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SERIES G: TRANSMISSION SYSTEMS AND MEDIA, DIGITAL SYSTEMS AND NETWORKS

Access networks – In premises networks

Coexistence mechanism for wireline home networking transceivers

Recommendation ITU-T G.9972

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Recommendation ITU-T G.9972

Coexistence mechanism for wireline home networking transceivers

Summary

Recommendation ITU-T G.9972 specifies a coexistence mechanism for home networking transceivers capable of operating over powerline wiring. The coexistence mechanism allows ITU-T G.996x devices to coexist with other coexisting systems, as defined in this Recommendation, operating on the same powerline wiring.

History

Edition	Recommendation	Approval	Study Group
1.0	ITU-T G.9972	2010-06-11	15

FOREWORD

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The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

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In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

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As of the date of approval of this Recommendation, ITU had received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

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Coexistence mechanism for wireline home networking transceivers

1 Scope

This Recommendation specifies a coexistence mechanism for home networking transceivers capable of operating over powerline wiring. The coexistence mechanism allows ITU-T G.996x devices to coexist with other coexisting systems, as defined in this Recommendation, operating on the same powerline wiring.

Specifically, this Recommendation defines:

- the coexistence signal structure and characteristics;
- the coexistence signalling scheme and timing requirements;
- the allocation of resources to each coexisting system;
- the start-up, synchronization and resynchronization procedures;
- the generic messages required to be supported by each coexisting system;
- the time slot reuse requirements;
- the signal transmission and detection requirements.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T G.996x] Recommendations ITU-T G.996x (in force), *Test procedures for digital subscriber line (DSL) transceivers*.

[ITU-T G.9960] Recommendation ITU-T G.9960 (2010), *Unified high-speed wire-line based home networking transceivers – System architecture and physical layer specification*.

3 Definitions

This Recommendation defines the following terms:

3.1 access system: A powerline communications system carrying high-speed digital communications on frequencies above 2 MHz over medium and low voltage electric powerlines that distribute electricity to end-user premises enabling a communication link between the power utility infrastructure and the home. The electric powerlines may be both outside and within buildings.

3.2 coexistence: The capability that allows two or more non-interoperable systems to share the same medium, while minimizing mutual interference to each other.

3.3 coexisting system: A powerline communications system that belongs to one of the coexisting system categories and uses ISP to coexist with other non-interoperable systems.

3.4 coexisting systems categories: ITU-T G.996x, IHC1, IHC2 and ACC. IHC1, IHC2 and ACC are reserved by ITU-T. [ITU-T G.996x] is the family of home networking Recommendations including [ITU-T G.9960].

NOTE – IHC1 and IHC2 are to be allocated to [b-IEEE 1901].

3.5 ISP field: The region in frequency and time within which an ISP signal is transmitted.

3.6 ISP phase vector: The sub-carriers of the ISP signal, each of which may be transmitted with either phase 0 or phase π. The phase vector defines which sub-carriers are transmitted with which phase. Five phase vectors are defined.

3.7 ISP sequence: A series of consecutive ISP windows to which one or more coexisting systems are synchronized.

3.8 ISP signal: An OFDM-based signal used by coexisting systems to indicate their status or requests to other coexisting systems. ISP signals are transmitted within ISP fields.

3.9 ISP window: A group of two ISP fields that is contiguous in time. Consecutive ISP windows are separated by the period T_{ISP}.

3.10 master node: A node in a coexisting system that determines the overall ISP timing, resource allocation, and start-up/resynchronization behaviour with other coexisting systems.

3.11 slave node: Any node in a coexisting system other than the master node.

3.12 synchronization period (T_H): The period between consecutive ISP windows of the same type. Consists of several T_{ISP} periods and forms the period for an entire cycle of ISP signalling.

3.13 synchronization point (sync point): A point in time located at multiples of 60 degrees from a zero-crossing point on an AC mains. The first ISP field begins at a set offset (ISP_OFFSET) from a sync point.

3.14 TDM unit (TDMU): A sub-division of the time between consecutive ISP windows. A TDMU is further divided into TDM slots.

3.15 TDM slot (TDMS): The smallest amount of time that may be allocated to a coexisting system in TDM mode. Particular TDMSs are allocated to particular systems depending upon the current network status.

4 Abbreviations

This Recommendation uses the following abbreviations:

ACC	Access
AWGN	Additive White Gaussian Noise
EMI	Electromagnetic Interference
FB	Full Bandwidth
FDM	Frequency Domain Multiplex
IFFT	Inverse Fast Fourier Transform
IH	In-Home
IHC1	In-Home Category 1
IHC2	In-Home Category 2
IH-G	ITU-T G.996x
ISP	Inter-System Protocol

OFDM	Orthogonal Frequency Division Multiplexing
PB	Partial Bandwidth
TDM	Time Domain Multiplex
TDMA	Time Division Multiple Access

5 Overview

Inter-system protocol (ISP) allows for the powerline medium to be shared between coexisting systems in the time domain, called time domain multiplex (TDM), the frequency domain, called frequency domain multiplex (FDM), or both. ISP supports coexistence between up to four non-interoperable coexisting systems. This Recommendation assumes that there is only one access system operating over the distribution lines that provide power to a given customer premises.

The frequency range used by ISP signalling ranges from 2 MHz to 50 MHz.

Sharing of the powerline medium between coexisting systems is determined by the following:

- number of coexisting systems on the powerline;
- type of coexisting system;
- access system capacity request.

An overview of the ISP is provided in the next clause, followed by clauses describing the details of each component of the protocol.

5.1 Inter-system protocol

5.1.1 Coexistence signalling

Coexistence signalling is carried out by the use of periodically repeating ISP windows that are used to convey information on coexisting system presence, resource requirements and resynchronization request. Each coexisting system category is allocated a particular ISP window in a round robin fashion.

5.2 Network status

By monitoring the signals transmitted within the ISP windows allocated to other coexisting systems, a coexisting system is able to detect the number and type of other coexisting systems present on the line and the resource requirements of the access system (i.e., partial/full bandwidth).

By monitoring the signals within its own ISP window, a coexisting system is able to detect a resynchronization request from one of the other coexisting systems.

This set of instantaneous information is termed the network status. Network status is used to determine the allocation of resources to each coexisting system.

5.3 Resource allocation

5.3.1 Frequency domain multiplex (FDM)

Within ISP, FDM may only be invoked by an access system. The overall FDM scheme consists of two frequency bands. The upper band is shared using TDM by in-home systems, the lower band reserved for access systems. One of two FDM band separation frequencies (10 MHz or 14 MHz) is chosen by the access system.

5.3.2 Time domain multiplex (TDM)

ISP allows TDM to be implemented between coexisting in-home systems or between coexisting in-home systems and an access system. The allocation of resources in the time domain is described in clause 9.

The period between each ISP window is divided into smaller units and sub-units that are used as the basis for TDM resource allocation.

5.4 Start-up and re-synchronization procedures

In order to allow coexisting systems to synchronize to the appropriate ISP sequence and hence to effectively coexist, the ISP defines:

- procedures for system start-up;
- triggers and procedures for re-synchronizing to a different ISP sequence.

6 Coexistence signal definition

The structure of the ISP signal shall be as follows:

- The ISP signal consists of 16 consecutive OFDM symbols.
- Each OFDM symbol is formed using a 512-point inverse fast fourier transform (IFFT) with each sub-carrier having a phase shift defined in clause 6.2.
- The ISP time domain signal is then multiplied by a window function W(n) to reduce the out-of-band energy in order to be compliant with the transmit spectrum mask. The window function W(n) is vendor proprietary.

The ISP signal is depicted in Figure 6-1.

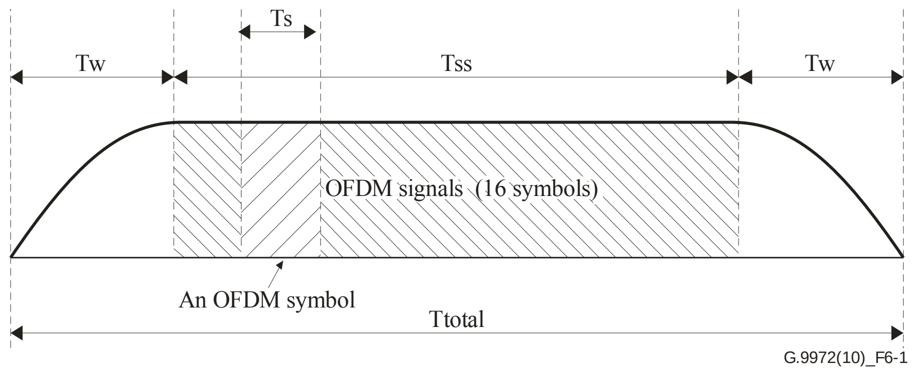


Figure 6-1 – Timing of the ISP signal

The parameters that define the signal are shown in Table 6-1.

Table 6-1 – ISP signal parameters

Symbol	Description	Time samples (assuming a 100 MHz sampling rate)	Time (µs)
Ts	OFDM symbol duration	512	5.12
Tss	OFDM signals duration	Ttotal – 2 * Tw	Ttotal – 2 * Tw
Tw	Windowing duration	Less than or equal to 1024	Less than or equal to 10.24
Ttotal	ISP signal duration	8192	81.92

6.1 Signal generation

The ISP signal, $S_I(n)$, is defined as time-domain samples assuming a 100 MHz sampling rate:

$$S_I(n) = N_c \cdot W(n) \cdot \sum_{C_a} \cos\left(\frac{2 \cdot \pi \cdot C_a \cdot n}{512} + \phi(C_a)\right)$$

where:

$0 \le n < 8192$

N_c is a normalization factor

W(n) is a windowing function

C_a is the sub-carrier index

$Ø(C_a)$ is the phase vector

The choice of windowing function, W(n), is implementation dependent. W(n) shall be chosen to meet the following requirements:

$$W(n) = 1 \text{ for } 1024 \le n \le 7167$$

$$0 \le W(n) \le 1 \text{ for } 0 \le n \le 1023 \text{ and } 7168 \le n \le 8191$$

W(n) shall enable the ISP signals to comply with the transmit spectrum mask.

The ISP signal is composed by cascading 16 identical OFDM symbols with windowing applied at the beginning and at the end. A single OFDM symbol, $S_S(n)$ within an ISP signal is defined below as time-domain samples assuming a 100 MHz sampling rate:

$$S_S(n) = N_c \sum_{C_a} \cos\left(\frac{2 \cdot \pi \cdot C_a \cdot n}{512} + \phi(C_a)\right)$$

where:

$0 \le n < 512$.

The sub-carrier frequencies used in the above equation are shown in Table 6-3. The sub-carrier frequency values given in Table 6-3 are normative, according to the clock tolerance specified in clause 14, signal detection and transmission. The transmit PSD requirements are specified in clause 14.

The lower limit of the frequency range of the ISP signal shall be fixed at 2.1484375 MHz (i.e., sub-carrier #11).

The maximum value of the upper limit of the frequency range of the ISP signal shall be 49.8046875 (i.e., sub-carrier #255).

For those coexisting systems with maximum operating frequency at 30 MHz and above, the value of the upper limit of the frequency range of the ISP signal shall be at least 29.8828125 MHz (i.e., sub-carrier #153).

