Proceedings of APCC2008 copyright © 2008 IEICE 08 SB 0083

Performance Enhancement of GPRS Transmission using Switched Beam Antennas at Mobile Station

P. Sriploy, M. Uthanskul and R. Wongsan
School of Telecommunication Engineering
Suranaree University of Technology
Muang, Nakhon Ratchasima, Thailand 30000
Email: m5040179@g.sut.ac.th, {mtp and rangsan}@sut.ac.th

***Abstract*- As the users call for the improvement of the datarate in GPRS system, so far an adaptive antenna implemented at Base Station is envisaged to be the solution. However, this concept introduces the problems of high expense and complexity. Alternatively, a switched beam antenna avoiding those impairments is worthwhile considering. Therefore, this paper investigates into the use of switched beam antenna compared with adaptive antenna in GPRS system. To achieve a fraction of expense, the implementation is considered at the Mobile Station instead. The simulation results reveal that employing the switched beam system provides higher performance in term of Carrier-to-Interference ratio and throughput, compared with adaptive antenna. The obtained results also confirm the advantages of switched beam antenna even though the system is situated in non-Line-of-Sight environment.**

Keywords: Antenna arrays; Array signal processing; Beam steering; Suited beam antenna

I. INTRODUCTION

The GSM (Global System for Mobile communication) was first developed in 1990 for a 900 MHz band all of Europe based on Time Division Multiple Access and Frequency Division Duplex (TDMA/FDD) scheme [1]. As its advantages, the GSM system has been applied to 2.5G (2.5 Generation) using TDMA standard, so called GPRS (General Packet Radio Service) [2]. The possible GPRS applications are such as web browsing, FTP, e-mail, telnet and video conference. The GPRS is "always on" access automatically instructed to tune to dedicated GPRS radio channel and particular Time Slots (TS). The GPRS system utilizes four different coding schemes to control the operating power. These coding schemes are CS-1, CS-2, CS-3 and CS-4 corresponding to the datarate of 9.05, 13.4, 15.6 and 21.4 kbps per TS respectively [3]. Because of the delay of implementation for full 3G TDMA standard and requirement of users to improve signal strength and throughput of GPRS system, a smart antenna has been envisaged to increase datarate and signal quality of the system.

A smart antenna is a system consisting of antenna arrays and signal processing unit. The processing unit is used to identify Direction of Arrival (DOA) of signal and track the main beam to the direction of desired signal. Also, it can steer nulls and sidelobes to interference directions when operating in the environment having rich interference signals [4]. The smart antenna system can be categorized into two types which are adaptive and switched beam antennas. The adaptive antenna can steer its main beam to desired direction. Additionally, side lobe or nulls are generated in the direction of interferers by adjusting or weighting received/transmitted signal. On the other hand, the switched beam antenna selects the maximum signal strength from the predefined beams of an antenna arrays. This system can also generate its main beam to the desired user but the directions of nulls and sidelobes cannot be adjusted according to the positions of interference.

The performance and discussion of smart antenna utilized in GSM systems has been presented in [5] and [6]. They have shown that the smart antenna is able to improve the signal strength and capacity of the system. However, those improvements are not promising for GPRS system because the data transfer capability of GPRS transmission can be indicated by Carrier-to-Interference ratio (C/I) and throughput. In recent years, the capacity and throughput of GPRS and Enhanced Datarates for GSM Evolution (EDGE) systems can be enhanced by implementing an adaptive antenna at Base Station (BS), [7] and [8]. Nonetheless, this is not practical as its implementation is complex and costly [9]. According to that reason, this paper considers implementing the antenna system at Mobile Station (MS) instead. Also, the work presented in [10] has revealed that adaptive antenna performs similarly to switched beam antenna when employing few antenna elements. Furthermore, they indicated that switch beam antenna outperforms adaptive antenna when the desired signal is not adequately higher than interferences. However, those works have not demonstrated the system performance in GPRS transmission. At this light, this paper investigates into the use of switched beam antenna compared with adaptive antenna on GPRS module at MS.

