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Mode S TRANSPONDERS TEST BENCHES
FUNCTIONAL REQUIREMENTS
(new version)

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MODE-S TRANSPONDERS TEST BENCHES FUNCTIONAL REQUIREMENTS
(new version)

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Abstracts :

This note presents user requirements for test tools for Mode A/C/S transponders.
Based on both past experiences in transponder verification and present (and near future) maintenance necessities, a set of tests is proposed for what should be a minimum Ramp Test set.
A second part develops the tests for Laboratory units, conceived as an extension to the Ramp version.

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Mode S TRANSPONDERS TEST BENCHES FUNCTIONAL REQUIREMENTS (new version)

by

Michel BIOT

Summary

Ramp test equipment for Mode A/C transponders exist at present, but generally perform only the mandatory tests to assure the safe behavior of these avionics, in an environment of Elementary SSR Surveillance.

There is a need for standardized test tools, for Mode A/C and Mode S transponders, that would execute defined sets of measurements in defined test conditions so as to give comparable results for all users.

A Ramp version would be necessary for maintenance, and Laboratory versions for repair and research and development .

Based on multiple experiences of transponder performance measurements, as well as on actual test tools, the present paper develops the test needs, followed by the functional requirements that should be discussed with the interested parties before writing technical specifications.

LIST of ACRONYMS and ABBREVIATIONS

ACAS	Traffic alert and Collision Avoidance System
ADLP	Aircraft Data Link Processor
ADS	Automatic Dependent Surveillance
ADS-B	Automatic Dependent Surveillance-Broadcast
AICB	Air Initiated Comm-B
BDS	Binary Data Store : subfield in MB downlink field
BDS x,x	now renamed GICB register x,x
CMC	Central Maintenance Computer (of the aircraft)
CMS	Central Maintenance System (of the aircraft)
GDLP	Ground Data Link Processor
GICB	Ground Initiated Comm-B
GTVS	Ground Transponder Verification System
MOPS	Minimum Operating Performance Specifications (of the Transponders, edited by EUROCAE)
MTL	Minimum Trigger Level
POEMS	Pre-Operational (development) European Mode S Enhanced Surveillance
STFTV	Surveillance team Task Force for Transponder Verification
XPDR	Transponder (Mode A/C and Mode S)

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1 PRESENT SITUATION & NEEDS

1.1 NEED FOR TEST BENCHES

1.1.1 A bit of history

The ramp equipment for XPDR maintenance testing did evolve from totally manual test sets - only capable of fixed, Mode A/C interrogations (only the spacing P1 - P3 was variable), fixed PRF and SLS conditions, and few reply analyses (frequency, rough power, % of reply, pulse position of F2 only and acceptance window for other ones), - up to the present generation in use, capable of measuring under variable interrogation parameters (pulses, SLS) most of the pulse characteristics (including frequency variations) with a higher accuracy.

Presently equipment are digitally controlled but through long and semi-automatic procedures. Most ramp tools in use are variants with capabilities reduced on both interrogations and replies, characteristic and display; part of the problem is linked to the time limits, to user technicality, to price.

Mode S is now included in these equipment, limited to electrical parameters and some protocols.

1.1.2 Laboratory tests

Several test benches exist for Mode A/C but new bench tools are needed for Mode S XPDRs :

- to analyse new errors,
- to investigate new problems, new developments,
- to examine protocols,
- to help certify the airborne installation.

1.1.3 Ramp tests

Several ramp test sets exist for Mode A/C & Mode S but

- they are outdated,
- they are not yet adapted to - rapid testing of protocols,
  - the increased set of tests (data link functions).

1.1.4 Concerning tests in both situations

Data link function that add new domains of investigation that are only partially fulfilled (e.g. enhanced surveillance functions) by the test sets presently in use.

European Harmonisation is necessary for both tools and maintenance requirements (for Mode A/C & S airborne equipment) based on the same EUROCAE MOPS *(reference 2*).

1.1.5 Some useful references

We refer first to the "Annex 10", the bible of any equipment for SSR and ACAS systems (*reference 1*).

We based the present document initially on an information paper called "Off-line tools for Airborne Equipment" (*see reference 3*) developed by EUROCONTROL's DED.3 dated Feb 96, philosophy in support of the IIMSES requesting a coherent bench policy for these equipment, compatible with the future ATN.

Concerning the measurements to be executed in Mode A/C, the following documents are also used:

- the GTVS (Ground Transponder Verification System) feasibility (*references 4 & 5*)
- the STFTV (Task Force on Transponder Verification) (*references 6*)
- an FAA report " Field Study of Transponder Performance in General Aviation Aircraft (*references 7*).

1.2 THE LABORATORY TEST BENCH

1.2.1 A need for aeronautical administrations research and technical services

These equipment are developed in support of the EUROCONTROL's Initial Implementation Mode S Enhanced Surveillance Program (IIMSES) which requests a coherent policy be developed for bench testing of airborne equipment.

Data link, ADLP, ADS-B, ACAS, CMS developers in various European industries may take advantage of the availability of such a common instrument.

Existing test benches either measure only Mode A/C & S electric characteristics or some protocol but always off-line. The proposed bench go further in testing systematically all electric parameters and protocols on-line, giving way to up-down sequences, each reply influencing the next interrogation; these protocols include Comm A, B, C & D messages.

1.2.2 Test set-up for a complete test bench

Basically, the tests will be executed on the bench, but finally a ramp installation is necessary to validate “in situ “ the complete airborne chain (incl. antenna), that is, with ACAS, CMC,.. in a real environment " on the ground " or, simulated, " in the air ".

For this purpose, some extension towards ramp use (power, antenna, physical support) has to be envisaged. In addition to this operational validation, acceptance of the maintenance procedures will also use the laboratory benches.

Finally, mixed installations, combining the laboratory bench and a connected ground station can be used to investigate special problems or new configurations. A setup of this kind exist already between the EEC and French and UK technical services.

1.2.3 Objectives of the bench

- validation of SARPS;
- validation in view of equipment certification (not the certification itself);
- maintenance validation before delivering the certificate of conformity;
- evaluation and definition of the maintenance procedures to adopt for each version of airborne set-up (configurations certification);
- new investigations & operational evaluations.

1.2.4 Sets of tests

- Testing is based on ICAO Annex 10, the relevant RTCA & EUROCAE MOPS : signals in space - reply capability - messages exchange protocols - test conditions (see in Annexe 1 a cross-reference list between these various documents).
- Although some equipment will be connected to the XPDR & ADLP, they will not be tested by the proposed tool, they are only in and output to XPDR & ADLP (e.g. they could be replaced by a bench controlled airborne data simulator), but the validity of the complete chain will be tested.
- The lab bench will need 2 parallel units for testing the diversity of both channels of the transponders.
- Two versions of the lab test bench could be produced, differing by their software size (and possibly their "box") :

  a "complete" version for aeronautical research centres,

  another for maintenance labs, using a reduced set of software programs.

1.3 THE RAMP TEST BENCH

1.3.1 A need for aircraft operators (maintenance services)

Existing Ramp test sets are more or less outdated and cannot support all the requirements of

- complete set of Mode A/C tests
- all Mode S protocols
- BDS, squitter and long squitter validations

and the economy of fast and automatic testing.

1.3.2 A need for administrations (technical services)

The administrations must control

- the validity of the proposed maintenance requirement
- the execution of this maintenance.

They need also a mixed form of testing, for validation of different equipment in a pseudo-real environment; a set-up of this kind exist presently but this subset is not the purpose of the present document.

1.3.3 Objectives of the bench

The first objective being the testing in real conditions of Enhanced Surveillance transponders, the RAMP test bench has to be developed first, the laboratory equipment being an extension of the ramp unit.

1.3.4 Test conditions

- Testing is based on ICAO Annex 10, the relevant RTCA & EUROCAE MOPS : signals in space - reply capability - messages exchange protocols - test conditions (see also Annexe 1).
- The transponders will be tested in real situation, that is, aboard stationary aircraft, preferably out of the hangar to avoid reflection.

1.3.5 Availability

New ramp test sets are in preparation, that include automatic sequences; it is highly probable that their incresed capabilities will join our present request, at least partially. The present document is then a way of standardising these tools, to reach the minimum commonality.

1.4 COMBINED BENCHES

Grouping the various above described benches and taking into account that the ramp unit is basically a reduced version of the maintenance bench, itself a reduced version of the research bench, one may propose a common development and the building case like shown on the Figure 1 below

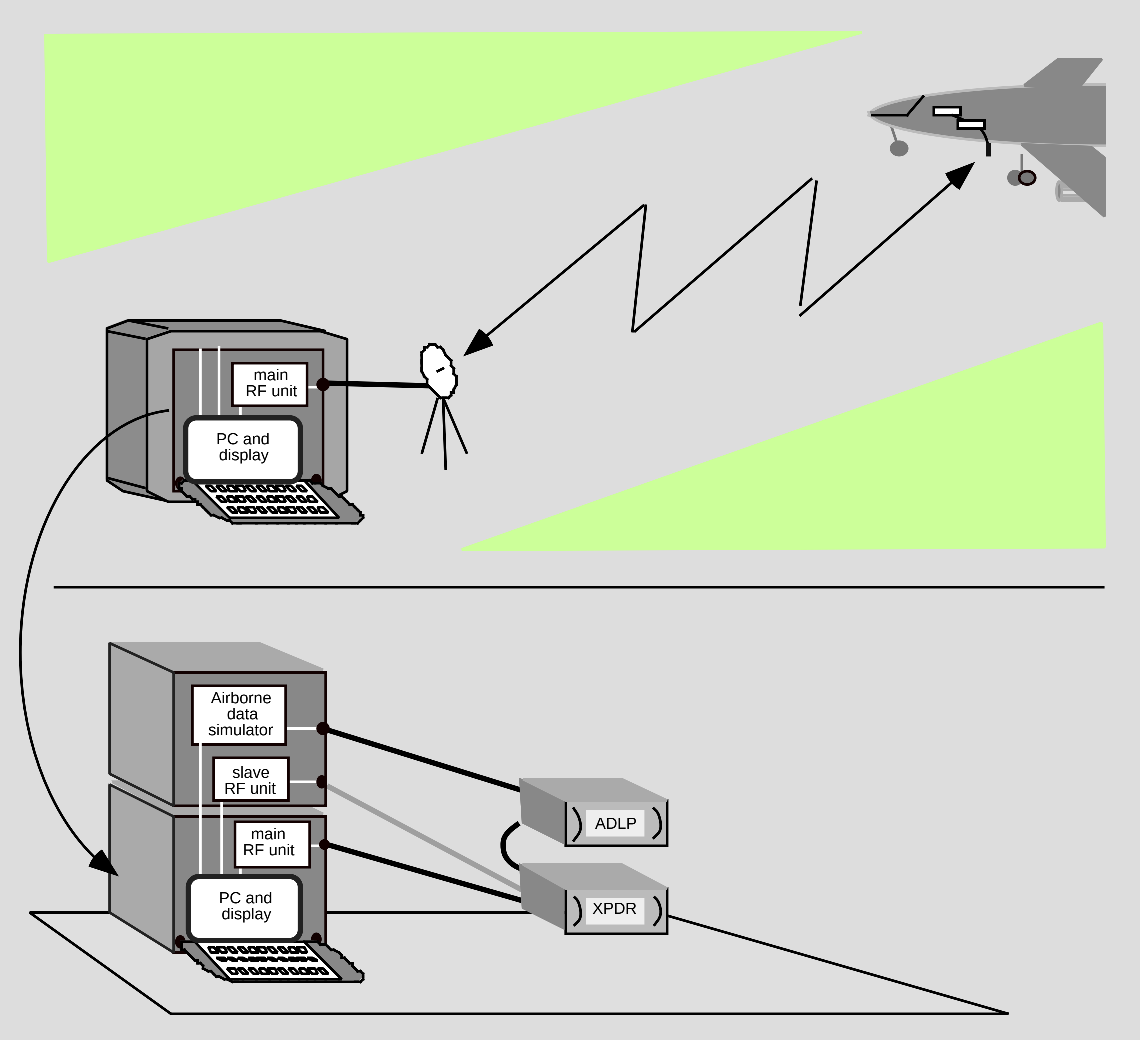

Figure 1 : Ramp and Laboratory benches for XPDR & ADLP

2 TEST LIST DETERMINATION

2.1 MODE A&C TESTING HISTORY *(see Table 1)*

2.1.1 Transponder measurements

Starting in 1984, two successive mobile test installations - the MTPA first, and then the DATAS - were built by EUROCONTROL for measuring transponders either on the bench or aboard aircraft moving on runways of several European airports.

Thousands of transponders have been measured and statistical data collected, served as support for ATC surveillance planning. Information on the defective transponders was also transmitted to administrations and companies, but the follow-up of this procedure was not really engaged.

During the same period, the equipment served as a very useful tool for transponder problem analysis and for development, investigations and pre-certification of the first European Mode S transponders.

The technology and the use of these equipment are since obsolete, but they form a first base for the present test definition in Mode A&C.

2.1.2 Automatic testing project

As a follow-up of these equipment, a feasibility study was submitted for an equipment called GTVS (Ground Transponder Verification System), to be installed on airports for measuring automatically the transponders aboard the landing aircraft (*see refs. 4 & 5*).

The required list of tests took into account

- the results of 5 years of measurements with the MTPA, reporting in particular fault percentages
- the theoretical consequences of malfunctions
- the real consequences observed during combined MTPA campaigns (where MTPA result was linked to simultaneous radar observations)
- the administrations reports (" Central Transponder File")
- the possibility of automatic measuring and realistic field results.

Trials and theoretical works executed by the study contractors showed that a set of additional measurements could probably be executed in their GTVS proposal. However, "variable" opinions existed about the possibility to execute these tests on moving aircraft with valid and operational results.

For the BENCH or RAMP test sets to develop here, the aircraft position is not a problem, and time is not limited, at least it is not a question of seconds). Therefore, we may consider that ALL the tests developed in Table 1 are a first minimum for all the benches.

2.1.3 STFTV priorities (*see ref. 6*)

The Task Force for Transponder Verification issued in 1995-96 a report that developed considerations and propositions concerning the verification of transponder behavior in the ATC surveillance environment.

As a conclusion of this task force, periodicity of testing, minimum set of tests and some other considerations were proposed. They are also included in Table 1.

2.1.4 Recent FAA field study *(see ref. 7)*

A recent field study of transponders aboard General Aviation aircraft in the USA was made using the modified FAA-DATAS equipment ; made on 548 flying aircraft, the test covered 31 parameters.

The percentage of failures are significantly high if one considers the strict ICAO norms; but they refer to General Aviation and in particular to aircraft rarely flying IFR.

The study concludes in showing the importance for ATC to test the following parameters : altiude validity, altitude reporting, delay time difference between Modes, sidelobe suppression *vs.* P1/P2 ratio, Mode A&C acceptance *vs.* P1 & P3 width.

2.1.5 A first list of tests in Mode A/C

The lists of parameters to test, executed or mentioned above, are presented next page in Table 1 , first list for a Bench Test System, concerning Mode A/C only.

It includes two columns revealing the importance of the measured parameter (theoretical consequences of malfunctions on ATC), the occurrence of faults during 1984-1988 and 1991-1993 MTPA-DATAS campaigns.

2.2 MODE S CHARACTERISTICS

The emergence of Mode S engaged the equipment manufacturers to develop Mode S transponder test sets some years ago; this generation of tools allows a series of electric characteristics to be tested, combined with a few essential protocol exchange verifications.

2.2.1 Ramp test set capabilities for Mode A/C/S transponders

The possibilities of presently available ramp test sets are given in Table 2. Due to time limits and some other considerations (economy, technical difficulties and unawareness of some misbehavior), the full amount of tests developed in Table 1 is not available or desirable on this sort of tool. (1)

2.2.2 RTCA & EUROCAE documents in Mode S / Intermode

RTCA 's MOPS DO-181A and EUROCAE's MOPS ED-73A (*see ref. 2*) describe the Mode S transponder and the tests procedures to ensure the transponder is complying with the ICAO requirements; chapter 3 contains the minimum performance specifications, chapter 5 the tests procedures to be executed in the laboratory, chapter 6 some additional ones executed on the ramp.

Although not being a maintenance document, but a manufacturing verification / certification test description, it is used as a main source document for establishing maintenance procedures and rules.

The document being a mandatory reference for the definition of the characteristics, it will serve as such in the present paper; more, in order not to reinvent the wheel, the protocol procedures will be used directly as listed in this document (and e.g. their numbering: procedures 1 to 39); these protocol procedures are shown in Table 3.

2.3 LATEST REQUIREMENTS

In order to support the Enhanced Surveillance program (see POEMS) and future ADS- applications, the ramp tool must,

- analyse long squitters,
- extract & display in clear all parameters contained in the GICB registers as defined in the Mode S Specific Service Manual,
- extract & display in clear AICB messages (ACAS essential).

The maintenance lab tool must, in addition

- test all protocols for DATA LINK and some ACAS protocols,

and the research lab tool

- be able to vary the interrogator's frequency
- test all ACAS protocols.

2.4 GLOBAL PROPOSAL

2.4.1 Note

To develop new ramp & lab test benches, one has to consider the following points:

- the research lab tool shall be able to test ALL the parameters defined in the various MOPS mentioned above
- the ramp tool shall be able to test all the IMPORTANT parameters, as shown in the above chapter; JAA43, STFTV and MOPS protocols list contains obligations for ramp testing, but this is far from being enough
- to preserve the future, the tools will be able to enlarge their capabilities, at least in the protocol domain.

2.4.2 Procedures

All tests in Tables 1, 2 & 3, plus the equivalent tests in other Modes whenever it applies, are grouped into test "PROCEDURES" . See the following Tables 4 & 5. (Hereafter, procedure ° x is labelled " P X ").

A subset of this “maximum” list is then proposed for the maintenance lab test set; a further reduced list is then eventually proposed for the Ramp test set.

Each procedure will describe a set of n [interrogation --> reply] sequences, that must be carried out to verify each characteristic or action of the transponder. For the electric tests, it corresponds to n identical sequences, where n is a function of the required accuracy. For the protocol tests, it is a series of necessary transactions.

Whenever possible, the procedures adopted in this paper will group several parameter measurements in one reply (or reply sequence) in order to gain time, especially useful in the Ramp test set. The way chosen for this grouping allows separation between the tests executed by the ramp test sets and those done in the laboratory or workshop.

2.4.3 Tests in different modes (electrical characteristics)

The way the characteristic is measured in Mode A&C or Intermode or Mode S may differ not only in the interrogations patterns and reply data, but also in the importance for ATC or by the fact that the parameter is already measured under another mode.

This explains the variety of testing between modes and between Ramp / Bench test sets, and also the way the tests are grouped into procedures.

2.5 LIST OF PROCEDURES FOR THE RAMP TEST SET

2.5.1 Preamble

The fact that a test or a procedure is proposed for the ramp test set does not implies it is mandatory for maintenance; the rules are defined by regulation bodies (JAA or others). The test sets here defined must at least be able to execute the present ramp imposed tests plus those recently proposed (see above).

2.5.2 Presentation

Some of the tests listed in the Tables 4 and 5 are already executed on the present generation of ramp test sets. Naturally they include, at least, all what is mandatory in FAR43 for Mode A&C.

The objective is to enlarge the capacity of these equipment to

- all tests proposed to be mandatory on ramp, in the STFTV report,
- similar tests in Mode S / Intermodes A&C, whenever it applies,
- some tests considered as important (see § 2.1) and generally already executable on lab test sets and/or suggested for bench testing in the STFTV report (see § 2.1.3),
- protocol tests necessary for long squitter and GICB register extraction, as recently required.

The procedures are listed as follows : P1 to P37 for protocol testing (same numbers as in the MOPS document), P51 to P87 for electrical parameters testing.

2.5.3 Details

2.5.3.1 *Modes A&C parameters*

In addition to present equipment's capability, one adds the tests

- pulse amplitude variation,
- delay time difference Mode A *vs*. Mode C,
- Mode A code validity, Mode C height validity (on the ground value),
- reply rate at various PRF instead of only 235 Hz or 500 Hz,
- Mode A & C acceptance *vs*. P1 >> P3 spacing;

all tests that can be easily implemented.

Test 4 was presently limited to the F2 position; the offset of ALL pulses should be verified and the maximum value (in fact, the worst) displayed.

2.5.3.2 *Intermodes A&C parameters*

The Intermode A&C acceptance *vs*. P4 short or long pulse is enlarged to a complete test, the acceptance *vs.* P4 width.

Important also is the test T32, Intermode A&C acceptance *vs*. P3 >> P4 spacing.

