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(54) METHODE D'EQUILIBRAGE DE PUISSANCES CONJOINTES OPTIMALES POUR VOIES DE DONNEES CONSTITUANTES CODEES/MRT

(54) JOINT OPTIMAL POWER BALANCE FOR CODED/TDM CONSTITUENT DATA CHANNELS

$$\frac{\{E_c / I_o \vert_{data}\}\vert_i}{\{E_c / I_o \vert_{pilot}\}\vert_i} = \sqrt{(R \cdot SNR) / 2B(1 + SNR)}$$

(57) A method of balancing transmit signal power among a plurality of constituent Welsh channels in a CDMA celleular communications system, comprises the steps of: (a) determining a pilot filter bandwidth and a quality for each channel; (b) determining $\{E_c / I_o \vert_{data}\}\vert_i$; for each constituent Welsh channel, based on E_b / I_o and processing gain data G_{data}, or $E_c / I_o \vert_{data} = E_b / I_o - G_{data}$; (c) determining an optimum pilot E_c / I_o requirement for each constituent Walsh channel, or $\{E_c / I_o \vert_{pilot}\}\vert_i$, where i ={fundamental channel, supplemental channel, control channel}, using (see above formula) (d) selecting a maximum pilot E_c / I_o, or $\max\{E_c / I_o \vert_{pilot}\}\vert_i$ and $\{E_c / I_o \vert_{data}\}\vert_i$, for each constituent Walsh channel in step (b).

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Abstract of the Disclosure

A method of balancing transmit signal power among a plurality of constituent Walsh channels in a CDMA celleular communications system, comprises the steps of:

(a) determining a pilot filter bandwidth and a quality for each channel;

(b) determining $\{E_c / I_o |_{data}\} |_i$ for each constituent Walsh channel, based on E_b / I_o and processing gain data G_{data}, or $E_c / I_o |_{data} = E_b / I_o - G_{data}$;

(c) determining an optimum pilot E_c / I_o requirement for each constituent Walsh channel, or $\{E_c / I_o |_{pilot}\} |_i$, where i = {fundamental channel, supplemental channel, control channel}, using

$$\frac{\{E_c / I_o|_{data}\}|_i}{\{E_c / I_o|_{pilot}\}|_i} = \sqrt{(R \cdot SNR) / 2B(1+SNR)}\text{; and}$$

(d) selecting a maximum pilot E_c / I_o, or $\max\{E_c / I_o |_{pilot}\} |_i$ and $\{E_c / I_o |_{data}\} |_i$, for each constituent Walsh channel in step (b).

1.0 Power Balance of RL Code Channels

Reverse Link, i.e. Mobile Station to Base Station

As in Ref [1] and [2], in this contribution, we propose to use the default table stored in the MS for the initial set up based on the optimum power balance for the constituent Walsh channels. Mobile Station

The optimum pilot and data channel power balance is function of (see Ref [2])

- Processing gain of the constituent code channel (data rate)
- Pilot estimation accumulation window size (pilot channel filter bandwidth)
- QoS requirement of the constituent code channel (BER/FER, coding, frame size)

Quality of Service

For the simplicity of the base station pilot processing, *the pilot estimation window is preferred to be fixed*, such a window size is limited by the worst case of the Doppler fading and carrier offset. Using the fixed pilot processing window, the pilot power can vary under different configuration of data channel rates and QoS.

On the other hand, due to the variable rate employed in the fundamental channel, especially for a voice call, the dynamic optimum power balance can vary even frame by frame. In order to simply the base station implementation, we consider the following constraints as in [4]:

- Maintain the same pilot Ec/Io for the all the fundamental channel sub-rates by using a fixed threshold for pilot based power control.
- Maintain the FER=1% across all the fundamental channel sub-rates.

Frame Error Rate

We chose the optimum power balance solution in the AWGN channel as the initial default value. In reality, the optimum power balance can vary

- With the increase of processing gain for the data channel, the pilot overhead increases.
- With the increase of number of multi-path, the pilot over head increases.

However, our studies show the optimum power balance does not vary drastically as the channel condition varies, we have the following conclusions:

- The overall power balance difference does not exceed 9% of the optimum power balance as the Rayleigh faded multi-path number increases from 1 to 4.
- Signal to Noise Ratio
- The SNR loss exhibits a flat region around the optimum balance, the loss does not exceed 0.1dB as the Rayleigh faded multi-path number increases from 1 to 4.

In this case, we recommend to use the optimum power balance as the default table to minimize the messaging required to assign the initial MS power balance. Therefore, the power balance will change on-the-fly if the QoS is for a specific constituent code channel is changed. This can be done via the messaging defined in [2].

The basic parameters required to define the default table is listed in Table-1.

Table 1: Reverse Link Attribute Gain for 20ms Frame

Constituent Channel	Requirement (QoS)	Data Rate¹ [kbps]	Coding	Processing Gain		Eb/Io[dB]	
			Conv/Turbo	1X	3X	Conv	Turbo
R-FCH RS-1	FER = 10^{-2}	1.5	C	819	24576	2.3	NA
		2.7	C	455	1365		
		4.8	C	256	768		
		9.6	C	128	384		
R-FCH RS-2	FER = 10^{-2}	1.8	C	85	2048	TBD	NA
		3.6	C	170	1024		
		7.2	C	341	512		
		14.4	C	682	256		
R-SCH	BER = 10^{-6}	9.6	C	128	384	TBD	NA
		14.4	C	NA	256	TBD	
		19.2	C/T	64	192	TBD	TBD
		28.8	C/T	NA	128	TBD	TBD
		38.4	C/T	32	96	TBD	TBD
		57.6	C/T	NA	64	TBD	TBD
		76.8	C/T	16	48	TBD	TBD
		115.2	C/T	NA	32	TBD	TBD
		153.6	C/T	8	24	TBD	0.32
		230.4	C/T	NA	16	TBD	TBD
		307.2	C/T	4	12	TBD	TBD
		460.8	C/T	NA	8	TBD	TBD
		614.4	C/T	NA	NA	TBD	TBD
		921.6	C/T	NA	NA	TBD	TBD
		1,036.8	C/T	NA	3.56	TBD	TBD
R-DCCH	FER = 10^{-2}	9.6	C	128	384	2.3	NA

2.0 Joint-Optimal Walsh Channel Power Gain

We propose to use the following joint optimal constituent Walsh channel gain assignment strategy to configure the power balance:

STEP-1: Determine the pilot filter bandwidth and default QoS operation point, E_b/I_o for each constituent Walsh channel.

STEP-2: Determine the $\{E_c/I_o|_{data}\}|_i$ for each constituent Walsh channel, based on E_b/I_o and processing gain G_{data} i.e. $E_c/I_o|_{data} = E_b/I_o - G_{data}$

STEP-3: Compute the optimum pilot E_c/I_o requirement for each constituent Walsh channel: $\{E_c/I_o|_{pilot}\}|_i$, where $i = \{fund, supp, control\}$ by using

$$\frac{\{E_c/I_o|_{data}\}|_i}{\{E_c/I_o|_{pilot}\}|_i} = \sqrt{(R \cdot SNR)/2B(1+SNR)} \qquad \text{Eq.1}$$

STEP-4: Select the largest pilot E_c/I_o, i.e. $max\{E_c/I_o|_{pilot}\}|_i$ and $\{E_c/I_o|_{data}\}|_i$ for each constituent Walsh channel in **STEP-2**

As a comparison, a per-constituent Walsh channel gain assignment (so-called 1-D table approach) is proposed in Ref. [2]. The basic procedure of such a approach is as follows:

STEP-1: Determine the plot filter bandwidth and default QoS operation point, E_b/I_o for each constituent Walsh channel.

STEP-2: Fix the $E_c/I_o|_{pilot}$ for all constituent Walsh channels.

STEP-3: Compute $E_c/I_o|_{data}$ for each constituent Walsh channel (Eq.1)

As we can see the 1-D table based power assignment depends only on the data rate for individual constituent Walsh channel, while the joint-optimization based power assignment proposed in Ref[1] (M-D table approach) depends on the data rates of all the constituent Walsh channels

We can show that the 1-D table based approach will assign excessive power for low rate constituent Walsh channel, i.e. the fundamental and control channel, while the joint optimal approach will guarantee the minimization of the power assigned to each and constituent Walsh channel and also the total MS transmission power.

In what follows, we present an example of the initial power assignment for the RL constituent Walsh code channel. In Table.2, we compare a typical scenario where one low rate convolutional encoded fundamental channel and a high rate supplemental channel are operating simultaneously in a 1X system. The pilot estimation filter bandwidth is chosen as 230Hz. Note that the pilot Ec/Io is determined by the high rate data channel SNR at the decoder input with respect to the targeted QoS.

As we can see, following the Qualcomm 1-D table approach in Ref [2] [4] [5], the fundamental channel will transmit 4.5dB excessive power. Thus results in a 0.55dB of total Ec/Io increase. This non-optimal power assignment will cause the following consequence:

- BS need to send 4.5/0.25=18 correct message to minimize the fundamental power to optimal level.
- The closed loop power control will adjust to decrease the total MS transmit power to the target FER=1% (fundamental starts @ FER<<1%), then the supplemental channel will fail to operate.
- The excessive fundamental channel power will take additional 3 voice capacity in the cell.

