PROPAGATION ISSUES FOR EMERGING MOBILE AND PORTABLE COMMUNICATIONS, A SYSTEMS PERSPECTIVE

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1. INTRODUCTION

This paper presents the view point of a system engineer regarding the format of propagation information and models suitable for the design of mobile and portable satellite communications systems for the following services: audio broadcast, two way voice, and packet data.

II. PROPAGATION IMPAIRMENTS FOR PORTABLE INDOOR RECEPTION IN SATELLITE COMMUNICATIONS SYSTEMS

The propagation experiments conducted by the University of Texas [1] for the NASA/VOA DBS-R Program have provided critical information on

The overall signal attenuation into buildings and the variation of such attenuation with frequency,

The fine signal structure (spatial. and spectral) inside buildings.

However these measurements have the following limitations:

- Measurements were conducted over the 0.75 to 1.8 GHz and the results extrapolated to 3.0 GHz, it would be very useful to extend the measurements to 3.0 GHZ.
- Measurements were conducted using a low gain antenna, corresponding information regarding moderate gain antennas (6-12 dBic) is needed.
- Measurements were conducted using a transmitter atop a mast to simulate the satellite signal, validation using a satellite signal. is needed.
- Measurements were conducted inside a few buildings, a larger data-base is required to define the morphological characteristics for indoor satellite reception in various types of buildings around the world.

III. PROPAGATION IMPAIRMENTS AND MITIGATION TECHNIQUES FOR MOBILE SATELLITE COMMUNICATIONS SYSTEMS

The most significant propagation impairment for mobile reception is the intermittent blockage of satellite's line of sight by roadside objects such as trees, buildings, utility poles, highway signs, hills, etc.

Despite the intermittent interruptions of the radio link, a relatively uninterrupted voice circuit has to be maintained for audio broadcast and duplex voice applications. Short interruptions of the RF signal can be mitigated by combination of interleaving and channel coding. Interleaving duration is limited in the order of 30 msec for duplex voice but can be as high as 1 seconds for audio broadcasts.

Satellite Packet Networks communicate via small data packets. Lost packets due to intermit.tent signal blockage can be repeated in ARQ systems. Although interleaving is not absolutely necessary for packet data, the channel performance improves if forward error correcting codes with interleaving length equal to packet size is adopted.

IV. CHARACTERIZA'I'1ON OF MOBILE SATELLITE COMMUNICATIONS CHANNELS IN THE PRESENCE OF ROADSIDE BLOCKAGE WHEN INTERLEAVING AND FEC CODING ARE IMPLEMENTED

The model to be presented here tries to directly describe the performance of mobile satellite communications systems in the present of roadside blockage when interleaving and FEC are implemented. The model needs to satisfactorily describe both the fine structure of the signal under fading/shadowing conditions, and the morphological aspects of the reception environments. The present paper presents a methodology to model the fine structure of the signal on the scale of the interleaving block. We are also exploring models to present the morphological aspects of the reception environment, this will be reported later,

IV.1 CI1ARAC'I'ERIZA'I'1ON OF S11OR1'-TERM MOBILE SATELLITE SIGNAL VARIATIONS

The temporal statistics of the satellite signal received by a mobile receiver during one interleaver block can be best described by the cumulative distribution of the signal recorded during the same period. Since interleaving removes the signal level correlation among adjacent signal samples, the second (and higher) -order statistics of the signal within the interleave is not needed to determine the performance of the decoder over the interleave block. The block-by block performance of the channel decoder can be estimated as described below from the cumulative signal distribution for each block.

Figure 1 shows a typical. example of cumulative signal distribution [2] for mobile reception at L-band (1.5 GHz) with heavy signal interruption by foliage. Next we will estimate the required link margin so that a typical block of data with the given cumulative signal distribution can be satisfactorily detected by the combination of interleaving and FEC. The estimation will be performed by approximating the continuous fade distribution as the envelope of a number of step-distributions Al, A2, A3, . . . as shown in Figure 1. For example step distribution Al describes a situation where the signal is suffering from hard blockage 30% of the time and soft blockage of 2?.7 dB the remainder 70% of the time. An examination of Figure 1 shows that Al, A2, A3, . . ., are conservative estimates of the continuous fade distribution. For each step-dist.ribution we will estimate the required link margin for the proper operation of the decoder. As we can choose any one of the step-functions to approximate the actual signal distribution, the minimum link-margin calculated over the family of step-functions will be chosen as an estimate of the required link margin for the interleaver block in question.

