Channel Sounding Inline Phase Correction Term Transfer

Bluetooth® Validation Specification

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This Validation Specification (VS) proposes changes to the following specification ("Source Specification"):

- Bluetooth Core Specification, Version 6.2 [1]

Abstract:

This document specifies the changes to the Bluetooth Core Specification required to add the Channel Sounding (CS) Inline PCT Transfer (IPT) feature.

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Contents

1 Language

1.1 Language conventions

Refer to and follow any terminology, language conventions, and interpretation sections of the Source Specification.

2   Conventions used in this specification

The formatting and color conventions described in Table 2.1 below are used in the CR to describe the specific changes and additions that are proposed to the Source Specification(s) identified on the cover page.

Text Color	Description
black	Text that is unmodified from the Source Specification. Note: The text of the Source Specification may not be black and may contain tracked changes or other colored text that are reflected as black text in this document.
red	Text that is added to the Source Specification.
red strikethrough	Text that is deleted from the Source Specification.
[green bracketed text]	Comments that explain the changes made to the Source Specification.
[…]	Indicates the section of the Source Specification that includes additional text that is not included in black text.
blue	Default color used for section numbers and headings of this document.

Table 2.1: Color key for headings, captions, and body text

3   Changes to Source Specification

This Section sets forth the specific changes and additions, using the formatting and color conventions described in Section 2, that are proposed to the Source Specification.

3.1   Changes to Volume 0, Part D Core Configuration

3.1.1   [Modified Section] 4 Features and their types

[Add the following row to the end of the table.]

Table 4.2 lists the features added in versions 1.2 and higher of this specification, their types, and the version or addendum where the feature was first introduced.

Feature	Version	Type
[...]		
Channel Sounding Inline PCT Transfer	TBD	2

Table 4.2: Features and their types

3.2   Changes to Volume 1, Part A Architecture

3.2.1   [Modified Section] 9.2 Distance estimation based on phase and amplitude information

[Add the following text between the 7th and 8th paragraphs of the section. The new equations should not be numbered.]

[...]

Then the relative phases of a carrier measured at the reflector and initiator's antenna is

$$\theta_{REFL}(f) = \theta_{CH}(f) + \Delta\theta_{LO}(f) \text{ and } \theta_{INIT}(f) = \theta_{CH}(f) - \Delta\theta_{LO}(f).$$

Further, let $A_{REFL}(f)$ and $A_{INIT}(f)$ represent the amplitude of that measured carrier at the reflector and initiator's antenna. Let a phase correction term (PCT) be defined by the angle that, if added to the internal angle of the local oscillator, would result in a phase identical to that of the incoming signal. Then IQ values represented by the PCT measured at the reflector and initiator are given by

$$PCT_{REFL}(f) = A_{REFL}(f)e^{i\theta REFL(f)} \text{ and } PCT_{INIT}(f) = A_{INIT}(f)e^{i\theta INIT(f)}$$

Assume that the communication channel is symmetrical between the initiator and reflector. Then the measured phases are dependent on both the communication channel and the relative difference in phase of the RF carrier between the devices.

The communication channel transfer function can then be estimated from

$$H^2(f) = A_{REFL}(f)e^{i\theta REFL(f)} \times A_{INIT}(f)e^{i\theta INIT(f)} = A_{CH}^2(f)e^{i2\theta CH(f)}$$

Assume that from $H^2(f)$ it is possible to calculate the actual channel transfer function $H(f)$. Assuming that $H(f)$ is a linear-time invariant transfer function, then an under-resolved estimate of the impulse response $h(t)$ can be calculated from the inverse Fourier transform of $H(f)$. Assuming that there is only one propagation path, then the maximum peak in the estimate of the impulse response will occur at the delay between the two devices, and assuming communication is at the speed of light, it is possible to estimate the distance.

If the reflector supports Inline PCT Transfer (IPT) and this feature is enabled, then the reflector compensates the phase of its outgoing carrier using the measured PCT ($\theta_{REFL}(f)$). The relative phase of the carrier measured at the initiator's antenna is then

$\theta_{INIT}(f) = \theta_{CH}(f) - \Delta\theta_{LO}(f) + \theta_{REFL}(f) = 2\theta_{CH}(f)$.

The IQ value represented by the PCT reported at the reflector with the IPT feature enabled is given by

$PCT_{REFL}(f) = A_{REFL}(f)e^{i0}$

Accordingly, the communication channel transfer function with the IPT feature enabled remains the same as before

$H^2(f) = A_{REFL}(f)e^{i0} \times A_{INIT}(f)e^{i\theta INIT(f)} = A_{CH}^2(f)e^{i2\theta CH(f)}$

In the case of a single propagation path, a simplification may be made. Here, the distance can also be estimated by the change in phase as a function of frequency. Assume that the distance between initiator and reflector is x. The total distance traveled by a reflected signal will then be $2x$.

