Side lobe reduction of Micro strip array antenna based on modified Differential Evaluation Algorithm

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Abstract: Microstrip antenna arrays play important role in RADAR applications because of their light weight, tiny structure, easy and mass production. While designing the RADAR antennas side lobe level is the significant parameter in majority of applications to avoid false targets. In the present work microstrip antenna array considered for low SLL without effecting it's gain and bandwidth by providing effective amplitudes, phase and position in terms of standard evolutionary algorithm. Evolutionary algorithms are used to provide an effective amplitude to individual antenna elements. For a microstrip antenna array DE algorithm was applied and side lobe level obtained up to -20.12dB.

Keywords: Microstrip array, Sidelobe reduction.

Introduction:

Over the last decade microstrip antenna array in RADAR applications playing vital role, it provides wide band width, easy feeding, dual and circular polarization, polarization agility, adaptability. Above features made microstrip antennas more familiar in satellite communications, RADAR applications, medical applications. For large array antennas side lobe level is an unfortunate parameter which degrades the performance of the device. Side lobes are transmitted energy outside to that of major beam direction. In the present work side lobes are reduced based on the amplitude weights that are provided to the individual microstrp antenna. In the antenna array synthesis process to get desired radiation pattern assigning an effective vector weights plays vital role. Desperate numerical techniques have been developed to fulfil above challenges.

Microstrip antenna array design:

The performance of microstrip antenna increases based on the count of patch elements which placed on the substrate.

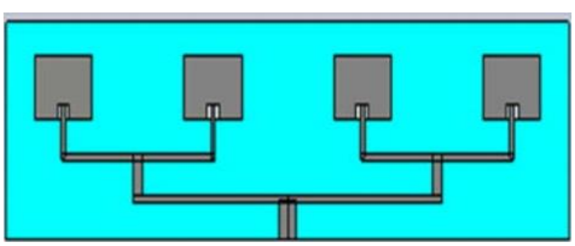

Fig 1: Microstrip antenna array

Rectangular micro strip patch antenna designed based on following equations :

Free Space Wavelength: $\lambda_0 = \frac{C_0}{f_0}$ (4)

where 'C_0' represents velocity of light in vacuum and the resonant frequency represented by f_0

Patch Width given as : $W_p = \frac{C_0}{2f_0}\sqrt{\frac{2}{(1+\varepsilon_r)}}$ (5)

Effective Dielectric constant : $\varepsilon_{eff} = \frac{\varepsilon_r+1}{2} + \frac{\varepsilon_r-1}{2}\left[1 + 12\frac{T}{W_p}\right]^{\frac{-1}{2}}$ (6)

Extra Length of the Patch due to fringing: $\Delta L_p = 0.412h\frac{(\varepsilon_{eff} + 0.3)\left(\frac{W_p}{T}+0.264\right)}{(\varepsilon_{eff} - 0.258)\left(\frac{W_p}{T}+0.8\right)}$ (7)

Length of the Patch: $L_p = \frac{C_0}{2f_0\sqrt{\varepsilon_{eff}}} - 2\Delta L_p$ (8)

Impedance of the Patch: $Z_p = 90\frac{{\varepsilon_r}^2}{\varepsilon_r-1}\left(\frac{L_p}{W_p}\right)^2$ (9)

Ground Plate width : $W_g = W_p + 6T$ (10)

Ground plate length : $L_g = L_p + 6T$ (11)

Feed position (X_f,Y_f): $Z_0 = \sqrt{50 * Z_p}$ (12)

