CCT

MD75X / 76X / 78X /79X

FCC Submission For 5.8G/ 2.4GHz Hybrid EDCT FHSS System

Table of Contents

DEFINITIONS, ACRONYMS AND ABBREVIATIONS 4

1 INTRODUCTION 5

1.1 SCOPE 5

2 BRIEF SYSTEM DESCRIPTION 6

2.1 FREQUENCY CHANNELS 6

2.2 TDMA FRAMES STRUCTURE 7

2.3 RESIDENTIAL / DOMESTIC SYSTEM 7

2.4 BEARERS 8

3 OVERVIEW OF FREQUENCY HOPPING ALGORITHM 10

3.1 HOPPING RATE 10

3.2 HOPPING SEQUENCE 10

3.2.1 HOPPING PATTERN BASE-TABLE 10

3.2.2 LCG RANDOM NUMBER GENERATOR 11

3.2.3 LOGICAL AND PHYSICAL CHANNEL NUMBERS 11

3.3 IDENTIFYING CHANNEL INTERFERENCE 13

3.4 HOP SEQUENCE ADAPTION 13

3.5 STARTING A DUMMY BEARER 13

3.5.1 AVOIDING DUMMY BEARER 'SEQUENCE COLLISION' 14

3.6 GAINING SYNC WITH A DUMMY BEARER 14

3.6.1 DETERMINING THE PATTERN AND HSI FROM AN N_T MESSAGE 14

3.7 FOLLOWING A DUMMY BEARER 14

3.8 STARTING A TRAFFIC BEARER 15

3.8.1 AVOIDING TRAFFIC BEARER 'SEQUENCE COLLISION' 15

3.9 STARTING A COMBINED DUMMY/TRAFFIC BEARER 15

3.9.1 AVOIDING COMBINED DUMMY/TRAFFIC BEARER 'SEQUENCE COLLISION' 16

4 CONFORMANCE TO FCC REQUIREMENTS 17

4.1 SECTION 15.247(A)(1) 17

4.2 SECTION 15.247(B)(1) 17

4.3 SECTION 15.247(G) 17

4.4 SECTION 15.247(H) 18

APPENDIX A – CHANNEL CENTRE FREQUENCIES 19

APPENDIX B – BASE TABLE HOPPING SEQUENCE..20

APPENDIX C – LCG RANDOM HOPPING SEQUENCE...21

APPENDIX D – LOGICAL TO PHYSICAL MAPPING TABLE 30

DEFINITIONS, ACRONYMS AND ABBREVIATIONS

Channel collision	The simultaneous occupancy of a hopping channel by multiple transmitters.
DECT	Digital Enhanced Cordless Telecommunications.
EIRP	Equivalent isotropically Radiated Power.
ETSI	European Telecommunications Standards Institute.
FCC	Federal Communications commission (the body in the USA that regulates the use of the radio spectrum).
FH	Frequency Hopper: the name of the software component responsible for frequency hopping.
FHSS	Frequency Hopping Spread Spectrum.
FP	Fixed Part or base-station.
Hand-over	A process by which a second traffic bearer is established to carry an existing call. Once established the first traffic bearer can be released.
HSI	Hope Sequence Index: used to index into the pattern table.
ISM	Industrial, Scientific, Medical band: a radio frequency band in the range 2400 – 2483.5 MHz
LCG	Linear Congruential Generator: a type of random number generator
LDC	Low Duty Cycle: a power saving feature.
OET	Office of Engineering and Technology, a division of the FCC.
PP	Portable Part or handset.
PSCN	Primary Scan Carrier Number; used in DECT.
PSPN	Primary Scan Pattern Number; the analogue of the PSCN for frequency hopping.
Radio Cell	The area covered by a single FP.
RFPI	Radio Fixed Part Identity
RNG	Random Number Generator; more accurately a Pseudo-Random Number Generator or PRNG.
RSSI	Received Signal Strength Indication.
Sequence collision	When two transmitters, with overlapping radio cells, are using the same slot, pattern and phase within the pattern. Channel collisions will occur on every frame, until the slot, pattern or phase is changed.
TDD	Time Division Duplexing.
TDMA	Time Division Multiple Access.

1 INTRODUCTION

In the US the 2400 – 2483.5 MHz band / 5759-5839MHz is subject to FCC regulations, in particular Part 15 Section 247.

DSP Group has developed a base-band chip, RF solution and protocol stack for the cordless telephony market that uses the 2.4 GHz band. This system is known as EDCT. The EDCT protocol stack is based on a DECT standard protocol stack that has been modified to use frequency hopping spread spectrum (FHSS) techniques in order to meet the FCC requirements.

1.1 Scope

This document describes the salient features of the EDCT protocol stack as they relate to the FCC requirements for using the 2.4 GHz band / 5.8GHz.

2 BRIEF SYSTEM DESCRIPTION

The basic system is a cordless telephone system, based on DECT. Because DECT is such a fundamental part of the proposed system, a brief description of this is given first.

DECT is a low-power two-way digital wireless communications system. Whilst DECT is a general digital communications system, it is most commonly used for cordless telephone systems. In particular it is used for residential telephone systems.

DECT uses TDMA to provide two-way communication between a base-station and multiple hand-sets. In this document the base-station is referred to as the Fixed Part (FP) and the hand-set is referred to as the Portable Part (PP).

Unlike a DECT system, the EDCT system does not have exclusive use of the spectrum. It has to share the spectrum with other users. The EDCT system uses frequency hopping to share the spectrum with other users according to the requirements specified by the FCC.

It is the frequency hopping requirement that creates the biggest difference between a DECT and an EDCT system. The other main difference between the two systems is the TDMA frame structure (EDCT has to use fewer 'slots' in the frame due to a lower bit rate).

2.1 Frequency channels

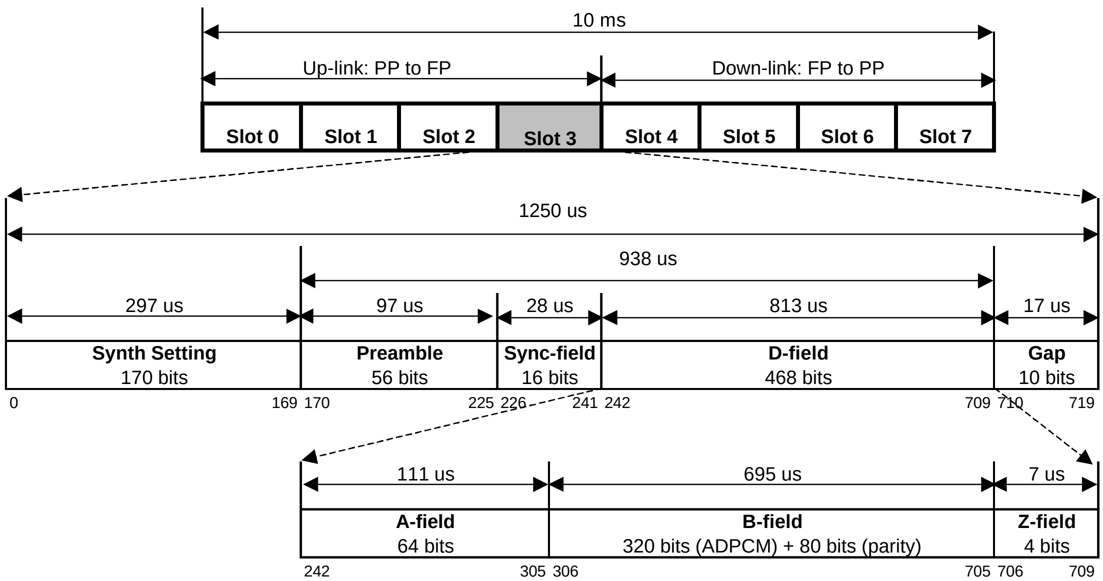
EDCT uses carriers whose centre frequencies are shown in "Appendix A – Channel Centre Frequencies".

This gives 88 possible channels, lying between 2401.808203 MHz and 2479.398926 MHz. For the purposes of this document, the channels are numbered 1 ..88.

