

Comments and Corrections

Comments on “On the Self-Generation of Electrical Soliton Pulses”

Gary J. Ballantyne

Abstract—A recent paper on soliton oscillators gave a parsimonious account of earlier work and omitted a critical reference.

In [1]–[4], an electrical soliton oscillator was reported. We called it the *Baseband Soliton Oscillator* (BSO) because [4] also considered a similar device that supported envelope solitons (the ESO). A recent paper remarked that the BSO lacked “robustness, reproducibility and controllability” and claimed priority for such a device [5]. This is difficult for readers to assess for themselves as [1] (the only published record of the bulk of our work) is not cited. A few words of clarification are thus required.

A single soliton oscillation, where one pulse circulates endlessly in the loop, was easy to arrange in the BSO (for example, Fig. 2 of [1]). We were careful to identify the fundamental stability mechanism (tall solitons are narrow, and experience greater loss), and to form and solve the governing nonlinear partial differential equation. The steady-state solution showed how to control the soliton with respect to the device’s parameters (which we verified with repeatable experiments).

Many types of robustness may be contemplated for the BSO: for example, structural robustness (e.g., the number of circulating solitons) and amplitude robustness (e.g., the sensitivity of the soliton amplitude to the loop gain). As to structural robustness, we found that if the loop gain was increased beyond a critical level, multiple pulses could be observed in some configurations, and we identified subtle behavior corresponding to the double-cnoidal solutions of the Korteweg–De Vries equation.¹ However, even these were well-behaved (i.e., reproducible and controllable)—and absent if the loop gain was below the threshold value. Furthermore, it was observed in Sec. 2.2.2 of [4] that double-pulse waveforms could be eliminated using either the length of the loop or the strength of the nonlinearity. Unfortunately, [5] unfairly equates the mere presence of multiple pulses to an “oscillation instability” without noting the legitimate double-cnoidal solution, and omits entirely the existence of structurally robust single soliton oscillations. This is significant, as structural stability is a major element of [5].

As to amplitude robustness, [5] correctly identifies the sensitivity of the BSO oscillation amplitude to the loop gain. Unfortunately, [5] does not mention that this conclusion is based on a single design instance, or explore options given by the steady-state analysis in [1]

(such as increasing either the frequency-dependent losses or nonlinearity strength, as shown in Figs. 10 and 11 of [1]). Nevertheless, it is fair to note that some form of gain control, be it that suggested in [5] or some standard means, would be required for robustness in a commercial device—but this does not indicate a lack of reproducibility or controllability. Even with the stated loop gain sensitivity, the BSO is determinedly attracted to a reproducible and controllable soliton oscillation, and [5] neither makes this clear nor cites the accessible reference [1] for comparison. In general, claims that solitons are “unruly” in the BSO are unjustified.

A pivotal element of [5] is the use of saturable absorption (SA). Unfortunately, [5] omits to note either the use of SA in the ESO (a closely related device in [4]) or the conclusion that SA is implicit in the dissipative nonlinear dynamics of the BSO (in [1] and [4] we noted that smaller pulses experience a relatively larger loss upon collision with larger pulses [6]). These references are required to give a proper context to [5] and conclusions about the “necessity” of explicit SA (e.g., localized in the amplifier) cannot be drawn before the self-organization in [6] is better understood.²

By adding gain control, [5] may well ease the implementation when factors of process, voltage and temperature are at play. However, suggestions that the BSO in [1] is generally unstable, unruly, or uncontrollable are unsupported. The BSO is indeed a “general concept”, but not one established in [5] or its related work.