Figure 2 shows an upper bound on the degradation of a Viterbi decoder when the signal is completely blocked during a given percentage of the interleave block. This figure is based on the ongoing work on DBS-R at JPI, [3]. The result is given as a blockage penalty which is defined as the additional link margin compared to the unblocked signal. for a Bit Error Rate (BER) performance of 1.0 E-4.0. This figure is based on the assumption of convolutional encoding with constraint length 7 and assumes channel state information is available to the decoder. Figure 3 shows the superpositi.on of the soft-fade and hard-fade penalties form Figures 1 & 2. The sum of the fade-depth for the soft-blockage and the penalty for the hard--blockage provides an upper limit for the link margin required for the satisfactory decoding of this signal distribution (L-band under heavy roadside blockage conditions) by the Viterbi. decoder. As discussed in the preceding paragraph the required link margin is the minimum value of the link-margin envelope, namely 6.1 dB for the rate 1/2 convolutional coding and the assumed L-band fade distribution. The link margin requirements presented in Figure 3 for L-band can be extended to S-band by using the experimental. finding that the soft fade due to roadside vegetation at one frequency can be scaled to another frequency by in proportion with the square root of the frequency [4]; the results are given in Figure 4. Finally the estimated link margin requirements for the four cases under considerations (two code rates of 1/2 & 1/3 and two frequencies L & S-band) are compared in Figure 5.

IV.2 CHARACTERIZATION LONG-TERM SIGNAL VARIATIONS

Mobile signal attenuation data for an arbitrary length of roadway can be divided into blocks each corresponding to one interleaver distance (the product of the interleave duration and the vehicle speed) . Typical interleave distances for mobile voice and packet data satellite communication applications are given in table 1. Then the link margin required for satisfactory reception of each block of signal can be estimated as described in section IV.1. The end result is a time series listing the link margins required for reception of each interleave block of the data. The results may also be presented in more compact form as a link margin distribution. Link-margin time series and distributions arc very useful for trading design link-margin versus system performance. We are also exploring this model to present the morphological aspects of the reception environment. Results will be reported later.

V SUMMARY AND CONCLUSIONS

The propagation experiments conducted by the University of Texas for the NASA/VOA DBS-R Program provided adequate models on the overall signal attenuation into buildings and the fine signal structure (spatial and spectral) inside buildings. These measurements based on the use of a transmitter atop a mast to simulate a satellite signal over the frequency range of 0.75 to 1..8 GHz need to be extended to 3 GHz and also validated using a signal source on a satellite such as TDRS.

While a substantial volume of data exists regarding fade statistics for mobile reception of UHF, L, and S-band signals from satellites, system engineers will greatly benefit if the results are converted into link margin statistics. The link margin statistics will be system specific. A simple procedure for converting fade statistics into link-margin statistics has been worked out for a system using interleaving and convolutional (rates 1/2 and 1/3) error correcting channel coding.

Acknowledgment

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References

[1] Vogel, W.J and G.W. Torrence, "Signal Variability Measurements for Satellite Radio Broadcasting into Buildings'^t, Technical Report No. 9101, Electrical Engineering Research Laboratory, The University of Texas at Austin, January, 1.991.

[2] Goldhirsh, Julius, and W.J. Vogel, "Mobile **Satellite** System Fade Statistics for Shadowing and Multipath from Roadside Trees at UHF and L-band", IEEE Transactions on Antennas and Propagation, Vol.. AP 37, No. 4, April 1989, pp 489-498.

[3] Simon, M., "Analysis of Channel Performance in a Shadowing Environment for DBS-R Receiver Development.'^t, Interoffice Memorandum 3392-92-039, JPL, 1992.

[4] Goldhirsh, Julius, and W.J. Vogel", Results of 1987 Helicopter Propagation Experiments at UHF and I,-band in Central. Maryland", Proceedings of NAPEX X11, June 1988, JPL Publication 88-22, pp 18-26.

