Mathematics

http://www.aimspress.com/journal/Math

AIMS Mathematics, 5(3): 1881–1892.
DOI: 10.3934/math.2020125
Received: 04 October 2019
Accepted: 18 January 2020
Published: 18 February 2020

Research article

New complex wave patterns to the electrical transmission line model arising in network system

Wei Gao[1,*], Mine Senel[2], Gulnur Yel[3], Haci Mehmet Baskonus[4] and Bilgin Senel[2]

[1] School of Information Science and Technology, Yunnan Normal University, Yunnan, China
[2] Mugla Sitki Kocman University, Fethiye Faculty of Business Administration, Mugla, Turkey
[3] Faculty of Educational Sciences, Final International University, Kyrenia, Mersin 10, Turkey
[4] Harran University, Faculty of Education, Sanliurfa, Turkey

* **Correspondence:** Email: gaowei@ynnu.edu.cn; Tel: +8613529457727.

Abstract: This study reveals new voltage behaviors to the electrical transmission line equation in a network system by using the newly presented sine-Gordon equation function method. It is commented about these behaviors which come from different simulations of results obtained in this paper. Many illustrations are offered to validate our analytical results. Linear stability analysis is also investigated in a detailed manner.

Keywords: nonlinear electrical transmission line equation; SGEM; exponential results with complex; contour graphs; density surfaces
Mathematics Subject Classification: 35Axx, 34Axx

1. Introduction

In the modern century, almost all computational programs use energy including electrical transmission line (ETL) with voltage. Such a line is one of the most important properties of energy transfer concepts. It has been seen that these properties of lines may rotate the behaviors of electrons in ETL. In this regards, F. Kenmogne *et al.* [1] have investigated the ETL in compact-like pulse signals in terms of its stability equilibrium points and weak linear dispersions. Khan *et al.* [2] have observed heat dissipation in ETL circuit. They have introduced a new model to symbolize heat propagation in ETL which results in damages the electrical tools. Dynamic behaviors of the nonlinear models arising in ETL have been presented by Tian *et al.* in [3]. They have used the modified Zakharov-Kuznetsov equation to symbolize physical phenomena. With the help of several analytical tools, physical dynamical properties of ETL have been obtained. Motcheyo *et al* have studied on the Chameleon's behavior of modulable ETL in [4]. They have also derived a mathematical description of

ETL, and also, investigated some numerical behaviors of the model. Yemele *et al.* [5] have modulated the mathematical structures which are dynamics of signals in the network with ETL by considering peaked wave propagation and gray compactons. Mostly, such applications have been observed in communication systems where solitons are used to codify data. They have obtained compact gray compacton and peakon structures. Kanaya *et al.* [6] have designed an electrical small planner antenna with ETL. This is important in matching circuit on the thin patterned circuit board. In this tiny device, they have utilized the concept between interdigital gap and ETL which is composed of coplanar waveguide. Kuusela and his team [7] have conducted an experiment on the original Toda lattice and the dissipative lattice via nonlinear ETL. This is realized in investigating of soliton phenomena in nonlinear discrete systems. In 1987, R.Uklejewski *et al.* [8] have analyzed the transmission of vibrations in a porous vibroisolator with ETL theory. Senel *et al.* [9] have investigated the correlation among electricity and economic simulations. They have characterized the porous damping element of a vibroisolator, and also, they have presented reflection of waves among filtration velocity and fluid pressure. E. Tala-Tebue *et al.* [10,11] have presented a nonlinear model defined by

$$v_{tt} - \alpha(v^2)_{tt} + \beta(v^3)_{tt} - \varpi_0^2\delta_1^2 v_{xx} - \varpi_0^2\frac{\delta_1^4}{12}v_{xxxx} - \omega_0^2\delta_2^2 v_{yy} - \omega_0^2\frac{\delta_2^4}{12}v_{yyyy} = 0, \tag{1.1}$$

where $\alpha, \beta, \varpi_0, \omega_0$ are real constants with non-zero or complex while $v = v(x, y, t)$ defines the voltage in lines. δ_1 symbolize the space in longitudinal while δ_2 is used to explain the space in the transverse direction. This nonlinear electrical transmission line model (NETLM) explains the wave distributions on the network lines [10,11]. Therefore, many new mathematical systems have been introduced to the literature and they have been investigated by various experts [12–28, 33–35].

The contents of this paper are as follows. Section 2 presents the sine-Gordon expansion method [29–31]. Section 3 presents some new mixed dark-bright optical soliton solutions to the Eq (1.1). The main conclusions are presented in the last section of the paper.

2. The SGEM

In this section we discuss the general facts of SGEM. Consider the following sine-Gordon equation:

$$u_{xx} - u_{tt} = m^2 \sin(u), \tag{2.1}$$

where $u = u(x,\ t)$ and m is a real constant. Applying the wave transformation as $u = U(\xi), \xi = \mu(x - ct)$ to Eq (2.1), yields the following nonlinear ordinary differential equation (NODE):

$$U'' = \frac{m^2}{\mu^2(1 - c^2)}\sin(U), \tag{2.2}$$

where μ is the amplitude of the travelling wave and c is the velocity of the travelling wave. Reconsidering Eq (2.2), we can write its full simplification as:

$$\left[\left(\frac{U}{2}\right)'\right]^2 = \frac{m^2}{\mu^2(1 - c^2)}\sin^2\left(\frac{U}{2}\right) + K, \tag{2.3}$$

where K is the integration constant.

