Determining the Differences in Performance Between Two Techniques of Radio Frequency Scanning at Telecommunication Towers

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Abstract

The technique for site surveys at telecommunication towers in Malaysia has always been the conventional way rather than the new technique. A Radio Frequency (RF) site survey is arranging and scheming a wireless network to administer a wireless elucidation that will give the necessary circumstances. The results of these RF readings using a spectrum analyser to determine the non-overlapping frequencies when planning for a new RF transmission later. The current RF observation process may be time-consuming, but the safety and accuracy could be improved, affecting cost and quality. There have been many past tests that have used drones as tools to carry tools according to their respective objectives based on previous research, and most carry an improvement. The information gathered on whether the conventional or the new technique is more sustainable, which based on a case study on several similar sites using two distinct techniques, the conventional and a drone, as carrier agents of measurement tools. From the comparison, the RF scanning survey using the drone technique was much faster in execution, cheaper, and collected better data than the conventional method. This proves that this new technique can be practised for how it works in the future.

Keywords
Radio Frequency, frequency scanning, drone.

1. Introduction
In Malaysia, the technique for frequency scanning (FS) at telecommunication towers has always been the conventional way which requires a competent person with a degree of knowledge in the matter that has to climb the telecommunication tower while carrying a lot of tools and equipment to get the reading at a certain height of the tower (Farahani 2008). In another part of the world, a new technique has been introduced to perform the FS that requires less cost and is much safer than the conventional technique (Griffin et al. 2006).

This new technique utilizes a drone to perform the tasks that have been carried out by human practitioners before. These drones are in line with opinions such as although initially drones were primarily used for military applications, they have been recently adopted by the leisure sector, thus becoming cheaper and more feature-rich. This has opened the doors for researchers and businesses to find applications of this technology for various purposes (López et al. 2017). López et al. 2017, also said that the possibility of using drones that can fly autonomously reduces the risk of accidents caused by an error of the human and drones can be equipped with a wide variety of sensors. The most common sensors that can be found on drones are categorized by purpose.

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However, most drone use in the telecommunications sector focuses on image problems, for Line Of Sight (LOS) determination (Shi et al. 2018), cellular sector determination (Dhekne et al. 2017), or even damage surveys (Díaz & Cáceres 2018). There have been no experiments making frequency scanning using drones before.

On the other hand, this frequency scanning process is essential as where a wireless site survey, now and then mentioned as an RF scanning survey, is the procedure of arranging and scheming a wireless network to administer a wireless elucidation that will deliver the necessary roaming capability, wireless coverage, network capacity, data rates, and Quality of Service (Yang et al. 2018). This paper describes how the process of making RF scanning using a drone is compared to the conventional method; we will look further into why we are determining the optimum approach for an RF scanning survey.

In this part, we will also study the analysis of drone usage in the industry, and the mathematical approach for determining the optimum approach. Many challenges in the future demand that the implementation process from start to finish always needs to be improved among them like; future mobile networks will face significant challenges, including higher capacity, higher performance, lower power consumption, higher spectrum efficiency, more spectrum resource, and lower cost (Chen & Zhao 2014). These wireless devices will also have diverse characteristics in terms of RF hardware, baseband processing capabilities, and overall platform form factor and cost (Talwar et al. 2014). Simultaneous transmission and reception work are also expected to reduce latency significantly (Talwar et al. 2014).

In implementing the workflow in the industry, studies for more optimal implementation are necessary, such as a framework applied to Chinese and other telecommunication network companies with few environmental experiences and practices using new eco-design methods (Zhu & Liu 2010). Meanwhile, academic institutions have started to look into the advancement (technology) towards 5G communication networks due to some main demands that are meliorated data rates, better capacity, minimised latency and better Quality of Service (QoS) (Jain et al. 2018).

Furthermore, there is space that needs to be addressed as challenges that are not adequately addressed by state-of-the-art deployed networks (Long Term Evolution-Advanced, LTE-A): higher capacity, higher data rate, lower E2E latency, massive device connectivity, reduced capital and operations cost, and consistent QoS provisioning (Agyapong et al., 2014). This shows that things like operating costs need to be at the forefront; hence the idea of changing how we work to be more cost-effective needs to be made.

