ORDER

DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

1010.51A

8 Mar 71

SUBJ: SELECTION ORDER: U. S. NATIONAL AVIATION STANDARD FOR THE MARK X (SIF) AIR TRAFFIC CONTROL RADAR BEACON SYSTEM (ATCRBS) CHARACTERISTICS

1. PURPOSE. This Order revises the ATCRBS Standard in the following respects:

   a. A relaxation in the level of transponder self-test interrogation signal from -70 dBm to -40 dBm.

   b. A relaxation in transponder spurious radiation from -70 dB below one watt to a recommendation that CW spurious radiation be limited to -70 dB below one watt.

   c. Transponder desensitization action has been clarified.

2. CANCELLATION. Order 1010.51 dated 10/10/68 is cancelled.

3. REQUIREMENT. The National Airspace System will utilize ATCRBS, including the revised transponder, as a primary data acquisition source for aircraft position, identity, and pressure-altitude data.

4. SELECTION DECISION. The ATCRBS Standard described in Paragraph 5 of this Order has been shown to be responsive to the requirement stated in Paragraph 3. Accordingly, it is hereby selected for incorporation in the National Airspace System, pursuant to Section 312(c) of the Federal Aviation Act.

5. DESCRIPTION. The attached National Standard for ATCRBS specifies the performance required of each component to meet the overall operational requirements of the common civil/military system. It specifies the technical parameters, tolerances, and techniques to the extent required to ensure proper operation and compatibility between elements of the ATCRBS.

   The Radio Technical Commission for Aeronautics (RTCA) Sub-Committee 116B has completed a report on Minimum Operational Characteristics (MOC) for airborne ATCRBS transponders. This report is not compatible with the National Standard in three areas. An RTCA Ad Hoc Group on Proposed

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Distribution: W-1 (minus AS/AT/FS/LG/NS/RD/SM/FI/BU); WAS/AT/FS/LG/NS/RD/SM/FI/BU-3; RAF/AT/AS/FS-2; CFS/PR-2; CAY-3; M-2; N-3

Initiated by: RD-242

Changes to the U. S. National Standard on ATCRBS has recommended that the Standard be revised.

The relaxation of transponder self-test interrogation signal and spurious radiation does not conflict with the International Civil Aviation Organization (ICAO) Standards and Recommended Practices for Secondary Surveillance Radar (SSR).

The wording which describes transponder desensitization has been revised in accordance with the RTCA document to clarify the desired action. This does not change the substance of the paragraph from the previous wording.

The attached Standard is revised in accordance with the above recommendations. Paragraphs 2.7.7.1, 2.7.16.2, 2.11.1, and 2.11.1.1 are marked with an asterisk to indicate the changes.

6. INITIAL IMPLEMENTATION CRITERIA. The National Standard for ATCRBS shall be used as the basic document for defining the technical parameters, tolerances, and performance of all ATCRBS components.

7. DIRECTED ACTION. Subject to applicable rulemaking, programming, and budgetary procedures, action shall be taken by the elements of the agency concerned to implement this selection in accordance with the foregoing initial implementation criteria.

J. H. Shaffer
Administrator

U.S. NATIONAL STANDARD FOR THE IFF MARK X (SIF)/AIR TRAFFIC CONTROL RADAR BEACON SYSTEM CHARACTERISTICS

1. GENERAL.

1.1 System Characteristics.

1.1.1 Under Public Law 85-726, the Federal Aviation Administration is charged with providing for the regulation and promotion of civil aviation in such manner as to best foster its development and safety, and to provide for the safe and efficient use of the airspace by both civil and military aircraft, and for other purposes. Explicitly, the Administrator shall develop, modify, test, and evaluate systems, procedures, facilities, and devices, as well as define the performance characteristics thereof, to meet the needs for safe and efficient navigation and traffic control of all civil and military aviation operating in a Common Civil/Military System of Air Navigation and Traffic Control.

1.1.2 A System Characteristic, the logical result of such development effort, specifies the performance required of a component (or subsystem) to meet the overall operational requirements of the System. It specifies the technical parameters, tolerances, and techniques to the extent required to insure proper operation and compatibility between elements of the National Airspace System.

1.1.3 If optimum performance is to be obtained, these System Characteristics must be met by all civil and military users of the Air Traffic Control Radar Beacon System under all expected operating conditions. It is recognized that certain existing equipment does not comply with all requirements of these characteristics. Since such equipment may degrade the quality of service to all users, it is expected that its usage will be phased out as soon as practicable.

1.2 System Characteristics and Guidance Material.

1.2.1 The System Characteristics and Guidance Material provided herein are restricted to those system elements which must be treated in a uniform manner by all concerned, both civil and military, if the IFF Mark X (SIF)/Air Traffic Control Radar Beacon System is to function satisfactorily. In this connection, it is necessary to define closely many characteristics of the airborne component of the system (transponder). The system composed of the Mode 3 portion of the IFF Mark X (SIF) and Modes A and C of the Air Traffic Control Radar Beacon System shall be referred to herein as ATCRBS.

1.2.2. The following are the modes provided by the system, and their associated functions:

Mode 1—For Military use.

Mode 2—For Military use.

Mode 3/A—To initiate transponder response for identification and tracking.

Mode B—In some parts of the world, during a transition period, to initiate transponder response for identification and tracking.

Mode C—To initiate transponder responses for automatic pressure altitude transmission.

Mode D—For future expansion of the system to satisfy operational requirements that may be agreed by the International Civil Aviation Organization. No functional need for Mode D has been defined.

1.2.3 The Air Traffic Control (ATC) System will use Mode 3/A with 4096 identity codes and Mode C with pressure altitude transmission in 100-foot increments in providing separation service to both military and civil aircraft. There are no plans for use of Modes B and D in the United States.

1.2.4 The ATC System will provide vital support to military operation during periods of national emergency through the continued ATC use of Modes 3/A and C.