For those coexisting systems with maximum operating frequency below 30 MHz, the value of the upper limit of the frequency range of the ISP signal shall be the closest value that is equal to or lower than the maximum operating frequency of the coexisting system.

Table 6-2 – Upper limit of the ISP signal frequency range as a function of maximum operating frequency

Upper value of operating frequency range (*f*)/MHz	Lower value of ISP signal sub-carrier index (Note)	Upper value of ISP signal sub-carrier index	Limit of upper value of ISP signal sub-carrier index
> 50	11	≥ 153 and ≤ 255	255
30 ≤ *f* ≤ 50	11	≥ 153 and ≤ 255	255
2.1484375 ≤ *f* < 30	11	C_a value closest and less than upper value of operating frequency range	255
NOTE – IH systems operating in FDM mode may set the lower value of ISP signal sub-carrier index to the C_a value closest and greater than the lower value of the operating frequency range. In this case, ACC may not be able to detect the "interference threshold exceeded" signal transmitted by the IH system.			

It must be noted that the frequency of each sub-carrier corresponds to the following expression:

$$f_{C_a} = C_a \frac{f_s}{N_{IFFT}} = C_a \frac{100}{512} \text{MHz} = C_a \cdot 195.3125 \text{ kHz}$$

Table 6-3 – ISP signal sub-carrier frequencies

C_a	Freq [kHz]	C_a	Freq [kHz]	C_a	Freq [kHz]	C_a	Freq [kHz]
0	0.0000	64	12500.0000	128	25000.0000	192	37500.0000
1	195.3125	65	12695.3125	129	25195.3125	193	37695.3125
2	390.6250	66	12890.6250	130	25390.6250	194	37890.6250
3	585.9375	67	13085.9375	131	25585.9375	195	38085.9375
4	781.2500	68	13281.2500	132	25781.2500	196	38281.2500
5	976.5625	69	13476.5625	133	25976.5625	197	38476.5625
6	1171.8750	70	13671.8750	134	26171.8750	198	38671.8750
7	1367.1875	71	13867.1875	135	26367.1875	199	38867.1875
8	1562.5000	72	14062.5000	136	26562.5000	200	39062.5000
9	1757.8125	73	14257.8125	137	26757.8125	201	39257.8125
10	1953.1250	74	14453.1250	138	26953.1250	202	39453.1250
11	2148.4375	75	14648.4375	139	27148.4375	203	39648.4375
12	2343.7500	76	14843.7500	140	27343.7500	204	39843.7500
13	2539.0625	77	15039.0625	141	27539.0625	205	40039.0625
14	2734.3750	78	15234.3750	142	27734.3750	206	40234.3750
15	2929.6875	79	15429.6875	143	27929.6875	207	40429.6875
16	3125.0000	80	15625.0000	144	28125.0000	208	40625.0000
17	3320.3125	81	15820.3125	145	28320.3125	209	40820.3125
18	3515.6250	82	16015.6250	146	28515.6250	210	41015.6250
19	3710.9375	83	16210.9375	147	28710.9375	211	41210.9375
20	3906.2500	84	16406.2500	148	28906.2500	212	41406.2500

Table 6-3 – ISP signal sub-carrier frequencies

C_a	Freq [kHz]	C_a	Freq [kHz]	C_a	Freq [kHz]	C_a	Freq [kHz]
21	4101.5625	85	16601.5625	149	29101.5625	213	41601.5625
22	4296.8750	86	16796.8750	150	29296.8750	214	41796.8750
23	4492.1875	87	16992.1875	151	29492.1875	215	41992.1875
24	4687.5000	88	17187.5000	152	29687.5000	216	42187.5000
25	4882.8125	89	17382.8125	153	29882.8125	217	42382.8125
26	5078.1250	90	17578.1250	154	30078.1250	218	42578.1250
27	5273.4375	91	17773.4375	155	30273.4375	219	42773.4375
28	5468.7500	92	17968.7500	156	30468.7500	220	42968.7500
29	5664.0625	93	18164.0625	157	30664.0625	221	43164.0625
30	5859.3750	94	18359.3750	158	30859.3750	222	43359.3750
31	6054.6875	95	18554.6875	159	31054.6875	223	43554.6875
32	6250.0000	96	18750.0000	160	31250.0000	224	43750.0000
33	6445.3125	97	18945.3125	161	31445.3125	225	43945.3125
34	6640.6250	98	19140.6250	162	31640.6250	226	44140.6250
35	6835.9375	99	19335.9375	163	31835.9375	227	44335.9375
36	7031.2500	100	19531.2500	164	32031.2500	228	44531.2500
37	7226.5625	101	19726.5625	165	32226.5625	229	44726.5625
38	7421.8750	102	19921.8750	166	32421.8750	230	44921.8750
39	7617.1875	103	20117.1875	167	32617.1875	231	45117.1875
40	7812.5000	104	20312.5000	168	32812.5000	232	45312.5000
41	8007.8125	105	20507.8125	169	33007.8125	233	45507.8125
42	8203.1250	106	20703.1250	170	33203.1250	234	45703.1250
43	8398.4375	107	20898.4375	171	33398.4375	235	45898.4375
44	8593.7500	108	21093.7500	172	33593.7500	236	46093.7500
45	8789.0625	109	21289.0625	173	33789.0625	237	46289.0625
46	8984.3750	110	21484.3750	174	33984.3750	238	46484.3750
47	9179.6875	111	21679.6875	175	34179.6875	239	46679.6875
48	9375.0000	112	21875.0000	176	34375.0000	240	46875.0000
49	9570.3125	113	22070.3125	177	34570.3125	241	47070.3125
50	9765.6250	114	22265.6250	178	34765.6250	242	47265.6250
51	9960.9375	115	22460.9375	179	34960.9375	243	47460.9375
52	10156.2500	116	22656.2500	180	35156.2500	244	47656.2500
53	10351.5625	117	22851.5625	181	35351.5625	245	47851.5625
54	10546.8750	118	23046.8750	182	35546.8750	246	48046.8750
55	10742.1875	119	23242.1875	183	35742.1875	247	48242.1875
56	10937.5000	120	23437.5000	184	35937.5000	248	48437.5000
57	11132.8125	121	23632.8125	185	36132.8125	249	48632.8125
58	11328.1250	122	23828.1250	186	36328.1250	250	48828.1250

Table 6-3 – ISP signal sub-carrier frequencies

C_a	Freq [kHz]	C_a	Freq [kHz]	C_a	Freq [kHz]	C_a	Freq [kHz]
59	11523.4375	123	24023.4375	187	36523.4375	251	49023.4375
60	11718.7500	124	24218.7500	188	36718.7500	252	49218.7500
61	11914.0625	125	24414.0625	189	36914.0625	253	49414.0625
62	12109.3750	126	24609.3750	190	37109.3750	254	49609.3750
63	12304.6875	127	24804.6875	191	37304.6875	255	49804.6875

6.2 Phase vectors

The ISP protocol establishes the necessity for five different signal phases, all of them based on the previously defined OFDM symbol but using different phases at each sub-carrier.

Detailed definitions of each phase vector are shown in Tables 6-4 and 6-5. "Start No." in Table 6-5 shows how the original phase vector shown in the reference Table 6-4 is shifted for the corresponding phase vector. Namely, if the "Start No." is m, the phase of ith sub-carrier is equal to the phase reference whose sub-carrier index is (i+m) mod 256.

Table 6-4 – Phase vector reference

C_a	$Ø(C_a)$	C_a	$Ø(C_a)$	C_a	$Ø(C_a)$	C_a	$Ø(C_a)$	C_a	$Ø(C_a)$	C_a	$Ø(C_a)$	C_a	$Ø(C_a)$	C_a	$Ø(C_a)$
0	π	32	0	64	0	96	0	128	0	160	0	192	0	224	π
1	0	33	0	65	0	97	π	129	0	161	0	193	0	225	π
2	0	34	0	66	0	98	π	130	0	162	0	194	π	226	π
3	0	35	0	67	π	99	π	131	0	163	0	195	0	227	π
4	0	36	0	68	0	100	π	132	0	164	π	196	π	228	π
5	0	37	π	69	π	101	π	133	0	165	π	197	0	229	π
6	0	38	π	70	0	102	π	134	π	166	0	198	π	230	π
7	π	39	0	71	π	103	π	135	0	167	0	199	0	231	0
8	0	40	0	72	0	104	0	136	0	168	π	200	π	232	0
9	0	41	π	73	π	105	0	137	0	169	π	201	π	233	0
10	0	42	π	74	π	106	0	138	π	170	0	202	π	234	0
11	π	43	0	75	π	107	0	139	0	171	π	203	π	235	π
12	0	44	π	76	π	108	π	140	0	172	0	204	π	236	π
13	0	45	0	77	π	109	π	141	π	173	π	205	0	237	π
14	π	46	π	78	0	110	π	142	π	174	0	206	π	238	0
15	π	47	0	79	π	111	0	143	0	175	0	207	0	239	π
16	0	48	0	80	0	112	π	144	0	176	π	208	0	240	π
17	0	49	π	81	0	113	π	145	0	177	π	209	π	241	π
18	0	50	π	82	π	114	π	146	π	178	π	210	0	242	π
19	π	51	π	83	0	115	π	147	0	179	0	211	π	243	0
20	0	52	0	84	π	116	0	148	π	180	0	212	0	244	0
21	π	53	0	85	0	117	0	149	π	181	π	213	0	245	π

Table 6-4 – Phase vector reference

C_a	Ø(C_a)	C_a	Ø(C_a)	C_a	Ø(C_a)	C_a	Ø(C_a)	C_a	Ø(C_a)	C_a	Ø(C_a)	C_a	Ø(C_a)	C_a	Ø(C_a)
22	π	54	π	86	0	118	π	150	π	182	π	214	0	246	0
23	π	55	π	87	0	119	0	151	0	183	π	215	π	247	π
24	0	56	π	88	π	120	π	152	π	184	π	216	π	248	π
25	π	57	π	89	π	121	π	153	0	185	0	217	0	249	0
26	0	58	0	90	0	122	0	154	π	186	π	218	π	250	0
27	π	59	π	91	π	123	0	155	π	187	π	219	π	251	π
28	π	60	π	92	π	124	π	156	0	188	0	220	π	252	0
29	0	61	0	93	π	125	0	157	π	189	π	221	0	253	0
30	π	62	π	94	0	126	0	158	π	190	0	222	0	254	0
31	π	63	0	95	0	127	π	159	0	191	0	223	0	255	0

Table 6-5 – Phase vector start numbers

Phase vector	Start No.	Use
Phase 1	1	ACC
Phase 2	2	IHC1, resync
Phase 3	14	IHC2, resync
Phase 4	42	ACC, FDM interference
Phase 5	58	IH-G, resync

6.3 Sync point

A sync point is defined as a time located at 0 degree, 60 degrees, 120 degrees, 180 degrees, 240 degrees or 300 degrees relative to a zero-cross point of the AC mains. Requirements for zero-crossing detection are specified in clause 14.3. Sync points for single-phase AC mains and three-phase AC mains are shown in Figures 6-2 and 6-3, respectively. The interval between consecutive sync points is given by T_0. The first ISP field begins at ISP_OFFSET time after a sync point.

