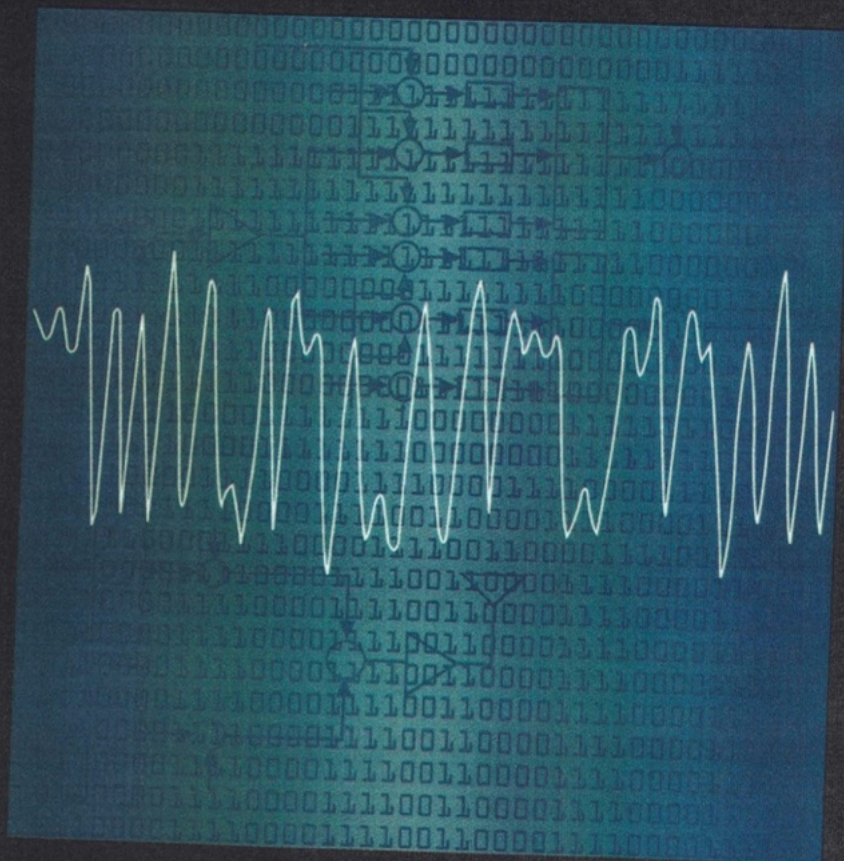


MOBILE COMMUNICATIONS SERIES

CDMA SYSTEMS ENGINEERING HANDBOOK



JHONG SAM LEE
LEONARD E. MILLER

 Artech House Publishers BOSTON • LONDON

CDMA Systems Engineering Handbook

Jhong Sam Lee
Leonard E. Miller

Artech House
Boston • London

Library of Congress Cataloging-in-Publication Data

Lee, Jhong S.

CDMA systems engineering handbook / Jhong S. Lee, Leonard E. Miller.

p. cm. — (Artech House mobile communications library)

Includes bibliographical references and index.

ISBN 0-89006-990-5 (alk. paper)

1. Code division multiple access. 2. Mobile communication systems.

I. Miller, Leonard E. II. Title. III. Series.

TK5103.45.L44 1998

621.382—dc21

98-33846

CIP

British Library Cataloguing in Publication Data

Lee, Jhong S.

CDMA systems engineering handbook.— (Artech House mobile communications library)

1. Code division multiple access—Handbooks, manuals, etc.

I. Title II. Miller, Leonard E.

621.3'84'56

ISBN 0-89006-990-5

Cover design by Lynda Fishbourne

© 1998 J. S. Lee Associates, Inc.

All rights reserved. Printed and bound in the United States of America. No part of this book may be reproduced or utilized in any form or by any means, electronic or mechanical, including photocopying, recording, or by any information storage and retrieval system, without permission in writing from the publisher.

All terms mentioned in this book that are known to be trademarks or service marks have been appropriately capitalized. Artech House cannot attest to the accuracy of this information. Use of a term in this book should not be regarded as affecting the validity of any trademark or service mark.

