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Intelligent Antenna Array Systems for Modern Communication Networks

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Abstract

In last two decades, Smart Antenna Systems (SAS) as well as Multiple Input Multiple Output (MIMO) systems have emerged as strong and efficient contenders for 5G wireless communication networks due to the advantages they may bring based on the improvements in transmission and reception of electromagnetic signals concerning omnidirectional antennas. Although a fair amount of academic software is previously available in this field, cross-use systems simulators do not utilize sufficient wireless system requirements to implement all requirements. Therefore, they do not provide the opportunity to emulate on the broadest lines where SAS or MIMO is more widely used. In this work, a new idea will be formed to improve MIMO 5th generation (5G) smart antenna using adaptive equalizer technology. This new proposal will appear distinctly and noticeably to improve the performance and efficiency of transmission and reception, in addition to its high sensitivity.

Keywords: 5G, Wireless Communication Networks, MIMO systems, SAS, Adaptive Equalizer Technology.

Introduction

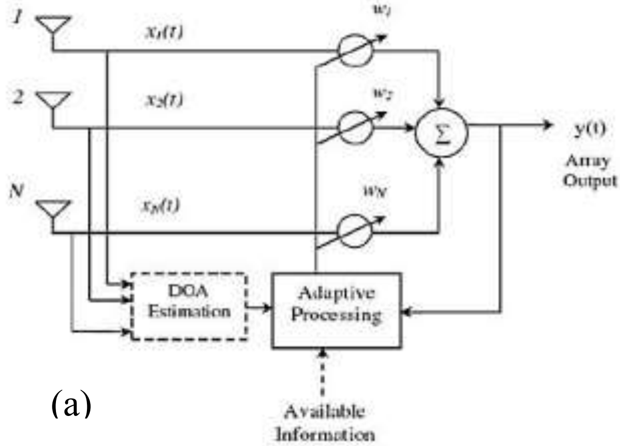
Through the beginning of telecommunications, regarding to the network hub physical layer [1], there are two principal sorts of receiving wire that might being utilized as a method for making a specific way of behaving upon omnidirectional antennas sending /receiving terminals that transmits as well collects similarly every which way, and directional antennas which can radiate in a particular course [2]. Omnidirectional methodologies might be straight and inconveniently way on phantom effectiveness of the plan, confining recurrence reuse [3]. Such constraints force plot originators and network organizers to foster continuously advanced and cost heals. In the present time, the prerequisites of broadcast radio antenna modern upon the q limit, quality, and inclusion of wireless plans have roused the improvement in the principal plan and job of the receiving wire in a wireless plan [4]. In unavoidable conditions, like mobile ad hoc network (MANET) or Wireless Sensor Networks (WSN), utilizing an omnidirectional methodology is difficult and a badly arranged method for making proficient plans, due to the high weight of force of network hubs that might bring about horrendous peculiarities like low battery exhaustion and obstruction [5]. A solitary radio wire may likewise be worked to have specific rigid particular communication and gathering bearings to augment its power utilization in a particular course rationing energy this method [6]. Utilizing directional receiving wire might lead to a few advantages, as far as decrease of parcel postponement or improvement of the in general steering process [7]. In telecommunications, when a solitary radio wire is used both to the transmission as well reception, the authors in [8] discussed the single information, single result (SISO) plans. In this way, nowadays, as to the most recent radio wire advances, the concept of shrewd receiving wire plans has spread [9]. SAS are canny plans furnished with high effectiveness information handling unit [10]. This kind of plans might support the inclusion region and the capacity of a radio correspondence plot [11]. The inclusion region is just the region where the correspondence connect among a cell phone with the receiver might be obtained [12]. The ability is an approach to estimating how much clients a plan might uphold in specific region [13]. A brilliant radio wire structure for the most part consolidates a radio antenna exhibit with an advanced transmission handling ability to transmitting and receiving in an adaptive, spatial path [14]. Just, such a design might rapidly change the directionality of its radiation designs because of its current circumstance [15].

