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Using TRIZ Theory to Create Prototypes to Reduce the Potential Impact of a Phone's Magnetic Field on the Human Body

Chao-Jung Lai [1], Ming-Hsien Hsueh [2,*], Cheng-Wen Chang [2,*] and Tsz-Ming Ip [2]

[1] Department of Fashion Design and Management, National Pingtung University of Science and Technology, Pingtung 912301, Taiwan; lcj@mail.npust.edu.tw
[2] Department of Industrial Engineering and Management, National Kaohsiung University of Science and Technology, Kaohsiung 807618, Taiwan; f109143131@nkust.edu.tw
* Correspondence: mhhsueh@nkust.edu.tw (M.-H.H.); maxchang@nkust.edu.tw (C.-W.C.)

Abstract: Currently, people spend many more hours on smartphones, and the potential impact of phone radiation is receiving more attention. Reducing the impact of a phone's magnetic field on human health is vital. Although many studies advise changing phone use habits, such as reducing call times to impede phone radiation, there are no specific products found in the literature to prevent or reduce phone radiation. Therefore, this study used TRIZ theory as a research method to design prototypes in order to reduce the potential impacts of magnetic fields generated by smartphones on the human body. The results show that the distance between the human body and the phone is negatively related to phone radiation; the longer the distance is, the less phone radiation there is. Three prototypes have been designed through this research in order to reduce a phone's radiation. The first testing condition simulates a phone conversation in which the prototypes are installed on the phone while having a WhatsApp conversation. The second testing condition simulates phone standby mode in which the prototypes are installed on a phone while the phone's Wi-Fi, Bluetooth, data, GPS, and hotpot are on. A magnetic field tester was used to measure the magnetic fields every 5 s, and each measurement set lasted for 3 min. Five sets of measurements were completed at the end, and the average result shows that the use of prototypes under these two conditions can reduce 100% and 90% of the magnetic field generated by a smartphone during a phone conversation and the phone's standby mode, respectively.

Keywords: smartphone; phone accessories; TRIZ; Teoriya Resheniya Izobretatelskikh Zadatch; magnetic field

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1. Introduction

The use of mobile phones has grown extensively. However, the use of mobile phones raises a health concern as they emit electromagnetic fields (EMF) during the transmission of data that could potentially affect human health by causing DNA damage [1], human reproductive system damage [2], and inducing brain cancer [3]. Mobile phones communicate by emitting radiofrequency electromagnetic fields from the antennas inside the phone to the base stations nearby [4]. Many studies have figured out how the EMF emitted by phones affects human health, but few of them mention how to prevent it. Apart from changing the habit of using mobile phones [5], not many studies provide practical solutions or physical devices to prevent the EMF emitted by phones. There are some products in the market that claim to prevent the EMF emitted by phones; however, most of them use a shielding method, which does not reduce the harm to human health [6]. Although the ICNIRP international guideline for phone radiation safety has been established, it does not reflect the actual EMF amount that can safely be absorbed by the human body [5]. In addition, a study investigated the effects of the distances between the human head and a mobile phone's antenna on the specific absorption rate (SAR) and found that SAR is decreased when the distance between the user's head and the antenna is increased, showing that increasing the distance between the phone and the human body is one of the most effective ways to prevent the EMF induced by mobile phones [7]. In order to prevent the potential impact of phones' magnetic fields on our health, this research aims to use TRIZ to design prototypes to protect our bodies, especially our brains and reproductive systems. Finally, three prototypes have been created, and the result shows that they effectively reduce the phone's radiation during phone conversations and the phone's standby mode.

2. Materials and Methods

2.1. Prototypes Design Directions and Focuses

Based on the results we found in our literature review, there are 2 feasible means by which to reduce the potential effect of phone radiation on human health that will not affect the functions and the connectivity of the mobile phone. The first one is increasing the distance between the phone and the human body. The antennas inside the phone, which emit and receive the radio signal, are the source of the phone's radiation. Increasing the distance between the source of the radiation when we are using it or when the phone is on standby could reduce the absorption rate of radiation. The second one is using a shielding method to isolate or seal the phone; however, the shielding method will result in difficulty for the phone to establish a connection between the antenna and the base station, and the phone will emit a stronger signal to reconnect and hence create much stronger radiation. These 2 directions found in the literature review will be adopted and practiced in this thesis. Based on the result we found in the literature review, phone radiation can potentially affect human health, especially the reproductive system and brain. It was also found that the EMF generated by phones affects sperm morphometry, sperm head area, and sperm binding to the hemizona [2]. Moreover, the radiation emitted by phones facilitates the development of brain cancer [4]. Holding the phone in direct contact with their ears during conversation or putting the phone in their trouser pocket is potentially dangerous to users. Since these 2 potential effects on human health are vital and irreversible, reducing the potential effect of phone radiation on the head and reproductive system will be the focus of this thesis.

