Generalized Analysis Model of Information Security of Computer System Based on Electromagnetic Topology

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***Abstract*—According to the character of the typical serial information leakage and the feature in the information leakage problem that multiple points(zone) converge and couple toward one point(zone), several key concepts, such as the emission zone, transmission zone and receiving zone, are defined in this paper. Based on the idea of electromagnetic topology, a completely new construction method of system topological graph is proposed. Then, this method is applied to analyze a simplified serial information leakage system, the generalized transmission coupling model is also established. What's more, the modeling process of field-to-field coupling is discussed emphatically. Therefore a solid foundation is laid for the electromagnetic topology analysis of serial information leakage.**

Keywords-computer system; serial information; radiation leakage; Electromagnetic Topology

I. INTRODUCTION

VARIOUS serial information in computer systems exists severe safety hidden danger of radiation leakage, correspondingly, the technique on radiation leakage suppression of computer information becomes the key research content of computer information security. In a practical computer system , a great many shielding structures have numerous coupling paths such as aperture , display window, joint slot and many modules which like power, CD-ROM, hard disk and so on, have metal shell themselves except metal mainframe-box. All of them will couple with each other, so it is rather miscellaneous to analyze. Therefore it is very important to set a standard and unified analysis model to the system which exists many electromagnetic coupling approaches and layered shielding structures.

Electromagnetic Topology [1][2] is a method which combines Electromagnetic theory with topological graph theory in Mathematics. Its essential points lies in how to express the coupling regimes and coupling paths which exist in complicated coupling problems by means of the point and directed line segment in topological graph theory. What's more, the system to be studied could be decomposed according to the relationship between point and line which is expressed by topological graph. Then the complicated Electromagnetic Interference problems could be separated into a group of relatively independent, easy to solve and smaller problem to deal with, and then what we should do is to integrate them.

II. CHARACTERISTICS OF INFORMATION RADIATION LEAKAGE IN COMPUTER SYSTEM

Serial information such as Video, RS232 is the main source of information leakage in computer system, therefore the radiation leakage elements of system are concentrated on circuit and structures relating to this type of information. In this paper, Video information will be taken for example to analyze the leakage structure of computer system. A simplified computer system structure is shown in Fig.1. Dotted portion is a zone where Video information to be treated and transmitted, which can be regarded as multiple distributed source of leakage. Electromagnetic shielding structures of system have the shielding characteristics of multi-layer/multi-regional isolation. In addition, all these shielding structures have multiple leakage ways such as aperture, display window, joint slot and so on. Therefore the information radiation leakage in computer system belongs to the typical multi-leakage source of electromagnetic leakage problem which has complicated layered shielding structure and coexisting a variety of electromagnetic coupling ways

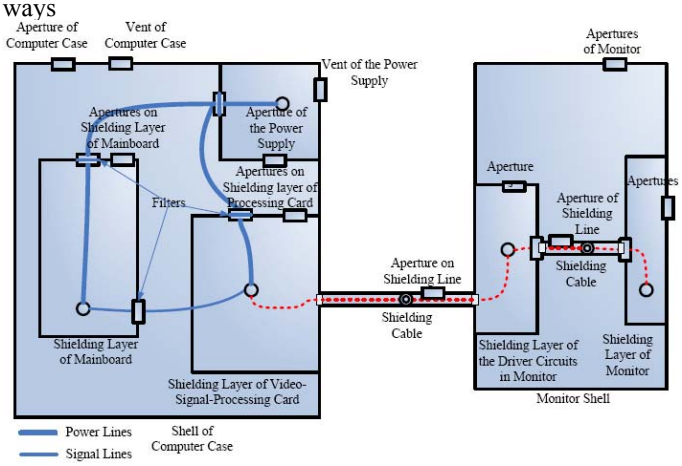

Figure1. Construction of shielded computer system

III. SYSTEM TOPOLOGY GRAPH CONSTRUCTION BASED ON INFORMATION LEAKAGE

978-0-7695-3744-3/09 $25.00 © 2009 IEEE
DOI 10.1109/IAS.2009.306

This paper is based on the characteristics of information leakage, according to the characteristic that multiple points(zone) converge and couple toward one point(zone), introducing the concepts of **Emission Zone**, **Transmission Zone** and **Receiving Zone** ,proposing a completely new construction method of system topological graph, as is shown in Fig.2.Corresponding topological volume should be firstly defined, and the construction process of the system topological graph which based on red information leakage should be given.

