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A SIMPLE ASYMPTOTICAL MODEL FOR ANALYZING WIRE ANTENNA WITH DIFFERENT RADIUS

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ABSTRACT: *In this research letter, a simple asymptotical model is present for analyzing wire antenna with different radius. Method of moments (MoM) based on sinusoidal basis function is used to give the analysis. In the process of using MoM for different radius, if we neglect the monopole along normal axis at the joint part, the different consideration of endpoint charges will make the final results different for conventional methods, and final results are also different with the results from HFSS and measurement results. In view of that, a simple asymptotical model is present to approximately deal with the joint part at the position of different radius. One advantage for the introduction of the present model is that the final results will be the same and independent of conventional methods. The other advantage is that the final results based on the present model have better agreement with HFSS and measurement results. Fabricated loop antennas with different radius are given as practical examples to show the advantages of the present model.* © 2012 Wiley Periodicals, Inc. Microwave Opt Technol Lett 54:960–964, 2012; View this article online at wileyonlinelibrary.com. DOI 10.1002/mop.26689

Key words: *method of moments; wire antenna with different radius; sinusoidal basis function; loop antenna with different radius*

1. INTRODUCTION

Method of moments (MoM) is one of most popular methods for many scholars and engineers to analyze and design the wire antenna [1]. In the implementation process of MoM for wire structure, wire function is commonly used as basis and weighting functions. Though volume basis function can be used, wire basis function gives many advantages for wire antenna problem, such as its simple expression, less unknowns, simple modeling, and fast simulation. Sinusoidal basis function as one of better wire basis and weighting functions for extracting the wire current was well studied by many scholars [2–7].

As we know, the wire structure with uniform radius has been well studied in [2–6]. In the process of MoM for filling with the self impedance, to avoid the singularity, we can simply choose the source current along the center line, and choose the outline of metal cylinder as the weighting line.

But when we meet the wire structure with different radius, we will encounter the junction problem if sinusoidal function is still used. If we use the sinusoidal basis function on the connection line between two endpoints of two different radius, connection line's self impedance will be difficult to solve, such as for the monopole (half sinusoidal basis function) denoted by using red line in the connection part shown in Figure 1. Thus, the approximate method is required for sinusoidal basis function to be extended to the different radius problem.

As a common approximate method, we may neglect the monopoles denoted by using red part line in Figure 1. As a result, the sinusoidal basis function at the corner will not be continuous. The sinusoidal basis function is composed of two monopoles. However, the endpoint charge of one monopole at the discontinuity position of sinusoidal basis function will appear. Different conventional methods give different endpoint charge's consideration for single monopole of the sinusoidal function: In filling with the mutual impedance between two monopoles (two half sinusoidal basis functions), partial endpoint charges are considered in [3]; In [4], both endpoint charge are considered by delta functions; No endpoint charges (or zero) are considered in [5]. The mutual impedance between two

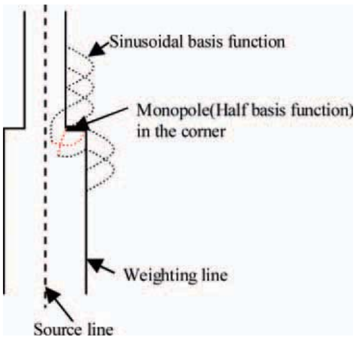


Figure 1 Original wire antenna with different radius. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

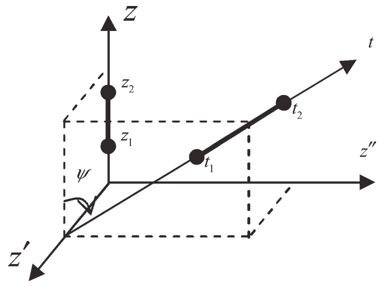


Figure 2 Coordination for two wire monopoles

monopoles will be different from the different consideration for endpoint charges. These cases are also discussed in [6] and [7]. Though this approximate method still can simply extend the sinusoidal basis function for the different radius problem, the discontinuity of endpoint charge will make final results different from different methods.

