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Design Of A Fiber Optic Sensor-Based Respiration Monitoring System

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Article Info	ABSTRACT
Keywords: SMS fiber optic sensor, Respiratory rate, Multimode, Beat Per minute (BPM)	Human breathing rate is an essential marker for assessing one's health, especially regarding respiratory issues. Precise breathing measurements are vital in medicine as they help detect problems early and devise effective treatment plans. The use of fiber optic sensors to monitor breathing offers excellent potential in health monitoring, both medically and independently. Such sensors have advantages such as ease of manufacturing, high sensitivity, compact size, and affordable cost. In this study, a Singlemode-Multimode-Singlemode (SMS) optical fiber-based breathing sensor was designed by fitting it as a belt around the abdomen to measure abdominal breathing. This SMS sensor has variations in multimode length and wavelength used. Tests were conducted in sitting and standing positions, and the results showed the best performance of the SMS sensor at a multimode length of 3.5 cm with an accuracy rate of 99.2525%, linearity of 0.9997, and sensitivity of 2.9725 Hz/dBm. In addition, the standing body position provides 96.5% accuracy with a multimode length of 3.5 cm, while the sitting position provides 96.8% accuracy with a multimode length of 2 cm.
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INTRODUCTION

The body requires oxygen for metabolic processes and produces carbon dioxide as a byproduct during respiration. Respiratory rate is one of the parameters in measuring vitality that can provide early clues to changes in health, such as in detecting heart disease (Costa et al., 2015a). Normal respiratory rate frequency (per minute) is considered an important indicator of health and varies depending on the age and physical condition of the individual. Normal adult breathing is 12-20 bpm or in the frequency range of 0.2-0.33 Hz (Pitero, 2019). Measuring the vibration every time breathing in one minute can be one of the indicators in this research to measure the frequency of breathing. Parameters can be reviewed to observe breathing, such as monitoring the condition of human breathing, by looking at the movement of the chest and abdominal walls (D'Angelo et al., 2008). Usually, these parameters are measured by manual calculation using a watch (Smith et al., 2011). However, this method is considered inappropriate because of the possibility of errors in performing manual calculations. Thus, to be able to effectively monitor breathing, namely by utilizing the various types of sensors, one of which is a fiber optic sensor, are used in this study to reduce the occurrence of respiratory disorders, anticipate every situation, and provide a quick response.

Optical Fibers have played a significant sensing role in several fields, particularly in biomedical applications, due to their inherent advantages such as compactness, flexibility, biocompatibility, chemical inertness, and their feasibility to be machined and functionalized. Optical fibers work on the principle of guiding light waves (WHO., 2019). Light entering the optical fiber will be adequately transmitted if there is a perfect reflection at the boundary plane between the core and cladding. Based on the mode propagated, optical fibers are divided into 2 types: single mode and multimode. A single- mode optical fiber (SMF) has a smaller core diameter, and only one mode is propagated. However, many modes are propagated compared to multimode optical fiber (MMF), which has a larger core diameter. In the context of advances in sensor technology, singlemode- multimode-singlemode (SMS) structured optical fibers represent a significant step forward. This SMS structure results from a combination of single-mode and multimode optical fibers that increase flexibility in various uses. As shown below.

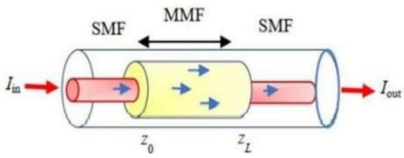

Figure 1. Structure of singlemode-multimode- singlemode (SMS) optical fiber

The light emitted from the light source will be sent through the single-mode optical fiber and then flow into the fiber multimode optics, which can cause the phenomenon of multimode interference (MMI). There is a difference in the profile of light input in the optical fiber, which is caused by repeated reflection of light in the core and cladding arrangement in the optical fiber, causing this phenomenon to occur. This structured sensor has advantages in fabrication and high sensitivity, and the costs required in designing sensors are relatively cheap (Muhamad Hatta, 2009).

Therefore, the SMS structured fiber optic sensor can be used flexibly or more efficiently to monitor health or the presence of respiratory disease and determine changes in respiratory frequency. In this study, singlemode-multimode-singlemode (SMS) structured fiber optic sensors can help in diagnosis because of their ability to identify small changes in respiratory function. The use of variations in multimode length and the condition of the experiment during data recording, namely in a sitting and standing position, is one of the novelties in this study, which can provide a more comprehensive insight into the sensor's response to changes in body posture and respiratory activity.

