

Walter H.W. Tuttlebee (Ed)

Cordless Telecommunications Worldwide



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The Evolution of Unlicensed PCS

With 153 Figures



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23 The PHS Standard

Yuichiro Takagawa

The development process of the Personal Handyphone System in Japan has been described earlier in Chapter 9 of this book and initial products in Chapter 10. In this chapter we present the technical details of the PHS base technology and standard [1, 2], explaining the air interface structure and parameters, signalling structures and briefly summarising the network interface standards.

23.1 System Overview

The PHS system has been designed to allow all of the normal public and private network functionality associated with cordless systems. In addition, PHS supports direct “personal station–personal station” (PS–PS) communications for handsets registered to the same home basestation. In PHS terminology, the handset is referred to as a personal station (PS). The term “cell station” (CS) is used to describe what is often in other systems referred to as a public basestation (BS) or radio fixed part (RFP).

PHS has been standardised as a common air interface for public applications, whereas for private applications the standard is in effect a coexistence specification, with manufacturers allowed to introduce different proprietary features. Thus, for example, an NTT handset can be re-registered to operate on public PHS networks of other operators, but such a handset will not operate with the other PHS service provider’s home basestations.

The main system parameters for the PHS air interface standard are presented in Table 23.1. In the sections below we discuss several of these parameters, as well as broader aspects of system standardisation and operation.

23.2 Radio Aspects

23.2.1 Modulation

PHS employs $\pi/4$ -shifted QPSK modulation with Nyquist roll-off factor $\alpha = 0.5$. This modulation scheme permits a variety of demodulation techniques to be used, such as delay detection, coherent detection and frequency discrimination

Table 23.1
PHS system parameters

Parameter	Specification
Radio access and duplex method	TDMA/TDD
Number of TDMA multiplexed circuits (i.e. speech traffic channels per RF carrier)	Four (when full-rate codec is used)
Carrier spacing	300 kHz
Modulation	$\pi/4$ -shift QPSK with $\alpha = 0.5$
Bit rate	384 kb s ⁻¹
Speech coding	32 kb s ⁻¹ ADPCM G.726
Diversity	Provided in cell station: Post-detection selection for uplink Transmitter antenna selection for downlink
Frame duration	5 ms
Cell station RF power average (peak):	
Outdoor CS – high power	100–500 mW (4 W max)
Outdoor CS – standard power	20 mW (160 mW)
Indoor CS – low power	10 mW (80 mW)
Maximum antenna gain	2.14 dBi (private basestation or PS) 10 dBi (public cell station)
Average (peak) RF power (handset PS)	10 mW (80 mW)
Receiver sensitivity	-95 dBm (for a 10 ⁻³ BER)
Channel planning	Quasi-static autonomous frequency assignment for common control channel, CCCH, carrier Dynamic channel assignment per call for traffic channel, TCH

detection. Furthermore, the use of the QPSK modulation method makes it possible to use the allocated bandwidth more efficiently than with GMSK modulation – i.e. good spectrum efficiency.

23.2.2 Multiple Access/Duplexing Method

Time-division multiple access with time-division duplexing (TDMA/TDD) is employed, avoiding the need for paired frequency bands. The use of TDMA multiplexing also makes it possible to modify service bit rates with relative ease, making the system a promising one with room for expansion to include radio multimedia services in the future.

23.2.3 Diversity

For both uplink and downlink, diversity is provided in the cell station, avoiding the need for circuitry for diversity in the handset. For the downlink, transmitting antenna diversity at the cell station is utilised, taking advantage of the time-

division duplex scheme with short frame duration; this is effective for small handset equipment. For the uplink, post-detection selection diversity is used in the cell station.

23.2.4 Speech Coding

The full-rate speech codec uses the ITU-T G.726 standard 32 kb s^{-1} ADPCM algorithm. This provides good speech quality and small path delay, as well as efficient integrated circuit implementation. A super-frame configuration allows multiple codecs with lower rates, down to 8 kb s^{-1} , to be incorporated in the system when they become available.

23.2.5 Radio Frequency Band

The radio frequency band allocated for PHS service is some 23 MHz in the 1.9 GHz region (1.8950–1.9181 GHz) in Japan. The report from the Radio Regulatory Council recommends allocation of 11 MHz, 1895–1906 MHz, for public and private use, including direct communications between handsets, and an additional 12 MHz, 1906.1–1918.1 MHz, exclusively for public use; these recommendations are based upon considerations of anticipated traffic density and spectrum requirements. There are 77 communication channels in this band (control channels and traffic channels are included); the channel numbering plan is shown in Table 23.2.

