Lucent Technologies
Bell Labs Innovations

Gena L. Ashe
Corporate Counsel

Lucent Technologies Inc.
450 Spring Park Place
Suite 500
Herndon, Virginia 20170
703.925.4133 (voice)
703.925.4170 (fax)

ELECTRONIC FILING

January 27, 2003

Marlene Dortch
Office of the Secretary
Federal Communications Commission
445-12th Street, S.W.
Washington, D.C. 20554

Re: ET Docket No. 02-135

Dear Ms. Dortch:

Attached please find Lucent's comments in response to the FCC's Public Notice of November 25, 2002, calling for comment on the Commission's Spectrum Policy Task Force Report also released in November of 2002.

Should you have any questions regarding this matter, please contact me at 703-925-4133.

Sincerely,

/s/ Gena L. Ashe
Corporate Counsel

Before the
Federal Communications Commission
Washington, D.C. 20554

In the Matter of	)	
	)	
Commission Seeks Public Comment on	)	
Spectrum Policy Task Force Report	)	ET Docket No. 02-135
	)	
	)	
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COMMENTS OF LUCENT TECHNOLOGIES INC.

Lucent Technologies Inc. (Lucent) commends the FCC's efforts to identify spectrum policy directions that will improve the efficiency of spectrum use and ultimately increase the public interest benefit derived from spectrum. Further, Lucent appreciates the opportunity to comment on the Report of the Commission's Spectrum Policy Task Force.

Flexibility of Spectrum Use

Lucent agrees that technological innovation and economically efficient use of spectrum are enhanced through flexible regulatory models. Accordingly, Lucent supports the suggestion that its carrier customers be afforded maximum flexibility in the use of their assigned spectrum.

Lucent has long supported technological neutrality in spectrum allocation and welcomes its continued support by the Commission. Further, Lucent recognizes the potential benefits that can be obtained from the development of a secondary market for spectrum and, therefore, supports policies that would allow spectrum licensees to transfer their assigned spectrum through sale, lease, or subdivision.

Notwithstanding the need for flexibility that would allow carriers to select, within their assigned spectrum, the service to be provided and the technology to be deployed, the Commission should not completely abandon its control over spectrum usage. Specifically, it is appropriate for the Commission to impose some constraints on spectrum usage through policies that will mitigate the potential for interference. As the report suggests, such policies would encourage the grouping of like systems in adjacent bands, which the Commission identifies as "spectrum neighborhoods". Indeed, such an arrangement might avoid situations similar to the interference problems being confronted within the 800 MHz band, which the Commission is currently seeking to resolve (see WT Docket No. 02-55).

Additional Commission directives and oversight are appropriate relative to the band plans that are described with spectrum allocations. Specifically, the Commission, subject to industry input, should continue to describe parameters such as directions of transmission (i.e., reverse and forward links) in given frequency blocks, the duplex spacing that defines the spectral distance between the reverse and forward links, and the center gap that provides the space between the frequency blocks allocated to the reverse and forward directions of transmission. Allocations that place like directions of transmission in adjacent bands and provide the necessary gap between opposite directions of transmission clearly mitigate situations that inherently increase the likelihood of interference.

Interference Avoidance

The Task Force is correct in predicating its suggestions for increased flexibility of spectrum usage and improved access to spectrum on the premise that any arrangements used to promote flexibility and access must not generate interference into systems operated by any licensee. Lucent does not object to the suggestion of the Task Force that, in the long term, the measure of interference be focused on the receive environment and that interference should be represented as a metric identified as "interference temperature".

The Task Force suggests that an interference temperature would be developed from empirical measurements (through the deployment of a multitude of noise monitoring devices) for each band of interest, in given geographic areas, and that this metric would provide a level of certainty relative to the noise environment. The Report correctly notes, however, that the degree of certainty would depend in large part on the uniformity of signal levels throughout the area of interest and the density of monitoring devices. Consequently, it appears that a single, uniform measure that accurately describes the noise environment in a given area may be difficult to develop.