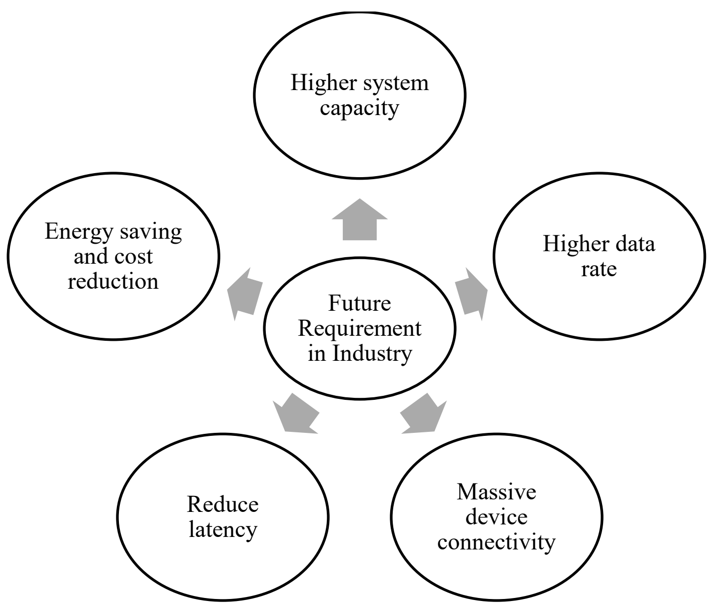

Figure 1. Future of requirements in the industry (Onoe 2016)

Figure 1 shows the things that should be in the future requirement (Onoe 2016); comparative findings from the idea to implementing the work of frequency scanning by using this drone can be shown later in this paper. This frequency scanning work involves work at high places causing many accidents occur when involving work at high themes.

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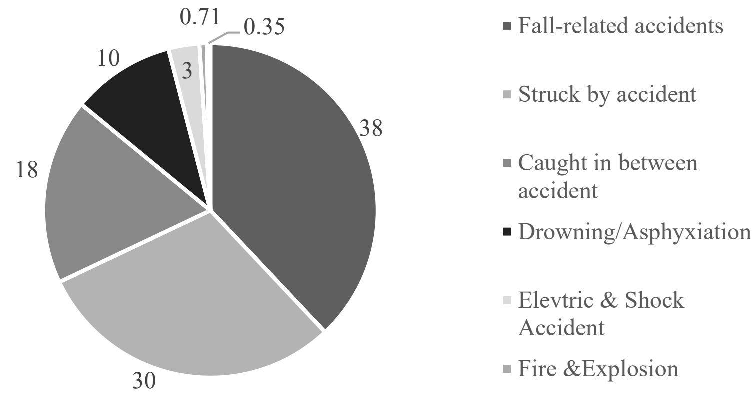

Figure 2. Percentage of occurrences of type of accidents in Malaysia from 2010-2018 (Rafindadi et al. 2020)

Figure 2 shows that fall-related accidents have the highest percentage of it to occur at the site, whether at the construction site or telecommunication towers. Since site surveys at telecommunication towers are heavily involved in working at height, fall-related accidents are the number one problem practitioners face at the site. Fall-related accidents (FREDAs) are the most common type of deadly accident in many countries worldwide, such as the United States (J. Hinze et al. 2005). FREDA is caused by many aspects, including dangerous actions, particular traits, location, administration, and natural circumstances (Nadhim et al. 2016). They are also the result of a lack of knowledge about potentially dangerous situations (Lestari et al. 2019).

2. Literature Review

Based on several previous studies for various industries, the idea of performing frequency scanning using a drone is as follows.

Demand for uncrewed aerial systems (UAS) is expected to rise as countries emphasise technology (Campion et al., 2018). Uncrewed aerial vehicles, or drones, are uncrewed aerial vehicles that are powered by programmed, automated systems from ground stations. The military has utilised drones and protection organisations in war, as well as in the fight against terrorism and other crimes, for decades (David 2020).

The Royal Malaysian Air Force (RMAF) is announcing the inception of a squad committed to UAS utilisation at the RMAF base in Gong Kedak, Terengganu, showing our nation's crucial enthusiasm for technology. All local companies, such as Tenaga Nasional Berhad, used UAS for grid lines, Telekom Malaysia exploited UAS for telecommunication towers and other practicality, Petronas applied UAS for oil and gas pipelines, highway authorities operated UAS for traffic monitoring, and railway companies used UAS in monitoring tracks. (Alsharif et al. 2020).

Drones are only in their early stages of adoption in the drone industry, and many businesses need to be reassured of the advantages of using a drone instead of a human for commercial applications like tower surveying (Jeong et al., 2018). This paper also demonstrates that not only does it show cheaper and safer new techniques, but comparisons can also show more accurate readings and more useful observations for engineers to analyse frequencies more accurately according to their objectives.