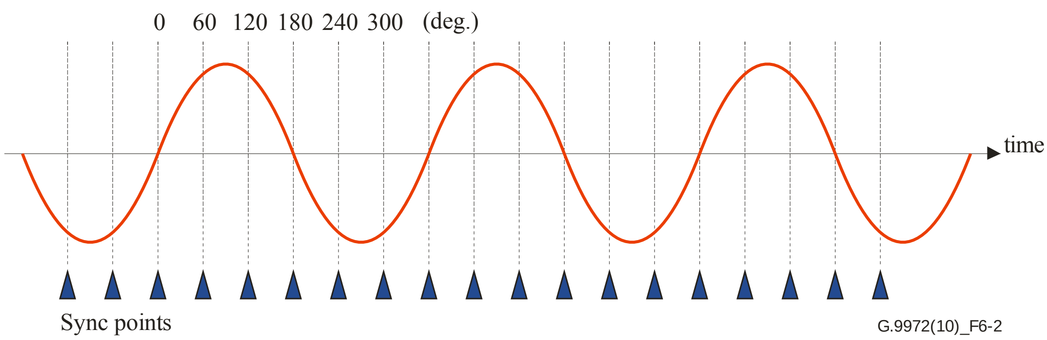


Figure 6-2 – Sync points (single-phase AC mains)

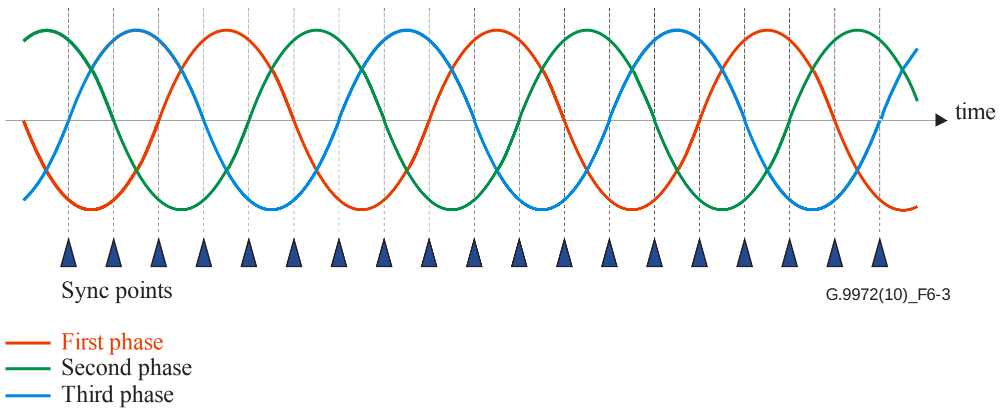


Figure 6-3 – Sync points (three-phase AC mains)

7 Coexistence signalling scheme

Each ISP window consists of two ISP fields. A coexisting system may transmit ISP signals within both fields of its allocated window, may transmit ISP signals within the second field of other coexisting systems' allocated windows, monitors the signals within the second field of its allocated window, and monitors the signals within the first field of other coexisting systems' allocated windows. Additionally, an access system monitors the signals within the second field of other coexisting systems' allocated windows. Per each ISP field, a node may be either transmitting ISP signals or monitoring ISP signals transmitted but not both.

The ISP signal may be transmitted using one of a range of designated phase vectors. This allows information to be conveyed by a given ISP field.

7.1 ISP window

The ISP window is a region of time used by coexisting systems exclusively for transmitting/detecting ISP signals. The ISP window shall be allotted periodically every T_{ISP}, a multiple of AC_CYCLE at a fixed offset, ISP_OFFSET, from a sync point. The period formed by four consecutive T_{ISP} is given by T_H. Synchronization of the coexisting systems to a common sync point is described in clause 10. Each ISP window consists of two ISP fields. The ISP window and ISP fields are shown in Figure 7-1.

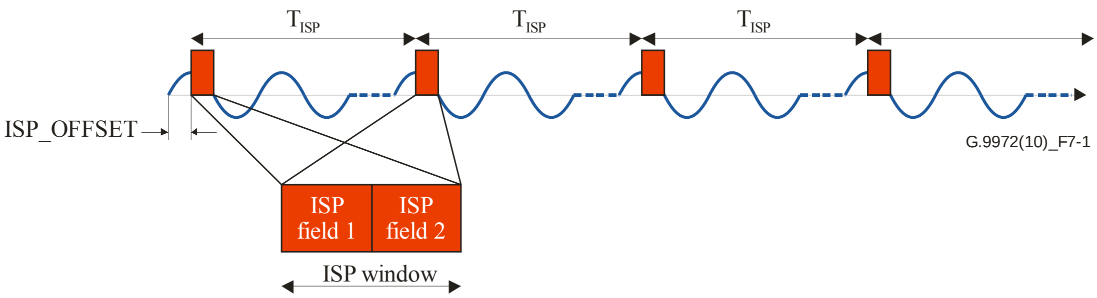


Figure 7-1 – ISP time window and ISP fields concept

Each coexisting system is allocated a particular ISP window. ACC shall use an ISP window, IHC1 shall use the following ISP window, IHC2 shall use the next ISP window, and ITU-T G.996x shall use the next ISP window, as shown in Figure 7-2.

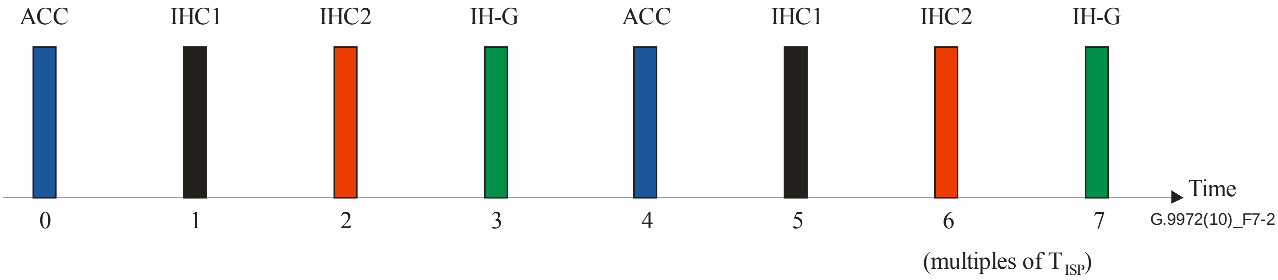


Figure 7-2 – Periodicity of ISP windows

All devices that belong to the same system shall transmit ISP signals in the ISP window allocated to their system with a periodicity of $4 \cdot T_{ISP}$, with the exceptions specified in clause 11.

Every device shall monitor the remaining ISP windows in order to assess the network status, with the exceptions specified in clause 11.

NOTE – It is recommended that devices occasionally scan for ISP signals in sync points outside the known ISP windows, in order to detect the presence of other, unsynchronized, systems. The frequency of this scan is vendor discretionary.

7.2 ISP fields

The ISP window contains two ISP fields. The devices of a coexisting system transmit ISP signals within these fields. The signals within each field are transmitted with a defined phase in order to convey a particular status or request. The combination of system category, field, and signal phase contributes to the network status.

The ISP can be applied to the case of an access system coexisting with an ITU-T G.996x system and two mutually non-interoperable IHC1 and IHC2 systems. This most comprehensive case is described here.

The ISP window occurs at the beginning of TDMU #0, TDMU#3, TDMU#6 and TDMU#9, with a periodicity T_{ISP} equal to three TDMUs, as shown in Figure 7-3.

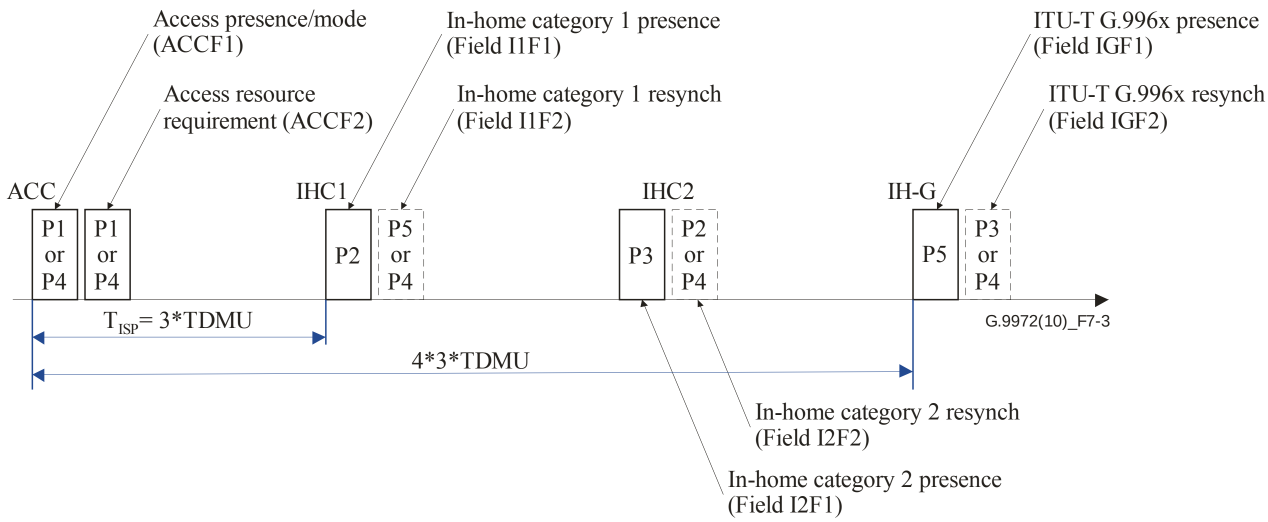


Figure 7-3 – ISP fields

Figure 7-3 shows the ISP fields. Solid lines denote fields where ISP signals are always transmitted if coexisting systems belonging to the appropriate system category are present. Dashed lines denote fields where ISP signals may or may not be present.

7.2.1 Access system

The ISP fields allocated to an access system are denoted ACCF1 and ACCF2. The valid combinations of the presence and phase of signals within these fields and their meaning are as shown in Table 7-1, where "Ph1" indicates ISP signal phase 1 and "Ph4" indicates ISP signal phase 4.

Table 7-1 – Meaning of the access ISP fields

ACC ISP window		Meaning for network status
ACCF1	ACCF2	
Ph1	Ph1	Access TDM request partial bandwidth
Ph1	Ph4	Access TDM request full bandwidth
Ph4	Ph1	Access FDM below 10 MHz on all TDMSs
Ph4	Ph4	Access FDM below 14 MHz on all TDMSs

From Table 7-1, it may be seen that an access system is able to use:

- ACCF1 to indicate its presence and whether it is using TDM or FDM.
- ACCF2 to indicate whether it is using all its allocated resources (TDM full bandwidth, FDM below 14 MHz) or partial allocated resources (TDM partial bandwidth, FDM below 10 MHz).

7.2.2 In-home systems

The ISP fields allocated to the in-home systems are denoted I1F1, I1F2, I2F1, I2F2, IGF1 and IGF2. The valid combinations of the presence and phase of signals within these fields and their meaning are as shown in Tables 7-2, 7-3 and 7-4.

