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## Radar Based Lie Detection Technique

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**Keywords:** *lie detection, EEG, ECG, polygraph testing, f-MRI, brain fingerprinting, ultra-wideband (UWB) radar, stealthy etc.*

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# Radar Based Lie Detection Technique

Kedar Nath Sahu <sup>α</sup>, Dr. Challa Dhanunjay Naidu <sup>σ</sup> & Dr. K Jaya Sankar <sup>ρ</sup>

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## I. INTRODUCTION

In recent times, need for lie detection has enormously increased to combat tremendous growth rate of crimes in the society. The lie detection procedure adopted by various investigating agencies may be simple or rigorous depending on the intensity of the crime under investigation. The procedural steps of a particular lie detection method are executed either in complete or in part based on the order of the crime. In ancient Hindu and Chinese civilization as reported in [1], lie detection was done by asking the suspect to chew a grain of rice and spit it out. In China, a dry grain of rice indicates the dry mouth of a liar. In India, rice stuck to the mouth was the sign of guilt. Astrology, tea-leaf readings etc. were also some of the primitive methods used for lie detection. All these primitive and non-

scientific methods highlight the psychological state of lying. Cardiovascular activity represent the physiological sign of lying as documented first by Lombroso, an Italian criminologist in late 19<sup>th</sup> century[1]. The blood pressure and heart rate increases noticeably while lying.

As technology advanced more powerful lie detection techniques have emerged. They include Polygraph testing, Facial Thermal Imaging, Electroencephalograph (EEG), functional-Magnetic Resonance Imaging (f-MRI), Event Related Potentials (ERP), Brain fingerprinting etc. DNA profile test, dactylography, cheiloscopy have been followed by the investigators since long. [3-6]. Of all the other existing methods for lie detection viz. examining documents, analytical fingerprints, DNA profiling, authenticating audio and video records, investigating a crime scene, screening a suspect from a psychological perspective etc., polygraph testing has been very popularly used since long. Later more advanced technique like functional-magnetic resonance imaging (f-MRI) was developed [7]. This method studies the change of brain metabolism that takes place when a person tells a lie. Event related potential (ERP) was yet another method [8] to study the changes during information processing of the brain but suffered from the limitation that led to the development of another method called as multifaceted electroencephalograph response analysis (MERA) as reported in [9]. Brain fingerprinting, a computer based technology was Dr. Lawrence A. Farwell's invention [10] and exploits the brainwave response characteristics when the criminal is subjected to crime related images. As EEG has undergone tremendous advancement in the recent years, its ability to read the brain activity simultaneously from all parts of the head has increased.

As a technological breakthrough of radar applications, medical uses of ultra-wideband (UWB) radars were presented in 2002 [11]. The UWB radar pulse passes through the human thorax and gets echoed back by the cardiac structure i.e. the heart wall. Using this principle an ultra-wideband (UWB) radar based lie detector was reported in [2].

## II. COMMON SIGNS OF DECEPTION

The common signs of deceptive behavior have been reported in the literature [12] such as body language, emotional gestures and contradiction, interactions and reactions, verbal context and content, facial micro-expressions, statement analysis, change of topic etc. These deception techniques are used by

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police, forensic psychologists, security experts and other investigators to help prevent them from being victim of fraud or scams and other deceptions.

Of course, these signs don't strictly indicate that someone is lying, but that they are more likely to be lying. Just because some exhibits one or more of these sign does not make them a liar. The above behaviors should be carefully observed and compared to a person's base or normal behavior (the behavior that precedes the instant of lying) whenever possible. Some of the very common signs of deceptive behavior are discussed below.

#### a) *Body Language*

Liars have a typical body language as they avoid making eye contacts, move the hands on their face, throat, mouth, touch or scratch the nose or behind the ear, take up less space by having hand, arm and leg movements toward their own body.

#### b) *Emotional Gestures and Contradiction*

It is found that the gestures or expressions of a liar do not match the verbal statement. There is no timing and duration between emotional gestures and words of expressions. Expressions are limited to mouth movements and not the whole face.