However, channel 71 is dropped from the hopping sequence because it has poor receiver sensitivity due to the RF design. This leaves a total of 87 hopping channels.

2.2 TDMA frames structure

The EDCT TDMA frame structure is shown below:



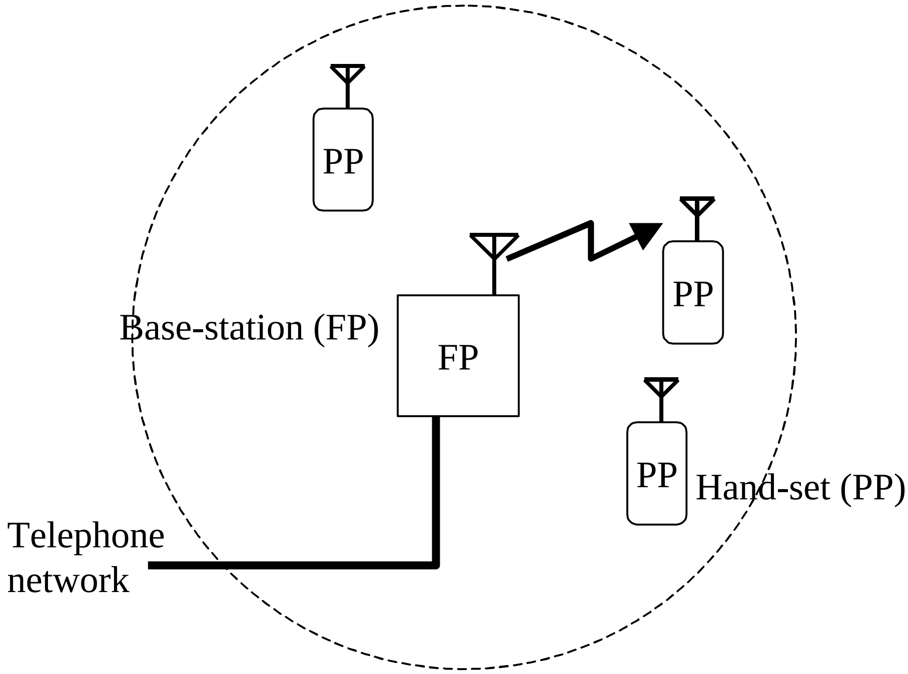
The basic, repeating, frame structure is 10 ms long. It is sub-divided into 8 slots, each 1250 ì s long. The active transmission time is 937.5 ì s. The first 4 slots form the ‘ up-link’ , when the PPs transmit to the FP. The last 4 slots form the ‘ down-link’ , when the FP transmits to the PPs.

EDCT uses TDD to carry a two-way voice communication. This is always by using slot-pairs: 0 and 4, 1 and 5, 2 and 6, 3 and 7. In this way the down-link transmission of the duplex communication is always 5ms after the corresponding up-link transmission.

There is only one transceiver in FP or PP therefore in any single slot, the FP or PP can only ever be receiving or transmitting.

2.3 Residential / domestic system

A residential or domestic system is for use in the home. A single FP is used with multiple PPs. There can be any number of PPs, although only 4 simultaneous duplex connections to the FP are allowed; this limit is due to the number of slot-pairs in the TDMA frame structure. The figure illustrates the basic system configuration.



2.4 Bearers

An important concept in DECT and EDCT is the notion of a “bearer”. A bearer is the medium used for carrying a communication.

In a DECT system a bearer is defined by a combination of channel number and slot number. However, because EDCT is a frequency hopping system, a bearer is defined by a hopping sequence and slot number.

There are two types of bearer in the EDCT system:

Dummy bearer

- This is used to carry a ‘beacon’ and other broadcast information.
- The FP will broadcast a dummy bearer all the time it is powered up and operating.
- Only the FP transmits a dummy bearer.
- As it is a simplex transmission, only a down-link slot is used.
- The broadcast information is contained in the ‘A-field’ section of the transmission (the ‘B-field’ section is not required, and is therefore not transmitted).

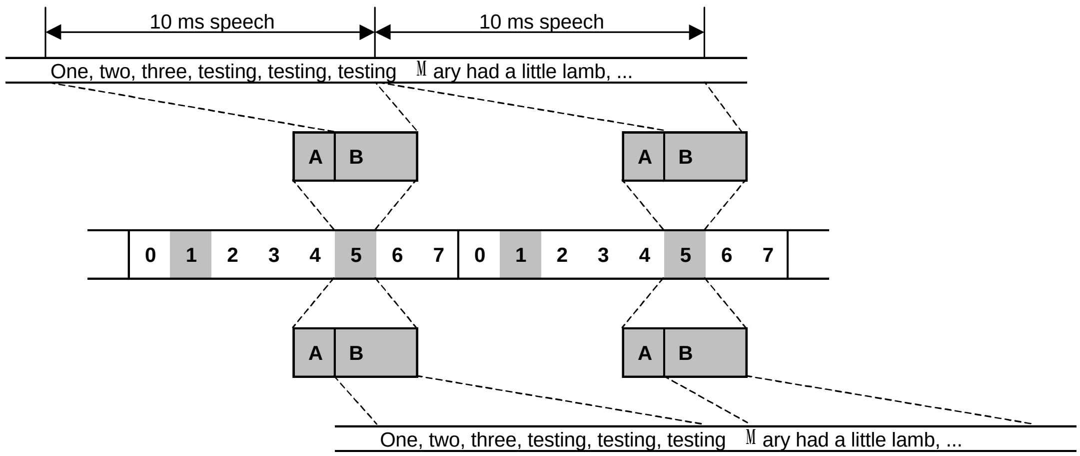
Traffic bearer

- This is used to carry a voice call.
- As it is a duplex transmission both a down-link and up-link slot are used. The slots used are always a slot-pair.
- The ‘A-field’ section contains the same information as the dummy bearer, with the addition of extra signalling required for the call. The voice data is contained in the ‘B-field’ section.

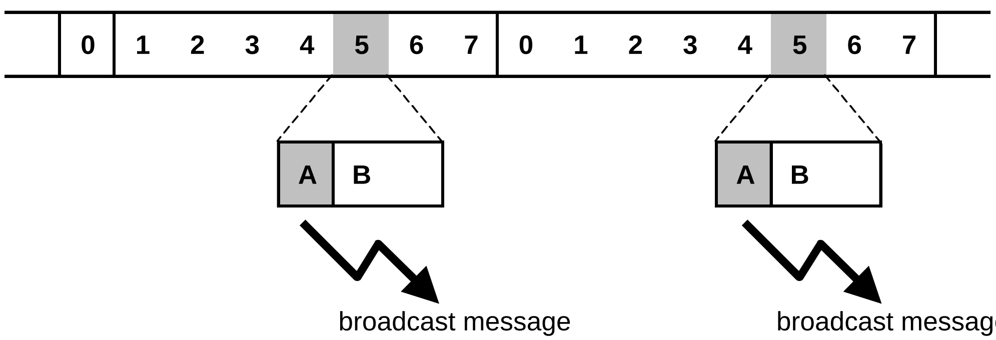
In EDCT the dummy bearer is usually separate to the traffic bearers, i.e. they are on different slots. In the case that 4 traffic bearers are required (the maximum number that can be supported by the FP) then one of the traffic bearers will also take over the responsibilities of the dummy bearer. In the remainder of the document this shall be referred to as a ‘combined dummy/traffic bearer’.

Since the traffic bearer is already carrying the same information as the dummy bearer, the ‘ combined dummy/traffic bearer’ is the same length as a normal traffic bearer. However, the combined dummy/traffic bearer has some restrictions (compared to a normal traffic bearer) with regards to frequency hopping as detailed later.

The following diagram shows the down-link transmission of a traffic bearer; the up-link transmission is in slot 1.



The following diagram shows a dummy bearer transmission. Note, that it uses only a down-link slot and the A-field of the packet.