The remainder of this paper is organized as follows. Following introduction, a brief discussion of the adaptive and switched beam antennas is presented in section II. Also, the performance comparison of adaptive and switched beam antennas in term of beamforming capability is shown in this section. In section III, path loss model, fading and coding scheme of GPRS system are discussed. Afterward, the simulation parameters used in this paper are shown in section IV. In section V, the simulation results which demonstrate the performance of switched beam antenna compared with adaptive antenna are shown. To show the performance compared with existing antenna at MS of GPRS system, the

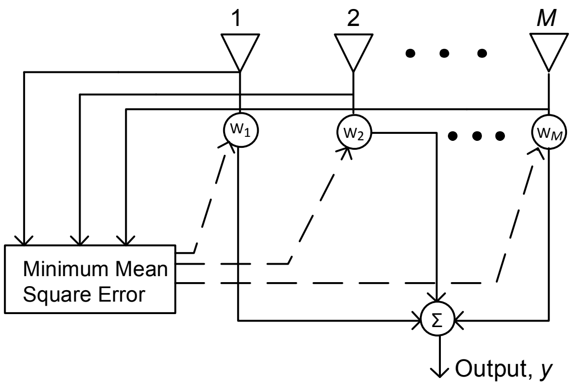

Figure 1. Adaptive antenna employing MMSE algorithm.

omnidirectional antenna is also assumed in this section. Finally, section VI concludes the paper.

II. SMART ANTENNA SYSTEM

Firstly, a smart antenna was introduced to use in Radio Detection and Ranging (RADAR) application. Recently, the smart antenna has gained more attention in wireless communications because it is able to reduce overall network interference leading to an increase in system quality. The smart antenna is constituted by antenna arrays and signal processing. It can be classified into two types which are adaptive and switched beam antennas.

The adaptive antenna has two major functions: beamforming and Direction-Of-Arrival (DOA) estimation. In this paper we focus on the beamforming performance. The beamforming is the process to direct the main beam to the desired users while pointing nulls and sidelobes to the interfering directions. This action is accomplished by applying complex weights to individual antenna elements in order to adjust amplitude and/or phase of the received signal, namely beamforming algorithm. Fig.1 shows the configuration of an adaptive antenna consisting M antenna elements which are usually spaced by half-wavelength of the operational frequency. From this figure, the optimum weighting coefficients are calculated using Minimum Mean Square Error (MMSE). The MMSE is one typical beamforming algorithm which attempts to minimize the difference between the array output and desired signal. The weight vector (**W**) calculated using this algorithm is expressed in (1).

$$\mathbf{W} = \mathbf{R}^{-1}\mathbf{p} \tag{1}$$

where **R** is the correlation matrix of the signals received from the array and **p** is the cross-correlation vector between the received and reference signal. Hence, the output signal can be given by (2)

$$y = \mathbf{W}\mathbf{x} \tag{2}$$

where **x** is the received signal vector.

For switched beam system, a number of beams are simultaneously produced. This can be done by multiplying the weighting coefficients to the signal received by array antennas. The typical beamforming network for this type of smart antenna is Butler matrix. Fig. 2 shows the configuration of the switched beam antenna constituted by M antenna elements. The beamformer is used to produce N beams from M antenna elements, and beam selector selects a particular beam having the maximum signal strength. As we can see, the switched beam antenna is not complex resulting in low expense for implementation.

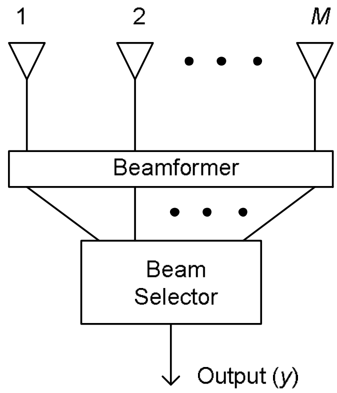

Figure 2. Configuration of switched beam antenna.

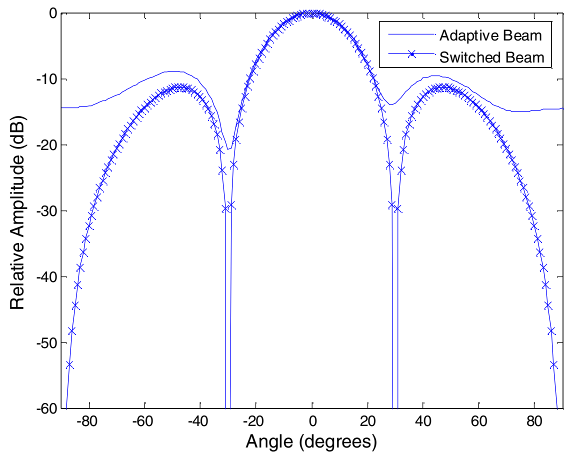

Figure 3. Radiation pattern of adaptive and switched beam antennas employing 4×1 array antenna.