Such think might impressively expand the presentation qualities (like limit) of a wireless construction [16]. The action of SAS in cellular phones conditions permits a considerably further solid channel usage concerning the old-style omnidirectional methodology [17]. For example, Spatial Division Multiple Accessing (SDMA) endeavors to raise the limit of a design [18]. For the most part, brilliant antenna wires get towards three significant classes: single info, numerous results (SIMO), different information, single result (MISO), and various information and different (MIMO) result. In SIMO innovation, single radio antenna is utilized at the origin, and at least two antenna units are utilized at the objective [19]. In MISO innovation, a few antenna units are utilized at the transmitting end, as well single receiving antenna is applied at the objective. In MIMO innovation, various antennas are utilized at each origin and objective [20]. In the SISO situation, either the transmission or the reception involves a solitary radio antenna for the correspondence cycle; whereas in the MIMO, a relieving wire exhibit is utilized. In writing, it has been exhibited how the utilization of directional antennas and the latest smart antenna structures (SAS) innovation is able to do altogether permitting excellent of administration (QoS) necessities notwithstanding the omnidirectional designs that predict restricted functionalities [8].

In any case, these arrangements are probably not going to fulfill the prerequisites for 5G telecommunication structures innovation. With such reason, the enormous MIMO innovation has been suggested as proficient answer for fulfilling the necessities for 5G which positively incorporate extremely high radio antenna gain and exceptionally high data rate to accomplish tremendous plan execution [10]. The term gigantic, implies that this sort of plans utilizes countless radio antenna components (no less than 50 antennas) in the equipment architecture; for sure, connecting with the advanced wireless networks, for accomplishing high correspondence benefits as far as throughput, we want for countless components that isn't under 70-80 antennas [11,12]. This is chiefly because of the path which, hypothetically, as the quantity of components improves, the general addition of the plan likewise increments, and truth be told, every single radio antenna component adds to upgrade the absolute increase. All the more explicitly, along the receiving wire exhibit hypothesis, it is realized that the general addition is impacted by the single component factor as well as the cluster variable, and this gain increments with the quantity of radio wire components. Quite possibly the most basic perspectives in telecommunication climate are addressed by the reality of utilizing an adequate network test system that might well copy and replicate a fitting real situation. Tragically, the majority of the current network test systems offer no help for directional and uneven interchanges, and in this manner for SAS and MIMO innovation. With such area, just an incredibly restricted measure of network test systems permits to imitate these extremely mind-boggling advancements. Sadly, in this issue, as to these network test systems, the expense of the permit permitting the terminal client to admittance to the 5G bundle modules might yield extravagant [13,14].

Design Methodology

In this Section, the suggested SAS adaptive Improved Affine Projection Signal Algorithm (IAPSA) model design methodology will be explained and discussed in details. In fact, for this study, we have nominated MATLAB2020b simulation program with m. files scripts codes to be the implementation environment for designing our suggested model. This software environment was chosen for its efficiency and superior ability to write and implement applied algorithms and equations easily and for it being rich in ready-made tools and functions that facilitate many calculations for various engineering applications. Moreover, the MATLAB environment is characterized by powerful presentation, drawing tools, and downloading diagrams easily and with high resolution. The block diagram of the SAS suggested model to be simulated in this study is presented in Fig. 1.



(a)