3 OVERVIEW OF FREQUENCY HOPPING ALGORITHM

3.1 Hopping rate

Each bearer will change frequency channel, or hop, once per frame, i.e. the bearer hopping rate is 100 hops/second.

In the case of a traffic bearer this means that in a particular frame, both the down-link and up-link slots will use the same frequency channel.

With 4 active traffic bearers, each hopping at 100 hops/sec, there will be 800 frequency changes/second. However, because down-link and up-link use the same channel, this is only actually 400 channels/second.

3.2 Hopping Sequence

There are two methods employed for generating the hopping sequences: tables and random number generators (RNGs). Tables are hand-crafted to have specific properties and reverse table-lookup can be used to deduce the position in the table. RNGs generate very long period sequences which are less prone to ‘sequence collision’. <u>Both methods are employed in the EDCT system.</u>

3.2.1 Hopping pattern base-table

A dummy bearer or combined dummy/traffic bearer uses a table-generated hop sequence.

A single base-table is constructed containing a permutation of the channel numbers 0, 1, 2,…,74 (there are no repeats in the sequence). An extract is shown in the following table where ‘i’ is the index, and ‘F_0‘ is the base-table sequence.

i	**F_0(i)**
0	0
1	27
2	38
3	14
…	…
74	44

(This is only an extract; the full base table is shown in “Appendix B – Base-Table Hopping Sequence”).

From this one base-table, additional sequences are generated using the formula:

$$F_x(i) = (F_0 (i) + x) \bmod 75$$

The sequence index ‘i’ in the above formula is incremented, modulo 75, each frame. The value ‘x’ is used to select the required pattern. Due to the modulus there are 75 unique patterns permuted from this single base-table.

The following table shows an extract of the patterns.

i	$F_0(i)$	$F_1(i)$	$F_2(i)$	$F_3(i)$	…	$F_{74}(i)$
0	0	1	2	3	…	74
1	27	28	29	30	…	26
2	38	39	40	41	…	37
3	14	15	16	17	…	13
…	…	…	…	…	…	…
8	73	74	0	1	…	72
…	…	…	…	…	…	…
74	44	45	46	47	…	43

The base-table is hand-crafted to meet the following criteria:

- Pseudo-random.
- When any pattern is time-shifted with respect to any other pattern, the number of direct and adjacent channel collisions is minimised. In this context, because of the expected RF performance, adjacent should be taken to mean within 3 channels or less.
- When any pattern is time-shifted with respect to any other pattern, the number of direct or adjacent channel collisions on consecutive hops is minimised. Collisions are minimised for 2, 3 and 4 (or more) consecutive hops.
- Successive channels in the sequence are separated sufficiently to avoid microwave oven interference. In this context, a minimum channel separation of 6 or 8 MHz should be considered sufficient.

3.2.2 LCG random number generator

Traffic bearers use a pseudo-random number generated hop sequence. The random number generator (RNG) is a Linear Congruential Generator (LCG). The general form of an LCG is:

$$R_{n+1} = (a \times R_n + c) \mod m$$

A channel number in the range 0..74 is obtained by applying:

Channel number = $(75 \times R_n) / m$

In the above formula integer division is used. A particular LCG is denoted by LCG(m, a, c, R_0). The proposed RNG for EDCT is LCG(3000, $(2\times3\times4\times5\times7+1) = 841$, 787, R_0):

The modulus (m) is less than 2^{16} so that the ‘state’ can be stored in a single word (16 bits).

This is a full period generator, with a period of 3000, equivalent to 30 seconds and is also a multiple of 75. As such, all channels are used equally and all channels are used equally over a 30 second period.

The full 3000-long sequence is shown in “Appendix C – LCG Random Hopping Sequence”.

3.2.3 Logical and physical channel numbers

The techniques described so far generate channel numbers in the range 0..74. The EDCT system can use a total of 87 hopping channels (numbered from 1..88, avoiding channel 71, as described in section 2.1).

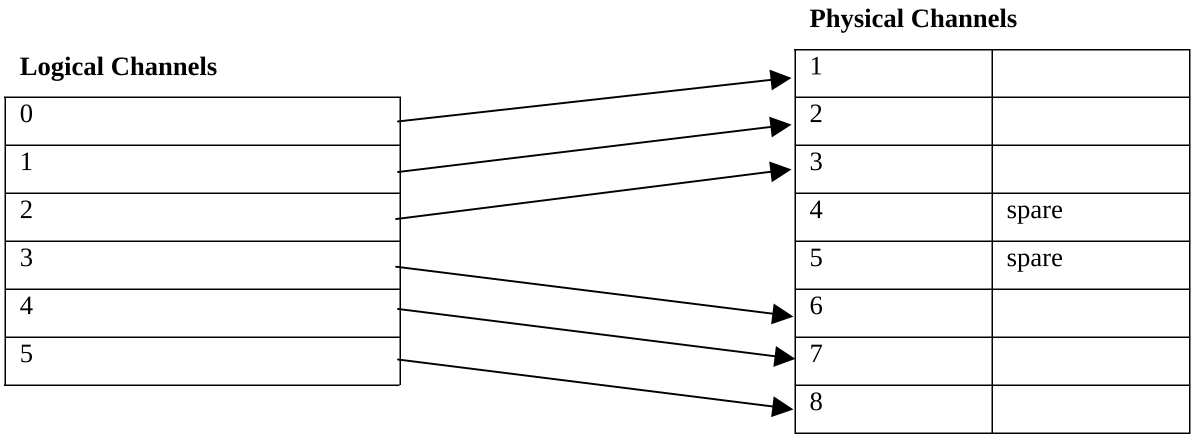
This results in 12 channels that are not part of the normal sequence and these are reserved as ‘ spare channels’ .

The spare channels are used to adapt the hop sequence, which is a method used by EDCT to avoid noisy frequency channels (see later).

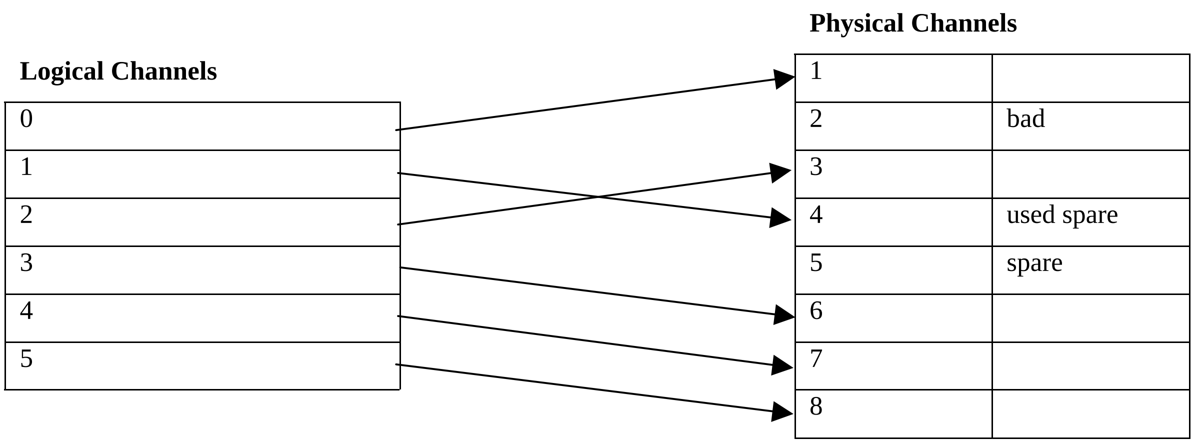
A mapping table is used to convert the ‘ logical channel number’ (in the range 0 ..74) given by the hopping sequence to the ‘ physical channel number’ (in the range 1 ..88) that is actually used.

An important feature of the mapping table is that it is always a one-to-one mapping, i.e. a physical channel is only ever ‘ mapped-onto’ by one logical channel. In this way the channel usage characteristics of the hop sequence are preserved.

