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APPENDIX A

TABLE OF PROJECTIVE GEOMETRY DIFFERENCE SET

M	Vp	X	{Dp}
3	7	1	1 2 4
4	13	1	0 1 3 9
5	11	2	1 3 4 5 9
5	21	1	3 6 7 12 14
6	31	1	1 5 11 24 25 27
7	15	3	0 1 2 4 5 8 10
8	57	1	1 6 7 9 19 38 42 49
9	19	4	1 4 5 6 7 9 11 16 17
9	37	2	1 7 9 10 12 16 26 33 34
9	73	1	1 2 4 8 16 32 37 55 64
10	91	1	0 1 3 9 27 49 56 61 77 81
11	23	5	1 2 3 4 6 8 9 12 13 16 18
12	133	1	1 11 16 40 41 43 52 60 74 78 121 128
13	40	4	1 2 3 5 6 9 14 15 18 20 25 27 35

M	Vp	X	{Dp}
14	183	1	0 2 3 10 26 39 43 61 109 121 130 136 141 155
15	31	7	1 2 3 4 6 8 12 15 16 17 23 24 27 29 30
17	35	8	0 1 3 4 7 9 11 12 13 14 16 17 21 27 28 29 33
17	273	1	1 2 4 8 16 32 64 91 117 128 137 182 195 205 234 239 256
98	9507	1	1 13 68 97 137 360 568 611 657 670 696 717 833 889 963 1070 1071 1073 1107 1122 1261 1378 1402 1503 1984 1989 2054 2163 2225 2301 2308 2670 2748 2793 2802 2825 2843 2896 3000 3008 3169 3186 3211 3527 3782 3929 4128 4257 4536 4594 4725 4745 4818 5209 5215 5253 5367 5371 5588 5598 5670 5790 5847 6034 6113 6124 6246 6338 6399 6426 6566 6596 6671 6687 6987 6921 7221 7243 7561 7609 7829 7848 7862 7948 8091 8233 8296 8360 8560 8720 8817 8930 9011 9098 9126 9224 9374 9409 9440

APPENDIX B

CODE SEQUENCES CONSTRUCTED FROM SOME DIFFERENCE SETS

B.1 Sequences from PG sets

{Dp} = { 1,3,4,5,9 }

where Vp = 11, M = 5, and X = 2

S_0	1	3	4	5	9
S_1	2	4	5	6	10
S_2	3	5	6	7	0
S_3	4	6	7	8	1
S_4	5	7	8	9	2
S_5	6	8	9	10	3
S_6	7	9	10	0	4
S_7	8	10	0	1	5
S_8	9	0	1	2	6
S_9	10	1	2	3	7

S_{10}	0	2	3	4	8

total number of sequence = L_p = 11

{Dp} = { 3,6,7,12,14 }

where Vp = 21, M = 5, X = 1

S_0	3	6	7	12	14
S_1	4	7	8	13	15
S_2	5	8	9	14	16
S_3	6	9	10	15	17
S_4	7	10	11	16	18
S_5	8	11	12	17	19
S_6	9	12	13	18	20
S_7	10	13	14	19	0
S_8	11	14	15	20	1
S_9	12	15	16	0	2
S_{10}	13	16	17	1	3
S_{11}	14	17	18	2	4
S_{12}	15	18	19	3	5
S_{13}	16	19	20	4	6
S_{14}	17	20	0	5	7
S_{15}	18	0	1	6	8

S_{16}	19	1	2	7	9
S_{17}	20	2	3	8	10
S_{18}	0	3	4	9	11
S_{19}	1	4	5	10	12
S_{20}	2	5	6	11	13

total number of sequence = L_p = 21

B.2 Sequences from EG set

{De} = { 0,3,8,10,23 }

where V = 25, M = 5, X = 1

S_0	0	3	8	10	23
S_1	1	4	9	11	0
S_2	2	5	10	12	1
S_3	3	6	11	13	2
S_4	4	7	12	14	3
S_5	5	8	13	15	4
S_6	6	9	14	16	5
S_7	7	10	15	17	6
S_8	8	11	16	18	7
S_9	9	12	17	19	8

S_{10}	10	13	18	20	9
S_{11}	11	14	19	21	10
S_{12}	12	15	20	22	11
S_{13}	13	16	21	23	12
S_{14}	14	17	22	0	13
S_{15}	15	18	23	1	14
S_{16}	16	19	0	2	15
S_{17}	17	20	1	3	16
S_{18}	18	21	2	4	17
S_{19}	19	22	3	5	18
S_{20}	20	23	4	6	19
S_{21}	21	0	5	7	20
S_{22}	22	1	6	8	21
S_{23}	23	2	7	9	22
S_{24}	0	6	12	18	24
S_{25}	1	7	13	19	24
S_{26}	2	8	14	20	24
S_{27}	3	9	15	21	24
S_{28}	4	10	16	22	24
S_{29}	5	11	17	23	24

total number of sequence = L_e = 30

APPENDIX C

DERIVATION OF EQUATION

C.1 Derivation of Equation (3-7)

From Eq.(3-3), we have

$$W(t)=\sum_{k=1}^{M} S_k(t-\tau_k)+n(t)$$

where

$$\begin{aligned}
S_1(t-\tau_1) &= \sqrt{P}\, b_1(t-\tau_1)\Big\{ \cos[\omega_1(t-t_0-\tau_1)\theta_{1,1}] \\
&\quad + \cos[\omega_0(t-t_2-\tau_1)+\theta_{1,0}] + \cos[\omega_1(t-t_2-\tau_1)+\theta_{1,1}]\Big\} \\
&= \sqrt{P}\, b_1(t-\tau_1)\Big\{\cos[\omega_1(t-t_0)-(\omega_1\tau_1-\theta_{1,1})] \\
&\quad + \cos[\omega_0(t-t_2)-(\omega_0\tau_1-\theta_{1,0})] + \cos[\omega_1(t-t_2)-(\omega_1\tau_1-\theta_{1,1})]\Big\}
\end{aligned}$$

$$\begin{aligned}
S_2(t-\tau_2) &= \sqrt{P}\, b_2(t-\tau_2)\Big\{\cos[\omega_0(t-t_0-\tau_2)\theta_{2,0}] \\
&\quad + \cos[\omega_2(t-t_0-\tau_2)+\theta_{2,2}] + \cos[\omega_1(t-t_2-\tau_2)+\theta_{2,1}]\Big\} \\
&= \sqrt{P}\, b_2(t-\tau_2)\Big\{\cos[\omega_0(t-t_0)-(\omega_0\tau_2-\theta_{2,0})] \\
&\quad + \cos[\omega_2(t-t_0)-(\omega_2\tau_2-\theta_{2,2})] + \cos[\omega_1(t-t_2)-(\omega_1\tau_2-\theta_{2,1})]\Big\}
\end{aligned}$$

$$
\begin{aligned}
S_3(t-\tau_3) = {} & \sqrt{P}\, b_3(t-\tau_3)\Big\{ \cos[\,\omega_0(t-t_0-\tau_3)\theta_{3,0}] \\
& + \cos[\omega_1(t-t_0-\tau_3)+\theta_{3,1}] + \cos[\omega_0(t-t_1-\tau_3)+\theta_{3,0}]\Big\} \\
= {} & \sqrt{P}\, b_3(t-\tau_3)\Big\{\cos[\omega_0(t-t_0)-(\omega_0\tau_3-\theta_{3,0})] \\
& + \cos[\omega_1(t-t_0)-(\omega_1\tau_3-\theta_{3,1})] + \cos[\,\omega_0(t-t_1)-(\omega_0\tau_3-\theta_{3,0})]\Big\}
\end{aligned}
$$

$$
\begin{aligned}
S_4(t-\tau_4) = {} & \sqrt{P}\, b_4(t-\tau_4)\Big\{ \cos[\,\omega_1(t-t_0-\tau_4)\theta_{4,1}] \\
& + \cos[\omega_2(t-t_0-\tau_4)+\theta_{4,2}] + \cos[\omega_1(t-t_1-\tau_4)+\theta_{4,1}]\Big\} \\
= {} & \sqrt{P}\, b_4(t-\tau_4)\Big\{\cos[\omega_1(t-t_0)-(\omega_0\tau_4-\theta_{4,1})] \\
& + \cos[\omega_2(t-t_0)-(\omega_2\tau_4-\theta_{4,2})] + \cos[\,\omega_1(t-t_1)-(\omega_1\tau_4-\theta_{4,1})]\Big\}
\end{aligned}
$$

$$
\begin{aligned}
S_5(t-\tau_5) = {} & \sqrt{P}\, b_5(t-\tau_5)\Big\{ \cos[\,\omega_2(t-t_0-\tau_5)\theta_{5,2}] \\
& + \cos[\omega_0(t-t_1-\tau_5)+\theta_{5,0}] + \cos[\omega_2(t-t_1-\tau_5)+\theta_{5,2}]\Big\} \\
= {} & \sqrt{P}\, b_5(t-\tau_5)\Big\{\cos[\omega_2(t-t_0)-(\omega_2\tau_5-\theta_{5,2})] \\
& + \cos[\omega_0(t-t_1)-(\omega_0\tau_5-\theta_{5,0})] + \cos[\,\omega_2(t-t_1)-(\omega_2\tau_5-\theta_{5,2})]\Big\}
\end{aligned}
$$

$$
\begin{aligned}
S_6(t-\tau_6) = {} & \sqrt{P}\, b_6(t-\tau_6)\Big\{ \cos[\,\omega_0(t-t_1-\tau_6)+\theta_{6,0}] \\
& + \cos[\omega_1(t-t_1-\tau_6)+\theta_{6,1}] + \cos[\omega_0(t-t_2-\tau_6)+\theta_{6,0}]\Big\} \\
= {} & \sqrt{P}\, b_6(t-\tau_6)\Big\{\cos[\omega_0(t-t_1)-(\omega_0\tau_6-\theta_{6,0})] \\
& + \cos[\omega_1(t-t_1)-(\omega_1\tau_6-\theta_{6,1})] + \cos[\,\omega_0(t-t_2)-(\omega_0\tau_6-\theta_{6,0})]\Big\}
\end{aligned}
$$

$$
\begin{aligned}
S_7(t-\tau_7) = {} & \sqrt{P}\, b_7(t-\tau_7)\Big\{ \cos[\,\omega_1(t-t_1-\tau_7)+\theta_{7,1}] \\
& + \cos[\omega_2(t-t_1-\tau_7)+\theta_{7,2}] + \cos[\omega_1(t-t_2-\tau_7)+\theta_{7,1}]\Big\} \\
= {} & \sqrt{P}\, b_7(t-\tau_7)\Big\{\cos[\omega_1(t-t_1)-(\omega_1\tau_7-\theta_{7,1})] \\
& + \cos[\omega_2(t-t_2)-(\omega_2\tau_7-\theta_{7,2})] + \cos[\,\omega_1(t-t_2)-(\omega_1\tau_7-\theta_{7,1})]\Big\}
\end{aligned}
$$

$$S_8(t-\tau_8)= \sqrt{P}\ b_8(t-\tau_8)\Big\{ \cos[\,\omega_0(t-t_0-\tau_8)+\Theta_{8,0}] + \cos[\omega_2(t-t_1-\tau_8)+\Theta_{8,2}] + \cos[\omega_0(t-t_2-\tau_8)+\Theta_{8,0}]\Big\}$$

$$= \sqrt{P}\ b_8(t-\tau_8)\Big\{\cos[\omega_0(t-t_0)-(\omega_0\tau_8-\Theta_{8,0})] + \cos[\omega_2(t-t_1)-(\omega_2\tau_8-\Theta_{8,2})] + \cos[\,\omega_0(t-t_1)-(\omega_0\tau_8-\Theta_{8,0})]\Big\}$$

$$S_9(t-\tau_9)= \sqrt{P}\ b_9(t-\tau_9)\Big\{ \cos[\,\omega_0(t-t_0-\tau_9)+\Theta_{9,0}] + \cos[\omega_1(t-t_1-\tau_9)+\Theta_{9,1}] + \cos[\omega_2(t-t_2-\tau_9)+\Theta_{9,2}]\Big\}$$

$$= \sqrt{P}\ b_9(t-\tau_9)\Big\{\cos[\omega_0(t-t_0)-(\omega_0\tau_9-\Theta_{9,0})] + \cos[\omega_1(t-t_1)-(\omega_1\tau_9-\Theta_{9,1})] + \cos[\,\omega_2(t-t_2)-(\omega_2\tau_9-\Theta_{9,2})]\Big\}$$

$$S_{10}(t-\tau_{10})= \sqrt{P}\ b_{10}(t-\tau_{10})\Big\{ \cos[\,\omega_1(t-t_0-\tau_{10})+\Theta_{10,1}] + \cos[\omega_2(t-t_1-\tau_{10})+\Theta_{10,2}] + \cos[\omega_2(t-t_2-\tau_{10})+\Theta_{10,2}]\Big\}$$

$$= \sqrt{P}\ b_{10}(t-\tau_{10})\Big\{ \cos[\omega_1(t-t_0)-(\omega_1\tau_{10}-\Theta_{10,1})] + \cos[\omega_2(t-t_1)-(\omega_2\tau_{10}-\Theta_{10,2})] + \cos[\,\omega_2(t-t_2)-(\omega_2\tau_{10}-\Theta_{10,2})]\Big\}$$

$$S_{11}(t-\tau_{11})= \sqrt{P}\ b_{11}(t-\tau_{11})\Big\{ \cos[\,\omega_2(t-t_0-\tau_{11})+\Theta_{11,2}] + \cos[\omega_0(t-t_2-\tau_{11})+\Theta_{11,0}] + \cos[\omega_2(t-t_2-\tau_{11})+\Theta_{11,2}]\Big\}$$

$$= \sqrt{P}\ b_{11}(t-\tau_{11})\Big\{ \cos[\omega_2(t-t_0)-(\omega_2\tau_{11}-\Theta_{11,2})] + \cos[\omega_0(t-t_2)-(\omega_0\tau_{11}-\Theta_{11,0})] + \cos[\,\omega_2(t-t_2)-(\omega_2\tau_{11}-\Theta_{11,2})]\Big\}$$

$$S_{12}(t-\tau_{12})= \sqrt{P}\ b_{12}(t-\tau_{12})\Big\{ \cos[\,\omega_0(t-t_1-\tau_{12})+\Theta_{12,0}] + \cos[\omega_1(t-t_2-\tau_{12})+\Theta_{12,1}] + \cos[\omega_2(t-t_2-\tau_{12})+\Theta_{12,2}]\Big\}$$

$$= \sqrt{P}\ b_{12}(t-\tau_{12})\Big\{ \cos[\omega_0(t-t_1)-(\omega_0\tau_{12}-\Theta_{12,0})] + \cos[\omega_1(t-t_2)-(\omega_1\tau_{12}-\Theta_{12,1})] + \cos[\,\omega_2(t-t_2)-(\omega_2\tau_{12}-\Theta_{12,2})]\Big\}$$

