Electronic Safety System for Table Saw

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***Abstract*—This article proposes a safety sensor for table saw, based on impedance measurement between two electrodes placed in front of blade. A multitone system is developed, acting as a selective barrier able to distinguish the proximity of a hand with respect to wood, both dry and wet. Due to conductivity of human body, the proximity of the hand introduces a shielding effect, causing a reduction in capacitive coupling between electrodes. On the contrary, wood cannot induce the same effect for all frequencies, even if it is wet. This results in achieving a very sensitive and cost-effective safety system, able to respond effectively to hazard situations. An electronic prototype, realized through digital synchronous detection of two tones at 10 kHz and 1 MHz, demonstrates the effectiveness of the proposed sensing technique. To better describe the working principles, a simple system simulator is studied, able to describe the experimental results. The proposed technique opens the way to a new generation of safety systems for table saw.**

***Index Terms*—Capacitance measurement, impedance measurement, object detection, safety devices.**

I. Introduction

PREVENTING life-changing injuries such as amputation of fingers caused by sliding table saw or other machine tools is the main goal of any safety system. To achieve this, recognizing a hazard situation and respond immediately to it are the essential characteristics of desired protection systems. Such a safety system consists of a reliable proximity sensor which can detect the presence of the nearby objects without any physical contact in addition to a rapid actuator (braking system) as response to the dangerous conditions. As well as human-machine interface, bio-electronic devices, robotic technologies, transportation, and industrial Internet of Things are fields of application for proximity sensors. Different sensor technologies have been employed to develop various proximity sensors such as optical, vision, ultrasonic, inductive, capacitive sensors etc. The braking system is not included in this article, but it has been already realized by some companies, through a hydraulic actuator that drives the blade down [1].

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Working principle of optical proximity sensors is based on triangulation. In general, infrared (IR) sensors emit and detect IR emission which depends on the angle where the reflected light returns to the sensor [2]. Near IR (NIR)spectroscopy have been employed in various human tissue analysis since it can have a tissue penetration depth of many micrometers, millimeters or centimeters depending upon wavelength. In the NIR, water molecules show two clear absorption bands at 1450 nm and 1940 nm [3], [4]. In [5], a safety device for sliding table saw able to distinguish the human body from the other surfaces through reflectivity measurement at different wavelengths is proposed. A diffuse reflectance near-IR sensor utilized in conjunction with a near-IR source to detect the presence of molecular structures associated with human tissues and/or human body parts. Once the presence of the body is detected, an active brake stops the saw blade by damaging the blade. Although the spectral level of human skin is clearly distinguishable from wood or other surfaces, the reliability of such nonpunctual system can be affected by numerus false alarms. This is often due to receiving the reflected light from whole illuminated surface, where number of situations could affect the signals that are difficult to interpret. Several camera vision-based techniques have been developed in hand gesture and posture recognition because of the ability to provide a natural means of interaction and facilitate communication [6], [7]. To detect hazard situations and protect the operator, an industrial camera can be utilized to monitor the area in front of saw guard as a classic solution. In [8], a finger localization and classification for sliding table saw safety system is proposed. The proposed detection scheme includes multistage image data processing following a segmentation and future extracting based on the generalized Hough transform. Although the demonstrated methods of probabilistic hand models, their localization and classification are working reliably, the computational complexity is demanding.

A hazard analysis system based on tracking of hand position is developed in [9] by implementing condensation algorithm. The condensation algorithm choses randomly the pixels to process instead of processing every single pixel [10]. Despite of robust performance to varieties of hand motion patterns and environmental conditions of sliding table saws, a finer color model should be applied in case presenting of dark woods in addition to an independent motion detection subsystem. Although an advance image processing system can recognize an operator's hand and measure its proximity to circular saw, the implementation is challenging due to requirement of more than one camera to guarantee reliability. It should be fast enough to detect the hand and evaluate its proximity in the order of milliseconds. Considering the componential complexity and implementation cost, realizing a robust system based on vision techniques at industrial level is challenging.

Thermal measurement can be seen as a simplified version of the vision technique, in which it is not intended to recognize the operator's hand by its shape, but by its temperature. The basic idea is to place a thermal sensor with a matrix of pixels (e.g., MLX90621 16x4 IR array) above the circular saw while keeping one of sides of the saw in the field of view. In case of presenting an object with a different temperature, such as the operator's hand, in the field of view of the sensor, the thermal image shows deterministic variations. Therefore, it is possible to generate an alarm signal through appropriate algorithms.

Although the thermal measurement systems are slower and have lower resolution to compare with vision system, the state of the art is significantly improving, in terms of accuracy, speed, spatial resolution and cost [11], [12]. Despite the low cost and ease of installation, such systems are not able to work properly in case of ambient temperature close to the human one, or local heating like thermal footprint. In addition, it has the same limits as those with vision in case covering the sight of the hand with something which makes it very difficult to detect the presence of hand.

