Generation of Discrete Frequencies for Wireless Sensor Network Using ZigBee

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Abstract: In this study, a system of discrete frequencies generation via a series of microring resonator (MRR) is presented. Chaotic signals can be generated by a Gaussian pulse within a MRR system. Large bandwidth signals of optical soliton are generated by input pulse propagating within the MRRs, which can be used to form continuous frequency with large tunable channels. In order to filter the desired frequency channels, an add/drop filter with the appropriate parameters is proposed. In this work, 16 frequency channels with 2 MHz FWHM and 5 MHz FSR are localized. Selected discrete channels are applicable for wireless sensor network using ZigBee and compatible with IEEE standard 802.15.4.

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1. Introduction

Wireless Sensor Networks are fully autonomous self-configuring ad-hoc networks. Monitoring and control in home, office, industrial, and outdoor environments are some typical WSN applications. WSNs can include hundreds of tiny and very energy constrained nodes, which communicate wirelessly with each other or sense their environment. ZigBee is an open specification for low-power wireless networking, which complements the LR-WPAN standard with network and security layers, and application profiles. The ZigBee Alliance is an association of companies working together to develop standards and products for reliable, cost-effective, low-power wireless networking. ZigBee technology is embedded in a wide range of products and applications across commercial, consumer, industrial and government markets worldwide (Mofarrahi, Rahiminezhad Galankashi et al. 2013). ZigBee builds upon the IEEE 802.15.4 standard which defines the physical and MAC layers for low cost, low rate personal area networks. ZigBee defines the network layer specifications for star, tree and peer-to-peer network topologies and provides a framework for application programming in the application layer (Gutierrez, Callaway et al. 2004). The advantages of an LR-WPAN are ease of installation, reliable data transfer, short-range operation, extremely low cost, and a reasonable battery life, while maintaining a simple and flexible protocol stack.

The physical layer supports three frequency bands; 2450 MHz band with 16 channels, 915 MHz band with 10 channels and a 868 MHz band with 1 channel. The 2450 MHz band applies Offset Quadrature Phase Shift Keying (O-QPSK) as modulation and two other bands work based on Binary Phase Shift Keying (BPSK). Table 1 summarizes the main features of the three bands. Besides radio on/off operation, the physical layer supports functionalities for channel selection, link quality estimation, energy detection measurement and clear channel assessment (Baronti, Pillai et al. 2007).

Table 1. Radio front-end and physical layer specification

Frequency	2450 MHz	915 MHz	868 MHz
No. of channel	16	10	1
Data rate	250 kbps	40 kbps	20 kbps
Modulation	O-QPSK	BPSK	BPSK

This paper proposes a system of microring resonators to generate applicable frequency channel for wireless sensor networks using ZigBee. MRR consists of a single coupler and a microring resonator. Light of appropriate frequency is injected to the loop by the input waveguide. Over multiple round-trip, the intensity will build up due to constructive interference. Since only some frequencies resonate within the loop, it functions as a filter. Characterization of light inside a MRR system is investigated in (Shahidinejad, Anwar et al. 2014; Amiri, Ranjbar et al. 2012). MRR has many interesting and effective applications because of its own nature. It shows an effective performance for generating mm-wave and micro wave generation (Amiri, Nikmaram et al. 2012; Amiri, Shahidinejad et al. 2012) and it can be an interesting tool to generate solitonic pulses needed in inter-satellite systems

(Shahidinejad, Soltanmohammadi et al. 2014). Shahidinejad et al. (Amiri, Nikoukar et al. 2013; Amiri, Soltanmohammadi et al. 2013; Sadegh Amiri, Nikmaram et al. 2013; Shahidinejad, Nikoukar et al. 2013) have shown that MRR can be used to generate multi wavelength when a soliton pulse is propagating inside the system. Recently some MRR systems, which are able to generate solitonic pulse shapes and WDM channels, are proposed (Shahidinejad, SOLTANMOHAMMADI et al. 2013; Shahidinejad, Amiri et al. 2014). Dense frequency channels can be generated when the soliton pulse is propagating within the nonlinear MRR system and causes large bandwidth signals to be achieved, which are offered for wireless sensor networks using ZigBee.

2. Theoretical Modeling

The proposed system consists of a series of ring resonators R1, R2 and R3, as shown in Figure 1. The input signal can be inserted into the system via the input port. Here, a mathematical equation of the propagating input pulse inside the nonlinear ring system has been solved in order to show the nonlinear behavior of the output signals. When an optical soliton pulse input into the nonlinear MRR, the large frequency channels of the output signals can be generated where the nonlinear behavior of self-phase modulation (SPM) keeps the large output power. Chaotic signals cancelation can be done using an optical add/drop filter system (Amiri, Sarkhanlou et al. 2012).