1.3 Operational Requirements.

Revised operational requirements for the Common System ATCRBS were originally established by the President's Air Coordinating Committee in Paper ACC 59/20.1-1 dated February 24, 1953, which endorsed the recommendations of the Joint Chiefs of Staff, Joint Communications-Electronics Committee as set forth in their memorandum CECM 58-53, Case 386-G, dated January 15, 1953. These recommendations were subsequently modified by classified correspondence to include a recognition of the 64-code capability of the ATCRBS and to provide for compatibility with the Military IFF Mark X System. Common System Component Characteristics for the ATCRBS were established by the President's Air Coordination Committee in Paper ACC 59/20.4 dated September 1957. Compatible system characteristics were approved by the International Civil Aviation Organization (ICAO), Sixth Communication Division, and published in the International Standards and Recommended Practices Aeronautical Telecommunications, Annex 10, Fifth Edition dated October 1958. Three-pulse side lobe suppression, automatic pressure-altitude transmission and other improvements were recommended by the ICAO Seventh Communications Division and included in the report of the Seventh Session dated February 9, 1962. At the ICAO COM/OPS Meeting in 1966, the three-pulse method was designated as the sole means of side lobe suppression and 4096 identity codes were raised to Standards. A standard of correspondence (paragraph 2.7.13.2.5) was established for automatic pressure-altitude transmission and a functional description of the modes and their intended usage was defined.

1.3.1 Compatibility. The required compatibility of the Military Mark X (SIF) airborne transponders with the ICAO SSR (ATCRBS) has been established using the Military Mode 3 and Civil Mode A which are identical in characteristics. This mode of operation is referred to herein as Mode 3 A. The Memorandum of Understanding between the Department of De fense and the Federal Aviation Administrati on the Joint Operational Use of the Military IFF Mark X (SIF) System and the Common System Air Traffic Control Radar Beacon System, dated March 18, 1966, contains the agreement on the use of Modes 3/A and C.

1.3.2 System Coverage. The ATCRBS is intended to provide the air traffic controller with continuous, reliable, and accurate information concerning the plan-position (rho-theta), altitude, and identity of any or all equipped aircraft in the airspace under his control. With a properly sited Air Traffic Control Radar Beacon Interrogator-Receiver and other units having characteristics as stated herein, the ATCRBS will provide spatial line-of-sight coverage equal to or greater than the following limits:

a. Range	1 to 200* nautical miles
b. Elevation	½ to 45° above the horizontal plane
c. Altitude	Limited only by service ceiling of aircraft

*Interrogators having limited range may be emplc at many locations.

While it is necessary to establish specific standards for the airborne components of the System and to define the characteristics of the radiated signals from both the interrogator and transponder, the power and sensitivity requirements for the interrogator-receiver may be modified on the basis of the intended usage with due regard for the precautions outlined in the guidance material.

1.3.3 System Accuracy. The system accuracy is determined by the characteristics of the ATC beacon interrogator-receiver (including its antenna), transponder, altimeter and transducer, ground processing equipment, and the associated display. With equipment of present day design meeting the characteristics stated herein, ATCRBS is capable of providing data within the following accuracies:

a. Range: ±1000 feet.

b. Azimuth: ±1.0 degree

c. Altitude Correspondence: Within ±[illegible] feet, on a 95 percent probability basis, [illegible] the pressure altitude information (referenced to the standard pressure setting of 29.92 inches of mercury) used on board the aircraft to adhere to the assigned flight profile.

1.3.4 Identification Coding

1.3.4.1 The ATCRBS is a valuable tool for identifying aircraft, as well as for providing radar target reinforcement.

The inherent capability of the system to provide radar identification of participating aircraft will be utilized to provide the controller with the specific radar beacon target identity of those aircraft equipped. The characteristics specified herein provide for 4096 discrete reply codes. In addition to the 4096 discrete reply codes, a Special Position Identification (SPI) pulse is available for transmission upon request of the control agency, on any mode except Mode C.

1.3.4.2 Two codes shall be reserved for transmission of distinct emergency and radio communications failure indications.

1.3.4.2.1 Code 7700 shall be used on Mode 3/A to provide recognition of an aircraft in an emergency.

NOTE.—Some existing military transponders transmit four trains of the code in use as an emergency reply. Other military transponders transmit the code in use followed by three trains of Code 0000 as the emergency reply. New military transponders will transmit Code 7700 followed by three trains of Code 0000 as an emergency reply.

1.3.4.2.2 Code 7600 shall be used on Mode 3/A to provide recognition of an aircraft with radio communications failure.

1.3.5 Altitude Transmission. The system provides for automatic pressure-altitude data transmission in 100-foot increments from −1000 feet to 126,700 feet.

1.3.5.1 This pressure altitude data transmission capability will be used to:

a. Reduce the volume of communications between controllers and pilots by obviating the need for oral altitude reports.

b. Improve utilization of airspace in connection with the provision of ATC services to climbing and descending aircraft.

c. Enable the controller, when desirable, to assure himself that vertical separation between two aircraft is being maintained.

d. Provide ATC an improved means of determining when greater vertical separation is required due to turbulence.

e. Improve the integrity of the Air Traffic Control Radar Beacon System (ATCRBS) for ATC purposes by automatically displaying to the controller the targets and altitudes or flight levels of aircraft in or near the airspace under his jurisdiction which are not otherwise selected for display.

f. Reduce the number of advisories and traffic avoidance vectors required in the provision of radar traffic information and vectoring service.

g. Improve ATC efficiency in serving high performance aircraft during cruise-climb profiles.

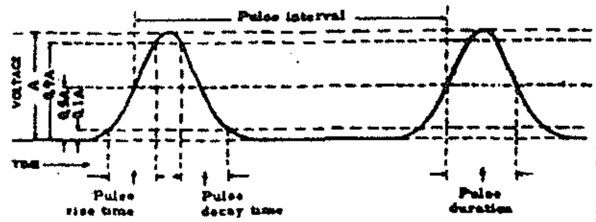
h. At a future date, enable automatic prediction of projected flight conflicts in elevation using electronic data processing systems.