International Standard Book Number: 0-89006-990-5

Library of Congress Catalog Card Number: 98-33846

10 9 8 7 6 5 4 3 2

IPR2025-00756, OnePlus Ex. 1015

Page 3 of 9

Table 3.12 Margins required for single cell

P_{rel}	M_{dB}	
	$\sigma_{dB} = 8 \text{ dB}$	$\sigma_{dB} = 2.5 \text{ dB}$
0.9	10.25	3.20
0.95	13.16	4.11
0.98	16.43	5.13

3.3.2.2 Determination of Multicell Margin Requirements

Having found the link margin needed for the reverse link based on an analysis of the single-user, single-cell case (i.e., no interference), we now consider how the internetworking of the base stations (and sectors of the same base station) in a cellular system affects the link budget. Specifically, we consider how the required margin in dB is modified by a "handoff gain" (which may be negative) to account for the particular handoff technique employed by the system, either:

- Hard handoff, in which the call is transferred to the adjacent cell or sector when the signal level in the current cell falls below a certain threshold.
- Soft handoff (to be discussed in Chapters 4 and 10 under CDMA handoff considerations), which allows simultaneous transmission to and from the mobile station through two base stations or cells.

Hard handoff is commonly used by FDMA cellular systems, such as AMPS, because transferring the call to another cell site involves retuning the oscillators in the mobile's transmitter and receiver to new frequencies. When the mobile is near the border of two cells, the signal levels usually fluctuate at both cell sites, resulting in a *pingpong* effect. The case of a mobile traveling a route that crosses and recrosses a cellular boundary is handled in hard handoff systems by engineering a slight amount of overlap of the cellular coverage areas. As illustrated in Figure 3.23, in order to engineer an overlap of coverage areas, the link margin must be increased to ensure reliable operation at the extended range κR_c , where R_c is the cell radius and $\kappa \geq 1$ is a cell range extension factor.

At or about the cell edge—the distance $d = R_c$ from the base station—the median propagation path loss can be modeled as being proportional to

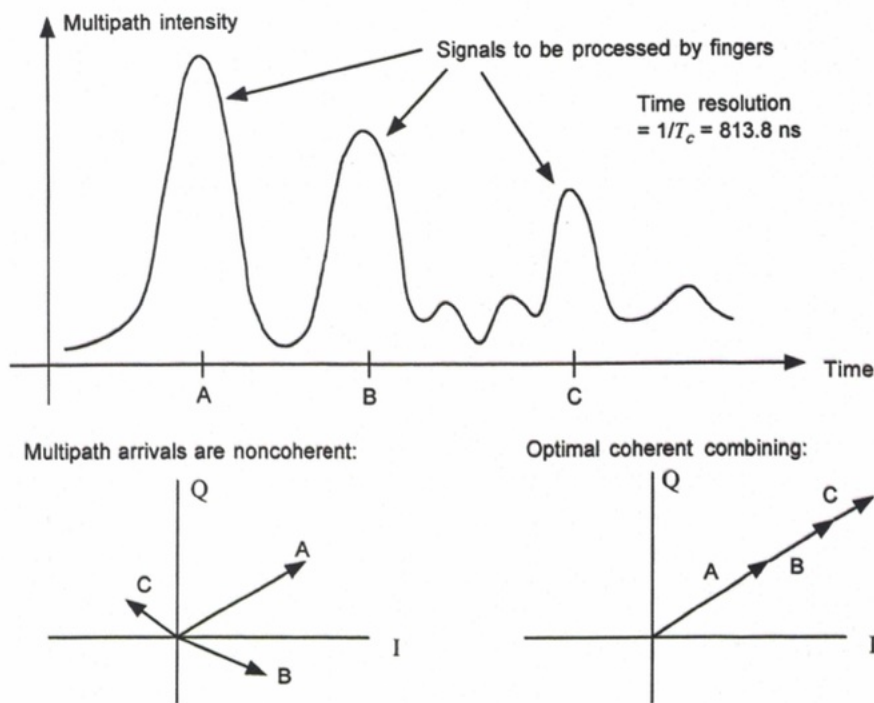


Figure 4.41 Concept of coherent combining.

to demodulation and decoding decisions. At the MTSO, the frames of data from the two base stations are selection-diversity "combined"; that is, the frame with the better quality is chosen. (These diversity combining methods are treated in Chapter 9.)

