Mobile Camouflage System and Combined Camouflage System for Support Vehicles

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ABSTRACT

We have two basic concepts on the field of camouflage. One is mobile camouflage and the other is static camouflage. The mobile camouflage has some advantages and disadvantages. The static camouflage has some advantages and disadvantages as well. We supplemented mobile camouflage system with camouflage system for stationary camouflage and created a combined camouflage system. With the aim of making more flexible system with better efficiency.
Camouflage was tested and compared on standard middle trucks, which are used by Czech army (standard off-road trucks 6x6).
We compared camouflaged truck in two steps:
1. We were compared truck without camouflage, with truck with mobile camouflage system in medium infrared 3 -5 µm and far infrared 8- 12 µm and radar 9.41 GHz.
2. We were compared truck without camouflage, with truck with combined camouflage system in medium infrared 3 -5 µm and far infrared 8- 12 µm and radar 9.41 GHz.
Combined camouflage system has better results than mobile camouflage system in this comparison. In situations where it can be used the combined camouflage system represents very effective solution. Parts for stationary camouflage are very light and storable, if compared with standard static camouflage system for vehicles and trucks.

1.0 INTRODUCTION

During the history of armed conflicts military vehicles developed from the most primitive vehicles used by ancient civilizations to modern vehicles. The need for camouflage of military vehicles has quickly became apparent. Thou it may be obvious to camouflage main battle tanks or infantry fighting vehicles camouflaging support vehicles is equally important. Nowadays there are two basic ways to camouflage a vehicle, static and mobile. Static camouflage could look different, but in this case it is basically a camouflage net and support and deformation structure. Basic static camouflage is in Fig. [1.A.]. Real static camouflage set in terrain is in Fig. [1.B.]. Static camouflage has its advantages such as versatility and simplicity. It could be set up quickly by a trained vehicle crew and it does not require any special equipment. Also it is not dependent on the vehicle and could be used for various purposes. It also has its disadvantages the most obvious one being its immobility.

The most important advantage of mobile camouflage is that once installed it moves with the vehicle and protects it even while moving. That also represents its most serious limit - as the vehicle has to move there are parts that cannot be masked in order to not interfere with vehicle operation. Also the shape of the vehicle could not be changed. Mobile camouflage on Tatra truck is in Fig. [2.]. Further disadvantages are e.g. its single purpose - mask is designed for a specific vehicle and could not be used anywhere else. The vehicle has to be camouflaged in advance as it takes a few hours and an experienced team of workers to set up a mobile mask properly.

We tried to merge the advantages of both static and mobile camouflage into a combined camouflage system consisting of mobile mask and an additional camouflage net. The net is tied to a vehicle and moves with it while it goes, but once the vehicle stands it could be untied within minutes to create an additional camouflage for the lower part of vehicle. In Fig. [3.] there is a photo of a standing vehicle with installed combined camouflage on right side and front side of the vehicle. Camouflaged left side is identical. Back side could be camouflaged as well but it this case it was not because the back side of the truck is where the crew operate.

2.0 EXPERIMENTAL

Tatra 810 is a three-axel military support truck produced by Tatra Truck a.s. [1]. It was introduced into the army in 2008. It is intended for road and off-road use. Parameters important for camouflage: outer dimensions (height 3320 mm, width 2550 mm and length between 7 365 mm – 8 100 mm), fuel tank is on the right side, tool box is on the left side. The truck is covered with mobile mask MM-BF/L in the colours of summer forest. Additional net is M-BF/L in the same colours. Measurements took place in army training centre Vyškov, on the 1st of June 2011 during morning and early afternoon. Sky was clear, atmospheric temperature 22 ºC, reflected temperature 20 ºC, humidity 70%. Vehicles were situated 530 m from the measurement station.

Infrared measurements were taken with two different thermovision analyzers. FLIR ThermaCAM P20 was used in the range 8 – 12 µm and AGEMA Thermovision 550 in the range 3 – 5 µm. Measurements were processed in FLIR Reporter 8.5 Professional.

Microwave measurements were taken with a monostatic puls radar made by ERA a.s. Pardubice [2]. It consists of a satellite dish of 1.4 m diameter working on a frequency of 9.41 GHz. Pulse length is 45 ns, power 3 kW. Angular width of the circular beam is 1.8º. Radar is linearly polarised and polarisation could be changed from vertical to horizontal relative to the ground surface.

