Proposed Method of Antenna Array for Receiving Signals from Satellite Mobile Communication

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Abstract:- There are many researches which study a design of antenna used in mobile communication. Adaptive arrays are expected to improve the performance of future wireless communication systems. The proposed reception system from mobile Satellite for handsets is an adaptive antenna system with a half wave and a loop antenna. The proposed adaptive antenna array is capable of improving the quality of the service of wireless systems through the ability to steer the radiation pattern in the direction of a desired signal source and to receive signals at a constant level despite the variations in the elevation angle and the attitude of the mobile satellite station. Antenna system was tested in the libratory and the result showed a good agreement between the simulation and measurements. By using the field strength meter (FSM) and for different distances from (3-33) cm, antenna system showed good performance in receiving signals from a moving satellite. The received signal is 4.3 dB more in the direction vertical to the antenna system access.

Keywords – Antennas, Antenna array, Half wave dipole, Loop antenna.

1. Introduction

In mobile satellite communications it is desirable to receive signals at a constant level despite the variations in the elevation angle and the attitude of the mobile station. Consequently, wide angle circular polarization characteristics are required for the antenna element [1]. Although the world uses geostationary orbit satellite (GEO) to receive digital communication in specific spots on the earth, but now the situation has been changed by using new systems to communicate in low earth orbit (LEO) satellites like Iridium system which uses 66 satellites in different polar orbits.

The distance to LEO from the earth surface is much smaller than to the GEO. This allows using a low level of transmitting power. Hence, real time voice communications can be achieved via a small size handheld phone.

The situation for LEO satellite systems is more critical in terms of multipath than for a GEO satellite. This is because there is a higher probability of signal blockage or fading when LEO satellite systems operate at low elevation angles.

In Iridium system, there is the provision of 16, 5 dB link margin to compensate for the losses due to fading [2], but this margin is smaller compared to terrestrial system (30dB). The small link margin will cause high call dropping rate. In the case of LEO systems, it is not unusual due to fading and human body effect. In addition LEO satellite base stations are moving at high speed all the time and the exact positions of an operator and a handset are impossible to know or predict. The changing environment (including human body influence) degrades the quality of a reception system.

To solve this problem we must use adaptive antenna array which is capable of improving the quality of the service of wireless systems through the ability to steer the radiation pattern in the direction of a desired signal source, by changing number of elements in antenna array and angle of beam steering [3].

The phases and amplitudes of the currents exciting the elements determine the gain of the array in a certain direction [4]. In order to better estimating a signal arriving from a particular direction, the phases and amplitudes of the currents on the antenna array elements can be electronically adjusted so that received signals from this direction add in phase, and maximum gain is achieved in that direction. Due to the reciprocal nature of antennas, this approach is also applicable to focus the array beam for transmission.

For low mutual coupling, antennas must be far away from each other. As the distance between two antennas is decreased, the mutual coupling is increased and the radiation efficiency of each antenna is rapidly degraded. To overcome this problem the space (distance) between two antennas must be chosen equal to half wave length. The work shows a design of an array of antennas showing improvements in radiation pattern, return loss, and good performance in receiving signals from moving satellite.

Section 2 of this research will propose an antenna array design to work as array of transmitting-receiving antennas. Section 3 proposes a **s**imulation and results of the work of the antennas. Section 4 shows the analysis of using antennas to enhance the performance of antenna array.

2. Design and Structure

The antenna array under consideration consists of two antennas the first one is small loop antenna and the other is half wave dipole. The radiation of each antenna is shown in Fig. 1.

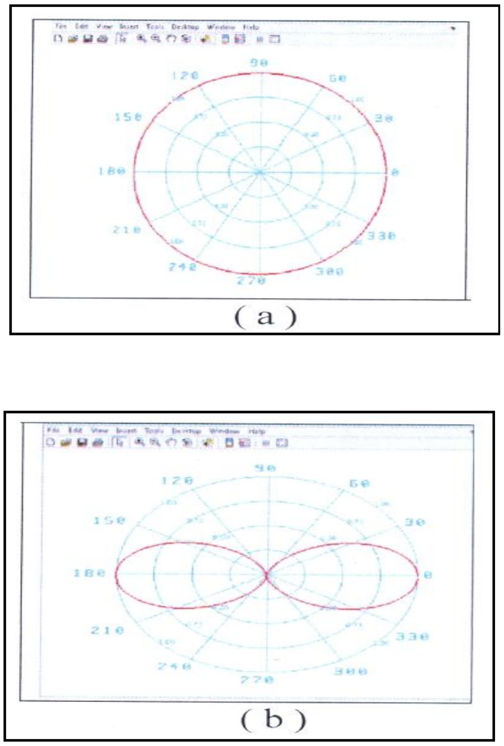

Figure 1: horizontal polar diagram of (a) vertical half dipole (b) square small loop antenna.

