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Evaluating android smartphone's bluetooth received signal strength indicator measurements for social distancing

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ABSTRACT

This paper presents a digital solution to reduce transmission of coronavirus disease 2019 (COVID-19) by maintaining social distance between the general public. The object is achieved by using bluetooth, which is already handy for almost everyone in the general public and comes as a standard feature in smartphones. The present technique uses an indirect method to calculate the range between the two objects. 5,300 samples were collected by adjusting the receiver at a range of angles to calculate the intensity of the bluetooth signal. The observations are presented in the form of plotted graphs between the number of samples and the average received signal strength indicator (RSSI) value at a particular angle of rotation.

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1. INTRODUCTION

The present pandemic caused by the coronavirus disease 2019 (COVID-19) has impacted hard on our lives at all levels (health, social, and economy) [1]. This has changed our lifestyle heavily [2]. The pandemic has forced us to apply several protective measures in our general life [3]. Out of these measures, a basic one is keeping the safe distance between individuals and wearing a facial mask [4], [5]. These protective measures have proved to be extremely effective [6]. Social distancing refers to a non-pharmaceutical measure to reduce the rate of recurrence of infection which normally spreads due to physical contact between the individuals [7], [8]. Various measures have been suggested by medical experts to reduce the infection rates. These suggested measures include [9]: i) avoid public gatherings, ii) washing of hands again and again for at least 20 seconds, iii) use of sensitizer, iv) isolation of infected individuals, v) quarantine after travel, and vi) social distancing.

Social distancing has played an effective role to control the pandemic. The methods to control can be classified under the general public and individual measures [10]. Public measures include closing down or reducing the access of students and staff to educational organizations and offices [11]. This helps to prevent mass gatherings, enforce travel limitations, implement strict border control, and quarantine buildings. Whereas, individual measures consist of isolation, quarantine, and encouragement to keep physical distance between individuals [12]. Though these measures cause some undesirable effects on the economy and individual freedom yet they play a crucial role in reducing the severity of the pandemic [13]. Figure 1 depicts a comparison of disease spread due to start-up of social distance by a difference of one day. Which advises how social distancing measures can lower the total number of infection cases. Application of social distancing by a difference of one day can reduce the overall cases by around 40% [14].

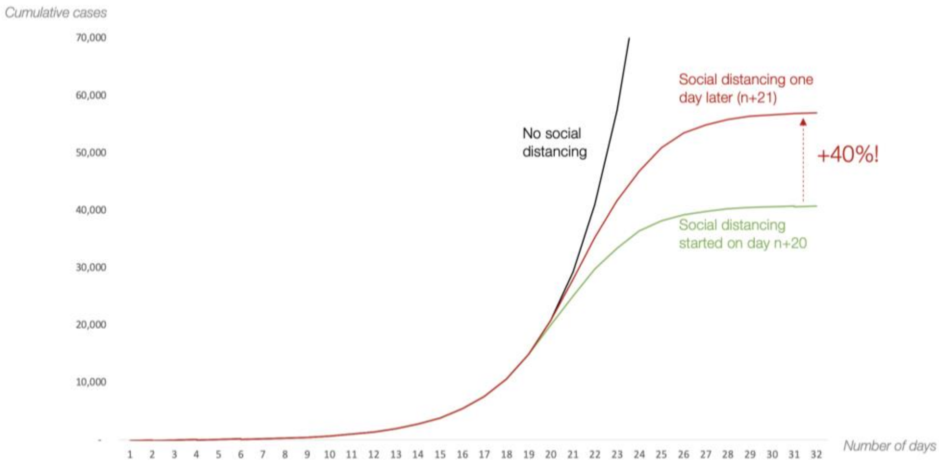

Figure 1. The effectiveness of social distancing for reducing the overall cases

Therefore, the best defense remains by keeping a safe distance between individuals [15]. To maintain this safe distance technologies can help to cater for reducing infected cases. This can be achieved by designing an alerting mechanism to check for the failure to keep the social distance. The alarm would blow a whistle to raise alert to limit the physical contacts hence preventing the spread of disease [16]. There stands a dire need for the technology to satisfy at least three principles that would encourage individuals to get trained to use it so that the practices of social distancing become easy. The basic benefits are i) no cost, ii) privacy protection, and iii) access by anyone. Having these three advantages in mind the bluetooth classic and bluetooth low energy (BLE) transceivers stand as the right choice for the purpose. Since bluetooth is available in all smartphones therefore it remains anonymous while working at low power consumption.