[…]

3.3 Changes to Volume 1, Part B Acronyms & Abbreviations

3.3.1 [Modified Section] 1 LIST OF ACRONYMS AND ABBREVIATIONS

Acronym or abbreviation	Writing out in full	Comments
[…]		
IPT	Inline PCT Transfer	
[…]		

3.4   Changes to Volume 4, Part E Host Controller Interface Functional Specification

3.4.1   [Modified Section] 3 OVERVIEW OF COMMANDS AND EVENTS

[Update the table 3.1 as shown. Add the C.X definition at the end of the [first] group of conditionals starting from C.1.]

Name	Vers.	Summary Description	BR/EDR	LE
[...]				
LE CS Read Local Supported Capabilities command	6.0 TBD	The HCI_LE_CS_Read_Local_Supported_Capabilities command is used by a Host to query CS capabilities.	E	[v1] C.75 [v2] C.X
[...]				
LE CS Read Remote Supported Capabilities Complete event	6.0 TBD	The HCI_LE_CS_Read_Remote_Supported_-Capabilities_Complete event is used to report the CS capabilities of a remote device.	E	[v1] C.75 [v2] C.X
[...]				
LE CS Write Cached Remote Supported Capabilities command	6.0 TBD	The HCI_LE_CS_Write_Cached_Remote_-Supported_Capabilities command is used by a Host to write a cached copy of the remote CS capabilities in a local Controller.	E	[v1] C.75 [v2] C.X
[...]				

C.X: Mandatory if LE Feature (Channel Sounding Enhancement-1) is supported, otherwise optional if LE Feature (Channel Sounding) is supported, otherwise excluded.

3.4.2   [Modified Section] 6.27 Supported Commands

[Add the following row to the table in the assigned positions in numerical order of octet, and then of bit within octet.]

Octet	Bit	Command Supported
20	5	HCI_LE_CS_Read_Local_Supported_Capabilities [v1]
[...]		
20	7	HCI_LE_CS_Write_Cached_Remote_Supported_Capabilities [v1]

[…]		
49	2	HCI_LE_CS_Read_Local_Supported_Capabilities [v2]
49	3	HCI_LE_CS_Write_Cached_Remote_Supported_Capabilities [v2]

3.4.3   [Modified Section] 7.7.65.39 LE CS Read Remote Supported Capabilities Complete event

[Modify the table and text as shown.]

Event	Event Code	Event Parameters
HCI_LE_CS_Read_Remote_Supported_Capabilities_Complete [v2]	0x3E	[Include all existing event parameters listed in current [v1] version. Add the following at the bottom of existing list.] T_IP2_IPT_Times_Supported, T_SW_IPT_Times_Supported
HCI_LE_CS_Read_Remote_Supported_Capabilities_Complete [v1]	0x3E	[Include all existing event parameters in current version.]

[…]

The Subfeatures_Supported parameter indicates which of the following optional subfeatures are supported by the remote Controller:

- A Frequency Actuation Error of zero for all allowed CS channels as described in [Vol 6] Part A, Section 3.5.

- Channel Selection Algorithm #3c as described in [Vol 6] Part H, Section 4.1.4.2.

- Phase-based ranging from a sounding sequence as described in [Vol 6] Part H, Section 3.3.1.

- IPT in the CS reflector as described in [Vol 6] Part H, Section 4.3.3.

The T_IP1_Times_Supported, T_IP2_Times_Supported, T_FCS_Times_Supported, T_PM_Times_Supported, and T_SW_Time_Supported parameters indicate the supported optional time durations used in CS steps as described in [Vol 6] Part H, Section 4.3.

The TX_SNR_Capability parameter indicated the supported SNR levels used for the CS_SYNC packets used in mode-1 and mode-3 steps as described in [Vol 6] Part A, Section 3.1.3.

The T_IP2_IPT_Times_Supported and T_SW_IPT_Times_Supported parameters indicate the supported optional time durations used in CS steps if the CS reflector supports the Channel Sounding Enhancement-1 feature and IPT capability (see [Vol 6] Part H, Section 4.3).

Event parameters:

Subevent_Code: *Size: 1 octet*

Value	Parameter Description
0x38	Subevent code for the HCI_LE_CS_Read_Remote_-Supported_Capabilities_Complete event [v2]
0x2C	Subevent code for the HCI_LE_CS_Read_Remote_-Supported_Capabilities_Complete event [v1]

[…]

[Update the Event Parameter as shown.]