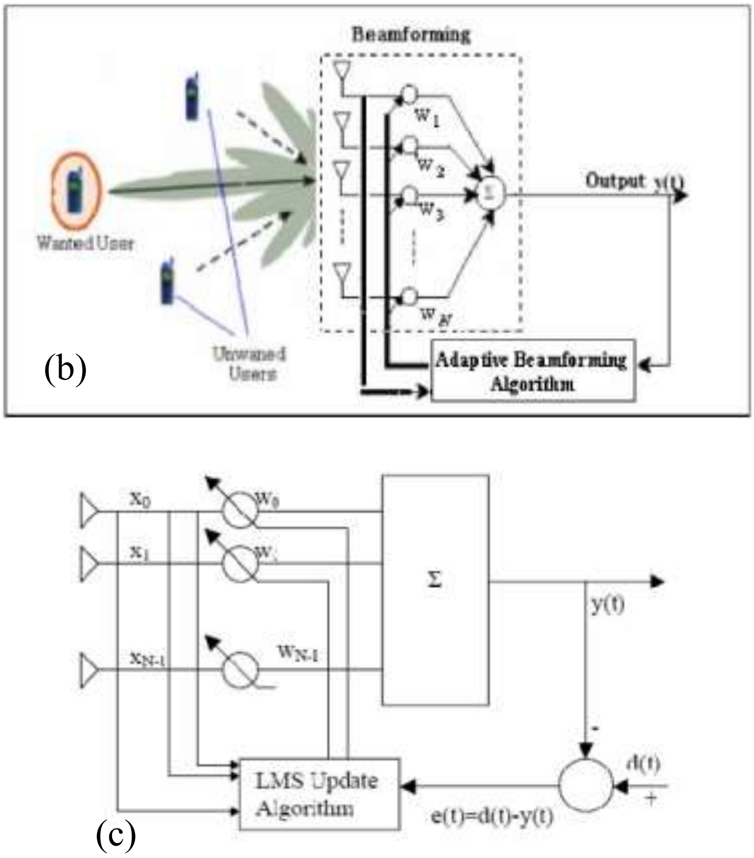


Figure 1: The block diagram of the SAS suggested model to be simulated in this study, (a) General scheme, (b) Beamforming scheme, (c) Detailed adaptive scheme.

As presented from Fig. 1, the suggested smart antenna model will consist of several antenna arrays connected to varying weights elements which are controlled by the nominated adaptive digital Improved Affine Projection Signal Algorithm (IAPSA) algorithm. The varying weights will change their values according to the instructions coming from the adaptive IAPAS algorithm, which will adjust these weights according to the resulting error signal obtained by finding the difference between the received SAS signal and the desired signal. Also, the flow chart of the suggested adaptive SAS model implemented in this study is shown in Fig. 2.

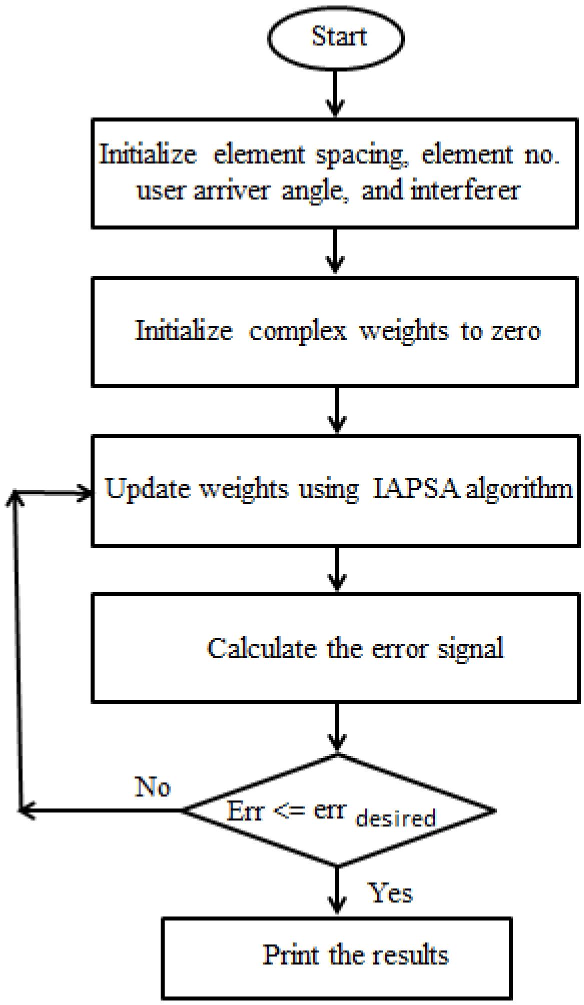


Figure 2: The flow chart of the suggested SAS model implemented in this study.