Substituting $K = 0$, $w(\xi) = \frac{U}{2}$ and $a^2 = \frac{m^2}{\mu^2(1-c^2)}$ in Eq (2.3), gives:

$$w^{'} = a\sin(w). \tag{2.4}$$

Putting $a = 1$, we have:

$$w^{'} = \sin(w). \tag{2.5}$$

Equation (2.5) is variables separable equation, we obtain the following two significant equations from solving it;

$$\sin(w) = \sin(w(\xi)) = \left.\frac{2pe^{\xi}}{p^2e^{2\xi}+1}\right|_{p=1} = \operatorname{sech}(\xi), \tag{2.6}$$

$$\cos(w) = \cos(w(\xi)) = \left.\frac{p^2e^{2\xi}-1}{p^2e^{2\xi}+1}\right|_{p=1} = \tanh(\xi), \tag{2.7}$$

where p is the integral constant.

For the solution of the following nonlinear partial differential equation;

$$P(u, u_x, u_t, u^2, \ldots) = 0, \tag{2.8}$$

we consider the wave transformation as $u = U(\xi)$, $\xi = \mu(x - ct)$, which converting this equation following nonlinear ordinary differential equation (NODE)

$$N(U, U', U'', \cdots) = 0.$$

In this NODE, according to the general properties of SGEM, it may be chosen that the trial solution form is

$$U(\xi) = \sum_{i=1}^{n} \tanh^{i-1}(\xi)[B_i \operatorname{sech}(\xi) + A_i \tanh(\xi)] + A_0. \tag{2.9}$$

Equation (2.9) can be rewritten according to Eqs (2.6) and (2.7) as follows:

$$U(w) = \sum_{i=1}^{n} \cos^{i-1}(w)[B_i \sin(w) + A_i \cos(w)] + A_0. \tag{2.10}$$

We determine the value n under the terms of NODE by balance principle which is considered as a relationship between the highest degree of the nonlinear terms and highest order of nonlinear differential equation. Letting the coefficients of $\sin^i(w)\cos^j(w)$ to be all zero, yields a system of equations. Solving this system by using various computational programs gives the values of A_i, B_i, μ and c which is being real or complex values. Obtaining the different values of these coefficients giving exact solutions to the considered model produce new physical important of nonlinear mathematical models. Finally, substituting the values of A_i, B_i, μ and c in Eq (2.9), we obtain the new travelling wave solutions to Eq (2.8). The SGEM is an analytical method which is based on two properties of Sine-Gordon equation (SGE). SGE is very important in explaining the wave propagation of the mathematical model.

3. Application of SGEM

In this sub-section, we apply SGEM to the Eq (1.1). With the help of travelling wave transform

$$v = v(x, y, t) = V(\xi), \quad \xi = k(x + y - ct), \tag{3.1}$$

Equation (1.1) may be converted the following nonlinear ordinary differential equation

$$12(c^2 - \varpi_0^2\delta_1^2 - \omega_0^2\delta_2^2)V + 12\beta c^2 V^3 - 12\alpha c^2 V^2 - k^2(\varpi_0^2\delta_1^4 + \omega_0^2\delta_2^4)V'' = 0. \tag{3.2}$$

Using balance principle, yields $n = 1$. Putting $n = 1$ into Eq (2.9) produces

$$V(\xi) = B_1 \operatorname{sech}(\xi) + A_1 \tanh(\xi) + A_0. \tag{3.3}$$

and into Eq (2.10) gives

$$V(w) = B_1 \sin(w) + A_1 \cos(w) + A_0. \tag{3.4}$$

and

$$V'' = B_1 \cos^2(w)\sin(w) - 2A_1 \sin^2(w)\cos(w) - B_1 \sin^3(w). \tag{3.5}$$

Inserting Eqs (3.4) and Eq (3.5) into Eq (3.2), gives an algebraic equation in trigonometric function including various form of $\sin^i(w)\cos^j(w)$. Getting the coefficients of trigonometric terms in the same power to zero, give a system. Solving this system with aid of symbolic software to obtain the values of the coefficients involved, we find following coefficients in each case obtained from the set of algebraic equation systems, and it gives the travelling wave solutions to Eq (1.1).

Case-1: If

$$A_0 = A_1 = \frac{\alpha}{3\beta}, B_1 = \frac{\alpha i}{3\beta}, k = \frac{2\sqrt{6}\sqrt{-\alpha^2(\varpi_0^2\delta_1^2 + \omega_0^2\delta_2^2)}}{\sqrt{(2\alpha^2 - 9\beta)(\varpi_0^2\delta_1^4 + \omega_0^2\delta_2^4)}}, c = \frac{3i\sqrt{\beta(\varpi_0^2\delta_1^2 + \omega_0^2\delta_2^2)}}{\sqrt{(2\alpha^2 - 9\beta)}},$$

produces following new mixed dark-bright optical soliton

$$v_1(x, y, t) = \frac{\alpha}{3\beta}[1 + i\operatorname{sech}(f(x, y, t)) + \tanh(f(x, y, t))], \tag{3.6}$$

where

$$f(x, y, t) = \frac{2\sqrt{6}i\sqrt{\alpha^2(\varpi_0^2\delta_1^2 + \omega_0^2\delta_2^2)}}{\sqrt{(2\alpha^2 - 9\beta)(\varpi_0^2\delta_1^4 + \omega_0^2\delta_2^4)}}(x + y - ct).$$

