CM Conducted EMI mitigation in flyback PFC converter

M. Ashritha¹ · M. L. Sudheer¹

Received: 7 June 2019 / Accepted: 15 November 2019 / Published online: 2 December 2019
© Springer-Verlag GmbH Germany, part of Springer Nature 2019

Abstract

The switched mode power supplies offer many advantages in power conversion. But they offer low power factor and generate electromagnetic interference (EMI). The low power factor can be improved by a front-end power factor correction (PFC) unit. However, they also generate EMI in both differential mode and common mode (CM). The interwinding capacitance of the transformer and parasitic capacitance between the heat sink and ground are major contributors to CM noise. The traditional method to minimize the CM noise by using a line filter consists of CM choke and Y capacitor. But, CM noise causes leakage current to flow to the ground through the Y capacitor. This leakage current has to be restricted as per the standards for commercially used equipment and medical instruments. The technique proposed here reduces the values of Y capacitor thereby reducing the leakage current. This can be reduced by minimizing the predominant parasitic capacitances of the HF transformer used in the PFC converter. This paper presents a technique for reducing these parasitic capacitances by incorporating an additional parasitic capacitance noise cancellation winding (PCW). A flyback transformer winding capacitance model depicting the parasitic capacitances is considered, and a novel method to determine this parasitic capacitance is presented. Using this model, the CM Conducted EMI in a flyback PFC is determined by simulation and experimentation. These simulation and experimentation results are used to design an EMI line filter to reduce the Conducted CM noise to complaint levels. The value of Y capacitor now is reduced due to the addition of PCW thereby reducing the size and cost of the filter. This technique has been validated experimentally on a 30-W power factor correction flyback converter working in critical conduction mode.

Keywords EMI · LISN · PFC converters · Differential mode (DM) · Common mode (CM) · Flyback converter

1 Introduction

Offline switched mode power supply (SMPS) offers a low power factor, so it is necessary to improve its power factor. The power factor correction (PFC) circuits offer power factor correction (PFC) and low harmonics to the power line, which is located at the front end of the converters. The PFC can be classified into two types, namely continuous conduction mode (CCM) and critical conduction mode (CrCM). The CrCM design approach for PFC converters has been related to the low power range below 300 W because of the low cost and simplicity of the circuitry and

CCM for converters above 300 W. The PFC converters used here are a flyback type built using commercially available control IC L6561 [1–4]. These PFC converters are a vital source of EMI which has led to complication in meeting the EMC regulations. EMI is increased by an increase in switching frequency of the converters [5]. Conducted EMI propagates in two modes, namely the DM Conducted EMI which conducts on the line and neutral, and CM Conducted EMI which conducts on both line and neutral to the ground. The CM Conducted EMI is predominantly generated due to the stray capacitance of the semiconductor devices to the ground.

The conventional passive EMI filters have been used to attenuate EMI in converters for many years, which usually introduces an extra cost and increases the size of the converter. To reduce the EMI, CM and DM chokes, X and Y capacitors are usually used in the front end of the converter. The Y capacitor provides a low impedance path to shunt the leakage current. In most isolated converter, the Y capacitor

✉ M. Ashritha
ashritha4297@gmail.com
M. L. Sudheer
dr.mlsudheer@gmail.com

¹ Centre for Excellence in EMC and Power Quality Department
of Electronics & Communication, UVCE, Bangalore
University, Bengaluru, India

increases leakage current that flows from primary and secondary of the isolation barrier to the equipment connected to the protective ground. If a person comes in contact with the equipment having defective ground, the leakage current will flow through the person to earth. There are stringent leakage current limits set by international standards [6]. However, it is essential to prevent this leakage current for the safety of the operating person.

The major part of CM Conducted EMI is generated due to the displacement current from parasitic capacitances in the transformer. The models developed for extracting parasitic capacitance of the transformer should be accurate. At the same time, it is essential that the model complexity should be as low in order to reduce time consumption and cost. The available transformer models are mostly dedicated to high power transformers [7,8], and their method cannot be applied to low power transformers without significant modifications. The drawback of the existing models created a need for the development of the transformer model which could overcome the complexity of designs.