Fig.1. A) Example of a static camouflage made of camouflage net and support structure. B) Static camouflage in terrain.

Fig.2. Full mobile camouflage on Tatra truck 810.

Fig.3. Combined camouflage on Tatra 810 consisting of mobile camouflage and additional nets.
A) Right view of the vehicle B) Front view.

3.0 RESULTS AND DISCUSSION

3.1 Infrared measurements

Infrared measurements were taken on all sides of the unmasked vehicle and vehicle with mobile mask. Combined camouflage was installed on sides and on front only. We analysed two ranges - medium infrared 3 – 5 µm and far infrared 8-12 µm. Emissivity was set at 0.92. Thermographs were analysed on FLIR Reporter programme.

In Fig. [4.A.] there is a photo of the real situation, unmasked truck compared to truck with mobile mask. Unmasked truck compared to truck with combined camouflage is in Fig. [4.B.]. Corresponding thermographs taken in 8 – 12 µm range are in Figs. [4.C.] and [4.D.]. From the thermographs the areas of the vehicles were manually marked and the histograms of temperatures in the area were plotted. Histograms corresponding to thermograph C. are in Figs. [4.E.] and [4.G.]. From Figs E. and G. it is apparent that mobile camouflage significantly reduced the infrared signature. We see a decrease in all characteristics, minimal, maximal and weighted average temperatures. The camouflage also narrowed the temperature range. Temperature range of truck with mobile camouflage ΔT_{mobile} is 21.4 K. Temperature range of corresponding unmasked truck $\Delta T_{unmasked1}$ is 27.6 K.

Histograms obtained from thermograph D. are in Figs. [4.F.] and [4.H.]. Similar trends are observed, i.e. decrease in minimal temperature and significant decrease in both maximal temperature and weighted average temperature. Temperature range measured on truck with combined camouflage $\Delta T_{combined}$ is 18.3 K and it is better than corresponding measurement on unmasked truck $\Delta T_{unmasked2}$ = 22.9 K. Combined camouflage suppressed higher temperatures better than the mobile camouflage and blends nicely with the background.

Also it is not the objective of this work, but from both photograph in visible range as well as from thermograph it could be seen that combined camouflage changes the truck shape. That makes it more difficult to recognize and identify the vehicle.

Thermographs taken in the range 3 – 5 µm are in Fig. [5.A.] and [5.B.]. They were processed same as far infrared measurements. Histograms corresponding to Fig. [5.A.] are in Fig. [5.C.] unmasked truck and Fig. [5.E.] truck with mobile mask. From the comparison of Fig. [5.C.] and Fig. [5.E.] we can see, that mobile camouflage improve the infrared signature compared to unmasked truck. We see drop in minimal temperature, significant drop in maximal temperature and a drop in weighted average temperature by almost 3 K. $\Delta T_{unmasked1}$ is 30.2 K compared to ΔT_{mobile} = 21.7 K.

Figs. [5.D.] and [5.F.] compare unmasked truck with combined camouflage. There is a slight drop in minimal temperature and weighted average temperature and significant drop in maximal temperature. We see narrower temperature range $\Delta T_{unmasked2}$ is 26.8 K compared to $\Delta T_{combined}$ = 19.2 K. As well as in far infrared range we see that the combined camouflage suppresses higher temperatures. Unfortunately for the medium infrared we cannot make direct comparison between truck with mobile camouflage and truck with combined camouflage. That is mainly because the measurements were not taken at the same time but tens of minutes apart (due to adjustments on combined camouflage). As measurements took place in June from 10 am to 2 pm the combined camouflage was exposed to more sunlight than mobile camouflage. It is still apparent that combined camouflage is good, in this case it just could not be directly compared to mobile camouflage.