METHODS

The manufacture of optical fiber sensors uses two types of sensors, namely singlemode and multimode. This research uses 4 length variations on multimode: 2 cm, 2.5cm, 3cm, and 3.5cm with straight configuration. Removing the jacket and cladding in optical fiber allows the connection of both types of optical fiber using a fusion splicer. To determine the effect of vibration on fiber optic sensors, a calibration process is carried out with a test vibration frequency of 3-21 Hz as an initial test in this study. This test uses an infrared light source

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with a wavelength of 1550 nm. Then, the singlemode-multimode-singlemode (SMS) structured optical fiber is glued using tape on the jacket and fiber, which is then attached to the vibration generator device. The first single-mode structure optical fiber sensor is connected to an Optical Light Source (OLS) as a light source. Then, an Optical Power Meter (OPM) is connected to the second singlemode as a light detector and data acquisition. The Thorlabs application then connects the Optical Power Meter (OPM) to the user's computer. The following is the setup of the calibration process as an initial test in this study.

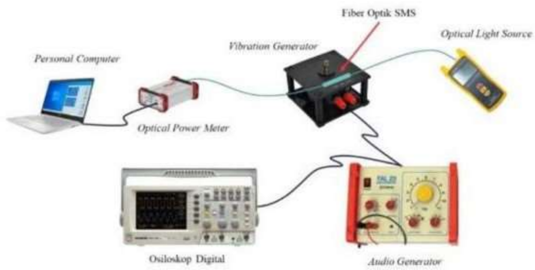

Figure 2. Set up data calibration

The next test was carried out on one of the 21-year-old subjects with a normal BMI to test the breathing rate per minute. This test was carried out 5 times in 120 seconds and was taken in 2 positions, namely sitting and standing. The test was carried out simultaneously by attaching the SMS fiber optic sensor and the reference sensor to the exact location on the abdomen to monitor the breathing rate. The following is the setup for testing the respiratory monitoring system using a singlemode-multimode-singlemode (SMS) structured fiber optic sensor.

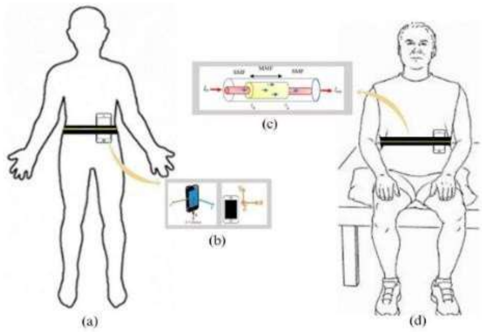

Figure 3. Illustration of data retrieval || (a) Illustration of subjects with a standing position for data retrieval. (b) The mobile phone's accelerometer sensor's x, y, and z axes. (c) Straight configuration of the fiber optic sensor. (d) Illustration of the trial with a seated position for data collection.

Then, data processing is carried out using a filtering method, namely a bandpass filter, to reduce noise in the data. Then, the raw data obtained in the time domain is transformed in the frequency domain with the Fast Fourier Transform (FFT) method with a cut-off frequency of 3-21 Hz, which has been determined in the calibration testing process using a vibration generator. Thus, the results of comparing static sensor characteristics such as accuracy, linearity, and sensitivity are obtained to see the performance of fiber optic sensors in responding to changes in vibration and the resulting optical power. To obtain respiratory frequency information in bpm is the same as the data processing process obtained from calibration testing. However, the cut-off frequency represents normal breathing in adults, which is 0.2 -0.33 Hz (12-20 BPM).

Furthermore, raw data is obtained in the form of a time domain and transformed in the frequency domain using the FFT (Fast Fourier Transform) method, which then the peak value of the FFT results is multiplied by 60 to get or convert data to BPM values. Thus, adults' normal breathing frequency can be obtained as bpm values. To check the validity of a fiber optic sensor that monitors a person's breathing pattern and number of breaths. Then, a reliable reference sensor is needed, one of which is using an accelerometer sensor on a cellphone. Although it cannot measure breathing patterns directly, it at least moves the phone in one direction.