1.4 ATCRBS System Description.

The System consists of airborne transponders, ground interrogator-receiver, processing equipment, and an antenna system. The antenna may or may not be associated with, or slaved to, a primary surveillance radar. In operation, an interrogation pulse-group transmitted from the interrogator-transmitter unit, via an antenna assembly, triggers each airborne transponder located in the direction of the main beam, causing a multiple pulse reply group to be transmitted from each transponder. These replies are received by the ground receiver and, after processing, are displayed to the controller. Measurement of the round-trip transit time determines the range (rho) to the replying aircraft while the mean direction of the main beam of the interrogator antenna, during the reply, determines the azimuth (theta). The arrangement of the multiple-pulse reply provides individualized pressure altitude and identity information pertaining to the responding aircraft. The ATCRBS is the preferred means of obtaining aircraft three dimensional position and identification data in the National Airspace System.

2. SYSTEM CHARACTERISTICS.

Pulse Shape and Spacing Definitions



DEFINITIONS

Pulse amplitude A. The peak voltage amplitude of the pulse envelope.

Pulse duration. The time interval between 0.5A points on leading and trailing edges of the pulse envelope.

Pulse interval. The time interval between the 0.5A point on the leading edge of the first pulse and the 0.5A point on the leading edge of the second pulse.

Pulse rise time. The rise time as measured between 0.1A and 0.9A on the leading edge of the pulse envelope.

Pulse decay time. The decay time as measured between 0.9A and 0.1A on the trailing edge of the pulse envelope.

2.1 Interrogation and Control (Interrogation Side Lobe Suppression) Radio Frequencies (ground-to-air).

2.1.1. Center frequency of the interrogation and control transmissions shall be 1030 MHz.

2.1.1.1 The frequency tolerance shall be ±0.2 MHz.

2.1.2 Center frequencies of the control transmission and each of the interrogation pulse transmissions shall not differ from each other by more than 0.2 MHz.

2.2 Reply Radio Frequency (air-to-ground).

2.2.1 Center frequency of the reply transmission shall be 1090 MHz.

2.2.1.1 The frequency tolerance shall be ±3 MHz.

2.3 Polarization.

2.3.1 Polarization of the interrogation, control, and reply transmissions shall be predominantly vertical.

2.4 Interrogation Modes (signals-in-space).

2.4.1 The interrogation shall consist of two transmitted pulses designated P_1 and P_3. A control pulse P_2 shall be transmitted following the first interrogation pulse P_1.

2.4.2 The interrogation modes shall be as defined in 2.4.3.

2.4.3 The interval, between P_1 and P_3, shall determine the mode of interrogation and shall be as follows:

Mode 1	3±0.1 Microseconds
Mode 2	5±0.2 Microseconds
Mode 3/A	8±0.2 Microseconds
Mode B	17±0.2 Microseconds
Mode C	21±0.2 Microseconds
Mode D	25±0.2 Microseconds

2.4.4 The interval between P_1 and P_2 shall be 2.0±0.15 microseconds.

2.4.5 The duration of pulses P_1, P_2, and P_3 shall be 0.8±0.1 microsecond.

2.4.6 The rise time of pulses P_1, P_2, and P_3 shall be between 0.05 and 0.1 microsecond.

NOTE.—The intent of the lower limit of rise time (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which theoretically would be produced by a trapezoidal wave having the stated rise time.

2.4.7 The decay time of pulses P_1, P_2, and P_3 shall be between 0.05 and 0.2 microsecond.

NOTE.—The intent of the lower limit of decay time (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which theoretically would be produced by a trapezoidal wave having the stated decay time.

2.5 Interrogation and Side Lobe Suppression Transmission Characteristics (signals-in-space).

2.5.1 The system relies on pulse amplitude comparison between pulses P_1 and P_2 in the transponder to prevent response to side lobe interrogation. The radiated amplitude of P_2 at the antenna of the transponder shall be (1) equal to or greater than the radiated amplitude of P_1 from the greatest side lobe transmission of the antenna radiating P_1, and (2) at a level lower than 9 dB below the radiated amplitude of P_1 within the desired arc of interrogation, (see 3.2.2).

2.5.2 Within the desired arc of the directional interrogation (main lobe), the radiated amplitude of P_3 shall be within 1 dB of the radiated amplitude of P_1.

2.6 Reply Transmission Characteristics (signals-in-space).

2.6.1 Framing Pulses. The reply function shall employ a signal comprising two framing pulses spaced 20.3 microseconds, as the most elementary code.

2.6.2 Information Pulses. Information pulses shall be spaced in increments of 1.45 microseconds from the first framing pulse. The designation and position of these information pulses shall be as follows:

Pulse	*Position Microseconds*
C_1	1.45
A_1	2.90
C_2	4.35
A_2	5.80
C_4	7.25
A_4	8.70
X	10.15
B_1	11.60
D_1	13.05
B_2	14.50
D_2	15.95
B_4	17.40
D_4	18.85

NOTE.—The Standard relating to the use of these pulses is given in 1.3.4 and 2.7.13. However, the position of the "X" pulse is specified only as a technical standard to safeguard possible future use. Further guidance on this matter is given in 3.3.6.

2.6.3 Special Position Identification (SPI) Pulse. In addition to the information pulses provided, a Special Position Identification pulse, which may be transmitted with the information pulses, shall occur at a pulse interval of 4.35 microseconds following the last framing pulse.

2.6.4 Reply Pulse Shape. All reply pulses shall have a pulse duration of 0.45±0.10 microsecond, a pulse rise time between 0.05 and 0.1 microsecond, and a pulse decay time between 0.05 and 0.2 microsecond. The pulse amplitude variation of one pulse with respect to any other pulse in a reply train shall not exceed 1 dB.

NOTE.—The intent of the lower limit of rise and decay times (0.05 microsecond) is to reduce sideband radiation. Equipment will meet this requirement if the sideband radiation is no greater than that which theoretically would be produced by a trapezoidal wave having the stated rise and decay times.