#### c) *Reactions During Interactions*

It is not uncommon that an innocent person goes on offensive whereas the guilty behaves defensive. Mostly it is found that a person telling a lie feels uncomfortable to face the investigator and often turns the head or body away while being interrogated. Another peculiar behavior is that the guilty might unconsciously keep some object like a water bottle, a note book between him and the interrogator.

#### d) *Verbal Context and Content*

The liars use the words of the interrogator to make the answer of the question asked to them, speak more than natural, and add unnecessarily more details to convince the questioner as they are uncomfortable with silence or pauses in the conversation. They speak in a monotonous tone and the pronouns of their statements are not emphasized. The words may be garbled and spoken softly with no usage of grammar. Sentences will be muddled instead of having emphasized. One of the verbal signs of lying is that the liar tries to invent the answer and hence spends more time for searching a right word while speaking, doesn't use contractions and takes long time to provide an answer.

#### e) *Facial Micro-expressions*

Sometimes a momentary involuntary facial expressions such as anger, disgust, fear, sadness, surprise and contempt known as micro expressions are unconsciously displayed when the person attempts to hide an emotion. These actions are quick (even

sometimes not easily noticeable), intense expressions of concealed emotion, appear and suddenly disappear off the face in a fraction of second. This theory of micro expressions was discovered first by Haggard and Isaacs in 1966 [13]. These micro expressions betray the person while lying as the one will be trying to cover his feelings with fake smiles, but involuntary face muscles reveal the hidden emotions.

Like micro-expressions, forced smile (that involves only the muscles of the mouth and not the rest of the face), increased blinking, scratching the face or nose, placing the hand over the mouth while speaking are also other good indicators of change of a person's normal behavior and known as the non-verbal signs of lying [14].

#### f) *Statement Analysis*

This is also known as linguistic text analysis and detecting anomalies and was developed in 1970s [15]. The method involves studying the language, grammar and syntax of a person's event description. Text analysis represents the subject's verbal behavior i.e. usage of words (written and oral statements). Text analysis or statement analysis is a two-part process according to Susan Adams, senior instructor at FBI Academy [15].

Sometimes police and other investigators adopt this technique to indicate the presence of lies by analyzing the subject's words, because, people always phrase a statement according to their knowledge and therefore their statement may even include the information which they really did not intend to share. It is nearly impossible to give a long deceptive statement with an idea of protecting it from revealing it as a lie.

#### g) *Change of Topic*

When someone is guessed for lying, then the theme of the conversation should be changed quickly. By doing so, it is found that the liar follows the change and feels more relaxed. In contrast, an innocent subject gets confused by such a sudden change of topic under interrogation and may try to go back to the previous topic. The liar may try to use humor or sarcasm to avoid the subject of issue.

#### h) *Other General Signs*

The possible deception in oral and written statements can also be detected in the following various ways also as reported in [16].

Truthful people frequently use the pronoun 'I' to describe their actions whereas deceptive people are lack of self references as they describe the events in passive voice. Truthful people use past tense in order to describe a past event whereas the deceptive people describe the past events using the present tense. A deceptive person usually tries to avoid answering the question and prefers not to lie. The liar responds with a question and tries to dodge. By using non-committal verbs such as think, believe, guess, suppose, assume

etc., equivocating adjectives and adverbs: sort of, almost, mainly, perhaps, may be, about etc. and vague statements like you might say, more or less etc. the subject avoids answering the interrogator. Liars usually try to convince the interrogators that what they say is true by using mild oaths such as I swear, as God is my witness so that their statements sound more convincing.

Also a guilty person uses mild or vague words which are explicit synonyms or euphemistic terms such as missing instead of stolen, warned instead of threatened etc. Liars speak fabricated stories to make up a detailed description and hence are lack of details. "I try to", "I decided to", "I also needed" etc. are the statements used by liars to allude to all these actions with talking anything definitively. As described in [16], Mean Length of Utterance (MLU) of the suspect is defined to be the total number of words in a statement divided by the number of sentences. When people become anxious to speak about an issue they speak in sentences much longer or much shorter than the MLU.