3. Objectives

In this study, we have made a comparison case study comparison to determine the difference in results between the conversational technique which is frequency scanning performed by professional practitioners who carry frequency measuring instruments, and the new technique, which is frequency measuring equipment is placed on the modified drone and some drones operators fly according to the specified objectives. A few steps and data collection needed to be done to determine which method is better and more sustainable going into the future.

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4. Research Method

Mainly, despite various improvements proposed in a particular work process, we also ensure that the improvements do not compromise the effectiveness and efficiency of the results from improvements from the point of view of the original objectives as done by Oyesiku et al. (2019) when doing a case study comparing transportation trailers between using bicycles and motorcycles.

In the first comparison, we take both techniques' duration time from start to finish. Time was recorded using the same measuring tool, the first using human techniques and the second using drones as a carrier. The time taken starts from the tool at the bottom until the scanning is completed and the data collected. Cycle time is one of the viable parameters which needs to be optimised as much as possible whenever the manufacturing industry is trying to improve efficiency, cost base, and customer responsiveness. This systematic study presents the reduction of cycle time for productivity improvement in manufacturing that needs to be done (Taifa & Vhora 2019). So, we assume that every industry is also included in this telecommunications industry.

The second comparison is for two groups of data from frequency scanning that is done using the two techniques using Analysis Of Variance (ANOVA) based on (Kim, 2014). Models for evaluating differences among means include a wide range of linear models. The classic ANOVA is a general linear model (Fisher 1997) used for over 100 years (Midway et al. 2020; Intelligent Energy 2013; Aldrich 1997) and is often used when categorical or factor data need to be analysed. The Fisher LSD is used to compare the individual error rate and the number of comparisons to calculate the simultaneous confidence level for all confidence intervals. "Pairwise comparison" means that each compares the difference between the means of a pair of design conditions. This research design has only two conditions; the omnibus-F test will be sufficient to test our research hypothesis. The formula for the number of independent pairwise comparisons is $k(k-1)/2$, where k is the number of conditions. This analysis using Minitab 18.

The third step was comparing the flowchart of work between the conventional technique and the drone technique. We are taking all the features that have been compared to fit into the project management triangle to determine which is the better method. The project management triangle comprises time, money, and quality (Chiu & Su, 2010). In this part, we determine the flow of works for both technique methods. The flow is then broken down into details and compared with each other to determine which is the better and more sustainable for practice. From this, we can estimate the time needed for the work that needs to be done from start to finish. We can also determine at which point some parts can be cut to save the exact cost.

5. Results

5.1 Comparing Operation Time

In Figure 3, M2 represents the drone technique, while M1 represents the conventional technique. From the table above, we can observe that the average time taken for the drone to complete a site is 16.4 minutes, while it takes an average of 132.1 minutes for the conventional to complete one site. The ratio of time completion is around 1:8. That means the drone can complete a site eight times faster than the conventional method.

