UDC 341.241

Nihal GÜL, Phd Student
(Istanbul Gelisim University, Turkey)
Belgin GENC OZTOPRAK, Assoc. Prof. Dr.
(Kocaeli University, Turkey)

Investigation of Electromagnetic Properties of Quartz Fiber Reinforced Polymer Composite Material (QFRP)

In this study, it is aimed to increase the electrical conductivity of QFRP. The modified nanoparticles were added into the aircraft paint and applied on the QFRP composites used in the radome part of the aircraft, and it is aimed to either increase or keep the electromagnetic permeability stable.

Introduction

Composite materials have many application fields such as aviation, aerospace, defense, automotive and maritime due to their superior advantages. Although composites are light and durable, which is important for aircraft structure, , their electrical conductivity is low [1,2]. The aim of this study is, QFRP composites are also used in the construction of the radome, which protects the weather radar located at the front of the aircraft, it is aimed to increase the electrical conductivity while keeping or increasing the electromagnetic permeability of the composite in the X band (8-12 GHz). While having the electromagnetic permeability occured at the specified targets, it is also aimed to contribute the operation of the radome protecting the weather radar or not to effect its operation.

Material and Methods

In this study, QFRP (Quartz Fiber Reinforced Polymer) composite from FRP composites, which is a type of composite used on aircraft structure, was used. The QFRP composite material, whose surface will be painted with additive paint, was obtained from the out-of-use radome section of an Airbus 320 aircraft. The paint layers applied on the composite according to the aircraft painting procedure[3]. The samples named according to the additive material and their ratios are shown in Table 1.

Table 1

Nomenclature of samples stained with 1%, 2%, 3%, 4% graphene added dyes

Sample No	Additive Material	Doping Rate
N0	Undoped	0%
N1	Graphene	1%
N2	Graphene	2%
N3	Graphene	3%
N4	Graphene	4%

After the surfaces of QFRP composite materials were painted with nanoparticle added paints. Information on the preparation and application of additive paints can be found in our article [4]. In addition, a probe with a contact diameter of 4 mm and a distance of 50 mm between two contacts was used for measurements.To obtain information about the electromagnetic permeability of the samples, the Rohde&Schwarz ZVB20 Vector Network Analyzer and 2 horn antennas were used in the non-contact measurement method test setup was established to obtain the S_{11} (reflection coefficient) and S_{21} (transmission coefficient) parameter values of each sample.

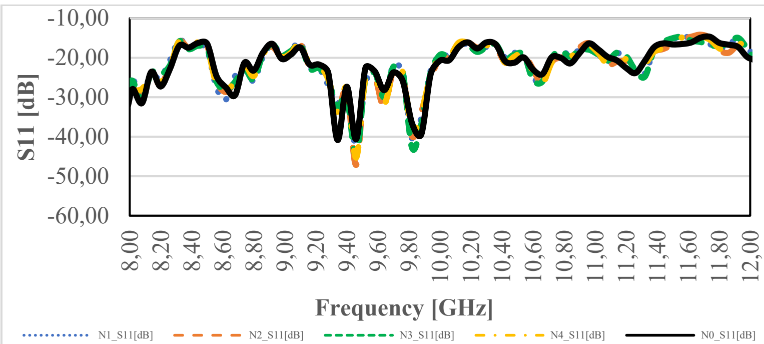
Results

In this study, to increase the electrical conductivity of the FRP composite surface, Graphene nanoparticles at the rate of 1%, 2%, 3%, 4% were used separately mixed into anti-static paint, and 5 different samples, one of which was painted with pure original paint, was obtained. In this section, the electrical surface resistance test setup used in the experiments, the non-contact measurement method test setup, the obtained electrical conductivity, and electromagnetic properties analyses are explained in detail.

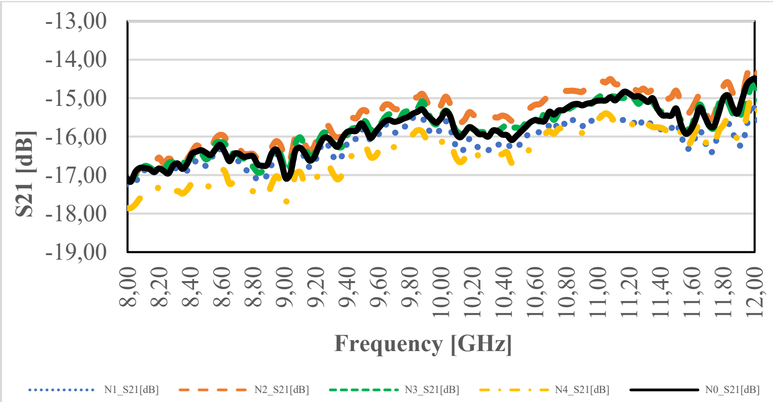
After staining the QFRP composite samples with the obtained additive paints, firstly, resistance measurements were made using the C.A 6525 Megohmmeter according to the Airbus electrical surface resistance measurement procedure [5]. Three measurements were taken from each sample and the average was taken. Thus, measurement errors that may occur in non-homogeneous samples with different resistance values in each measurement were tried to be minimized.