Table 7-2 – Meaning of the IHC1 ISP fields

IHC1 ISP window		Meaning for network status
I1F1	I1F2	
Ph2		IHC1 system present
Ph2	Ph5	IHC1 system must start resynchronization procedure
Ph2	Ph4	Interference threshold exceeded

Table 7-3 – Meaning of the IHC2 ISP fields

IHC2 ISP window		Meaning for network status
I2F1	I2F2	
Ph3		IHC2 system present
Ph3	Ph2	IHC2 system must start resynchronization procedure
Ph3	Ph4	Interference threshold exceeded
NOTE – A coexisting system may ignore undefined signals detected in ISP window.		

Table 7-4 – Meaning of ITU-T G.996x ISP fields

IH-G ISP window		Meaning for network status
IGF1	IGF2	
Ph5		ITU-T G.996x in-home system present
Ph5	Ph3	ITU-T G.996x in-home system must start resynchronization procedure
Ph5	Ph4	Interference threshold exceeded
NOTE – A coexisting system may ignore undefined signals detected in ISP window.		

From Tables 7-2, 7-3 and 7-4, it may be seen that in-home systems are able to use:

- I1F1/I2F1/IGF1 to indicate presence.
- I1F2/I2F2/IGF2 to indicate whether or not the device supports FDM.

An ITU-T G.996x system enters the resynchronization procedure whenever it detects a signal with Phase 3 in IGF2. Similarly, an IHC1 system enters the resynchronization procedure whenever it detects a signal with Phase 5 in I1F2, and an IHC2 system enters the resynchronization procedure whenever it detects a signal with Phase 2 in I2F2.

7.2.3 ISP signal placement

In order to compensate for variations in synchronization, zero-crossing detection, load induced phase shifts, etc., the duration of the ISP signal is less than that of the ISP window. When transmitting an ISP signal, it should be placed in the centre of the ISP field. The structure of the ISP field is shown in Figure 7-4. Requirements for zero-crossing detection are specified in clause 14.3.

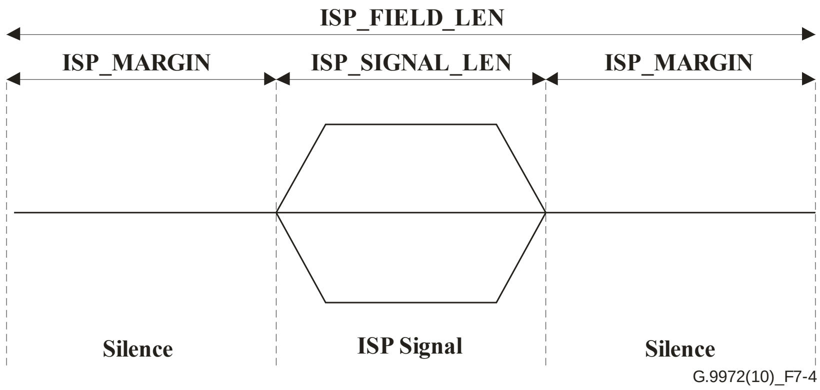


Figure 7-4 – Composition of an ISP field: ISP signal and two ISP margins (silence periods)

7.3 Network status

By monitoring the signals transmitted within the ISP windows allocated to other coexisting systems, a coexisting system is able to detect the number and type of other coexisting systems present on the line and the resource requirements of the access system (i.e., partial/full bandwidth).

By monitoring the signals within its own ISP window, a coexisting system is able to detect a resynchronization request from any of the other coexisting systems.

Signals are valid if they occur in VALID_SIGNAL_COUNT consecutive ISP windows for a given system. Any node shall decide that a system is present if the node detects at least VALID_SIGNAL_COUNT consecutive ISP signals of the appropriate phase in the appropriate ISP field and shall update its network status accordingly. Any node shall recognize that a system is no longer present if it does not detect such signals for SYSTEM_NOT_DETECTED consecutive synchronization periods and shall update the network status accordingly.

Information about the systems on the powerline includes:

– In-home systems
  • Presence
  • Resynchronization request from other system
  • "Interference threshold exceeded" to access system
– Access system
  • Presence
  • TDM or FDM
  • Full or partial resource allocation requirement

This set of instantaneous information is termed the network status. Network status is used to determine the allocation of resources to each coexisting system.

Coexisting devices are able to determine the network status every $4 \cdot T_{ISP}$ and update the network status every T_{ISP}. The network status of a coexisting system is determined by the systems that are present and detected by that device on the shared medium.

In the example shown in Figure 7-5, ISP signals are not transmitted in the ISP window assigned to IHC1, hence ACC, IH-G and IHC2 do not detect signals in the IHC1 ISP window and infer that IHC1 is not present. The network status = {ACC, IHC2, IH-G}. In this case, ACC, IH-G and IHC2 are able to share the resources that would be allocated to IHC1, according to a policy defined in clause 9.

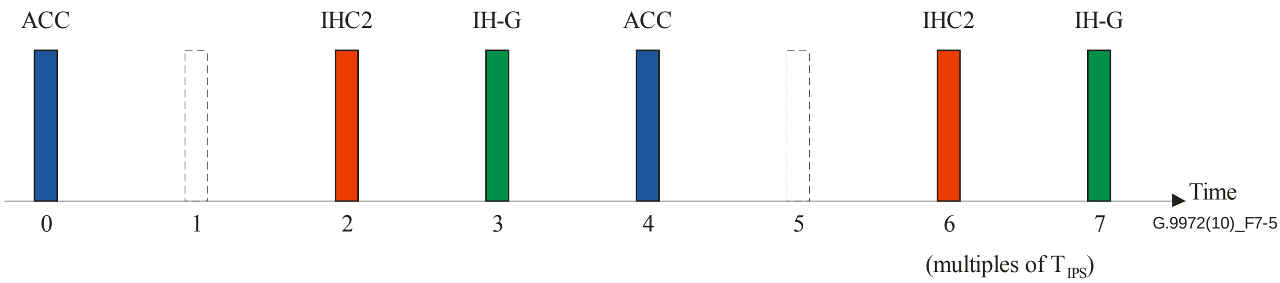


Figure 7-5 – Example ISP window sequence when no IHC1 is present

8 Coexistence resources

The ISP allows coexisting systems to coexist in the time domain (TDM) and/or the frequency domain (FDM). This clause defines the resource allocation.

8.1 Frequency domain multiplex (FDM)

Within ISP, FDM may only be invoked by an access system. The overall FDM scheme consists of two frequency bands. The upper band is shared by in-home systems, the lower band reserved for access systems.

One of two FDM band separation frequencies (10 MHz or 14 MHz) are signalled by the access system, denoting "Full Bandwidth" and "Partial Bandwidth" FDM modes. The "Full Bandwidth" FDM band separation frequency is 14 MHz, the "Partial Bandwidth" FDM band separation frequency is 10 MHz. Whichever mode is chosen by the access system is dependent upon its overall bandwidth requirements.

8.2 Time domain multiplex (TDM)

The ISP allows TDM to be implemented between coexisting in-home systems and between coexisting in-home systems and an access system.

The access system may indicate its TDM resource requirements as either "Full Bandwidth" or "Partial Bandwidth". This request impacts the TDM resource allocation between the coexisting systems.

The period between each ISP window is divided equally into three "TDM Units" (TDMU). In a period of T_H, there are 12 TDMUs numbered from 0 to 11. Each TDMU, in turn, is divided equally into eight "TDM Slots" (TDMS), numbered 0 to 7. The duration of a TDMU is given by TDM_UNIT_LEN and that of a TDMS by TDM_SLOT_LEN. The overall ISP TDMA structure is shown in Figure 8-1 with the TDMU structure shown in Figure 8-2.

If two adjacent TDMSs are assigned to different coexisting system categories, then a silence period is included. Figure 8-3 shows the general TDMA structure with an example of silence periods in a certain TDM allocation. The TDMS silence period is the duration of the ISP_MARGIN (see clause 7) and shall be inserted at the beginning of the TDMS. In the case that the TDMS starts with an ISP window, the silence period is already part of the ISP window.

Depending on the network status, each TDMS within a TDMU is allocated to a particular system category. The same TDMS is allocated to the same system category in each TDMU (e.g., ACC could be allocated "TDMS#3" and "TDMS#4" in each TDMU).

The network status sensed by one node of a coexisting system may be different to the network status sensed by another node of the same coexisting system.

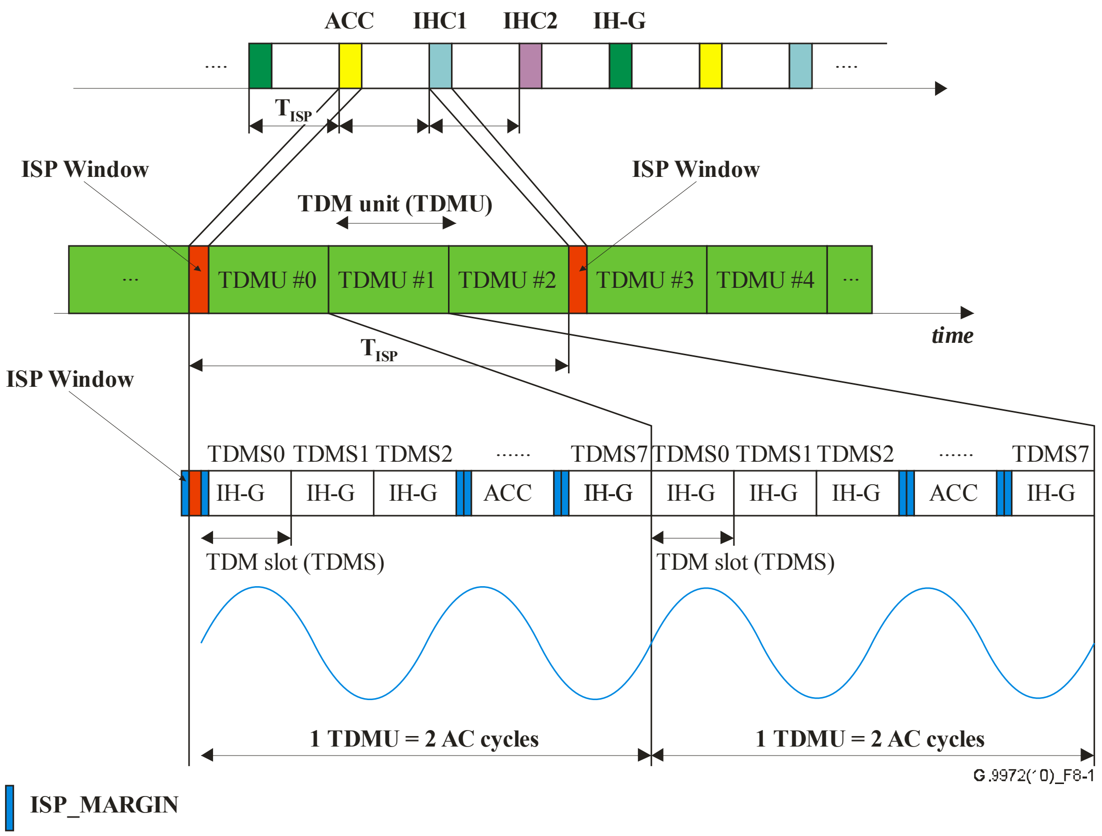
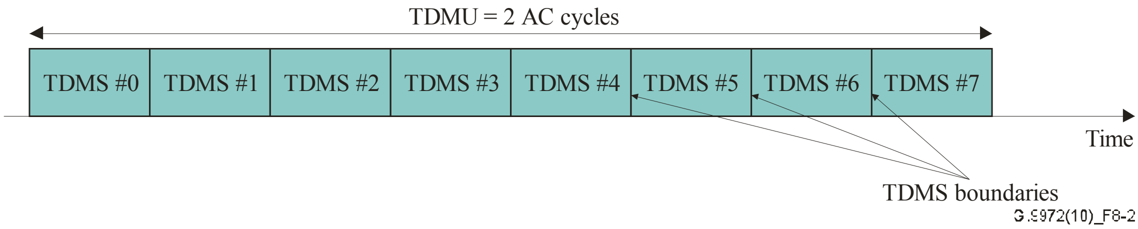


Figure 8-1 – General TDMA structure of the ISP



NOTE – Each TDMS is used exclusively by a coexisting system category.