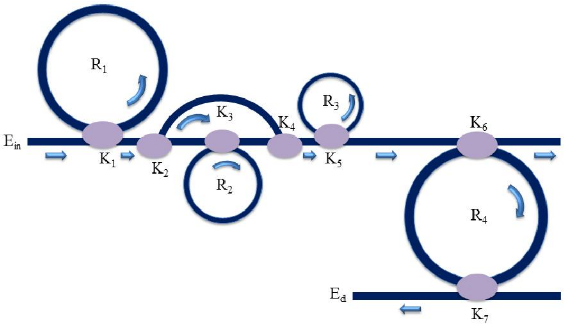

Figure 1. System of desecrate frequency generation

The Gaussian pulse is introduced into the proposed system. The input optical field (Ein) of the Gaussian pulse can be expressed as (Amiri, Nikoukar et al. 2014),

$$E_{in} = A\tan h\left[\frac{T}{T_0}\right]\exp\left[\left(\frac{z}{2L_D}\right) - i\omega_0 t\right] \qquad (1)$$

A and z are the optical field amplitude and propagation distance, respectively. T is the Gaussian pulse propagation time in a frame moving at the group velocity, T = t-β_1*z, where β_1 and β_2 are the coefficients of the linear and second order terms of Taylor expansion of the propagation constant. $L_D = T_0^2/|\beta_2|$ is the dispersion length of the Gaussian pulse. The frequency shift of the input pulse is ω_0 and L_D is dispersion length. When light propagates within the nonlinear medium, the refractive index (n) of light within the medium is given by (Amiri, Ahsan et al. 2012)

$$n = n_0 + n_2 I = n_0 + \left(\frac{n_2}{A_{eff}}\right)P, \qquad (2)$$

n_0 and n_2 are the linear and nonlinear refractive indexes, respectively. I and P are the optical intensity and optical power, respectively. The effective mode core area of the device is given by A_{eff}. For the MRR, the effective mode core area ranges from 0.50 to 0.10 μm^2 (Amiri, Nikoukar et al. 2012). The resonant output can be formed; therefore the normalized output signals of the light field which is the ratio between the output and input fields (E_{out} (t) and E_{in} (t)) in each roundtrip can be expressed by (Shahidinejad, Nikoukar et al. 2012).

$$\left|\frac{E_{out}(t)}{E_{in}(t)}\right|^2 = (1-\gamma)\left[1 - \frac{(1-(1-\gamma)x^2)\kappa}{(1-x\sqrt{1-\gamma}\sqrt{1-\kappa})^2 + 4x\sqrt{1-\gamma}\sqrt{1-\kappa}\sin^2(\frac{\phi}{2})}\right] \qquad (3)$$

Equation (3) specifies that a ring resonator in the exacting case is very similar to a Fabry-Perot cavity, which has an input and output mirror with a field reflectivity, (1-κ), and a fully reflecting mirror. κ is the coupling coefficient, and x=exp(-αL/2) represents a roundtrip loss coefficient, $\Phi_0 = kLn_0$ and $\Phi_{NL} = kLn_2|E_{in}|^2$ are the linear and nonlinear phase shifts, k=2π/λ is the wave propagation number in a vacuum. L and α are a waveguide length and linear absorption coefficient, respectively. In this investigation, the iterative method is introduced to obtain the results as shown in equation (3), similarly, when the output field is connected and input into the next ring resonators. In order to retrieve the signals from the chaotic noise, we propose to use the add/drop device with the appropriate parameters. The optical outputs of a ring resonator add/drop filter are given by Eq. (4) and Eq. (5) (Nikoukar, Amiri et al. 2012).

$$\left|\frac{E_t}{E_{in}}\right|^2 = \frac{(1-\kappa_1) - 2\sqrt{1-\kappa_1}\cdot\sqrt{1-\kappa_2}\,e^{-\frac{\alpha}{2}L}\cos(k_n L) + (1-\kappa_2)e^{-\alpha L}}{1 + (1-\kappa_1)(1-\kappa_2)e^{-\alpha L} - 2\sqrt{1-\kappa_1}\cdot\sqrt{1-\kappa_2}\,e^{-\frac{\alpha}{2}L}\cos(k_n L)} \qquad (4)$$

and

$$\left|\frac{E_d}{E_{in}}\right|^2 = \frac{\kappa_1\kappa_2 e^{-\frac{\alpha}{2}L}}{1+(1-\kappa_1)(1-\kappa_2)e^{-\alpha L} - 2\sqrt{1-\kappa_1}\cdot\sqrt{1-\kappa_2}\,e^{-\frac{\alpha}{2}L}\cos(k_n L)} \qquad (5)$$

