APPENDIX
A1. MATHEMATICAL MODEL FOR REVERSE LINK

A1.1. CELL CAPACITY FOR A CDMA SYSTEM

The capacity of a CDMA system is limited by the reverse link. The reverse link uses uncorrelated, non-orthogonal PN codes, which makes it limited by interference from other users. Each other user appears as noise as additional noise to the cell. If we initially assume a single cell then the noise in the system will be determined by the number of users in the cell [87]. If we let the number of users be N, and the transmitted power from each user to be S, the received signal will consists of the received signal power for the desired user (S) and the interference from N-1 other users, thus the signal to noise ratio will be.

\[
\text{SNR} = \frac{S}{S + \frac{1}{N-1}}
\]

Since, the noise in the channel is reduced by the process gain during demodulation, the noise on each data bit seen after demodulation will be less. The process gain is the ratio of the total bandwidth (W) to the base band information bit rate (R). Thus the received energy per bit to noise ratio (E_b/N_0) is

\[
\frac{E_b}{N_0} = \frac{W}{R \left(\frac{N}{N-1}\right)}
\]
The above equation does not take into account thermal noise. The thermal noise simply increased the effective amount of noise. Let the thermal noise be \( n \). Thus, the Eb/No becomes

\[
\frac{E_b}{N_0} = \frac{W}{R(N-1)} \frac{1}{d/S} \]

In order to achieve an increased capacity, the interference from users needs to be reduced. This can be achieved by monitoring the voice activity so that the transmitter is switched off during periods of no voice activity. This reduces the effective interference level by the reduced duty cycle of the transmitted signal. Using antenna sectorization can also reduce the interference [88]. If for example the cell was subdivided using three antennas, each having a beam width of 120°, then the interference seen by each antenna is one third that of an omni-direction antenna. If we let \( d \) be the duty cycle of the voice activity, and \( G \) be the cell sectorization then equation becomes

\[
\frac{E_b}{N_0} = \frac{W}{R(N-1) \frac{d}{G}} \frac{1}{d/S} \]

Thus, the capacity of a single cell CDMA system would be

\[
\frac{N}{d} \frac{G}{E_s} \frac{N_s W}{R} \frac{n}{S} \]

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Where,

- $G$ is the antenna sectorization,
- $d$ is the voice duty cycle,
- $Eb/No$ is the energy per bit to noise ratio,
- $W$ is the total transmission bandwidth,
- $R$ is the base band bit rate,
- $n/S$ is the ratio of received thermal noise to user signal power.