As we could recognize from Figure 2, that the program starts by setting the spacing of the elements, and determining the element number of the designed adaptive SAS. Next, the program will adjust the user's access angle, and the expected overlap. After that, we move to the next stage through initializing the adaptive algorithm complex weights to zero, and then updating these weights using the recommended IAPSA algorithm. This will be followed by a process of error signal calculation, error checking, and at last printing the results. Moreover, and to simulate the suggested adaptive smart antenna model designed based on the adaptive IAPSA algorithm and tested using the design parameters shown in Table 1.

Table 1: The design parameters of the adaptive SAS model.

Center Frequency	f_c = 2.670 GHz
Dielectric Constant	e_r = 4.2
The sub-strait Height of	h = 1.524 mm
Micro-strip width for 50 ohms	2.685 mm
Micro-strip width for 100 ohms	0.565 mm
Length of antenna patch L = c/(2*fc*sqrt(e_r)) m	L = 0.02560 m
Width of antenna patch	W =0 .03 m
Length of ground plane	L_g = 0.045 m

The Simulation Results

By implementing the programs of the proposed model of the our work idea for the smart antenna, Fig. 3 shows the printed circuit board design form for the proposed smart antenna.

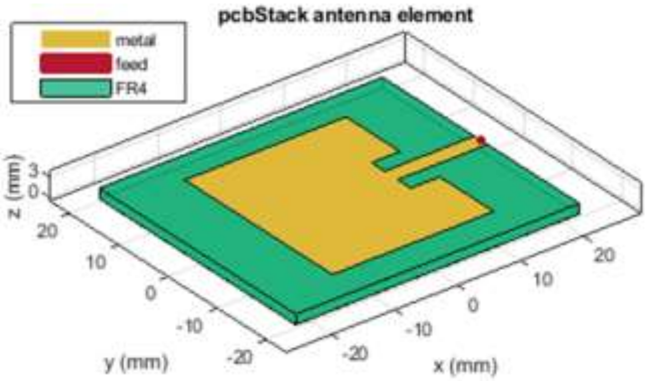


Figure 3: The simulated printed circuit board (PCB) design form for the proposed smart antenna.

By looking at Fig. 3, we notice the design details of the proposed smart antenna, which appear to have dimensions of 40 mm in length and width, with 3 mm in thickness. The resulting figure also shows the details of the physical composition of the alloy that makes up the antenna, which contains the conductive material feeding the transmitted and received signal, shown in red, in addition to the area of the transmitted and received electromagnetic radiation FR4, shown in yellow, in addition to the area of the insulating material for the smart antenna alloy, shown in green. Fig. 4 also shows the results of the obtained electromagnetic field radiation pattern for the proposed smart antenna.

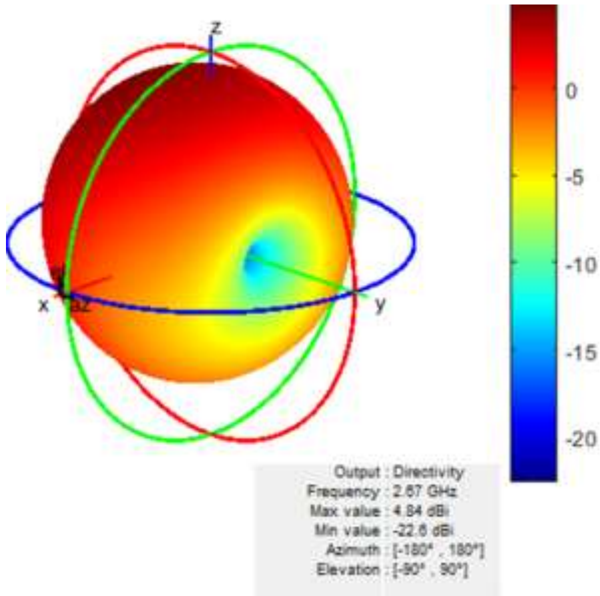


Figure 4: The results of the obtained electromagnetic field radiation pattern for the proposed smart antenna