Table 23.2
Channel numbering plan

Carrier	Frequency (MHz)	Carrier	Frequency (MHz)	Carrier	Frequency (MHz)	Carrier	Frequency (MHz)
1	1895.15	21	1901.15	41	1907.15	61	1913.15
2	.45	22	.45	42	.45	62	.45
3	.75	23	.75	43	.75	63	.75
4	1896.05	24	1902.05	44	1908.05	64	1914.05
5	.35	25	.35	45	.35	65	.35
6	.65	26	.65	46	.65	66	.65
7	.95	27	.95	47	.95	67	.95
8	1897.25	28	1903.25	48	1909.25	68	1915.25
9	.55	29	.55	49	.55	69	.55
10	.85	30	.85	50	.85	70	.85
11	1898.15	31	1904.15	51	1910.15	71	1916.15
12	.45	32	.45	52	.45	72	.45
13	.75	33	.75	53	.75	73	.75
14	1899.05	34	1905.05	54	1911.05	74	1917.05
15	.35	35	.35	55	.35	75	.35
16	.65	36	.65	56	.65	76	.65
17	.95	37	.95	57	.95	77	.95
18	1900.25	38	1906.25	58	1912.25		
19	.55	39	.55	59	.55		
20	.85	40	.85	60	.85		

Source: from [2].

Two fixed-frequency control carrier frequencies are assigned for private use: 1898.45 MHz and 1900.25 MHz in Japan, and 1903.85 MHz and 1905.65 MHz for other countries. Four fixed-frequency control carriers are assigned for public service in Japan, one for each public PHS service operator and one spare. For public usage, guard channels are assigned around the control channels. The channel usage plan is shown in Table 23.3.

Table 23.3
Channel usage plan

Channel number	Usage
1–10	Direct communication between PSs <i>and</i> Private use (can also be shared with public use)
11–37	Private use (can also be shared with public use) Channels 12 and 18 assigned as control channels in Japan Channels 30 and 36 assigned as control channels outside Japan
38–77	Public use Channels 38 to 69 assigned as traffic channels Channels 73, 75 and 77 assigned as control channels Channels 71 assigned as a spare control channel Channels 70, 72, 74 and 76 assigned as guard channels

Source: from [2].

23.2.6 Microcellular Architecture

Microcellular architecture, which permits efficient spectrum utilisation and the use of low-power handset terminals, is a key technology for the PHS. The ability to be able to deploy large numbers of cell stations without the need for coordination of frequency planning is indispensable for microcellular systems.

23.2.7 Cell Layout

Cell stations with 10 mW of average power are deployed at about 200 m spacing in the downtown area. Wider separations between cell stations is possible using cell stations with the higher-power transmitter and extremely low-noise amplifiers.

23.2.8 Handover

PHS has two handover types – “recalling type” and “traffic channel switching type” [2]. In the recalling type, the change of communication channel is done in such a manner that the handset establishes a connection to the new cell station in the same way as a new call originating in that cell. In the traffic channel switching type, the handset establishes a connection in the new cell by synchronising burst signals, and a new channel must be assigned from the new cell before handover occurs. There is a short time intermission when handover occurs in the recalling-

type handover, for which the handover process is longer than for the traffic-switching-type handover.

Basically, measurement of the transmission quality is conducted in both the cell station and the handset during communication. The handover is triggered by both stations. The candidate cell and channel are determined by the handset without concern as to whether this will involve inter-cell or intra-cell handover. When agile frequency synthesisers and frame synchronisation between the cell stations become available, seamless handover will be supported.

23.2.9 Adaptive Channel Assignment

The channel assignment is conducted by a quasi-static autonomous algorithm for the common control channel and by an adaptive algorithm per call for the traffic channel. A distributed control architecture is introduced for radio channel management as well as handover.

23.2.10 Spectrum Sharing

The adaptive channel assignment used in PHS is based on slot-unit interference detection. Before transmitting, both stations sense their local interference, then automatically allot channels where there is little interference. This channel management will allow coexisting independent operators without the need for coordination of the spectrum sharing. This is also effective for coexistence with fixed wireless systems. This idea, based on frequency and slots assignment, is effective for not only outdoor applications but also indoor applications for office and residential use as a digital cordless telephone system.

23.3 Radio Channel Structures

The functional channel structure of the air interface is shown in Figure 23.1 and the composition and usage of these channels is described below. The detailed bit structures supporting these channels are shown in Figure 23.2. The way in which these map onto the PHS time slot structure is described in section 23.4.

23.3.1 Control Channel (CCH)

The control channel (CCH) is composed of a combination of a common control channel (CCCH) and an associated control channel (ACCH), which together make up a single dedicated channel, giving it improved performance in conditions of intermittent communications reception.