Readers may find that the technical issues, and the devices’ provenance, to be moot—and ultimately they should judge for themselves. Unfortunately, the omission of [1] (published in an accessible and well-known journal) in favor of [4] (unpublished and remotely located) has made this judgment unreasonably difficult.³

REFERENCES

- [1] G. J. Ballantyne, P. T. Gough, and D. P. Taylor, “A baseband soliton oscillator,” *Chaos, Solitons & Fractals*, vol. 5, no. 6, pp. 1013–1029, Jun. 1995.
- [2] G. J. Ballantyne, P. T. Gough, and D. P. Taylor, “Periodic solutions of the Toda lattice in a nonlinear transmission line,” *Electron. Lett.*, vol. 29, no. 7, pp. 607–609, Apr. 1993.
- [3] G. J. Ballantyne, P. T. Gough, and D. P. Taylor, “Deriving average soliton equations with a perturbative method,” *Phys. Rev. E*, vol. 51, no. 1, pp. 825–828, 1995.
- [4] G. J. Ballantyne, “Periodically amplified soliton systems” Ph.D. dissertation, Dept. Elect. Electron. Eng., Univ. of Canterbury, Christchurch, New Zealand, 1994.
- [5] D. S. Ricketts, X. Li, N. Sun, K. Woo, and D. Ham, “On the self-generation of electrical soliton pulses,” *IEEE J. Solid-State Circuits*, vol. 42, no. 8, pp. 1657–1668, Aug. 2007.
- [6] A. Hasegawa, Y. Kodama, and K. Watanabe, “Self-organization in Korteweg-de Vries turbulence,” *Phys. Rev. Lett.*, vol. 47, no. 21, pp. 1525–1529, 1981.

²In this context it is difficult to justify the claim in [5] that understanding of the BSO “does not warrant detailed mathematical description.”

³The author will make an electronic version of [4] available upon publication of these comments.

Manuscript received October 4, 2007; revised December 13, 2007.

The author resides in Christchurch 8081, New Zealand (e-mail: gary.ballantyne@ieee.org).

Digital Object Identifier 10.1109/JSSC.2008.923729

¹In [4] more exotic behavior was observed in an initial prototype (soliton lattices), but represents an insignificant part of the work.

Authors' Response

David Ricketts, Xiaofeng Li, Nan Sun, Kyoungho Woo, and Donhee Ham

We are fully confident that our citation and description of G. J. Ballantyne's work in our publications, including our IEEE JOURNAL OF SOLID-STATE CIRCUITS (JSSC) paper [5]¹ of concern, is fair and correct. This is substantiated by the major results of Ballantyne's own experiments in his paper [1], contrary to his comments, as we will expound upon shortly.

A. On Reference [1]

It is an incorrect insinuation that our not citing paper [1] in our JSSC paper [5] is an attempt to avoid comparison to his work. First, at his personal request a few years ago, we cited paper [1] in our IEEE TRANSACTIONS ON MICROWAVE THEORY AND TECHNIQUES (T-MTT) paper [7] where we introduced the concept of our soliton oscillator. Second, the part Ballantyne is addressing in the JSSC paper is the review of the T-MTT paper. Thus, rather than citing all references, we constantly refer readers to the T-MTT paper, where paper [1] can be readily found. Moreover, the JSSC paper cited Ballantyne's Ph.D. thesis [4] instead of all his papers, for the thesis entirely subsumes paper [1]. Third, and most importantly, contrary to his comments, the major portion of experiments in his paper [1] vividly reveal marginal stability and lack of robustness in his design. We now elaborate on this third point, with evidence found from no more than paper [1].

B. On Robustness and Stability

Solitons are pulses created in nonlinear media. The goal of our work (JSSC [5], T-MTT [7]) is to build an oscillator that self-generates a periodic train of voltage soliton pulses with *stability*, that is, with constant amplitude and constant period. As in any engineering design, our goal is also to make the oscillator *robust*, i.e., immune to foreseeable variations and resistant to perturbations.

As we duly acknowledged (JSSC [5], T-MTT [7]), Ballantyne indeed observed a soliton pulse train with constant amplitude and period in what he called a baseband soliton oscillator or BSO, but only within a very narrow range(s) of gain values [1]. Within this range, maintaining a given waveform mandated a gain adjustment down to the third significant digit (e.g., 1.093, Fig. 2, [1]), and a slight change of gain by 1.6% from 1.093 to 1.110 drastically altered the waveform, changing its amplitude by more than seven-fold from 0.08 V to 0.6 V. This extreme sensitivity to gain is evident in Fig. 2 of [1], and obvious in Figs. 10 and 11 of [1]. Now when gain goes outside the narrow range(s), which is expected to happen with any reasonable variations (temperature, supply, components), two solitons appear and collide with each other in Ballantyne's system. Soliton collisions cause varying amplitudes and periods, as seen in his experiments: Fig. 3, [1]. This prevents the maintenance of a stable pulse stream of constant amplitude and period. Results in [1] serve as unassailable evidence for marginal stability and lack of robustness in Ballantyne's design. This design, whose gain needs to be tuned to the third significant digit within a very narrow range to maintain an oscillation of constant amplitude and period, would hardly survive any practical engineering scenario fraught with variations. We add

