Processing Gain Document for FCC ID:APYSJY0007

1. Introduction

This document describes requirements and measurement results for the processing gain in accordance with the Sub-clause 15.247 of FCC Part 15. This report includes the test method and procedure.

2. FCC Requirement

FCC requires for FHSS systems operating in the 2.4 GHz band to use at least 75 hopping channels in the FCC 15.247.

In normal communication the channel hopping system is represented by a pseudo-random hopping sequence through the 79 channels. Therefore, the system meets the FCC requirement. During the inquiry or paging mode, however, the system only uses 32 hopping channels. In these modes the system is regarded as a combination of both direct sequence and frequency hopping modulation techniques, and the system is required to achieve a processing gain of at least 17 dB from the combined techniques in the Sub-clause 15.247(f) of FCC Part 15.

Since the use of 32 hopping channels during the inquiry or paging mode is equivalent to 15.1 dB of processing gain, further processing gain must be achieved by the direct sequence operation of the access code. As a result at least 1.9 dB processing gain must be demonstrated by the measurement.

3. FCC Proposal of the Processing Gain Measurement

FCC proposes the jamming margin test method to demonstrate the processing gain of the DSSS component in APPENDIX C of the FCC Public Notice 97-114 and also in the Sub-clause 15.247(e)(2) of FCC Part 15.

In the APPENDIX the proposal describes measurement method in detail with a configuration of jamming test setup;

The Processing Gain may be measured using the CW jamming margin method. The test consists of stepping a signal generator in 50 kHz increments across the pass-band of the system. At each point, the generator level required to produce the recommended Bit Error Rate (BER) is recorded. This level is the jammer level. The output power of the transmitting unit is measured at the same point. The Jammer to Signal (J/S) ratio is then calculated. Discarded the worst 20 percents of the J/S data points. The lowest remaining J/S ratio is used when calculating the Processing Gain. In a practical system, there are always implementation losses which degrade the performance below that of an optimal theoretical system of the same type. Losses occur due to non-optimal filtering, lack of equalization, LO phase noise, “corner cutting in digital processing”, etc. Total losses in a system, including transmitter and receiver, should be assumed to be no more than 2 dB.

In order to calculate the Processing Gain (Gp) of the system, the following equation is used:

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

where, (S/N)o = Signal to noise ratio

Mj = J/S ratio

Lsys = System losses.

4. Test Arrangement and Test Procedure

Figure 1 shows the measurement block diagram with the list of equipment used.

The generator, AMIQ, generates I/Q modulation data and is installed a BER measurement function as the option. SMIQ is an RF signal generator for desired signal. The signal generator, SMP, generates Jammer signals for undesired signal. The dual directional coupler, Agilent 778, combines the desired and undesired signals and outputs the combined signal to the DUT (device under test). Demodulated signals from the DUT are sent to AMIQ through a level converter and are compared with original signals to measure bit errors. Two PC’s are used for DUT control and BER calculation, respectively.

The following test procedure is used to verify the processing gain of DS component for the receiver:

1. Hopping off. Bluetooth transmitter (SMIQ) at an arbitrary fc (for example, 2441 MHz) chosen from the inquiry/paging hopping sequence.
2. CW jammer starts at fc.
3. Bluetooth transmitter (SMIQ) sends access codes (for example, 65B333) at signal level S. The timing of the transmitter signal is aligned to the scan window of the DUT (device under test) receiver.
4. Based on the correlation output of the DUT receiver, bit errors are counted.
5. Jammer level J is increased until BER requirement is violated (> 1x10e-3).

The BER will be calculated based on 1x10e4 transmitted access codes.

6. This J/S level is recorded.

7. Jammer signal frequency 50 kHz is increased/decreased.
8. Steps 3 to 7 is repeated until the J/S values are comfortably compliant.
9. The processing gain is calculated as described in the FCC procedure:

Discarding the worst 20 percents of the J/S data points, the lowest remaining J/S ratio is used to calculate the processing gain, as follows:

Gp = (S/N)o + (J/S) + Lsys

5. Measurement Results

Test conditions are:

(a) Signal to noise ratio (S/N)o

(S/N)o is required signal to noise ratio at the receiver input for a BER 1x10e-3.
The ideal equation/curve for GFSK is used to determine this value.
For the DUT a signal to noise ratio of 16.4 dB is given. The system loss Lsys of maximal 2 dB is included.

