DOCUMENT
GSM-G-ATP.035

DOCUMENT TITLE
RADIO NAVIGATION

CHAPTER 12 – DISTANCE MEASURING EQUIPMENT (DME) AND RNAV

Version 1.0
January 2013

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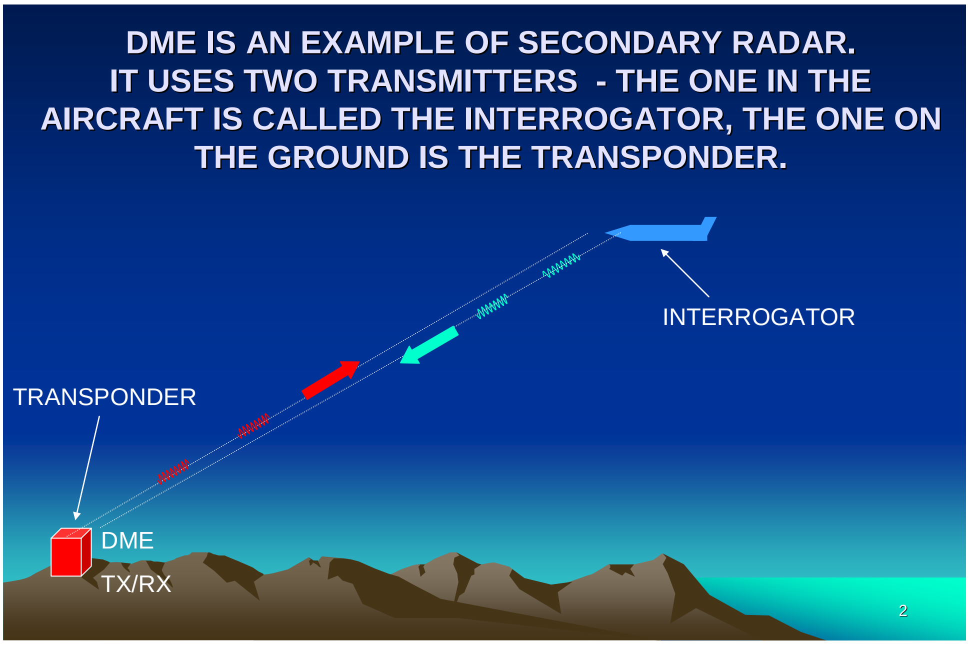
DISTANCE MEASURING EQUIPMENT (DME)

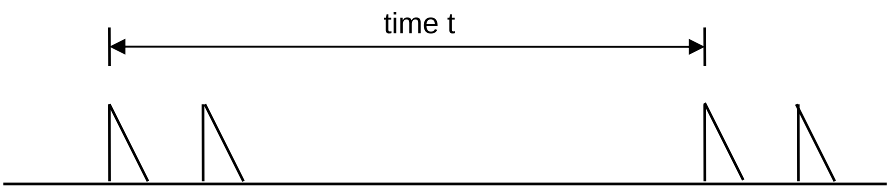
The purpose of DME is to measure aircraft range from a known ground position. Range is measured from knowledge of the time taken for radar pulses to travel between the aircraft and the DME facility at the ground position. DME is used primarily in conjunction with VOR for position fixing but it is also used for en route separation, approach to airports, avoiding protected airspace, holding and computation of ground speed.

PRINCIPLE OF DME

DME is an example of SECONDARY RADAR. Both the aircraft and the DME ground facility transmit and receive radar pulses, using two frequencies that are always 63 MHz apart.



The aircraft's DME equipment which is the INTERROGATOR transmits a series of pulses in pairs. The time interval between the two pulses in pairs is constant but the time interval between pairs of pulses (t) is varied randomly. This random rate of pulse pairs is called a RANDOM or JITTERED PRF.



The DME ground facility known as the TRANSPONDER receives the pulse pairs from the aircraft and replies after a short delay (normally 50 μsecs) with pulse pairs on a frequency 63 MHz removed from the INTERROGATOR (aircraft) frequency. The use of pairs of pulses allows DME to reject single pulses from other sources that would otherwise cause interference.

The aircraft receiver detects all the responses of the DME transponder, those meant for other aircraft as well as those meant for itself. The receiver looks for reply pairs that occur at approximately the same time interval after each transmitted pulse pair. The random or jittered PRF ensures that no two aircraft will transmit pulse pairs in the same pattern so the replies intended for other aircraft do not match the aircraft's pattern of transmissions and are therefore ignored. A gate in the receiver" locks on" to the time interval corresponding to the lag between the time of transmission and the time of reception of the transponder replies. Range is measured from this time interval.