2.6.5 Reply Pulse Interval Tolerances. The pulse interval tolerance for each pulse (including the last framing pulse) with respect to the first framing pulse of the reply group shall be ±0.10 microsecond. The pulse interval tolerance of the Special Position Identification Pulse with respect to the last framing pulse of the reply group shall be ±0.10 microsecond. The pulse interval tolerance of any pulse in the reply group with respect to any other pulse (except the first framing pulse) shall not exceed ±0.15 microsecond.

2.6.6 Code Nomenclature. The code designations shall consist of four digits, each of which lies between 0 and 7, inclusive, and is determined by the sum of the pulse subscripts given in 2.6.2, employed as follows:

Digit	*Pulse Group*
First (most significant)	A
Second	B
Third	C
Fourth	D

2.6.6.1 Examples:

a. Code 3600 would consist of information pulses A_1, A_2, B_2, and B_4.

b. Code 2057 would consist of A_2, C_1, C_4, D_1, D_2, and D_4.

c. Code 0301 would consist of B_1, B_2, and D_1.

2.7 Technical Characteristics of the Airborne Transponder.

2.7.1 Reply. When selected to reply to a particular interrogation mode, the transponder shall reply (not less than 90% efficiency) when all of the following conditions have been met:

2.7.1.1. The received amplitude of P_3 is in excess of a level 1 dB below the received amplitude of P_1 but no greater than 3 dB above the received amplitude of P_1.

2.7.1.2 Either the received amplitude of P_1 is in excess of a level 9 dB above the received amplitude of P_2, or no pulse is received at the position 2±0.7 microseconds following P_1.

2.7.1.3 The received amplitude of a proper interrogation is more than 10 dB above the received amplitude of random pulses where the latter are not recognized by the transponder as P_1, P_2, or P_3.

2.7.2 No Reply. The Transponder shall not reply to more than 10% of the interrogations under the following conditions:

2.7.2.1 To interrogations when the interval between pulses P_1 and P_3 differs from that specified in 2.4.3 for the mode selected in the transponder by more than ±1.0 microsecond.

2.7.2.2 Upon receipt of any single pulse which has no amplitude variations approximating a normal interrogation condition.

2.7.3. Dead Time. After reception of a proper interrogation, the transponder shall not reply to any other interrogation at least for the duration of the reply pulse train. This dead time shall end no later than 125 microseconds after the transmission of the last reply pulse of the group.

2.7.4 Suppression. Upon receipt of an interrogation, complying with 2.4 in respect of the mode selected manually or automatically, the transponder shall be suppressed (not less than 99% efficiency) when the received amplitude of P_2 is equal to or in excess of the received amplitude of P_1, and spaced 2±0.15 microseconds.

NOTE.—It is not the intent of this paragraph to require the detection of P_3 as a prerequisite for initiation of suppression action.

2.7.4.1 The transponder suppression shall be for a period of 35±10 microseconds.

2.7.4.2 The suppression shall be capable of being reinitiated for the full duration within two microseconds after the end of any suppression period.

2.7.5 Receiver Sensitivity and Dynamic Range.

2.7.5.1 The minimum triggering level (MTL) of the transponder shall be such that replies are generated to 90% of the interrogation signals when:

2.7.5.1.1 The two pulses P_1 and P_3 constituting an interrogation are of equal amplitude and P_2 is not detected; and,

2.7.5.1.2 The amplitude of these signals received at the antenna end of the transmission line of the transponder is nominally 71 dB below 1 milliwatt with limits between 69 and 77 dB below 1 milliwatt.

NOTE.—For this MTL requirement, a nominal 3 dB transmission line loss and an antenna performance equivalent to that of a simple quarter wave antenna are assumed. In the event the assumed conditions do not apply, the MTL of the installed transponder system must be comparable to that of the assumed system.

2.7.5.2 The variation of the minimum triggering level between modes shall not exceed 1 dB for nominal pulse spacings and pulse widths.

2.7.5.3 The reply characteristics shall apply over a received signal amplitude range between minimum triggering level and 50 dB above minimum triggering level.

2.7.5.4 The suppression characteristics shall apply over a received signal amplitude range between 3 dB above minimum triggering level and 50 dB above minimum triggering level.

2.7.6 Pulse Duration Discrimination. Signals of received amplitude between minimum triggering level and 6 dB above this level, and of a duration less than 0.3 microsecond at the antenna, shall not cause the transponder to initiate more than 10% reply or suppression action. With the exception of single pulses with amplitude variations approximating an interrogati[on], any single pulse of a duration more than [illegible] microseconds shall not cause the transponder to initiate reply or suppression action over the signal amplitude range of minimum triggering level (MTL) to 50 dB above that level.

2.7.7 Echo Suppression and Recovery. The transponder shall contain an echo suppression facility designed to permit normal operation in the presence of echoes of signals in space. The provision of this facility shall be compatible with the requirements for suppression of side lobes given in 2.7.4.

2.7.7.1 Desensitization. Upon receipt of any pulse more than 0.7 microsecond in duration, the receiver shall be desensitized by an amount that is within at least 9 dB of the amplitude of the desensitizing pulse, but shall at no time exceed the amplitude of the desensitizing pulse, with the exception of possible overshoot during the first microsecond following the desensitizing pulse. Single pulses of duration less than 0.7 microsecond are not required to cause the specified desensitization, and shall not cause desensitization of duration greater than that permit[ted] herein or by 2.7.7.2.

2.7.7.2 Recovery. Following desensitization, the receiver shall recover sensitivity (within 3 dB of minimum triggering level) within 15 microseconds after reception of a desensitizing pulse having a signal strength up to 50 dB above minimum triggering level. Recovery shall be nominally linear at an average rate not exceeding 3.5 dB per microsecond.

NOTE.—Transponders that respond to military modes will recover within 15 microseconds, but may employ methods other than nominally linear recovery.

2.7.8 Random Triggering Rate. Installation in the aircraft shall be made in such manner that, with all possible interfering equipments installed in the same aircraft operating in their normal manner on operational channels of maximum interference, but with the absence of bona fide interrogations, the random triggering rate (squitter) of the transponder shall not exceed thirty replies per second as integrated over an interval equivalent to at least 300 random triggers, or 30 seconds, whichever is less.