From Eq.(3-4), $\phi_{k,u} = \omega_u \tau_k - \theta_{k,u}$

The summation of all information signal can be rewritten as

$$
\begin{aligned}
\sum_{k=1}^{K} S_k(t-\tau_k) = \sqrt{P}\, b_1(t-\tau_1) \Big\{ & \cos[\omega_1(t-t_0) - \phi_{1,1}] \\
& + \cos[\omega_0(t-t_2) - \phi_{1,0}] + \cos[\omega_1(t-t_2) - \phi_{1,1}] \Big\} \\
+ \sqrt{P}\, b_2(t-\tau_2) \Big\{ & \cos[\omega_0(t-t_0) - \phi_{2,0}] \\
& + \cos[\omega_2(t-t_0) - \phi_{2,2}] + \cos[\omega_1(t-t_2) - \phi_{2,1}] \Big\} \\
+ \sqrt{P}\, b_3(t-\tau_3) \Big\{ & \cos[\omega_0(t-t_0) - \phi_{3,0}] \\
& + \cos[\omega_1(t-t_0) - \phi_{3,1}] + \cos[\omega_0(t-t_1) - \phi_{3,0}] \Big\} \\
+ \sqrt{P}\, b_4(t-\tau_4) \Big\{ & \cos[\omega_1(t-t_0) - \phi_{4,1}] \\
& + \cos[\omega_2(t-t_0) - \phi_{4,2}] + \cos[\omega_1(t-t_1) - \phi_{4,1}] \Big\} \\
+ \sqrt{P}\, b_5(t-\tau_5) \Big\{ & \cos[\omega_2(t-t_0) - \phi_{5,2}] \\
& + \cos[\omega_0(t-t_1) - \phi_{5,0}] + \cos[\omega_2(t-t_1) - \phi_{5,2}] \Big\} \\
+ \sqrt{P}\, b_6(t-\tau_6) \Big\{ & \cos[\omega_0(t-t_1) - \phi_{6,0}] \\
& + \cos[\omega_1(t-t_1) - \phi_{6,1}] + \cos[\omega_0(t-t_2) - \phi_{6,0}] \Big\} \\
+ \sqrt{P}\, b_7(t-\tau_7) \Big\{ & \cos[\omega_1(t-t_1) - \phi_{7,1}] \\
& + \cos[\omega_2(t-t_2) - \phi_{7,2}] + \cos[\omega_1(t-t_2) - \phi_{7,1}] \Big\} \\
+ \sqrt{P}\, b_8(t-\tau_8) \Big\{ & \cos[\omega_0(t-t_0) - \phi_{8,0}] \\
& + \cos[\omega_2(t-t_1) - \phi_{8,2}] + \cos[\omega_0(t-t_2) - \phi_{8,0}] \Big\} \\
+ \sqrt{P}\, b_9(t-\tau_9) \Big\{ & \cos[\omega_0(t-t_0) - \phi_{9,0}] \\
& + \cos[\omega_1(t-t_1) - \phi_{9,1}] + \cos[\omega_2(t-t_2) - \phi_{9,2}] \Big\}
\end{aligned}
$$

$$+\sqrt{P}\, b_{10}(t-\tau_{10})\Big\{\cos[\omega_1(t-t_0)-\phi_{10,1}]$$
$$+\cos[\omega_2(t-t_2)-\phi_{10,2}]+\cos[\omega_2(t-t_2)-\phi_{10,2}]\Big\}$$
$$+\sqrt{P}\, b_{11}(t-\tau_{11})\Big\{\cos[\omega_2(t-t_0)-\phi_{11,2}]$$
$$+\cos[\omega_0(t-t_2)-\phi_{11,0}]\cos[\omega_2(t-t_2)-\phi_{11,2}]\Big\}$$
$$+\sqrt{P}\, b_{12}(t-\tau_{12}\ \Big\{\cos[\omega_0(t-t_1)-\phi_{12,0}]$$
$$+\cos[\omega_1(t-t_2)-\phi_{12,1}]\cos[\omega_2(t-t_2)-\phi_{12,2}]\Big\}$$

The input signal to the first correlation receiver of # 1 user is given by

$$Z_{L1} = W(t)\cos\omega_1(t-t_0)$$
$$= \sum_{k=1}^{12} S_k(t-\tau_k)\cos\ \omega_1(t-t_0)+n(t)\cos\omega_1(t-t_0)$$

The expression for the output from the same correlation receiver is written as

$$C_{L1} = \int_0^T n(t)\cos\omega_1(t-t_0)\,dt + \int_0^T\Big\{\sum_{k=1}^{12} S_k(t-\tau_k)\Big\}\cos\omega_1(t-t_0)\,dt$$

Given that $\Theta_1 = 0$, $\tau_1 = 0$, and $\phi_{1,u} = 0$, result in

$$C_{L1} = \int_0^T n(t)\cos\omega_1(t-t_0)\,dt + \sqrt{P}\int_0^T\Big[b_1(t)\Big\{\cos\ \omega_1(t-t_0)$$
$$+\cos\omega_0(t-t_2)+\cos\omega_1(t-t_2)\Big\}+b_2(t-\tau_2)\Big\{\cos[\omega_0(t-t_0)-\phi_{2,0}]$$
$$+\cos[\omega_2(t-t_0)-\phi_{2,2}]+\cos[\omega_1(t-t_2-\phi_{2,1}\ \Big\}\ -------$$

$$+ b_{12}(t-\tau_{12}) \Big\{ \cos\left[\omega_0(t-t_1) - \phi_{12,0}\right] + \cos\left[\omega_1(t-t_2) - \phi_{12,1}\right]$$

$$+ \cos\left[\omega_2(t-t_{12}) - \phi_{12,2}\right] \Big\} \Big] \times \cos\, \omega_1(t-t_0)\, dt \qquad \text{(C-1)}$$

Since the data bit duration (T) is much larger than the period of any carrier (f_n, $f_m >> 1/T$)

$$\int_0^T \cos(\omega_n \pm \omega_m)t\ dt = 0 \qquad \text{(C-2)}$$

Hence,

$$C_{1,1} = \int_0^T n(t) \cos \omega_1 (t-t_0)\, dt + \frac{\sqrt{P}}{2} \int_0^T \Big[b_1(t) \Big\{ 1 + \cos\ \omega_1 (t_2 - t_0) \Big\}$$

$$+ b_2(t-\tau_2) \cos\left[\omega_1(t_2-t_0) + \phi_{2,1}\right] + b_3(t-\tau_3) \cos \phi_{3,1}$$

$$+ b_4(t-\tau_4) \Big\{ \cos \phi_{4,1} + \cos\left[\omega_1 (t_1 - t_0) + \phi_{4,1}\right] \Big\}$$

$$+ b_6(t-\tau_6) \cos\left[\omega_1 (t_1 - t_0) + \phi_{6,1}\right] + b_7 (t-\tau_7)\ \cos\left[\omega_1 (t_1 - t_0) + \phi_{7,1}\right]$$

$$+ b_7(t-\tau_7) \cos\left[\omega_1 (t_2 - t_0) + \phi_{7,1}\right] + b_9 (t-\tau_9)\ \cos\left[\omega_1 (t_1 - t_0) + \phi_{9,1}\right]$$

$$+ b_{10}(t-\tau_{10}) \cos\ \phi_{10,1} + b_{12}(t-\tau_{12}) \cos\left[\omega_1(t_2 - t_0) + \phi_{12,1}\right] \Big] dt \qquad \text{(C-3)}$$

From Eqs.(C-3),(3-5), and (3-6), the output from the first correlation receiver of # 1 user becomes

$$C_{1,1} = \frac{\sqrt{P}}{2}\, B_1(T) + \int_0^T n(t)\cos\omega_1(t-t_0)dt$$

$$+\frac{\sqrt{P}}{2}\Big\{ B_3(\tau_3)\cos\phi_{3,1} + B_4(\tau_4)\cos\phi_{4,1} + B_{10}(\tau_{10})\cos\phi_{10,1}$$

$$+ B_1(T)\cos[\omega_1(t_2-t_0)] + B_2(\tau_2)\cos[\phi_{2,1} + \omega_1(t_2-t_0)]$$

$$+ B_7(\tau_7)\cos[\phi_{7,1} + \omega_1(t_2-t_0)] + B_{12}(\tau_{12})\cos[\phi_{12,1} + \omega_1(t_2-t_0)]$$

$$+ B_4(\tau_4)\cos[\phi_{4,1} + \omega_1(t_1-t_0)] + B_6(\tau_6)\cos[\phi_{6,1} + \omega_1(t_1-t_0)]$$

$$+ B_7(\tau_7)\cos[\phi_{7,1} + \omega_1(t_1-t_0)] + B_9(\tau_9)\cos[\phi_{9,1} + \omega_1(t_1-t_0)]\Big\}$$

(C-4)

C.2 Derivation of Equation (3-15)

From Eq.(3-13), we have

$$Q_{Ln} = \sqrt{\frac{P}{2}} \sum_{k=1}^{L} B_k(\tau_k) \cos \phi_{k,u}$$

Then,

$$E[(Q_{Ln})^2] = \frac{P}{4} E\left[\sum_{k=1}^{L} B_k^2(\tau_k) \cos^2 \phi_{k,u}\right]$$

$$= \frac{P}{8} \frac{1}{T} \int_0^T \frac{1}{2\pi} \int_0^{2\pi} \sum_{k=1}^{L} \left\{ b_{k,1}^2(\tau_k^2) + b_{k,0}^2 (T-\tau_k)^2 \right\}$$

$$\times \left\{ \cos 2\phi_{k,u} + 1 \right\} d\phi_{k,u} \, d\tau_k$$

$$= \frac{P}{8} \frac{1}{T} \sum_{k=1}^{L} \left[\int_0^T \left\{ b_{k,1}^2(\tau_k^2) + b_{k,0}^2 (T-\tau_k)^2 \right\} d\tau_k \right]$$

$$\times \frac{1}{2\pi} \int_0^{2\pi} \left\{ \cos 2\phi_{k,u} + 1 \right\} d\phi_{k,u}$$

$$= \frac{P}{8T} \sum_{k=1}^{L} \left\{ \int_0^T (\tau_k^2 + T^2 - 2T\tau_k + \tau_k^2) \, d\tau_k \right\}$$

$$= \frac{P}{8T} \sum_{k=1}^{L} \left[\frac{2\tau_k^3}{3} + T^2\tau_k - \frac{2T\tau_k^2}{2} \right]_{\tau_k = 0}^{T}$$

$$E[(Q_{Ln})^2] = \frac{P}{8T}\left(\frac{2T^3}{3}\right) \hat{R}_{Ln} = \frac{PT^2}{12} \hat{R}_{Ln} \qquad \text{(C-5)}$$

C.3 Derivation of Equation (3-16)

From Eq.(3-14), we have

$$X_{Ln} = \sqrt{\frac{P}{2}} \sum_{\substack{t_p=t_0 \\ t_p \neq t_m}}^{t_{max}} \sum_{k'=1}^{L} B_{k'}(\tau_{k'}) \cos[\phi_{k',u} + \omega_u(t_p - t_m)]$$

We can derived $E[(X_{i,n})^2]$ as followed:

$$E[(X_{Ln})^2] = \frac{P}{4} E\left[\sum_{\substack{t_p=t_0 \\ t_p \neq t_m}}^{t_{max}} \sum_{k'=1}^{L} B_{k'}^2(\tau_{k'}) \cos^2[\phi_{k',u} + \omega_u(t_p - t_m)] \right]$$

$$= \frac{P}{8} \frac{1}{T} \int_0^T \frac{1}{2\pi} \int_0^{2\pi} \sum_{\substack{t_p=t_0 \\ t_p \neq t_m}}^{t_{max}} \sum_{k'=1}^{L} \left\{ b_{k',-1}^2(\tau_{k'}^2) + b_{k',0}^2 (T-\tau_{k'})^2 \right\}$$

$$\times \left\{ \cos 2[\phi_{k',u} + \omega_u(t_p - t_m)] + 1 \right\} d\phi_{k',u}\, d\tau_{k'}$$

$$= \frac{P}{8T} \sum_{\substack{t_p=t_0 \\ t_p \neq t_m}}^{t_{max}} \sum_{k'=1}^{L} \left[\int_0^T \left\{ b_{k',-1}^2(\tau_{k'}^2) + b_{k',0}^2 (T-\tau_{k'})^2 \right\} d\tau_{k'} \right.$$

$$\left. \times \frac{1}{2\pi} \int_0^{2\pi} \left\{ \cos 2[\phi_{k',u} + \omega_u(t_p - t_m)] + 1 \right\} d\phi_{k',u} \right]$$

$$= \frac{P}{8T} \sum_{\substack{t_p=t_0 \\ t_p \neq t_m}}^{t_{max}} \left(\frac{2T^3}{3} \right) R'_{Ln}(t_p)$$

$$E[(X_{Ln})^2] = \frac{PT^2}{12} \sum_{\substack{t_p=t_0 \\ t_p \neq t_m}}^{t_{max}} R'_{Ln}(t_p) \qquad (C-6)$$

APPENDIX D

PROBABILITY OF ERROR AS A FUNCTION OF SIGNAL-TO-NOISE RATIO

Table D.1 Pe = Q(SNR)

SNR	SNR(dB)	Pe
3.0	9.54	1.3E-03
3.1	9.83	9.7E-04
3.2	10.1	6.95E-04
3.3	10.37	4.80E-04
3.4	10.73	3.4E-04
3.5	10.88	2.3E-04
3.6	11.13	1.6E-04
3.7	11.36	1.05E-04
3.8	11.59	7.0E-05
3.9	11.82	4.9E-05
4.0	12.04	3.0E-05
4.1	12.26	2.2E-05
4.2	12.46	1.4E-05
4.3	12.67	8.9E-06
4.4	12.87	5.7E-06
4.5	13.06	3.56E-06
4.6	13.26	2.2E-06
4.7	13.44	1.36E-06
4.8	13.62	8.3E-07
4.9	13.8	4.99E-07
5.0	13.98	2.98E-07

SNR	SNR(dB)	Pe
5.1	14.15	1.76E-07
5.2	14.32	1.03E-07
5.3	14.85	5.99E-08
5.4	14.65	3.45E-08
5.5	14.8	1.96E-08
5.6	14.96	1.1E-08
5.7	15.12	6.18E-09
5.8	15.27	3.42E-09
5.9	15.42	1.87E-09
6.0	15.56	1.01E-09
6.1	15.7	5.45E-10
6.2	15.85	2.9E-10
6.3	15.97	1.53E-10
6.4	16.12	7.97E-11
6.5	16.26	4.11E-11
6.6	16.39	2.1E-11
6.7	16.52	1.07E-11
6.8	16.65	5.35E-12
6.9	16.78	2.66E-12
7.0	16.9	1.31E-12

