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Considerations in the Selection of the Universal Access Transceiver (UAT) Operating Frequency

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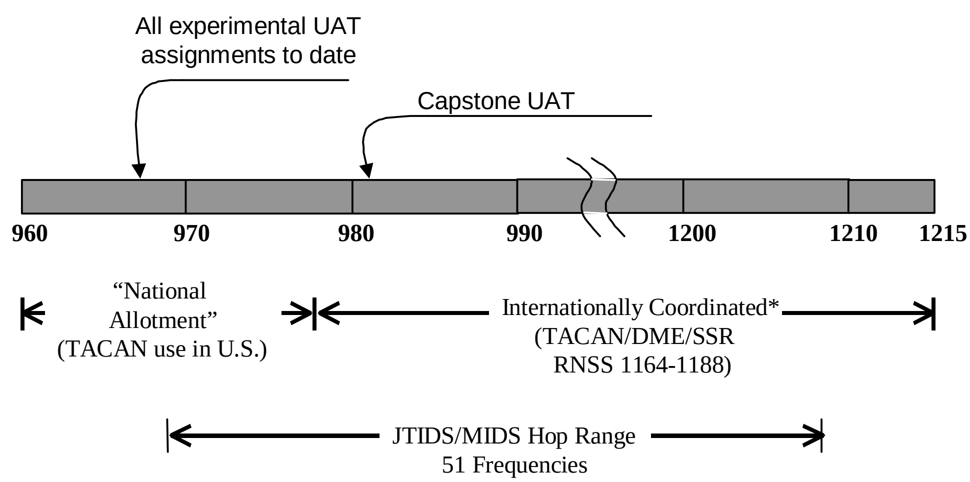
SUMMARY

This paper gives an overview of the current use of the 960-1215 MHz Aeronautical Radionavigation band. It also discusses the past assignments for the UAT, and discusses where a permanent assignment may be possible with minimal impact on current DME assignments

1) 960-1215 MHz Band Background

Figure 1 gives an overview of the 960-1215 MHz Aeronautical Radio Navigation Service (ARNS) band. Because of the fixed frequency pairing between Distance Measuring Equipment and Tactical Air Navigation (DME/TACAN) interrogations and replies, and due to the overwhelming desire to protect secondary surveillance radar, portions of the band are not considered as part of the civil national airspace system (NAS). In particular, ICAO Annex 10 identifies the frequencies of 977 and below as the portion of the band that is available for use "internally by nation States", referred to here as the "National Allotment" portion. Within the US this National Allotment is utilized by DOD for shipboard and air-to-air TACAN, and as a portion of their Joint Tactical Information Distribution System/Multifunctional Information Distribution System (JTIDS/MIDS) tuning range[1]. Internationally, use of that band is mixed, and varies country-to-country.

The remainder of the ARNS band—labeled as "Internationally Coordinated"—has a more consistent use worldwide. In addition, in the US, the FAA is the band coordinator for assignments within that portion of the band. For these reasons, it is within this portion of the band where FAA desires the "MOPS" UAT operational frequency.



*The portion of the band 1148-1156 MHz is also national allotment

Figure 1. Overview of 960-1215 MHz Band

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2) Past UAT Assignments

Prior to Capstone with its provision of "Radar-Like Services" to ADS-B equipped users, the UAT was operated on temporary experimental assignments at 966 MHz. This was convenient for experimental use as it required no NAS reassignments, and there tended to be little conflict with TACAN use in areas where the assignments were requested.

[1] JTIDS/MIDS is allowed to operate in several countries on a non-interference basis through much of the band using a frequency hopping spread spectrum technique. The system operates on 51 discrete carrier frequencies nominally spaced 3 MHz apart from 969 to 1206 MHz, with exclusion "notches" about both 1030 and 1090 MHz.