Figure 8-2 – Structure of TDMU

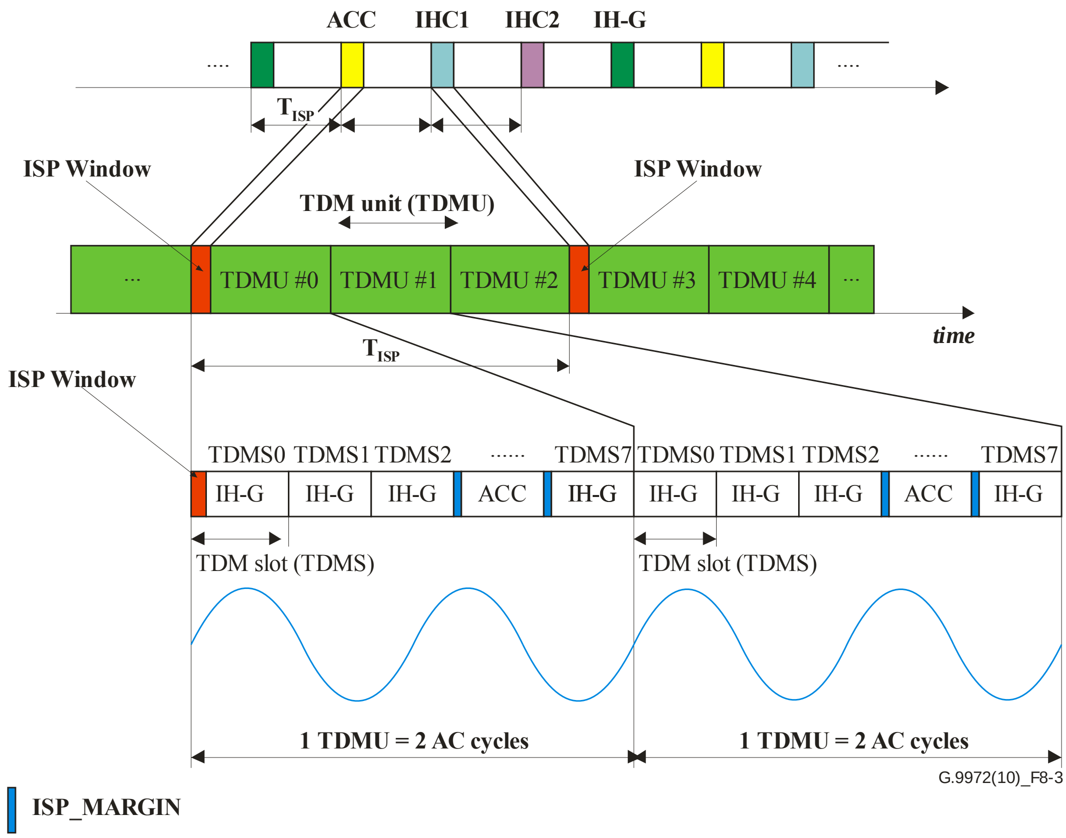


Figure 8-3 – General TDMA structure and an example of silence margins in a certain TDMA allocation

8.3 FDM/TDM modes

Access and in-home systems shall be capable of operating in TDM mode and may be capable of operating in FDM mode.

An FDM access system shall monitor all fields in other ISP windows in order to:

- detect the presence of in-home systems; and
- detect the interference level value caused to them in the access FDM band ("interference threshold exceeded" or "interference threshold not exceeded").

An FDM access system shall detect the FDM interference level value at an in-home device and act accordingly within 5 seconds of the in-home device beginning to indicate the interference level by transmitting in the appropriate ISP window.

When an in-home system detects the presence of an FDM access system, then the in-home system may indicate "interference threshold exceeded" by signalling in the appropriate field of its own ISP window. The in-home system may signal in two different ways:

- Transmitting a burst of VALID_SIGNAL_COUNT signals to indicate to access that it is requesting it to reduce the interference level. In this case, access will attempt to reduce the interference level in the in-home band. After 5 seconds, the in-home system may re-evaluate the interference level caused by access.
- Transmitting the signals continuously to indicate to access that it has to switch to TDM mode. In this case, the access system shall enter the TDM mode and signal such in the access fields. The access system may continue to utilize only the frequency region used in the FDM mode rather than the whole bandwidth. The in-home system shall synchronize to the access system.

The criteria on how to transmit the "interference threshold exceeded" signal by the in-home system is vendor discretionary.

Transmission of "interference threshold exceeded" signal by in-home system shall only be allowed when access is signalling FDM mode.

8.4 Parameters

This clause specifies values for parameters used in this Recommendation. These parameters are referenced in various clauses.

Tables 8-1, 8-2 and 8-3 indicate timing parameters in terms of nominal line cycle frequencies. Since the line cycle frequencies vary around these nominal values, the actual parameter values shall be interpreted in terms of the number of AC line cycles.

Table 8-1 – Synchronization parameters

Parameter	Definition	Value
AC_CYCLE	AC mains cycle	
T_0	Sync point interval	(1/6) × AC_CYCLE
TDM_UNIT_LEN	Time length of TDM unit	2 × AC_CYCLE
TDM_SLOT_LEN	Time length of TDM slot	(1/8) × TDM_UNIT_LEN
T_{ISP}	Period of ISP windows	3 × TDM_UNIT_LEN
T_H	Synchronization period for in-home systems and for access systems	4 × T_{ISP} (24 × AC_CYCLE)
VALID_SIGNAL_COUNT	Number of consecutive ISP windows required to judge that the detected ISP signal is valid.	2
VALID_SIGNAL_COUNT_ SEARCH	Number of consecutive ISP windows required to judge that the detected ISP signal is valid when it searches for ISP signals for ISP_STARTUP_TIME or ISP_RESYNC_WAIT.	1
SYSTEM_NOT_DETECTED	Number of consecutive ISP windows required to judge that a system is no longer present.	5

Table 8-2 – ISP window parameters

Parameter	Definition	Value
ISP_FIELD_LEN	Time length of an ISP field	245.76 µs
ISP_SIGNAL_LEN	Time length of an ISP signal	81.92 µs
ISP_MARGIN	Margins within an ISP field which are located on both sides of the ISP signal	81.92 µs
ISP_OFFSET	Offset length from the sync point to the beginning of the ISP window	200 µs

Table 8-3 – Start-up and resynchronization parameters

Parameter	Definition	Value
ISP_STARTUP_TIME	Duration for access and in-home systems to search for ISP signals from other coexisting systems (the coexisting system shall not transmit any signals during this time)	$2T_H$
ACCESS_ENTER_TIME	Duration for an access system master node to consecutively transmit resynchronization signals to unsynchronized systems	$10T_H$
RESYNC_SIG	The randomly selected number of resynchronization signal transmissions by the current system to those systems with which it is attempting to resynchronize. Minimum value = RESYNC_SIG_MIN (5) Maximum value = RESYNC_SIG_MAX (10)	5~10
ISP_RESYNC_WAIT	Duration for an in-home system to stop all ISP signal/data transmission in the network and search for ISP signals from other coexisting systems, after receiving resynchronization request signals	T_H
RESOURCE_RE-ALLOCATION_TIME	Duration for access and in-home systems to re-allocate their resource allocation after detecting a new network status	T_H

9 Resource allocation

9.1 TDM resource allocation for access systems

The policy for resource sharing between access and a group of in-home systems shall be based on the following rule:

When the access system requires 50% or more of the available resources, and the group of in-home systems requires 50% or more of the available resource, the access system shall receive 50% of the resources and the group of in-home systems shall receive the remaining 50% of the resources.

The access system or the group of in-home systems may use additional resources above 50% if not required by the other coexisting system. A system shall change its use of resources within a duration given by RESOURCE_RE-ALLOCATION_TIME.

9.2 TDM resource allocation

The general procedure for TDMS allocation is to start allocating TDMS for the case of a full network status {ACC, IH-G, IHC1, IHC2}, and then to create other allocations by assigning the TDMS of the absent system to the present systems.

The TDM resource allocation is shown in Figure 9-1. The right hand side of this table indicates which systems are allocated to which TDMS within the TDMU. The left hand side indicates which systems are present on the powerline – i.e., the network status.

Each system shall determine the network status and adjust its use of resources accordingly.

Each node may use TDMSs specified in Figure 9-1, according to the network status, and shall not use TDMSs allocated to other systems. As the network status changes, a system shall change its use of resources within a duration given by RESOURCE_RE-ALLOCATION_TIME.

Index	ISP Field				TDM Slot number							
	ACC	IHC1	IHC2	IH-G	0	1	2	3	4	5	6	7
1	-	-	-	IH-G	IH-G	IH-G	IH-G	IH-G	IH-G	IH-G	IH-G	IH-G
2	-	IHC1	-	-	IHC1	IHC1	IHC1	IHC1	IHC1	IHC1	IHC1	IHC1
3	-	-	IHC2	-	IHC2	IHC2	IHC2	IHC2	IHC2	IHC2	IHC2	IHC2
4	-	IHC1	-	IH-G	IHC1	IHC1	IH-G	IHC1	IHC1	IH-G	IH-G	IH-G
5	-	IHC1	IHC2	-	IHC1	IHC1	IHC2	IHC2	IHC2	IHC1	IHC1	IHC2
6	-	-	IHC2	IH-G	IH-G	IHC2	IHC2	IHC2	IHC2	IH-G	IH-G	IH-G
7	-	IHC1	IHC2	IH-G	IHC1	IHC1	IHC2	IHC2	IHC2	IH-G	IH-G	IH-G
8	ACC (FB)	-	-	-	ACC	ACC	ACC	ACC	ACC	ACC	ACC	ACC
9	ACC (PB)	-	-	IH-G	IH-G	IH-G	IH-G	IH-G	ACC	ACC	IH-G	IH-G
10	ACC (FB)	-	-	IH-G	IH-G	IH-G	IH-G	ACC	ACC	ACC	ACC	IH-G
11	ACC (PB)	IHC1	-	-	IHC1	IHC1	IHC1	IHC1	ACC	ACC	IHC1	IHC1
12	ACC (FB)	IHC1	-	-	IHC1	IHC1	IHC1	ACC	ACC	ACC	ACC	IHC1
13	ACC (PB)	-	IHC2	-	IHC2	IHC2	IHC2	IHC2	ACC	ACC	IHC2	IHC2
14	ACC (FB)	-	IHC2	-	IHC2	IHC2	IHC2	ACC	ACC	ACC	ACC	IHC2
15	ACC (PB)	IHC1	-	IH-G	IHC1	IHC1	IH-G	IHC1	ACC	ACC	IH-G	IH-G
16	ACC (FB)	IHC1	-	IH-G	IHC1	IHC1	IH-G	ACC	ACC	ACC	ACC	IH-G
17	ACC (PB)	IHC1	IHC2	-	IHC1	IHC1	IHC2	IHC2	ACC	ACC	IHC1	IHC2
18	ACC (FB)	IHC1	IHC2	-	IHC1	IHC1	IHC2	ACC	ACC	ACC	ACC	IHC2
19	ACC (PB)	-	IHC2	IH-G	IH-G	IHC2	IHC2	IHC2	ACC	ACC	IH-G	IH-G
20	ACC (FB)	-	IHC2	IH-G	IH-G	IHC2	IHC2	ACC	ACC	ACC	ACC	IH-G
21	ACC (PB)	IHC1	IHC2	IH-G	IHC1	IHC1	IHC2	IHC2	ACC	ACC	IH-G	IH-G
22	ACC (FB)	IHC1	IHC2	IH-G	IHC1	IHC1	IHC2	ACC	ACC	ACC	ACC	IH-G

Figure 9-1 – Resource allocation

It must be noted that the ISP window occurs in TDMS#0 of every TDMU#0, TDMU#3, TDMU#6 and TDMU#9. Therefore, the system category that occupies TDMS#0 will be very slightly penalized as no data can be transmitted during the ISP window.