In view of that, a simple asymptotical model as an approximate method is present in this letter for wire sinusoidal basis function to be extended for wire antenna with different radius.

2. A SIMPLE ASYMPTOTICAL MODEL

The sinusoidal basis function is composed of two monopoles. In general, the mutual impedance between two sinusoidal basis function are composed of the mutual impedances among four monopoles [2], where the two general monopoles are shown in Figure 2,

The two wire monopoles are expressed by

$$\begin{cases} f_j(z) = \frac{\sinh[\gamma(z-z_u)]}{\sinh(\gamma d_1)}\hat{z}, & (u = 1\, or\, 2,\ z_1 < z < z_2) \\ f_i(z) = \frac{\sinh[\gamma(t-t_v)]}{\sinh(\gamma d_2)}\hat{t}, & (v = 1\, or\, 2,\ t_1 < t < t_2) \end{cases}. \tag{1}$$

The corresponding wire point charge for the two wire monopoles can be expressed by

$$\begin{cases} q_j(z) = \frac{-1}{j\omega}\left[\frac{\cosh[\gamma(z-z_u)]}{\sinh(\gamma d_1)} - \Delta_z\right], \\ q_i(t) = \frac{-1}{j\omega}\left[\frac{\cosh[\gamma(t-t_v)]}{\sinh(\gamma d_2)} - \Delta_t\right] \end{cases} \tag{2}$$

where, $\gamma = jk_0$, $d_1 = |z_2 - z_1|$, $d_2 = |t_2 - t_1|$; Δ_z and Δ_t denote the two monopoles' endpoints charges, which are different from methods. In [3], $\Delta_z = 0$ and $\Delta_t = \delta(t - t_2)$. In [4], $\Delta_z = \delta(t - t_2)$ and $\Delta_t = \delta(t - t_2)$. In [5], $\Delta_z = 0$ and $\Delta_t = 0$. The cases are also discussed in [6] and [7].

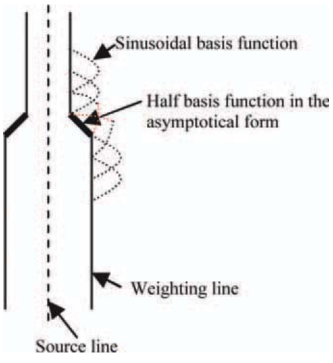


Figure 3 Asymptotical model for the junction part. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

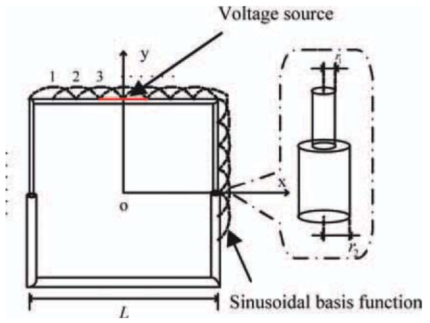


Figure 4 Original Model with different radius with sinusoidal basic function. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

In general, when one sinusoidal function is composed of two continuous monopoles, the choose of endpoint charges have no effect on the final mutual impedance between two sinusoidal basis functions, because the effects of two connected point charges will be cancelled. The problem for wire structure with uniform radius will not appear, because two neighbor monopoles are continuous.

However, when we deal with the wire antenna with different radius using sinusoidal basis function, if we neglect the monopoles along the normal axis, the discontinuity of two neighbor monopoles will appear. Mutual impedance between two sinusoidal basis function and the final results will be different according to choose of endpoint charges from different methods [6, 7].

To avoid above problems, here we present a simple asymptotical model, which is shown in Figure 3.

The advantage of the asymptotical model is that we will have no endpoint charge problem because any two neighbor monopoles will be continuous, and the mutual impedance between two sinusoidal basis functions will be the same for the junction part using any conventional method. The accuracy or effectiveness of the present model will be discussed in the following section.

3. NUMERICAL AND MEASUREMENT RESULTS

3.1. Numerical Results from Present Model and HFSS Results

To show the accuracy or effectiveness of the present model, we will adopt a detailed loop antenna with different radius. In Figure 4, an original model with different radius by using sinusoidal basis function is shown. The voltage source is shown by using red line.