With the prospect of providing more critical air traffic services in the Capstone program, FAA shifted the frequency to within the Internationally Coordinated portion of the band. The frequency of 981 MHz was selected based primarily on the following considerations:

- Minimal impact to existing Capstone radio hardware
- Required minimal shifting of DME frequencies within Alaska (only one DME in Fairbanks)

3) Current Utilization of band from 978-984 MHz

The considerations in finding a "final" home for UAT are slightly different. First the constraints due to existing hardware need not be as great. Second, the scope of existing DME assignments affected to make room for UAT is NAS wide, making this a significant consideration. Finally, more consideration needs to be given to compatibility with other systems when in close proximity to UAT such as aircraft cosite and aircraft when very close to DME ground stations. For these reasons the low end of the band still appears most favorable:

- Provides best frequency separation from 1090 replies from cosited SSR transponders and reasonable separation from 1030 interrogations from cosited TCAS.
- It puts UAT in a part of the band where transmissions from "legacy" systems (DME) are from the ground only. This offers FAA reasonable control of nearby interfering sources through shifting affected assignments. Preliminary test results suggest that as few as 3 contiguous clear DME channels (of 1 MHz each) NAS-wide may be sufficient for acceptable operation of UAT.
- Minimizes interaction of UAT on DME ground transponders since these do not receive in this portion of the band.

Given these factors, an examination was made for existing NAS-wide assignments on the 7 lowest 1 MHz DME reply channels in the Internationally Coordinated portion of the band: the frequencies from 978-984 MHz. Table 1 below shows each DME (ground reply) frequency, its paired VHF Nav frequency (either a LOC or VOR), and the number of current assignments in the FAA's assignment data base for the DME frequency[2].

DME Ground Reply Frequency	978	979	980	981	982	983	984
Paired VHF Nav Frequency per ICAO Annex 10	108.0 (VOR Test)	108.1 (LOC)	108.2 (VOR)	108.3 (LOC)	108.4 (VOR)	108.5 (LOC)	108.6 (VOR)
Number of US Assignments that include DME	0	0	24	9	21	19	24

Table 1. US DME Assignments as of 31 July 2000

[2] In some cases, a LOC or VOR may operate without an associated DME. These cases are not reflected in the assignment counts.

Note that the frequencies 978 and 979 each have no assignments within the US. This is because the close proximity of their paired VHF equipment to high powered FM broadcast channels results in those VHF channels being reserved for test facilities. As a result, the paired DME channels are reserved for DME test equipment[3]. Discussions with frequency managers from other countries indicate that, at least for 978 MHz, this designation as a test frequency is quite widespread.

4) DME Ramp Testers

Information on a DME tester was obtained from one manufacturer--IFR Systems Incorporated. Specifications for a popular model of tester from this manufacturer are attached. In addition, the following information was obtained by email contact with a representative of IFR Systems:

- The maximum power supplied to the tester antenna for DME testing is approximately –15 dBm
- The test set antenna is to be placed 21 inches from the aircraft DME antenna
- The test set is always run in an attended mode. It will shut itself off when the controls are not operated for 10 minutes

5) Preliminary Compatibility Analysis

Testing will be completed at the FAA Technical Center to determine both the impact of UAT on DME interrogators and of DME pulse transmissions on UAT. In the absence of measured data however, preliminary analysis work indicates that compatibility between the two systems may be achievable.

5.1 Impact of DME Ramp Tester Operations on UAT

Due to the 63 MHz offset between DME transmissions and replies, any interference impact to UAT will be due to emissions from the test set (acting as the ground station). Taking as a conservative compatibility criteria that the transmitted DME pulses must fall below the UAT sensitivity level (-95 dBm), the –15 dBm tester transmission must be attenuated by 80 dB. Assuming free space propagation

$$\mathrm{Log}^{-1}(80 - 20\mathrm{Log}(978) + 26.8)/20 = 224 \text{ meters}$$

a separation of 224 meters between the tester probe antenna and the UAT receiver achieves the 80 dB path loss. With proper tester operation this should pose no problems for UAT installations.

5.2 Impact of UAT on DME Ramp Tester Operations

Again, due to the 63 MHz offset between DME transmissions and replies, any UAT effects on the DME system would be limited to interference to the interrogator receiver under test. DME interrogators are generally built to RTCA or Eurocae Minimum Operational Performance Standards (MOPS). Of particular note in the DME MOPS are

[3] Title 47, Code of Federal regulations, Part 87.475

requirements for operation in the presence of CW between pulses, and operation in the presence of high level, on-frequency off-code interference. The former provides a threshold signal level for UAT sources that must be considered, while the latter can be used to determine how much UAT interference above this threshold can be tolerated by the DME interrogator receiver.

5.2.1 Inter-pulse CW.

The MOPS requires that the interrogator perform all functions in the presence of inter-pulse CW at a level 50 dB below the desired signal. For a Tester transmission at –15 dBm, 21 inches from the DME interrogator antenna, the received desired signal is

-15 dBm – [20log(978) + 20log(21/12) – 37] = -15 – 28 = -43 dBm.