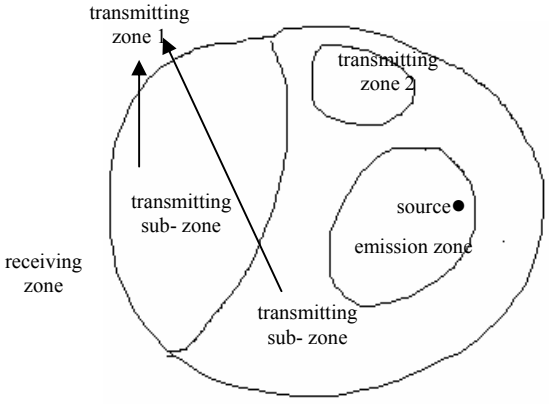

Figure 2. Emission, transmitting and receiving zone graph

Definition1: The zone which is surrounded by shielding layer, including leakage signal source, and the shielding layer is nearest to the signal source. This zone is known as **Emission Zone**, which is signed as Z_{sm}, representing the m-th emission zone.

Definition 2: The zone receiving signal is known as **Receiving Zone**, which is represented by Z_R.

Definition 3: The set which is composed of some non-receiving zones meeting the following conditions is known as **Transmission Zone**.

- Does not contain any red signal source or contain non-transmission zone of red signal source.
- From the transmission zone which has the most shielding layers (compared with receiving zone), the least layer number must be equal when reaches these regions respectively.

Definition 4: In the definition 3, each part of region which composes transmission zone is known as Transmission Sub-Zone, which is signed as Z_T, representing the k-th transmission zone's l-th transmission sub-zone. ($l = 1,2,\ldots l_{max}$)

Definition 5: On the above definitions, the shielding layer between any two zones is known as interface which is represented by SL .For example $SL_{Sm;Tkl}$ represents the interface between transmission zone Z_{Sm} and transmission sub-zone Z_T.

General process of information leakage is **emission zone → transmission zone →receiving zone**.It can be divided for any given computer system by means of the above ways.

IV. THE MODEL OF ELECTROMAGNETIC LEAKAGE TOPOLOGY SEQUENCE USING THE TEMPLATE

Without loss of generality, a simplified information leakage system is used to establish the electromagnetic leakage topology model in this paper. The systematic diagram is shown in Fig.3.

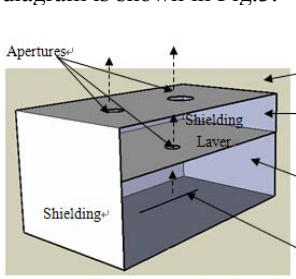

Figure 3. Simplified Signal Leakage System

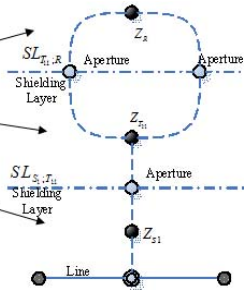

Figure 4. Electromagnetic Leakage Sequence Diagram

This system includes an emission zone, a transmission zone and a acceptance zone, the emission zone has an information source, the signal will generate radiation information to the external environment when it transmits in the cable.

According to the topology graph construction method in the 3rd section, by applying the binary relation of point-to-zone and line-to-path in graph theory, combining with the practical electromagnetic leakage pathway, then we will get the electromagnetic leakage sequence graph of Fig. 4.However,for the cable, we model it simply here because there is no classification of zone and interface, we use L_1 and L_2 to number the points of cable in sequence. In Fig.4, ○ represents shielding layer; ◎ represents Emission source of signal where exists field-to-line coupling or line-to-field coupling, ---- represents the signal leakage path from one zone to another.

This sequence diagram reflects the binary relations of different zones with the points or zones of the interface. But it can not reflects the relation of multi-pathway coupling of the practical system, at the same time it can not decide the energy type of each point or each zone (such as the difference of transmission/field quantity or incident quantity/reflecting quantity) and can not be decomposed conveniently.

So a naming norm for the coupling path is given as follows:

Definition 6: path naming, $P_m^{\mu,n}$ **:** it represents the incident/reflecting spatial sub-path of the μ-th branch-path of the m-th path. For n=1, it is the sub-path of the incident space; for n=2, it's the sub-path of the transmission space.

Definition 7: field quantity naming, we divide the variable of each point into space field and conducted quantity of the line, for example, V_E^i and V_E^r represent the incident quantity and reflecting quantity of the space field and V_L^i and V_L^r represent the incident quantity and reflecting quantity of the line respectively. For the space field, it can

be divided into zone field quantity and interconnection shielding layer field quantity, V_{EZ}^{r} and V_{EZ}^{i} represent the reflecting quantity and incident quantity of zone field and V_{ESL}^{r} and V_{ESL}^{i} represent the reflecting quantity and incident quantity of shielding layer field.

Based on the above naming modes, the leakage sequence diagram of considering coupling path and field quantity distinguish respectively are shown in Fig.5.

