ioLink4

System Description and Processing Gain Test

January 26, 1999

Summary

Under the FCC rules, direct sequence systems are required to exhibit a processing gain of at least 10 dB. Section 15.247(e) of the FCC rules specifies test procedures for processing gain measurement of a single channel direct sequence spread spectrum system. This report discusses the CW jamming margin method (Gp = (S/N)o + Mj + Lsys) to determine the processing gain of ioLink4, which is a multi-channel synchronous-CDMA direct sequence spread spectrum system with forward error correction. In our approach to adapt this method to ioLink4 tests, (S/N)o is derived for each orthogonal channel, and Mj is modified by multiplying N to the measured N-channel J/S, or by adding $10*\log_{10}(N)$ dB.

Test Procedures

The first measurement method mentioned in Section 15.247(e) is to take the signal-to-noise ratio difference between disabled and enabled states of spreading. This method of measurement is not readily applicable to ioLink4 testing, because (i) it does not have the capability to easily turn off the spreading code, and (ii) even if we can disable the spreading, the S-CDMA signal structure is totally destroyed.

The second recommended method is an indirect measurement of processing gain, called the CW jamming margin method; see Section 15.247(e)(2) and Reference [1]. This is the measurement technique proposed for ioLink4 with the following interpretations. In the defining equation of processing gain

$$Gp = (S/N)o + Mj + Lsys,$$

(S/N)o = ideal signal to noise ratio required for the chosen BER (2e-6) for an ideal single-channel non-spread-spectrum DQPSK receiver, Mj = J/S ratio modified to meet the special requirement for CDMA signal structure, and Lsys = system losses (≤ 2dB). Defining Mj’ to be the measured J/S with all the N-channels present, we have a modified equation to compute the processing gain of ioLink4:

$$Gp = (S/N)o + Mj' + 10*\log_{10}(N) + Lsys.$$

The test configuration is shown in Figure 1.

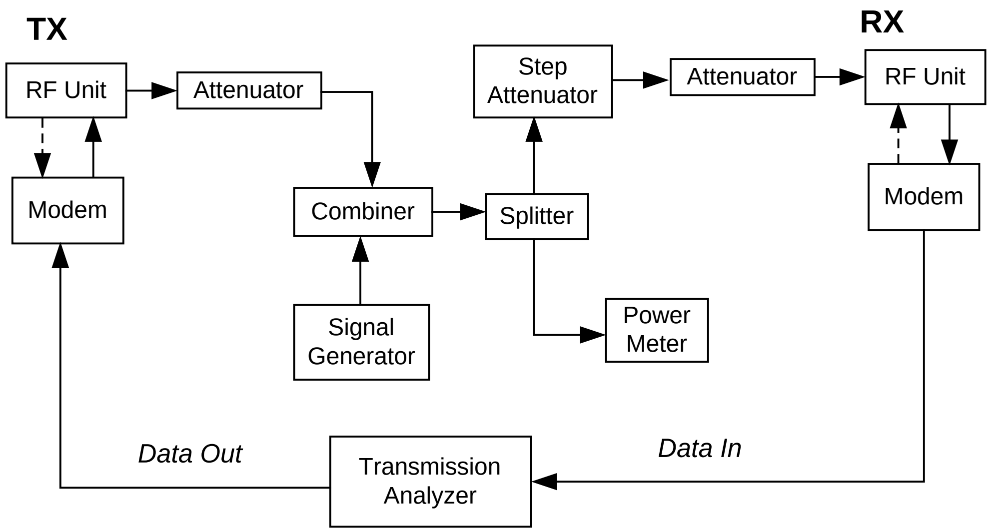

Figure 1. Processing gain test setup.

ioLink4 System Description

ioLink4 operates in one of the two different modes, T2 and E2. The baseband processing of T2 and E2 transmitter is shown in Figures 2 and 3, respectively.