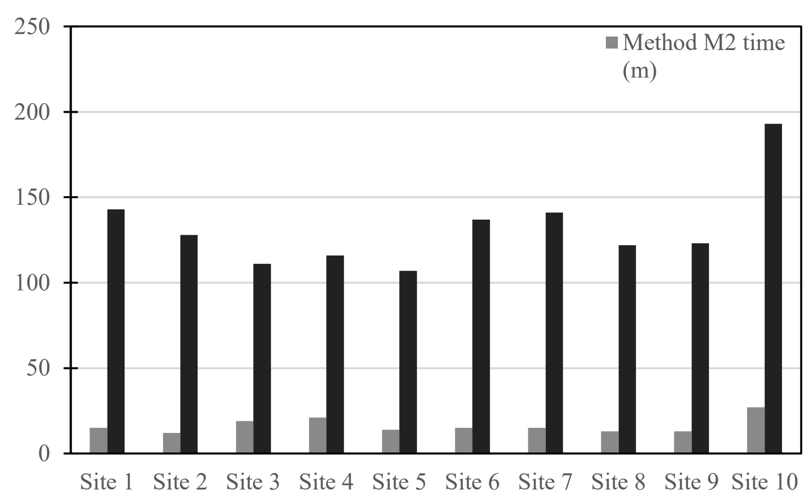

Figure 3. Frequency scanning work process time

5.2 Analysis of Data from Frequency Scanning
5.2.1 Technique 1: Conventional (By Man as Carrier)

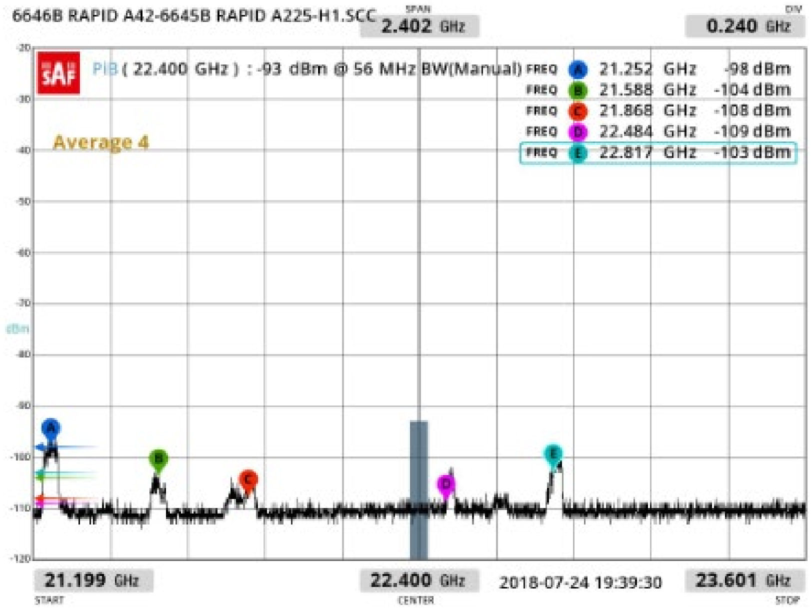

Figure 4. Reading of conventional technique

Figure 4 exhibits the sample of reading collected by workers using the conventional technique. Per observation, the frequency reading obtained is only 5, ranging from 21 GHz to 23 GHz, with the power level ranging from –98 dBm to –103 dBm.

5.2.2 Technique 2: New Method (Drone as Carrier)

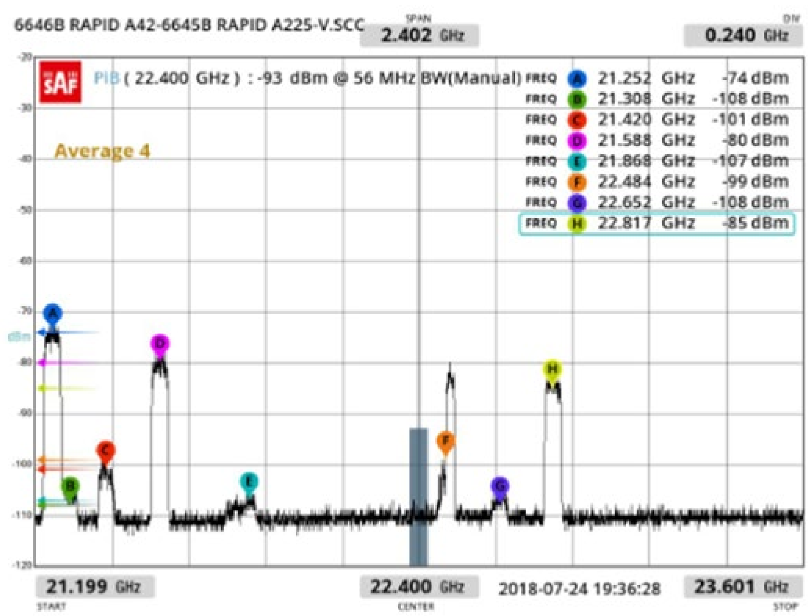

Figure 1. Reading with drone technique

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Figure 5 illustrates the reading collected by workers using the drone technique with the same objective and place. Per observation, the frequency reading obtained is 8, with frequencies ranging from 21 GHz to 23 GHz with the power level ranging from –74 dBm to –108 dBm.

From this, we can see that drone techniques can capture more data with higher accuracy than the conventional method. The reading captured are more; hence, the power level range also varies. Since the power level captured by the drone is much higher than the power level captured by the conventional method, we can conclude that the drone technique is better at this process. Previous research said that Automatic Transmit Power Control (ATPC) was designed and implemented into the microwave link and the triggering value of the ATPC is +30 dB (Hope et al. 2016) as the transmitter's maximum mean output power before the feeder shall not exceed +30 dBm (Rahman & Leng 2003). So we assumed RSL at –30dBm as a benchmark (Sujatmoko, n.d.) and took the differences for both techniques' scanned frequency with the benchmark. Readings close to the benchmark will show better in terms of reading performance. From the total number of readings, the drone technique got eight readings while the conventional got five readings which is a 40% improvement.

