Multilayer Structure for IR and Radar Stealth

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Introduction

Stealth technology plays a crucial role in the security of our country and the safety of our military personnel. The continual development of IR and Radar detection and tracking systems creates a necessity for the continual development of stealth technology for both.

The invention of radar made it possible to detect and track targets at large distances, this launched the start of research into stealth technologies that could camouflage targets against radar detection and tracking. The research lead to successful solutions for radar camouflage but now there is a need for both radar and IR camouflage simultaneously.

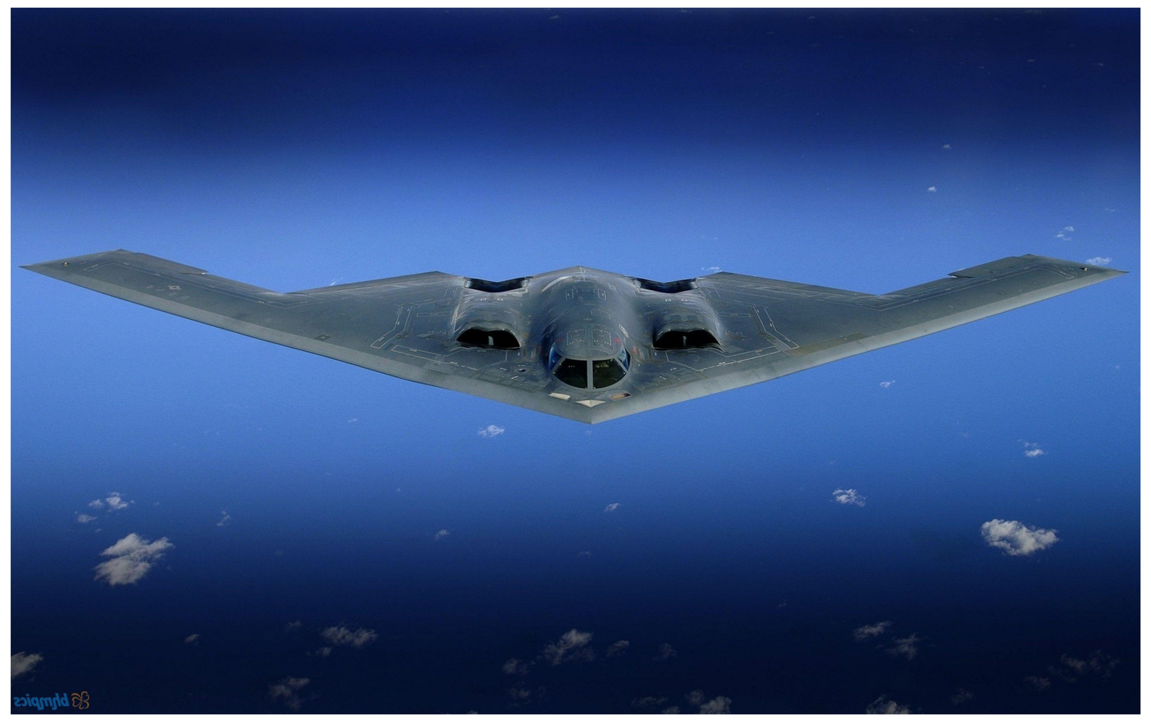
Objective

The purpose for this research was to discover possible solutions for creating a dual stealth structure that works to camouflage against both radar and IR detection and tracking systems. Such a solution is difficult to find due to the opposing nature of the independent stealth solutions for radar and IR. This poster is to display one of the possible solutions to this problem and the objective.

Background

In the past the main focus was placed on radar stealth which requires the reduction of reflected radar waves that can be received by the radar receiver. Radar stealth was first created by the use of different shapes that reflected the radar waves away from the radar receiver but this method became less effective with the development of bistatic radar systems. The other method for radar stealth was the creation of a radar absorbing material that would absorb radar waves in order to keep them from reflecting to the radar receivers. This is the method that will be represented in this poster.

In order to create IR stealth the observability of IR must be low which means that the radiant difference between the target and its background must be small. One solution to this would be to use an active temperature adjustment system that would match the targets temperature to the temperature of the environment. The other method uses an IR reflective layer to contain IR radiant waves inside the target.



