Performance analysis of spread spectrum random access for GEO satellite communication system

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***Abstract*—In this work, we focus on a geostationary earth orbit (GEO) satellite communication system based on the spread spectrum random access technique. We analyze the link budget between ground devices and the GEO satellite, as well as the performance degradation caused by signal collisions and co-channel interference. The simulation results show that the performance degradation due to signal collisions is dominant in area with a high signal-to-noise ratio. These findings are expected to be utilized in determining the maximum number of devices that can be accommodated within the satellite communication system.**

***Keywords*—GEO, Satellite, Random access, Spread spectrum**

I. INTRODUCTION

The orbital configuration of a satellite communication system depends on the specific requirements of the system and its intended applications. A recent trend in satellite communication system is to use broadband low Earth orbit (LEO) satellites, which are capable of high data rates and low latency [1]. However, LEO satellites possess a very short orbital period and a small footprint due to their low altitude (2,000 km or less). Consequently, a LEO satellite communication system requires multiple satellites in a constellation, frequent handovers, and complex network management [2]. These inherent characteristics and requirements may not be suitable for certain types of satellite communication systems. Hence, the geostationary Earth orbit (GEO) satellite communication system remains a subject of ongoing use and study [3-11].

For example, a regional short message service devoid of terrestrial infrastructure is more suitable for the GEO satellite communication system than for LEO satellites. Safety confirmation service (Q-ANPI) serves as a case in point, currently being discussed for provision through the quasi-zenith satellite system (QZSS) GEO satellite—Japan's regional navigation satellite system. Its primary function is to transmit evacuation shelter information to control stations and gather data during disaster events [5,6]. China also provides a regional short message communication (RSMC) service through its own satellite navigation system, the beidou navigation satellite system (BDS). RSMC service is provided by three GEO satellites within the BDS constellation, and access is limited to authorized users [7-9].

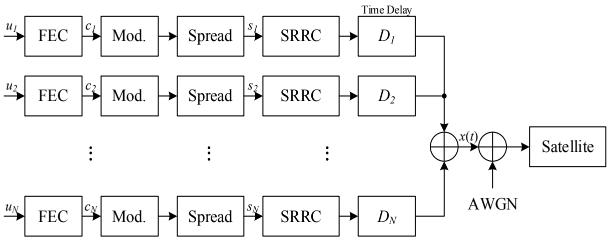

Fig. 1. Uplink Structure Diagram

In this paper, our analysis focuses on examining the error performance and capacity of a satellite communication system using a GEO satellite above the Korean peninsula. We specifically study a GEO satellite positioned above the Korean Peninsula, assuming a spread spectrum random access scheme.

II. SYSTEM MODEL

The uplink structure of a satellite communication system with spread spectrum random access is shown in Fig. 1. The uplink consists of N independent transmitters and a satellite. Information frames, u_i, $i = 1,2,\dots,N$, of size K, are encoded using a truncated convolutional encoder with the code rate r and the constraint length L. The resulting code frames c_i, $i = 1,2,\dots,N$, of size $\frac{K}{r} + L - 1$ are mapped to quadrature phase shift keying (QPSK) symbols by symbol mapper. The output of the symbol mapper is spread with a common pseudo-random (PN) sequence, which is utilized for all transmitters. Finally, the transmitted signal $x(t)$ is given by

$$x(t) = \sum_{n=1}^{N} s_n h(t - nT_s - D_n) \tag{1}$$

where $s_n, n = 1,2,\dots,N$ is spread signal of n-th transmitter, $h(t)$ is the impulse response of a square root raised cosine (SRRC) filter and $1/T_s$ is the chip rate of spread code. D_n denotes transmission time delay of n-th transmitter and it is randomly generated number from a uniform distribution for random access modeling.