For example, consider the following scenario for a small number of logical and physical channels:



Noisy channels can be adapted out of the sequence by ‘ channel swapping’ , i.e. swapping a good spare channel for a noisy channel. For example, swapping physical channels 1 and 3 gives:



Obviously, the above mapping table is an example. The actual mapping table is shown in “Appendix D – Logical To Physical Mapping Table”. It satisfies the following criteria:

It maps the 75 logical channels onto 87 physical channels, with a one-to-one mapping. This leaves 12 spare channels that are not used in the unadapted hopping sequence.

The spare channels are only positioned around the 2.45 GHz area. The reason for this is that interference from microwave ovens is most likely[1] to be centred on 2.45 GHz.

To facilitate robust 'sequence adaption' a requirement is that the basic underlying pattern should be changed as little as possible. This is achieved by always ensuring that the channels are swapped back to their original positions when the channel stops being noisy.

3.3 Identifying channel interference

Both the FP and PP can determine channel interference. Interference can be determined by:

- CRC errors on received packets.
- RSSI measurements.

Due to other users of the 2.4 GHz band, the EDCT system has to be tolerant to some interference. EDCT will not be able to avoid the 'random interference' produced by other frequency hopping systems such as Bluetooth or even other EDCT systems. However, it is possible to avoid 'relatively static interference' such as that caused by residential microwave ovens.

In order to distinguish between 'random interference' and 'relatively static interference' it is necessary to detect several successive CRC errors or take several RSSI measurements on a suspect channel. Only then is a channel flagged as being 'bad' – and therefore a candidate for adapting out of the sequence.

3.4 Hop sequence adaption

The hopping sequence will be adapted by channel swapping as described already in section 3.2.3.

In this system, there are only 12 spare channels. Therefore, a maximum of 12 channels can be adapted at any one time.

Only traffic bearers and combined dummy/traffic bearers will have their hop sequence adapted.

The FP decides which channels to swap based on information obtained about channel interference (see section 3.3). The FP will send a message to the PP to indicate the swapped channels. When the PP has acknowledged the message both the FP and the PP will adapt their mapping tables and hence their hopping sequences.

3.5 Starting a dummy bearer

As already mentioned, a FP will broadcast a dummy bearer all the time it is powered up and operating.

When creating a dummy bearer, the FP will select a slot and initial pattern at random.

In addition the FP will select an initial 'hop sequence index' (HSI) at random. The HSI indexes into the base table to select a logical channel. The HSI is incremented (modulo 75) each frame thereafter.

Once the slot, pattern and initial HSI are selected, a sequence of logical channels can be produced at the bearer hopping rate i.e. one hop *per* frame or 100 hops/sec.

The randomising of slot, pattern and HSI helps to spread out the use of hopping sequences amongst different FPs. However, because each FP will select their own slot, pattern and HSI independently there will be the occasional 'sequence collision'.

---

[1] Actual interference from residential microwave ovens varies greatly with model, loading, environment, time, etc. However, this is a good starting point – the spare channels have to go somewhere!

3.5.1 Avoiding dummy bearer ‘sequence collision’

Prior to starting a dummy bearer the FP takes RSSI measurements using the proposed slot and pattern. If these indicate no sequence collision then the dummy bearer is started on the proposed slot and pattern combination. Otherwise, a different slot/pattern pair will be selected, until no sequence collision is detected (or a maximum number of attempts).

Once the dummy bearer has been established, no further action is taken to detect (or correct for) sequence collision on the dummy bearer.

3.6 Gaining sync with a dummy bearer

A PP needs to gain sync with a FP’s dummy bearer. This involves:

- Synchronising in time, to align the TDMA frame structure.
- ‘Locking-on’ to the dummy bearer hopping sequence.

In order to align the TDMA frame structure the PP selects an initial channel to start searching. It then waits on that channel until a valid packet is received; this requires the hard-ware to lock onto the ‘sync-field’ at the start of the packet, which results in the TDMA frame structure being aligned. If a valid packet is not received in a certain time period then the PP will move to another channel and repeat the process.

The most frequently broadcast message on the dummy bearer is the N_T message. It is transmitted slightly less than every other frame. This message is used to convey the information required for a PP to ‘lock-onto’ a FP’s dummy bearer. However, the PP can only lock-onto a table-generated hopping sequence and so the PP can not use all N_T messages.

When an N_T message is received the PP checks he contents to see if it is from a table-generated hopping sequence. If it is then the PP can determine the dummy bearer pattern and the HSI (see section 3.6.1).

Searching continues, with the PP changing slot and/or channel until it receives an N_T message that it is able to use to ‘lock-onto’ an FP’s dummy bearer.

3.6.1 Determining the pattern and HSI from an N_T message

A dummy bearer hop sequence is table-generated. The sequence is 75 hops long. Knowing only the pattern number, which is encoded in the N_T message, and the channel number that the N_T message was received on, then the HSI can be found directly by reverse table-lookup. Only channels that are in the unadapted sequence are checked, as a PP can not deduce the HSI on an adapted channel.

Once the pattern number and HSI are determined the PP is able to follow the FP’s dummy bearer and it is said to be ‘locked-onto’ the FP.

3.7 Following a dummy bearer

Once the PP has locked-onto a FP’s dummy bearer it follows the dummy bearer hop sequence and receives broadcast messages from the FP. During this process it collects system information broadcast by the FP, including the dummy bearer slot number and PSPN (see later).

Any number of PPs can be locked-onto a particular FP’s dummy bearer.

A PP can enter into Low Duty Cycle (LDC) mode. In this mode the PP saves battery power by only receiving dummy bearer transmissions every 16 or 64 frames. This is sufficiently frequent for the PP to stay synchronised and to pick up ‘paging messages’ which contain information on incoming calls (and other system status information).

3.8 Starting a traffic bearer

In DECT and EDCT it is the PP that initiates the establishment of a traffic bearer. The PP does this by transmitting an ACCESS_REQUEST message to the FP. The FP constantly listens for ACCESS_REQUEST messages from PPs on all idle up-link slots, i.e., up-link slots that are not already being used for other traffic bearers.

Successive attempts to establish a traffic bearer use different patterns. This is achieved by the use of the Primary Scan Pattern Number (PSPN). The PSPN determines which pattern is used for a traffic bearer started in the current frame. The FP listens for ACCESS_REQUESTs on the channel determined by the PSPN pattern and its HSI.

The PSPN is incremented (modulo 75) in each frame whilst the FP is powered up and operating.

The PSPN is known to the PP because it is periodically transmitted on the dummy bearer. Thus once a system’s PSPN is known and a FP’s HSI is determined, the PP can determine what channel the FP will be listening to during its idle up-link slots.

The PP will select a pattern and slot to use and when the PSPN indicates the selected pattern, the ACCESS_REQUEST is transmitted on the appropriate channel and slot. To avoid a long latency whilst the selected pattern ‘comes around’ on the PSPN, the PP selects a pattern that will occur in N frames time. Where N is both small and determined randomly so as to avoid multiple PPs continually colliding whilst trying to establish traffic bearers.

The ACCESS_REQUEST message contains the identity of the FP to indicate which FP the message is directed at. The requested FP must respond in the next half-frame either with a WAIT or with a BEARER_CONFIRM or with a RELEASE.

(This system may seem obscure, but it is a direct consequence of the DECT protocol from which the EDCT protocol was derived.)

In EDCT there are two possible modes of operation:

- The selected pattern is only used for the very first frame. After which both the FP and PP will have synchronised their RNG with the same ‘seed’ and the random sequence is started and used for the next frame’s channel.
- The FP and PP never switch to using a RNG generated hop sequence and instead continue to use the selected table-based pattern.

Traffic bearers normally use a RNG generated hop sequence.

3.8.1 Avoiding traffic bearer ‘sequence collision’

Due to the longer period of a RNG-generated hop sequence, the probability of ‘sequence collision’ on a traffic bearer is much lower than on a table-generated sequence.

Prior to starting a traffic bearer RSSI measurements are taken using the proposed slot and pattern. If these indicate no sequence collision then the traffic bearer is started on the proposed slot and pattern combination. No further action is taken to detect (or correct for) sequence collision.