Until lock-on is achieved, the DME receiver searches from zero nm out to maximum range (300 nm) using a high PRF. This search is indicated by the numbers scanning over, possibly with a bar shown across the digits. Once lock-on has occurred, the PRF is lowered so reducing the load on the ground station and thus allowing more aircraft to be serviced. A typical DME interrogator operates initially at 150 pulse pairs per second (pps) in SEARCH mode and 22.5 pps in track (LOCK-ON) mode. Some DME interrogators reduce their search rate to 60 pps after the equivalent of 15000 pulse pairs. This is after 100 seconds for a DME with an initial search rate of 150 pps.

MEMORY MODE

If the transponder reply, detected at the aircraft, drops below a pre-set value, the airborne equipment will go to memory mode for about 10 seconds. During this period range will continue to be shown increasing or decreasing at the last known rate of change.

BEACON SATURATION

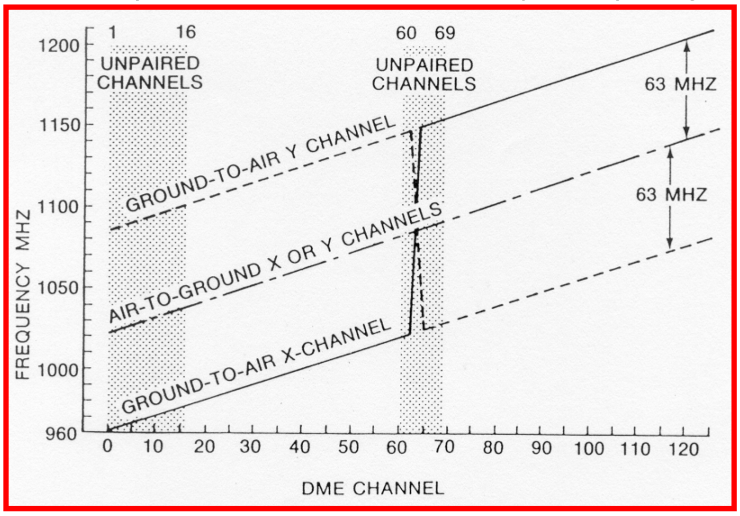
The DME ground equipment is normally limited to 2700 pulse pairs per second and can therefore only service about 100 aircraft simultaneously. If more than 100 aircraft interrogate the ground station, it will limit its receiver sensitivity (by reducing gain) and reply to the strongest 100 interrogations.

A new generation of high power, high capacity transponders is under development which are not subject to the same limitations.

DME FREQUENCIES

DME transmits in the UHF band using frequencies between 962 and 1213 MHz. The airborne DME interrogator transmits and receives on one of 252 channels. For each channel, the transmit and receive frequencies are separated by 63 MHz.

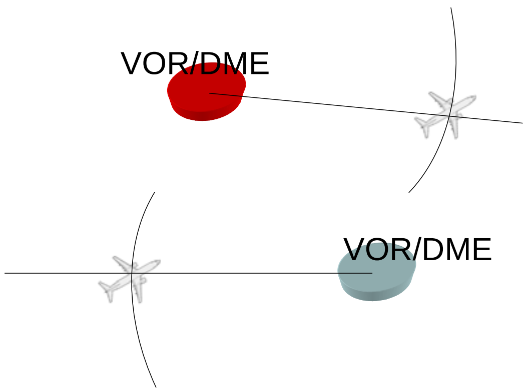
Of the 252 channels, there are 126 X and 126 Y channels differentiated between X and Y by the frequencies that are used and by the spacing between pulses in each pulse pair. The ground-to-air and air-to-ground frequencies allocated to the X and Y channels are shown in the following diagram.



The pulse spacing for X channels is 12 µsec and for Y channels, it is 36 µsec.

FREQUENCY PAIRING

DME provides a circular, range position line and it is only when this is combined with another position line that the fix position of the aircraft is known. DME is commonly used in conjunction with VOR, ILS and MLS and to facilitate the use of navigation aids together, DME channels are frequency paired. Frequency pairing allows the pilot to select one frequency as a means of obtaining the use of two nav. aids. For example, by setting the frequency to obtain a VOR, the DME channel selector will change automatically to the frequencies appropriate to a DME at the same site as the VOR. This permits range and bearing to be obtained from the same point.



Ideally VOR and DME facilities are co-located (both aerials at the same position) but sometimes this is not possible. The aids are said to be "associated" and will be frequency paired provided that they are co-located or within the following limits for aerial separation:

a) 100 feet when intended for use within a terminal area
b) 2000 feet when intended for en-route use.

VOR and DME transmissions contain call-signs for the purposes of identification with co-located and associated facilities have identical call-signs. Facilities, which serve the same location but are too far apart to be associated, will be frequency paired. Their call-signs will have the same first two letters. The last letter of one identifier will be Z.
VOR may also be paired with TACAN which is a UHF aid providing range and bearing to military aircraft. The range element of TACAN is identical to DME so civil aircraft can obtain range (only) from TACAN. The TACAN may be frequency paired with a VOR at the same site and in this case, the VOR frequency can be selected to obtain the use of both aids. If there is no VOR at the location of the TACAN, a "ghost" VOR frequency will be shown which will allow access.