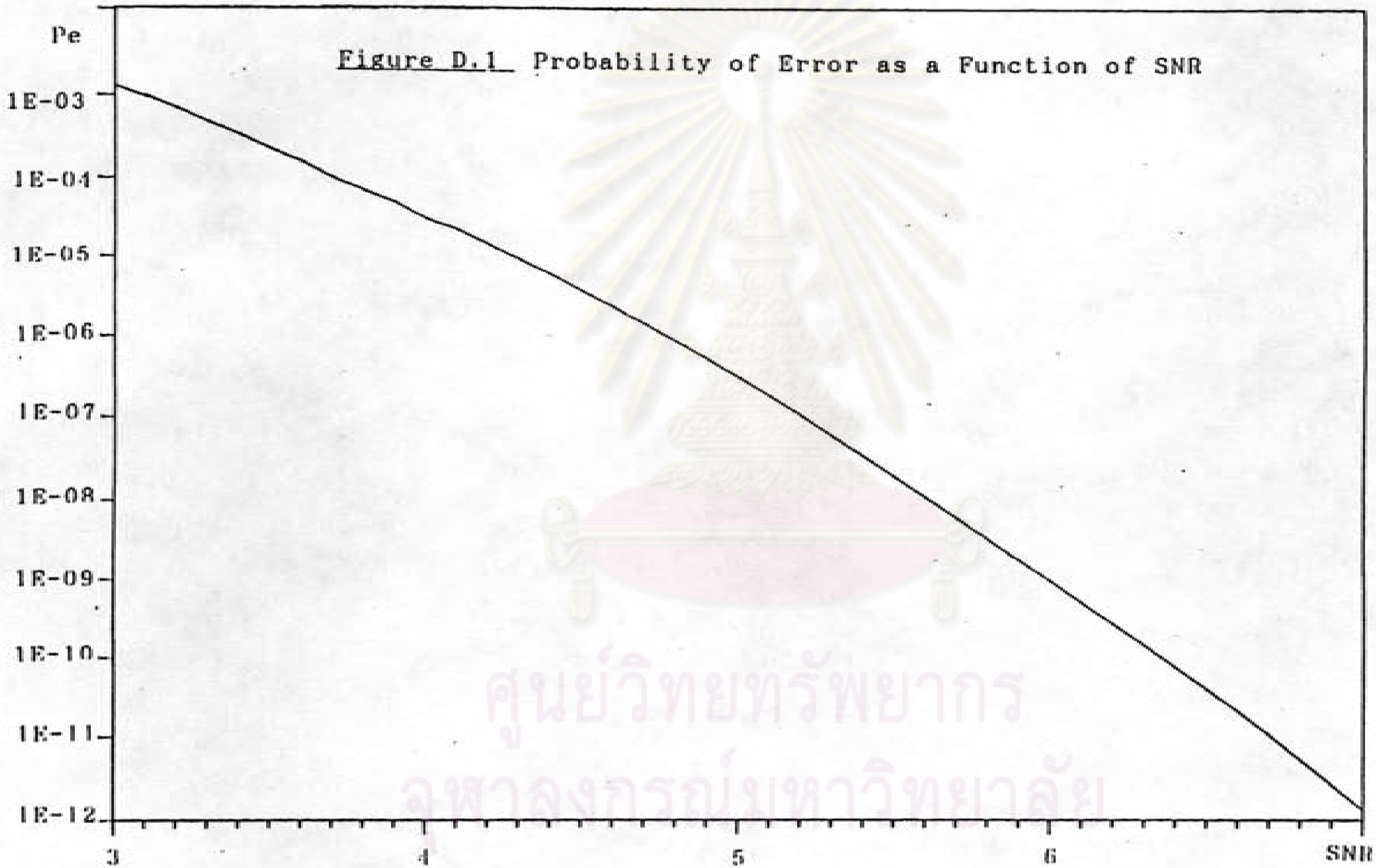


Figure D.1 Probability of Error as a Function of SNR

APPENDIX E

PROBABILITY OF ERROR AS A FUNCTION OF NUMBER OF SIMULTANEOUS USERS

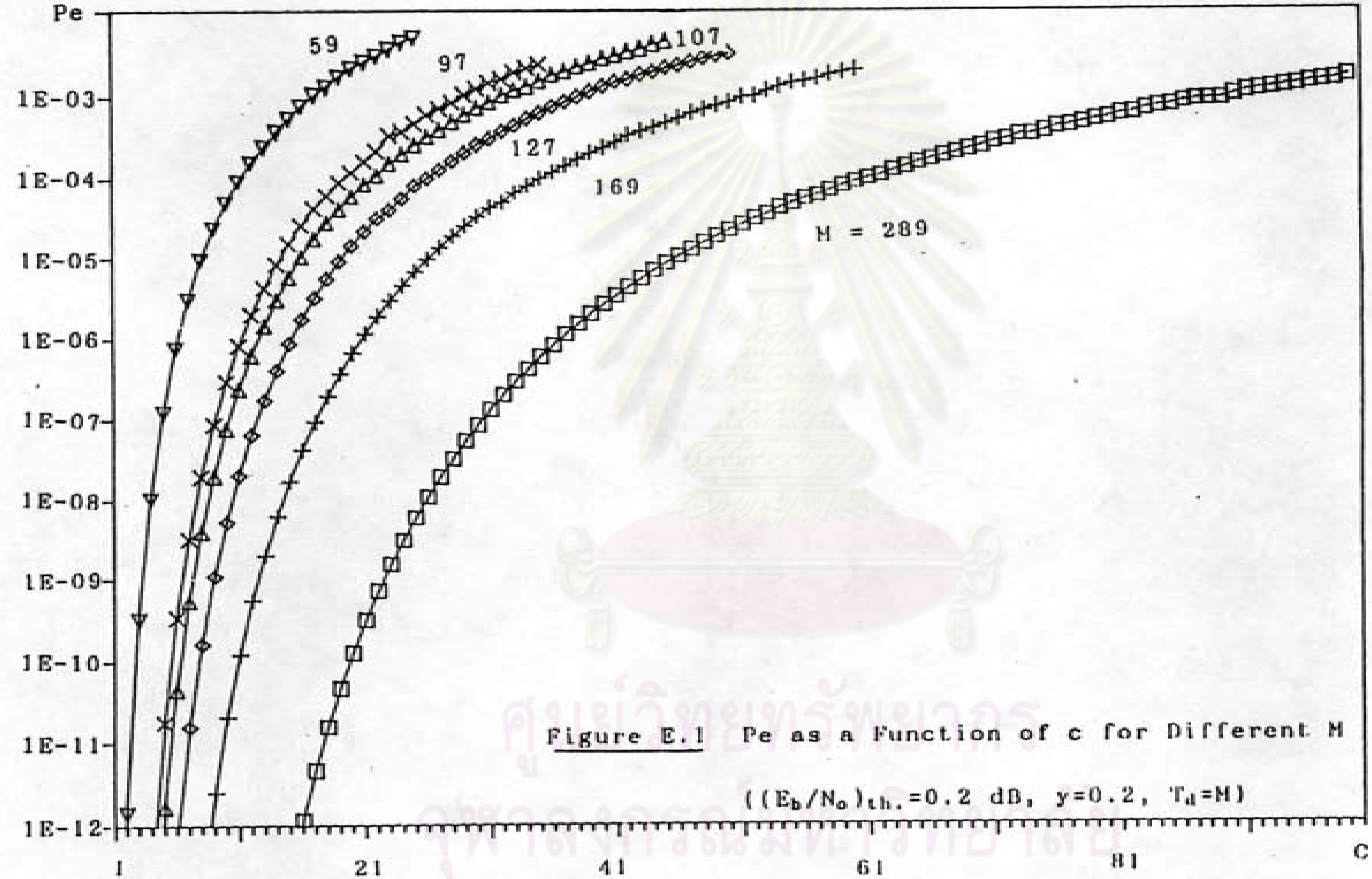


Figure E.1 Pe as a Function of c for Different M

$((E_b/N_o)_{th.}=0.2$ dB, $y=0.2$, $T_d=M)$

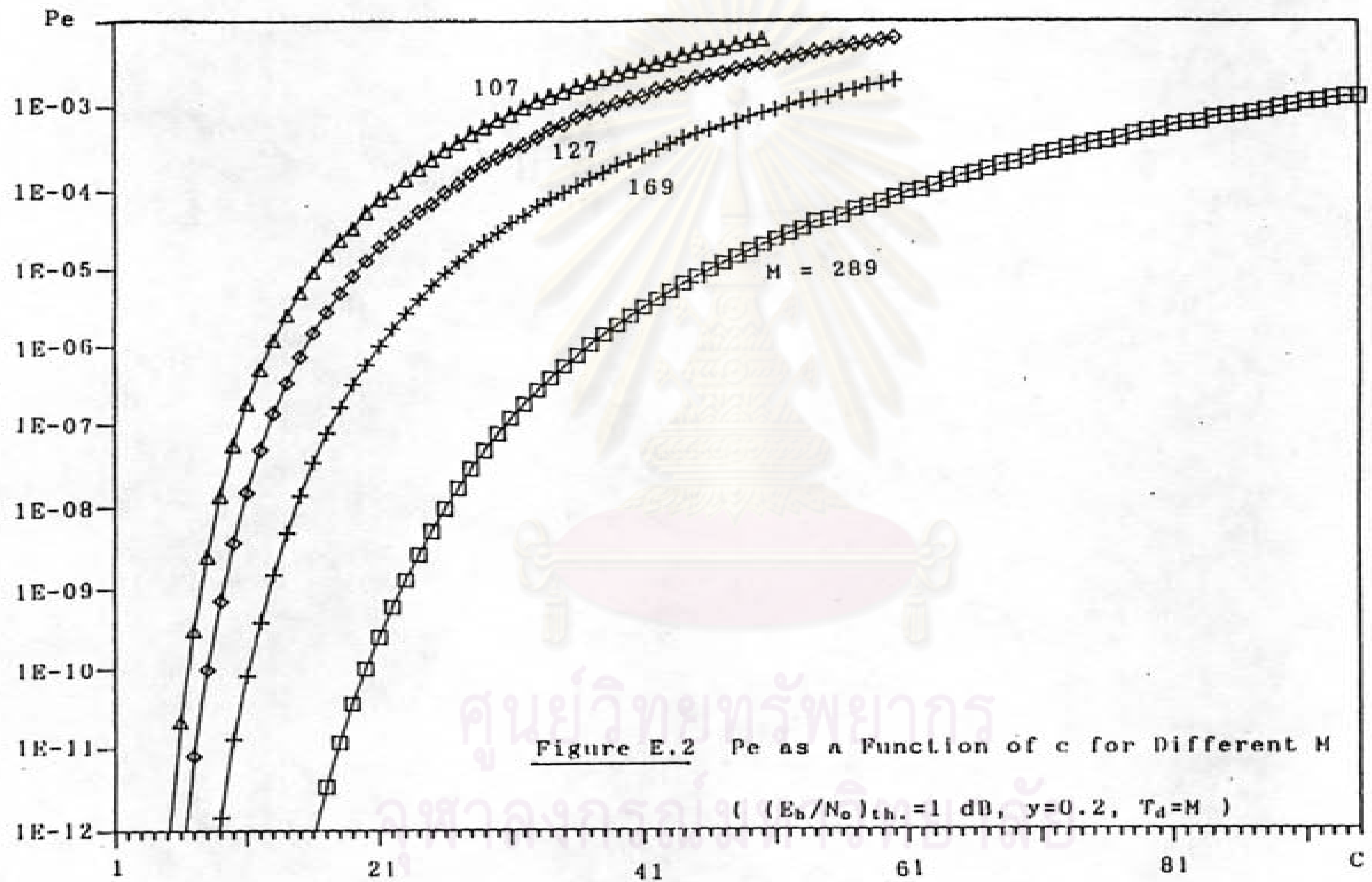


Figure E.2 Pe as a Function of c for Different M

($(E_b/N_o)_{th.}$=1 dB, y=0.2, T_d=M)

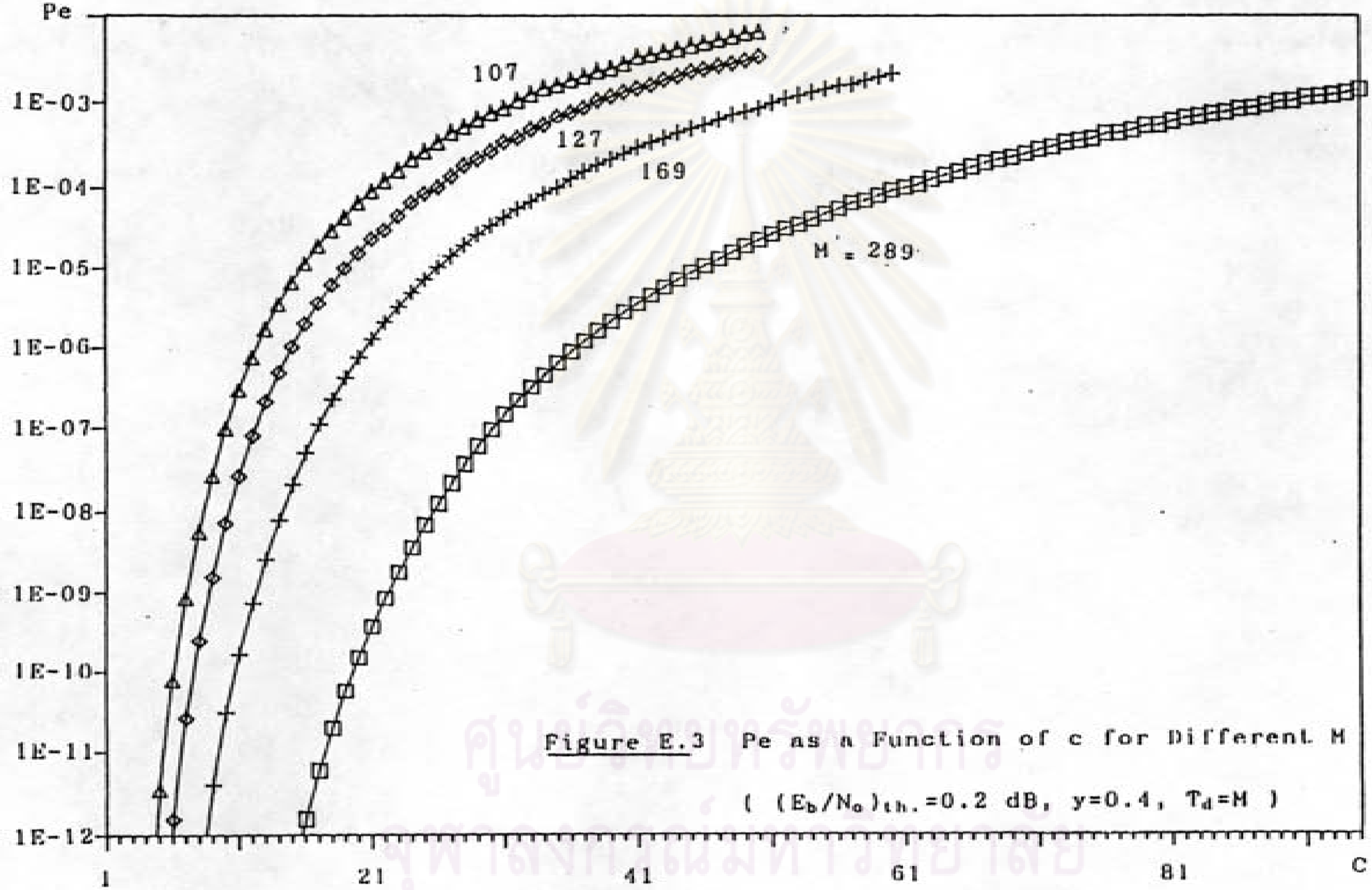


Figure E.3 Pe as a Function of c for Different M

($(E_b/N_o)_{th.}$=0.2 dB, y=0.4, T_d=M)

