

# The Performance of Turbo Coding Over Power-Controlled Fading Channel in Ka-Band LEO Satellite Systems

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**Abstract**—In this paper, the integration of power control and turbo coding is adopted to achieve reliable communications over Ka-band code-division multiple-access (CDMA)-based low earth orbit (LEO) satellite systems. The effect of imperfect power control on the bit error ratio (BER) performance is analyzed, and the upper bounds on BER are also derived for the case of slow and fast imperfect power control. The analytical and simulation results show that power control error (PCE) degrades the BER performance of turbo-decoded systems significantly in the waterfall region. In the region of error floor, the degradation effect slows down and the BER obtained under imperfect power control eventually converges with the BER under perfect power control. Moreover, in the waterfall region, the correlation characteristics of the PCE fluctuation do not degrade the BER performance as anticipated.

**Index Terms**—Imperfect power control, Ka-band, low earth orbit (LEO) satellite, pairwise error probability (PEP), turbo coding.

## 1. INTRODUCTION

THE wide bandwidth of Ka-band is attractive for high-data-rate traffic and is favored by satellite system designers as the most suitable frequency band for satellite broadband multimedia services [1], [2]. However, as compared to mobile satellite systems operating in lower frequency bands, Ka-band land mobile satellite systems (LMSS) face a much more hostile propagation environment and have their own unique propagation characteristics. Its propagation impairments mainly include the effects due to the troposphere and the mobile environment [3], [4]. The Ka-band mobile propagation suffers from more severe shadowing and faster multipath fading [4]. The time variation of its multipath fading is directly related to Doppler effects, described by the Doppler power spectrum of the channel. The reciprocal of Doppler spread is a measure of the coherence time of the channel. Doppler effects are more serious at Ka-band due to higher frequency (20/30 GHz) than the lower frequency bands (L/S bands). Hence, the multipath fading at Ka-band is much faster and the corresponding channel correlation time is much shorter. The propagation in Ka-band is also more susceptible to atmospheric effects [1]–[3].

Power control is a feasible solution to combat severe Ka-band propagation impairments [2]. However, the link budget of the Ka-band low earth orbit (LEO) satellite has low margin due to limited satellite power. Furthermore, due to the limited size and weight of the mobile terminal, realistic changes in power level for the mobile terminal are generally in the range of 5–10 times [2], whereas the signal fading caused by shadowing and weather impairments can be easily up to tens of decibels. Therefore, power control alone cannot meet the required power budget, and other techniques are required. One possible solution is the use of adaptive bit rates during periods of severe fading. However, this approach, which might be satisfactory for traffic such as Internet access, is unsuitable for many real-time applications. Another possible approach to achieve good performance involves the use of concatenated coding [2] with high coding gain.

As turbo codes represent the most significant advance in concatenated coding in terms of their ability to achieve performance close to the theoretical limit [17], they are considered in this paper. The integration of power control and turbo coding, whose functions are complementary in combating fast and slow propagation loss, is a promising solution to severe Ka-band propagation impairments. First, turbo codes with high coding gain can offer the high link margin that power control needs. Second, the correlation time of the channel is quite short at Ka-band due to severe Doppler effects. An interleaver with a relatively short size can effectively randomize the small-scale burst errors. Thus, turbo codes combined with a channel interleaver can combat fast multipath fading effectively. At the same time, power control can efficiently compensate for long-term impairments but has little influence on fast multipath fading. Therefore, turbo codes and power control can play a complementary role for combating fast and slow fading. Hence, the integration of these two techniques can provide an effective solution. Furthermore, advances in very-large-scale integration technology and the simplification in decoding algorithms make it possible for the processor onboard the satellite to implement a very efficient low-complexity digital turbo encoder/decoder. In this paper, taking the mobile environment fading and tropospheric impairments into account, the uplink power control and powerful turbo coding are integrated and analyzed for reliable Ka-band LEO satellite communications.

Many papers have presented tight union bound for turbo codes in additive white Gaussian noise (AWGN) channels [7], [8], uncorrelated Rayleigh/Rician fading channels, and correlated Rayleigh/Rician fading channels [9], [11]. In AWGN channels, it is assumed that the amplitudes of the signals

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