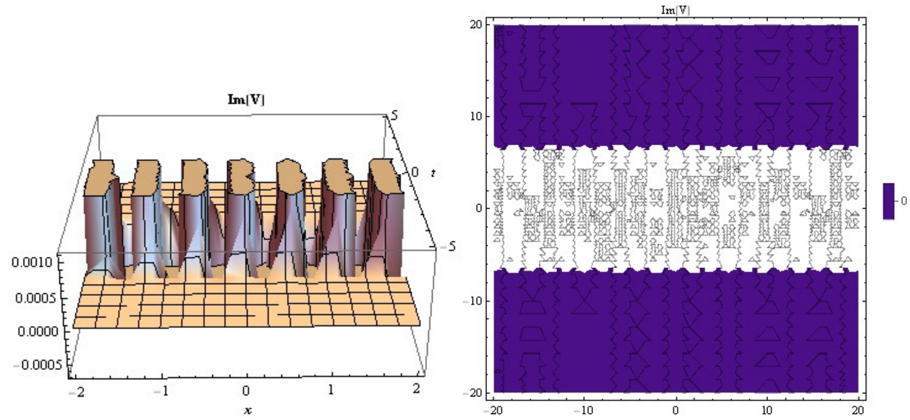

Figure 1. The 3D and Contour surfaces of Eq (3.6).

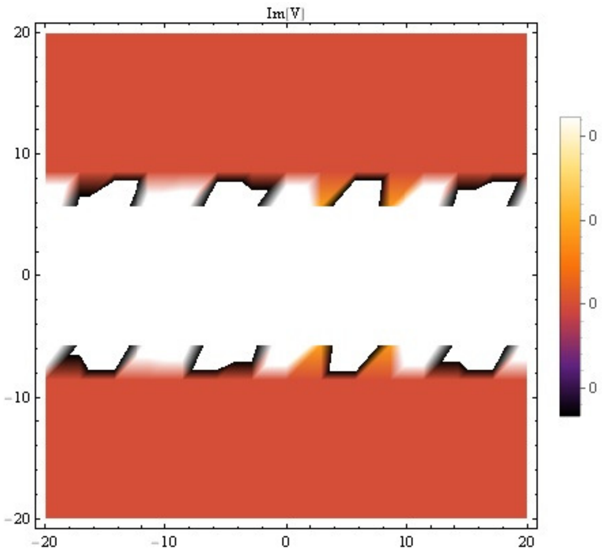

Figure 2. Density graph of Eq (3.6).

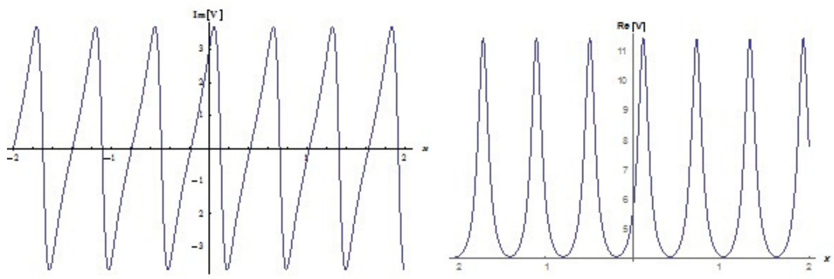

Figure 3. The 2D simulation of Eq (3.6).

Case-2: Choosing these coefficients as $A_0 = \frac{\sqrt{c^2-\varpi_0^2\delta_1^2-\delta_2^2\omega_0^2}}{c\sqrt{2\beta}}$, $A_1 = \frac{\sqrt{c^2-\varpi_0^2\delta_1^2-\delta_2^2\omega_0^2}}{c\sqrt{2\beta}}$, $B_1 = i\frac{\sqrt{c^2-\varpi_0^2\delta_1^2-\delta_2^2\omega_0^2}}{c\sqrt{2\beta}}$, $k = \frac{2\sqrt{3}\sqrt{c^2-\varpi_0^2\delta_1^2-\delta_2^2\omega_0^2}}{\sqrt{\varpi_0^2\delta_1^4+\delta_2^4\omega_0^2}}$, $\alpha = \frac{3\sqrt{\beta}\sqrt{c^2-\varpi_0^2\delta_1^2-\delta_2^2\omega_0^2}}{c\sqrt{2}}$,
we can find other new mixed dark-bright optical soliton

$$v_2(x,y,t) = i\frac{\sqrt{c^2-\varpi_0^2\delta_1^2-\delta_2^2\omega_0^2}}{c\sqrt{2\beta}}\operatorname{sech}(g(x,y,t)) + \frac{\sqrt{c^2-\varpi_0^2\delta_1^2-\delta_2^2\omega_0^2}}{c\sqrt{2\beta}}(1+\tanh(g(x,y,t)), \tag{3.7}$$

where

$$g(x,y,t) = \frac{2\sqrt{3}(x+y-ct)\sqrt{c^2-\varpi_0^2\delta_1^2-\omega_0^2\delta_2^2}}{\sqrt{\varpi_0^2\delta_1^4+\omega_0^2\delta_2^4}}.$$