Fig. 3 shows radiation patterns of adaptive and switched beam antennas when desired signal is coming from boresight direction and interference directions are 30° and -30°. As we can see, the switch beam antenna provides nulls depth deeper than adaptive antenna while the sidelobe levels are similar. This is because interference signal affects process of beamforming (weighting algorithm) for adaptive antenna while switched beam antenna needs only desired direction to perform beamforming. However, further investigation indicates that adaptive antenna needs more antenna elements to provide deeper null depth in this situation.

III. GPRS TRANSMISSION

Use The GPRS was designed for GSM system which operates in the 900 MHz band, 890 – 915 MHz in Uplink Channel and 935 – 960 MHz in Downlink Channel. The separation of carriers is 45 MHz or 3 TS. Each carrier is

TABLE I
CODING SCHEME FOR POWER CONTROL IN GPRS TRANSMISSION [3].

Coding Scheme	**Minimum C/I for Coding Scheme (dB)**	**Datarate (kbps)**
CS -1	less than 7	9.05
CS -2	7 – 12	13.4
CS -3	12 - 17	15.6
CS -4	more than 17	21.4

multiplexed in 8 TS which can be used for a specific purpose such as carrying data traffic or controlling user.

The GPRS system provides power controlling according to four Coding Schemes (CS) defined for the packet data traffic channels as shown in Table I. For GPRS radio resource management, Link Adaptation (LA) algorithm is used to select the optimum CS according to condition of radio link base on C/I [3].

In cellular system, a signal transmitted by a radio connection is attenuated along the propagation path. This attenuation of received power is called path loss. The path loss in case of Line-Of-Sight (LOS) is expressed as follow [1].

$$L(dB) = 32 + 20\log f + 20\log d \tag{3}$$

where f is the operational frequency in MHz and d is the distance in km.

When the antenna positions lower than surrounding building, the LOS path loss can not be applied. In this case, the radio signals arrives the user receiver from different directions resulting in signal fading. The fading can be classified into two types which are slow and fast fading. In this paper, we consider only slow fading case because the users are assumed to be static. The expression of path loss for slow fading is shown in (4).

$$m(dB) = \sqrt{-2\sigma p(m)\sqrt{2\pi\sigma^2}} + \overline{L(dB)} \tag{4}$$

where $\overline{L(dB)}$ is the mean value of path loss, $p(m)$ is the randomly uniform distribution value and σ is the standard deviation value in dB.

The received power C (dB) at the user can be calculated using (5) and (6) in case of LOS and non LOS cases, respectively.

$$C = T_x + G_b + G_u + L(dB) \tag{5}$$

$$C = T_x + G_b + G_u + m(dB) \tag{6}$$

where T_x is the transmitting power, G_b is the antenna gain at BS and G_u is the user antenna gain. Note that all parameters appeared in (5) and (6) are in dB.

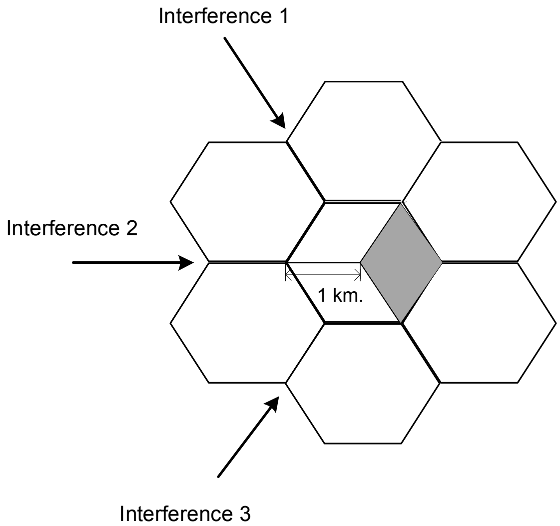

Figure 4. Cellular model for GPRS transmission.

IV. SIMULATION PARAMETERS

The computer simulation in this paper begins with the following assumptions:

1) Every cell is assumed to be a hexagonal shape.
2) The 120° sectoring antennas employed in the system is assumed to be perfect.
3) Frequency reuse factor is 7.
4) Co-channel interferences are coming from 3 directions with 3-km distance referring to [1].
5) The GPRS transmission is modeled using the same concept of cellular network shown in Fig. 4. Note that the shade area is the sector of interest.
6) The radius of cell is 1 km being a macro cell.
7) The 100 users are assumed to be uniformly distributed in each sector.
8) 4×1-dipole array antenna is assumed at individual users when switched beam and adaptive antennas are assumed.
9) Antenna gain of the switched beam antenna is 6.76 dB and 0 dB for omnidirectional case. The antenna gain at BS is 14 dB [3].
10) The standard deviation value of path loss model is 6 dB [3].
11) The system noise floor is -100 dBm.