2.2. Experimental Design, Procedures, and Measurement

We assume when listening to phone calls, with the phone being held against an ear, the phone is the closest to our brain, and while putting the phone in a trouser pocket, the phone is the closest to our reproductive system. Based on our above focus, we created prototypes using a distancing method to reduce the phone's radiation during a phone conversation and when in phone standby mode. We used methods and ideas generated by TRIZ theory to design prototypes.

After creating the prototypes based on TRIZ, the prototypes were installed on the phone, and we used the magnetic field tester [8] to measure the magnetic field of the phone on which the 3 prototypes were installed. Three different thicknesses of Prototype 1—10 mm, 15 mm, and 20 mm, respectively—were tested while the phone conversation was on. Four different thicknesses of Prototype 2—5 mm, 10 mm, 15 mm, and 20 mm, respectively—were tested while the Wi-Fi, Bluetooth, GPS, data, and hotspot settings were on. Three different thicknesses of Prototype 3—10 mm, 15 mm, and 20 mm, respectively—were tested while the phone conversation was on. Four different thicknesses of Prototype 3—5 mm, 10 mm, 15 mm, and 20 mm, respectively—were tested while the Wi-Fi, Bluetooth, GPS, data, and hotspot settings were on.

We placed the magnetic field tester on top of the prototypes that were installed on the phone. Then, we measured and recorded the magnetic fields every 5 s, and each trial lasted for 3 min. For each distance, we conducted 5 trials, so in total, there were 180 measurements in each prototype's distance. After the measurement of the magnetic field, we took the average and standard deviation of the measured data as the result. Finally, we verified if the result could reduce the phone's radiation towards the human body.

2.3. Using TRIZ Theory as a Research Method

TRIZ theory is used as a research method to design prototypes. Compared to other optimization and design prototype methods, TRIZ offers a comprehensive and structured approach that combines analytical thinking with creativity. It goes beyond traditional brainstorming techniques by providing a systematic framework for problem-solving and solution generation, making it particularly useful for complex and challenging problems. This study was conducted by changing the engineering parameters to increase the distance between phone and head and phone and reproductive system during phone conversations and phone standby mode, respectively. However, improving one parameter in the prototype might worsen other parameters; thus, 40 inventive principles from TRIZ contradiction matrix will be used to solve possible contradictions.

After creating the initial design using the software Solidworks Vision 2014, we will use the software Kisslicer V1.6 to adjust the in-fill rate of the material and nozzle temperature and export the 3D STL files into G-code files, which a 3D printer can read. Then, we will import the G-code files into 3D printer to print out the prototypes using the material Polylactic Acid (PLA). Different sizes or thicknesses of the prototypes will be made in order to determine the optimum distance that effectively reduces the phone radiation. After all sizes and thicknesses of prototypes have been made, we will install it on phone to measure the magnetic field and determine if it could effectively reduce phone's magnetic field.

Prototype 1 is designed to reduce potential phone radiation effects on our brain during phone conversations by increasing distance between phone and head. Based on the TRIZ contradiction matrix, improving one feature will worsen other features, as shown in Table 1. In order to solve these conflicts, 40 inventive principles from TRIZ contradiction matrix are picked to solve these design conflicts.

Table 1. TRIZ contradiction matrix of Prototype 1.

Improving Feature	Worsening Feature	Solution from Contradiction Matrix
7, Volume of moving object	33, Ease of Operation	1, Segmentation 16, Partial or excessive action 15, Dynamics * 35, Parameter change
14, Strength	15, Durability of moving object	27, Cheap short-living things 3, Local quality * 26, Copying
11, Tension, Stress	12. Shape	34, Discard and recover 10, Preliminary action 15, Dynamics 14, Curvature *
21, Power	27, Reliability	11, Beforehead cushioning 21, Skip/Rush through 31, Porous Materials * 26, Copying
12, Shape	15, Durability of moving object	14, Curvature * 26, Copying 28, Mechanical substitution 25, Self-service

* Solution will be adopted.