V. THE SYSTEM MODEL OF THE INFORMATION LEAKAGE AND COUPLING

The leakage of the information source toward the receiving zone is by means of the following three coupling methods which are field-to-field[3] coupling, field-to-line[4] coupling and line-to-line coupling. In these three methods, both line-to-line coupling and field-to-line coupling can apply the transmission line theory directly or indirectly to equivalent modeling, using the naming norm in this paper, and the analysis is skipped here. The modeling process of field-to-field coupling is discussed emphatically and the unified model of equivalent transmission line is built in the end.

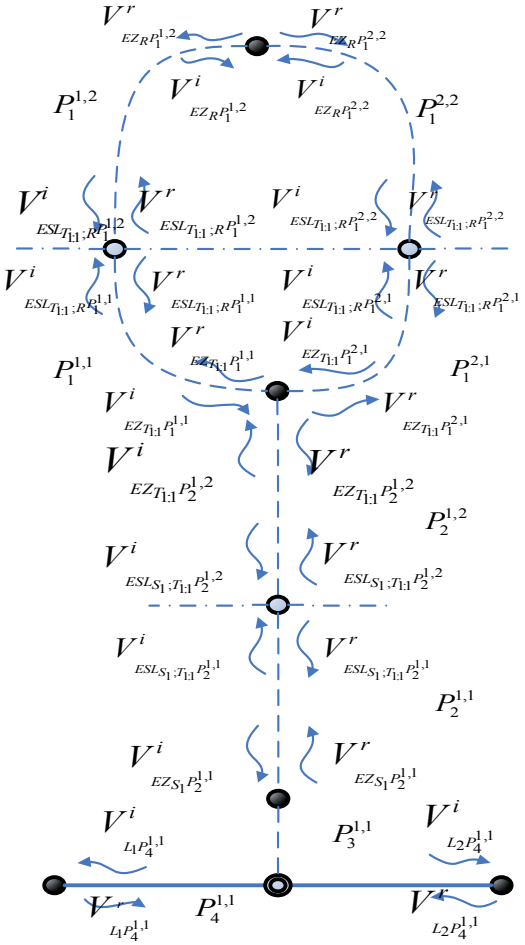

Figure 5 Multi-pathway Field Qualities in Electromagnetic Leakage Sequence Diagram

For the field-to-field coupling mode which has space electromagnetic energy transmission of the shielding. Due to the fact that the wave impedance of the propagation space is mismatched with the characteristic impedance of the shielding, incidence, reflection and transmission is generated on the shielding layer. The basic characteristics of transmission coupling depends on whether the impedance of the beginning of transmission and the end of transmission is matched with he characteristic impedance of the transmission or not. Both of them have the similar description relationship and characteristic equation. Therefore, the field-to-field coupling with the shielding layer can be modeled equivalently by the transmission line theory.

For the single coupling line, the width of the shielding layer will be equivalent to zero, it will become a two-port network, and there are n lines on the same shielding layer, so it will form n parallel two-port network.

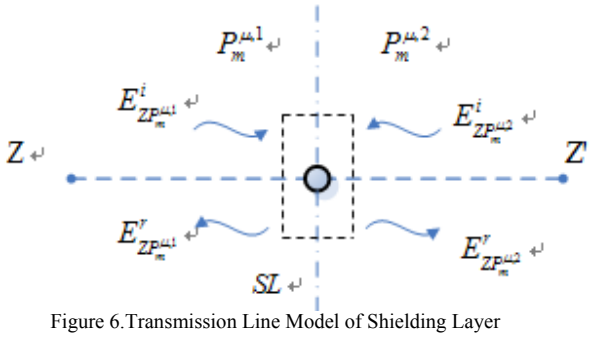

Figure 6.Transmission Line Model of Shielding Layer

The symbols' definition of the parameters in the above diagram meet the variable naming norm which is described in the 3rd section of this paper. For instance $E_{SLP_m^{\mu n}}^{r}$ represents that the incident quantity/reflecting quantity of the incident/transmitting space sub-path (n=1) of the μ -th branch path of the m-th primary path on the shielding layer .