Laser detector also can detect muscular, circulatory and other physiological changes during the anxiety of lying. The voice and tone can be analyzed by using computer programs as the vocal cords produce a distorted sound wave caused by an involuntary interference of the nerves while lying. In another method called as the lie detecting keyboard, when a person types into a computer the change in the typing pattern is observed, moistures in finger tips is sensed, body heat is recorded and how fast the fingers move on the keyboard is monitored.

According to Aldert Vrij, Professor of Applied Social psychology at University of Portsmouth, UK [17] there is no verbal and non-verbal cues that can be completely relied upon because the assumption that liars are more nervous than truth-tellers is incorrect. Thus any machine may be accurate in measuring nervousness but that doesn't mean someone is lying. With technological advancements, humans will be able to better correlate the psychological state of lying with physiological responses.

According to some lie detection experts, a combination of body language, micro expressions, eye movement and direction as well as other cues must also be used to make an educated guess on whether someone tells a lie. But in order to reveal the truth or lies of a person, the interrogator should first establish and understand the base behavior of a person by having sufficient conversation before applying any or all of the above signs of lying.

### III. LIE DETECTION TECHNOLOGIES

The lie detection methods can be broadly categorized as (i) invasive and (ii) non-invasive from the subject's privacy view point.

#### a) *Invasive Methods*

##### i. *Polygraph Theory*

Ratio of inhaling and exhaling time during breathing change when someone lies. The first polygraph was invented [1] by John Larson, medical student working for the Berkeley police department. The use of polygraph for lie detection emerged in late nineteenth century. Irregularities in blood pressure and breathing patterns indicate the liar. Also a person while lying sweats more than a truth-telling person which reduces the skin resistance due to higher concentration of negative charged chloride ions on the surface of ion. Leonarde Keeler included "skin resistance" as the third polygraph channel [1]. Measurement of three physiological vectors: cardio logical, respiratory and perspiratory activities are still used by modern polygraphs.

The underlying theory of the polygraph is that when people lie they also get measurably nervous about lying. The heartbeat increases, blood pressure goes up, breathing rhythms change, perspiration increases, etc. A baseline for these physiological characteristics is established by asking the subject questions whose answers the investigator knows. Deviation from the baseline for truthfulness is taken as sign of lying. Hence, deliberate lying produces bodily reactions reflected in blood pressure, breath and heart rates, skin sensitivity (Galvanic Skin Resistance) etc. A Polygraph ("Lie-Detector") testing instrument simultaneously measures and records physiological changes caused by the sympathetic nervous system through the couplings to the body of the person while the subject is asked a series of questions for which he has to answer 'yes' or 'no'. The machine measures changes in blood pressure, breath rate, and respiration rate. From these a trained expert detects whether the person is lying. But these can also be caused by many causal factors like nervousness, anger, sadness, embarrassment, fear and number of medical conditions such as colds, headaches, constipation, or neurological and muscular problems. For many, the phrase "lie detection" brings to mind an image of a polygraph machine and an intimidating movie-style interrogation. But the method does not have scientific validity as there is no scientific evidence that polygraph experts can detect lies using their machine at a significantly better rate than non-experts using other methods. There is no evidence that the polygraph is really able to detect lies.

The method suffers from the problem of countermeasures. The effectiveness or better accuracy of polygraph test could be guessed if it would have been stealthiest. But since polygraph examination requires the consent of the person to be examined and nobody can undergo the test without their willingness the method suffers from having no stealthiness. As heart and breath rates along with blood pressure and electro dermal activity are important measurement parameters



in a polygraph procedure, the person undergoing polygraph analysis should necessarily be in a calm and healthy condition. But subject's emotional state is a serious cause of interference. Though high blood pressure does not affect the accuracy of the Polygraph test, it is necessary to ensure medical fitness of the subject prior to examination. It usually takes from 2 to 3 hours to administer a Polygraph test for each individual. The polygraph is an admirable but not impermeable tool.