Figure 1. Cumulative fade distribution for mobile reception on a typical stretch of road with severe blockage of the signal by roadside trees

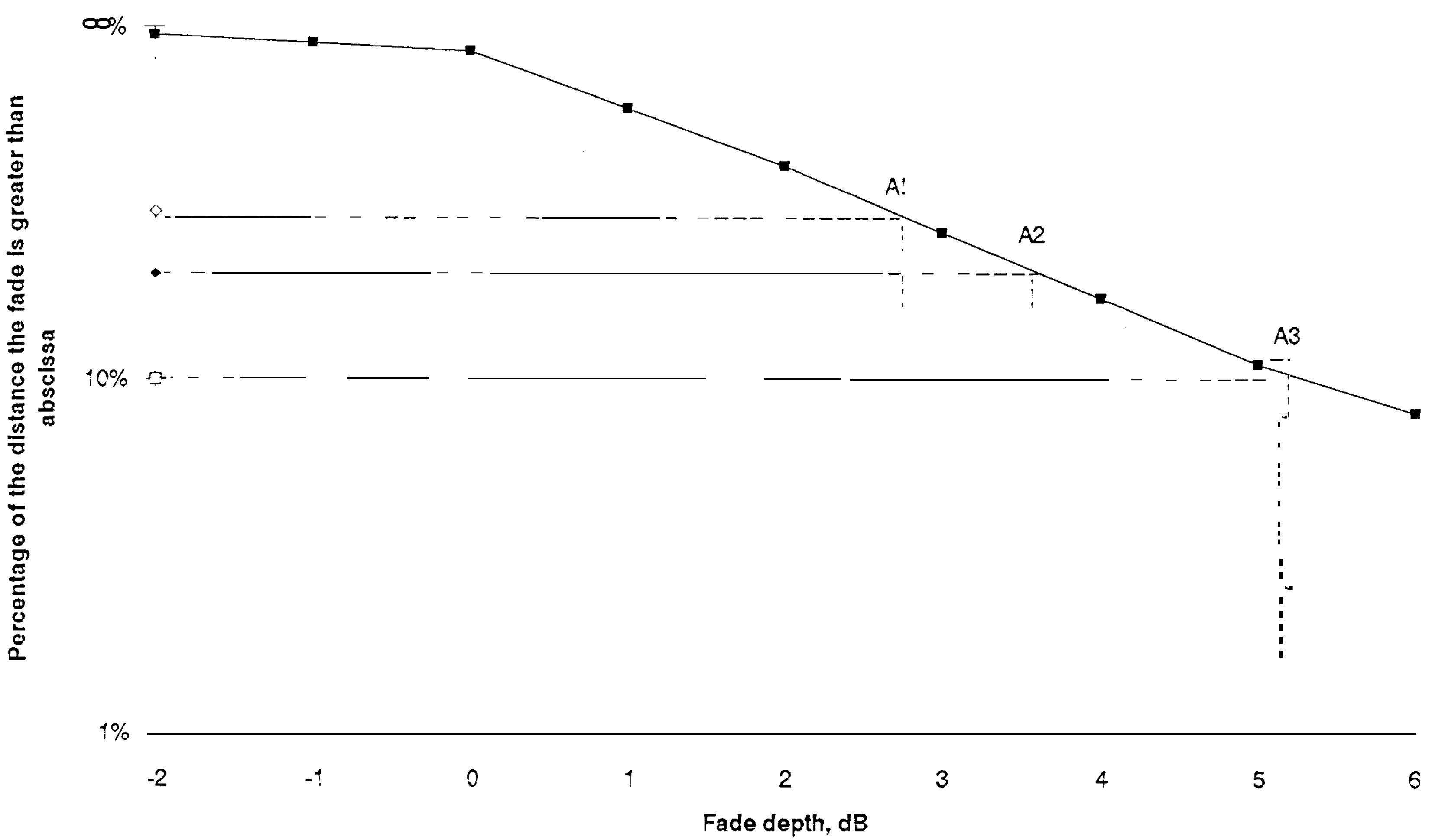

Figure 2. Eb/No penalty for partial hard for BER objective of 1.0 E-4, Gaussian channel with hard blockage, Conv code with k rates 1/2, 1/3, and 1/4