2. BLUETOOTH FOR SOCIAL DISTANCING

Bluetooth is a short-range wireless communication that operates in the frequency range from 2.4 to 2.485 GHz. Bluetooth is managed by bluetooth special interest group (bluetooth SIG) which has more than 35,000 member companies in various areas. In January 2019 bluetooth 5.1 was presented by bluetooth SIG which came with major improvement especially in locating and tracking services. Whereas, bluetooth low energy (BLE) has been designed to operate at very low power consumption [17]. The bluetooth technology features have been wildly used even more after the appearance of the pandemic [18]. By making use of the received signal strength indicator (RSSI) of the bluetooth, the distance can be estimated [19]. Figure 2 shows how the bluetooth RSSI values can be used to estimate the distance and warn when getting to a certain RSSI value. Bluetooth RSSI measurements are sensitive to the device orientation [20].

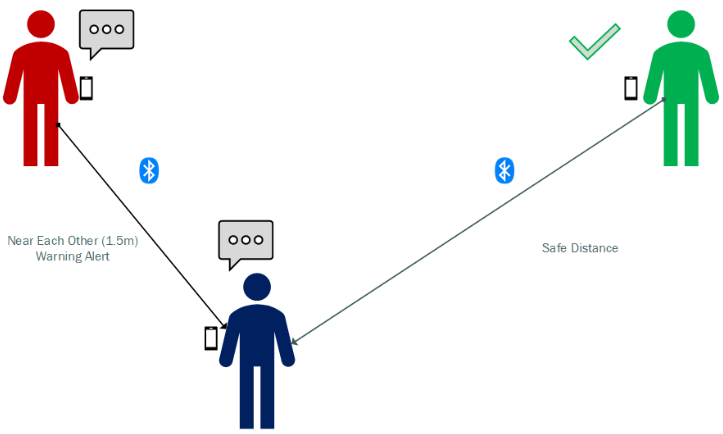

Figure 2. Bluetooth application using the RSSI to estimate the distance

3. BACKGROUND

Tiwari *et al*. [21] presented a non-smartphone approach. They used ST-BlueNRG-2 based device which enabled a social distancing solution. Whereas ST-BlueNRG-2 is a very low power, bluetooth low energy (BLE) single-mode system-on-chip [10], this device alerts the users if they get too close (2 m) to other devices. This is achieved using the received signal strength indicator (RSSI) technique. The RSSI value may vary a lot depending upon multi-path reflections. Therefore, electronic filtering has been essential in order to reduce the variation (noise) in the RSSI. Figure 3 shows the process from initializing to alerting [21].

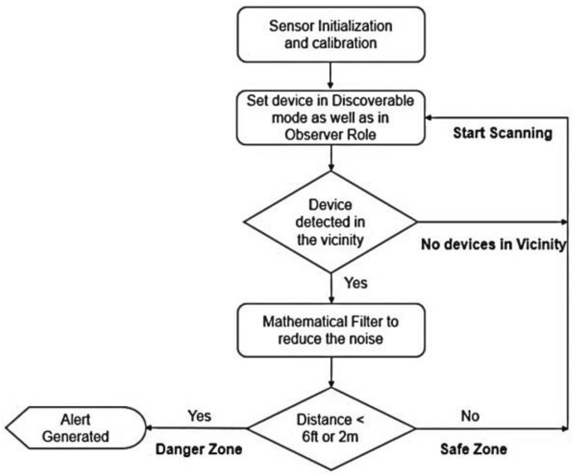

Figure 3. Application flowchart used

To reduce the noise first, assigned a positive weightage β (0.6 to 0.7 showed the minimal noise in experimental performance) to the received value of the RSSI and 1-β to the next RSSI value represented by (1).

$$Filtered\ RSSI = (1 - \beta) \times X + \beta \times Y \quad (1)$$

Where X and Y are RSSI measured experimentally from same beacon.

Filtered RSSI value coming from is compared and replaced with current value, which acts as feedback and an input to moving average filter. Finally pass the signal to a moving average filter with estimated value as an average to reduce the noise further more. Noise-reduced RSSI is used (2) to calculate the distance [21], [22].

$$Distance = 10^{(Measured\ Power - RSSI)/(10 \times N)} \quad (2)$$

Where measured power is a factory-calibrated. N is constant factor which depends on the environmental factor. Normally, N is defined between 2 to 4.

