

Expansion of a Y-Shaped Antenna Array and Optimization of the Future Antenna Array in Malaysia for Astronomical Applications

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Abstract

To achieve high quality images from the sky by extending an existing interferometric array, in this work, the Geometrical Method (GM), Genetic Algorithm (GA), and Division Algorithm (DA) are compared. These methods are each applied independently to an interferometer array starting from the same initial conditions. Using the GM method, the spiral configuration is suggested as an optimum arrangement that provides the desired u-v coverage with low side lobe levels (SLLs). Using the GA method, as the number of generations is increased, the unsampled cells are reduced, enhancing the imaging quality. As such, the algorithm improves the overlapped samples as it works with a greater number of generations. Moreover, the GA is able to suppress the SLL. Finally, the DA is applied to such an array. Results show that the DA is able to process the sampled data with less overlapping of the data in the snapshot observations, in comparison to the other discussed configurations in this paper; effectively the DA reduces the overlapped samples, such that it is more efficient than the GA. The configuration of antennas that arrives by applying the DA method can achieve a certain image quality with less overlapping, as compared to the configuration arriving by applying the GA method. The calculated SLLs for the DA configuration are used to demonstrate that the efficiency of the DA is potentially better than that of the GA. Moreover, the GA and DA algorithms discussed in this study are applied to an array of 10 antennas with coordinates that represent the antennas deployed in Malaysia. Results show that the DA can reduce the overlapping of the samples more efficiently than the GA for a 6-hour tracking observation and in terms of unsampled cells the DA has the same efficiency of the GA.

Keywords

Interferometers, Telescopes, Genetic Algorithm, Array of Antennas

1. Introduction

In order to measure with fine angular detail in the radio frequency range from the sky, two-element radio interferometers, or alternatively synthesis arrays can be used. The angular resolution of a single telescope does not provide sufficient information for astronomy applications; therefore, a synthesis array or radio interferometer is used to fulfill the aim of the end user. On the other hand, the light waves from very distant stars or galaxies take a long time to travel through space to our telescopes; therefore, it limits the astronomers to visually observe light waves that occurred a very long time ago.

The time lag to observe events has led astronomers to build more powerful telescopes to study the first stars and galaxies formed. One of the most powerful arrays is the Giant Meterwave Radio Telescope (GMRT). To get higher resolution than what the current GMRT array can provide, additional antennas were added to the array. To improve existing correlator antenna arrays like the Giant Metrewave Radio Telescope (GMRT), an expansion of the array is required to obtain higher resolution. A project called the Square Kilometre Array (SKA), which involves more than ten countries worldwide, will be the most powerful radio telescopes array. It allows observation of the sky and it can produce images from radio waves with very high resolution. However, the location of the telescope limits the image quality and has a direct effect on the side lobe levels (SLLs) [1].

In the design of an array for astronomy applications, the choice of each antenna's localization in the array is key. An ideal arrangement must ensure optimal configuration to capture a clear image of a radio source by either decreasing the side lobe level (*SLL*) in the *I-m* domain or increasing the sampled data in the spatial frequency domain, which is referred to as *u-v* plane coverage [2].

In this work, we focus on the comparison of different methods: the Geometrical Method (GM), the Genetic Algorithm (GA), and the Division Algorithm (DA) [1] [2] [3] and [4]. These techniques and methods for assisted interferometry and how they can be implemented in a correlator antenna array, particularly applied to the *SKA* are described. The ability of the proposed receiver to suppress the severe *SLL* effect, to increase the *u-v* plane coverage, and to smoothen the linear ridges in the *u-v* plane coverage at a low number of snapshots or low duration of observation will be demonstrated through simulations, using Matlab.

The first method (*GM*) uses the optimization of the array configuration problem with various changes of coordinates in a specific area with the *GMRT*'s arms as an illustrative example. The results show that spiral configurations give very good improvement in both *u*-*v* plane coverage and reduction of side lobe levels.

