3.1 Definition of Shielding Effectiveness

The shielding effectiveness (SE) is typically defined as the ratio of the magnitude of the incident electric field, $E_i$, to the magnitude of the transmitted electric field, $E_t$:

$$SE = \frac{|E_i|}{|E_t|}$$

$$SE(dB) = 20 \cdot \log_{10}\left(\frac{E_i}{E_t}\right)$$

The above definition of shielding effectiveness is sometimes referred to as the electric field shielding effectiveness (ESE) since it involves the ratio of electric field amplitudes. Shielding effectiveness can also be defined in terms of the ratio of the incident and transmitted magnetic field amplitudes, which is sometimes referred to the magnetic field shielding effectiveness (MSE). For plane waves and the same media (e.g., air) on both sides of the shield, these two definitions are equivalent (i.e., ESE = MSE).

3.2 Factors that Determine Shielding Effectiveness

There are several factors that determine the effectiveness of an electromagnetic shield. These factors include the following:

1. frequency of the incident electromagnetic field;
2. shield material parameters (conductivity, permeability, and permittivity);
3. shield thickness;
4. type of electromagnetic field source (plane wave, electric field, or magnetic field);
5. distance from the source to the shield;
6. shielding degradation caused by any shield apertures and penetrations; and
7. quality of the bond between metal shield surfaces.

3.3 Electromagnetic Shielding Theory

Electromagnetic fields, in a classical sense, are governed by Maxwell's equations subject to a set of boundary conditions. Schelkunoff [5], using a transmission line analogy, laid out the basic theory for plane wave attenuation through shields. The theory has subsequently been expanded upon by other authors [e.g., 6]. Using Schelkunoff's formulation (which assumes that the shield is located in the far field of the source), the plane wave shielding effectiveness (in \( \text{dB} \)) can be expressed as the sum of an absorption loss (\( A \)) and a reflection loss (\( R \)) plus a multiple reflection correction term (\( B \)):

\[
SE = A + R + B
\]

Electromagnetic shielding processes are shown pictorially in Fig. 3.1. A shield has two boundaries where reflection and transmission of electric (E) and magnetic (H) fields occur. Incident fields are depicted by \( "i" \) subscripts, reflected fields by \( "r" \) subscripts, and transmitted fields by \( "t" \) subscripts. At each air/metal interface, a portion of the field is reflected and the remainder of the field is transmitted. Some of the power is absorbed within the shield. Reflection occurs due to an impedance mismatch. Absorption occurs due to energy losses within the shield material. The boundary conditions, which require the tangential fields to be continuous at the interfaces, determine the magnitude of the reflection and transmission coefficients.

For a good shield, a large portion of the incident field (\( E_i \)) is reflected and only a small portion is transmitted (\( E_t \)). Thus, there is usually a large reflection loss (\( R \)) at the first air/shield interface. The transmitted portion experiences an absorption loss (\( A \)) before encountering the second shield/air interface. A small portion of this field (\( E_t \)) is then transmitted through the shield to the other air medium. If the absorption loss is large, this transmitted portion determines the overall shielding effectiveness of the shield (i.e., \( SE = A + R \)). However, if the absorption loss is small, multiple reflections within the shield can cause a reduction in shielding effectiveness due to the presence of many significant higher order terms (i.e., \( E_{r2t}, E_{r4t}, E_{r6t}, \) etc.) that add vectorially to the transmitted field (\( E_t \)). This reduction in shielding effectiveness due to multiple reflections manifests itself as a large, negative \( B \) term in Eq. 3.2. The absorption, reflection, and multiple reflection correction terms in Eq. 3.2 are dependent upon the impedance of the incident electromagnetic field and/or the characteristics of the shield material as described below.

3.3.1 Absorption Loss

Absorption loss is incurred as the electromagnetic wave penetrates the shield. The amplitude of the electric and magnetic fields decay exponentially due to the