Prototype 2 is designed to reduce potential phone radiation effects on our reproductive system during phone standby mode by increasing distance between phone and body. Based on the TRIZ contradiction matrix, improving one feature will worsen other features, as shown in Table 2. In order to solve these conflicts, 40 inventive principles from TRIZ contradiction matrix are picked to solve these design conflicts.

Table 2. TRIZ contradiction matrix of Prototype 2.

Improving Feature	Worsening Feature	Solution from Contradiction Matrix
35, Adaptability	27, Reliability	13, Other way round 35, Parameter change 8, Anti-weight 24, Intermediary *
8, Volume of stationary object	2, Weight of steady object	5, Merging 35, Parameter change 14, Curvature 2, Taking out *
14, Strength	2, Weight of steady object	28, Mechanical Substitution 2, Taking out 10, Preliminary action * 27, Cheap short-living things
11, Tension, Stress	33, Ease of Operation	2, Taking out * 32, Color Change 12, Equipotentiality
12, Shape	4, Length of stationary object	13, Other way round 14, Curvature * 15, Dynamics 7, Nested doll
12, Shape	13, Stability of object	1, Segmentation * 33, Homogeneity 18, Vibration 4, Asymmetry

* Solution will be adopted.

Prototype 3 is a combination of Prototype 1 and Prototype 2, which is designed to reduce potential phone radiation effects on our brain and reproductive system during phone conversations and phone standby mode, respectively, by increasing distance between phone and head and phone and our body, respectively. Based on the TRIZ contradiction matrix, improving one feature will worsen other features, as shown in Table 3. In order to solve these conflicts, 40 inventive principles from TRIZ contradiction matrix are picked to solve these design conflicts.

Table 3. TRIZ contradiction matrix of Prototype 3.

Improving Feature	Worsening Feature	Solution from Contradiction Matrix
7, Volume of moving object	33, Ease of Operation	1, Segmentation 16, Partial or excessive action 15, Dynamics * 35, Parameter change
14, Strength	15, Durability of moving object	27, Cheap short-living things 3, Local quality * 26, Copying
21, Power	27, Reliability	11, Beforehead cushioning 21, Skip/Rush through 31, Porous Materials * 26, Copying

Table 3. *Cont.*

Improving Feature	Worsening Feature	Solution from Contradiction Matrix
12, Shape	15, Durability of moving object	14, Curvature * 26, Copying 28, Mechanical substitution 25, Self-service
35, Adaptability	27, Reliability	13, Other way round 35, Parameter change 8, Anti-weight 24, Intermediary *
8, Volume of stationary object	2, Weight of steady object	5, Merging 35, Parameter change 14, Curvature 2, Taking out *
14, Strength	2, Weight of steady object	28, Mechanical Substitution 2, Taking out 10, Preliminary action * 27, Cheap short-living things
11, Tension, Stress	33, Ease of Operation	2, Taking out * 32, Color Change 12, Equipotentiality
12, Shape	4, Length of stationary object	13, Other way round 14, Curvature * 15, Dynamics 7, Nested doll
12, Shape	13, Stability of object	1, Segmentation * 33, Homogeneity 18, Vibration 4, Asymmetry

* Solution will be adopted.

3. Results and Discussion

3.1. Prototype 1

Figure 1 shows Prototype 1 with a slider cover. In order to increase the distance between the phone and our head during phone conversations while remaining user-friendly when not having a phone conversation, a slider cover is made based on the TRIZ contradiction matrix–Dynamics. Users can slide the slider to 90 degrees, which is perpendicular to the ear speaker, in order to increase the distance during phone conversations. After the phone conversation, users can slide the slider back to 0 degrees, which is located on top of the phone. Figure 2 shows Prototype 1 with a stopper added to the slider cover. In order to prevent the slider cover of Prototype 1 from sliding off while not worsening the durability during a phone conversation, a stopper is added based on the TRIZ contradiction matrix–Local Quality. After adding the stopper, the cover part of the slider can firmly stand at 90 degrees while our ear is in contact with the cover part during a phone conversation.