To show the performance effect of the two techniques, we performed the ANOVA test as follows:
We performed an ANOVA test on two types of factors. First is the difference between the data acquisition technique, and the second is if there is a difference in readings at two different frequency bands. We take data from 10 different sites to get more data sets (Warne 2014).

Table 1. Analysis of variance

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Method	1	386.0	386.02	4.22	0.042
Band	1	84.9	84.89	0.93	0.337
Error	115	10517.2	91.45		
Lack-of-Fit	1	277.5	277.52	3.09	0.081
Pure Error	114	10239.7	89.82		
Total	117	10961.8			

Table 2. Coefficients

1Term	Coef SE	Coef	T-Value	P-Value	VIF
Constant	–99.068	0.980	–101.05	0.000	
Method 1	–1.929	0.939	–2.05	0.042	1.01
Band A	0.905	0.939	0.97	0.337	1.01

Table 1 and 2 shows the comparisons of the method and their respective band results. From the analysis, the P-Value for the method is 0.042 and was smaller than α 0.05, which there is a huge significant difference between both process and the Received Signal Level (RSL) rate. Meanwhile, the P-Value for Band is 0.337, which is more significant than α 0.05; consequently, there is a small to no significant difference between both processes and the Received Signal Level (RSL) rate. This indicates that the findings in RSL observations are significantly better when using drones. However, using drones does not differentiate the observation findings at different frequency bands (Kim 2014).

In Figure 6, 7, 8 and 9, we observed the residual plot for RSL against the percentage, fitted value frequency and observation order. For against the percentage, we obtain a Normal Probability Plot as the data spread on the graph is almost a straight line. Based on the Versus Fits, the residual RSL against the Fitted value show a constant reading for the data. In the frequency domain, the histogram data shows the frequent/highest value of residuals at –5 with a frequency of 20. The graph shows a pattern of going up early, then immediately going down and staggered at a particular frequency. For Versus Order, the residual against Observation Order patterns is random, going up and down from beginning to end. This discloses the observed data set in a state that can be considered and continued with other different analyses (Warne 2014).

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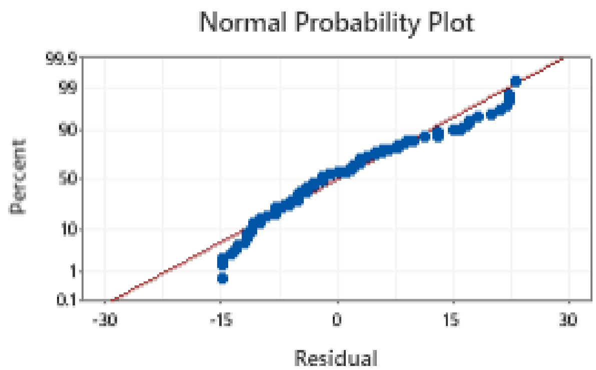