10 Start-up and resynchronization procedures

In order to allow coexisting systems to synchronize to the appropriate ISP window, and hence to effectively coexist, the ISP defines:

- procedures for system start-up;
- triggers and procedures for re-synchronizing to a different set of ISP windows.

10.1 Start-up procedure

This clause is concerned with the case when a new node joins a system and when global start-up is required, for example, after a power outage. The start-up procedure ensures that the new station is able to detect the presence of other networks already transmitting ISP signals, and to coordinate with the existing networks.

10.1.1 Start-up procedure for an access system

This Recommendation assumes the presence of, at most, one access system; therefore, if a new access station joins the network, it will never detect two unsynchronized access networks. The access system is likely to span a relatively large geographic area, and thus may occupy the same powerline medium with any number of in-home systems.

If an access system is deployed for the first time in the area or when a new access node joins an existing access network, then the access station(s) shall follow the start-up procedure defined in this Recommendation for access networks.

- The access station(s) shall search for ISP signals from other coexisting systems at every sync point for a period given by ISP_STARTUP_TIME. Any node shall decide that a system is present if the node detects at least VALID_SIGNAL_COUNT_SEARCH consecutive ISP signals of the appropriate phase in the appropriate ISP field and shall update its network status accordingly.
- Once an access station successfully joins an access network and the ISP_STARTUP_TIME duration has expired, it shall send a message to the ACC master node notifying the presence and status of any in-home systems.
- Additionally, the ACC master node shall send a message to the new station indicating the mode of the access network and timing of the ISP signal which it shall begin transmitting in the ISP access fields.
- If any in-home coexisting systems are detected that are not synchronized with the access system, then a resynchronization signal shall be transmitted in the resynchronization field of the out of sync in-home systems for ACCESS_ENTER_TIME.
- The new access stations shall be restricted to transmission and reception of management messages for joining the access network and ISP management only until the procedure described herein is complete, including resynchronization of any out of sync in-home networks.

Access systems should have the possibility of initiating a resynchronization (similar to a global start-up after power outage).

10.1.2 Start-up procedure for an in-home system

When a new in-home node is powered up or joins an existing in-home network, then the in-home station(s) shall follow the start-up procedure defined in this Recommendation for in-home networks.

- The in-home station(s) shall search for ISP signals from other coexisting systems at every sync point for a period given by ISP_STARTUP_TIME. The detection information from each slave node shall be sent to the master node using the ISP_DetectionReport management message. Any node shall decide that a system is present if the node detects at least VALID_SIGNAL_COUNT_SEARCH consecutive ISP signals of the appropriate phase in the appropriate ISP field and shall update its network status accordingly.

- The master node shall determine the ISP sequence with which to synchronize, based on the detection information received from the slave nodes and according to the following rules:
  - If no ISP sequence is detected during the search period given by ISP_STARTUP_TIME, then the network manager of the in-home system shall determine the timing of the ISP windows itself and shall start transmitting ISP signals in its designated ISP window.
  - If only one ISP sequence is detected during the search period, then:
    - If the detected sequence does not include any resynchronization requests, then the network manager of the in-home system shall lock onto the detected sequence and shall start transmitting ISP signals in its designated ISP window.
    - If the detected sequence includes a re-synchronization request, then the network manager of the in-home system shall re-enter the start-up procedure and shall begin to search for ISP signals once again.
  - If two or more ISP sequences are detected during the search period, then:
    - If one of the ISP sequences includes an access system, the network manager of the in-home system shall lock onto this sequence and shall start transmitting an ISP signal in its designated ISP window.
    - If none of the ISP sequences includes an access sequence, then:
      - If there is only one ISP sequence that does not include a re-synchronization request, the network manager of the in-home system shall select and lock onto this sequence and shall start transmitting an ISP signal in its designated ISP window.
      - If there are two or more ISP sequences that do not include a resynchronization request, the network manager of the in-home system shall select one from these sequences, lock onto it and shall start transmitting an ISP signal in its designated ISP window.
      - If there is no in-home ISP sequence that does not include a resynchronization request, the network manager of the in-home system shall re-enter the start-up procedure and shall begin to search for ISP signals once again.
- If the master node determines, based on the detection information, that there are more than one ISP sequence, it shall transmit the ISP_DirectResyncTransmission message to the slave nodes instructing them to transmit resynchronization signals with phase vector Ph5 or Ph2 or Ph3 (as appropriate) to the ISP sequences with which the master node has not synchronized. The number of re-sync transmissions (RESYNC_SIG) is randomly selected between RESYNC_SIG_MIN and RESYNC_SIG_MAX.
- Once an in-home node successfully joins an in-home network and the ISP_STARTUP_TIME duration has expired, if it is not the master node of the in-home network, it shall send a system specific management message to the master node notifying the presence and status of any access and/or in-home systems. The new node shall follow any instructions indicated in any system specific management messages transmitted to it.
- If the master node detects the presence of an access system either directly or indirectly, from receiving a system specific management message, it shall immediately execute the resynchronization procedure defined in clause 10.2, in order to synchronize with the access system.
- If the master node detects the presence of an out of sync in-home coexisting system either directly or indirectly, from receiving a system specific management message, it shall immediately execute the resynchronization procedure defined in clause 10.2.

- Any new in-home station shall be restricted to transmission and reception of management messages for joining the in-home network and ISP management only until the procedure described herein is complete, including resynchronization of any out of sync in-home networks. When the new station detects no ISP signals of its category, it shall not transmit any frames until it starts to transmit ISP signals.

10.2 Resynchronization procedure

- Note that an access system cannot be resynchronized.
- An in-home system that is synchronized with an access system shall not resynchronize and shall ignore any resynchronization signal transmitted in its resynchronization field. Resynchronization is always handled by the master node.

10.2.1 Access requests resynchronization

- If an out of synchronization in-home system is detected by a station belonging to an access system, the station should immediately send a message to the ACC master notifying that an out of sync in-home coexisting system was detected.
- The access station that detected the out of sync in-home coexisting system shall transmit in the re-sync field of the in-home system an ISP signal of Ph5 if the in-home system is IHC1, Ph2 if the in-home system is IHC2 or Ph3 if the in-home system is ITU-T G.996x for RESYNC_SIG_MAX times.
- At the same time, the access station shall continue to transmit its own ISP sequence (i.e., ISP signals in its access ISP window) in order to provide the reference to which the in-home system shall synchronize.

10.2.2 In-home detects re-sync signal in its window

Whether an in-home system resynchronizes to a different ISP sequence or not is decided by the master node according to the following procedure:

- If the in-home system is already synchronized with an access system, then it shall ignore the re-sync request.
- An in-home slave node that detects an ISP resynchronization signal (Ph5 or Ph2 or Ph3) in the resynchronization field of its ISP window shall immediately send an ISP_ResyncDetected message to the master node indicating a resynchronization signal was detected.
- A master node that:
  - either detects a resynchronization signal in its ISP window or receives an ISP_ResyncDetected message; and
  - is not synchronized with an access system; and
  - is not currently transmitting resynchronization signals;
  - shall immediately start the resynchronization procedure.

The master node shall comply with the following:

- The master node transmits an ISP_StartResync message to all slave nodes in the system. The master node and slave nodes suspend transmission of ISP signals and search for ISP signals at all sync points for ISP_RESYNC_WAIT. Any node shall decide that a system is present if the node detects at least VALID_SIGNAL_COUNT_SEARCH consecutive ISP signals of the appropriate phase in the appropriate ISP field and shall update its network status accordingly.

- After ISP_RESYNC_WAIT and an access system is detected, the master node synchronizes to the access system, resumes transmission of ISP signals and data, and transmits the ISP_ResyncFinished management message to all slave nodes. In this case, the resynchronization procedure is finished at this step.
- If the master node does not detect an access system during ISP_RESYNC_WAIT, the master node resumes transmission of data and ISP signals (at the same sync points as before the resynchronization procedure started). The master node then begins a second ISP_RESYNC_WAIT period.
- After the second ISP_RESYNC_WAIT, the master node decides the sync point to lock onto from both what it detected during the first ISP_RESYNC_WAIT and what it is informed by its slave nodes (using the ISP_DetectionReport message) during the second ISP_RESYNC_WAIT. If any slave node detected an access ISP sequence, then the master node selects the access sequence. Otherwise, a sync point that does not include a re-sync signal and is not the same as the sync point before this state is selected. The master node resumes transmission of data and transmits the ISP_ResyncFinished management message to all slave nodes.
- If the master node neither detects nor is informed of any ISP sequences that satisfy the above conditions, then the master node continues synchronizing with the current sync point.

Slave nodes shall comply with the following during resynchronization:

- Immediately after it receives the ISP_StartResync message from its master node, an in-home slave node stops all ISP signals and frame transmissions, and searches for ISP signals at all sync points for ISP_RESYNC_WAIT. Any node shall decide that a system is present if the node detects at least VALID_SIGNAL_COUNT_SEARCH consecutive ISP signals of the appropriate phase in the appropriate ISP field and shall update its network status accordingly.
- After ISP_RESYNC_WAIT, the slave node resumes transmission of ISP signals and transmits an ISP_DetectionReport message to its master node if any ISP sequence was detected during the search period.
- The slave node updates the location of the ISP window starting from the next ISP window after receiving the ISP_ResyncFinished management message from its master node. The sync point that the slave node synchronizes to is informed by the ISP_ResyncFinished management message.

Just after the resynchronization procedure, the master node and all slave nodes shall transmit re-sync request signals to both those sync points that were detected but not selected and the sync point to which the system synchronized before the resynchronization procedure started. The number of re-sync signal transmissions (RESYNC_SIG) is decided by the master node. If the master node's system is synchronized to an access system, RESYNC_SIG is always equal to RESYNC_SIG_MAX. Otherwise, the master node decides the value of RESYNC_SIG randomly between RESYNC_SIG_MIN and RESYNC_SIG_MAX and shall transmit this to all slave nodes using the ISP_DirectResyncTransmission message.