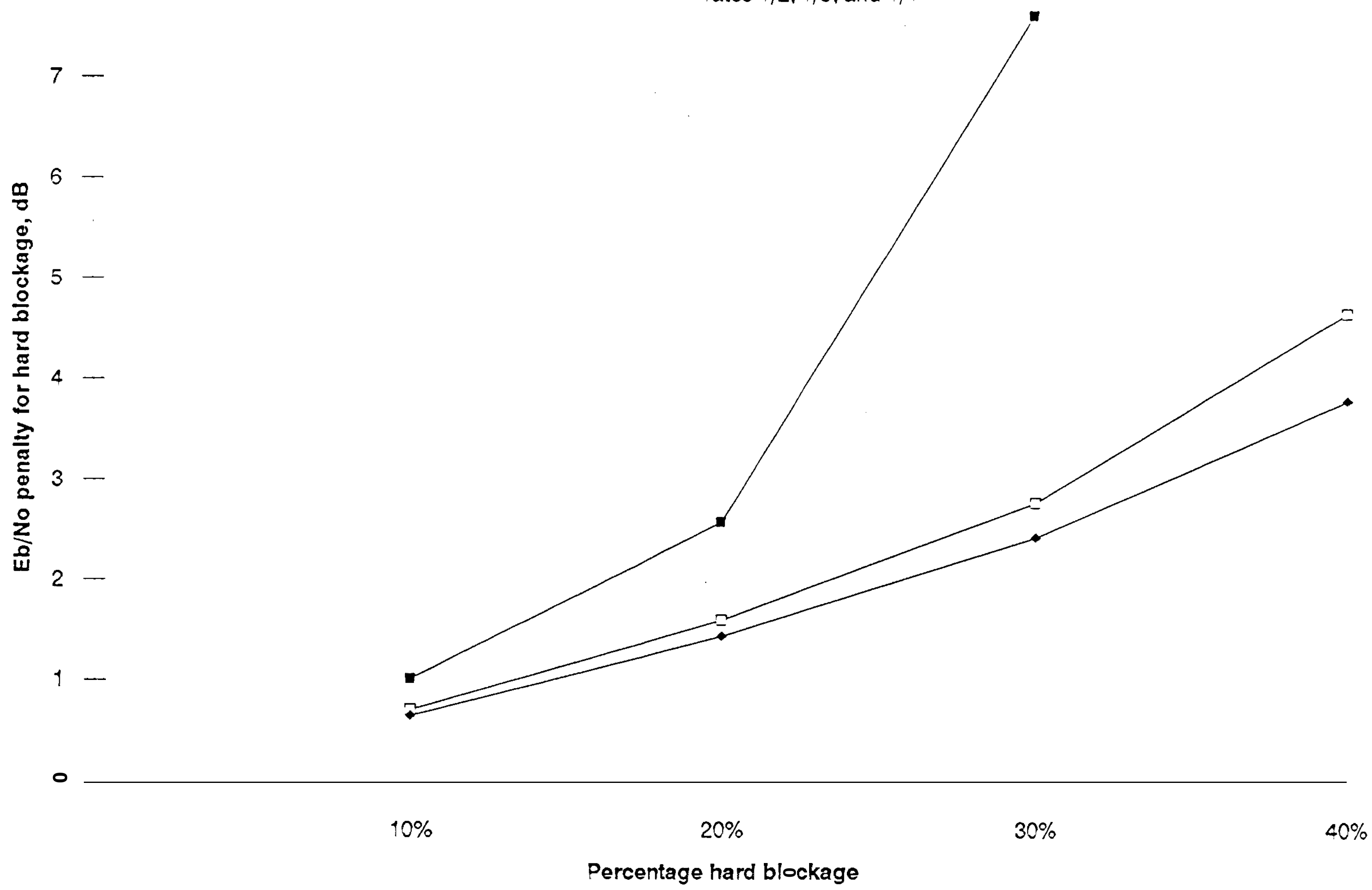

Figure 3 Soft fade-depth and additional penalty due to hard blockage for the typical example of heavy signal blockage