Subfeatures_Supported: *Size: 2 octets*

Bit Number	Parameter Description
1	CS with no transmitter Frequency Actuation Error
2	CS Channel Selection Algorithm #3c
3	CS phase-based ranging from RTT sounding sequence
4	IPT in the CS reflector
All other bits	Reserved for future use

[…]

[Add the following Event Parameters after TX_SNR_Capability, which is the last entry.]

T_IP2_IPT_Times_Supported: *Size: 2 octets*

Bit Number	Parameter Description
0	10 µs supported
1	20 µs supported
2	30 µs supported
3	40 µs supported

4	50 μs supported
5	60 μs supported
6	80 μs supported
All other values	Reserved for future use

T_SW_IPT_Times_Supported: *Size: 1 octet*

Value	Parameter Description
0x00, 0x01, 0x02, 0x04, or 0x0A	Time in microseconds for the antenna switch period of the CS tones
All other values	Reserved for future use

3.4.4 [Modified Section] 7.7.65.42 LE CS Config Complete event

[Modify the table and text as shown.]

Event	Event Code	Event Parameters
HCI_LE_CS_Config_Complete	0x3E	[…] Ch3c_Jump, ~~Reserved~~CS_Enhancements T_IP1_Time, […]

[…]

The Channel_Selection_Type parameter indicates the Channel Selection Algorithm to be used during the CS procedure for non-mode-0 steps. When the Channel_Selection_Type parameter is set to 0x01, the Ch3c_Shape and the Ch3c_Jump parameters indicate the selected shape and channels to be skipped as described in [Vol 6] Part H, Section 4.1.4.2.

The CS_Enhancements parameter indicates which CS enhancements are enabled. For each enhancement that is not enabled, the corresponding bit shall be set to 0.

The T_IP1_Time, T_IP2_Time, T_FCS_Time, T_PM_Time, and T_SW_Time parameters indicate the time durations used in CS steps as described in [Vol 6] Part H, Section 4.3.

[…]

[Add the following Event Parameters between Ch3c_Jump and T_IP1_Time instead of the "Reserved" field.]

Ch3c_Jump: *Size: 1 octet*

Value	Parameter Description
0x02 to 0x08	Number of channels skipped in each rising and falling sequence
All other values	Reserved for future use

~~Reserved~~CS_Enhancements: *Size: 1 octet*

~~Value~~ Bit Number	Parameter Description
0	IPT is enabled in the CS reflector
All other bits	Reserved for future use

T_IP1_Time: *Size: 1 octet*

Value	Parameter Description
0x0A, 0x14, 0x1E, 0x28, 0x32, 0x3C, 0x50, or 0x91	Interlude time in microseconds between the CS_SYNC packets used in mode-0 and mode-1 steps
All other values	Reserved for future use

3.4.5   [Modified Section] 7.7.65.44 LE CS Subevent Result event

[Modify the Event Parameters as shown.]

[…]

Tone_PCT[k]:   *Size: (Num_Antenna_Paths + 1) × 3 octets*

Value	Parameter Description
0xXXXXXX	Phase Correction Term (bits 0 to 11 are the I sample with type sint12 and bits 12 to 23 are the Q sample with type sint12). The unitless I and Q values may be combined with Reference_Power_Level to convert to power in dBm, as described in [Vol 6] Part H, Section 4.6. If IPT is enabled in the reflector, then the Q sample shall be set to 0 on the reflector. The I sample conveys the measured signal amplitude as described in [Vol 6] Part H, Section 4.6. On the initiator side, the Tone_PCT format remains unchanged to when IPT is not enabled in the reflector.

3.4.6 [Modified Section] 7.8.1 Set Event Mask command

[Add the following amended entry and new entry in the table.]

[…]

Bit	LE subevent Types
[…]	[…]
43	LE CS Read Remote Supported Capabilities Complete event [v1]
[…]	[…]
55	LE CS Read Remote Supported Capabilities Complete event [v2]
[…]	[…]

3.4.7 [Modified Section] 7.8.130 LE CS Read Local Supported Capabilities command

[Modify the tables and text as shown, including adding a Missing parameters section and table.]

Command	OCF	Command Parameters	Return Parameters
HCI_LE_CS_Read_Local_Supported_Capabilities [v2]	0x00A5	none	[Include all existing return parameters listed in current [v1] version. Add the following at the bottom of existing list.]

			T_IP2_IPT_Times_Supported, T_SW_IPT_Times_Supported
HCI_LE_CS_Read_Local_Supported_Capabilities [v1]	0x0089	none	[Include all existing return parameters in current version.]