2.7.9. Interference Suppression Pulses. If the equipment is designed to accept and respond to suppression pulses from other electronic equipment in the aircraft (to disable it while the other equipment is transmitting), the equipment must regain normal sensitivity, within 3 dB, not later than 15 microseconds after the end of the applied suppression pulse.

2.7.10 Reply Rate.

2.7.10.1 For equipment intended for installation in aircraft which operate at altitudes above 15,000 feet, the transponder shall be capable of at least 1200 replies per second for a 15-pulse coded reply.

2.7.10.2 For equipment intended for installation in aircraft which operate at altitudes not exceeding 15,000 feet, the transponder shall be capable of at least 1,000 replies per second for a 15-pulse coded reply.

2.7.10.3 A sensitivity reduction type reply rate limit control shall be incorporated in the transponder. The range of this control shall permit adjustment, as a minimum, to any value between 500 and 2000 replies per second, or to the maximum reply rate capability if less than 2000 replies per second, without regard to the number of pulses in each reply. Sensitivity reduction in excess of 3 dB shall not take effect until 90% of the selected value is exceeded. Sensitivity reduction shall be at least 30 dB for rates in excess of 150% of the selected value.

2.7.10.3.1 Recommendation. The reply rate limit should be set at 1200 replies per second, or the maximum value below 1200 replies per second of which the transponder is capable (see 2.7.10.2).

2.7.11 Reply Delay and Jitter. The time delay between the arrival at the transponder of the leading edge of P_3, and the transmission of the leading edge of the first pulse of the reply shall be 3±0.5 microseconds. The total jitter of the reply pulse code group, with respect to P_3, shall not exceed ±0.1 microsecond for receiver input levels between 3 and 50 dB above minimum triggering level. Delay variations between modes on which the transponder is capable of replying shall not exceed 0.2 microsecond.

2.7.12 Transponder Power Output.

2.7.12.1 For equipment intended for installation in aircraft which operate at altitudes above 15,000 feet, the peak pulse power available at the antenna end of the transmission line of the transponder shall be at least 21 dB and not more than 27 dB above 1 watt.

2.7.12.2 For equipment intended for installation in aircraft which operate at altitudes not exceeding 15,000 feet, the peak pulse power available at the antenna end of the transmission line of the transponder shall be at least 18.5 dB and not more than 27 dB above 1 watt.

NOTE.—For the power output requirement of 2.7.12.1 and 2.7.12.2, a nominal 3 dB transmission line loss and an antenna performance equivalent to that of a simple quarter-wave antenna are assumed. In the event these assumed conditions do not apply, the peak pulse power of the installed transponder system must be comparable to that of the assumed system.

2.7.13 Reply Codes.

2.7.13.1 Identification. The 4096 codes available in the Standard at 2.6.2 shall be manually selectable for reply to interrogations on Mode 3/A.

2.7.13.2 Pressure-Altitude Transmissions.

2.7.13.2.1 Independently of the other modes and codes manually selected, the transponder shall automatically reply to Mode C interrogations.

NOTE.—Military transponders may include provisions to disable Mode C replies.

2.7.13.2.2 The reply to Mode C interrogations shall consist of the two framing pulses specified in 2.6.1 together with information pulses specified in 2.6.2.

2.7.13.2.3 At as early a date as practicable, transponders shall be provided with means to remove the information pulses, but to retain the framing pulses when the provision of 2.7.13.2.6 is not complied with, in reply to Mode C interrogation.

NOTE.—The information pulses should be capable of being removed either in response to a failure detection system or manually at the request of the controlling agency.

2.7.13.2.4 The information pulses shall be automatically selected by an analog-to-digital converter connected to a pressure-altitude data source in the aircraft referenced to the standard pressure setting of 29.92 inches of mercury.

2.7.13.2.5 Pressure altitude shall be reported in 100-foot increments by selection of pulses as shown in Figure 1.

NOTE.—Some transponders in service transmit the Special Position Identification (SPI) pulse in addition to the D_4 pulse.

2.7.13.2.6 The digitizer code selected shall correspond to within ±125 feet, on a 95 percent probability basis, with the pressure altitude information (referenced to the standard pressure setting of 29.92 inches of mercury) used on board the aircraft to adhere to the assigned flight profile.

NOTE.—Guidance material relating to pressure altitude transmission is contained in 3.3.4 and 3.3.5.

2.7.14 Transmission Time of Special Position Identification (SPI) Pulse. When manually selected, the SPI pulse shall be transmitted for a period of between 15 and 30 seconds and must be capable of being reinitiated at any time.

2.7.15 Transponder Receiver Bandwidth. The skirt bandwidth should be such that the sensitivity of the transponder is at least 60 dB down at frequencies outside the band 1030±25 MHz.

2.7.16 Transponder Self-Test and Monitor.

2.7.16.1 Self-test and monitor devices that radiate test interrogation signals, or prevent transponder reply to proper interrogation during the test period, shall be limited to intermittent use which is no longer than required to determine the transponder status.

2.7.16.2 The test interrogation rate shall not exceed 450 per second and the test interrogation signal level at the antenna end of the transmission line shall not exceed a level of −40 dBm.

2.7.17 Antenna.

2.7.17.1 The transponder antenna system, when installed on an aircraft, shall have a radiation pattern which is essentially omni-directional in the horizontal plane.

2.7.17.2 Recommendation. The vertical beamwidth (half power points) should be at least 30 degrees above and below the horizontal plane.

NOTE.—Guidance material relating to airborne transponder antennas is contained in 3.3.2.

2.8 Technical Characteristics of the Interrogator-Receiver.

2.8.1 Interrogation Repetition Frequency. The maximum interrogation repetition frequency shall be 450 interrogations per second.

NOTE.—This value is the sum total of the interrogation rate of all modes in use.