In terms of distance measurement, ultrasonic sensors have been applied as proximity sensors in various field of applications ranging from robotics, self-driving vehicles as well as industrial process [13], [14]. To compare with modern time-of-flight optical sensors integrated by ST into a single chip (e.g., ST VL6180X), the ultrasonic sensors have an intrinsically larger angle of view. Working principle of such sensors is based on measuring travelling time for acoustic wave emitted by a transmitter to object and reflected to the receiver [14]. Distance measurement techniques have been studied to measure distance or velocity of an approaching object to the rotating saw blade. In fact, a fast approach of any object is an indication of a situation of potential danger. Such technique can be useful for detecting high speed approaches, which may not be covered by other slower techniques. However, the position of these sensors should be carefully studied to optimize the measurement of approaching objects (for example, it should be avoided that the first echo is that of the work surface). Capacitive proximity sensors are most extensively applied technology in field of proximity sensors due to their design and read-out circuits flexibility [16]. The basic idea behind such proximity sensors is the influence of electric field caused by nearby object. In terms of operating modes, capacitive proximity sensors are classified as passive and active modes [17]. Passive sensing approach is based on existing, external, or ambient electric fields such as the low frequency electrostatic fields produced by the triboelectric effect, power lines and appliances. Since there is no control on transmitting signal, such methods are limited in terms of accuracy. In contrast, an excitation signal is generated and transmitted by transmitter in active sensing methods. This generated signal is capacitively coupled onto an approaching object and then coupled onto receiver.

Depending on the relative position between the object, transmitting and receiving electrodes, the active methods are divided into loading (self-capacitance), transmitter, receiver, and shunt (mutual capacitance) modes. In self-capacitance mode, only one electrode is used as transmitter and receiver. As in any touch sensors, approaching body results in flowing more displacement current through the body to ground indicating increased capacitive coupling. This is the basic operation principle behind the capacitive contact systems to detect contact between operator and blade of table saw [18]. The generated signal on the blade is monitored to detect any variation as result of contact between the operator and blade. Although the contact between the operator and blade is detected, it is desired to minimize any possible injuries. Therefore, such protection system is not practically able to detect proximity of the operator. In both transmit and receive modes, the operator's body is an extension of the transmitting or receiving electrodes, respectively.

In [19], a protection system based on transmitter mode is proposed for portable cutting tool. Since the operator's body is an extension of the transmitter, the coupling between the operator's body and the transmitting electrode (installed on rear handle) is much greater than the coupling between the operator's body and the receiving electrode (blade). Therefore, approaching receiver increases the coupling between the operator's body and the receiving electrode. Instead of influencing the main electric field, shunt mode affects fringe electric field lines. This reduces displacement current flowing from transmitting electrode to receiving electrode due to approaching human body. Considering an amplitude attenuation measurement and the range of fringe fields (which are normally low), dedicated electronics required to achieve optimum results.

In this article, a safety system is proposed for circular saw by evaluating the impedance variation between the electrodes as result of approaching object. In proposed system, the presence of the human body is detected because of its conductivity instead of its different dielectric constant as in classical techniques (self-capacitance, transmitter, and receiver modes). A multitone sinusoidal signal is generated and transmitted by transmitting electrode. Through a synchronous digital detection, the modulus and phase of measured signal on receiver are extracted at the desired frequency. Despite of preventing injuries by detecting the proximity of operator's hand with high sensitivity, the proposed sensor overcomes the difficulties in distinguishing between the operator's hand and wood with a high moisture content using classical techniques. The rest of the article is structured as follows. Section II represents the numerical computation and simulation results to evaluate electromagnetic coupling between two electrodes in presence of approaching object. In Section III, measuring circuit in addition to experimental setup is explained in more detail where the results are discussed in Section VI. Finally, a conclusion and future works are presented in Section V.

II. Theoretical Analysis and Numerical Computation

The material property of the approaching object may affect bending of the electric flux lines near the edge of two parallel plate capacitor known as firing field lines. Considering transmitting and receiving electrodes, placed in front of the blade as shown in Fig. 1, interaction of the generated electric field with the different materials can be evaluated in addition to the degree of

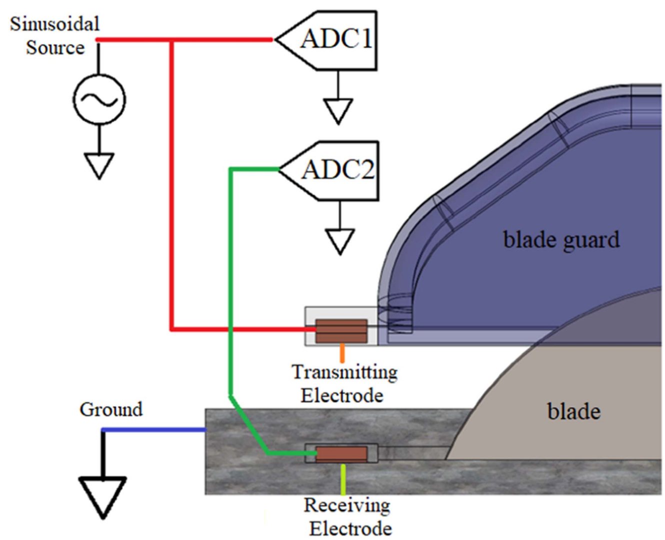

Fig. 1. Position of the receiving and transmitting electrodes in addition to the acquisition points for the proposed safety system.