[…]

The Subfeatures_Supported parameter indicates which of the following optional subfeatures are supported by the local Controller:

- • A Frequency Actuation Error of zero for all allowed CS channels relative to mode-0 transmissions when in the reflector role as described in [Vol 6] Part A, Section 3.5.

- Channel Selection Algorithm #3c as described in [Vol 6] Part H, Section 4.1.4.2.

- Phase-based ranging from a sounding sequence as described in [Vol 6] Part H, Section 3.3.1.

- IPT in the CS reflector as described in [Vol 6] Part H, Section 4.3.3.

[…]

The T_IP1_Times_Supported, T_IP2_Times_Supported, T_FCS_Times_Supported, T_PM_Times_Supported, and T_SW_Time_Supported parameters indicate the supported optional time durations used in CS steps as described in [Vol 6] Part H, Section 4.3.

The TX_SNR_Capability parameter indicates the supported SNR levels used for the CS_SYNC packets used in mode-1 and mode-3 steps as described in [Vol 6] Part A, Section 3.1.3.

The T_IP2_IPT_Times_Supported and T_SW_IPT_Times_Supported parameters indicate the supported optional time durations used in CS steps if the CS reflector supports the Channel Sounding Enhancement-1 feature and the IPT capability (see [Vol 6] Part H, Section 4.3).

[…]

Missing parameters:

When a version of this command is issued that does not include all the parameters, the following values shall be used for any missing parameters:

Parameter	Value
T_IP2_IPT_Times_Supported	0x0000
T_SW_IPT_Times_Supported	0x00

Return parameters:

[Modify the Return parameter as shown.]

[…]

Subfeatures_Supported: *Size: 2 octets*

Bit Number	Parameter Description
1	CS with a Frequency Actuation Error of zero relative to mode-0 transmissions in the reflector role
2	CS Channel Selection Algorithm #3c
3	CS phase-based ranging from an RTT sounding sequence
4	IPT in the CS reflector
All other bits	Reserved for future use

[…]

[Add the new tables shown below beneath the existing Return parameters tables.]

[…]

T_IP2_IPT_Times_Supported: *Size: 2 octets*

Bit Number	Parameter Description
0	10 μs supported
1	20 μs supported
2	30 μs supported

3	40 µs supported
4	50 µs supported
5	60 µs supported
6	80 µs supported
All other values	Reserved for future use

T_SW_IPT_Times_Supported: *Size: 1 octet*

Value	Parameter Description
0x00, 0x01, 0x02, 0x04, or 0x0A	Time in microseconds for the antenna switch period of the CS tones
All other values	Reserved for future use

Event(s) generated (unless masked away):

When the HCI_LE_CS_Read_Local_Supported_Capabilities command has completed, an HCI_Command_Complete event shall be generated.

3.4.8   [Modified Section] 7.8.132 LE CS Write Cached Remote Supported Capabilities command

[Modify the table and text as shown.]

Command	OCF	Command Parameters	Return Parameters
HCI_LE_CS_Write_Cached_Remote_Supported_Capabilities [v2]	0x00A6	[Include all existing parameters listed in current [v1] version. Add the following at the bottom of existing list.] T_IP2_IPT_Times_Supported, T_SW_IPT_Times_Supported	Status, Connection_Handle
HCI_LE_CS_Write_Cached_Remote_Supported_Capabilities [v1]	0x008B	[Include all existing parameters in current version.]	Status, Connection_Handle

[…]

The Subfeatures_Supported parameter indicates which of the following optional subfeatures are supported by the remote Controller:

- A Frequency Actuation Error of zero for all allowed CS channels relative to mode-0 transmissions when in the reflector role as described in [Vol 6] Part A, Section 3.5.

- Channel Selection Algorithm #3c as described in [Vol 6] Part H, Section 4.1.4.2.

- Phase-based ranging from a sounding sequence as described in [Vol 6] Part H, Section 3.3.1.

- IPT in the CS reflector as described in [Vol 6] Part H, Section 4.3.3.

[…]

The T_IP1_Times_Supported, T_IP2_Times_Supported, T_FCS_Times_Supported, T_PM_Times_Supported, and T_SW_Time_Supported parameters indicate the supported optional time durations used in CS steps as described in [Vol 6] Part H, Section 4.3.

The TX_SNR_Capability parameter indicates the supported SNR levels used for the CS_SYNC packets used in mode-1 and mode-3 steps as described in [Vol 6] Part A, Section 3.1.3.