LT is particularly concerned with the suggestion that interference temperature be used to develop a noise cap that would be used to permit spectrum sharing by operators who can operate below that recommended temperature cap. Specifically, the Task Force proposes – as part of its "Commons Model" of spectrum usage – that unlicensed systems could operate as an "underlay" in licensed spectrum after dynamically sensing that there exists a margin for operation under the temperature cap. Assuming that such operation can be practically implemented, it should be recognized that it does not come without cost. That is, the acceptance of a noise cap or interference temperature above the noise floor necessarily subjects the licensed, victim wireless system to increased external interference in the form of additional noise and can result in reduced signal to noise ratios, and, consequently, reduced call quality.

The Task Force states in its findings that advances in technology will permit wireless systems to be more tolerant of interference. Although third generation technologies may better accommodate some types of noise, they are still subject to the adverse impacts of interference. Specifically, CDMA technology, which will comprise a large part of 3G infrastructure, offers inherent protection from internally generated system noise, but is susceptible to degradation caused by noise from external sources.

Spread spectrum (i.e., CDMA) systems use complex signal processing to permit the use of multiple users in the same frequency space. For any given user the processing identifies and extracts the signal containing the desired conversation and represents signals from all other conversations as noise. The signal processing further minimizes this residual noise contributed by the multiple users, increasing the desired signal to noise ratio for a given conversation. This permits an increase in the total number of users up to the level where the signal to noise ratio is degraded such that call quality is adversely impacted.

The presence of additional sources of noise, such as that caused by out of band energy from interferers in adjacent spectrum, or from systems operating in the same spectrum as the victim system, necessarily degrades the signal to noise ratio and impacts the call quality of the victim system. Absent the ability to control the level of such interference within the interfering system, resolution may require action within the victim system, such as a reduction in noise power generated by multiple system users. The effect of external interference may, therefore, result in the need to reduce system capacity. Alternatively, if it is necessary to maintain capacity, the presence of external noise could be accommodated through a reduction in cell coverage.

Lucent has investigated the impact of external noise on CDMA systems, specifically by examining the effect on reverse link coverage and capacity. The Lucent study (attached as Annex A) explains that call quality at the base station receiver is ideally a function of the propagation path loss, the base station receiver noise floor, and the loading factor (or number of active subscribers). The Lucent study also notes that the maximum allowable path loss dictates cell size or coverage and, therefore, that maintenance of a given level of call quality can require a trade off between cell coverage and capacity (loading). Specifically, to maintain call quality when there is an increase in base station receiver noise caused by external interference, it is necessary to reduce the maximum allowable loss and the associated cell coverage, or reduce the loading (number of subscribers) supported by the system. Practically, if it is desired to maintain system capacity, a reduction in cell size is necessary. Similarly, a desire to retain a given cell size will require a reduction in system capacity.

Although a quantitative assessment of the impact of external noise is subject to specific scenarios and system values (e.g., propagation slope, receiver noise figure and sensitivity), the study offers examples, based upon given assumptions, that indicate the impact could be significant. The study suggests that if system capacity is to remain constant, the effect of an external noise power of –109 dBm – equal to the assumed receiver noise floor of –109 dBm – will demand a 30% cell coverage reduction. A second example shows that if the strategy is to maintain cell size, external noise equal to the receiver noise floor of –109 dBm demands a capacity loss of 82%.

This potential for significant degradation from external interference supports the widely accepted view that spectrum offered for Commercial Mobile Radio System (CMRS) use, and specifically for CDMA providers, be unencumbered and, therefore, that spectrum sharing is at best problematic.

The Task Force further suggests that interference temperature mechanisms would be used together with out-of-band emissions limits. They also suggest the possibility that in the future, the use of the interference temperature metric could be used as an alternative to out of band emissions limits and that some users might find the use of interference temperature sensing more economical than employing transmitter filtering. Lucent believes, however, that the absence of transmitter filtering generally requires greater spectral separation between systems, and that users who choose this alternative would necessarily be severely limited in their ability to identify spectrum that could tolerate the use of an unfiltered signal. Accordingly, a user may avoid the use of "expensive" transmitter filters, but preclude its access to a scarce and relatively more costly resource.