10.2.3 In-home detects an unsynchronized access system

If an in-home coexisting system detects the presence of an unsynchronized ISP sequence that includes an access system, then the in-home system shall comply with the following procedure:

- The in-home system synchronizes its ISP signal transmission with the access system and transmits ISP signals in its corresponding ISP window.
- The master node transmits an ISP_IndicateState message to all its slave nodes in the same system to inform them of the coexistence state and the location of the next ISP window corresponding to the timing of the access system.

- The master node transmits ISP signals with phase vector Ph5 or Ph2 or Ph3 in the re-sync field of any ISP sequence with which the in-home system had synchronized before it detected the access system. The re-sync signals are transmitted for each unsynchronized ISP sequence for RESYNC_SIG_MAX times.
- The master node transmits an ISP_DirectResyncTransmission message to command the slave nodes to transmit re-sync signals in the ISP sequence to which the in-home system had synchronized before it detected the access system. The number of re-sync signal transmissions shall be RESYNC_SIG_MAX, and it is contained within the ISP_DirectResyncTransmission message.

A node that also detected unsynchronized in-home coexisting systems that were not synchronized to the detected access system shall transmit re-sync signals to the sync points corresponding to the detected in-home systems. The number of re-sync signal transmissions shall be RESYNC_SIG_MAX.

10.2.4 In-home system detects unsynchronized in-home systems

If an in-home system detects the presence of one or more unsynchronized in-home ISP sequences and does not detect an unsynchronized access system, the in-home master node shall select whether it enters the resynchronization procedure itself or requests the unsynchronized systems to do so.

When the master node selects the former, then the in-home system shall comply with the following procedure:

- The master node selects one of the detected ISP sequences to synchronize with and transmits ISP signals in the corresponding ISP window of that detected ISP sequence.
- The master node transmits an ISP_IndicateState message to all its slave nodes in order to inform them of the coexistence state and the location of the next ISP window (corresponding to the timing of the new system). All slave nodes that receive this message shall cease to transmit any signals in the presence field of the previous ISP sequence and start transmitting in the new ISP sequence.
- The master node transmits an ISP_DirectResyncTransmission message in order to command slave nodes to transmit re-sync signals, with phase vector Ph5 or Ph2 or Ph3 (as appropriate), within the ISP sequence to unselected ISP sequences and to which the in-home system had previously synchronized. The value of RESYNC_SIG is randomly selected between RESYNC_SIG_MIN and RESYNC_SIG_MAX by the master node, and is informed by the ISP_DirectResyncTransmission message.

When the master node decides to keep its sync point and requests other systems to synchronize to it, the in-home system shall comply with the following procedure:

- The master node transmits an ISP_DirectResyncTransmission message to all its slave nodes in order to command them to transmit re-sync signals in the ISP sequences of any unsynchronized systems they detected. The number of re-sync transmissions (RESYNC_SIG) is randomly selected by the master node between RESYNC_SIG_MIN and RESYNC_SIG_MAX and is communicated to the slave nodes within the ISP_DirectResyncTransmission message.
- The master node also transmits re-sync signals in the ISP sequences of the unsynchronized systems that the master node detected. The re-sync signals are transmitted RESYNC_SIG times.

11 Power control procedures

Nodes within a system may reduce the frequency or cease transmission of the ISP signals under certain circumstances, providing they continue to monitor the network status. If the network status contains only one system category, then the node may stop transmitting the ISP signals while still scanning for unsynchronized systems or for a new network status. Each node can make this decision autonomously based on the network status.

If the sensed network status changes and other systems appear, then the node shall resume transmitting the ISP signals.

Nodes shall transmit the ISP signals continuously for at least 60 s after the start-up and resynchronization procedure is completed.

12 Time slot reuse

For further study.

13 Generic management message

13.1 State indication messages

Management messages in this clause are used to transfer ISP signal detection status information between the master node and slave nodes.

Table 13-1 – ISP state indication messages

Message	Direction
ISP_IndicateState	Master node → Slave nodes
ISP_DetectionReport	Slave nodes → Master node

13.1.1 ISP_IndicateState

13.1.1.1 Function

ISP_IndicateState management message is used by the master node to inform slave nodes of the current coexistence state and the location of the next ISP window for its own system.

This message has some parameters.

- Information that is sufficient for slave nodes to decide the utilizable frequency band and TDMS.
- The location of the next ISP window.

13.1.1.2 Generation of ISP_IndicateState

A master node generates this message and sends to all slave nodes in the same system periodically. This message shall be sent to new slave nodes, all slave nodes every time the coexistence state changes, and all slave nodes antecedent to the change of the sync point to which the system is synchronized.

13.1.1.3 Effect of receipt

A slave node that receives this message updates its coexistence state according to both the received message and ISP signals that the slave node has detected itself. The slave node shall also update the location of ISP windows according to the information contained within the message and should start signalling according to the new position.

13.1.2 ISP_DetectionReport

13.1.2.1 Function

The ISP_DetectionReport management message is used by a slave node to inform its master node of information relating to detected ISP signals.

Parameters for this message are classified into two categories. An ISP_DetectionReport message may contain information relating to one or both of these categories.

The first category consists of information about detected ISP signals synchronized to the same sync points as the slave node itself. Parameters of the first category are as follows. A state parameter indicating the system's own technology is not necessary.

- Access system state (TDMFull, TDMPartial, FDMFull, FDMPartial, not detected).
- In-home system state for each technology (Detected, not detected).

The second category consists of information about detected ISP signals synchronized to different sync points as the slave node itself. Parameters of the second category are as follows. The second category information may be a list of sets of the following parameters.

- Access system state (TDMFull, TDMPartial, FDMFull, FDMPartial, not detected).
- In-home system state for each technology (detected, not detected).
- Resynchronization flag (Resynchronization signal detected, not detected).
- Offset of the sync point to the current sync point.

13.1.2.2 Generation of ISP_DetectionReport

A slave node shall generate and send this message to its master node when:

- the coexistence state communicated from the master node is different from the coexistence state determined by the slave node according to locally detected ISP signals;
- the slave node detects one or more out-of-sync coexisting systems;
- the slave node finishes the ISP_RESYNC_WAIT search period on the RE-SYNC state.

13.1.2.3 Effect of receipt

When a master node receives this message from a slave node, it shall either update the coexistence state or start the re-synchronization procedure according to the information contained within the message.

13.2 Resynchronization messages

Management messages defined in this clause are used for the resynchronization procedure.

Table 13-2 – ISP resynchronization messages

Message	Direction
ISP_StartResync	Master node → Slave node
ISP_ResyncFinished	Master node→ Slave nodes
ISP_ResyncDetected	Slave node → Master node
ISP_DirectResyncTransmission	Master node → Slave nodes

13.2.1 ISP_StartResync

13.2.1.1 Function

The ISP_StartResync management message is used to inform slave nodes that the master node has started the resynchronization procedure.

13.2.1.2 Generation of ISP_StartResync

A master node shall generate and send this message to all slave nodes in the same system when the master node starts the resynchronization procedure.

13.2.1.3 Effect of receipt

A slave node that received this message shall enter the RE-SYNC state.

13.2.2 ISP_ResyncFinished

13.2.2.1 Function

The ISP_ResyncFinished management message is used to inform slave nodes that the resynchronization procedure is finished by the master node.

This message shall contain parameters that show a new sync point to which the system shall synchronize and the number of transmissions of the re-sync signal.

13.2.2.2 Generation of ISP_ResyncFinished

A master node shall generate and send this message to all slave nodes in the same system when the master node finishes the resynchronization procedure.

13.2.2.3 Effect of receipt

A slave node that receives this message shall immediately lock onto the specified sync point. The slave node shall also start to transmit re-sync signals at the sync points that are detected during the search period. The sync point with which the system had synchronized before the resynchronization procedure is also the target of re-sync signal transmission. The re-sync field of the sync point that is specified by this message shall not be signalled.

13.2.3 ISP_ResyncDetected

13.2.3.1 Function

The ISP_ResyncDetected management message is used by a slave node to inform the master node that it has detected re-sync signals in its own ISP window.

13.2.3.2 Generation of ISP_ResyncDetected

A slave node shall generate and send this message to the master node when the slave node detects re-sync signals in its own ISP window.

13.2.3.3 Effect of receipt

A master node that receives this message may start the resynchronization procedure.

13.2.4 ISP_DirectResyncTransmission

13.2.4.1 Function

The ISP_DirectResyncTransmission management message is used to command slave nodes to transmit re-sync signals to out-of sync ISP windows.

This message has a parameter to inform slave nodes of the number of transmissions of the re-sync signal.

13.2.4.2 Generation of ISP_DirectResyncTransmission

A master node shall generate and send this message to all slave nodes in the same system when the master node decides to make out-of-sync coexisting systems synchronize with itself.

13.2.4.3 Effect of receipt

A slave node that received this message shall start to transmit re-sync signals to out-of-sync coexisting systems, according to the contents of the message.

14 Signal transmission and detection

14.1 Transmit PSD

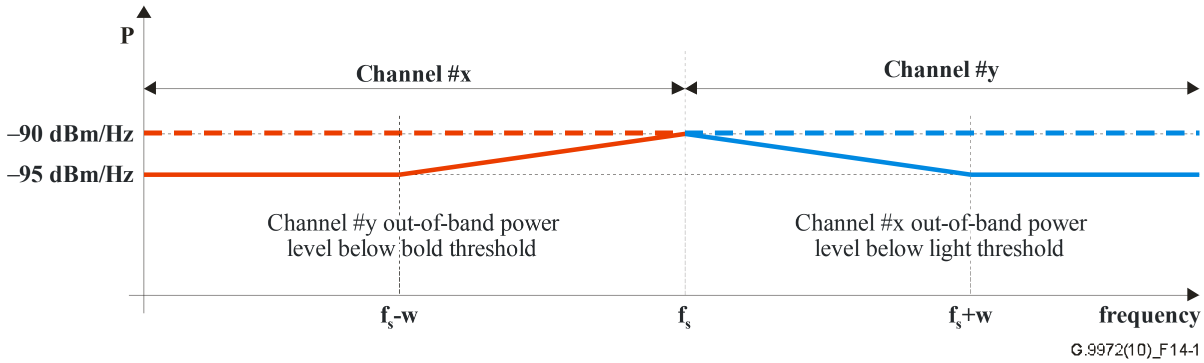
The PSD of ISP signals transmitted by a node shall be 8 dB lower than the PSD of the signals transmitted by the node when communicating with other nodes in the same coexisting system, except for the notches and the out-of-band PSD where the maximum PSD level could be the same as the signals transmitted by the node when communicating with other nodes in the same coexisting system.

NOTE 1 – All devices send the ISP signal simultaneously, so the transmitted power is reduced in order to avoid non-compliance with radiated emissions regulations.

NOTE 2 – The purpose of ISP is to allow sharing of the medium between coexisting systems when there could be interference. If the energy from one system reaches the other system below the noise level, then there is no real interference and so both systems could use the channel simultaneously without the need for ISP (avoiding the loss of up to 50% of the bandwidth). Sometimes there could be some interference causing some decrease in bandwidth, but this is better than directly losing 50% of the channel.