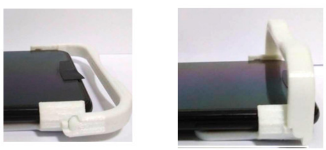

Figure 1. Slider cover of Prototype 1 at 0 and 90 degrees.

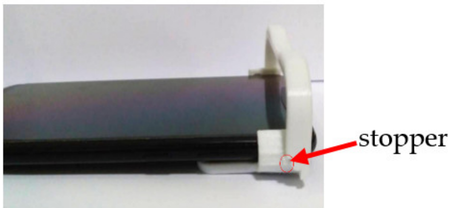

Figure 2. Stopper is added to the slider cover of Prototype 1.

Figure 3 is a curve design made for the bottom part of Prototype 1. In order to increase the stress to grip the phone tightly while not blocking the rear camera, a curve design of the bottom part is made based on the TRIZ contradiction matrix—Curvature. The shape of the bottom part is curved, and it surrounds the outer area of the rear camera such that it is not blocking the rear camera.

Figure 3. Curve design made for the bottom part of Prototype 1.

Figure 4 presents the small holes in the slider cover. In order to enhance the clarity of the ear speaker during phone conversations while also not worsening the reliability, small holes are added in the slider cover based on the TRIZ contradiction matrix—Porous materials. Several holes are added to the slider cover, which is perpendicular to the ear speaker, so that the sound can pass through these small holes and enhance the clarity of the speaker. Figure 5 shows the curve of the slider cover. In order to improve the shape of the slider cover so that it fits the ear's shape while not worsening the durability, the curve shape of the slider cover is made based on the TRIZ contradiction matrix—Curvature. During a phone conversation, when a user's ear is in contact with the slider cover, a curve-shaped slider cover fits the shape of the ear and increases the user's comfort during the phone conversation.

Figure 4. Small holes added to the slider cover.

Figure 5. Slider cover with a curved shape that fits the ear shape.

3.2. Prototype 2

Figure 6 is Prototype 2, made as an intermediary. In order to improve the adaptability of Prototype 2 while keeping the distance between the human body and the phone, a phone case design is made as an intermediary based on the TRIZ contradiction matrix—Intermediary. It helps to isolate the phone from the human body and adapt to different uses, such as placing the phone in a trouser pocket or for general use.

Figure 6. Prototype 2 is designed as a phone case and intermediary.

Figure 7 shows Prototype 2 with a hollow design. In order to increase the distance between the phone and the human body without increasing the weight too much, a hollow design is made based on the TRIZ contradiction matrix—Taking out. Using a hollow design removes unnecessary material and increases the volume of Prototype 2 without increasing the weight. In order to improve the strength of Prototype 2 without increasing the weight too much, a high in-fill rate and hard plastic material are used based on the TRIZ contradiction matrix—Preliminary action. Using a high in-fill rate during 3D printing and using PLA as a hard plastic material improves the strength of Prototype 2 so that it will not break easily. To increase the stress to grip the phone firmly while not affecting user-friendliness when holding or using the phone, the bottom grips are removed based on the TRIZ contradiction matrix—Taking out. Since grips protrude from the phone's edges, and users usually hold the bottom part of the phone, removing the bottom grips can increase the user-friendliness of holding the phone.

Figure 7. Prototype 2 is designed with a hollow design and with the bottom grips removed.

Figure 8 shows the curved handle of Prototype 2. In order to improve the shape for users to hold the phone easily while not reducing the thickness of Prototype 2, a curved handle is made based on the TRIZ contradiction matrix—Curvature. A curved handle is designed ergonomically so that it fits the size and shape of hands such that users can hold the phone easily. Figure 9 shows the segmenting of the grips in Prototype 2. In order to improve the shape of the grips so that the power button and the volume button of the phone will not be covered while also maintaining the stability of Prototype 2, a design of segmented grips is made based on the TRIZ contradiction matrix—Segmentation. By segmenting the grips according to the phone button locations, the power button and volume button of the phone will not be covered.

Figure 8. Curved handle of Prototype 2.

