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PULSE AND FREQUENCY CHARACTERISTICS OF MICROWAVE ANTENNA BASED ON CARBON FIBERS

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Introduction

Carbon fibers make it possible to design various microwave elements due to the unique electrical and mechanical characteristics [1, 2]. Strip transmission lines based on carbon fibers were studied in [3] and the experimental results of researching the pulse and frequency characteristics of carbon strip lines were presented. Authors these and others works have shown the applicability of carbon fibers for design of the strip transmission lines.

[1] Aidin Mehdipour; Abdel R. Sebak; Christopher W. Trueman; Iosif. D. Rosca; Suong V. Hoa. Advanced conductive carbon fiber composite materials for antenna and microwave applications. Proceedings of the 2012 IEEE International Symposium on Antennas and Propagation, 8-14 July 2012. DOI:10.1109/APS.2012.6349125.

[2] Mahan Rudd; Thomas C. Baum; Benjamin Mapleback; Kamran Ghorbani; Kelvin J. Nicholson. Reducing the Attenuation in CFRP Waveguide Using Carbon Fiber Veil. IEEE Microwave and Wireless Components Letters, Volume 27, Issue: 12, Dec. 2017. Pp. 1089 – 1091. DOI: 10.1109/LMWC.2017.2762243.

[3] V.N. Fedorov, and N.D. Malyutin "Nonlinear Properties of a Strip Transmission Line Based on Carbon Fiber," 2016 International Symposium on Fundamentals of Electrical Enginiaring. University Politechnica of Bucharest, Romania, June 30 – Julay 2, 2016. 78-1-46-73-9575-5/16$31.00© IEEE.

The model of carbon antennas over an aluminum grounded plate, carbon coating and the appearance of the experimental setup are shown in Fig. 1.

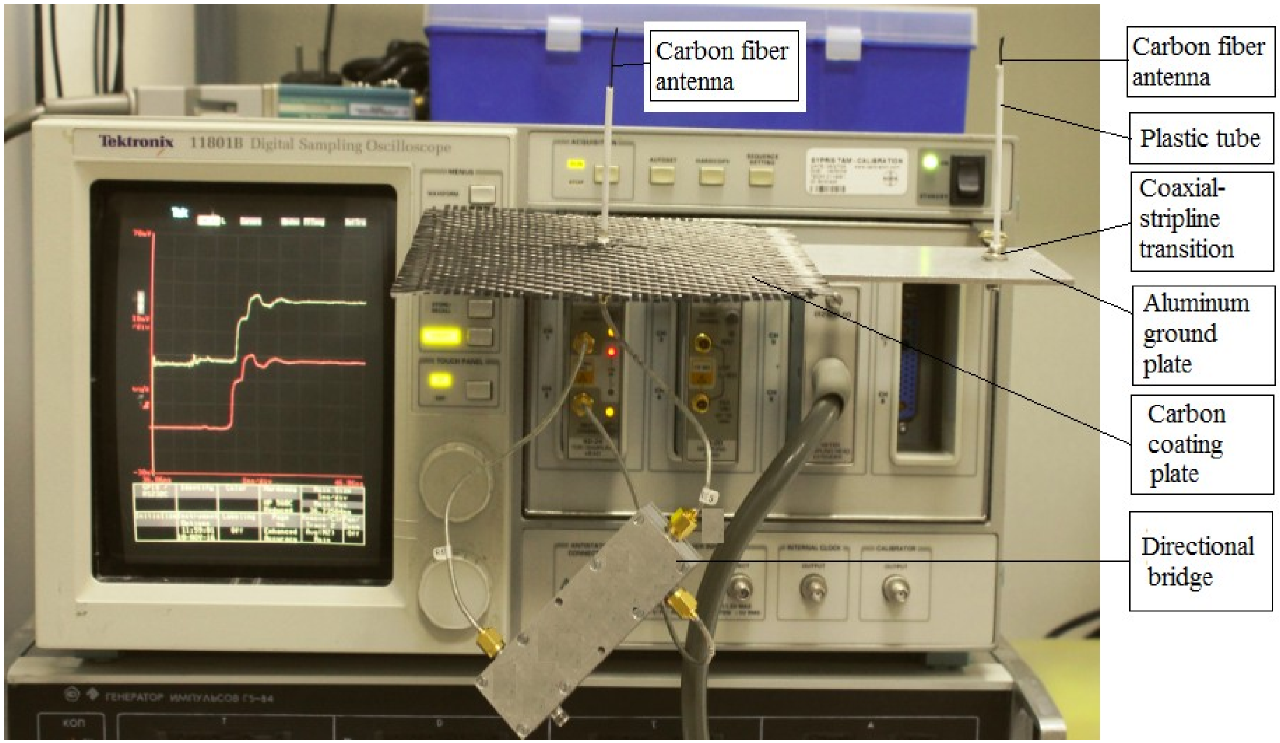

Fig. 1. The appearance of carbon antennas and the setup for the study of pulse characteristics of random antennas.