$$Y_0 = \frac{1}{\pi}\cos^{-1}\sqrt{\frac{50}{Z_0}}$$

$$Y_f = Y_0 - \Delta L_p$$

$$X_f = \frac{W_p}{2}$$

Array factor of micro strip antenna given as

$$AF = \frac{\sin(N\pi d_x(u-u_0))}{\sin(\pi d_x(u-u_0))} \tag{13}$$

Validating the results using 3D Electromagnetic field solver CST

In this work, we have optimized the amplitude excitations of the 10 element isotropic antenna array using the proposed MDE to suppress the SLL and to place the nulls at 129^0 and 142^0.Figure 2 represents the microstrip patch antenna at operating frequency of 2.27GHz. Figure 3 represents reflection coefficient (S11) of the patch antenna. S11 of -37dB level has observed. Figure 4 represents radiation pattern of the patch antenna at 2.27GHz. Thereafter the performance of antenna increased in terms of multiple element array at a frequency of 2.27GHz which is in figure 5. Reflection coefficient of all the antenna elements in the antenna array shown in figure 6 which is almost -38dB. Fiure 7 represents the 3D-Radiation pattern of the 10 element uniformly illuminated Microstrip patch antenna array (UIMPAA). Figure 8 represents the radiation pattern of the 10 element Microstrip patch antenna array with MDE amplitude optimized.

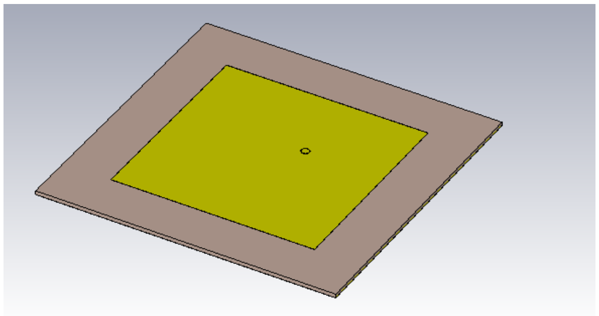

Figure. 2. Single patch antenna operating 2.27GHz.

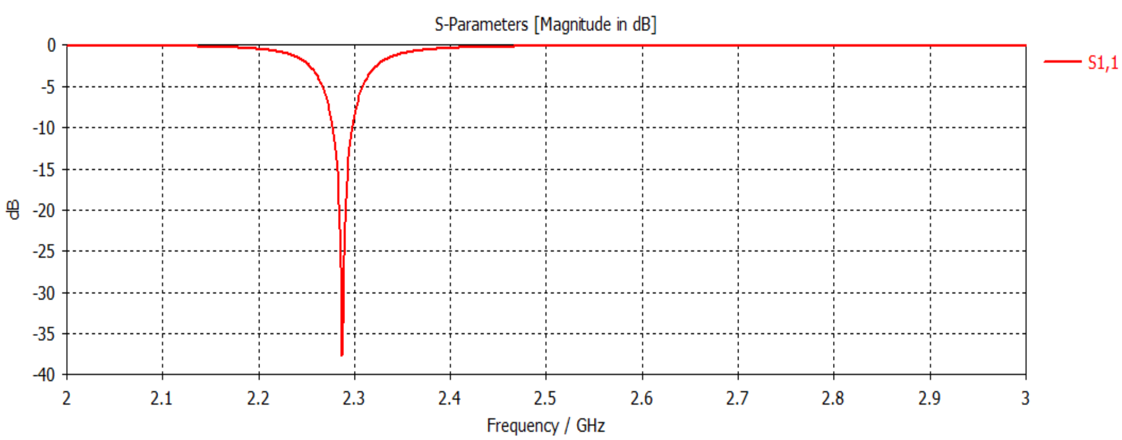

Figure 3. Reflection coefficient (S11) of the patch antenna. S11 of -37dB level has observed.

