

# Radar Based Lie Detection Technique

Kedar Nath Sahu<sup>1</sup> and Dr. Challa Dhanunjay Naidu<sup>2</sup>

<sup>1</sup> Stanley College of Engineering and Technology for Women, Hyderabad, INDIA

*Received: 7 December 2013 Accepted: 2 January 2014 Published: 15 January 2014*

---

## Abstract

The need for lie detection is to resolve disputes that arise over inheritance, forgery, impersonation as well as in forensic science which deals with application of science to law aiding to deliver justice by eliciting truth, scientific evaluation of physical evidence usually encountered in many civil, criminal regulatory and statutory cases. All the methods for lie detection including the most popular polygraph testing depend on the measurement of variation of physiological conditions like heart beat rate, respiratory rate (breath rate), etc. by establishing physical contact of some medical device with the person's body and thus are invasive and obtrusive. But these physiological conditions vary due to the effect on the autonomic nervous system (ANS) for any reason irrespective of whether the person tells a lie or the person is innocent but feels nervous for being under test. This leads to an ambiguous and/or inaccurate decision about the person telling lies. A radar based lie detector proposed recently can be a remote, non-contact, non-invasive and unobtrusive method. This review paper summarizes the common signs of deceptive behavior, major non-radar based methods used earlier and finally, the radar based technique for lie detection that has emerged as a technical breakthrough in lie detection.

---

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

## 1 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 th century [2]. 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, cheiloscropy have been followed by the investigators since long. [3][4][5][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

44 tells a lie. Event related potential (ERP) was yet another method [8] to study the changes during information  
45 processing of the brain but suffered from the limitation that led to the development of another method called  
46 as multifaceted electroencephalograph response analysis (MERA) as reported in [9]. Brain fingerprinting, a  
47 computer based technology was Dr. Lawrence A. Farwell's invention [10] and exploits the brainwave response  
48 characteristics when the criminal is subjected to crime related images. As EEG has undergone tremendous  
49 advancement in the recent years, its ability to read the brain activity simultaneously from all parts of the head  
50 has increased.

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

## 55 2 II.

### 56 3 Common Signs of Deception

57 The common signs of deceptive behavior have been reported in the literature [12] such as body language, emotional  
58 gestures and contradiction, interactions and reactions, verbal context and content, facial micro-expressions,  
59 statement analysis, change of topic etc. These deception techniques are used by Of course, these signs don't  
60 strictly indicate that someone is lying, but that they are more likely to be lying. Just because some exhibits one  
61 or more of these sign does not make them a liar. The above behaviors should be carefully observed and compared  
62 to a person's base or normal behavior (the behavior that precedes the instant of lying) whenever possible. Some  
63 of the very common signs of deceptive behavior are discussed below.

#### 64 4 a) Body Language

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

#### 68 5 b) Emotional Gestures and Contradiction

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

#### 72 6 c) Reactions During Interactions

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

#### 77 7 d) Verbal Context and Content

78 The liars use the words of the interrogator to make the answer of the question asked to them, speak more than  
79 natural, and add unnecessarily more details to convince the questioner as they are uncomfortable with silence  
80 or pauses in the conversation. They speak in a monotonous tone and the pronouns of their statements are not  
81 emphasized. The words may be garbled and spoken softly with no usage of grammar. Sentences will be muddled  
82 instead of having emphasized. One of the verbal signs of lying is that the liar tries to invent the answer and  
83 hence spends more time for searching a right word while speaking, doesn't use contractions and takes long time  
84 to provide an answer. e) Facial Micro-expressions Sometimes a momentary involuntary facial expressions such  
85 as anger, disgust, fear, sadness, surprise and contempt known as micro expressions are unconsciously displayed  
86 when the person attempts to hide an emotion. These actions are quick (even sometimes not easily noticeable),  
87 intense expressions of concealed emotion, appear and suddenly disappear off the face in a fraction of second. This  
88 theory of micro expressions was discovered first by Haggard and Isaacs in 1966 [13]. These micro expressions  
89 betray the person while lying as the one will be trying to cover his feelings with fake smiles, but involuntary face  
90 muscles reveal the hidden emotions.