The aluminum plate has the following dimensions 70×269×2 mm. Two coaxial-strip transitions are mounted on the plate. Carbon fibers with a length of 74 mm were connected via a conductive adhesive to conductors of the coaxial-strip transition located on the front face of the aluminum plate. Carbon fibers are placed in plastic tubes to retain a sufficiently flexible beam of carbon fibers. One of the antennas served as a transmitting antenna at pulse excitation, and the other served as a receiving antenna.

The scheme of the experimental setup for the investigation of pulse characteristics of carbon antennas is shown in Fig. 2

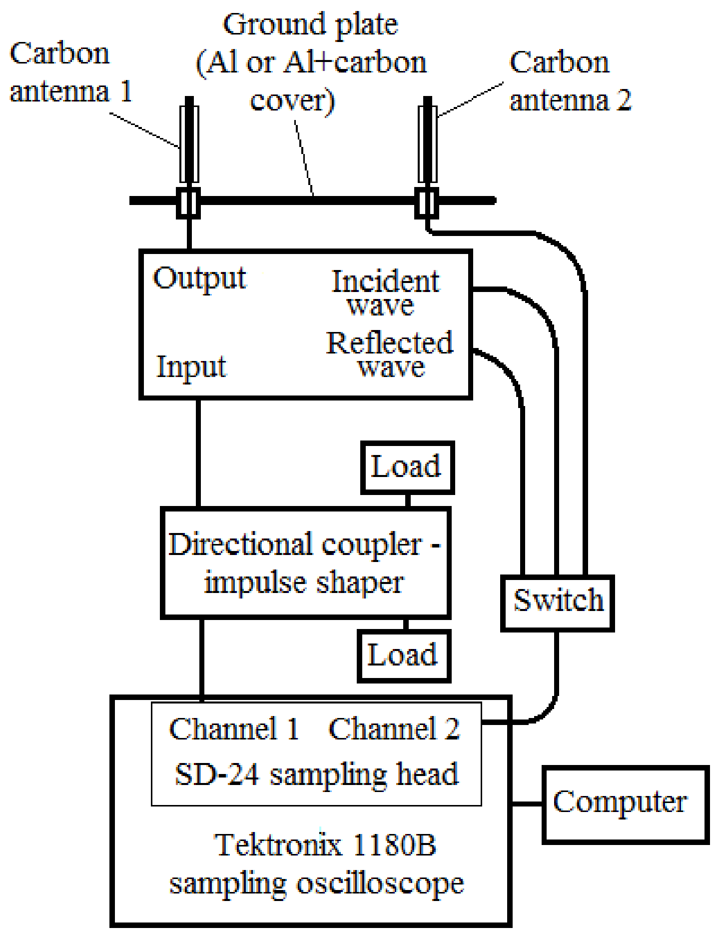

Fig. 2. The scheme of the setup for the study of pulse characteristics of random carbon antennas.

The oscilloscope Tektronix 11801B with a generator unit and a receiver SD-24 served as a base meter. On the output channel 1 SD-24 there is a step-like pulse with a leading edge of nearly 150 ps (Fig. 3).

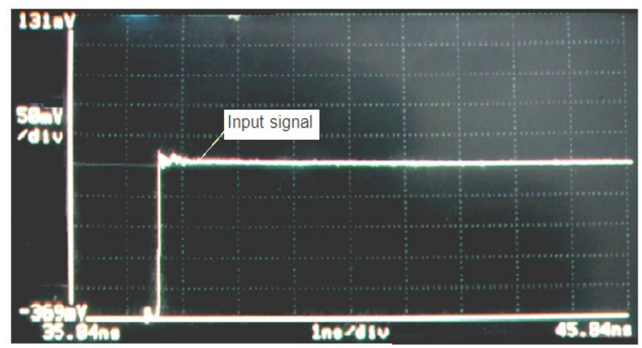

Fig. 3. A signal as a dependency of voltage on time $U_1(t)$ at the output “Channel 1” SD-24.

