

On the Selection of Training Sequence Code Pair for MIMO Technology in 3GPP GERAN System

Jae-Hyuk Lee, Jun-Ho Baek, Seung-Hoon Hwang*, Byoung-Jo Choi**

* Dept. of Electronics Engineering, Dongguk University, Seoul, Korea

** University of Incheon, Incheon, Korea

Tel: +82 (0)2 2260 3994, Fax: +82 (0)2 2279 3994 E-mail: shwang@dongguk.edu

Abstract — In this paper, we investigate to relationship between TSCs (training sequence codes) and find optimal pair to decrease the channel estimation error in GSM/EDGE evolution system. For the proposed pair, the cross-correlation between the TSCs is employed. Such TSC codes as in normal symbol rate, high symbol rate, and MUROS (Multi User Reusing One Slot) scheme are considered. To decrease the channel error variance may result in improving the performance of channel estimation.

Keywords — TSC, TSC pair, Cross-correlation, Channel estimation, MUROS

I. Introduction

Beyond dispute, GSM (Global System for Mobile communications) network is the most successful commercial cellular mobile communication system hitherto. It is reported that the number of GSM users all over the world had reached 4 billion by 2009.[1] The increase in the number of users and voice traffic puts a huge pressure on operators especially in populous countries. GSM launched GPRS (General Packet Radio Service) to support high speed packet data. As a result of the transition from voice communications to multimedia applications, EDGE (Enhanced Data for GSM Evolution) has been involved in GSM [2]. Since 2000, 3GPP TSG (Technical Specification Group) GSM/EDGE Radio Access Network (GERAN) had been enhanced performance toward 4G. According to the latest standard, GERAN Evolution was introduced high order modulation order, Turbo coding high symbol rate [3] to support higher symbol rate (325k symbol/s), which is 1.2 times faster than normal symbol rate (271k symbol/s). GSM/EDGE standard specifies a set of eight training sequences code (TSC) for channel estimation that have 26 symbols for normal burst (L-TSC) and 31 symbols for high symbol burst (H-TSC)[3]. The 4G candidate technologies, such as HSPA-Evolution, LTE-advance and WiMAX phase-2, etc., were commonly adapted the SM (Spatial Multiplexing)-MIMO scheme [4]-[6]. Theoretically, SM-MIMO can increase throughput as number of min (Tx, Rx) antennas increases. From this trend, it is not impossible to adapt SM-MIMO antennas technique for the GERAN Evolution [7]. For 2 by 2 case, two different TSC should be sent simultaneously from both transmitter antennas. In generally, the TSC has good auto-correlation property but its cross-correlation properties are good only for certain combination of sequence. Lower

performance due to channel estimation error will occur if we select unsuitable TSC pairs.

Considering SM-MIMO transmission scheme for GSM/EDGE, in this paper, we investigate how to find suitable TSC pairs for MIMO (using 2 transmit and 2 receive antennas) in 3GPP GERAN Evolution.

II. Training Sequence Code

High-order modulation schemes such as 16QAM or 32QAM were employed in the GERAN Evolution system with a single antenna in order to increase data rate. The receiver uses the MLSE (Maximum Likelihood Sequences Estimation) which is optimized equalizer to estimate transmitted symbol, under multi-path fading channel. In case of MLSE, the number of state is M^k where, M is modulation order. Generally on the urban channel environment TU (Typical Urban) and considering Tx Rx's filter, k is 3~4. Therefore, the number of states is in the range of $16^3 \sim 16^4$ in case of the high-order modulation MLSE makes it impossible to implement the mobile handsets. Thus in order to increase data rate in GERAN Evolution system, we use the high-order modulation scheme along with to SM-MIMO scheme.

