically and structurally effective antenna structures, termed *composite smart structure* (*CSS*). Structurally effective materials with high electrical loss must not reduce antenna efficiency. Design is focused electrically toward high gain and wide bandwidth, and mechanically toward high strength and stiffness. An open condition [8] is used in order to allow composite materials without loss of antenna performances and give good gain and bandwidth. Stacked-patch microstrip antenna is used for the wideband performance. A sandwich structure composed of composites facesheets and Nomex honeycomb is used to give good mechanical performances. After fabrication of the designed structure, its electrical performances are measured.

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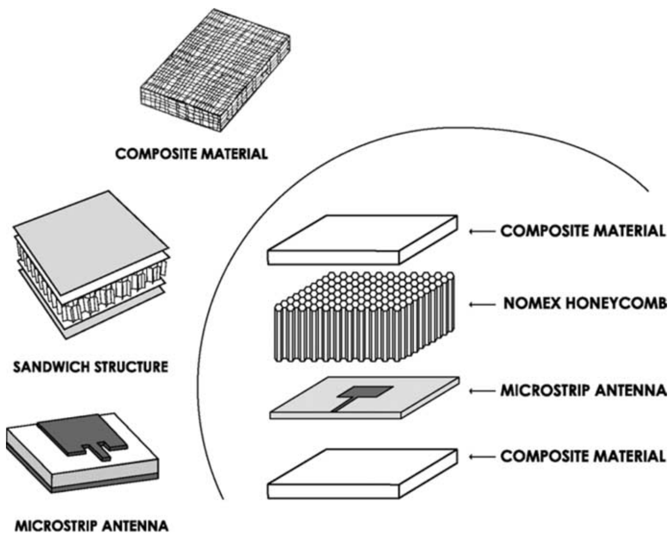


Fig. 1. Basic concept.

Table 1
Material properties of layers

Material	Properties
Glass/epoxy $[0/90]_{ns}$, SK Chemical	Dielectric constant: 4 Loss tangent: 0.03 Elastic modulus: 25.4 GPa[a] Tensile strength: 573.6 MPa[a]
Nomex Honeycomb, HRH-10-1/8-6, Hexcel	Dielectric constant: 1.1 Loss tangent: 0 Compressive modulus: 414 MPa Compressive strength: 7.76 MPa Shear modulus: 88.6 MPa
RT/duroid5880, Rogers	Dielectric constant: 2.2 Loss tangent: 0.0009 Elastic modulus: 1076 MPa

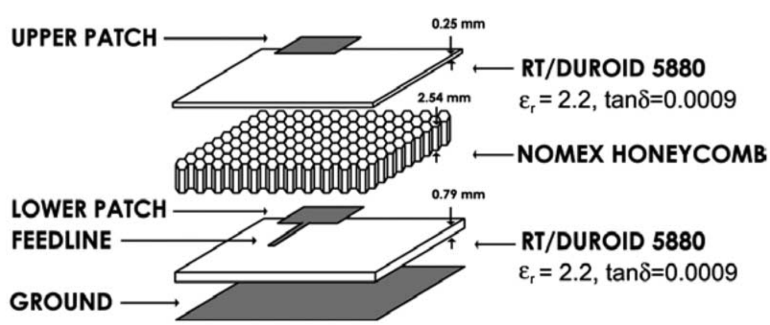
[a] Properties obtained from experiments in NSCS Lab. in Postech.

2. Basic concept of CSS

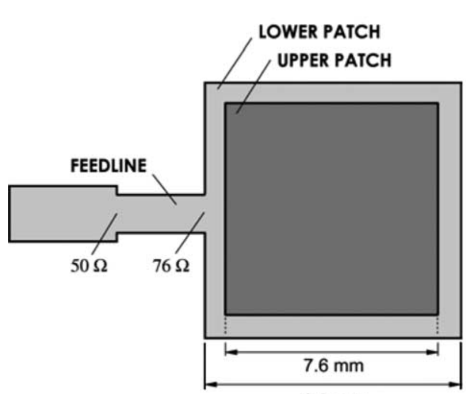
The fundamental design concept of the CSS panel is an organic composite multilayer sandwich panel in which microstrip antenna is inserted, as shown in Fig. 1.

Microstrip antennas [9,10] can be used in high-performance aircraft, spacecraft, and satellite and missile applications, where constraints include size, weight, cost, performance, ease of installation, and aerodynamic profile. This antenna is low-profile, conformable to planar and nonplanar surfaces and simple and inexpensive to manufacture using modern printed-circuit technology.

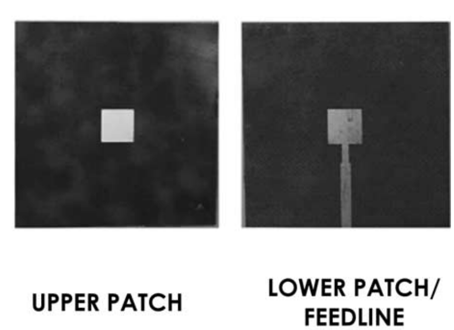
Sandwich construction [11,12] consists of two relatively dense and stiff facesheets that are bonded to either side of a low-density core. The facesheets carry bending-induced axial loads, and the core sustains shear stresses as well as



(a) Structure and materials



(b) Element dimensions



(c) Fabrication

Fig. 2. Antenna layers.