2.5.3.3 *Mode S - electric parameters*

Are added to the present test sets possibilities:

- pulse positions (mean offset is enough here),
- pulse amplitude variation from the 1st to the 56th or 112^{th,},
- mean pulse width,
- mixed reply rate capability (a complex series of various interrogations at various rates),
- Mode S acceptance *vs*. P1 >> Sync. Phase Reversal spacing.

All these tests are important for a correct decoding (a 112-bit long message is much more sensitive to a deviating clock than a 12-bit in the Mode A reply); including the Sync Phase Reversal, where the acceptance of the P2 >> P6 spacing should be verified inside a large window and not just limited to YES or NO at nominal time.

The squitter verification in Mode S is included in the protocol procedures (a complex combination of short and long squitters whose contents vary in accordance to GICB / Mode S Specific Service Manual).

It is not possible to test on the ramp (that is, without cable connections) the diversity parameters, the two antennas receiving simultaneously the signals, albeit with very small time delay and power difference.

2.5.3.4 Mode S protocols - compared to EUROCAE MOPS

The test procedure n° 1 (“P1”), Error Protection, is not possible with a XPDR installed in an aircraft, the address being “cabled” in the rack. Only the correct address will be verified as part of any other tests.

Test procedure P 3, the capability, and P 8, the PI verification, are checked in the replies DF11 in P 2 .

Squitter verification protocol n° 6 : these last years, the squitter protocols (simple and extended) have changed and may change further, since their increasing role in ATC. The ramp test bench shall be built such as only to accept and analyse the various squitter periodicity (P 6) .

Mode S addresses are tested in various combinations to discover e.g. incorrect cabling or bad contact in the transponder rack mounting (procedure P 9).

Procedure 1 0 verifies the altitude reports, but this depends on the installation possibilities.

Procedure 1 1 corresponds to the Mode A code validity executed on Mode A&C transponders, but contained here in a Mode S downlink messages; the importance is therefore the same.

Aircraft identification and stochastic behavior of the transponder are important data for a smooth radar behavior; these characteristics are easily tested in procedures 1 2 & 1 3 .

Comm-B messages are important in the exchanges between ground and aircraft, for various reasons, including ADS; they are not mandatory for all levels of transponders; more, some characteristics are not yet adopted neither definitive. But many BDS (see Mode S Specific Services) are already defined and they are included in the Basic and Enhanced Surveillance Functionalities. Therefore a new procedure P 1 7 concerning the GICB registers is developed for ramp testing.

Finally, an ACAS detection capability test (P35) seems useful in the ramp version.

2.5.4 Proposed List of Procedures

Finally, the following list of procedures is proposed for the Ramp Test set :

Mode A&C	:	procedures P 51, 52, 53, 57, 58, 62 &66 .
Mode S and Intermode A&C	:	procedures P 71, 72, 75, 77, 85, 86 &87 .
Mode S Protocol	:	procedures P 2, 6, 9, 10, 11, 12, 13, 17 & 35.

2.6 LIST OF PROCEDURES FOR THE LABORATORY TEST SETS

This version of the test set is of course much more complete as well as more flexible, because different types of users are interested.

For research centres, the complete list of procedures developed in the Tables 4 & 5 should be executable; this is developed in chapter 4. For maintenance labs, the set of tests (of procedures) will be reduced to those mandatory plus some easily executable; their list will be defined later, it is a subset of the complete list.

Mode A&C	:	procedures P 51 to 67 .
Mode S and Intermode A&C	:	procedures P 71 to 87 .
Mode S Protocol	:	procedures P 1 to 28 (there are no P 3, P8, P14)
		(other ACAS tests are reserved for a later version of this document).

Table 1 : FIRST SERIES of MODE A/C TESTS

Transponder's transmission characteristics (1090 MHz)	MTPA + DATAS mean failure occurrence (%) 84-88 / 91-93	MTPA + DATAS impor-tance	GTVS impor-tance	FAA impor-tance	STFTV require-ments
1 - reply frequency	3.8 / 2.0	XXX	XXX	XX	F
2 - mean output power	4.6 / 1.9	XX	XX	XX	F
3 - pulse amplitude variation during a reply	-		XX	-	
4 - pulse positions : max offset . " " : mean offset	1.9 / 1.8	XX	XXX XXX	XXX	S_A
5 - pulse width (mean of all pulses)	4.7 / 1.8	XX	XX	XX	S_B
6 - Mode A code validity	- / (a)		XX	-	
7 - Mode C : altitude report . " " on the ground	- (a)		XX	XXX	F
8 - delay time, delay time jitter	3.0 / 0.8 -	X	XX	X	S_B
9 - delay time difference Mode A *vs.* Mode C	-			XXX	
10 - delay time *vs*. input level				-	
11 - squitter periodicity (no interrogations)	-		XXX	-	
12 - reply pulse rise & decay times	-		X	-	
13 - reply rate *vs*. PRF @ 235 Hz . @ 500 Hz	- - / 0.8	 x	 xx	-	 F S_A
Receiver parameters (1030 MHz)					
21 - MTL Mode A, Mode C . MTL difference Mode A *vs*. Mode C	- / (a) - / (a)	X -	XX -	X	F
22 - dead time	≈ 0 / -		X	-	
23 - suppression time	0.7 / 0.6	X		X	
24 - receiving frequency acceptance	-		XXX	-	
25 - sidelobe suppression *vs*. P1 / P2 level ratio	0.8 / ≈ 0			XX	F (0 &9 dB)
26 - sidelobe suppression *vs*. P1 >> P2 spacing	4.7 / 0.8 (b)	XX		XXX	S_B
27 - sidelobe suppression *vs*. P2 pulse width	≈ 0 / -			-	
28 - interference (additional P1* - P1 - P3)	(a) / -				
29 - Mode A acceptance *vs*. P1 >> P3 spacing . *idem* Mode C	0.6 / 2.3 1.4 / 2.1	XX XX	X X	X X	S_A S_A
30 - Mode A&C acceptance *vs*. P1 & P3 width	0.3 / 16.3 (c)			X	S_B

- ***not measured***
a ***few measurements only; not statistically significant***
b ***one old series of transponder showed some strange behavior***
c ***one or two old series of transponder reacted to very short P1&P3 pulses (< 200 ns)***
X, XX, XXX ***by increasing importance***
F ***FAR 43 mandatory biennial Ramp test ; included in STFTV***
S_A ***STFTV addition to the FAR 43 requirements, for Ramp testing***
S_B ***STFTV supplementary addition for Bench testing.***
Test numbering (1 to 33) ; see note bottom of Table 2 next page

Table 2 : PRESENT RAMP TESTER CAPABILITIES

Transmission parameters (1090 MHz)	**Mode A/C**	**Intermodes**	**Mode S**
1 - reply frequency	Y	Y	Y
2 - mean output power	Y	Y	Y
4 - pulse positions : mean offset	Y		
5 - pulse width (mean of all pulses)	Y		
8 - delay time , delay time jitter	Y	Y	Y
11 - squitter periodicity	n a	n a	Y
15 - diversity isolation	n a		Y
Receiver parameters (1030 MHz)			
21 - MTL all Mode s	Y	Y	Y
25 - sidelobe suppression *vs*. P1 / P2 level ratio . (in Mode S : " " *vs*. P5 / P6 level ratio	Y n a	Y n a	 /
31 - Intermode A&C acceptance *vs*. P4 width . Intermode A&C only All-Call	- n a	- Y	- (Y) *(1)*
32 - Intermodes acceptance . *vs*. P3 >> P4 spacing	n a	n a	
33 - Mode S acceptance . *vs*. P2 >> Sync Ph.Rev. spacing	n a	n a	(Y) On / Off only
Messages control Up / Down			
- uplink address control			Y
- long squitter			Y
- UF 4			Y
- UF 5			Y
- UF 11 / Mode S Only All-Call	n a	n a	Y
- UF 16			Y
- UF 20			Y
- UF 21			Y
- Comm - A			limited *(2)*
- Comm - B			limited *(2)*
- Comm - C			
- Comm - D			

Note ***Y yes, available***

n a ***not applicable to this Mode***

(1) should not reply

(2) in octal; Comm-A only MA field programmable, limited and uneasy,
Comm-B difficult to extract the GICB registers (BDS) .

For the sake of cross-reference, the test numbers (first column) are common to <u>Tables 1,2 & 4</u> ;

n° 1 ⇒ 15 : electrical characteristics of the transponder's transmission (1090 MHz)

n° 21 ⇒ 33 : electrical characteristics, transponder's reception capability (1030 MHz)

no numbers for the message / protocol tests, as they will be regrouped with the MOPS procedure tests that follow.

Table 3 : MOPS ED-73A , PROTOCOL PROCEDURES

Procedures	MOPS procedure number	XPDR level	Laboratory tests	Ramp tests
Error protection	1	ALL	Y	
Interrogation acceptance	2	ALL	Y	Y
CA verification	(3 : in 2)	ALL	Y	Y
Non-selective lockout	4	ALL	Y	
Selective lockout	5	ALL	Y	
Squitter verification	6	ALL	Y	Y
FS & VS protocol / code	7	ALL	Y	
Parity - identity (PI) verification	(8 : in 2)	ALL	Y	Y
Address verification	9	ALL	Y	Y
Altitude report	10	ALL	Y	Y
4096 code	11	ALL	Y	Y
RI, acquisition & maximum airspeed	12	ALL	Y	
PR reply probability, stochastic acquisition	13	ALL	Y	
Comm-A, interface & information content	15	2	Y	
Broadcast All-Call formats (uplink)	16	2	Y	
Downlink interface DF 0, DF 16	(17 : in 18)	2	Y	Y
Comm-B protocol	18	2	Y	
Enhanced Comm-B protocol	18A	(2)		
AIS flight ident protocol & interface	19	2	Y	
Basic / extended capability report	20	2	Y	
Directed Comm-B	21	2	Y	
Comm-B broadcast	21A	2	Y	
Downlink interface, storage design, buffer rate	22	2	Y	
Downlink interface, no-storage design	23	2	Y	
Comm-C protocol	24	3	Y	
Uplink interface, ELM Comm-C	25	3	Y	
Comm-D protocol	26	4	Y	
Enhanced Comm-D protocol	26A	(4)		
Directed Comm-D	27	4	Y	
Comm-D interface, rate & content	28	4	Y	
Comm-U uplink interface	29	2	Y	
Sensitivity level operation	30	ACAS	Y	
RA report to Mode S ground interrogator	31,31A,31B	ACAS	Y	
Transmission of ACAS capability information	32,32A,32B	ACAS	Y	
ACAS or XPDR/ACAS failure during transmission	33	ACAS	y	
Coordination	34	ACAS	Y	
ACAS broadcast message	35	ACAS	Y	Y
XPDR replies to incoming ACAS resolution mess.	36	ACAS	Y	
XPDR / ACAS throughput	37	ACAS	Y	
XPDR communication timing	38	ACAS	Y	
ACAS crosslink	39	ACAS	Y	

Numbers in brackets means the parameter can be tested during another procedure in order to reduce the total measurement time

Table 4 : MAXIMUM TEST LIST - ELECTRICAL PARAMETERS

Transponder's transmission characteristics (1090 MHz	All XPDRs		Mode S XPDRs only		
	Mode A/C	procedure	Inter-mode	Mode S	procedure
1 - reply frequency	X	***P51***	X	X	***P71***
2 - mean output power	X	***P52***	X	X	***P72***
3 - pulse amplitude variation during a reply	√		XX	XX	
4 - pulse positions : max & mean offset	X		√	√	
5 - pulse width (mean of all pulses)	√		√	√	
6 - Mode A : code validity	√		*see P11*		
7 - Mode C : altitude	√	***P53***	*see P10*		
8 - delay time , delay time jitter	XX		√	√	P73
9 - delay time difference Mode A *vs*. Mode C	XX				
10 - delay time , delay time jitter	√	P54			
11 - squitter periodicity	√	P55	-	*see P6*	
12- reply pulse rise & decay times	√	P56	-	√	P73
13 - reply rate *vs*. PRF	X	***P57***			
14 - mixed reply rate capabilty Mode A + S			-	XX	***P75***
15 - diversity isolation			-	X	P76
Receiver capabilities (1030 MHz)					
21 - reveiver dynamic range (MTL) all Modes	X	***P58***	X	X	***P77***
22 - dead time	√	P59	√	√	P78
23 - suppression time	√	P60	-	√	P79
24 - receiving frequency acceptance	√	P61	-	√	P80
25 - sidelobe suppression *vs*. P1 / P2 level ratio (in Mode S : " " *vs*. P5 / P6 level ratio	X	***P62***	-	√	P81
26 - sidelobe suppression *vs*. P1 >> P2 spacing	√	P63	√	-	P82
27 - sidelobe suppression *vs*. P2 pulse width	√	P64			
28 - interference (additional P1* -P1-P3)	√	P65	-	√	P83
29 - Mode A&C acceptance *vs.* P1>> P3 spacing	X	***P66***	√	-	P84
30 - Mode A&C acceptance *vs.* P1 & P3 spacing	√	P67			
31 - intermode A&C acceptance *vs*. P4 width			X	-	***P85***
32 - intermode A&C acceptance *vs*. P3 >> P4 spacing			√	-	***P86***
33 - Mode S acceptance *vs*. P2 >> SyPhRev spacing			-	X	***P87***

Legend ***- not applicable***

√ applicable

X id, mandatory and/or recommende by STFTV + test similar in Mode S

XX id, and/or important for ATC >> to be executed also by the ramp test set

In BOLD OBLIQUE : procedures for the ramp test set (see 2.5.4)

Test numberingin the first column (1 to 33) : see note bottom of Table 2.

Table 5 : MAXIMUM TEST LIST - PROTOCOLS

Procedures	MOPS number	XPDR level applicable	procedures
Error protection	1	ALL	P 1
Interrogation acceptance	2	ALL	***P 2***
CA verification	(3)	ALL	*use instead tests P2 & P6*
Non-selective all-call lockout	4	ALL	P 4
Multisite Selective lockout	5	ALL	P 5
Squitter verification	6	ALL	***P 6 red*** / P6
FS & VS protocol / code	7	ALL	P 7
Parity - identity (PI) verification	(8)	ALL	*results obtained in tests P2, P4 & P5*
Address verification	9	ALL	***P 9***
Altitude report	10	ALL	***P 10***
4096 code (code set)	11	ALL	***P 11***
RI, acquisition & maximum airspeed	12	ALL	P 12
PR reply probability, stochastic acquisition	13	ALL	P 13
Comm-A, interface & information content	15	2	P 15
Broadcast All-Call formats (uplink)	16	2	P 16
Downlink interface DF 0, DF 16	(17)	2	*results obtained in test P18*
GICB register extraction / decoding only	-	2	***P 17***
Comm-B protocol Enhanced Comm-B protocol	18 18A	2	P 18
GICB regiter extraction & interface, Incl. AIS flight ident & other BDS	19	2	P 19
Basic / extended capability report	20	2	P 20
Directed Comm-B	21	2	P 21
Comm-B broadcast	21A		
Downlink interface, storage design, buffer rate	22	2	P 22
Downlink interface, no-storage design	23	2	P 23
Comm-C protocol	24	3	P 24
Uplink interface, ELM Comm-C	25	3	P 25
Comm-D protocol Enhanced Comm-D protocol	26 26A	4	P 26
Directed Comm-D	27	4	P 27
Comm-D interface	28	4	P 28
Comm-U uplink interface	29	2 , ACAS	
Sensitivity level operation	30	ACAS	
RA report to Mode S ground interrogator	31,31A&B	ACAS	
Transmission of ACAS capability information	32,32A&B	ACAS	
ACAS or XPDR/ACAS failure during transmission	33	ACAS	
Coordination	34	ACAS	
ACAS broadcast message	35	ACAS	***P 35***
XPDR replies to incoming ACAS resolution mess.	36	ACAS	
XPDR / ACAS throughput	37	ACAS	
XPDR communication timing	38	ACAS	
ACAS crosslink	39	ACAS	

Note : ***In BOLD OBLIQUE ; procedures for the Ramp Test set (see 2.5.4).***

3 RAMP TEST SET

3.1 PROCEDURE DESCRIPTION

There are 3 groups of procedures :

- Mode A&C procedures (§ 3.1.1)
- Mode S & Intermode A&C electrical procedures (§ 3.1.2)
- Mode S protocol procedures (§ 3.1.3)

<u>Legend</u>

1 - MS = Eurocae MOPS ED-73A (*see ref. 2*) for SSR transponders
: performance specifications (its § 3.2 ...);
MT = " " " : test procedures data (its § 5.4 & 5.5.8);
It is useful to refer also to the Cross-Reference table in Annexe,
which gives the relevant ICAO-Annex10paragraphs.

2 - Mean: in the 3 paragraphs 3.1.1 to 3.1.3, all values are computed as the mean of
100 replies (100 identical [interrogation--reply] sequences);
Time spacing are counted from the pulse front edges, at half-amplitude.

3 - Unless otherwise stated,
- PRF is 450 Hz for Mode A&C and 50 Hz for Intermodes and Mode S;
- When maximum load is requested, Mode A code is set to 7377 (+ the SPI if necessary)
because the highest load code (A 7777) could mislead safety on radar's in the vicinity;
- When a variation between successive bits is desirable, A 1642 is used.

4 - The sign ♋ means in a sequence : the interrogation followed by its reply.

5 - The sign ✈ shows settings on the transponder side (fixed and / or modified during the test)
that is entered or executed by the " pilot ".

<u>Note</u>

Procedures P58 & 77, measuring the MTLs, must be executed before the other Receiver Capability tests (58 before 59 to 66, and 77 before 80 to 87) that need the MTL values.
So, it is recommended to follow simply the numerical order (51 to 66, 71 to 87, 2 to 19) in the automatic sequence (see 4.2.4 for more details).

3.1.1 Mode A&C Procedures

Procedure *P 51*

a *Verification*

Reply Frequency.

b *Performance specifications*

MS 3.3.1 - MT 5.4.2.1.

c *Fixed settings*

interrogator at nominal setting; level at XPDR input : -50 dBm; Mode A.

✈ XPDR code : A 7377 + SPI.

d *Test progress*

100 [interrogation ♋ reply] sequences.

e *Measurement & display*

Frequency (1090 MHz): mean value of all pulses.

Procedure *P 5 2*

a *Verification*

Mean Output Power, Pulse Amplitude Variation, Mean Pulse Width, Pulse Positions, Mode A pulse decoding.

b *Performance specifications*

MS 3.3.3, 3.5.1 *to* 6 - MT 5.4.2.2, 5.4.3.1 .

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm; Mode A.

d *Test progress*

100 [interrogation ♋ reply] sequences with ✈ XPDR set to code A 7377 repeated with successively ✈ codes A 4000 and A 0400.

e *Measurement & display*

Reply code displayed;

for each code:

power : . . . . . . mean value of all pulses / mean value of lowest pulse
maximum variation between all pulse in a reply (min-max).

position of ALL pulses (vs. F1 + n x 1.45 µs) : mean value of each pulse
and the maximum offset (that is, the offset of the “worst” pulse)

pulse width : . . . mean value of all pulses.

Procedure P 53

a *Verification*

Delay Time, Delay Time Jitter, Delay Time Difference Mode A *vs*. C, Code C .

b *Performance specifications*

MS 3.7.1 , Annex 10 (Gilham conversion) - MT 5.4.3.3 .

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm .

d *Test progress*

100 [interrogation ♋ reply] sequences in Mode A; idem Mode C
✈ XPDR code A 1642, altimeter switched out if possible;
(if not : the altimeter will correspond to the “ground altitude”).

e *Measurement & display*

Delay time (P3 >> F1) : mean value Mode A and Mode C are compared ;
jitter on delay time σ of 100 replies);
reply altitude decoded (either C 0000 or xxxx, corresponding to -1000 ft or to “ground altitude”).

Procedure P 57

a *Verification*

Reply Rate *vs.* PRF.

b *Performance specifications*

MS 3.4.1 - MT 5.4.2.5 .

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm
✈ XPDR code : A 7377 + SPI .

d *Test progress*

PRF 500 interrogations per sec during one sec, followed by 5 or 10 sec rest,
then idem at 600, 700, . . . 1500 interrogations per sec.

e *Measurement & display*

Diagram : reply % *vs.* PRF.

Procedure P 58

a *Verification*

Mode A & C Sensitivity (MTL).

b *Performance specifications*

MS 3.2.4 - MT 5.4.1.2 .

c *Fixed settings*

Interrogator at nominal setting;

✈ XPDR code : A 1642, altimeter at zero if possible;

(if not : the altimeter will correspond to the "ground altitude").

d *Test progress*

100 [interrogation ♋ reply] sequences, level at XPDR input : -60 >> -80 dBm, per 1 dB steps

first with Mode A, then repeated using Mode C.

e *Measurement & display*

Diagram : reply % *vs.* input power; MTL = interrogator's level when reply rate crosses 90 %

MTL difference Mode A <-> C displayed.