2.8.1.1 Recommendation. To minimize unnecessary transponder triggering and the resulting high density of mutual interference, all interrogators should use the lowest practicable interrogation repetition frequency that is consistent with the display characteristics, interrogator antenna bandwidth, and antenna rotation speed employed.

2.8.2 Power Output.

2.8.2.1 The effective radiated peak power of interrogation pulses (P_1 and P_3) shall not exceed 52.5 dB above one watt, and P_1 shall be within 1 dB of P_3.

NOTE.—The effective radiated peak power includes the antenna gain and the transmission line losses. The effective radiated peak power of interrogation should be the minimum required to provide the system coverage. The system coverage stated in 1.3.2 can be met by an interrogator having a nominal 1000 watts power (peak pulse), a transmission line loss of 3 dB, and an antenna gain of 21 dB.

2.8.2.2 Interrogators with range coverage requirements of less than 200 miles will be employed at many locations. The effective radiated peak power of interrogation at these sites shall be reduced to the minimum required level which is practical to achieve.

2.8.3 Receiver Sensitivity.

2.8.3.1 The maximum receiver sensitivity shall be not less than 85 dB below one milliwatt, to produce a tangential signal output, for a 200-mile facility.

NOTE.—For this receiver sensitivity requirement, a nominal 3 dB transmission line loss and an antenna gain of 21 dB are assumed. In the event these assumed conditions do not apply, the receiver sensitivity of the installed system should be comparable to that of the assumed system.

2.8.3.2 Interrogators with range coverage requirements of less than 200 miles will be employed at many locations. The maximum receiver sensitivity at these sites may be reduced to the minimum required level.

2.8.4 Sensitivity Time Control (STC). The receiver sensitivity shall be reduced at short ranges to minimize reply path reflections and pulse stretching. At 15.36 microseconds after the leading edge of pulse P_3 (1 nautical mile plus transponder delay), the gain shall be reduced to an adjustable value between 10 and 50 dB below maximum sensitivity. The recovery rate shall be adjusted to suit local conditions.

2.8.4.1 Recommendation. Following the initial reduction of sensitivity at 15.36 us after the leading edge of pulse P_3 (1 nautical mile plus transponder delay), a recovery rate of 6 dB for each doubling of range is satisfactory for most applications.

2.8.5 Receiver Bandwidth and Video Response. The bandwidth of the receiver shall be centered on 1090 MHz and shall be adequate to reproduce the transponder pulse train described in paragraph 2.6 and to accommodate the transponder transmitter frequency tolerance and interrogator receiver local oscillator drift. The bandwidth shall not be more than 24 MHz at 40 dB below maximum sensitivity. The video response shall be capable of reproducing the pulse trains described in paragraph 2.6 without appreciable pulse stretching or distortion over a dynamic range from receiver threshold to a level 24 dB above threshold, at any range with STC provisions operative.

2.8.5.1 Image Response. The image response shall be at least 60 dB below maximum sensitivity.

2.8.6 Azimuth Accuracy. The electrical alignment of the main lobe of the directional antenna radiation pattern, with respect to the associated display shall be such as to permit received replies to be displayed within 1 degree of true orientation.

2.9 Interrogator Radiated Field Pattern. Recommendation—The beamwidth of the directional interrogator antenna should not be wider than is operationally required. The side- and back-lobe radiation of the directional antenna should be at least 24 dB below the peak of the main-lobe radiation.

2.10 Interrogator Monitor.

2.10.1 The range and azimuth accuracy of the ground interrogator shall be monitored continuously.

NOTE.—Interrogators that are associated with and operated in conjunction with primary radar may use the primary radar as the monitoring device: alternatively an electronic range and azimuth accuracy monitor would be required.

2.10.2 Recommendation. In addition to range and azimuth monitoring, provision should be made to monitor continuously the other critical parameters of the ground interrogator for any degradation of performance exceeding the allowable system tolerances and to provide an indication of any such occurrence.

NOTE.—Guidance on those system parameters for which continuous or periodic monitoring provisions are of particular importance is to be found in paragraph 3.2.5.

2.11 Spurious Emissions and Spurious Responses.

2.11.1 Spurious Radiation. Spurious radiation shall not exceed 76 dB below 1 watt for the interrogator.

2.11.1.1 Recommendation. CW radiation should not exceed 70 dB below 1 watt for the transponder.

2.11.2 Spurious Responses. The response of both airborne and ground equipment to signals not within the receiver bandpass shall be at least 60 dB below maximum sensitivity.

3. GUIDANCE MATERIAL RELATED TO THE AIR TRAFFIC CONTROL RADAR BEACON SYSTEM CHARACTERISTICS

3.1 Factors Affecting Optimum Utilization of the System. A number of specific precautions may be taken in order to obtain maximum utilization of the ATCRBS system, such as:

3.1.1 Coordination of the number and type of interrogators installed in any particular area, and cooperative use of interrogators, where possible, for several related functions.

3.1.2 Use for each interrogator of the lowest interrogation rate which is required to perform its function.

3.1.3 Use for each interrogator of the lowest power output which is required for it to provide satisfactory performance.

3.1.4 Use of particular interrogators only during the periods necessary for them to perform their function.

3.1.5 Limitation of antenna beamwidth to the minimum required and use of low-side-lobe antennas.

3.1.6 Coordination of the interrogation repetition frequency used to minimize interference.

3.2 Application Considerations of the ATCRBS System.

3.2.1 Siting. Care should be taken in siting the ground interrogator to ensure that the number of ground installations is kept to a minimum consistent with the operational requirement for ATCRBS information. It should be emphasized that the effects obtained by reflection of the main lobe are more serious than those associated with primary radar. It is therefore necessary to ensure that no large vertical reflecting surfaces are within a reasonable distance of the ATCRBS interrogator antenna. This distance will depend on the area of the reflecting surface and its elevation with respect to the interrogator, but as a guide, it is desirable to site the interrogator at least half a mile away from large metal structures. Although it may be desirable to associate the interrogator antenna physically with a primary radar antenna, siting and maintenance considerations may make it necessary to have a separate site for the interrogator. When this is necessary, the rotation of the two antennas should be synchronized with a maximum error not to exceed one degree.