Table 1. TSCs for Normal Symbol Rate

L-TSC_(No.)	Training Sequence for Normal Symbol Rate (26 symbols)
0	00100101110000100010010111
1	00101101110111100010110111
2	01000011101110100100001110
3	01000111101101000100011110
4	00011010111001000001101011
5	01001110101100000100111010
6	10100111110110001010011111
7	11101111000100101111011100

Table 1 shows the regular structures of training sequences for normal symbol-rate in L-TSC case. L-TSC scheme is considered to be used in GSM/EDGE, but H-TSC shown by table 2, is not. Moreover, for H-TSC, auto-correlation is the only condition to be taken into account when choosing H-TSC for antennas. In this paper, we assume that GSM/EDGE

Evolution systems use H-TSCs with both auto-correlation and cross-correlation properties. And we consider to cross-correlation between the L-TSC and N-TSC under the MUROS scheme.

Table 2. TSCs for High Symbol Rate

H-TSC_(No.)	Training Sequence for Higher Symbol Rate (31 symbols)
0	010010001011111100101111001110
1	1110011000111110101101000100100
2	1001110111001011011111000101000
3	0000111000000100111010110010100
4	101001110001101100101111110100
5	0010100110101110010000001110000
6	101111101101000111011000111010
7	101111011010111000011011101100

Table 3. TSCs for MUROS

N-TSC_(No.)	New Training Sequence for MUROS (26 symbols)
0	01100010001001001111010111
1	01011110100110111011100001
2	01000001011000111011101100
3	00101101110111001111010000
4	01110100111101001110111110
5	01000001001101010011110011
6	00010000110100001101110101
7	01000101110011111100101001

Table 3 shows the TSCs for MUROS scheme. [8]

III. Proposed Method

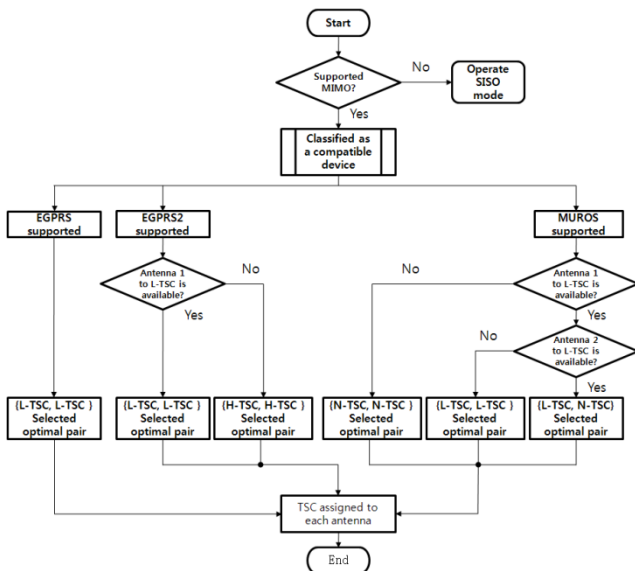


Figure 1. Flow chart of the proposed method

Figure 1 shows a flow chart of the proposed method. In receiver side, if receiver can support MIMO scheme, the receiver classified as a compatible device. Otherwise, the receiver is operates SISO mode. When the receiver operates in MIMO mode, we try to find out best TSC-pairs for each antenna. In GSM/EDGE, GERAN Evolution system, to increase the capacity, we use multiple antennas (with a assigned to the TSC code for each one) to transmit and receive the signal. The next subsection will show the algorithm to choose TSC pairs to reduce interference while using MIMO technology.

Using 2 by 2 MIMO antennas for transmitting and receiving in burst high-symbol GERAN Evolution scenario, the received signal from two antennas simultaneously transmit the discrete model as follows

$$r'_t = A'_t h_t + n'_t + q'_t \quad (1)$$

Where, r'_t is the TSC symbol matrix received by two antennas, defined as $r'_t = [r'_{t,1} r'_{t,2}]^T$. n'_t and q'_t are respectively noise and co-channel interference and can be defined in the same way with r'_t . A'_t is the TSC symbol matrix, transmitted by two antennas, defined as $A'_t = \begin{bmatrix} A_{t,1} & 0 & A_{t,2} & 0 \\ 0 & A_{t,1} & 0 & A_{t,2} \end{bmatrix}$. $A_{t,1}$ and $A_{t,2}$ is consist of TSC symbols and the size of the Toeplitz convolution matrix. L is the number of the taps in multi-path channel. All 4-channel stream matrix is defined as $h_t = [h_{11}^T h_{21}^T h_{12}^T h_{22}^T]^T$. Using the Joint-LS(Least Square) channel estimation techniques to obtained following channel estimation matrix. $\hat{h}_{JLS}$ can be defined as

