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## Update to the Starlink and SpaceBEE Packet Formats

In December 2022, SpaceX commenced launching its Starlink Version 2 spacecraft into orbit to which was added a VHF beacon package based on the Swarm SpaceBEE LoRa format [1] and operates in the same VHF band of 137-138 MHz. The Starlink VHF Beacon [2] provides early orbit telemetry, Tracking and command for the orbit raising phase.

A fourth channel on 137.25 MHz has been added to provide increased downlink capacity.

This frequency is also used by Orbcomm FM-107/37 and FM-109/39 which may cause Radio Frequency Interference to Starlink, SpaceBEE or both spacecraft downlinks.

This frequency has not been in use since late 2023.

The Starlink Beacon uses packet lengths of 87, 81 and 73-byte message is used on Starlink V2 satellites. The 15-byte message structure is not by Starlink.

The Starlink packet structure is an 11-byte header followed by a variable length frame that has a two-byte header indicating the format and frame length.

Table 1 SpaceBEE 15-byte Request to Send Acknowledgement Format

Table 2 SpaceBEE 87-byte Beacon Format

Table 3 SpaceBEE N-byte encrypted downlink message

Table 4 Starlink VHF Beacon 87-byte Format

Table 5 Starlink VHF Beacon 73-byte Format

Table 6 Starlink VHF Beacon 81-byte Format

Table 7 LoRa Packet Data

Table A: SpaceBEE Hex SCID to SpaceBEE-*nnn*

Table B SpaceBEE launches and decays to 26 June 2024

Analysis of the data continues.

### References:

1. Notes on the Swarm SpaceBEE Satellites <https://emitters.space/SpaceBEE.pdf>
2. Notes on the SpaceX Starlink VHF Beacon Satellites <https://emitters.space/Starlink.pdf>

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<b>Table 1 SpaceBEE 15-byte Request to Send Acknowledgement Format</b>				
Segment	Parameter	Bytes	Little Endian Data	Value
<b>Header</b> 6 bytes	Message Number	3	532293	
	Spacecraft ID	2	830a	
	Packet Type	1	8C	
<b>Data</b> 9 bytes		2	6d15 84	Device ID + Flag
		2	e17f 03	unknown
		2	3b5993	Device Message Number

This downlink packet is in response to a ground device or ground station up linking a “Request to Send” packet to the spacecraft. Upon receipt of this packet, the ground device transmits its message. The spacecraft then acknowledges receipt the uplinked message in the next 87-byte Beacon message

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Table 2 SpaceBEE 87-byte Beacon Format				
Segment	Parameter	Bytes	Little Endian Data	Value
<b>Header</b> 11 bytes	Message Number	3	cd828b	9142989
	Spacecraft ID	2	840a	SpaceBEE-175
	Packet Type	2	cc	204
	Packet Seed	2	0000	0 = Un-encrypted
	Packet Source	2	c0	c0 = SpaceBEE
	Header CRC?	2	14d3	?
<b>Frame Header</b> 2 bytes	Frame Length	1	4b	75
	Frame Format	1	01	1
<b>Frame Data 1</b> 39 bytes	UTC Timecode	4	5f701f65	6 October 2023 02:26:39
	Latitude	4	a5ca0bc2	-34.9478951° (South)
	Longitude	4	18281e43	158.156616° (East)
	Altitude	4	60e00700	516192 metres
	Semi-fixed TBD	16	0000c4b7 15000f28 c2fc3400 05030020	
	Downlink channel	1 6	82 2a700e 060000	137.055 MHz
<b>Frame Data 2</b> 35 bytes		3	dc0c11	
		4	1f631f65	
		3	be8f13	
		4	603f1f65	
		3	432d11	
		4	67361f65	
		3	ea2711	
		4	f4111f65	
		3	ff9c13	
		4	6d081f65	

SB-175

cd828b840acc0000c014d3 4b01 5f701f65 a5ca0bc2 18281e43 60e00700 0000c4b7 15000f28  
c2fc3400 05030020 822a700e 060000  
dc0c111f631f65be8f13603f1f65432d1167361f65ea2711f4111f65ff9c136d081f65

See Table 1 for SCID to SpaceBEE-*nnn*

The Message Number least significant byte is incremented each packet.