23.3.2 Broadcast Channel (BCCH)

This is a one-way downlink channel to report control information from the cell station to the mobile station. It transmits information related to channel structure, system information, etc.

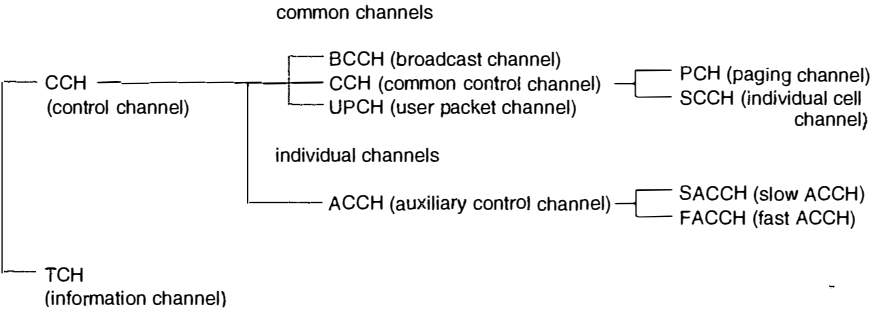


Figure 23.1 Function channel structure.

Control Slot	RS 4 2	PR 62	UW 32	CAC 108				CRC 16	R GT (4) 16	
BCCH				CI 4	FPID + I (BCCH) 104				CRC 16	
PCH				CI 4	FPID + I (PCH) 104				CRC 16	
SCCH				CI 4	ORG.ID + I (SCCH) 104				CRC 16	
Traffic Slot	RS 4 2	PR 6	UW 16	CI 4	SA 16	I 160			CRC 16	R GT (4) 16
TCH				CI 4	SA 16	I (TCH) 160				CRC 16
FACCH				CI 4	SA 16	I (FACCH) 160				CRC 16

Key: BCCH - Broadcast Control Channel
PCH - Paging Channel
SCCH - Specific Cell Channel
TCH - Traffic Channel
FACCH - Fast Associated Control Channel

Figure 23.2 PHS channel structures.

23.3.3 Common Control Channel (CCCH)

This channel carries out control information transmission necessary for call connection. The common control channel performs in an inherently random access manner. In the CCCH, a preamble of 64 bits and unique word of 32 bits

are allotted at the starting position of the frame to assure frame synchronisation and permit low standby power consumption. This also provides the packet-type data transmission capability in PHS service.

23.3.4 Paging Channel (PCH)

The paging channel (PCH) subset of the CCCH is a one-way downlink, point-to-multipoint, channel that simultaneously transmits identical information to individual cells or a wide area of multiple cells (the paging area) from a cell station to the mobile station.

23.3.5 Specific Cell Channel (SCCH)

The specific cell channel (SCCH), again a subset of the CCCH, is a bi-directional, point-to-multipoint, channel that transmits information needed for call connection between the cell station and the mobile station, and it transmits independent information to each cell. The uplink channels are random access.

23.3.6 User Packet Channel (UPCH)

This is a bi-directional point-to-multipoint channel. It carries control signal information and user packet data transmission.

23.3.7 Associated Control Channel (ACCH)

This is a bi-directional channel that is associated to the traffic channel (TCH). It carries out transmission of control information and user packet data needed for call connection. The channel that is ordinarily auxiliary to TCH is the slow ACCH (SACCH), and the channel that primarily steals TCH and carries out high-speed data transmission is designated the fast ACCH (FACCH).

23.3.8 Traffic Channel (TCH)

This channel transmits user traffic information. It is a point-to-multipoint bi-directional channel.

23.4 Radio Circuit Control

23.4.1 Control procedures

Control procedures are defined as those which connect in receiving and sending to a mobile station, register mobile station location and switch channels during communication, and identify services and so forth. It is necessary for these procedures to be performed reliably by common and individually assigned slots.

23.4.2 Slot structure

Figure 23.3 shows the slot arrangement considering appropriate sending/receiving slot separation in the TDD transmission. A three-phase link set-up process is used in PHS. This process provides signal compactness for spectrum efficiency in the radio channel access phase and sufficient signalling capacity, with flexibility to support high-level protocols and expanded services.

23.4.3 Radio Channel Access Phase (Phase 1)

The radio channel resource necessary for phase 2 is assigned in this handshake sequence using a non-layered signal structure.

23.4.4 Link Connection Phase (Phase 2)

Ordinary call control (CC) and higher-level mobility management (MM) and radio transmission management (RT) functions are performed in this phase. Various user protocols can be provided depending on service demand and network conditions such as service validation, authentication sequences, etc. A layered structure is most suitable for this phase.