For the second technique, the proposed GA presented in [2] is used to optimize a correlator array of antennas. The algorithm is able to distribute the u-vplane more efficiently than GMRT with 49.77% overlapped samples. The configuration arrived at with this algorithm is able to sample the u-v plan more efficiently than the current GMRT configuration.

The third method is the new proposed algorithm named Division Algorithm (DA) that has been recently presented in [3] to solve optimization problems.

The above methods are used to yield the optimum configuration for an extended interferometric array, and effectively to investigate the feasibility of extending the interferometric array using 10 antennas that would be deployed in Malaysia.

This paper is organized as such; Section 2 introduces the material and methods for expanding a *Y*-shape array and to represent the antenna array in Malaysia. Section 3 presents the simulation results. Finally, Section 4 and 5 cover the discussion and conclusions, respectively.

2. Material and Methods

2.1. Expanded Y-Shape

To extend the *GMRT*, it is proposed to add 15 antennas for cost-effectiveness and to realize the scientific goals. In order to add the antennas to the current array, the position of each antenna using rectangular coordinates (x, y, z) is calculated using:

$$X = R \times \sin \theta \times \cos \varphi$$

$$Y = R \times \sin \theta \times \sin \varphi$$
 (1)

$$Z = R \times \cos \theta$$

where *R*, θ , and φ are the latitude, longitude, and radial distance *R* (equal to about 6378.1 km, the value of earth's radius), respectively. The extended configuration is placed at 110 km along the arms of the *GMRT*. The declination of the radio frequency source of interest for all configurations is the same (and is equal to 45°). Spiral configurations follow the theory of a logarithmic spiral [1].

Results in [1] show that the spiral antenna array configuration provides low *SLL* and good u-v coverages and therefore achieves high image resolution. Therefore, the following equations are used to calculate the gridded cells in u-v domain:

$$N_{\text{grid}} = \sqrt{\left(\frac{A_t}{A}\right) \times \left(\text{nosmp}\right)}$$
(2)

$$\Delta u = \frac{u_{\text{max}} - u_{\text{min}}}{N_{\text{orid}}} \tag{3}$$

$$\Delta v = \frac{v_{\text{max}} - v_{\text{min}}}{N_{\text{grid}}} \tag{4}$$

where nosmp, A_t , A, and N_{grid} are the number of samples in the snapshot or hour tracking observation, the total desired area, the covered area by the current configuration, and the number of gridded cells, respectively.

And Δu , Δv , u_{max} , u_{min} , v_{max} , v_{min} and N_{grid} are the dimension of the cell in the u direction, the dimension of the cell in the v direction, the maximum value of u in the spatial frequency domain, the minimum value of u in the spatial frequency domain, the maximum value of v in the spatial frequency domain, the minimum value of v in the spatial frequency domain and the number of gridded cells as defined in Equation (2), respectively [1].

Also, results in [2] show the good performance of the *GA* configuration in terms of *SLL* and sampling. The algorithm provides an optimum solution for both a snapshot observation and a 6-hour tracking observation with minimum values of overlapping. This happens due to the discrete grid locations of the plane as defined in:

$$N_{\rm grid} = {\rm nearest}\sqrt{\left(n \times (n-1) \times A_{\rm total} / A_{\rm first}\right)}$$
(5)

where *n* is the number of antennas, A_{total} is the total area, A_{first} is the first calculated area of tracking observation from the first random population, and nearest rounds N_{grid} to the nearest integer. This selection helps distribute the samples in the *u-v* plane with less overlapping in both snapshot and hour tracking simultaneously [1].

The new algorithm (DA), explained in [3], shows good results in optimizing an interferometric array. Therefore, these three methods are used in this section to investigate an optimum configuration, in order to extend an interferometric array.