The T_IP2_IPT_Times_Supported and T_SW_IPT_Times_Supported parameters indicate the supported optional time durations used in CS steps if the CS reflector supports the Channel Sounding Enhancement-1 feature and the IPT capability (see [Vol 6] Part H, Section 4.3).

[Insert the following new section directly above the Command parameters section and modify the Command parameters table as shown.]

Missing Parameters:

When a version of this command is issued that does not include all the parameters, the following values shall be used for any missing parameters:

Parameter	Value
T_IP2_IPT_Times_Supported	The value of T_IP2_Times_Supported
T_SW_IPT_Times_Supported	The value of T_SW_Time_Supported

Command parameters:

Subfeatures_Supported: *Size: 2 octets*

Bit Number	Parameter Description
1	CS with a Frequency Actuation Error of zero relative to mode-0 transmissions in the reflector role
2	CS Channel Selection Algorithm #3c

3	CS phase-based ranging from an RTT sounding sequence
4	CS IPT in the CS reflector
All other bits	Reserved for future use

[…]

[Add the following tables after TX_SNR_Capability parameter, as the last two command parameters.]

TX_SNR_Capability: *Size: 1 octet*

Bit Number	Parameter Description
0	18 dB supported
1	21 dB supported
2	24 dB supported
3	27 dB supported
4	30 dB supported
All other bits	Reserved for future use

T_IP2_IPT_Times_Supported: *Size: 2 octets*

Bit Number	Parameter Description
0	10 µs supported
1	20 µs supported
2	30 µs supported
3	40 µs supported
4	50 µs supported
5	60 µs supported

6	80 µs supported
All other values	Reserved for future use

T_SW_IPT_Times_Supported: *Size: 1 octet*

Value	Parameter Description
0x00, 0x01, 0x02, 0x04, or 0x0A	Time in microseconds for the antenna switch period of the CS tones
All other values	Reserved for future use

3.4.9   [Modified Section] 7.8.137 LE CS Create Config command

[Modify the table as shown.]

Command	OCF	Command Parameters	Return Parameters
HCI_LE_CS_Create_Config	0x0090	… Ch3c_Jump, ~~Reserved~~CS_Enhancements	none

[…]

The Channel_Selection_Type parameter indicates the Channel Selection Algorithm to be used during the CS procedure for non-mode-0 steps. When the Channel_Selection_Type is set to 0x01, the Ch3c_Shape and the Ch3c_Jump parameters shall each be set to the selected shape and channels to be skipped as described in [Vol 6] Part H, Section 4.1.4.2. Otherwise, the Ch3c_Shape and the Ch3c_Jump parameters shall be ignored.

The CS_Enhancements parameter indicates which CS enhancements to be used during the CS procedure. For each enhancement that is not enabled, the corresponding bit shall be set to 0.

If the Host issues this command with parameters that are not supported by the local or remote Controllers, then the Controller shall return the error code *Unsupported Feature or Parameter Value* (0x11).

[Insert the following table after Ch3c_Jump instead of the "Reserved" table as the last command parameters.]

Ch3c_Jump: *Size: 1 octet*

Value	Parameter Description
0x02 to 0x08	Number of channels skipped in each rising and falling sequence
All other values	Reserved for future use

~~Reserved~~CS_Enhancements: *Size: 1 octet*

Bit Number	Parameter Description
0	IPT enabled in the CS reflector
All other bits	Reserved for future use

3.4.10 [Modified Section] 7.8.142 LE CS Test command

[Modify the table and text as shown.]

Command	OCF	Command Parameters	Return Parameters
HCI_LE_CS_Test	0x0095	[…] Tone_Antenna_Config_Selection, ~~Reserved~~CS_Enhancements, SNR_Control_Initiator, […]	Status

[…]

The Tone_Antenna_Config_Selection parameter indicates the Antenna Configuration Index used during antenna switching during the tone phases of CS steps as described in [Vol 6] Part A, Section 5.3.

The CS_Enhancements parameter indicates which CS enhancements to be used during the CS procedure. For each enhancement that is not enabled, the corresponding bit shall be set to 0. If IPT is enabled, then the T_IP2_Time and T_SW_Time parameters indicate the time durations used in CS steps.

The SNR_Control_Initiator parameter indicates the SNR control adjustment for the CS_SYNC transmissions of the initiator.

[…]

[Insert the following table inside Command parameter section between Tone_Antenna_Config_Selection table and SNR_Control_Initiator table instead of the "Reserved" parameter.]