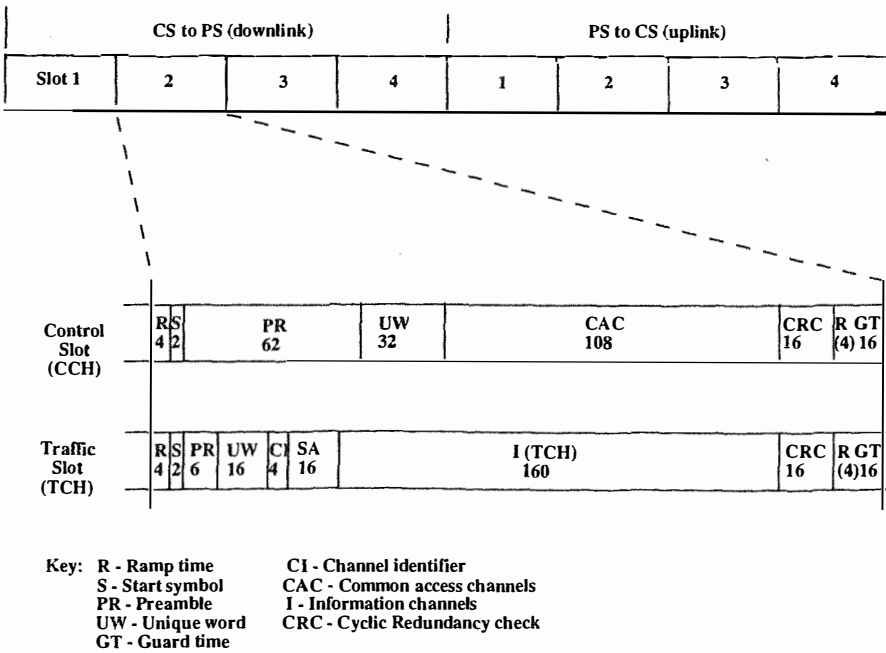


Figure 23.3 PHS time slot structure.

23.4.5 Communication Phase (Phase 3)

User information such as voice and non-voice data are transmitted in this phase. Layered control signals are transmitted through an associated control channel (FACCH and SACCH – see above).

23.5 Network Interfaces

The PHS system has been defined to allow operators a variety of different network architecture options (see [2]) in the sense of the way in which cell stations are interconnected and managed. Table 23.4 summarises the functions of the main network interface standards and their relationship to existing international (ITU) standards.

Table 23.4
PHS network interface standards

Standard	Description	Features
TTC JT-Q 921b	Limited version of ITU-T Q.921	Layer 2 of CS-switch interface
TTC JT-Q 931b	ITU-T Q.931 plus TTC supplements	Layer 3 of CS-switch interface: paging
TTC JT-Q 932a	ITU-T Q.932 plus TTC supplements	Layer 3 of CS-switch interface: location registration, handover, authentication
TTC JT-Q 761, 762, 763	ITU-T Q.761, 762, 763 plus TTC supplements	Internetworking: functions to connect a PHS call between different PHS carrier networks
TTC JT-Q 1218	ITU-T Q.1218 plus TTC supplements	Basic IN for switch-switch interface
TTC JT-Q 1218a	TTC supplement to ITU-T Q.1218	PHS capability of IN for switch-switch interface: roaming (conforms to IN CS-1 architecture)

Source: from [3].

The CS-network interface, the I' interface (or modified I interface), is based upon the ISDN interface (I interface) with supplements. The layer 1 (physical layer), layer 2 (data link layer) and call control function of layer 3 (network layer) are identical to the ISDN protocol; however, application parts have been modified to support PHS-specific functions. The enhancements to the ITU-T Q.931 specification include:

- *PS number notification* – a function to send and receive the PS number in order to identify a PS in an outgoing or incoming call.
- *Multiple interface paging* – a function to enable a group of interfaces to support handset paging in support of an incoming call.
- *D-channel sharing* – a function to allow multiple basic rate (2B+D) interfaces connected to a single CS to share a common D channel.
- *Incoming call when busy* – a function to allow reception of an incoming call even when all channels are busy.

The enhancements to the ITU-T Q.932 specification include:

- *Recalling type handover* – a function to allow the call to be maintained whilst the traffic channel is switched between CSs or interfaces as the personal station moves during the call.
- *PB tone transmission* – a function to generate the PB signal by the network on request through the D channel.
- *Location registration* – a function to enable the network to be informed of the location of a PS, or through which interfaces a PS is to be paged as the PS moves to another area.
- *Authentication* – a function to allow the network to authenticate a PS whenever it attempts to originate or receive a call, or to make a location registration.

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