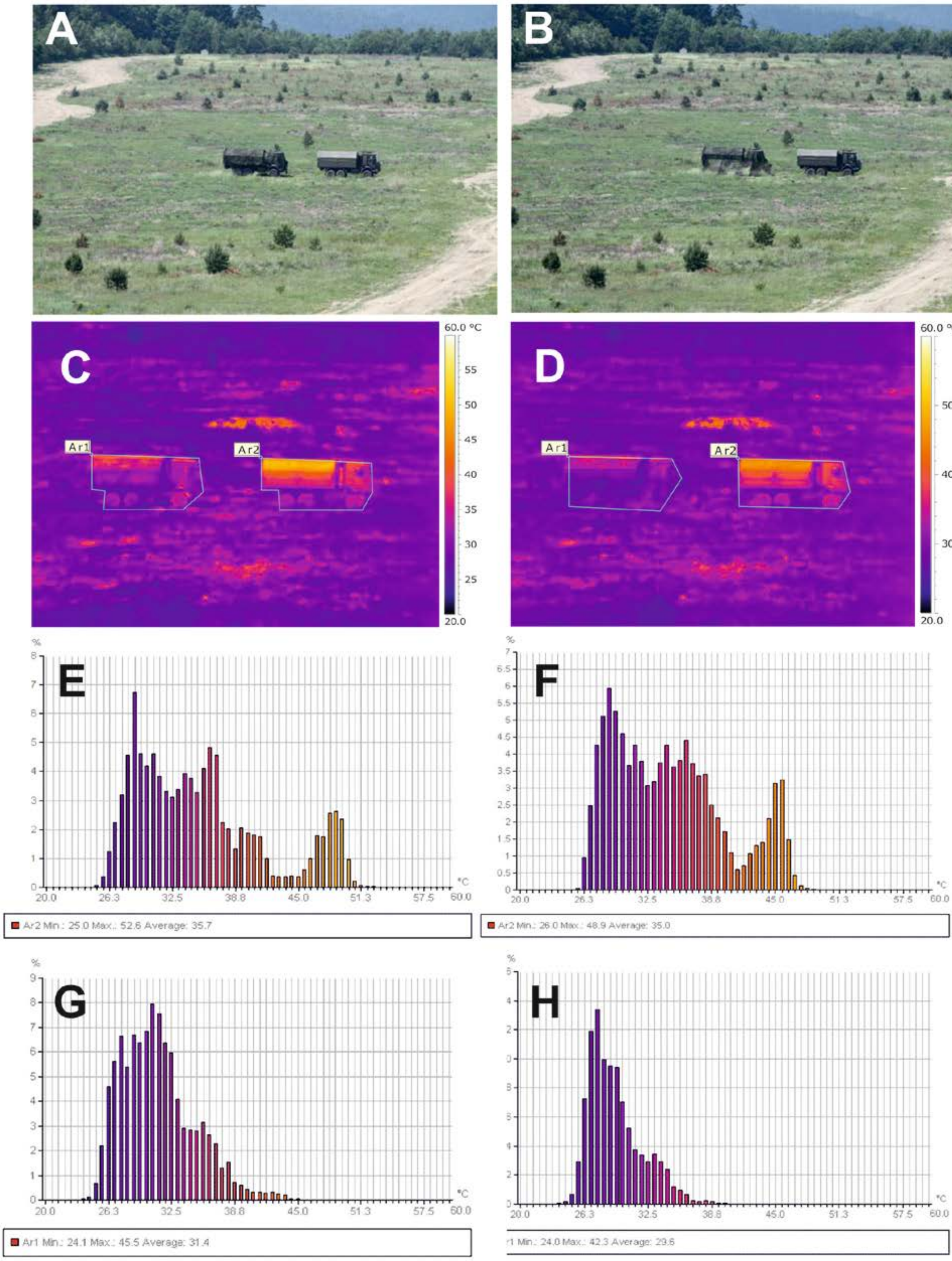

Fig. 4. A) Photograph of truck with mobile mask and unmasked truck. B) Photograph of truck with combined mask and unmasked truck. C) Thermograph of truck with mobile mask and unmasked truck 8-12 µm D) Thermograph of truck with combined mask and unmasked truck 8 -

12 µm. E) Histogram of unmasked truck from measurement C. F) Histogram of unmasked truck from measurement D. G) Histogram of truck with mobile mask. H) Histogram of truck with combined mask.

