Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Ranging Procedure: Motorola's contribution comments**
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Re:	**Ranging Improvement for 802.16e OFDMA PHY**
Abstract	Comparison of the current and Motorola's ranging scheme
Purpose	Informative contribution
Notice	
Release	
Patent Policy and Procedures	

1. Background

Problem of initial and periodical ranging users is one of the most important tasks in OFDMA applications, since errors and mistakes in synchronization can greatly reduce performance of OFDMA telecommunication system in whole.

The problem is that receiving side should decide two tasks contemporaneously: detection of the users and estimation of user's parameters. One of the most important parameter for estimation is propagation delay of the user.

Users are able to collide between each other during ranging within the limits of one sub-band, specially allocated for this task.

In the current version of the standard [1] the method of scattered subcarriers modulation by 144-length M-sequence is proposed. BPSK sequence is derived by randomly selection of the code seed number from a long Pseudo-Random Binary Sequence (PRBS) set, generated by the polynomial $1+X_1+X_4+X_7+X_{15}$.

Another approach, based on Generalized Chirp Like (GCL) sequences and contiguous subcarriers allocation technique was proposed by Motorola [2].

GCL sequence is generated according to the formula:

, (0.1)

where is the desired length and (prime number of) is the length of the whole sequence before truncation, index is used for user identification.

OFDM signal generation of symbols is performed according to the formula:

, (0.2)

where - is fast frequency transform (FFT) size.

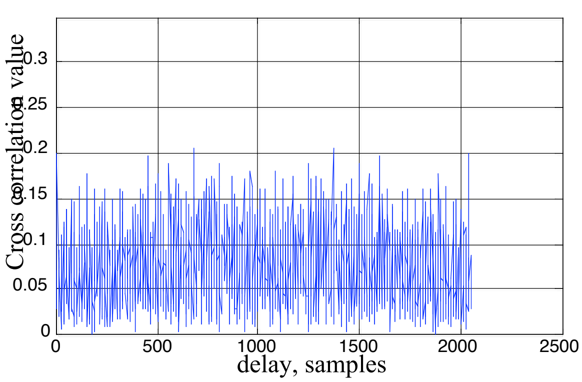
This document contains comparative analysis of both approaches with simulation results.

2. Comparison of the cross correlation properties

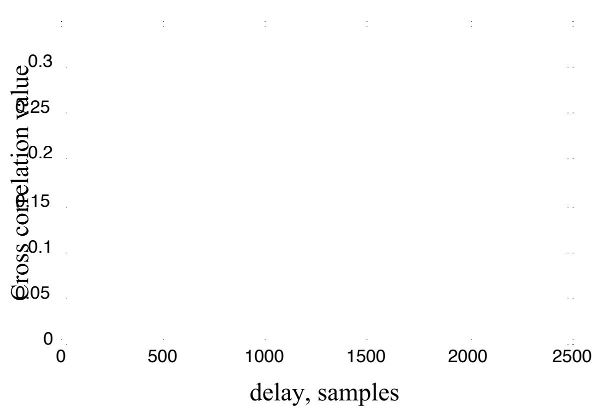
The following conclusion of document [2] is under discussion here:

a. The placement of ranging subcarriers across the whole band degrades the performance in both code detection and timing offset estimation.

The cross correlation properties of both investigating approaches were calculated to consider the first sentence. Results of simulations are presented in the Figure 1. Parameters used in this document are the same as presented in bottom part of Figure 4 of [2].



a



b

Figure 1 M-sequence cross correlation properties, scattered subcarriers, 2048-fft size, code length 144

( ) (a), GCL sequence cross correlation properties, contiguous subcarriers - 2048-fft size, code length 144 (,) (b).

Comparative analysis of two functions from Figure 1 shows, that statistical properties of both of them have much in common. The total power of interference produced by GCL sequence is equal to , and the same parameter for M-sequence is equal to .

Considerable difference is present in standard deviation of cross correlation values only: GCL sequence has , and the corresponding parameter for M-sequence is equal to .

All computed values are calculated per 1 sample. The typical results of simulations are presented in the table below.

Table 1 Comparison of contiguous GCL & scattered M – sequenced cross correlation factors.