As the analysis in Section 2, here we will use a simple and asymptotical model to deal with the junction part, which is shown in Figure 5.

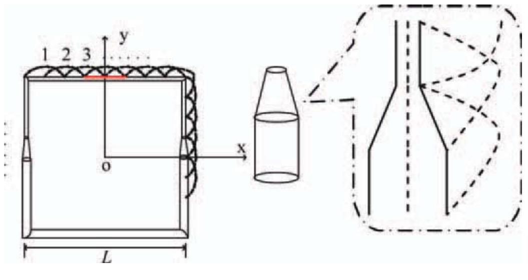
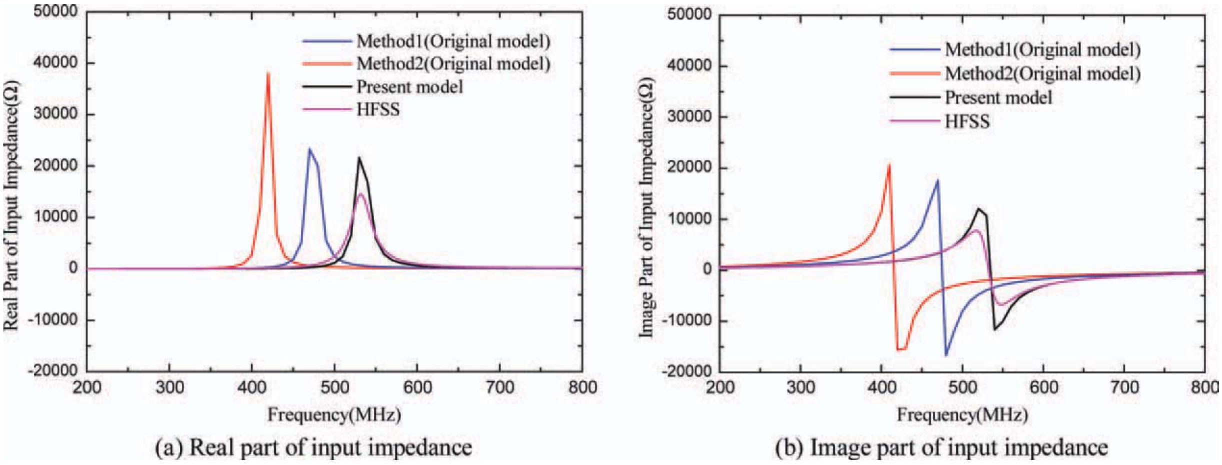


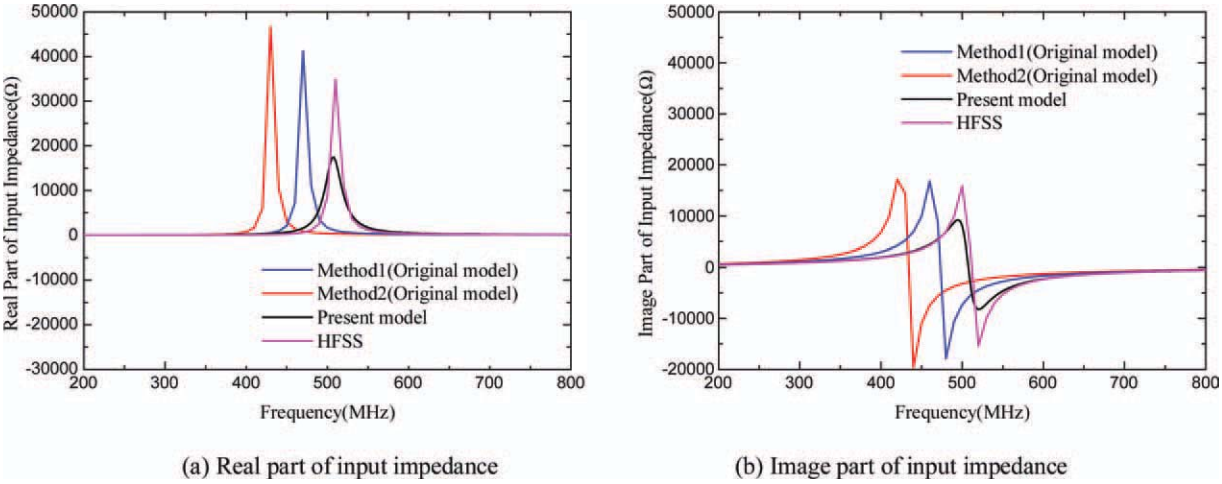
Figure 5 The asymptotical model with sinusoidal basic function. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]