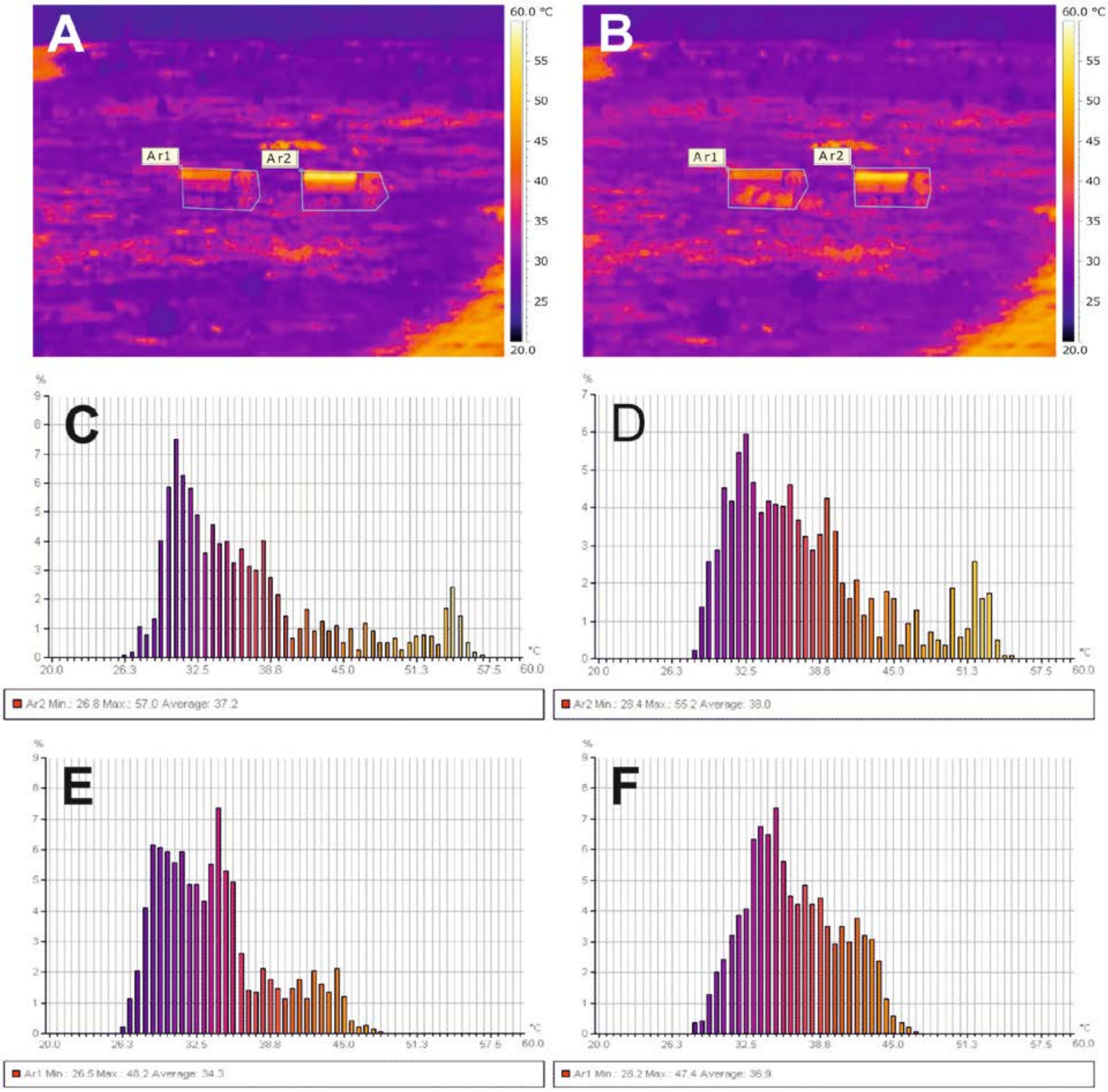

Fig.5. Measurements and evaluation in range 3 – 5 µm. A) Thermograph of truck with mobile mask and unmasked truck 3-5 µm. B) Thermograph of truck with combined mask and unmasked truck 3-5 µm C) Histogram of unmasked truck from measurement A. D) Histogram of unmasked truck from measurement B. G) Histogram of truck with mobile mask. H) Histogram of truck with combined mask.

3.2 Radar measurements

To evaluate the radar measurements known radar cross section (RCS) of a corner reflector was used to calculate RCS of unmasked truck, truck with mobile mask and truck with combined mask. Details on what

RCS is and how it its measured could be found easily in literature, e.g. [3.]. Results obtained on RCS are plotted in Figs. [6.] and [7.] for vertical and horizontal polarization of the radar wave, respectively. Data from unmasked truck confirm the fact that the right side and left side of the vehicle are not identical. RCS of the front is lower than RCS of the sides as expected. RCS of the back is high, however that is not much of a problem because in real life situation the truck crew can choose how to position the truck and the back of the vehicle is not supposed to be exposed.

