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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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Recommendation ITU-T G.9972

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.

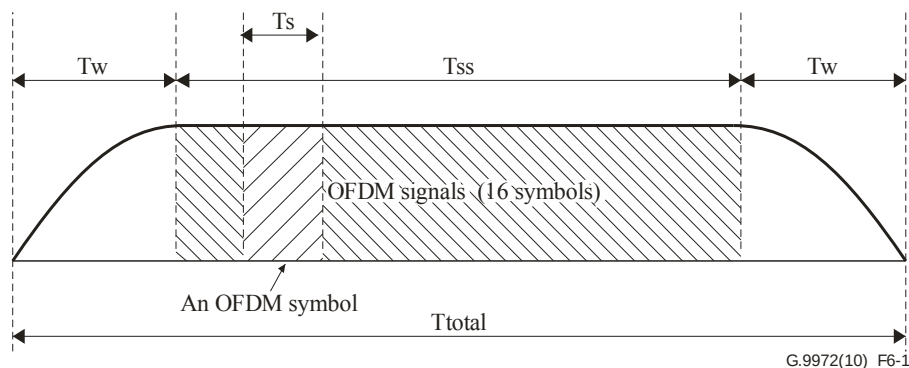


Figure 6-1 – Timing of the ISP signal

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 (μ s)
T_s	OFDM symbol duration	512	5.12
T_{ss}	OFDM signals duration	$T_{total} - 2 * T_w$	$T_{total} - 2 * T_w$
T_w	Windowing duration	Less than or equal to 1024	Less than or equal to 10.24
T_{total}	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:

$$0 \leq n < 8192$$

N_c is a normalization factor

$W(n)$ is a windowing function

C_a is the sub-carrier index

$\phi(C_a)$ is the phase vector

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

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

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

$W(n)$ 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:

$$0 \leq n < 512.$$

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
$30 \leq f \leq 50$	11	≥ 153 and ≤ 255	255
$2.1484375 \leq f < 30$	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 i th sub-carrier is equal to the phase reference whose sub-carrier index is $(i+m) \bmod 256$.

Table 6-4 – Phase vector reference

C_a	$\Theta(C_a)$	C_a	$\Theta(C_a)$	C_a	$\Theta(C_a)$	C_a	$\Theta(C_a)$	C_a	$\Theta(C_a)$	C_a	$\Theta(C_a)$	C_a	$\Theta(C_a)$	C_a	$\Theta(C_a)$
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