Analysis of a novel EMI shielding technology

Thin, flexible and lightweight, this shielding material made from sintered steel fibers can be used in harsh environments where most EMI shielding materials lose their shielding properties.

DONALD WEBER, P.E.
ElectroMagnetic Engineering Technology
Seattle, WA

ROBERT BONSEN
Orion Scientific
Houston, TX

Engineers have an abundance of options when it comes to controlling and reducing electromagnetic interference in devices. Rather than apply EMI reduction techniques during the initial design stages of a project, engineers often add suppression devices to a prototype design to bring the emission and immunity performance in compliance with the EMC requirements. Passive devices like ferrite cores, absorbing materials, and shielding materials are used to enhance the EMI performance of a product.

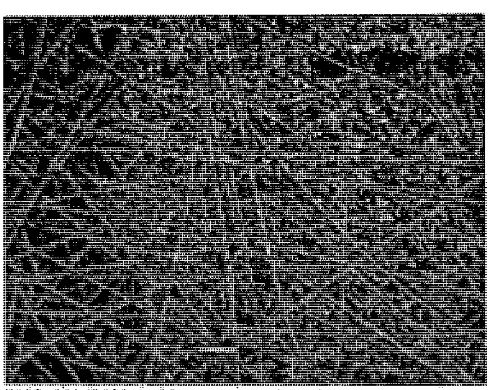

Figure 1. Stainless steel fabric, magnified 100 times.

This article describes the synergy of two existing technologies, a papermaking technology and an electromagnetic shielding technology. The result is a process that has produced a novel and innovative shielding material—sheets made of sintered stainless steel fibers (Figures 1 and 2). The product was primarily developed for shielding applications in electronic devices that require thin, flexible and lightweight, yet robust, materials. Its unique physical properties allow for use in harsh environments where most shielding materials lose their shielding properties over time.

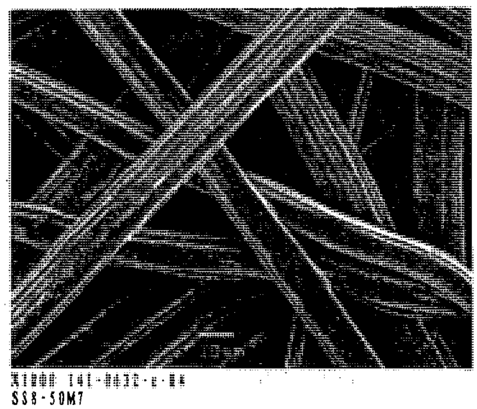

Figure 2. Stainless steel fabric, magnified 1000 times.

MANUFACTURING METHOD

The material, manufactured by Tomoegawa Paper Company of Japan, and distributed in North America by Mitsui & Co., Inc., consists of stainless steel fibers of specific, accurately controlled diameters of 1, 2, 4 or 8 microns, respectively. A modified wet papermaking method is used to manufacture very thin stainless steel sheets of uniform thickness. The fibers are made out of SUS316L (Table 1), equivalent to SAE number 30316L steel, which is a stainless steel material with a very low carbon content. Low carbon content makes steel easier to weld or sinter. During the manufacturing stage, these fibers are immersed in a liquid and stirred to ensure uniform distribution of fibers with random orientation. A sifting mesh run through the liquid forms a thin sheet of fibers. The sheet is then dried and bonded with a temporary binder.

During the sintering process, the sheet of randomly distributed fibers is placed in an oxygen-free atmosphere within a furnace at a temperature of over 1000 degrees Celsius. The temporary binder vaporizes by thermal decomposition, leaving only the stainless steel fibers. Simultaneously, the fibers are melted together at the points where the fibers make contact. As a result, a sheet of paper-thin material consisting of 100% pure stainless steel is produced, with its mechanical and electrical integrity ensured by the sintering process.

MATERIAL PROPERTIES

The mechanical parameters of the material are highly consistent because of the manufacturing techniques employed. The product features a uniform thickness, with consistent fiber density across the sheet. It is lightweight but still maintains good mechanical integrity. It is also pliable and flexible, similar to a very thin sheet of paper or fabric. Currently, the material is being supplied in a cut sheet form. Production of long continuous sheets on rolls is expected in the near future.