From Table 3 and 4, we can see the excessive transmit power is not improved as suggested in Ref [5].

TABLE 2. Comparison of 1-D and M-D Based Power Balance for 1X System (Fund: 9.6kbps/Conv, Supp: 153.6kbps/Turbo)

	Data Channel	QoS (FER)	Pilot Ec/Io	Ptraf/Ppilot	Data Eb/Nt	SNR	Processing Gain	Data Ec/Io
M-D	Fund	1%	-22.8dB	4dB	2.30dB	-3.72dB	21.1dB	-18.8dB
M-D	Supp	5%	-18.4dB	9.7dB	0.32dB	-4.45dB	9dB	-8.7dB
1-D	Fund	<<1%	-18.4dB	4dB	6.8dB		21.1dB	-14.3dB
			Pilot Ec/Io	Data Eb/Nt (Fund)	Data Ec/Io (Supp)	Total Ec/Io		
1-D Balance			-18.4dB	-14.3dB	-8.7dB	-7.285dB		
M-D Balance			-18.4dB	-18.8dB	-8.7dB	-7.839dB		
Excessive Power			0	4.5dB	0	0.55dB		

Table 2 shows the 1X system with low rate fundamental (convolutional) and high rate supplemental (Turbo) power assignment for M-D and 1-D approaches.

Table 3 shows the 3X system with low rate fundamental (convolutional) and high rate supplemental (Turbo) power assignment for M-D and 1-D approaches.

Table 4 shows the 3X system with low rate fundamental (convolutional) and high rate supplemental (Conv.) power assignment for M-D and 1-D approaches.

TABLE 3. Comparison of 1-D and M-D Based Power Balance for 3X System (Fund: 9.6kbps/Conv, Supp: 153.6kbps/Turbo)

	Data Channel	QoS (FER)	Pilot Ec/Io	P_{DATA}/P_{PILOT}	Data Eb/Io	SNR	Processing Gain	Data Ec/Io
M-D	Fund	1%	-27.6dB	4dB	2.30dB	-3.72dB	25.8dB	-23.5dB
M-D	Supp	5%	-23.2dB	9.7dB	0.32dB	-4.45dB	13.8dB	-13.5dB
1-D	Fund	<<1%	-23.2dB	4dB	6.6dB		25.8dB	-19.2dB
			Pilot Ec/Io	Data Ec/Io (Fund)	Data Ec/Io (Supp)	Total Ec/Io		
1-D Balance			-23.2dB	-19.2dB	-13.5dB	-12.11dB		
M-D Balance			-23.2dB	-23.5dB	-13.5dB	-12.68dB		
Excessive Power			0	4.3dB	0	0.57dB		

TABLE 4. Comparison of 1-D and M-D Based Power Balance for 3X System (Fund: 9.6kbps/Conv, Supp: 460.8kbps/Turbo)

	Data Channel	QoS (FER)	Pilot Ec/Io	P_{DATA}/P_{PILOT}	Data Eb/Io	SNR	Processing Gain	Data Ec/Io
M-D	Fund	1%	-27.6dB	4dB	2.30dB	-3.72dB	25.8dB	-23.5dB
M-D	Supp	5%	-20.8dB	12dB	0.18dB	-4.59dB	9.0dB	-8.8dB
1-D	Fund	<<1%	-20.8dB	4dB	7.0dB		25.8dB	-16.8dB
			Pilot Ec/Io	Data Ec/Io(Fund)	Data Ec/Io(Supp)	Total Ec/Io		
1-D Balance			-20.8dB	-16.8dB	-8.8dB	-7.93dB		
M-D Balance			-20.8dB	-23.5dB	-8.8dB	-8.40dB		
Excessive Power			0	6.7dB	0	0.50dB		

TABLE 5. Comparison of 1-D and M-D Based Power Balance for 3X System (Fund: 9.6kbps/Conv, Supp: 460.8kbps/Conv.)

	Data Channel	QoS (FER)	Pilot Ec/Io	P_{DATA}/P_{PILOT}	Data Eb/Io	SNR	Processing Gain	Data Ec/Io
M-D	Fund	1%	-27.6dB	4dB	2.30dB	-3.72dB	25.8dB	-23.5dB
M-D	Supp	5%	-19.3dB	12.8dB	2.30dB	-2.47dB	9.0dB	-6.5dB
1-D	Fund	<<1%	-19.3dB	4dB	10.5dB		25.8dB	-15.3dB
			Pilot Ec/Io	Data Ec/Io(Fund)	Data Ec/Io(Supp)	Total Ec/Io		
1-D Balance			-19.3dB	-15.3dB	-6.5dB	-5.77dB		
M-D Balance			-19.3dB	-23.5dB	-6.5dB	-6.19dB		
Excessive Power			0	8.2dB	0	0.43dB		

Comments: In terms of total Ec/Io, use Turbo coding can reduce the high rate user Ec/Io by 2dB. However, such a reduction is contributed from the lower operation Eb/Io operating point of Turbo decoder. Instead the optimal P_{data}/P_{pilot} value for the convolutional and Turbo coding does not vary much. This means that the value of P_{data}/P_{pilot} in RL attribute gain table can be does not vary significantly with respect to convolutional/Turbo coding, single/multi-frame interleaving and antenna diversity.

3.0 Default Power Balance Table

Based on the discussion above, we propose to use joint-optimal M-D default table for the initial power assignment of the constituent Walsh channel. In Table 6, we present all the combinations of the 4 constituent Walsh channels (R-PICH, R-FCH, R-SCH-1, R-DCCH) with convolutional coding. We are working on the extension of the table to include the cases with the presence of R-SCH-2 and Turbo coding.

Table 6: Walsh Channel Power Balance Default Table for 3X System

Rate		$P_{R\text{-}PICH}$ Ec/Io [dB]	P_{DATA}/P_{PILOT}[dB]				Rate		$P_{R\text{-}PICH}$ Ec/Io [dB]	P_{DATA}/P_{PILOT}[dB]			
R-SCH (kbps)			$P_{R\text{-}FCH}$ (FullRate)		$P_{R\text{-}SCH}$	$P_{R\text{-}DCCH}$	R-SCH (kbps)			$P_{R\text{-}FCH}$ (FullRate)		$P_{R\text{-}SCH}$	$P_{R\text{-}DCCH}$
			RS-1	RS-2						RS-1	RS-2		
921.6		-21.5	-7.2	-5.3	14.7	-10.7	57.6		-23.6	0	1.7	9.6	-3.5
460.8		-20.0	-4.7	-2.7	14.0	-8.1	38.4		-24.5	0.9	2.5	8.8	-2.6
307.2		-20.4	-4.3	-2.3	12.8	-7.6	28.8		-25.1	1.6	3.2	8.2	-1.9
230.4		-20.5	-3.1	-3.2	12.4	-6.8	19.2		-26.0	2.6	4.0	7.3	-0.9
153.6		-21.9	-1.6	-2.4	12.3	-4.9	14.4		-26.6	3.2	4.6	6.8	-0.2
115.2		-22.1	-1.6	-1.9	11.0	-5.0	9.6		-27.5	4.2	5.4	6.1	0.8
76.8		-23.0	-0.7	-1.1	10.2	-4.2							
R-FCH [kbps]		$P_{R\text{-}PICH}$ Ec/Io [dB]	$P_{R\text{-}FCH}$ [dB]		$P_{R\text{-}SCH}$ [dB]	$P_{R\text{-}DCCH}$ [dB]	R-FCH [kbps]		$P_{R\text{-}PICH}$ Ec/Io [dB]	$P_{R\text{-}FCH}$ [dB]		$P_{R\text{-}SCH}$ [dB]	$P_{R\text{-}DCCH}$ [dB]
RS-1	9.6	-27.5	3.0		OFF	OFF	RS-1	9.6	-27.5	5.6		OFF	
	4.8		-0.1		OFF	OFF		4.8		4.4		OFF	4.0
	2.7		-1.8		OFF	OFF		2.7		3.0		OFF	4.3
	1.5		-4.8		OFF	OFF		1.5		0.02		OFF	4.3
R-FCH [kbps]		$P_{R\text{-}PICH}$ Ec/Io [dB]	$P_{R\text{-}FCH}$ (Offset) [dB]		$P_{R\text{-}SCH}$ [dB]	$P_{R\text{-}DCCH}$ [dB]	R-FCH [kbps]		$P_{R\text{-}PICH}$ Ec/Io [dB]	$P_{R\text{-}FCH}$ [dB]		$P_{R\text{-}SCH}$ [dB]	$P_{R\text{-}DCCH}$ [dB]
RS-2	14.4	-26.6	4.5		OFF	OFF	RS-2	14.4	-26.6	6.2		OFF	0.8
	7.2		-1.7		OFF	OFF		7.2		5.2		OFF	2.8
	3.6		-1.1		OFF	OFF		3.6		3.4		OFF	4.0
	1.8		-3.9		OFF	OFF		1.8		0.6		OFF	4.1

Table 6 consists of 3 major parts.