Various CM Conducted noise reduction techniques for switched mode converters have been proposed in the literature [9–15]. One such noise reduction technique [9] has been proposed by D. Cochrane et.al. to reduce it by employing a compensation capacitor with the antiphase winding of the high-frequency (HF) transformer used in them. Chan et al. [10] have discussed another technique of using an antiphase winding which is constructed based on equipotential line theory to reduce CM noise. Wang and Lee [12] have proposed a method to cancel the CM noise by creating negative capacitance that balances the parasitic capacitances of the HF transformer. But, the technique proposed in [9,10,12] requires the value of parasitic capacitance of such transformers that need to be measured or calculated before implementing their proposed mitigation techniques. Also, these papers do not present the quantity of reduction in parasitic capacitance due to the compensation by antiphase winding, although they present the reduction in CM Conducted noise. This paper presents firstly a technique for calculating the parasitic capacitance of such transformers which is also validated experimentally. Secondly, it shows the quantitative reduction in the parasitic capacitances experimentally. This has been implemented on a typical HF transformer used in a PFC flyback converter. Using these techniques, the paper presents the mitigation of CM Conducted EMI in PFC flyback converter both by simulation and by experimentation.

Section 2 presents the novel analytical method to find the parasitic capacitance value of the transformer used in flyback PFC, and two methods to mitigate CM Conducted EMI are discussed. Section 3 presents the comparison of CM Conducted EMI noise with the measured values. In Sect. 4, experimental and simulation results for three different cases

have been presented. An EMI filter has been designed for flyback PFC converter to mitigate it to compliant levels. Firstly, the CM Conducted EMI results of flyback PFC without line filter and without PCW are presented. Secondly, the results of the flyback PFC with line filter but without PCW are presented. Finally, the results of flyback PFC with line filter and PCW are presented and they are compared. In the flyback PFC converter, CM Conducted EMI is below the limit line by employing PCW and EMI filter with reduced Y capacitor value.

2 Analytical formulation

Unfortunately, the parasitic capacitance is a distributed parameter and their value depends on the operating frequency [16]. Therefore, the analytical prediction of the frequency response of the flyback transformer is a difficult problem. Here, a novel method for predicting the parasitic capacitance of flyback transformer and comparison of the analytical and experimental result are presented.

2.1 Transformer model

The capacitance between winding to the core and from one layer of the winding to the other is the major distributed parasitic capacitance in flyback transformer. A lumped parameter model for the flyback transformer is shown in Fig. 1; it comprises of distributed parasitic components. The leakage inductance of primary is represented as l_{w1} , and the secondary is represented as l_{w2} . The r_{w1} and r_{w2} are equivalent resistance of the primary and secondary of the transformer, and r_e is the equivalent resistance due to eddy current. The parasitic capacitance of the transformer can be divided into three categories:

1. Turn-to-turn parasitic capacitance (C_{tt}),
2. Layer-to-layer parasitic capacitance (C_l), and
3. Interwinding parasitic capacitance (C_w).

The turn-to-turn parasitic capacitance can be neglected as it is not effective in high frequency and for a low number

Fig. 1 Equivalent transformer circuit

Fig. 2 Equivalent circuit with secondary parameters referred to the primary side

Fig. 3 Equivalent circuit of transformer

of turns transformer. The equivalent circuit is redrawn with secondary parameters which are referred to the primary side as shown in Fig. 2.

$$C_{l1eq} = C_{l2} + \left(1 - \frac{1}{n}\right) C_w \quad (1)$$

$$C_{l2eq} = C_{l1} + (1 - n) C_w \quad (2)$$

At first, to examine the resonance of noise transmission in transformer here we derive a transfer function. Assuming that r_{w1} and r_{w2} are equal to zero and r_e is infinitely large [17], the equivalent circuit of the transformer can be redrawn as shown in Fig. 3.