In summary, it appears that the Task Force's attempt to identify a means to afford more certainty in the measure of interference and use this measure to support increased access to spectrum could come at a high price. That is, the adverse impact on incumbent, licensed providers who, when confronted with a definitive worst case scenario, would be compelled to incur added limitations and associated greater costs in the design of their systems and the use of their assigned spectrum.

Alternative Methods of Interference Control

Lucent agrees with the Task Force recommendation that additional methods of interference control should be explored and implemented in the near term, and specifically that voluntary receiver performance specifications would be beneficial. Recommendations relative to receiver front-end selectivity, for example, could mitigate the potential for interference resulting from receiver front-end overload and the impact of intermodulation products. The Task Force also notes that the use of transmitter power control to adjust transmitted power to the amount needed would help in reducing the impact of interference. It should be recognized that many wireless systems already employ this feature. Indeed, current CDMA systems use power control in both base station and handset transmitters.

Finally, Lucent strongly supports the Task Force suggestion for improvements in access to interference related matters within the Commission's Rules. As noted in the Report of the Task Force's Interference Protection Working Group, interference related rules are spread throughout many sections of Title 47 of the CFR. A web site that could help a user locate the locations of relevant interference information and provide the associated links would be most helpful. Such an arrangement might also offer an efficient means of contact with the Commission staff to resolve questions related to interpretation of interference related rules.

Experimental Licensing

Lucent supports the suggestions offered by the Task Force for improvements in the issuance of experimental licenses. In addition to the need for experimental licenses for development of products that might use government shared bands in the U.S., Lucent believes that development of products for non-U.S. markets will increase the requests for experimental licenses in government spectrum. Delays in the license application process negatively impact the product development schedule and could be detrimental to a U.S. based manufacturer in the competitive infrastructure market.

Lucent suggests that the time interval from first submittal to the issuance of the license should not exceed thirty days. The Task Force recommendations for a process that makes information about the relevant bands available, and minimizes the impact of the need for third party involvement would be beneficial and should help realize this goal.

ANNEX A

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IMPACT OF EXTERNAL INTERFERENCE ON CDMA

1. Introduction

This document discusses the impact of reverse link external (non-system) interference to a CDMA system. General coverage and capacity degradations are considered. The computations underscore the need to adequately clear spectrum of all sources of external interference in order to achieve system performance.

The definitions of *external interference* and *performance degradation* in this context must be offered with care. In network applications, the CDMA Base Station (BS) clearly receives in-band interference from other CDMA mobiles. In our discussions, we reserve the term *external interference* for in-band interference from all possible sources except the operating CDMA system. The term *performance degradation* refers to the performance impact relative to the performance achievable with clean spectrum. These definitions are further expanded, below.

Pre-commercial spectrum sweeps can determine the level of external interference present within the CDMA system. Full spectrum clearance can yield maximal capacity and coverage; however, if spectrum cannot be cleared, the presence of external interference can be compensated for *in design* through sacrifice of capacity and/or coverage. Such design solutions, although valid, are generally not considered acceptable by operators since this strategy implies that scarce, expensive radio spectrum is not being used to its full potential. For example, "noisy" spectrum can be tolerated if cells *in design* are spaced sufficiently close together; alternatively, noisy spectrum may be acceptable at full coverage if the system's design capacity is appropriately reduced.

In the following, we presume full spectrum clearance in design. *The performance degradation as a function of external interference is therefore relative to maximum coverage or maximum capacity*. The results can therefore be interpreted in two ways:

- The values can be used in design planning to trade off the ability to clear radio spectrum against the performance degradation caused by embedded interference. For example, a narrowband interferer at –115 dBm can degrade cell coverage relative to that achieved by clean spectrum by 10%. If this interferer cannot be removed, the network can still achieve full capacity provided that the design coverage is reduced by this amount. Note that, strictly speaking, this interpretation can apply only to steady-state sources of interference, since—by definition—transient sources are difficult to capture or characterize, thus making it impractical to compensate for their impact in design.