Figure 2. Residual plot for RSL against the percentage

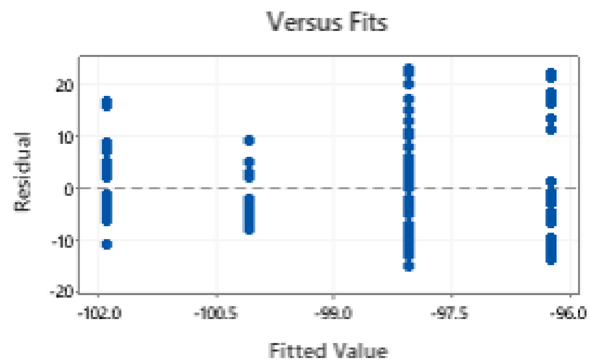

Figure 3. Residual plot for RSL against the fitted value

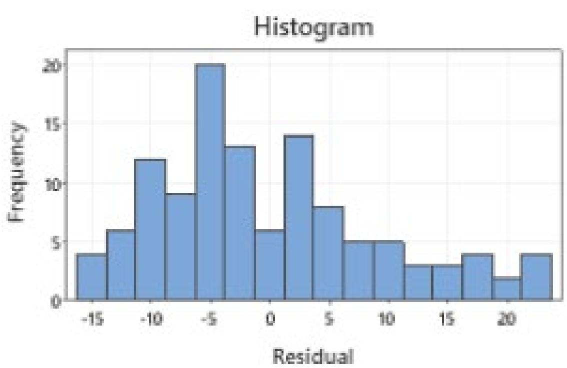

Figure 4. Residual plot for RSL against frequency

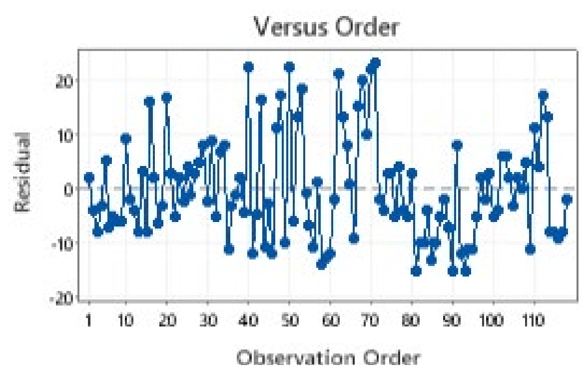

Figure 5. Residual plot for RSL against observation order

5.3 Fisher Pairwise Comparison

5.3.1 Method Technique Comparison

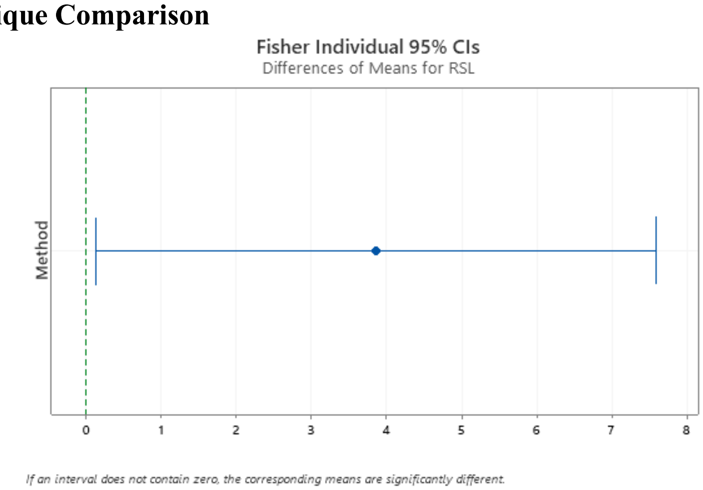

Figure 10. Fisher pairwise comparisons (technique)

From Fisher Pairwise as Figure 10, if an interval does not contain zero, the corresponding means this comparison between these two techniques was significantly different. Similarly, group information using the fisher LSD Method and 95% Confidence show both techniques are at the different group, which is these two techniques are significantly different, as shown in Table 3.

Table 3. Grouping information using the fisher LSD method and 95% confidence

Method	N	Mean	Grouping
2	79	–97.139	A
1	39	–100.996	B

From Fisher Pairwise as Figure 10, if an interval contains zero, the corresponding means this comparison between these two techniques is no different. Likewise, group information using the fisher LSD Method and 95% Confidence show both techniques are in the same group, which is that these two techniques are no different from Table 4.

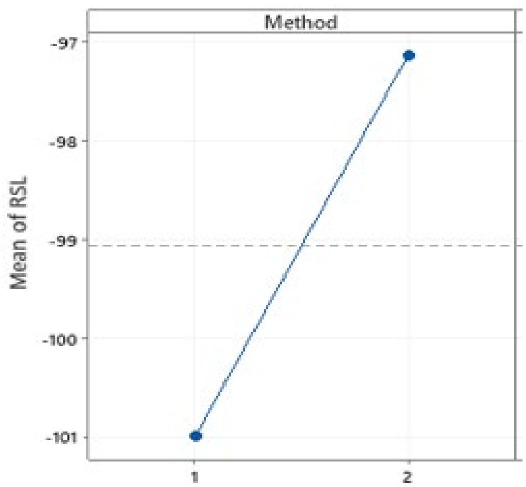

Figure 61. Mean effect plot for RSL between method technique

Figure 11 indicates the Mean Effect Plot for RSL between Method techniques. The Method Mean of RSL displays it goes up from 1 to 2. Since the significant difference in method. Using a drone as the carrier agent of the RSL data from Frequency Scanning is the most efficient since these techniques' mean is closely related to the desired RSL.