$$l_w = l_{w1} + n^2 l_{w2} \quad (3)$$

The primary impedance (Z) is calculated when the secondary (that is ne_{out}) is open circuited (Z_0). The transfer function equation for the equivalent circuit of the transformer is given by:

$$\frac{e_{out}(s)}{e_{in}(s)} = \frac{C_w}{C_{l2} + C_w} \frac{s^2 + \alpha}{s^2 + \gamma}$$

$$\alpha = \frac{n}{C_w l_w}$$

$$\gamma = \frac{n^2}{l_w (C_{l2} + C_w)}$$

Fig. 4 CM noise current path

2.2 Antiphase winding and parasitic capacitance noise cancellation winding (PCW) in the transformer

Figure 4 shows the CM Conducted EMI path of 30-W, 15-V/2-A output PFC flyback converter. The parasitic capacitance between the drain of the MOSFET and the ground is C_h and C_d , respectively. The interwinding parasitic capacitance C_w forms a path for the CM noise to flow from primary to secondary of the transformer. The CM noise current flowing to the ground through the primary winding (W_p) parasitic capacitance (C_{l1}) of the transformer and drain of the MOSFET Q_1 to the heat sink forms the first path as shown in Fig. 4. The second path is interwinding parasitic capacitances of the transformer and fast switching diode to the ground, as shown by the dashed line in Fig. 4.

In the first case, the antiphase winding method for mitigation of CM Conducted EMI is introduced to cancel the noise current flowing via the primary winding to secondary winding (i.e. through C_w). To meet the balancing condition, an extra winding opposite in phase is placed as shown in Fig. 5. The antiphase winding turns are limited to one layer as shown in Fig. 6. The gauge of the antiphase winding is similar to the primary winding gauge. The extra winding also called antiphase winding does not limit the turn ratio between primary and secondary windings. It does not need to carry any power current, and it has no power consumption; therefore, it does not affect the efficiency of the converter significantly. The antiphase winding number of turns can be calculated from [18], which was recorded to be 19 turns for the lumped parasitic capacitance from primary to secondary to be 0.32 pF.

A compensation capacitor (C_c) with an antiphase winding (also called PCW) is employed in a PFC flyback converter to mitigate HF CM Conducted EMI. The C_c impedance is high

Fig. 5 Antiphase winding placed at point A

Fig. 6 Cross-sectional view of flyback PFC transformer with antiphase winding

at lower frequencies. Therefore, no noise current will flow to the ground at low frequency. The C_c impedance is low at high frequency, and it provides a low impedance path for the noise current to flow to the ground as shown in Fig. 7. Placing PCW which is 180 degrees out of phase at the point 'A' produces electric field opposite to primary winding of the flyback PFC transformer. Here, no displacement current will flow through the parasitic capacitor. The principle of suppressing ground leakage current with this approach is based on diverting high-frequency CM current. This is achieved by placing a compensation capacitor which bypasses the high-frequency CM current. However, the compensation capacitor value is chosen by the trial-and-error method. Four experiments were conducted in the first case without compensation capacitor, and antiphase winding measurement was carried out. In the second case with the antiphase winding, the compensation capacitor was chosen to be 50 pF. Then, in the third and fourth experiments, the compensation capacitor values were chosen to be 27 pF and 100 pF, respectively, and its respec-

Fig. 7 PCW employed in flyback PFC converter

Fig. 8 Comparison of magnitude of CM Conducted EMI for different compensation capacitors placed in circuit

tive CM noise level measured is shown in Fig. 8 in which the second case with the compensation capacitor value of 50 pF gave a considerable reduction in CM Conducted EMI in the high-frequency range.

The investigation of CM noise generated and mitigated frequency range has been carried out by the resonance method. The resonance frequency obtained by the experimental method can be used to obtain the parasitic capacitance values. The resonance method [19] is used to extract interwinding parasitic capacitance (C_w) and layer-to-layer parasitic capacitance (C_{11} and C_{12}). The flyback transformer designed for a minimum switching frequency 25 kHz and maximum up to 300 kHz uses E25/13/7 core from 3R Enterprises [20]. The 90-turn winding of primary is employed. The impedance analyser used for measurement is PSM3750. The impedance magnitude can be measured in the frequency range from 100 Hz to 30 MHz as shown in Figs. 9 and 10.