RESULTS AND DISCUSSION

Calibration results of single mode-multimode- singlemode structured fiber optic sensor (SMS)

In the calibration test, light with a wavelength of 1550 nm as a light source is connected to a single mode-multimode-singlemode (SMS) structured optical fiber sensor. The sensor is attached to a vibration generator device connected to an audio generator. The audio generator can generate vibrations of a frequency that can be adjusted as needed, which the vibration generator will then translate into mechanical vibrations. Thus, the resulting light intensity in the sensor will change according to the vibrations detected from the fiber optic sensor. Then, the oscilloscope device connected to the vibration generator will display the sensor's response to the vibration. The optical power meter device connected to the fiber optic sensor will measure the light intensity received by the sensor, and the resulting data is recorded on a laptop. Then, by going through the data processing process, the calibration results of the SMS-structured fiber optic sensor have been produced in the form of a sinusoidal graph, as shown below.

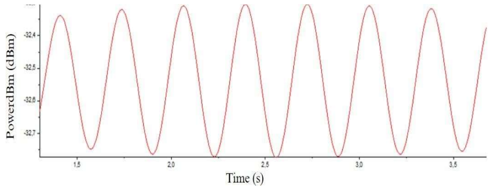

Figure 4. Graph resulting from the calibration process with a vibration generator with a source frequency of 3 Hz on a fiber optic sensor with a multimode length of 2.5 cm step index type.

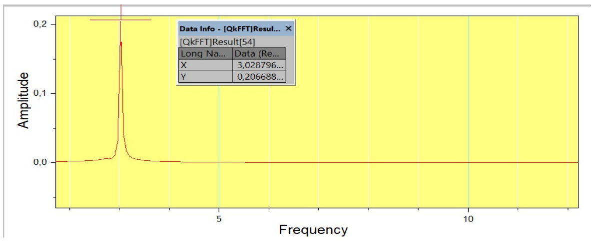

Figure 5. Frequency peaks were detected after performing a Fast Fourier Transform (FFT) on fiber optic sensors with a multimode length of 2.5 cm step index type.

The results have shown that fiber optic sensors can measure vibrations effectively from several different source frequencies, namely 3Hz, 6Hz, 9Hz, 12Hz, 15Hz, 18Hz, and 21 Hz, which were conducted in this study. The results of the analysis of sinusoidal waves detected due to calibration using a vibration generator have shown that the vibration generator can produce consistent and controlled vibrations. Then, when the Fast Fourier Transform (FFT) is performed, it displays a frequency peak, which is the frequency detected in the calibration process. So, the sensor can respond effectively at a predetermined frequency because it can measure vibrations at a specific frequency. The bandpass filter successfully isolates the frequency components in the desired range, where the peak frequency is detected at around 3.028796 Hz with a source frequency of 3 Hz. It blocks the frequency components outside the range. Therefore, the analyzed results of the calibration process have shown that the vibration frequency measured by the SMS-structured optical sensor is almost the same as the source frequency. This can be further shown in the table below.

Table 1. Calibration results with a multimode length of 2 cm

Calibration sensors fiber optics *singlemode-multimode-singlemode* (text) with *vibration generator*			
Frequency source(Hz)	Frequency Detected (Hz)	Error (%)	Accuracy (%)
3	2.933521	2.21597	97.78403
6	5,800696	3.321733	96.678267
9	8.853899	1.62334	98.37666
12	11.83046	1.41283	98.58717
15	15.14528	0.968533	99.031467
18	18.11718	0.651	99,349
21	21.08908	0.42419	99.57581

Table 2. Calibration results with a multimode length of 2.5 cm

Calibration sensors fiber optics *singlemode-multimode-singlemode* (text) with *vibration generator*			
Frequency source(Hz)	Frequency Detected (Hz)	Error (%)	Accuracy (%)
3	3,028796	0,95987	99,04013
6	5,9203789	1,32702	98,67298
9	8,800563	2,21597	97,78403
12	12,05410	0,45083	99,54917
15	15,04096	0,273067	99,726933
18	18,13449	0,74717	99,25283
21	20,854668	0,692057	99,307943

Table 3. Calibration results with a multimode length of 3 cm

calibration sensors fiber optics *singlemode-multimode-singlemode* (text) with *vibration generator*			
Frequency source(Hz)	Frequency Detected (Hz)	Error (%)	Accuracy (%)
3	3.086208	2.8736	97.1264
6	6.0270524	0.450873	99.549127

calibration sensors fiber optics *singlemode-multimode-singlemode* (text) with *vibration generator*			
Frequency source(Hz)	Frequency Detected (Hz)	Error (%)	Accuracy (%)
9	8.858560	1.57155	98.42845
12	12.05907	0.49225	99.50775
15	14.98762	0.082533	99.917467
18	17.83142	0.93655	99.06345
21	21.068015	0.323881	99.676119