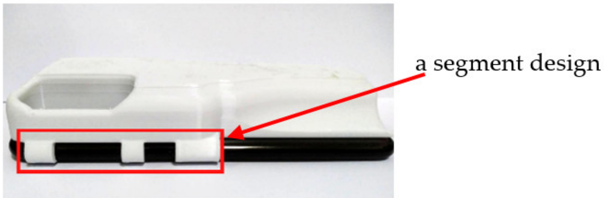

Figure 9. Segmented grips of Prototype 2.

3.3. Prototype 3

Figure 10 shows Prototype 3, which is an amalgamation of the designs of Prototypes 1 and 2. Figure 11 presents the slider cover of Prototype 3. In order to increase the distance between the phone and our head during phone conversations while remaining user-friendly when not having a phone conversation, a slider cover is made based on the TRIZ contradiction matrix—Dynamics. Users can slide the slider to 90 degrees, which is perpendicular to the ear speaker, in order to increase the distance during a phone conversation. After the phone conversation, users can slide the slider back to 0 degrees, which is located on top of the phone.

Figure 10. The back and front view of Prototype 2.

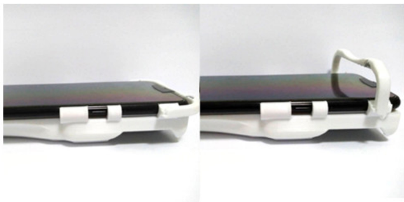

Figure 11. Slider cover of Prototype 3 at 0 and 90 degrees.

Figure 12 shows the stopper added to the slider cover of Prototype 3. In order to prevent the slider cover of Prototype 3 from sliding off while also not worsening the durability during phone conversations, a stopper is added based on the TRIZ contradiction matrix—Local Quality. After adding the stopper, the cover part of the slider can firmly stand at 90 degrees while our ear is in contact with the cover part during phone conversations. Figure 13 presents the small holes added to the slider cover of the prototype. In order to enhance the clarity of the ear speaker during phone conversations while also not worsening the reliability, small holes are added in the slider cover based on the TRIZ contradiction matrix—Porous materials. Several holes are added to the slider cover, which is perpendicular to the ear speaker, so that the sound can pass through these small holes and enhance the clarity of the speaker.

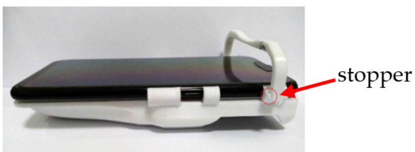

Figure 12. Stopper is added to the slider cover of Prototype 3.

Figure 13. Small holes are added in Prototype 3.

Figure 14 shows the curve shape of the slider cover in Prototype 3. In order to improve the shape of the slider cover so that it fits the ear's shape while not worsening the durability, the curve shape of the slider cover is made based on the TRIZ contradiction matrix—Curvature. During phone conversations, when the user's ear is in contact with the slider cover, a curve-shaped slider cover fits the shape of the ears and increases the user's comfort during phone conversations. Figure 15 presents the phone case design made as an intermediary. In order to improve the adaptability of Prototype 3 while keeping the distance between the human body and the phone, a phone case design is made as an intermediary based on the TRIZ contradiction matrix—Intermediary. It helps to isolate the phone from the human body and adapt to different uses, such as placing the phone in a trouser pocket or for general use.

Figure 14. Curve-shaped slider cover of Prototype 3.

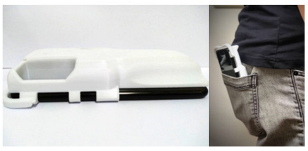

Figure 15. The phone case design made as an intermediary.

Figure 16 shows the hollow design of Prototype 3. In order to increase the distance between the phone and the human body without increasing the weight too much, a hollow design is made based on the TRIZ contradiction matrix—Taking out. Using a hollow design removes unnecessary material and increases the volume of Prototype 3 without increasing the weight. In order to improve the strength of Prototype 3 without increasing the weight too much, a high in-fill rate and hard plastic material are used based on the TRIZ contradiction matrix—Preliminary action. Using a high in-fill rate during 3D printing and using PLA as a hard plastic material improves the strength of Prototype 3 so that it will not break easily. Figure 17 presents the bottom grips removed in Prototype 3. To increase the stress to grip the phone firmly while not affecting user-friendliness when holding or using the phone, the bottom grips are removed based on the TRIZ contradiction matrix—Taking out. Since grips protrude from the phone's edges, and users usually hold the bottom part of the phone, removing the bottom grips can increase the user-friendliness of holding the phone.