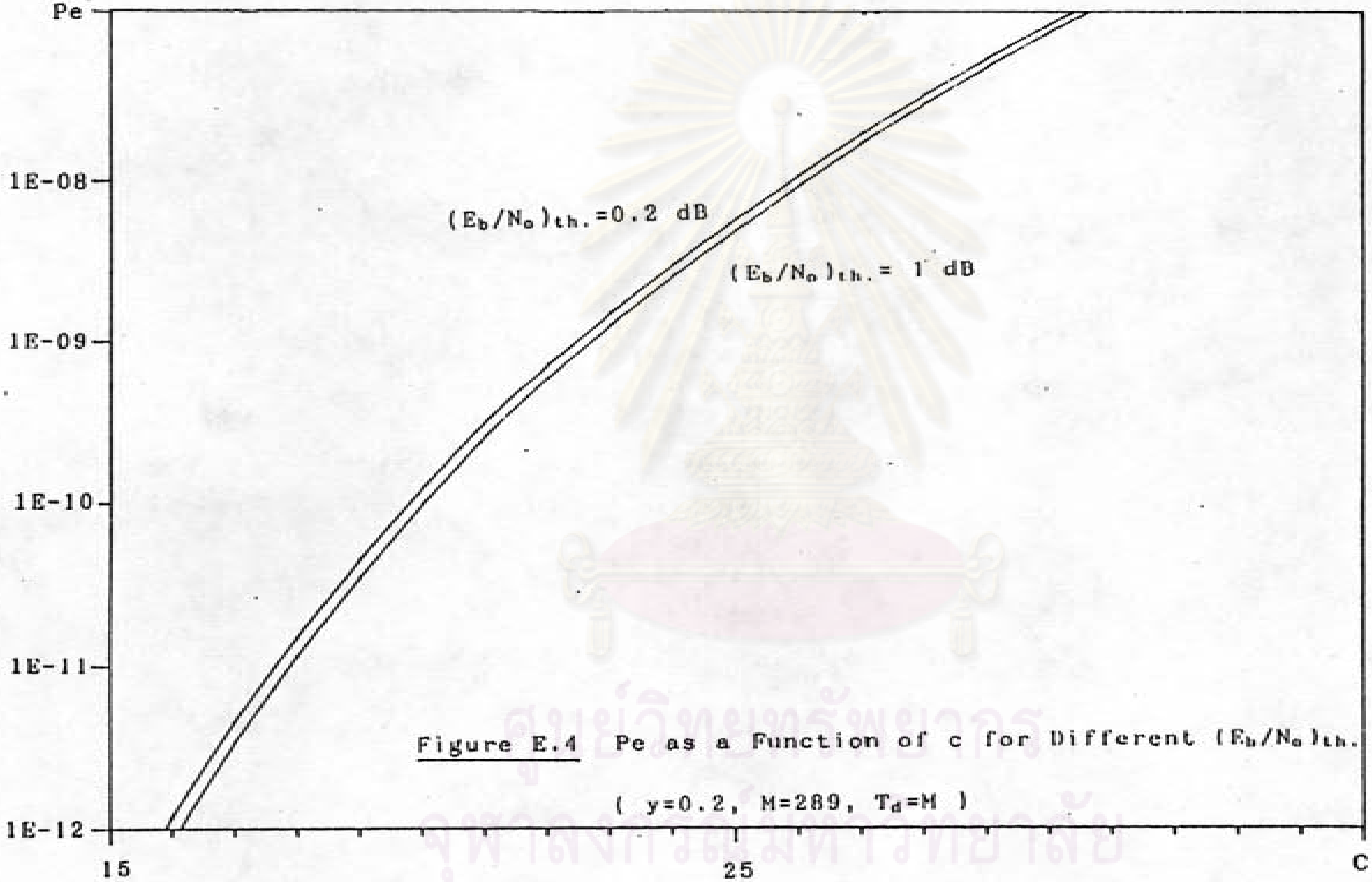


Figure E.4 Pe as a Function of c for Different $(E_b/N_o)_{th.}$

(y=0.2, M=289, T_d=M)

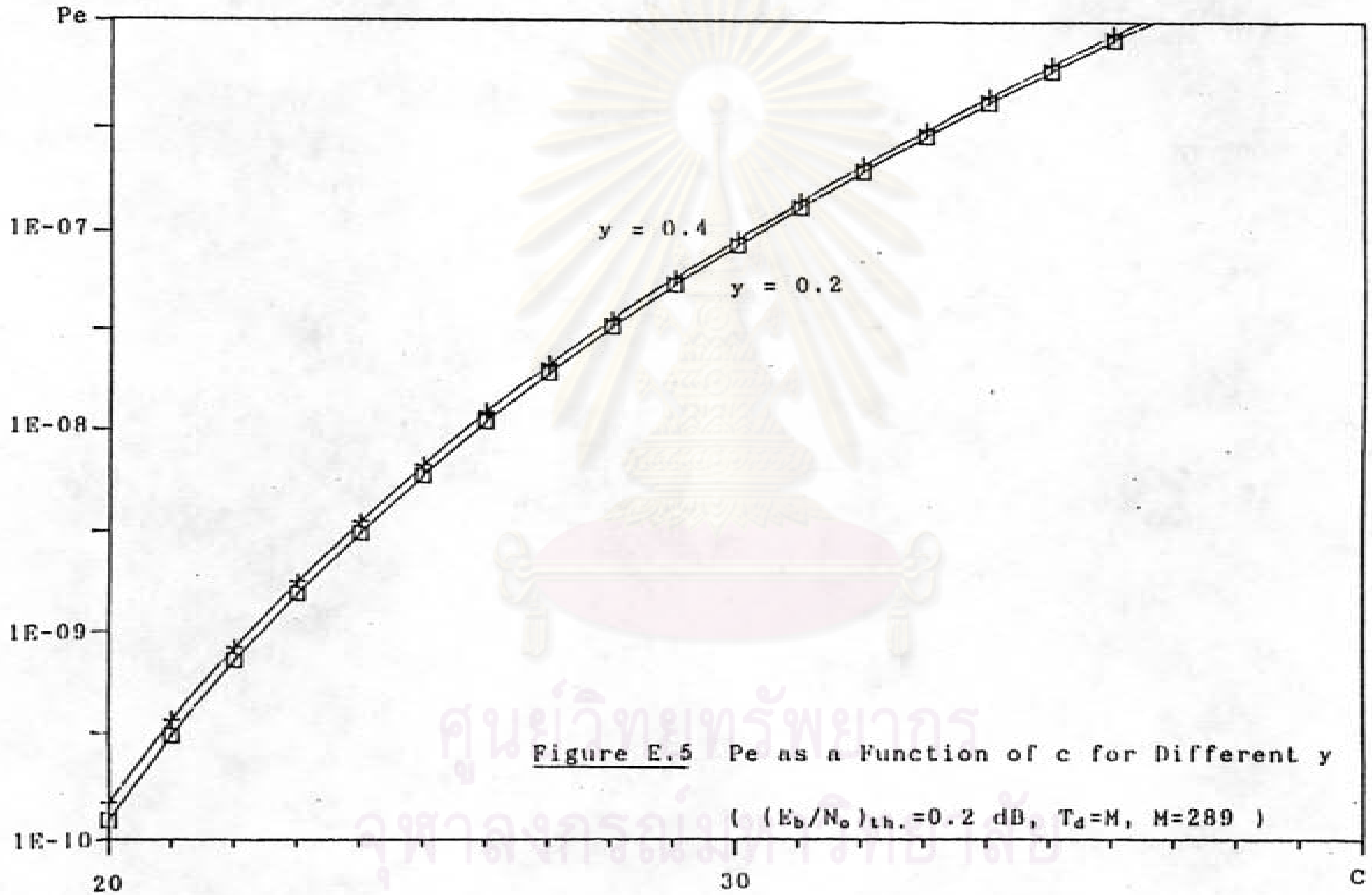


Figure E.5 Pe as a Function of c for Different y

($(E_b/N_o)_{th.}$=0.2 dB, T_d=M, M=289)

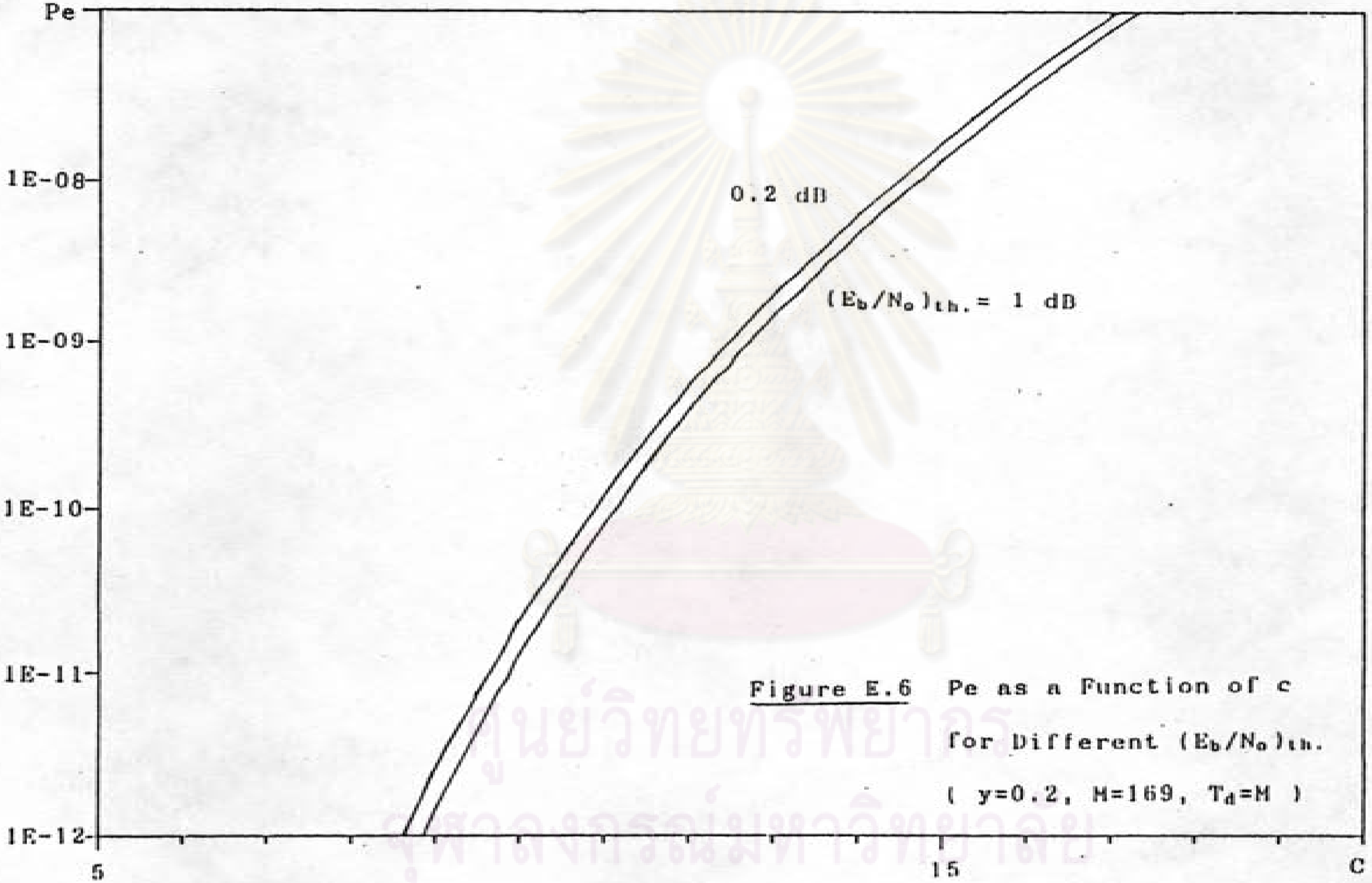


Figure E.6 Pe as a Function of c for Different $(E_b/N_o)_{th.}$ (y=0.2, M=169, T_d=M)

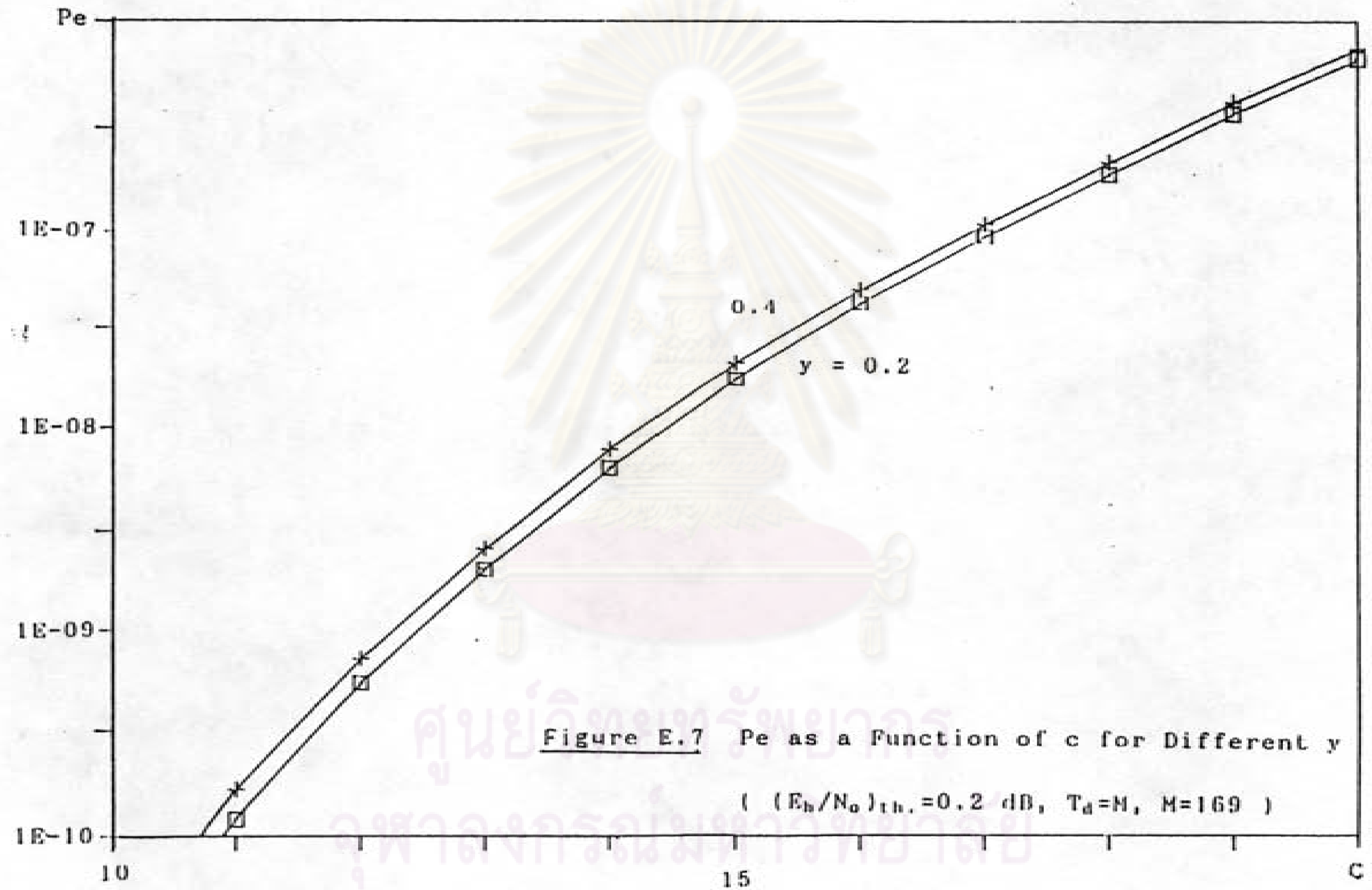


Figure E.7 Pe as a Function of c for Different y

($(E_b/N_o)_{th.}$=0.2 dB, T_d=M, M=169)