To evaluate the position of each antenna using GA and DA methods, the fitness function elaborated in [2] is used:

$$fitness(k) = -\frac{ol_{sam}(k)}{\max(ol)} - \frac{D(k)}{R} - \frac{(A_{tofsam} - A_{sam}(k))}{A_{tofsam}}$$
(6)

where: fitness (k) is the fitness value of k^{th} baseline in n^{th} generation. $oI_{sam}(k)$ indicates the number of overlapped samples generated by k^{th} baseline in n^{th} generation. Max(ol) provides the maximum value of overlapping that is in n^{th} generation. D(k) is the sample distance from the grid center. R is the gridded cell radius. $A_{sam}(k)$ is the calculated area generated by k^{th} baseline's samples in n^{th} generation. A_{tofsam} is the total area generated by n^{th} generation [2].

Finally, the mean *SLL* for all the aforementioned methods are calculated using the following equation [1]:

$$mean SLL = -mean(first SLL + second SLL + third SLL)$$
(7)

2.2. Antenna Array in Malaysia

Malaysia has started to fund major research astronomy projects recently with two telescopes. In this work, we apply the proposed theory of localization using an array of antennas for astronomy applications to suppress the *SLLs* and/or increase the number of samples in the u-v plane coverage for the future array configuration in Malaysia.

We expect that the proposed methods can optimize the number of data samples and minimize the side lobe levels in the angular domain to enhance the image quality as much as possible. The methods discussed in this study are applied to 10 antennas which will be placed at the coordinates of the antennas in Malaysia.

The materials and methods used in this section are taken from [2] [3]. Here, the *GA* and *DA* algorithms are used to investigate the optimum solutions for ten antennas in Malaysia.

3. Results

3.1. Expanded Y-Shape

To expand the existing array, 15 antennas are added for the following configurations: 1) extended Y-shaped; 2) spiral; 3) 25^{th} generation using GA; 4) 150^{th} generation using GA; and 5) DA. Figure 1 shows the different configurations. The u-v plane coverage achieved from these different configurations are shown in Figure 2 and Figure 3 for the snapshot and 6-hour tracking observations, respectively. The results are summarized in Figures 1-3, and Table 1 & Table 2.

In the first step, extension of the Y-shaped array is investigated. In this configuration, 15 antennas are located along the three arms of the *GMRT*. Five antennas are added in each arm and broadened around to 110 km. This array gets a Y-shape to investigate the effect of extending the arms in the original Y-shape. This new arrangement, its snapshot observation, and 6-hour image synthesis are shown in **Figure 1(a)**, **Figure 2(a)**, and **Figure 3(a)**, respectively.





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Figure. 1. Configuration for (a) extended *GMRT*, (b) spiral, (c) twenty-five generations, (d) one hundred fifty generations using Genetic Algorithm and (e) Division Algorithm.





Figure 2. Snapshot u-v plane coverage for (a) extended *GMRT*, (b) configuration of spiral, (c) *GA* using 25 generations, (d) *GA* using 150 generations and (e) Division Algorithm.





Figure 3. Spatial frequency coverage for a 6-hour tracking observation u-v plane coverage for configuration of (a) extended *GMRT*, (b) spiral, (c) twenty-five generations, (d) one hundred fifty generations using Genetic Algorithm and (e) Division Algorithm.

Configuration	Overlapped samples% (Snapshot)	Overlapped samples% (Hour tracking)	Unsampled cells% (Snapshot)	Unsampled cells% (Hour tracking)
Extended GMRT	89.19	88.89	78.67	75.19
Spiral	86.77	85.51	72.56	67.59
25th generation	85.91	86.58	76.34	70.74
150th generation1	85.05	84.76	74.56	66.65
DA array	79.45	83.87	72.00	63.76

Notes: 6-hour is used in hour tracking synthesize.

Configuration	First <i>SLL</i> (dB) (Hour tracking)	mean <i>SLL</i> (dB) (Hour tracking)	Peak <i>SLL</i> (dB) (Hour tracking)
Extended GMRT	-11.18	-11.97	-10.59
Spiral	-11.25	-12.46	-10.86
25th generation	-11.88	-13.85	-12.55
150th generation1	-12.04	-13.88	-13.75
DA array	-19.30	-16.86	-14.80

Table 2. Comparison of GMRT's SLL and different configurations' SLL.