The material tested for this article is designated "SS8-50M7". The material is composed of stainless steel fibers with a diameter of 8 micron and has a material weight of 50 grams per square meter. Its mechanical properties are outlined in Table 2. The maximum amount of stretch the material can withstand without deformation is approximately 2.0% of the dimension in the direction of stretching. Since it consists of 100% pure stainless steel, it is heat, corrosion and acid resistant.

The material is highly porous, which makes it suitable for applications in the filtering of air and liquids. Also, adhesives and resins permeate easily between the fibers, a property that solid sheet materials or woven conductive fibers do not exhibit.

Material	SUS316L (SAE# 30316L)
Maximum Carbon Content	0.03%
Chromium Content	16% to 18%
Nickel Content	10% to 14%

Table 1. Stainless steel fiber properties.

SHIELDING EFFECTIVENESS MEASUREMENTS

To assess the suitability of a new material for a specific application, a number of functionality tests must be conducted. For shielding materials, the shielding effectiveness, or insertion loss, is the most important property. Shielding effectiveness is a number, often expressed on a logarithmic scale in decibels. The number represents the attenuation a stray signal undergoes in the presence of the shielding material, compared to a situation in which the shielding material is not present.

To test the shielding effectiveness of the stainless steel sheets, the Boeing Electro-Magnetic Effects Laboratory in Seattle was contracted to perform a series of tests. A setup was devised in which the free-space shielding effectiveness of the new material could be tested. The rationale behind the use of a simulated free-space setup was that free-space attenuation is a generic type of measurement, producing results suitable for comparison with other free-space measurements. To minimize interference to and from the environment, the choice was made to perform these measurements in a completely electromagnetically shielded environment.

SETUP AND PROCEDURE

The test location consisted of two adjacent shielded rooms, with a square opening in the wall which separated the two rooms. The size of the aperture was approximately 50 cm x 50 cm. The transmit antenna was located in one room; the receive antenna was located in the other. Each room contained strategically placed absorber materials behind the antennas and on the side walls to reduce the effect of the standing wave patterns formed inside each shielded room.

A stabilized RF source generated the signal which was wired into the transmit antenna. The receiver, a spectrum analyzer, was connected to the receive antenna. For the electric field measurements, the antennas used were biconical antennas (up to 300 MHz), log-periodic antennas (up to 1 GHz) and horn antennas for the microwave frequency range. For the magnetic field measurements, loop antennas were used. The distance between the phase centers of the two antennas was 1.8 meters (6 feet).

First, a reference measurement was taken through the aperture without the material-under-test in place (Figure 3). This step marked a slight deviation from the traditional

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Property	Typical Value	Applicable Test Method*
Thickness	34 ± 7 µm	JISC 2111
Weight	50 ± 5 g/m^2	JISP 8124
Density	1.5 ± 0.2 g/cm^3	JISP 8118
Tensile strength	3.0 ± 0.06 N/15 mm	JISP 8113
Surface resistivity	0.25 Ω	DC ohm meter

*Test standards applied are Japanese Industrial Standards promulgated by the Japanese Standards Association.

Table 2. Stainless Steel Sheet Properties (SS8-50M7 material).

free-space method, which requires a measurement with as few as possible reflective materials near and between the antennas. However, by taking the reference measurement through the aperture and thus not changing the measurement setup, the insertion loss due to the presence of the material is more accurately assessed. The reference measurement was recorded in the spectrum analyzer as the reference level. The measurement with the shielded material in place was taken relative to the new reference level, and thus directly showed the shielding effectiveness in the readout on the spectrum analyzer.

The test material was then fitted into the aperture between the two rooms and was securely fastened with copper tape which had a conductive glue backing (Figure 4). To verify the electromagnetic seal between the sheet and the shielding of the wall, the receiving antenna was scanned around the opening to determine leakage. Subsequently, data was gathered with the material in place, and the shielding effectiveness was recorded from the spectrum analyzer.

