Shielding effectiveness of carbon fiber eoxy at microwave frequencies

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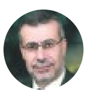

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SHIELDING EFFECTIVENESS OF CARBON FIBER - EPOXY COMPOSITE AT MICROWAVE FREQUENCIES

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ABSTRACT:

This paper reports results of measurements performed on carbon fiber-epoxy composite (unidirectional sample) at microwave frequencies in the X-band (8-12 GHz). These measurements were performed on pure epoxy and 50 wt% composites using one and two specimens with different separating distances between them. The measurements included the insertion loss (IL), the return loss (RL) where the shielding effectiveness (SE) was deduced from both the IL and RL as a function of the frequency. The return loss, insertion loss and shielding effectiveness show relatively low frequency dependence. It was found that the SE value reaches around 12dB for one specimen, and 15 dB for two specimens in contact at 8 GHz. The SE increases to 28 dB when the spacing between the two specimens exceeds 50 mm, at 8 GHz. The two specimen arrangements enhances the SE of this unidirectional composite material compared with one layer case. The results suggest that this carbon fiber-epoxy composite could be used in some micro-wave applications.

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INTRODUCTION:

The shielding capability of a material is very important for the protection of vulnerable communication equipment from unwanted electromagnetic energy(1-3). Recent results in the literature (4-12) indicate that this shielding capability of a material could be enhanced substantially either by incorporating metallic fillers or by using two spaced specimens producing peaks at certain frequencies so as to shield against troublesome transmitters operating at these frequencies.

In the last few years a considerable effort has been put by scientists and engineers to study and improve the properties and quality of new products to meet technology requirements. The recent improvement of the properties of these materials is related to the commercial scenario of polymer/fiber composites in the international markets. For example, uncoated, and metal-coated carbon fibers are used as conducting additives in polymer matrices to produce conductive polymer composites. Furthermore, modifying the carbon fibers sizes and concentrations allows the optimization of reinforcement in a variety of resin systems to achieve the desired electrical conductivity for the product (1,4). So it is important to specify the electrical and mechanical characteristics of the material under different testing conditions and different frequency bands.

The return loss (RL) is the difference between the incident and reflected signal levels, while the insertion loss (IL) is the difference between the incident and the transmitted signal levels (13). The shielding effectiveness (SE) is the attenuation energy of the electromagnetic wave , and the magnitude of the (SE) is proportional to the power (or the energy) ratio between the incident and transmitted electromagnetic wave.

In this paper, the shielding characteristics of epoxy-carbon fiber composite of one and two specimens under spaced arrangement is considered in the microwave frequency range (8-12 GHz), both the insertion loss (IL) and the return loss (RL) were obtained directly and the shielding effectiveness (SE) was determined from these measurements (5).

MATERIALS AND METHODS:

The composite material used in this work is cured epoxy (matrix) with carbon-fiber weight content 0 and 50 wt% as a filler. The epoxy was Epon 828 and the curing agent was V-40. The epoxy and the curing agent were mixed thoroughly and later the required amount of carbon fiber was added. The system was mixed by means of a mechanical stirrer at temperature of 80°C.

The material was poured into a hot mould and pressed at 80C°. The mould was released and compressed successively many times in order to remove the trapped air. Finally the mould was kept under pressure (about 2 tons) in a common heated and cured chamber for 12h at 150C°.
By repeating the preparation procedure , different composites were obtained as sheets of about 2.2 mm thickness with carbon fiber contents of O and 50 wt %.

Specimens (21.9 mm X 11.9 mm X 2.2 mm) were cut carefully from the composite sheet . Measurements were carried out using a conventional microwave bench operating in the X-band with swept frequency source. The specimen was placed perpendicular to the wave guide axis [13] . The transmitted and the reflected signals from the specimen were detected and compared with the incident signal. Special care was taken to reduce the noise and mismatch in the apparatus. Uncertainties in the measurements were reduced by correct matching of the set -up, i.e. reducing the multireflections and disturbances of the wave inside the wavegide to a minimum.

RESULTS AND DISCUSSION:

The shielding capability of a material is determined from the measurements of the reflected, absorbed, and transmitted components of the incident electromagnetic wave. The measurements were performed on one and two composite specimens for different concentrations and separations.

The shielding effectiveness (SE) in decibels (dB), is given by[11].
$SE = A + R + B$ where
A is the energy of the absorbed wave
R is the energy of the reflected wave
B is the energy of the multi-internal reflected waves.
The (SE) is related to the measured quantities as follows [9].

$$SE = 10 \log\left(1 + 10^{(IL-RL)/10}\right)$$

Results of RL, IL and SE are given in a set of curves to help in the assessment of the electromagnetic behavior of this epoxy-carbon fiber composite material.

The measured values of the RL as a function of frequency for one specimen are shown in Fig. 1 which shows that RL increases very slightly with frequency. However, the RL values do not exceed 5 dB for all measurements. For the 50% carbon fiber, the RL decreased to the half of the pure sample because of the filler concentration which provides an excellent attenuation capability for electromagnetic interference.

