RTCA Special Committee 186, Working Group 3

ADS-B 1090 MOPS

Meeting 2

1090 MHz TIS-B Message Formats

(Presented by James Maynard, UPS Aviation Technologies)

SUMMARY
1. Use the CF field in the DF=18 message format to distinguish between message formats for the ADS-B and TIS-B services on the1090 MHz data link. Reserve one CF value for possible future use to denote TIS-B management messages. Reserve three CF values for other future uses.
2. For targets for which the 24-bit ICAO address is unknown, the AA field would convey other information, such as the TIS-B service volume ID, the target's Mode A identity code, and a surveillance tracker file ID number.
3. Modify Vince Orlando's initial proposed "coarse TIS-B" message format so as to represent the target's horizontal velocity in polar form, with more bits assigned to the ground track angle than to the speed.

TO: Members of RTCA/SC-186/WG-3 DATE: 2001 January 2

CC: Members of RTCA/SC-186/WG-2

FROM: James Maynard, UPS Aviation Technologies

RE: TIS-B Message Formats

I've been thinking about Vince Orlando's proposed formats for TIS-B messages on the 1090 MHz data link. This paper proposes some changes to those formats.

First, some preliminary information:

- The TIS-B working group, SC-186/WG-2, has defined the term, "TIS-B service volume," as follows: "A Service Volume (SV) shall be defined for each area of TIS-B service. The SV shall represent an area of full operation of TIS-B (e.g., no gaps in surveillance coverage) and of a specified minimum TIS-B update period."
- The TIS-B trials in Italy used VDL M4 "management messages" by which a TIS-B transmitting station could communicate information about its service volume to the aircraft that use its TIS-B service. (In those trials, a series of management messages from a TIS-B ground station each contained the geographic coordinates of a vertex of a polygon bounding the station's service volume in the horizontal plane.)
- WG-*2* has agreed on the concept of a service volume, but it might not require any particular data link implementation to declare the service volume boundaries by actual over-the-air TIS-B management messages.

I would like to provide, in the AA field, for either (a) an aircraft's 24-bit ICAO address, or (b) a unique address assigned by the surveillance radar for an aircraft for which the 24-bit ICAO address is unknown (because it's an ATCRBS target), or (c) an "anonymous" code for use by people who don't want to be "surveilled." The latter is, of course, a purely political consideration, but it may be desirable to make it obvious to everyone that the 1090 MHz data link can accommodate a desire for anonymity.

I think that a logical place to indicate the meaning of the AA field would be in the 3-bit "CF' field that precedes the AA field in the DF=18 format. However, Vince Orlando has pointed out that it would be desirable to reserve several CF code values for other uses. Therefore, I propose that <u>both</u> the CF value <u>and</u> the value of an "ATCRBS / Mode S flag" in the ME field should be used to determine the use of the AA field. Table 1 below shows my current thoughts on the subject.

Table 1. "CF" Field Code Definitions in DF=18 ADS-B and TIS-B Messages.

CF Value	"ATCRBS or Mode S" Flag	Meaning
0	N/A	ADS-B message, AA field holds 24-bit ICAO aircraft address
1	N/A	ADS-B message, AA field holds anonymous address or ground vehicle address or fixed obstruction address
2	0	Fine TIS-B message, AA field holds 24-bit ICAO aircraft address
	1	Fine TIS-B message, AA field holds TIS-B service volume ID + Mode A code + tracker file #
3	0	Coarse TIS-B airborne position and velocity message, AA field holds 24-bit ICAO aircraft address
	1	Coarse TIS-B airborne position and velocity message, AA field holds TIS-B service volume ID + Mode A code + tracker file #
4	N/A	Reserved for TIS-B management message AA field holds TIS-B service volume ID + other information TBD
5 – 7	N/A	Reserved for other uses (e.g., for FIS-B messages)

This scheme moves some of the TIS-B data out of the ME field and into the CF and AA fields. It has the following advantages:

- The existing ADS-B "ME" field message formats can also be used, unchanged, as the "fine" TIS-B formats. (It's a rather challenging task to develop even experimental airborne ADS-B/TIS-B receiving equipment in time for Op Eval 3. UPS AT would prefer that TIS-B receiving equipment should differ only slightly from ADS-B receiving equipment.)
- An anonymity flag can be added to ADS-B message formats without disturbing the existing formats of the ME fields in ADS-B messages.
- We provide for TIS-B "management messages" to describe the TIS-B service volume, should we deem it desirable to broadcast service volume information over the air.