- The values can be used to project the performance impact for existing networks *originally deployed with clean spectrum* where new interference sources develop. This interpretation may be more useful for mature markets, where cell site spacing is already well established. Any performance impact on existing networks must be relative to an original (baseline) spectrum present at the time of deployment*; in this interpretation, the impact is relative to a presumed baseline clean spectrum.* Original (baseline) coverage and capacity for the network were therefore at optimal values prior to the introduction of the new interference. The degradation caused by new interference for a network deployed with a baseline spectrum that was already noisy at the time of deployment requires additional (but similar) calculations. If the interference is short-lived, these effects may be more apparent as transient sources of origination failure or dropped calls rather than constant, systematic impacts on coverage or capacity.

The rest of this memorandum is organized as follows: Section 2 addresses the relationship between the average external interference power and the CDMA reverse link coverage. Section 3 discusses the relationship between the average external interference power and the CDMA reverse link capacity. Section 4 provides a summary.

2. Effect on Reverse Link Coverage

In the typical CDMA reverse link budget for RF planning, no margin is allocated for external interference. If the cell layout is designed to the maximum allowable propagation loss dictated by the link budget analysis, the receiver noise rise caused by external interference may result in a reduction in the maximum propagation loss (used to determine the cell radius and cell coverage). In other words, when the CDMA mobile is located at the cell edge, the BS receiver quality target cannot be maintained. Since the maximum path loss in the CDMA link budget is a function of the BS receiver noise floor and loading factor, there exists a penalty tradeoff between the cell coverage and capacity.

In this section, it is assumed that the cell layout is designed to the maximum propagation loss dictated by the reverse link budget and the service objective is to maintain the capacity. In the presence of external interference from non-CDMA systems, the CDMA BS receiver noise floor rises and therefore the reverse link coverage shrinks. It is shown in A.1 that when the number of CDMA users (i.e., capacity) remains the same, the CDMA BS receiver sensitivity degradation (*D*) (defined as the ratio of the sensitivity ($S_{w/\,ext}$) with external interference to the sensitivity ($S_{w/o\,ext}$) without external interference) equals the noise rise caused by average external interference power, i.e.,

$$D = \frac{S_{w/\,ext}}{S_{w/\,o\,ext}} = \frac{I_{ext} + FN_oW}{FN_oW} \qquad (1)$$

where N_o is the spectral density of thermal noise, F is the BS receiver noise figure, I_{ext} is the average external interference power (falling into the CDMA carrier bandwidth) received by the CDMA BS antenna connector and W is the system bandwidth. If the propagation loss slope is known, then the receiver sensitivity degradation can be translated into the coverage area reduction. It follows that the CDMA reverse link cell coverage reduction ratio (R_{cov}) due to external interference can be expressed by:

$$R_{\text{cov}} = 1 - \left(\frac{L_{w/\,ext}}{L_{w/\,o\ ext}} \right)^{2/\gamma} = 1 - \left(\frac{S_{w/\,o\ ext}}{S_{w/\,ext}} \right)^{2/\gamma} = 1 - \left(\frac{FN_o W}{I_{ext} + FN_o W} \right)^{2/\gamma} \qquad (2)$$

where L denotes the maximum allowable propagation loss and γ denotes the propagation loss exponent. This equation shows that the penalty in the CDMA reverse link cell coverage (or maximum propagation loss) depends on the CDMA BS receiver noise rise as well as the propagation loss slope, and is independent of the CDMA loading.

As an example, Figure 1 shows the relationship between the CDMA reverse link coverage loss and the average external interference power when the capacity remains constant and the propagation loss slope is 35 dB/decade. It is observed that an external interference power of –105 dBm/1.23 MHz will cause about 5.5 dB noise rise and 51% cell coverage loss. As the average external interference power is -120 dBm (11 dB below the receiver noise floor, -109 dBm/1.23 MHz) causing a 0.3 dB noise rise, then the cell coverage reduction becomes about 4%. Service providers can determine a tolerable reverse link external interference power level for spectrum clearance based on the elected acceptable coverage reduction when performing the network deployment study. Note that Figure 1 should be viewed as an example only and not universally applied to all products and scenarios, since the shape of the curve will differ as the noise figure and required receiver sensitivity vary.