Therefore the DME interrogator should be immune to any UAT pulses below –43 – 50 = –93 dBm.

5.2.2 Interference Tolerance

With a desired signal of –44 dBm, the DME interrogator must also be able to operate in the presence of on-tune, off-code DME 3600 pulse pairs per second at a level of –10 dBm. By making a few assumptions, we can calculate the UAT traffic load that can be tolerated by the DME interrogator receiver under test:

a) On tune UAT signals can be considered similar to "off code" DME pulses.
b) The interrogator receiver's tolerance to off code interference is related to the receiver blanking duty factor due to the off code pulse energy.
c) This duty factor sets a baseline that can be used to establish an allowable UAT traffic load that can be tolerated.
d) Pulse width of DME is 5 usec (low on gaussian pulse skirts)
e) The UAT environment in the test set area consists of the following transmissions above the –93 dBm threshold:
    - one ground uplink transmissions per second of 4000 usec in duration
    - *n* aircraft transmissions of 380 usec in duration where n is to be calculated.

Baseline threshold

The duty factor of the off code pulse energy that can be tolerated is

$$DF = 3600\, ppps \times 2 \times 5u\sec$$

= 36 msec

Tolerable UAT channel load

Number of aircraft *n* to reach baseline interference threshold

$$36m\sec = 4000u\sec + n \cdot 380u\sec$$

$$n = 84$$

Therefore the UAT channel load—*as seen at or above –93 dBm at the DME interrogator antenna*—can be high as 1 uplink messages plus the ADS-B transmissions from 84 aircraft each second. It seems unlikely this load would ever be seen, especially considering that the point of observation is the DME antenna on the belly of the aircraft installation being tested. Furthermore, the aircraft with the DME under test may also be in a hangar.

6) Conclusions and Further Work

Based on the specifications and design of the IFR Systems test set, the standards for DME interrogator receivers, and the assumptions stated, it seems promising that UAT and DME test set operations could coexist for a UAT assignment at 978 or 979 MHz. The advantage of an assignment on one of these frequencies is that the number of DME stations requiring a frequency shift would be significantly reduced or perhaps eliminated. These factors could reduce the time and cost to FAA in preparing for an operational UAT system. The following items should also be investigated prior to selecting one of these test frequencies for UAT:

- Obtain information from any other manufacturers of test sets
- Investigate assignment practices in Europe relative to 978, 979 MHz
- Perform tests with DME interrogators, representative test sets and UAT radios to confirm their mutual compatibility

ATC-600A
Portable Transponder/DME Test Set

A portable transponder/DME ramp test set, the rugged ATC-600A is the ideal solution for both ramp or bench use

- Read XPDR code and altitude numerically
- Measure transponder frequency and check for correct DME channel
- Measure transponder receiver sensitivity
- Performs all tests required by the revised Federal Aviation Regulations (91.177 and 43 appendix F)
- Two-year limited warranty

A portable transponder/DME ramp test set, the rugged ATC-600A is the ideal solution for both ramp or bench use. Providing simulation of the ground station or airborne environment, the ATC-600A meets the latest ARINC specifications and FAA regulations concerning transponder receiver sensitivity and SLS tests.

Transponder tests allow quick determination of transmitter power, frequency, percent reply, pilot's code and encoded altitude. For DME testing, the unit includes accurate range and velocity simulation, power and frequency and PRF measurements.

Performance Features

The ATC-600A will perform, with radiated signals, all the tests required by the revised Federal Aviation Regulations (91.177 and 43 appendix F, as amended December 19, 1973).

- Reads out XPDR code and altitude numerically and also displays binary pulse information for code and altitude
- Measures transponder frequency and checks for correct DME channel
- Front panel connector provided to directly check the output of altitude encoders
- Capable of checking XPDR input pulse decoder gate for marginal operation
- Checks position of XPDR second framing pulse relative to F_1
- Measures transponder receiver sensitivity and SLS tests
- Precision DME range and velocity signals, both X and Y channel
- Uses remote tripod mounted antenna - can be accurately spaced from aircraft antenna for power measurements

Specification

Transponder

Interrogations Output

Frequency
1030 MHz, ±0.006%

Level
Variable from -66 dBm to -79 dBm, ±1.5 dBm with 34 dB pad or radiated with properly spaced antenna