Kumar *et al*. [23] developed an android application social distancing alert system (SDAS), that detects and calculate the distance between other phone running the same application nearby. It calculates the distance by comparing the received RSSI value with a reference RSSI values which corresponds to the distance. The application will give an alert when two objects get near to each other (i.e., less than 2 m). Table 1 and Figure 4 shows the bounds used in the application developed by [23]. We can request a copy of SDAS application from the developers in this page, we can scan this QR code in Figure 5 and request a copy [23].

Table 1. Bounds used in SDAS application

Signal strength	Displayed status
27 dBm and lower	Safe
Between 28 dBm and 37 dBm	Caution
Between 38 dBm and 52 dBm	Warning
53 dBm and higher	Danger

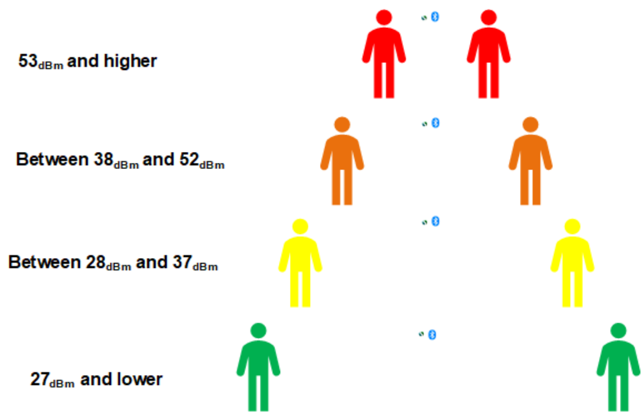

Figure 4. Illustration of the signal strength bounds in the SDAS application

Figure 5. QR code for the android application generated by Google Chrome

In both examples, it was required to either use the same device or the same application which will affect the solution for acceptance with the masses. Therefore, the ideal solution should not require both individuals to have special devices or applications to work. Only the person who wants to practice social distancing should use the application or device. The smartphone can play a major part in this solution but, there are challenges to this approach such as the orientation of the device and multi-path of the signal.

4. THE EXPERIMENT

An effort was made to evaluate the effect of orientation of the device concerning the RSSI values. This helps to learn how the signal gets better while using this technology for social distancing. Therefore, a setup was made in the laboratory, a solid object (Obj1) was placed at a height of 0.5 m above the ground. Obj1 was able to rotate at 360°, to record the sample readings with more accuracy and control. Another object (Obj2) was placed at a distance of 1.5 m away from Obj1. Obj2 was maintained at the same height (0.5 m) above the ground. A smartphone (A) (SM-G970F) having its bluetooth feature 'ON' was attached to Obj1. Another smartphone (B) (SM-N981B) also having its bluetooth feature 'ON' was attached to Obj2 which was 1.5 m away from the smartphone A. Smartphone B recorded the RSSI values being received due to smartphone A. The RSSI was recorded by using an android application called "BLE scanner" [24]. More than 600 samples of RSSI values per angle were collected before obj1 was rotated by an angle of 45° clockwise. Obj1 was rotated through a step angle of 45° (i.e., 0°, 45°, 90°, 135°, …, and 315°) (360° = 0°). Figure 6 illustrates the experimental setup used for collecting observations.

After collection of RSSI value at a particular angle, there arose a need to save the file on the computer as the storage on the smartphone would overwrite the file recorded earlier. Some software was required to smooth up the process of data transfer from the smartphone to PC. "*Resilio Sync*" [25] was used to synchronize the data between the smartphone and PC, this made the analyzing process smoother and faster.