PRESENTATION OF RESULTS

Figures 5 and 6 show the measured shielding effectiveness (insertion loss) for the electric and magnetic field measurements, respectively.

Figure 7 contains additional data gathered to verify the electric field measurements, as well as to gain insight in the low frequency performance of the material. The measurement uncertainty on the low frequency measurements is greater due to the limited effect of the presence of the absorber materials at those frequencies on the formation of standing wave patterns in both shielded rooms and the limited size of the opening between the two shielded rooms.

CONCLUSIONS FROM SE MEASUREMENTS

The new material performs very well over the entire frequency range at which it was tested. As is to be expected, at the low end the performance of the material is primarily determined by the thickness of the sheet. A thicker sheet will have a better shielding effectiveness.

The measurements demonstrate a very high shielding effectiveness even into the microwave frequency region. This result can be attributed to the dense and random distribution of the fibers as well as to the very good conductivity between individual fibers, which is

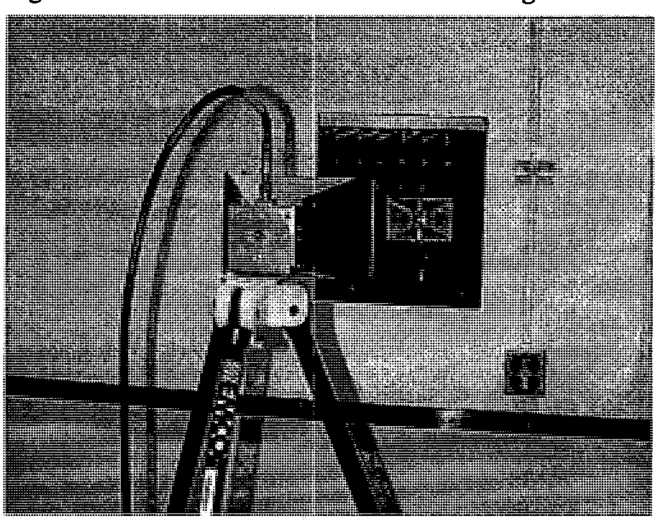

Figure 3. Test setup with horn antenna, reference measurement.

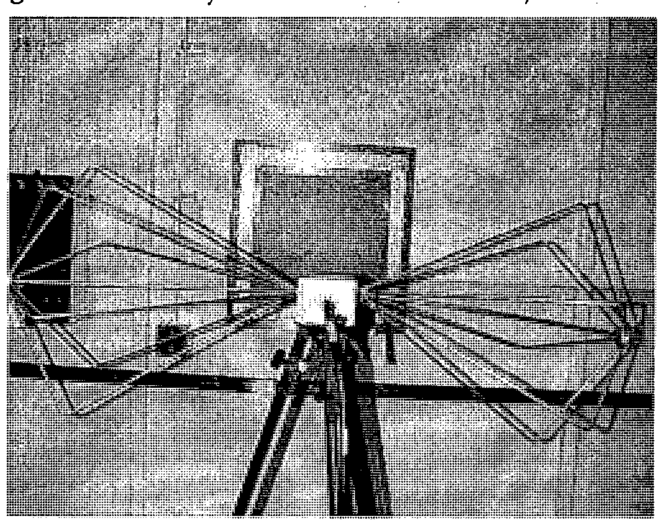

Figure 4. Test setup with biconical antenna, with material in place.