Examples of Paired Aids

<u>Adelaide</u>

VOR	116.4MHz	Ident. AD	co-located
DME	111 X	Ident AD	
	(paired with 116.4)		

<u>Sydney</u>

VOR	115.4MHz	Ident SY	co-located
DME	101 X	Ident SY	
	(paired with 115.4)		
			serving RWY 16
ILS	110.9 MHz	Ident. ISS	
DME	46 X	Ident. ISS	L
	(paired with 110.9)		

RANGE OF DME

As DME operates in the UHF band, reception of the pulse transmissions is only possible within "line of sight". Maximum range is given by the formula:-

Range (nm) = $1.25\sqrt{h_1} + 1.25\sqrt{h_2}$
where h_1 is the transponder elevation
and h_2 is the aircraft altitude

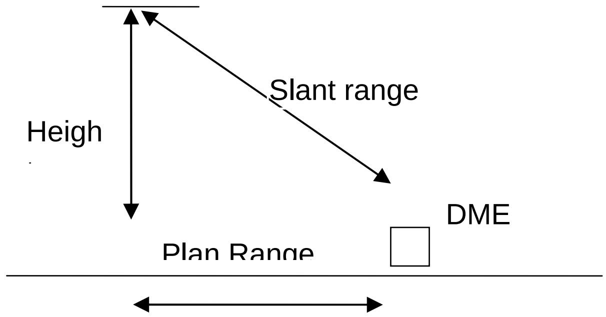
Some airborne equipment may only display range to 200nm whereas more modern equipment extends range to 300 nm.

ACCURACY OF DME

DME is generally more accurate than either VOR or ADF. Designed total system error should not exceed 1/2nm or ± 3% of the distance measured, up to a slant range of 200nm.

ERRORS OF DME

The only significant error occurs when slant range is confused with plan range. This error is maximum over the DME when the reading will correspond to aircraft height.



SOME QUESTIONS ABOUT DME

Why is the airborne receiver not confused by echoes of the airborne interrogator transmissions?

Reflections of transmissions from weather or from the ground are not a problem as the receiver is tuned to a frequency 63 MHz removed from that of the transmitter.

Why does DME transmit pairs of pulses?

The airborne and ground receivers only recognise pulses in pairs and can therefore reject pulses from other sources that would cause interference.

Why is the DME transponder not triggered by reflections of its own transmissions?

The ground receiver is tuned to a frequency 63 MHz removed from that of the ground transmitter.

Some DMEs compute and display Groundspeed and Time-to-Station. Can this be considered accurate?

Ground speed and time-to-station are calculated from the changing slant range. The data displayed will be inaccurate when close to the DME station, because of the difference between slant and plan range. The data should be ignored if the aircraft is not tracking directly to or away from the station.

VOR/DME AREA NAVIGATION (RNAV)

RNAV is described in ICAO Annex II (Air Traffic Services) as a method of navigation which permits aircraft operation on any desired flight path within range of station-referenced navigation aids, or within the limits of the capability of self-contained aids, or a combination of these. When equipped with RNAV, aircraft have the ability to maintain track and time on any flight path without over-flying point source aids. By maintaining position (along track and across track) and time, RNAV can be said to operate in three dimensions.

Because RNAV routes are not limited to tracks between navigation aids, more direct tracks are available so reducing distances, flight times and fuel requirements. RNAV routes also have the potential to reduce congestion by opening up new routes, including tracks parallel to existing routes. The implementation of RNAV has been taking place progressively as not all existing aircraft have the equipment to meet the required navigation performance standards and furthermore direct, random routes can only be approved by ATC as controller workload permits. The carriage of B-RNAV (basic RNAV) equipment by aircraft flying in ECAC (European) airspace became mandatory from January 1998.

RNAV is used in conjunction with a Flight Management Computer (FMC) so allowing the aircraft to be flown along routes between pre-stored waypoints. A typical system is operated with the VHF Nav Radios selected to AUTO so that the FMC automatically tunes stations having DME capability (DME or VOR/DME). The FMC has stored knowledge of the frequencies and exact location of the nav. aids and these are selected to obtain the best available signals for updating the RNAV/FMC position. With AUTO tuning, each radio is normally tuned to a separate DME but a single radio can be made to cycle between two DMEs. The lowest priority is the use of both VOR and DME from a single station. Alternatives to VOR and DME include GPS. Note that ADF is never used by RNAV.

In a typical system, with the radio selected to MAN (manual), the FMC will continue to update its position using manually tuned DMEs or VOR/DME. The VOR/DMEs used by RNAV are normal navigation aids and are not required to be adapted to RNAV.