3.9 Starting a combined dummy/traffic bearer

The PP may require to establish a traffic bearer on the slot currently carrying the dummy bearer, usually only when it is the last slot available to it. The PP must use the same pattern that the dummy bearer is currently using.

If the PP has to wait for the dummy bearer pattern to ‘ come around’ on the PSPN this might introduce a long latency. To avoid this, the FP always listens to the channel dictated by the dummy bearer pattern on the slot that is the pair of the dummy bearer transmission.

3.9.1 Avoiding combined dummy/traffic bearer ‘ sequence collision’

No action is taken to avoid sequence collision.

4 CONFORMANCE TO FCC REQUIREMENTS

The following sections show how the EDCT system conforms to the appropriate FCC requirements:

4.1 Section 15.247(a)(1)

The hopping channel carrier frequencies are separated by 891.871KHz.

Each bearer is independent and hops at a rate of 100 hops/sec.

The hopping sequence is either table generated or RNG generated:

A table-generated hop sequence is 75 hops long, each channel is used exactly once in the sequence. Therefore, in a 30 second period each frequency channel is used exactly 40 times in that sequence.

An RNG-generated hop sequence is 3000 hops long, each channel is used exactly 40 times in the entire sequence. Therefore, in a 30 second period each frequency channel is used exactly 40 times in that sequence.

The hopping sequence contains 75 logical channels these are mapped-onto 75 physical channels using a mapping table (see section 3.2.3 and "Appendix D – Logical To Physical Mapping Table").

The highest channel occupancy occurs when a FP has 4 traffic bearers, i.e. 4 Tx slots utilised, each using the same hopping sequence. As shown previously, for a given sequence, in a 30 second period each frequency channel is used exactly 40 times. The active transmission time in a slot is 937.5µs. Therefore the average time of occupancy on any frequency channel in a 30 second period is:

$T = 937.5\mu s \times 40 \times 4 = 150.0$ ms < 400mS (FCC Occupancy Limit)

As a comparison, the lowest channel occupancy occurs when only a single dummy bearer is being transmitted. Because only the A-field is used on a dummy bearer, the transmission is only 236.1µs long, therefore the average time of occupancy on any frequency channel in a 30 second period is:

$T = 236.1\mu s \times 40 \times 1 = 9.444$ ms

The maximum 20 dB bandwidth of the hopping channel is less than 891.871 kHz.

The 3 dB bandwidth of the receiver input is 850KHz.

A packet is sent once *per* frame *per* bearer for the duration of the bearer; packets are not resent.

See section 3.6 for a description of how the receiver gains synchronisation with the transmitter, i.e. a dummy bearer.

4.2 Section 15.247(b)(1)

The maximum peak output power of the intentional radiator is <u>90mW</u>

4.3 Section 15.247(g)

In the case of the dummy bearer, which the FP transmits all the time it is powered up and operating, the hopping sequence cycles through the 75 hops in the selected hopping pattern and then repeats.

In the case of a traffic bearer presented with continuous data, which is the normal case --- as this is a voice system, the hopping sequence cycles through either 3000 hops before repeating for a RNG based sequence or cycles through 75 hops before repeating for a table-based sequence.

In the case of a traffic bearer transmitting short bursts, for example, which may happen if a PP has several failed attempts[2] to establish a traffic bearer, then successive traffic bearers will start on different patterns because the PSPN is incremented each frame – see section 3.8.

Note that this system is a voice system and short burst transmissions are not typical.

4.4 Section 15.247(h)

There is no coordination between transmitters for the purpose of avoiding the simultaneous occupancy of hopping frequencies by transmitters in multiple EDCT systems.

Communication only ever takes place between one FP and a PP, never between two FPs or two PPs. (In handset-to-handset mode a PP becomes effectively a FP.) It is actually impossible for a FP to receive a FP packet or a PP to receive a PP packet because their respective 'sync-fields' are different.

An FP and a PP that have an active traffic bearer between them share a common hopping sequence and hop sequence adaption information, i.e. swapped channels. However, neither the FP nor the PP transmits this information to a third party, for any purpose whatsoever.

In actual fact, channel collisions between FPs and PPs can and will take place. These may result in reduced voice quality, but this has to be tolerated.

When two transmitters with overlapping radio cells are using the same slot, pattern and phase within the pattern there is sequence collision. This is detected by the occurrence of multiple, consecutive, corrupted packets. If sequence collision happens on a dummy bearer or a combined dummy/traffic bearer then the FP will randomly select a new pattern. If sequence collision happens on a traffic bearer no action is taken.

[2] The protocol actually limits the number of re-tries to 11 before giving up on the connection.

APPENDIX A – CHANNEL CENTRE FREQUENCIES

The following table lists the channel centre frequencies as detailed in section 2.1.

Physical Channel Number	Centre Frequency (MHz)	Physical Channel Number	Centre Frequency (MHz)	Physical Channel Number	Centre Frequency (MHz)
1	2401.808203	31	2428.564307	61	2455.320410
2	2402.698096	32	2429.454199	62	2456.210303
3	2403.591943	33	2430.348047	63	2457.104150
4	2404.481836	34	2431.237939	64	2457.994043
5	2405.375684	35	2432.131787	65	2458.887891
6	2406.265576	36	2433.021680	66	2459.777783
7	2407.159424	37	2433.915527	67	2460.671631
8	2408.050000	38	2434.805420	68	2461.561523
9	2408.943164	39	2435.699268	69	2462.455371
10	2409.833057	40	2436.589160	70	2463.345264
11	2410.726904	41	2437.483008	71	2464.239111
12	2411.616797	42	2438.372900	72	2465.129004
13	2412.510645	43	2439.266748	73	2466.022852
14	2413.400537	44	2440.156641	74	2466.912744
15	2414.294385	45	2441.050488	75	2467.806592
16	2415.184277	46	2441.940381	76	2468.696484
17	2416.078125	47	2442.834229	77	2469.590332
18	2416.968018	48	2443.724121	78	2470.480225
19	2417.861865	49	2444.617969	79	2471.374072
20	2418.751758	50	2445.507861	80	2472.263965
21	2419.645605	51	2446.401709	81	2473.157813
22	2420.535498	52	2447.291602	82	2474.047705
23	2421.429346	53	2448.185449	83	2474.941553
24	2422.319238	54	2449.075342	84	2475.831445
25	2423.213086	55	2449.969189	85	2476.725293
26	2424.102979	56	2450.859082	86	2477.615186
27	2424.996826	57	2451.752930	87	2478.509033
28	2425.886719	58	2452.642822	88	2479.398926
29	2426.780566	59	2453.536670		
30	2427.670459	60	2454.426563		

APPENDIX B – BASE-TABLE HOPPING SEQUENCE

The following table, arranged as an 8 $\times$ 10 grid, is the base table for the hopping sequence as detailed in section 3.2.1. The sequence is 75 hops long.

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	0	27	38	14	26	49	13	33	73	55
10	16	1	11	54	8	64	2	48	28	61
20	4	40	65	6	23	67	57	42	12	29
30	62	36	47	5	71	43	32	56	21	59
40	39	15	53	18	45	37	74	63	46	3
50	51	31	72	58	9	70	35	69	25	34
60	50	60	68	22	52	24	41	7	17	30
70	19	10	20	66	44					

APPENDIX C – LCG RANDOM HOPPING SEQUENCE

The following table, is the random channel sequence produced by the LCG random number generator as detailed in section 3.2.2. The sequence is 3000 hops long.