5.4 Comparing the flowchart of work between the conventional and new method

5.4.1 Conventional

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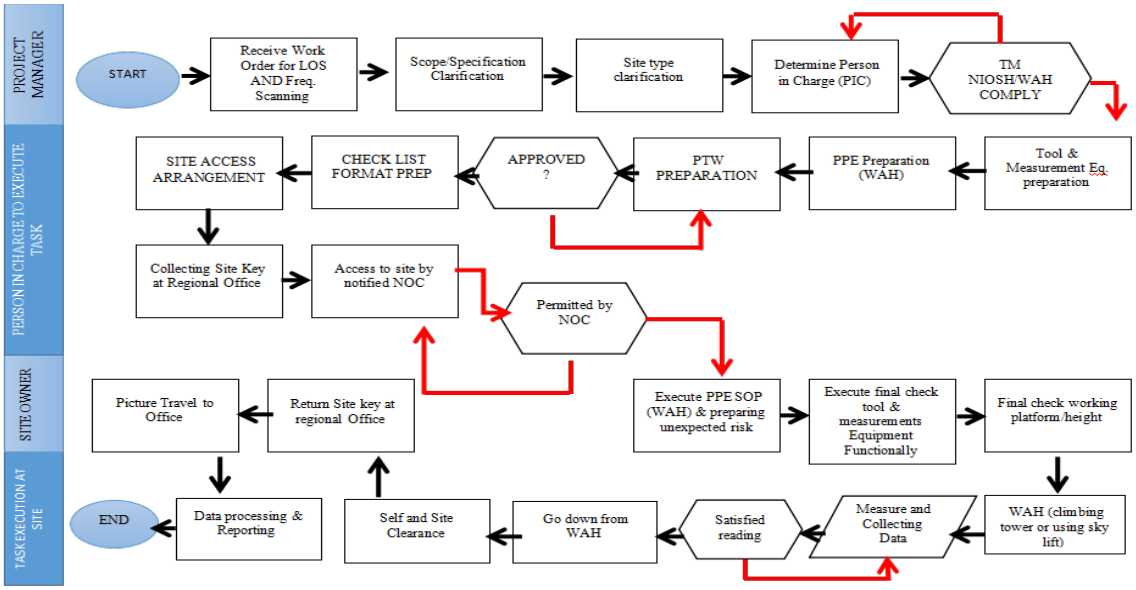

Figure 12. Flowchart of work for the conventional method of RF surveys

Figure 12 parades the flow of work that needs to be done in order to complete a frequency scanning. Firstly the initial part concerns the project manager, where the project manager receives a work order for LOS and frequency scanning from the client. From the work order, they then clarified the project's specifications and scope. Only from that the site type clarification can be done. A person-in-charge (PIC) is then appointed based on the qualifications and certification required by the client.

Then the job is carried out by the person appointed by the project manager to prepare all the tools and measurement kits. Personal Protective Equipment (PPE) also needed to be prepared alongside the tools and measurement kit. After that, the PIC needs to get the Permit to Work (PTW) for access to the site. They can prep the checklist and arrange for site access if all the equipment and certificate are approved. They must obtain the site key at the regional office and notify the NOC for site access. If approved, the workflow is then continued by the site owner.

For the site owner, after the site has been approved and notified by NOC, they have to execute the PPE Standard of Procedure (SOP) and prepare for unexpected risks. Then, they have to execute the final checking on all the tools and measurement equipment functionality so the tower work will go smoothly. A final check for the working platform/height will be done for the final safety measure. Once all that has been done, the sky lift/climbing tower can be utilised on-site for working at height. From there, data collecting and measuring are executed. The workers can go down from the sky lift/ climbing tower if all the readings are satisfying. The workers can then proceed with self and site clearance and immediately return the site key to the owner at Regional Office. Then the workers can travel back to their office, where they can finish the data processing and report.

5.4.2 New Method

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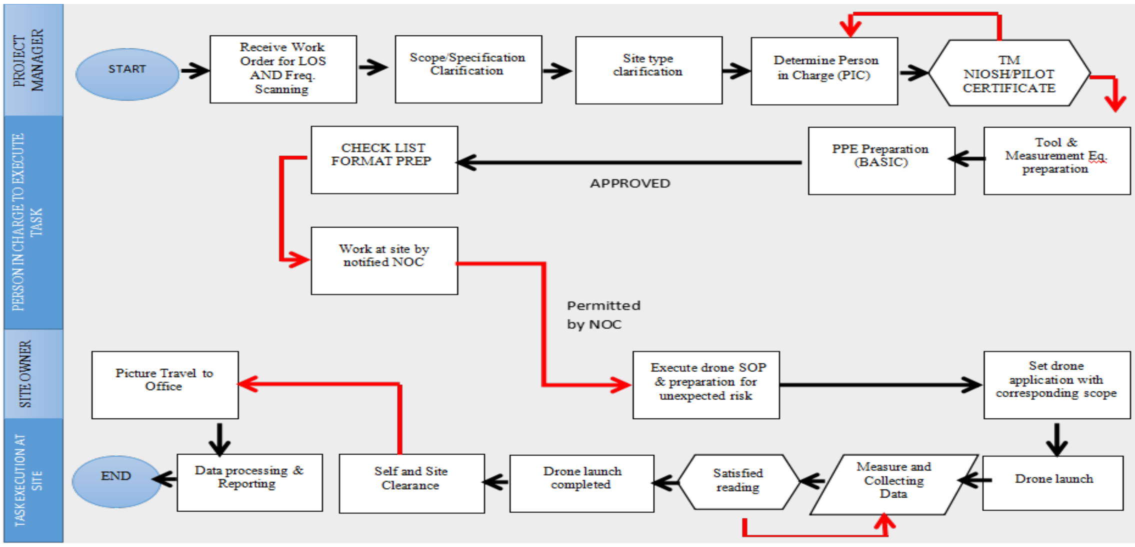