Table 4. Calibration results with a multimode length of 3.5 cm

Calibration sensors fiber optics *singlemode-multimode-singlemode* (text) with *vibration generator*			
Frequency source(Hz)	Frequency Detected (Hz)	Error (%)	Accuracy (%)
3	2.986857	0.4381	99.5619
6	6.000960	0.016	99,984
9	9,201472	2.23858	97.76142
12	11.84075	1.32708	98.67292
15	14.98762	0.082533	99.917467
18	17.921147	0.438072	99.561928
21	20.854668	0.692057	99.307943

Then, a linearity equation graph evaluates the static characteristics of each multimode length variation of the step-index type in the single mode-multimode-singlemode (SMS) structured optical fiber sensor. In addition, several parameters, such as linearity, accuracy, and sensitivity equations, will be tested.

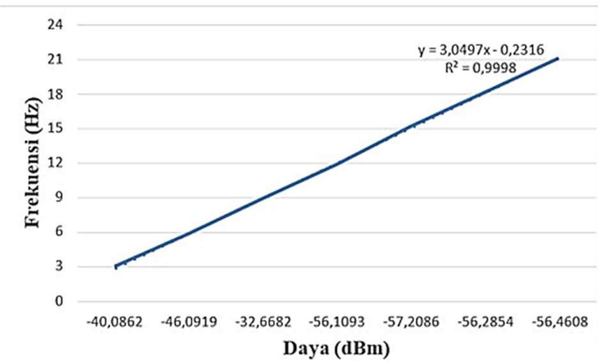

Figure 6. Linearity equation for SMS-structured fiber optic sensor with 2 cm multimode length of step index type

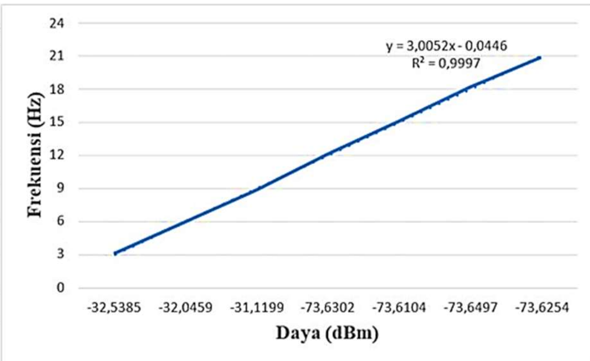

Figure 7. Linearity equation for SMS-structured fiber optic sensor with 2.5 cm multimode length of step index type

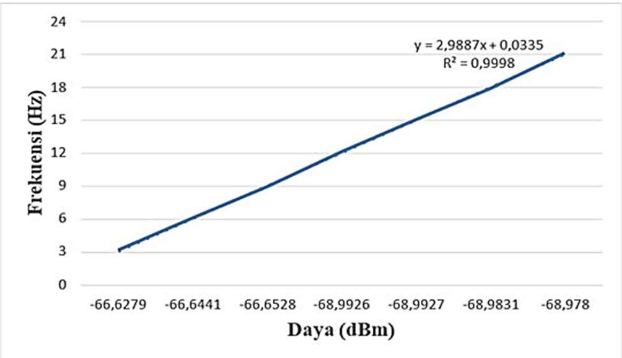

Figure 8. Linearity equation for SMS-structured fiber optic sensor with 3 cm multimode length of step index type

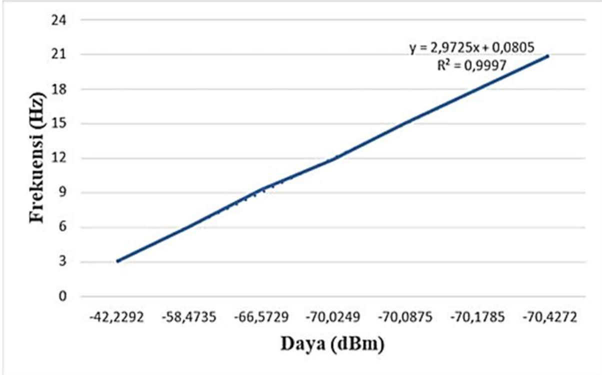

Figure 9. Linearity equation for SMS-structured fiber optic sensor with 3.5 cm multimode length of step index type.