Table 2 below summarizes the proposed ADS-B and TIS-B formats. The rule for determining whether a format is an ADS-B or TIS-B format is as follows:

- If DF = 17, or if DF = 18 and CF = 0 or 1, then the message is an ADS-B message.
- If DF = 18 and CF is 2, 3, or 4, then the message is a TIS-B message.
- If DF = 18 and CF is 5, 6, or 7, the message format is reserved for future standardization.

Table 2. Summary of Proposed 1090 MHz ADS-B and TIS-B Message Formats.

		ME [56 bits]		Message Type
		Bits 1-5	**Bits 6-56**	
ADS-B Messages (DF = 17, or DF = 18 and CF = 0 or 1)		0	(Table 4)	ADS-B Unknown Position Message (with Pressure Altitude)
		1-4	(Table 5)	ADS-B Identification and Category Message
		5-8	(Table 6)	ADS-B Surface Position Message
		9-18	(Table 4)	ADS-B Airborne Position Message (with Pressure Altitude)
		19	(Table 7)	ADS-B Airborne Velocity Message
		20-22	(Table 4)	ADS-B Airborne Position Message (with Height Above Ellipsoid)
		23		Reserved for test purposes
		24		Reserved for surface system status
		25-27		Reserved
		28		ADS-B Aircraft Status Message
		29		ADS-B Aircraft Trajectory Intent Message
		30		ADS-B Aircraft Operational Coordination Message
		31		ADS-B Aircraft Operational Status Message
TIS-B Messages (DF = 18, CF = 2 to 4)	CF = 2	0	(Table 4)	TIS-B Unknown Position Message (with Pressure Altitude)
		1-4	(Table 5)	TIS-B Identification and Category Message
		5-8	(Table 6)	Fine TIS-B Surface Position Message
		9-18	(Table 4)	Fine TIS-B Airborne Position
		19	(Table 7)	Fine TIS-B Airborne Velocity Message
		20-31	(TBD)	Reserved
	CF=3	(Table 3)		Coarse TIS-B Position and Velocity Message (with Pressure Altitude)
	CF = 4	(TBD)		Reserved for TIS-B management messages

Table 3 shows a possible format for the ME field in the coarse TIS-B airborne position and velocity message.

Table 3. ME field in TIS-B Coarse Airborne Position and Velocity Message.

Bit Number		TIS-B Coarse Airborne Position and Velocity Message		Notes
Msg	ME			
33	1	**ATCRBS / Mode S Flag**		0 = Mode S, 1 = ATCRBS
34	2	**Surveillance Status**	MSB	0 = normal, 1 = emergency,
35	3		LSB	2 = changed Mode A code, 3 = SPI
36	4	**TIS-B Service Volume ID**	MSB	This would probably be the II, Interrogator ID, code for a radar or other ground surveillance source.
37	5			
38	6			
39	7		LSB	
40	8	**Pressure Altitude**	MSB	Same coding as in the Altitude subfield of the ADS-B and the Fine TIS-B Airborne Position Messages.
41	9			
42	10			
43	11			
44	12			
45	13			
46	14			
47	15			
48	16			
49	17			
50	18			
51	19		LSB	
52	20	**Ground Track Status**	(1 = valid, 0 = invalid)	It may be desirable to allocate more of these bits to the ground track angle, and fewer to the ground speed. That is, it may be more important to know just where a target appears to be going (determined by the ground track angle and its most recently reported position) than when it is going to reach a particular position (determined from its ground speed).
53	21	**Ground Track Angle**	MSB (180º)	
54	22		(90º)	
55	23		(45º)	
56	24		(22.5º)	
57	25		(11.25º)	
58	26		LSB (5.625°)	
59	27	**Ground Speed**	MSB (512 knots)	
60	28		(256 knots)	
61	29		(128 knots)	
62	30		(64 knots)	
63	31		LSB (32 knots)	
64	32	**CPR Format (F)**	(0 = even, 1 = odd)	
65	33	**CPR-Encoded Latitude**	MSB	
66	34			
67	35			
68	36			
69	37			
70	38			
71	39			
72	40			
73	41			
74	42			
75	43			
76	44		LSB	
77	45	**CPR-Encoded Longitude**	MSB	
78	46			
79	47			
80	48			
81	49			
82	50			
83	51			
84	52			
85	53			
86	54			
87	55			
88	56		LSB	

In Table 3, I've described a target's horizontal velocity in polar form (ground speed and track angle) rather than rectangular form (N-S and E-W velocity components). The committee may, of course, decide to use the Cartesian form, as it did in the ADS-B airborne position message. There are two reasons, however, why I prefer the polar form for the coarse TIS-B message:

- We have only 12 bits available for the horizontal velocity and its validity flag. If the velocity were represented in Cartesian format, there would be only six bits each for the N-S and E-W velocity components. With only six bits, these velocities would necessarily be represented with a fairly coarse resolution. If the range were to be up to 1024 knots, the LSBs of the N-S and E-W velocities would have a weight of 32 knots. With 32-knot resolution, the track angle resolution would vary with the ground speed, as follows:

Ground Speed	Track Angle Resolution
125 knots	14.67°
250 knots	7.33°
500 knots	3.67°

  A track angle resolution of more than 14 degrees seems rather too coarse a resolution to me.

- If, however, the horizontal velocity is represented in polar format, the track angle resolution does not vary with the ground speed, since the ground speed and track angle are encoded separately. Also, we are not required to allocate the same number of bits to the ground speed as to the track angle. (I think that it is more important to know the track angle accurately than it is to know the ground speed accurately.) Suppose we assign 5 bits to the ground speed, 6 bits to the track angle, and 1 bit to a validity flag. Then the track angle would have a resolution of 2^{-6} circles, or 5.63°, independent of the ground speed. With 5 bits for the ground speed field, speeds up to more than 1000 knots can be represented with 32-knot resolution.

Table 4 shows formats for the ME field in the ADS-B and TIS-B "fine" position messages.

Table 4. ME Field in ADS-B Airborne Position and TIS-B Fine Airborne Position Messages.

Bit Number		ADS-B or TIS-B Unknown Position Message		ADS-B Airborne Position Message		TIS-B Fine Airborne Airborne Position Message	
Msg	ME						
33	1	**Format Type Code**	0	**Format Type Code**	MSB	**Format Type Code**	
34	2		0	(In range 9-18 or 21-22)		(In range 9-18)	
35	3		0				
36	4		0				
37	5		0		LSB		
38	6	**Surveillance Status**	MSB	**Surveillance Status**	MSB	**Surveillance Status**	MSB
39	7		LSB		LSB		LSB
40	8	**Single Antenna Flag**		**Single Antenna Flag**		**ATCRBS / Modes S Flag**	
41	9	**Pressure Altitude**	MSB	**Altitude**	MSB	**Pressure Altitude**	MSB
42	10						
43	11			(pressure altitude if format type code is in range 9-18, or geometric altitude if format type code is in range 20-22)			
44	12						
45	13						
46	14						
47	15						
48	16						
49	17						
50	18						
51	19						
52	20		LSB		LSB		LSB
53	21		0	**Time Synchronization (T)**		(Reserved)	
54	22		0	**CPR Format (F)**		**CPR Format (F)**	
55	23		0	**CPR-Encoded Latitude**	MSB	**CPR-Encoded Latitude**	MSB
56	24		0				
57	25		0				
58	26		0				
59	27		0				
60	28		0				
61	29		0				
62	30		0				
63	31		0				
64	32		0				
65	33		0				
66	34		0				
67	35		0				
68	36		0				
69	37		0				
70	38		0				
71	39		0		LSB		LSB
72	40		0	**CPR-Encoded Latitude**	MSB	**CPR-Encoded Longitude**	MSB
73	41		0				
74	42		0				
75	43		0				
76	44		0				
77	45		0				
78	46		0				
79	47		0				
80	48		0				
81	49		0				
82	50		0				
83	51		0				
84	52		0				
85	53		0				
86	54		0				
87	55		0				
88	56		0		LSB		LSB

Table 5. ME Field in ADS-B / TIS-B Identification and Category Messages.

Bit Number		ADS-B / TIS-B Identification and Category Message	Notes
Msg	ME		
33	1	**Format Type Code** 1 = Category Set D 2 = Category Set C 3 = Category Set B 4 = Category Set A	To provide for an ATCRBS / Mode S flag in TIS-B ID and Category messages, we might define Category Set D to be the same as Category Set A, except that the ATCRBS / Mode S flag is deemed to be zero for Category Set A and 1 for Category Set D.
34	2		
35	3		
36	4		
37	5		
38	6	**Category Code** (within the particular Category Set)	
39	7		
40	8		
41	9	**Flight ID,** character #1	
42	10		
43	11		
44	12		
45	13		
46	14		
47	15	**Flight ID,** character #2	
48	16		
49	17		
50	18		
51	19		
52	20		
53	21	**Flight ID,** character #3	
54	22		
55	23		
56	24		
57	25		
58	26		
59	27	**Flight ID,** character #4	
60	28		
61	29		
62	30		
63	31		
64	32		
65	33	**Flight ID,** character #5	
66	34		
67	35		
68	36		
69	37		
70	38		
71	39	**Flight ID,** character #6	
72	40		
73	41		
74	42		
75	43		
76	44		
77	45	**Flight ID,** character #7	
78	46		
79	47		
80	48		
81	49		
82	50		
83	51	**Flight ID,** character #8	
84	52		
85	53		
86	54		
87	55		
88	56		

Table 6. ME Field in ADS-B and TIS-B Surface Position Messages.