GCL			M-sequence		
GCL sequence numbers	Average interference power	STD of interference	M-sequence seed number	Average interference power	STD of interference
106, 37	0.076857	0.001041	0125 (hex), 0252 (hex)	0.073251	0.001579
89, 6	0.076753	0.001057	016 (hex), 0271 (hex)	0.074356	0.001416
1, 101	0.076035	0.001166	0137 (hex), 071 (hex)	0.073538	0.001537
61, 51	0.080331	0.000494	0360 (hex), 061 (hex)	0.073662	0.001519

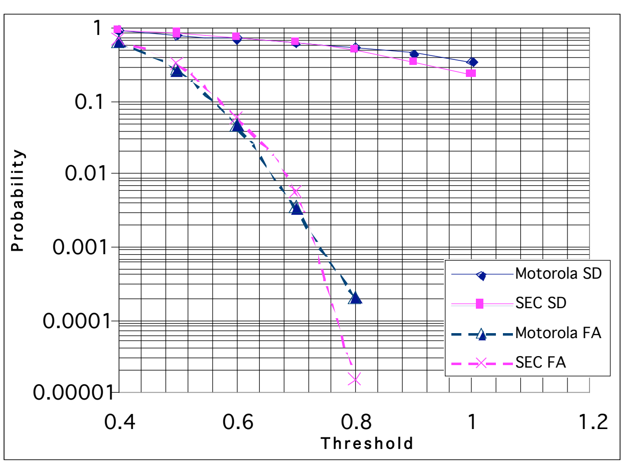
According to the mentioned above, the total power of cross correlation interference of GCL sequence is equal to average cross correlation interference power of M-sequence.

The results of simulations of code detection of GCL- and M- sequences in Jakes fading multipath environment [3] are presented in Figure 1, and in Table 2 - Table 5. Threshold value is encountered in parts of desired user signal energy. Recommended threshold value is distinguished by color.

The following designations are used in results:

SEC: M-sequence cross correlation properties, scattered subcarriers;

Motorola: GCL sequence cross correlation properties, contiguous subcarriers.



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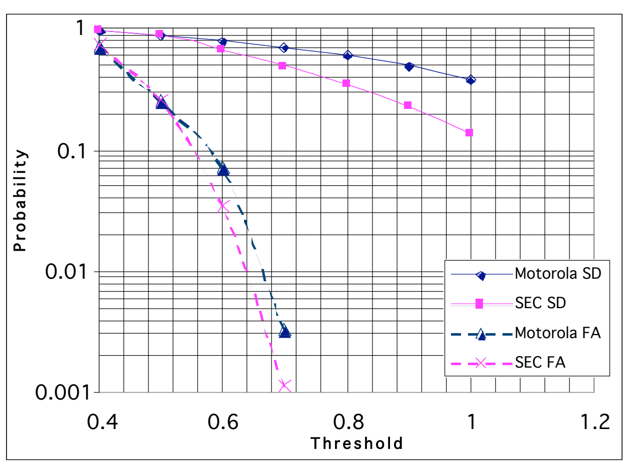


b

Figure 2. Successive detection (SD – solid lines) and false alarm (FA – dashed lines) rates in Vehicular B (a) and Pedestrian B (b) environment, 5 users. 1024-fft size, code length 144

Table 2 Successive detection, false alarm rates, and timing errors estimation STD, Vehicular B environment, 5 users. 1024-fft size, code length 144

Vehicular B						
Threshold	Successive detection		False Alarm		Timing errors estimation STD	
	Motorola	SEC	Motorola	SEC	Motorola	SEC
0.9	0.455333	0.364667			1.342057	1.959781
0.8	0.549083	0.501917	0.000201	0.000015	1.338898	1.939067
0.7	0.635583	0.640833	0.003472	0.005895	1.329356	1.991287
0.6	0.730667	0.771417	0.048225	0.06284	2.819343	2.399049
0.5	0.83275	0.875167	0.282701	0.334614	9.564295	4.615978
0.4	0.932833	0.963	0.669985	0.758657	18.6985	10.32935

Table 3 Successive detection, false alarm rates, and timing errors estimation STD, Pedestrian B environment, 5 users. 1024-fft size, code length 144

Pedestrian B						
Threshold	Successive detection		False Alarm		Timing errors estimation STD	
	Motorola	SEC	Motorola	SEC	Motorola	SEC
0.9	0.490333	0.228583			0.825119	1.769595
0.8	0.610417	0.34625			0.808328	2.039471
0.7	0.7	0.498167	0.003256	0.001127	0.820357	2.415189
0.6	0.79825	0.692	0.071852	0.034722	2.597975	3.9717
0.5	0.90025	0.886667	0.254429	0.262485	6.59576	8.960902
0.4	0.969417	0.980167	0.711728	0.746867	14.17923	13.31457

Table 4 Successive detection, false alarm rates, and timing errors estimation STD, Vehicular B environment, 2 users. 1024-fft size, code length 144

Vehicular B						
Threshold	Successive detection		False Alarm		Timing errors estimation STD	
	Motorola	SEC	Motorola	SEC	Motorola	SEC
0.9	0.5275	0.4795			1.270932	1.448036
0.8	0.626167	0.620167			1.270162	1.420586
0.7	0.719917	0.7505		0.000072	1.279662	1.425272
0.6	0.796583	0.8485	0.00015	0.002089	1.296998	1.467001
0.5	0.873	0.922333	0.016394	0.060461	1.320065	1.47669
0.4	0.938768	0.974457	0.259819	0.398913	1.499228	2.25488

Table 5 Successive detection, false alarm rates, and timing errors estimation STD, Pedestrian B environment, 2 users. 1024-fft size, code length 144.