that even such a marginal stability was possible only after taking an impractical measure of adding losses. Not only is this approach counter to engineers' efforts to minimize dissipation, but it also points to the inherently unstable nature of his oscillator.

The very point of our work (JSSC [5], T-MTT [7]) was to do what Ballantyne's paper [1] had not been able to achieve, that is, to robustly produce a stable train of soliton pulses. Our design entails no gain tuning. It self-adjusts to produce a stable pulse train upon being switched on, just as any familiar *LC* oscillator would produce a sinusoidal signal upon connection to a DC supply. Furthermore, even when multiple solitons are generated, while in Ballantyne's system of [1] they collide to cause varying amplitudes and periods, our system forces them to march at the same speed, preventing their collision and maintaining a stable oscillation with constant amplitude and period. Our three prototypes from MHz to GHz, all using different components and technologies, robustly produce stable oscillations.

C. On "Unruly" Behaviors of Solitons

Ballantyne remarks that "two colliding solitons in [his] system were well-behaved" and "[our] calling solitons unruly is unjustified," but these are out of context. Whether or not two colliding solitons can be called well-behaved depends on what one desires to do. In our design, the aim is to attain a stable pulse train of constant amplitude and period, and hence, colliding solitons are absolutely unruly. On the other hand, Ballantyne is content with colliding solitons (and resulting varying amplitude and period), and calls them well-behaved, but this only speaks to the fact that he does not seek to eliminate soliton collisions for stable oscillation. No matter how one characterizes colliding solitons, the point is that permitting soliton collisions destroys a stable pulse stream viable for engineering applications, as seen in Ballantyne's system [1].

In this connection, we also note that his comments incorrectly state that colliding solitons are stable because they are solutions to the system differential equation. As is well known from the elementary theory, differential equations can have stable and unstable solutions, e.g., even chaotic signals are solutions to differential equations. Many engineering designs are focused on preventing unstable solutions by adjusting system parameters. Colliding solitons are *unstable solutions* that must be avoided, as one seeks a stable pulse stream.

D. On Saturable Absorption (the Fifth Paragraph of the Comments)

Saturable absorption is a mechanism by which a higher portion of a pulse receives a larger gain (or smaller loss) and its lower portion receives a smaller gain (or larger loss). Introduced by C. Cutler in 1955 in electronics, it has been adopted in optics as the method of choice for stabilizing laser pulses for decades. Our oscillator realizes saturable absorption in a transistor amplifier to stabilize soliton pulse trains (JSSC [5], T-MTT [7]).

Ballantyne comments on his use of saturable absorption in what he calls an envelope soliton oscillator or ESO from his thesis [4], where he indeed discussed saturable absorption. This, however, is a standard mathematical model with no circuit implementation, and the model had been used in optics long before his work. Moreover, we cited (JSSC [5], T-MTT [7]) the 1955 work by Cutler (39 years earlier than [4]) for saturable absorption, including a dedicated section on Cutler's work (T-MTT [7]). Furthermore, we stated (JSSC [5], T-MTT [7]) the correspondence between our design and pulse lasers with saturable absorption, which had been extensively developed well before the reference [4]. It was not only unnecessary but also irrelevant to cite his mathematical model of the well-known saturable absorption.