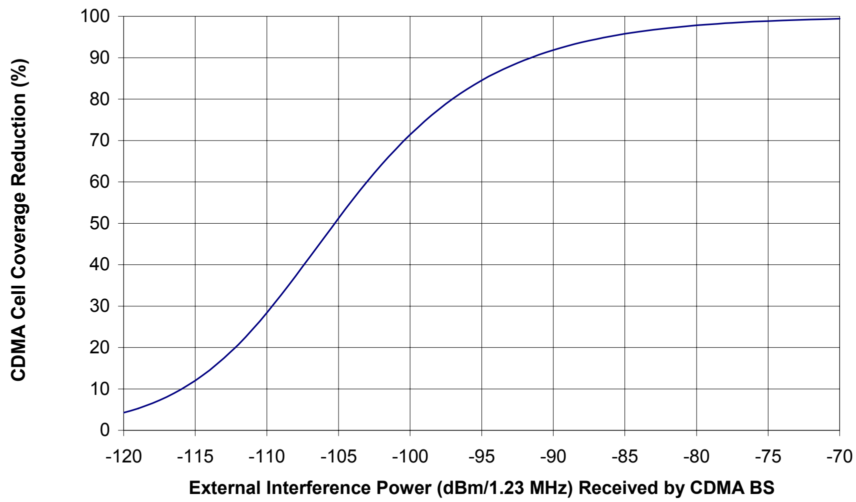


Figure 1: Effect of average external interference power on CDMA reverse link cell coverage

3. Effect on Reverse Link Capacity

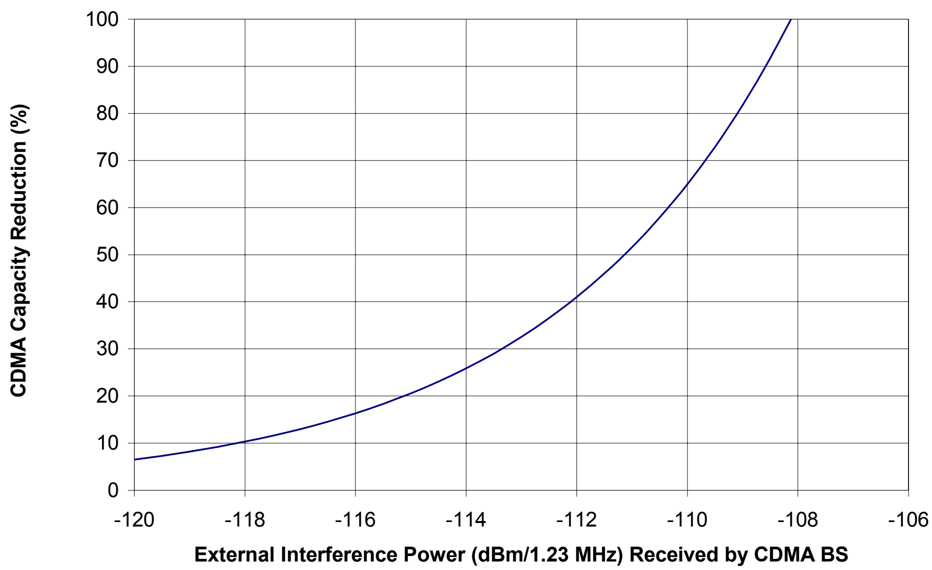
In this section, it is assumed that the cell layout is designed to the maximum propagation loss dictated by the reverse link budget and the service objective is to maintain the coverage. In the presence of external interference from non-CDMA systems, the CDMA BS receiver noise floor will be raised and therefore the reverse link capacity will be reduced. It is shown in A.2 that when the receiver sensitivity and cell coverage remain the same and the cell layout is designed to the maximum propagation loss dictated by the reverse link budget, the CDMA reverse link capacity reduction ratio (R_{cap}) due to external interference can be determined by:

$$R_{cap} = 1 - \frac{N_{w/\,ext}}{N_{w/o\ ext}} = \left(\frac{I_{ext} + FN_oW}{FN_oW} - 1\right)\left(\frac{1}{\rho} - 1\right) \qquad (3)$$

where $N_{w/\ ext}$ denotes the CDMA capacity with external interference, $N_{w/o\ ext}$ the CDMA capacity without external interference and ρ denotes the CDMA reverse link loading factor. The above equation indicates that the penalty in CDMA reverse link capacity depends on the CDMA BS loading factor and the receiver noise rise caused by external interference.