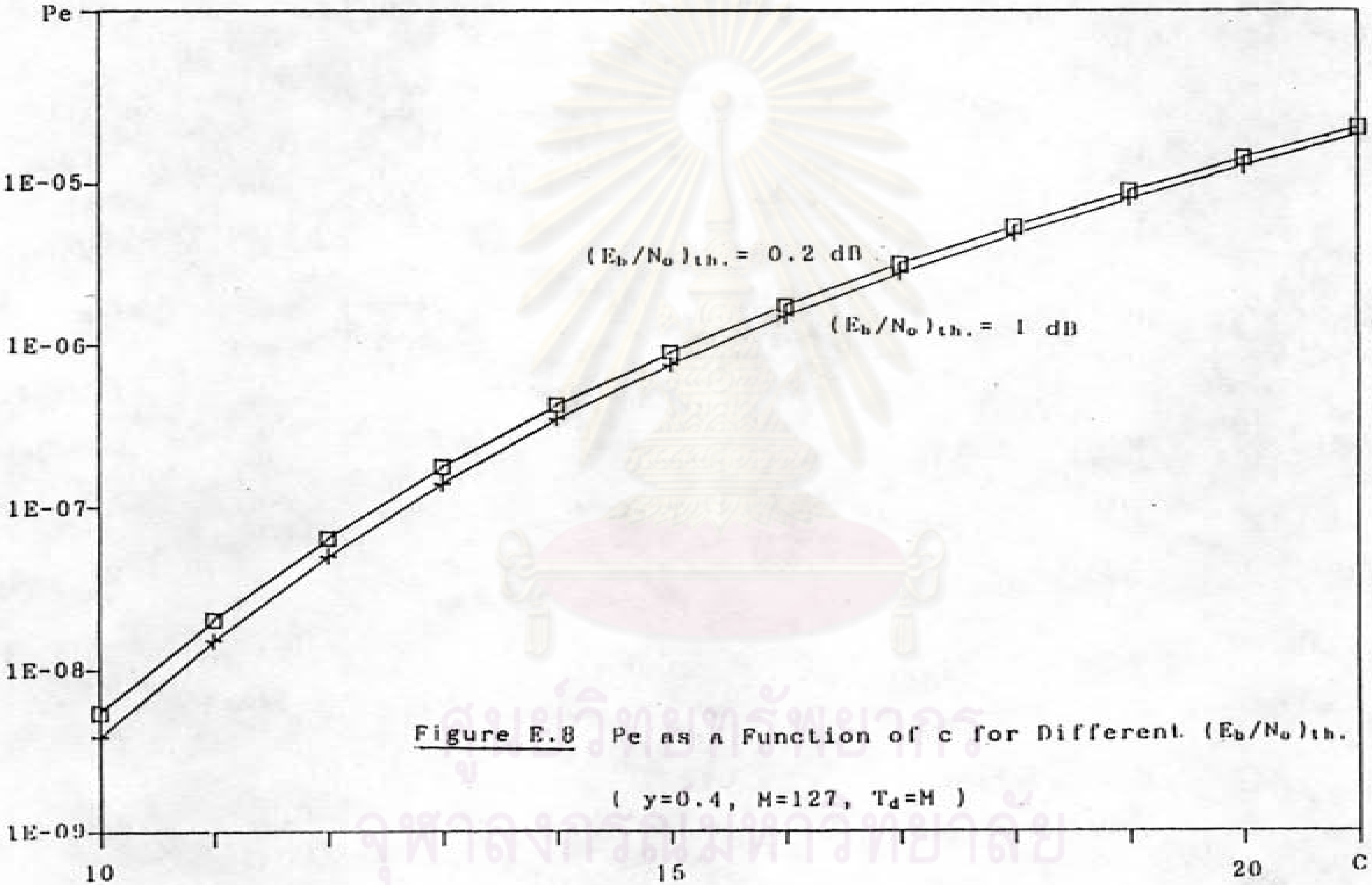


Figure E.8 Pe as a Function of c for Different $(E_b/N_o)_{th.}$

(y=0.4, M=127, T_d=M)

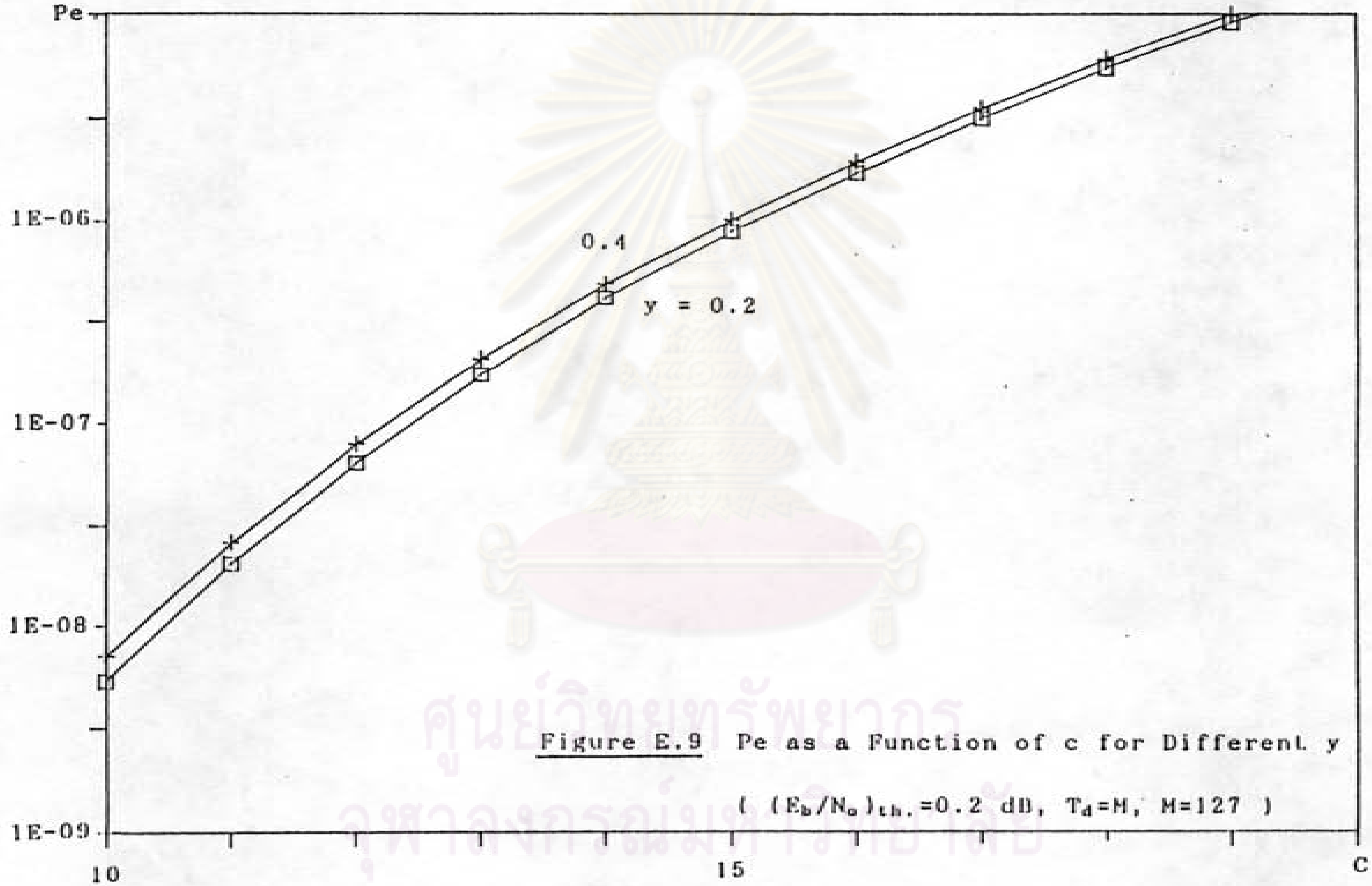


Figure E.9 Pe as a Function of c for Different y

($(E_b/N_o)_{th.}$=0.2 dB, T_d=M, M=127)

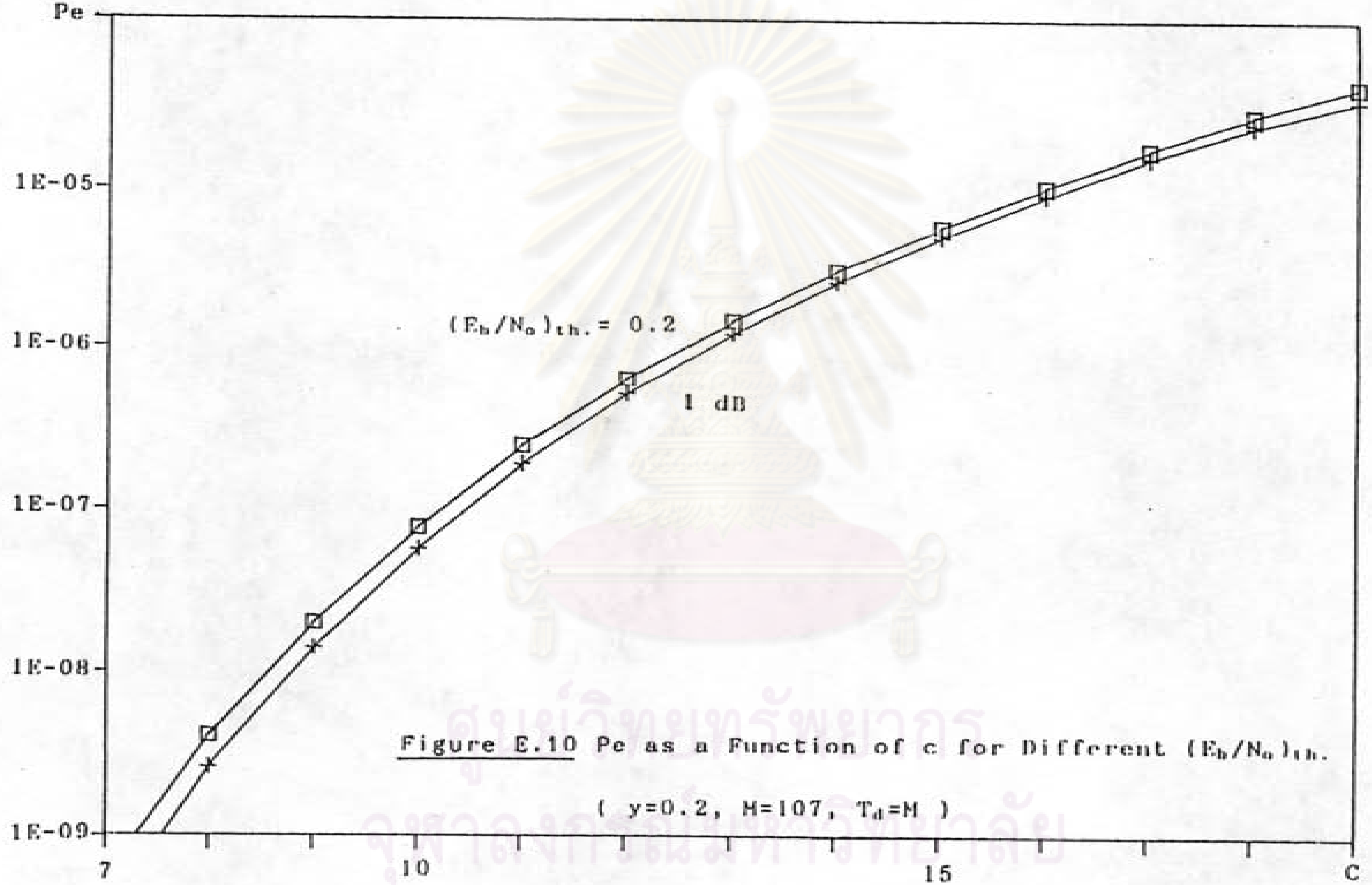
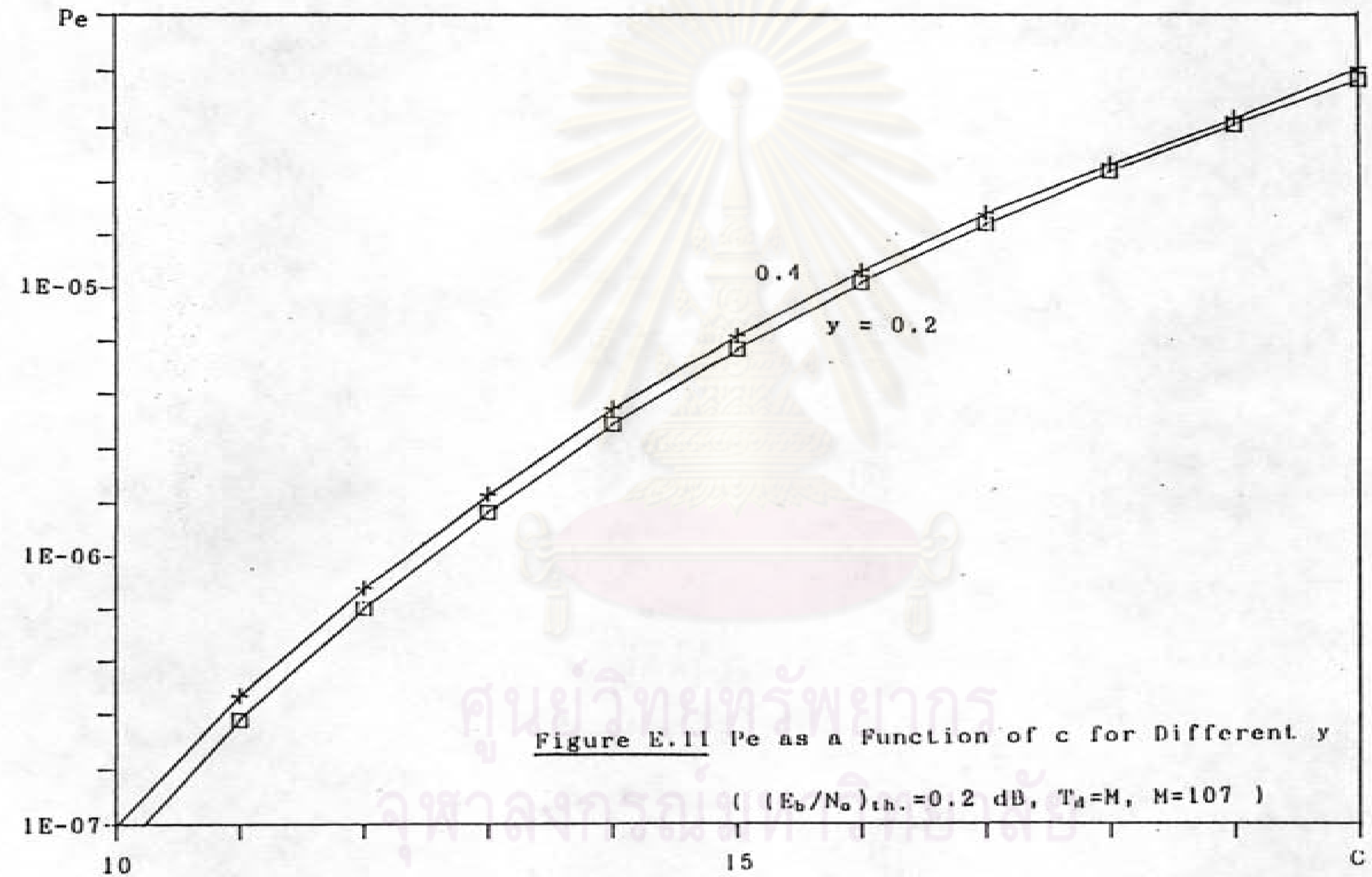