TABLE I
RESISTIVITY AND CONDUCTIVITY VALUES FOR HUMAN BODY AND WOOD

Material	RESISTIVITY ($\Omega.m$)	Conductivity (S/m)
Human body	$2\times10^1 - 2\times10^3$	$5\times10^{-4} - 5\times10^{-2}$
Wet wood	$10^3 - 10^4$	$10^{-4} - 10^{-3}$
Dry wood	$10^{14} - 10^{16}$	$10^{-16} - 10^{-14}$

coupling of the object with the metal structure of the circular saw. To better describe the physics of the proposed safety system, a simple simulation of the electric field distribution between two square electrodes with side of 2 cm is realized in COMSOL Multiphysics.

The distance between two electrodes is about 20 cm. A 6 V_{pk-pk} excitation sinusoidal signal at 10 kHz is applied on upper electrode (transmitter), while the grounded receiver is placed on the surface of the metal structure, but it is electrically isolated from it. Fig. 2(a) shows the distribution of electric potential (contour line) in addition to the electric field lines (arrows) and power loss density for approaching seasoned (dry) wood with electrical conductivity $\sigma_{\text{dry-wood}} \sim 10^{-12}$ S/m. The distribution of electric potential, the electric field lines, and power loss density for approaching human body with electrical conductivity $\sigma_{\text{skin}} \sim 10^{-2}$ S/m is represented in Fig. 2(b). As simulation results show, the divergence of the electric filed lines is more evident in presence of the body than the wood. This is mainly due to higher conductivity of human body with respect to the wood as given in Table I. Therefore, the flowing of displacement current through the body to the ground reduces displacement current flowing from transmitting electrode to receiver one.

Unlike the reflection-based safety systems, covering the hand (e.g., wearing the gloves) will not affect the sensitivity of the system. Considering the conductivity of the wet wood, evaluating the proximity of operator's hand by its conductivity instead of dielectric constant results into distinguishing the hazard situation and protecting the operator's hand even in presence of unseasoned (wet) wood.

Although, the circular saw safety system can be realized through electromagnetic coupling between circular blade and the operator, the proposed system in this article consists of separate transmitting and receiving electrodes.

This is mainly due to possible failures and lack of reliability in case of using the circular blade as transmitter such as follows.

1) Very limited sensitivity due to strong capacitive coupling between the blade and structure.
2) Shield electrode cannot connect directly to the structure (ground), as the operator cannot be connected directly to an electrode and its contact with the structure strongly attenuates the signal.
3) The movement of the sliding table provides a significant variation of the coupling signal.

The transmitting and receiving electrodes can be placed horizontally or vertically.

As shown in Fig. 1, the transmitter is installed on saw guard and excited through sinusoidal source. The excitation signal is acquired using a first analog-to-digital converter (ADC1). The receiver is placed on the DeWalt table while it is isolated form the grounded structure. The signal on the receiver is acquired by ADC2. Considering the approaching object, Fig. 3 shows a simple lumped-element model, useful to extract an approximate transfer function of proposed system. In the model, Z_1 represents the capacitive coupling between two electrodes, Z_2 and Z_3 represent the capacitive coupling of the approaching object with the transmitter and the receiver, respectively. The impedance to ground of the approaching object is represented by Z_4.

To generate stimulus signal and acquire both voltages on transmitter and receiver, a data acquisition (DAQ) board, such as digilent analog discovery 2 is included in the proposed system. The DAQ board has two differential analog input capable to acquire analog signals with analog bandwidth up to 30 MHz using two synchronous ADCs at 100 MSPS with 14-bit resolution.

In the model of Fig. 3, the impedance of analog front-end for both inputs (Z_5 and Z_6) are included. The signals on both electrodes are measured with respect to the ground of the circuit, directly connected to the negative pin of both differential analog inputs. Finally, Z_7 and Z_8 model the impedances between the electrodes and the ground. It should be noted that Z_7 does not provide any effect on the measurement since the transmitting electrode is driven at low impedance by voltage generator. The transfer function is defined as ratio between the measured voltage by ADC2 (V_{out}) and ADC1 (V_{in}). It is a function of frequency and position of the approaching object, but also depends on the characteristics of the object itself. Indeed, the values of Z_1 , Z_2, Z_3, and Z_4 depend on electrical and geometric characteristics of approaching object. Proximity of the object acts as a shield for the electric field, reducing capacitive coupling between electrodes (Z_1). This reduction will be linked to the size of the object and its effectiveness as an electromagnetic shield. To simplify the problem, we assume an empirical exponential dependence with object distance d for modeling the reduction of the capacitance between the electrodes. It is a drastic approximation of the real behavior of such three-dimensional phenomenon, but it allows us