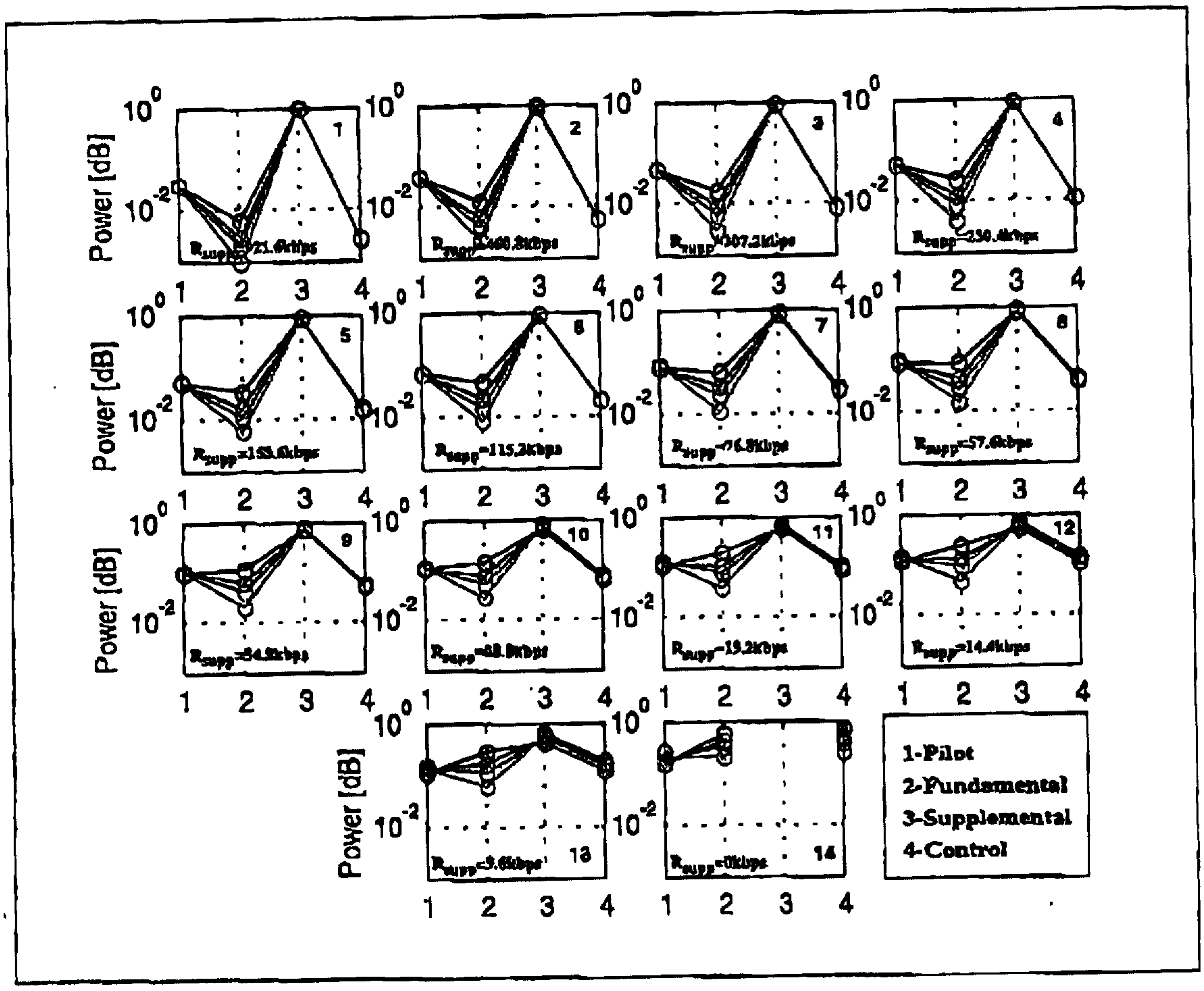
- **CONFIG-1**: R-PICH,R-FCH, R-SCH-1 and R-DCCH operate simultaneously.
- **CONFIG-2**: R-PICH, R-FCH and R-DCCH operate simultaneously without R-SCH-1
- **CONFIG-3**: R-PICH and R-FCH only.

The gain assignment for R-SCH-1 R-FCH and R-DCCH are relative to the power of R-PICH with associated R-SCH of R-FCH data rates:

- $P_{R\_SCH\text{-}1}=P_{R\_PICH}+P_{R\_SCH\text{-}1}$;
- $P_{R\_DCCH}=P_{R\_PICH}+P_{R\_DCCH}$;
- $P_{R\_FCH}=P_{R\_PICH}+P_{R\_FCH}$, where $P_{R\_FCH}=P_{R\_FCH}(\text{Base})+P_{R\_FCH}(\text{Offset})$.

Figure 1 represents the power distribution profile of the joint-optimal power assignment. As we can see, in the presence of high rate R-SCH, the power assigned to the R-FCH can be significantly lower than the R-PICH, to reduce the excessive power on R-FCH, which using -1D default table technique, the power of R-FCH is always higher than the R-PICH.

FIGURE 1. Power Distribution of Constituent Walsh Channels with Joint-Optimal Assignment



Summary

In this contribution, we show that the joint-optimal power assignment based M-D default table for the constituent Walsh channel has significnat advantages over the per-constituent Walsh channel based 1-D default table approach:

- Minimize excessive power for the lower rate data channel (by 5dB)
- Mininize the totoal MS excessive transmit power (by 0.5dB)
- Mininize the frequency of meesage form BS toadjust power of each lower rate constituent code channels (by 18-32 mesg.)
- We propose to adopt joint-optiaml default table for MS to minimize the RL interference

4.0 References

[1] *Power Balance of RL Constituent Walsh Code Channels*, Nortel Networks, TR45.5.3.1/99.01.12.17

[2] *Preliminary Method for Setting the Gains of Reverse Link Walsh Channels*, Qualcomm, TR45.5.3.1 RLPC/98.12.17

[3] *On the Selection of Pilot to Data Ratio for Pilot Assisted Coherent CDMA Reverse Link*, Motorola, TR45.5.4/98.01.08.03

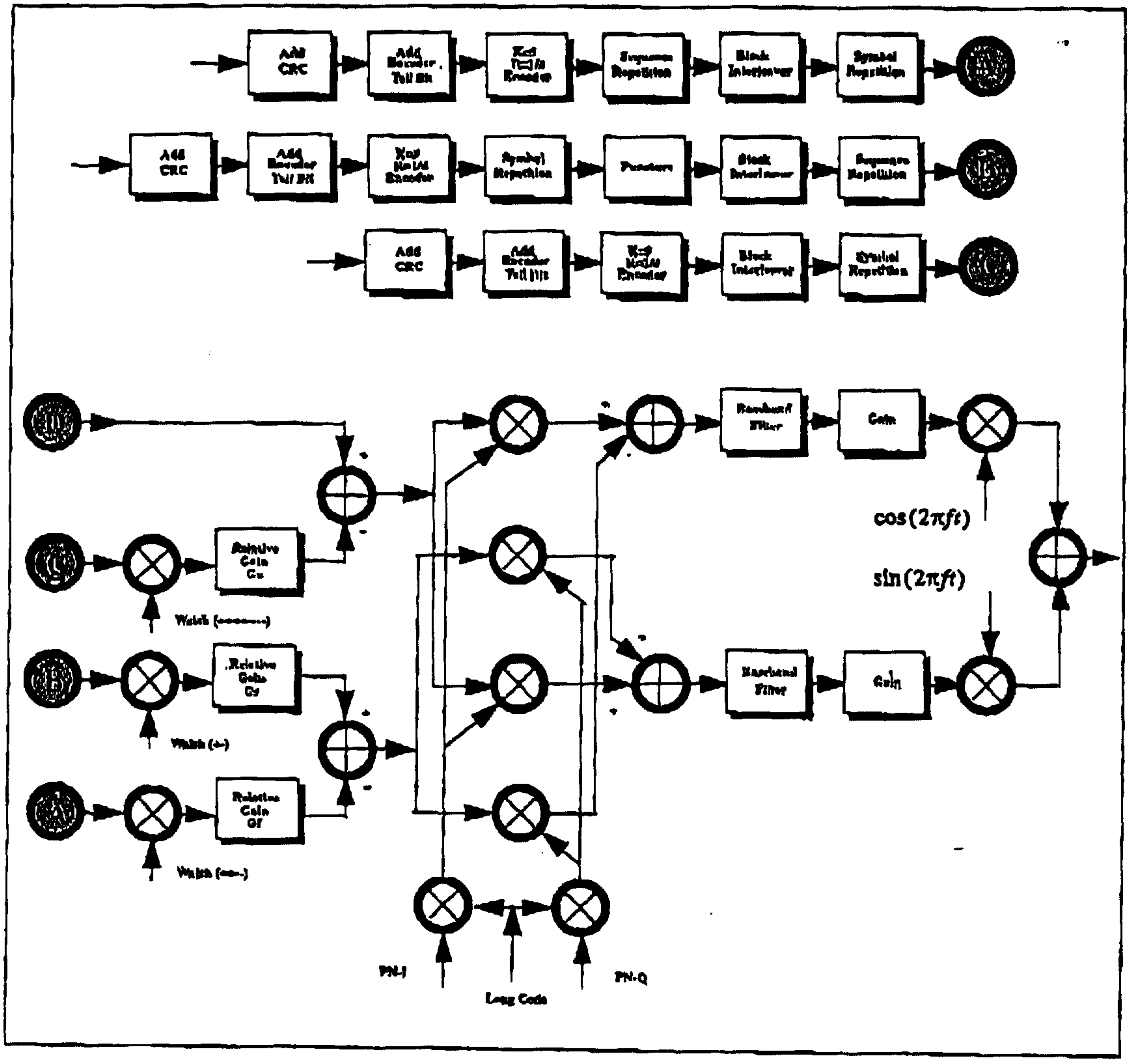
[4] *Preliminary Reverse Link Walsh Channel Gain Simulation Results*, Qualcomm, TR45.5.3.1/99.01.12.41