Figure 16. Hollow design of Prototype 3.

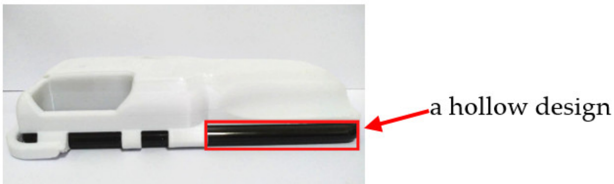

Figure 17. Bottom grips removed in Prototype 3.

Figure 18 shows the curved handle made in Prototype 3. In order to improve the shape for users to hold the phone easily while not reducing the thickness of Prototype 3, a curved handle is made based on the TRIZ contradiction matrix—Curvature. A curved handle is designed ergonomically so that it fits the size and shape of hands such that users can hold the phone easily. Figure 19 presents the segmenting of the grips designed in Prototype 3. In order to improve the shape of the grips so that the power button and the volume button of the phone will not be covered while also maintaining the stability of Prototype 3, a design of segmented grips is made based on the TRIZ contradiction matrix—Segmentation. By segmenting the grips according to the phone button locations, the power button and volume button of the phone will not be covered.

Figure 18. Curved handle of Prototype 3.

Figure 19. Segmenting the grips in Prototype 3.

3.4. Prototypes' Effectiveness in Reducing a Phone's Magnetic Field

In order to determine the optimum distance that reduces phone radiation during phone conversations and phone standby mode, respectively, we will prepare three to four thicknesses or distances for the above three designs, respectively. After that, we will measure the phone radiation before and after using the prototypes during phone conversations and phone standby mode, respectively. Finally, we will input the radiation measured into the below equation to determine the three prototypes' effectiveness in reducing the phone's magnetic field.

Equation of effectiveness in reducing a phone's magnetic field:

$$\mathrm{RDi\%} = \frac{\mathrm{X_i} - \mathrm{Y_i}}{\mathrm{X_i}} \times 100\% \quad (1)$$

where X_i is the magnetic field measured without the use of the prototypes, Y_i is the magnetic field measured with the use of prototypes, RDi% is the percentage of the phone's radiation that has been reduced, and *i* is the prototype case. Figure 20 shows the experiment of measuring phone radiation when the prototype is installed on the phone under four conditions. RD1 presents the phone with the Prototype 1 case during an in-app phone conversation. RD2 presents the phone with the Prototype 2 case while Wi-Fi, data, GPS, Bluetooth, and Hotspot are on. RD3 presents the phone with the Prototype 3 case during an in-app phone conversation. RD4 presents the phone with the Prototype 3 case while Wi-Fi, data, GPS, Bluetooth, and Hotspot are on. Tables 1–4 show the percentage of the phone radiation reduced after using RD1 to RD4, respectively.

Figure 20. Experiment with measuring phone radiation when the phone is used with RD1 to RD4.

Table 4. Percentage of phone radiation reduced (RD1) after using Prototype 1 during an in-app phone conversation.

Cover Size	Magnetic Field (μT)—Without Use of Prototype 1 (X1)		Magnetic Field (μT)—Installed with Prototype 1 (Y1)		RD1% of Phone (%)
	Mean	Standard Deviation	Mean	Standard Deviation	
5 mm	0.66	0.12	N/A	N/A	N/A
10 mm			0	0	100%
15 mm			0	0	100%
20 mm			0	0	100%

In RD1 of Figure 20, the phone with Prototype 1 installed is measured during an in-app phone conversation while Wi-Fi is on. In RD2 of Figure 20, the phone with Prototype 2 installed is measured while Wi-Fi, data, GPS, Bluetooth, and Hotspot are on. In RD3 of Figure 20, the phone with Prototype 3 installed is measured during an in-app phone conversation while Wi-Fi is on. In RD4 of Figure 20, the phone with Prototype 3 installed is measured while Wi-Fi, data, GPS, Bluetooth, and Hotspot are on. As per the result shown, phone radiation is negatively related to distance. An increase in the distance away from the phone will lead to a decrease in magnetic field. This occurs in the results of Prototype 1, Prototype 2, and Prototype 3 and without installing any prototypes. The percentage of the phone's radiation is more reduced when the distance away from the phone is short, while the percentage of the phone's radiation is less reduced when the distance away from the phone increases. Let us take Table 5 as an example: using a 5 mm thick phone case reduces phone radiation by 57%, using a 10 mm thick phone case reduces phone radiation by 91%, using a 5 mm thick phone case reduces phone radiation by 57%, using a 15 mm thick phone case reduces phone radiation by 94%, and using a 20 mm thick phone case reduces phone radiation by 97%. To conclude, phone radiation is negatively related to the distance away from the phone, and it is more reduced when the distance away from the phone is short.