According to the two port network theory, the formula can be written as:

$$\begin{Bmatrix} E_{ZP_m^{\mu,1}}^{r} \\ E_{Z'P_m^{\mu,2}}^{r} \end{Bmatrix} = (S) \begin{Bmatrix} E_{ZP_m^{\mu,1}}^{i} \\ E_{Z'P_m^{\mu,2}}^{i} \end{Bmatrix} = \begin{pmatrix} S_{11} S_{12} \\ S_{21} S_{22} \end{pmatrix} \begin{Bmatrix} E_{ZP_m^{\mu,1}}^{i} \\ E_{Z'P_m^{\mu,2}}^{i} \end{Bmatrix} \quad (1)$$

From the shielding theory, the electromagnetic wave propagate from the incident space Z to the transmission space Z', when the shielding efficiency is calculated the incident field quantity will be set to zero which is accorded with the matched condition[5] of the two port network. There are

$$S_{21} = \frac{E_{Z'P_m^{\mu,2}}^{r}}{E_{ZP_m^{\mu,1}}^{i}} \quad (2)$$

Similarly

$$S_{11} = \frac{E_{ZP_m^{\mu,1}}^{r}}{E_{ZP_m^{\mu,1}}^{i}} \quad (3)$$

According to the definition of the shielding efficiency:

$$\mathrm{SE}=20\lg\left(\frac{1}{S_{21}}\right)=20\lg\frac{E^{i}_{ZP_m^{\mu,1}}}{E^{r}_{Z'P_m^{\mu,2}}}=SE_{SLP_m^{\mu}} \quad (4)$$

Then

$$S_{21}=10^{-\frac{SE_{SLP_m^{\mu}}}{20}} \quad (5)$$

S_{11} is the reflection coefficient of the incident space Z:

$$\begin{cases}\rho_{SLP_m^{\mu,1}}=\mathrm{S}_{11}=\dfrac{E^{r}_{ZP_m^{\mu,1}}}{E^{i}_{ZP_m^{\mu,1}}}\\ \rho_{SLP_m^{\mu,2}}=\mathrm{S}_{22}=\dfrac{E^{r}_{ZP_m^{\mu,2}}}{E^{i}_{ZP_m^{\mu,2}}}\end{cases} \quad (6)$$

Similarly, S_{12} and S_{22} can be obtained. According to the reciprocity of the shielding $S_{12}=S_{21}$ .Obviously, $\mathrm{SE}_{SLP_m^{\mu}}$ represents shielding efficiency of the μ-th branch path of the m-th primary path on the shielding layer SL, SL is $(T_{k,l}/S_m/R):(T_{k',l'}/S_{m'}/R)$; $\rho_{SLP_m^{\mu,n}}$ represents the reflection coefficient of incident space(n=1)/transmission(n=2) space of the μ-th branch path of the m-th primary path on the shielding layer SL.

$$\begin{Bmatrix}E^{r}_{ZP_m^{\mu,1}}\\ E^{r}_{Z'P_m^{\mu,2}}\end{Bmatrix}=\begin{pmatrix}\rho_{SLP_m^{\mu,1}} & 10^{-\frac{SE_{SLP_m^{\mu}}}{20}}\\ 10^{-\frac{SE_{SLP_m^{\mu}}}{20}} & \rho_{SLP_m^{\mu,2}}\end{pmatrix}\begin{Bmatrix}E^{i}_{ZP_m^{\mu,1}}\\ E^{i}_{Z'P_m^{\mu,2}}\end{Bmatrix} \quad (7)$$

The (7) obtains the [S] parameter which is got by relating shielding efficiency with the reflection coefficient; obviously, we can use the above formulas to calculate after the meaning of the [S] parameter is determined. For convenience, all of the above incident variables and reflecting variables are represented by V^r and V^i respectively, then the general formula can be gotten as follows:

$$\{V^r\}=[S]\{V^i\} \quad (8)$$

However, the variables in the (8) are only the field on the shielding layer, but the model in the 4th section, where the radiation field quantity reaches the shielding layer after partly attenuation in the propagating, so here the propagation equation is represented as (9).

$$\{V^r\}=[\Gamma]\{V^i\}+\{S_s\} \quad (9)$$

In the above formulas, $[\Gamma]$ is the attenuation matrix, $\{S_s\}$ is the source vector.

According to (8) and (9) ,the field-to-field coupling can also be modeled equivalently by applying the basic transmission line equation. Integrated a forementioned field-to-line and line-to-line modeling, we can get the result that the process of the interference and coupling of the information leakage can be unified into the category of the transmission line.

VI. SUMMARY

This paper first gives the harmfulness of radiation leakage in computer system and introduces the analysis model of electromagnetic topology according to the multi-layer shielding characteristics of computer system. For multi-layer shielding system, it is important to make use of computer in most cases because of its complexity. Therefore the unified level division and name is necessary. This paper gives a set of complete method of space as well as variable name according to the characteristics that the information radiation leakage is from internal to external.

Due to the fact that the main ways of the radiation leakage in computer system include three ways: line-to-line coupling, line-to-field coupling and field-to-field coupling. Among these ways, both line-to-line coupling and line-to-field coupling can model by means of transmission equivalent model, while line-to-field coupling is similar to the transmission line equation in form of formula. So the there models can be united using the transmission equation. To sum up, a set of modeling methods based on the generalized model of radiation leakage in computer system are established in this paper.

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