The obtained values for IL as a function of frequency for one specimen are shown in Fig. 2. which indicates the IL depends on frequency. The observed values for the IL lie between 2 dB for the pure epoxy sample and 13 dB for the 50% carbon specimen: This increase in the attenuation is due to the nature of the structure and the high electrical conductivity of this composite which allows the electromagnetic waves to transmit through the specimen. Furthermore, the filler characteristics (aspect ratio, distribution and particle orientation) play a major role in the attenuation of the electromagnetic waves.

The calculated values for the SE as a function of frequency for one specimen are shown in Fig. 3. The results show a behavior similar to that of the IL because the return loss is small compared to the insertion loss. The maximum value of the SE is about 12 dB at 8 GHz and at 9.5 GHz.

Figure 4 shows The obtained values for the IL as a function of frequency with different spacing for the two specimens with 50 wt% carbon-fiber epoxy. The curves indicate that the IL depends on the frequency although a weak and broadening peaks appear at different frequencies for different spacing. These peaks may be related to the nature of the 50 wt% carbon-fiber epoxy behavior (i.e. contact effect, size and concentration, voids around the fillers). The maximum observed value for the IL is 30 dB at 8 GHz for the 50 mm spacing.

The shielding capability of a given polymer composite can be expressed by the magnitude of its shielding effectiveness (SE) obtained form the measured values of IL and RL.

The variation of the SE as a function of specimen spacing is shown in Fig. 5. The SE is 28 dB for a spacing of 30 mm at 8 GHz. The

SE exhibits oscillatory behavior as a function of frequency for spacing of 10, 20 and 30 mm. From Fig. 4. we see that at 10 GHz, the IL is maximum for 30 mm distance separation, where the average applied wavelength of the incident electromagnetic radiation in the X-band is also about 30 mm. Hence, one can expect that specimens separated by 30 mm can operate as a cavity, in which the incident wave makes multireflections between specimens which cause gradual increases in the insertion loss, resulting in an equivalent enhancement in the observed SE values. This fluctuation is due to an interference effect which takes place between the two specimens.

The behavior in figures 4 and 5 are in agreement with the behavior recently reported for carbon fiber composites in the X-band(11,12).

CONCLUSION

The shielding capability of the epoxy-carbon fiber composite was studied in the X-band and is characterized by its shielding effectiveness (SE) which can be deduced from the measurements of the IL and RL. The IL as well as SE show great dependence on the filler concentration and by using the two-specimens arrangement with appropriate spacing. The value of the SE for the 50 wt% specimens is greater than 28 dB with 50 mm spacing

ملخـــــص:

يقدم هذا التقرير بحث أجري على متراكب الأبوكسي كاربون فايبر في نطاق الترددات الميكروويـة (٨-١٢ ميجا هيرتز). أجريت هذه القياسات على ابوكسي نقـي وعلـى مـتراكب ٥٠٪ باستخدام عينة واحدة وعينتين وعلى مسافات مختلفة. إن فقدان الإدخال وفقدان الرجـوع وفعاليـة الحجب تعتمد اعتمادا قليلا على التردد.

تبين نتائج الدراسة أن فعالية الحجب تصل إلى ١٢ ديسبال لعينة واحدة والى ١٥ ديسبال لعينتيـن متلاصقتين عند ٨ ميجا هيرتز وتصل هذه الفعالية إلى ٢٨ ديسبال عندما تصل المسـافة الفاصلـة إلى ٥٠ م عند ميجا هيرتز. نستنتج من هذه النتائج انه يمكن استخدام مـتراكب الابوكسـي ٥٠٪ هذا في بعض التطبيقات الميكروويـة.

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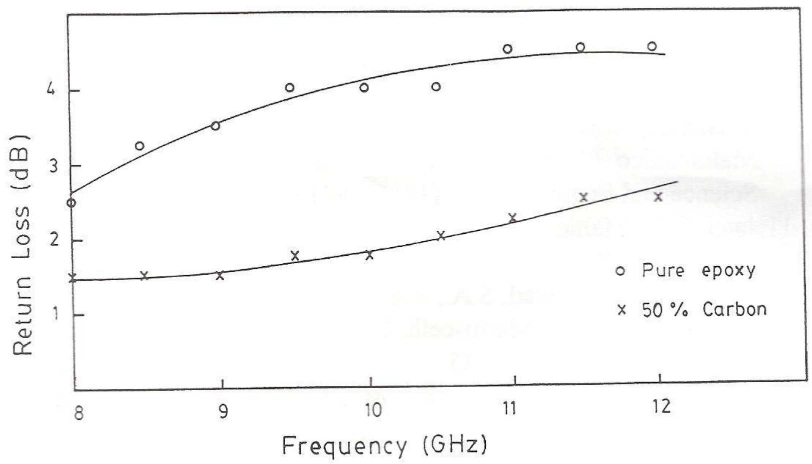

Fig. 1 : Variation of the return loss as a function of frequency for the two specimens case.