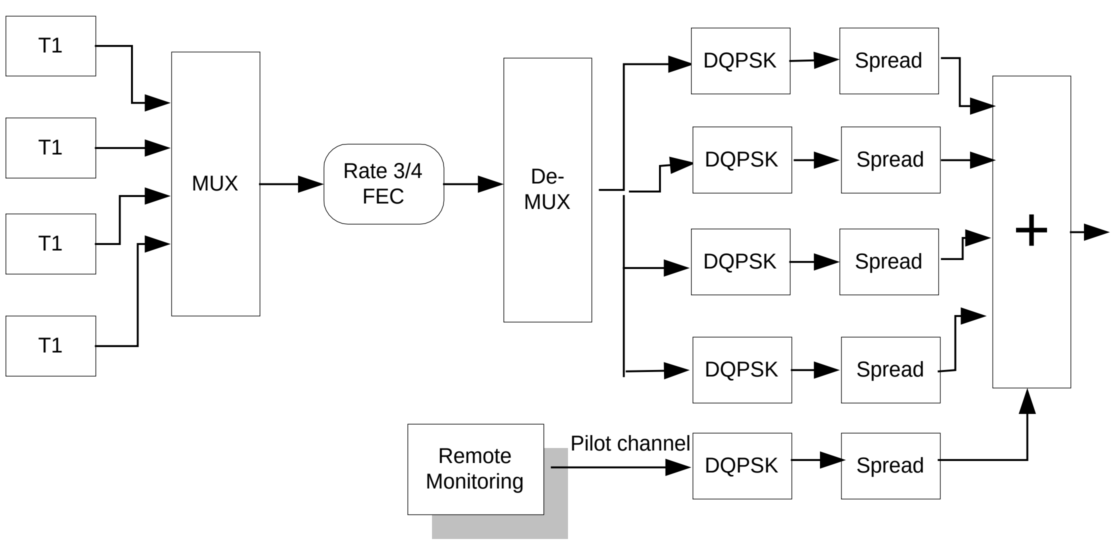

Figure 2. T2 transmitter baseband processing.

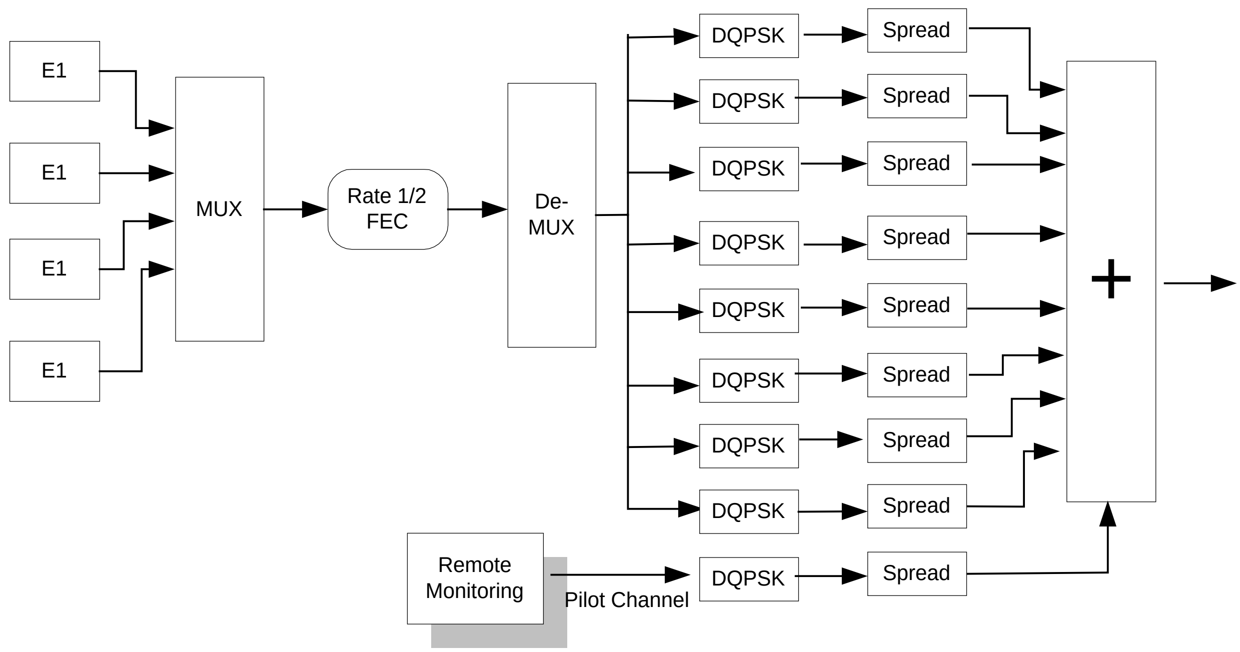

Figure 3. E2 transmitter baseband processing.

In T2, four T1 data channels are sequenced through a multiplexer. The data is then passed to a rate ¾ convolutional encoder. The encoded data is then de-multiplexed into four tributary channels. The data from both tributary channels and the pilot channel is spread by different spread codes of length 12 that are mutually orthogonal. The pilot channel is used to transmit remote monitoring data. The spread data is then combined together into a multi-level signal through an adder. Therefore, there are a total of five S-CDMA channels.

In E2, the rate of the convolutional encoder is ½, and the encoded data is de-multiplexed into eight tributary channels. All nine channels, including the pilot channel, are spread orthogonally with length 12 codes.