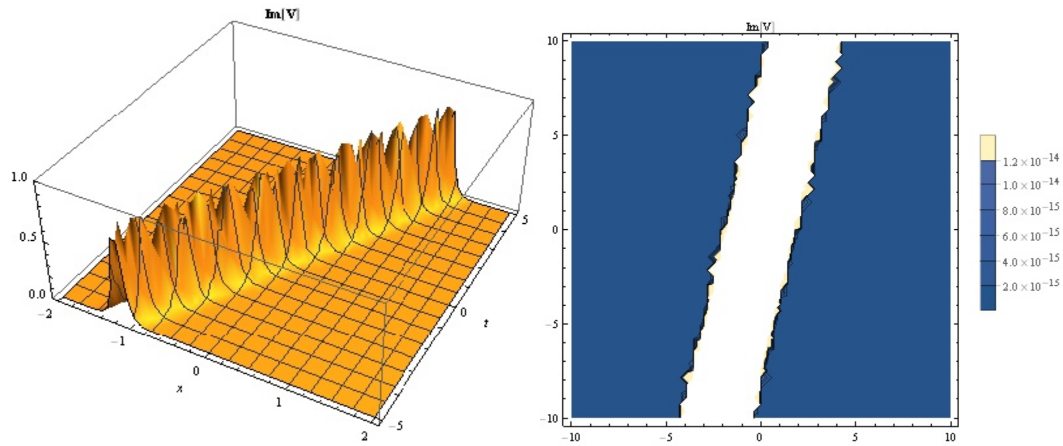

Figure 4. The 3D and Contour surfaces of Eq (3.7).

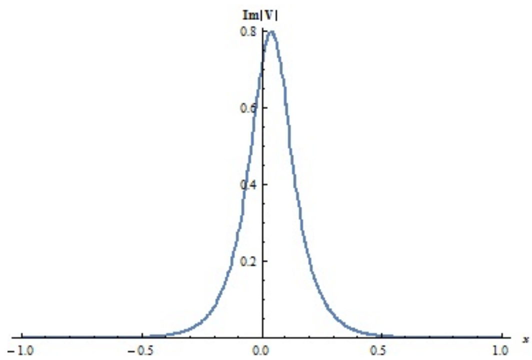

Figure 5. The 2D surface of Eq (3.7).

Case-3: When $A_0 = \frac{\alpha}{3\beta}, A_1 = \frac{-\alpha}{3\beta}$, $B_1 = \frac{-i\alpha}{3\beta}$, $k = \frac{-2\sqrt{6}i\sqrt{\alpha^2(\varpi_0^2\delta_1^2+\delta_2^2\omega_0^2)}}{\sqrt{(2\alpha^2-9\beta)(\varpi_0^2\delta_1^4+\delta_2^4\omega_0^2)}}$, $c = \frac{3i\sqrt{\beta(\varpi_0^2\delta_1^2+\delta_2^2\omega_0^2)}}{\sqrt{2\alpha^2-9\beta}}$, produces another mixed soliton as

$$v_3(x,y,t) = \frac{-\alpha}{3\beta}(-1 + i\sec(g(x,y,t)) - i\tan(g(x,y,t))), \tag{3.8}$$

where

$$g(x,y,t) = \frac{2\sqrt{6}\sqrt{\alpha^2(\varpi_0^2\delta_1^2 + \omega_0^2\delta_2^2)}}{\sqrt{(2\alpha^2 - 9\beta)(\varpi_0^2\delta_1^4 + \omega_0^2\delta_2^4)}}(x + y - ct)$$

.

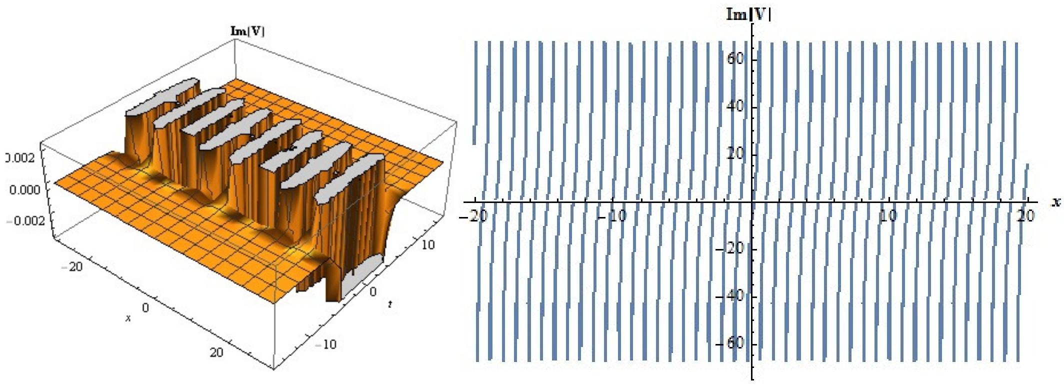

Figure 6. The 3D and 2D surfaces of Eq (3.8).