The power-combiner/divider network was used which is connected to the feed point of every antenna. The adjustment can be performed directly by phase shifters and attenuators after linear down-conversion and analog to digital conversion by a DSP. The ratio of the array-parameter and the wavelength d/λ is crucial for optimal results. The horizontal pattern is a circle; with an increasing ratio d/λ. The gain of the array increases also. For $d/\lambda > 1$ the side lobe level is growing at the cost of the main lobe. With increasing d/λ the number of side lobes (and nulls) and the energy radiating into unwanted directions are increasing. The optimum region for obtaining maximum gain, high side lobe attenuation and/or an unambiguous null is [5]:

$$\frac{1}{2} \leq \frac{\square}{\lambda} \leq \frac{3}{2} \qquad (1)$$

Within this region it is possible to better adjust every azimuth angle of the beam with side lobe attenuation, and to provide an unambiguous null [3].

The radiation pattern for small loop antenna is [3].

$$E_{\phi} = \frac{120\pi^2[I]\sin\theta}{r}\frac{A}{\lambda^2} \qquad (2)$$

Where;
I- the current passing the dipole,
θ-the angle to measuring point,
A-the area of the loop antenna (dipole),
r- the distance from dipole to measuring point, and
λ-wave length of the Electromagnetic waves.

The radiation pattern for half wave dipole is [3].

$$E_{\theta} = \frac{j60\pi[I]\sin\theta}{r}\frac{\ell}{\lambda} \qquad (3)$$

ℓ-the length of the half wave dipole

The size and price of a handset limit the number of elements that can be installed on it. Its size also limits the distance between the elements [4]. Therefore, only a small number of elements (e.g. two elements) can be used on a LEO Satellite transceiver [5] to get good results in the experimental measurements of signals from LEO Satellite communication.

The proposed reception system for LEO Satellite handset is an antenna system with an electric and magnetic field antenna [6]. The electric field and magnetic field antennas are separated in space by half the wavelength. In [7] the research used an electric field antenna and magnetic loop antenna at the same space coordinate to provide field component diversity.

3. Basic Description of LMS Algorithm

The LMS algorithm was first introduced by Widrow et al [8] and operates with a priori knowledge of the direction of arrival and the spectrum of the signal but with no knowledge of the noise and interference in the channel. This algorithm is useful when the interference contains some spectral correlation with the signal of interest.

The particular method that the LMS algorithm uses is known as the steepest decent technique. For this particular technique, the changes in the weight vector are made along the direction of the estimated gradient vector. The basic description of the LMS Algorithm is as follows [8]:

$$e(k) = r(k) - x^T(k)w(k) \qquad (4)$$

$$w(k+1) = w(k) + 2\mu e(k)x(k) \qquad (5)$$

Where;
e(k): Error signal between the reference signal and the desired output.
W(k): Weight vector before adaptation.
W(k+1): Weight vector after adaptation.
μ: Gain constant controlling rate of convergence and stability.

Here we can see that the LMS algorithm does not require squaring, averaging or differentiating and hence can be implemented in most practical systems [8]. Its popularity is accredited to the fact that it is simple, easy to compute and efficient. However, the drawback is that the weights for this algorithm take a long time to converge.

4. Simulation and Results

In the simulation, a two element adaptive antenna system is used and Least Mean Square (LMS) is utilised as the control algorithm of the adaptive antenna. The distance between the antennas is placed half the wavelength apart. Quadrature Phase Shift Keying (QPSK) modulation is used as in the Iridium communication system. Signals received by the two antennas are assumed to be uncorrelated. In this research simulation models, three signals are present: a Desired signal (D), and a significant interference signal (I1) [9]. I1 has the mean amplitude of 4dB (relative to the desired signal) and I2 has mean amplitude of 12dB (relative to the desired signal). The loop antenna and half wave dipole antennas were manufactured and tested to identify, their characteristics [10].