[5] *Using a Simple Reverse Link Walsh Channel Gain Default Table*, Qualcomm, TR45.5.3.1 RLPC/99.02.09

1.0 Introduction

In cdma2000 standard, the reverse link consists of 4 orthogonal channels which are Walsh code division. There channels are the pilot, control, fundamental, supplemental channels. The optimum balance of the channel gains among these 4 Walsh channels will have a significant impact on the overall system performance and capacity. In this memo, we present a solution for the optimum gain balance for the conventional Rake receiver. However, such a gain balance strategy may be significant different when the advanced receiver is employed at Base Station, e.g. Multi-user Detection.

FIGURE 1. cdma2000 Reverse Link Walsh Channel Mutiplexing



1.1 Required MS Transmission Power for Individual Walsh Channels

In order to compute the optimum gain balance among the Walsh channels, first we need to compute the signal-to-noise ratio and transmission power requirement for pilot, control, fundamental and supplemental channels. As defined by IMT-2000, we have the following requirements:

TABLE 1. Performance Requirements Data Channels

Channels	Supp.	Fund.	CTRL
Performance	BER = 10^{-6}	FER = 10^{-2}	BER = 10^{-3}

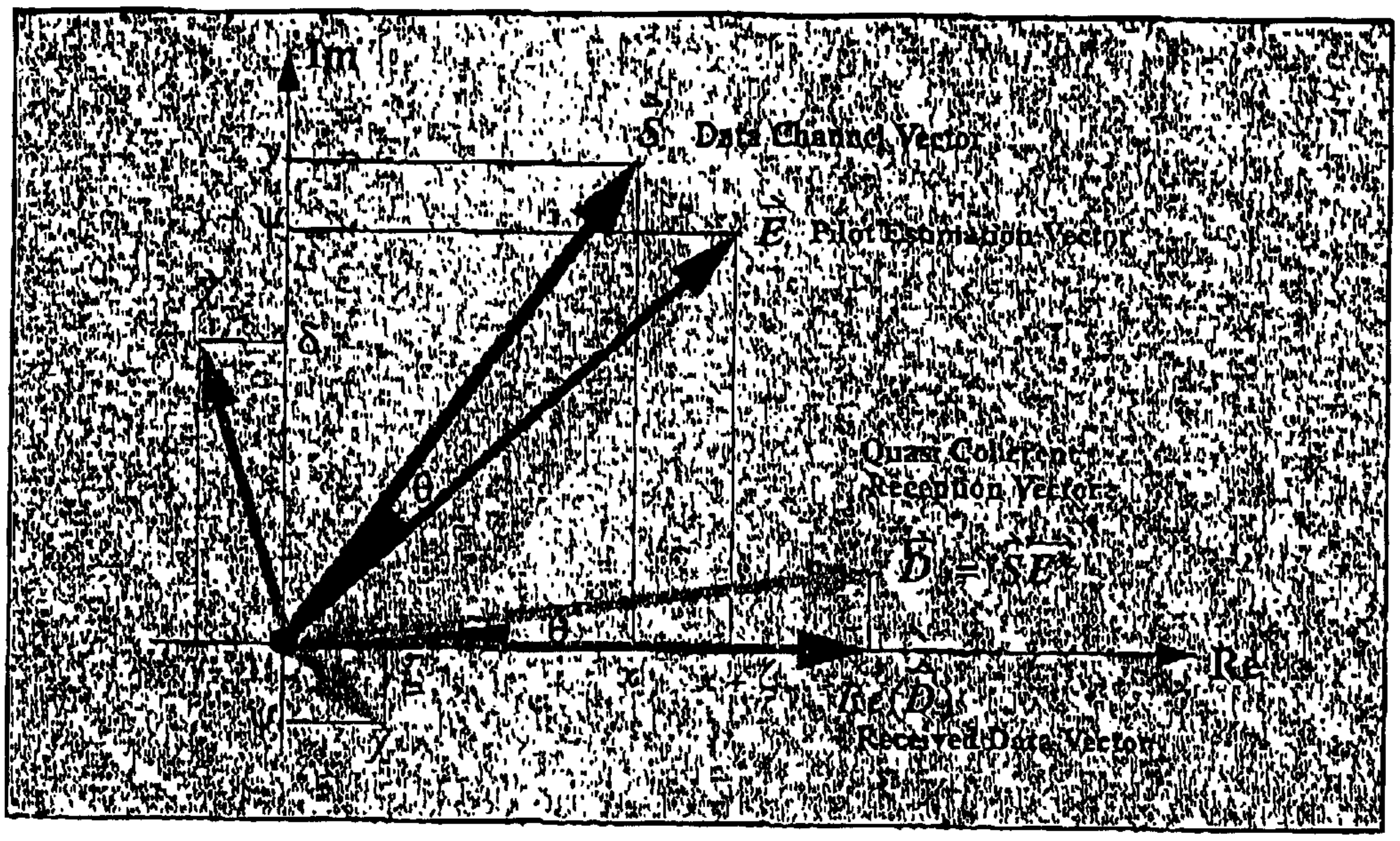
The fundamental channel is assumed to achieve FER = 1% and the control channel requires to have BER = 10^{-3}. Base on this requirement, we can find the signal-to-noise requirement for conventional demodulator for AWGN one path channel in Table2

1.2 The Optimum Orthogonal Walsh Channel Power Balance in AWGN Channel

1.2.1 SNR Loss for Pilot Assisted Quasi-Coherent Reception

In Figure 1. Here, $\overline{S}$ - is a vector for data channel, ξ - is an interference vector in the pilot channel, χ - is an interference vector is in data channel and, $\overline{E} = \overline{S} + \overline{\xi}$ -is channel vector from pilot channel.

FIGURE 2. For the quazi-coherent receiving loss estimation



Write the average signal-to-interference ratio at the decision device input in the following manner:

$$\Gamma^2 = \frac{\left\{E\left[\Re e(\vec{S}+\vec{\chi}|\vec{E}^{*})\right]\right\}^2}{E\left[\left(\Re e(\vec{S}+\vec{\chi}|\vec{E}^{*})\right)^2\right]-\left\{E\left[\Re e(\vec{S}+\vec{\chi}|\vec{E}^{*})\right]\right\}^2} \qquad \text{Eqn. (1)}$$

where $E[\bullet]$ - is an averaging operator.

Assuming the real and imaginary components of the interference vectors $\vec{\zeta}$ and $\vec{\chi}$ are zero mean Gaussian distributed. We have, $E[\zeta^2] = E[\psi^2]$, $E[\gamma^2] = E[\delta^2]$, $E[\zeta^2 \cdot \gamma^2] = E[\psi^2 \cdot \delta^2]$ and $x^2 + y^2 = |\vec{S}|^2$. Then,

$$\Gamma^2 = \frac{|\vec{S}|^4}{|\vec{S}|^2 \cdot E[\gamma^2] + |\vec{S}|^2 \cdot E[\zeta^2] + 2 \cdot E[\gamma^2 \cdot \zeta^2]} \qquad \text{Eqn. (2)}$$

If the interference in the pilot channel and data channel are statistically independent, hence $E[\gamma^2 \cdot \zeta^2] = E[\gamma^2] \cdot E[\zeta^2]$ and the above expression can be re-written in the following form:

$$\Gamma^2 = \frac{|\vec{S}|^4}{|\vec{S}|^2 \cdot E[\gamma^2] + |\vec{S}|^2 \cdot E[\zeta^2] + 2 \cdot E[\gamma^2] \cdot E[\zeta^2]} \qquad \text{Eqn. (3)}$$

and furthermore,

$$\Gamma^2 = \frac{1}{\frac{E[\gamma^2]}{|\vec{S}|^2} + \frac{E[\zeta^2]}{|\vec{S}|^2} + 2 \cdot \frac{E[\gamma^2]}{|\vec{S}|^2} \cdot \frac{E[\zeta^2]}{|\vec{S}|^2}} \qquad \text{Eqn. (4)}$$

Note, $E[\zeta^2] = \frac{1}{2} \cdot \sigma_r^2$, where σ_r^2 - is the noise power in the data channel and, $E[\gamma^2] = \frac{1}{2} \cdot \sigma_e^2$, where σ_e^2 - is the noise power in the pilot channel. Therefore,

$$\Gamma^2 = \frac{2 \cdot \gamma_D^2 \cdot \gamma_P^2}{\gamma_D^2 + \gamma_P^2 + 1} \qquad \text{Eqn. (5)}$$

where

- γ_D^2 - is the signal-to-interference ratio in the data channel,
- γ_P^2 - is the signal-to-interference ratio in the pilot channel.