(b) Jammer to signal ratio (J/S)

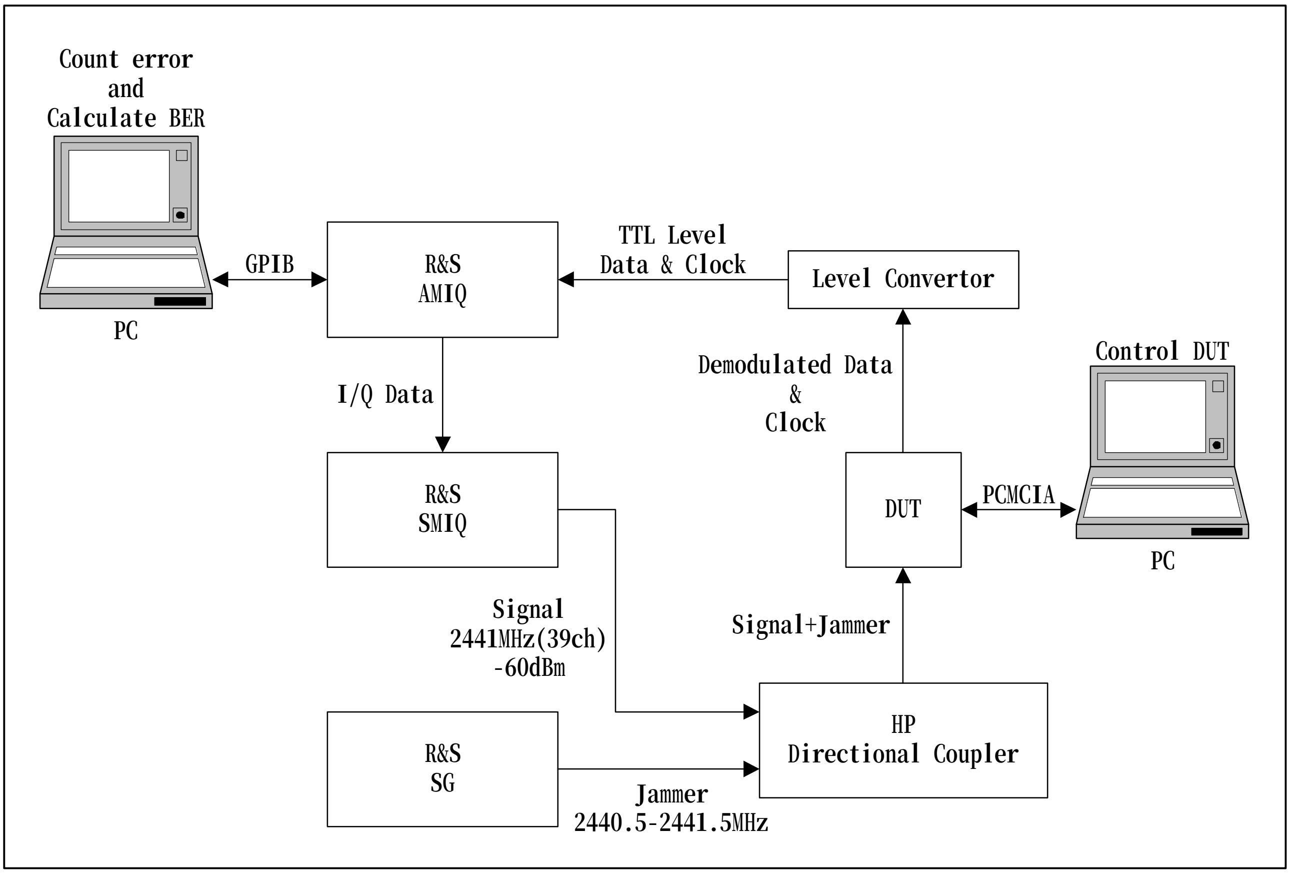
(J/S) is measured according to the test setup.

The test result are shown with the processing gain calculation in Fig. 2.
After discarding the worst 20 percents of the J/S data points, the lowest J/S data is found at -400 kHz and +400 kHz.
The measured processing gain during inquiry and paging modes shows 2.8 dB.
As a result the total processing gain is 17.9 dB (15.1 dB + 2.8 dB).