As expected we see a significant decrease in RCS values for truck with mobile mask for all orientations of the truck. However the lowest values are obtained for the front side. That applies to both vertical and horizontal polarisation. Back side of the truck was not equipped with a combined mask, therefore no values were measured. For the three remaining sides of the truck that were camouflaged with combined mask we see even greater decrease in RCS not even compared to unmasked truck but also compared to truck with only mobile mask. For some orientations of the truck RCS is even lower than 1 m^2.

We can calculate a percentage decrease in RCS according to Eq.1. where σ_{masked} is radar cross section of masked object, $\sigma_{unmasked}$ is radar cross section of unmasked object and RCS_{dec} is a decrease of radar cross section

$$RCS_{decrease} = \frac{\sigma_{masked}}{\sigma_{unmasked}} . 100 \ [\%] \qquad \text{Eq.1.}$$

Calculated decreases of RCS for masked truck relative to unmasked truck for both mobile camouflage and combined camouflage for both polarisations are summarized in Tab.1. The number represents how much the RCS decreases when each type of camouflage is used.

Tab.1. RCS decrease for both types of mask, both polarizations and all position of the truck relative to the unmasked truck.

Vertical [%]			Horizontal [%]		
	Mobile mask	Combined mask		Mobile mask	Combined mask
LEFT	39	99.9	LEFT	63	91
FRONT	73	76	FRONT	87	97
RIGHT	28	98	RIGHT	89	99.9
BACK	84	---	BACK	83	---

Insertion loss could be expressed according to Eq.2. where σ_{masked} is radar cross section of masked object, $\sigma_{unmasked}$ is radar cross section of unmasked object and L_{RCS} is an insertion loss expressed in decibels.

$$L_{RCS} = 10 \log\left(\frac{\sigma_{masked}}{\sigma_{unmasked}}\right) \ [\text{dB}] \qquad \text{Eq.2.}$$

Insertion losses for vertical and horizontal polarization are shown in Fig. [8.] and [9.], respectively. In agreement with values in Figs. [6.] and [7.] we see insertion loss higher for combined mask than for mobile mask only. Highest insertion loss on left side for vertical polarization that is as high as 48 dB. For horizontal polarization the insertion loss is 49 dB but on the right side of the truck. On front side the difference between mobile camouflage and combined camouflage is not so important, but the combined camouflage makes a significant difference on left and right side of the truck.

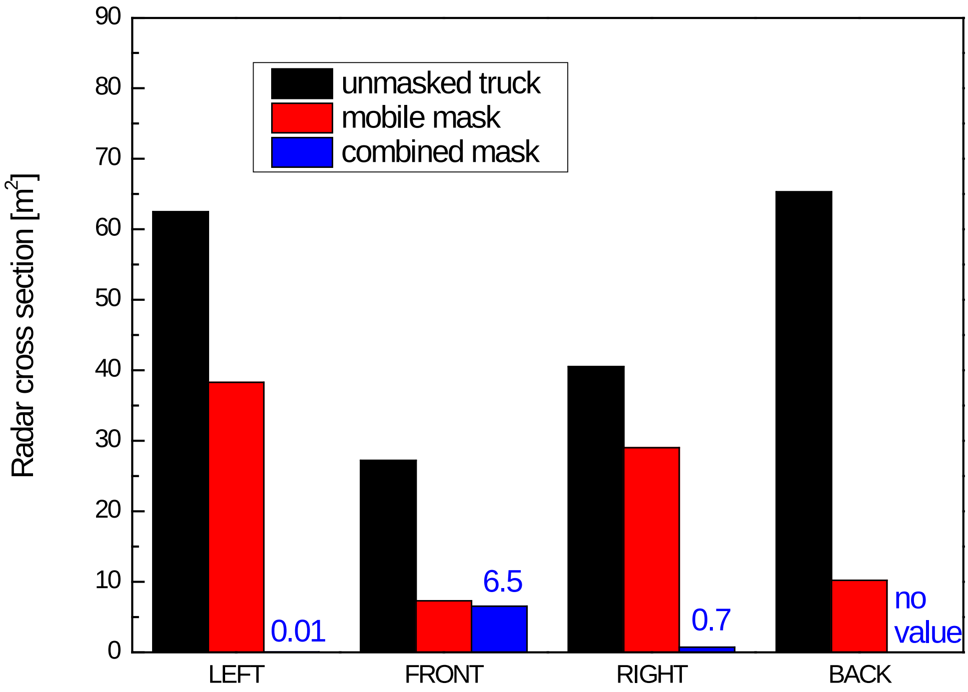

Fig. 6. Comparison of RCS of unmasked truck, truck with mobile mask and truck with combined mask. Measurement performed with vertical polarization of the wave.