Procedure P 62

a *Verification*

Sidelobe Suppression *vs.* P1 / P2 Level Ratio.

b *Performance specifications*

MS 3.8.2 - MT 5.4.4.1 .

c *Fixed settings*

interrogator at nominal setting;

✈ XPDR code : A 1642, altimeter at zero if possible;

(if not : the altimeter will correspond to the "ground altitude").

d *Test progress*

With a P2 at nominal position & width, P2/ P1 ratio varying from -12 dB >> + 3 dB, per 1 dB steps

100 [interrogation ♋ reply] sequences for each step

repeated for the level at XPDR input : -50 dBm & MTL + 3 dB.

e *Measurement & display*

Diagram : reply % *vs*. P2 / P1 ratio, tolerance areas shown (for the 2 input power levels).

<u>Reduced version</u> (if available time is too short) : replace the diagrams by reply % at -9.0 dB and 0 dB only.

Procedure ***P 66***

a *Verification*

Mode A & C Acceptance *vs.* P1 >> P3 Spacing.

b *Performance specifications*

MS 3.9.3 - MT 5.4.5.2.

c *Fixed settings*

Interrogator at nominal setting;
✈ XPDR code : A 1642

d *Test progress*

P1 >> P3 spacing varying from 6.5 >> 9.5 µs and 19.5 >> 22.5 µs, per 25 ns steps
100 [interrogation ♋ reply] sequences for each step.

e *Measurement & display*

Diagram : reply % *vs*. P1 / P3 spacing, tolerance areas shown
for both Mode A (6 >> 10 µs) and Mode C (19 >> 23 µs).

<u>Reduced version</u> (if available time is too short) : replace the diagrams by a set of values;
reply % at -7.0, 7.8, 8.2, 9.0 µs and 20.0, 20.8, 21.2, 22.0 µs only.

3.1.2 Modes S and Intermode A&C Electrical Procedures

Procedure ***P 71***

a *Verification*

Reply Frequency.

b *Performance specifications*

MS 3.3.1 - MT 5.4.2.1.

c *Fixed settings*

Interrogator at nominal setting; PRF 50 Hz; level at XPDR input : -50 dBm;
✈ XPDR code : A 1642.

d *Test progress*

100 [interrogation UF 05 ♋ reply DF 05] sequences
or [Intermode A ♋ reply DF11] sequences.

e *Measurement & display*

Frequency (1090 MHz) : mean value of all Mode S pulses.

Procedure P 72

a *Verification*

Mean Output Power, Pulse Amplitude Variation, Mean Pulse Positions, Mean Pulse Width.

b *Performance specifications*

MS 3.3.3, 3.6.1 to 3.6.6 - MT 5.4.2.2, 5.4.3.2 .

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm;

✈ XPDR code : A 1642.

d *Test progress*

100 [interrogation UF 05 ♋ or 21* ♋ reply DF 05 or 21*] sequences

or [Intermode A ♋ reply DF11] sequences.

e *Measurement & display*

Frequency (1090 MHz) : mean value of all Mode S pulses.

power : . . . . . . mean value of all Mode S pulses

+ diagram : amplitude of each reply datapulse (1st >> 56th or 112 th *).

pulse position : mean offset (nominal vs. 1st pulse + (0.5 x n) µs)

pulse width: . . .mean value of, separately, the preamble pulses, the 0.5 µs pulses & the 1 µs pulses.

*Note * : depending on the capability of the transponder.*

Procedure P 7 5

a *Verification*

Mixed Reply Rate Capability.

b *Performance specifications*

MS 3.4.2 - MT 5.4.2.5 .

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm;

✈ XPDR code : A 7377 + SPI.

d *Test progress*

4 separated sequences lasting 1 sec each :

a - 500 interrogations Mode A uniformly mixed with 50 UF 05 interrogations * in 1 s

b - 120 interrogations Mode A uniformly mixed with 18 UF 05 interrogations * in 0.1 s, followed by 0.9 s rest

c - 30 interrogations Mode A uniformly mixed with 8 UF 05 interrogations * in 0.025 s, followed by 0.975 s rest

d - 2 interrogations Mode A uniformly mixed with 4 UF 05 interrogations * in 0.0016 s, followed by 0.9984 s rest .

note * : if the XPDR is equipped for long replies, respectively 16 of the 50, 6 of the 18, 4 of the 8 and 2 of the 4 interrogations must require long replies.

e *Measurement & display*

The XPDR must reply to ALL these interrogations.

Procedure *P 77*

a *Verification*

Intermode A/C and Mode S Sensitivity (MTL).

b *Performance specifications*

MS 3.2.4 - MT 5.4.1 .

c *Fixed settings*

Interrogator at nominal setting;

✈ XPDR code : A 1642, altimeter at zero if possible;

(if not, the altitude will correspond to the "ground altitude").

d *Test progress*

- 100 [interrogation Intermode A ♋ reply DF11] sequences,
  level at XPDR input : -60 >> -80 dBm, 1 dB steps;
- repeated for Intermode C.
- 100 [interrogation UF 11 (with PR = 0) ♋ reply DF 11] sequences,
  level at XPDR input : -60 >> -80 dBm, per 1 dB steps.

e *Measurement & display*

Diagrams : reply % *vs*. input power; MTL = interrogator's level when reply rate crosses 90 %.

MTL difference Mode A ⇔ C displayed

(for MTL + 3 dB and higher, the reply rate must be 99 %).

Procedure *P 85*

a *Verification*

Intermode A/C Acceptance *vs*. P4 width.

b *Performance specifications*

MS 3.9.4 - MT 5.4.5.2 .

c *Fixed settings*

Interrogator at nominal setting; no P2;

✈ XPDR code : A 1642, altimeter at zero if possible;

(if not, the altitude will correspond to the "ground altitude").

d *Test progress*

Level at XPDR input : -21, -40 & -60 dBm

P4 varying from 1.0 >> 3.0 µs, per 25 ns steps

100 (interrogation ♋ reply) sequences for each step and each input level.

e *Measurement & display*

Diagram : reply % *vs* P4 width, tolerance areas shown

for both Intermode A & C and for each of the 3 input levels.

Procedure P 86

a *Verification*

Intermode A/C Acceptance *vs*. P3 >> P4 Spacing.

b *Performance specifications*

MS 3.9.3 - MT 5.4.5.2 .

c *Fixed settings*

Interrogator at nominal setting; no P2;

✈ XPDR code : A 1642, altimeter at zero if possible;

(if not, the altitude will correspond to the "ground altitude").

d *Test progress*

Level at XPDR input : -21, -40 & -60 dBm

P3 >> P4 spacing varying from 1.4 >> 2.7 µs, per 25 ns steps

100 [interrogation ♋ reply] sequences for each step & each input level.

e *Measurement & display*

Diagram : repy % *vs*. P3 >>P4 spacing, tolerance areas shown
for both Intermode A & C and for each of the 3 input levels.

Procedure P87

a *Verification*

Mode S Acceptance *vs.* P2 >> P6 (Sync. Phase Reversal) Spacing.

b *Performance specifications*

MS 1.6.4, 3.9.5 - MT 5.4.5.2 .

c *Fixed settings*

Interrogator at nominal setting;

✈ XPDR code : A 1642.

d *Test progress*

P2>> Sy. Ph. Rev. spacing varying from 2.4 >> 3.1 µs, per 25 ns steps;

level at XPDR input : MTL +3 dB and -50 dBm ;

100 [interrogation ♋ reply] sequences for each step for each power level.

e *Measurement & display*

Diagram : reply % *vs.* P2 >> Sync. Phase Reversal spacing, tolerance areas shown,
both level curves shown.

3.1.3 Mode S Protocol Procedures

<u>Note</u>

For all the protocol tests, the interrogator is at nominal regarding “electric” values; no pulse P2 is used; level at XPDR input is -50 dBm; uplink address is the XPDR address; XPDR code is A 7377.
Unless especially mentioned.
Some test are only applicable to some types of XPDRs, depending on their level (see third column in table 5) or whether they are “Mark 4 “ or not (see the double asterisks **); for this last type of transponders, see *reference 8* "Transponders with extended interface functions (Mark 4)".
For these ramp tests, diversity operation must be inhibited to avoid unequal, unknown reception by the XPDR and “jumping” problems : the power and delay differ, and, worse, the upper antenna may be totally invisible to the test set located on the ground; or simpler, the test set ignores which antenna is replying; therefore, the top channel must be terminated by its characteristic impedance.
Successive signs ♋ mean a sequence containing more than 1 interrogation followed by 1 reply.

<u>Attention</u>

The Mode S Specific Services as well as the squitter protocol may still change in the near future; so, in some of the protocol tests (see : “ ATTENTION : THE SPECIFICATIONS MAY VARY”), the BDS definition, their use, the sequences, and the repetition rate (if applicable) may be different from what is developed; but the principle of the measurement remains. Always refer to the latest version of the Mode S Specific Services (*reference 9*) and Mode S Subnetwork SARPS.

<u>The formats</u> used in these tests are the following :

Uplink Formats :

UF 00	000	RL :1	0000	AQ : 1	DS : 8	00 0000 0000	**AP : 24**

UF 04	PC :3	RR : 5	DI : 3	SD : 16	**AP : 24**

UF 05	PC :3	RR : 5	DI : 3	SD : 16	**AP : 24**

UF 11	PR : 4	IC : 4	CL : 3	0000 0000 0000 0000	**AP : 24**

UF 16	000	RL :1	0000	AQ : 1	00 0000 0000 0000 0000	MU : 56	**AP : 24**

UF 20	PC: 3	RR : 5	DI : 3	SD : 16	MA : 56	**AP : 24**

UF 21	PC: 3	RR : 5	DI : 3	SD : 16	MA : 56	**AP : 24**

11	RC : 2	NC : 4	MC : 80	**AP : 24**

(YY : x means x bits are devoted to this field YY ; 0000 show a series of zeros between fields)

Downlink Formats :

DF 00	VS : 1	0	CC : 1	SL : 3	00	RI : 4	00	AC : 13	**AP : 24**	
DF 04	FS : 3	DR : 5	UM : 6	AC : 13	**AP : 24**					
DF 05	FS : 3	DR : 5	UM : 6	ID : 13	**AP : 24**					
DF 11	CA : 3	AA : 24	**PI : 24**							
DF 16	VS : 1	00	SL : 3	00	RI: 4	00	AC : 13	MV : 56	**AP : 24**	
DF 17	CA : 3	AA : 24	ME : 56	**AP : 24**						
DF 20	FS : 3	DR : 5	UM: 6	AC : 13	MB : 56	**AP : 24**				
DF 21	FS : 3	DR : 5	UM: 6	ID : 13	MB : 56	**AP : 24**				
11	0	KE : 1	ND : 4	MD : 80	**AP : 24**					

(YY : x means x bits are devoted to this field YY ; 0000 show a series of zeros between fields)

Procedure *P 2*

a *Verification*

Interrogation Acceptance.

b *Performance specifications*

MS 3.20.2.2 & 3, 3.21.1.1 & 4 , 3.21.3 - MT 5.5.8.2 / protocol procedure n° 2 -
Ref. 8 Mark 4 Transponders.

c *Interrogation ♋ reply sequences*

- Mode A, Mode C, Intermodes A/S & C/S, Intermodes A Only & C Only :
  without P2 first, then with P2 (P2 level = P1) pulse included ;
- Mode S:

UF 0	{ with RL = 0, =1 }		
UF 11	{ PR = 0 , IC (= II) = 0, CL = 0 } { address =[FF FFFF] hex }		
UF 4, 5,	{ with RR = 0, 15, 16, 17, 18, & 19 } { PC, DI, SD = 0 }		
UF 20, 21	{ with RR = 0, 15, 16, 17, 18, & 19 } { PC, DI, SD, MA = 0 }	(**)	
UF 16	{ with RL = 0, =1 }	(**)	
UF 24	{ with RC = 2 }	(**)	

d *Control*

The correct reply in each of the Modes (incl. II = 0);
in DF11 replies, verify the CA depending on the XPDR type (CA = 0, 4, 5, 6 & 7)

Procedure *P 6 reduced*

(Ramp limited version of the Lab test set P6 procedure).

a *Verification*

Acquisition and Extended Squitters : Capability, rate (only ground position here).

b *Performance specifications*

MS 3.20.2.6, 3.21.2.6, 3.21.1.12 - MT 5.4.3.2.2 & 3

ANNEX 10 (*ref.1*) § 3.1.2.8.5 & 6.

c *Interrogation ♋ reply sequences*

Unsolicited replies in Mode S - No interrogations for the squitter themselves, but interrogations are sent to determine the choice of contents in the extended squitter ME field.

Remark : If existing, the onboard mutual suppressing system must be inhibited.

1 - XPDRs with ACQUISITION SQUITTER ONLY

the DF 11's are transmitted with the following contents:

DF11	CA	AA (24 bits) address in clear	PI parity on II = 00

300 squitters are observed, without any interrogations.

2 - XPDRs with EXTENDED SQUITTER

the DF 11's are transmitted like above:

then , DF 17's are transmitted with the following contents:

DF17	CA	AA (24 bits) address in clear	ME (56 bits) broadcast message	PI parity on II = 00

Fill XPDR register 0,6 with surface format type = 6 and movement field set to 30 kts

(data {35 6A AA AA AA AA AA}^{H}; refresh it each second. Enable the On-the-ground condition.

Sequence:

UF04 with RR=16, DI = 2 and SD = { TCS=2, RCS=1, SAS=2, ….}

(for enabling Ground position, fast rate, bottom antenna).

UF04 with RR=16, DI = 7 and SD = { RRS=6, ….} to generate a GICB = 0,6 content.

50 sec of squitters are observed.

Repeat the sequence with RCS=2 (to provoke the low rate)

d *Control*

The random transmission rates for the various squitters:

diagrams of Number of events *vs.* time between messages (in steps of 15 ms); values are as follows :

DF 11 mean rate 1 / sec (limits : 0.8 *to* 1.2 s)

DF 17 register 06 2 / sec (limits : 0.4 *to* 0.6 s) for the high rate

DF 17 register 06 2 / 10 sec (limits : 4.8 *to* 5.2 s) for the low rate

Observe the contents of the ME fields (0,6 registers).

Procedure *P 9*

a *Verification*

Mode S Address.

b *Performance specifications*

MS 3.17.1, 3.18.4.7 & 34, 3.20.2.1, 2 &11 - MT 5.5.8.9 / extract of protocol procedure n° 9 .

c *Interrogation ♋ reply sequences*

UF 05 : [PC = 0] [RR = 0] [DI = 0] [SD = F000^H] [AP = X]
UF 11 : [PR = 0] [IC = Y] [CL = Z] [. . . . . zeros . . . .] [AP = X]
where X = the 552 combinations of 2 ONEs & 22 ZEROs and of 2 ZEROs & 22 ONEs
plus the known (the sole) address of the transponder in test in the aircraft
and Y,Z equal successively 1,0 -- 14,0 -- 1,1 -- 14,1 -- 1,2 -- 14,4.

(these Y and Z variations are proposed to verify the reply to the "new" SI codes, which contains the "old" II field and are a combination of IC and CL fields).

d *Control*

The non-reply to all 7 x 552 combinations (to UF 05, to UF 11 with the 6 different Y,Z combinations);
the reply with correct contents for the 7 interrogations that must be accepted:
DF 05 : [FS = 1] [DR = 0] [UM = 0] [ID = code 7377] [AP = XPDRs address]
DF 11 : [CA = 0, 4, 5 or 6 depending on the capability] [AA = XPDRs address] [PI as hereunder]
PI = 0000 0000 0000 0000 0, Z, Y *(see ref.1, § 3.1.2.3.3.2*)
For "old" transponders having not the SI code possibility, the uplink CL is ignored and Z = 0 in the reply.

Procedure *P 1 0*

a *Verification*

Altitude Report.

b *Performance specifications*

MS 2.5, 3.5.6, 3.17.1 b - MT 5.5.8.10 / extract of protocol procedure n°10.

c *Interrogation ♋ reply sequences*

Intermode C (Mode C / S All-call P1- P3 -P4) ←DF 11 reply with AA =XPDRs address ←
UF 04 : [PC = 0] [RR = 0] [DI = 0] [SD = 0000^H] [AP = the address] ←DF 04 reply ←
UF 04 : [PC = 0] [RR = 20] [DI = 0] [SD = 0000^H] [AP = the address] ←DF 20 reply .
Two options, depending on whether or not
a pressure / altitude variator is available , and
sufficient time for these repeated sequences is acceptable;
if NO : test only the “ground altitude” and , if possible to switch off the altitude data, 0000 value
if YES : install the altitude-pressure variator at the relevant captor output and introduce successively a series of defined altitudes such arranged as to give a diversity of bit patterns :
-975 , -600, +600, 2800, 8700, 11800, 12400, 18800, 24300, 24600,
30800, 33400, 36800, 62800, 94800, 100800, 120800 & 1266700 ft .

d *Control*

The correct contents in the replies :
DF 11 : [CA = 0, 4, 5 or 6 depending on the capability] [AA = XPDRs address] [PI = 0].
if NO : DF 04 : [FS = 1] [DR = 0] [UM = 0] [AC= x] [AP = XPDRs address]
DF 20 : [FS = 1] [DR = 0] [UM = 0] [AC= x] [MB = 0] [AP = XPDRs address]
x = Gilham conversion of the ground altitude and - 1000 ft if altitude is switched off;
if YES : idem with x = each of Gilham conversion of the various altitudes set on the variator.

Procedure *P 1 1*

a *Verification*

Mode A Report.

b *Performance specifications*

MS 2.5, 3.5.6, 3.20.2.11 - MT 5.5.8.11 / protocol procedure n° 11.

c *Interrogation ♋ reply sequences*

UF 05 : [PC = 0] [RR = 20] [DI = 0] [SD = 0000^H] [AP = the address] ←DF 21 reply

The " pilot " manipulates the control box switches to follow a list of the 66 combinations containing 2 ONEs and 10 ZEROs plus 66 others with 2 ZEROs and 10 ONEs.

d *Control*

The correct replies for each of the successive codes (X) introduced by the pilot :

<u>DF 05</u> : [FS = 1] [DR = 0] [UM = 0] [AC= X] [AP = XPDRs address]

DF 21 : [FS = 1] [DR = 0] [UM = 0] [AC= X] [MB = 0] [AP = XPDRs address].

<u>Reduced version</u> (if available time is too short) :

only the A 1642 code is used instead of the 66 + 66 combinations.

Procedure *P 12*

a *Verification*

RI, Acquisition and Maximum Airspeed.

b *Performance specifications*

MS 3.17.1, 3.18.4.30 & 35 , 3.23.1.5 - MT 5.5.8.12 / protocol procedure n° 12.

c *Interrogation _ reply sequences*

Depends on whether the XPDR is ACAS-compatible or not:

1 - NOT ACAS-compatible:

UF 00 : [000] [RL = 0] [000] [AQ = 0 & 1] [000....000] [AP = the address] ←DF 00 replies

2 - The XPDR is ACAS-compatible : the same UF 00 plus

UF 00 : [000] [RL = 1] [000] [AQ = 0 & 1] [000....000] [AP = the address] ←DF 16 replies ←

UF 16 : [000] [RL = 0] [000] [AQ = 0 & 1] [000....000] [MU = 0] [AP = address] ←DF 00 replies ←

UF 16 : [000] [RL = 1] [000] [AQ = 0 & 1] [000....000] [MU = 0] [AP = address] ←DF 16 replies .

d *Control*

The correct replies :

If **<u>1</u>** :

<u>DF 00 replies</u> :

[VS =1] [SL = 0] [RI = x] [AC = altitude on the ground] [AP = XPDRs address]

where x = | 8 to 14 depending on the max airspeed, when bit AQ was 0
| 0 when bit AQ was 1.

if **<u>2</u>** : (*see MS 3.23.1.5*)

<u>DF 00 replies</u> :

[VS =1] [SL = 0 to 7 depending on the ACAS level or the a/c] [RI = x] [AC = altitude of the ground] [AP = XPDRs address]

where x = | 0, 2, 3, 4 , depending on the ACAS capability of the a/c, when bit AQ was 0
| 8 to 14 , depending on the max airspeed, when bit AQ was 1 .

<u>DF 16 replies</u> : same contents, plus MV filled with zeros.

Remark : More complete tests of the ACAS exchange protocol are executed in Bench test set procedures 31, ...