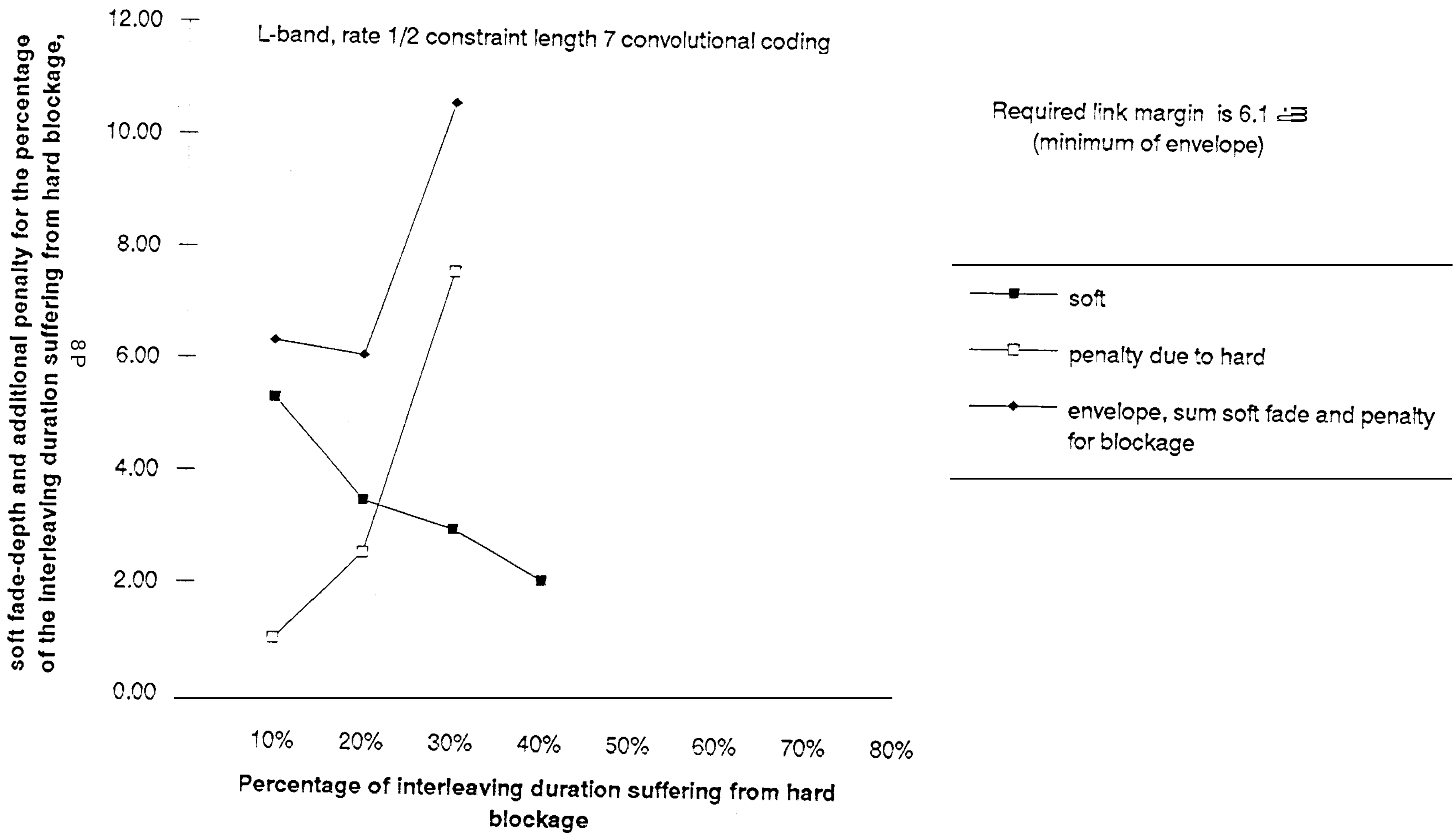

Figure 4 Soft fade-depth and additional penalty due to hard blockage for the typical example of heavy signal blockage