The resultant field pattern of the adaptive array antenna as shown in Fig.3 is equal to the vector product of an electric field for small loop antenna as in (2) by electric field for vertical dipole antennas as in (3) by using MATLAB programming.

The system of coordinates was introduced as follows: the origin is placed in the feeding point of the half wave antenna, the x-axis is directed along the radiator of the second element, and the z-axis is along the longitudinal axes of the array. To evaluate the directional characteristics of the array in vertical plane (E-plane) [6], we will use the system which is shown in Fig.3, and the receiving antennas directed along the vector i_φ

$$E_\varphi = -\frac{ik\eta}{4\pi}\frac{e^{-ikr}}{r}\sum_{n=1}^{N} I_0\, e^{ikz_n \cos\theta} \,.$$
$$.\int_{-l_n}^{l_n} \sin k(l_n - |x_n|)dx_n \qquad (6)$$

where (r,θ) are the coordinates of observation point, x_n is the longitudinal coordinate of the radiator, η - is free space impedance.

By analogy, to estimate the directional characteristics of the antenna in horizontal plane (H plane) we obtain:

$$E_\theta = -\frac{ik\eta}{4\pi}\frac{e^{-ikr}}{r}\cos\theta \sum_{n=1}^{N} e^{ikz_n \cos\theta}.$$

$$.\int_{-l_n}^{l_n} I_n(x) e^{ikx_n \cos\theta}\, dx_n \qquad (7)$$

To calculate the directional characteristics of the array we take advantage of theorem of multiplication of radiation patterns. Then, taking into account the phase shift between the elements of the two antennas, we obtain the following expression for the array:

$$E_{\sum} = e^{i(k(r_1+r_2)+\pi)} + e^{ik(r_1+r_1\ sin\theta} + \\ + e^{ik(r_2+(r_1+2r_2)sin\theta)} + \\ e^{i(k(r_1+r_2)+\pi+2k(r_1+r_2)sin\theta} \qquad (8)$$

The given result is derived under the assumption that the amplitudes of excitation currents in the elements of array are identical.

5. Experiment test

Experiment test is carried out at a laboratory by connecting small loop antenna and half wave dipole antennas to a matching impedance transformer. The transmitter is coupled directly to the antenna connector since the transmitted power is enough by antenna and impedance matching transformer will not play much roll in this case as shown in Fig.3.

We can only get the Field strength by the meter FSM. The degradation was made to show Field pattern of the array (both antennas working together).

At the beginning we got the measurement of the half wave dipole alone, the radiation we received as shown in Fig. 1 (b). That is suitable for omnidiaration antenna. When we added the Loop antenna and made the measurements for Field strength we got the Field pattern as shown in Fig. 2 [10].

The dead zone of radiation of half wave dipole is around θ=0° so there is no radiation. By adding the second dipole (loop antenna), we can compensate this disadvantages and we will have the best radiation in all directions so we can receive the signals from low orbit satellites for any position of the handset telephone. Besides, the radiation in the direction to the human who is using this telephone will be very low to protect the human from radiation.

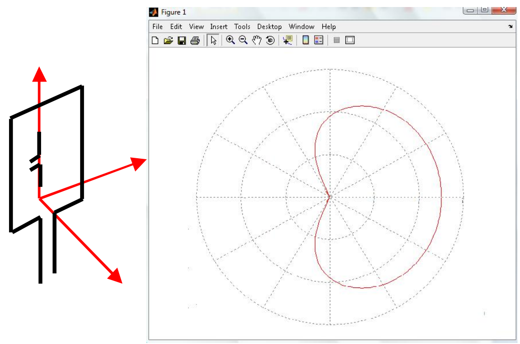

Figure2.The field pattern of adaptive array antenna

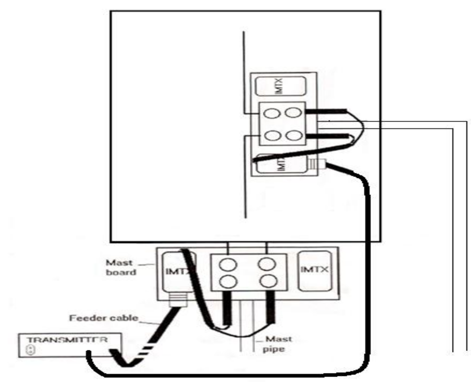

Figure3. Connection of experiment test

Connect feeder cable (BNC connector to transmitter's output socket and other RF to impedance matching transformer RF female connector). Switch on the transmitter and align field strength meter (FSM) antenna vertically with respect to transmitter antenna and note FSM the percentage reading.