Procedure P 1 3

a *Verification*

Stochastic Acquisition.

b *Performance specifications*

MS 3.18.4.28 , 3.20 2.2.i - MT 5.5.8.13 / protocol procedure n° 13.

c *Interrogation ♋ reply sequences*

UF 11	PR = X	IC = II = 0	CL = 0	0000 0000 0000 0000	**AP =** XPDRs address

where X is varying from 0 to 15, with 100 interrogations each;

1 - with no lockout set

2 - with one lockout set.

d *Control*

The correct % of replies in each case (with a tolerance of ± 30% for the values other than 99 or 0) :

if **1** - PR =	0 & 8	%	> = 99
	1 & 9		= 50 (35 >> 65 replies to 100 interrogations)
	2 & 10		= 25 (18 >> 32)
	3 & 11		= 12.5 (9 >> 15)
	4 & 12		= 6.2 (4 >> 8)
	other		= 0
if **2** - PR =	8	%	>= 99
	9		= 50 (35 >> 65)
	10		= 25 (18 >> 32)
	11		= 12.5 (9 >> 15)
	12		= 6.2 (4 >> 8)
	other		= 0

Procedure P 17

a *Verification*

GICB Register Extraction / decoding only.

b *Performance specifications*

MS 3.18.4.32, 3.21.1.12 &13, 3.21.2.1 - *Ref. 9* : Mode S Specific Services Manual.

ATTENTION : THE SPECIFICATIONS MAY STILL VARY :
In any case, refer to the latest version of Mode S Specific Services Manuals.

c *Interrogation ♋ reply sequences*

UF 05 : [PC = 0] [RR = x] [DI = 7] [SD = zy00] [AP = XPDRs address] ⇐DF 21 replies ;
where z is the interrogator's ident (IIS subfield), e.g. = 15
x and y vary so as to request various BDS presently in us or proposed (see hereunder),
x = sum of 16 + BDS1 subfield
y = RRS subfield = BDS2 subfield.
Hence, if the desired BDS = 4,1 , BDS1 = 4 & BDS2 =1, hence RR = 20 & RRS = 1 .
The list of registers proposed for the Basic and Enhanced Surveillance is
1,0 -1,7 - 2,0 - 4,0 - 4,1 - 5,0 - 6,0

✈ The transponder must be linked to the corresponding interfaces (ADLP ...) that will input the relevant information in the corresponding register (255 x 56 bit buffer).

d *Control*

For each of the desired register, the Ramp test set must only test the protocol process, that is, to see if the transponder sends back a correct DF21 reply; this DF 21 contains the following fields:
[DF = 21] [FS = 1] [DR = 0] [UM = X] [ID = a/c code A] [MB = message ≠ 0] [AP = XPDRs address] .
with UM = IIS followed by IDS (IIS = z above and IDS = 1 = active CommB reservation).

Procedure P 35

a *Verification*

ACAS Detection Capability.

b *Performance specifications*

MS 3.23.1.3 & 4. - MT 5.5.8.39 / protocol procedure n° 35.

c *Interrogation ♋ reply sequences*

UF 16 : [RL = 1] [AQ = 0] [UDS1 = 3] [UDS2 = 2] [rest of MU = any value] [AP = 16 different addresses]
⇐DF 16 : [VS = 1] [SL = …] [RI = …] [AC = altitude=0] [MV = *see hereunder*] [AP = XPDRs address]
where MV =[VDS1 = 3] [VDS2 = 0] [ARA = 0] [RAC = 0] *[the rest = any value]* .

d *Control*

Check DF16 replies, in quantity and in the above mentioned contents.

3.2 RAMP TEST PROGRAM

3.2.1 Operation

The installation of the test procedures in the Ramp test set is based on a set of successive software modules, that control the sequences developed in paragraph 3.1.

The execution of the tests are dependant of acknowledgement (approval), continue, interrupt or re-start buttons. These buttons may be physically installed in front of the equipment or touch-screen operation.

3.2.2 Modules

Each module controls a succession of displays and waiting periods for any order given by the buttons:

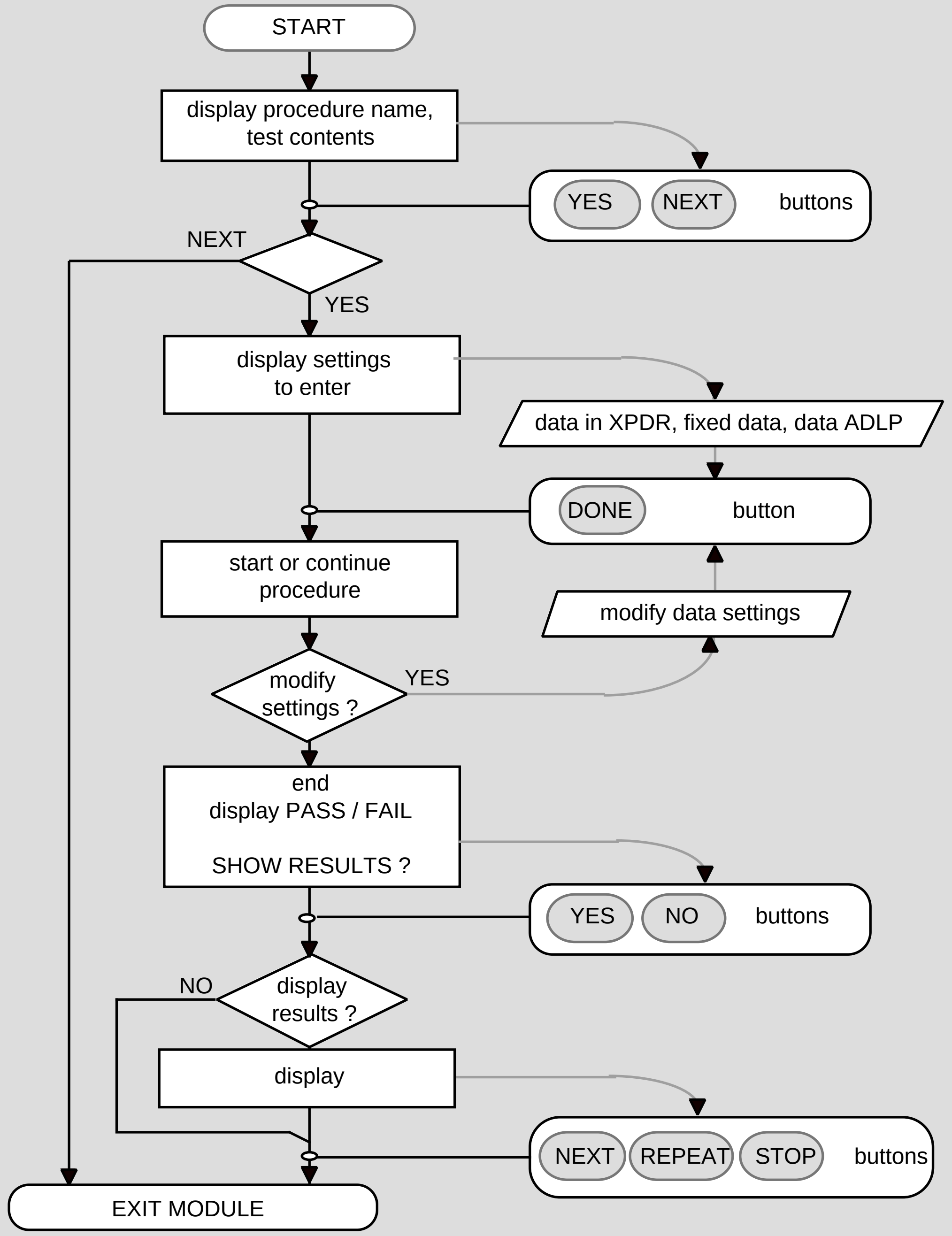

Figure 2 : module for one procedure / basic schematics

· display the procedure name and tests contents, wait for approval or stop or next procedure;
· display the settings: the data to enter in the transponder via its control box (e.g. the code) or, if applicable, to the external equipment linked to it (ADLP, ...), wait for execution order;
· start of the procedure, stops whenever a new setting has to be applied during the procedure (e.g. change of code), wait for continue order;
· stops at end of testing, display of the information " PASSED " or " FAILED ", wait for order display result or go to the next procedure;
· if result display button has been "pushed", the successive results are presented in the form corresponding to the measurement :

a data: e.g. Pulse Width = 455 ns (mean of 100 replies, 14 pulses) the tolerances is 350 >> 550 ns
a X/Y diagram : e.g. reply % *vs*. P3 width with the tolerance areas in gray
a list of reply messages e.g. DF11, CA = 7, AA = 808080, II = 0 with the text : correct / wrong

after which the system switches over to another module.

3.2.3 Trial modules

A trial is a planned sequence of procedures defined by the above modules; see the figure 3 :

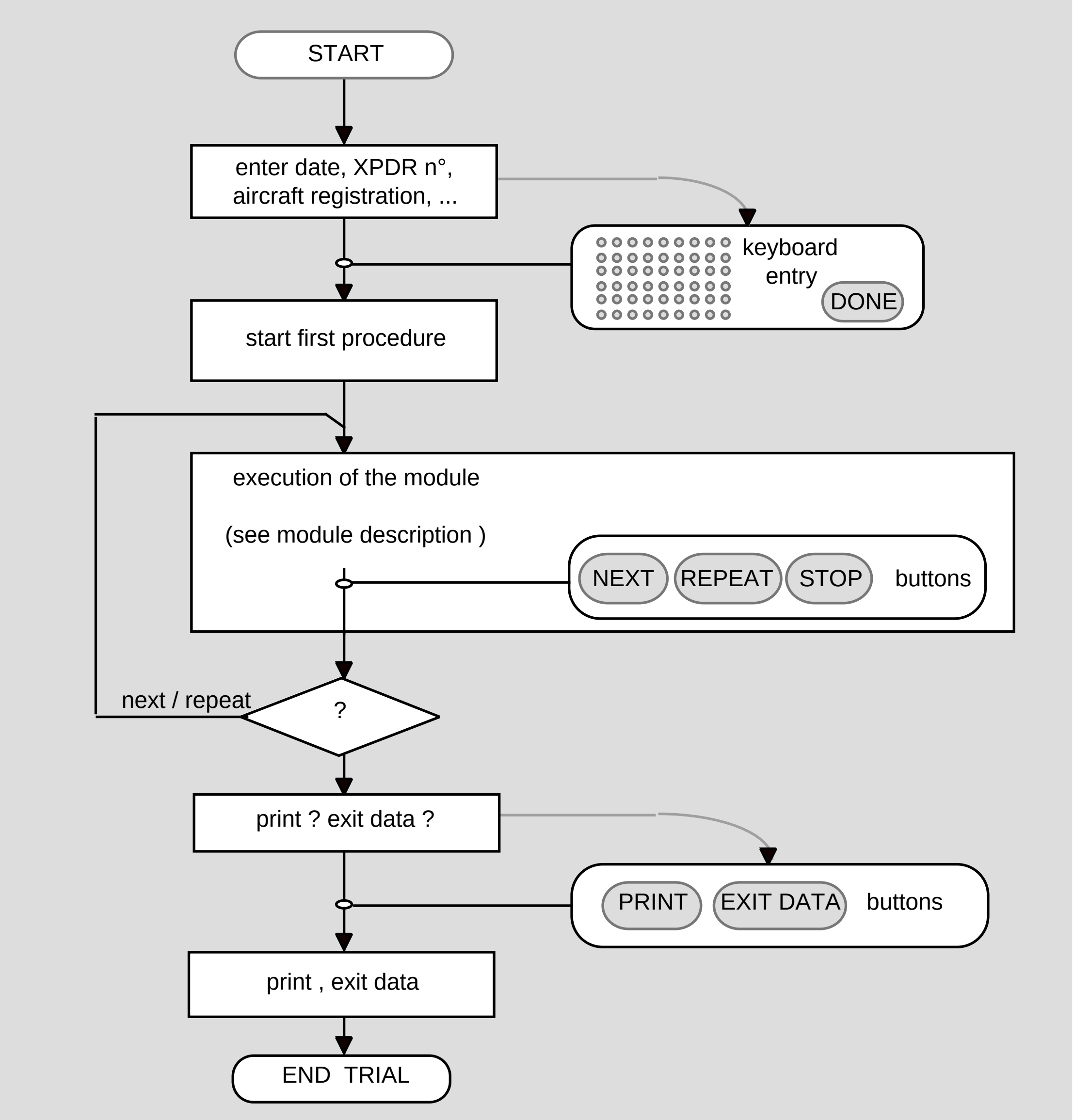

Figure 3 : 1 module for 1 trial (a series of procedures) / basic schematics

A planned sequence is a list established depending on the user needs (planned maintenance, repair, research, ...)

3.2.4 Fast trials

In order to speed up the trial, one can adopt a succession of test sequences, each sequence being arranged in such a way that the same settings are used for all the tests contained, and no interrupt messages appears during or between tests (like “ modify settings ? “ or “ display results ” or “ exit data ?“); all data are stored in memory and printed at the end if wanted.
The only interruption in the trial is then the necessary change of settings between two sequences; see the following figure :

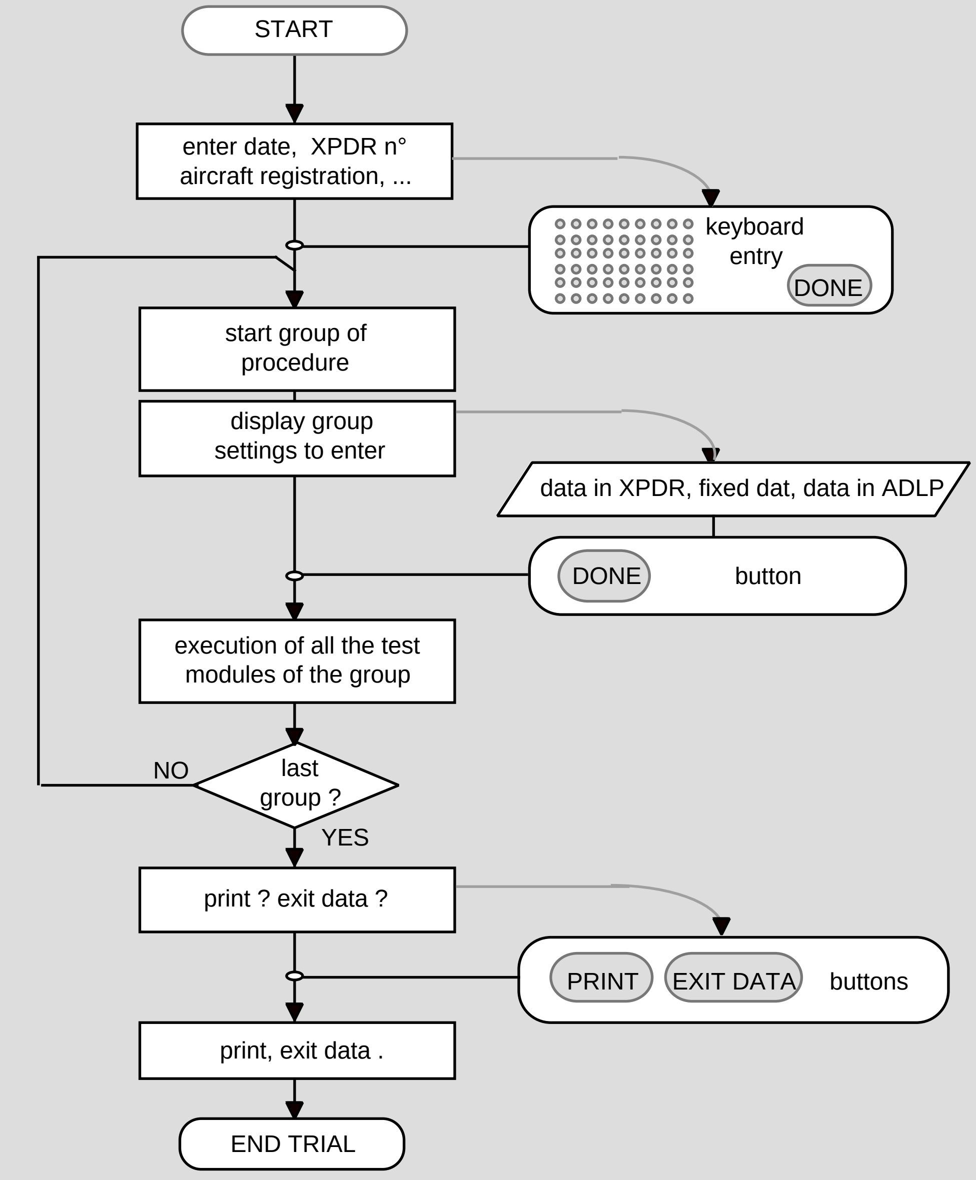

Figure 4   :   fast trial   (planified group of test procedures)   / basic schematics

Example of succession of sequences :

- Set code to A 7377 + SPI ← sequence P51 - P57 - P75 -P52 ;
- change code to 4000 ← P52 again ;
- change code to 0400 ← P52 again ;
- change code to 1642 and switch off the altimeter
  ← sequence P53 - P58 - P62 - P66 - P71 - P72 - P77 - P85 - P86 - P87 ;
- print the result.

3.2.5 Other possibilities

The system built for the ramp test set needs some flexibility; one must be able to modify the characteristics of the tests. It is an obligation to allow

- the evolution of maintenance rules, these being adapted to the ATC SSR problems and to manufacturing changes,
- the research and developments of administrations and airliner maintenance services,
- the easy building of the laboratory test set variant.

This implies the “availability” of the modules: one must be able to access the measurement parameters (number of iterations, succession of Mode S formats, etc...), with the sole limitations that only authorized technicians may control these elements and that in any case, the default values are set back for the usual operator. Unauthorized values (too large, ..., impossible message subfield, ...) for the test parameters are announced to the operator and the system wait for new entry.

3.2.6 Results management

3.2.6.1 *Memory*

All results are automatically written in memory; it contains the date, the transponder under test references (serial number, aircraft registration, Mode S address), each successive test protocol (number, name), the conditions of the test (settings), the resulting data (whatever the form) even if no display was asked by the operator during the test.

3.2.6.2 *Result transfer*

The contents of the memory must be transferable by any actual means (floppy disk or equivalent, GPIB bus, RS232, ...) to another computer base or local network. Printer output is required.

3.2.7 Autotest

The system must contain an autotest device, that is automatically launched before any operation starts.
This autotest verifies the input and output of the system and can control the exactness of the measurements through a reference transponder.
It must be possible to introduce the distance ramp tool -- aircraft antenna before starting the tests, in order to the apply the corresponding time delay correction.

3.3 TECHNICAL DATA

The equipment must be able to generate all the tests described in the test lists above and therefore must have the following capacities:

3.3.1 Output / Uplink characteristics

- frequency : 1020 - 1040 MHz, in steps of 0.2 MHz
- pulse : minimum width 250 ns, in steps of max 25 ns,
  with intervals of 200 ns between one pulse decay and the next pulse rise
  pulse rise and decay times respecting ICAO Annex 10
  DPSK modulation for uplink P6 pulses (idem)
- pulse sequences : all Mode A, C, Intermode A, C,S
  that is, all combinations of two following P1, P2, P3, P4 trains;
  Mode S UF / DF 00, 04, 05, 11, 16, 17, 20, 21, 24 with any field and subfield contents;
  time delays up to 30 sec (use in lockout tests if these test are added)
- repetition rate : PRF 1 to 100 Hz in Mode S, to 2000 Hz in the other Modes
- power : for measurements at 2 to 25 (or 15) meters: up to 37 or 44 dBm (5 or 25 W)
  (at output of antenna), in steps of 0.5 dB
  difference between channels : up to . . . . .
- physical output : 10 W maximum to antenna through connecting cable (connector "N")
- antenna : directional, on a tripod.

3.3.2 Input / Downlink characteristics

- frequency : 1070 - 1110 MHz, resolution 0.01MHz
- pulse : minimum width 200 ns, resolution 25 ns (or shorter)
  with intervals of 200 ns between one pulse decay and the next pulse rise pulse rise
  and decay times measurable
- power : up to 0.1W (17 dBm) at input to antenna, with a resolution of 0.5 dB.

3.3.3 Display

- active matrix for confortable external natural light
- 9 inch screen 800 x 600 pixels
- either 20 lines of text or diagram X/Y
- dialog windows with on-screen buttons data result presentation.

3.4 COMBINED BENCH

As presented in § 1.4 and displayed in Figure 1 (*see page 4*), it would be recommended to foresee the physical capacity of inserting the ramp tool in the maintenance laboratory equipment, that is,
- to give the possibility to insert the ramp tool as a rack subpart of the lab tool,
- with the necessary connections for synchronisation
(The lab tool has two RF channels with independant clocks and pulse generation but their starts must be synchronisable, for diversity tests and similar measurements).

3.5 TESTING ENVIRONMENT

The equipment will be used essentially on external.
- Power input : 90 to 240 V , 45 - 440 Hz
- Temperature, humidity and other similar characteristics : as usual for this type of equipment.

