RAM-WAIM Technique used in Aircraft

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ABSTRACT

Today the major challenge of a country is the safety of its aircraft, defense weapons and its border. This technical paper highlights the technology, which plays a major role to enhance the defense system. This study focused on the radar mata-dome and proposed an absorber with a meta-dome structure for ultra- wideband radar absorption using a glass-reinforced epoxy laminate material well known as FR-4 dielectric material on the electromagnetic meta-surface absorber for protection. In addition to protecting the absorber, the meta-surface absorber exhibited ultra-wideband frequency absorptivity from radar signals, with an absorptivity band from 4.6 to 12 GHz, including the C and X Radio frequency bands of radar signals. A wide incidence angle should also be considered in addition to the absorption frequency band. Experimental results were obtained for all polarization angles at normal incidence for 5 to 14GHz. Sensitivity to incident angle from 0° to 40° in the transverse electric mode and 0° to 60° in the transverse magnetic mode were observed. The proposed concept was demonstrated using full-wave simulation and experimental measurements.

INTRODUCTION

Radar meta dome is a compound word for a radar dome, a device that maintains radar performance and protects the radar from the external environment. For example, since aircraft move at very high speeds, it is essential to protect the radar from wind pressure too, lightning, hail, etc.

RAM-WAIM is radar-dome technology, the dielectric materials are commonly used that can protect while maintaining the characteristics of the radar. In addition, the dielectric materials can be used to maintain the impedance matching for wide incident angle which is called as the wide-angle impedance matching (WAIM).

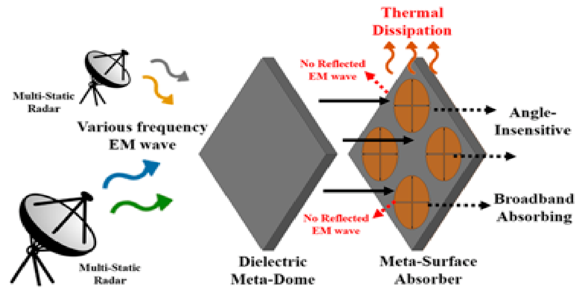
The WAIM techniques have been mostly applied in planar array antennas by loading the dielectric constant sheet, dielectric slab, or frequency selective surface (FSS) on the top of the antenna array. When the WAIM concept is applied to RF absorbers, wide incidence angle and wide bandwidth absorption can be achieved.

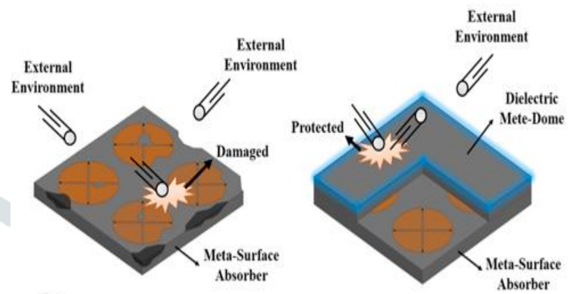
Metamaterial absorber applications used in stealth technology should be protected from external environments, such as wind pressure, bird strike, and weather conditions, as well as be undetectable by radar signals. Hence, the radar-absorbing structures should be outermost. However, radar-absorbing structures can be significantly affected by the external environment. An evaluation of their radar absorbing performance in the range of 2–18 GHz revealed that the mixed single-layered radar absorbing materials had improved absorbing characteristics with thinner matching thicknesses. Radar is the most common technique for the detection and tracking of aircraft. Although radar is an indispensable tool in aviation traffic management, it is a problem in offensive military operations which require aircraft to attack their target and then escape without being detected. Radar involves the transmission of electromagnetic waves into the atmosphere; they are then reflected off the aircraft back to a receiving antenna. Conventional aircraft, such as passenger airliners, are easily detected by radar because of their cylindrical shape together with bumps from the engines and tail plane. In general metals used in present aircraft are also strong reflectors of RF waves and so can be easily detected using radar. Composites are also detected using radar, although usually not as easily as metals.