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

#### 94 8 f) Statement Analysis

95 This is also known as linguistic text analysis and detecting anomalies and was developed in 1970s [15]. The  
96 method involves studying the language, grammar and syntax of a person's event description. Text analysis

---

97 represents the subject's verbal behavior i.e. usage of words (written and oral statements). Text analysis or  
98 statement analysis is a two-part process according to Susan Adams, senior instructor at FBI Academy [15].

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

## 103 **9 g) Change of Topic**

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

## 108 **10 h) Other General Signs**

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

111 Truthful people frequently use the pronoun 'I' to describe their actions whereas deceptive people are lack of  
112 self references as they describe the events in passive voice. Truthful people use past tense in order to describe  
113 a past event whereas the deceptive people describe the past events using the present tense. A deceptive person  
114 usually tries to avoid answering the question and prefers not to lie. The liar responds with a question and tries to  
115 dodge. By using non-committal verbs such as think, believe, guess, suppose, assume Global Journal of Researches  
116 in Engineering ( ) F Volume XIV Issue V Version I etc., equivocating adjectives and adverbs: sort of, almost,  
117 mainly, perhaps, may be, about etc. and vague statements like you might say, more or less etc. the subject avoids  
118 answering the interrogator. Liars usually try to convince the interrogators that what they say is true by using  
119 mild oaths such as I swear, as God is my witness so that their statements sound more convincing.

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

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

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

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

## 141 **11 III.**

## 142 **12 Lie Detection Technologies**

143 The lie detection methods can be broadly categorized as (i) invasive and (ii) non-invasive from the subject's privacy  
144 view point. The underlying theory of the polygraph is that when people lie they also get measurably nervous  
145 about lying. The heartbeat increases, blood pressure goes up, breathing rhythms change, perspiration increases,  
146 etc. A baseline for these physiological characteristics is established by asking the subject questions whose answers  
147 the investigator knows. Deviation from the baseline for truthfulness is taken as sign of lying. Hence, deliberate  
148 lying produces bodily reactions reflected in blood pressure, breath and heart rates, skin sensitivity (Galvanic  
149 Skin Resistance) etc. A Polygraph ("Lie-Detector") testing instrument simultaneously measures and records  
150 physiological changes caused by the sympathetic nervous system through the couplings to the body of the person  
151 while the subject is asked a series of questions for which he has to answer 'yes' or 'no'. The machine measures  
152 changes in blood pressure, breath rate, and respiration rate. From these a trained expert detects whether  
153 the person is lying. But these can also be caused by many causal factors like nervousness, anger, sadness,  
154 embarrassment, fear and number of medical conditions such as colds, headaches, constipation, or neurological

155 and muscular problems. For many, the phrase "lie detection" brings to mind an image of a polygraph machine  
156 and an intimidating movie-style interrogation. But the method does not have scientific validity as there is no  
157 scientific evidence that polygraph experts can detect lies using their machine at a significantly better rate than  
158 nonexperts using other methods. There is no evidence that the polygraph is really able to detect lies.

159 The method suffers from the problem of countermeasures. The effectiveness or better accuracy of polygraph  
160 test could be guessed if it would have been stealthiest. But since polygraph examination requires the consent  
161 of the person to be examined and nobody can undergo the test without their willingness the method suffers  
162 from having no stealthiness. As heart and breath rates along with blood pressure and electro dermal activity  
163 are important measurement parameters Global Journal of Researches in Engineering ( ) F Volume XIV Issue V  
164 Version I polygraph analysis should necessarily be in a calm and healthy condition. But subject's emotional state  
165 is a serious cause of interference. Though high blood pressure does not affect the accuracy of the Polygraph test,  
166 it is necessary to ensure medical fitness of the subject prior to examination. It usually takes from 2 to 3 hours to  
167 administer a Polygraph test for each individual. The polygraph is an admirable but not impermeable tool.

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

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

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

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

### 188 13 iii. Electroencephalograph (EEG)

189 By means of the electrodes attached to the subject's head this method measures the brain waves and detects  
190 brain processing related patterns while making the subject recognize a scene or a person during the course of  
191 questioning. The perceived trustworthiness interpreted by the individual from looking at the face of the subject  
192 decreases when someone is lying.

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

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

### 205 14 v. Event Related Potentials

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

### 210 15 vi. Brain Fingerprinting

211 In the event of a crime, a lot of physical evidences related to the crime may be unavailable but the sequence of  
212 the events is silently recorded by the subject's brain. This makes a difference between a criminal and an innocent

---

213 person that the criminal has the details of the crime stored in his brain whereas the innocent does not possess  
214 any such record. Brain fingerprinting or uses EEG to determine if the subject is familiar to an image.