Tone_Antenna_Config_Selection: *Size: 1 octet*

Value	Parameter Description

0x00 to 0x07	Antenna Configuration Index used during antenna switching during the tone phases of CS steps as described in [Vol 6] Part A, Section 5.3
All other values	Reserved for future use

~~Reserved~~CS_Enhancements: *Size: 1 octet*

~~Value~~Bit Number	Parameter Description
~~0x00~~0	IPT is enabled in the CS reflector
All other bits	Reserved for future use

SNR_Control_Initiator: *Size: 1 octet*

Value	Parameter Description
0x00	SNR control adjustment of 18 dB
0x01	SNR control adjustment of 21 dB
0x02	SNR control adjustment of 24 dB
0x03	SNR control adjustment of 27 dB
0x04	SNR control adjustment of 30 dB
0xFF	SNR control is not to be applied
All other values	Reserved for future use

3.5   Changes to Volume 6, Part A Physical Layer Specification

3.5.1   [New Section] 6.X Inline PCT Transfer

This section applies when the CS reflector has inline phase transfer (IPT) enabled.

A CS reflector shall only return PCT values where the imaginary (Q) part of each PCT value is zero. For such PCT values, the real (I) part of the PCT is used to convey the measured signal amplitude as described in [Vol 6] Part H, Section 4.6.

A CS reflector shall satisfy the phase accuracy requirements (see Section 6.2). When IPT is enabled, the phase of each PCT value is zero. Because the phase of the PCT is zero, a device that supports IPT must adjust the phase of its CS Tone transmissions accordingly.

3.6 Changes to Volume 6, Part B Link Layer

3.6.1 [Modified Section] 2.4.2 LL Control PDU

[Insert a new paragraph after the fifth paragraph.]

[…]

The CtrData field in the LL Control PDU is specified by the Opcode field and is defined in the following subsections.

An LL Control PDU may have more than one format, indicated by "[v1]", "[v2]", etc. If so, then each field within the CtrData field has the same meaning in all formats it appears in. If a reference to such a PDU does not mention the version number, then any version that includes the fields mentioned may be used.

[…]

3.6.2 [Modified Section] 2.4.2.44 LL_CS_CAPABILITIES_REQ and LL_CS_CAPABILITIES_RSP

[Modify Figure 2.65 and text as shown.]

[…]

CtrData						
All versions						
Mode_Types (1 octet)	RTT_Capability (1 octet)	RTT_AA_Only_N (1 octet)	RTT_Sounding_N (1 octet)	RTT_Random_Seuence_N (1 octet)	NADM_Sounding_Capability (2 octets)	NADM_Random_Capability (2 octets)
CtrData (Continued)						
All versions						
CS_SYNC_PHY_Capability (1 octet)	Num_Ant (4 bits)	Max_Ant_Path (4 bits)	Role (2 bits)	RFU [v1] IPT [v2] and above (1 bit)	No_FAE (1 bit)	Channel Selection #3c (1 bit)
CtrData (Continued)						
All versions						
Sounding_PCT_Estimate	RFU (2 bits)	Num_Configs (1 octet)	Max_Procedures_Supported	T_SW (1 octet)	T_IP1_Capability (2 octets)	T_IP2_Capability (2 octets)

(1 bit)			(2 octets)			
CtrData (Continued)						
All versions				**[v2] and above**		
T_FCS_C apability (2 octets)	T_PM_C apability (2 octets)	RFU (1 bit)	TX_SNR_ Capability (7 bits)	T_IP2_IPT_Capability (2 octets)		T_SW_IPT (1 octet)

[…]

A device that supports either the initiator or reflector role shall support the following section of this document:

- [Vol 6] Part H

The IPT bit shall be set to 1 if the CS reflector supports the Inline PCT Transfer (IPT) (see [Vol 6] Part A, Section 6.X). It shall be set to 0 otherwise.

The No_FAE bit shall be set to 1 if the transmitting device supports only an FAE of 0 (see Section 2.4.2.52, for all allowed CS channels as specified in [Vol 6] Part H, Section 1, for the device's mode-0 transmissions when in the reflector role. Otherwise, the No_FAE bit shall be set to 0.

[…]

A device that supports TX_SNR_CAPABILITY shall support the following section of this document:

- [Vol 6] Part A, Section 3.1.3

The T_IP2_IPT_Capability field shall contain the supported optional durations for the T_IP2 parameter if the CS reflector supports the Channel Sounding Enhancement-1 feature and the IPT capability. Each supported duration is represented by a bit positioned according to the T_IP2 index defined in [Vol 6] Part H, Section 4.3.3. If IPT is not supported in the reflector role, then the value of T_IP2_IPT_Capability shall be set to 0 and ignored by the receiver.

The T_SW_IPT field shall be set to one of the valid values, in units of microseconds, of the duration of the antenna switch period used by the local Controller in the reflector role. If IPT is not supported in the reflector role, then the value of T_SW_IPT shall be set to 0 and ignored by the receiver.