Fig. 4 shows the dependence of voltage of the incident wave U1in(t) on time at the output of the directional bridge, i.e., at the input of the transmitting carbon antenna.

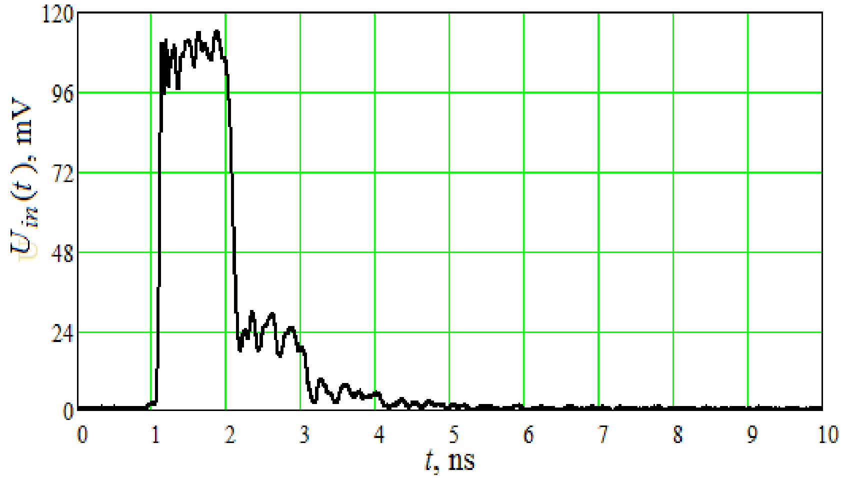

Fig. 4. The dependence of the incident wave voltage Uin(t) on time at the output of the directed bridge (acting pulse).

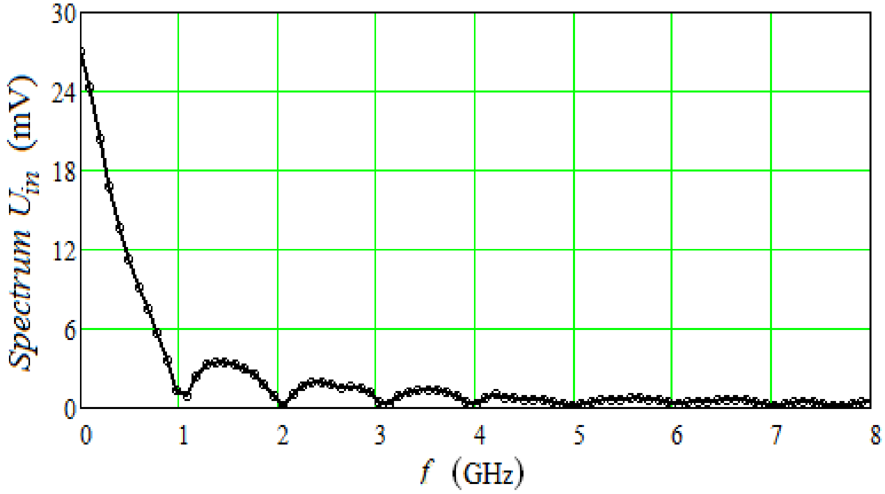

Fig. 5. Spectral envelope of signal Uin(t) at input carbon antenna 1.

The pulse Uin(t) in excites forced and free oscillations in the random carbon antenna 1. Spectral components of the pulse Uin(t) in , coinciding with the frequency f0 that corresponds to a quarter of the antenna wavelength in the random carbon monopole antenna 1, radiate into free space. Measurements of pulse characteristics with an aluminum ground plate and a plate made of carbon fabrics have been carried out. Fig. 6 shows the dependency of voltage at the second antenna U (t) out for both specified options. A spectral analysis of signals Uout (t) has been carried out using a direct Fourier transformation. The results are presented in Fig. 7 in the form of envelops of spectral components.