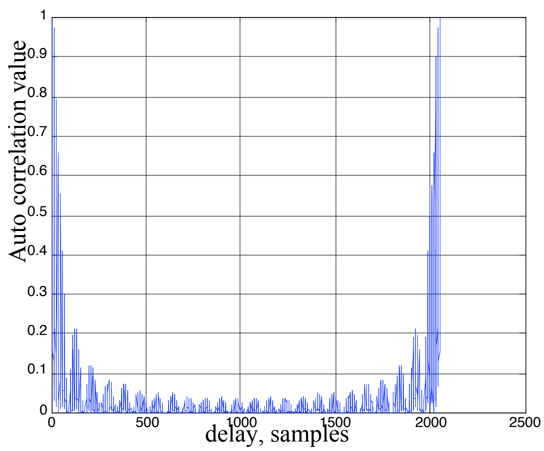
Pedestrian B						
Threshold	Successive detection		False Alarm		Timing errors estimation STD	
	Motorola	SEC	Motorola	SEC	Motorola	SEC
0.9	0.59075	0.378			0.968402	1.156085
0.8	0.68025	0.558167			0.988485	1.199164
0.7	0.768167	0.738083			0.975808	1.358474
0.6	0.84575	0.853083		0.000889	0.986895	1.514311
0.5	0.93239	0.950927	0.006075	0.018709	1.193052	1.689751
0.4	0.984314	0.977537	0.148296	0.245714	1.043282	2.104002

As it could be seen from the simulation results, for correctly selected threshold values the difference in code detection and false alarm probability between two schemes is not considerable.

3. Auto correlation properties and time estimation

Let us investigate also the auto correlation properties of two approaches, and connected with these properties timing estimation error performances.

Typical auto correlation properties of GCL and M – sequences are presented in the Figure 3 (no propagation channel), Figure 4 -Figure 5 (Vehicular B propagation channel model).



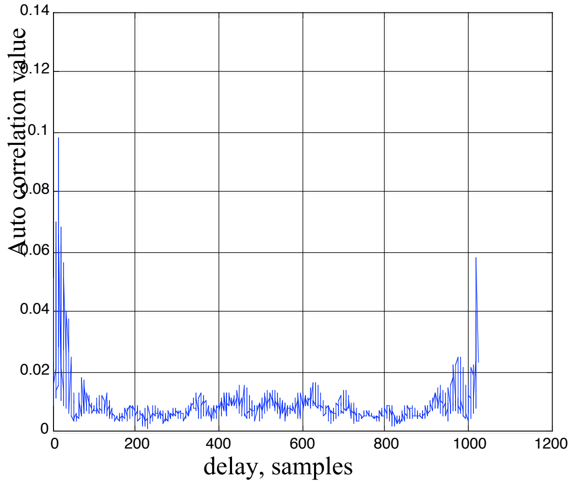
a

Auto correlation value

delay, samples

b

Figure 3. Scattered subcarriers M-sequence auto correlation properties (a) 2048-fft size, code length 144, contiguous subcarriers GCL sequence auto correlation properties (b) 2048-fft size, code length 144.



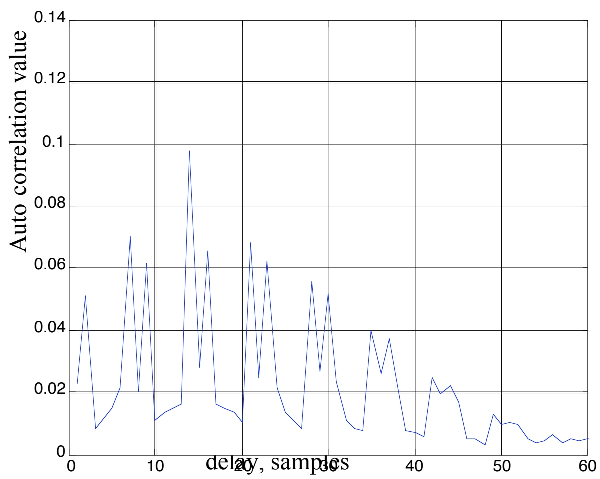
a

Auto correlation value

delay, samples

b

Figure 4. Scattered subcarriers M-sequence auto correlation properties (a) 1024-fft size, code length 144, contiguous subcarriers GCL sequence auto correlation properties (b) 1024-fft size, code length 144. Vehicular B Channel.



a

Auto correlation value

delay, samples

b

Figure 5. Scattered subcarriers M-sequence auto correlation properties (a) 1024-fft size, code length 144, contiguous subcarriers GCL sequence auto correlation properties (b) 1024-fft size, code length 144. Vehicular B Channel, Details.