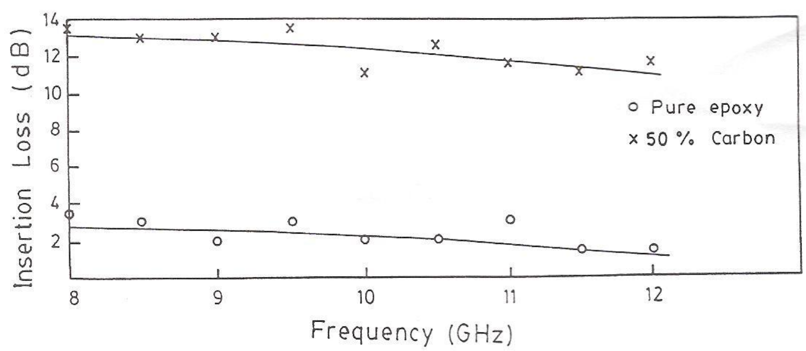

Fig. 2 : Variation of the insertion loss as a function of frequency for the two specimens case.

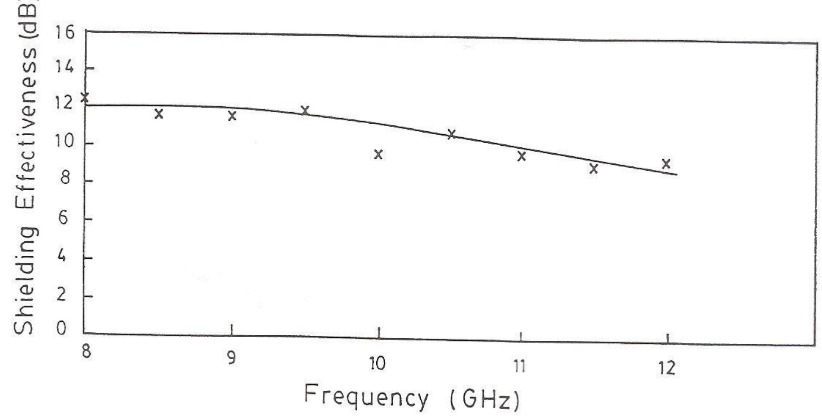

Fig. 3 : Variation of the shielding effectiveness as a function of frequency for the 50 wt% specimen case.

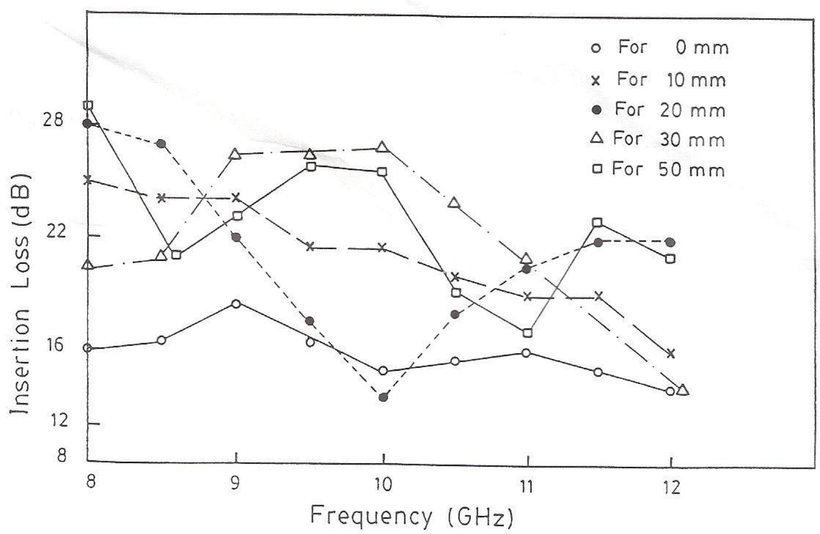

Fig. 4 : Variation of the insertion loss as a function of frequency for the two specimens case with different spacing at 50 wt% carbon fiber concentration.

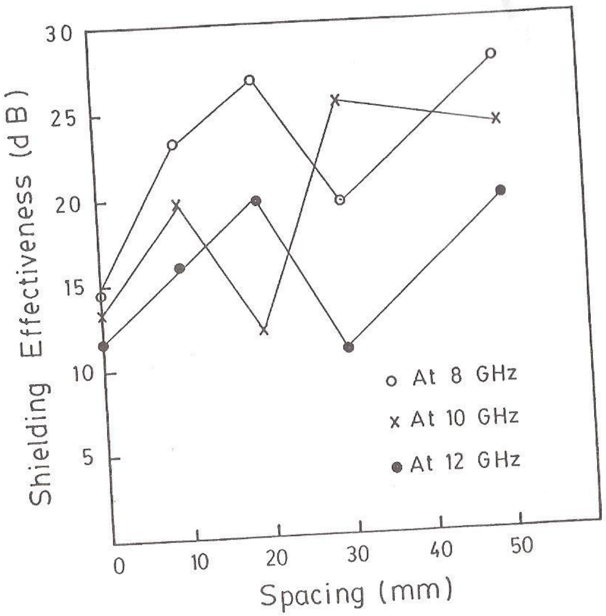

Fig. 5 : Variation of the shielding effectiveness as a function of the spacing between adjacent specimens at 50% wt carbon fiber concentration at different frequencies.