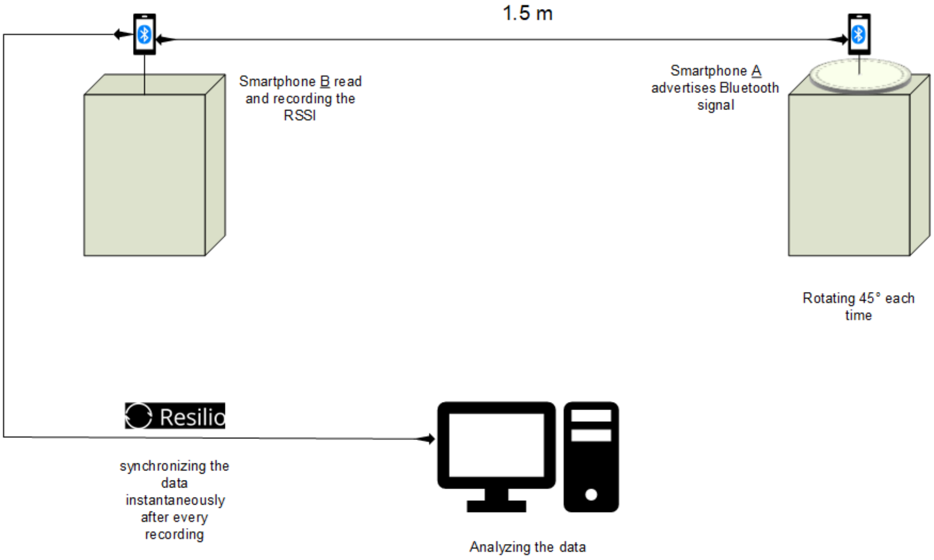

Figure 6. Illustration of the experimental setup that used to collect the observations

5. RESULTS AND DISCUSSION

A total of 5300 sample readings were recorded at a fixed distance of 1.5 m and a range of rotation angles, represented by (3).

$$Avrg.RSSI(\theta) = \frac{\sum_{k=1}^{\alpha} rssi\ \theta(k)}{\alpha} \quad (3)$$

Where Avrg. RSSI(θ) is the average value at θ, $rssi\ \theta$ is recorded value of rssi at θ and α is the number of records.

Out of these observations, 622 samples of RSSI values were recorded at a reference of 0°, this contributed to an average value of -62.62 dBm. 678 samples of RSSI values were recorded at the angle of 45°, the average value for this step appeared to be -64.96 dBm. An average of -64.59 dBm was calculated with the help of 605 recorded samples of the RSSI values at a rotated angle of 90°. At a rotated angle of 135°, 784 samples of RSSI had been collected which gave rise to an average signal value of -67.45 dBm. Whereas at an angle of 180° the average value of RSSI remained at -66.24 dBm, this was based on 703 samples readings. An average value of -65.44 dBm was obtained for a rotation of 225°, and this was based on 618 samples of RSSI values. At 270° samples of 657 were collected and contributed to an average of -65.91 dBm. Finally, the RSSI averaged with -66.88 dBm and was due to samples of 634 were observed at 315°. This variation is due to the sensitivity to the orientation of the device, so if we want to use the RSSI for social distancing with the three principles in mind (no cost, privacy protection, and access by anyone). We need to have a value of the RSSI that responded to the distance desired (1.5 m). After collecting the samples of the RSSI value and analyzing them.

The grand average (GV) is -65.51 dBm which can give an estimation of the distance so we can use it as a reference to any application to alert the user, represented by (4).

$$Avrg.RSSI = \frac{\sum_{k=1}^{\alpha_1} rssi\ \theta_1(k) + \sum_{k=1}^{\alpha_2} rssi\ \theta_2(k) + \cdots + \sum_{k=1}^{\alpha_n} rssi\ \theta_n(k)}{\alpha_1 + \alpha_2 + \cdots + \alpha_n} \quad (4)$$

Where $Avrg.RSSI$ is the grand average, θ_n is the rotated angle in degree, and α_n is the number of recorded samples for each angle (θ). Figures 7-14 are set of scatter charts for all the angles studied in this experiment that illustrate the effect of the orientation of the device starting from 0° to 315°, (360°=0°).