(a) Real part of input impedance

(b) Image part of input impedance

Figure 6 Comparisons of simulation methods and measurement. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]



(a) Real part of input impedance

(b) Image part of input impedance

Figure 7 Comparisons of simulation methods and measurement. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

We will adopt four methods: conventional method1 [2] with original model and neglect the monopoles along normal axis, conventional method2 [3] with original model and neglect the monopoles along normal axis, HFSS with original model, and the present model with any conventional method. From analysis in Section 2, the present model is independent of conventional methods, so for the result "Present model" in the following figures will not denote a detailed method. The loop antennas and their parameters are given in the followings. The input impedances of the loop antenna1(L = 0.08 m, r1 = 0.0001m, r2 = 0.001m, V = 1V/m) by the four methods are shown in Figure 6.

The parameters for the second loop antenna with different radius are: L = 0.08m, r1 = 0.0001m, r2 = 0.0005m, V = 1V/m and the input impedances of the loop antenna by the four methods are also shown in Figure 7.

From above comparisons in Figures 6 and 7, we can conclude that the results from present model by conventional method have better agreements with HFSS with original model.

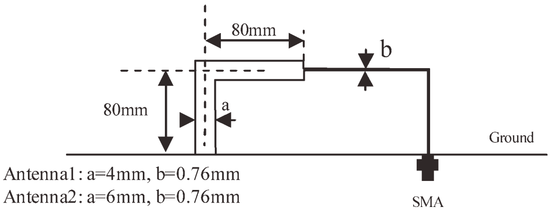
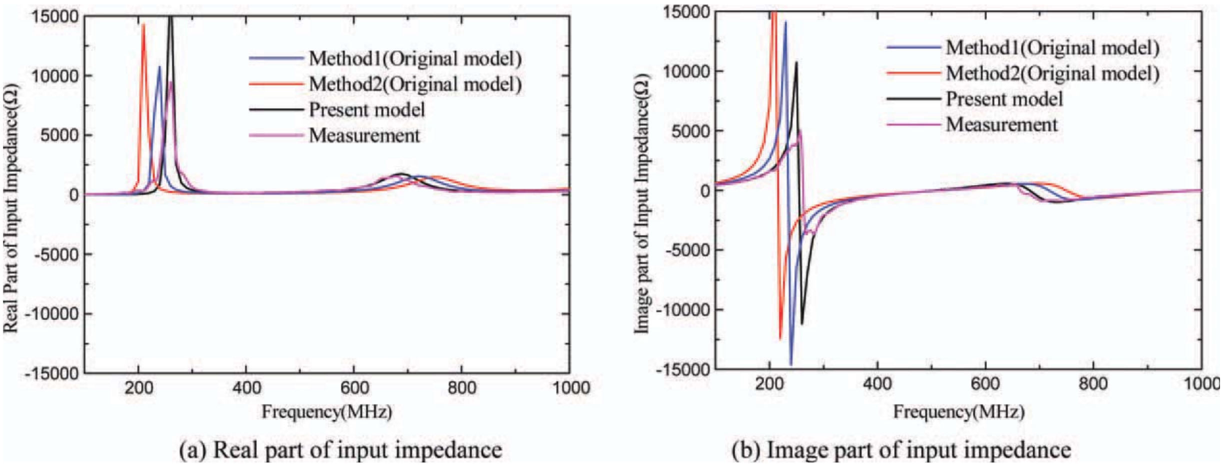


Figure 8 Loop antenna by using mirror theory

Figure 9 Fabricated loop antenna1 with different radius. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]



(a) Real part of input impedance

(b) Image part of input impedance

Figure 10 Comparisons of simulation methods and measurement. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

Figure 11 Fabricated loop antenna2 with different radius. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

In other words, the present model can more effectively analyze the original different radius problem.