3.2.2 Interrogator Antenna.

3.2.2.1 It is necessary that the side lobe level of the antenna relative to the main lobe be as low as practicable. A level lower than −24 dB is desirable. It is important that the interrogation beamwidth be kept as narrow as possible, normally of the order of 8 degrees, but it should be noted that there is a minimum number of replies necessary for processing and display. This minimum will depend on the particular processing and display facilities provided, but would, typically, fall in the range of 4 to 8 replies per beamwidth on each interrogation mode.

3.2.2.2 Side lobe suppression requires two radiation patterns: A directional pattern to radiate the interrogation pulses, and an omni-directional pattern to radiate the control pulse. It should be noted that "omni-directional", as used here, assumes that adequate power is radiated in all directions, not necessarily that equal power is radiated in all directions. It is necessary that the control pattern be in the right relationship to the interrogation pattern over the operational angles of elevation. This may demand that the antennas be designed in a common assembly so that the same effective height above the ground can be maintained for both.

3.2.2.3 Some antenna sites may experience severe reflections from buildings and re-siting may not be practicable. If the reflections are not adequately suppressed by side lobe suppression, satisfactory performance is possible by use of modified three-pulse side lobe suppression techniques. One technique makes use of the omni-directional antenna during transmission of the P_1 interrogation pulse. The P_1 interrogation is fed to both the directional and omni-directional antennas in a power ratio depending on the particular reflection problem and assists transponder suppression in the side lobe areas.

3.2.3 Sensitivity Time Control (STC). This feature is extremely effective in minimizing the undesirable processing and display of side lobe replies from older transponders that do not have side lobe suppression (SLS) capability. Even with SLS fully implemented, the use of STC will be required to minimize the effects of flected signals and pulse stretching. The setting of STC is critical since too much attenuation will cause target loss and too little allows reflection and side lobe breakthrough. Once an optimum setting is determined, it should be maintained with close tolerance. A tolerance of ±1.5 dB is recommended.

3.2.4 Rejection of Unwanted Responses.

3.2.4.1 In an area where a large number of ground interrogators are necessary, there will be a considerable number of transponder responses, which have been triggered by other interrogators, received at any one ground equipment. The responses will be received at recurrence frequencies which will, in all probability, be different from that of the interrogator receiving the information and will constitute a nuisance called "fruit" (unsynchronized replies) on the radar display.

3.2.4.2 Defruiting techniques which use delay lines, storage tubes, or digital storage to defruit on a pulse-to-pulse basis should be employed to remove these non-synchronous replies. The defruiting function may also be an integral part of the digital detection process.

3.2.5 Monitoring of ATCRBS Interrogator.

3.2.5.1 The performance monitoring of the ground interrogator called for in 2.10 is required to provide responsible personnel with an indication that the equipment is functioning satisfactorily within the system limits and to give an immediate indication of any significant fault developing in the equipment. Additionally, it is desirable that continuous monitoring provisions with respect to at least the system parameters listed hereafter in 3.2.5.1.1 and 3.2.5.1.2 be provided and that an alarm indication be given in the event of a failure of the monitor itself.

3.2.5.1.1 Pulse Intervals. Means should be provided to measure pulse spacings for all modes which are to be employed.

3.2.5.1.2 Interrogator Relative Radiated Pulse Levels. When side lobe suppression is provided, monitoring of this parameter is most important and should be associated with the tolerances indicated in 2.5.

3.2.5.2 Monitoring of the following ATCRBS system parameters is also desirable; however, checking on a periodic basis should suffice.

3.2.5.2.1 Interrogator Radio Frequencies. Assuming that a high stability crystal controlled oscillator is used as the frequency control element of the ATCRBS, it will be necessary only on a periodic basis to determine that the tolerances specified in 2.1 are satisfied.

3.2.5.2.2 Interrogator Pulse Duration.

3.2.5.2.3 Receiver Sensitivity.

3.2.5.2.4 Radiated Power.

3.2.5.2.5 Spurious Radiation.

3.2.5.3 The precise location of the monitor warning indication is a matter for determination by the Administration concerned in the light of local circumstances, but should take into account the need to prevent the presentation of erroneous information to the controller without his knowledge.

3.3 Airborne Equipment.

3.3.1 Transponder Peak Power Output and Sensitivity. System requirements can be met by a transponder having a nominal output power of 500 watts (peak pulse) and a nominal minimum triggering level (MTL) of −74 dBm, when used in an aircraft having a nominal 3 dB transmission line attenuation and mismatch loss and an antenna performance equivalent to that of a simple quarter-wave antenna. Other combinations of transponder peak pulse power output and MTL, transmission line loss and antenna performance, which result in comparable installed system effective radiated peak pulse power and MTL may be considered equally acceptable.

3.3.2 Antenna.

3.3.2.1 A technique which uses two transponders connected to separate antennas must be considered with extreme caution. Such an arrangement, unless carefully controlled, could result in unsatisfactory performance because of the difficulty of matching transponder parameters. This technique requires matching of the relevant characteristics specified in 2.7 and in particular, matching of the reply delay (2.7.11) to within 0.2 microsecond.

3.3.2.2 Any switching device that alternately changes the transponder from one antenna to another at a preset rate should be avoided. A preferred method, if dual antennas are used, is through received signal amplitude comparison whereby the transponder reply is routed to the antenna which receives the stronger interrogation signal.

3.3.3 Transponder Self-Test and Monitor. If self-test and/or monitor devices are installed and used in aircraft to indicate normal or faulty operation, care should be exercised to minimize any system derogation (particularly fruit generation) that may result. The duration of use of the test mode should be an absolute minimum and limited to that required by the pilot to determine the transponder status. In order to minimize suppression of replies to ground interrogations, the test signal interrogation rate and level should be the lowest practicable for test.