Using AUTO or MAN tuning, position fixing is more accurate when using DME information only. The best accuracy is achieved with AUTO DME-DME because the FMC selects stations based on best geometry. VOR is less accurate than DME and some systems do not use VOR beyond a range of 25nm.

The capability to carry out automatic dual DME position fixing and updating is described as P-RNAV (precision RNAV) and it requires a track-keeping accuracy of 0.5nm standard deviation or better. B-RNAV (basic RNAV) requires a track-keeping accuracy of 5nm and equates to the navigation performance currently achieved by aircraft without RNAV capability operating on existing routes defined by VOR or VOR/DME.

WORKSHEET – DISTANCE MEASURING EQUIPMENT

1. In total DME is available on _________ channels. The spacing between the pulses on the Y channels is __________ microseconds

(a)	126	12
(b)	126	36
(c)	252	24
(d)	252	36

2. The use by the interrogator of a random PRF:

   (i) varies the time interval between the pulses in each pair.
   (ii) gives each aircraft a unique pattern to its transmissions.
   (iii) prevents the aircraft receiver from locking on to interrogations from other aircraft.

   (a) (i) and (ii) only are true
   (b) (ii) and (iii) only are true
   (c) (i) and (iii) only are true
   (d) (ii) only is true.

3. When correctly tuned to a VOR/DME, the ident. is heard every 30 seconds. It is likely that:

   (a) both VOR and DME are serviceable
   (b) only the VOR is serviceable
   (c) only the DME is serviceable
   (d) neither the VOR nor the DME is serviceable.

4. An OFF warning flag will appear on the DME indicator if:-

   (i) the received signals are below the minimum strength
   (ii) no signal is being received
   (iii) the aircraft is out of range

   (a) All the above statements are true
   (b) Only (ii) and (iii) are true
   (c) Only (i) and (ii) are true
   (d) Only (i) and (iii) are true

5. The airborne receiver is not affected by primary echoes of the interrogations because:

   (a) there is a random variation in the time interval between pulse pairs
   (b) the use of pulse pairs practically eliminates interference
   (c) primary echoes will return to the airborne receiver on a different frequency to that of the interrogator.
   (d) ground and airborne transmitter frequencies differ by 63 MHz.

6. If the transponder reply detected by the aircraft is below a pre-set value:

   (a) there will be an immediate indication of failure warning and the DME will revert to the search mode.
   (b) the OFF flag will immediately appear and the equipment will enter the lock-on mode.
   (c) the equipment will go on to memory mode for about 10 seconds and then revert to the search mode.
   (d) the equipment will immediately search from the last measured range to 200 nm and if the range is not established, then enter the search mode.

7. Total system error of DME should not be greater than:

   (a) 6 nm at 200 nm
   (b) $^1/_2$ nm at 20 nm
   (c) 5 nm at 50 nm
   (d) $7^1/_2$ nm at 150 nm

8. The DME beacon may become saturated if more than __________ aircraft are interrogating. If this occurs the DME transponder will __________.

   (a) 27 / revert to memory
   (b) 50 / reply to the strongest interrogations
   (c) 70 / shut down immediately
   (d) 100 / reduce its receiver gain

9. A DME with a fixed delay of 30 μsec provides an airborne interrogator with reply pulses 600 μsec after the interrogator's transmission . What is the range of the aircraft?

   (a) 43 nm
   (b) 46 nm
   (c) 86 nm
   (d) 92 nm

10. Where VOR and DME stations are at entirely different locations:-

    (a) the last letter of the DME ident. will be Z
    (b) they will not be frequency paired but may have the same ident.
    (c) they may or may not be frequency paired
    (d) they are certain to have different idents and will not be frequency paired.

11. When DME is operating in the memory mode:

    (a) the PRF is increased to 150 pulse pairs per second.
    (b) the PRF is decreased to 30 pulse pairs per second.
    (c) the range will remain constant according to the last measured value.
    (d) range will change according to the last known rate of change.

12. What are the planes of polarisation associated with DME, VOR and ILS (localiser?

	DME	VOR	ILS
(a)	vertical	horizontal	horizontal
(b)	horizontal	vertical	vertical
(c)	horizontal	vertical	horizontal
(d)	vertical	vertical	horizontal

13. An aircraft flying at FL 240 is at a plan range of 8nm from a DME. Allowing for total system error, what is the range of readings that may be obtained?

    (a) 8 nm ± 3%
    (b) 7.5 – 8.5 nm
    (c) 9 nm ± 3%
    (d) 8.5 - 9.5 nm

14. DME equipment may give indications of groundspeed. In which of the following situations would the indicated groundspeed be most accurate?

    (a) When abeam the DME at range 10nm.
    (b) When tracking towards the DME at range 5nm.
    (c) When tracking away from the DME at range 100nm.
    (d) When abeam the DME at range 30nm.