	0	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**
0	0	19	66	20	60	68	73	29	43	69
10	61	51	68	66	2	55	29	31	15	10
20	48	8	69	38	19	41	61	33	61	27
30	35	39	71	10	35	28	18	34	33	44
40	22	71	73	57	52	15	50	36	5	61
50	8	28	0	28	69	2	6	38	52	2
60	70	60	1	0	11	63	38	40	23	19
70	57	16	3	47	27	50	70	41	70	36
80	44	48	5	19	44	37	27	43	42	53
90	30	5	7	65	61	24	58	45	14	69
100	17	37	8	37	3	10	15	47	60	11
110	4	68	10	9	19	72	47	48	32	28
120	66	25	12	56	36	59	4	50	4	45
130	52	57	14	27	53	46	35	52	51	61
140	39	14	15	74	70	32	67	54	22	3
150	26	45	17	46	11	19	24	55	69	20
160	13	2	19	18	28	6	56	57	41	37
170	74	34	21	64	45	68	12	59	13	53
180	61	66	22	36	62	54	44	61	59	70
190	48	22	24	8	3	41	1	62	31	12
200	35	54	26	55	20	28	33	64	3	29
210	21	11	28	26	37	15	64	66	50	45
220	8	43	29	73	54	1	21	68	21	62
230	70	74	31	45	70	63	53	69	68	4
240	57	31	33	17	12	50	10	71	40	21
250	43	63	35	63	29	37	41	73	12	37
260	30	20	36	35	46	23	73	0	58	54
270	17	51	38	7	62	10	30	1	30	71
280	4	8	40	54	4	72	62	3	2	13
290	65	40	42	25	21	59	18	5	49	29

300	52	72	43	72	38	45	50	7	20	46
310	39	28	45	44	54	32	7	8	67	63
320	26	60	47	16	71	19	39	10	39	5
330	12	17	49	62	13	6	70	12	11	21
340	74	49	50	34	30	67	27	14	57	38
350	61	5	52	6	46	54	59	15	29	55
360	48	37	54	53	63	41	16	17	1	72
370	34	69	56	24	5	28	47	19	48	13
380	21	26	57	71	22	14	4	21	19	30
390	8	57	59	43	38	1	36	22	66	47
400	70	14	61	15	55	63	68	24	38	64
410	56	46	63	61	72	50	24	26	10	5
420	43	3	64	33	14	36	56	28	56	22
430	30	34	66	5	30	23	13	29	28	39
440	17	66	68	52	47	10	45	31	0	56
450	3	23	70	23	64	72	1	33	47	72
460	65	55	71	70	6	58	33	35	18	14
470	52	11	73	42	22	45	65	36	65	31
480	39	43	0	14	39	32	22	38	37	48
490	25	0	2	60	56	19	53	40	9	64
500	12	32	3	32	73	5	10	42	55	6
510	74	63	5	4	14	67	42	43	27	23
520	61	20	7	51	31	54	74	45	74	40
530	47	52	9	22	48	41	30	47	46	56
540	34	9	10	69	65	27	62	49	17	73
550	21	40	12	41	6	14	19	50	64	15
560	8	72	14	13	23	1	51	52	36	32
570	69	29	16	59	40	63	7	54	8	48
580	56	61	17	31	57	49	39	56	54	65
590	43	17	19	3	73	36	71	57	26	7
600	30	49	21	50	15	23	28	59	73	24
610	16	6	23	21	32	10	59	61	45	40
620	3	38	24	68	49	71	16	63	16	57
630	65	69	26	40	65	58	48	64	63	74
640	52	26	28	12	7	45	5	66	35	16

650	38	58	30	58	24	32	36	68	7	32
660	25	15	31	30	41	18	68	70	53	49
670	12	46	33	2	57	5	25	71	25	66
680	74	3	35	49	74	67	57	73	72	8
690	60	35	37	20	16	54	13	0	44	24
700	47	67	38	67	33	40	45	2	15	41
710	34	23	40	39	49	27	2	3	62	58
720	21	55	42	11	66	14	34	5	34	0
730	7	12	44	57	8	1	65	7	6	16
740	69	44	45	29	25	62	22	9	52	33
750	56	0	47	1	41	49	54	10	24	50
760	43	32	49	48	58	36	11	12	71	67
770	29	64	51	19	0	23	42	14	43	8
780	16	21	52	66	17	9	74	16	14	25
790	3	52	54	38	33	71	31	17	61	42
800	65	9	56	10	50	58	63	19	33	59
810	51	41	58	56	67	45	19	21	5	0
820	38	73	59	28	9	31	51	23	51	17
830	25	29	61	0	25	18	8	24	23	34
840	12	61	63	47	42	5	40	26	70	51
850	73	18	65	18	59	67	71	28	42	67
860	60	50	66	65	1	53	28	30	13	9
870	47	6	68	37	17	40	60	31	60	26
880	34	38	70	9	34	27	17	33	32	43
890	20	70	72	55	51	14	48	35	4	59
900	7	27	73	27	68	0	5	37	50	1
910	69	58	0	74	9	62	37	38	22	18
920	56	15	2	46	26	49	69	40	69	35
930	42	47	4	17	43	36	25	42	41	51
940	29	4	5	64	60	22	57	44	12	68
950	16	35	7	36	1	9	14	45	59	10
960	3	67	9	8	18	71	46	47	31	27
970	64	24	11	54	35	58	2	49	3	43
980	51	56	12	26	52	44	34	51	49	60
990	38	12	14	73	68	31	66	52	21	2

1000	25	44	16	45	10	18	23	54	68	19
1010	11	1	18	16	27	5	54	56	40	35
1020	73	33	19	63	44	66	11	58	11	52
1030	60	64	21	35	60	53	43	59	58	69
1040	47	21	23	7	2	40	0	61	30	11
1050	33	53	25	53	19	27	31	63	2	27
1060	20	10	26	25	36	13	63	65	48	44
1070	7	41	28	72	52	0	20	66	20	61
1080	69	73	30	44	69	62	52	68	67	3
1090	55	30	32	15	11	49	8	70	39	19
1100	42	62	33	62	28	35	40	72	10	36
1110	29	18	35	34	44	22	72	73	57	53
1120	16	50	37	6	61	9	29	0	29	70
1130	2	7	39	52	3	71	60	2	1	11
1140	64	39	40	24	20	57	17	4	47	28
1150	51	70	42	71	36	44	49	5	19	45
1160	38	27	44	43	53	31	6	7	66	62
1170	24	59	46	14	70	18	37	9	38	3
1180	11	16	47	61	12	4	69	11	9	20
1190	73	47	49	33	28	66	26	12	56	37
1200	60	4	51	5	45	53	58	14	28	54
1210	46	36	53	51	62	40	14	16	0	70
1220	33	68	54	23	4	26	46	18	46	12
1230	20	24	56	70	20	13	3	19	18	29
1240	7	56	58	42	37	0	35	21	65	46
1250	68	13	60	13	54	62	66	23	37	62
1260	55	45	61	60	71	48	23	25	8	4
1270	42	1	63	32	12	35	55	26	55	21
1280	29	33	65	4	29	22	12	28	27	38
1290	15	65	67	50	46	9	43	30	74	54
1300	2	22	68	22	63	70	0	32	45	71
1310	64	53	70	69	4	57	32	33	17	13
1320	51	10	72	41	21	44	64	35	64	30
1330	37	42	74	12	38	31	20	37	36	46
1340	24	74	0	59	55	17	52	39	7	63

1350	11	30	2	31	71	4	9	40	54	5
1360	73	62	4	3	13	66	41	42	26	22
1370	59	19	6	49	30	53	72	44	73	38
1380	46	51	7	21	47	39	29	46	44	55
1390	33	7	9	68	63	26	61	47	16	72
1400	20	39	11	40	5	13	18	49	63	14
1410	6	71	13	11	22	0	49	51	35	30
1420	68	28	14	58	39	61	6	53	6	47
1430	55	59	16	30	55	48	38	54	53	64
1440	42	16	18	2	72	35	70	56	25	6
1450	28	48	20	48	14	22	26	58	72	22
1460	15	5	21	20	31	8	58	60	43	39
1470	2	36	23	67	47	70	15	61	15	56
1480	64	68	25	39	64	57	47	63	62	73
1490	50	25	27	10	6	44	3	65	34	14
1500	37	57	28	57	23	30	35	67	5	31
1510	24	13	30	29	39	17	67	68	52	48
1520	11	45	32	1	56	4	24	70	24	65
1530	72	2	34	47	73	66	55	72	71	6
1540	59	34	35	19	15	52	12	74	42	23
1550	46	65	37	66	31	39	44	0	14	40
1560	33	22	39	38	48	26	1	2	61	57
1570	19	54	41	9	65	13	32	4	33	73
1580	6	11	42	56	7	74	64	6	4	15
1590	68	42	44	28	23	61	21	7	51	32
1600	55	74	46	0	40	48	53	9	23	49
1610	41	31	48	46	57	35	9	11	70	65
1620	28	63	49	18	74	21	41	13	41	7
1630	15	19	51	65	15	8	73	14	13	24
1640	2	51	53	37	32	70	30	16	60	41
1650	63	8	55	8	49	57	61	18	32	57
1660	50	40	56	55	66	43	18	20	3	74
1670	37	71	58	27	7	30	50	21	50	16
1680	24	28	60	74	24	17	7	23	22	33
1690	10	60	62	45	41	4	38	25	69	49