By considering the results appeared in Fig. 4, we could observe the behavior of the resulting electromagnetic field radiation pattern for the proposed smart antenna, which appears in three dimensions x, y, and z. The electromagnetic field radiation spreads unilaterally and in all directions, where the direction is distributed and not specific to a specific direction. Also, the resulting operating frequency of the smart antenna has been presented with 2.67 GHz, with maximum gain of 4.84dBi with minimum value of -22.6dBi with azimuth angle of (-180^o, to 180^o) and evolution angle od (-90^o, to 90^o). After that, the design impedance and reactance curves of the smart antenna simulation model were extracted with operating frequencies, as shown in Fig. 5.

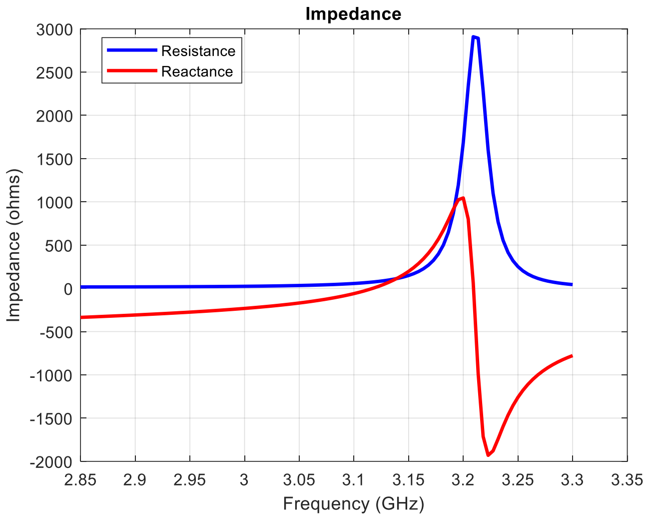


Figure 5: The extracted design impedance and reactance curves of the smart antenna simulation model with operating frequencies.

By viewing the results of Fig. 5, we might conclude that the results of the SAS section for the future behavior of the reactance or permittivity values of the proposed smart antenna model, which appeared in red, also appear "almost linear and constant" with the operating frequencies of the designed smart antenna model, but with negative values. Starting from 300 ohms at working frequencies with non-linear changes at high frequencies. On the other hand, we note that the resulting resistance values of the proposed smart antenna simulation model remain stable, approaching 0 ohms along the operating frequency range, which indicates confirmation of the successful operation of the antenna as it is free of losses for the receiving part. In fact, as it is well known that, in electronic circuits, negative resistance refers to the relationship in which the voltage across a circuit element is inversely proportional to the current passing through it. This means that the higher the applied voltage, the lower the current. Also, Fig. 6 shows the response results of the proposed smart antenna model with the operating frequencies of the transmitting and receiving parts.