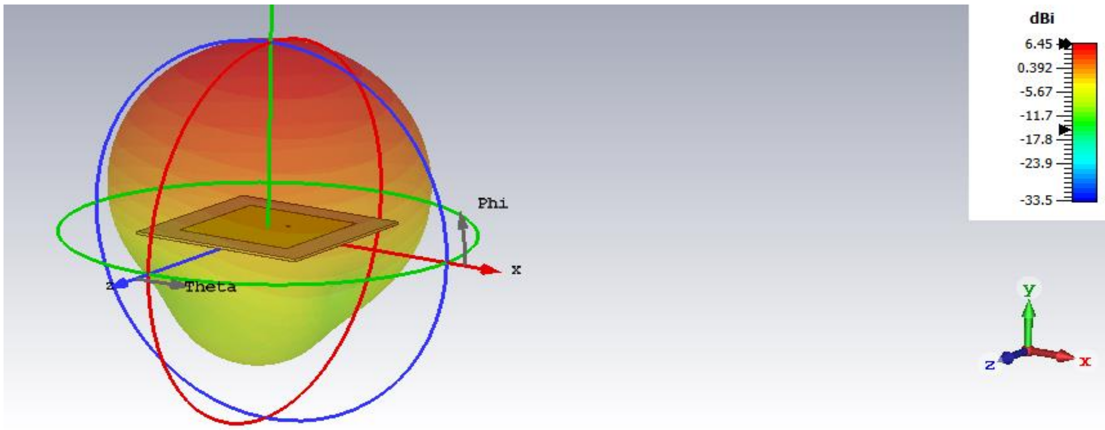

Figure 4. Radiation pattern of the patch antenna at 2.27GHz

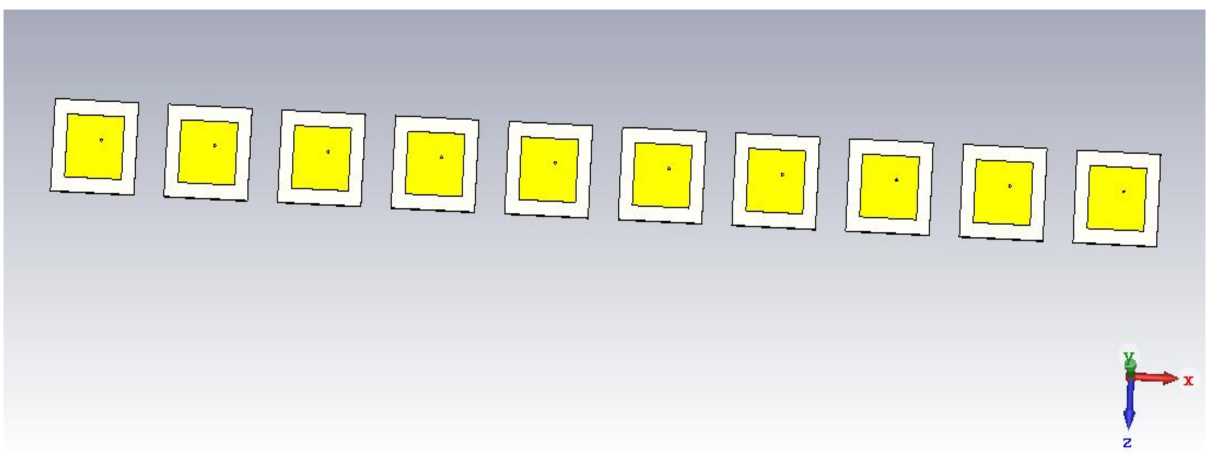

Figure 5. Structure of the 10 element microstrip patch antenna array at 2.27GHz

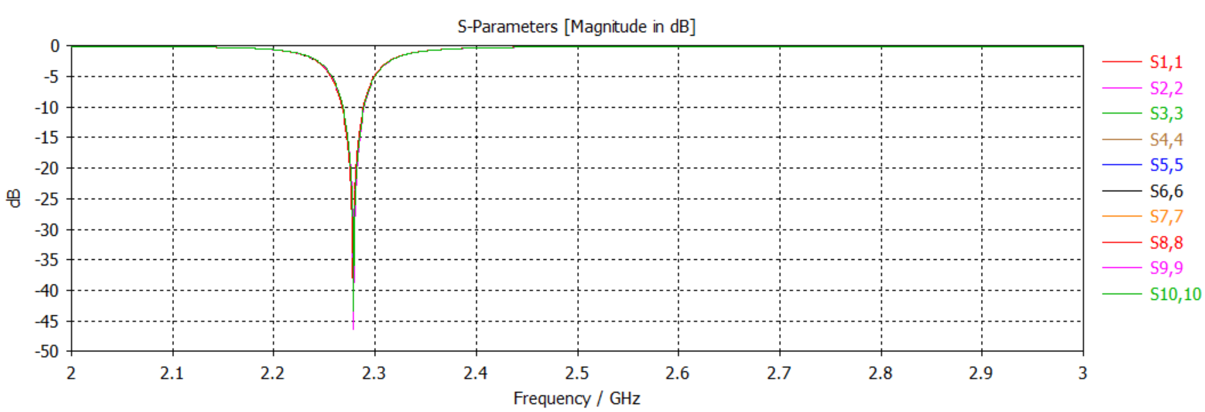

Figure 6. Reflection coefficient of all the antenna elements in the antenna array.

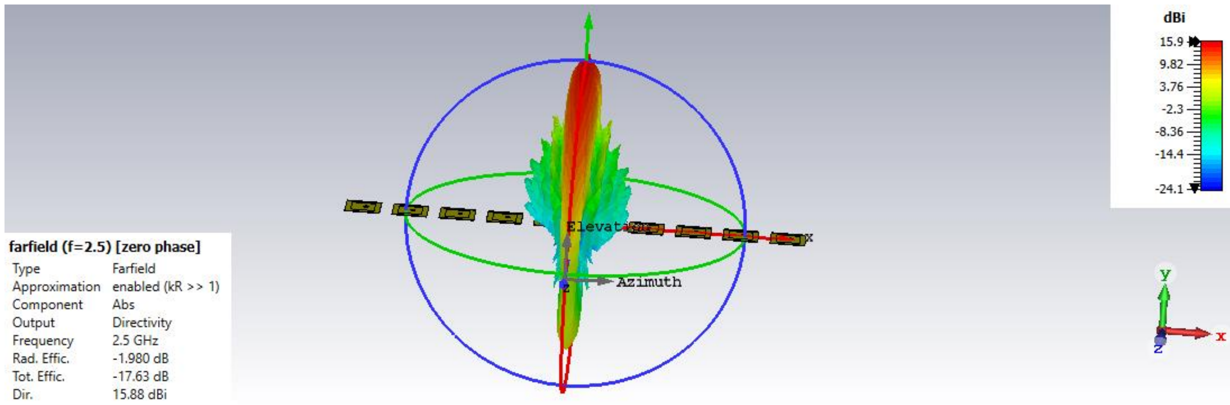