3.6.3 [Modified Section] 2.4.2.45 LL_CS_CONFIG_REQ

[Modify Figure 2.66 and text after the figure as shown.]

[…]

CtrData (continued)						
…	…	Role (2 bits)	IPT (1 bit)	RFU (2 1 bit)	ChSel (4 bit)	…

Figure 2.66 CtrData field of the LL_CS_CONFIG_REQ PDU

The IPT bit shall be set to 1 to enable the IPT in the CS reflector and 0 otherwise.

The ChSel field shall be set to the channel selection algorithm to be used within the CS procedure for non-mode-0 steps, as described in [Vol 6] Part H, Section 4.1.

[…]

3.6.4 [Modified Section] 4.6 Feature support

[Add the following entries to Table 4.9, in numerical order based on bit position.]

[…]

Bit position	Link Layer Feature	Send to Peer	Host Controlled
75	Channel Sounding Enhancement-1	Y	N

Table 4.9 FeatureSet field's bit mapping to Controller features

3.6.5 [New Section] 4.6.X Channel Sounding Enhancement-1

A Controller that supports the Channel Sounding Enhancement-1 feature shall support the Channel sounding feature and the following section of this document:

- [Vol 6] Part A, Section 6.X

- LL_CS_CAPABILITIES_REQ [v2] (Section 2.4.2.44)

- LL_CS_CAPABILITIES_RSP [v2] (Section 2.4.2.44)

- Channel Sounding Capabilities Exchange procedure (Section 5.1.24)

3.6.6 [Modified Section] 5.1.24 Channel Sounding Capabilities Exchange procedure

[…]

The Link Layer that receives an LL_CS_CAPABILITIES_REQ PDU shall respond with an LL_CS_CAPABILITIES_RSP PDU. The [v2] version of the these PDUs shall not be used unless both the initiator and reflector support the Channel Sounding Enhancement-1 feature.
[…]

3.6.7 [Modified Section] 5.1.25 Channel Sounding Configuration procedure
[…]

[Insert the following row between Role and ChSel rows in the Table 5.2]

Parameter	Content of the LL_CS_CONFIG_REQ PDU
[…]	
Role	Shall be selected to be compatible with what was included in the peer's LL_CS_CAPABILITIES_REQ or LL_CS_CAPABILITIES_RSP PDU. Specifically, if the peer indicated support for the initiator role, then the reflector role may be selected; if the peer indicated support for the reflector role, then the initiator role may be selected.
IPT	Shall be set by default to not enabled and may be set to enabled if support for IPT was indicated in the peer's LL_CS_CAPABILITIES_REQ [v2] or LL_CS_CAPABILITIES_RSP [v2] PDU.
ChSel	Shall be set by default to Channel Selection Algorithm #3b and may be set to Channel Selection Algorithm #3c if support for this parameter was indicated in the peer's LL_CS_CAPABILITIES_REQ or LL_CS_CAPABILITIES_RSP PDU.
[…]	

[…]

3.7 Changes to Volume 6, Part H Channel Sounding

3.7.1 [Modified Section] 4.3.3 Channel Sounding step mode-2

[…]

After T_IP2, the reflector transmits its CS tone. The duration of the CS tone shall be (T_SW+T_PM)×(N_AP+1), where T_PM is the Phase Measurement period, T_SW is the antenna switch duration, and N_AP is the number of antenna paths. The N_AP parameter is common to the entire CS procedure and is described in [Vol 6] Part A, Section 5.3. An extension transmission slot like the one that was present in the initiator to reflector direction shall immediately follow the last valid N_AP transmission. If a transmission is present, it shall be identical to the transmission of the last T_PM slot and shall use the same antenna element used in that prior slot. If a transmission is not present in the CS tone extension slot, then that T_PM period shall still be present but shall not carry a transmission. The presence of a physical transmission in the extension transmission slot shall be seeded by the CS DRBG described in Section 4.8. The process of determining if a transmission is present is described in Section 4.4. If the reflector has the IPT configuration enabled (see [Vol 6] Part A, Section 6.X), then there is no requirement to compensate the phase of the CS tone over the CS tone extension slot. In this section, both the T_SW and T_SW_IPT parameters are represented by T_SW in Table 4.7 and in the corresponding formulas in Section 4.3.3.

