# MARS 2.4GHz

## Frequency hopping and Dual slot diversity description

## History

| | | | |
|---|---|---|---|
| Ver 0.1 | JTP | 980909 | Initial version |
| Ver 0.2 | FM | 990111 | Updated/changed for type approval |
| Ver 0.3 | FM | 990204 | Updated/changed for type approval with new crystal |
| Ver 0.4 | FM | 990730 | Updated/New frequencies /new delay |
| Ver 0.5 | FM | 990909 | Updated/New frequencies |

# 1. Introduction

The Mars system is based on DECT the ETSI standard ETS-300-175-1 to ETS-300-175-9. The Mars system is improved by implementing extra features to combat the interference at 2.4 GHz.
The frequency hopping method for 2.4 GHz ISM band has to provide optimal performance and connection quality in environment with 5 different types of interference:

1. Other interference of MARS-type, known hopping algorithm and avoidance method (synchronized/unsynchronized).
2. Microwave ovens, sweeping the most of the band and running on 60Hz mains supply.
3. Interference on fixed RF carrier, CW interference. Direct sequence CDMA is also detected as this type of interference.
4. Other hoppers using the ISM band, with unknown hopping algorithm, example: Wireless LAN based on IEEE802.11, etc.
5. “Range / multi-path propagation”

The frame format is based on DECT, but modified from 24 timeslots to 18 or 20 timeslots and 79/23/27/35 possible RF carriers. Frequency hopping is implemented on a frame by frame basis. The system is implemented with encryption based on DECT.

# 2. Avoidance method

### 2.1 Known hoppers

Use 79 RF channels. Re-map though hopping table. Part of RFPI/RPN defines which hopping sequence to use. Bearer hand-over: change of slot-position and hopping index. Avoid modulo 16 sequences (= DECT sequences).
Different connection/bearer should use different hopping index.

### 2.2 Microwave ovens

Use dual slot diversity. Transmission of same B-field content in two slots on different carrier. Normal one frame delay extended to two frames delay in each direction in order to ensure seamless selection of best received burst. Total extra round-trip delay is two extra frames.

### 2.3 CW interference on fixed RF carriers

Exclude discrete RF carriers and adaptive use of dual-slot diversity.

### 2.4 Other hoppers

Appears like random interference. Adaptive usage of dual-slot diversity.

### 2.5 Improve range / multi-path performance

Use prolonged preamble. In the base the frequency hopping sequence must be: RX – TX

# 3. Adaptation to 2.4GHz ISM band

### 3.1 Frame format:

Down-link (FP to PP) Up-link (PP to FP)

| | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |

length 11.15 ms
or

Down-link (FP to PP) Up-link (PP to FP)

| | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 |

length 10 ms

#### 3.1.1 Crystal frequency 9.302131 MHz

Symbol rate: 1.033570 Mbit/sec.
Frame length: 20 timeslots, same as 11.1458 msec.
Frame frequency: 89.72 Hz
Number of symbols for frame: 11520
Number of symbols per slot: 576 (440 in burst and 136 in guard space)

#### 3.1.2 Crystal frequency 9.216000 MHz

Symbol rate: 1.024 Mbit/sec.
Frame length: 18 timeslots with 568 bits + 18 bits, same as 10 msec.
Frame frequency: 100 Hz
Number of symbols for frame: 10240
Number of symbols per slot: 568 (440 in burst and 128 in guard space)

For the remaining part of the document the 10 slots are replaced with 9.

Frequency hopping frame begins from slot 10. Slots are used in pairs for duplex bearers (0,10), (1,11), etc. The same RF carrier used in up-link direction of a slot-pair in frame N is used in down-link direction in frame N+1.

Frequency versus slot

| Frame | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | | | | | | | | | | | x | | y | | | | | | | |
| N+1 | x | | y | | | | | | | | z | | w | | | | | | | |
| N+2 | z | | w | | | | | | | | | | | | | | | | | |

### 3.2 Burst format:

| Sync field | A field | B field | XZ | Guard space |
|---|---|---|---|---|

#### 3.2.1 Sync-field

Length: up to 48 symbols consisting of

| | |
|---|---|
| Possibly Prolonged preamble: | 16 bit data |
| Preamble for bit-synchronization: | 16 bit data |
| Frame synchronization word: | FP: E98Ah |
| | PP: 1675h |

Pattern for transmission from FP:
1010 0101 1010 1010 1110 1001 1000 1010

Pattern for transmission from PP:
0011 0011 0011 0011 0101 1010 0101 0101 0001 0110 0111 0101

#### 3.2.2 A-field

Total length 64 symbols
Header: 8 bit
Tail: 40 bit
CRC: 16 bit

##### 3.2.2.1 T-MUX:

NT: RFPI is normally broadcast 7 out of every 8 frames.
QT: Static system information
PT: Broadcast, paging
MT: MAC layer control
CT: Connection oriented higher layer signaling

##### 3.2.2.2 Derive hopping SeQuenceCode (SQC) from RFPI

In order to distribute usage of different hopping sequences, the actual used sequence is derived from the FP identity, RFPI. The RFPI is normally broadcast 7 out of every 8 frames which then allows immediate recognition of hopping sequence by the PP during the initial synchronization.