Figure 7. 3D-Radiation pattern of the 10 element uniformly illuminated Microstrip patch antenna array (UIMPAA)

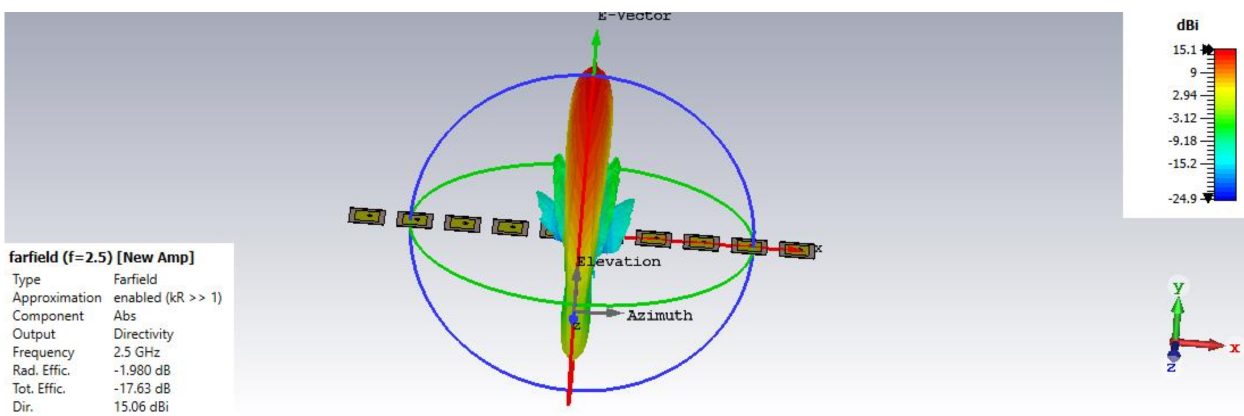

Figure 8. 3D-Radiation pattern of the 10 element MDE amplitude optimized Microstrip patch antenna array (MDE-AMP-MPAA)

The optimized amplitude values obtained using MATLAB simulation those are given at Table 1 for the 10 element antenna array.