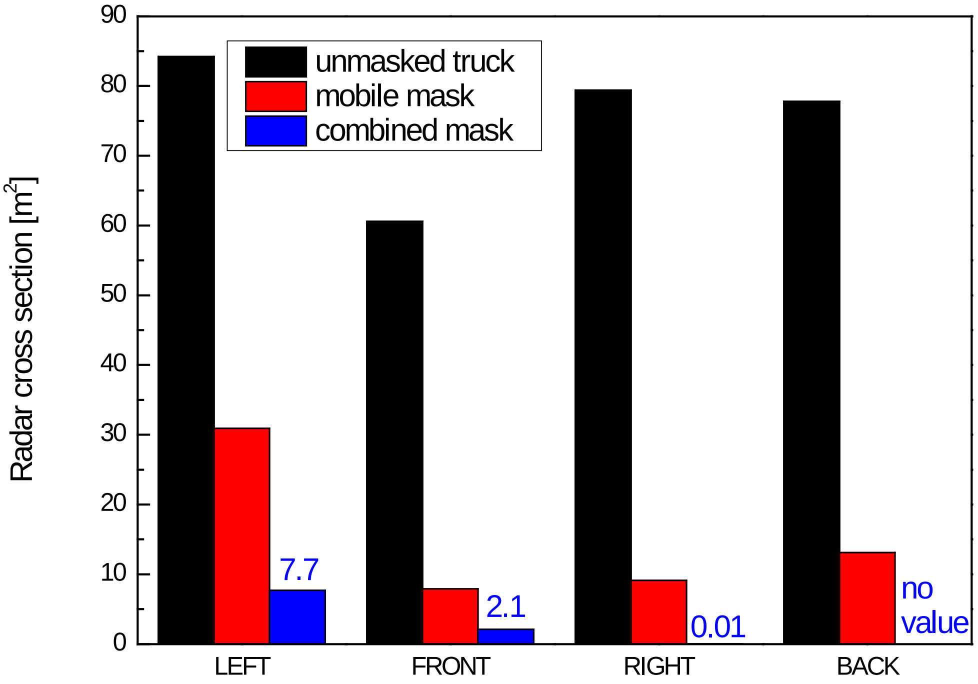

Fig.7. Comparison of RCS of unmasked truck, truck with mobile mask and truck with combined mask. Measurement performed with horizontal polarization of the wave.