The linearity graph shows a change in frequency followed by a change in the optical power obtained from the SMS-structured fiber optic sensor. Thus, the linearity graph can determine the fiber optic sensor's performance, including its sensitivity and ability to provide a linear response and ensure accuracy.

ResultsComparison Static Characteristics with Variation of Length Size of multimode fiber with Step Index type in single mode-multimode-singlemode structured fiber optic sensor (SMS)

Table 5. Comparison results of static characteristics of fiber optic sensors with various length variations

Variation in length of multimode fiber (MMF) with step index type	wavelength of the light source 1550 nm			
	Error (%)	Accuracy (%)	Linearity	Sensitivity (Hz/dBm)
2 cm	1,5168	98,4832	0,9998	3,0497
2,5 cm	0,9523	99,0477	0,9997	3,0052
3 cm	0,9616	99,0384	0,9998	2,9887
3,5 cm	0,7475	99,2525	0,9997	2,9725

Based on the results above, the fiber optic sensor with a multimode length of 3.5 cm is the result with the best performance, namely 0.7475% for the error obtained with an accuracy of 99.2525% as well as a linearity of 0.9997 and a sensitivity of 2.9725 hz/dbm. This has shown that in the calibration process, the fiber optic sensor is still classified as feasible and in good condition to be used as a respiratory monitoring system, where the sensor can detect the presence of vibrations that occur from various frequency ranges. Then, high sensitivity to external interference due to interference between various modes of light propagating through the fiber optic sensor. Multimode fiber has a simple structure, making it easy to manufacture and integrate into various sensing systems.

Results of Data Collection and Data Processing for Respiration Monitoring System

In the data collection process, the researcher involved an experimental subject, a 21-year-old male with a normal BMI value. Data was collected with 2 variations of the experimental condition: sitting and standing. Then, data recording was carried out for 120 seconds for 5 repetitions. Data collection is carried out simultaneously with a reference sensor and an accelerometer sensor on a smartphone with an Android type, as shown below.

Figure 11. Set up respiratory data collection with fiber optic sensor and accelerometer sensor || (a) the research subject is seated and viewed from the right side. (b) the research subject was seated and viewed from the left side. (c) The research subject is in standing condition and viewed from the left side.

This research has applied a bandpass filter with a frequency range of 0.2 Hz—0.33 Hz, showing normal adult breathing at 12-20 bpm (Pitero, 2019). The following is the shape of the breathing pattern on the fiber optic sensor and accelerometer sensor on the cellphone as a reference sensor.

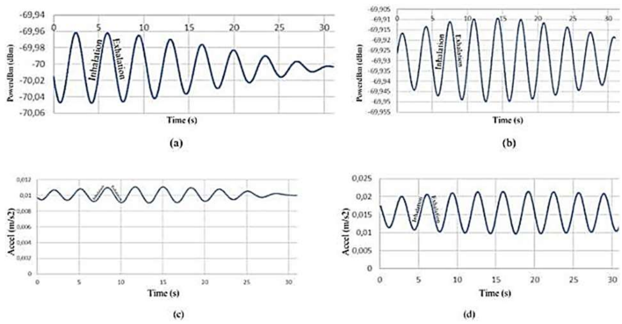

Figure 12. Respiration breathing pattern in subject || (a) pattern from single mode-multimode-single mode fiber optic sensor (SMS) with 2 cm MMF length in a standing condition. (b) The pattern of a single mode-multimode-singlemode (SMS) fiber optic sensor with 2 cm MMF length is in sitting condition. (c) the pattern of the accelerometer sensor on the mobile phone with the standing condition. (d) the pattern of the accelerometer sensor on the mobile phone with the sitting condition.

The figure above shows the similarity of the patterns obtained from the two sensors. The fiber optic sensor identified the breathing pattern (inspiration-expiration) within 30 seconds. The data taken on the accelerometer sensor is on the z-axis (forward and backward), which causes the phone's movement at least in one direction, just like the fiber optic sensor. This observed breathing pattern has passed the filtering technique using a bandpass filter with a frequency of 0.2 Hz - 0.33 Hz, which aims to reduce existing noise. Based on the results, the respiratory response could be more stable, as shown in the inconsistent peak-to-peak relationship. On the other hand, accelerometer sensors may be less affected by such environmental conditions but tend to be more sensitive to vibration or mechanical movement. Furthermore, there is a difference in the time resolution when recording data, whereas optical sensors have better time resolution capabilities or are more

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sensitive to rapid changes. Thus, it can more quickly identify breathing-related changes than the accelerometer sensor. Furthermore, the data that has passed the filtering process will be further processed by converting it from the time domain to the frequency domain to make it easier to obtain respiratory information based on its frequency. Here are the frequency response results using the Fast Fourier Transform (FFT), which is processed through filtering.