Table 1. Optimized amplitude excitations using MDE

0.0532	0.0431	0.1407	0.2163	0.2631	0.2670	0.2523	0.3062	0.2352	0.1644

Microstrip antenna simulated with equal amplitudes and MDE optimized amplitudes using 3D electromagnetic field solver CST.

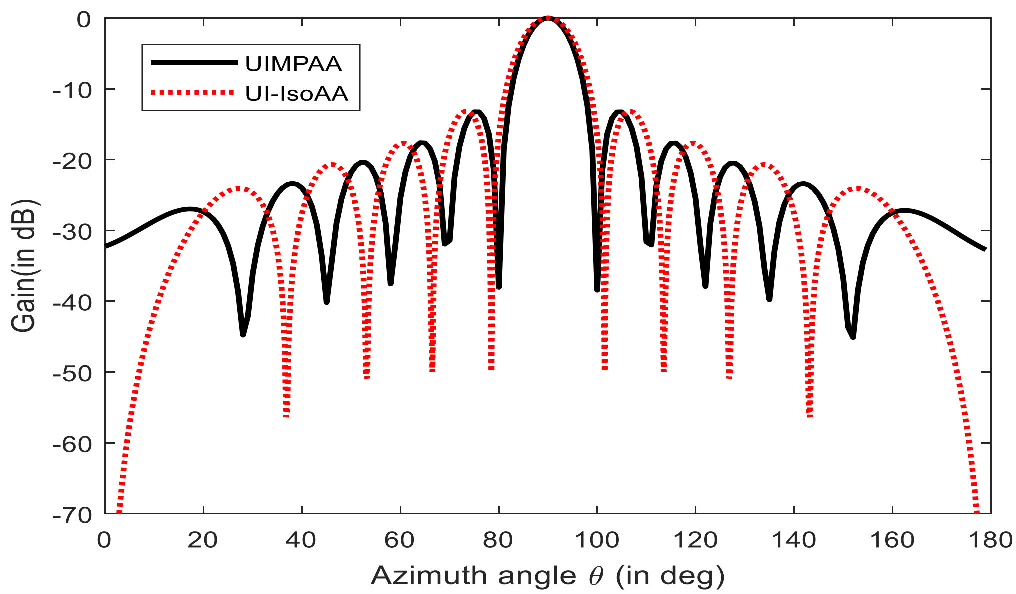

Figure 9. Radiation patterns of uniformly illuminated 10 element microstrip patch antenna array (UIMPAA) and uniformly illuminated isotropic antenna array (UI-IsoAA).