The RFPI consists of 40 bits (5 bytes):

| E ARC | | | | | RPN |
|---|---|---|---|---|---|

a8 a47

If the ARC equal 000 the RPN has three bits in length and is a Park type A, otherwise the RPN has a length of eigth and is.

| E ARC | | | | | RPN |
|---|---|---|---|---|---|

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Two different positions of the SeQuenceCode (SQC) inside the RFPI is defined, in order to flexibility in deciding usage of same or different hopping sequence in multi-cell systems.

**Option 0:**
Park type A (residential):

| | | | | | | |
|---|---|---|---|---|---|---|
| E ARC | 0 | | | | | SQC |

a8 a47
The SQC is located from bit a42 to a47.

Park type different from A:

| | | | | | | |
|---|---|---|---|---|---|---|
| E ARC | 0 | | | | | SQC |

a8 a47
The SQC is located from bit a42 to a47.

**Option 1:**
Park type A (residential):

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| E ARC | 1 | | | | | SQC | |

a8 a47
The SQC is located from bit a40 to a44.

Park type different from A:

| | | | | | | |
|---|---|---|---|---|---|---|
| E ARC | 1 | | | | SQC | |

a8 a47
The SQC is located from bit a34 to a39.

#### 3.2.2.3 Excluding fixed carriers.

List of excluded RF carriers or parts hereof is broadcast using paging (reserved code 3). Two different methods are defined:
$PT_3$ (1): *EXCN0*[7], *EXCN1*[7], *EXCN2*[7], *EXCN3*[7] (28 bits used)
$PT_3$ (2): *ExcpPattern0*[32] (32 bits used)
$PT_3$ (3): *ExcpPattern1*[32] (32 bits used)
$PT_3$ (4): *ExcpPattern2*[15] (15 bits used)

$EXCN_x$ is the carrier number of an excluded RF carrier. Up to four individual carriers may be excluded using this method.
ExcpPatternx describes a complete pattern of excluded RF carriers.

### 3.2.3 B-field

Format and usage of B-field is similar to DECT. 320 bits of ADPCM data.

### 3.2.4 XZ-field

Format and usage of XZ-field is similar to DECT. X-field is a 4-bit CRC on the B-field content. Z-field is a copy of the X field and is used to detect sliding collision.

## 3.3 Frequency hopping algorithm

The number of used frequencies (NUF) in hopping algorithm is:

| | |
|---|---|
| North America | 79 |
| Most of Europe | 79 |
| Japan | 23 |
| Spain | 27 |
| France | 35 |

In FP and PP exists a PrimaryHoppingIndexNumber (PHIN). This number is incremented modulo NUF in the end of the normal downlink half-frame. It is broadcast in Q0 message instead of PSCN.

To a simplex or an established duplex bearer is assigned a HoppingIndexOffset (HIO), which is analogue to the used RF carrier in a FDMA system. This value is broadcast in place of CN in Q0 message. In the FP in all unused slots in up-link direction the receiver is scanning with HIO=0. The receiver scanning doesn't exclude RF-carriers.

Different FPs use different hopping sequences. The different sequences are derived from the hopping table by adding an offset, SeQuenceCode (SQC). This is a value in the range 0 – (NUF-1), extracted from the FP identity (RFPI).
A hopping table maps an index I to a carrier number: CN = f (I)

The physical RF carrier is calculated by the formula:

CN = ( f ((PHIN+HIO) mod NUF) + SQC ) mod NUF

### 3.3.1 Excluded carriers

Excluded carriers (exceptions) are fixed carriers that constantly are interfered by CW RF-carrier. The decision for excluding a RF carrier, are based on:

- RSSI monitor during scanning in the FP.
- Bearer quality in FP correlated to specific RF-carriers.
- Bearer quality detected in PP and reported using Q1 in MAC-header.

When exception carriers are included the complete algorithm is:

```
I  =  (PHIN+HIO) mod NUF
CN  = ( f (I) + SQC ) mod NUF
While CN in ExclusionList
{
  I  =  I + ((FrameNumber16 / NUF) mod (NUF-1)) +1
  CN  = ( f (I) + SQC ) mod NUF
}
```

FrameNumber16 equals 1

### 3.3.2 Hopping tables

Three different hopping tables are defined.