Due to advances in computer programming in 1990s, polygraph could be administered through computers unlike the analog polygraph of 1970-80s [1]. Physiological irregularities of the examinee could be identified by the examiner more efficiently.

Commonly used polygraphs have error rates of 40% or more. Since polygraphs rely heavily on interpretation by polygraph examiners, human error and bias can create inaccurate results.

#### ii. *Facial Thermal Imaging*

Whenever someone during anxious states tries to make something up e.g. someone starts lying, the changes in the brain activity makes the temperature of the periorbital areas i.e. areas around his eyes and the cheeks rise because of the blood flow redistribution during the states of anxiousness. Detecting and monitoring of this temperature on face can be used as an indicator of someone lying. Researchers in UK are using at airports this novel method of lie detection based on thermal imaging technology to spot the liars [17]. University of Bradford, North England has conducted experiments on this lie detection technology which yielded promising results, according to Professor Hassan Ugail, Director for Center for Visual Computing, University of Bradford in North England [17]. In [18], thermal image analysis is described as a novel method with the anticipation that it will play an important role in scoring polygraph testing. Thermal image analysis consists of three stages: image acquisition (acquiring facial thermal imaging by means of mid-infrared camera), physiological correlation (transforming the raw thermal data to blood flow rate through heat transfer modeling) and pattern classification (classifying the subject as deceptive or non-deceptive on the basis of nearest-neighbor classification method).

Thus the traditional invasive 1D physiological measurement in conjunction with normal non-invasive 2D physiological measurement might increase the accuracy and reliability of polygraph testing.

#### iii. *Electroencephalograph (EEG)*

By means of the electrodes attached to the subject's head this method measures the brain waves and detects brain processing related patterns while making the subject recognize a scene or a person during the course of questioning. The perceived trustworthiness interpreted by the individual from looking

at the face of the subject decreases when someone is lying.

#### iv. *Functional MRI*

Lying causes a conflict between lie and the truth within the brain. The increased activity can be detected by fMRI which records brain activity by identifying changes in brain blood flow and the metabolic rate. This discovery is a step closer to developing a lie detector which doesn't depend on nonspecific physiological vectors that can be induced by conditions other than lying.

This technique maps the brain activity by means of powerful magnets. This measures the usage of oxygen throughout the brain. Different parts of the brain of a person are activated while telling a lie than telling the truth. As active parts of the brain involve increased blood flow, more oxygen usage than the inactive parts this increases the intensity of magnetic resonance signal. This feature is exploited in the functional MRI technique. Though this technology has tremendous potential for lie detection but still not trustworthy due to its own drawbacks such as invasiveness, inaccuracy etc. Moreover this technology finds it tough for the real time application as the f-MRI machines are bulky, highly expensive and sensitive to motion. The responses of multiple voxels in the brain are evoked by stimulus and then detected by fMRI in order to decode the original stimulus during brain-reading.

#### v. *Event Related Potentials*

This method involves the measurement of positive and negative change of potentials corresponding to information processing of brain but suffers from the disadvantage that the signal averaging eliminates all the complex patterns which lead to loss of meaningful signals. This led to the development of another lie detection technique known as multifaceted EEG response analysis (MERA).

#### vi. *Brain Fingerprinting*

In the event of a crime, a lot of physical evidences related to the crime may be unavailable but the sequence of the events is silently recorded by the subject's brain. This makes a difference between a criminal and an innocent person that the criminal has the details of the crime stored in his brain whereas the innocent does not possess any such record. Brain fingerprinting or uses EEG to determine if the subject is familiar to an image.

In this technique three types of stimuli viz. targets, irrelevant and probes are attached to the subject's headband to measure electrical brain responses.