Notes: 6-hour is used in hour tracking synthesize.

Table 1 shows the number of overlapped samples using snapshot as well as for a 6-hour tracking observation. This parameter is valued at 89.19% using the snapshot and 88.89% for a 6-hour tracking observation. The unsampled cells ratio achieved with this configuration (expanded *GMRT*) are 78.67% using the snapshot observation and 75.19% for a 6-hour tracking observation.

As shown in Figure 2(a), for the u-v plane coverage using the snapshot observation, the linear ridges are not smooth, and this configuration provides a poor sensitivity and consequently a poor signal to noise ratio [1]. Therefore, the linear ridges need to be smoothened. In order to perform this requirement, the arms are curved in the next arrangement as is shown in Figure 2(b).

Arms in the spiral configuration cover the angular position of 60 to 96, 180 to 216 and 300 to 336 degrees. The angular positions of five added antennas in each arm are 62 to 70, 182 to 190 and 302 to 310 degrees. The overlapped sample ratio is equal to 86.77% for the spiral using the snapshot observation. Similarly, it is equal to 85.51% for a 6-hour tracking observation. The unsampled cells ratio from the *u*-*v* coverage indicate the percentage of the cells without any sample. This ratio is equal to 72.56% using the snapshot (see Figure 2(b)) and 67.59% for a 6-hour tracking observation (see Figure 3(b) and Table 1). This means the spiral configuration is able to sample the Fourier space of the image better than the extended Y-shape. In comparison to the extended *GMRT*, the lower ratios of overlapped samples and unsampled cells resulting from the spiral suggest that this configuration provides more information about the source due to a greater number of samples in the *u*-*v* plane. Therefore, the configuration of the spiral provides a better *u*-*v* plane coverage in both types of observations in comparison to the extended *GMRT*'s as shown in Figure 2(b) and Figure 3(b).

In the next step, the *GA* is applied to this extended interferometric array, to investigate the effect of the algorithm.

From the results achieved using the previous configurations (see Figure 1(a) and Figure 1(b)), the data in the spatial frequency domain needs to be spread out to get less overlapping. Therefore, the GA is applied to work on sampled data using the snapshot to provide the desired resolution.

For the GA, the optimum ratio values of mutation and crossover (25% mutation ratio and 25% crossover ratio) are used in the proposed algorithm. The

number of antennas (chromosomes) is set to 45 and for each the diameter is equal to 45 m to assess the efficiency of the algorithm. To distribute the sampled data in u-v plane coverage more smoothly, the algorithm works on 150 generations to optimize the image resolution.

The position of the antennas (chromosomes) in the array for the 25^{th} , and the 150^{th} generations using the *GA* are shown in Figure 1(c) and Figure 1(d), respectively. The snapshot in the *u-v* plane coverage for the 25^{th} , and the 150^{th} generations that are shown in Figure 2(c) and Figure 2(d). These illustrate how the sampled data distribution are from the results using the extended *GMRT*. As can be observed qualitatively, the data in the 150^{th} generation improves the distribution of the data somewhat more evenly. The calculated ratios shown in Table 1 summarize the ability of the *GA* (when using snapshot) in distributing the samples and obtaining more samples rather than the extended *GMRT*.

The calculated ratios in **Table 1** show that the *GA* can sample data with less overlapped data using the snapshot observation. Specifically, for the 150^{th} generation the ratio is equal to (85.05%), in comparison to 89.19% for the extended *GMRT*. This indicates that as the algorithm works with more generations, it distributes sampled data in the *u*-*v* plane coverage more efficiently than extended *Y*-shaped.

The calculated ratio of overlapped samples for a 6-hour tracking is shown in **Table 1**. From the results, this value is improved from 88.89% to 86.58%, and then to 84.76% using the extended *GMRT*, the 25^{th} , and the 150^{th} generation configurations, respectively. It means the algorithm improves the ratio of overlapped samples since it works with a greater number of generations.