In the case of the ideal coherent reception, the signal vector becomes $\vec{E} = \vec{S}\Big|_{\gamma_D^2 \to \infty}$ and, the average signal-to-interference ratio at the demodulator input is

$$\Gamma_{max}^2 = 2 \cdot \gamma_D^2 \qquad \text{Eqn. (6)}$$

In this case, the loss associated with the signal vector errors can be defined as $L = \frac{\Gamma_{max}^2}{\Gamma^2}$.

Hence,

$$L = \frac{\gamma_D^2 + \gamma_P^2 + 1}{\gamma_P^2} \qquad \text{Eqn. (7)}$$

The following step are taken to determine the pilot signal level:

- To determine the relative pilot channel power for the fundamental, supplemental and control channels, independently;
- To normalize three obtained pilot channel powers based on relative data channel powers for each fundamental, supplemental and control channel transmission combination;
- To use the pilot channel with the highest level among the selected fundamental, supplemental and control channel.

TABLE 2. Input SNR for Fundamental, Supplemental, and Control Channels

Channel	Requirement	Required SIR, dB	Rate, kbps	Processing coefficient	Input SIR, dB	Relative Power
Fundamental Set 1	FER = 10^{-2}	-3.971	9.6	96	-23.783	6
			4.8	192	-26.804	3
			2.4	288	-28.565	2
			1.2	576	-31.575	1

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TABLE 2. Input SNR for Fundamental, Supplemental, and Control Channels

Channel	Requirement	Required SIR, dB	Rate, kbps	Processing coefficient	Input SIR, dB	Relative Power
Fundamental Set 2	FER = 10^{-2}	-3.808	14.4	64	-21.870	9.343
			7.2	128	-24.880	4.672
			3.6	256	-27.890	2.336
			1.8	512	-30.901	1.168
Supplemental	BER = 10^{-6}	-2.121	9.6	96	-21.943	9.188
			14.4	64	-20.182	13.782
			19.2	48	-18.933	18.374
			28.8	32	-17.172	27.561
			38.4	24	-15.923	36.745
			57.6	16	-14.162	55.119
			76.8	12	-12.912	73.502
			115.2	8	-11.151	110.256
			153.6	6	-9.902	146.994
			230.4	4	-8.141	220.496
			460.8	2	-5.131	440.961
		-0.771	307.2	4	-6.792	300.815
		1.09	921.6	2	-1.921	823.422
Control	BER = 10^{-6}	-4.421	1.2	192	-27.254	2.705

In order to compute the optimum pilot channel power level, we need to minimize the following equation:

$$\Gamma^2_{req} = \frac{(1-P_P)\cdot G_D}{P_I\cdot L} = \frac{(1-P_P)\cdot G_D}{P_I}\cdot\frac{P_P\cdot G_P}{(1-P_P)\cdot G_D+P_P\cdot G_P+P_I} \qquad \text{Eqn. (8)}$$

Where

- L - SNR loss for pilot channel estimation defined in Eqn. (1);
- Γ^2_{req} - the required SNR for the data channels, (last column of Table.2)
- P_P - pilot power
- P_I - multi-user interference power in data channel;
- G_P - pilot channel processing window;
- G_D - data channel processing gain

The optimum pilot channel level is determined such that required SNR is achieved at the highest interference level in data channel. From Eqn. (2), P_{Int} can be written as:

$$\boxed{P_I = \frac{\sqrt{D}}{2 \cdot \Gamma_{req}^2} - \frac{1}{2} \cdot [(1-P_P) \cdot G_D + P_P \cdot G_P]} \qquad \text{Eqn. (9)}$$

where,

$$D = \Gamma_{req}^4 \cdot ((1-P_P) \cdot G_D + P_P \cdot G_P)^2 + 4 \cdot \Gamma_{req}^2 \cdot G_D \cdot G_P \cdot P_P \cdot (1-P_P) \qquad \text{Eqn. (10)}$$

We need to find the $max_{P_P}\{P_I\}$, with respect to the pilot channel power P_P, i.e.

$$\frac{d}{dP_P} P_I(P_P) = 0. \qquad \text{Eqn. (11)}$$

We have the solution:

$$P_P = \frac{1}{2} \frac{2\Gamma^2 G_D^2 - 2\Gamma^2 G_D G_P - 4 G_D G_P + 2\sqrt{\Gamma^4 G_D^3 G_P + \Gamma^2 G_D^3 G_P - 2\Gamma^4 G_D^2 G_P^2}}{\Gamma^2 G_D^2 - 2\Gamma^2 G_D G_P + \Gamma^2 G_P^2 - 4 G_D G_P}$$

$$\frac{\overline{-2\Gamma^2 G_D^2 G_P^2 + \Gamma^4 G_P^3 G_D + \Gamma^2 G_P^3 G_D}}{\Gamma^2 G_D^2 - 2\Gamma^2 G_D G_P + \Gamma^2 G_P^2 - 4 G_D G_P}$$

$$\frac{-\Gamma^2 G_D^2 + \Gamma^2 G_D G_P + 2 G_D G_P - \sqrt{\Gamma^2 G_D G_P (-G_D + G_P)^2 (1+\Gamma^2)}}{\Gamma^2 G_D^2 - 2\Gamma^2 G_D G_P + \Gamma^2 G_P^2 - 4 G_D G_P} -$$

The relative pilot channel signal power can be written in the form $\frac{P_P{*}}{1-P_P{*}}$, where $P_P{*}$ - is the solution of the above equation.

Due the lengthy expression of solution for Eqn.5, we present its numberable solutions by incorporating the Table.2. Considering the worst case of Doppler fading and carrier offset, we chose the pilot accumulation window size as: $G_P = 3072$, we obtain the optimum power balance in Table 3 and Table 4 for the Rate Set-1 and Rate Set-2, respectively.

TABLE 3. Walsh Channel Power Balance for Rate Set-1 (cdma2000 Reverse Link)

Rate		Relative Power				Rate		Relative			
Sup	Fund	Pilot	Fund	Supl	Cont	Sup	Fund	Pilot	Fund	Supl	Cont
921.6	9.6	0.033	6.227e-3	0.958	2.807e-3	57.6	9.6	0.086	0.086	0.789	0.039
	4.8	0.033	3.128e-3	0.961	2.816e-3		4.8	0.09	0.045	0.825	0.04
	2.4	0.033	2.084e-3	0.962	2.819e-3		2.4	0.091	0.03	0.837	0.041
	1.2	0.033	1.043e-3	0.963	2.822e-3		1.2	0.093	0.015	0.85	0.042
	Off	0.033	0	0.964	2.825e-3		Off	0.094	0	0.864	0.042
307.2	9.6	0.048	0.018	0.925	8.319e-3	38.4	9.6	0.096	0.115	0.731	0.054
	4.8	0.049	9.312e-3	0.934	8.396e-3		4.8	0.103	0.063	0.777	0.057
	2.4	0.049	6.227e-3	0.937	8.423e-3		2.4	0.105	0.043	0.794	0.058
	1.2	0.049	3.123e-3	0.94	8.449e-3		1.2	0.107	0.022	0.811	0.06
	Off	0.049	0	0.943	8.475e-3		Off	0.109	0	0.829	0.061
460.8	9.6	0.038	0.013	0.944	5.789e-3	28.8	9.6	0.103	0.148	0.682	0.067
	4.8	0.038	6.461e-3	0.95	5.826e-3		4.8	0.111	0.08	0.736	0.072
	2.4	0.038	4.317e-3	0.952	5.838e-3		2.4	0.114	0.055	0.757	0.074
	1.2	0.038	2.163e-3	0.954	5.851e-3		1.2	0.117	0.028	0.778	0.076
	Off	0.038	0	0.956	5.864e-3		Off	0.121	0	0.801	0.079
230.4	9.6	0.052	0.025	0.912	0.011	19.2	9.6	0.11	0.197	0.604	0.089
	4.8	0.053	0.013	0.923	0.011		4.8	0.122	0.109	0.67	0.099
	2.4	0.053	8.412e-3	0.927	0.011		2.4	0.127	0.076	0.695	0.102
	1.2	0.053	4.224e-3	0.931	0.011		1.2	0.132	0.039	0.723	0.106
	Off	0.053	0	0.935	0.011		Off	0.137	0	0.752	0.111
153.6	9.6	0.061	0.036	0.886	0.016	14.4	9.6	0.113	0.237	0.544	0.107
	4.8	0.062	0.018	0.903	0.017		4.8	0.128	0.134	0.617	0.121
	2.4	0.063	0.012	0.908	0.017		2.4	0.134	0.094	0.646	0.127
	1.2	0.063	6.217e-3	0.914	0.017		1.2	0.14	0.049	0.678	0.133
	Off	0.063	0	0.92	0.017		Off	0.148	0	0.713	0.14
115.2	9.6	0.068	0.047	0.864	0.021	9.6	9.6	0.113	0.298	0.456	0.134
	4.8	0.07	0.024	0.884	0.022		4.8	0.132	0.175	0.535	0.158
	2.4	0.07	0.016	0.892	0.022		2.4	0.14	0.124	0.561	0.167
	1.2	0.071	8.152e-3	0.899	0.022		1.2	0.15	0.066	0.606	0.178
	Off	0.072	0	0.906	0.022		Off	0.16	0	0.648	0.191
76.8	9.6	0.078	0.067	0.823	0.03	None	9.6	0.158	0.58	0	0.262
	4.8	0.082	0.035	0.852	0.031		4.8	0.16	0.442	0	0.398
	2.4	0.083	0.023	0.862	0.032		2.4	0.175	0.351	0	0.474
	1.2	0.084	0.012	0.872	0.032		1.2	0.212	0.213	0	0.575
	Off	0.085	0	0.883	0.032		Off	0.27	0	0	0.73