As an example, we consider IS-95 EVRC. The typical reverse link budget for the IS-95 EVRC with mobility and voice applications, considers a 3.5 dB CDMA BS receiver interference margin (i.e., the noise rise due to other user interference), which corresponds to a 55% loading. Figure 2 shows the relationship between the IS-95 EVRC reverse link capacity loss and the average external interference power when the CDMA cell coverage remains constant. It is observed that an external interference power of –109 dBm/1.23 MHz will cause about 3 dB noise rise and 82% capacity loss. As the external interference power is -120 dBm causing a 0.3 dB noise rise, then the cell capacity reduction becomes about 6%. Service providers can determine a tolerable reverse link external interference power level based on the elected acceptable capacity reduction when performing the network deployment study.

Note that Figure 2 should be viewed as example only and not universally applied to all products and scenarios, since the result will vary with noise figure and receiver sensitivities.



4. Summary

The presence of reverse link external interference will negatively impact the capacity and coverage of CDMA systems. The impact of external interference can be viewed as degrading capacity while maintaining coverage; alternatively, it can be shown that the cell footprint can be maintained if capacity is degraded.

The computed capacity and coverage degradation may be used to assess the impact of external interference that develops *after* deployment; i.e., new interference that develops relative to the baseline condition of the spectrum. Alternatively, the computed capacity and coverage degradation can be used in pre-deployment design planning to compensate for noisy spectrum if clearance is not practical. For example, closely spaced cells can yield full capacity since a coverage penalty can be tolerated. This strategy is generally considered undesirable since it implies that scarce, expensive radio spectrum is not being fully utilized; however, it may be tolerable in areas where cells must be closely spaced regardless of interference conditions in order to address capacity demands.

In all cases, the degradation of performance in the presence of external interference can be significant. Accordingly, it is critical that spectrum be completely cleared in order to fully realize CDMA performance.

Appendix – CDMA Reverse Link Coverage or Capacity versus Noise Rise

In Section A.1, we derive the relationship between the CDMA reverse link cell coverage loss and the BS receiver noise rise (or sensitivity degradation) caused by external interference from non-CDMA systems. In Section A.2, we solve the relationship between CDMA reverse link capacity loss and the BS receiver noise rise caused by external interference.

A.1 CDMA Reverse link Coverage versus Noise Rise

We first consider the equation for receiver Eb/Nt. For simplicity, we make the conservative assumption that the external interference Iext is present uniformly; i.e., within all (as opposed to a single) base station(s). Considering the desired signal, other user interference from the serving cell and other cells, external interference and receiver noise floor, the CDMA base station received Eb/Nt can then be expressed as:

$$\frac{E_b}{N_t} = \frac{S/R}{FN_o + \frac{I_{ext}}{W} + \frac{\alpha(1+\beta)(N-1)S}{W}} = g\frac{S}{FN_oW + I_{ext} + \alpha(1+\beta)(N-1)S} \qquad \text{(A.1)}$$

where Eb is the bit energy, N_t is the spectral density of thermal noise plus interference, N_o is the spectral density of thermal noise, F is the BS receiver noise figure, Iext is external interference from non-CDMA systems, S is the received signal strength, R is the bit rate, α is the voice activity factor, β is the ratio of other sector interference to serving sector interference, N is the number of mobiles in a sector, W is the system bandwidth, and g (= W/R) is the processing gain.