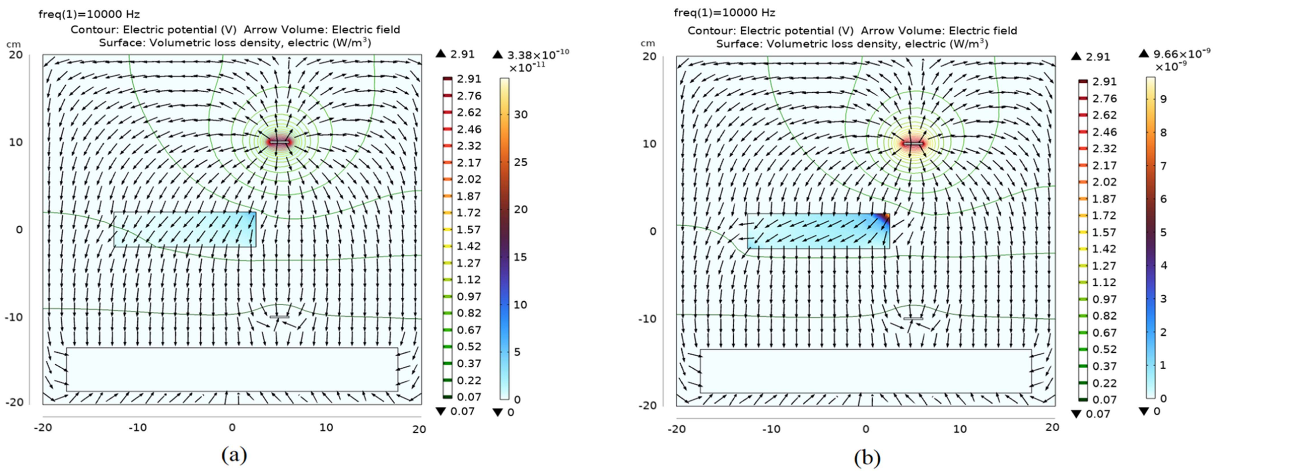

Fig. 2. Distribution of electric field lines and loss density for (a) approaching dry wood and (b) human body.

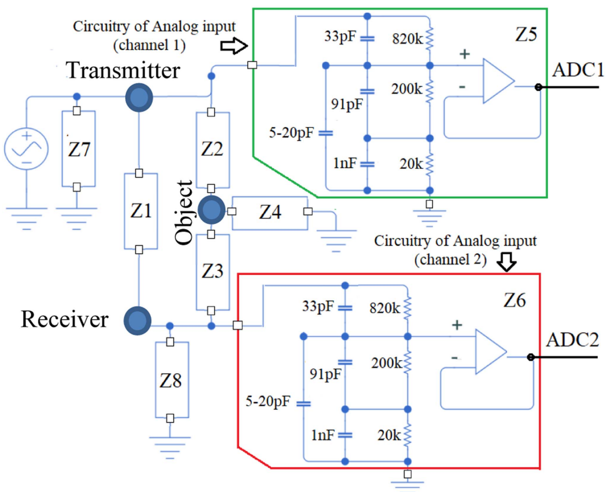

Fig. 3. Lumped-element model of proposed safety system for table saw.

to simplify the transfer function and give a simple explanation of the system's working principle. This empirical model was chosen after several measurements on a real system, for different geometry and position of various approaching objects. Equation (1) reports the approximate expression for Z_1 as function of frequency and distance d

$$Z_1\,(s,d) = 1/sC_\infty\ \left(1 - \alpha\,\exp\left[-d/D\right]\right), \qquad (1)$$

where C_∞ is the capacitance between the electrodes in the absence of any object, and the coefficient α models the effectiveness of object acting as a shield. For our simulation we set $\alpha = 0.1$, corresponding to 10% of capacitance reduction when the object is between the electrodes. This value was empirically found, for the best matching with the measured values. The distance between approaching object and the proposed active barrier is indicated by d, while D represents a scale factor for the shielding sensitivity (set to 1 cm in our simulations). When the object is in proximity to the barrier, the value of Z_2 and Z_3 is increased due to polarization of approaching object by applied electric field. The polarized object attracts additional charges on the electrodes while approaching to the barrier resulting in stronger capacitive couplings. Following the approximation of (1), we can assume the same exponential dependence with d, as reported in

$$Z_2\ (s,d) = 1/\left(sC_{12} \times\ exp\left[-d/D\right]\right)$$
$$Z_3\,(s,d) = 1/\left(sC_{13} \times\ exp\left[-d/D\right]\right), \qquad (2)$$

where C_{12} and C_{13} model the capacitive coupling between approaching object and electrodes. In our simulation we assumed $C_{12} = C_{13} = 200$ fF for all cases. Since the coax cable is used to connect the DAQ board to both electrodes, Z_8 can be replaced by capacitive component with value of about 100 pF/m. The values of Z_8, Z_5, and Z_6 are not function of the object position and are constant for the simulation. Next paragraphs show the transfer function $V_{\text{out}}/V_{\text{in}}$ simulated by MATLAB, for three different approaching objects: human body, dry and wet woods.