Fig. 9 Comparison of Z measurement of primary open circuit and short circuit of flyback transformer and CM noise frequency response without antiphase winding

Fig. 10 Comparison of Z measurement of primary open circuit and short circuit of flyback transformer with antiphase winding and CM noise frequency response with and without antiphase winding employed

In order to confirm the validity of the equivalent circuit of transformer presented here, a comparison of the analytical and experimental frequency response is presented in Fig. 9. The analytically obtained resonant frequency coincides with the practical measurements. As CM Conducted noise is generated due to the resonance of inductance and capacitances, it is necessary to analyse the resonant frequency to predict the effect of parasitic capacitance in the CM Conducted EMI. Therefore, the equivalent transformer model designed here is best suitable for CM noise analysis. The measurement in Figs. 9 and 10 is carried out for two cases: In the first case, the flyback transformer primary impedance was measured with secondary open and short circuit. This measurement

was compared with the CM noise measured without employing any antiphase/ cancellation winding as shown in Fig. 9. In the second case, the antiphase winding was employed in flyback transformer primary impedance and was measured by secondary open and short circuit. This measurement was compared with the CM noise measured with employing antiphase winding as shown in Fig. 10. There are three peaks f_1 , f_2 and f_4 and one valley f_3 as noted in Figs. 9 and 10. The impedance characteristics are taken up to 10 MHz only; the instrument was not accurate enough to measure at higher frequencies. The experimental determination could not be performed due to the limitation of the frequency range of impedance analyser that was used.

As shown in Figs. 9 and 10, impedance valley and peaks show their effect in the CM noise spectrum on the corresponding frequencies. The CM noise spectra are high at the transformer impedance peak frequency f_1 , f_2 and f_4 . The spectra of CM noise are small at the impedance valley frequency such as f_3 . In case 2, the transformer impedance measured with antiphase winding the peak f_4 magnitude is reduced as shown in Fig. 10. Therefore, by employing antiphase winding method the parasitic capacitance value is reduced which in turn reduces high-frequency CM noise from 10 MHz to 30 MHz. The four characteristic frequencies which appear in Figs. 9 and 10 are given by:

$$f_1 = \frac{1}{2\pi\sqrt{L_0C_w}} \quad (4)$$

$$f_2 = \frac{1}{2\pi\sqrt{l_w(C_w - C_{12})}} \quad (5)$$

$$f_3 = \frac{1}{2\pi\sqrt{l_w\frac{(C_wC_{12})}{(C_w+C_{12})}}} \quad (6)$$

$$f_4 = \frac{1}{2\pi\sqrt{l_w(C_w - \frac{(C_{11}C_{12})}{(C_{11}+C_{12})})}} \quad (7)$$

Accordingly, parasitic capacitance is extracted by the resonant frequencies f_1 , f_2 , f_3 and f_4 , respectively, and the results are shown in Table 1. It was found that analytical resonance and practical resonance measured are in good agreement. It is also observed that by employing antiphase winding method there is a considerable reduction in parasitic capacitances.

3 Validation based on simulations

If Conducted EMI is not reduced at the design stage itself, then an expensive and bulky line filter may be required for its reduction. Predicting the Conducted EMI for a given circuit through simulation will help in reducing the design time. A detailed simulation circuit is used which covers

Table 1 Measured parasitic capacitance before connecting antiphase winding and with antiphase winding

	Analytical	Practical	
	Normal	Normal	With only antiphase
	Flyback	Flyback	Winding, flyback
	Transformer	Transformer	Transformer
C_w	100 pF	105.16 pF	87.95 pF
C_{l1}	700 pF	728.54 pF	216.92 pF
C_{l2}	90 pF	102.03 pF	47 pF

Fig. 11 Experimental and simulated measurement of CM noise without antiphase winding

essential Conducted EMI characteristics of the real hardware for a frequency range 150 kHz to 30 MHz. The analytical value obtained and CM Conducted EMI reduction technique described in Sect. 2 is employed in the simulation model. The CM Conducted EMI spectrum is obtained for a flyback PFC converter by this technique. Simulation is carried out using LTspice software.

The predicted Conducted EMI spectrum is compared with experimental results. The experimental measurement was done using LISN HM6050-2 and Spectrum Analyzer HMS-X of Rohde and Schwarz. The testing of Conducted EMI was done as per CISPR 22 ClassB for pre-compliance measurement as shown in Figs. 11, 12 and 13. Three experimental and simulation comparisons were carried out: In the first case, the CM Conducted EMI is measured without any antiphase winding as shown in Fig. 11. In the second case, the values obtained in Sect. 2 for the antiphase winding are substituted in the simulation and the comparison of experimental and simulated results is shown in Fig. 12. In the third case, PCW is incorporated and considerable reduction in CM Conducted EMI is observed in higher frequency range as shown in Fig. 13. The predicted Conducted EMI noise by simulation

Fig. 12 Experimental and simulated measurement of CM noise with antiphase winding method **Fig. 13** Experimental and simulated measurement of CM noise with PCW method

matches the measured result closely. The maximum observed difference between the simulation and measurement does not exceed 30% nearer to the desired accuracy. By these results, it is shown that the simulation reinforces the validation of theoretical analysis.