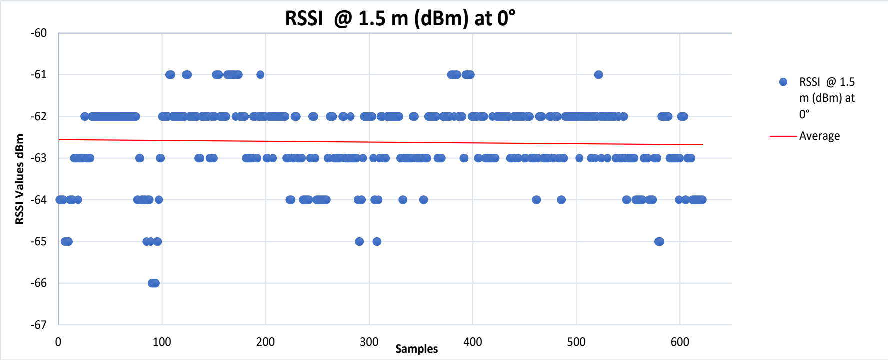

Figure 7. The RSSI values at rotation of 0°

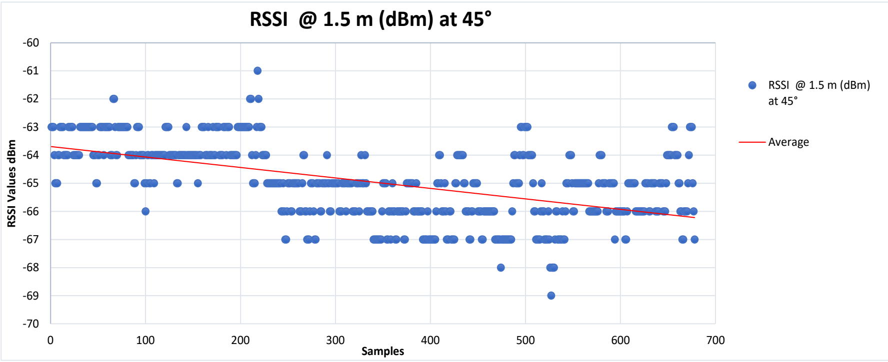

Figure 8. The RSSI value at rotation of 45°

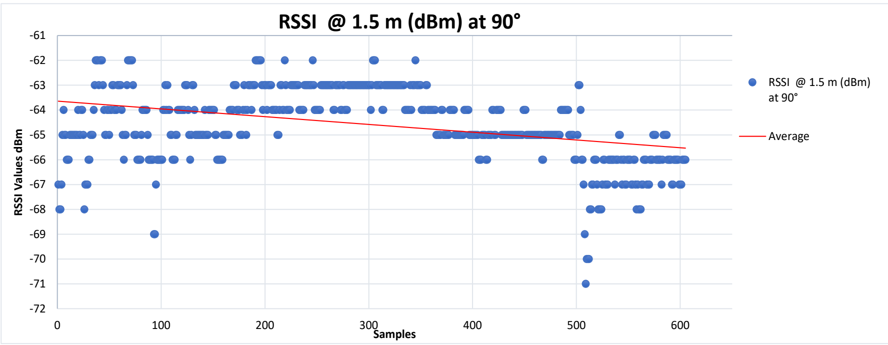

Figure 9. The RSSI values at the rotation of 90°

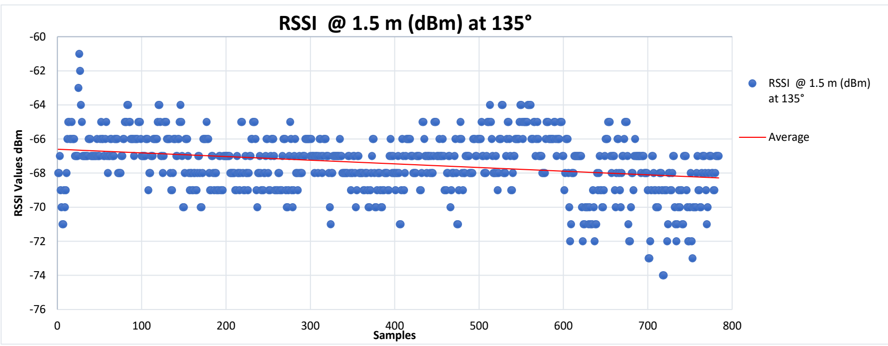

Figure 10 The RSSI values at the rotation of 135°

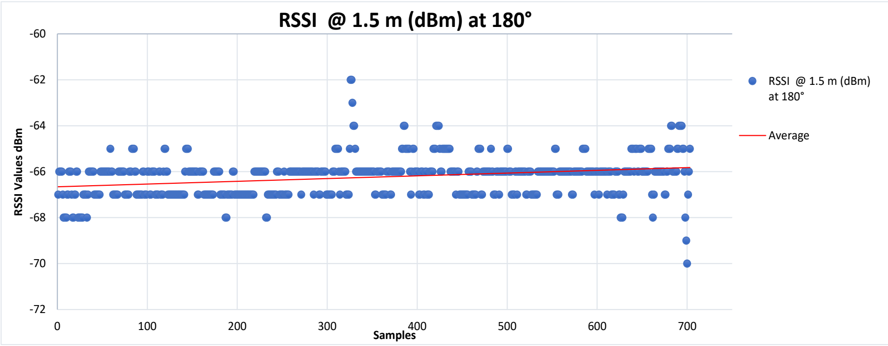

Figure 11. The RSSI values at the rotation of 180°

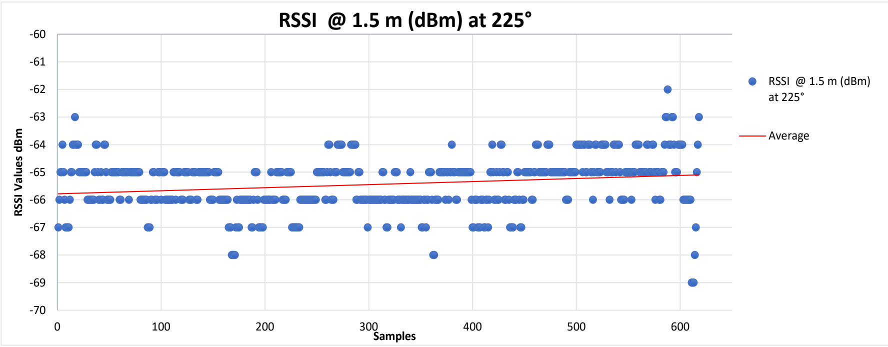

Figure 12. The RSSI values at the rotation of 225°

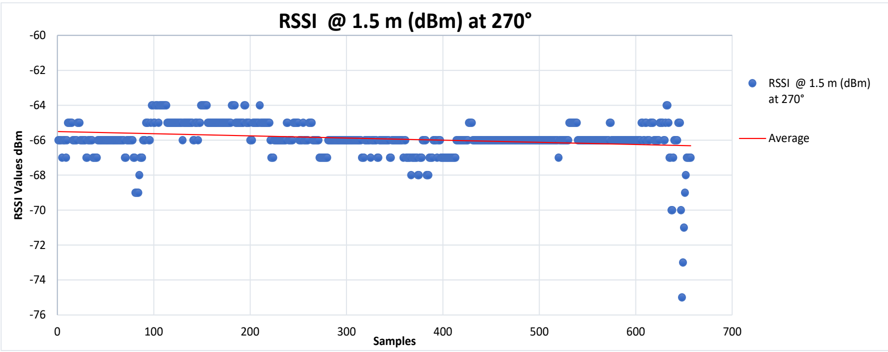

Figure 13. The RSSI value at the rotation of 270°

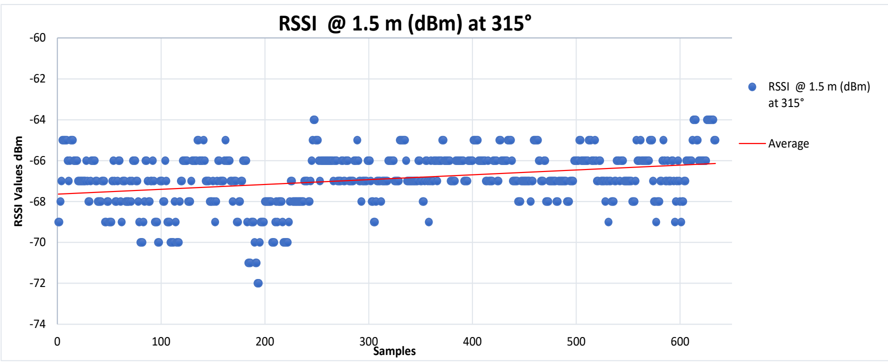

Figure 14. The RSSI values at the rotation of 315°

We also see that each angle can be represented as a percentage of the grand average (-65.51 dBm). It can be summarized in this Table 2.

Table 2. Summarization of the averages and grand average

θ	Angle average $_{dBm}$	% of grand average
0°	-62.62	95.59%
45°	-64.96	99.16%
90°	-64.59	98.59%
135°	-67.45	102.95%
180°	-66.24	101.11%
225°	-65.44	99.89%
270°	-65.91	100.61%
315°	-66.88	102.10%
Grand average	-65.51	100%

6. CONCLUSION

This experiment was set up to study the effectiveness of bluetooth for social distancing and raising an alert. The experiment covered a range of rotational strategies to cover up possible signal strengths. This confirms the effects of the orientation of smartphones to the RSSI measurements using smartphones. The RSSI value is not measured directly rather a special code was required for the purpose. The social distancing under consideration may become even more efficient if the RSSI values are displayed directly. However, the benefit is, such measures would be that the requirement of both the users for the same application is eliminated. We showed the grand average of the RSSI at 1.5 m, it can be used to calibrate other applications. This experiment module can be scaled up to cover more bluetooth devices and more orientation axes.

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