In next section, we show the C/I at user receivers when omnidirectional, switched beam and adaptive antennas are assumed. Also, the system throughput is employed to indicate the quality of GPRS transmission.

V. SIMULATION RESULTS

The Probability Density Function (PDF) of C/I and throughput are used to show the performance of GPRS system utilizing omnidirectional, adaptive and switched

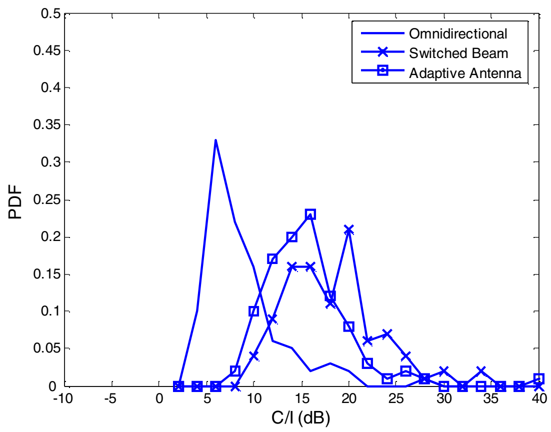

Figure 5. C/I probability distribution when the fading of signal is not included (LOS case).

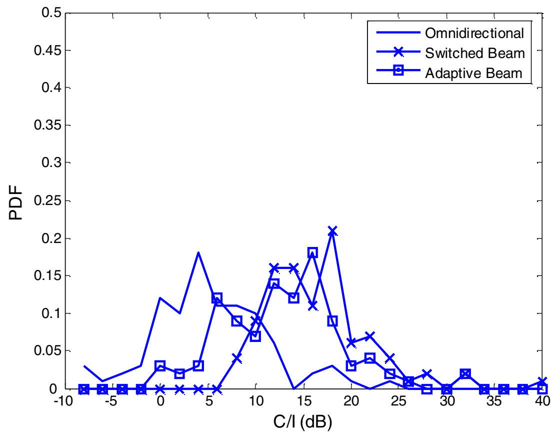

Figure 6. C/I probability distribution when the fading of signal is included (non-LOS case).

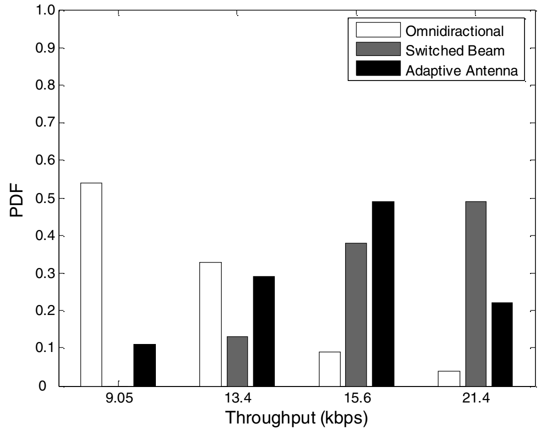

Figure 7. Throughput probability distribution when the fading of signal is not included (LOS case).

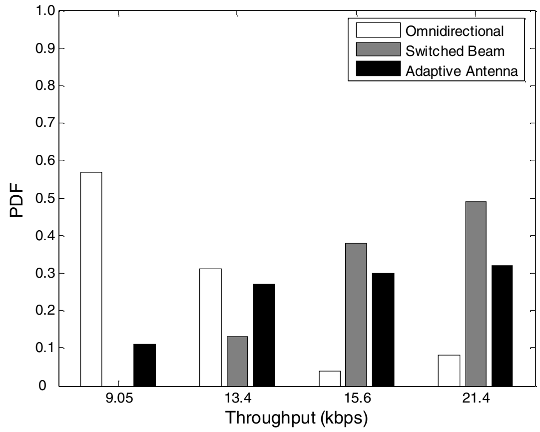

Figure 8. Throughput probability distribution when the fading of signal is included (non-LOS case).

beam antennas. Note that the parameters for simulations have been detailed in last section.