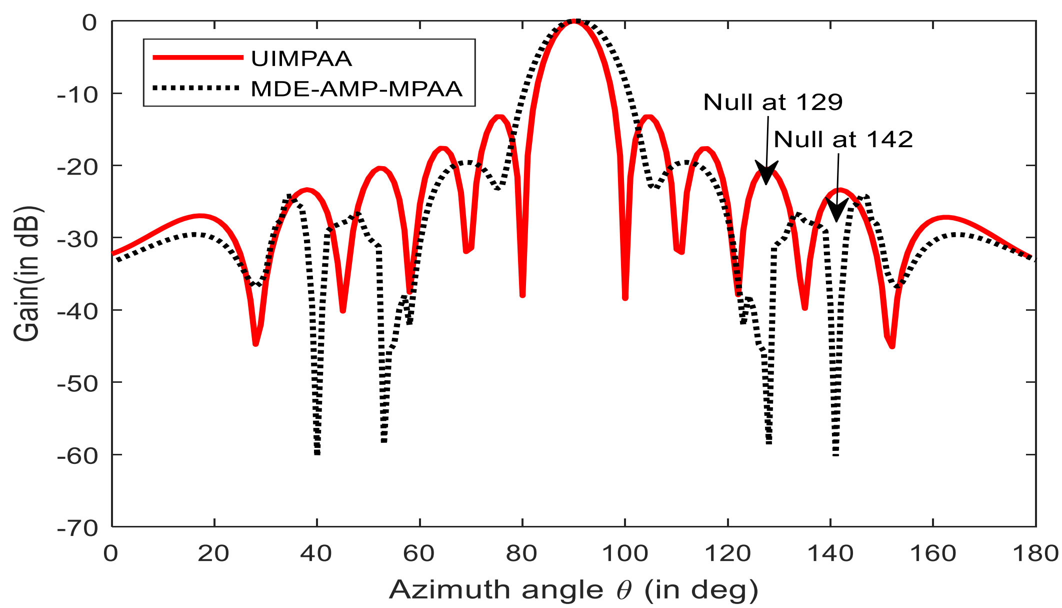

Figure 10. Radiation patterns of uniformly illuminated 10 element microstrip patch antenna array (UIMPAA) and proposed MDE amplitude optimized Microstrip patch antenna array (MDE-AMP-MPAA).

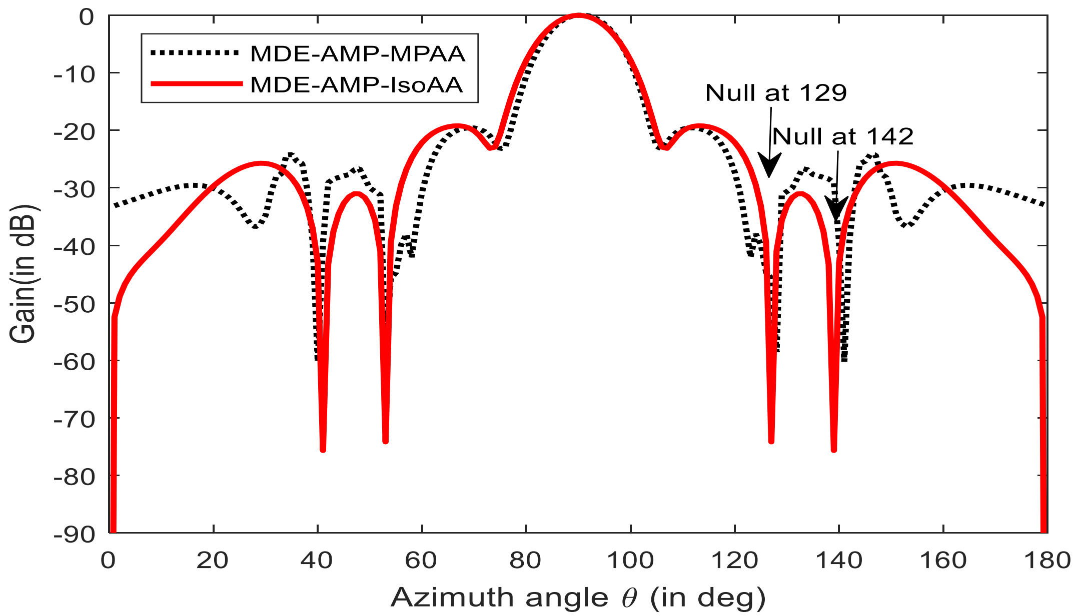

Figure 11. Radiation patterns of MDE amplitude optimized isotropic antenna array (MDE-AMP-IsoAA) and proposed MDE amplitude optimized Microstrip patch antenna array (MDE-AMP-MPAA).