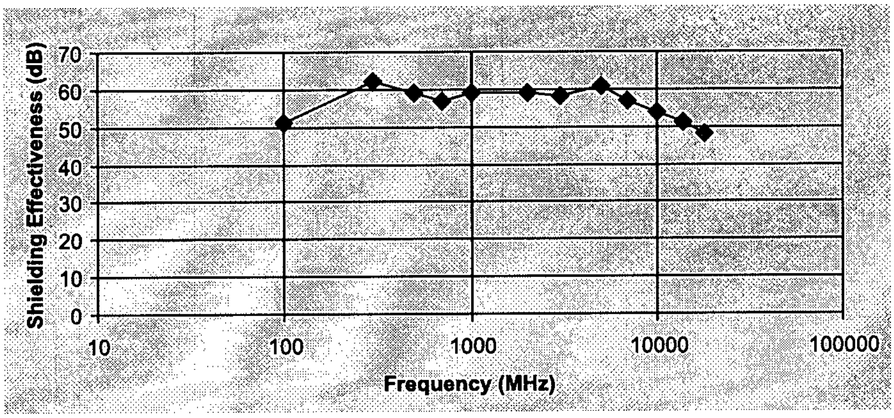

Figure 5. Electric field shielding effectiveness.

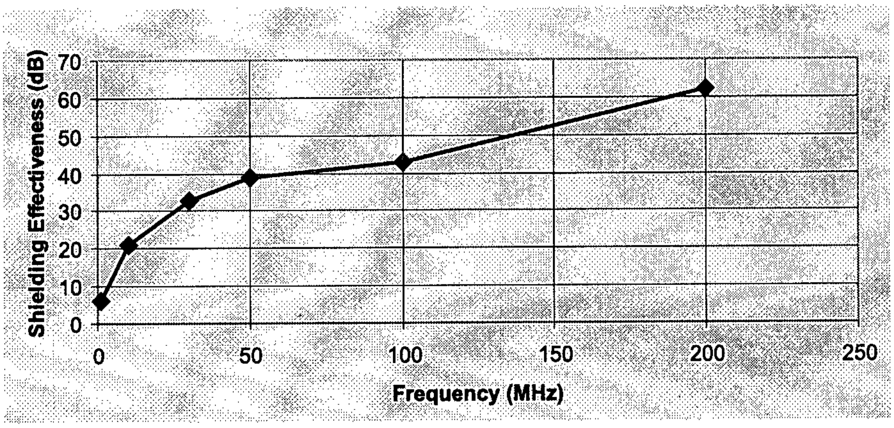

Figure 6. Magnetic field shielding effectiveness.

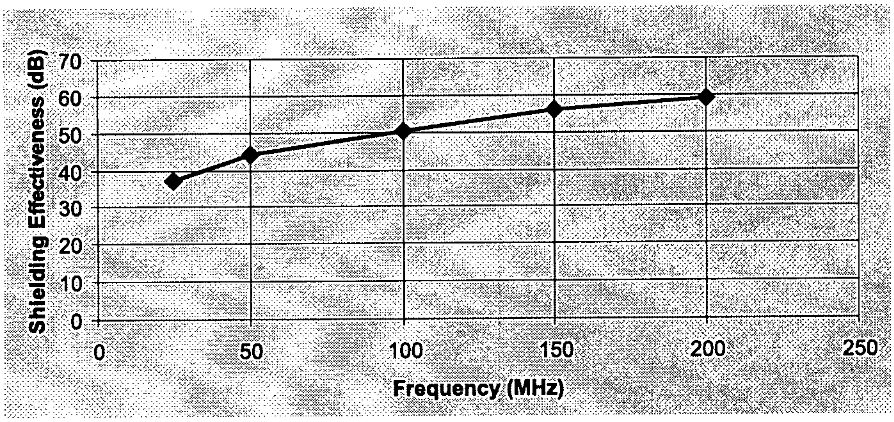

Figure 7. Electric field shielding effectiveness plotted with additional data.

achieved in the sintering process. The measured results suggest a small tapering off of the shielding effectiveness at the highest frequencies measured, which can be attributed at least partially to the method used to mount the material.

The insertion loss measurements show good consistency. A typical variation of less than 1 dB is observed after repeating the entire setup and reference measurement process.

APPLICATIONS

The new manufacturing technique has resulted in the production of a uniformly thick, very thin sheet of material, which has a number of interesting applications. With its paper-like structure, it easily conforms to complex shapes. It can be fixed in place by regular or conductive glue, which permeates easily through the porous fiber material. This quality allows for its use in applications that, until now, have been the sole domain of conductive paints. It is a very suitable replacement material in most shielding applications due to its light weight and strength combined with its extremely high shielding effectiveness.