The PSD shall be compliant with regulations in effect in the country where the system is used.

The leakage signal level that may be output to the unused frequency band (#x or #y) when using FDM mode is shown in Figure 14-1, where f_s is the FDM band separation frequencies (10 MHz or 14 MHz) between access and in-home networks, and w is 6 MHz. The measurement for the limit is made using equipment with a resolution bandwidth of 10 kHz (dBm/10 kHz) or 9 kHz (dBm/9 kHz) and an RMS detector. The continuous line shall be met with the average measurement. The dashed line shall be met with Max hold measurement.



NOTE – The leakage signal level assumes that two nodes are not co-located and that there is some minimum attenuation between them. If this is not the case, lower leakage signal is recommended or additional filters should be added.

Figure 14-1 – Leakage signal level

14.1.1 Clock frequency tolerance

Clock frequency tolerance shall be ±100 ppm maximum.

14.2 Signal detection

The minimum ISP signal detection requirements are:

- ISP signal shall be detected with 99% success in an additive white Gaussian noise (AWGN) with SNR higher or equal to 5 dB.
- Probability of detecting an ISP signal with a wrong phase shall be lower than 1% in an AWGN with the SNR higher or equal to 0 dB.
- Probability of falsely detecting an ISP signal when no signal is present (just noise) in an AWGN shall be lower than 1 detection every 5 seconds.

For signal levels of –124 dBm/Hz and above in –140 dBm/Hz AWGN, the ISP signal detection error rate shall not exceed 1%. The measurement for the limit is made using a peak-hold detector with a resolution bandwidth 10 kHz (dBm/10 kHz) or 9 kHz (dBm/9 kHz).

14.3 Zero-crossing detection

The master node in each coexisting system shall have a zero-cross detector. Other nodes in the coexisting system may also have a zero-cross detector. The master node distributes information that can be used to determine the location of the ISP window to other nodes via the ISP_IndicateState message. For slave nodes with zero-cross detector, vendors may decide whether to use the zero-cross detector or the information distributed by the master node or a combination of both.

The zero-cross detector of the node shall detect the AC zero-cross with a tolerance lower than ±25 µs in 95% of the cases.

NOTE – Additional filtering of the zero-cross point detected by the circuit is recommended.

Annex A

ITU-T G.996x coexistence management messages

(This annex forms an integral part of this Recommendation.)

A.1 ITU-T G.996x coexistence management message parameters

A description of the generic management messages required for coexistence is provided in clause 13. Each coexisting system maps these generic messages to its own messaging scheme. ITU-T G.996x implements these messages as ITU-T G.9961 management messages, with OPCODES listed in clause 8.10.1 of [ITU-T G.9961]. The OPCODE and ITU-T G.9961 management message name corresponding to each generic ISP management message are summarized in Table A.1.

This clause provides the management message parameter lists (MMPLs) corresponding to each of these management messages. The messages described in this clause shall be used only by those systems that operate as specified in [ITU-T G.996x].

Table A.1 – Mapping of ISP generic messages to ITU-T G.9961 specific messages

ISP generic message		ITU-T G.9961 management message	
Name	**Reference**	**Name**	**OPCODE (hex)**
ISP_IndicateState	13.1.1	ISP_IndicateState.ind	040
ISP_DetectionReport	13.1.2	ISP_DetectionReport.ind	041
ISP_StartResync	13.2.1	ISP_StartResync.req	042
ISP_ResyncFinished	13.2.2	ISP_ResyncFinished.ind	043
ISP_ResyncDetected	13.2.3	ISP_ResyncDetected.ind	044
ISP_DirectResyncTransmission	13.2.4	ISP_DirectResyncTransmission.req	045

A.1.1 Format of ISP_IndicateState.ind

Message ISP_IndicateState.ind is a management message that is transmitted by the domain master and provides coexistence network status, ISP operation mode and ISP sequence timing information.

This message contains at least the elements as shown in Table A.2. The criteria used by the domain master for determining the value of the "ISP_Suspend" sub-field are for further study.

Table A.2 – Format of the ISP_IndicateState.ind message

Field	Octet	Bits	Description
Access state	0	[3:0]	Described in Table A.3
IHC1 state		[4]	Shall be set to 1 when an IHC1 domain is present in the current ISP sequence. Shall be set to 0 when an IHC1 domain is not present in the current ISP sequence.
IHC2 state		[5]	Shall be set to 1 when an IHC2 domain is present in the current ISP sequence. Shall be set to 0 when an IHC2 domain is not present in the current ISP sequence.

Table A.2 – Format of the ISP_IndicateState.ind message

Field	Octet	Bits	Description
ISP_Suspend		[7:6]	This field shall be set to "00" to indicate that the node shall continue to perform all ISP operations as required. This field shall be set to "01" to indicate that the node shall suspend transmission of ISP signals and shall periodically monitor for ISP signals. This field shall be set to "10" to indicate that the node shall suspend all ISP signal transmission and detection. The value "11" is reserved by ITU-T.
Next SP counter	1	[1:0]	The value of the internal sync point counter of the domain master at the next ISP window occurrence for [ITU-T G.9961]
Reserved		[7:2]	Reserved by ITU-T
Next ZeroX counter	2-5	[31:0]	This is a 32-bit unsigned integer that indicates the zero-crossing point immediately before the next ISP window occurrence for ITU-T G.996x. It shall be based on the domain master's transmit clock with a resolution of 10 ns. The start of the next ISP window = Next ZeroX Counter + (Next SP Counter * 2 * T_o) + T_{off}.

Table A.3 – Values for the access state sub-field

Value	Description
0000_2	No access system detected
0001_2 – 0011_2	Reserved by ITU-T
0100_2	Access system detected indicating TDM, partial bandwidth
0110_2	Access system detected indicating TDM, full bandwidth
0101_2	Access system detected indicating FDM, partial bandwidth
0111_2	Access system detected indicating FDM, full bandwidth
1000_2	Detect access system indicating FDM, partial bandwidth, but cannot support it
1001_2	Detect access system indicating FDM, full bandwidth, but cannot support it
1010_2	Detect access system indicating FDM, partial bandwidth. Request interference level reduction
1011_2	Detect access system indicating FDM, full bandwidth. Request interference level reduction
1100_2 – 1111_2	Reserved by ITU-T

A.1.2 Format of ISP_DetectionReport.ind

The ISP_DetectionReport.ind message is a unicast management message sourced by the node and is used for indicating the network status of the node. This message shall be sent by the node whenever there is a change in its network status. Other triggers of this message are for further study.

ISP_DetectionReport.ind message contains at least the elements shown in Table A.4.

Table A.4 – Format of the MMPL field of the ISP_DetectionReport.ind message

Field	Octet	Bits	Description
Access state	0	[2-0]	Described in Table A.5
IHC1 state		3	1, when an IHC1 domain has been detected. 0, when no IHC1 domain has been detected.
IHC2 state		4	1, when an IHC2 domain has been detected. 0, when no IHC2 domain has been detected.
Reserved		[7:5]	Reserved by ITU-T
Number of out-of-sync sequences	1	[7:0]	Number of detected out-of-sync ISP sequences (Also shows the number of elements of the out-of-sync sequence list field)
Out-of-sync sequence list	2-3	[15:0]	List of detected out-of-sync ISP sequences Described in Table A.6

Table A.5 – Values for the access state field

Value	Description
000_2	No access system detected
100_2	Access system detected indicating TDM, partial bandwidth
110_2	Access system detected indicating TDM, full bandwidth
101_2	Access system detected indicating FDM, partial bandwidth
111_2	Access system detected indicating FDM, full bandwidth
Others	Reserved by ITU-T

Table A.6 – Format of an element of the out-of-sync sequence list sub-field

Sub-field	Octet	Bits	Description
ISP offset	0	[7:0]	Offset of the out-of-sync ISP sequence from the current sync point in units of the number of sync points
Access state	1	[2:0]	Described in Table A.5
IHC1 state		3	1, when an IHC1 domain has been detected. 0, when no IHC1 domain has been detected.
IHC2 state		4	1, when an IHC2 domain has been detected. 0, when no IHC2 domain has been detected.
IH-G state		5	1, when an ITU-T G.996x domain has been detected. 0, when no ITU-T G.996x domain has been detected.
Resync flag		6	1, when resync ISP signals have been detected in this ISP sequence. 0, when no resync ISP signals have been detected.
Reserved		7	Reserved by ITU-T

A.1.3 Format of ISP_StartResync.req

The ISP_StartResync.req message is a unicast/broadcast management message sourced by the domain master and shall be used to request the node to start the coexistence resynchronization process. The ISP_StartResync.req message does not require a MMPL.

A.1.4 Format of ISP_ResyncFinished.ind

The ISP_ResyncFinished.ind message is a unicast/broadcast management message sourced by the domain master and shall be used to indicate that the coexistence resynchronization sequence has been finished.

The ISP_ResyncFinished.ind message contains at least the elements shown in Table A.7.

Table A.7 – Format of the MMPL field of the ISP_ResyncFinished.ind message

Field	Octet	Bits	Description
Number of re-sync signals	0	[7:0]	Number of transmissions of resynchronization ISP signals to the sync points that were not selected.
Access state	1	[2:0]	Described in Table A.5
IHC1 state		3	1, when an IHC1 domain is working at the new sync point. 0, when no IHC1 domain is working at the new sync point.
IHC2 state		4	1, when an IHC2 domain is working at the new sync point. 0, when no IHC2 domain is working at the new sync point.
Reserved		5	Reserved by ITU-T
Next SP counter		[7:6]	Value of the internal sync point counter of the domain master at the next ISP window for ITU-T G.996x.
Next ZeroX counter	2-5	[31:0]	Value of the internal zero-cross counter of the domain master at the next ISP window for ITU-T G.996x.

A.1.5 Format of ISP_ResyncDetected.ind

The ISP_ResyncDetected.ind message is a unicast management message sourced by the node to the domain master and shall be used to indicate that the node has detected a coexistence resynchronization request. The ISP_ResyncDetected.ind message does not require an MMPL.

A.1.6 Format of ISP_DirectResyncTransmission.req

The ISP_DirectResyncTransmission.req message is a unicast/broadcast management message sourced by the domain master and shall be used to request the node to transmit coexistence resynchronization request ISP signals to out-of-sync domains.

The ISP_DirectResyncTransmission.req message contains at least the elements shown in Table A.8.

Table A.8 – Format of the MMPL field of the ISP_DirectResyncTransmission.req message

Field	Octet	Bits	Description
Number of re-sync signals	0	[7:0]	Number of transmissions of resynchronization ISP signals.
Number of sync points	1	[7:0]	Number of sync points (N) at which it is required to transmit resynchronization ISP signals (this also shows the number of elements of the ISP offset list field). Valid values of this field are 1, 2, …, 143.
ISP offset list for sync point 1	2	[7:0]	List of sync points at which the node transmits resynchronization ISP signals. The number N is equal to the value of the number of sync points field.
…	…	…	…
ISP offset list for sync point *N*	*N*+1	[7:0]	

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[b-IEEE 1901] IEEE 1901-2010, *IEEE Standard for Broadband over Power Line Networks: Medium Access Control and Physical Layer Specifications.*

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