The Message Number most significant byte seem to be incremented modulo 65536, approximately daily and is not synchronised to 0000 UTC.

Acknowledgement packet of ground Device's "Request to Send" uplink message?

E.G. Uplink Device ID (**2f12**) appears in the next 87-byte packet's Device Acknowledgement field, two seconds later.

Downlink Channel: 81 137.845 MHz, 82 137.055 MHz, 83 137.985 MHz, 84 137.25 MHz

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Table 3 SpaceBEE N-byte encrypted downlink message					
Segment	Parameter	Position	Bytes	LE Data	Value
Header 11 bytes	Message Number	1 2 3	3	588900	
	Spacecraft ID	4 5	2	870a	
	Packet Type	6	1	ac	
	Seed	7 8	2	cb7b	
	Source	9	1	b3	B1 to b4
	Unique	10 11	2	c6cd	
Header 16 bytes	Bytes remaining	12	1	40	64
	GD MN	13 14 15	3	720145	
	GD ID	16 17	2	5751	
	Flag bits	18	1	a4	24, 2c or a4
	Fixed	19 20 21 22 23	5	0000b4e269	
	Bytes remaining	24	1	34	52
	Fixed or coded	25 26 27	3	060000 or xxxxxx	
Coded Data N-28 bytes	Bytes remaining	28	1	30 or xx	
	Coded data	29 to N	N-28	8d861.....c07f48	

AES 256 with Galois/Counter Mode (AES-GCM) provides both authenticated encryption (confidentiality and authentication) and the ability to check the integrity and authentication of additional authenticated data (ADD) that is sent in the clear. AES-GCM is specified in NIST Special Publication 800-38D. [https://www.cryptosys.net/pki/manpki/pki\\_aesgcmauthentencryption.html](https://www.cryptosys.net/pki/manpki/pki_aesgcmauthentencryption.html)

SB-178 ac 76-byte packet example (N =76)

```
588900870aacb7bb3c6cd
407201455751a40000b4e269
34060000
308d861877a2e33fb95522fa53c4a36f0b1b8c5c06b4fe4da6443ef4a8abf49a694b15e49bdb6ff66879
3eea14d4c07f48
```

Notes:

N-byte packets, where N varies from 70 to 248 byte encrypted message to ground devices.

Value of Coded Data Length (Byte 24, **34** hex, 52 decimal) = Number of bytes (64) in AES section following.

For 165-byte AC packets, byte 18 is 24 indicting that bytes 25,26, 27 and 28 are also coded.

```
7f34445706acfd90b2818e
995d0144969d240000b4aac3
8de3d649c3c507eb352f45aee06168ffd173fac018d1d321ac56aa97a5854c78160e1aefcdf457
485446bff975983ce0f3e1157e0498ee8b8a02b64e6730c410936d7eb1d2329424f39a78a479
250addbf72ba8b5889347a09ab4e8d5797cf9819e754b3be501066
```

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<b>Table 4 Starlink VHF Beacon 87-byte Format</b>				
Segment	Parameter	Bytes	Data as little endian	Value
<b>Header</b> 11 bytes	Message Number	3	ae803e	4096174
	Spacecraft ID	2	5109	2385
	Packet Type	1	cc	
	Packet Seed	2	0000	
	Packet Source	2	D0	D = Starlink
	Unique	2	0eb4	
<b>Frame Header</b> 2 bytes	Frame Length	1	4b	75
	Frame Format	1	03	3 = Starlink 87-byte
<b>Frame Data 1</b> 39 bytes	UTC Timecode	4	6d765564	5 May 2023 21:34:37
	Latitude	4	313d06c2	-31.5597572 °
	Longitude	4	62100f43	143.064 °
	Altitude	4	19530600	414489 metres
	Semi-fixed TBD	23	0000 98a3 1400 0430 90fc 21ba 0403 0000 82ca 660e 0608 00	
<b>Frame Data 2</b> 35 bytes	GPS Week	2	d408	2260
	GPS Week Seconds	4	c0ba0903	5 May 2023 21:34:34
	TBD	29	18b6 01e5 8f2f 4b14 81d 8bce9 3eb3 fcff 2b74 f6ff 674a fbff 1e10 d2dc 07	