A. Human Body Interaction With Proposed Barrier

The electrical model of the human body consists of approximately 200 Ω resistance in parallel to 10 pF capacitance. The coupling between human body and table structure is modeled with 400 pF capacitor [20], mainly through the upper part of its body, close to the metal structure of the table saw, which is grounded (this method requires a conductive material for the table). Fig. 4 shows the modulus and the phase of the transfer function for different positions of the hand with respect to the barrier. Simulation results show a constant reduction of modulus in the frequency range between 10 kHz and 1 MHz, while the phase shows no sensitivity with respect of the hand position. The results are identical even increasing the resistance from 200 Ω up to 20 kΩ, for representing the different geometries of body-blade approach (e.g., simple fingertip or entire forearm).

B. Dry Wood Interaction With Proposed Barrier

Considering very low conductivity, the electrical model of dry wood consists of approximately 1 GΩ resistance in parallel to a negligible capacitance. The coupling between sample of dry wood and the grounded metal structure is modeled with 100 pF

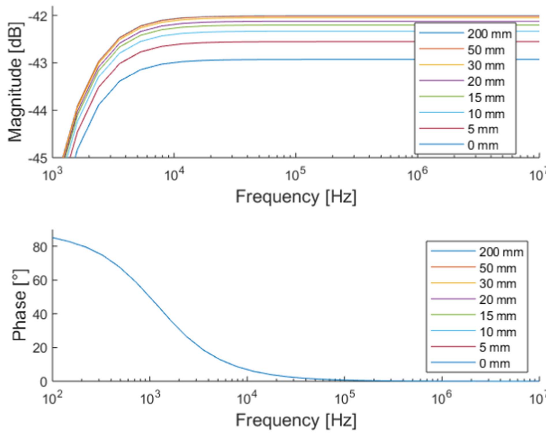

Fig. 4. Trend of modulus and phase of the transfer function, for different positions of the operator's hand with respect to the barrier.

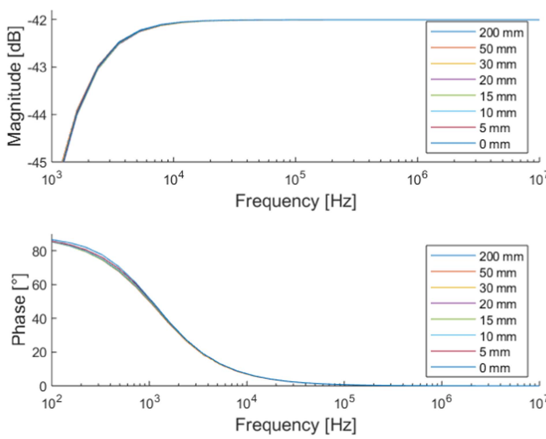

Fig. 5. Trend of modulus and phase of the transfer function, for different positions of the dry wood with respect to the barrier.

capacitor. As shown in Fig. 5, there is no significant variation in modulus and the phase of the transfer function when approaching the dry wood to the barrier.

C. Wet Wood Interaction With Proposed Barrier

The electric model of wet wood consists of approximately 10 MΩ resistance in parallel to a negligible capacitance. The value of the series resistance is five orders of magnitude higher than the one for the human body, due to lower conductivity of the wood as given in Table I. The coupling between sample of wet wood and the grounded metal structure is modeled with 100 pF capacitor. Fig. 6 shows the trend of the modulus and the phase of the transfer function as the position of the wet wood with respect to the barrier.

Both modulus and phase show a dependence to the position of the wet wood at low frequencies (below ∼20 kHz), while the sensitivity is reduced at high frequencies (higher than ∼200 kHz). From simulation results, we can conclude that measuring modulus and phase of $V_{\text{out}}/V_{\text{in}}$ at two frequencies simultaneously, such as 10 kHz and 1 MHz, should allow to effectively detect the approach of the operator hand, while distinguish it from dry or wet wood. Figs. 7 and 8 show simulation results of the

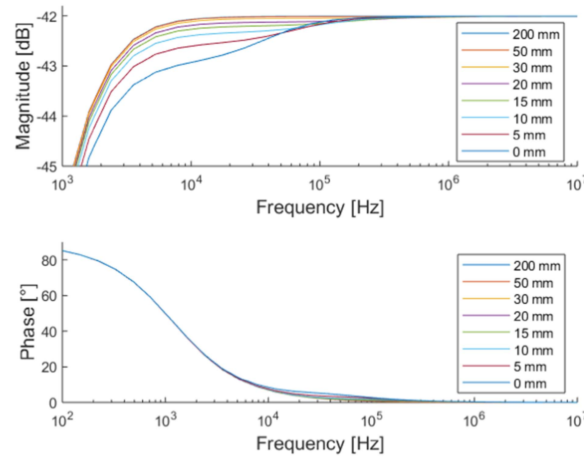

Fig. 6. Trend of the modulus and the phase of the transfer function as the position of the wet wood with respect to the barrier.