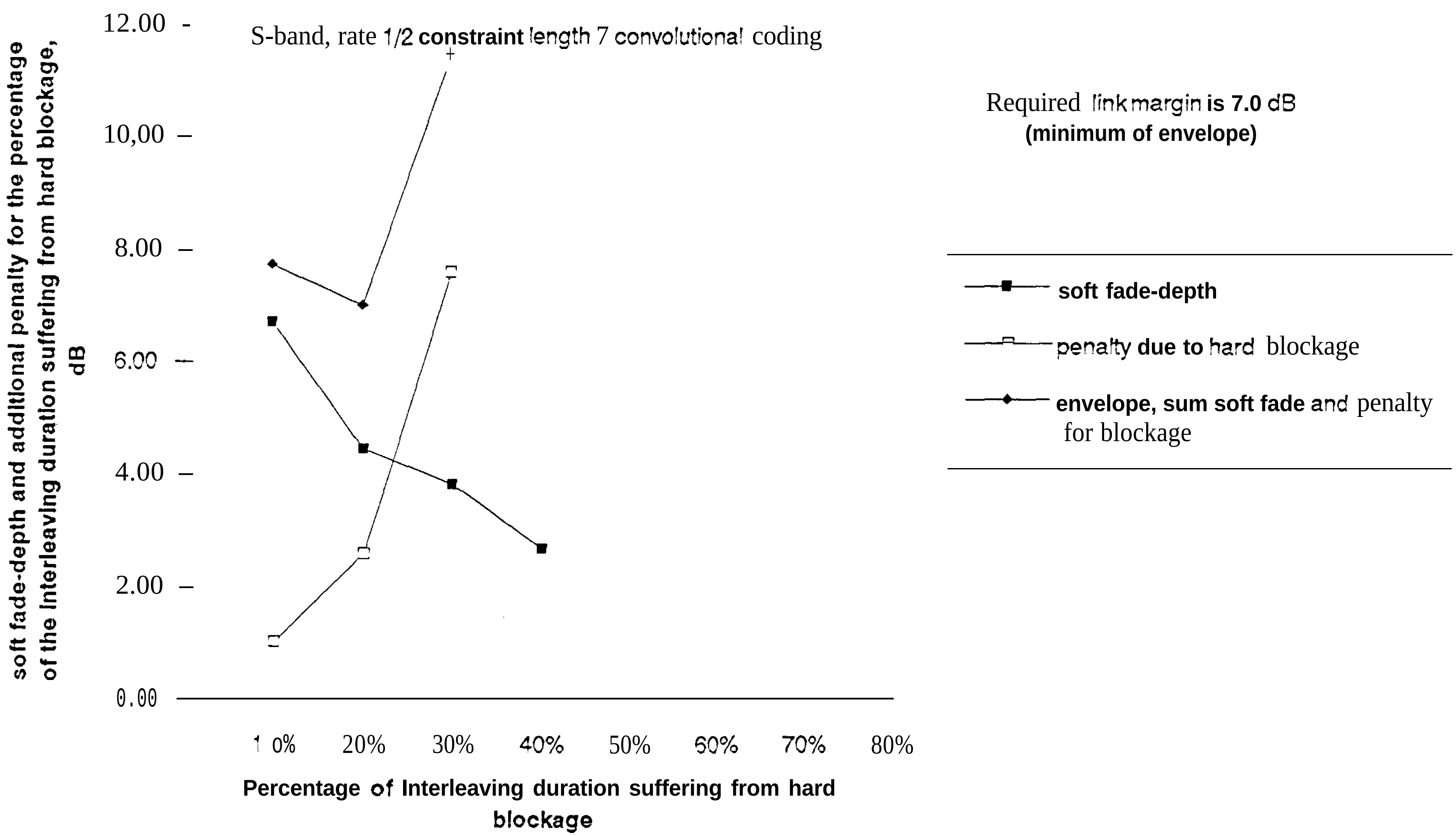

Figure 5. Envelope of estimated link margin for the approximate blockage model for the typical example