When the number of generations goes up, the number of unsampled cells is lower; specifically, this percentage is 78.67% using the extended *GMRT* configuration and becomes 76.34%, and 74.56% values using the 25th, and 150th generations using the snapshot, respectively. This ratio is equal to 75.19% using the extended *GMRT* observation and is equal to 70.74% and 66.65% values using the 25th, and the 150th generations for 6-hour tracking observations, respectively.

In the last step, the DA is applied to this extended interferometric array, to investigate the effect of the algorithm. The algorithm provides an optimum solution for both the snapshot and for the hour-tracking observations with minimum ratios of overlapping.

The position of the antennas, u-v coverages at snapshot and 6-hour tracking observations in the array using DA are shown in Figure 1(e), Figure 2(e), and Figure 3(e), respectively. The calculated parameters shown in Table 1 express the ability of the DA in distributing the samples and obtaining more samples rather than the extended GMRT s at the snapshot.

The results calculated in **Table 1** show that the *DA* can achieve the sampled data with less overlapped data at snapshot observation among all discussed configurations in this study (79.45%). The calculated overlapped samples ratio for a 6-hour tracking is shown in **Table 1**. From the results, this value is equal to 83.87%. It means the algorithm improves the overlapped number of samples

more efficiently than GA. When the number of generations goes up, the unsampled cells get reduced; specifically, this percentage is 72% at snapshot and 63.76% for a 6-hour tracking observation.

The calculated *first SLL*, mean of the first three *SLL* (*mean SLL*), and the worst *SLL* defined as the *peak SLL* are shown in **Table 2**. The calculated *SLLs* show that the spiral geometry has lower side lobes (SLL = -11.25 dB and *mean SLL* = -12.46 dB, and *peak SLL* = -10.86 dB) than the extended *GMRT* (SLL = -11.18 dB and *mean SLL* = -11.97 dB, and *peak SLL* = -10.59 dB) and the linear ridges using the snapshot is also smoother than for the extended *GMRT* (see Figure 2(b)). As such, the spiral configuration smoothens the linear ridges.

The first and the mean values of the first three *SLLs* of 25th and 150th generation using *GA* are also calculated **Table 2**. The *first SLL* is -11.18 dB in extended *GMRT* and -11.88 dB, and -12.04 dB for the 25th, and the 150th generation configurations, respectively. The calculated mean value of the first *SLL* shown in **Table 2** depicts that the configurations have the *mean SLL* of -13.85 dB and -13.88 dB at the 25th, and the 150th generation, respectively (this ratio is valued at -11.97 dB using the extended *GMRT*). The algorithm is also able to decrease the level of the *peak SLL* as the number of generations goes up (this ratio is -12.55 dB and -13.75 dB using 25th and 150th generation configurations, respectively). The calculated *first SLL, mean SLL*, and *peak SLL* values of *DA* configuration are -19.3 dB, -16.86 dB, and -14.8 dB, respectively. These values show the better efficiency of the *DA* in comparison to the *GA*.

The evolution of the average fitness in each generation for the *u*-*v* plane coverage using the snapshot observation and *SLL* reduction are shown in **Figure 4**. As shown in **Figure 4(a)**, the optimum solution occurred at the 47^{th} generation for the first 50 generations, and the optimum value in the range of 82^{th} to 150^{th}





Figure 4. The evolution of average fitness in each generation in (a) the spatial frequency domain and (b) the l-m domain.

generation remains constant. The fitness value for the first 50 generations in **Figure 4(b)** obtains the optimum solution at 23^{rd} generation. Since the algorithm seeks the solutions randomly, it provides different solutions each time. The aim of this study is to demonstrate optimum solutions for an extended interferometric array. It is not written for any specific constraints for astronomy applications; however, it can work with different constraints.

From the results obtained from the different configurations in this study, a spiral shape suggests good results in the angular domain as well as in the u-v domain and the GA and DA provide improved *SLLs*, and u-v plane coverages.

3.2. Antenna Array in Malaysia

The simulated source declination is 45 degrees. The duration for the fully synthesized observation is a 6-hour tracking with 10 minutes time interval between each two samples.