6. Conclusion

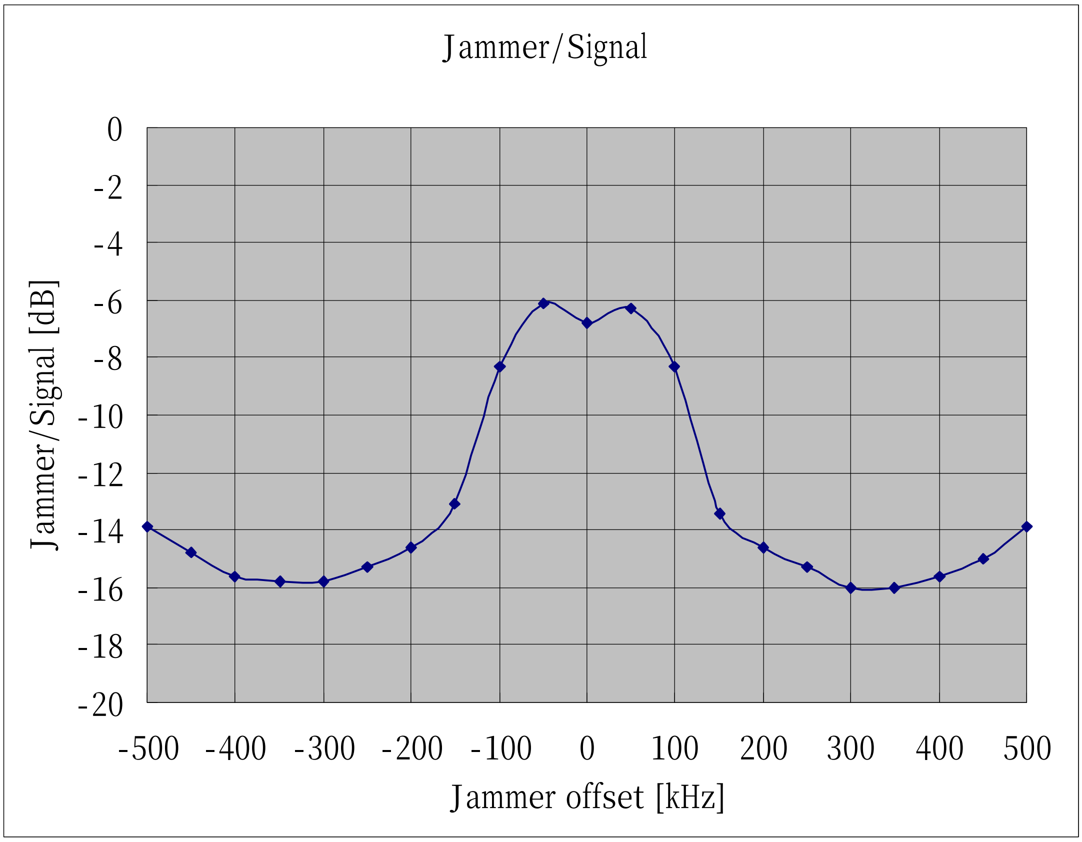
During normal communication, all 79 hopping channels are always used and the DUT complies with FCC requirement in the sub-clause 15.247(b)(1) of the FCC Part 15.
During inquiry and paging modes, the DUT is regarded as a hybrid system employing a combination of both direct sequence and frequency hopping modulation techniques and complies with FCC requirement in the sub-clause 15.247(f) of the FCC Part 15 from measurement results described in this report.

Fig. 1 Measurement Arrangement and Equipment List



Equipment	Function	Type	Manufacturer
R&S AMIQ	I/Q Modulation DATA Generator	AMIQ	Rohde&Schwarz
R&S SMIQ	RF Signal Generator	SMIQ03B	Rohde&Schwarz
R&S SG	RF Signal Generator	SMP02	Rohde&Schwarz
HP Directional Coupler	Dual Directional Coupler	778D012	Hewlett Packard

Fig. 2 Measurement Result



Discarding the worst 20% of the data points (-350, -300, 300, and 350kHz), the lowest data is –15.6dB at –400 and 400kHz. Thus, the processing gain is as follows.

$PG_{DS} = (S/N) + (J/S) + L_{SYS} = 16.4dB - 15.6dB + 2dB = 2.8dB$

$PG_{FH} = 32MHz / 1MHz = 32 = 15.1dB$

$PG = PG_{FH} + PG_{DS} = 15.1dB + 2.8dB = 17.9dB$