Gradually move FSM away from two transmitter antenna. By step equal 3 cm circularly steps by 30 degrees and note (as in table 1) the reading of FSM that represent the field pattern diagram (Plot the graph of distance along X, Y-axis by reading of FSM) as shown in Fig. 3 [10].

In practice, these methods require a calibration algorithm to measure the errors and to correct them. Many such calibration methods have been proposed in the literature.

The horizontal polar diagram of a vertical dipole antenna is a circle, while the horizontal polar diagram of a square small loop antenna is a figure of eight as shown in Fig. 1. The forward radiation is 180 out of phase with back radiation when a vertical dipole antenna is placed behind a square loop antenna as shown in Fig. 2 [11].

6. Conclusion

In this paper, we have proposed a system for adaptively grouping array elements to get a simple design in order to receive the desirable signals at a constant level despite the variations in the elevation angle and the attitude of the mobile satellite station; reduce hardware costs with minimal compromise on capacity performance and achieve a good performance.

We were able to receive signals from a moving satellite with a minimum effect on the organism of the human body, low cost, and small size of antenna system. The received signal is 4.3 dB more in the direction vertical to the antenna system access.

Further it can be summarized that in satellite communication system, beam of adaptive antenna array by using LMS algorithm can be steered in direction of desired signal by changing number of elements in antenna array and angle of beam steering. It is proposed that maximum radiation may be received at an appropriate angle.

Table 1: FSM readings for two antennas

Φ / d	0 OR 360	30	60	90	110	120 to 240	250	270	300	330
3	**4.3**	4	3.8	3.7	3.5	0	3.5	3.7	3.8	4
6	**4.1**	4.2	3.6	3.5	3	0	3	3.5	3.6	4.2
9	**4**	4	3.3	3	1.5	0	1.5	3	3.3	4
12	**3.8**	3.5	3	2.5	.5	0	.5	2.5	3	3.5
15	**3.5**	3	2.5	2	0	0	0	2	2.5	3
18	**3**	2.5	2	1.5	0	0	0	1.5	2	2.5
21	**2.5**	2	1.5	1	0	0	0	1	1.5	2
24	**2**	1.5	1	.5	0	0	0	.5	1	1.5
27	**1.5**	1	.5	0	0	0	0	0	.5	1
30	**1**	.5	0	0	0	0	0	0	0	.5
33	**.1**	0	0	0	0	0	0	0	0	0

REFERENCES

[1] I. Ahmed, and W. F. Perger, "Effects of Ground on Antenna Mutual Impedance for DOA Estimation Using Dipole Arrays" Progress In Electromagnetics Research C, PIER C, Vol. 46, pp.179-185, 2014.

[2] Iridium media center http://www.iridium.com/english/1998.htm

[3] J.D. Kraus; Antennas for all applications. McGraw Hill. 2002.

[4] Y, Madhuri, B. Suresh. Design aspects of Phased Array antenna at L-band. International Journal of Engineering and advanced Technology (IJEAT) ISSN: 2249-8958 Vol.2. April 2013.

[5] M.J. Alevs. Marcelo Sampaio de Alencar, " A Linear Adaptive Antenna array with Random Spacing and Coupling Effects Journal of Microwaves", Optoelectronics and Electromagnetic Applications, Vol. 7, No. 1, June 2008.

[6] L.H Abderrahmane, New Optimization algorithm for planar Antenna Array synthesis, International Journal of Electronics and Communication AEU pp 752-757 , 2012.

[7] J. Berkebile and A. Alla, "A two Element Phased Array Antenna For Reducing Multipath Effects" Microwave Journal,pp.24-36, 1999.

[8] S. Kamboj, and R. Dahiya. "Adaptive Antenna Array for Satellite Communication Systems", Proceedings of the International Multi Conference of Engineers and Computer Scientists IMECS, Vol. II, pp.1491-1494, 2008.

[9] W.C Lee. "An Energy-Density Antenna for Independent Measurement Of the Electric and Magnetic Field" The Bell System Technical Journal, Vol. XLV pp. 1587-1599. 2009.

[10] C.A Balanis. "Antenna Theory Analysis and Design", John Wily & SONS, INC, 2005.

[11] Data sheet of field strength meter devise Experiments in (comm. Lab 2 Dept. of Electrical Engineering - University of Technology).