4 Experimental analysis

The experimental part of this study is meant to evaluate the two methods presented and compare its effectiveness in the reduction in CM Conducted EMI in PFC flyback converter. The experiments were carried out on a PFC flyback converter working in CrCM. The circuit was designed for the following specifications: 240 V 50 Hz input and 15 V, 30 W output and

Fig. 14 Comparison of measured different CM noise reduction performances of PFC flyback converter

Fig. 15 EMI filter

the minimum switching frequency of 25 kHz to a maximum 300 kHz.

Three experiments were carried out: In the first, case the CM Conducted EMI is measured without antiphase winding. In the second case, with the antiphase winding the CM Conducted EMI decreased by 10 dB from 10 MHz to 30 MHz. In the third case, PCW was employed the CM Conducted EMI reduced by 5 dB in the frequency range of 2 MHz to 5 MHz and remains unaltered from 5 MHz to 10 MHz. But a reduction of 10 dB was observed above 10 MHz to 30 MHz. Hence, maximum attenuation is obtained by using PCW as shown in Fig. 14. The noise in this frequency range can be reduced by using a line filter of a smaller size (Fig. 15).

4.1 Reduction in EMI filter size

The full compliance test for Conducted EMI was conducted in the ETDC. The experiment for compliance test was carried out using the EMI test receiver of Rohde and Schwarz of the working frequency of 9 kHz to 3 GHz and LISN SMLIN100-4 of 9 kHz–30 MHz, 100 A from m/s Scientific. In Fig. 16, case 1 presents CM Conducted EMI without employing any

Fig. 16 Comparison of CM noise in PFC flyback converter

Fig. 17 Experimental and simulated measurement of CM noise with only filter

mitigation technique. Case 2 presents EMI mitigation to levels below the CISPR limits using the EMI filter. The filter designed values were C_{X1} of 0.68 μF , C_{X2} of 0.22 μF , L_{CM} of 1.5 mH, C_{Y1} and C_{Y2} of 4700 pF as shown in Fig. 15. In case 3, the antiphase winding with a compensation capacitor and the EMI filter is employed. It was found that the C_Y capacitor in the EMI filter can be of a lesser value of 1000 pF for the same reduction in CM Conducted EMI.

A comparison of experimental results and the simulated results is shown in Figs. 17 and 18. Figure 17 shows simulation and measured CM noise with EMI filter, without antiphase winding and compensation capacitor. In Fig. 18, case 1 is the same as shown in Fig. 17. In case 3, the antiphase winding with a compensation capacitor and with the reduced value of C_Y is used. The generated CM Conducted EMI profile is compared with the simulation result (i.e. case 2). The

Fig. 18 Experimental and simulated measurement of CM noise with filter (C_y reduced) and PCW

comparison in Figs. 17 and 18 infers that the simulation of Conducted EMI matches the measured result very well, especially in a frequency between 150 kHz and 30 MHz.

5 Conclusion

A technique to reduce the CM Conducted EMI in a flyback PFC converter by adding extra PCW winding is used, and this also reduces the C_y capacitor in-line filter for reduction in Conducted EMI. For analysis of this extra winding, the interwinding parasitic capacitance of the flyback transformer was essential. An analytical method to calculate the interwinding parasitic capacitance of the flyback transformer is presented. The analytical model obtained has been validated by simulation and experimentation. The proposed analytical model is based on the transfer characteristics method which can be easily implemented on any topology. A flyback transformer was incorporated with compensation capacitor and antiphase winding (PCW); by this method considerable reduction in CM noise was observed. A significant reduction in the value of the C_y capacitor was also achieved. This is also resulted in the reduction in the size of the Line filter. With this technique, CM noise in the PFC flyback converter was brought down to compliance level in the frequency range of 150 kHz to 30 MHz. This technique can be used in applications where the leakage current to the ground due to C_y capacitor needs to be limited as in medical applications. Simulations and analytical methods are presented and are verified by experimentation.

