

TC-4 Studies Shielding Theory and Practice

By Kermit Phipps, TC-4 Committee Chair

As TC-4 Chair, I would like to announce an official open invitation to anyone who would like to attend this year's meeting that will be held in conjunction with the 2008 IEEE International Symposium on EMC in Detroit.

Just who, or what, is TC-4? TC-4 is the Technical Committee for Interference Control and our official charter is: "This committee is concerned with design, analysis, and modeling techniques useful in suppressing interference or eliminating it at its source. Bonding, grounding, shielding, and filtering are within the jurisdiction of this committee. These activities span efforts at the system, subsystem, and unit levels."

This year, as well as the past several years, we have had a sub-committee for the study of "Shielding Theory and Practice." At this year's symposium, we will have the annual meeting of the sub-committee working group where findings will be discussed and debated. Regrettably, without further participation and involvement from the EMC community as a whole, we may have to close this study with many unanswered questions and unexplored areas of interest. Your attendance and constructive participation is welcomed.

But what is so special this year? With great anticipation, a new subject has brought some renewed interest and participation from many in the EMC community that we are very excited about. We anticipate several presenters on basic theory of transmission line models from Maxwell's equations and actual laboratory measurements of thin film materials. In particular, the group has been reviewing Schelkunoff's 1943 classic equations and has started to look at Leontovich Boundary Conditions. These may explain some unusual conditions of extremely thin film materials and may eventually lead to a mathematical solution for near and far field conditions in a single closed expression.

Interested in Learning More About TC-4 – the Technical Committee for Interference Control?

If so, you are invited to attend this year's meeting that will be held in conjunction with the 2008 IEEE International Symposium on EMC in Detroit. "Drop-ins" are welcome!

Date: Wednesday, August 20, 2008

Time: 12:00 pm - 2:00 pm

Location: Cobo Center (Symposium venue),

Room Number TBD

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Please check the final program of the 2008 IEEE International Symposium on EMC in Detroit to confirm the meeting specifics, including the meeting room number.

Traditionally, Schelkunoff's equation (Equation 1 simplified in the basic expression below) is used universally in teaching and practice throughout the EMC community as a whole.

$$SE = A + R + B$$

Equation 1 – Schelkunoff's shielding equation

The term A represents an absorption loss by the field during a single transient through the boundary of the shield. The R term represents the loss due to the first reflection at both surfaces of the boundary. Finally, the B term is for all other reflections within the boundary. This B term is often neglected due to the extremely small size of the term, except where the A term is found to be less than 10 or 6 dB then the B term must be treated.

Schelkunoff's approach in the development of his theories was to use a basic model, based on a transmission line driven by a generator, which was terminated at the other end with lumped impedance. One should remember that the transmission line model considers the traveling electromagnetic waves to be planar; meaning, it is uniform to the direction of propagation and that the electric field is perpendicular to the magnetic field in the direction of the propagation. Schelkunoff substituted the voltage and current waves associated with the transmission line with transverse electromagnetic fields. From here he derived solutions using Maxwell's equations for the electric and magnetic fields for both surfaces of the shield. He later published these derivations in his text book "Electromagnetic Waves"; [1] and applied these solutions to the three classic problems listed below:

1. **Plane sheet** – exposed to plane waves
2. **Cylindrical shell** – exposed to current fields on the center axis of the cylinder
3. **Spherical shell** – exposed to fields from a loop antenna in its center

So what is special about Schelkunoff's equations? It is basically that shielding effectiveness may be expressed as a single term regardless if the unit is based on electric or magnetic fields (refer to Equations 2, 3, and 4). This is the traditional approach for materials that are of several skin depth thicknesses, are uniform in nature and the measurements are performed in the far field.

$$SE(H) = 20 \log \left[\frac{|H^i|}{|H^t|} \right]$$

Equation 2 – Shielding effectiveness expressed for magnetic fields

$$SE(E) = 20 \log \left[\frac{|E^i|}{|E^t|} \right]$$

Equation 3 – Shielding effectiveness expressed for electric fields

$$SE = SE(H) = SE(E)$$

Equation 4 – Universal shielding effectiveness

Many practicing engineers use this traditional approach. However, the basic problem with using Schelkunoff's equations is the fact that the techniques which are published most are illustrated as planer waves which exist in the far field where the impedance is considered to be that of free space, 377 ohms. More often than not, shielding measurements are made in the near field where the wave impedance is not equal to 377 ohms and the general axiom of $SE = SE(H) = SE(E)$ does not hold up. Figure 1 below illustrates the basic impedance transition region, where these theories hold up, the associated test and the typical measurement approach that is used.

