Circuit Description

Model: 35818

The following circuit description for model 35818 is based on the circuit diagram and block diagram of 35818

Handset Unit

1. Receiving Path

The receiving path is established as below sections

Antenna, Low Noise Filter, Mixer, Band Pass Filters, and Demodulator

RF signal is pick up by a RX soft wire antenna (ANT1) and then filtered by the 5.8GHz Band Pass filter (F1), it then go through the 5.8GHz Low Noise Filter make by 2SC5594 (Q5), and then mix with the 3.36GHz signal which produced by S1T8825B (U2) PLL IC, 2SC5066 (Q3), BFR183T (Q4) and 2SC5594 (Q6) Local Oscillator, and the 3.36GHz Band Pass Filter constructed by L15 and C75 in the NESG2031 (Q7) Mixer. After that, the signal passes the 2.4GHz Band Pass Filter make by L1 and C13. Finally it inputs to RX of U1 (DH24RF17) transceiver IC. Then though mixer and FSK data output from demodulator

FSK data demodulate

The FSK data is output form DH24RF17 transceiver IC, then go to EDCT controller chip DLH36107 for decode to an audio signal before output to the handset speaker though audio amplifier.

2. Transmitting Path

The transmitting path is established as below sections

MIC amplifier and encoder

Audio signal pick up by handset microphone is amplified by internal MIC amplifier of U2 DLH36107 EDCT controller, then go to encoding.

Modulator, RF Power amplifier and Antenna

The FSK data is output from the EDCT controller chip, then input to transceiver IC DH24RF17. The modulated signals go to power amplifier is constructed by Q1A (2SC5754), then pass though the 2.4GHz Band Pass Filter (FL1). Finally, the RF signal propagates though a TX solid wire antenna (ANT2).

Base Unit

1. Receiving Path

The receiving path is established as below sections

Antenna, Mixer, Demodulator

RF signal is picked up by a RX solid wire antenna (ANT2) and then filtered by the 2.4GHz Band Pass filter (FL2), and input to RX of U1 (DH24RF17) transceiver IC. Then though mixer and FSK data output from demodulator

FSK data demodulate

The FSK data is output form DH24RF17 transceiver IC, then go to EDCT controller chip DLH36569 for decode to an audio signal before output to the handset speaker though audio amplifier.

2. Transmitting Path

The transmitting path is established as below sections

Amplifier and encoder

Audio signal come from line interface is amplified by internal amplifier of U1 DLH36569 EDCT controller, then go to encoding.

Antenna, Low Noise Filter, Mixer, Band Pass Filters, and Modulator

The FSK data is output from the EDCT controller chip, then input to transceiver IC DH24RF17. The 2.4GHz modulated signals first mix with the 3.36GHz signal produced by S1T8825B (U2) PLL IC, 2SC5065 (Q8, Q3), 2C5594 (Q5) Local Oscillator, 3.36GHz Band Pass Filter (F3) in NESG2031 (Q4) Mixer to produce a 5.8GHz signal. The 5.8GHz signal then pass through the 5.8GHz Band Pass Filter (F1) before it pass the Buffer Amplifier constructed by Q6, Q7 2SC5594, and Q10 NESG2031. After that, it goes through a

5.8GHz Band Pass Filter (F4) and input to Murata XM5060PC Power Amplifier IC. Finally, after it passing a Low Pass Filter constructed by C23 and C90, the RF signal propagate through a TX solid wire antenna (ANT1)

3. Telephone Line interface

The telephone line interface circuit is established by below sections

Line seize and isolation

Line isolation is mainly preformed by Q13, Q14 and Q7, Q8. Q7, Q8 also have a function of controlling Line-seize. Both audio input and output will though Q13 and Q14.

Input audio signal from the telephone line is fed to U1 by Q12.

Output audio signal from U1 is sent to line after amplified by Q15 and Q18.

The incoming call can be answered with cordless handset through RF channel, or with Speakerphone on Base side or by Answering Machine on the Base Unit.

Ring detect circuit.

The ring signals though C43, C44, R113 and R114 input to U1 DLH36569 EDCT controller to detect the ring and then alert the user to answer the call.

Caller ID System

The CID signals through C43, C44, R113, and R114 input to U1 DLH36569 EDCT controller to demodulate the CID data and then displayed on LCD displays of both the base and the handset.

Answering Machine

All answering machine signals are processed by U1 DLH36569 EDCT controller, and the voice prompt is stored in U8 AT45DB041B Flash Memory IC.

Duplex Speakerphone System

Duplex Speakerphone signals are processed by U1 DLH36569 EDCT controller.

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'. Both methods are employed in the EDCT system.

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, (2×3×4×5×7+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).