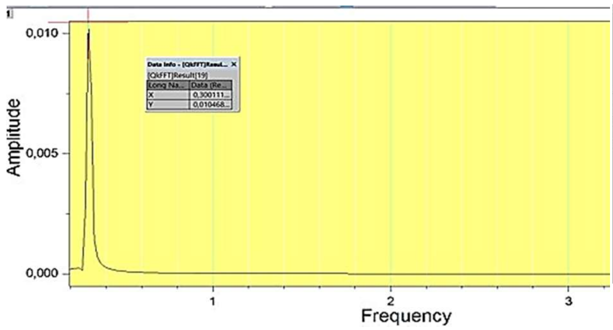

Figure 13. Peak frequency in the first minute in the standing position generated by the fiber optic sensor with a multimode length of 2 cm in the first measurement

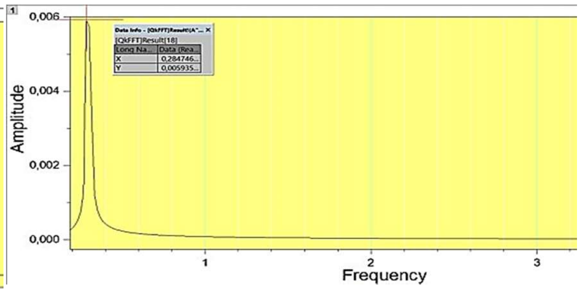

Figure 14. Peak frequency in the first minute in the sitting position generated by the fiber optic sensor with a 2 cm multimode length in the first measurement

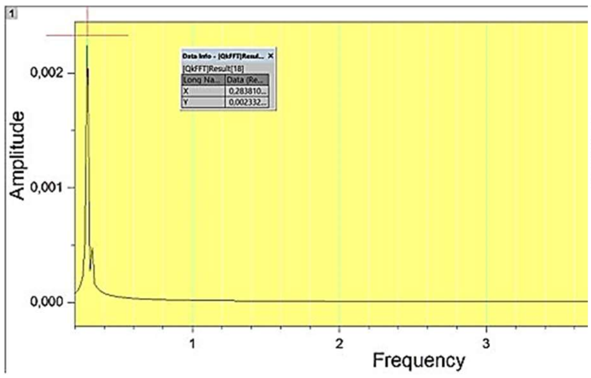

Figure 15. Peak frequency in the first minute in the standing position generated by the accelerometer sensor (as a reference sensor) in the first measurement

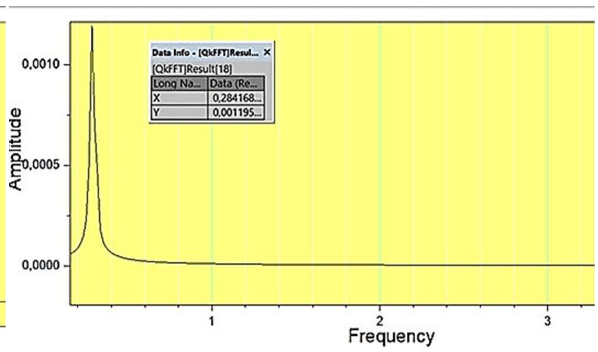

Figure 16. Peak frequency in the first minute in the sitting position generated by the accelerometer sensor (as a reference sensor) in the first measurement

The detected peak frequency is multiplied by 60 seconds to calculate the respiratory value in BPM. In Figure 13, the peak frequency was detected as 0.300111 Hz, equivalent to 18 bpm, while in Figure 15, the peak frequency was detected as 0.283810 Hz, equivalent to 17 bpm. This indicates a difference of 1 bpm between the optical sensor and the reference sensor understanding conditions in the first minute. However, in Figure 14 and Figure 16, the peak frequencies were detected at 0.284746 Hz (17 bpm) and 0.284168 Hz (17 bpm) for the sitting condition in the first minute, respectively. This indicates no difference between the optical sensor and the sensor reference in the sitting condition at the first minute. Frequency analysis can provide information about the stability and quality of breathing. Identifying the dominant frequency through Fast Fourier Transform (FFT) analysis provides a practical and accurate way to measure and analyze respiratory signals. Thus, the work of SMS optical fiber as a respiratory sensor can be identified. The results of respiratory monitoring in BPM can be seen in the table below.