For the no propagation channel case statistical properties of auto correlation functions of both signals do not depend on the code number ("u" value in case of GCL, and seed number in case of M) (Table 6).

Table 6 Comparison of contiguous GCL & scattered M – sequenced auto correlation factors. No multipath, no

fading. 1024-fft size, code length 144

GCL			M-sequence		
GCL sequence numbers	Average interference power	STD of interference	M-sequence seed number	Average interference power	STD of interference
106	0.020373	0.006041	0125 (hex)	0.026622	0. 006671
89	0.020373	0.006041	016 (hex)	0.026622	0.006671
1	0.020373	0.006041	0137 (hex)	0.026622	0.006671
61	0.020373	0.006041	0360 (hex)	0.026622	0.006671

As it could be seen from the Table 6, no considerable auto correlation power losses of M-sequence comparing to GCL is obtained, as well as no considerable STD losses are observed.

The results of timing estimation errors for case of no multiple access interference (1 user) are presented in Table 7, Table 8; for multiple access interference (5,3 users) - Table 2 - Table 5.

The typical delay profile estimation is presented in Figure 6.

Table 7 Successive detection, false alarm rates, and timing errors estimation STD, Vehicular B environment, 1 users. 1024-fft size, code length 144

Vehicular B						
Threshold	Successive detection		False Alarm		Timing errors estimation STD	
	Motorola	SEC	Motorola	SEC	Motorola	SEC
0.8	0.5155	0.466917			1.340769	1.411387
0.7	0.615917	0.602083			1.323772	1.364429
0.6	0.72145	0.7589			1.31559	1.30568
0.5	0.774977	0.84621			1.309922	1.257932
0.4	0.8628	0.9114	0.000194	0.001306	1.335304	1.277814
0.3	0.932211	0.967656	0.005431	0.061357	1.393061	1.165751

Table 8 Successive detection, false alarm rates, and timing errors estimation STD, Pedestrian B environment, 1 user. 1024-fft size, code length 144

Vehicular B						
Threshold	Successive detection		False Alarm		Timing errors estimation STD	
	Motorola	SEC	Motorola	SEC	Motorola	SEC
0.8	0.600417	0.556417			1.065371	0.835854
0.7	0.7356	0.7154			1.10658	0.84562
0.6	0.88668	0.845068		0.000384	1.166981	0.866124
0.5	0.9407	0.9475		0.002845	1.115127	0.919789
0.4	0.968378	0.98567	0.062145	0.082718	1.124682	0.938809

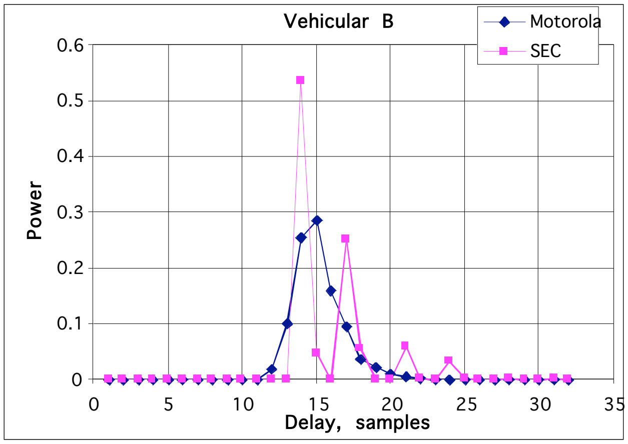


Figure 6. Typical delay profile. Vehicular B.

4. Conclusions

In accordance to obtained simulation results let us made several conclusions:

a) two schemes of ranging users, namely current approach (M-sequence with scattered subcarriers allocation scheme) and Motorola's proposals (GCL sequence with contiguous subcarriers allocation scheme) demonstrate comparable code detection, as well as timing estimation performances;

b) research in designing of ranging scheme for 802.16e standard should be continued.

List of Publications

1. Draft IEEE Standard for Local and metropolitan area networks Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems Amendment for Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, IEEE P802.16e/D4, August 2004, 270 p.
2. Xiangyang (Jeff) Zhuang, Kevin Baum, Vijay Nangia, Mark Cudak, Ranging Improvement for 802.16e OFDMA PHY, IEEE C802.16e-04/143r1, 2004-07-07, 43 p.
3. IEEE C802.16d-04/47r1, "OFDMA PHY Enhancement for Ranging," March 2004, 43 p.
4. Rec. ITU-R M.1225 1 RECOMMENDATION ITU-R M.1225 GUIDELINES FOR EVALUATION OF RADIO TRANSMISSION TECHNOLOGIES FOR IMT-2000* (Question ITU-R 39/8), 1997, 60 p.