After measuring the electrical resistance values of the samples, the electrical conductivity values were calculated. The electrical conductivity of N1 sample is $1.01x10^{-4}$ S/m, the electrical conductivity of N2 sample is $1.68x10^{-4}$ S/m, the electrical conductivity of N3 sample is $4.37x10^{-4}$ S/m, the electrical conductivity of N4 sample is $9.26x10^{-4}$ S/m [4].

Non-contact measurement method test setup was used for the examination of electromagnetic properties of samples from N0 to N4. The samples in this study were obtained from the radome structure of an Airbus 320 aircraft that was out of use and protected the weather radar antenna from environmental effects.



(a)



(b)

Figure 1. (a) Comparison of (a) S_{11} and (b) parameters of N1 (1%), N2 (2%), N3 (3%) and N4 (4%) samples painted with graphene doped aircraft paint at different rates and S_{11} parameters of N0 sample painted with pure aircraft paint.

Since the operating frequency of the weather radar antenna protected by Radome is between 8 GHz and 12 GHz (X band), S_{11} (reflection coefficient) and S_{21} (transmission coefficient) parameters of all samples were measured. The measurement results of each of the N1, N2, N3 and N4 samples were compared with the N0 reference sample.

When the Figure 1a is examined, the S_{11} value, which has the most significant increase compared to the N0 sample, is seen as -32.52 dB at 9.34 GHz in the N3 sample. When Figure 1b is examined, It is seen that the S_{21} values of N3 and N0 samples are close to each other. This shows that the N3 sample is close to the N0 sample in terms of electromagnetic permeability. In addition to the increase in the electrical conductivity of N2 (σ=1.68 x10^{-4} S/m, S_{21} = -15.52 dB) sample compared to N0 (σ=4.83x10^{-5} S/m, S_{21} = -15.83 dB) sample, it is the sample with the highest increase in the transmission coefficient S_{21}, that is, the best increase in electromagnetic permeability. The obtained results in the N2 and N3 samples show that the intended targets related to electromagnetic permeability in this study have been achieved. In addition, it is seen that the sample that gives the best results for applications where electromagnetic absorption (shielding) is important as well as electrical conductivity is the N4 sample, which has both the best electrical conductivity and the best electromagnetic shielding feature.

Discussion

In this study "to obtain a surface resistance between 5MΩ and 100 MΩ specified in the Airbus Electrical Surface Resistance Measurement Procedure" and the targets of the obtained surface resistance values being lower than the surface resistance values of the reference sample (N0) were achieved in N1, N2, and N3 samples. Thanks to the obtained high conductivity values, the static electricity generated in the fuselage due to friction and lightning strikes while the aircraft is in flight can be discharged from the fuselage faster as intended.

To obtain information about the electromagnetic permeability of the samples, the parameters S_{11} (reflection coefficient) and S_{21} (transmission coefficient) were measured. When all samples painted with graphene doped aircraft paint are compared with the N0 sample, the average of the S_{21} values of the N0 sample is -15.83 dB, while the average of the S_{21} values of the N3 sample is -15.81 dB. This shows that the electromagnetic permeability of the N3 sample is very close to the electromagnetic permeability of the N0 reference sample. While the average of the S_{21} values of the N0 sample is -15.83 dB, the average of the S_{21} values of the N2 sample is -15.52 dB. As a result, among the samples painted with aircraft paint doped with graphene, the samples that give the closest result to the intended targets of electromagnetic transmittance in this study are the N2 and N3 samples. For applications where electromagnetic absorption (shielding) is important, it is seen that the N4 sample has both the best electrical conductivity and the best electromagnetic shielding feature in the samples we work with Graphene.

Conclusion

When the S_{21} (transmission coefficient) values of all samples are compared, the sample with the best S_{21} value compared to the reference sample N0 is the N2 sample. When all sample are examined in line with the objectives of increasing electrical conductivity and either increase or keep the electromagnetic permeability stable compared to the reference sample (N0), the samples that give the best results are N2 and N3 samples. When evaluating these three samples in terms of cost, it can be seen that the N2 sample would be more appropriate to use.

Acknowledgment

This study was supported by Kocaeli University Scientific Research Projects Coordination Unit. Project Code: FYL-2021-2364. The authors thank to the THY Teknik A.Ş. for their support in material supply tests and analysis, Microwave and Antenna Laboratory managers and Research Assistant Hande BODUR for electromagnetic analysis.

References

1. Haghgoo M, Ansari R, Hassanzadeh-Aghdam M.K. Prediction of electrical conductivity of carbon fiber-carbon nanotubereinforced polymer hybrid composites. Composites Part B. 2019;167:728-735. https://doi.org/10.1016/j.compositesb.2019.03.046.
2. Gaztelumendi I, Chapartegui M, Seddon R, Flórez S, Pons F, Cinquin J. Enhancement of electrical conductivity of composite structures by integration of carbon nanotubes via bulk resin and/or buckypaper films. Composites Part B. 2017. doi: 10.1016/j.compositesb.2016.12.059.
3. Airbus Operations S.A.S.. Component Maintenance Manual. 2020. 6146 - 6154.

4. Gul, N., & Genc Oztoprak, B. (2022). Investigation of electrical and electromagnetic properties of quartz fiber reinforced polymer composite material by using modified paints with carbon nanoparticles (graphene/double-walled carbon nanotube). *Journal of Composite Materials*, 00219983221099332.

5. Airbus Operations S.A.S.. Component Maintenance Manual. 2018. 5015-5019.