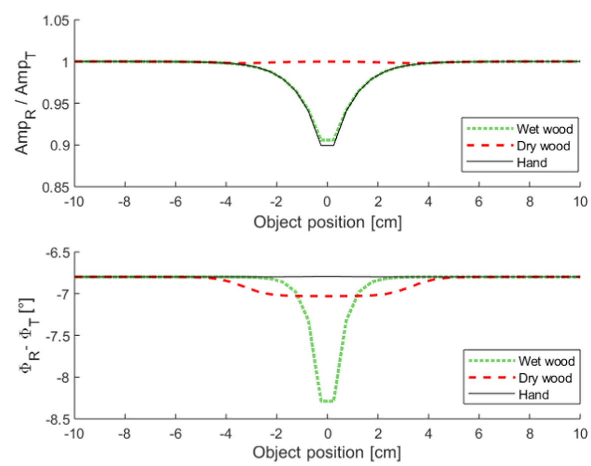

Fig. 7. Variation in magnitude (normalized to 1) and phase shift versus the position of approaching objects, measured at 10 kHz.

transfer function for different material at 10 kHz and 1 MHz frequencies, respectively. The horizontal axis is the distance between the object and the electrodes position, negative while approaching and positive while moving away. As expected, at 10 kHz wet wood is like hand on modulus, but it exhibits a visible phase shift, not present for the hand. On the contrary, at 1 MHz the hand proximity is absolutely distinguishable from the wood, both wet and dry. Wet wood presence is still indicated by a little change in signal phase.

III. Experimental Setup and Results

Fig. 9 shows the experimental setup of the proposed safety system for a table saw. The measurement setup consists of two square electrodes, with 2 cm of side, placed about 17 cm apart.

The excitation voltage signal V_{in} is given by the sum of two sinusoidal signals at 10 kHz and 1 MHz. It is generated by the DAQ board, limited to 6 V_{pk-pk}, and it is connected to the first analog input (ADC1) of the same board. The receiver is placed on the surface of the metal structure, grounded, but it is electrically isolated from it. This electrode is connected to the second channel (ADC2) of the acquisition board. To evaluate the

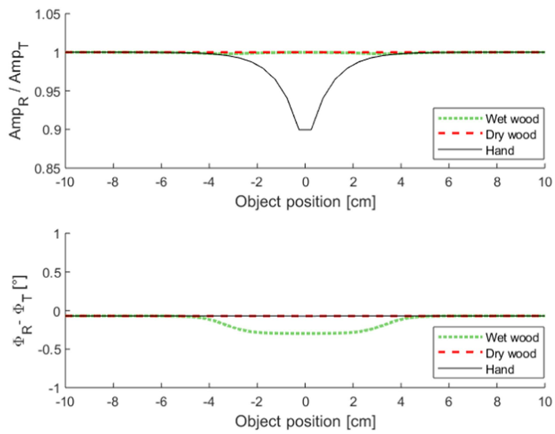

Fig. 8. Variation in magnitude (normalized to 1) and phase shift versus the position of approaching objects, measured at 1 MHz.

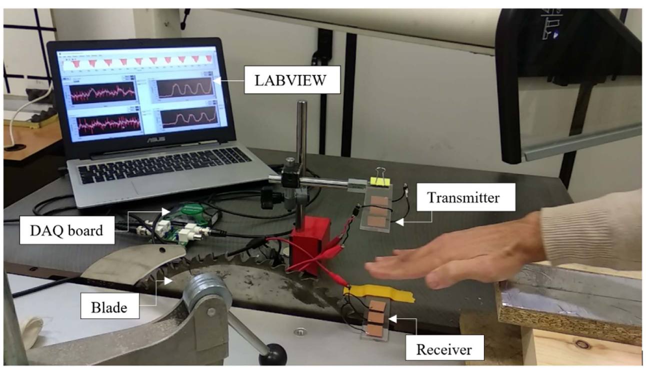

Fig. 9. Experimental setup of the proposed safety system for sliding table saw.

transfer function V_{out}/V_{in}, discrete Fourier transform (DFT) is performed: the Fourier coefficients are evaluated by multiplying the acquired signals by two vectors of sine and cosine at two frequencies. In this way modulus and phase values of the acquired signals V_{out} and V_{in} are measured through a synchronous detection [21]. Each signal is acquired at 10 MSPS and DFT is computed on 8000 samples. The DFT algorithm and elaboration of the results are managed by software developed in LabVIEW, one measurement every 10 ms. Several tests were carried out to verify the simulation results, considering different approaching objects such as operator's hand, wet and dry wood. In addition to the raw amplitude and phase measurements, the result of moving average filtering (over 100 samples) is presented in all measurement. The variation in amplitude and phase measurements for proximity of the operator's hand (three consecutive approaches) is shown in Fig. 10: for each approach the amplitude variation is evident. Since the amplitude variation is identical at 10 kHz and 1 MHz, only the high frequency response is shown in this case. Experimental results are in good agreement with simulations (see Fig. 8), there is almost 11% reduction in relative amplitude as result of less coupling due to the presence of human body, while the phase remains constant.