1700	72	17	63	17	58	65	70	27	40	66
1710	59	48	65	64	74	52	27	28	12	8
1720	46	5	67	36	16	39	59	30	59	25
1730	32	37	69	7	33	26	15	32	31	41
1740	19	69	70	54	50	12	47	34	2	58
1750	6	25	72	26	66	74	4	35	49	0
1760	68	57	74	73	8	61	36	37	21	17
1770	54	14	1	44	25	48	67	39	68	33
1780	41	46	2	16	42	34	24	41	39	50
1790	28	2	4	63	58	21	56	42	11	67
1800	15	34	6	35	0	8	13	44	58	9
1810	1	66	8	6	17	70	44	46	30	25
1820	63	23	9	53	34	56	1	48	1	42
1830	50	54	11	25	50	43	33	49	48	59
1840	37	11	13	72	67	30	65	51	20	1
1850	23	43	15	43	9	17	21	53	67	17
1860	10	0	16	15	26	3	53	55	38	34
1870	72	31	18	62	42	65	10	56	10	51
1880	59	63	20	34	59	52	42	58	57	68
1890	45	20	22	5	1	39	73	60	29	9
1900	32	52	23	52	18	25	30	62	0	26
1910	19	8	25	24	34	12	62	63	47	43
1920	6	40	27	71	51	74	19	65	19	60
1930	67	72	29	42	68	61	50	67	66	1
1940	54	29	30	14	10	47	7	69	37	18
1950	41	60	32	61	26	34	39	70	9	35
1960	28	17	34	33	43	21	71	72	56	52
1970	14	49	36	4	60	8	27	74	28	68
1980	1	6	37	51	2	69	59	1	74	10
1990	63	37	39	23	18	56	16	2	46	27
2000	50	69	41	70	35	43	48	4	18	44
2010	36	26	43	41	52	30	4	6	65	60
2020	23	58	44	13	69	16	36	8	36	2
2030	10	14	46	60	10	3	68	9	8	19
2040	72	46	48	32	27	65	25	11	55	36

2050	58	3	50	3	44	52	56	13	27	52
2060	45	35	51	50	61	38	13	15	73	69
2070	32	66	53	22	2	25	45	16	45	11
2080	19	23	55	69	19	12	2	18	17	28
2090	5	55	57	40	36	74	33	20	64	44
2100	67	12	58	12	53	60	65	22	35	61
2110	54	43	60	59	69	47	22	23	7	3
2120	41	0	62	31	11	34	54	25	54	20
2130	27	32	64	2	28	21	10	27	26	36
2140	14	64	65	49	45	7	42	29	72	53
2150	1	20	67	21	61	69	74	30	44	70
2160	63	52	69	68	3	56	31	32	16	12
2170	49	9	71	39	20	43	62	34	63	28
2180	36	41	72	11	37	29	19	36	34	45
2190	23	72	74	58	53	16	51	37	6	62
2200	10	29	1	30	70	3	8	39	53	4
2210	71	61	3	1	12	65	39	41	25	20
2220	58	18	4	48	29	51	71	43	71	37
2230	45	49	6	20	45	38	28	44	43	54
2240	32	6	8	67	62	25	60	46	15	71
2250	18	38	10	38	4	12	16	48	62	12
2260	5	70	11	10	21	73	48	50	33	29
2270	67	26	13	57	37	60	5	51	5	46
2280	54	58	15	29	54	47	37	53	52	63
2290	40	15	17	0	71	34	68	55	24	4
2300	27	47	18	47	13	20	25	57	70	21
2310	14	3	20	19	29	7	57	58	42	38
2320	1	35	22	66	46	69	14	60	14	55
2330	62	67	24	37	63	56	45	62	61	71
2340	49	24	25	9	5	42	2	64	32	13
2350	36	55	27	56	21	29	34	65	4	30
2360	23	12	29	28	38	16	66	67	51	47
2370	9	44	31	74	55	3	22	69	23	63
2380	71	1	32	46	72	64	54	71	69	5
2390	58	32	34	18	13	51	11	72	41	22

2400	45	64	36	65	30	38	43	74	13	39
2410	31	21	38	36	47	25	74	1	60	55
2420	18	53	39	8	64	11	31	3	31	72
2430	5	9	41	55	5	73	63	4	3	14
2440	67	41	43	27	22	60	20	6	50	31
2450	53	73	45	73	39	47	51	8	22	47
2460	40	30	46	45	56	33	8	10	68	64
2470	27	61	48	17	72	20	40	11	40	6
2480	14	18	50	64	14	7	72	13	12	23
2490	0	50	52	35	31	69	28	15	59	39
2500	62	7	53	7	48	55	60	17	30	56
2510	49	38	55	54	64	42	17	18	2	73
2520	36	70	57	26	6	29	49	20	49	15
2530	22	27	59	72	23	16	5	22	21	31
2540	9	59	60	44	40	2	37	24	67	48
2550	71	15	62	16	56	64	69	25	39	65
2560	58	47	64	63	73	51	26	27	11	7
2570	44	4	66	34	15	38	57	29	58	23
2580	31	36	67	6	32	24	14	31	29	40
2590	18	67	69	53	48	11	46	32	1	57
2600	5	24	71	25	65	73	3	34	48	74
2610	66	56	73	71	7	60	34	36	20	15
2620	53	13	74	43	24	46	66	38	66	32
2630	40	44	1	15	40	33	23	39	38	49
2640	27	1	3	62	57	20	55	41	10	66
2650	13	33	5	33	74	7	11	43	57	7
2660	0	65	6	5	16	68	43	45	28	24
2670	62	21	8	52	32	55	0	46	0	41
2680	49	53	10	24	49	42	32	48	47	58
2690	35	10	12	70	66	29	63	50	19	74
2700	22	42	13	42	8	15	20	52	65	16
2710	9	73	15	14	24	2	52	53	37	33
2720	71	30	17	61	41	64	9	55	9	50
2730	57	62	19	32	58	51	40	57	56	66
2740	44	19	20	4	0	37	72	59	27	8

2750	31	50	22	51	16	24	29	60	74	25
2760	18	7	24	23	33	11	61	62	46	42
2770	4	39	26	69	50	73	17	64	18	58
2780	66	71	27	41	67	59	49	66	64	0
2790	53	27	29	13	8	46	6	67	36	17
2800	40	59	31	60	25	33	38	69	8	34
2810	26	16	33	31	42	20	69	71	55	50
2820	13	48	34	3	59	6	26	73	26	67
2830	0	4	36	50	0	68	58	74	73	9
2840	62	36	38	22	17	55	15	1	45	26
2850	48	68	40	68	34	42	46	3	17	42
2860	35	25	41	40	51	28	3	5	63	59
2870	22	56	43	12	67	15	35	6	35	1
2880	9	13	45	59	9	2	67	8	7	18
2890	70	45	47	30	26	64	23	10	54	34
2900	57	2	48	2	43	50	55	12	25	51
2910	44	33	50	49	59	37	12	13	72	68
2920	31	65	52	21	1	24	44	15	44	10
2930	17	22	54	67	18	11	0	17	16	26
2940	4	54	55	39	35	72	32	19	62	43
2950	66	10	57	11	51	59	64	20	34	60
2960	53	42	59	58	68	46	21	22	6	2
2970	39	74	61	29	10	33	52	24	53	18
2980	26	31	62	1	27	19	9	26	24	35
2990	13	62	64	48	43	6	41	27	71	52

APPENDIX D – LOGICAL TO PHYSICAL MAPPING TABLE

APPENDIX E – MEASUREMENT METHODS FOR VALIDATING FCC CHANNEL OCCUPANCY COMPLIANCE

This Appendix describes 2 methods for validating FCC Channel Occupancy compliance of the EDCT system:

Method 1: Simple test setup using Spectrum Analyzer, 1BS and 1 HS. This method involves some approximation

Method 2: More complex test setup, accomodating 1BS and up to 4 HS, with exact result

Refer to separate plot sequence called “FCC Chan Ocu, Mar24” for referenced plots. Best to perform these tests with a BS/HS pair at close range, with no interferers in the vicinity such that Channel Adaptation is not activated.