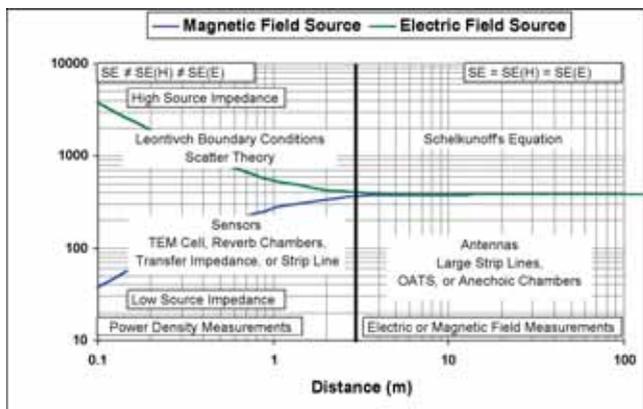


Figure 1: Wave Impedance vs. Distance and Demarcation Point for Near and Far Field Measurements

One key concept that may produce some areas of question and interest is that Schelkunoff based his theories on a continuous shield with single walls, which were made of uniform composition and thickness. As may be seen in Figure 2 below, aluminized plastic film is often times not constructed of a uniform composition or thickness.



Aluminized Surface x 200 Light Passes through Imperfections x 200
Figure 2: Aluminized Plastic Film

We can see under magnification that there is "pitting" in the material and also absence of material which allows light to pass through it. There is an excellent paper by C.L. Holloway, "Reflection and Transmission Properties of a Metalfilm: With an Application to a Controllable Surface Composed of Resonant Particles," *IEEE Transactions on Electromagnetic Compatibility*, vol. 47, no. 4, November 2005, [2] which gives an thorough discussion about metalfilms and their properties.

In 1985, R.L. Monroe introduced the Impedance Boundary Condition which was thought to be an improvement upon Schelkunoff's transmission line model. This approach is often referred to as the Leontovich Boundary Condition and was used by several others during World War II in their work regarding

ground wave propagation. In short, the question as to when and how to use transmission line models or other approaches is not a new question, but one worthy of a closer look.

The intent of the working group is to help identify equations that are practical for a practicing EMC engineer. This engineer would not need a background in advanced mathematics and physics in order to specify correctly the material or shielding effectiveness that may be required.

In conjunction with this study, the working group for IEEE P299.1 has been working on a shielding effectiveness standard for enclosures less than two meters in volume. Some of the members of TC-4 have also been working on this standard. Of particular interest is the use of a strip-line to measure shielding effectiveness for electrically small enclosures with frequencies less than 100 MHz. Refer to Figure 3 below for a generic test setup.

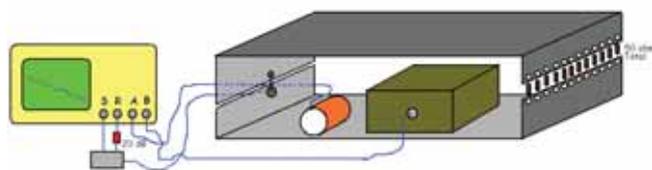


Figure 3: Strip Line Test Setup

Although this method is not a new approach, it has still been employed by some in the shielding theory working group in an attempt to better understand thin film shielding characteristics. Figure 4 below illustrates such a measurement comparing the shielding effectiveness of generic aluminum foil and aluminized plastic film.