Figure 13. Flow chart of work for the new method with drone technique of RF surveys

Observations were made for flow charts for both techniques that were affected due to the change in the way they worked. Refers to Figure 13; this part's earlier stage is mostly the same. The flow starts almost the same as the conventional method to complete frequency scanning. Firstly the initial part concerns the project manager, where the project manager receives a work order for LOS and frequency scanning from the client. From the work order, they then clarified the project's specifications and scope. Only from that the site type clarification can be done. A person-in-charge (PIC) is then appointed based on the qualifications and certification required by the client.

Then the job is carried out by the person in charge to execute the task appointed by the project manager to prepare all the tools and measurement kits. Personal Protective Equipment (PPE) also needed to be prepared. If all the equipment measurements are approved, they can move to prep the checklist and work at the site by notifying the NOC. When the NOC is permitted to work, we can move to executing drone SOP and preparing for unexpected risks. In doing so, we can set the drone through its application with the corresponding work scope. All of this is under the site owner's responsibility.

When all is set, the drone can be launched to collect data. From there, data collecting and measuring are executed. If all the readings are satisfying, the drone can land, thus completing the flight. The workers can then proceed with self and site clearance and immediately return the site key to the owner at Regional Office. Then the workers can travel back to their office, where they can proceed to finish the data processing and report.

As we can observe from both flowcharts above, the workflow for the drone technique is significantly less than the conventional method. The drone techniques skip numerous steps at the PIC to Execute Task and Site Owner. This proves that drone techniques are much faster than the conventional method as it cuts much human interaction and the need for certification and permits. It also cuts the time on getting the key for site access.

A drone is also much cheaper and longer lasting than the conventional method. This is because the drone itself can be used for as long it is still functional for the RF survey and does not require plentiful certification to handle the drone compared to the conventional method, which requires a Working at Height (WAH) certificate, TM Niosh, Green Card CIDB and more not to mention all the permit to enter the site.

Since the scope of work remains the same, it can be said that based on the Project Management Triangle where the concerns are at the cost, time and scope, the drone techniques prove to be better than the conventional method. As a result of changing the technique of this method, some steps can be left out due to not having to prepare to enter the premises and not having to climb the tower.

6. Conclusion

Table 4 outlines the RF site survey using a drone, showing that it excels in the Project Management Triangle, which is cheaper, much faster, and has higher quality data than the conventional method. It is sufficient to say that the drone RF site survey is a more sustainable practice for the future.

Table 4. Comparison of conventional and drone method

	Conventional	**Drone**
Work Flow	Long and tedious	Much faster and more efficient
Frequency Data Collected	Datasets that are not highly accurate and limited	A much better output as it eliminates human errors and risk
Time Completion	It was very slow as it needed time to set up and follow the SOP given by the authority.	Very fast and efficient as it eliminates the need for setup for every site and workflow.
RSL measurement	Observations can only be made on the rest platform, where it is often not accurate to the objective frequency path causing low RSL strength, and some RSLs cannot be observed	Using a drone as a carrier agent can be done exactly to the objective, and there is no need for humans to climb many benefits in terms of safety, and time can also be done immediately in every situation, including in times of disaster.

Based on the comparisons, we can conclude that the new RF site survey method using drones as the carrier for measurement tools is better than the conventional method. The RF site survey is a lot faster in terms of execution which is the ratio is 8 to 1. This practice is not just great but also can increase productivity. The workflow of the work that needs to be done is also cut, thus shortening the operation schedule. The cost for the RF site survey using the drone is also much cheaper since the cost that must be spent is only for the drone, the competent person, and many more. The RF site survey using drone also collect better data than the conventional method. This proves that the RF site survey using the drone is a more sustainable practice for the future. It can be said that practitioners look forward to using drone technique methods in the future.

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