The soft handoff depicted as in progress in Figure 4.43 is termed "soft" because the connection of the mobile with one station is not broken off until one is established with the new station, rather than the "hard" handoff procedure that is necessary in analog FDMA cellular systems because the receiver must tune to a new frequency. Because the combining is done at the MTSO, however, under soft handoff, it is necessary to make hard data decisions to transmit the data frame to the MTSO. A "softer" handoff can occur in an IS-95 CDMA system when the mobile is in transition between two sectors of the same cell site. As illustrated in Figure 4.44, up to four multipath components of the mobile's transmission, as received at up to four antennas, can be combined before making a hard data decision. The figure indicates that the handoff process involves a gradually increasing preference for multipath

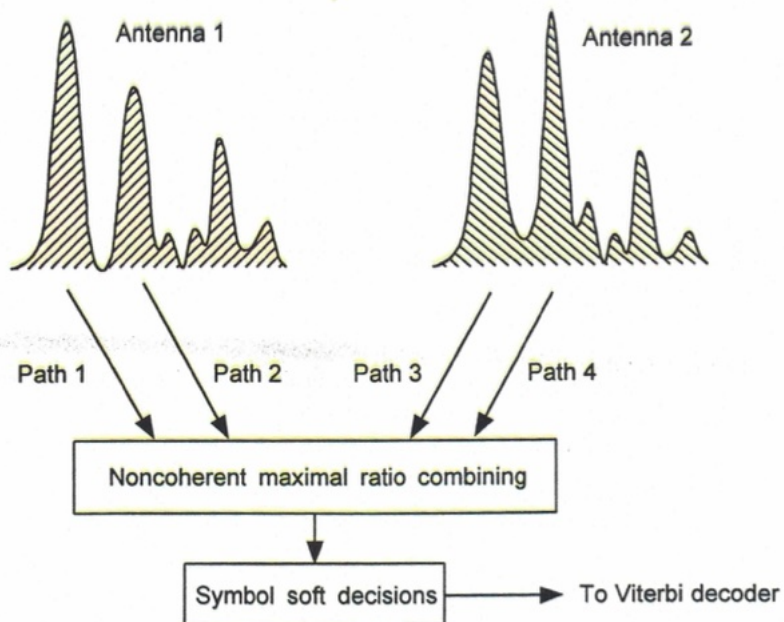


Figure 4.42 Reverse link multipath/antenna diversity.

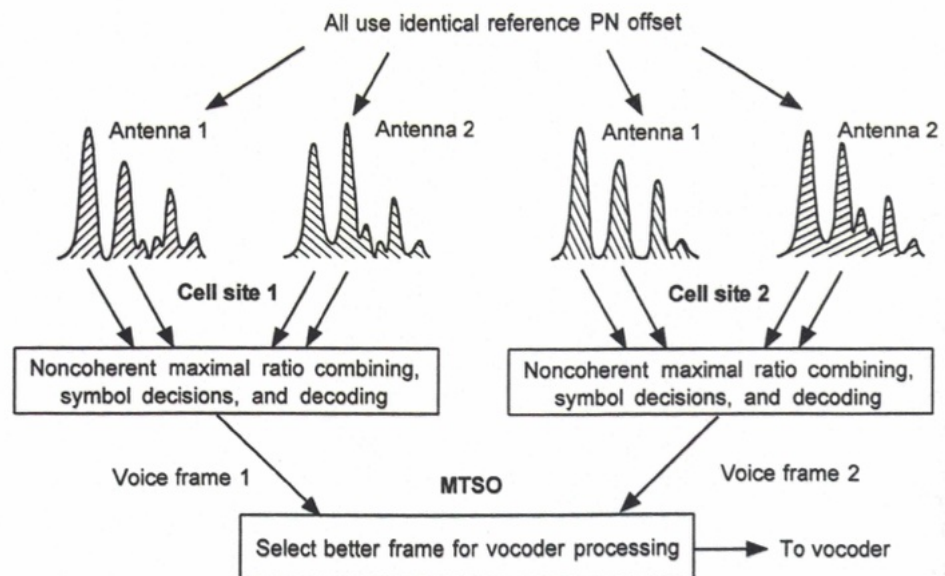


Figure 4.43 Reverse link soft handoff/multipath/base station diversity.