Figs. 11 and 12 show the experimental result in case approaching dry wood at 10 kHz and 1 MHz, respectively, which are in

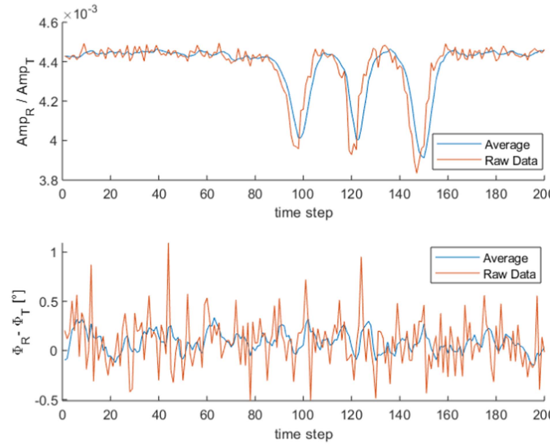

Fig. 10. Variation in relative magnitude and phase of receiver and transmitter at 1 MHz for three consecutive approaches of operator's hand.

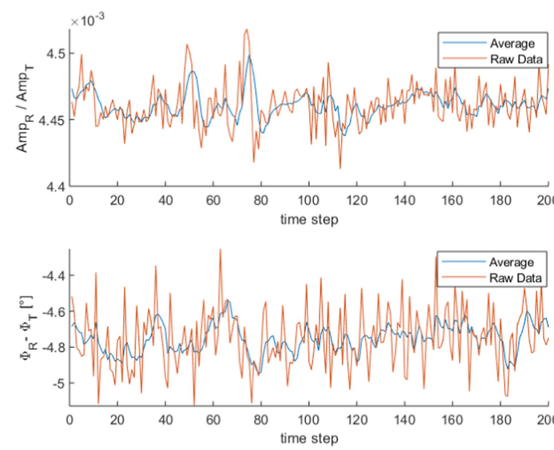

Fig. 11. Variation in relative magnitude and phase of receiver and transmitter at 10 kHz for three consecutive approaches of dry wood.

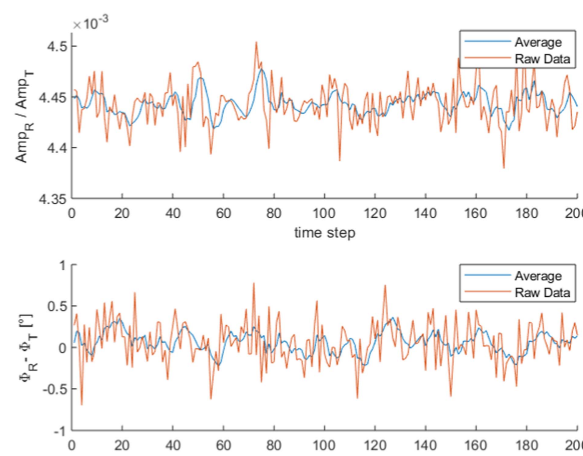

Fig. 12. Variation in relative magnitude and phase of receiver and transmitter at 1 MHz for three consecutive approaches of dry wood (same experiment shown in Fig. 11).

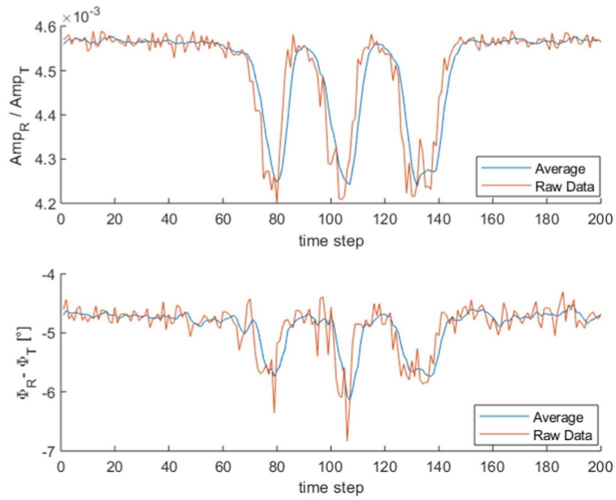

Fig. 13. Variation in relative magnitude and phase of receiver and transmitter at 10 kHz for three consecutive approaches of wet wood.

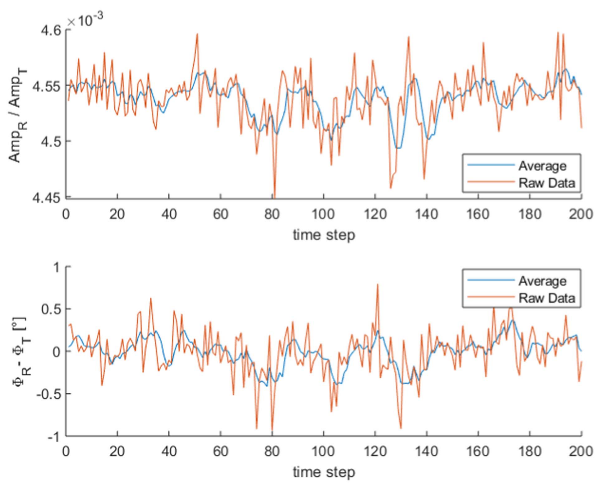

Fig. 14. Variation in relative magnitude and phase of receiver and transmitter at 1 MHz for three consecutive approaches of wet wood.

a good agreement with simulation results: due to the very low conductivity of dry wood, there is no sensitivity to its presence in both relative amplitude and phase shift.