Radar-absorbing material (RAM) is a polymer-based material applied to the surface of stealth military aircraft, such as the F-22 Raptor and F-35 Lightning II, to reduce the radar cross-section and thereby make them harder to detect by radar. These materials are also applied in stealth versions of tactical unmanned aerial systems, such as the Boeing X-45. RAM is applied over the entire external skin or (more often) to regions of high radar reflection such as surface edges. RAM works on the principle of the aircraft absorbing the electromagnetic wave energy to minimise the intensity of the reflected signal. RAMs are used in combination with other stealth technologies, such as planar design and hidden engines, to make military aircraft difficult to detect.

PROPOSED IDEA

The proposed technology also offers ultra-wideband radar absorption to protect the radar-absorbing structure. A meta-surface is a structure where an infinite number of artificial structures are periodically arranged. These meta-surfaces can control material permittivity and permeability, and various meta-surfaces characteristics can be applied to electromagnetic absorbers such as stealth technologies, sound waves, human body, super lenses, terahertz applications, and electromagnetic interface (EMI) /electromagnetic compatibility (EMC) solutions. Meta-surface based absorbers have advantages over materials based absorbers, such as wedge tapered absorbers and Jaumann absorbers. Wedge tapered absorbers have excellent absorptivity, but are bulky and ferrite used is an expensive material.





Jaumann absorbers use quarter wavelength (λ/4) thickness of dielectric materials. Although one can make thinner wedge tapered absorbers, they remain quite bulky since they must be λ/4 thick. In contrast, hand, meta-surface absorbers are based on LC resonance and thus not affected by material thickness. Consequently, meta-surface absorbers exhibit high absorptivity, thin structure, and are easy to fabricate; cost-effective. Broadband absorbers are required for practical applications radar signals and comprise several frequency bands, hence meta-surface absorbers should also have broadband absorptivity to absorbing the various radar signals. Several methods have been proposed to construct broadband meta-surface absorbers, including multiple resonance, resistive ink or pattern, and lumped elements. Meta-surface absorbers must be angle insensitivity to absorb multiple angle radar signals. Most wide incidence angle metamaterial absorbers have been realized using angle insensitive unit cell designs, such as the split ring cross resonator, circular sector and surrounding via array, subwavelength unit cell, and four-fold rotational symmetric electric resonator structure. Wide incidence angle absorption can be achieved by loading a dielectric material on the metamaterial absorber, due to WAIM, which also increases the absorption bandwidth due to the high loss of WAIM.

Broadband absorptivity is required for modern stealth technology applications, because radar signals are detected through multiplexed frequency bands. This paper proposed a meta-dome structure for ultra-wideband radar absorption, and we placed dielectric materials on the meta-surface absorber to protect the meta-surface absorber from the external environment, and incorporated fan shaped conductive patterns in the meta-surface absorbers.

The proposed radar antenna and meta-dome achieved broadband absorptivity with chip resistors and demonstrated polarization and angle insensitivity when absorbing multi-static radar signals. We simulated the proposed device using a full-wave simulation tool to demonstrate operational performance, and fabricated a 280 × 280 mm sample of 20 × 20 unit cells. The fan-shaped conductive patterns were fabricated using PCB etching, and employed SMT chip resistors. Mono and bi-static measurements stations were setup for experimental validation. We used horn antennas and VNAs to measure normal incidence, and a time-gating method to measure the reflected signals. Two horn antennas and a VNA were employed to measure oblique incidence incorporating time-gating to obtain TE and TM mode outcomes simultaneously.

Consequently, we confirmed that normal incidence was insensitive to 0°–90° polarization with 90% absorptivity for 4.8 to 14.4 GHz. The proposed meta-dome was angle insensitive 0°–40° for oblique incidence in TE mode and 0°–60° in TM mode. Thus, the proposed meta-dome successfully improved radar detection demonstrated through full-wave simulations and experimental verification.

CONCLUSION

In addition to enhance broadband radar-absorbing structure, it is necessary and, but also to protect the structure from the external environment. For example, meta-domes are placed on radar-absorbing structures to protect them from mechanical damage. The proposed meta-dome structure has broadband absorptivity in addition to its protecting properties. We also propose a polarization and incidence angle insensitive structure for both transverse electric (TE) and transverse magnetic (TM) modes. Performance of the proposed structure was demonstrated through full wave simulations and measurements. In particular, we studied the effects of the dielectric materials on the top of the metasurface by comparing absorptivity of the metamaterial absorber with and without the dielectric material.

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