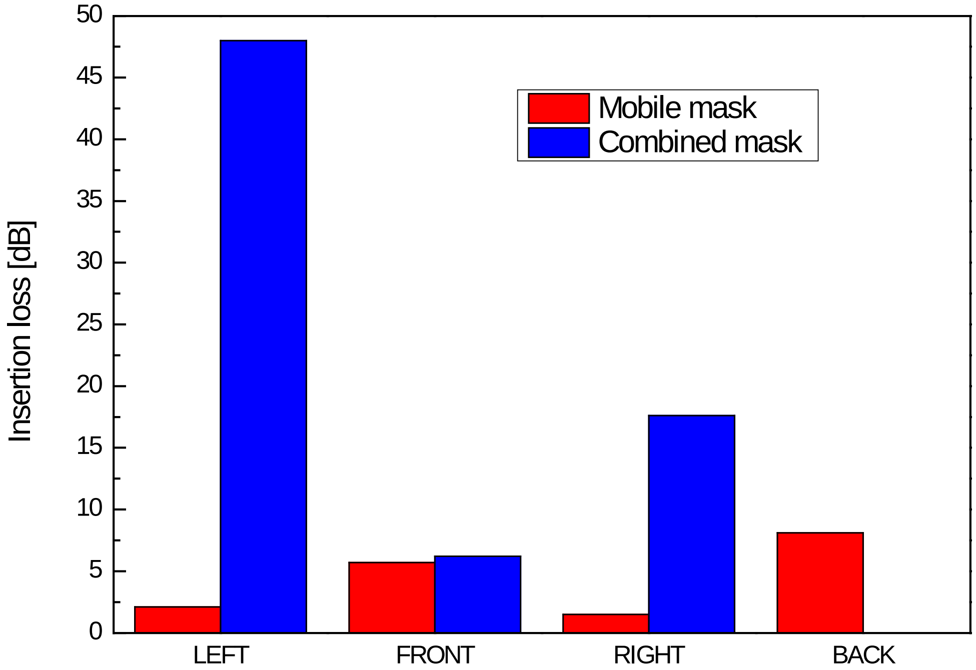

Fig.8. Insertion loss of mobile mask compared to combined mask. Vertical polarization.

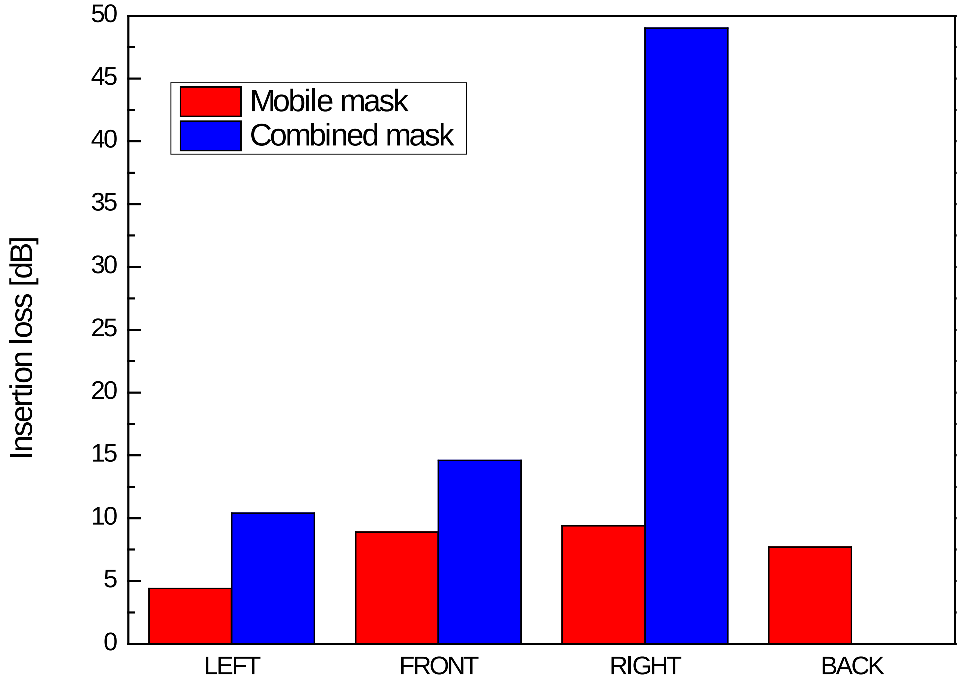

Fig.9. Insertion loss of mobile mask compared to combined mask. Horizontal polarization.

4.0 CONCLUSION

Military support truck Tatra 810 was camouflaged with two different types of camouflage. One is mobile camouflage MM-BF/L. The other is combined camouflage that consists of mobile camouflage supplemented with camouflage net M-BF/L. During a field test both types of camouflage were examined in medium infrared, far infrared and microwave range. Test performed at 9.41 GHz showed that mobile camouflage can cause significant decrease in RCS. RCS could be decreased even further with the use of combined camouflage.

Both types of camouflage also improve infrared signature of the truck in both examined ranges. Usage of combined camouflage was especially successful in 8-12 µm. For the range 3-5 µm the combined camouflage is an improvement compared to an unmasked vehicle, however its use must be carefully considered especially on direct sunlight. Apart from improving infrared and microwave properties the combined camouflage also changes the shape of the vehicle and helps to camouflage the vehicle also in visible range.

Combined camouflage is interesting and simple tool how to improve mobile camouflage system when conditions allow it.

5.0 REFERENCES

[1] https://www.tatra.cz/nakladni-automobily/produktovy-katalog/t-810/

[2] https://www.era.aero/en

[3] Skolnik M. I. *Radar Handbook.* The McGraw-Hill Companies, 2008.