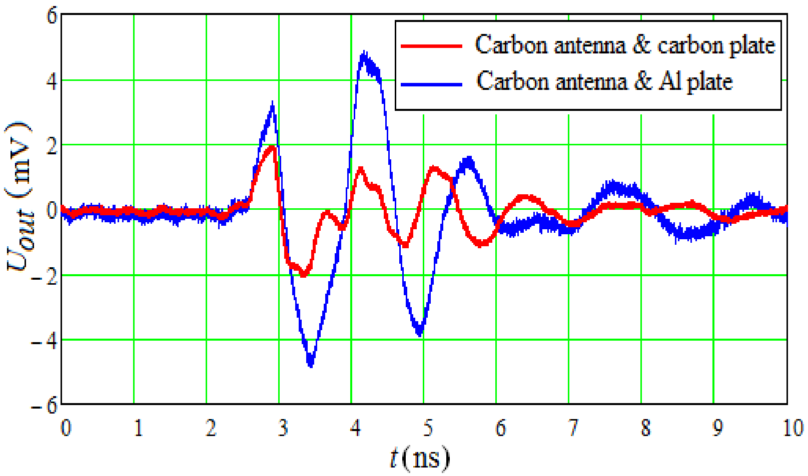

Fig. 6. The signal at the output of the antenna 2 with a ground plane in the shape of an aluminum sheet and the carbon fabric coating.

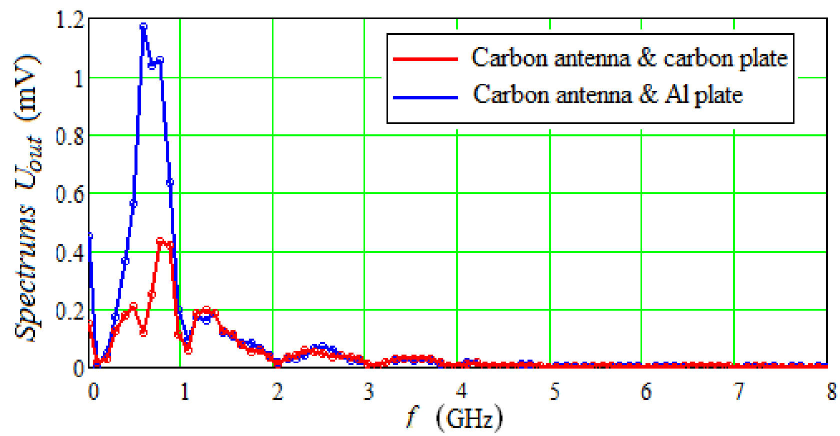

Fig. 7. Envelops of spectral components of signals received by the antenna 2 with a carbon plate (red) and an aluminum plate (blue).

Comparing signal envelopes of the spectra (Fig. 7) shows that when the aluminum plate is coated with a carbon cloth the maximum of the spectral component at the resonance frequency of the receiving antenna is shifted from 0.6836 GHz up to frequency 0.7823 GHz, and the maximum amplitude decreases to 2.375 times.

The transmission coefficient S 21(f) was determined by two methods. The first method consists in calculating the expression |S21(f)|=20log(|Uout(f)/Uin(f)| wherein Uout(f) – the amplitude of the spectral components of the signal voltage at the output of the antenna 2 (Fig. 7) and Uin(f) – the amplitude of the spectral components of the incident signal voltage shown in Fig. 5. The change in the coefficient |S21(f)| when the ground plate is coated with carbon fabric is evaluated. Fig. 8 shows the dependences |S21(f)| in a frequency band, obtained at the excitation of the antenna 1 by a rectangular pulse (Fig.4).

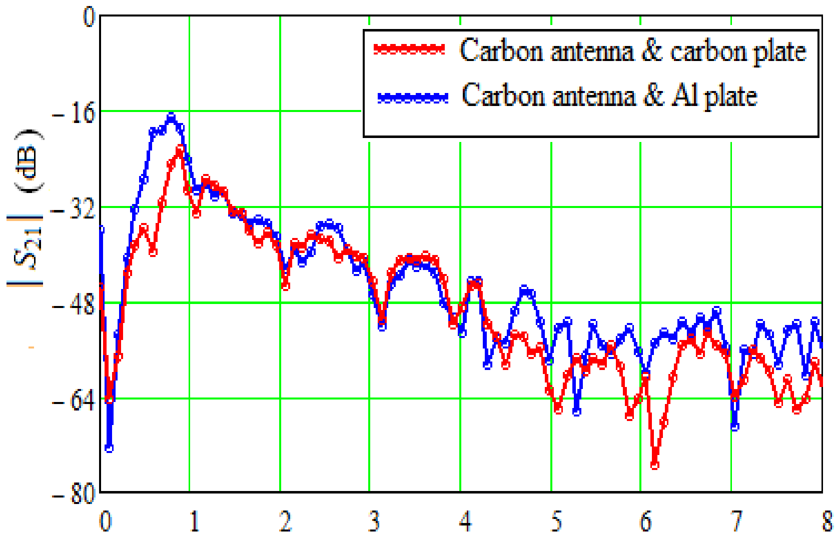

Fig. 8. The frequency dependence of the transmission coefficient |S21(f)|, between two carbon antennas on the aluminum plate and coated carbon fabric. A rectangular pulse with a duration of 1 ns is fed to the transmitting antenna.