Figure E.10 Pe as a Function of c for Different $(E_b/N_o)_{th.}$

($y=0.2$, $M=107$, $T_d=M$)



<u>Figure E.11</u> Pe as a Function of c for Different y

($(E_b/N_o)_{th.}$=0.2 dB, T_d=M, M=107)

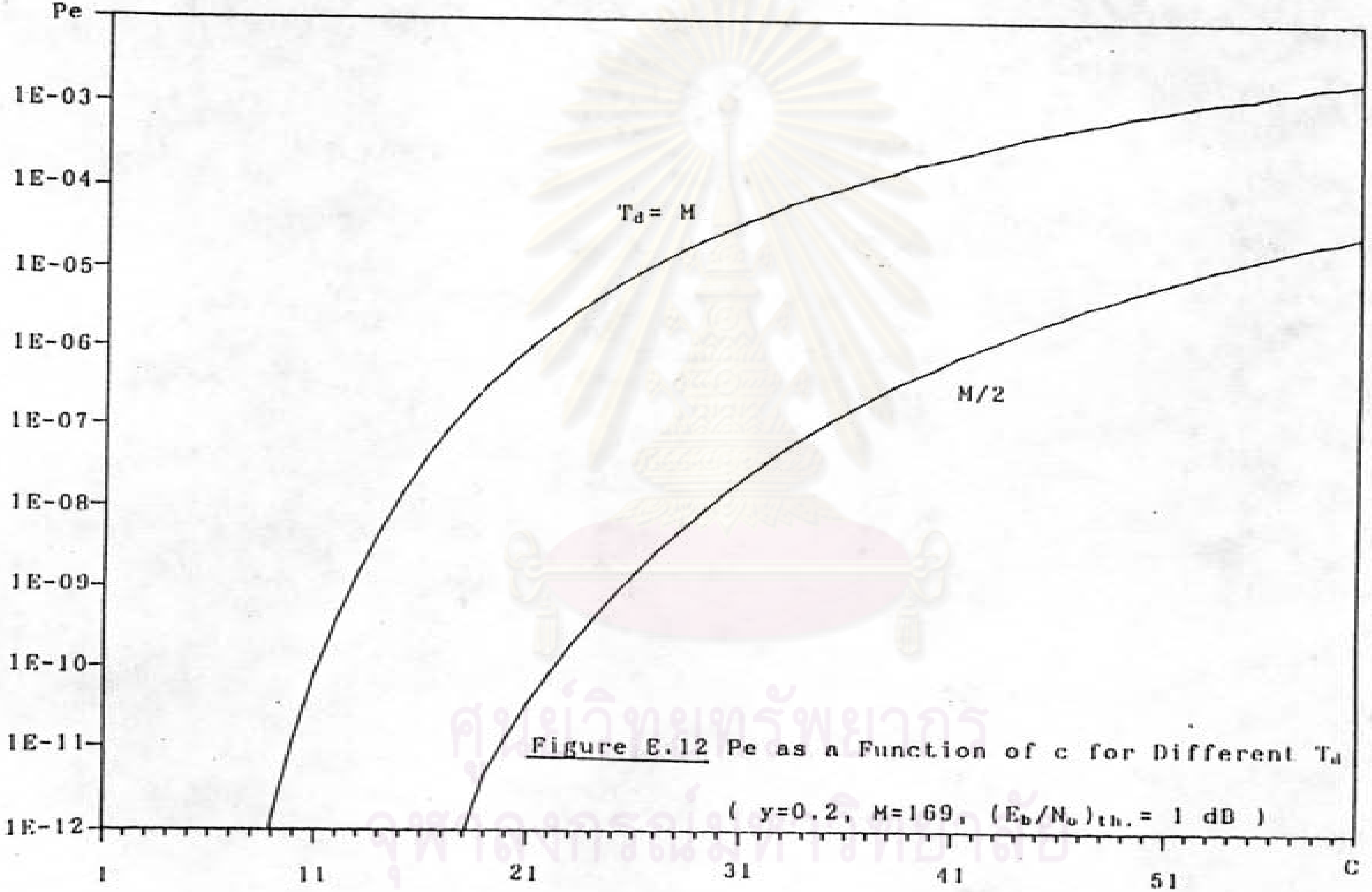


Figure E.12 Pe as a Function of c for Different T_d

(y=0.2, M=169, $(E_b/N_o)_{th.}$ = 1 dB)

Table E.1 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}=0.2$ dB, $\gamma=0.2$, $T_d=M$), Given M=289

C	(E/N)MAI	SNR(dB)	Pe
1	2.5	25.18	5.23E-74
2	1.363636	23.78	3.37E-54
3	0.9375	22.73	6.16E-43
4	0.714285	21.88	1.14E-35
5	0.576923	21.17	1.38E-30
6	0.483870	20.56	7.83E-27
7	0.416666	20.02	6.04E-24
8	0.365853	19.54	1.18E-21
9	0.326086	19.12	8.55E-20
10	0.294117	18.72	2.98E-18
11	0.267857	18.37	5.95E-17
12	0.245901	18.04	7.67E-16
13	0.227272	17.73	6.99E-15
14	0.211267	17.44	4.81E-14
15	0.197368	17.17	2.63E-13
16	0.185185	16.92	1.19E-12
17	0.174418	16.68	4.58E-12
18	0.164835	16.45	1.54E-11
19	0.15625	16.24	4.60E-11
20	0.148514	16.03	1.24E-10
21	0.141509	15.83	3.09E-10
22	0.135135	15.65	7.09E-10
23	0.129310	15.47	1.53E-09
24	0.123966	15.29	3.09E-09
25	0.119047	15.13	5.95E-09
26	0.114503	14.97	1.09E-08
27	0.110294	14.81	1.92E-08
28	0.106382	14.66	3.26E-08
29	0.102739	14.52	5.35E-08
30	0.099337	14.38	8.50E-08
31	0.096153	14.24	1.31E-07
32	0.093167	14.11	1.98E-07
33	0.090361	13.99	2.92E-07
34	0.087719	13.86	4.20E-07
35	0.085227	13.74	5.94E-07
36	0.082872	13.63	8.25E-07
37	0.080645	13.51	1.13E-06

Table E.1 cont.

C	(E/N)MAI	SNR(dB)	Pe
38	0.078534	13.40	1.51E-06
39	0.076530	13.29	2.01E-06
40	0.074626	13.19	2.62E-06
41	0.072815	13.08	3.39E-06
42	0.071090	12.98	4.33E-06
43	0.069444	12.88	5.47E-06
44	0.067873	12.79	6.85E-06
45	0.066371	12.69	8.48E-06
46	0.064935	12.60	1.04E-05
47	0.063559	12.51	1.27E-05
48	0.062240	12.42	1.54E-05
49	0.060975	12.34	1.84E-05
50	0.059760	12.25	2.20E-05
51	0.058593	12.17	2.60E-05
52	0.057471	12.09	3.06E-05
53	0.056390	12.01	3.50E-05
54	0.055350	11.93	4.20E-05
55	0.054347	11.85	4.80E-05
56	0.053380	11.77	5.50E-05
57	0.052447	11.70	6.00E-05
58	0.051546	11.63	7.00E-05
59	0.050675	11.55	8.00E-05
60	0.049833	11.48	9.00E-05
61	0.049019	11.41	1.00E-04
62	0.048231	11.34	1.10E-04
63	0.047468	11.28	1.26E-04
64	0.046728	11.21	1.40E-04
65	0.046012	11.14	1.60E-04
66	0.045317	11.08	1.75E-04
67	0.044642	11.02	1.90E-04
68	0.043988	10.95	2.10E-04
69	0.043352	10.89	2.30E-04
70	0.042735	10.83	2.50E-04
71	0.042134	10.77	2.80E-04
72	0.041551	10.71	3.00E-04
73	0.040983	10.65	3.40E-04
74	0.040431	10.59	3.45E-04

Table E.1 cont.

C	(E/N)MAI	SNR(dB)	Pe
75	0.039893	10.54	3.80E-04
76	0.039370	10.48	4.25E-04
77	0.038860	10.42	4.45E-04
78	0.038363	10.37	4.80E-04
79	0.037878	10.32	5.15E-04
80	0.037406	10.26	5.45E-04
81	0.036945	10.21	6.00E-04
82	0.036496	10.16	6.30E-04
83	0.036057	10.11	6.95E-04
84	0.035629	10.05	7.40E-04
85	0.035211	10.00	7.70E-04
86	0.034802	9.95	8.50E-04
87	0.034403	9.90	8.90E-04
88	0.034013	9.86	9.00E-04
89	0.033632	9.81	9.10E-04
90	0.033259	9.76	1.03E-03
91	0.032894	9.71	1.13E-03
92	0.032537	9.67	1.18E-03
93	0.032188	9.62	1.23E-03
94	0.031847	9.57	1.30E-03
95	0.031512	9.53	1.35E-03
96	0.031185	9.48	1.43E-03
97	0.030864	9.44	1.49E-03
98	0.030549	9.40	1.56E-03
99	0.030241	9.35	1.72E-03
100	0.029940	9.31	1.79E-03

Table E.2 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}$=0.2 dB, y=0.2, T_d=M), Given M=169

C	(E/N)MAI	SNR(dB)	Pe
1	2.5	22.85	3.76E-44
2	1.363636	21.45	1.54E-32
3	0.9375	20.40	6.24E-26
4	0.714285	19.55	1.16E-21
5	0.576923	18.84	1.12E-18
6	0.483870	18.23	1.81E-16
7	0.416666	17.69	9.06E-15
8	0.365853	17.21	2.02E-13
9	0.326086	16.79	2.53E-12
10	0.294117	16.39	2.06E-11
11	0.267857	16.04	1.21E-10
12	0.245901	15.71	5.46E-10
13	0.227272	15.40	2.02E-09
14	0.211267	15.11	6.32E-09
15	0.197368	14.84	1.73E-08
16	0.185185	14.59	4.23E-08
17	0.174418	14.35	9.41E-08
18	0.164835	14.12	1.93E-07
19	0.15625	13.91	3.70E-07
20	0.148514	13.70	6.69E-07
21	0.141509	13.50	1.15E-06
22	0.135135	13.32	1.89E-06
23	0.129310	13.14	2.98E-06
24	0.123966	12.96	4.54E-06
25	0.119047	12.80	6.71E-06
26	0.114503	12.64	9.65E-06
27	0.110294	12.48	1.35E-05
28	0.106382	12.33	1.86E-05
29	0.102739	12.19	2.49E-05
30	0.099337	12.05	3.29E-05
31	0.096153	11.91	4.28E-05
32	0.093167	11.78	5.00E-05
33	0.090361	11.66	6.50E-05
34	0.087719	11.53	8.00E-05
35	0.085227	11.41	1.00E-04
36	0.082872	11.29	1.20E-04
37	0.080645	11.18	1.45E-04

Table E.2 cont.

C	(E/N)MAI	SNR(dB)	Pe
38	0.078534	11.07	1.75E-04
39	0.076530	10.96	2.10E-04
40	0.074626	10.86	2.40E-04
41	0.072815	10.75	2.80E-04
42	0.071090	10.65	3.40E-04
43	0.069444	10.55	3.80E-04
44	0.067873	10.46	4.25E-04
45	0.066371	10.36	4.80E-04
46	0.064935	10.27	5.45E-04
47	0.063559	10.18	6.30E-04
48	0.062240	10.09	7.00E-04
49	0.060975	10.01	7.70E-04
50	0.059760	9.92	8.45E-04
51	0.058593	9.84	9.70E-04
52	0.057471	9.76	1.00E-03
53	0.056390	9.68	1.15E-03
54	0.055350	9.60	1.30E-03
55	0.054347	9.52	1.43E-03
56	0.053380	9.44	1.49E-03
57	0.052447	9.37	1.60E-03
58	0.051546	9.30	1.79E-03
59	0.050675	9.22	1.92E-03
60	0.049833	9.15	2.05E-03

Table E.3 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}$=0.2 dB, y=0.2, T_d=M), Given M=127

C	(E/N)MAI	SNR(dB)	Pe
1	2.5	21.61	1.11E-33
2	1.363636	20.21	6.16E-25
3	0.9375	19.15	5.87E-20
4	0.714285	18.31	9.70E-17
5	0.576923	17.60	1.74E-14
6	0.483870	16.98	8.06E-13
7	0.416666	16.45	1.55E-11
8	0.365853	15.97	1.62E-10
9	0.326086	15.54	1.10E-09
10	0.294117	15.15	5.35E-09
11	0.267857	14.80	2.04E-08
12	0.245901	14.46	6.41E-08
13	0.227272	14.16	1.73E-07
14	0.211267	13.87	4.11E-07
15	0.197368	13.60	8.82E-07
16	0.185185	13.35	1.74E-06
17	0.174418	13.11	3.19E-06
18	0.164835	12.88	5.52E-06
19	0.15625	12.66	9.06E-06
20	0.148514	12.46	1.42E-05
21	0.141509	12.26	2.15E-05
22	0.135135	12.07	3.13E-05
23	0.129310	11.89	4.00E-05
24	0.123966	11.72	5.50E-05
25	0.119047	11.56	8.00E-05
26	0.114503	11.40	1.00E-04
27	0.110294	11.24	1.30E-04
28	0.106382	11.09	1.65E-04
29	0.102739	10.95	2.10E-04
30	0.099337	10.81	2.65E-04
31	0.096153	10.67	3.10E-04
32	0.093167	10.54	3.80E-04
33	0.090361	10.41	4.45E-04
34	0.087719	10.29	5.40E-04
35	0.085227	10.17	6.30E-04
36	0.082872	10.05	7.40E-04
37	0.080645	9.94	8.45E-04

Table E.3 cont.

C	(E/N)MAI	SNR(dB)	Pe
38	0.078534	9.83	9.70E-04
39	0.076530	9.72	1.13E-03
40	0.074626	9.62	1.30E-03
41	0.072815	9.51	1.45E-03
42	0.071090	9.41	1.56E-03
43	0.069444	9.31	1.79E-03
44	0.067873	9.22	1.92E-03
45	0.066371	9.12	2.14E-03
46	0.064935	9.03	2.30E-03
47	0.063559	8.94	2.55E-03
48	0.062240	8.85	2.79E-03
49	0.060975	8.77	3.00E-03
50	0.059760	8.68	3.17E-03

Table E.4 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}=0.2$ dB, y=0.2, $T_d=M$), Given M=107

C	(E/N)MAI	SNR(dB)	Pe
1	2.5	20.87	1.10E-28
2	1.363636	19.47	2.62E-21
3	0.9375	18.41	4.18E-17
4	0.714285	17.56	2.18E-14
5	0.576923	16.85	1.75E-12
6	0.483870	16.24	4.48E-11
7	0.416666	15.71	5.46E-10
8	0.365853	15.23	3.98E-09
9	0.326086	14.80	2.01E-08
10	0.294117	14.41	7.69E-08
11	0.267857	14.05	2.39E-07
12	0.245901	13.72	6.31E-07
13	0.227272	13.41	1.46E-06
14	0.211267	13.13	3.05E-06
15	0.197368	12.86	5.84E-06
16	0.185185	12.60	1.04E-05
17	0.174418	12.36	1.74E-05
18	0.164835	12.14	2.77E-05
19	0.15625	11.92	4.10E-05
20	0.148514	11.71	5.90E-05
21	0.141509	11.52	8.50E-05
22	0.135135	11.33	1.10E-04
23	0.129310	11.15	1.55E-04
24	0.123966	10.98	2.05E-04
25	0.119047	10.81	2.65E-04
26	0.114503	10.65	3.30E-04
27	0.110294	10.50	4.00E-04
28	0.106382	10.35	5.00E-04
29	0.102739	10.20	6.00E-04
30	0.099337	10.06	7.30E-04
31	0.096153	9.93	8.45E-04
32	0.093167	9.80	1.03E-03
33	0.090361	9.67	1.18E-03
34	0.087719	9.55	1.30E-03
35	0.085227	9.43	1.50E-03
36	0.082872	9.31	1.79E-03
37	0.080645	9.20	1.96E-03

Table E.4 cont.