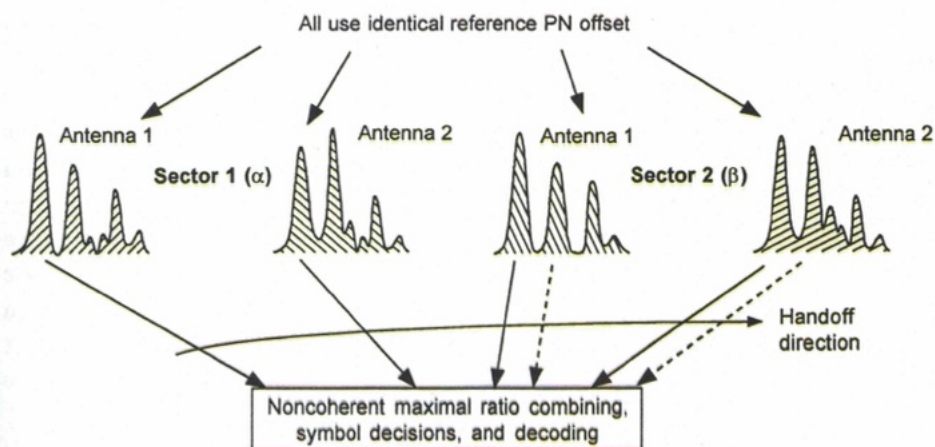


Figure 4.44 Reverse link "softer" handoff between sectors of a cell site.

components received in one sector, until the mobile signal is being processed by just one sector.

Note that on reverse link transmissions, the mobile transmits using zero-offset short PN codes; during handoff, each base station must align its receiver to the unique value of propagation delay experienced by the mobile signal, using the preamble sent on reverse link access channel and traffic channel transmissions as an aid to acquisition. On the forward link, during handoff each base station or sector uses its usual short PN code offset.

As shown previously in Figures 4.8 and 4.9, the IS-95 system modulates the same data on both the in-phase and quadrature-phase channels. This modulation is different from conventional QPSK where different data are modulated on the I and Q channels. The IS-95 scheme is not conventional QPSK but a form of diversity transmission that reduces multiple access interference relative to a conventional BPSK scheme. A derivation of this fact is presented in Chapter 7.

The IS-95 CDMA system "soft handoff" greatly reduces the number of failed handoffs. As a call is initiated, the base station sends the mobile, among other parameters, a set of handoff thresholds and candidate base stations for handoff. The mobile tracks all possible pilot phase offsets in the system, with the emphasis on the candidates and the current base station. Those base stations that have a signal above the candidate threshold are kept on a periodically updated list. The list is updated when (1) a new candidate exceeds the "add threshold," (2) an old candidate remains below the "drop threshold" for

a predetermined time, (3) the list becomes too large, or (4) a handoff forces a change in the candidates.

When the pilot signal level of another base station exceeds the currently active base station's signal by a specified amount, the mobile relays this information to the active base station. The system controller then assigns a modem in the new cell to handle the call and the original base station transmits the information necessary for the mobile to acquire the new base station. The mobile continues to monitor the E_c/I_0 of the original base station and assigns at least one digital data receiver to demodulate data from the other base station. Digital data receivers are assigned to the strongest multipath components from either base station, providing a form of space diversity as discussed above in Section 4.4.2.