3.2. Numerical Results from Present Model and Measurement Results

The model of fabricated loop antennas with different radius by using mirror theory is shown in Figure 8, where the antenna1: $a = 4$ mm, $b = 0.76$ mm; and antenna2: $a = 6$ mm, $b = 0.76$ mm.

The fabricated loop antenna1 with different radius is shown in the Figure 9.

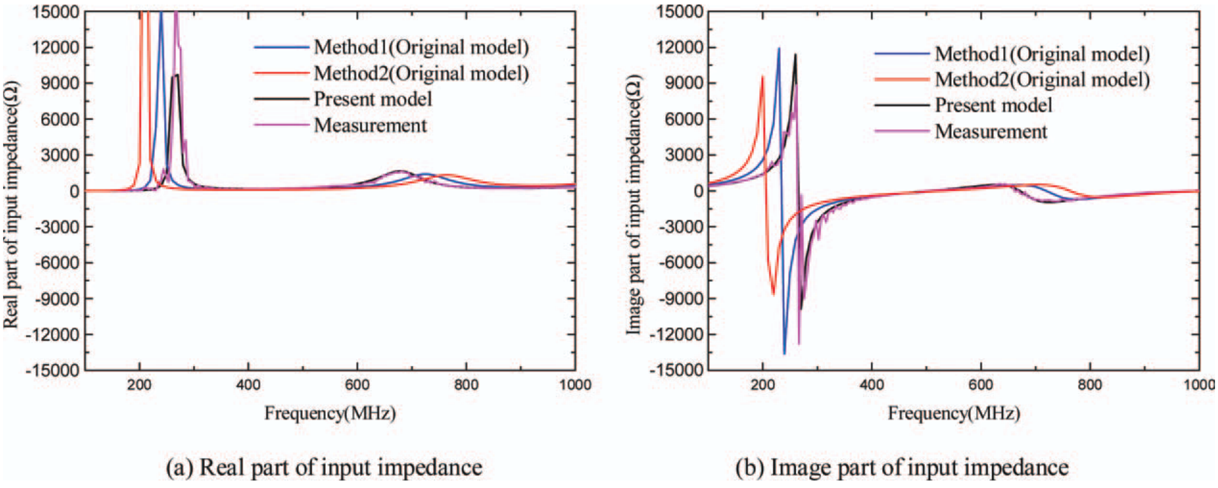
The input impedances from simulation methods and measurement are shown in Figure 10.

The fabricated loop antenna2 with different radius is shown in Figure 11. The comparisons among different methods are also shown in Figure 12.

From the comparison among the results in Figures 10 and 12, we can clearly see that the results from the present model using conventional method with sinusoidal basis function have better agreement with measurement data.

4. CONCLUSION

In this research, a simple asymptotical model is present for analyzing the wire antenna with different radius by using sinusoidal basis function. The introduction of the present asymptotical model effectively avoid the endpoint charge's effect of monopole at the connection part between the different radiuses, and the results from conventional methods are the same. The better agreements are achieved among the results from HFSS, measurement and the asymptotical model. Therefore, the present model can be used as a better approximate method for sinusoidal basis function to simulate the property of the wire antenna with different radius.



(a) Real part of input impedance

(b) Image part of input impedance

Figure 12 Comparisons of simulation methods and measurement. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]

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DESIGN OF A VERTICALLY STACKED RECONFIGURABLE DIPOLE ANTENNA FOR A BASE STATION

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ABSTRACT: *A new design for a frequency reconfigurable antenna for a base station is presented with the use of a vertically stacked dipole structure and switches based on PIN diodes. The proposed antenna provides three frequency reconfigurations including Cellular (824–849 MHz), PCS, WCDMA, Wibro, WLAN (1700–2500 MHz), and WiMAX (3300–3600 MHz). Measured results on return losses, radiation patterns, and gains are provided, and these show good agreement with simulations. The proposed antenna in this article can be applied for the small base station or repeaters of future mobile wireless communications because of the small size and high-gain features.*