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Table 5 Starlink VHF Beacon 73-byte Format					
Segment	Byte Position	Parameter	Bytes	Data as little endian	Value
<b>Header</b> 11 bytes	1-3	Message Number	3	81828a	90773777
	4-5	Spacecraft ID	2	4a0b	2890
	6	Packet Type	2	cc	204
	7-8	Packet Seed	2	00 00	0 0
	9	Packet Source		d0	208
	10-11	Header CRC?	2	0c13	
<b>Frame Header</b> 2 bytes	12	Frame Length	1	3d	61
	13	Frame Format	1	04	4
<b>Frame Data 1</b> 19 bytes	14	?	1	00	0
	15-18	UTC Timecode	4	8dcb1c65	4 October 2023 02:18:53
	19-32	Semi-fixed TBD	14	53002450 fb340a00 21e204ba 7103	
<b>Frame Data 2</b> 41 bytes	33-34	GPS Week	2	ea08	
	35-36	GPS Week Seconds	4	2b3f9801	
	36-67	TBD	29	d0a621e6	
				86884111	
d00d77e6					
68-73	TBD	6	4128fcff		
			9aacf5ff		
			c113dff		
				1ee195e5	
				18	
				e16c1c	
				657262	

81828a 4a0b cc 0000 d0 0c13 3d04 008dcb1c6553002450fb340a0021e204ba7103  
ea082b3f9801d0a621e686884111d00d77e64128fcff9aacf5ffc113dff1ee195e518 e16c1c65726

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Table 6 Starlink VHF Beacon 81-byte Format					
Segment	Byte Position	Parameter	Bytes	Data as little endian	Value
<b>Header</b> 11 bytes	1-3	Message Number	3	b98657	
	4-5	Spacecraft ID	2	2712	2890
	6	Packet Type	2	cc	204
	7-8	Packet Seed	2	00 00	0 0
	9	Packet Source		d0	208
	10-11	Header CRC?	2	d30b	
<b>Frame Header</b> 2 bytes	12	Frame Length	1	45	69
	13	Frame Format	1	05	4
<b>Frame Data 1</b> 19 bytes	14	?	1	02	2
	15-18	UTC Timecode	4	af 9a 77 66	23 June 2024 03:46:55
	19-32	Semi-fixed TBD	14	43 00 30 fa fb 34 0a 00 21 00 05 12 74 05	
<b>Frame Data 2</b> 49 bytes	33-34	GPS Week	2	10 09	2320
	35-38	GPS Week Seconds	4	60 cc 14 00	1363040/100
	39-81	TBD	43	58 bd 87 e5 8b ea d0 0f 74 9e 8c e6 2b 9b fc ff 33 b4 f5 ff b0 20 fd ff 22 08 68 18 05 00 00 00 00 00 00 90 8e c7 ff a6 ff fc ff	

b98657 2712 cc 0000 d0 d30b  
45 05  
02 af 9a 77 66  
43 00 30 fa fb 34 0a 00 21 00 05 12 74 05  
10 09 60 cc 14 00  
58 bd 87 e5 8b ea d0 0f 74 9e 8c e6 2b 9b fc ff 33 b4 f5 ff b0 20 fd ff 22 08 68 18 05 00 00 00 00 00  
00 90 8e c7 ff a6 ff fc ff 49 79