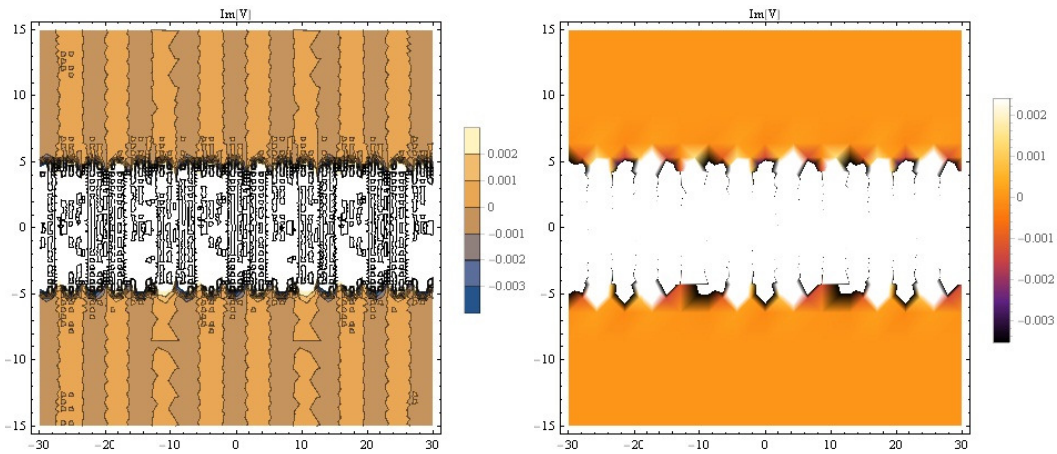

Figure 7. The Contour and density surfaces of Eq (3.8).

Case-4: If $A_0 = \frac{\alpha}{3\beta}$,$A_1 = 0$,$B_1 = \frac{-\sqrt{2}\alpha}{3\beta}$, $\omega_0 = \frac{-ik(2c^2\alpha^2-9\beta c^2+9\beta\delta_2^2\omega_0^2)}{\sqrt{108c^2\alpha^2\beta+81k^2\beta^2\delta_2^4\omega_0^2}}$, $\delta_1 = \frac{-\sqrt{12c^2\alpha^2+9k^2\beta\delta_2^4\omega_0^2}}{\sqrt{k^2(c^2(2\alpha^2-9\beta)+9\beta\delta_2^2\omega_0^2)}}$, gives new bright optical soliton as

$$v_4(x, y, t) = \frac{\alpha}{3\beta}(1 - \sqrt{2}\,\mathrm{sech}(k(x + y - ct))). \tag{3.9}$$

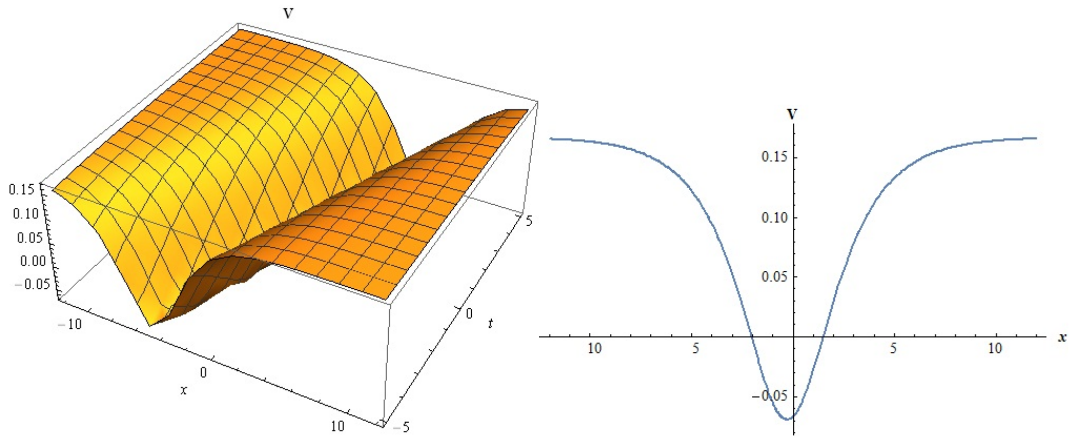

Figure 8. The 3D and 2D surfaces of Eq (3.9).

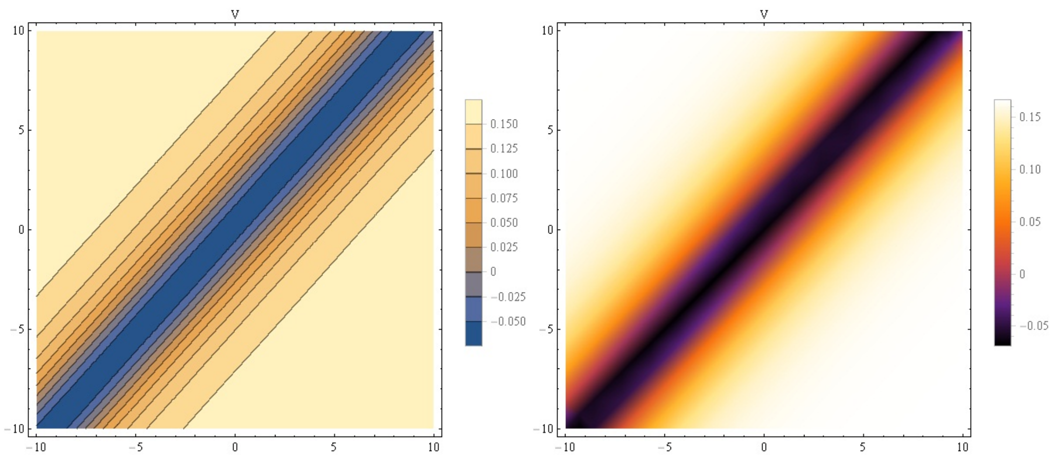

Figure 9. The Contour and density surfaces of Eq (3.9).