Method 1: Simple, approximation method

Setup: BS airlinked to 1HS (no multi-slot) via airlink, one antenna outfitted with coaxial connector cabled to SA. Due to SA “video” limitations, it is much easier to perform this measurement with 1HS and extrapolate result to 4HS.

Step 1: Establish close range, Frequency Hopping “Talk Link” between BS and HS and use the Max Hold SA function to verify that CH55dec (2400.157MHz or any other desired CH) is currently in use – See Plot 1.

Step 2: Establish Single Channel BS/HS Link on Ch55 and measure peak output power using RBW=VBW = 100KHz and Max Hold – See Plot 2 (ie 17dBm). Verify also that when other antenna is selected, that the output level is approximately –10dBc (not shown).

Step 3: Establish Single Channel BS/HS Link on Ch54 and measure how many dBc down the energy is in Ch55 – See Plot 3 (ie –30dBc).

Step 4: Establish Single Channel BS/HS Link on Ch56 and measure how many dBc down the energy is in Ch55 – See Plot 4 (ie –41dBc).

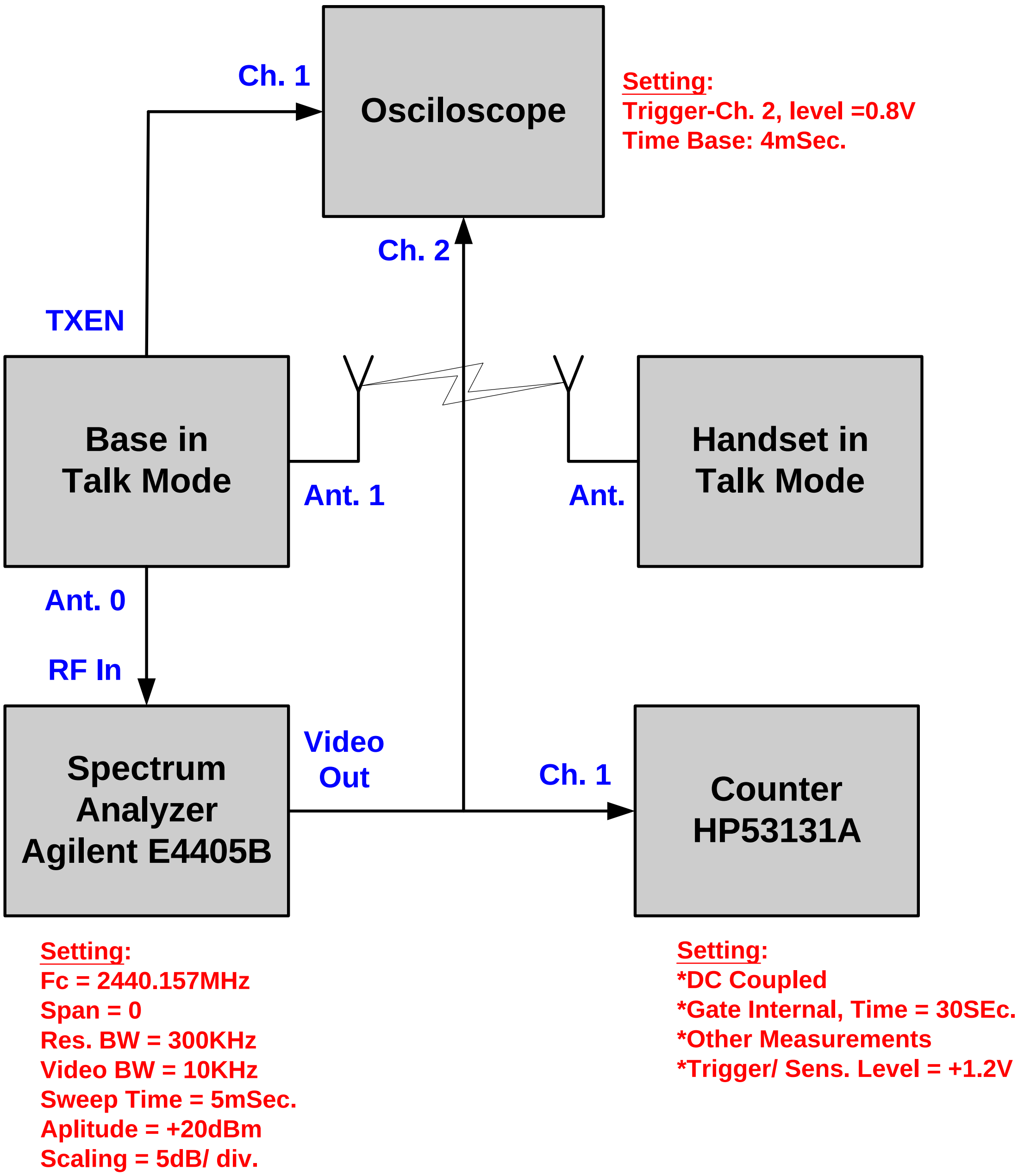
Step 5: Reinstate Frequency Hopping “Talk” Link and retune SA for 3s Sweep and perform a Single Sweep - See Plot 5. All peak power and –10dBc “spikes” are labeled as CH55 hits. All “spikes” at –30 and –40dBc are adjacent channel “hits” and are ingnored. Thus, 8 “hits” are recorded over this particular 3s period. Repeat this Single Sweep ~10 times and record average number of “hits” on Ch. 55 = HIT_AVG_{55}. Extrapolating from 3s to 30s we have 10* HIT_AVG_{55} = # of hits for 30s period.

Step 6: Hit the OFF button to discontinue the traffic bearer and observe only the “dummy bearer” – See Plot 6. Note 4 Ch55 “hits” for the case of a single dummy bearer. Again, Single sweeps can be used to obtain an average for 3s which can be extrapolated to 30s.

Discussion: Given the discussion on Section 4 above, for the case of a dummy bearer only, we would expect 40 hits over the 30s period. For a dummy bearer + traffic bearer, we would expect 80 hits. Extrapolating to 4 HS (4 traffic bearers) we would expect 4*40 = 160 “hits” . Each “hit” has duration of ~1mS. Thus a “fully loaded” BS has a 160mS duration on Ch55 over the 30s period. The averaging method above should bear this out pretty closely.

Method 2: Exact Method

Setup: See Figure below



Step 1: Establish Single Channel "Talk mode" BS/HS Link on Ch55. Note SA Video output level on Scope for both Antenna Selections. Repeat for Adjacent Channels – See Plot 7. Note that a "pulse threshold" = 1.2V clearly indicates a Ch55 "hit".

Step 2: Test "hypothesis" by setting Counter, GATE Internal Time = 1s. For "Talk Mode" on Ch55 you should obtain a "solid" 200 reading (2 "hits" per frame). For Talk mode on Ch54 or Ch56 you should obtain a "solid" 0.

Step 3: Now return to Frequency Hopping Link, keeping SA setting as above and returning Gate Internal Timing = 30s. In this case (dummy + traffic), the Ch55 “hit” count will = 80 precisely. Return to Dummy bearer only and count 40, configure 2 HS in Talk and count 3*40 = 120 etc…