III. SYSTEM DESIGN AND ANALYSIS

A. Link budget of the uplink channel

TABLE I. LINK BUDGET OF THE UPLINK CHANNEL

Parameters	Value
Frequency	L band
Symbol rate, R_s	500 sps / device
Device EIRP	7 dBW (Linear antenna)
Distance	38,611 km
Free space loss, L_F	188.35 dB
Atmospheric loss, L_A	0.8 dB
Polarization loss, L_P	3 dB (Linear to Circular)
Satellite G/T	-7 dB/k
C/N_0	36.45 dB-Hz
SNR	9.45 dB

The link budget for the uplink channel in the GEO satellite system we considered is shown in Table 1. Since the link budget of the downlink is better than uplink channel due to the antenna gain of the ground station, the downlink is not considered. The modulated symbol rate each device is 500 sps, and the carrier-to-noise density ration (C/N_0) is calculated by

$$\mathrm{C/N_0} = \mathrm{EIRP} \times L_F \times L_A \times L_P \times \mathrm{G/T} \tag{2}$$

where the result $\mathrm{C/N_0}$ is linear value. The signal-to-noise ratio (SNR) after dispreading is given by

$$SNR = \mathrm{C/N_0/R_S} \tag{3}$$

where the result SNR is linear value. As a results, the operating SNR of the system is approximately 9 dB.

B. *Co-channel interferece and collision*

Combination of spread-spectrum and random access technique improves the performance. When same spreading sequence used for all transmitters, if more than one time difference occurs, the information frame can be recovered due to the spreading gain. At in this case, other signals are affected by an interference. In the spread spectrum system, signal-to-interference plus noise ratio (SINR) can be computed as follow:

$$SINR = \frac{S}{\frac{(N-1)}{I}S+\eta} \tag{4}$$

Here, S is the received signal power from each device, N is the number of devices I is length of PN sequence, η is the thermal noise power. The frame collision probability, P_c is given by

$$P_c = \frac{N-1}{I} \tag{5}$$

IV. NEMERICAL SIMULATION RESULTS

For all the numerical results, the truncated convolutional code of rate ½ is used for channel code whose parameters are summarized in Table 1. It is assume that the PN sequence length is 1,023 and 4,095 corresponding chip rates are 0.5115 and 2.0475 Mcps, respectively.

TABLE II. PARAMETERS FOR SATELLITE SYSTEM

Data length	250 bits
FEC	Truncated convolutional code (r = ½) Generating polynomials $g = (171,133)_8$
Frame length	512 coded bits
Modulation	QPSK
PN seq. length, I	1,023 and 4,095 chips
Chip Rate	0.5115 and 2.0475 Mcps
Data Rate	500 bps / device
Pulse Shaping	SRRC filter, roll-off 0.25
Multiple Access	Spread Spectrum Random Access

The frame error rate (FER) performances of the system considered under AWGN channel for various values of N and I are shown in Fig. 2. As can be seen in Fig. 2, the FER performances according to the PN sequency length, I are practically identical when number of devices, N is 1. In the low signal-to-noise area, performance degrades due to co-channel interferences generated from other device signals, especially as N increases. On the other hand, in the operating SNR ≈ 9dB region, the FER performance converges to collision probability. Therefore, it can be seen that the collision effect is dominant at a high SNR.

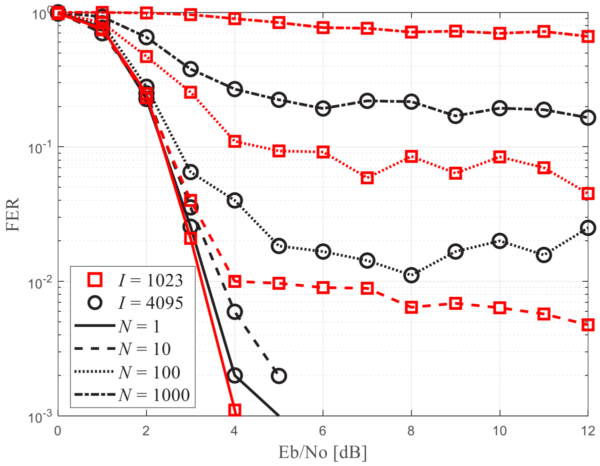

Fig. 2. FER performances versus sequence length and number of devices

V. CONCLUSION

In this paper, we have analyzed the performances of a GEO satellite system based on spread spectrum random access. We have confirmed that performance degradation results from collision probability and the length of the PN sequence. The simulation results indicate that the performance degradation due to signal collisions dominates in areas with a high signal-to-noise ratio. The results are expected to be helpful in determining the maximum number of devices acceptable in the satellite system.

ACKNOWLEDGMENT

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