4. Linear stability analysis

We consider the perturbed solution of the form

$$v(x, y, t) = a_1 + a_2 V(x, y, t), \tag{4.1}$$

where the a_1 is a steady state of the solution of Eq (1.1). Putting Eq (4.1) into Eq (1.1), we get

$$(6a_1a_2^2\beta - 2a_2^2\alpha)(V_t^2) + 6a_2^3\beta V(V)_t^2 + (a_2 - 2a_1a_2\alpha + 3a_1^2a_2\beta)V_{tt} + (6a_1a_2^2\beta - 2a_2^2\alpha)VV_{tt}$$
$$+ 3a_2^3\beta V^2V_{tt} - a_2\delta_2^2\omega_0^2V_{yy} - \frac{1}{12}a_2\delta_2^4\omega_0^2V_{yy} - a_2\varpi_0^2\delta_1^2V_{xx} - \frac{1}{12}a_2\varpi_0^2\delta_1^4V_{xxxx} = 0, \quad (4.2)$$

Taking the linearization of Eq (4.2), we get

$$(a_2 - 2a_1a_2\alpha + 3a_1^2a_2\beta)V_{tt} - a_2\delta_2^2\omega_0^2V_{yy} - \frac{1}{12}a_2\delta_2^4\omega_0^2V_{yyyy} - a_2\varpi_0^2\delta_1^2V_{xx} - \frac{1}{12}a_2\varpi_0^2\delta_1^4V_{xxxx} = 0, \quad (4.3)$$

Letting that Eq (4.3) has solution of the form

$$V(x, y, t) = e^{i(klx+2ky)+t\Omega}, \quad (4.4)$$

where $k_i, i = 1, 2$ are the normalized wave number. Inserting Eq.(4.4) into Eq.(4.3), we get

$$a_2e^{i(klx+2ky)+t\Omega}\Big(12(1 - 2a_1\alpha + 3a_1^2\beta)\Omega^2 + k_1^2\varpi_0^2\delta_1^2(12 - k_1^2\delta_2^2) + k_2^2\delta_2^2(12 - k_2^2\delta_2^2)\omega_0^2\Big) = 0, \quad (4.5)$$

Solving Eq (4.5) for Ω, the result yields

$$\Omega_1; \quad \Omega(k_1, k_2) = -\frac{\sqrt{k_1^2\varpi_0^2\delta_1^2(-12 + k_1^2\delta_1^2) + k_2^2\delta_2^2(-12 + k_2^2\delta_2^2)\omega_0^2}}{2\sqrt{3 - 6a_1\alpha + 9a_1^2\beta}}, \quad (4.6)$$

or

$$\Omega_2; \quad \Omega(k_1, k_2) = \frac{\sqrt{k_1^2\varpi_0^2\delta_1^2(-12 + k_1^2\delta_1^2) + k_2^2\delta_2^2(-12 + k_2^2\delta_2^2)\omega_0^2}}{2\sqrt{3 - 6a_1\alpha + 9a_1^2\beta}}, \quad (4.7)$$

From solution 1, if $k_1^2\varpi_0^2\delta_1^2(-12 + k_1^2\delta_1^2) + k_2^2\delta_2^2(-12 + k_2^2\delta_2^2)\omega_0^2 > 0$ and $3 - 6a_1\alpha + 9a_1^2\beta > 0$ or $k_1^2\varpi_0^2\delta_1^2(-12 + k_1^2\delta_1^2) + k_2^2\delta_2^2(-12 + k_2^2\delta_2^2)\omega_0^2 < 0$ and $3 - 6a_1\alpha + 9a_1^2\beta < 0$, then the real is always negative, in this case the dispersion is stable. If $k_1^2\varpi_0^2\delta_1^2(-12 + k_1^2\delta_1^2) + k_2^2\delta_2^2(-12 + k_2^2\delta_2^2)\omega_0^2 < 0$ and $3 - 6a_1\alpha + 9a_1^2\beta > 0$ or $k_1^2\varpi_0^2\delta_1^2(-12 + k_1^2\delta_1^2) + k_2^2\delta_2^2(-12 + k_2^2\delta_2^2)\omega_0^2 > 0$ and $3 - 6a_1\alpha + 9a_1^2\beta < 0$, then the real part is zero, so in this case, it is more difficult to assess the long term behavior in this case, and it is label as the marginally stable.

From solution 2, if $k_1^2\varpi_0^2\delta_1^2(-12 + k_1^2\delta_1^2) + k_2^2\delta_2^2(-12 + k_2^2\delta_2^2)\omega_0^2 > 0$ and $3 - 6a_1\alpha + 9a_1^2\beta > 0$ or $k_1^2\varpi_0^2\delta_1^2(-12 + k_1^2\delta_1^2) + k_2^2\delta_2^2(-12 + k_2^2\delta_2^2)\omega_0^2 < 0$ and $3 - 6a_1\alpha + 9a_1^2\beta < 0$, then the real is always positive, in this case the dispersion is unstable. If $k_1^2\varpi_0^2\delta_1^2(-12 + k_1^2\delta_1^2) + k_2^2\delta_2^2(-12 + k_2^2\delta_2^2)\omega_0^2 < 0$ and $3 - 6a_1\alpha + 9a_1^2\beta > 0$ or $k_1^2\varpi_0^2\delta_1^2(-12 + k_1^2\delta_1^2) + k_2^2\delta_2^2(-12 + k_2^2\delta_2^2)\omega_0^2 > 0$ and $3 - 6a_1\alpha + 9a_1^2\beta < 0$, then the real part is zero, so in this case, it is more difficult to assess the long term behavior in this case, and it is label as the marginally stable.