In case of approaching wet wood, the low and high frequency responses are different from each other. The variation in amplitude and phase of receiver and transmitter at 10 kHz and 1 MHz are shown in Figs. 13 and 14, respectively, for three consecutive approaches of wet wood.

As expected from simulations, there is a variation in both relative amplitude and phase at 10 kHz. While the relative amplitude is reduced by almost 8%, the phase shift is decreased by almost 1° (as predicted by the simulation in Fig. 7).

In contrast to the human hand, there is very-small sensitivity in amplitude at 1 MHz for proximity of wet wood, and a small sensitivity in phase (lower than 0.5°, as expected from simulation of Fig. 8). This is the key property of the proposed safety system, for the discrimination between the operator's hand and the wood. Finally, the response of the proposed safety system is evaluated in case of wearing gloves. As discussed earlier, this is a challenge in optical based safety systems where the amplitude of reflected

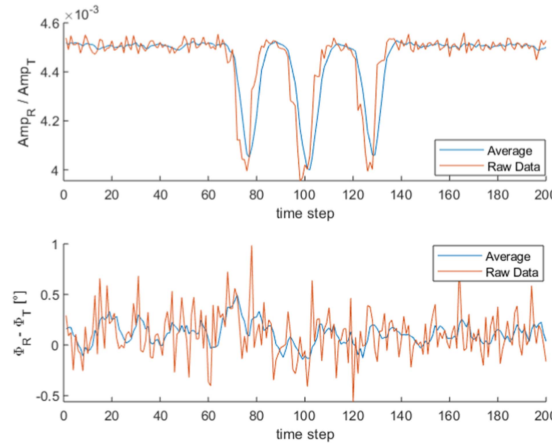

Fig. 15. Variation in relative magnitude and phase of receiver and transmitter at 1 MHz for three consecutive approaches of the operator's hand covered by a glove.

signal depends on the reflectivity of the approaching object. Fig. 15 shows the relative amplitude and phase shift at 1 MHz. As expected, the system response remains identical with or without wearing gloves (see Figs. 10 and 15). In this measurement we used latex-coated rubber work gloves, but the results do not change with different kind of gloves, always acting as a small layer of dielectric material.

Considering simulations and empirical evidences, it is easy to propose an elaboration algorithm to detect a dangerous situation. It should be based on a threshold on the transfer function modulus at 1 MHz, sensitive to human body but not to wood. A first implementation with adaptive threshold has been implemented with absolute reliability: in all tests the system was always able to advice a danger situation, without false alarms in the case of normal wood cutting. To improve the intelligence and self-adaptation of the safety system, also the low frequency response should be included in the algorithm. The system works properly also with the saw in movement: disturbances are filtered out by the DFT filter. It is worth to note that a conductive object tricks the system, giving a response similar to that of a hand, but for most industrial applications this is not a problem, on the contrary it can warn the operator while trying to cut a nail or other type of metal fitting.

IV. Conclusion

To respond effectively to hazard situations, this article proposes an active, sensitive, and cost-effective safety system based on impedance measurement. A multitone sinusoidal signal was applied on a couple of electrodes placed as in Fig. 1, acting as a selective barrier able to distinguish the proximity of a hand with respect to wood, both dry and wet. The working principle was introduced by an equivalent circuit for simulations, mainly useful to describe the system, and demonstrated by experimental evidences. Due to different conductivity of approaching object, fringe field lines between electrodes were attracted in different manner, resulting in changes in impedance network. Approaching the operator's hand induces strong reduction in relative amplitude, as result of reduced coupling between transmitter and receiver, while the wood does not induce this effect. This was mainly due to the human body conductivity, clearly higher than wood. The proposed safety system can therefore distinguish between the operator's hand and wet wood, which was a challenge for dielectric based proximity sensors. The main limitation of the proposed method was the false alarm in the presence of conductive objects, like metal-clad panels. This limit was well known and accepted from a commercial point of view, because it affects a very small percentage of the market. A further advantage of the system was its insensitivity to the presence of gloves. The described demonstrator was based on a commercial DAQ board, but it was engineered on embedded electronics, considering signal frequencies and elaboration required. In addition to high sensitivity, its simple design eases a real installation on the blade guard, already present in high-level system. The system was now under final engineering stage, to be presented at the most important trade fairs and finally marketed.

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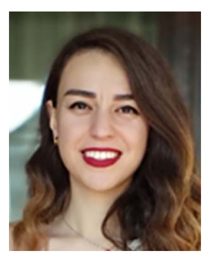

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