TABLE 4. Walsh Channel Power Balance for Rate Set 2 (cdma2000 Reverse Link)

Rate		Relative Power				Rate		Relative			
Sup	Fund	Pilot	Fund	Supl	Cont	Sup	Fund	Pilot	Fund	Supl	Cont
921.6	14.4	0.032	9.663e-3	0.955	2.798e-3	57.6	14.4	0.082	0.128	0.752	0.037
	7.2	0.033	4.858e-3	0.96	2.811e-3		7.2	0.088	0.068	0.805	0.039
	3.6	0.033	2.434e-3	0.962	2.818e-3		3.6	0.091	0.035	0.833	0.041
	1.8	0.033	1.218e-3	0.963	2.822e-3		1.8	0.092	0.018	0.848	0.042
	Off	0.033	0	0.964	2.825e-3		Off	0.094	0	0.864	0.042
307.2	14.4	0.048	0.028	0.916	8.234e-3	38.4	14.4	0.09	0.174	0.685	0.05
	7.2	0.048	0.014	0.929	8.353e-3		7.2	0.099	0.095	0.75	0.055
	3.6	0.048	7.266e-3	0.936	8.414e-3		3.6	0.104	0.05	0.788	0.058
	1.8	0.049	3.646e-3	0.939	8.444e-3		1.8	0.107	0.026	0.808	0.059
	Off	0.049	0	0.943	8.475e-3		Off	0.108	0	0.829	0.061
460.8	14.4	0.037	0.02	0.937	5.747e-3	28.8	14.4	0.095	0.213	0.63	0.062
	7.2	0.038	0.01	0.946	5.805e-3		7.2	0.106	0.119	0.705	0.069
	3.6	0.038	5.038e-3	0.951	5.834e-3		3.6	0.113	0.064	0.75	0.074
	1.8	0.038	2.526e-3	0.953	5.849e-3		1.8	0.117	0.033	0.774	0.076
	Off	0.038	0	0.956	5.864e-3		Off	0.121	0	0.801	0.078
230.4	14.4	0.051	0.038	0.9	0.011	19.2	14.4	0.099	0.277	0.544	0.08
	7.2	0.052	0.019	0.917	0.011		7.2	0.115	0.161	0.632	0.093
	3.6	0.053	9.811e-3	0.926	0.011		3.6	0.125	0.087	0.687	0.101
	1.8	0.053	4.93e-3	0.931	0.011		1.8	0.131	0.046	0.718	0.106
	Off	0.053	0	0.935	0.011		Off	0.137	0	0.752	0.111
153.6	14.4	0.06	0.055	0.869	0.016	14.4	14.4	0.098	0.326	0.48	0.094
	7.2	0.062	0.028	0.894	0.016		7.2	0.119	0.195	0.574	0.113
	3.6	0.063	0.014	0.906	0.017		3.6	0.132	0.108	0.636	0.125
	1.8	0.063	7.254e-3	0.913	0.017		1.8	0.139	0.057	0.672	0.132
	Off	0.063	0	0.92	0.017		Off	0.146	0	0.713	0.14
115.2	14.4	0.066	0.071	0.842	0.021	9.6	14.4	0.097	0.397	0.391	0.115
	7.2	0.069	0.037	0.873	0.021		7.2	0.12	0.248	0.488	0.144
	3.6	0.07	0.019	0.889	0.022		3.6	0.138	0.142	0.557	0.164
	1.8	0.071	9.508e-3	0.898	0.022		1.8	0.148	0.076	0.599	0.176
	Off	0.072	0	0.906	0.022		Off	0.16	0	0.649	0.191
76.8	14.4	0.076	0.101	0.794	0.029	None	14.4	0.15	0.659	0	0.191
	7.2	0.08	0.053	0.836	0.031		7.2	0.161	0.531	0	0.307
	3.6	0.082	0.027	0.859	0.032		3.6	0.165	0.387	0	0.448
	1.8	0.084	0.014	0.871	0.032		1.8	0.205	0.24	0	0.555
	Off	0.085	0	0.883	0.032		Off	0.27	0	0	0.73

1.3 Recommendation to cdma2000

Based on the results in Table 3, and 4, the gains for 4 Walsh channel in the reverse link of cdma200 can be represented in Table 5, and 6.

Table 5. Walsh Channel Gain Coefficients for Rate Set 1 cdma2000 Reverse Link

Rate		Coefficients				Rate		Coefficients			
Sup	Fund	Pilot	Fund	Supl	Cont	Sup	Fund	Pilot	Fund	Supl	Cont
921.6	9.6	18	6	95	5	57.6	9.6	22	22	66	15
	4.8	18	6	96	5		4.8	23	17	71	16
	2.4	18	5	99	5		2.4	24	14	73	16
	1.2	18	3	100	5		1.2	25	10	76	17
	Off	19	0	102	6		Off	27	0	82	18
307.2	9.6	20	12	87	6	38.4	9.6	23	25	62	17
	4.8	20	9	89	9		4.8	24	19	65	18
	2.4	21	7	90	9		2.4	25	16	66	18
	1.2	21	5	92	8		1.2	26	12	70	19
	Off	22	0	96	9		Off	28	0	78	21
460.8	9.6	19	11	91	7	28.8	9.6	23	27	59	18
	4.8	19	8	93	7		4.8	24	21	62	20
	2.4	19	6	94	8		2.4	25	17	65	20
	1.2	19	5	95	7		1.2	26	13	67	21
	Off	20	0	99	8		Off	29	0	75	22
230.4	9.6	20	14	84	9	19.2	9.6	23	31	53	20
	4.8	21	10	87	8		4.8	25	23	57	22
	2.4	21	8	88	10		2.4	26	20	59	23
	1.2	21	6	90	10		1.2	27	14	62	24
	Off	23	0	94	10		Off	30	0	70	27
153.6	9.6	21	16	79	11	14.4	9.6	22	33	50	22
	4.8	22	12	82	11		4.8	24	25	54	24
	2.4	22	10	84	11		2.4	25	21	56	25
	1.2	22	7	86	12		1.2	27	15	58	26
	Off	24	0	91	12		Off	30	0	67	30
115.2	9.6	21	18	76	12	9.6	9.6	22	36	45	24
	4.8	22	13	79	13		4.8	24	28	48	26
	2.4	23	11	81	12		2.4	25	24	51	27
	1.2	23	8	83	13		1.2	27	18	53	29
	Off	25	0	86	14		Off	31	0	62	34
76.8	9.6	22	20	71	14	None	9.6	30	58	0	39
	4.8	23	15	75	14		4.8	30	50	0	47
	2.4	24	12	76	15		2.4	31	44	0	52
	1.2	24	9	78	15		1.2	35	35	0	67
	Off	26	0	82	18		Off	46	0	0	79

Table 6. Channel transmission coefficient with the used of the rate Set 2

Rate		Coefficients				Rate		Coefficients			
Sup	Fund	Pilot	Fund	Supl	Cont	Sup	Fund	Pilot	Fund	Supl	Cont
921.6	14.4	17	10	85	5	57.6	14.4	21	27	65	14
	7.2	18	7	87	5		7.2	23	20	69	15
	3.6	18	5	90	5		3.6	24	15	72	16
	1.8	18	4	100	5		1.8	25	11	75	18
	Off	18	0	102	6		Off	27	0	82	19
307.2	14.4	19	15	86	8	38.4	14.4	22	30	59	16
	7.2	20	11	88	8		7.2	22	23	64	17
	3.6	20	8	90	9		3.6	26	17	67	18
	1.8	21	6	91	9		1.8	25	13	70	19
	Off	22	0	96	9		Off	28	0	78	21
460.8	14.4	18	13	89	7	28.8	14.4	22	32	56	17
	7.2	18	10	92	7		7.2	23	25	60	19
	3.6	19	7	94	7		3.6	25	18	64	20
	1.8	18	5	96	7		1.8	28	14	66	21
	Off	20	0	99	8		Off	28	0	75	23
230.4	14.4	18	17	82	8	19.2	14.4	22	36	50	18
	7.2	20	12	85	10		7.2	23	28	55	21
	3.6	21	9	87	10		3.6	25	21	59	22
	1.8	21	7	89	10		1.8	26	15	62	24
	Off	23	0	94	10		Off	30	0	70	27
153.6	14.4	20	19	77	11	14.4	14.4	21	38	47	21
	7.2	21	14	81	11		7.2	23	30	51	23
	3.6	22	11	83	11		3.6	25	23	55	24
	1.8	22	8	85	12		1.8	28	17	58	26
	Off	24	0	91	12		Off	30	0	67	30
115.2	14.4	21	21	73	12	9.6	14.4	21	42	42	22
	7.2	22	16	77	12		7.2	23	33	46	25
	3.6	22	12	80	13		3.6	25	26	50	27
	1.8	23	9	82	13		1.8	26	19	53	28
	Off	25	0	88	14		Off	31	0	62	34
76.8	14.4	21	25	68	13	None	14.4	30	63	0	24
	7.2	23	18	72	14		7.2	30	55	0	42
	3.6	23	13	76	15		3.6	30	47	0	50
	1.8	24	10	78	15		1.8	34	37	0	68
	Off	26	0	85	16		Off	48	0	0	79