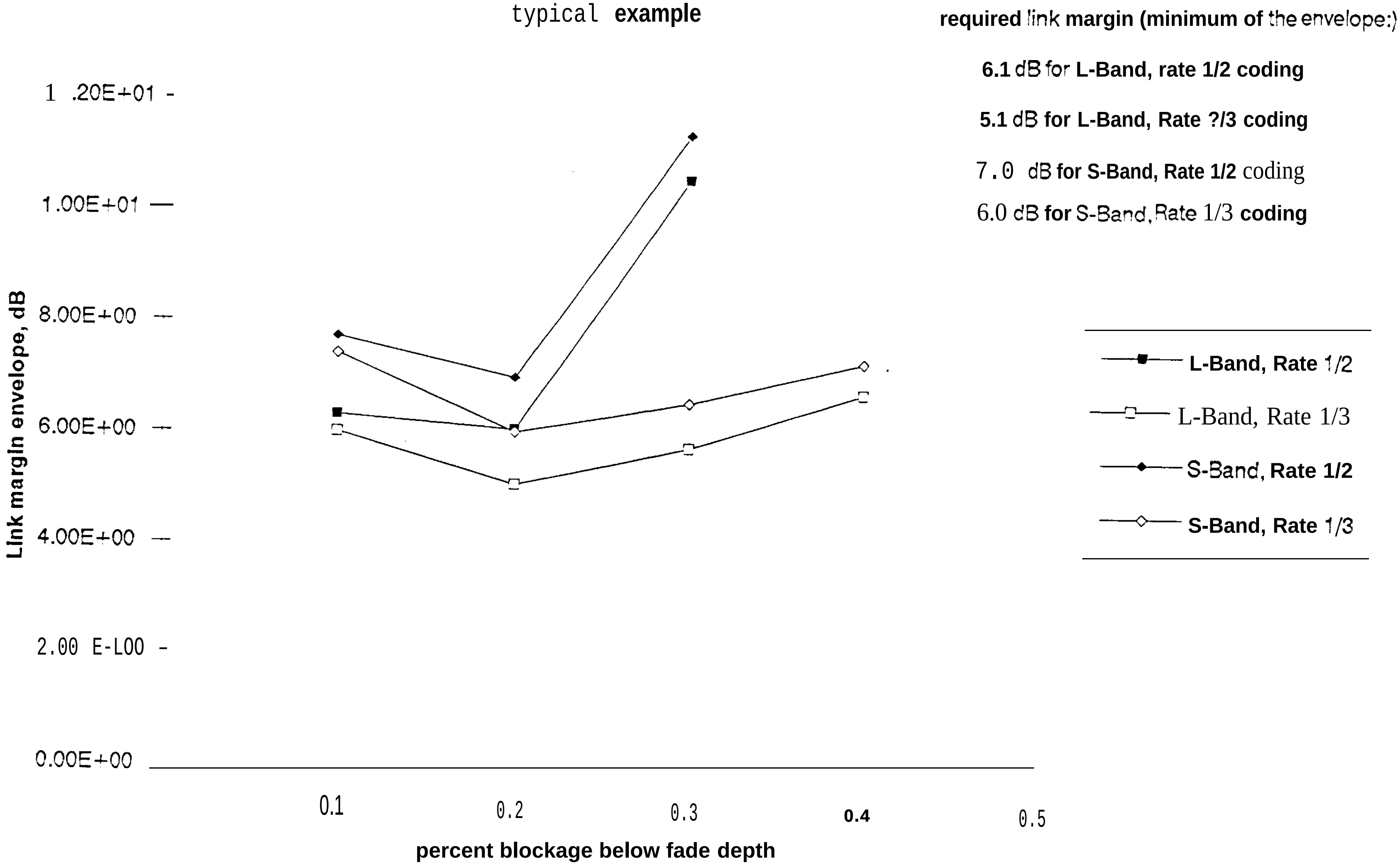

Table 1 Typical interleaving distances for **mobile reception of satellite audio broadcast, voice communication** and **packet data.**

SERVICE	SPEED KM/HOUR	INTERLEAVING SIZE DURATION (S)	DISTANCE(M)
DUPLEX VOICE	36	0.03	0.3
DUPLEX VOICE	72	0.03	0.6
DUPLEX VOICE	108	0.03	0.9
AUDIO BROADCAST	36	0.50	5.0
AUDIO BROADCAST	72	0.50	10.0
AUD10 BROADCAST'	108	0.50	15.0
PACKET DATA*	36	0.05	0.5
PACKET DATA*	72	0.05	1.0
PACKET DATA*	108	0.05	1.5

* FOR A TYPICAL 264 bit **packet-size over a 4.8 kbps channel**