As a first step, the GA is applied to an interferometric array, to investigate the effect of the algorithm.

The algorithm provides an optimum solution for both the snapshot and the hour-tracking observations with minimum values of overlapping (this happens due to the grounding of the plane as defined in (2) and (3)).

The optimum ratio values of mutation and crossover (25% mutation ratio and 25% crossover ratio) are used in the algorithm. The number of antennas (chromosomes) is fixed to 10. To distribute the sampled data in u-v plane coverage more smoothly, the u-v plane is gridded with the dimension of $D_u \times D_v$ as defined in (3) and the algorithm works on 150 generations to optimize the resolu-

tion of the image.

The positions of the antennas (chromosomes) in the array of the 25^{th} and 150^{th} generations using the *GA* are shown in **Figure 5(a)** and **Figure 5(b)**, respectively. Using the snapshot, the *u-v* plane coverages for the 25^{th} , and 150^{th} generations in **Figure 6(a)** and **Figure 6(b)** and 6-hour tracking in **Figure 7(a)** and **Figure 7(b)** show how the sampled data is distributed using 25^{th} generation gradually to 150^{th} generation.

The calculated parameters shown in **Table 3** express the ability of the *GA* to distribute the samples and obtaining more samples as the number of generations goes up at the snapshot. The calculated results summarized in **Table 3** show that the *GA* achieves the sampled data with less overlapped data at snapshot observation from the 25^{th} generation (12%) to the 150^{th} generation (2%). This indicates





Figure 5. Configuration for (a) twenty-five generations, (b) one hundred fifty generations using Genetic Algorithm and (c) Division Algorithm.





Figure 6. Snapshot *u-v* plane coverage for (a) twenty-five generations, (b) one hundred fifty generations using Genetic Algorithm and (c) Division Algorithm.





Figure 7. Spatial frequency coverage for a 6-hour tracking observation *u*-*v* plane coverage for (a) twenty five generations, (b) one hundred fifty generations using Genetic Algorithm and (c) Division Algorithm.

Configuration	Overlapped samples% (Snapshot)	Overlapped samples% (Hour tracking)	Unsampled cells% (Snapshot)	Unsampled cells% (Hour tracking)
25th generation	13.34	25.23	94.89	93.23
150th generation1	2.23	24.45	94.00	92.49
DA array	0.00	22.28	91.56	92.16

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Notes: 6-hour is used in hour tracking synthesize.

that as the algorithm works with more generations, it can distribute sampled data in the u-v plane coverage more efficiently.

The calculated overlapped samples ratio for a 6-hour tracking is shown in **Table 3**. From the results, this value is varied from 13.34% to 2.23% using the 25^{th} and the 150^{th} generation configurations, respectively. It means the algorithm improves the overlapped samples as it works with more numbers of generations.

Since the number of generations goes up, the number of unsampled cells are decreased; specifically, the ratio is 94.89% using the 25^{th} generation observation and becomes 94.00% using the 150^{th} generations at the snapshot. This ratio is equal to 93.23% using the 25^{th} generation observation and becomes 92.49% using the 150^{th} generation for a 6-hour tracking observation.

Finally, the DA is applied to the extended interferometric array, to investigate the effect of the algorithm. The algorithm provides an optimum solution for both the snapshot and the hour-tracking observations with minimum values of overlapping (this happens due to the gridding of the plane as defined in (2) and (3)).

The position of the antennas, the u-v coverage for the snapshot observation and for a 6-hour tracking observation in the array using the DA are shown in Figure 6(c), Figure 7(c), and Figure 8(c), respectively. The calculated ratios shown in Table 3 express the ability of the *DA* in distributing the samples and obtaining more samples rather than the *GA* for the snapshot.

The calculated results that are summarized in **Table 3** show that the DA can achieve the sampled data with the same efficiency as the GA for the snapshot observation. The calculated overlapped samples ratio for a 6-hour tracking is shown in **Table 3**. From the results, this ratio is valued at 22.28%. It means the algorithm improves the overlapped samples more efficiently than GA for a 6-hour tracking observation.