In order for a CDMA call to maintain target quality, the power control algorithm should ensure that the receiver achieves the minimum Eb/Nt requirement:

$$\left(\frac{E_b}{N_t}\right)_{\text{required}} \equiv d \qquad \text{(A.2)}$$

Equation (A.1) can be rewritten to explicitly indicate the number of mobile calls N:

$$N = \frac{g}{\alpha d}\frac{1}{(1+\beta)} + 1 - \frac{1}{\alpha(1+\beta)}\frac{FN_oW + I_{ext}}{S} \qquad \text{(A.3)}$$

In the above equation, the finite limit on capacity can be conveniently reached by letting the signal-to-cell-site noise ratio go to infinity (i.e., by letting the received signal power become unbounded with respect to the cell site noise). This capacity is called the pole point, Nmax, and represents a theoretical maximum that cannot be reached but serves as a useful reference point for the reverse link.

$$N_{\max} = \frac{g}{\alpha d}\frac{1}{(1+\beta)} + 1 \qquad \text{(A.4)}$$

Therefore, the receiver sensitivity (i.e., the minimum desired signal strength) can be obtained by substituting Equation (A.4) into Equation (A.3):

$$S = \frac{FN_o W + I_{ext}}{\alpha(1+\beta)(N_{\max} - N)} = \frac{FN_o W + I_{ext}}{\alpha(1+\beta)N_{\max}(1-\rho)} \qquad \text{(A.5)}$$

where ρ = N/Nmax is the reverse link loading factor. When the number of CDMA mobiles (i.e., capacity) remains the same with and without external interference, the sensitivity degradation (D) (defined as the ratio of the CDMA BS receiver sensitivity (S w/ ext) with external interference to the sensitivity (S w/o ext) without external interference) is given by:

$$D = \frac{S_{w/\,ext}}{S_{w/\,o\,ext}} = \frac{I_{ext} + FN_o W}{FN_o W} \qquad \text{(A.6)}$$

It is observed that the sensitivity degradation equals the noise rise caused by the external interference, regardless of the CDMA loading. From the link budget point of view, the maximum allowable propagation loss (L) between a CDMA mobile and the serving BS can be determined by:

$$L = \frac{P_{CDMA\_M}}{G_{CDMA\_BS} G_{CDMA\_M} M_{fade} G_{Handoff} S} \qquad \text{(A.7)}$$

where PCDMA_M denotes the CDMA mobile transmit power at the antenna connector, GCDMA_BS denotes the CDMA BS antenna minus cable loss, GCDMA_M denotes the CDMA mobile antenna, Mfade denotes the log-normal fade margin and Ghandoff denotes the soft handoff gain. It follows that with external interference, the CDMA reverse link cell coverage reduction ratio (R_{cov}) can be expressed by:

$$R_{\text{cov}} = 1 - \left(\frac{L_{w/\,ext}}{L_{w/\,o\,ext}}\right)^{2/\gamma} = 1 - \left(\frac{S_{w/\,o\,ext}}{S_{w/\,ext}}\right)^{2/\gamma} = 1 - \left(\frac{FN_o W}{I_{ext} + FN_o W}\right)^{2/\gamma}$$

where γ denotes the propagation loss exponent. This equation shows that the penalty in the CDMA reverse link cell coverage (or maximum propagation loss) depends only on the CDMA BS receiver noise rise caused by external interference, and is independent of the CDMA loading.

A.2 – CDMA Reverse link Capacity Loss versus Noise Rise

Equations (A.5) and (A.7) indicate that when the receiver sensitivity and cell coverage remain the same, the relationship between the CDMA capacity (Nw/ ext) with external interference and the capacity (Nw/o ext) without external interference is determined by:

$$\frac{FN_{\mathrm{o}}W + I_{ext}}{N_{\max} - N_{w/\,ext}} = \frac{FN_{\mathrm{o}}W}{N_{\max} - N_{w/o\,ext}}$$

Rearranging the above equation, we obtain that the CDMA reverse link capacity reduction ratio (R_{cap}) due to external interference:

$$R_{cap} = 1 - \frac{N_{w/\,ext}}{N_{w/o\ ext}} = \left(\frac{I_{ext} + FN_oW}{FN_oW} - 1\right)\left(\frac{N_{\max}}{N_{w/o\ ext}} - 1\right) = \left(\frac{I_{ext} + FN_oW}{FN_oW} - 1\right)\left(\frac{1}{\rho} - 1\right)$$

The equation indicates that the penalty in CDMA reverse link capacity depends on the CDMA BS loading factor and the receiver noise rise caused by external interference.