An example of soft handoff can be seen in Figure 4.45, where the mobile is originally communicating through base station A. When the pilot signal of base station B exceeds the add threshold, the mobile informs base station A, and base station B is put on the candidate list. Once the signal strength of base B exceeds the signal strength of base A by a specified margin, base B is put on the active list and begins to handle the call also. The signals to and from both base stations are diversity combined. As soon as the signal

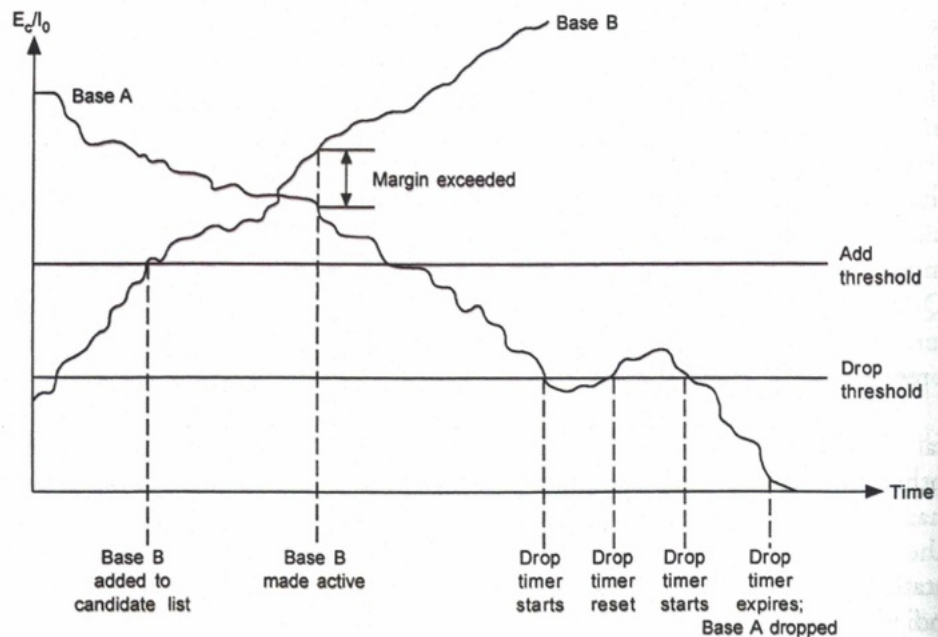


Figure 4.45 Signal levels during soft handoff.

from base station A crosses the drop threshold, the drop timer is started. The timer is reset when the signal exceeds the drop threshold. When the signal falls below the drop threshold, the drop timer is restarted. After the drop timer expires, base station A is dropped from active service.

Soft handoff methods have several advantages over conventional hard handoff methods. Contact with the new base station is made before the call is switched, which prevents the mobile from losing contact with the system if the handoff signal is not heard or incorrectly interpreted. Diversity combining is used between multiple cell sites, allowing for additional resistance to fading. Because more than one base station is used in the soft handoff region, the ping-ponging effect can be virtually eliminated. Thus, the system is relieved from unnecessary switching operations. The system is further relieved from determining signal strengths, because this processing is done at the mobile. If the new cell is loaded to capacity, handoff can still be performed if all users accept a small increase in the bit-error rate. This type of handoff can be likened to make-before-break switching. Note that in soft handoff, neither the mobile nor the base station is required to change frequency. Conventional hard handoff is performed if the mobile is required to switch to an analog system or change to another CDMA frequency. Frequency changes may be necessary if the current frequency is crowded or the mobile enters a new CDMA network.

References

- [1] "Mobile Station-Base Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System," TIA/EIA Interim Standard 95 (IS-95), Washington, D.C.: Telecommunications Industry Association, July 1993 (amended as IS-95-A in May 1995).
- [2] "Cellular System Dual-Mode Mobile Station-Base Station Compatibility Standard," TIA/EIA Interim Standard 54 (IS-54-B), Washington, D.C.: Telecommunications Industry Association, April 1992.
- [3] Viterbi, A. J., *Principles of Spread Spectrum Multiple Access Communication*, New York: Addison-Wesley, 1995.
- [4] Carlson, B. C., *Special Functions of Applied Mathematics*, New York: Academic Press, 1977.