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

217 For any reason if the techniques mentioned above do match with the crime scene evidences then even innocent  
218 will be proved guilty. Moreover, all of the above lie detection techniques to some or all extent whether justifiable  
219 or not but, invade the privacy of Global Journal of Researches in Engineering ( ) F Volume XIV Issue V Version  
220 I someone's mind and thus are invasive. Hence, this gave rise to the need for some non-invasive, non-obtrusive  
221 method of lie-detection that takes care of the subject's privacy.

## 222 16 vii. Cognitive Chronometry

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

## 227 17 a. Non-invasive Method

228 Radar Principle: Radio Detection and Ranging (RADAR) is an electromagnetic device used to detect (i.e. to  
229 confirm the presence) and locate (to measure the distance or range) an object (the target). In principle, as  
230 explained in [19], radar transmits a modulated signal aimed at the target and detects the echoed signal. It  
231 consists of a transmitting antenna that radiates the electromagnetic energy, a receiving antenna and a receiver.  
232 A part of the transmitted energy is intercepted by a reflecting object or the target and is reradiated in all  
233 directions. But the fractional energy reradiated in the backward direction toward the radar location is collected  
234 by the receiver via the receiving antenna. The signal returned is processed to extract the desired information  
235 about the target. The range to the target is determined by measuring the two-way propagation time for the  
236 radar signal. For moving objects there exists a relative motion between the radar and the object and hence there  
237 is a shift in the carrier frequency of the returned signal. This shift of frequency is due to the Doppler effect on  
238 the carrier signal that is also a measure of the relative velocity. As reported in [2], the emission limit of medical  
239 UWB radars is 2 to 3 orders of magnitude less than a cell phone and hence talking over a cell phone for more  
240 than 5 minutes is equivalent to UWB monitoring of 10 hours. The power level and electric field intensity of the  
241 UWB radar based stealthy lie detector described in [2] are 7 to 9 order lesser. This explains the safety concern  
242 of UWB radar based heart rate monitoring that it is less dangerous and safer than the cell phones.

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

## 249 18 ? Radar based lie detection

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

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

264 Figure ?? : Schematic of the stealthy vital parameters monitor mounted on the back of a chair [10] As reported  
265 in [2], the subject was asked to sit on a chair and the radar was placed on the back of a implemented to obtain  
266 heartbeat period from an electrocardiograph (ECG) signal and an UWB echo signal. The ECG signal comprising  
267 of P, Q, R waves was passed through a high pass filter and only the R waves were detected in successive beats.  
268 Then the peaks and valleys of the signal were obtained from the UWB echo tracings and the time lag between the  
269 two consecutive valleys was considered as the heart beat period. The heart-cycle period simultaneously estimated  
270 from both ECG and UWB radar are depicted in Fig. 2 and Fig. 3 respectively during five minutes (400 heart  
271 beats) considering the subject in a rest condition. It was seen that both UWB radar and ECG derived HRV

272 signals are equivalent. The heartbeat period for both UWB detected beats and ECG detected was found to be  
273 713 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  
274 for further signal processing. The heartbeat rate, respiration rate provided by the radar can be compared with  
275 those of a normal human being. Discrepancies if any infers about the person lying.

276 IV.

## 277 19 Conclusion

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

280 Radar based technology seems to have tremendous potential for lie detection but still a lot of work has to be  
281 done for trustworthiness. There exists no true and scientific lie detector or can be developed within the present  
282 state of the art, nevertheless HRV detected by means of an UWB based radar seems to be a viable method.

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

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

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

## 293 20 This page is intentionally left blank



Figure 1:

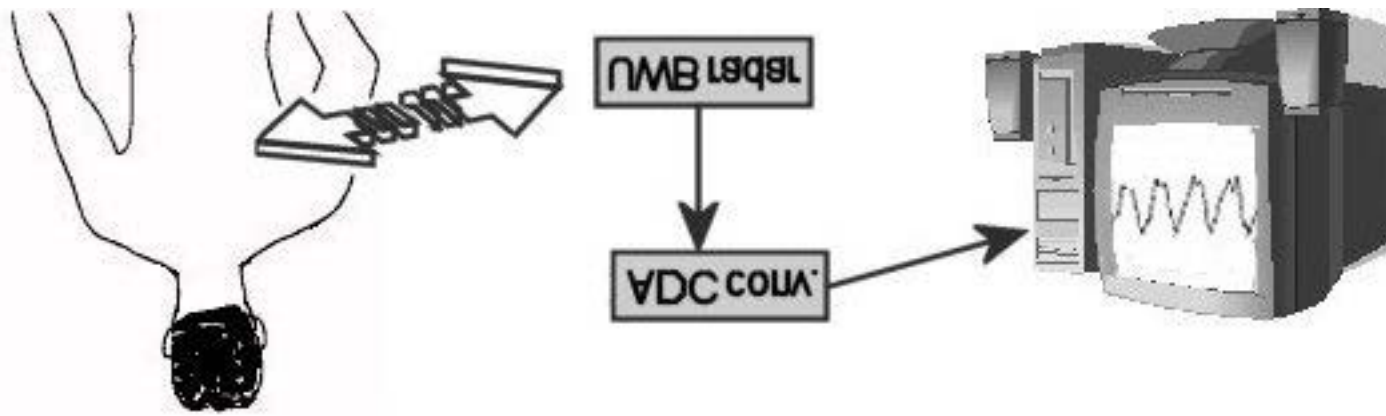


Figure 2: ?

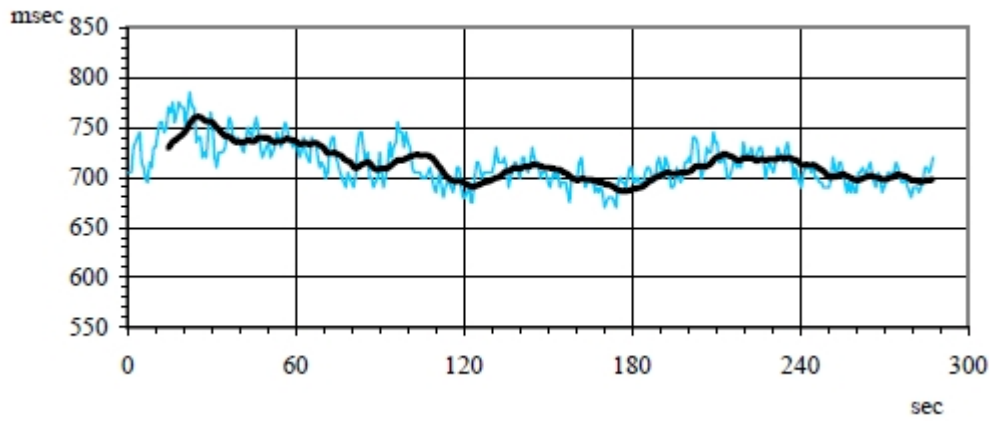
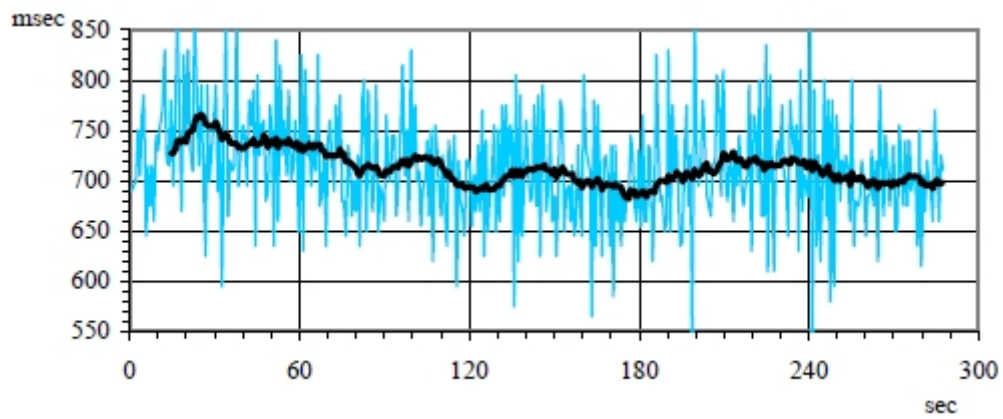


Figure 3:



2

Figure 4: Figure 2 :

XIV Issue V Version I  
( ) F Volume  
I of Researches in Engineering  
Global Journal

Figure 5:

294

1 2 3 4 5 6

---

<sup>1</sup>Year 2014 © 2014 Global Journals Inc. (US) Radar Based Lie Detection Technique

<sup>2</sup>© 2014 Global Journals Inc. (US)

<sup>3</sup>© 2014 Global Journals Inc. (US) in a polygraph procedure, the person undergoing Radar ased Lie Detection Technique B

<sup>4</sup>Radar ased Lie Detection Technique B

<sup>5</sup>Global Journal of Researches in Engineering

<sup>6</sup>© 2014 Global Journals Inc. (US)Radar based Lie Detection Technique

- 
- 295 [Staderini ()] ‘An UWB radar based radar lie detector’. E Staderini . *Ultra-Wideband Short-Pulse Electromag-*  
296 *netics 6*, E L Mokole, M Kragalott, K R Gerlach (ed.) (New York, USA) 2003. Kluwer Academic/Plenum  
297 Publishers. p. .
- 298 [Simpson (1989)] *Courts ready to Accept DNA Profiling as Evidence. Sydney Morning Herald*, L Simpson . 4  
299 March 1989. 3.
- 300 [Lander ()] ‘DNA fingerprinting on trial’. E Lander . *Nature* 1989. 339 p. .
- 301 [Parry and Matthews] *Functional Magnetic Resonance Imaging (f-MRI): A Window into the Brain*, A Parry ,  
302 P M Matthews .
- 303 [How Lying Works by Tom Scheve] <http://people.howstuffworks.com> *How Lying Works by Tom Scheve*,
- 304 [Burleigh et al. ()] ‘Lie detection using thermal imaging, Pav lidis, Loannis T’. Douglas Burleigh , D Cramer ,  
305 K Elliot , G Peacock , Raymond . [http://edition.cnn.com/2011/TECH/innovation/09/13/lie.](http://edition.cnn.com/2011/TECH/innovation/09/13/lie.detector.thermal.imaging18)  
306 [detector.thermal.imaging18](http://edition.cnn.com/2011/TECH/innovation/09/13/lie.detector.thermal.imaging18) *Proceedings of the SPIE*, (the SPIE) 2004. 5405 p. .
- 307 [Haggard and Isaacs ()] ‘Micromomentary facial expressions as indicators of ego mechanisms in psychotherapy’.  
308 E A Haggard , K S Isaacs . *Methods of Research in Psychotherapy*, L A H Gottschalk & A, Auerbach (ed.)  
309 (New York) 1966. Appleton-Century-Crofts. p. .
- 310 [Kasprzak ()] ‘Possibilities of Cheiloscopy’. J Kasprzak . *Forensic Sci Int* 1990. 46 p. .
- 311 [Skolnik Merrill I. Introduction to Radar Systems, 2 nd ed ()] *Skolnik Merrill I. Introduction to Radar Systems,*  
312 *2 nd ed*, 2007. India: Tata McGraw-Hill Publishing Company.
- 313 [Adams (1996)] ‘Statement analysis: What do suspects’ words really reveal?’. Susan H Adams . *FBI Law*  
314 *Enforcement Journal* October 1996.
- 315 [Clikeman ()] ‘The 10 Tell-Tale Signs of Deception’. Paul M Clikeman . *The Words Reveal* 2012. FRAUD  
316 Magazine, Justice Institute of British Columbia
- 317 [Donchin et al. ()] ‘The Endogenous Components of the Event Related Potential-A diagnostic Tool’. E Donchin  
318 , G A Miller , L A Farwell . *Advances in Brain research*, (Amsterdam) 1986. Elsevier. p. 70.
- 319 [Farwell and Donchin ()] ‘The Truth Will Out: Interrogative Polygraphy With Event Related Potentials’. L A  
320 Farwell , E Donchin . *Psychophysiology* 1991. p. .
- 321 [Lambourne ()] ‘The Use of Fingerprints in Identification’. Gtc Lambourne . *Med. Sci Law* 1979. 19 p. .
- 322 [Farwell and Smith ()] ‘Using Brain MERMER Testing to Detect Concealed Knowledge Despite Efforts to  
323 Conceal’. L A Farwell , S S Smith . *Journal of Forensic Sciences* 2001. 46 p. .
- 324 [Staderini (2002)] ‘UWB Radars in Medicine’. E M Staderini . *IEEE Aerospace and Electronic System Magazine*  
325 Jan.2002. 17 (1) p. .