E_t and E_d represent the optical fields of the through port and drop ports, respectively. $\beta = kn_{\text{eff}}$ is the propagation constant, n_{eff} is the effective refractive index of the waveguide, and the circumference of the ring is $L=2\pi R$, with R as the radius of the ring (Ali, Raman et al. 2010). New parameters are introduced for simplification with $\phi = \beta L$ as the phase constant. By using the specific parameters of the add/drop device, the chaotic noise cancellation can be obtained and the required signals can be retrieved by the specific users. κ_1 and κ_2 are the coupling coefficients of the add/drop filters, $k_n=2\pi/\lambda$ is the wave propagation number in a vacuum, and the waveguide (ring resonator) loss is α = 0.5 dBmm^{-1}. The fractional coupler intensity loss is γ = 0.1. In the case of the add/drop device, the nonlinear refractive index is neglected (Shahidinejad, Azarpira et al. 2014). High capacity of optical pulses can be obtained when the full width at half maximum (FWHM) of these pulses are very small, where the amplification is performed inside the micro or Nano-ring system (Amiri, Shahidinejad et al. 2012).

3. Results and Discussion

As shown in Figure 2, the input Gaussian pulse has100 MHz pulse width, peak power of .5 W. The ring radii are R_1= 17 µm, R_2= 10 µm, R_3= 7 µm, and R_4 = 220 µm. The fixed parameter are selected to n_0 = 3.34 (InGaAsP/InP), A_{eff} = 0.22 µm^2, α = 0.5 dBmm^{-1}, γ = 0.1. The coupling coefficients range from 0.40 to 0.93, where the nonlinear refractive index is $n_2 = 3.7 \times 10^{-15}$ m^2/W and the wave guided loss used is 0.5dBmm^{-1}. Optical signals are sliced into smaller signals broadening over the band as shown in Figure 2. Therefore, large frequency band is formed within the first ring device, where compress bandwidth with smaller group velocity is attained inside the rings R_2 and R_3, such as filtering signals. Localized soliton pulses are formed, when resonant condition is performed, given in Figure 2. In fact the second and the third ring in the system are used to trap the solitonic pulse shape. The proposed add/drop in the system, order and tune the desired frequency bands. Specific amounts are assigned for the parameters of the add/drop system in order to generate applicable frequency bands for WSN using ZigBee. As can be seen in Figure 2, 16 discrete frequency bands from 2400 MHz to 2450 MHz have been obtained. The FSR of each channel is 5 MHz and the FWHM is 2 MHz which are the same channels with IEEE standard 802.15.4.

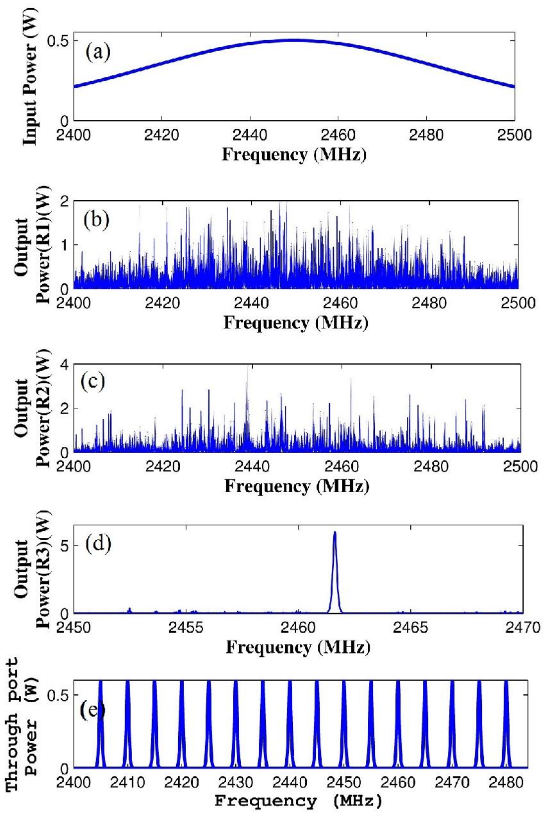

Figure 2: Discrete frequency generation steps for WSN using ZigBee, (a): Input Gaussian pulse, (b) Chaotic signals generated in ring 1, (c): Chaotic signal cancelation in ring 2, (d): Chaotic cancelation in ring 3, (e): discrete frequency channels generation.

Therefore, the proposed system is suitable for the multi frequency channel generation, which is available for WSN using ZigBee. The advantages of the proposed system are that, the channels have a solitonic shape. Therefore, the communication security is formed by using the temporal soliton. Also the proposed system is so small and it can be easily integrated with WSN transmitter and receivers.

4. Conclusion

A system of micro-ring resonators are used to generate discrete frequency channels applicable for WSN using ZigBee. Chaotic signal generation using a soliton pulse in the nonlinear MRRs is presented. The required channels are obtained by filtering the large bandwidth signals using an add/drop filter system. The advantage of the system is that the clear signal can be retrieved by the specific add/drop filter. Generated solitonic frequency channels can be applied in ZigBee communication systems to achieve security. However, more researches are needed to practically implement the proposed system.