4 LABORATORY TEST BENCH

4.1 PROCEDURE DESCRIPTION

<u>Legend</u>

1 - MS = Eurocae MOPS ED-73A for SSR transponders : performance specifications;
2 - MT = " " " " " : test procedures data;
3 - Mean: in the 3 paragraphs 4.1, 4.2 & 4.3, all values are computed as the mean of
100 replies (identical [interrogation -- reply] sequences);
4 - Time spacing are counted from the pulse front edge at half amplitude.
5 - As the transponder is cable connected to the bench test set, the codes used in Mode A may be set to their maximum load, that is, 7777 (this could not be done in the air with the Ramp test set, as this code is used for emergency!).

<u>Note about the Test Sequence</u>

Procedures P 58 & 77 should be executed before the other Receiver capability tests (58 before 59 to 67, and 77 before 78 to 87) as they measure the different MTLs whose values are used in other tests. So, it is recommended to follow simply the numerical order (51 to 67, 71 to 87) when usually testing the Electric Parameters.

<u>Installations</u>

This simplest installation of Figure 5 hereunder is used for all tests, except when otherwise stated.

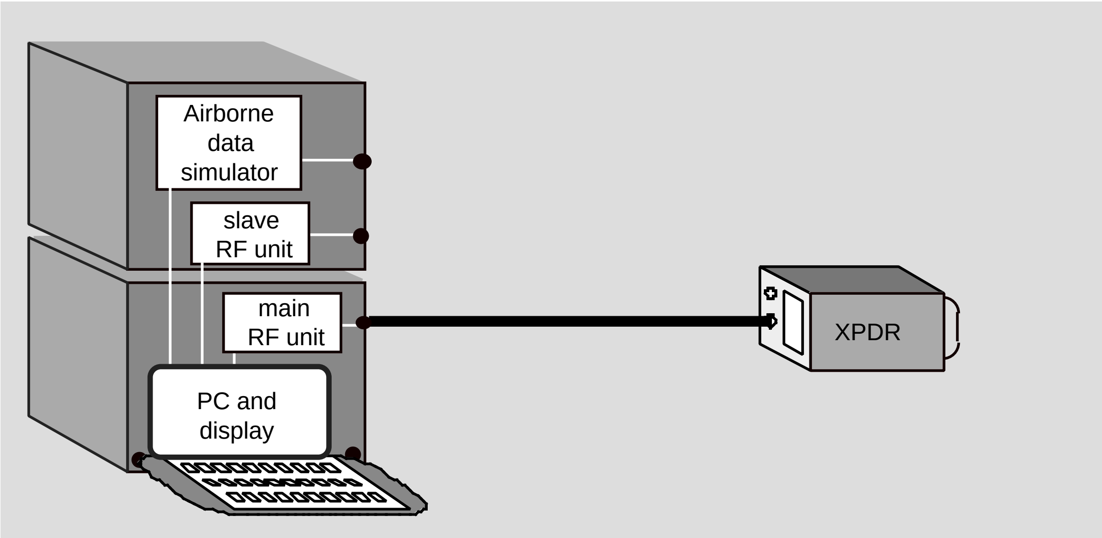

Figure 5

Test procedures P 51 and P71 use the following installation :

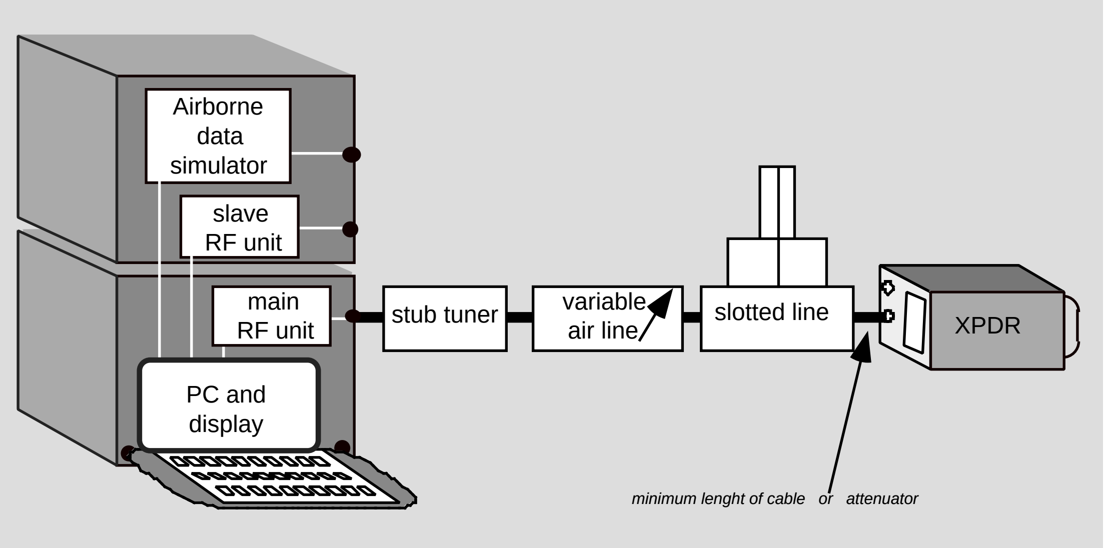

Figure 6

Test procedures P1, P56 and P74 use the following installation :

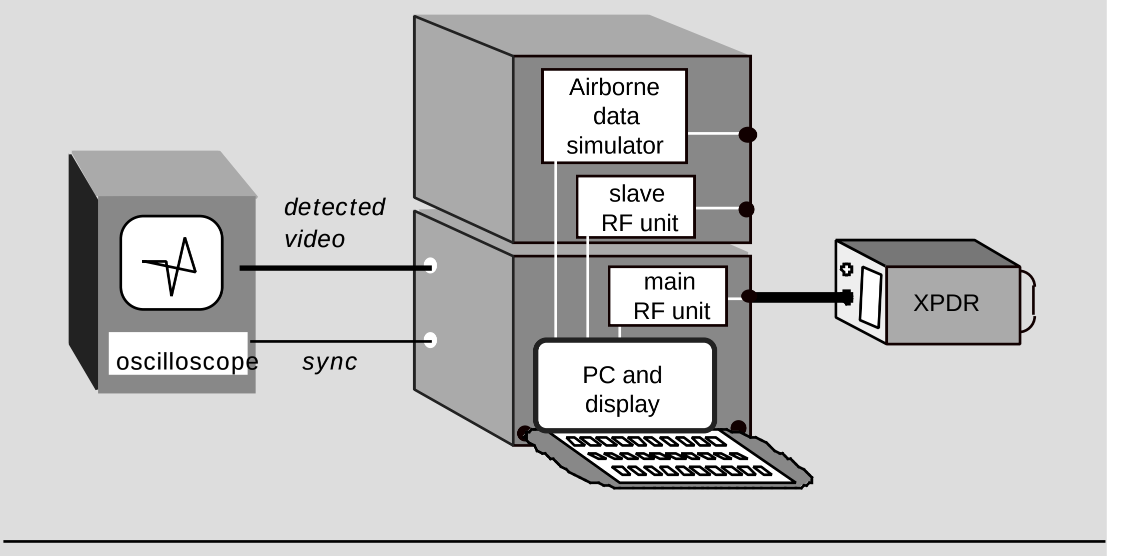

Figure 7

Test procedures P 65, P79 and P83 use the following installation :

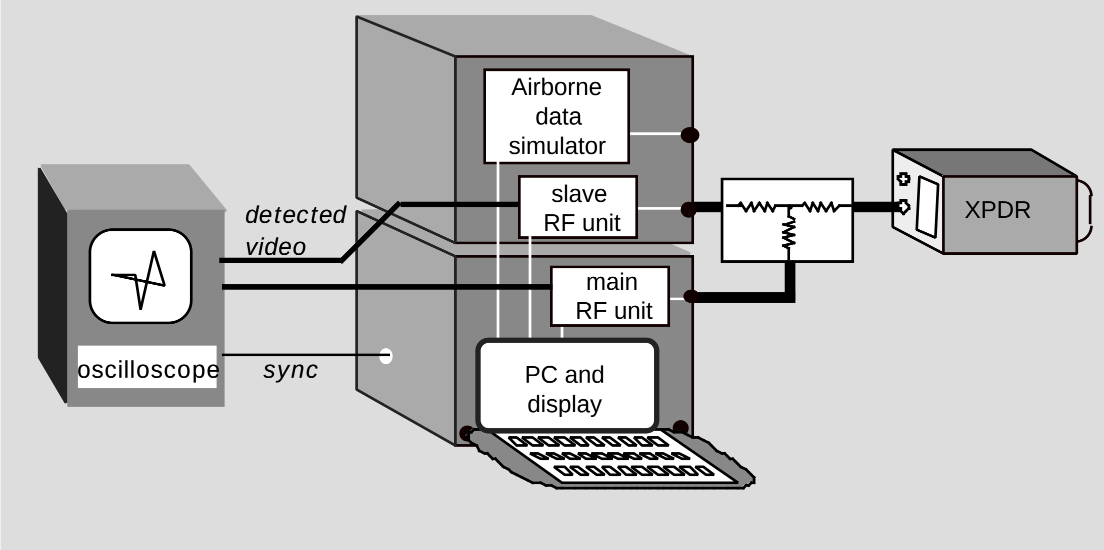

Figure 8

Test procedures P 76 uses the following installation :

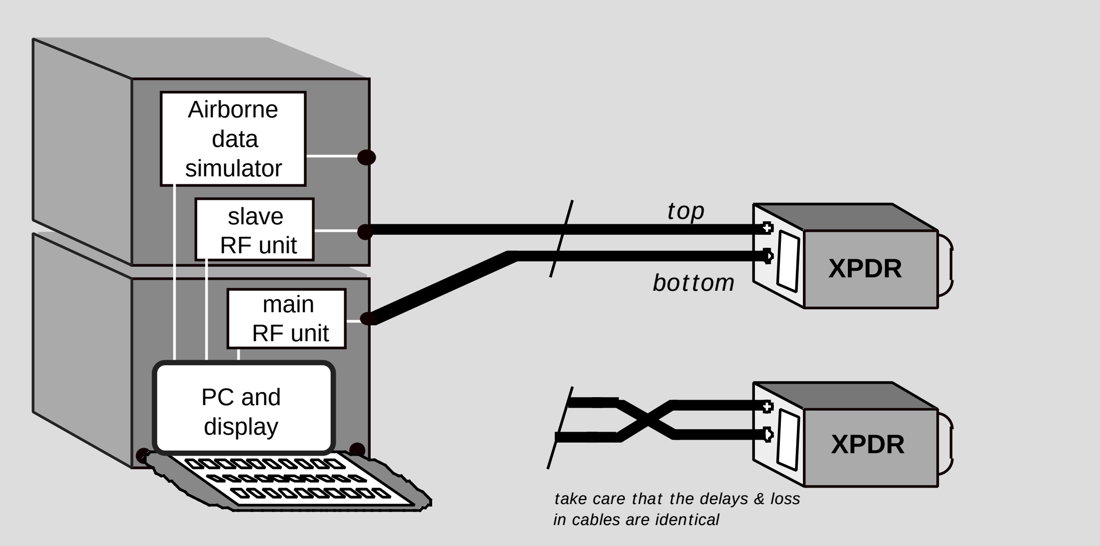

Figure 9

Test procedures P 7 uses the following installation :

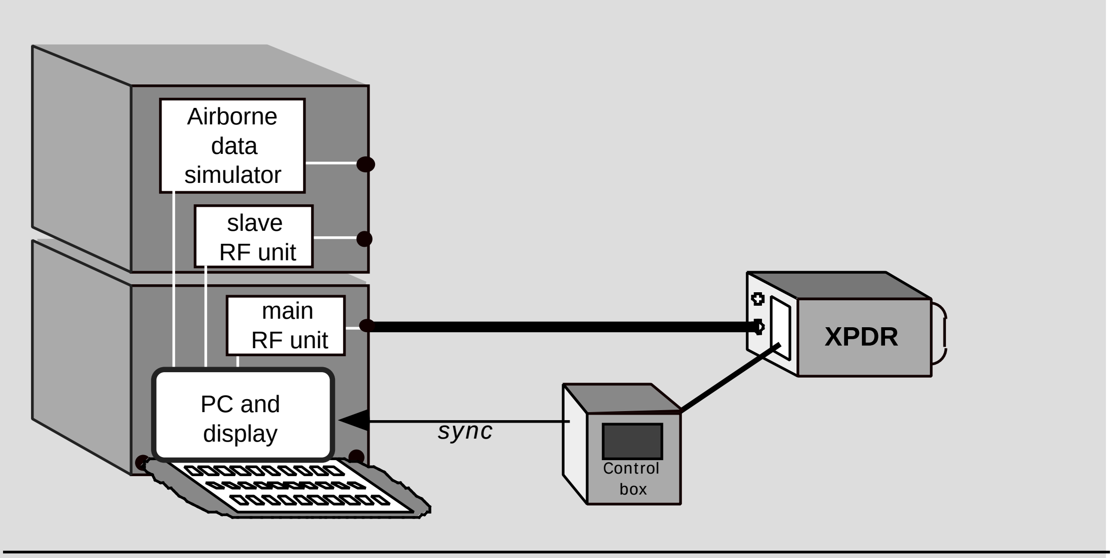

Figure 10

Test procedures P 6, P15, P16, P18, P21 to P28 use the following installation :

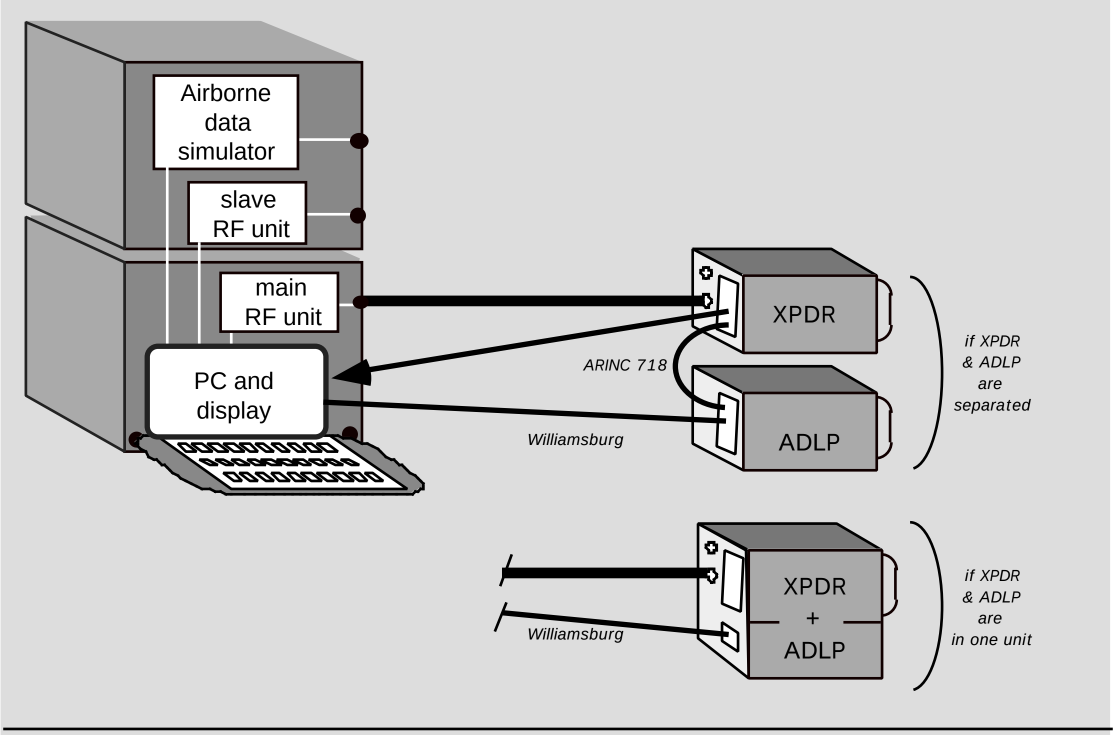

Figure 11

4.1.1 Mode A&C Procedures

Procedure *P 51*

a *Verification*

Reply Frequency.

b *Performance specifications*

MS 3.3.1 - MT 5.4.2.1.

c *Installation & fixed settings*

Connect the equipment's as on figure 6;
interrogator at nominal setting; level at XPDR input : -50 dBm; Mode A ; XPDR code : A 7777 .

d *Test progress*

To measure the frequency, adjust the line stretcher for maximum transmitter frequency shift above or below 1090 MHz .

e *Measurement & display*

Record the frequency (mean value of all pulses).

Procedure *P 52*

a *Verification*

Mean Output Power, Pulse Amplitude Variation, Mean Pulse Width, Pulse Positions,
Mode A Pulse Decoding.

b *Performance specifications*

MS 3.3.3, 3.5.1 *to* 6 - MT 5.4.2.2 , 5.4.3.1 .

c *Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm; Mode A.

d *Test progress*

100 [interrogation ♋ reply] sequences with XPDR set to code A 7777 & PRF 200 Hz;
repeated with successively code A 7777 & PRF 1000 Hz; code A 7777 & PRF 1200 Hz;
code A 4000 & PRF 500 Hz; code A 0400 & PRF 500 Hz.

e *Measurement & display*

Reply code displayed;
for each code and power combination:
power : mean value of all pulses / mean value of lowest pulse
maximum variation between all pulse in a reply (min-max);
position of ALL pulses (vs. F1 + n x 1.45 μs) : mean value of each pulse
and the maximum offset (that is, the offset of the "worst" pulse);
pulse width: mean value of all pulses.

Procedure ***P 5 3***

a *Verification*

Delay Time, Delay Time Jitter, Delay Time Difference Mode A *vs.* C, Code C .

... *idem Ramp Test set (see page 17).*

Procedure ***P 5 4***

a *Verification*

Delay Time *vs.* Input Level .

b *Performance specifications*

MS 3.7.1 - MT 5.4.3.3 .

c *Fixed settings*

Interrogator at nominal setting; PRF 500 Hz; Mode AXPDR code set to A 7777;
(repetition under Mode C is not necessary);
XPDR altimeter switched out.

d *Test progress*

100 [interrogation ♋ reply] sequences.

e *Measurement & display*

Diagram : delay time *vs.* input level; being different from one transponder to another, the form of the curve may be interpreted as the “ signature” of the transponder.

Procedure ***P 5 5***

a *Verification*

Unsollicited replies.

b *Performance specifications*

MS 3.1.3 - MT 5.4.8 .

c *Fixed settings*

No interrogations;
for Mode S transponders, inhibit the squitter generation with one of the external equipment's switch.

d *Test progress*

Wait 30 sec.

e *Measurement & display*

Count the number of (unsollicited) replies Mode A; should not be greater than 5 per sec;
idem Mode C; same limit;
idem Mode S; should not be greater than 1 per 10 sec.

Procedure ***P 56***

a *Verification*

Pulse Rise & Decay Times.

b *Performance specifications*

MS 3.5.4 - MT 5.4.3.1 .

c *Installation & Fixed settings*

Connect the equipment’s as on figure 7;
interrogator at nominal setting; PRF 500 Hz; level at XPDR input : -50 dBm; Mode A.

d *Test progress*

continuous [interrogation ♋ reply] sequences (time to examine the screen);
XPDR code : successively A 7777, A 0400, A 1010, A 0010.

e *Measurement & display*

determine rise and decay times with screen markers,
for the various combinations of pulses, give the variation if there is one.

Procedure ***P 57***

a *Verification*

Reply Rate *vs.* PRF.

b *Performance specifications*

MS 3.4.1 - MT 5.4.2.5 .

c *Installation & Fixed settings*

Interrogator at nominal setting; level at XPDR input : -50 dBm;
XPDR code A7777 + SPI.

d *Test progress*

PRF ; 100 interrogations per sec during one sec, followed by 5 sec rest,
Then increase the PRF in steps of 50 Hz up to 2000 Hz, with 5 sec rest between each step.

e *Measurement & display*

Diagram : reply % *vs.* PRF.

Procedure ***P 58***

a *Verification*

Modes A & C Sensitivity (MTL).

... *idem Ramp Test set (see page 18) but with levels at XPDR input running from -21 to -80 dBm.*

Procedure *P 59*

a *Verification*

Dead Time.

b *Performance specifications*

MS 3.10.3 - MT 5.4.4.1 .

c *Installation & Fixed settings*

Interrogator at nominal setting; PRF 450 Hz;

XPDR code A 1642 .

d *Test progress*

100 [interrogation ♋ reply] sequences as follows:

Mode A (level at XPDR input : -21dBm)

followed by a variable delay

followed by a Mode A interrogation (level MTL + 3 dB);

the delay varies from 50 to 125 µs per 1µs steps.

e *Measurement & display*

Diagram : reply % *vs.* delay; the dead time = the value when reply rate crosses 90 %.