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Table 7 LoRa Packet Data									
	Packet Header						Packet Data		
Packet Length	Message Number	Spacecraft Identification	Type	Seed	Source	Tab	Data Remaining	Data Format	Data
Bytes	1-3	4-5	6	7-8	9	10-11	12	13	14 +
76-248	000000 To FFFFFF	0000 To FFFF	AC	xxxx	B1-B4	xxxx	N-12		
87			CC	0000	C0	xxxx	75	1	
87			CC	0000	D0	xxxx	75	3	
73			CC	0000	D0	xxxx	61	4	
81			CC	0000	D0	xxxx	69	5	
	Packet Header				Packet Data				
	MN	SCID	TYPE	GDID	Flag1	Unk	Flag2	GD MN	
15	1 2 3	4 5	8C	7 8	9	10 11	12	13 14 15	

MN            Message Number  
 SCID        Spacecraft Identification. See Table A  
 Type        Packet Type: 8C is 15-byte, AC is N byte, CC is 73, 81 or 87 byte  
 Seed        a unique number. See <https://csrc.nist.gov/glossary/term/nonce>  
 Source      SpaceBEE is C, Starlink is D  
 Tag         A unique number for each packet, possibly a CRC.  
 Format      Frame format  
 Remaining   Length of Frame  
 Data  
 GD ID      Ground Device Identification  
 GD MM     Ground device Message Number  
 Flag1      MSB toggle, 0x84 -> 0x04  
 Flag2      unknown function  
 Unk        Unknown function



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**Table A: SpaceBEE Hex SCID to SpaceBEE-*nnn*** (*nnn* is 1 to 179)

SB-1 to 155 have decayed except for SB-6 and 7 which are in still in orbit but non-operative. Refer Table B.

	050X	051X	052X	053X	054X	055X	056X	057X	058X	059X	05AX	05BX	05CX	05DX	05EX	05FX	060X	061X	062X	063X	064X	065X	0A7x	0A8x	
0																									
1																									
2																									173
3																							156		174
4																							157		175
5																							158		176
6																							159	168	177
7																							160	169	178
8																							161	170	179
9																							162		
A																							163	171	
B																							164	<u>172</u>	
C																							165		
D																							<u>166</u>		
E																							167		
F																									

nnn on 137.050 MHz, *nnn* on 137.25 MHz, *nnn* on 137.845 MHz, **nnn** on 137.975 MHz. NB: Downlink channels can and do change!

LoRa sync word 12 hex, Bandwidth 41667 Hz, Spreading Factor 8 for 137.05 MHz and 137.845 MHz, Spreading Factor 7 for 137.25 MHz and 137.975 MHz

**Table B: SpaceBEE launches and **decays****

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**Table B SpaceBEE launches and decays to 26 June 2024**

12/1/2018	3/12/2018	29/6/2019	3/9/2020	21/11/2020	24/1/2021	28/2/2021	3/6/2021	15/3/2022	1/4/2022	2/5/2022	31/1/2023	12/6/2023			
1	5	8	10	22	40	76	88	112	128	140	156	168			
2	6	9	11	23	41	77	89	113	129	141	157	169			
3	7		12	24	42	78	90	114	130	142	158	170			
4			13	25	43	79	91	115	131	143	159	171			
			14	26	44	80	92	116	132	144	160	172			
			15	27	45	81	93	117	133	145	161	173			
			16	28	46	82	94	118	134	146	162	174			
			17	29	47	83	95	119	135	147	163	175			
			18	30	48	84	96	120	136	148	164	176			
			19	31	49	85	97	121	137	149	165	177			
			20	32	50	86	98	122	138	150	166	178			
			21	33	51	87	99	123	139	151	167	179			
				34	52		100	124		152					
				35	53		101	125		153					
				36	54		102	126		154					
				37	55		103	127		155					
				38	56		104								
				39	57		105								
					58		106								
					59		107								
					60		108								
					61		109								
					62		110								
					63		111								
					64										
					65										
					66										
					67										
					68										
					69										
					70										
					71										
					72										
					73										
					74										
					75										
4	3	2	12	18	36	12	24	16	12	16	12	12			179
4	1	2	12	18	36	12	24	16	12	16	0	0			152

Source: Space-Track.org Satellite Catalog, [SATCAT](#)