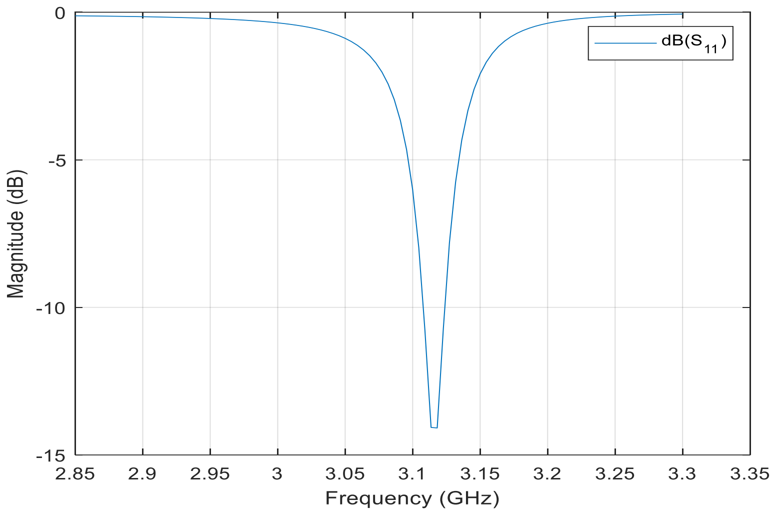
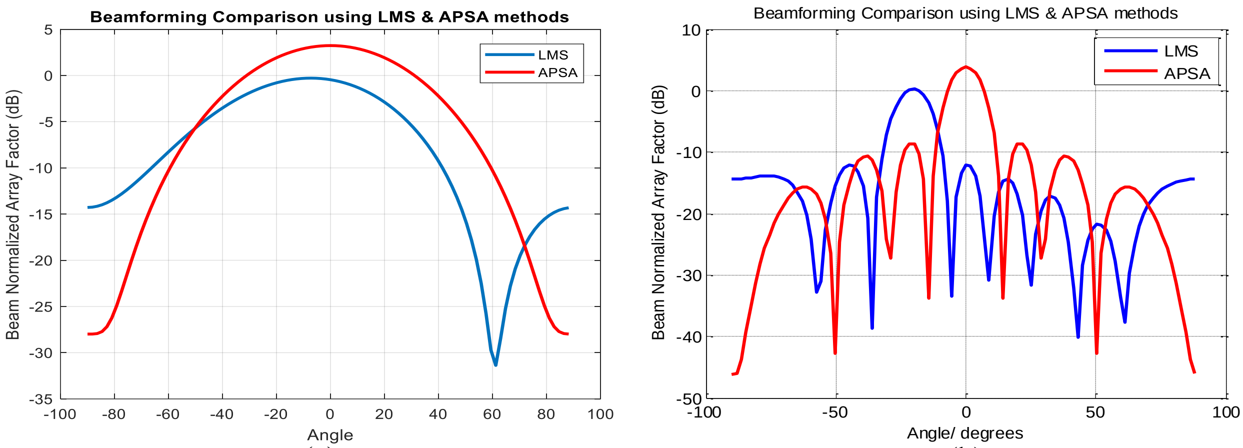


Figure 6: The response results of the proposed smart antenna model with the operating frequencies

By reviewing and referring to Fig. 6, we could observe the results of the capacitive response of the spectrum of the proposed antenna model, which appear in a smooth manner with the range of operating frequencies for the transmitting and receiving sides of the antenna model. Moreover, the normalized beam Array Factor (AF) in dB versus Angle-Of-Arrival (AOA) is plotted in Fig. 7 for the Least Mean Square (LMS) and APSA adaptation algorithms for initial comparison.



(a) (b)

Figure 7: Results of the normalized beam Array Factor (AF) against the AOA using LMS and APSA adaptive algorithms, (a) Ne=2, (b) Ne=16.

By following the results of Fig. 7, above, we can analyze the results of the standard beam Array Factor (AF) versus AOA using the LMS and APSA adaptation algorithms, for different values of antenna element numbers, Ne. We see that the response of the standard beam Array Factor (AF) appears in the form of a wide-range curve with the arrival angle AOA and is centered at a value of 0 degrees when the number of elements is 2, while you notice that the response of the standard beam Array Factor (AF) appears in the form of narrow oscillating curves around an angle of 0 degrees with increasing the number of elements to 16. We conclude from this, that the efficiency of the response of the transmitted and received radiation matrix of the proposed smart antenna model improves with increasing the number of antenna elements. Furthermore, for initial testing and settling of the Finite Impulse Response (FIR) filter coefficients, the Mean Square Error (MSE) of the proposed adaptive smart antenna scheme has been plotted in Fig. 8 for LMS and APSA adaptive algorithms with Ne=2.