Procedure *P 60*

a *Verification*

Suppression Time.

b *Performance specifications*

MS 3.8 - MT 5.4.4.1 .

c *Fixed settings*

Interrogator at nominal setting; PRF 450 Hz;

XPDR code : A 1642 .

d *Test progress*

100 [interrogation ♋ reply] sequences as follows:

P1 - P2 (δ t 2 µs , same level) followed by a variable delay followed by a Mode A interrogation

delay : from 15 to 55 µs per 1µs steps;

test done at: -21, -50, -65 dBm & MTL + 3 dBm.

e *Measurement & display*

Diagram : reply % *vs.* delay; the suppression time = the value when reply rate crosses 10 %;

shown for each level.

Procedure ***P 6 1***

a *Verification*

Receiving Frequency Acceptance.

b *Performance specifications*

MS 3.2.2 - MT 5.4.1.2 .

c *Fixed settings*

Interrogator at nominal setting except the frequency; PRF 450 Hz

XPDR code : A 1642 .

d *Test progress*

100 [interrogation ♋ reply] sequences for levels at input XPDR from –60 dBm >> –80 dBm

repeated for 1029 >> 1031 MHz in 0.1 MHz steps.

e *Measurement & display*

The program extracts each input power level where the reply % crosses the value 90%;
Diagram : MTL *vs.* input frequency.

Procedure ***P 6 2***

a *Verification*

Sidelobe Suppression *vs.* P1 / P2 Level Ratio.

... *idem Ramp Test set* *(see page 18)* *but with levels at XPDR input running from -21 to MTL + 3dB.*

Procedure ***P 6 3 + 8 2***

a *Verification*

Sidelobe Suppression *vs.* P1 >> P2 Spacing.

b *Performance specifications*

MS 3.8 - MT 5.4.4 .

c *Fixed settings*

Interrogator at nominal setting; PRF 450 Hz; P2 at nominal width;

XPDR code : A 1642, altimeter at zero;

d *Test progress*

P2/ P1 ratio varying from -12 >> + 3 dB, per 1 dB steps

100 [interrogation ♋ reply] sequences for each step

repeated for 3 levels at XPDR input : -21, -50 dBm & MTL + 3 dB.

Mode A, C & Intermode A, C.

e *Measurement & display*

For each of the 4 Modes and the 3 input power levels :

a diagram : reply % *vs.* P1 >> P2 spacing, tolerance areas shown.

Procedure P 64

a *Verification*

Sidelobe Suppression *vs.* P2 Width.

b *Performance specifications*

MS 3.8.2 - MT 5.4.4.1 .

c *Fixed settings*

Interrogator at nominal setting; PRF 450 Hz; level P2 = level P1;
XPDR code : A 1642, altimeter at zero.

d *Test progress*

Width P2 varying from 0.20 µs >> 1.20 µs, per 25 ns steps
100 [interrogation ♋ reply] sequences for each step
repeated for the level at XPDR input : -21, -50 dBm & MTL + 3 dB .

e *Measurement & display*

Diagram : reply % *vs.* P2 width, tolerance areas shown (for the 3 input power levels).

Procedure P 65 + 83

a *Verification*

Interference.

b *Performance specifications*

MS 3.12 - MT 5.4.7 .

c *Installation & fixed settings*

Connect the equipment's as on figure 8;
master interrogator at nominal settings for both Mode A/C and Mode S,
slave interrogator synchronized <u>in PRF only</u>;
the other parameters are defined hereunder.

d *Test progress*

Pulse(s) in variable positions & levels is/are added by the slave unit to the master interrogation,
following the procedure described in MT 5.4.7.2 (steps 1 to 5).

e *Measurement & display*

Diagram : reply % *vs.* interference pulses relative positions & levels.

Procedure P 66

a *Verification*

Mode A & C Acceptance *vs.* P1 >> P3 Spacing.

... *idem Ramp Test set (see page 19)*

but more levels at XPDR input: -21dBm, -50 dBm, MTL + 10 dB, MTL + 3dB.

Procedure P 6 7

a *Verification*

Mode A & C Acceptance *vs.* P1 & P3 Width.

b *Performance specifications*

MS 3.9.4 - MT 5.4.5.2 .

c *Fixed settings*

Interrogator at nominal except width P1 & P3; no P2; PRF 450 Hz; level at XPDR input: MTL +10 dB;
XPDR code : A 1642 .

d *Test progress*

P1 & P3 width varying from 0.20 >> 1.20 µs, per 25 ns steps
100 [interrogation ♋ reply] sequences for each step.

e *Measurement & display*

Diagram : reply % *vs.* P1 & P3 width (both Modes A & C), tolerance areas shown.

4.1.2 Mode S electric and Intermode A&C Procedures

Procedure P 7 1

a *Verification*

Reply Frequency.

b *Performance specifications*

MS 3.3.1 - MT 5.4.2.1 .

c *Installation & Fixed settings*

Connect the equipment's as on figure 6;
interrogator at nominal setting; PRF 50 Hz; level at XPDR input : -50 dBm; Intermode A ;
XPDR code : A 7777 .

d *Test progress*

To measure the frequency, adjust the line stretcher for maximum transmitter frequency shift above or below 1090 MHz.

e *Measurement & display*

Record the frequency (mean value of all pulses).

Procedure P 7 2

a *Verification*

Mean Output Power, Pulse Amplitude Variation, Mean Pulse Positions, Mean Pulse Width.

... *idem Ramp Test set (see page 20).*

Procedure ***P 7 3***

a *Verification*

Delay time, Delay Time Jitter.

b *Performance specifications*

MS 3.7.2 - MT 5.4.3.3

c *Fixed settings*

Interrogator at nominal setting; PRF 50 Hz; level at XPDR input : -50 dBm.

d *Test progress*

100 [interrogation ♋ reply] sequences.

e *Measurement & display*

Delay time (P6 / Sy Ph Rev to first preamble pulse) : mean value and σ .

Procedure ***P 7 4***

a *Verification*

Pulse Rise & Decay Times in (Inter)Mode S.

b *Performance specifications*

MS 3.6.5 - MT 5.4.3.2 .

c *Installation & fixed settings*

Connect the equipment's as on figure 7.

d *Test progress*

Continuous [interrogation ♋ reply] sequences (time to examine the screen);
XPDR code : A 1642 .

e *Measurement & display*

Observe the rise and decay times with screen markers, of the various pulses
and give the variation if there is one.

Remark : this test requires the same installation as test 56, so both should be executed sequentially.

Procedure ***P 7 5***

a *Verification*

Mixed Reply Rate Capability.

... *idem Ramp Test set (see page 20).*

Procedure *P 7 6*

a *Verification*

Diversity Isolation.

b *Performance specifications*

MS 3.16 - MT 5.4.11 .

c *Installation & fixed settings*

Connect the equipment as on figure 9;
master interrogator at nominal setting;
slave unit synchronized with a controlled difference in start time and power level;
used : Mode A, Mode C, Intermode A + S, Intermode C only, UF04 (& UF 21 if applicable).

d1 *Test progress* ***1***

Single channel interrogations at 3 different levels :
MTL + 3 dB / -50 dBm (only Mode C & UF04) / -21 dBm (*id*.)
applied first on Bottom channel, then onTop channel.

e1 *Measurement & display* ***1***

record in each case, output power, delay time, reply percentage
compare theses values between each channel
the power transmitted on the “ unwanted “ channel must beat least 20 dB lower.

d2 *Test progress* ***2***

Dual channel interrogations at 4 level combinations :

1 - Top @ MTL, Bottom @ MTL + 4 dB :
2 - Top @ MTL + 4 dB, Bottom @ MTL
3 - Top @ MTL + 4 dB, Bottom @ - 50 dBm
4 - Top @ - 50 dBm, Bottom @ MTL + 4 dB

vary the Δtime between Top & Bottom interrogations from – 600 ns to + 600 ns.

e2 *Measurement & display* ***2***

Diagram : reply % at each channel output *vs.* Δ time between interrogations;

tolerance areas shown.

Procedure *P 7 7*

a <u>*Verification*</u>

Intermode A & C and Mode S Sensitivity (MTL).

... *idem Ramp Test set (see page 21) but with levels at XPDR input running from -21 to -80 dBm.*

Procedure P 78

a *Verification*

Dead Time.

b *Performance specifications*

MS 3.10.3 - MT 5.4.6.2 .

c *Fixed settings*

Interrogator at nominal setting; PRF 50 Hz.

d *Test progress*

100 [interrogation ♋ reply] sequences as follows:

Mode S (level at XPDR input : -21dBm) / wait for the reply end /

followed by a variable delay followed by a Mode S interrogation at level MTL + 3 dB;

the delay varies from 50 to 125 µs per 1µs steps.

e *Measurement & display*

Diagram : reply % *vs.* delay; the dead time = the value where reply rate crosses 90 %.

Procedure P 79

a *Verification*

Suppression Time.

b *Performance specifications*

MS 3.8.3 - MT 5.4.4.3 .

c *Fixed settings*

Connect the equipment's as on figure 8;

Interrogator at nominal setting; PRF 50 Hz.

d *Test progress*

100 [interrogation ♋ reply] sequences as follows:

P1 - P2 (Δ t = 2 µs , same level) followed by a variable delay followed by a Mode A interrogation

delay : from 15 to 55 µs per 1µs steps;

test done at: -21, -50, -65 dBm & MTL + 3 dBm.

e *Measurement & display*

Diagram : reply % *vs.* delay; the suppression time = the value where reply rate crosses 10 %;

shown for each level.

Procedure P 8 0

a *Verification*

Receiving Frequency Acceptance, Bandwidth.

b *Performance specifications*

MS 3.2.2 & 3 - MT 5.4.1.2 .

c *Fixed settings*

Interrogator at nominal setting except the frequency; PRF 50 Hz.

d *Test progress*

1 - 100 [interrogation ♋ reply] sequences for levels at input XPDR from -60 >> -80 dBm
repeated for 1029 >> 1031 MHz in 0.1 MHz steps;
2 - 100 [interrogation ♋ reply] sequences for levels at input XPDR MTL + 60 dB
repeated for 1000 >> 1020 MHz & 1040 >> 1060 MHz in 0.5 MHz steps.

e *Measurement & display*

Diagram : MTL *vs.* input frequency;
in part **2** , the program extracts the power level where the reply % crosses the value 90.

Procedure P 8 1

a *Verification*

Sidelobe Suppression *vs.* P5 / P6 Level Ratio.

b *Performance specifications*

MS 3.8.3 - MT 5.4.4.3 .

c *Fixed settings*

Interrogator at nominal setting; UF04.

d *Test progress*

with a P2 at nominal position & width, P5/ P6 ratio varying from -15 dB >> + 6 dB, per 1 dB steps
100 [interrogation ♋ reply] sequences for each step
repeated for the level at XPDR input : -21 dBm, -50 dBm & MTL + 3 dB.

e *Measurement & display*

Diagram : reply % *vs.* P5/P6 ratio, tolerance areas shown (for the three input power levels).

Procedure P 8 2

see page 43, tests P63 + 82.

Procedure P 8 3

see page 44, tests P65 + 83.

Procedure ***P 84***

a *Verification*

Intermode A % C Acceptance *vs.* P1 >>P3 Spacing.

b *Performance specifications*

MS 3.9.3 - MT 5.4.5.2.

c *Fixed settings*

Interrogator at nominal setting ; no P2; P3 >> P4 spacing nominal;
(XPDR code : A 1642.

d *Test progress*

Level at XPDR input: -21, -40 & -60 dBm
P1 >> P3 spacing varying from 6.5 >> 9.5 µs and 19.5 >> 22.5 µs, per 25 ns steps
100 [interrogation ♋ reply] sequences for each step.

e *Measurement & display*

Diagram : reply % *vs.* P1 >> P3 spacing, tolerance areas shown
for both Intermode A (6 >> 10 µs) and Intermode C (19 >>23 µs)..

Procedure ***P 85***

a *Verification*

Intermode A & C Acceptance *vs.* P4 Width.

… idem Ramp Test set (see page 21).

Procedure ***P 8 6***

a *Verification*

Intermode A & C Acceptance *vs.* P3 >> P4 Spacing.

… idem Ramp Test set (see page 22).

Procedure ***P 8 7***

a *Verification*

Mode S Acceptance *vs.* P2 >> P6 (Sync. Phase Reversal) Spacing.

… idem Ramp Test set (see page 22).

4.1.3 Mode S Protocol Procedures

Procedure *P 1*

a *Verification*

Error Protection.

b *Performance specifications*

MS 3.20.2.1 - MT 5.5.8.1 / protocol procedure n° 1.

c *Installation & fixed settings*

Connect the equipment's as on figure 7;

interrogator at nominal setting; level at XPDR input : -50 dBm.

d *Test progress and Control*

1 – Downlink coding for PI fields

If the XPDR has a static CA: set the address (manually on the back connector) as follows :

if	CA = 0,	AA	set to	[03 13 D4]hex
	CA = 4,	AA	set to	[03 2B E2]hex
	CA = 5,	AA	set to	[FC DF EB]hex
	CA = 6,	AA	set to	[03 37 F9]hex
	CA = 7,	AA	set to	[FC C3 F0]hex.

Send an Intermode A/S and verify that in the reply PI is all zeros (detected video on the oscilloscope).

If the XPDR is of dynamic CA type, adopt the procedure to vary the CA as necessary with simultaneously changing the address as above, and verify similarly.

2 – Downlink coding for AP fields

Interrogate the XPDR to get DF05 and DF21 replies that are observed on the oscilloscope;

set the address (manually on the back connector) to

AA =	[20 78 CE]hex	>>	DF05 should contain all zeros,
	[75 2D 9B]hex	>>	DF05 should contain [55 55 55]hex ,
	[0B 15 4F]hex	>>	DF21 should contain all zeros,
	[75 2D 9B]hex	>>	DF05 should contain [55 55 55] hex.

Procedure *P 2*

a *Verification*

Interrogation Acceptance.

... *idem Ramp Test set (see page 24).*

(There are no P3, P8 & P14; see table 5 page 14).

Procedure *P 4*

a *Verification*

Non-selective All-call Lockout.

b *Performance specifications*

MS 3.20.2.4 - MT 5.5.8.4 / protocol procedure n° 4 - *Ref.11* "Mode-S … SI-code validation".

c *Installation, preparation & fixed settings*

Connect the XPDR to the Bench test, as on figure 5;
interrogator at nominal setting; in Modes A/C & Intermodes: no P2; P3 >> P4 spacing nominal;
Mode S UF04, 05 &11 ; and UF20 & 21 if XPDR is Mark 4 type (see the dual asterisks**).
Two interrogations sequences are prepared:
- sequence 4P, the positive tests: at well defined times, they test the XPDR's no reply when it must be locked & the replies when lockout must be finished;
- sequence 4N, the negative tests: when the lockout has not to be engaged.

Sequence of interrogations 4P – Positive tests

a at t = 0 send [UF04][PC = 1][RR=0][DI=1][SD : IIS=1, 00000, LOS=0, 000000][AP]

b	at t = 0.02 s	send Intermode A/S	No Reply expected
c	at t = 0.04 s	send Intermode C/ S	No Reply expected
d	at t = 0.06 s	send ModeS (UF11, IC = 0, CL=0, PR = 0)	No Reply expected
e	at t = 16.90 s	repeat sequences b, c & d	
f	at t = 19.10 s	send Intermode A/S All-Call	lockout is finished
g	at t = 19.12 s	send Mode A, Mode C & Mode S	lockout is finished
h	at t = 19.14 s	send ModeS (UF11, IC = 0, CL=0, PR = 0)	lockout is finished
i	at t = 21.00 s	send [UF05][PC =1][same data . . .]	
j	at t = 21.02 s	repeat sequences b, c & d	
k	at t = 26.00 s	send [UF20][PC = 1][same data . . .]	(**)
l	at t = 26.02 s	repeat sequences b, c & d	(**)
m	at t = 31.00 s	send [UF21][PC = 1][same data . . .]	(**)
n	at t = 31.02 s	repeat sequences b, c & d	(**)
o	at t = 41.90 s	repeat sequences b, c & d	(**)
p	at t = 46.90 s	repeat sequences b, c & d	(**)
q	at t = 50.10 s	repeat sequences f, g & h.	(**)

Sequence of interrogations 4N – Negative tests

The non-lockout is verified against PC values, broadcast interrogations, addresss,and II/SI-codes;
send a first [UFxx][PC = ..][RR=0][DI=1][SD = IIS .. , 00000, LOS, 000000][AP = ..],

UF04, 05, 20 & 21 (**), PC = 0, 2 to 7, IIS = 0, LOS = 1
UF04, 05, 20 & 21 (**), PC = 0 to 7, IIS =1, LOS = 0, Address = [FFFFFF]hex
UF04, 05, 20 & 21 (**), PC = 1, IIS = 0, LOS = 1, Address is not the XPDR's one

then verify NO LOCKOUT is engaged by sending sequentially the Intermode A/S & C/S and
UF11, with PR = 0, II =1 to 15

etc…

see *ref.11* and MT 5.5.8.4 for the details.

d *Test progress and Control*

Start the sequence 4P; the program displays line after line each uplink messages and the related reply or no reply, both with time marks; an "OK" symbol is added at line end, replaced by the reply contents if faulty (e.g. if no reply is expected) or "sorry, No Reply" when so where one reply is expected;
start the sequence 4N; same verification.

Procedure *P 5*

a *Verification*

Multisite Selective Lockout.

b *Performance specifications*

MS 3.20.2.5, 3.21.2.1 - MT 5.5.8.5 / protocol procedure n° 5 - *Ref.11* "Mode-S … SI-code validation".

c *Installation, preparation & fixed settings*

As in procedure P 4, but the lockout is now selective : that is, the XPDR does not reply to All-call's coming from the interrogator that initiated the lockout; in the interrogations sequences hereunder, message are sent at well defined times to test the XPDR's non-reply to the correct UF11 when it must be locked & positive replies either when lockout must be finished, or when interrogated by another interrogator, or when the lockout has not to be engaged; restarts of lockouts is also tested.
x = 1 to 15; y = 1 to 63; to gain time, UF04 and 05 are mixed, as well as UF20 and 21 (see the sequences).

Sequence of interrogations 5/1 – Timer duration and insensivity to non-valid signals tests

a) sequences for IIS

at t = 0 send

UF04	PC=0	RR=0	**DI =1**	SD : IIS=x , 00000 , LOS=1, 000000	AP

at t = 0.02 s	send UF11 with II = x	No Reply expected
at t = 0.04 *to* 9.90 s	send UF11 with II not = x	No Reply expected
at t = 0.3 s	interlace : send UF05 with IC = x+1	
at t = 10.0 *to*.. s	send UF05 with II = x but with all 6x2 other DI / LOS incorrect combinations	
at t = 13.3 *to*.. s	send UF04 with II = x but with all 8x2 other DI / LSS combinations	
at various t	send Mode A/C and Intermode all-call interrog.	Reply expected
at t = 16.9 s	send UF11 with II = x	No Reply expected
at t = 19.1 s	send UF11 with II = x	Reply expected

repeat the sequence inverting simultaneously UF04 <-> 05, DI =1 <-> 7.

b) sequence for SIS

at t = 0 send

UF05	PC=0	RR=0	**DI =3**	SD : SIS=y , LSS=1, 000000000	AP

at t = 0.02 s	send UF11 with SI = y	No Reply expected
at t = 0.04 *to* 9.90 s	send UF11 with SI not = y	No Reply expected
at t = 0.3 s	interlace : send UF04 with ISI = y+1	
at t = 10.0 *to*.. s	send UF04 with SI = y but with all 8x2 other DI / LOS combinations	
at t = 13.3 *to* .. s	send UF04 with SI = y but with all 6x2 other DI / LSS incorect combinations	
at various t	send Mode A/C and Intermode all-call interrog.	Reply expected
at t = 16.9 s	send UF11 with SI = y	No Reply expected
at t = 19.1 s	send UF11 with SI = y	Reply expected

Sequence of interrogations 5/2 – Restart capability and Sensivity to valid signals tests

a) sequences for IIS

at t = 0 send

UF04	PC=0	RR=0	**DI =1**	SD : IIS=x , 00000 , LOS=1, 000000	AP

at t = 0.02 s	send UF11 with II = x	No Reply expected
at t = 0.04 + n x 0.3s	interlace with UF04 with II not = x	
at t = 4.5 s	restart : send UF05 with II = x	
at various t	send Mode A/C and Intermode all-call interrog.	Reply expected
at t = 21.4 s	send UF11 with II = x	No Reply expected
at t = 23.6 s	send UF11 with II = x	Reply expected

repeat the sequence inverting simultaneously UF04 <-> 05, DI =1 <-> 7.

b) sequence for SIS

at t = 0 send

UF05	PC=0	RR=0	**DI =3**	SD : SIS=y , LSS=1, 000000000	AP

at t = 0.02 s	send UF11 with SI = y	No Reply expected
at t = 0.04 + n x 0.3s	interlace with UF05 with SI not = y	
at t = 4.5 s	restart : send UF04 with SI = y	
at various t	send Mode A/C and Intermode all-call interrog.	Reply expected
at t = 21.4 s	send UF11 with SI = y	No Reply expected
at t = 23.6 s	send UF11 with SI = y	Reply expected

Sequence of interrogations 5/3 – Restart capability and Sensivity to valid signals tests

For XPDRs level 2 & above only

a) sequences for IIS

at t = 0 send

UF20	PC=0	RR=0	**DI =1**	SD : IIS=x , 00000 , LOS=1, 000000	MA	AP

at t = 0.02 s	send UF11 with II = x	No Reply expected
at t = 0.04 + n x 0.3s	interlace with UF04 with IIS not = x	
at t = 4.5 s		

restart with

UF21	PC=0	RR=0	**DI =1**	SD : IIS=x , 00000 , LOS=1, 000000	MA	AP

at various t	send Mode A/C and Intermode all-call interrog.	Reply expected
at t = 21.4s	send UF11 with II = x	No Reply expected
at t = 23.6 s	send UF11 with II = x	Reply expected.

repeat the sequence inverting simultaneously UF20 <-> 21, DI =1 <-> 7.

b) sequence for SIS

at t = 0 send

UF20	PC=0	RR=0	**DI =3**	SD : SIS=y , LSS=1, 000000000	MA	AP

at t = 0.02 s	send UF11 with SI = y	No Reply expected
at t = 0.04 + n x 0.3s	interlace with UF04 with SI not = y	
at t = 4.5 s		

restart with

UF21	PC=0	RR=0	**DI =3**	SD : SIS=y , LSS=1, 000000000	MA	AP

at various t	send Mode A/C and Intermode all-call interrog.	Reply expected
at t = 21.4s	send UF11 with SI = y	No Reply expected
at t = 23.6 s	send UF11 with SI = y	Reply expected.