Table 6. Results of monitoring breathing in BPM standing by a fiber optic sensor with a multimode length of 2 cm and an accelerometer sensor.

Measurement of	1st minute				2nd minute			
	Accelerometer sensor	SMS sensor	Abs error	Relative error	Accelerometer sensor	SMS sensor	Abs error	Relative error
1	17	18	1	0,06	18	18	0	0,00
2	18	18	0	0,00	19	18	1	0,05
3	17	17	0	0,00	18	17	1	0,05
4	17	17	0	0,00	17	17	0	0,00
5	18	18	0	0,00	17	18	1	0,06

Table 7. Results of respiratory monitoring in BPM in standing position by fiber optic sensor with a multimode length of 2.5 cm and accelerometer sensor.

Measurement of	1st minute				2nd minute			
	Accelerometer sensor	SMS sensor	Abs error	Relative error	Accelerometer sensor	SMS sensor	Abs error	Relative error
1	17	17	0	0,00	17	17	0	0,00
2	17	18	1	0,06	19	18	1	0,05
3	17	18	1	0,06	18	17	1	0,05
4	17	18	1	0,06	17	17	0	0,00
5	17	18	1	0,06	17	18	1	0,06

Table 8. Results of monitoring breathing in BPM standing by a fiber optic sensor with a multimode length of 3 cm and an accelerometer sensor

Measurement of	1st minute				2nd minute			
	Accelerometer sensor	SMS senor	Abs error	Relative error	Accelerometer sensor	SMS sensor	Abs error	Relative error
1	18	18	0	0,00	19	19	1	0,05
2	19	17	2	0,10	19	19	0	0,00
3	18	17	1	0,05	19	17	2	0,10
4	17	18	1	0,06	18	18	0	0,00
5	18	19	1	0,05	19	19	0	0,00

Table 9. Results of monitoring breathing in BPM in the standing position by a fiber optic sensor with a multimode length of 3.5 cm and an accelerometer sensor

Measurement of	1st minute				2nd minute			
	Accelerometer sensor	SMS senor	Abs error	Relative error	Accelerometer sensor	SMS sensor	Abs error	Relative error
1	17	18	1	0,06	18	17	1	0,05
2	18	18	0	0,00	18	18	0	0,00
3	18	18	0	0,00	19	18	1	0,05
4	19	18	1	0,05	19	17	2	0,10

Measurement of	1st minute Accelerometer sensor	SMS senor	Abs error	Relative error	2nd minute Accelerometer sensor	SMS sensor	Abs error	Relative error
5	18	17	1	0,05	18	18	0	0,00

Table 10. Results of monitoring breathing in BPM in a sitting position by a fiber optic sensor with a multimode length of 2 cm and an accelerometer sensor

Measurement of	1st minute Accelerometer sensor	SMS senor	Abs error	Relative error	2nd minute Accelerometer sensor	SMS sensor	Abs error	Relative error
1	17	17	0	0,00	18	18	0	0,00
2	18	17	1	0,05	18	17	1	0,05
3	18	19	1	0,05	17	17	0	0,00
4	17	18	1	0,06	18	17	1	0,05
5	17	17	0	0,00	17	18	1	0,06

Table 11. Results of monitoring breathing in BPM in Subject in a sitting position by a fiber optic sensor with a multimode length of 2.5 cm and an accelerometer sensor

Measurement of	1st minute Accelerometer sensor	SMS senor	Abs error	Relative error	2nd minute Accelerometer sensor	SMS sensor	Abs error	Relative error
1	19	19	0	0,00	17	18	1	0,06
2	18	18	0	0,00	18	17	1	0,05
3	17	17	0	0,00	17	17	0	0,00
4	18	17	1	0,05	18	19	1	0,05
5	19	17	2	0,10	19	18	1	0,05

Table 12. Results of monitoring breathing in BPM in a sitting position by a fiber optic sensor with a multimode length of 3 cm and an accelerometer sensor.