Table 5. Percentage of phone radiation reduced (RD2) after using Prototype 2 while Wi-Fi, data, GPS, Bluetooth, and Hotspot are on.

Cover Size	Magnetic Field (μT)—Without Use of Prototype 2 (X2)		Magnetic Field (μT)—Installed with Prototype 2 (Y2)		RD2% of Phone (%)
	Mean	Standard Deviation	Mean	Standard Deviation	
5 mm	3.04	0.033	1.31	0.24	57%
10 mm			0.29	0.03	91%
15 mm			0.17	0.01	94%
20 mm			0.08	0.01	97%

The results of the Prototype 1 cover (Table 4) and Prototype 3 cover (Table 6) show that distances of 10 mm, 15 mm, and 20 mm away from the phone during in-app phone conversations can effectively reduce phone radiation to 0 μT. It can be concluded that the minimum distance away from the phone is 10 mm, and both Prototype 1 (10 mm cover) and Prototype 3 (10 mm cover) are effective in preventing phone radiation during phone conversations. The results of using the Prototype 2 case (Table 5) and Prototype 3 case (Table 7) show that phone radiation is negatively related to distance away from the phone. The thicker the phone case is, the less phone radiation is measured. Both results show that the highest phone radiation is measured when using a 5 mm thick phone case. The phone radiation measured gradually decreases when using a 10 mm thick phone case and a 15 mm thick phone case. The phone radiation reaches its lowest when a 20 mm thick phone case is used. In conclusion, in order to prevent 90% of phone radiation during phone standby when Wi-Fi, data, GPS, Bluetooth, and Hotspot are on, the minimum thickness of the phone case should be 10 mm. Using the 10 mm thick Prototype 2 and 10 mm thick Prototype 3 can both effectively prevent 91% and 90% of phone radiation, respectively. Both the Prototype 2 case and Prototype 3 case are made of the same material and thickness with the same experiment setting, but we can see the discrepancy of phone radiation measured between the 5 mm thick Prototype 2 case and Prototype 3 case is the highest. This is due to the magnetic field measured fluctuating over time. With the higher level of magnetic field at a distance of 5 mm away from the phone, the higher the standard deviation is and, as a consequence, the higher the discrepancy in phone radiation. The discrepancy of phone radiation measured between the 10 mm thick Prototype 2 case and Prototype 3 case is gradually reduced to 0.1 μT. This is because the level of the magnetic field at a distance of 10 mm away from the phone decreases and, as a consequence, the smaller the discrepancy in phone radiation. The discrepancy in phone radiation measured between 15 mm and 20 mm thick Prototype 2 case and Prototype 3 case becomes 0 μT. The reason is that the level of the magnetic field at distances of 15 mm and 20 mm away from a phone is low or close to negligible, and there is no discrepancy in phone radiation as a consequence.