Sequence of interrogations 5/4 – Broadcast discrimination tests / sequence for IIS

a) *For all XPDRs*

at t = 0 send

UF04	PC=0	RR=0	**DI =1**	SD : IIS=x , 00000 , LOS=1, 000000	ad=FFFFFF

at t = 0.02 s send UF11 with II = x Reply expected

at t = 0.04 s interlace with UF05 with II not = x

at t = 0.06 s send UF11 with II = x Reply expected

b) *For XPDRs level 2 & above only*

at t = 0 send

UF20	PC=0	RR=0	**DI =1**	SD : IIS=x , 00000 , LOS=1, 000000	MA	ad=FFFFFF

at t = 0.02 s send UF11 with II = x Reply expected

at t = 0.04 s interlace with UF21 with II not = x

at t = 0.06 s send UF11 with II = x Reply expected

Sequence of interrogations 5/5 – Broadcast discrimination tests / sequence for SIS

a) *For all XPDRs*

at t = 0 send

UF04	PC=0	RR=0	**DI =3**	SD : SIS=y , LSS=1, 000000000	ad=FFFFFF

at t = 0.02 s send UF11 with SI = y Reply expected

at t = 0.03 s interlace with UF05 with SI not = y

at t = 0.06 s send UF11 with SI = y Reply expected

b) *For XPDRs level 2 & above only*

at t = 0 send

UF20	PC=0	RR=0	**DI =3**	SD : SIS=y , LSS=1, 000000000	MA	ad=FFFFFF

at t = 0.02 s send UF11 with SI = y Reply expected

at t = 0.03 s interlace with UF21 with SI not = y

at t = 0.06 s send UF11 with SI = y Reply expected

d *Test progress and Control*

Start the sequence 5/1; the program displays line after line each uplink messages and the related reply or no-reply, both with time marks; an "OK" symbol is added at line end, replaced by the reply contents if faulty (e.g. if no reply is expected) or "sorry, No Reply" when so where one reply is expected;
start the other sequences; same verifications.

Procedure *P 6*

a *Verification*

Acquisition and Extended Squitters : complete test.

b *Performance specifications*

MS 3.20.2.6, 3.21.2.6, 3.21.1.12 - MT 5.4.3.2.2 & .3

ANNEX 10 (*ref.1*) § 3.1.2.8.5 & 6.

c *Interrogation ↔ reply sequences*

Unsolicited replies in Mode S - No interrogations for the squitter themselves, but interrogations are sent both - to determine the choice of contents in the extended squitter ME field

- to interleave the squitters with other replies.

Remark : if existing, the onboard mutual suppressing system must be inhibited.

1 - XPDRs with ACQUISITION SQUITTER ONLY

the DF 11's are transmitted with the following contents:

DF11	CA 3 bits	AA (24 bits) address in clear	PI parity on II = 00

300 squitters are observed, without any interrogations.

2 - XPDRs with EXTENDED SQUITTER

Connect the equipment's as on figure 11 ; DF 17's are transmitted with the following contents:

DF17	CA	AA (24 bits) address in clear	ME (56 bits) broadcast message	PI parity on II = 00

Prepare set of data to be filled into the airborne side of the XPDR to register 0,5 as follows:
$\{50\ AA\ AA\ AA\ AA\ AA\ AA\}^H$, $\{50\ 00\ 00\ 00\ 00\ 00\ 00\}^H$, $\{50\ FF\ FF\ FF\ FF\ FF\ FF\}^H$,
$\{50\ xx\ x5\ 55\ 55\ 55\ 55\}^H$ where xx x is an hex representation of code C altitude, in steps of 25 or 100 feet, depending on the XPDR performance.

Each of these data will be sent and refreshed each sec during 300 sec, then ceased;

send an UF04 with RR=16, DI = 7 and SD = { RRS=5, ….} to generate a GICB = 0,5 into the ME field (that register contains the airborne position);

interleave with at random UF04 as for short squitters.

Repeat the sequence successively with RRS = 6, 8, 9 or 10 ➔GICB = 06, 08, 09 or 0A ➔ME = surface position, aircraft ident, airborne velocity or event driven message. The set of data to be filled are described in MT 5.4.3.2.2 .

d *Control*

Verify the contents of DF 11 and DF 17 , as introduced in the transponder (ME field), *incl*. the DR field as given in MS 3.18 4.5 & 8;

verify the random transmission rates for the various squitters:

<u>diagrams</u>: Number of events *vs.* time between messages (in steps of 15 ms); values are the following :

DF 11	mean rate	1 / s	(limits: 0.8 *to* 1.2 s)	
DF 17	register 05	2 /	(limits: 0.4 to 0.6 s)	aircraft being set "AIRBORNE"
	register 06	2 / s	(limits: 0.4 *to* 0.6 s)	for the high rate
	register 06	2 / 10 s	(limits: 4.8 *to* 5.2 s)	for the low rate
	register 08	2 / 10 s	(limits: 4.8 to 5.2 s)	if AIRBORNE or GROUND, High rate (*)
		1 / 10 s	(limits: 9.6 to 10.4 s)	if GROUND, Low rate (*).
	register 09	2 / s	(limits: 0.4 to 0.6 s)	
	register 0A	2 / s	(limits: 0.4 to 0.6 s)	after reply to UF04 containing RRS = 10;

verify the maximum limit of transmission;

verify that the DF17 stops 2 sec after the last data refreshing.

*(* set through UF04 with corresponding RCS subfield).*

Procedure *P 7*

a *Verification*

Flight status and Vertical status verification.

b *Performance specifications*

MS 3.18.4.12 & .38, 3.20.2.7 & .11 - MT 5.5.8.7 / protocol procedure n° 7.

c *Installation & fixed settings*

Connect the equipment's as on figure 10; the test verifies the correct FS and VS fields contents after a jump to an alert code, a change of Mode A code, the setting of the SPI bit and a change of Flight status; the correct bits in fields FS and VS are given in MS 3.18.4.9 .

The test does not verify long squitter DF17 contents, wherein the flight status is also transmitted.

The interrogations sequences hereunder are different depending on the XPDR level:

for level 1 XPDRs, all tests are executed using UF04 & 05 with RR = 0, and under UF00;

for the other XPDRs (**),are used the UF04, 05, 20 & 21 with RR = 0 & 16 to 31, and UF00 & 16.

Sequence of interrogations 7A – Alert tests

t = 0 when the code is changed from 1642 to 7500 or 7600 or 7700

at t = 0.02 s	send UFxx (see above)	the reply should contain the correct code & FS field
at t = 16.9 s	send UFxx (see above)	*id*.
at t = 5 min	send UFxx (see above)	*id*. (alert status is permanent).

Sequence of interrogations 7B – Other code bit tests

t = 0 when the code is changed from 1642 to 1643

at t = 0.02 s	send UFxx (see above)	the reply should contain the correct code & FS field
at t = 16.95 s	send UFxx (see above)	*id*.
at t = 17.05 s	send UFxx (see above)	*id*.
at t = 18.95 s	send UFxx (see above)	the reply should be back to "normal"
at t = 19.05 s	send UFxx (see above)	the reply should be back to "normal"
at t = 5 min	send UFxx (see above)	the reply should be back to "normal".

Sequence of interrogations 7C – SPI bit tests

t = 0 when the SPI bit is added to the code

at t = 0.02 s send UFxx (see above) the reply should contain the correct code & FS field

at t = 16.95 s and after : as in sequence 7B.

Sequence of interrogations 7D – Flight status tests

t = 0 when the status is changed to " In flight"

at t = 0.02 s send UFxx (see above) the reply should contain the correct VS & FS fields

at t = 16.95 s and after : as in sequence 7B.

d *Test progress and Control*

Set Mode A code to 1642; prepare the sequence 7A; at the control box, change the code to 7500; this starts the bench test set (t = 0 s) by the sync link; the program verifies each reply and displays the correct code and FS field.

Repeat the execution with alert codes 7600 and 7700.

Reset Mode A code to 1642; prepare the sequence 7B; at the control box, change the code to 1643; this starts…

Reset Mode A code to 1642; prepare the sequence 7C; at the control box, add the SPI bit; this starts…

Reset Mode A code to 1642 and set Flight status to " Ground " ; prepare the sequence 7D; at the control box, change to " In flight"; this starts…

Repeat the execution reversing " In flight " to " Ground " and vice-versa.

Procedure P 9

a *Verification*

Mode S Address.

... *idem Ramp Test set (see page 26).*

Procedure P 10

a *Verification*

Altitude Report.

... *idem Ramp Test set (see page 26).*

Procedure P 11

a *Verification*

Mode A Report.

... *idem Ramp Test set (see page 27).*

Procedure P 12

a *Verification*

RI Acquisition and Maximum Speed.

... *idem Ramp Test set (see page 27).*

Procedure P 13

a *Verification*

Stochastic Acquisition.

... *idem Ramp Test set (see page 28).*

Procedure P 15

a *Verification*

Comm-A Interface and Information Content.
For Mark 4 and higher level transponders only.

b *Performance specifications*

MS 3.4.2, 3.17.3, 3.21.1.1 & .10 - MT 5.5.8.15 / protocol procedure n° 15.

c *Interrogation ♋ reply sequences*

Connect the equipment's as on figure 11; the avionic side output of the XPDR (or, of the ADLP, if both units are grouped in one box) is decoded as necessary, in the interface decoding card of the PC sub-unit; interrogator at nominal setting; Mode S UF20 & 21 .
Use the hereunder defined interrogations sequence 15A at the nominal 50 int/s rate, followed by the burst interrogations sequences 15 B & C.

Sequence of interrogations 15A

3080 interrogations, at the nominal 50 int/s rate, as follows:

[UF20 or 21][PC = x][RR = x][DI = 0][SD = random][MA = zz][AP= TP address]
where UF alternately equals 20 and 21, PC varies from 1 to 7 randomly, RR from 1 to 15 randomly, and MA uses the 1540 patterns with just two ONE's and 1540 patterns with just two ZERO's;

5 % of the XPDRs address are replaced by Broadcast address.

Sequence of interrogations 15B

100 interrogations out of any part of the sequence 15A, send in burst as follows:

at t = 0.00 s	send 4 interrogations at		2500 / s
at t = 0.08 s	send 4	"	2500 / s
at t = 0.16 s	send 8	"	320 / s
at t = 0.32 s	send 8	"	320 / s
at t = 0.48 s	send 8	"	320 / s
at t = 0.64 s	send 18	"	180 / s
at t = 1.00 s	send 4	"	2500 / s
at t = 1.08 s	send 4	"	2500 / s
at t = 1.16 s	send 8	"	320 / s
at t = 1.32 s	send 8	"	320 / s
at t = 1.48 s	send 8	"	320 / s
at t = 1.64 s	send 18	"	180 / s

Sequence of interrogations 15C

100 interrogations out of any part of the sequence 15A, send in burst as follows:

at t = 0.00 s	send 4 interrogations at		2500 / s
at t = 0.08 s	send 4	"	2500 / s
at t = 0.16 s	send 8	"	320 / s
at t = 0.32 s	send 8	"	320 / s
at t = 0.48 s	send 8	"	320 / s
at t = 0.64 s	send 18	"	180 / s
at t = 0.75 s	send 16	"	180 / s

d *Control*

Start the sequence 15A;

the program compares and displays line after line each uplink MA messages and the related output of the XPDR (or of the ADLP if both units are grouped in one box), both with time marks; an "OK" symbol is added at line end, or the differences, if not correct.

Start the sequence 15B;

for XPDRs without memory : same comparison;

for XPDRs with memory : it controls the sequence order is strictly the same as the one sent.

Start the sequence 15C *(for memory type XPDRs only)*;

1 sec after the burst, the program controls that at least the 50 first messages are present AND no reply has been generated that do not correspond to these messages present.

Procedure *P 16*

a *Verification*

Broadcast All-call Formats (uplink).

b *Performance specifications*

MS 3.21.1.11 - MT 5.5.8.16 / protocol procedure n° 16.

c *Interrogation ♋ reply sequences*

Most of the verification is executed in procedure 15 above; one must only verify that with short uplink formats with Broadcast address, no data are transferred to the avionic interface.

Same installation as for test procedure15.

d *Control*

Send UF 00, 04 and 05 interrogations with Broadcast addresses. No data should appear at interface.

Send UF11 with both XPDR address and Broadcast address. No data should appear at interface.

Procedure *P 17*

a *Verification*

GICB Register Extraction / decoding only.

... idem Ramp Test set (see page 29).

Procedure *P 18*

a *Verification* :

Comm-B Protocol Verification

Enhanced Comm-B Protocol Verification.

b *Performance specifications*

MS 3.21.12 & 13, 3.21.2.1 & .3 - MT 5.5.8.18 & 19 / protocol procedure n° 18 & 18A

+ *Ref. 9* : Mode S Specific Services Manual

MS 3.21.5.1 (for Enhanced Comm-B)

c1 *Interrogation ♋ reply sequences*

Connect the equipment's as on figure 11; the avionic side output data of the XPDR (or, of the ADLP, if both units are grouped in one box) is decoded as necessary, in the interface coding/decoding card of the PC sub-unit; the interrogator is at nominal setting.

Concerning Comm-B message transfer, the XPDR can be in 7 different states, depending on the setting of the B-register, of the T-register, the timer running state, the Interrogator identifier and the next message waiting state; the multisite timer being set for any of the 15 interrogators possible (IIS); this gives a total of 63 state combinations (see the *table of states* in the mentioned protocol procedure 18).

Besides, numerous interrogations can be sent (to the XPDR in one of the 63 states), that modify or may not modify the transponder state and generate or do not generate a reply; 24 interrogation patterns are possible, some of them being executed with the 16 IIS values, leading to 294 interrogation types combinations (see the *table of interrogations* in the protocol procedure 18).

So, the test bench must be able to generate interrogation sequences, that first set the transponder in a defined state, followed by one or more interrogations that extracts (or do not extract) the desired Comm-B. A total of 63 x 294 = 18522 different combinations are possible, but many are done successively, by setting the XPDR in a defined state, then sending interrogations that should not change the state, followed by those that should.

These sequences (lines of interrogations contents and related time of sending, time window for reply acceptance and comparison of the reply contents to the expected ones) are to be prepared and stored in the PC part of the test bench. These interrogation / expected replies sequences are too numerous to be listed here, they are listed in the MT / Protocol procedure 18.

c2 *Enhanced Comm-B*

Applicable to high level XPDRs.

Other (than above) XPDR states are existing; so, the procedure is expanded to include additional XPDR states, more interrogations are sent with various IIS to control the reactivity of the XPDR to various II codes, incl. timer expiration and the UM contents. Sensitive XPDR states are also added, like Messagers being extracted, waiting for IIS or waiting Broacast message.

As above, the interrogation / expected replies sequences are too numerous to be listed here, they are listed in the MT / Protocol procedure 18A.

d *Control*

First introduce a defined well-known message in the ADLP (see Mode S Specific Services Manual for its contents), followed by one of the prepared sequences described above. The reply / no reply as well as the contents of the message, accompanied by the related expected situation, received is shown on the PC display.

Procedure P 1 9

a *Verification*

GICB Register Extraction & Interface, *incl*. AIS, Flight Identification & other BDS Protocol.

b *Performance specifications*

MS 3.18.4.18 & 32, 3.21.1.13 & 17 , 3.21.2.1 - MT 5.5.8.20 / protocol procedure n° 19

+ *Ref. 9* : Mode S Specific Services Manual.

c *Interrogation ♋ reply sequences*

UF 04 or 05 : [PC = 0] [RR = x] [DI = 7] [SD = zy00] [AP = XPDRs address] ⇦DF 20 or 21 replies;

where z is the interrogator's ident (IIS subfield), e.g. = 15

x and y vary so as to request various BDS presently in us or proposed (see hereunder),

x = sum of 16 + BDS1 subfield

y = RRS subfield = BDS2 subfield.

Hence, if the desired BDS = 4,1 , BDS1 = 4 & BDS2 = , hence RR = 20 & RRS = 1 .

The list of registers proposed for the Basic and Enhanced Surveillance is

1,0 -1,7 - 2,0 - 4,0 - 4,1 - 5,0 - 6,0

✈ The transponder must be linked to the corresponding interfaces (ADLP ...) that will input the relevant information in the corresponding register (255 x 56 bit buffer).

d *Control*

The correct contents of the replies DF 20 or 21

[DF = 20] [FS = 1] [DR = 0] [UM = X] [AC = altitude =0] [MB = message] [AP = XPDRs address]

or

[DF = 21] [FS = 1] [DR = 0] [UM = X] [ID = a/c code A] [MB = message] [AP = XPDRs address]

with UM = IIS followed by IDS (IIS = z above and IDS = 1 = active CommB reservation).

For each of the desired register, the MB message must be converted following the contents as defined in the Mode S Specific Service Manual.

For example, for register = 4,0 “ Aircraft Intention” , the message content is:

bit 1 to 13 selected altitude , in steps of 16 ft (bit 1 = status, bit 2 = MSB)

bit 14 to 24 selected altitude rate, in steps of 32 ft /min (bit 14 = status, bit 15 = MSB)

bit 25 to 35 selected magnetic course(0) / heading(1), in steps of 360/512 deg

(bit 25 = switch (0 or 1), bit 26 = status, bit 27 = sign, bit 28 = MSB)

bit 36 to 47 selected airspeed (0) / mach number (1), in steps of 0.5 Kt or Mach 0.004

(bit 36 = switch (0 or 1), bit 37 = status, bit 38 = MSB)

bit 48 to 56 status and selection bits ...

Other example, for register = 2,0 “Flight Identification", the message content is:

[BDS = 2,0] [charac 1] [charac 2] [charac 3] [charac 4] [charac 5] [charac 6] [charac 7] [charac 8]

the characters giving, with ICAO international alphabet n°7, the aircraft’s registration or call sign.

Conversion software have already been developed by EUROCONTROL /EEC and could be obtained from this source. Example of the display of these converted BDS are shown in the EEC note

“ Mode-S Specific Services and Data Link Test Bench “ (*see ref. 10*).

More, a complete test would require to fill the MB field with successively 1128 codes containing 2 ONEs and 1128 codes with 2 ZEROs.

Procedure *P 2 0*

a *Verification*

Capability Report.

b *Performance specifications*

MS 3.18.4.18 & 32, 3.21.1.12 & 17, 3.23.1.2b - MT 5.5.8.21 / protocol procedure n° 20.

\+ *Ref. 9* : Mode S Specific Services Manual.

c *Interrogation ♋ reply sequences*

A particular case of procedure P19, with RR = 17, y = 0 and 7 (BDS = 1,0 and 1,7).

d *Control*

Same as for test procedure P19.

Depending on the level of the transponder, it determines the DataLink possibilities (BDS 1,0) and the other registers the transponder can provide (BDS = 1,7).

Control that the contents corresponds to the real capabilities of the transponder.