Fig. 5 shows the PDF of C/I when the fading of signal is neglected. Note that the peak of PDF indicates dominant C/I. As we can see, the most frequent C/I value in case of omnidirectional is lowest. This value increases when utilizing adaptive antenna. From the obtained results, switched beam antenna provides highest C/I considering at maximum PDF. This indicates that switched beam antenna provides highest performance for GPRS transmission compared with existing (omnidirectional) and adaptive antennas.

Fig. 6 presents the same results as shown in Fig. 5 but the signal is assumed to be fading (non-LOS case). We obtain similar manner of the C/I distribution presented in Fig. 5 in which we can achieve highest performance when utilizing switched beam antenna.

In order to examine the data transfer capability of GPRS system, we also investigate into the probability of throughput as shown in Fig. 7 and Fig. 8 when fading of signal is excluded and included respectively.

As seen in Fig. 7, the most frequent throughput is 9.05, 15.6 and 21.4 kbps when omnidirectional, adaptive and switched beam antennas are utilized, respectively. This confirms the performance of switched beam antenna over omnidirectional and adaptive antennas when the signal is coming LOS directions (no fading).

However, the fading of signal is included and the obtained results are shown in Fig. 8. As expected, the switched beam antenna provides highest throughput (21.4 kbps) at maximum PDF, compared with other antenna systems. This proves that switched beam antenna can be considered to be an effective antenna for GPRS system as it well performs even in non-LOS environment.

VI. CONCLUSION

This paper has proposed the idea to enhance the performance of GPRS system by employing switched beam antenna at Mobile Station. This is because switched beam antenna avoids impairment of complexity and expense. In this paper, the performance of switched beam antenna in GPRS transmission has been evaluated via computer simulation compared with existing (omnidirectional) and adaptive antennas. The obtained results show that switched beam antenna provides highest C/I and throughput even though the system is situated in non-LOS environment. This information is considerably useful for the Laptop designer who pursues the performance enhancement in GPRS system.

ACKNOWLEDGMENT

The authors acknowledge the financial support from Suranaree University of Technology and Thailand Research Fund.

REFERENCES

[1] T. S. Rappaport, *Wireless Communication:Principles And Practice 2nd*. Printice Hall PTR, NJ, 2002

[2] G. Brasche, B. Walke, "Concepts, services, and protocols of the new GSM phase 2+ general packet radio service," *IEEE Commun. Mag*., vol. 35, Issue 8, Aug. 1997, pp. 94-104.

[3] T. Halonen, J. Romero, J. Melero, *GSM, GPRS And EDGE Performance:Evolution Towards 3G/UMTS 2nd*. Wiley and Sons, England, 2003.

[4] J. C. Liberti, Jr., T. S. Rappaport, *Smart Antennas for Wireless Communications:IS-95 and Third Generation CDMA Applications*. Printice Hall PTR, NJ, 1999.

[5] L. Wei, T.A. Gulliver, "Smart antennas and transmit diversity for GSM systems," in *Proc. 2003 IEEE Pacific Rim Conference*, 28-30 Aug. 2003, pp.119 – 122.

[6] M. J. Ho, G. L. Stuber, M. D. Austin, "Performance of Switched-Beam Smart Antennas for Cellular Radio Systems," *IEEE Trans. Veh. Technol.*, Vol. 47, Feb. 1998, pp.10-20.

[7] C.F. du Toit, O.P. Gupta, W.J. Brown, D. He, J. Patel, P.F. Acsadi, C. Sui, M. Peyghaleh, "Smart multibeam phased array antenna for GSM, GPRS and EDGE," in *Proc. IEEE Inter. Sym. on Phased Array Systems and Tech.2003*, 14-17 Oct. 2003, pp. 146-151.

[8] U. Rehfuess, K.Ivanov, "Estimating the gains of adaptive antenna systems for GPRS and EDGE data services in GSM networks," *Veh. Tech. Conf. 2000*, vol.6, Sept. 2000, pp. 3026 - 3032.

[9] F. Rayal, "Why Have Smart Antennas Not Yet Gained Traction with Wireless Network Operators?," *IEEE Ant. And Prop. Mag*., Vol. 47, No.6, Dec. 2005.

[10] C. Seungwon, D. Shim, T.K. Sarkar, "A comparison of tracking-beam arrays and switching-beam arrays operating in a CDMA mobile communication channel," *IEEE Ant. and Prop. Mag*., vol. 41, Dec. 1999. pp.10 - 56.