B2 Spirit Bomber [1]

Design Obstacles

The major obstacle to designing a dual stealth structure for both radar and IR stealth comes from the independent requirements for each stealth component. From background we know that for radar stealth we need to decrease the reflection of the radar waves and for IR stealth we need to decrease the detectable IR radiation. In order to decrease the reflection of radar waves the use of a radar absorbing material is needed. The radar absorbing material will have low reflectance and transmittance but high absorptivity. The relationship between these three quantities is described by the equation below. [2-5]

$$\alpha + \Gamma + \tau = 1$$

This is a problem for IR stealth, unfortunately, because according to the Stefan-Boltzmann equation:

$$M = \varepsilon \sigma T^4$$

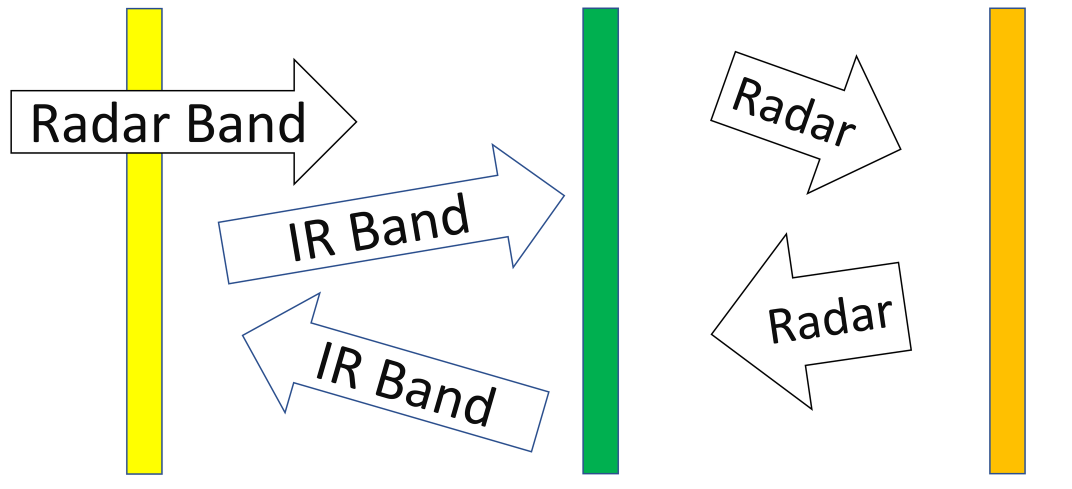
In order to decrease the radiant intensity we need to decrease the emissivity ε and according to Kirchhoff's law of thermal radiation for a body that is at thermodynamic equilibrium:

$$\varepsilon = \alpha$$

Therefore if we decrease the emissivity we effectively decrease the absorptivity. This is the opposite of what is needed for radar stealth. [2,3,5]

Proposed Design Solution

The structure layout that dominated the research results consisted of three main layers in the structure. In each of the designs the outer layer was chosen to be the IR stealth layer, the middle layer was the radar stealth layer, and the inner layer was a solid conductor layer. This design requires the IR layer to be transparent for radar band frequencies but reflective to IR band frequencies. The radar stealth layer must be able to absorb most of the incident radar wave frequencies and have very low reflectance. The bottom backing conductor layer is to block the transmittance of the radar waves past the stealth structure. [2,3,5]



This is a simple figure to explain the concept of the design. Ideally no radar waves will transmit through the RAM layer and no IR waves will transmit through the IR layer. If some waves do make it through the RAM layer they will reflect off the conductor layer and enter the RAM layer again.

Practical Implementation

The IR and Radar layers need to be frequency selective in order to allow the wanted frequencies to pass through and to block the unwanted frequencies. The frequency selective surfaces in the paper that had the best results use a periodic patch array to form a metasurface that produces their desired filter characteristics. The patches are embedded in a dielectric material and spaced according to the desired pass frequency specification. [2,3,5]

The paper with the best overall results was able to achieve a reflectance below -10 dB or an absorption of over 90% across the entire microwave frequency band and an emissivity of 0.3 in the IR frequency band. This means that their design performed well. [2]

Design Specifications and Results from the research paper with the best overall results [2]

