



# The Most Referenced IEEE Transactions on EMC Papers of the EMC Society

**Daniel D. Hoolihan,**  
Chairman, EMC Society 50th Anniversary Committee  
and the History Committee



## INTRODUCTION

As part of the 50th Anniversary Celebration of the EMC Society of the IEEE, a review and comparison of past papers in the *IEEE Transactions on Electromagnetic Compatibility* (EMC) was undertaken. Discussions with other members of the 50th Anniversary Committee plus some individual deliberations with my inner-self convinced me to do a thorough and tedious cross-comparison of references of *IEEE Transactions on EMC* papers by other *IEEE Transactions on EMC* papers. In other words, keeping track of how many times an earlier IEEE Transactions article was referenced by later Transactions articles would lead to an objective valuation of the earlier article.

## DETAILS

Over a period of months, the author of this article laboriously pored through the stack of older *IEEE Transactions on EMC* (including the Institute of Radio Engineers Transactions on Radio Frequency Interference – 1959-1962 and the *IEEE Transactions on Radio Frequency Interference* – 1963). By slowly compiling the number of times an article was referenced, a prioritized list of the “Most Referenced” *IEEE Transactions on EMC* was generated.

Since it seemed unfair to me that an article that was written forty years ago could be compared to an article written four years ago, I decided to generate two lists: one list was the most referenced article in the past 50 years and a second list was the most referenced article in the last 25 years of the Society. I thought this was fair to the most recently written articles, which hadn’t had as much time to accumulate cross-references from later *IEEE Transactions on EMC* papers.

## THE FIFTY YEARS: “Most Referenced” IEEE Transactions on EMC Papers

The top paper was a surprise since it was written by a series of authors, A.K. Agrawal, H.J. Price, and S. H. Gurbaxani that were not well known in the EMC Society. This was also true of the second most-referenced paper (by Gerrit Mur), but the third and fourth most-referenced papers were by two people well known in the EMC Society of today: Myron Crawford and Clayton Paul!

Other familiar names in the remaining top ten papers included David Hill, Mark Ma, A.R. Ondrejka, B.F. Riddle, Robert Johnk, Henning Harmuth, J.G. Costas, B. Boverie, Al Smith, Jr., Bob German and J.B. Pate.

## Final Top Ten IEEE Transactions on EMC - Papers Referenced by Other IEEE Transactions on EMC Papers – 50 Years of EMC Society History 1957-2007

A list of the “Most Referenced” papers in the last 50 years (1983 – June, 2007) is shown below.

No. of Times Referenced	Author(s)	Title of Paper
75	Agrawal, A. K. Price, H. J. Gurbaxani, S. H.	“Transient Response of Multiconductor Transmission Lines Excited by a Nonuniform Electromagnetic Field;” EMC-22, No. 2, May – 1980, Page 119.
38	Mur, G.	“Absorbing Boundary Conditions for the Finite- Difference Approximation of the Time-Domain Electromagnetic Field Equations,” EMC-23, No. 4, November – 1981, Page 377.
36	Crawford, M. L.	“Generation of Standard Electromagnetic Fields Using TEM Transmission Cells,” EMC-16, No. 4, November – 1974, Page 189.
33	Paul, C. R.	“Frequency Response of Multiconductor Transmission Lines Illuminated by an Electromagnetic Field,” EMC-18, No. 4, November – 1976, Page 183.
30	Kostas, J.G	“Statistical Model for a Mode-Stirred Chamber,” Boverie, B. Volume 33, No. 4, November – 1991, Page 366.
28	Harmuth, H. F.	“Correction of Maxwell’s Equations for Signals I” EMC-28, No. 4, November – 1986, Page 250.
27	Hill, D.A. Ma, M.T. Ondrejka, A.R. Riddle, B.F. Crawford, M.L. Johnk, R.T.	“Aperture Excitation of Electrically Large, Lossy Cavities,” Volume 36, No. 3, August – 1994, Page 169.

25	Hill, D.A.	“Plane Wave Integral Representation for Fields in Reverberation Chambers,” Volume 40, No. 3, August-1998, Page 209.
22	Harmuth, H. F.	“Correction of Maxwell’s Equations for Signals II;” Volume EMC-28, No. 4, November – 1986, Page 259.
22	Hill, D.A.	“Electronic Mode Stirring for Reverberation Chambers,” Volume 36, No. 4, November – 1994, Page 294.
20	Smith, Jr., A.A. German, R.F. Pate, J.B.	“Calculation of Site Attenuation from Antenna Factors,” Volume EMC-24, No. 3, August – 1982, Page 301.