2.0 Walsh Channel Power Balance for the Multi-Path Fading Reception

2.1 Graph-Method

The analytical solution for the optimum Walsh channel gain balance in the presence of multi-path fading is very complex. In order to find the practical solution, graphical method is developed. In the following, we describe step-by-step the technique we used:

1. To balance the power between pilot channel and data channel separately.
2. To define the balance between the data and pilot channels based on the criterion of minimum signal energy loss with respect to the ideal coherent receiving. These losses are defined by the following equation:

   $$Loss(k) = 10\cdot\log(1-P_p)+LE(\ \bullet\ ) \qquad \text{Eqn. (12)}$$

   - The coefficient $P_p < 1$ represents the pilot power percentage in terms of total reverse channel power, i.e. the pilot overhead.
   - The function $LE(\ \bullet\ )$ - represents the demodulation loss of quasi-coherent demodulation with respect to the ideal coherent demodulation.
3. To define $LE(\ \bullet\ )$, we need to know the ideal coherent receiving performance expression. This expression can be obtained by the using the generalized equation (see Appendix B).

   For the cdma2000 reverse link, the resulting equations are of the following form:

$$P_2(\gamma_b) = Q_1\left(\sqrt{\frac{\gamma_b}{2}}(m-1), \sqrt{\frac{\gamma_b}{2}}(m+1)\right)-\frac{1}{2}I_0\left(\frac{\gamma_b}{2}\cdot(m^2-1)\right)\cdot\exp(-\gamma_b(m^2+1)) \qquad \text{Eqn. (13)}$$

when N=1

$$P_2(\gamma_b) = Q_1(a,b)-I_0(ab)\cdot\exp\left[-\frac{1}{2}(a^2+b^2)\right]$$

$$+\frac{I_0(ab)\cdot\exp\left[-\frac{1}{2}(a^2+b^2)\right]}{2^{2L-1}}\cdot\sum_{k=0}^{N-1}\binom{2L-1}{k}+\frac{\exp\left[-\frac{1}{2}(a^2+b^2)\right]}{2^{2L-1}}$$

$$\times\sum_{n=1}^{N-1}I_n(ab)\sum_{k=0}^{N-1-n}\binom{2L-1}{k}\cdot\left[\left(\frac{b}{a}\right)^n-\left(\frac{a}{b}\right)^n\right] \qquad \text{Eqn. (14)}$$

when N>1

where:

$$a = (m-1) \cdot \sqrt{\frac{1}{2} \cdot \gamma_b} \qquad b = (m+1) \cdot \sqrt{\frac{1}{2} \cdot \gamma_b}$$

γ_b - SNR at the Rake receiver output.

$m^2 = P_P/P_D$ - represents the percentage of the pilot channel power with respect to the data channel power.

The Eqn.7 and 8 are true for AWGN channel, For the fading channel, we have the following expression:

$$P_2 = \int_0^{\infty} P_2(\gamma_b) \cdot \frac{1}{(L-1)!\overline{\gamma_c}^L} \cdot \gamma_b^{N-1} \cdot e^{-\frac{\gamma_b}{\overline{\gamma_c}}} d\gamma_b \qquad \text{Eqn. (15)}$$

where:

$\gamma_c = \frac{\gamma_b}{N}$ - SNR at the Finger output,

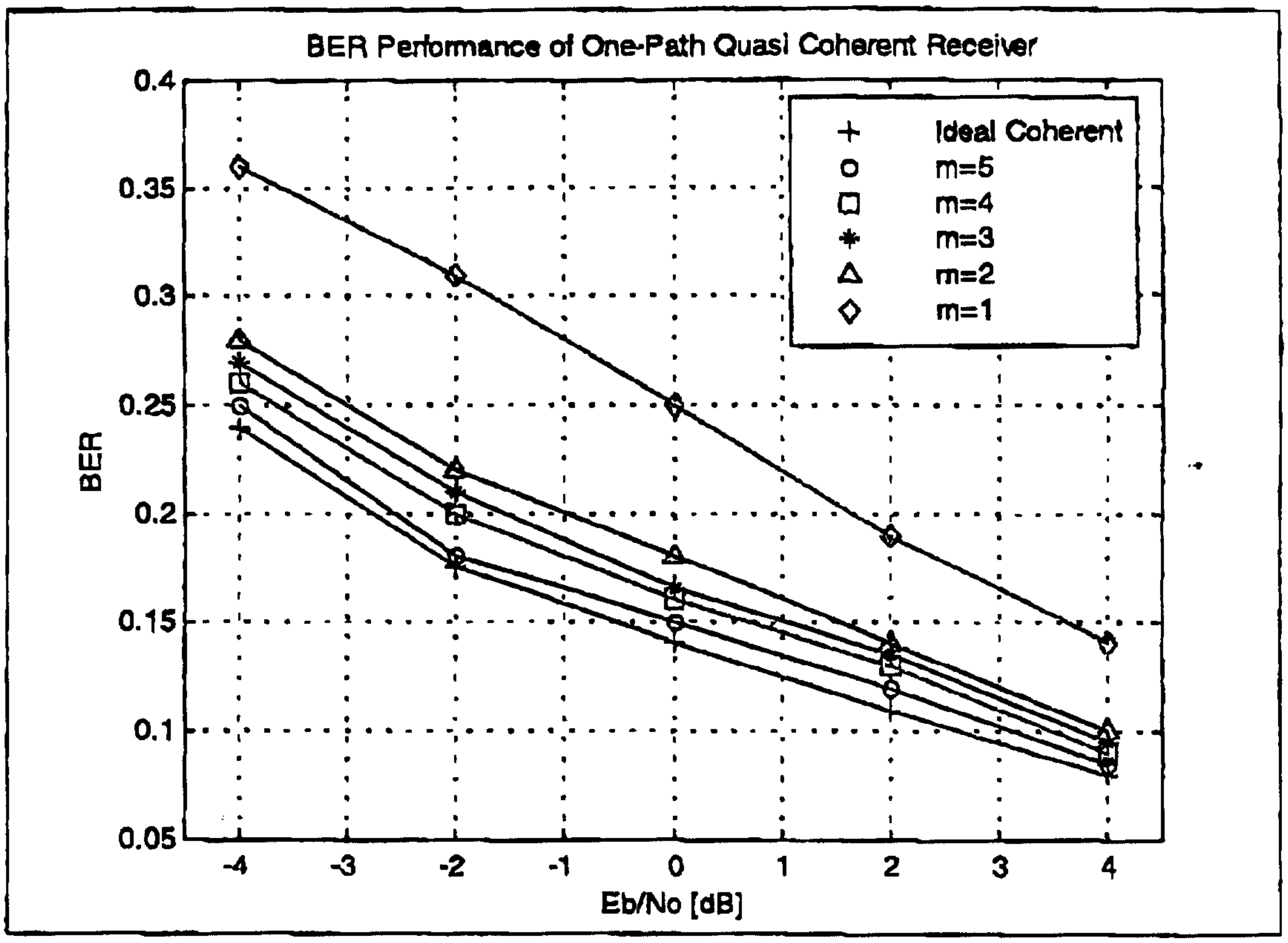
The accuracy of the equations (7) - (9) is confirmed by the computer simulation.

Figure 16 shows BER performance curves of the coherent receiving in one-path AWGN and fading channel for the different values of the coefficient m. As it can be seen, the more the value m, the more the loss with respect to the ideal coherent receiving. The loss are also decreased with the increasing of the absolute SNR values in the information and pilot channels. The dependence of the real coherent receiving energy loss with respect to the non-coherent one on the value m can be obtained by selecting an error probability level BER from the above curve family, Evidently, this dependence will be true function $LE(\ \bullet\ )$. The value m is defined by the equation:

$$m = \sqrt{\frac{P_P \cdot G_P}{(1-P_P) \cdot G_D}} \qquad \text{Eqn. (16)}$$

4. The Graph-Method is in the following. The function $LE(\ \bullet\ )$ is tabulated in details for a value BER using the great number of the BER curves for the different values m. The optimum balance value $P_P = P_P^{opt}$ is defined by minimizing the equation (6) with respect to k for the specified G_P and G_D.