Procedure *P 2 1*

a *Verification*

Comm-B, both Directed and Broadcast.

b *Performance specifications*

MS 3.17.3, 3.21.2 - MT 5.5.8.22 & 23 / protocol procedure n° 21 & 21A

\+ *Ref.9* : Mode S Specific Services Manual.

c *Interrogation ♋ reply sequences*

Connect the equipment's as on figure 11; messages are inserted through the avionic side of the ADLP, by the interface coding/decoding card of the PC sub-unit; the interrogator is at nominal setting.

Prepare Directed Comm-B messages with DR=1, IDS=1 (active Comm-B reservation) and IIS=1 to 15 successively. BDS equals 17, 18 or 19.

The interrogator sends UF 4 and 5 with its successively IIS = 1 to 15, expecting DF04, 05, 20 and 21 replies.

Broadcast Comm-B are also prepared and sent to the ADLP.

They are also combined (in time) with the Directed Comm-B 's.

d *Control*

The procedure uses the same transaction technique as in procedure 18, which is supposed to be already tested.

The system controls the correct transfer of the MB messages for each corresponding IIS, and no transfer for unequal IIS.

The Broadcast Comm-B are also controlled, and the interrogator verifies that

Broadcast messages do not interrupt neither corrupt Directed messages, and Directed messages do interrupt the possibility to send Broadcast, without suppressing neither corrupting them;

DR field is 4,5 6 or 7 only;

the Broadcast messages may be read during 18 ±1 s, after which a 2nd message can be inserted;

the second message has another DR.

Procedure P 22

a *Verification*

Downlink Interface : Transponders/ADLP with Storage Design

b *Performance specifications*

MS 3.4.2 & 3.17.3 - MT 5.5.8.24 / protocol procedure n° 22.

c *Interrogation ♋ reply sequences*

Connect the equipment's as on figure 11; messages are inserted, by the interface coding/decoding card of the PC sub-unit, to the buffer of the transponder; the interrogator is at nominal setting.

This buffer (minimum 16 memories) stores the MB, the BDS & the message types; it provides the means for correct sequencing.

Depending on it is an AICB or a GICB, one or several MB messages for each BDS (up to 256 values) can be stored.

Prepare a first set of Comm-B messages:

- a : 5 AICB messages;
- b : 254 GICB messages with various BDS available for GICB;
- c : 1 messages with same BDS as in b but with another contents,
- d : 1 message with the BDS not used in b above.

A second set of 16 different messages (each with a different BDS) is also prepared (it can be part of line b above)

d *Control*

The test verifies with the 1st set of data:

the correct transfer of the message contents (if not already done in procedure 19 if the downlink interface is common with the AIS one);

the rate of 16 messages per second can be accepted at buffer input;

the AICB messages are sent down in the same order as received;

the 254 + 1 GICB messages can be extracted by the interrogator (with RR, DI & RRS corresponding to the BDS) one or several times and in any order;

the last message in d above has replaced the previous one in the buffer and is now sent on ground request in lieu of the earlier one;

a MB filed with zeros is sent if the corresponding BDS is not filled in the buffer.

The test uses the procedure 18 transaction technique, and may even be included in it.

The buffer rate of transfer is tested by filling the buffer with the 2nd set and interrogating at 1250 /sec all 16 messages, then changing (speed 16/sec) the buffer messages with same BDS, then re-extracting them after 1 second, through 8 bursts of 2 interrogations (separated by 0.8 ms) that follows each 125 ms, then at 5 per sec. The data should not be mixed, and should be read irrespective of whether they have been transmitted or not.

Procedure P 2 3

a *Verification*

Downlink Interface : Transponders/ADLP , design without storage.

b *Performance specifications*

MS 3.5.6.b & 3.17.3.d - MT 5.5.8.25 / protocol procedure n° 23.
+*Ref.9* : Mode S Specific Services Manual

c *Interrogation ♋ reply sequences*

Connect the equipment's as on figure 11; messages are inserted, by the interface coding/decoding card of the PC sub-unit, corresponding to the message extraction commands received at the uplink interface; the interrogator is at nominal setting.
For the AICBs, the DR bit is set to 1; for the Directed Comm-B, IIS and IDS fields are required.

d *Control*

The 2256 test patterns of procedure 19 are used in a transaction similar to procedure 18. Verify that the messages are received correctly, that the bit DR is accepted by the transponder and that the IIS and IDS fields are accepted only if the UM field is not ued for another purpose.

Procedure P 2 4

--- ←*see next page*

Procedure P 2 5

a *Verification*

Uplink Interface, Comm-C acceptance rate and contents.

b *Performance specifications*

MS 3.17.4.a, b, c, d - MT 5.5.8.28 / protocol procedure n° 25.

c *Interrogation ♋ reply sequences*

This procedure is a complement to procedure P 24, dealing with the maximum rate of transfer of the ELM Comm-C messages. The contents of the message are already verified in procedure P 24 (as an extension to the MOPS protocol procedure n° 24).
Connect the equipment's as on figure 11; the avionics side output of the XPDR (or, of the ADLP, if both units are grouped in one box) is decoded as necessary, in the interface decoding card of the PC sub-nit.
Interrogator at nominal setting; UF24 interrogations are sent.
16 segments are sent within 1 second, followed by a rest duration of 1 sec and again a second burst of 16 segments.

d *Control*

The ADLP output is decoded as usual, and the PC verifies and displays the contents of both burst, the order or reception and the time of appearance of these data.

Procedure P 24

a *Verification*

Comm-C Protocol.

b *Performance specifications*

MS 3.21.2.1 *to* 3.21.2.4, 3.21.3 *to* 3.21.3.1.h - MT 5.5.8.26 / protocol procedure n° 24.

c *Interrogation ♋ reply sequences*

Connect the equipment's as on figure 11; the avionics side output of the XPDR (or, of the ADLP, if both units are grouped in one box) is decoded as necessary, in the interface decoding card of the PC sub-unit; interrogator at nominal setting.

Concerning Comm-D, the XPDR can be in 9 different states, depending on the Trc timer, the memorized interrogator identification, the activation of the Comm-C, and the reception of the last segment; with some states sensitive to the16 interrogators possible (IIS) and other depending on the total of 15 possible segments, it gives a total of 354 states (see in the protocol procedure 24, the table of states).

Besides, numerous interrogations can be sent, that generate reservations, close-outs, first segments (RC=0), intermediate RC=1) and final ones (RC=2); 12 non-UF24 (4,5,20 & 21) interrogations patterns (some of them being executed with the 16 IIS values) and 4 UF24 interrogations with RC=0,1 or 2 (some of them being executed with variable NC) are possible, leading to 88 interrogation types combinations (see in the protocol procedure 24, the table of interrogations).

So, the test bench must be able to generate interrogation sequences, making or not a multisite reservation and sending successively (without intermediate reply) up to 16 Comm-D UF24.

A total of 354 x 88 = 31152 different combinations are possible, but many are done successively, by setting the XPDR in a defined state, then sending interrogations that should not change the state, followed by those that should.

Negative tests are executed by modifying some PC values, some MES fields, some RC values and UF other than 4, 5, 20, 21 & 24. These modifications can be injected during normal sequences and should have no effect.

Some of the multisite sequences may be time extended so as to exceed the timer duration, to observe the transponder's reaction.

These sequences (lines of interrogations contents and related time of sending, time window for reply acceptance and comparison of the reply contents to the expected ones) are to be prepared and stored in the PC part of the test bench. They are too numerous to be shown here.

d *Control*

Send a prepared sequences described above; check on the display the reply after the final segment;

During the sequence, the PC interface must decode and display the ADLP output contents, including the TAS field that is to be updated after each segment reception.

Procedure ***P 26***

a *Verification*

Comm-D Protocol verification
Enhanced Comm-D Protocol verification.

b *Performance specifications*

MS 3.21.2.1, .2 & .5 , 3.21.4.1 - MT 5.5.8.29 & 30 / protocol procedure n° 26 & 26A
MS 3.21.5.3 for the Enhanced Comm-D.

c1 *Interrogation ♋ reply sequences*

Connect the equipment's as on figure 11; the avionic side output data of the XPDR (or, of the ADLP, if both units are grouped in one box) is decoded as necessary, in the interface coding/decoding card of the PC sub-unit; the interrogator is at nominal setting.
Concerning Comm-D message transfer, the XPDR can be in 4 different states, depending on the setting of the T_{rd}-register and the Interrogator identification field; the multisite timer being set for any of the 16 interrogators possible (IIS), this gives a total of 35 transponder states to use (see the *table of states* in the mentioned protocol procedure 26).
Besides, 14 types of interrogation can be sent, each with various filed contents, that modify or may not modify the transponder state and generate or do not generate a reply.
These sequences (lines of interrogations contents and related time of sending, time window for reply acceptance and comparison of the reply contents to the expected ones) are to be prepared and stored in the PC part of the test bench. They are too numerous to be shown here; their contents are to be prepared as explained in the protocol procedure.

c2 *Enhanced Comm-D*

To be used if the XPDR adheres to the enhanced multisite downlink ELM.
Here, the XPDR exist only in to different staes, each with 16 IIS; so 32 states are to be used (use (see the *table of states* in the mentioned protocol procedure 26A).

d *Control*

Through the use of various Comm-B and Comm-D request, the fields and subfields DR, UM , SRS and MD are verified as described in the procedure.
Negative tests are also executed.
DR fields are to be checked in additional cases,e.g. for all IIS codes under the conditions of concurrent messages, B broadcast messages and downlink ELM.
The transactions are similar to the one used in Procedure 18.
The procedures 27 and 28 are tested using the same transaction technique as the present one and may be executed in combination.

Procedure P 27

a *Verification*

Directed Comm-D.

b *Performance specifications*

MS 3.21.2.5. - MT 5.5.8.31 / protocol procedure n° 27.

c *Interrogation ♋ reply sequences*

The present test is in fact a sub-set of the procedure 26.

Introduce a DR field corresponding to the maximum segment number that the transponder in test is capable of sending in burst; field IDS = 3 and field IIS = the desired destination code.

Make use of all IIS and DF = 4, 5, 20 and 21.

d *Control*

Verify that this Directed Comm-D has not interrupted an existing reservation condition.

Procedure P 28

a *Verification*

Comm-D Interface

b *Performance specifications*

MS 3.17.4 - MT 5.5.8.32 / protocol procedure n° 28.

c *Interrogation ♋ reply sequences*

The present test uses the same installation as for the procedure 26.

Whatever the concept of the transponder interface, the avionic side of the transponder must generate as many ND field values as the maximum capacity of the transponder

(maximum maximorum : 16 segments in 4 sec).

The MD field will use successively all combinations of two ONES and all combinations of two ZEROS.

Prepare a sequence of requests containing each of the 6320 codes obtained hereabove, spread over groups of segments equaling the maximum capacity of the transponder at its maximum speed.

d *Control*

Verify that all codes input into the transponder are correctly received at the "ground".

4.2 BENCH TEST PROGRAM

4.2.1 Preparation

For each test, files must be filled, that will be part of uplink messages or input to the "back side" interface and hence into downlink messages; these data will be sent by either master and/or slave, at the required times (and sometimes depending on the transponder's reaction).

These series of data have been detailed in each of the test procedures, in paragraph § 4.1.

4.2.2 Operation

The installation of the test procedures in the Laboratory test set is based on a set of software modules, that control the sequences developed in § 4.1 .

Depending on the objectives of the trials, the operator must decide either

- to run a standard test, by giving the procedure number and the order "START";
- to run a "personalised" test, by giving its number and the order "STEP BY STEP"; so, he may input a modification of the prepared data file(s);
- to run a series of procedures e.g. in burst, by giving the procedures numbers in series followed by the order "START"; of course, such a series of tests is limited to those using the same equipment installation and set-up.

All orders and data modifications are being input through the PC keyboard.

Prior to any test, the equipment installation that is required for each test (see the figures 5 to 11 at the beginning of § 4.1) is displayed on the PC in order to allow the operator to verify that he has connected all equipment correctly.

The contents of the uplink data sent, downlink data received, interface data transmitted out of the "avionic" side of the transponder and those to be replied to (both managed by the interface card of the PC) are observable, on request, nearly on-line; they are also stored for later investigation.

4.2.3 Modules

Each module controls a succession of start orders, uplink interrogation(s) by the master unit, possibly data reception by the PC interface card out of the transponder avionic side, possibly data sent (by the same interface card) to the "backside" of the transponder, and downlink replies to the master unit.

The module contains the required installation equipment description, the prepared data files and the expected results; it generates output files for results investigation; it also displays signs like " OK " , "FAIL", " Does not reply " , " Tests xx OK, test yy Not OK ", after having compared the results of the test(s) to the expected results.

4.2.4 Other possibilities

The system being used for various developments and research, it must be able to accept new modules to be written by the user; the existing module softwares must be completely accessible.

4.2.5 Results Management

4.2.5.1 Memory

As in the Ramp test set, all results are systematically stored in memory; see 3.2.6.1 for details.

4.2.5.2 Result transfer

The contents of the memory must be transferable by any actual means (100 or 250 MB ZIP disks, internet,...) to other users. Printer output is also required.

4.3 TECHNICAL DATA

(*Refer to fig 5*) . The equipment contains two RF units and a PC with interface cards; the two units run with independant clocks and pulse generation (time, width and level) but their starts can be synchronised, to allow diversity and similar measurements. A PC with two interfaces, one to control internally the two RF units, another to act as an interface to the ADLP.

Both must be able to generate all the tests described in the test lists above and therefore must have the following capacities:

4.3.1 Both units Output - Uplink characteristics

- frequency : *idem Ramp test set (see § 3.3)* ;
- pulses : *idem Ramp test set* ;
- pulse sequences : *idem Ramp test set* ;
- repetition rate : *idem Ramp test set* ;
- power : to 44 dBm (5 or 25 W), in steps of 0.5 dB
  difference between channels : up to 40 dB.
- RF output : both units connector "N" .
- other output : both detected videos.

4.3.2 Both units Input - Downlink characteristics

- frequency : *idem Ramp test set* ;
- pulse : *idem Ramp test set* ;
- power range at input connector : -20dBm to +5 dBm, with a resolution of 0.5 dB

4.3.3 PC and its interfaces

- Of the shelf recent model, latest WINDOWS or MacOS operating system; of the shelf display;
- Memory and computing capability corresponding to the tests to be executed, including what is written in the § 4.2;
- An interface card controlling the two RF cards, with a synchro line to a possible external unit like an oscilloscope (see figure 9);
- An interface card simulating the avionic input/output to the ADLP or Transponder (depending on the transponder construction) with the relevant ARINC connections.

4.3.4 Autotest

The system must contain an autotest device, launched automatically by switching on and on request. This autotest verifies the input and output of the system and can control the exactness of the measurements by connecting a reference transponder.

It must be possible to insert a virtual delay to simulate any "reasonnable" range of the transponder.

4.4 TESTING ENVIRONMENT

In contrary to the Ramp Test unit, the Laboratory unit will be used mainly in technical areas (inside) and will therefore follow the common requests for this sort of equipment.

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📖 Ref. 8 . . . Equipment Characteristics for Mode S Transponders with Extended
Interface Functions (Mark 4 Transponders)
EUROCAE Doc ED-86 July 1997

📖 Ref. 9 . . . Mode-S Specific Services Manual
ICAO Doc 9688-AN/952 June 1997

📖 Ref. 10 . . Mode-S Specific Services and Data link Test bench
EEC note 11/98 April 1998.

📖 Ref. 11 . . Mode-S Airborne Equipment Assesment
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This paper provides a lists with all cross references between :

- Annex 10 requirements,
- the ED-73A chapter 3 requirements section and
- the ED-73A chapter 5 testing section.

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3.1.2.7.4.2.4	3.21.3.1	5.5.8.25	Final segment transfer
3.1.2.7.4.2.5	3.21.3.1	5.5.8.25	Acknowledgment reply
3.1.2.7.4.2.6	3.21.3.1	5.5.8.25	Completed message.
3.1.2.7.4.2.7	3.21.2.4	5.5.8.25	C-timer restart
3.1.2.7.4.2.8	3.21.2.4	5.5.8.25	Multisite uplink ELM closeout.
3.1.2.7.4.2.9	3.21.2.4	5.5.8.25	Automatic multisite uplink ELM closeout
3.1.2.7.5	3.21.3.1	5.5.8.25	Non-selective uplink ELM
3.1.2.7.6	3.21.5.2	N/A	Enhanced uplink ELM protocol
3.1.2.7.6.1	3.21.5.2.1	5.5.8.29	General
3.1.2.7.6.2	3.21.5.2.1	5.5.8.29	Reservation processing.
3.1.2.7.6.3	3.21.5.2.1	5.5.8.29	Enhanced uplink ELM delivery and closeout.
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3.1.2.7.7.2	3.21.2.5	5.5.8.29, .31 & .32	Delivery of downlink ELMs.
3.1.2.7.7.2.1	3.21.4.1	5.5.8.29	SRS, segment request subfield in MC.
3.1.2.7.7.2.2	3.21.2.5	5.5.8.29, .31 & .32	D-timer restart.
3.1.2.7.7.3	3.21.2.5	5.5.8.29, .31 & .32	Multisite downlink ELM closeout.
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3.1.2.7.8.1	3.21.4.1	5.5.8.29	Non-selective downlink ELM closeout.
3.1.2.7.9	3.21.5.3	N/A	Enhanced downlink ELM protocol
3.1.2.7.9.1	3.21.5.3	N/A	General
3.1.2.7.9.2	3.21.5.3	N/A	Enhanced multisite downlink ELM protocol
3.1.2.7.9.2.1	3.21.5.2.1	5.5.8.29	Transponder ELM Storage requirement
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3.1.2.7.9.2.4	3.21.5.3.2	5.5.8.33	Closeout:
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3.1.2.7.9.3	3.21.5.3.3	5.5.8.33	Enhanced multisite directed downlink ELM protocol
3.1.2.7.9.3.1	3.21.5.3.3	5.5.8.33	Initiation.
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3.1.2.7.9.3.3	3.21.5.3.3	5.5.8.33	Delivery.
3.1.2.7.9.3.4	3.21.5.3.3	5.5.8.33	Closeout.
3.1.2.7.9.3.5	3.21.5.3.3	5.5.8.33	Announcement of the next message waiting.
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3.1.2.8.1.1	3.18.4.4	implicit	AQ: Acquisition.
3.1.2.8.1.2	3.18.4.31	5.5.8.2.b, 5.5.8.17.2 & .4	RL: Reply length.
3.1.2.8.1.3	3.18.4.11	5.5.8.43	DS: Data selector.
3.1.2.8.2	3.8.1	5.4.4.1.2	Short air-air surveillance, downlink format 0
3.1.2.8.2.1	3.18.4.38	5.5.8.7	VS: Vertical status.
	3.21.1.6	5.4.12.2.2-e, 5.5.8.7	
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3.1.2.8.2.3	3.18.4.6	5.5.8.43	CC: Crosslink capability.
3.1.2.8.3	3.8.1	5.4.4.1.2	Long Air-Air Surveillance, Downlink Format 16
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3.1.2.8.5	3.16.7.2	5.4.11.2 d, 5.4.3.2.2 g	Acquisition squitter
3.1.2.8.5.1	3.20.2.6.1 a	5.4.3.2.2, 5.5.8.6	Acquisition squitter format
3.1.2.8.5.2	3.20.2.6.1 b	5.4.3.2.2, 5.5.8.6	Acquisition squitter rate.
3.1.2.8.5.3	3.16.7	5.4.11.2	Acquisition squitter antenna selection.
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3.1.2.8.6.3	3.21.2.6.2	5.4.3.2.3 & .4	Extended squitter types
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3.1.2.8.6.3.2	3.21.2.6.2.b	5.4.3.2.3 & .4, 5.5.8.6	
3.1.2.8.6.3.3	3.21.2.6.2.c	5.4.3.2.3 & .4, 5.5.8.6	Aircraft identification squitter.
3.1.2.8.6.3.4	3.21.2.6.2.d	5.4.3.2.3 & .4, 5.5.8.6	Airborne velocity squitter.
3.1.2.8.6.3.5	3.21.2.6.2.e	5.4.3.2.3 & .4, 5.5.8.6	Event driven squitter.
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3.1.2.8.6.4.2	3.21.2.6.3 a	5.4.3.2.3 & .4	Airborne position squitter rate.
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3.1.2.8.6.4.5	3.21.2.6.3 d	5.4.3.2.3 & .4	Airborne velocity squitter rate.

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3.1.2.8.6.8.2	3.21.2.6.9	5.4.3.2.3 & .4	ATS, altitude type subfield in MB.
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3.1.2.10.5.1.4	3.17.1 b	5.4.12.1, 5.4.12.2, 5.5.8.9 & .10, 5.5.8.12 & .17	Interfaces for variable direct data.
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