Acknowledgements This work made use of Impedance analyser; the authors of this work appreciate the help of Dr. Basu from the IISc

Department of Electrical and Electronics. This work needed a special setup for full compliance of Conducted EMI which was carried out in Electronics Test and Development Centre (ETDC), Department of Electronics and Information Technology, Ministry of Communication and IT, Govt. of India—STQC Bangalore. The authors of this work appreciate the help of Dr. Navin Chandra Joshy and Dr. Mandal from ETDC.

References

1. Ashritha M, Sudheer ML (2016) Low conducted EMI in NUPF converters. In: 2016 international conference on electromagnetic interference & compatibility (INCEMIC). Bangalore, pp 1–4
2. Ashritha M, Sudheer ML (2017) Mitigation of CM conducted EMI IN SMPS. In: 2017 IEEE workshop on power electronics and power quality applications (PEPQA). Bogota, pp 1–6
3. Adragna C, STMICROELECTRONICS design equations of high-power-factor Flyback converter based on the L6561. www.stmicroelectronics.com
4. Adragna C, Gattavari G, STMICROELECTRONICS Flyback converters with the L6561 PFC controller. www.stmicroelectronics.com
5. Paul CR (1992) Introduction to electromagnetic compatibility. Wiley, New York
6. Bai Y, Yang X, Zhang D, Li X, Chen W, Hu W (2017) Conducted EMI mitigation schemes in isolated switching-mode power supply without the need of a Y-capacitor. *IEEE Trans Pow Electron* 32(4):2687–2703
7. Biela J, Johann W (2008) Using transformer parasitics for resonant converters—a review of the calculation of the stray capacitance of transformers. *IEEE Trans Ind Appl* 44(1):223–233
8. Lu Hai Yan, Zhu Jian Guo, Hui S Y Ron (2003) Experimental determination of stray capacitances in high frequency transformers. *IEEE Trans Pow Electron* 18(5):1105–1112
9. Cochrane D, Chen DY, Boroyevic D (2003) Passive cancellation of common-mode noise in power electronics circuits. *IEEE Trans Pow Electron* 18(3):756–763
10. Chan YP, Pong BMH, Poon NK, Liu JCP (2012) Common-mode noise cancellation in switching-mode power supplies using an equipotential transformer modeling technique. *IEEE Trans Electromagn Compat* 54(3):594–602
11. Chan YP, Pong BMH, Poon NK, Liu JCP (2014) Common-mode noise cancellation by an antiphase winding in multilayer isolated planar transformer. *IEEE Trans Electromagn Compat* 56(1):67–73
12. Chu Y, Wang S (2015) A generalized common-mode current cancellation approach for power converters. *IEEE Trans Ind Electron* 62(7):4130–4140
13. Maniktala Sanjaya (2003) Fixing EMI across the board, principal engineer, power management group. National Semiconductor Corp, Santa Clara
14. Shoyama M, Li Ge, Ninomiya T (2003) Balanced switching converter to reduce common-mode conducted noise. *IEEE Trans Ind Electron* 50(6):1095–1099
15. Ashritha M, Sudheer ML (2018) CM Noise cancellation in near unity power factor converter. In: 2018 15th international conference on electromagnetic interference & compatibility (INCEMIC). Bengaluru, India, pp 1–4
16. Massarini A, Kazimierzuk MK (1997) Self-capacitance of inductors. *IEEE Trans Pow Electron* 12(4):671–676
17. Harada K, Ninomiya T, Kakiyama H (1981) Effects of stray capacitances between transformer windings on the noise characteristics in switching power converters. In: 1981 IEEE power electronics specialists conference. Boulder, Colorado, USA, pp 112–123
18. Li Y, Zhang H, Wang S, Sheng H, Chng CP, Lakshmikanthan S (2018) Investigating switching transformers for common mode

- EMI reduction to remove common mode EMI filters and Y-capacitors in Flyback converters. *IEEE J Emerg Sel Top Pow Electron* 6(4):2287–2301
19. Cogitore B, Keradec JP, Barbaroux J (1994) The two-winding transformer: an experimental method to obtain a wide frequency range equivalent circuit. *IEEE Trans Instruct Meas* 43(2):364–371
 20. 3R Enterprises for the design and manufacturing of Transformers and Coils used for SMPS. <http://3re.co.in/>

Publisher's Note Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.