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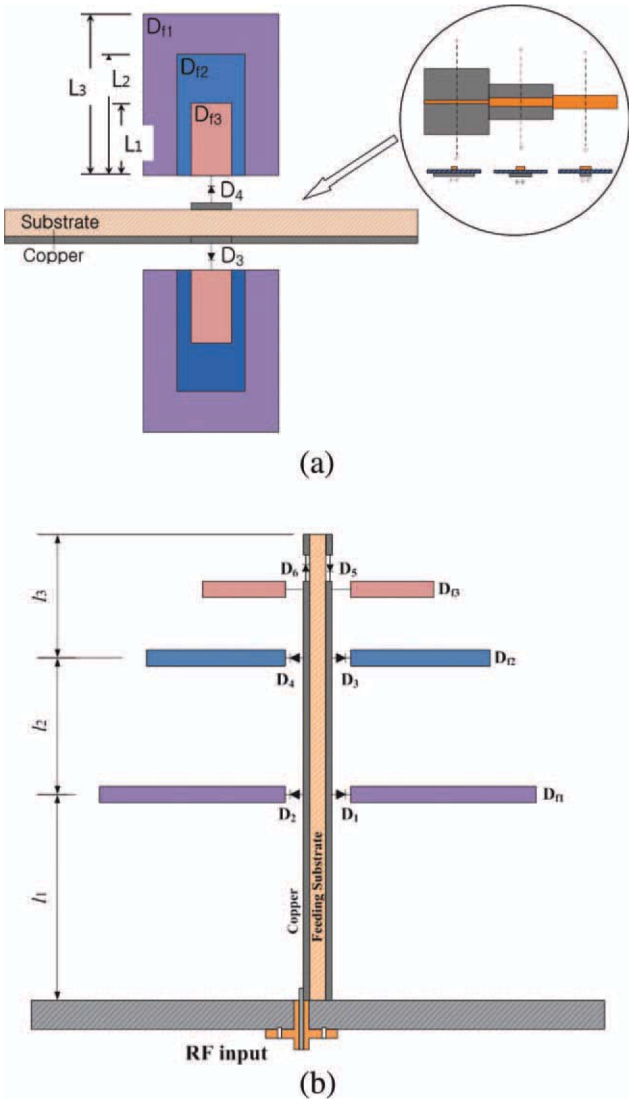
Key words: *reconfigurable antenna; base station antenna; dipole antenna*

1. INTRODUCTION

The rapid developments in wireless communication technologies demand the integration of more than one communication system into a singe compact module [1, 2]. To comply with this requirement, a compact high-performance frequency reconfigurable antenna with good radiation characteristics, a high gain, and a compact volume is needed. Most research on reconfigurable antennas results in a planar configuration for mobile devices that can be implemented by adding parasitic elements to create an additional resonant frequency [3]. New design for a compact reconfigurable antenna is introduced for base station in this article. The proposed reconfigurable antenna configuration uses vertically stacked planar dipole antennas to achieve triple band operation by PIN diode switching for base station applications. A frequency reconfigurable antenna with a 1.5:1 VSWR for two operating bands, specifically Cellular (824–849 MHz, Band1) and WiMAX (3300–3600 MHz, Band3), as well as a wide 2:1 VSWR for PCS/WCDMA/Wibro/WLAN (1700–2500 MHz, Band2), is presented.

2. ANTENNA STRUCTURE

The configuration of the proposed antenna is shown in Figure 1, where Figures 1(a) and 1(b) show the top view and the side view, respectively. In Figure 1(a), D_{f1}, D_{f2}, and D_{f3} are dipole



(a)

(b)

Figure 1 Vertically stacked reconfigurable antenna configuration. $L_1 = 17.0$ mm, $L_2 = 20.3$ mm, $L_3 = 61.4$ mm, $l_1 = 63.5$ mm, $l_2 = 35.5$ mm, and $l_3 = 16.0$ mm. [Color figure can be viewed in the online issue, which is available at wileyonlinelibrary.com]