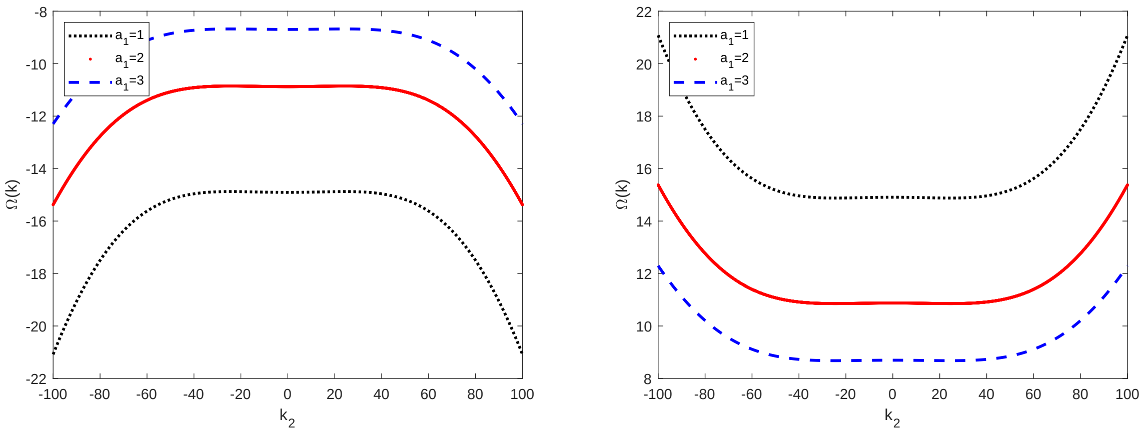

Figure 10. 2D of Eq (4.6) and Eq (4.7), respectively, when $\alpha = -1, \beta = 0.1; \delta_1 = 1, \delta_2 = 0.1, \varpi = 1, k_1 = 10$.

5. Conclusions

In this research, the newly presented sine-Gordon equation method has been developed. The newly presented technique gives variety of wave solutions when tested on the nonlinear electrical transmission line model. Dark, mixed dark-bright optical, singular and mixed singular solitons solutions are successfully constructed. The conditions which guarantee the existence of the valid solutions to this model are given. The 2-, 3-dimensional, contour and density graphs to this model have been plotted to observe voltage behaviors on the electrical transmission line. It can be observed from Figures 1,3,5,6,8 that voltage is travelling wave propagations in the same electrical line. From Figure 2,4,7,9, it can be inferred that electrical flow is stable and density between suitable places on this line. In this sense, linear stability analysis has been also investigated the strain conditions for the stability of Eq (1.1). After considering results obtained in this paper, it is estimated that these results have one of the most important properties of gravitational potential properties with dark and bright solutions [32]. The sine-Gordon equation method is an efficient and powerful mathematical approach which may be used in generating varieties of wave solutions to different kind of nonlinear wave equations.

Acknowledgments

Authors would like to express their thanks for the reviewers' valuable comments to improve this paper.

Conflict of interest

The Authors declare that there is no conflict of interest.

References

1. H. Y. Donkeng, F. Kenmogne, D. Yemele,et al., *Modulated compact-like pulse signals in a nonlinear electrical transmission line: A specific case studied*, Chin. J. Phys., **55** (2017), 683–691.
2. K. A. Abro, I. Khan, K. S. Nisar, *Novel technique of Atangana and Baleanu for heat dissipation in transmission line of electrical circuit*, Chaos Sol. Fract., **129** (2019), 40–45.
3. H. L. Zhen, B. Tian, H. Zhong, et al., *Dynamic behaviors and soliton solutions of the modified Zakharov-Kuznetsov equation in the electrical transmission line*, Comput. Math. with Appl., **68** (2014), 579–588.
4. A. B. T. Motcheyo, J. D. T. Tchameu, S. I. Fewo, et al., *Chameleon's behavior of modulable nonlinear electrical transmission line*, Commun Nonlinear Sci, **53** (2017), 22–30.
5. F. Kenmogne, D. Yemele, *Exotic modulated signals in a nonlinear electrical transmission line: Modulated peak solitary wave and gray compacton*, Chaos Sol. Fract., **45** (2012), 21–34.
6. H. Kanaya, Y. Nakamura, R. K. Pokharela, et al., *Development of electrically small planar antennas with transmission line based impedance matching circuit for a 2.4 GHz band*, AEU-Int. J. Eletron. C., **65** (2011), 148–153.
7. T. Kuusela, *Soliton experiments in a damped ac-driven nonlinear electrical transmission line*, Phys. Lett. A, **167** (1992), 54–59.
8. R. Uklejewski, *Analysis of transmission of vibrations in a porous vibroisolator on the basis of electrical transmission line theory*, J. Sound Vib., **113** (1987), 9–16.
9. M. Senel, B. Senel, L. Bilir, et al., *The relation between electricity demand and the economic and demographic state: A multiple regression analysis*, J. Energy Dev., **38** (2013), 257–274.
10. E. Tala-Tebue, D. C. Tsobgni-Fozap, A. Kenfack-Jiotsa, et al., *Envelope periodic solutions for a discrete network with the Jacobi elliptic functions and the alternative (G'/G)-expansion method including the generalized Riccati equation*, Eur. Phys. J. Plus, **129** (2014), 1–10.
11. E. Tala-Tebue, E. M. E. Zayed, *New Jacobi elliptic function solutions, solitons and other solutions for the (2+1)-dimensional nonlinear electrical transmission line equation*, Eur. Phys. J. Plus, **133** (2018), 1–7.
12. C. Cattani, *Harmonic wavelet solutions of the Schrodinger equation*, Int. J. Fluid Mech., **30** (2003), 463–472.
13. Z. Zhao, B. Han, *Residual symmetry, Bucklund transformation and CRE solvability of a (2+1)-dimensional nonlinear system*, Nonlinear Dyn., **94** (2018), 461–474.
14. E. I. Eskitascioglu, M. B. Aktas, H. M. Baskonus, *New complex and hyperbolic forms for Ablowitz-Kaup-Newell-Segur wave equation with fourth order*, Appl. Math. Nonlinear Sci., **4** (2019), 105–112.
15. A. Yokus, H. M. Baskonus, T. A. Sulaiman, et al., *Numerical simulation and solutions of the two a component second order KdV evolutionary system*, Numer. Math. Part. Dif. E., **34** (2018), 211–227.
16. A. Yokus, T. A. Sulaiman, M. T. Gulluoglu, et al., *Stability analysis, numerical and exact solutions of the (1+1)-dimensional NDMBBM equation*, Numer. Math. Part. Dif. E., **22** (2018), 1–10.
17. Z. Zhao, B. Han, *Lump solutions of a (3+1)-dimensional B-type KP equation and its dimensionally reduced equations*, Anal. Math. Phys., **9** (2019), 119–130.