For any reason if the techniques mentioned above do match with the crime scene evidences then even innocent will be proved guilty. Moreover, all of the above lie detection techniques to some or all extent whether justifiable or not but, invade the privacy of

someone's mind and thus are invasive. Hence, this gave rise to the need for some non-invasive, non-obtrusive method of lie-detection that takes care of the subject's privacy.

vii. *Cognitive Chronometry*

This refers to the systematic measurement of response time either to perform mental operations or time of mental associations and can be used to distinguish lying from truth-telling. Two measuring instruments relying on cognitive chronometry are the implicit association test (IAT) and the Timed Antagonistic response alethiometer (TARA).

a. *Non-invasive Method*

Radar Principle: Radio Detection and Ranging (RADAR) is an electromagnetic device used to detect (i.e. to confirm the presence) and locate (to measure the distance or range) an object (the target). In principle, as explained in [19], radar transmits a modulated signal aimed at the target and detects the echoed signal. It consists of a transmitting antenna that radiates the electromagnetic energy, a receiving antenna and a receiver. A part of the transmitted energy is intercepted by a reflecting object or the target and is reradiated in all directions. But the fractional energy reradiated in the backward direction toward the radar location is collected by the receiver via the receiving antenna. The signal returned is processed to extract the desired information about the target. The range to the target is determined by measuring the two-way propagation time for the radar signal. For moving objects there exists a relative motion between the radar and the object and hence there is a shift in the carrier frequency of the returned signal. This shift of frequency is due to the Doppler effect on the carrier signal that is also a measure of the relative velocity.

• *Definition of UWB*

According to the revision of part 15 of the governing rules and regulations laid by the Federal Communications Commission (FCC), Washington, D.C. 20554, ultra-wideband (UWB) is defined as the frequency band for which fractional bandwidth  $=2(f_H-f_L)/(f_H+f_L) \geq 20\%$  or has a UWB bandwidth equal to or greater than 500 MHz regardless of the fractional bandwidth. UWB medical systems must be operated in the frequency band 3.1 to 10.6 GHz.

• *Issue of Safety*

As reported in [2], the emission limit of medical UWB radars is 2 to 3 orders of magnitude less than a cell phone and hence talking over a cell phone for more than 5 minutes is equivalent to UWB monitoring of 10 hours. The power level and electric field intensity of the UWB radar based stealthy lie detector described in [2] are 7 to 9 order lesser. This explains the safety concern of UWB radar based heart rate monitoring that it is less dangerous and safer than the cell phones.

• *Heart-rate-variability (HRV)*

This is the physiological phenomenon of variation in the time interval between heartbeats i.e. the variation in the beat-to-beat interval. HRV is also an indicator of the emotional arousal. The main inputs received by the sinoatrial node (SA node) viz. the sympathetic nervous system (SNS), parasympathetic nervous system (PSNS) and humoral factors are affected due to thermoregulation, hormones, sleep-wake cycle, meals, physical activity, stress etc. HRV reduces due to decreased PSNS activity or increased SNS activity.

• *Radar based lie detection*

The radar based procedure which could perform remote, unobtrusive, non-invasive and stealthy lie detection is when an UWB radar pulse passes through the human thorax it gets echoed back by the cardiac structure i.e. the heart wall. This characteristic was exploited to design and build the UWB radar based lie detector. The most incredible feature is that it is a stealth detecting device as it is not physically connected and is invisible to the subject under test. Hence it bears no physiological and psychological discomforts, prevents the breathing and cardio countermeasures of the subject unlike the polygraph lie detector. In its experimental setup comprising of a UWB radar device and an ECG amplifier heartbeat rate could be detected from a distance of 15 to 20 cm from the heart. Both ECG and UWB radar methods yield the same heartbeat related data from the heart-rate-variability (HRV) characteristics.

In the event of human heartbeat detection, the parasympathetic and sympathetic sections of the autonomic nervous system play a major role and hence the time interval between successive heartbeats known as the Heart Rate Variability (HRV) is measured. The heart rhythm fluctuates around the mean heart beat rate due to continuous alteration in sympathetic-parasympathetic balance of the autonomic nervous system. The heartbeat rate decreases due to parasympathetic activity and increases due to sympathetic activation.