3.3.4 Pressure-Altitude Transmission.

3.3.4.1 In order to achieve maximum operational benefit from automatic pressure-altitude transmission, the altitude information used by the pilot and that automatically provided to the controller must closely correspond (2.7.13.2.5). The highest degree of correspondence will be achieved by having airborne systems which use the same static pressure source, same aneroid unit, same static pressure error correction device and same scale correction device for both the pilot and the automatically transmitted pressure-altitude data.

3.3.4.2 For aircraft installations which are not yet equipped with altitude digitizer units, the use of Mode C reply framing pulses only (2.7.13.2.3) is encouraged as an interim arrangement.

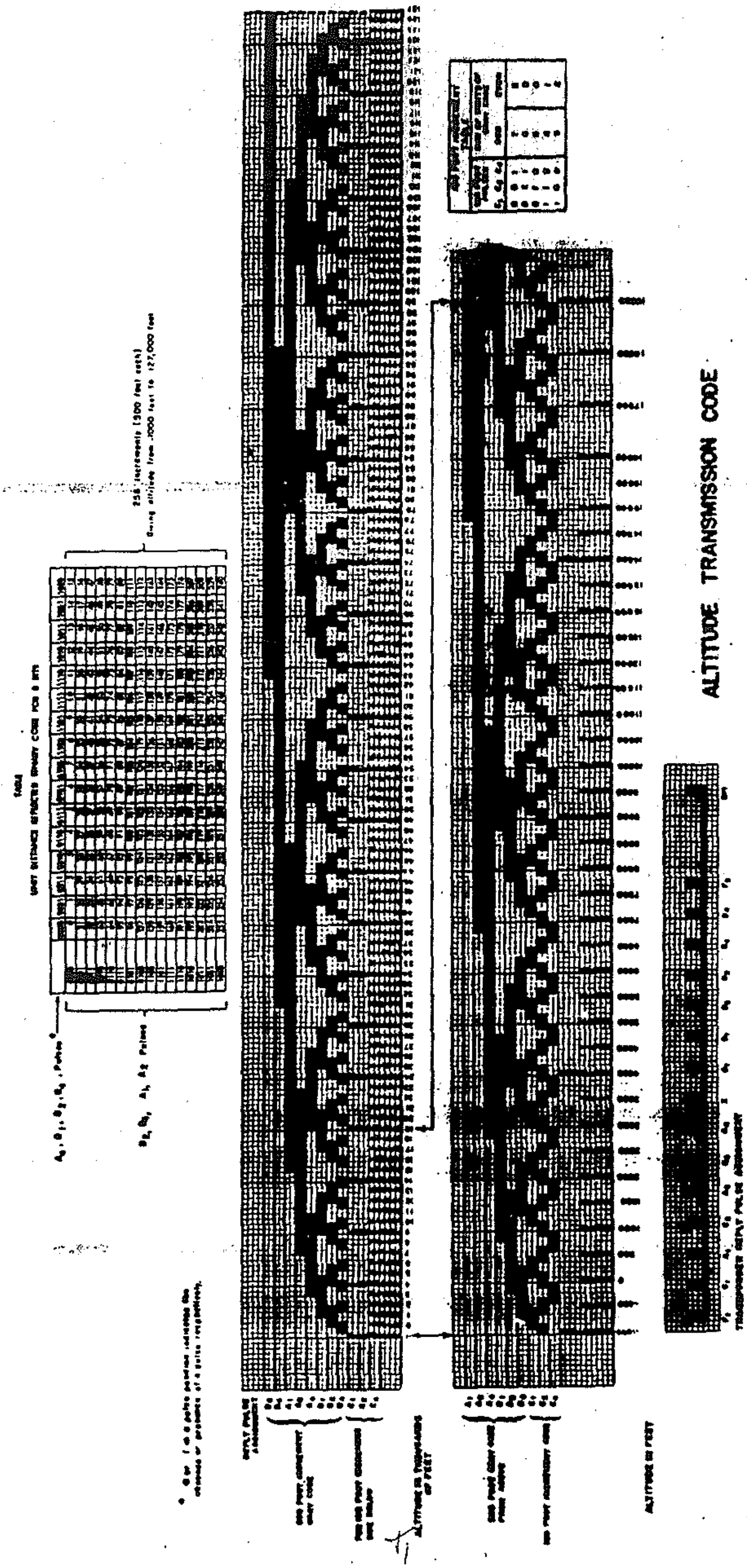
3.3.4.3 The wording of the standard recognizes that facilities are provided on many transponders in service which only enable the information and framing pulses to be removed together. But its main objective is to ensure that inaccurate information pulses are removed while retaining the capability of position determination. The framing pulses alone are useful in certain ground processing equipments for enhancing the detection probability and azimuth accuracy.

3.3.4.4 The capability required by the Standard at 2.7.13.2.2 should be provided in new installations.

3.3.5 Automatic Conversion of Pressure Altitude Data to Indicated Altitude. Automatically transmitted pressure altitude data obtained via ATCRBS may be displayed to air traffic controllers directly after being decoded when such data indicates that the aircraft from which it is received is at or above the transition level. When the aircraft is below the transition level, such data could be misleading, since it is based upon the standard atmospheric pressure reference datum of 29.92 inches of mercury, while the pilot's altimeter is adjusted to a different reference. In this case, therefore, the data must be converted by application of an appropriate correction factor based upon the same reference datum as that to which the pilot's altimeter is set.

3.3.6 Transmission of the "X" Pulse. In 2.6.2, the position of the "X" pulse is specified as a technical standard to provide for possible future expansion of the system. It is recognized that though a majority of airborne transponders of later design contain an "X" pulse position, there are no means at present embodied to permit the operational use of this pulse. To do so, modifications of existing transponders and/or ancillary equipment would be necessary. The extent of modifications required would depend on the future function of the "X" pulse.

3.3.7 Transponder Low Sensitivity Setting. Many existing transponders are equipped with a low sensitivity setting (minus 12 dB below normal sensitivity) which is manually selectable by the pilot upon request of the controlling agency. This feature has been found useful as an interim technique for reducing transponder side lobe response. However, SLS is being implemented at interrogator sites and the low sensitivity feature will not be needed in new transponders.



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