### Final Top Ten IEEE Transactions on EMC - Papers Referenced by Other IEEE Transactions on EMC Papers – 25 Years of EMC Society History 1983-2007

A list of the “Most Referenced” papers in the last 25 years (1983 – June, 2007) is shown below.

No. of Times Referenced	Author(s)	Title
30*	Kostas, J.G Boverie, B.	“Statistical Model for a Mode-Stirred Chamber,” Volume 33, No. 4, November – 1991, Page 366.
28*	Harmuth, H. F.	“Correction of Maxwell’s Equations for Signals I;” EMC-28, No. 4, November – 1986, Page 250.
28*	Hill, D.A. Ma, M.T. Ondrejka, A.R. Riddle, B.F. Crawford, M.L. Johnk, R.T.	“Aperture Excitation of Electrically Large, Lossy Cavities,” Volume 36, No. 3, August – 1994, Page 169.
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22*	Hill, D.A.	“Electronic Mode Stirring for Reverberation Chambers,” Volume 36, No. 4, November – 1994, Page 294.
19	Robinson, M.P. Benson, T.M. Christopoulos, C. Dawson, J.F. Ganley, M.D. Marvin, A.C. Porter, S.J. Thomas, D.W.P.	“Analytical Formulation for the Shielding Effectiveness of Enclosures with Apertures,” Volume 40, No. 3, August – 1998, Page 240.
19	Kami, Y. Sato, R.	“Circuit Concept Approach to Externally Excited Transmission Lines,” Volume EMC-27, No. 4, November – 1985, Page 177.
18	Schulz, R.B. Plantz, V.C. Brush, D.R.	“Shielding Theory and Practice,” Volume 30, No. 3, August – 1988, Page 187.
18	Rachidi, F. Nucci, C.A. Ianoz, M. Mazzetti, C.	“Influence of a Lossy Ground on Lightning-Induced Voltages on Overhead Lines,” Volume 38, No. 3, August – 1996, page 250.

Note: \* indicates that the paper was also in the top list of papers for the entire 50 years of the Society’s history.

### CONCLUSION

The Most-Referenced Paper of the first 50 years of the EMC Society is printed on the following page. In the future, with all the *IEEE Transactions on EMC* papers being available on the IEEE Xplore program, historians will be able to track the “number of downloads” per paper to provide an indication as to how referenced a paper is by other papers. This will certainly be less tedious than the “method of the moment” used by the author!

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TRANSIENT RESPONSE OF MULTICONDUCTOR TRANSMISSION LINES  
EXCITED BY A NONUNIFORM ELECTROMAGNETIC FIELD

Ashok K. Agrawal, Harold J. Price  
Mission Research Corporation, Albuquerque, NM 87108

and

Shyam H. Gurbaxani  
Dept. of Electrical Engineering and Computer Science  
University of New Mexico, Albuquerque, NM 87131

The time-domain transmission-line equations for uniform multi-conductor transmission lines in a conductive, homogeneous medium by a transient, nonuniform electromagnetic field, are derived from Maxwell's equations. Depending on how the line voltage is defined, two formulations are possible. One of these formulations is considerably more convenient to apply than the other. The assumptions made in the derivation of the transmission-line equations and the boundary conditions at the terminations are discussed. For numerical calculations, the transmission-line equations are represented by finite-difference techniques, and numerical examples are included.

The frequency-domain solution for the case of a two conductor line illuminated by a nonuniform electromagnetic field was obtained by Taylor, et al [1]. The frequency response of multiconductor lines illuminated by a nonuniform electromagnetic field was obtained by Paul [2], by extending the results of [1] to multiconductor lines. The formulation in [2] neglects the conductivity of the medium surrounding the conductors. In this paper, the transmission-line equations are derived in the time domain and the time-varying conductivity of the medium is included. The time-varying conductivity complicates the use of Fourier transforms, and thus the time domain formulation is more appropriate.

In the derivation of the transmission-line equations, the following assumptions are made:

1. The induced currents in the conductors flow parallel to the line, i.e., the propagation is transverse magnetic.
2. The sum of the induced currents in the conductors and corresponding axial component of the current in the reference conductor are equal in magnitude and opposite in sign.
3. The longitudinal derivative of the longitudinal electric field is small compared to the transverse derivative of the transverse field.
4. The conductivity of the medium surrounding any individual conductor is uniform.

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The total electric and magnetic fields are expressed as the sum of incident and scattered fields,

$$E_{\xi_i} = E_{\xi_i}^i + E_{\xi_i}^s$$

$$E_{z_i} = E_{z_i}^i + E_{z_i}^s$$

$$B_{\eta_i} = B_{\eta_i}^i + B_{\eta_i}^s$$

The superscripts  $i$  and  $s$  refer to incident and scattered, respectively.