Following are highlights of some interesting new applications for this novel shielding material. Of course, the application of the stainless steel sheet material is not limited to the examples given below.

PORTABLE ELECTRONICS SHIELDING

The material is designed primarily for use in the shielding of electronic devices. Its low weight, high strength, and high shielding effectiveness make it ideal for portable devices, or devices which have stringent space or weight limitations. For example, in Japan the material has been used to reduce EMI in laptop personal computers by adhering the material to flexible printed circuit boards to enhance the EMI shielding effectiveness.

Applications also include:

- Shielding of non-conductive enclosures, from laptop housings to small processor modules
- Shielding in Personal Communication Devices (because of its high shielding effectiveness at microwave frequencies)
- Cable shielding
- Gaskets

AEROSPACE AND MILITARY APPLICATIONS

Aerospace applications require lightweight materials that can stand up to environmental abuse. Typical applications in this area include:

- Shielding of on-board electronics systems
- Shielding of electronics bays against EMI from personal entertainment and communica-

tion devices in the passenger compartments
- Cable bundle shielding
- Post-installation shielding enhancement and hardening
- Temporary shielded rooms in environmentally harsh environments (TEMPEST)
- TEMPEST shielding of existing off-the-shelf electronics
- Spacecraft reflector antennas using memory alloys in the shape support structure will allow for extremely lightweight antennas with highly accurate deployment.

AUTOMOTIVE

In the automotive industry, weight is an issue but not as much as environmental toughness. The ability of this material to withstand high temperatures, moderate mechanical stress, as well as a humid environment, make it ideally suited for the vehicle environment. Similar applications to those listed for the aerospace industry could be considered.

ARCHITECTURAL SHIELDING

Currently, most shielded rooms and shielded facilities are built with sheet metal, usually galvanized steel. In architectural shielding, rooms and offices are shielded against EMI with aluminum and copper foils. The new stainless steel sheet shielding material is an interesting lightweight alternative to these. A double-insulated layer of the new material will easily outperform existing solutions in terms of weight and shielding effectiveness.

Also, due to its ability to withstand adverse environmental conditions, it can be used to build temporary shielded rooms for outdoor EMI or HIRF testing.

ANTENNAS

The material is ideally suited for use as the parabolic reflector of a large high-frequency reflector antenna system. It is weatherproof, as well as porous, which limits the accumulation of rain water. The use of this material will reduce the need for expensive and cumbersome radomes.

CONCLUSIONS

The stainless steel sheet material is a successful attempt at devising a material which is both extremely light in weight as well as very high in shielding effectiveness. It has many applications, some as a superior replacement for an existing product; some as a novel solution to problems which could not be efficiently solved with existing materials.

DONALD A. WEBER, P.E., is a Principal Consultant at ElectroMagnetic Engineering Technology, Seattle, WA. He has 40 years' experience in EMC Engineering, including analysis, design, and testing of shielding and anechoic test facilities. He is a Registered Professional Engineer and NARTE-certified Senior EMC Engineer. Mr. Weber can be contacted at (206) 431-9002 or dweber@hamiltonengr.com .

ROBERT BONSEN is the Principal Consultant at Orion Scientific, an independent consulting firm in Houston, TX. His responsibilities include EMC design, measurement and mitigation, telecommunication project studies, test facility design and RF design. He holds a M.Sc. degree in Electrical Engineering. His research interests include numerical simulation of EM and EMC problems, HIRF, and antenna and absorber design. He is a member of the IEEE EMC, APS, MTT and CS Societies and the IEEE Standards Association. Mr. Bonsen can be contacted at (877) 360-6636 or RBonsen@OrionScientific.com .

For further information about this new shielding material, contact Mr. Toru Izuta, Mitsui & Co. USA, (206) 223-5440, tizuta@sea.mitsui.com or Ms. Lori Wardenaar, (206) 223-5687, LWarden@sea.mitsui.com. ■

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