FIGURE 3. BER at quasi-coherent one-path receiver output



2.2 Discussion on the Graph-Method

Based on the different propagation channel model, the real coherent receiving BER is determined by different expressions, hence, the associated loss function *LE*(•) is different. The optimum balance should be re-calculated, e.g. with respect to the different number of the received multi-paths. On the other hand, the *LE*(•) function calculation is required once for the selected BER value. Eqn. (10) is only changed for the different transmission rate values. Since the required BER before the Viterbi decoder is within the range of 14-18%, we can apply one value of BER=18%, since the BER curve slope is approximately the same in between BER=14-18%.

3.0 Application of Graph-Method to Compute Gain Balance for cdma2000

In the following, we consider to apply the Graph-Method for the computation of the cdma2000 reverse Walsh channel power balance.

1. The Graph-Method application allows to set the optimum balance between two channels (data and pilot channels). With this aim, the processing gain and the table of the *LE*(•) function values corresponding to a specific propagation channel model should be defined for data and pilot channels.
2. Once the balances between the Control and Pilot, Fundamental and Pilot, Supplemental and Pilot channels are obtained by the Graph-Method described in section 2.1, then optimum balance between all these channels is calculated based on the approach disclosed in Section 1.2.

3.1 Optimum Power Balance for Multi-path Fading Channel

Since the power balance in the cdma2000 reverse channel is defined by a set of particular balances between two channels, the study of the reception environment impacts on the balance between the data and pilot channels is sufficient.

The fundamental, supplemental and control channels can be considered as an information channel with a certain processing gain. hence, the information channel processing gain G_{data} in the cdma2000 reverse link is within the range of 2 - 568. In Table 7, the optimum power balance between the data and pilot channels are calculated using the Graph-Method for a certain values G_{data} depending on the reception channel environment.

Table 7. Power Balance for Multi-path Fading Channel

G_{data} (Gp=3072)	No Fading	Fading			
	N=1	N=1	N=2	N=3	N=4
2	3	4	5	6	7
16	8	10	12	14	16
48	14	15	18	20	22
96	19	18	23	25	28
192	25	24	29	31	33
288	29	27	31	33	35
576	34	34	38	39	40

The analysis of Table 7 indicates that:

- with the increasing processing gain G_{data} the power allocated to the pilot channel increases.

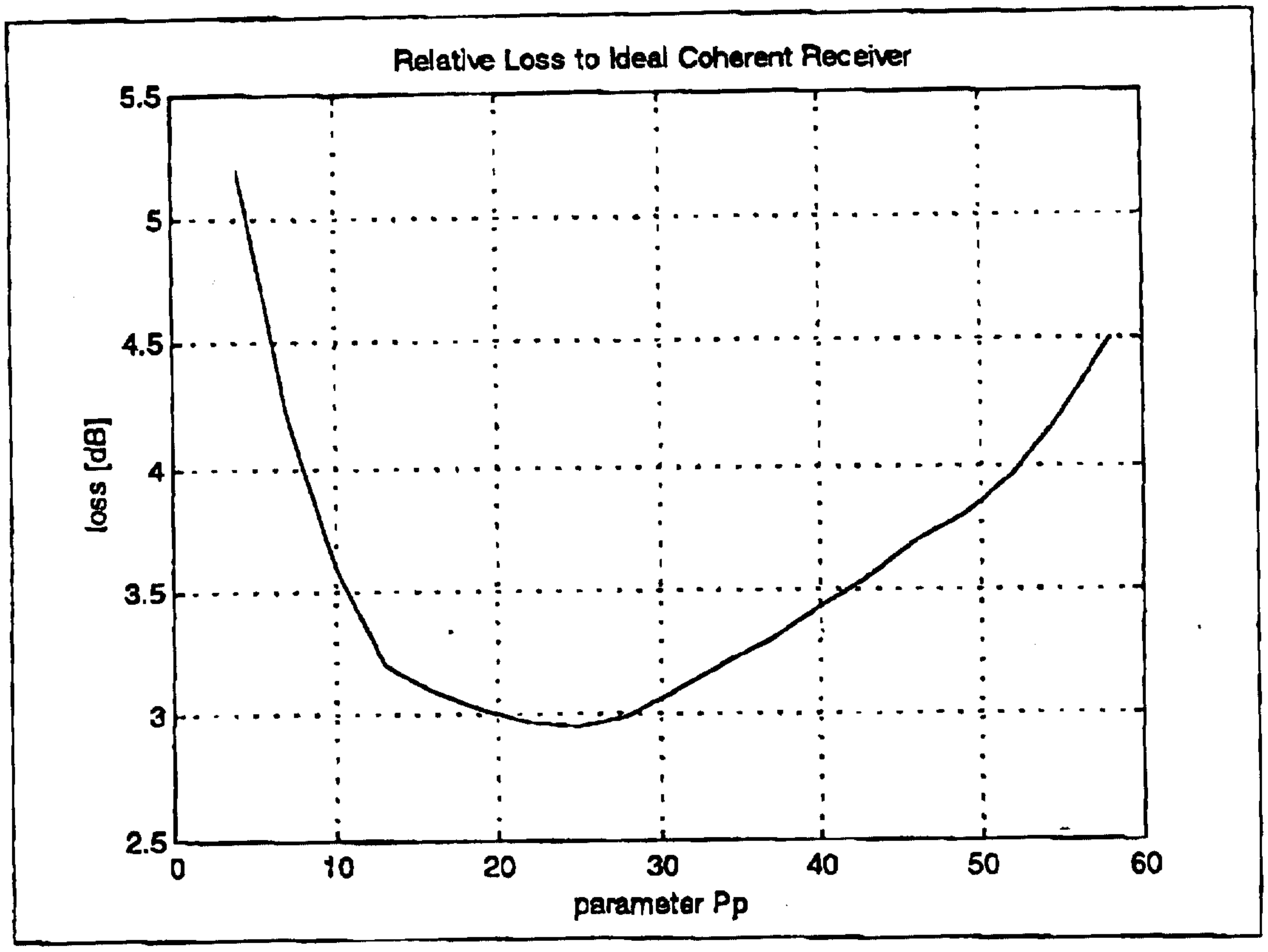
- with the increase of number of multi-path, the power allocated to the pilot channel increases.

Note, that the power balance change does not exceed 9% with the increasing of number of multi-path from 1 to 4.

3.2 Justification of Optimality of Power Balance

Figure 2 represents a typical loss function plot, defined by Eqn. (6), with the specific parameters $G_{data} = 96$ and $N = 3$ in the fading and AWGN channel environment. It can be seen that over a wide rang the losses vary slightly and insignificantly. For example, the difference between the losses in 0.1 dB (approximately) at P_P=19% and P_P=25% .

FIGURE 4. Relative Loss w.r.t. Ideal Coherent Reception



The same results can be obtained for different processing gain and number of multi-path. The power balance values (see Table 7) differ little for the different multi-path number. Hence, the average balance value in the line of Table 7 is reasonable for a particular G_{data}. In this case, the loss is less than 0.1 dB with respect to the optimum solution derived in Section 1.2.

3.2.0.1 Conclusions

1. The optimal Walsh channel power balance in cdma2000 reverse link is defined by the particular balances between the data and pilot channels.
2. The study of the multi-path receiving optimum balance demonstrates the insignificant change of the optimum balance (the pilot signal power should be increased) with the increasing of the equal power path number from 1 to 4.
3. The optimum balance change range corresponds to a flat region of the loss function, therefore, the average balance value can be selected for any path number with the loss is not more than 0.1 dB.

4.0 Reference

[1] J. Proakis:" Digital Communications" Third Edition

WHAT IS CLAIMED IS:

1. A method of allocating power to transmission channels in a celleular communications system providing pilot and data channels, comprising the steps of:

(a) optimizing a power ratio of individual data channels to the pilot channel;

(b) optimizing a power of the pilot channel obtained in step (a); and

(c) minimizing a power of each data channel obtained in step (a).

2. A method as claimed in claim 1 wherein the optimization in step (a) is carried out for a desired communication quality for each data channel.

3. A method of balancing transmit signal power among a plurality of constituent Walsh channels in a CDMA celleular communications system, comprising the steps of:

(a) determining a pilot filter bandwidth and a quality for each channel;

(b) determining $\{E_c / I_o |_{data}\}|_i$ for each constituent Walsh channel, based on E_b / I_o and processing gain data G_{data}, or $E_c / I_o |_{data} = E_b / I_o - G_{data}$;

(c) determining an optimum pilot E_c / I_o requirement for each constituent Walsh channel, or $\{E_c / I_o |_{pilot}\}|_i$, where i = {fundamental channel, supplemental channel, control channel}, using

$$\frac{\{E_c / I_o|_{data}\}|_i}{\{E_c / I_o|_{pilot}\}|_i} = \sqrt{(R \cdot SNR) / 2B(1 + SNR)}; \text{ and}$$

(d) selecting a maximum pilot E_c / I_o, or $\max\{E_c / I_o |_{pilot}\}|_i$ and $\{E_c / I_o |_{data}\}|_i$, for each constituent Walsh channel in step (b).