$$\hat{h}_{JLS} = (A_t^H A'_t)^{-1} A_t^H r'_t \quad (2)$$

As shown in table 3, there are 4 H-TSC pairs with the smallest values of cross-correlation, make channel estimation error minimized, as a result. Channel estimation, when self-correlation is taken into consideration, is defined as

$$\Phi_{e'e'} = \sigma_n^2 (A_t^H A'_t)^{-1} \quad (3)$$

Where, σ_n^2 is the dispersion of noise. From this equation, the higher the value of $A_t^H A'_t$ is, the smaller the value of channel estimation error is. In Other words, the smaller value of $A_t^H A'_t$ make channel estimation's performance decrease dramatically. Our proposal method is to use TSC pairs with smallest values base on cross-correlation for transmitting and receiving signal (under the 2 by 2 MIMO system) to increase the performance of channel estimation.

HSR Burst for Tx Ant 1	TB	DATA	H-TSC_(j)	DATA	TB	GP
	4	69	31	69	4	10.5
HSR Burst for Tx Ant 2	TB	DATA	H-TSC_(k)	DATA	TB	GP
	4	69	31	69	4	10.5

$\{H-TSC_{(j)}, H-TSC_{(k)}\} \in \{H-TSC_{(0)}, H-TSC_{(5)}, H-TSC_{(1)}, H-TSC_{(3)}, H-TSC_{(2)}, H-TSC_{(4)}, H-TSC_{(6)}, H-TSC_{(7)}\}$

Figure 2. HSR burst Structures with two H-TSCs

Figure 2 show the case that two transmit antennas use the same carrier, but different H-TSCs. Antenna 1 uses H-TSC(j), the other uses H-TSC(k). H-TSCs are chosen so that the cross-correlation is as small as possible by following equation.

$$CCF_{HH-TSC}(j, k) = \frac{1}{31} \times \sum_{H-TSC} (j) \times H-TSC (k), \quad j, k \in \{0, \dots, 7\}, j \neq k \quad (4)$$

Normal Burst for Tx Ant 1	TB 3	DATA 58	N-TSC (j) 26	DATA 58	TB 3	GP 8.25
Normal Burst for Tx Ant 2	TB 3	DATA 58	N-TSC (k) 26	DATA 58	TB 3	GP 8.25

{N-TSC_j, N-TSC_k} ∈ {{N-TSC₀, N-TSC₂}, {N-TSC₁, N-TSC₃}, {N-TSC₄, N-TSC₅}, {N-TSC₆, N-TSC₇}}

Figure 3. NSR burst Structure with two N-TSCs

As shown as figure 3, the transmit antenna 1 and other transmit antenna 2 are using the same carrier for MUROS scheme.

Normal Burst for Tx Ant 1	TB 3	DATA 58	L-TSC (j) 26	DATA 58	TB 3	GP 8.25
Normal Burst for Tx Ant 2	TB 3	DATA 58	N-TSC (k) 26	DATA 58	TB 3	GP 8.25

{L-TSC_j, N-TSC_k} ∈ {{L-TSC₀, N-TSC₇}, {L-TSC₁, N-TSC₅}, {L-TSC₂, N-TSC₂}, {L-TSC₃, N-TSC₃}, {L-TSC₄, N-TSC₄}, {L-TSC₅, N-TSC₀}, {L-TSC₆, N-TSC₆}, {L-TSC₇, N-TSC₁}}

