REPORT 1186

USE OF FREQUENCY BAND 4 200 TO 4 400 MHz BY RADIO ALTIMETERS

(Question 94/8)

(1990)

1. Introduction

1.1 In response to Recommendation 606 (MOB-87), Question 94/8 asks what is the bandwith required for radio altimeters to maintain the necessary operational accuracy. The International Civil Aviation Organization (ICAO) has conducted a survey among its Member States and major manufacturers of radio altimeters. In addition, a study covering both current and projected future types of radio altimeters has been carried out by the UK Civil Aviation Authority [Ingless, 1989].

2. Operational requirement

2.1 Radio altimeters are an integral and essential part of aircraft systems. They perform an important operational function to aircraft in flight and are in use in a wide range of aircraft types. Because of their great precision and accuracy at altitudes of 1,000 ft or less, they are used as a height controlling function in many aircraft automatic approach and landing systems. In particular, the height output from the radio altimeter is used to control the "flare-out" transition from descending flight to touchdown on the runway during the final stages of an automatic landing. Integrity standards of the order of one failure in 10^9 operations are not uncommon, denoting a very high reliability from individual equipments. Two or three element redundancy configurations are typical methods employed to achieve these very high orders of system reliability.

2.2 In many aircraft, radio altimeters are also directly coupled to Ground Proximity Warning Systems (GPWS) designed to give warning when an aircraft falls dangerously below its desired descent path or of the approach of an aircraft to high ground in its path. Many countries require the carriage of GPWS as a mandatory requirement in all commercial aircraft on their register.

2.3 For higher altitude measurement, pulsed type radio altimeters are in extensive use.

2.4 The type of radio altimeter fitted during the manufacture of an aircraft normally stays with it throughout its life. Thus it is unlikely that any change in specification or design would be totally effective for many years, at least 25 from agreed specifications to full implementation.

3. Operational accuracy requirement

3.1 To meet the operational requirements for altimeter accuracy which have been established by States' regulatory authorities, standards for altimeter performance have been agreed internationally. These performance standards are specified in Aeronautical Radio Incorporated Document ARINC 707-1 (based on Technical Standard Order C87 and RTCA Document DO-155) and the European Organization for Civil Aviation Electronics (EUROCAE) Document ED-30. Noting the direct relationship in FMCW altimeters between frequency excursion and accuracy, the accuracy specifications from the referenced documents as shown below are of special concern:

ARINC 707-1, Section 3.7

- Accuracy: within 1.5 ft or 2 per cent, whichever is greater, within the range 20 to 2500 ft
- Output noise: 0.25 ft (RMS)
- Output resolution: 0.125 ft

EUROCAE ED-30, Section 3.2.4

- Accuracy: within 1.5 ft or 2 per cent, whichever is greater, within a range 3 to 100 ft
- Output noise: 0.25 ft

3.2 In addition, requirements have been stated for improved accuracy over the figures shown above. Aircraft with fully automatic landing systems, coupled with new curved approach capability and other new technology, are being placed into service in an attempt to relieve some of the increasing congestion experienced at nearly all airports. This in turn, creates a requirement for more accurate altimeters.

4. Altimeter types and application

4.1 Frequency modulated continuous wave (FMCW) altimeters

4.1.1 FMCW altimeters are used in practically all civil aircraft, including many general aviation aircraft. The FMCW technique provides better accuracy than other types, thus it is inherently more suitable for coupling to ground proximity warning systems and precision landing systems.

4.1.2 The parameters of a number of current radio altimeters have been examined in the UK CAA [Ingless, 1989] and these are reproduced in Table I. It can be seen from this limited sample that it is possible for the lower deviation limit to be as low as 4 200 MHz and the higher deviation limit to as high as 4 392 MHz. This suggests that it would be imprudent to reduce the frequency band while current equipment is still in operation.

TABLE I

Details of FMCW altimeters

	Centre freq (MHz)	Stability (MHz)	Freq Dev[5] (MHz)	Freq Limit (MHz)
EQUIP 1	4 300	±30	123	4 208 - 4 392
EQUIP 2	4 300	±10	130[1]	4 210 - 4 390[2]
EQUIP 3	4 300	±15	100	4 200 - 4 300[3]
EQUIP 4	4 300	±40	100[1]	4 235 - 4 362[4]
EQUIP 5	4 300	±50	100	4 225 - 4 375

Note 1 - This is a nominal value.