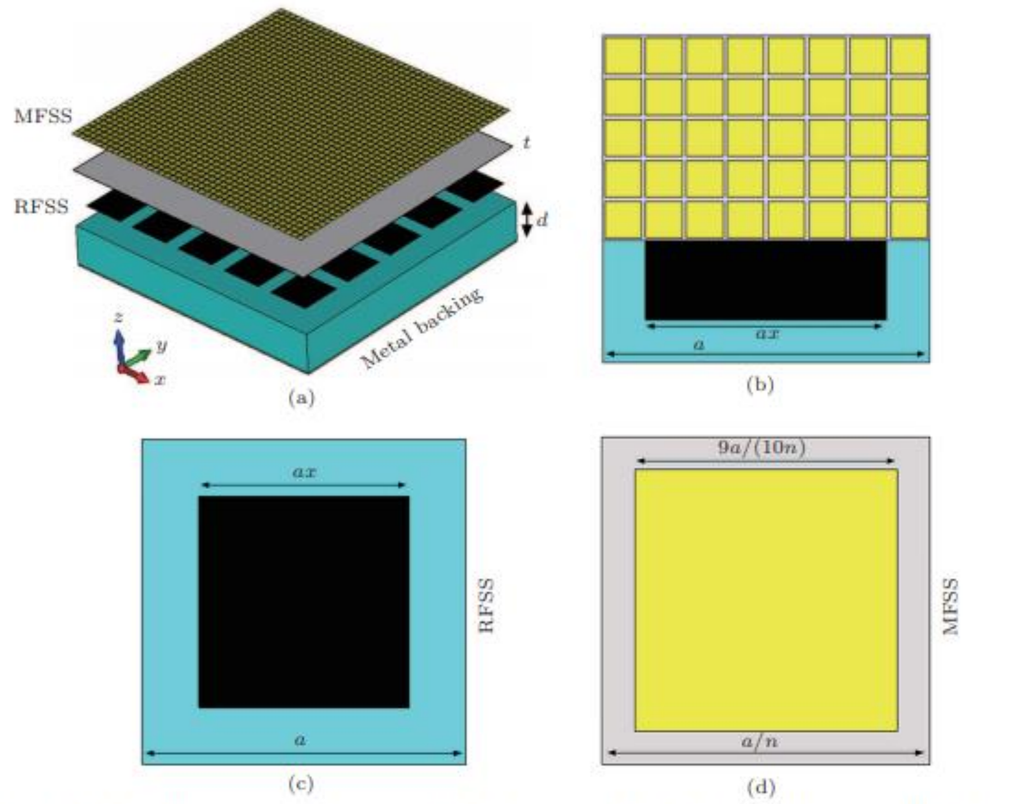
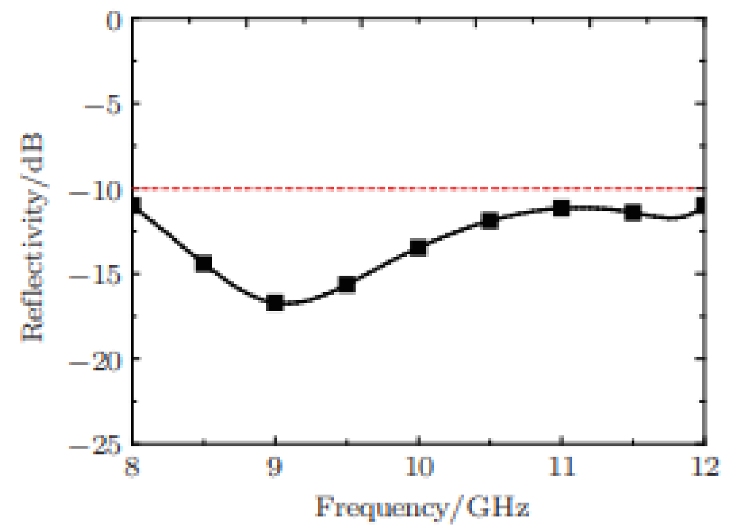


Fig. 1. (color online) (a) Three-dimensional view of the radar-infrared stealth-compatible structure, $d = 1.968$ mm, $t = 0.08$ mm. (b) Front view of the unit cell of the radar-infrared stealth-compatible structure, $a = 13.811$ mm, $x = 0.738$. (c) Front view of the unit cell of the RFSS. The square resistance of the capacitive resistive patches is 150 Ω/□. (d) Front view of a unit cell of MFSS, $n = 8$.



The figures above are both from source [2]

Conclusion

In conclusion, this poster is a summary of the material that I have been researching so far this semester. From the results of the papers that I have studied it is apparent that the design layout that was chosen does work to create a dual stealth structure that is effective in camouflaging against both radar and IR detection and tracking systems. This poster only displays the results from one of the research papers I have studied due to the space constraint. If I have the opportunity to perform more research on this topic I would like to develop my own designs and work to optimize each design aspect in order to create a more efficient and effective dual stealth structure.

References

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[2] C. Hai-Feng, T. Hao, and L. Hai-Tao, "A thin radar-infrared stealth-compatible structure: Design, fabrication, and characterization," Chin.Phys.B, (December 10, 2013).

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