18. C. Cattani, *On the existence of wavelet symmetries in archaea DNA*, Comput. Math. Method M., **2012** (2012), 1–21.
19. M. Guedda, Z. Hammouch, *Similarity flow solutions of a non-newtonian power-law fluid*, Int. J. Nonlinear Sci., **6** (2008), 255–264.
20. A. Prakash, M. Kumar, K. K. Sharma, *Numerical method for solving coupled Burgers equation*, Appl. Math. Comput., **260** (2015), 314–320.
21. M. Guedda, Z. Hammouch, *On similarity and pseudo-similarity solutions of Falkner-Skan boundary layers*, Fluid Dyn. Res., **38** (2006), 211–223.
22. H. Rezazadeh, *New solitons solutions of the complex Ginzburg-Landau equation with Kerr law nonlinearity*, Optik, **167** (2018), 218–227.
23. C. Cattani, *Haar wavelet-based technique for sharp jumps classification*, Math. Comput. Model., **39** (2004), 255–278.
24. G. Yel, H. M. Baskonus, H. Bulut, *Novel archetypes of new coupled Konno-Oono equation by using sine-Gordon expansion method*, Opt. Quant. Electron., **49** (2017), 1–10.
25. O. A. Ilhan, A. Esen, H. Bulut, et al., *Singular solitons in the Pseudo-parabolic model arising in nonlinear surface waves*, Results Phys., **12** (2019), 1712–1715.
26. L. D. Moleleki, T. Motsepa, C. M. Khalique, *Solutions and conservation laws of a generalized second extended (3+1)-dimensional Jimbo-Miwa equation*, Applied Math. Nonlinear Sci., **3** (2018), 459–474.
27. H. M. Baskonus, *New acoustic wave behaviors to the Davey-Stewartson equation with power-law nonlinearity arising in fluid dynamics*, Nonlinear Dyn., **86** (2016), 177–183.
28. C. M. Khalique, I. E. Mhlanga, *Travelling waves and conservation laws of a (2+1)-dimensional coupling system with Korteweg-de Vries equation*, Applied Math. Nonlinear Sci., **3** (2018), 241–254.
29. H. Bulut, T. A. Sulaiman, H. M. Baskonus, *New solitary and optical wave structures to the Korteweg-de Vries equation with dual-power law nonlinearity*, Opt. Quant. Electron., **48** (2016), 1–14.
30. H. Bulut, T. A. Sulaiman, H. M. Baskonus, et al., *New solitary and optical wave structures to the (1+1)-Dimensional combined KdV-mKdV equation*, Optik, **135** (2017), 327–336.
31. C. Yan, *A Simple Transformation for nonlinear waves*, Phys. Lett. A, **22** (1996), 77–84.
32. E. W. Weisstein, *Concise encyclopedia of mathematics*, Secnd Eds., New York, CRC Press, 2002.
33. W. Gao, H. F. Ismael, A. M. Husien, et al., *Optical soliton solutions of the nonlinear Schrodinger and resonant nonlinear Schrodinger equation with parabolic Law*, Applied Sci., **10** (2020), 1–20.
34. J. L. G. Guirao, H. M. Baskonus, A. Kumar, et al., *Complex soliton solutions to the (3+1)-dimensional B-type Kadomtsev-Petviashvili-Boussinesq equation*, Symmetry, **12** (2020), 1–17.
35. W. Gao, G. Yel, H. M. Baskonus, et al., *Complex solitons in the conformable (2+1)-dimensional Ablowitz-Kaup-Newell-Segur equation*, Aims Math., **5** (2020), 507–521.

AIMS Press