Measurement of	1st minute Accelerometer sensor	SMS senor	Abs error	Relative error	2nd minute Accelerometer sensor	SMS sensor	Abs error	Relative error
1	19	17	2	0,10	18	18	0	0,00
2	17	17	0	0,00	18	17	1	0,05
3	19	17	2	0,10	17	17	0	0,00
4	17	17	0	0,00	18	18	0	0,00
5	19	17	2	0,10	19	18	1	0,05

Table 13. Results of monitoring breathing in BPM on Subject in a sitting position by a fiber optic sensor with a multimode length of 3.5 cm and an accelerometer sensor

Measurement of	1st minute Accelerometer sensor	SMS senor	Abs error	Relative error	2nd minute Accelerometer sensor	SMS sensor	Abs error	Relative error
1	19	18	1	0,05	19	18	1	0,05
2	18	18	0	0,00	17	18	1	0,06

Measurement of	1st minute				2nd minute			
	Accelerometer sensor	SMS senor	Abs error	Relative error	Accelerometer sensor	SMS sensor	Abs error	Relative error
3	18	18	0	0,00	18	19	1	0,05
4	18	18	0	0,00	18	19	1	0,05
5	17	19	2	0,12	18	18	0	0,00

Tables 6 to 13 show the results of breathing monitoring carried out in two different conditions: sitting and standing. They also compare the values obtained from the fiber optic sensor with the reference sensor, with data collection carried out five times in 120 seconds of recording.

Table 14. Average Relative Error of each variation of multimode step index length against variation of trial position

average relative error		
Variation in length of multimode fiber (MMF) with step index type	trial position	
	standing	sitting
2 cm	0,044	0,032
2,5 cm	0,039	0,036
3 cm	0,041	0,040
3,5 cm	0,035	0,038

Table 15. Accuracy of each multimode step index length variation against the variation in the position of the experiment.

accuracy		
Variation in length of multimode fiber (MMF) with step index type	trial position	
	standing	sitting
2 cm	95,6	96,8
2,5 cm	96,1	96,4
3 cm	95,9	96,0
3,5 cm	96,5	96,2

Then, Table 14 and Table 16 above show the best performance at a multimode length of 3.5 cm with standing conditions for an average relative error of 0.035% with an accuracy of 96.5%. Meanwhile, in sitting conditions, the best performance is at a multimode length of 2 cm, with sitting conditions having a relative average of 0.032% and an accuracy of 96.8%. This shows that breathing frequency is influenced by body posture. Changes in body position affect the strength and function of the respiratory muscles in healthy adults (Costa et al., 2015b). Reduced tension in respiratory muscles, such as the diaphragm, can also reduce breathing rate and depth (Badr et al., 2002). The diaphragm has several attachments to the spine and ribs, and changes in the position of these bone structures alter its actual function. Abdominal breathing involves active use of the diaphragm rather than the intercostal muscles. Pressure within the abdominal cavity increases during inspiration due to the contraction and downward movement of the diaphragm. The opposite is also true during the expiratory process. When standing, the abdominal wall tension is 30% greater than when sitting, which is an essential component of the abdominal wall tension. Respiratory biomechanics and intra-abdominal pressure increase by 20% (Proceedings of the 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society : "Personalized Healthcare through Technology" : August 20-24, 2008, Vancouver Convention & Exhibition Centre, Vancouver, British Columbia, Canada, 2008) (Cobb et al., 2005). Gravity provides more space for the diaphragm to contract and relax when standing. As the diaphragm has more room to move, breathing is more efficient compared to sitting, where when the sitting position is slouched or unergonomic, the room for the diaphragm to contract may be reduced. Since it can quickly detect changes in respiratory movements, a fiber optic sensor-based respiration monitoring system can be a viable solution for occupational health and safety management. It can reduce various risks that can occur.

CONCLUSION

Based on the research that has been conducted, A fiber optic sensor with a single-mode-multimode-singlemode (SMS) structure has been developed for a respiratory monitoring system. The multimode length of step index type 2 cm, 2.5 cm, 3 cm, and 3.5 cm can be varied, and the wavelength is 1550 nm. The fiber optic sensor-based monitoring system was designed with a Velcro belt attached to the abdomen of the narcologist to test abdominal breathing. Tests were carried out in seated and standing body positions. Singlemode-multimode-singlemode (SMS) structured fiber optic sensors have shown the best accuracy, linearity, and sensitivity at 1550 nm wavelength and in sitting and standing body positions. The best accuracy reached 99.2525% at a step-index multimode length of 3.5 cm, with a linearity of 0.9997 and a sensitivity of 2.9725 Hz/dBm. In the body position test, the best accuracy value was 96.5% for the standing position with a multimode length of 3.5 cm and 96.8% for the sitting position with a multimode length of 2 cm.

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