Note 2 - Quoted by manufacturer.

Note 3 - Quoted by manufacturer but not consistent with other parameters.

Note 4 - Rounded value from actual sample measurements [Ingless, 1989].

Note 5 - Difference between maximum and minimum value of frequency during one modulation cycle.

4.1.3 In considering the integrity of the operation of radio altimeters it is essential to assess the potential interference from services in the adjacent bands with a view to establishing a guardband. In particular it should be noted that signals with a carrier or sideband frequency that can beat with the radio altimeter signal to produce a low frequency are potentially harmful.

4.1.4 There are indications that new or alternative FMCW techniques might provide the same accuracy in a smaller bandwith. If this proves to be true, it may be possible (around the year 2015) to reduce the allocated bandwith.

4.2 Pulsed type altimeters

4.2.1 The occupied bandwith of a typical pulsed type radio altimeter is 70 MHz. However some manufacturers and/or operators distribute the centre frequency across the 200 MHz band available to improve the signal integrity under certain operational conditions. Any reduction in the available bandwith would compromise this integrity gain. These pulsed type altimeters are designed for high altitude use and do not meet low altitude accuracy requirements.

4.3 Spread spectrum type of altimeters

4.3.1 Current development programmes are using spread spectrum techniques to achieve the required accuracy and signal integrity. One such a system about to be marketed employs the full 200 MHz bandwith. Future developments may enable operation with a smaller bandwith while retaining the required accuracy under adverse conditions.

5. Conclusion

5.1 The whole of the band 4 200 to 4 400 MHz currently allocated is required up to at least the year 2015.

5.2 Current accuracy requirements may be achievable in a smaller bandwith but further study is required taking into account possible new improved accuracy requirements.

6. References

INGLESS, R.M. [September, 1989] - Report on the feasibility of reducing the radio altimeter band (4 200 - 4 400 MHz).

REPORT 1174

POTENTIAL FOR INTERFERENCE FROM POWER-LINE-CARRIER SYSTEMS TO LORAN-C AERONAUTICAL RECEIVERS

(Question 33/8)

(1990)

1. Introduction

The phase-pulsed hyperbolic radionavigation system LORAN-C is recognized worldwide as a valuable tool in maritime navigation. Advancements in component and software technology have led to the development of LORAN-C equipment suitable for aeronautical use. LORAN-C coverage in the United States will be expanded to support aeronautical use for enroute navigation and nonprecision approaches throughout the country. Well over 40,000 aircraft, primarily small fixed- and rotor-wing, are already equipped with LORAN-C, though the coverage expansion is not yet complete. This growth is due to the system's combination of high accuracy and low cost.

The term "power-line-carrier" or "PLC" refers to a technique by which low frequency radio currents are propagated over metallic conductors. Though not restricted to such, the most notable instance of this technique is the use of three phase, high-voltage, AC transmission lines as the propagation medium for communications related to the functions of the power industry. The communications conducted over these power-line systems are extremely varied. Both voice and data signals are transmitted. Transmissions may be short duration bursts or continuous. Transmitter power may be between 1 and 100 watts. One of the primary uses is the control of the flow of electric power within the overall power system. Short burst signals (on the order of 300 milliseconds) are used to redirect power flow in response to line fault or power outages. Within the United States, at least 10,000 PLC transmitters are operating between 70 and 130 kHz. Approximately 3300 are in the frequency range 90-110 kHz.

2. Summary of Related Studies

PLC and LORAN-C use is the subject of a number of different studies and measurement programs.

In 1965, Ontario Hydro Research Division took measurements of the 283 kHz carrier radiation from high-voltage power-lines [Jones, 1965]. Though these measurements were intended to investigate the potential interference at 283 kHz from PLC to aeronautical beacons, they revealed several important facts applicable to potential interference to LORAN-C.

The maximum radiation field was found close to the transmitting terminal. The field strength measured at an altitude of 1000 feet (305 meters) above the power-line for a variety