[…]

3.7.2 [Modified Section] 4.3.4 Channel Sounding step mode-3

[…]

After T_IP2, the reflector transmits a CS tone followed by a CS_SYNC (CS_SYNC_3_R) as described in Section 2.6. This sequence begins with the transmission of the CS tone. The duration of the CS tone shall be either (T_SW+T_PM) ×N_AP or (T_SW+T_PM)×(N_AP + 1) depending on whether a transmission is selected for the CS tone extension slot. If a transmission is present, it shall be identical to that of the last T_PM slot and shall use the same antenna element used in that prior slot. If a transmission is not present in the CS tone extension slot, then that T_SW+T_PM period shall not be present but shall be compensated for as described below. The presence of a physical transmission in the extension transmission slot shall be seeded by the CS DRBG described in Section 4.8. The process of determining if a transmission is present is described in Section 4.4. There is no requirement for the phase of the reflector's tone during the CS tone extension slot. In this section, both the T_SW and T_SW_IPT values are represented by T_SW in Table 4.10 and in the corresponding formulas in Section 4.3.4.

[…]

3.7.3 [Modified Section] 4.6 Phase measurements during T_PM

[…]

The IQ terms shall each use 12 bits to encode their value.

If the reflector has the IPT configuration enabled for the current CS procedure (see [Vol 6] Part A, Section 6.X), then it shall adjust the phase of its CS tone such that in the reported PCT, the imaginary (Q) part is equal to 0 and real (I) part shall be non-negative and should reflect the magnitude of measurement.

[…]

3.7.4 [Modified Section] 4.7 Phase measurements with antenna switching
[…]

Antenna switching occurs just before the start of every T_PM period for each configuration with multiple antenna paths. T_SW and T_SW_IPT is are the switch period times and is are reserved for antenna switching, irrespective of whether the antenna to be switched is a local antenna or a remote antenna. During the period when an antenna is switched, the signal might not be stable and shall not be used for measurements. The T_SW and T_SW_IPT durations is are local device specific and each peer shall indicate its own preferred settings, as described in [Vol 6] Part B, Section 5.1.24. When antenna switching is performed, the duration of T_SW and T_SW_IPT shall be 1, 2, 4, or 10 µs. When no antenna switching is performed (e.g., in the 1:1 configuration), the values of T_SW and T_SW_IPT shall be set to 0. Devices switching transmitting antennae must control switching transients according to the requirements specified in Part A.

The values of T_SW and T_SW_IPT used in a CS procedure depends on the antenna switch configuration selected for that procedure, as described in the following subsections.

3.7.5 [Modified Section] 4.7.2 Antenna switching in the N_AP:1 configuration
[…]

In this configuration, with N_AP antennae in the initiator, the initiator shall be the only device performing antenna switching. The antenna switch duration selected shall be the T_SW value of the initiator. When IPT is disabled, the selected antenna switch duration shall be the T_SW value of the initiator. When IPT is enabled, the selected antenna switch duration shall be the greater of the initiator's T_SW value and the reflector's T_SW_IPT value. Both the T_SW and T_SW_IPT values are represented by T_SW in Figure 4.9.

[…]

3.7.6 [Modified Section] 4.7.3 Antenna switching in the 1:N_AP configuration
[…]

In this configuration, with N_AP antennae in the reflector, the reflector shall be the only device performing antenna switching. The antenna switch duration selected shall be the T_SW value of the reflector. When IPT is disabled, the selected antenna switch duration shall be the T_SW value of the reflector. When IPT is enabled, the selected antenna switch duration shall be the reflector's T_SW_IPT value. Both the T_SW and T_SW_IPT values are represented by T_SW in Figure 4.10.

[…]

3.7.7 [Modified Section] 4.7.4 Antenna switching in the 2:2 (N_AP = 4) configuration

[…]

Similarly, during its transmission phase, the reflector shall perform an antenna switch for the first T_PM interval and then may perform an antenna switch at each subsequent T_PM interval, depending on the antenna path selected for that interval. Each switch shall be performed immediately before the start of the T_PM period.

~~The antenna switch duration selected for all required antenna element switching shall be the larger of the T_SW values of the initiator and the reflector.~~ When IPT is disabled, the selected antenna switch duration for all required antenna element switching shall be the greater of the T_SW values of the initiator and the reflector. When IPT is enabled, it shall be the greater of the initiator's T_SW value and the reflector's T_SW_IPT value. Both the T_SW and T_SW_IPT values are represented by T_SW in Figure 4.11. The device acting as the receiver shall not perform any measurements during the switch duration of the device acting as the transmitter

The antenna switch duration selected for all required antenna element switching shall be the larger of the T_SW values of the initiator and the reflector. The device acting as the receiver shall not perform any measurements during the switch duration of the device acting as the transmitter.

[…]

Appendix A   References

[1]   Bluetooth Core Specification, Version 6.2