Figure 4. NSR burst structure with L-TSC and N-TSC

And we assumed the mobile handset supported to MUROS, each user used same carrier and different TSC. As shown as figure 4, antenna 1 transmitted L-TSC_j for normal symbol rate, and antenna 2 transmitted N-TSC_k for MUROS mode. At this point, between the one of L-TSC₀ to L-TSC₇ and the other of N-TSC₀ to N-TSC₇ is to used by selecting the cross-correlation values will be the key performance indicators can be calculates by the following formula.

$$CCF_{LN-TSC}(j, k) = \frac{1}{26} \times \sum_{L-TSC} (j) \times N-TSC (k), \quad j, k \in \{0, \dots, 7\} \quad (5)$$

Table 4 shows the cross-correlation values of H-TSC pairs used above equation. In table, {H-TSC 0, H-TSC 6} pair value is 0.4839 which is most large value in each pair of H-TSCs. And {H-TSC 0, H-TSC 5} pair value is 0.0323 which is most small value in each pair of H-TSCs. Four STC pairs with the lowest value of cross-correlation are {H-TSC₀, H-TSC₂}, {H-TSC₁, H-TSC₇}, {H-TSC₃, H-TSC₄}, {H-TSC₅, H-TSC₆} are the lowest pair of cross-correlation value of overall.

Table 4. Cross-correlation values for find optimal H-TSC pair

H-TSC (j) \ H-TSC (k)	0	1	2	3	4	5	6	7
0	•	0.0968	0.2258	0.1613	0.1613	0.0323	0.4839	0.0323
1	0.0968	•	0.0968	0.0323	0.2258	0.0323	0.0323	0.0323
2	0.2258	0.0968	•	0.2258	0.0323	0.3548	0.2258	0.0968
3	0.1613	0.0323	0.2258	•	0.0323	0.0323	0.0968	0.0323
4	0.1613	0.2258	0.0323	0.0323	•	0.0323	0.2903	0.2903
5	0.0323	0.0323	0.3548	0.0323	0.0323	•	0.0323	0.0968
6	0.4839	0.0323	0.2258	0.0968	0.2903	0.0323	•	0.0323
7	0.0323	0.0323	0.0968	0.0323	0.2903	0.0968	0.0323	•

Table 5. Cross-correlation values for find optimal N-TSC/L-TSC pair

N-TSC (j) \ L-TSC (k)	0	1	2	3	4	5	6	7
0	0.0769	0.2308	0	0.1538	0.0769	0	0.0769	0
1	0.1538	0	0.2308	0.3846	0.1538	0.0769	0	0.0769
2	0	0.1538	0.0769	0.2308	0	0.0769	0.1538	0.0769
3	0.2308	0.3846	0.1538	0	0.3846	0.1538	0.0769	0
4	0	0	0.0769	0.2308	0	0.0769	0.1538	0.0769
5	0	0	0.2308	0.0769	0.3077	0.0769	0	0.0769
6	0	0.1538	0.2308	0.2308	0.1538	0.2308	0	0.0769
7	0	0	0.0769	0.0769	0.1538	0.2308	0.1538	0.0769

Table 5 shows the cross-correlation values of N-TSC_j and L-TSC_k, in Table 4 {L-TSC₀, N-TSC₇}, {L-TSC₁, N-TSC₅}, {L-TSC₂, N-TSC₂}, {L-TSC₃, N-TSC₃}, {L-TSC₄, N-TSC₄}, {L-TSC₅, N-TSC₀}, {L-TSC₆, N-TSC₆}, {L-TSC₇, N-TSC₁} are the lowest pairs of cross-correlation value of overall.

IV. Conclusion

In this paper, we have investigated the cross-correlation of N-TSC, L-TSC, and H-TSC which are calculated to select the optimal pair base on its value value. In the GSM/EDGE evolution system, assuming the MIMO scheme is employed, we have proposed the best pair for two antennas in this paper. As a result, the channel estimation performance will be improved. Further work will be continued to analyze the throughput performances of the GERAN evolution system by link level simulation when the optimal pair are employed.

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