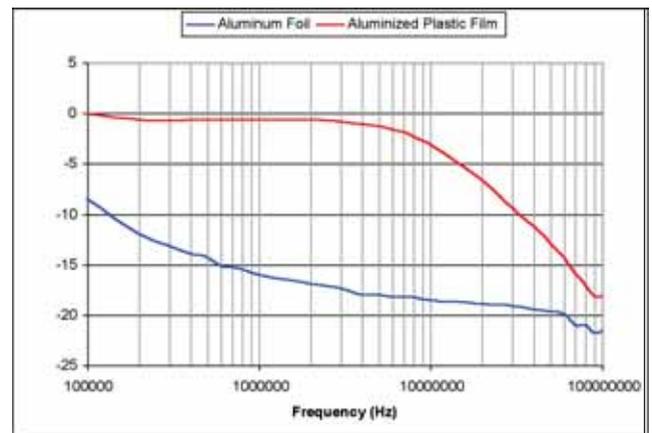


Figure 4: Strip-Line Measurement of Magnetic Field Shielding

As may be seen in Figure 4, there are some unusual attributes of the aluminized plastic film where there is practically no shielding effect at all when compared with aluminum foil. In particular, there is very little shielding from 100 kHz to 10 MHz by the aluminized plastic film. These characteristics and others are expected to be discussed at this year's symposium.

To conclude, I would ask that you feel free to attend the next TC-4 meeting where you will receive a warm and sincere welcome. These meetings will give you the opportunity to participate in the working group activities and/or just to learn or even refresh your background.

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Biography



Kermit O. Phipps is the Senior Power Quality and EMC Specialist at the Electric Power Research Institute, EPRI. Before joining EPRI, he was a Manual Test and Electronic Warfare Specialist in the U. S. Air Force, where he assisted Westinghouse/Bendix engineers in resolving software/hardware deficiencies for a new string of avionics test stations. In his 16 year tenure at EPRI, he has conducted laboratory investigations of electronic ballasts, transient voltage surge suppressors, and uninterruptible power supply hardening, among end-use equipment. His research and testing also focuses on electromagnetic compatibility (EMC), power-line filters, measurements of harmonics and characterization of distribution lines and related impedances. He has been responsible for the development of custom EMC test instrumentation for EPRI's customers. Mr. Phipps has been responsible for characterizing various types of radiated and conducted electromagnetic environments in healthcare facilities and power plants. Mr. Phipps is the author of test plans, protocols, and research papers presented at international power quality and IEEE conferences. He is also a member of the IEEE, and has served in the position of Secretary for six years, Vice-Chair for two years and is currently Chair of the IEEE EMC TC-4 Technical Committee on Interference Control, and served as the chairman of the working group that developed the new IEEE 1560 Standard for Methods of Measurement of Radio Frequency Power Line Interference Filter in the Range of 100 Hz to 10 GHz. Mr. Phipps is a Certified EMC Engineer by NARTE (National Association of Radio and Telecommunications Engineers). Mr. Phipps may be reached at khipps@epri.com.

The set of journals have been ranked according to their SJR and divided into four equal groups, four quartiles. Q1 (green) comprises the quarter of the journals with the highest values, Q2 (yellow) the second highest values, Q3 (orange) the third highest values and Q4 (red) the lowest values. Category. Year. Quartile. Language and Linguistics. 2012. Q3. The chart shows the evolution of the average number of times documents published in a journal in the past two, three and four years have been cited in the current year. The two years line is equivalent to journal impact factor (Thomson Reuters) metric. Cites per document. © 2012 academy publisher. Theory and practice in language studies. 649. common practices, best practices, collaboration, open discussion, incorporating images participants know, metaphors that reveal teaching strategies, assessment options, and step by step practice of new methods will empower the teachers seeking to review and reform curriculum and their own teaching practices. Grammar translation studies can engage students in revising topics, communication practice, role play, and creative writing that can alleviate learner anxiety. Falicov (2009) described cultural attunement that foreign teachers can develop through the study of adaptations, perspectives, values, stressors, and awareness of ethnic minorities within a culture. Shielding Theory. Electromagnetic compatibility (EMC) refers to the inter-relationship between various electrical/electronic systems within a component as well as the relationship between the component and the electromagnetic environment. There are three causes of problems which may occur individually or together This paper describes building theories from case studies. Several aspects of this process are discussed in the literature. For example, Glaser and Strauss (1967) detailed a comparative method for developing grounded theory, Yin (1981, 1984) described the design of case study research, and Miles and Huberman (1984) codified a series of procedures for analyzing qualitative data. However, confusion surrounds the distinctions among qualitative data, inductive logic, and case study research. Also, there is a lack of clarity about the process of actually building theory from cases, especially reg