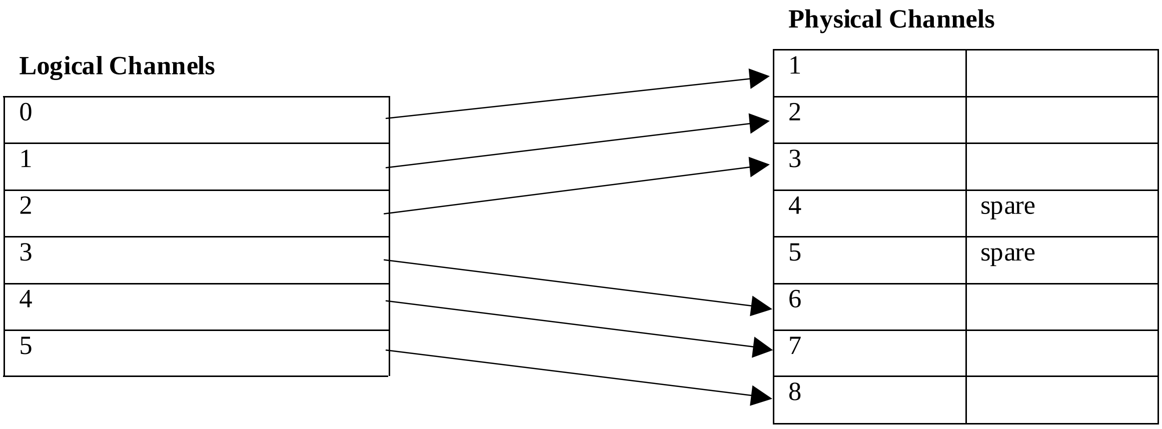
This results in 12 channels that are not part of the normal sequence and these are reserved as 'spare channels'.

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

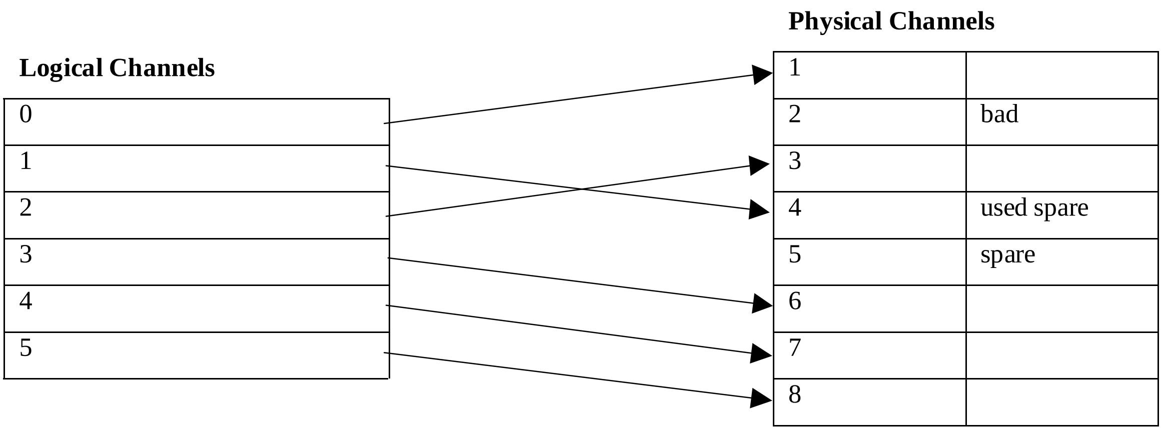
A mapping table is used to convert the 'logical channel number' (in the range 0 … 74) given by the hopping sequence to the 'physical channel number' (in the range 1 … 88) that is actually used.

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.
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'.

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[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 section3.6.1).

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 bythe 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 latencywhilst 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.

3.10 Seamless bearer hand-over & "multi-slot mode"

The 2.4 GHz band is prone to interference. In order to improve the robustness of the EDCT system it has the option to operate in a 'multi-slot mode', whereby two traffic bearers are used simultaneously to carry the same voice data. This achieved by operating in a state of permanent 'bearer hand-over'.

To do this the PP establishes a second traffic bearer with the FP, in the manner already described. In doing so, the PP indicates that this bearer is associated with an existing connection, and as a result, the voice data will get routed accordingly. This second traffic bearer uses a different frequency pattern to that of the first traffic bearer.

In a DECT system bearer hand-over normally occurs between a PP and two different FPs and simultaneous traffic bearers are only present for a short period. In EDCT with multi-slot mode enabled the bearer hand-over occurs between a PP and the same FP and the simultaneous traffic bearers are present, in principle, for the duration of the connection.

3.11 Handset-to-handset mode

The EDCT protocol stack supports a 'handset-to-handset' mode in which two handsets can be used to communicate independently of any FP. This is achieved by one of the handsets acting as a FP for the duration of the handset-to-handset call.

All links to the base-station (true FP) are released when a PP is switched to handset-to-handset mode.

The operation of the handset-to-handset mode is as described above for a regular PP / FP system (the part of the FP is effectively played by one of the PPs). The only difference is that a traffic bearer is always started on the dummy bearer slot, i.e. handset-to-handset communications always use a combined dummy/traffic bearer.

3.12 Scanning for noise

The PP will occasionally use spare TDMA slots to take RSSI measurements on frequency channels. These channels are not associated with a specific transmitter and therefore do not follow a specific hopping sequence.