#### 3.3.2.1 Hopping sequence for North America and most of Europe

For 9.302131 MHz crystal the frequencies are derived as:
Frequency: 2400.983 + CN * 1.033570 MHz

For 9.216000 MHz crystal the frequencies are derived as:
Frequency: 2401.280 + CN * 1.024000 MHz

| i | f(I) | i | f(i) | I | f(i) | i | f(i) | i | f(f) | i | f(i) | i | f(i) | i | f(i) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 10 | 76 | 20 | 18 | 30 | 34 | 40 | 14 | 50 | 20 | 60 | 48 | 70 | 55 |
| 1 | 23 | 11 | 29 | 21 | 11 | 31 | 66 | 41 | 57 | 51 | 73 | 61 | 15 | 71 | 35 |
| 2 | 62 | 12 | 59 | 22 | 36 | 32 | 7 | 42 | 41 | 52 | 64 | 62 | 5 | 72 | 53 |
| 3 | 8 | 13 | 22 | 23 | 72 | 33 | 68 | 43 | 74 | 53 | 39 | 63 | 17 | 73 | 24 |
| 4 | 43 | 14 | 52 | 24 | 54 | 34 | 75 | 44 | 32 | 54 | 13 | 64 | 6 | 74 | 44 |
| 5 | 16 | 15 | 63 | 25 | 69 | 35 | 4 | 45 | 70 | 55 | 33 | 65 | 67 | 75 | 51 |
| 6 | 71 | 16 | 26 | 26 | 21 | 36 | 60 | 46 | 9 | 56 | 65 | 66 | 49 | 76 | 38 |
| 7 | 47 | 17 | 77 | 27 | 3 | 37 | 27 | 47 | 58 | 57 | 50 | 67 | 40 | 77 | 30 |
| 8 | 19 | 18 | 31 | 28 | 37 | 38 | 12 | 48 | 78 | 58 | 56 | 68 | 1 | 78 | 46 |
| 9 | 61 | 19 | 2 | 29 | 10 | 39 | 25 | 49 | 45 | 59 | 42 | 69 | 28 | | |

### 3.3.3 Example.

This example shows receive and transmit frequencies in a number of consecutive frames. The example is seen from the FP side with two simultaneous connections. Transmission is indicated in bold.

Used hopping table: North America
Excluded RF carrier: 11
SeQuenceCode (SQC): 3
HoppingIndexOffset (HIO): 0 and 2

Frequency versus slot

| Frame | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 | 19 | PHIN |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| N | | | **49** | | **26** | | | | | | 3 | 3 | 3 | 3 | 65 | 3 | 3 | 3 | 3 | 3 | 0 |
| N+1 | | | **3** | | **65** | | | | | | 23 | 23 | 26 | 23 | 46 | 23 | 23 | 23 | 23 | 23 | 1 |
| N+2 | | | **26** | | **46** | | | | | | 62 | 62 | 65 | 62 | 46 | 62 | 62 | 62 | 62 | 62 | 2 |
| N+3 | | | **65** | | **46** | | | | | | 11 | 11 | 46 | 11 | 19 | 11 | 11 | 11 | 11 | 11 | 3 |
| N+4 | | | **46** | | **19** | | | | | | 46 | 46 | 46 | 46 | 74 | 46 | 46 | 46 | 46 | 46 | 4 |

### 3.4 PP synchronization procedure

PP selects a random RF carrier and tries to receive a frame within 0.9 sec. If nothing is received then a new RF carrier is selected.
When a burst with correct A-CRC is received and it is a Nt (RFPI) the hopping sequence (SQC) is known and the PP must receive in the following frames using the hopping sequence. If the received A-field is

different from a Nt, the PP selects a new RF carrier randomly and waits for Nt. In this state the PP do not have information of excluded RF carriers, but just follows the known hopping sequence without excluding any RF carriers. Only individual frames are missed on the excluded carriers. When PT3 is received, the PP is able to receive on exception carriers.

### 3.5 Dual slot diversity

Dual slot diversity is activated in case interference is detected. That is, two bearers are active, carrying the same B-field content. The receiver decides which of the received speech frames to use, depending on A-CRC and/or X-CRC. The setup and release of the 2nd bearer are performed dynamically by the FP-MAC and PP-MAC to adapt to current interference level. The two bearers are managed independently in the MAC, like a stalled intra-cell bearer hand-over with two established bearers. HoppingIndexOffset (HIO) for the two bearers are selected independently.

### 3.6 Power amplifier activation

#### 3.6.1 External connection

The FP has one connection active at all times to make synchronization of the PP possible. In case a speech connection is active one slot will be active in down-link direction and one slot will be active from in up-link direction. The power amplifier will be active from start of sync field to the end of XZ field, which is slightly less than 1/24 of the total frame. In case dual slot diversity is active, two slots will be active equal to 2/24 of a frame.

#### 3.6.2 Internal connection

Two handsets are able to make an internal connection. In this case two bearers will be active in the down-link direction from FP, and one bearer will be active from each handset. The two bearers in down-link direction are not correlated and uses different HoppingIndeOfffset. Dual slot diversity is activated independently towards each handset, i.e. up to four bearers may be activated in down-link direction, and two bearer may be active in up-link direction.