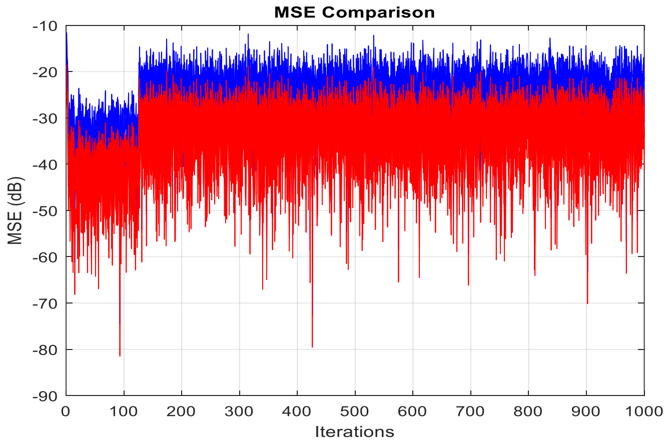


Figure 8: The initial testing and settling of the FIR filter coefficients, the MSE of the proposed adaptive smart antenna scheme has been plotted in for LMS and APSA adaptive algorithms with Ne=2.

By looking at Fig. 8 above, we might conclude that the Mean Square Error (MSE) rate resulting from the simulation of the smart adaptive antenna model shows values of -50 dB. These results are very good as compared with the MSE rate values for the rest of the adaptive SAS types, which appear at a rate of -30 dB, that is, an improvement of 20 dB, which indicates enhancement in the efficiency results of the proposed antenna model. Moreover, the resulting simulated adaptive FIR filter weights have been obtained for our suggested adaptive SAS model and the LMS type as shown in Fig. 9.

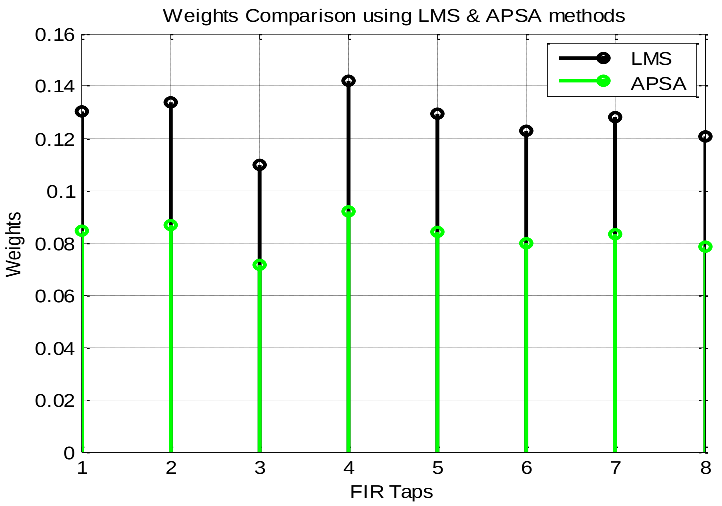


Figure 9: The resulting simulated adaptive FIR filter for our suggested adaptive IAPSA model and the LMS type.

By looking at Fig. 9 above, we could observe that the results of the weights achieved for the FIR digital filter used to filter the received antenna signals show lower and precise values for the proposed adaptive smart antenna model using the IAPSA technology as compared to other technologies such as LMS, which indicates an improvement in the efficiency results of the proposed antenna model.

Conclusion

In this work, the model of multiple and single smart antennas as well as the techniques used in the data transmission process was studied, experimented and simulated. Adaptive smart antennas were chosen for their efficiency in transmitting and receiving the electromagnetic signals used to transmit data that have been extensively studied. The characteristics of adaptive filters with different adaptive techniques were compared in terms of convergence speed, stability, steady-state error rate, and computational complexity. It has been demonstrated that the smart antennas proposed using IAPSA techniques provide better results than other adaptive algorithms. The simulation results showed a better response to the proposed model in terms of field pattern, MSE, energy saving and efficiency.

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