Because of this vector channel structure, the actual received signal power of each T2 channel is 1/5 of the total received power, and the ratio is 1/9 for E2. The power decrement in dB is 7 dB and 9.5 dB, respectively. In order to delineate this feature of S-CDMA systems, for the purpose of measuring the processing gain, single-channel reference systems for T2 and E2 are shown in Figures 4 and 5.

At bit error rate of 2x10^(-6), the coding gain for rate ¾ and rate ½ is 4.2 dB and 5.4 dB, respectively [4]. Without any coding, the required signal-to-noise ratio per bit at the receiver output to achieve the given bit error rate for DQPSK modulation is 12.6 dB [3]. Or, equivalently, the required signal-to-noise ratio per symbol is 15.6 dB. Therefore, the required signal-to-noise ratios per symbol for T2 and E2 reference systems are 11.4 dB and 10.2 dB, respectively.

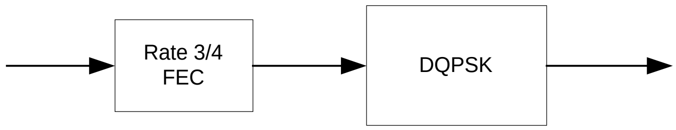

Figure 4. Reference system for ioLink4 T2 mode.

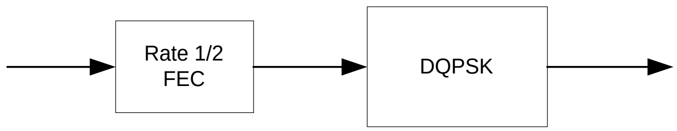

Figure 5. Reference system for ioLink4 E2 mode.

Justification for Implementation of FCC Rules in S-CDMA Systems

In an S-CDMA system, such as ioLink4, it is difficult to apply the FCC rules directly in the calculation of the processing gain. First, the difficulty lies in the choice of a proper reference system. If the spread codes are turned off, all the channels will be interfering with each other, making it impossible to measure the required signal-to-noise ratio of the reference system for a given bit error rate. To apply the CW jamming margin method, only one of the channels, with spread code turned off, can be considered as the reference; see Figures 4 and 5.

The second problem is the calculation of jammer to signal ratio. The measured signal power of the S-CDMA system is the total of all the channels, contribution of each channel being exactly *1/N* of the sum on the average. In fact, each demodulator of an ideal N-channel S-CDMA system receives only this fractional power, since all the other signals disappear after despreading with orthogonal codes. However, the jammer power is not divided among the users because there is no orthogonality with any of the spread code; i.e. the jammer power is the same for all users. Therefore, in the calculation of the jammer to signal ratio for S-CDMA systems, the signal power should be the actual received signal of each user, which is *1/N* of the measured signal power. This is also consistent with the definition of reference systems, mentioned above, from which the ideal (S/N)o values are derived.

CW Jamming Margin Lab Testing

The ioLink4 CW jamming margin lab test is setup according to Figure 1. The test procedures follow the FCC rules. The signal power, which is the power of the multi-level S-CDMA signal, is measured when the jammer is disabled. The jammer power level can be determined by adjusting the readings from the signal generator according to the amount of combiner/splitter attenuation. The system loss of 0.5 dB is used in calculation of the processing gain. The recommended bit error rate is set to 2x10^(-6).

The test equipment used in the testing is listed in Table 1.

Signal Generator	Hewlett Packard Digital Signal Generator ESG-D3000A 250 kHz – 3000 MHz
Power Meter	Hewlett Packard 435B Power Meter
Transmission Analyzer	TELINC WAN Tester
Variable Attenuator	Hewlett Packard OPT.001 110/11 dB
Power Combiner/Splitter	Mini-Circuit, 15542
Fixed Attenuator	KDI A6N-30 30 dB

Table 1. Test equipment.

Preliminary results are shown in the appendix. The test is repeated for a fixed signal carrier frequency and for uniform steps in frequency increments of 50 kHz across the receiver passband with the CW jammer. The carrier frequencies are 2452 and 2412 MHz, with the passband width of 22 MHz each.

Reference:

[1] Federal Communications Commission Public Notice No. 54797, "Guidance on measurement for direct sequence spread spectrum systems", July 12, 1995.

[2] Dixon, Robert, "Spread Spectrum Systems" 3rd Edition, 1994, pp. 350, John Wiley & Sons, 1994.

[3] Proakis, John, "Digital Communications", pp. 276-277, McGraw-Hill, 1989.

[4] Forward error correction data book, 80-2412801 A, 9/98, pp. 1-16, Figure 16, Qualcomm Inc.