C	(E/N)MAI	SNR(dB)	Pe
38	0.078534	9.08	2.24E-03
39	0.076530	8.98	2.45E-03
40	0.074626	8.87	2.79E-03
41	0.072815	8.77	3.00E-03
42	0.071090	8.67	3.31E-03
43	0.069444	8.57	3.60E-03
44	0.067873	8.47	4.02E-03
45	0.066371	8.38	4.45E-03

Table E.5 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}$=0.2 dB, y=0.2, T_d=M), Given M=97

C	(E/N)MAI	SNR(dB)	Pe
1	2.5	20.44	3.46E-26
2	1.363636	19.04	1.72E-19
3	0.9375	17.98	1.12E-15
4	0.714285	17.13	3.29E-13
5	0.576923	16.42	1.76E-11
6	0.483870	15.81	3.36E-10
7	0.416666	15.28	3.26E-09
8	0.365853	14.80	1.99E-08
9	0.326086	14.37	8.65E-08
10	0.294117	13.98	2.94E-07
11	0.267857	13.63	8.24E-07
12	0.245901	13.29	1.99E-06
13	0.227272	12.99	4.28E-06
14	0.211267	12.70	8.37E-06
15	0.197368	12.43	1.51E-05
16	0.185185	12.18	2.56E-05
17	0.174418	11.94	4.20E-05
18	0.164835	11.71	6.00E-05
19	0.15625	11.49	8.90E-05
20	0.148514	11.29	1.20E-04
21	0.141509	11.09	1.65E-04
22	0.135135	10.90	2.20E-04
23	0.129310	10.72	3.40E-04
24	0.123966	10.55	3.80E-04
25	0.119047	10.39	4.72E-04
26	0.114503	10.23	6.00E-04
27	0.110294	10.07	7.10E-04
28	0.106382	9.92	8.45E-04
29	0.102739	9.78	1.04E-03
30	0.099337	9.64	1.23E-03
31	0.096153	9.50	1.43E-03
32	0.093167	9.37	1.60E-03
33	0.090361	9.24	1.90E-03
34	0.087719	9.12	2.14E-03
35	0.085227	9.00	2.38E-03

<u>Table E.6</u> Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}$=0.2 dB, γ=0.2, T_d=M), Given M=59

C	(E/N)MAI	SNR(dB)	Pe
1	2.5	18.28	1.16E-16
2	1.363636	16.88	1.46E-12
3	0.9375	15.83	3.20E-10
4	0.714285	14.98	1.06E-08
5	0.576923	14.27	1.23E-07
6	0.483870	13.66	7.58E-07
7	0.416666	13.12	3.09E-06
8	0.365853	12.64	9.48E-06
9	0.326086	12.21	2.37E-05
10	0.294117	11.82	4.90E-05
11	0.267857	11.47	9.25E-05
12	0.245901	11.14	1.60E-04
13	0.227272	10.83	2.50E-04
14	0.211267	10.54	3.80E-04
15	0.197368	10.27	5.45E-04
16	0.185185	10.02	7.70E-04
17	0.174418	9.78	1.04E-03
18	0.164835	9.55	1.30E-03
19	0.15625	9.34	1.71E-03
20	0.148514	9.13	2.14E-03
21	0.141509	8.93	2.58E-03
22	0.135135	8.75	3.00E-03
23	0.129310	8.57	3.60E-03
24	0.123966	8.39	4.30E-03
25	0.119047	8.23	4.90E-03

Table E.7 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different

$(E_b/N_o)_{th.}$ = 1 dB, y=0.2, T_d=M), Given M=289

C	(E/N)MAI	SNR(dB)	Pe
1	2.5	25.60	3.67E-81
2	1.363636	24.08	7.40E-58
3	0.9375	22.96	3.74E-45
4	0.714285	22.06	3.73E-37
5	0.576923	21.32	1.19E-31
6	0.483870	20.69	1.24E-27
7	0.416666	20.14	1.43E-24
8	0.365853	19.65	3.71E-22
9	0.326086	19.21	3.32E-20
10	0.294117	18.81	1.35E-18
11	0.267857	18.45	3.05E-17
12	0.245901	18.11	4.32E-16
13	0.227272	17.80	4.25E-15
14	0.211267	17.51	3.11E-14
15	0.197368	17.23	1.79E-13
16	0.185185	16.98	8.44E-13
17	0.174418	16.73	3.37E-12
18	0.164835	16.50	1.17E-11
19	0.15625	16.29	3.58E-11
20	0.148514	16.08	9.90E-11
21	0.141509	15.88	2.50E-10
22	0.135135	15.69	5.86E-10
23	0.129310	15.51	1.28E-09
24	0.123966	15.33	2.63E-09
25	0.119047	15.17	5.11E-09
26	0.114503	15.00	9.49E-09
27	0.110294	14.85	1.69E-08
28	0.106382	14.70	2.89E-08
29	0.102739	14.55	4.77E-08
30	0.099337	14.41	7.63E-08
31	0.096153	14.28	1.19E-07
32	0.093167	14.14	1.80E-07
33	0.090361	14.02	2.67E-07
34	0.087719	13.89	3.86E-07
35	0.085227	13.77	5.48E-07
36	0.082872	13.65	7.64E-07
37	0.080645	13.54	1.05E-06
38	0.078534	13.43	1.41E-06
39	0.076530	13.32	1.88E-06
40	0.074626	13.21	2.46E-06

Table E.7 cont.

C	(E/N)MAI	SNR(dB)	Pe
41	0.072815	13.11	3.19E-06
42	0.071090	13.01	4.09E-06
43	0.069444	12.91	5.18E-06
44	0.067873	12.81	6.50E-06
45	0.066371	12.72	8.07E-06
46	0.064935	12.62	9.93E-06
47	0.063559	12.53	1.21E-05
48	0.062240	12.44	1.47E-05
49	0.060975	12.36	1.77E-05
50	0.059760	12.27	2.11E-05
51	0.058593	12.19	2.50E-05
52	0.057471	12.11	2.95E-05
53	0.056390	12.02	3.40E-05
54	0.055350	11.95	4.20E-05
55	0.054347	11.87	4.50E-05
56	0.053380	11.79	5.00E-05
57	0.052447	11.72	6.00E-05
58	0.051546	11.64	6.50E-05
59	0.050675	11.57	7.50E-05
60	0.049833	11.50	8.50E-05
61	0.049019	11.43	1.00E-04
62	0.048231	11.36	1.05E-04
63	0.047468	11.29	1.20E-04
64	0.046728	11.23	1.35E-04
65	0.046012	11.16	1.55E-04
66	0.045317	11.09	1.65E-04
67	0.044642	11.03	1.85E-04
68	0.043988	10.97	2.10E-04
69	0.043352	10.91	2.20E-04
70	0.042735	10.84	2.50E-04
71	0.042134	10.78	2.80E-04
72	0.041551	10.72	2.95E-04
73	0.040983	10.67	3.25E-04
74	0.040431	10.61	3.45E-04
75	0.039893	10.55	3.80E-04
76	0.039370	10.49	4.00E-04
77	0.038860	10.44	4.25E-04
78	0.038363	10.38	4.80E-04
79	0.037878	10.33	5.15E-04
80	0.037406	10.27	5.40E-04

Table E.7 cont.

C	(E/N)MAI	SNR(dB)	Pe
81	0.036945	10.22	6.00E-04
82	0.036496	10.17	6.40E-04
83	0.036057	10.12	6.60E-04
84	0.035629	10.07	7.40E-04
85	0.035211	10.02	7.70E-04
86	0.034802	9.97	8.05E-04
87	0.034403	9.92	8.45E-04
88	0.034013	9.87	9.05E-04
89	0.033632	9.82	9.70E-04
90	0.033259	9.77	1.04E-03
91	0.032894	9.72	1.13E-03
92	0.032537	9.68	1.15E-03
93	0.032188	9.63	1.23E-03
94	0.031847	9.59	1.30E-03
95	0.031512	9.54	1.30E-03

Table E.8 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.} = 1$ dB, y=0.2, T_d=M), Given M=169

C	(E/N)MAI	SNR(dB)	Pe
1	2.5	23.27	2.41E-48
2	1.363636	21.75	1.10E-34
3	0.9375	20.62	3.12E-27
4	0.714285	19.73	1.55E-22
5	0.576923	18.99	2.65E-19
6	0.483870	18.36	6.11E-17
7	0.416666	17.81	3.88E-15
8	0.365853	17.32	1.03E-13
9	0.326086	16.88	1.45E-12
10	0.294117	16.48	1.29E-11
11	0.267857	16.12	8.12E-11
12	0.245901	15.78	3.89E-10
13	0.227272	15.47	1.50E-09
14	0.211267	15.18	4.88E-09
15	0.197368	14.90	1.38E-08
16	0.185185	14.65	3.45E-08
17	0.174418	14.40	7.84E-08
18	0.164835	14.17	1.64E-07
19	0.15625	13.96	3.19E-07
20	0.148514	13.75	5.84E-07
21	0.141509	13.55	1.01E-06
22	0.135135	13.36	1.68E-06
23	0.129310	13.18	2.68E-06
24	0.123966	13.00	4.12E-06
25	0.119047	12.84	6.13E-06
26	0.114503	12.67	8.87E-06
27	0.110294	12.52	1.25E-05
28	0.106382	12.37	1.72E-05
29	0.102739	12.22	2.33E-05
30	0.099337	12.08	3.00E-05
31	0.096153	11.95	4.00E-05
32	0.093167	11.81	4.90E-05
33	0.090361	11.69	6.50E-05
34	0.087719	11.56	8.00E-05
35	0.085227	11.44	9.50E-05
36	0.082872	11.32	1.15E-04
37	0.080645	11.21	1.40E-04
38	0.078534	11.10	1.65E-04
39	0.076530	10.99	2.05E-04
40	0.074626	10.88	2.30E-04

Table E.8 cont.

C	(E/N)MAI	SNR(dB)	Pe
41	0.072815	10.78	2.65E-04
42	0.071090	10.68	3.10E-04
43	0.069444	10.58	3.60E-04
44	0.067873	10.48	4.25E-04
45	0.066371	10.39	4.80E-04
46	0.064935	10.29	5.40E-04
47	0.063559	10.20	6.00E-04
48	0.062240	10.11	6.60E-04
49	0.060975	10.03	7.70E-04
50	0.059760	9.94	8.45E-04
51	0.058593	9.86	9.30E-04
52	0.057471	9.78	1.04E-03
53	0.056390	9.69	1.15E-03
54	0.055350	9.62	1.23E-03
55	0.054347	9.54	1.30E-03
56	0.053380	9.46	1.49E-03
57	0.052447	9.39	1.60E-03
58	0.051546	9.31	1.79E-03
59	0.050675	9.24	1.87E-03
60	0.049833	9.17	2.05E-03

Table E.9 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}$ = 1 dB, y=0.2, T_d=M), Given M=127

C	(E/N)MAI	SNR(dB)	Pe
1	2.5	22.02	7.77E-37
2	1.363636	20.51	1.49E-26
3	0.9375	19.38	6.14E-21
4	0.714285	18.49	2.13E-17
5	0.576923	17.75	5.85E-15
6	0.483870	17.12	3.55E-13
7	0.416666	16.57	8.17E-12
8	0.365853	16.08	9.69E-11
9	0.326086	15.64	7.18E-10
10	0.294117	15.24	3.76E-09
11	0.267857	14.88	1.51E-08
12	0.245901	14.54	4.96E-08
13	0.227272	14.23	1.38E-07
14	0.211267	13.94	3.38E-07
15	0.197368	13.66	7.41E-07
16	0.185185	13.41	1.49E-06
17	0.174418	13.16	2.78E-06
18	0.164835	12.93	4.87E-06
19	0.15625	12.71	8.09E-06
20	0.148514	12.51	1.28E-05
21	0.141509	12.31	1.95E-05
22	0.135135	12.12	2.87E-05
23	0.129310	11.94	4.00E-05
24	0.123966	11.76	5.50E-05
25	0.119047	11.59	6.90E-05
26	0.114503	11.43	9.50E-05
27	0.110294	11.28	1.20E-04
28	0.106382	11.13	1.62E-04
29	0.102739	10.98	2.05E-04
30	0.099337	10.84	2.50E-04
31	0.096153	10.71	3.00E-04
32	0.093167	10.57	3.45E-04
33	0.090361	10.44	4.25E-04
34	0.087719	10.32	5.40E-04
35	0.085227	10.20	6.00E-04
36	0.082872	10.08	7.40E-04
37	0.080645	9.97	8.45E-04
38	0.078534	9.86	9.30E-04
39	0.076530	9.75	1.10E-03
40	0.074626	9.64	1.23E-03

Table E.9 cont.

C	(E/N)MAI	SNR(dB)	Pe
41	0.072815	9.54	1.30E-03
42	0.071090	9.44	1.56E-03
43	0.069444	9.34	1.71E-03
44	0.067873	9.24	1.87E-03
45	0.066371	9.14	2.14E-03
46	0.064935	9.05	2.25E-03
47	0.063559	8.96	2.45E-03
48	0.062240	8.87	2.79E-03
49	0.060975	8.79	2.99E-03
50	0.059760	8.70	3.17E-03
51	0.058593	8.62	3.50E-03
52	0.057471	8.53	3.80E-03
53	0.056390	8.45	4.02E-03
54	0.055350	8.37	4.45E-03
55	0.054347	8.30	4.70E-03
56	0.053380	8.22	4.90E-03
57	0.052447	8.15	5.40E-03
58	0.051546	8.07	5.60E-03
59	0.050675	8.00	6.00E-03
60	0.049833	7.93	6.45E-03

Table E.10 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}$ = 1 dB, y=0.2, T_d=M), Given M=107

C	(E/N)MAI	SNR(dB)	Pe
1	2.5	21.28	2.39E-31
2	1.363636	19.76	1.13E-22
3	0.9375	18.64	6.20E-18
4	0.714285	17.75	6.06E-15
5	0.576923	17.01	6.96E-13
6	0.483870	16.38	2.24E-11
7	0.416666	15.83	3.18E-10
8	0.365853	15.34	2.58E-09
9	0.326086	14.90	1.40E-08
10	0.294117	14.50	5.71E-08
11	0.267857	14.13	1.86E-07
12	0.245901	13.80	5.08E-07
13	0.227272	13.48	1.21E-06
14	0.211267	13.19	2.58E-06
15	0.197368	12.92	5.04E-06
16	0.185185	12.66	9.11E-06
17	0.174418	12.42	1.55E-05
18	0.164835	12.19	2.40E-05
19	0.15625	11.97	3.40E-05
20	0.148514	11.76	5.50E-05
21	0.141509	11.56	8.00E-05
22	0.135135	11.37	1.00E-04
23	0.129310	11.19	1.40E-04
24	0.123966	11.02	1.85E-04
25	0.119047	10.85	2.40E-04
26	0.114503	10.69	3.10E-04
27	0.110294	10.53	3.80E-04
28	0.106382	10.38	4.80E-04
29	0.102739	10.24	5.70E-04
30	0.099337	10.10	6.95E-04
31	0.096153	9.96	8.05E-04
32	0.093167	9.83	9.70E-04
33	0.090361	9.70	1.15E-03
34	0.087719	9.58	1.30E-03
35	0.085227	9.46	1.49E-03
36	0.082872	9.34	1.71E-03
37	0.080645	9.22	1.92E-03
38	0.078534	9.11	2.14E-03
39	0.076530	9.00	2.38E-03
40	0.074626	8.90	2.60E-03

Table E.10 cont.