Regarding Prototype 1, the purpose of it is to reduce the potential impact of phone radiation on the brain. The result in Table 4 shows that using Prototype 1 with a 10 mm cover, 15 mm cover, and 20 mm cover during an in-app phone conversation can effectively reduce phone radiation by 100%. Since the minimum preventive distance away from the phone is 10 mm, considering the factor of user-friendliness with less weight and smaller in size, Prototype 1 with a 10 mm cover is optimal and preferable. Regarding Prototype 2, if the goal is to prevent at least 90% phone radiation while the phone is on standby in the user's trousers pocket, considering the factor of user-friendliness with less weight and smaller in size, a 10 mm thick Prototype 2 case is optimal and preferable. Considering that the users are super concerned about the prevention of phone radiation and the goal is to prevent as much radiation as possible, a 20 mm thick Prototype 2 is preferable. Regarding Prototype 3's cover part, since the purpose of it is to reduce the potential impact of phone radiation on the brain, the result in Table 6 shows that using Prototype 3 with a 10 mm cover, 15 mm cover, and 20 mm cover during in-app phone conversations can effectively reduce the phone radiation by 100%. Since the minimum preventive distance away from the phone is 10 mm, considering the factor of user-friendliness with less weight and smaller size, Prototype 3 with a 10 mm cover is optimal and preferable. Regarding Prototype 3's bottom part, if the goal is to prevent at least 90% of phone radiation while the phone is on standby in the user's trousers pocket, considering the factor of user-friendliness with less weight and smaller size, the 10 mm thick Prototype 3 case is optimal and preferable. However, if the users are super concerned about the prevention of phone radiation and the goal is to prevent as much radiation as possible, the 20 mm thick Prototype 3 case is preferable.

Table 6. Percentage of phone radiation reduced (RD3) after installing Prototype 3 during an in-app phone conversation.

Cover Size	Magnetic Field (μT)—Without Use of Prototype 3 (X3)		Magnetic Field (μT)—Installed with Prototype 3 (Y3)		RD3% of Phone (%)
	Mean	Standard Deviation	Mean	Standard Deviation	
5 mm	0.66	0.096	N/A	N/A	N/A
10 mm			0	0	100%
15 mm			0	0	100%
20 mm			0	0	100%

Table 7. Percentage of phone radiation reduced (RD4) after installing with Prototype 3 while Wi-Fi, data, GPS, Bluetooth, and Hotspot are on.

Cover Size	Magnetic Field (μT)—Without Use of Prototype 3 (X4)		Magnetic Field (μT)—Installed with Prototype 3 (Y4)		RD4% of Phone (%)
	Mean	Standard Deviation	Mean	Standard Deviation	
5 mm	3.06	0.031	1.47	0.03	52%
10 mm			0.3	0.03	90%
15 mm			0.17	0.01	94%
20 mm			0.08	0.01	97%

3.5. Other Discussions

Using the above prototypes to increase distance during phone conversations will affect other factors, such as convenience and sound clarity. The use of the phone becomes less convenient, and the sound clarity becomes less clear. However, a trade-off must be made as there are no perfect products that can fulfill all aspects. The prototypes created are mainly for staying away from the radiation of the phones, which, in turn, lowers the convenience and sound clarity.

Overall, the obtained results are consistent in that distancing is an effective method to reduce the magnetic field while using phones. The result shows that it can reduce 100% and 90% of the magnetic fields generated by a smartphone during phone conversations and the phone's standby mode, respectively.

3.6. Limitations

The magnetic field tester measures the EMF emitted by a phone and is limited to a fixed range of frequency; the EMF, which is out of the range of frequency, cannot be measured. Moreover, the mobile phone we used in measuring the emittance of EMF is a Samsung A40S, and the result may be different when testing other mobile phone models. Furthermore, the distance between the base stations and the phone affects the EMF emitted by the phone; this is another factor that could vary the experiment's results, which we cannot control. Finally, some of the applications of mobile phones will automatically update or run in the background during the experiment, and this could vary the experiment's results.

4. Conclusions

This study uses TRIZ theory to develop prototypes to reduce the potential impacts of phone radiation on the human body. By adopting the concept of increasing distance between the phone and the human body into TRIZ theory to create prototypes that reduce the potential impacts of phone radiation on human brains and reproductive systems. According to the results mentioned, we can conclude the following:

1. Distance between the human body and the phone is negatively related to phone radiation. The further the distance away from the phone, the less phone radiation the body receives;
2. Prototypes designed through TRIZ to increase the distance between the phone and the human body could effectively reduce phone radiation towards the human body;
3. Using Prototype 1's cover size of 10 mm or above could reduce the phone's magnetic field by 100% during phone conversations;
4. Using Prototype 2's 10 mm or above thickness could reduce the phone's magnetic field by 90% or more during the phone standby mode;
5. Using Prototype 3's cover size of 10 mm or above and 10 mm or above the thickness of Prototype 3's case could reduce the phone's magnetic field by 100% and 90% or more during phone conversations and phone standby mode, respectively.

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