Modes
A/C, Altitude or Pilot Code, 2:1 interlace, or mode A, (B mode available on request)

Pulse Spacing
Mode A P_1 to P_3 8 µs, ±0.1 µs
Mode C P_1 to P_3 21 µs, ±0.1 µs
(In A/C Modes)
Mode C P_1 to P_3 17 µs, ±0.1 µs
SLS P_1 to P_2, ±0.1 µs

Variable Spacing
P_2 and P_3 variable with respect to P_1 ±1 µs, ±1 µs from nominal for input decoder gate tests

PRF
235 Hz ±10%

SLS Test
±1.0 dB P_2 inserted at 0 dB or -9 dB relative to P_1

Reply Measurements

Power (UUT)
10 W to 1.5 kW peak, ±20%; direct with 34 dB pad.
±3 dB radiated with properly spaced antenna

Frequency Check
1086 to 1093 MHz, ±0.3 MHz

Altitude Code
Binary and Numerical Readout, -1.0 to 126.7 thousand feet

Pilot Code
Binary and Numerical Readout, 0000 to 7777

Percent Reply
0-100%, either A/C or A(B) modes

F_2 Pulse Position
Measurement of rising and falling edge ±0.5 µs from nominal, ±0.05 µs

Status Lamps
Ident Pulses, Invalid Altitude Code and No Altitude Code

Encoder Test
Direct connection accepts altitude encoder

DME

Interrogations Measurements

PRF
Track PRF 0 to 30 Hz, ±5% full scale
Search PRF 0 to 300 Hz, ±5% full scale

Power (UUT)
10 W to 1.5 kW peak, ±20%; direct with 34 dB pad. ±3 dB radiated with properly spaced antenna

Frequency Check
1038 to 1045 MHz, ±0.3 MHz

Reply Output

Frequency
17X-channel: 978 MHz
±0.006% (108.00 MHz paired)

17Y-channel: 1104 MHz
±0.006% (108.05 MHz paired)

18X-channel: 979 MHz
±0.006% (108.10 MHz paired)

Level
Approximately -45 direct with 34 dB pad or radiated with properly spaced antenna

Reply Pulses
3.5 µs wide, ±0.5 µs

Pulse Spacing
X channel: 12 µs wide, ±0.2 µs
Y channel: 30 µs wide, ±0.2 µs

Range
0 to 399 NM in 1 NM steps. Accuracy ±0.07 NM ±0.02%

Velocity
Crystal-controlled digital velocity with rates of 50, 75, 100, 150, 200, 300, 400, 600, 800, 1200, 1600 and 2400 knots, ±0.02% of setting. Inbound or outbound starting from any selected range.
Range steps in velocity mode are 0.025 NM (system) 0.1 NM displayed

Percent Reply
100% or 50%

Squitter
2700 PRF, ±50 Hz

Ident Tone
1350 Hz (±8 Hz) with equalizing pulses

General

ENVIRONMENTAL

Temperature
-20 to 55°C

Relative Humidity
≤80% for temperature up to 31°C decreasing linearly to 50% at 40°C (Non-condensing)

Altitude
≤4000 meters (13,124 feet)

GENERAL

Calibration Interval
1 year

Power
102 to 120 VAC, 220 to 240 VAC, 50 Hz to 400 Hz, ≤±10% of the nominal voltage, 24 W maximum.
Internal 2.0 AH NICAD battery operation for approximately

Dimensions
Housed in a portable case 290 mm (11.4 in) wide, 130 mm (5.1 in) high, 410 mm (16.1 in) deep

Weight
8.1 kg (18 lb) approximately

Electromagnetic Compatibility
Complies with the limits in the following standards:
EN 55011 Class B
EN 50082-1

Safety
Complies with EN 61010-1 for class 1 portable equipment and is for use in a pollution degree 2 environment. The instrument is designed to operate from an installation category 1 or 2 supply.

Versions and Accessories

When ordering please quote full ordering number information

Ordering Numbers	*Versions*
600-110	ATC-600A Transponder/DME Ramp Test Equipment, 110 VAC operation
600-110-C	ATC-600A Transponder/DME Ramp Test Equipment, 110 VAC operation, with Certificate of Calibration
600-220	ATC-600A Transponder/DME Ramp Test Equipment, 220 VAC operation
600-220-C	ATC-600A Transponder/DME Ramp Test Equipment, 220 VAC operation, with Certificate of Calibration

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