Ballantyne incorrectly identifies "larger loss experienced by smaller pulses upon collision with larger pulses" in his system as another saturable absorption mechanism. Although he matches the words "larger loss for smaller pulses" to a partial definition of saturable absorption,

Digital Object Identifier 10.1109/JSSC.2008.923730

¹Note to Reader: References [1]–[6] in our response are identical to those in the "Comments" article by G. J. Ballantyne in this issue. This is to refer to the same papers with the same reference numbers given by Ballantyne's comments, and hence to avoid confusion of the reader. We actually use only a few of the six references. Reference [7] is the new reference added in our response.

the collision-induced phenomenon does not at all bear any functional relevance to saturable absorption. Saturable absorption is for stabilization. The collision phenomenon Ballantyne mentions instead causes instabilities, as in Fig. 3 of his paper [1]. If the phenomenon he describes had been a good saturable absorption mechanism, his design would not have suffered from the stability and robustness problems.

Contrary to other statements in his fifth paragraph, nowhere in our publications did we claim that our solution is necessary or the only way to attain robust stable oscillation. We presented one sufficient solution we found. We did not exclude possibilities for other solutions. Self-organization of solitons mentioned in Ballantyne's comments, whether or not it may be linked to his design of [1], could be a technique to leverage in the future. But the fact lies in that the design of [1] is certainly not a solution to robust stabilization.

E. Conclusion

Ballantyne's comments lack in basis and are unsupported by the facts. They are irrelevant to the theme of our work, and misleading especially from an engineering point of view. His system is useful in examining soliton dynamics, as we remarked in our T-MTT paper [7], but cannot be used as a source of stable pulses in a practical engineering environment. We made every effort to include accurate references of Ballantyne's work, to give them due credit, to describe them objectively, and to incorporate his feedback communicating with him for the past years. Many pieces of research are motivated by overcoming limitations of previous work, and as such, highlighting limitations of his work in our papers and building upon them was par for the course in our work.

REFERENCES

- [1] G. J. Ballantyne, P. T. Gough, and D. P. Taylor, "A baseband soliton oscillator," *Chaos, Solitons & Fractals*, vol. 5, no. 6, pp. 1013–1029, Jun. 1995.
- [2] G. J. Ballantyne, P. T. Gough, and D. P. Taylor, "Periodic solutions of the Toda lattice in a nonlinear transmission line," *Electron. Lett.*, vol. 29, no. 7, pp. 607–609, Apr. 1993.

- [3] G. J. Ballantyne, P. T. Gough, and D. P. Taylor, "Deriving average soliton equations with a perturbative method," *Phys. Rev. E*, vol. 51, no. 1, pp. 825–828, 1995.
- [4] G. J. Ballantyne, "Periodically amplified soliton systems" Ph.D. dissertation, Dept. Elect. Electron. Eng., Univ. of Canterbury, Christchurch, New Zealand, 1994.
- [5] D. S. Ricketts, X. Li, N. Sun, K. Woo, and D. Ham, "On the self-generation of electrical soliton pulses," *IEEE J. Solid-State Circuits*, vol. 42, no. 8, pp. 1657–1668, Aug. 2007.
- [6] A. Hasegawa, Y. Kodama, and K. Watanabe, "Self-organization in Korteweg-de Vries turbulence," *Phys. Rev. Lett.*, vol. 47, no. 21, pp. 1525–1529, 1981.
- [7] D. S. Ricketts, X. Li, and D. Ham, "Electrical soliton oscillator," *IEEE Trans. Microw. Theory Tech.*, vol. 54, no. 1, pp. 373–382, Jan. 2006.

Correction to "Design and Analysis of a Performance-Optimized CMOS UWB Distributed LNA"

Payam Heydari

In our paper [1], we compared our circuit with 13 other circuits. As pointed out to us by Xin Guan, who is the first author of Ref. [30] in [1], there is a small typo in reporting the gain of their amplifier. The gain should be 16 dB, not 10 dB. The confusion was partly because their amplifier is working in two modes of operation, high gain and low power. The results in the table are for the high-gain mode of operation.

We would like to thank Xin Guan for his valuable feedback.

REFERENCES

- [1] P. Heydari, "Design and analysis of a performance-optimized CMOS UWB distributed LNA," *IEEE J. Solid-State Circuits*, vol. 42, no. 9, pp. 1892–1905, Sep. 2007.

Digital Object Identifier 10.1109/JSSC.2008.923725