The proposed algorithm successfully suppressed the SLL and placed the nulls in the desired directions. Figure 9 represents Radiation patterns of uniformly illuminated 10 element microstrip patch antenna array (UIMPAA) and uniformly illuminated isotropic antenna array (UI-IsoAA). Figure 10 represents Radiation patterns of uniformly illuminated 10 element microstrip patch antenna array (UIMPAA) and proposed MDE amplitude optimized Microstrip patch antenna array (MDE-AMP-MPAA). Here null are considered in the direction of 129^0 and 142^0 with PSLL is of -20.12 for Matlab and -20.20 for CST observed. The CST simulated results are matched with Matlab simulated results. The proposed MDE optimized amplitude also works well in the real environment. But, all the simulations performed on isotropic antenna array using Matlab. In general, isotropic antenna will not exist. So, in order to validate the results in real scenario, we consider the real antenna element call microstrip patch antenna as the antenna element in the antenna array instead of isotropic antenna.

Table 2. Antenna array properties (Both for isotropic and microstrip antennas)

S. No.	Type	Software	PSLL (in dB)	Null at 129^0	Null at 142^0
1	Uniformly illuminated **isotropic** antenna array	**Matlab**	-13.23	-21.07	-23.78
2	Uniformly illuminated **Microstrip patch** antenna array	**CST**	-13.12	-21.25	-24.36
3	**MDE** amplitude optimized **isotropic** antenna array	**Matlab**	-20.12	-70.53	-81.25
4	**MDE** amplitude optimized **Microstrippatch** antenna array	**CST**	-20.20	-60.2	-62.25

Conclusion: The proposed system introduces antenna array with reduced side lobe level, nulls at desired direction without effecting the major beam. The results are considered for both isotropic and micro strip antennas with MDE Amplitude optimized. This analysis and approach would be useful for largescale micro strip antenna arrays with required PSLL. Nulls placed along the direction of 129^0 and 142^0 and PSLL is of -20.20 obtained.

References:

1. C. A. Balanis, Antenna theory: Analysis and design, Wiley, Newyork, 1997.
2. A. Tennat, M. M. Dawoud, and A. P. Anderson, “Array Pattern Nulling by Element Position Perturbations using a Genetic Algorithm”, Electron. Lett., vol. 30, no. 3, pp. 174-176, Feb. 1994
3. W. P. Liao and F. L. Chu, “Antenna Pattern Nulling by Phase and Position Perturbations with the use of Genetic Algorithm”, Microwave Opt. Technological Letters, vol. 15, 1997, pp. 251-256.
4. L. Cen, Z. L. Yu,W. Ser, andW. Cen, “Linear aperiodic array synthesis using an improved genetic algorithm,” IEEE Trans. Antennas Propag., vol. 60, no. 2, pp. 895–902, Feb. 2012
5. Prasad rao, CD Raj, B Srinu,”Study On The Improvement Of Bandwidth Of A Rectangular Microstrip Patch Antenna”. International Journal of Control Theory and Applications, 2016, 9, 153-157
6. D Ghosh, Pappula L “Linear antenna array synthesis using cat swarm optimization,” AEU-International Journal of Electronics and Communications, vol. 68, pp. 540-549, Jun 2014.
7. Lin, C., A.-Y. Qing, and Q.-Y. Feng, “Synthesis of unequally spaced antenna arrays by using differential evolution,” IEEE Transactions on Antennas and Propagation, Vol. 58, 2553-2561, 2010.
8. Prasad rao, CD Raj, B Srinu, “Synthesis of Aperiodic Antenna Array with Minimum Side lobe Levels Using Modified Differential Evolution”, International Journal of Innovative Technology and Exploring Engineering (IJITEE), 2019, 8, 218-224
9. Gong, W & Cai, Z. (2013). Differential evolution with ranking based mutation operators. IEEE Transactions on Systems Man and Cybernetics Part B- Cybernetics,43(6), 2066–2081
10. Wolfgang H. Kummer. Basic array theory. Proceedings of IEEE, 1992. p. 127-39.
11. CD Raj, B Srinu, “Bandwidth Enhancement of Rectangular Patch Antenna based on the Properties of Substrate. CIIT Digital Signal Processing, 2013, 5, 46-50.
12. Prasad rao, CD Raj, B Srinu,” Minimization of Side Lobe Level for Linear Antenna Arrays Using Improved Particle Swarm Optimization. International Journal of Pure and Applied Mathematics”, 2017, 117, 247-252