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References

1. Ali, J., K. Raman, et al. (2010). "Dark soliton array for communication security."
2. Amiri, I., R. Ahsan, et al. (2012). "Characterisation of bifurcation and chaos in silicon microring resonator." IET Communications 6(16): 2671-2675.
3. Shahidinejad, A., T. Anwar, et al. (2014). "Solitonic pulse generation for optical wireless communication using microring resonator." Journal of Computational and Theoretical Nanoscience.
4. Amiri, I., M. Nikmaram, et al. (2012). "Cryptography Scheme of an Optical Switching System Using Pico/Femto Second Soliton Pulse." International Journal of Advances in Engineering & Technology 5(1).
5. Amiri, I., A. Nikoukar, et al. (2013). "Quantum Transmission of Optical Tweezers Via Fiber Optic Using Half-Panda System." Life Science Journal 10(12s).
6. Amiri, I., A. Nikoukar, et al. (2012). "Generation of Quantum Photon Information Using Extremely Narrow Optical Tweezers for Computer Network Communication." GSTF Journal on Computing 2(1).
7. Amiri, I., M. Ranjbar, et al. (2012). Multi optical Soliton generated by PANDA ring resonator for secure network communication. Computer and Communication Engineering (ICCCE), 2012 International Conference on, IEEE.
8. Amiri, I., K. Sarkhanlou, et al. (2012). Generation of discrete frequency and wavelength for secured computer networks system using integrated ring resonators. Computer and Communication Engineering (ICCCE), 2012 International Conference on, IEEE.
9. Amiri, I., A. Shahidinejad, et al. (2012). "A Study of Dynamic Optical Tweezers Generation For Communication Networks." International Journal of Advances in Engineering & Technology 4(2).
10. Amiri, I., A. Shahidinejad, et al. (2012). "Digital Binary Codes Transmission via TDMA Networks Communication System Using Dark and Bright Optical Soliton." GSTF Journal on Computing 2(1).
11. Amiri, I., S. Soltanmohammadi, et al. (2013). "Optical quantum transmitter with finesse of 30 at 800-nm central wavelength using microring resonators." Optical and Quantum Electronics 45(10): 1095-1105.
12. Amiri, I. S., A. Nikoukar, et al. (2014). "The Proposal of High Capacity GHz Soliton Carrier Signals Applied for Wireless Communication." Reviews in Theoretical Science 2(4): 320-333.
13. Baronti, P., P. Pillai, et al. (2007). "Wireless sensor networks: A survey on the state of the art and the 802.15. 4 and ZigBee standards." Computer Communications 30(7): 1655-1695.
14. Gutierrez, J. A., E. H. Callaway, et al. (2004). Low-rate wireless personal area networks: enabling wireless sensors with IEEE 802.15. 4, IEEE Standards Association.
15. Mofarrahi, M., M. Rahiminezhad Galankashi, et al. (2013). "The State of the Art Information Sharing Technologies for Supply Chain Management." Journal of Theoretical and Applied Information Technology 9(1): 57-63.
16. Nikoukar, A., I. Amiri, et al. (2012). MRR quantum dense coding for optical wireless communication system using decimal convertor. Computer and Communication Engineering (ICCCE), 2012 International Conference on, IEEE.
17. Shahidinejad, A., A. Azarpira, et al. (2014). "Quantum Cryptography Coding System for Optical Wireless Communication." Journal of Optoelectronics and Advanced Materials 16(7-8).
18. Sadegh Amiri, I., M. Nikmaram, et al. (2013). "Generation of potential wells used for quantum codes transmission via a TDMA network communication system." Security and Communication Networks 6(11): 1301-1309.
19. Shahidinejad, A., I. S. Amiri, et al. (2014). "Enhancement of Indoor Wavelength Division Multiplexing-Based Optical Wireless Communication Using Microring Resonator." Reviews in Theoretical Science 2(3): 201-210.
20. Shahidinejad, A., A. Nikoukar, et al. (2012). Network system engineering by controlling the chaotic signals using silicon micro ring resonator. Computer and Communication Engineering (ICCCE), 2012 International Conference on, IEEE.
21. Shahidinejad, A., A. Nikoukar, et al. (2013). "Optical wireless quantum communication coding system using decimal convertor." Optical and Quantum Electronics: 1-9.
22. Shahidinejad, A., S. Soltanmohammadi, et al. (2014). "Solitonic pulse generation for inter-satellite optical wireless communication." Quantum Matter 3(2): 150-154.
23. Shahidinejad, A., S. Soltanmohammadi, et al. (2013). "Outdoor WDM-BASED Optical Wireless Communication." Journal of Theoretical & Applied Information Technology 51(2).

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