Since the number of generations goes up, the number of unsampled cells is reduced; specifically, this percentage is 91.56% at snapshot and 92.16% for a 6-hour tracking observation, which show the same efficiency of the *GA*.

The calculated *first SLL*, mean values of the first three *SLLs* (*mean SLL*), and the worst *SLL* defined as the *peak SLL* are shown in **Table 4**. The values of the



Figure 8. The evolution of average fitness in each generation in (a) the spatial frequency domain and (b) the l-m domain.

Configuration	First <i>SLL</i> (dB) (Hour tracking)	mean <i>SLL</i> (dB) (Hour tracking)	Peak <i>SLL</i> (dB) (Hour tracking)
25th generation	-6.99	-6.75	-3.03
150th generation1	-5.23	-8.45	-5.20
DA array	-10.00	-9.86	-5.88

 Table 4. Comparison of different configurations.

Notes: 6-hour is used in hour tracking synthesize.

first SLL, mean SLL, and peak SLL are -6.99 dB, -6.75 dB, and -3.03 using the 25th generation, -5.23 dB, -8.45 dB, and -5.2 dB using the 150th generation, and -10 dB, -9.86 dB, and -5.88 dB for the *DA* array, respectively. It shows that even though the *GA* decreases the *SLL*, the *DA* gains reasonable *SLL* and optimum ratios in the spatial frequency domain, with the same population.

The evolution of the average fitness in each generation for the u-v plane coverage at the snapshot and *SLL* reduction is shown in **Figure 8**. As shown in **Figure 8(a)**, for the first 50 generations, the optimum solution is reached at the 38th generation. In contrast, for a total of 150 generations, a better solution is obtained at the 112th generation. Similarly, the fitness value for the first 50 generations in **Figure 8(b)** obtains the optimum solution at 43th generation. Since, the algorithm seeks for the solutions randomly; it provides different solutions for each generation.

4. Discussion

Astronomical observations benefit from arrays that can achieve high resolution with low *SLLs*, smooth linear ridges, and good u-v plane coverage. The aim of the study was to extend such an array to optimize the configuration. Therefore, the principal aim of the present simulation was to compare different extended configurations. Based on the results shown in **Table 1**, the spiral configuration or curved arm achieves good results in *l*-m domain and u-v domain. Also, it was found that the curvature smoothens the linear ridges for a low duration observation. Finally, the *GA* was able to provide good results for all the desired requirements.

Malaysia has started to get involved in astronomy project recently with two telescopes. As such, the second part of this study has investigated an optimum solution for the future correlator array antennas in Malaysia. Based on the results, it has been shown that the *DA* is able to obtain a configuration that provides almost all desired requirements in both spatial frequency domain and angular domain.

5. Conclusions

In conclusion, the aim of this study was to investigate different solutions to extend an interferometric array and the future array in Malaysia. For expanding the existing array, initially, the expansion along the three arms configuration was studied and then the effect of expanding it to a spiral shape was evaluated. The results have shown that the spiral could provide better u-v plane coverage in a 6-hour tracking synthesized observations (in an aperture synthesis observation of six hours duration) with the lowest levels of the *SLL*. Then, the *GA* was applied to the interferometric array. From the results (different results of u-v plane coverage) shown in this paper, the extended curved arms have better u-v coverage results than the extended *Y*-shaped. It also suppressed the *SLLs*. As such, the algorithm improves the number of overlapped samples, as the number of generations increases. Finally, the *DA* was applied to such an array. Calculated results in **Table 1** show that the *DA* method can sample the data more efficiency for the snapshot observation compared to the other configurations discussed in this paper.

Then, the GA and DA were applied to 10 antennas. Calculated results show that the DA can achieve the sampled data with the same efficiency as the GA for the snapshot observation. The calculated overlapped samples ratios for a 6-hour tracking are discussed. It is shown that the DA improves the overlapped samples ratio more efficiently than the GA for a 6-hour tracking observation.

Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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