$E_{\xi_i}$  is the  $\xi$ -component of the total electric field in the direction of the straight line joining the  $i^{\text{th}}$  and the reference conductors,  $E_{z_i}$  is the  $z$ -component of the total electric field (line axis) on the  $i^{\text{th}}$  conductor, and  $B_{\eta_i}$  is the  $\eta$ -component of the total magnetic field density perpendicular to the plane formed by the  $z$ -axis and the line joining the centers of the  $i^{\text{th}}$  and the reference conductors.

The transmission-line equations in terms of the scattered and total voltages are:

$$\frac{\partial}{\partial z} [I_i(z)] + [G_{ij}] [V_i^s(z)] + [C_{ij}] \frac{\partial}{\partial t} [V_i^s(z)] = 0 \quad (1)$$

$$\begin{aligned} \frac{\partial}{\partial z} [V_i^s(z)] + [R_{ij}] [I_i(z)] + [L_{ij}] \frac{\partial}{\partial t} [I_i(z)] \\ = [E_{z_i}^i(z, h_i) - E_{z_0}^i(z, 0)] \end{aligned} \quad (2)$$

$$\begin{aligned} \frac{\partial}{\partial z} [I_i(z)] + [G_{ij}] [V_i^T(z)] + [C_{ij}] \frac{\partial}{\partial t} [V_i^T(z)] \\ = -[G_{ij}] \left[ \int_0^{h_i} E_{\xi_i}^i(\xi_i, z) d\xi_i \right] \\ - [C_{ij}] \frac{\partial}{\partial t} \left[ \int_0^{h_i} E_{\xi_i}^i(\xi_i, z) d\xi_i \right] \end{aligned} \quad (3)$$

$$\frac{\partial}{\partial z} [V_i^T(z)] + [R_{ij}] [I_i(z)] + [L_{ij}] \frac{\partial}{\partial t} [I_i(z)] = \frac{\partial}{\partial t} \left[ \int_0^{h_i} B_{n_i}^S(\xi_i, z) d\xi_i \right] \quad (4)$$

Equations 1 and 2 are the transmission line equations in terms of the scattered voltage on the line and equations 3 and 4 are the transmission line equations in terms of the total voltage on the line. The total voltage and the scattered voltage are related by the relation:

$$V_i^T(z) = V_i^S(z) + V_i^i(z) = V_i^S(z) - \int_0^{h_i} E_{\xi_i}^i(\xi_i, z) d\xi_i \quad (5)$$

In equations 1-5,  $h_i$  is the distance between the centers of the  $i$ th and the reference conductors.

Figure 1 shows the equivalent circuit of a small section of length  $\Delta z$  of the multiconductor transmission line. The sources appear only as voltage sources in series with the conductors.

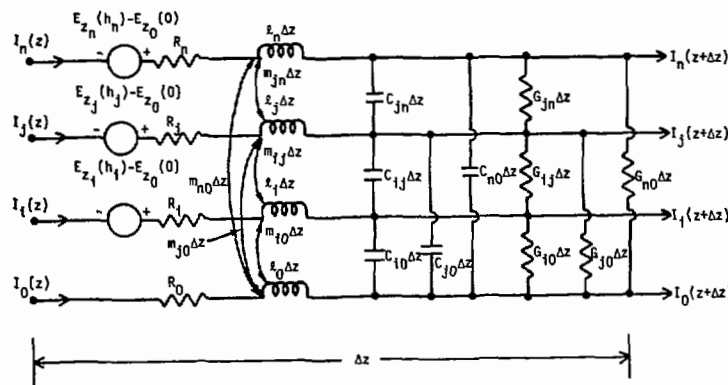


Figure 1. Equivalent Circuit of a Section of n+1 Conductor Line.

Note that the source term appears only in one equation in the scattered voltage formulation (equations 1 and 2), as the difference of incident tangential fields. The total voltages on the line are obtained from equation 5. In equations 4 and 5, the incident fields appear differentiated with respect to time, and in the case of fast-rising waveforms, the differentiated terms will have a faster risetime than the original waveform. Therefore, in the time-domain solution, a finer resolution of the differentiated terms is required, and hence more computation.

## REFERENCES

1. Taylor, C. D., R. S. Satterwhite, and C. W. Harrison, Jr., "The Response of a Terminated Two-Wire Transmission Line Excited by a Nonuniform Electromagnetic Field", IEEE Trans. Ant. Prop., Vol. AP-13, pp. 987-989, November 1965.
2. Paul, C. R., "Frequency Response of Multiconductor Transmission Lines Illuminated by an Electromagnetic Field", IEEE Trans. EMC, Vol. EMC-18, No. 4, November 1976.