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
Ver 0.6	FM	000130	Split into Minimars.
Ver 0.7	FM	010423	Corrected numbers in section 3.1.1.
Ver 0.8	JCM	011218	Header/footer corrected
Ver 0.9	ARO	020116	Updated (new template)
Ver 1.0	POL	040416	CVM
Ver 1.1	FNL	040419	Inserted channel allocation table
Ver 1.2	FNL	040426	Added Block diagram

1 Scope

This documents describes both the normal RTX Mars protocol.

2 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 half bit rate and modified from 24 timeslots to 8 timeslots and 95 possible RF carriers. Frequency hopping is implemented on a frame by frame basis. The system is implemented with encryption based on DECT.

3 Avoidance method

3.1 Known hoppers

Use 95 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.

3.2 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.

3.3 CW interference on fixed RF carriers

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

3.4 Other hoppers

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

3.5 Improve range / multi-path performance

Use prolonged preamble for antenna diversity in handset.

4 Adaptation to 2.4GHz ISM band

4.1 Frame format:

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

0	1	2	3	4	5	6	7

length 10 ms

4.1.1 Crystal frequency 10.368000 MHz

Symbol rate: 576 kbit/sec.
Frame length: 8 timeslots, same as 10 ms.
Frame frequency: 100 Hz
Number of symbols for frame: 5760
Number of symbols per slot: 720 (440 in burst and 280 in guard space)

4.1.2 Frequency hopping

Slots are used in pairs for duplex bearers (0,4), (1,5), etc. The FP transmit on a frequency in a slot-pair, and the PP responds on the same carrier in the up-link direction. Handset uses preamble antenna diversity to detect the best antenna for reception/transmission.

Frequency versus slot

Frame	0	1	2	3	4	5	6	7
N	x		y		x		y	
N+1	z		w		z		w	
N+2	v		t		v		t	

4.2 Burst format:

Sync field	A field	B field	XZ	Guard space

4.2.1 Sync-field

Length: 48 symbols consisting of

Prolonged preamble: 16 bit data (1010b sequence)
Preamble for bit-synchronization: 16 bit data (1010b sequence)
Frame synchronization word: FP: E98Ah (1110 1001 1000 1010b sequence)
PP: 1675h (0001 0110 0111 0101b sequence)

4.2.2 A-field

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

4.2.2.1 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

4.2.2.2 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	1					SQC	

a8 a47

The SQC is located from bit a40 to a44.

4.2.2.3 Excluding fixed carriers.

List of excluded RF carriers or parts hereof is broadcast using paging (reserved code 3).
The method is defined:

PT_3 (1): *ExcpPattern0*[32] (32 bits used)
PT_3 (2): *ExcpPattern1*[32] (32 bits used)
PT_3 (3): *ExcpPattern2*[15] (31 bits used)

ExcpPatternx describes a complete pattern of excluded RF carriers (If a bit is set the carrier is excluded).

4.2.3 B-field

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

4.2.4 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.

4.3 Frequency hopping algorithm

The number of used frequencies (NUF) in the hopping algorithm is 95.
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). See section 4.2.2.2.

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

4.3.1 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 + FreqHopIndexExcpShift) mod NUF
  CN = ( f (I) + SQC ) mod NUF
}
```

where FreqHopIndexExcpShift = (NUF-1).

4.3.2 Hopping tables

4.3.2.1 Hopping sequence for North America and most of Europe

For 10.368000 MHz crystal the frequencies are derived as:
Frequency: 2401.056 MHz + CN * 0.864000 MHz

i	f(I)	I	f(i)	i	f(i)	i	f(i)	i	f(i)
0	0	20	2	40	27	60	13	80	40
1	23	21	18	41	12	61	33	81	1
2	62	22	81	42	89	62	65	82	28
3	8	23	11	43	25	63	50	83	55
4	43	24	36	44	87	64	79	84	35
5	16	25	72	45	14	65	56	85	53
6	71	26	54	46	57	66	91	86	24
7	47	27	69	47	41	67	42	87	44
8	19	28	21	48	74	68	80	88	82
9	61	29	3	49	32	69	48	89	51
10	76	30	37	50	70	70	15	90	90
11	29	31	10	51	9	71	85	91	38
12	59	32	34	52	58	72	5	92	83
13	22	33	66	53	78	73	88	93	30
14	52	34	7	54	45	74	17	94	46
15	86	35	68	55	20	75	84		
16	63	36	94	56	73	76	6		
17	26	37	75	57	93	77	67		
18	77	38	4	58	64	78	49		
19	31	39	60	59	39	79	92		

4.4 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.

4.5 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.

4.6 Power amplifier activation

4.6.1 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 1/12 of the total frame. In case dual slot diversity is active, two slots will be active equal to 2/12 of a frame.

4.6.2 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 HoppingIndeOffset. 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.

4.7 Frequency channel allocation

Channel	Frequency	Channel	Frequency
0	2401.0560	48	2442.5280
1	2401.9200	49	2443.3920
2	2402.7840	50	2444.2560
3	2403.6480	51	2445.1200
4	2404.5120	52	2445.9840
5	2405.3760	53	2446.8480
6	2406.2400	54	2447.7120
7	2407.1040	55	2448.5760
8	2407.9680	56	2449.4400
9	2408.8320	57	2450.3040
10	2409.6960	58	2451.1680
11	2410.5600	59	2452.0320
12	2411.4240	60	2452.8960
13	2412.2880	61	2453.7600
14	2413.1520	62	2454.6240
15	2414.0160	63	2455.4880
16	2414.8800	64	2456.3520
17	2415.7440	65	2457.2160
18	2416.6080	66	2458.0800
19	2417.4720	67	2458.9440
20	2418.3360	68	2459.8080
21	2419.2000	69	2460.6720
22	2420.0640	70	2461.5360
23	2420.9280	71	2462.4000
24	2421.7920	72	2463.2640
25	2422.6560	73	2464.1280
26	2423.5200	74	2464.9920
27	2424.3840	75	2465.8560
28	2425.2480	76	2466.7200
29	2426.1120	77	2467.5840
30	2426.9760	78	2468.4480
31	2427.8400	79	2469.3120
32	2428.7040	80	2470.1760
33	2429.5680	81	2471.0400
34	2430.4320	82	2471.9040
35	2431.2960	83	2472.7680
36	2432.1600	84	2473.6320
37	2433.0240	85	2474.4960
38	2433.8880	86	2475.3600
39	2434.7520	87	2476.2240
40	2435.6160	88	2477.0880
41	2436.4800	89	2477.9520
42	2437.3440	90	2478.8160
43	2438.2080	91	2479.6800
44	2439.0720	92	2480.5440
45	2439.9360	93	2481.4080
46	2440.8000	94	**2482.2720**

4.8 Transceiver Block diagram