C	(E/N)MAI	SNR(dB)	Pe
41	0.072815	8.79	2.99E-03
42	0.071090	8.69	3.17E-03
43	0.069444	8.59	3.57E-03
44	0.067873	8.50	4.00E-03
45	0.066371	8.40	4.30E-03
46	0.064935	8.31	4.70E-03
47	0.063559	8.22	4.90E-03
48	0.062240	8.13	5.40E-03
49	0.060975	8.04	5.87E-03
50	0.059760	7.96	6.20E-03

Table E.11 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}$ = 1 dB, y=0.4, T_d=M), Given M=289

C	(E/N)MAI	SNR(dB)	Pe
1	2.142857	24.86	6.29E-69
2	1.25	23.55	1.78E-51
3	0.882352	22.54	3.05E-41
4	0.681818	21.72	1.64E-34
5	0.555555	21.04	9.52E-30
6	0.46875	20.44	3.39E-26
7	0.405405	19.92	1.91E-23
8	0.357142	19.46	2.97E-21
9	0.319148	19.03	1.83E-19
10	0.288461	18.65	5.65E-18
11	0.263157	18.30	1.02E-16
12	0.241935	17.97	1.22E-15
13	0.223880	17.67	1.05E-14
14	0.208333	17.39	6.88E-14
15	0.194805	17.12	3.61E-13
16	0.182926	16.87	1.58E-12
17	0.172413	16.63	5.89E-12
18	0.163043	16.41	1.93E-11
19	0.154639	16.19	5.65E-11
20	0.147058	15.99	1.50E-10
21	0.140186	15.80	3.67E-10
22	0.133928	15.61	8.31E-10
23	0.128205	15.43	1.76E-09
24	0.122950	15.26	3.54E-09
25	0.118110	15.09	6.74E-09
26	0.113636	14.94	1.23E-08
27	0.109489	14.78	2.14E-08
28	0.105633	14.63	3.61E-08
29	0.102040	14.49	5.88E-08
30	0.098684	14.35	9.30E-08
31	0.095541	14.22	1.43E-07
32	0.092592	14.09	2.14E-07
33	0.089820	13.96	3.14E-07
34	0.087209	13.84	4.51E-07
35	0.084745	13.72	6.35E-07
36	0.082417	13.60	8.79E-07
37	0.080213	13.49	1.20E-06
38	0.078125	13.38	1.60E-06
39	0.076142	13.27	2.12E-06
40	0.074257	13.17	2.77E-06

Table E.11 cont.

C	(E/N)MAI	SNR(dB)	Pe
41	0.072463	13.06	3.56E-06
42	0.070754	12.96	4.54E-06
43	0.069124	12.86	5.73E-06
44	0.067567	12.77	7.15E-06
45	0.066079	12.68	8.85E-06
46	0.064655	12.58	1.09E-05
47	0.063291	12.49	1.32E-05
48	0.061983	12.41	1.59E-05
49	0.060728	12.32	1.91E-05
50	0.059523	12.23	2.27E-05
51	0.058365	12.15	2.69E-05
52	0.057251	12.07	3.16E-05
53	0.056179	11.99	3.50E-05
54	0.055147	11.91	4.10E-05
55	0.054151	11.83	4.80E-05
56	0.053191	11.76	5.50E-05
57	0.052264	11.68	6.50E-05
58	0.051369	11.61	7.00E-05
59	0.050505	11.54	8.00E-05
60	0.049668	11.47	9.25E-05
61	0.048859	11.40	1.00E-04
62	0.048076	11.33	1.10E-04
63	0.047318	11.26	1.26E-04
64	0.046583	11.20	1.40E-04
65	0.045871	11.13	1.55E-04
66	0.045180	11.07	1.75E-04
67	0.044510	11.00	1.95E-04
68	0.043859	10.94	2.15E-04
69	0.043227	10.88	2.30E-04
70	0.042613	10.82	2.50E-04
71	0.042016	10.76	2.80E-04
72	0.041436	10.70	3.05E-04
73	0.040871	10.64	3.40E-04
74	0.040322	10.58	3.60E-04
75	0.039787	10.52	3.80E-04
76	0.039267	10.47	4.35E-04
77	0.038759	10.41	4.45E-04
78	0.038265	10.36	4.80E-04
79	0.037783	10.30	5.40E-04
80	0.037313	10.25	5.45E-04

Table E.11 cont.

C	(E/N)MAI	SNR(dB)	Pe
81	0.036855	10.20	6.00E-04
82	0.036407	10.15	6.60E-04
83	0.035971	10.09	6.95E-04
84	0.035545	10.04	7.40E-04
85	0.035128	9.99	7.70E-04
86	0.034722	9.94	8.45E-04
87	0.034324	9.89	8.70E-04
88	0.033936	9.85	9.40E-04
89	0.033557	9.80	1.02E-03
90	0.033185	9.75	1.04E-03
91	0.032822	9.70	1.15E-03
92	0.032467	9.66	1.18E-03
93	0.032119	9.61	1.23E-03
94	0.031779	9.57	1.30E-03
95	0.031446	9.52	1.41E-03

Table E.12 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}$ = 1 dB, y=0.4, T_d=M), Given M=169

C	(E/N)MAI	SNR(dB)	Pe
1	2.142857	22.53	3.57E-41
2	1.25	21.22	6.08E-31
3	0.882352	20.21	6.16E-25
4	0.681818	19.39	5.53E-21
5	0.555555	18.71	3.49E-18
6	0.46875	18.11	4.29E-16
7	0.405405	17.59	1.78E-14
8	0.357142	17.13	3.49E-13
9	0.319148	16.70	3.97E-12
10	0.288461	16.32	3.00E-11
11	0.263157	15.97	1.66E-10
12	0.241935	15.64	7.20E-10
13	0.223880	15.34	2.57E-09
14	0.208333	15.06	7.81E-09
15	0.194805	14.79	2.09E-08
16	0.182926	14.54	5.00E-08
17	0.172413	14.30	1.09E-07
18	0.163043	14.08	2.21E-07
19	0.154639	13.86	4.19E-07
20	0.147058	13.66	7.49E-07
21	0.140186	13.47	1.27E-06
22	0.133928	13.28	2.07E-06
23	0.128205	13.10	3.25E-06
24	0.122950	12.93	4.92E-06
25	0.118110	12.76	7.23E-06
26	0.113636	12.61	1.03E-05
27	0.109489	12.45	1.44E-05
28	0.105633	12.30	1.97E-05
29	0.102040	12.16	2.64E-05
30	0.098684	12.02	3.40E-05
31	0.095541	11.89	4.30E-05
32	0.092592	11.76	5.50E-05
33	0.089820	11.63	6.80E-05
34	0.087209	11.51	8.50E-05
35	0.084745	11.39	1.00E-04
36	0.082417	11.27	1.26E-04
37	0.080213	11.16	1.55E-04
38	0.078125	11.05	1.85E-04
39	0.076142	10.94	2.15E-04
40	0.074257	10.84	2.50E-04

Table E.12 cont.

C	(E/N)MAI	SNR(dB)	Pe
41	0.072463	10.73	2.95E-04
42	0.070754	10.63	3.40E-04
43	0.069124	10.53	3.80E-04
44	0.067567	10.44	4.45E-04
45	0.066079	10.34	5.00E-04
46	0.064655	10.25	5.45E-04
47	0.063291	10.16	6.30E-04
48	0.061983	10.08	7.10E-04
49	0.060728	9.99	7.70E-04
50	0.059523	9.90	8.50E-04
51	0.058365	9.82	9.70E-04
52	0.057251	9.74	1.10E-03
53	0.056179	9.66	1.18E-03
54	0.055147	9.58	1.30E-03
55	0.054151	9.50	1.41E-03
56	0.053191	9.43	1.56E-03
57	0.052264	9.35	1.60E-03
58	0.051369	9.28	1.80E-03
59	0.050505	9.21	1.96E-03
60	0.049668	9.14	2.14E-03

Table E.13 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}$ = 1 dB, γ=0.4, T_d=M), Given M=127

C	(E/N)MAI	SNR(dB)	Pe
1	2.142857	21.29	1.94E-31
2	1.25	19.98	9.83E-24
3	0.882352	18.97	3.30E-19
4	0.681818	18.15	3.15E-16
5	0.555555	17.47	4.09E-14
6	0.46875	16.87	1.55E-12
7	0.405405	16.35	2.58E-11
8	0.357142	15.88	2.45E-10
9	0.319148	15.46	1.54E-09
10	0.288461	15.08	7.12E-09
11	0.263157	14.73	2.60E-08
12	0.241935	14.40	7.91E-08
13	0.223880	14.10	2.07E-07
14	0.208333	13.81	4.82E-07
15	0.194805	13.55	1.02E-06
16	0.182926	13.30	1.97E-06
17	0.172413	13.06	3.58E-06
18	0.163043	12.84	6.12E-06
19	0.154639	12.62	9.95E-06
20	0.147058	12.42	1.55E-05
21	0.140186	12.22	2.32E-05
22	0.133928	12.04	3.00E-05
23	0.128205	11.86	4.50E-05
24	0.122950	11.69	6.50E-05
25	0.118110	11.52	8.50E-05
26	0.113636	11.36	1.00E-04
27	0.109489	11.21	1.35E-04
28	0.105633	11.06	1.80E-04
29	0.102040	10.92	2.15E-04
30	0.098684	10.78	2.65E-04
31	0.095541	10.65	3.40E-04
32	0.092592	10.52	3.80E-04
33	0.089820	10.39	4.80E-04
34	0.087209	10.27	5.45E-04
35	0.084745	10.15	6.60E-04
36	0.082417	10.03	7.40E-04
37	0.080213	9.92	8.50E-04
38	0.078125	9.81	1.03E-03
39	0.076142	9.70	1.15E-03
40	0.074257	9.59	1.30E-03

<u>Table E.13</u> cont.

C	(E/N)MAI	SNR(dB)	Pe
41	0.072463	9.49	1.41E-03
42	0.070754	9.39	1.56E-03
43	0.069124	9.29	1.79E-03
44	0.067567	9.20	1.96E-03
45	0.066079	9.10	2.24E-03
46	0.064655	9.01	2.38E-03
47	0.063291	8.92	2.60E-03
48	0.061983	8.83	2.79E-03
49	0.060728	8.75	3.00E-03
50	0.059523	8.66	3.31E-03

Table E.14 Pe, SNR, and $(E_b/N_o)_{MAI}$ for Different c

$(E_b/N_o)_{th.}$ = 1 dB, y=0.4, T_d=M), Given M=107

C	(E/N)MAI	SNR(dB)	Pe
1	2.142857	20.55	8.52E-27
2	1.25	19.23	2.71E-20
3	0.882352	18.23	1.79E-16
4	0.681818	17.41	5.91E-14
5	0.555555	16.72	3.61E-12
6	0.46875	16.13	7.77E-11
7	0.405405	15.61	8.42E-10
8	0.357142	15.14	5.65E-09
9	0.319148	14.72	2.68E-08
10	0.288461	14.34	9.80E-08
11	0.263157	13.98	2.94E-07
12	0.241935	13.66	7.54E-07
13	0.223880	13.35	1.71E-06
14	0.208333	13.07	3.50E-06
15	0.194805	12.80	6.59E-06
16	0.182926	12.55	1.16E-05
17	0.172413	12.32	1.92E-05
18	0.163043	12.09	2.95E-05
19	0.154639	11.88	4.30E-05
20	0.147058	11.67	6.50E-05
21	0.140186	11.48	9.00E-05
22	0.133928	11.29	1.20E-04
23	0.128205	11.12	1.60E-04
24	0.122950	10.94	2.15E-04
25	0.118110	10.78	2.65E-04
26	0.113636	10.62	3.40E-04
27	0.109489	10.47	4.45E-04
28	0.105633	10.32	5.15E-04
29	0.102040	10.18	6.30E-04
30	0.098684	10.04	7.40E-04
31	0.095541	9.90	8.50E-04
32	0.092592	9.77	1.04E-03
33	0.089820	9.65	1.23E-03
34	0.087209	9.52	1.43E-03
35	0.084745	9.40	1.56E-03
36	0.082417	9.29	1.80E-03
37	0.080213	9.17	1.96E-03
38	0.078125	9.06	2.25E-03
39	0.076142	8.96	2.45E-03
40	0.074257	8.85	2.79E-03

Table E.14 cont.

C	(E/N)MAI	SNR(dB)	Pe
41	0.072463	8.75	3.31E-03
42	0.070754	8.65	3.50E-03
43	0.069124	8.55	3.80E-03
44	0.067567	8.45	4.02E-03
45	0.066079	8.36	4.45E-03
46	0.064655	8.27	4.80E-03
47	0.063291	8.18	5.20E-03
48	0.061983	8.09	5.60E-03
49	0.060728	8.00	6.20E-03
50	0.059523	7.92	6.45E-03

Table E.15 Pe for Different c When T_d= M/2

$(E_b/N_o)_{th.}$= 1 dB, y=0.2) , Given M=169

C	Pe
18	8.44E-13
19	4.60E-12
20	1.29E-11
21	3.43E-11
22	8.12E-11
23	1.86E-10
24	3.89E-10
25	7.95E-10
26	1.50E-09
27	2.86E-09
28	4.88E-09
29	8.28E-09
30	1.38E-08
31	2.23E-08
32	3.45E-08
33	5.32E-08
34	7.84E-08
35	1.16E-07
36	1.64E-07
37	2.33E-07
38	3.19E-07
39	4.38E-07
40	5.84E-07
41	7.81E-07
42	1.01E-06
43	1.29E-06
44	1.68E-06
45	2.15E-06
46	2.68E-06
47	3.40E-06
48	4.12E-06
49	5.08E-06
50	6.13E-06
51	7.30E-06
52	8.78E-06
53	1.08E-05
54	1.25E-05
55	1.48E-05
56	1.72E-05
57	2.02E-05

Table E.15 cont.

C	Pe
58	2.33E-05
59	2.50E-05
60	3.00E-05

BIOGRAPHICAL NOTE

Miss Nongluck Phinainitisart was born in Bangkok, Thailand, on July 13, 1959. She enrolled at Chulalongkorn University in June, 1977, and received her B.Eng. degree in electrical engineering in April, 1981. In December, 1984, she received a M.S. degree in the same field from the University of Missouri at Columbia. From June, 1985, to the present time she has been a doctoral student in electrical engineering at Chulalongkorn University. She has been awarded a 1989-1990 Zonta Amelia Earhart Fellowship to support her study.

Since her graduation in 1981, she has been employed by the Post and Telegraph Department of Thailand. From August, 1986, to November 1987, she was employed by INTELSAT (International Telecommunication Satellite Organization).