Bit Number		ADS-B		TIS-B	
Msg	ME	Surface Position Messages		Surface Position Messages	
33	1	**Format Type Code**	(MSB)	**Format Type Code**	(MSB)
34	2	(in range from 5 to 8)		(in range from 5 to 8)	
35	3				
36	4				
37	5		(LSB)		(LSB)
38	6	**Movement Code**	(MSB)	**Movement Code**	(MSB)
39	7				
40	8				
41	9				
42	10				
43	11				
44	12		(LSB)		(LSB)
45	13	**Ground Track Status**		**Ground Track Status**	
46	14	**Ground Track Angle**	(MSB)	**Ground Track Angle**	(MSB)
47	15				
48	16				
49	17				
50	18				
51	19				
52	20		(LSB)		(LSB)
53	21	**Time Synchronization Flag (T)**		**ATCRBS/Mode S Flag**	
54	22	**CPR Format (F)**		**CPR Format (F)**	
55	23	**CPR-Encoded Latitude**	(MSB)	**CPR-Encoded Latitude**	(MSB)
56	24				
57	25				
58	26				
59	27				
60	28				
61	29				
62	30				
63	31				
64	32				
65	33				
66	34				
67	35				
68	36				
69	37				
70	38				
71	39		(LSB)		(LSB)
72	40	**CPR-Encoded Longitude**	(MSB)	**CPR-Encoded Longitude**	(MSB)
73	41				
74	42				
75	43				
76	44				
77	45				
78	46				
79	47				
80	48				
81	49				
82	50				
83	51				
84	52				
85	53				
86	54				
87	55				
88	56		(LSB)		(LSB)

Table 7. ME Field in ADS-B and TIS-B Airborne Velocity Messages.

Msg	ME		ADS-B Airborne Velocity Message	TIS-B Airborne Velocity Message
33	1	Type Code	**Format Type Code = 19** 1	**Format Type Code = 19** 1
34	2		0	0
35	3		0	0
36	4		1	1
37	5		1	1
38	6	Sub-Type	0 0 0 1	0 0 0 1
39	7		**1** 0 **2** 1 **3** 1 **4** 0	**1** 0 **2** 1 **3** 1 **4** 0
40	8		1 0 1 0	1 0 1 0
41	9		**Intent Change Flag**	**ATCRBS / Mode S Flag**
42	10		**IFR Capability Flag**	Reserved
43	11		(MSB)	
44	12		**NUC_R**	
45	13		(LSB)	
46	14		(Direction) Status	(Direction) Status
47	15		(MSB) (MSB)	(MSB) (MSB)
48	16			
49	17			
50	18		**E-W Velocity** **Magnetic Heading**	**E-W Velocity** **Magnetic Heading**
51	19			
52	20			
53	21			
54	22			
55	23			
56	24		(LSB) (LSB)	(LSB) (LSB)
57	25		(Direction) Type	(Direction) Type
58	26		(MSB) (MSB)	(MSB) (MSB)
59	27			
60	28			
61	29		**N-S Velocity** **Airspeed**	**N-S Velocity** **Airspeed**
62	30			
63	31			
64	32			
65	33			
66	34			
67	35		(LSB)	(LSB)
68	36		**Vertical Rate Source**	Reserved 0
69	37		Sign (0 = up, 1 = down)	Sign (0 = up, 1 = down)
70	38		(magnitude MSB)	(magnitude MSB)
71	39			
72	40			
73	41		**Vertical Rate**	**Vertical Rate**
74	42			
75	43			
76	44			
77	45			
78	46		(magnitude LSB)	(magnitude LSB)
79	47		**Turn Indicator** (MSB)	0
80	48		(LSB)	0
81	49		Sign (0 = up, 1 = down)	0
82	50		(magnitude MSB)	0
83	51			Reserved 0
84	52		**Geo. Alt. Difference**	0
85	53		**From Baro Alt.**	0
86	54			0
87	55			0
88	56		(magnitude LSB)	0