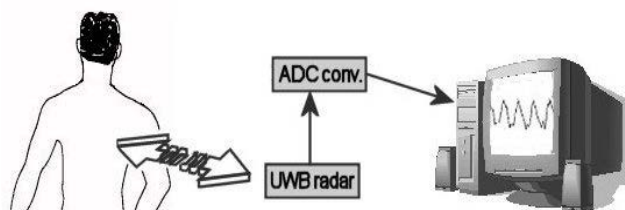


Figure 1 : Schematic of the stealthy vital parameters monitor mounted on the back of a chair [10]

As reported in [2], the subject was asked to sit on a chair and the radar was placed on the back of a chair as shown in figure 1. Two different detectors were

implemented to obtain heartbeat period from an electrocardiograph (ECG) signal and an UWB echo signal. The ECG signal comprising of P, Q, R waves was passed through a high pass filter and only the R waves were detected in successive beats. Then the peaks and valleys of the signal were obtained from the UWB echo tracings and the time lag between the two consecutive valleys was considered as the heart beat period. The heart-cycle period simultaneously estimated from both ECG and UWB radar are depicted in Fig.2 and Fig.3 respectively during five minutes (400 heart beats) considering the subject in a rest condition.

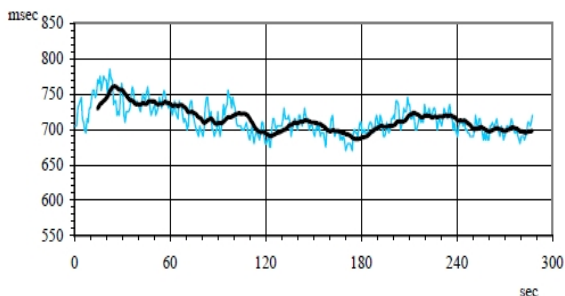


Figure 2 : ECG based heart-beat period detection estimated during five minutes (400 heart beats) [2]

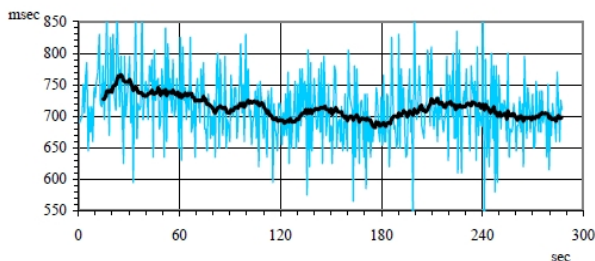


Figure 3 : UWB radar based heart-beat period detection estimated during five minutes (400 heart beats) [10]

It was seen that both UWB radar and ECG derived HRV signals are equivalent. The heartbeat period for both UWB detected beats and ECG detected was found to be 713 ms and hence a sampling rate equal to inverse of mean heartbeat period i.e.  $1/0.713$  Hz or 1.4 Hz was used for further signal processing. The heartbeat rate, respiration rate provided by the radar can be compared with those of a normal human being. Discrepancies if any infers about the person lying.

#### IV. CONCLUSION

A recent study by the author of [2] has proved that ECG results (invasive) were in confirmation with UWB radar (non-invasive) based results.

Radar based technology seems to have tremendous potential for lie detection but still a lot of work has to be done for trustworthiness. There exists no true and scientific lie detector or can be developed within the present state of the art, nevertheless HRV

detected by means of an UWB based radar seems to be a viable method.

The strength of UWB radar based lie detection is that the subject under test can be maintained unaware of being monitored and thus psychological discomfort can be avoided. Moreover the operation of this lie detector machine in a stealthy mode is a bonus of avoiding countermeasures. This factor adds to the strength to the legal aspects in delivering justice.

However from a practical viewpoint it is clear that any kind of criminal investigation accounts for the act of determination of innocence or guilt and this act is more a legal entity than just a scientific determination. Hence, for the best detection result, the investigating agencies should take the results of any of the methods in conjunction with the common signs of deception discussed as above before they announce a final verdict.

Most of the lie detection experts view that a combination of body language and other cues must be used to make an educated guess on whether someone is telling the truth or a lie.

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