The second method for determining |S21(21)|is based on the use of standard measurements of the frequency dependence with a vector network analyzer. Fig. 10, Fig. 11 illustrates the frequency dependence of the transmission coefficient |S21(f)| and return loss |S11(f)| of a pair of carbon fiber antenna and antenna made of copper conductors with a diameter of 0.5 mm. The substitution of carbon vibrators with copper has not led to a significant change |S21(f)|.

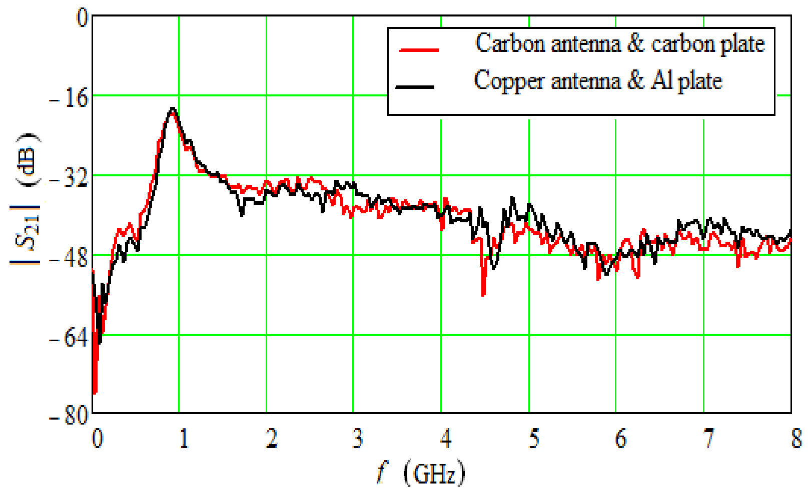

Fig. 10. The comparison of frequency characteristics of the transmission coefficient
|S21(f)|of carbon fiber antennas and a copper conductor on a carbon plate.

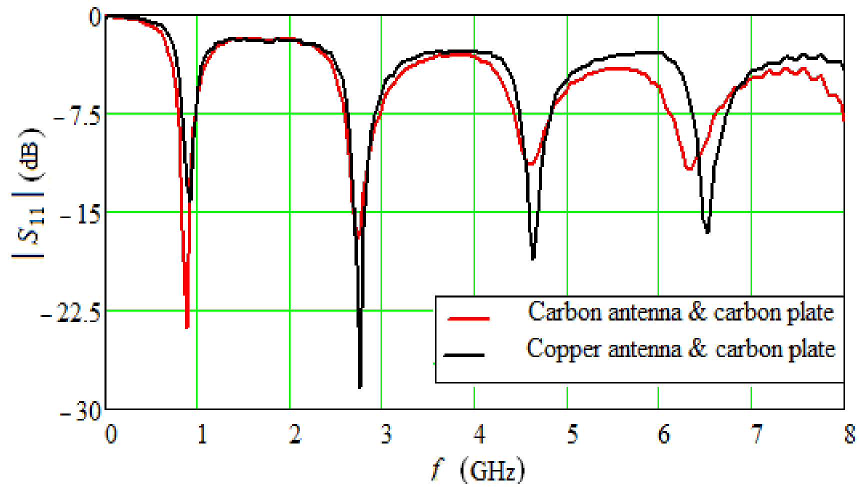

Fig. 11. The comparison of frequency characteristics |S11(f)|of carbon fiber antenna made and a copper antenna on a carbon plate.

CONCLUSION

Thus, it has been shown that pulse and frequency characteristics of carbon antennas obtained by two used methods are well comparable. Placing antennas of unmanned aerial vehicles (UAV) over the surface made of carbon materials leads to an increase in their broadband, and to an increase in losses. The use of transmitting and receiving antennas on UAVs and other objects made of carbon fiber introduces losses up to 5 dB, which must be considered in designing communication and control channels. The obtained results of the antenna response to a pulse action allow forecasting the electromagnetic radiation of construction elements made of carbon materials, as well as the radiation of metal elements over carbon surfaces.

Acknowledgments

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Thanks for yours attention

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