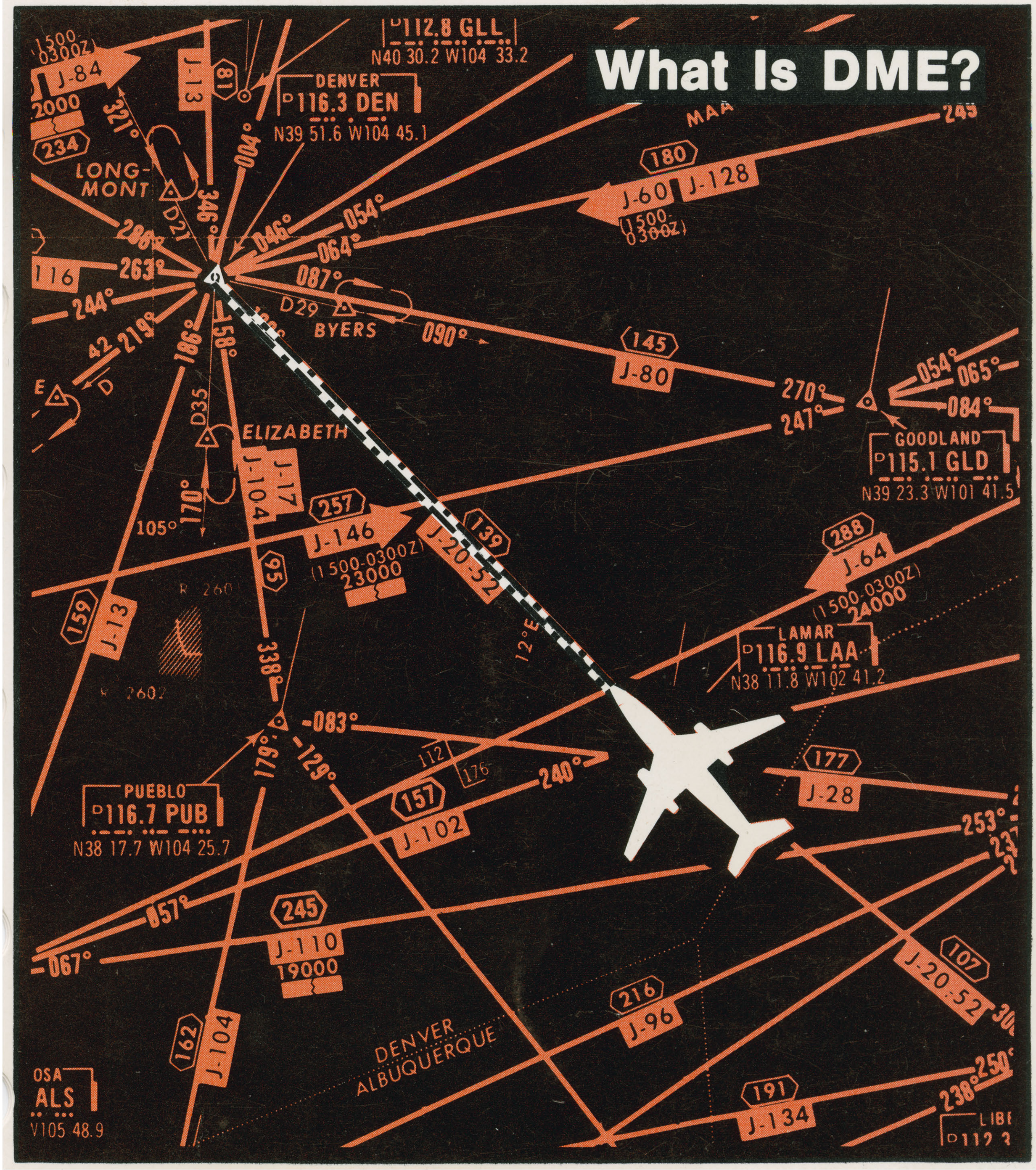
Rockwell International

instruction guide

Collins Air Transport Division

What Is DME?



contents

list of illustrations

glossary

DME: Acronym for distance measuring equipment, a system that provides distance information from a ground station to an aircraft.

ILS: Acronym for instrument landing system, a system that provides lateral, vertical, and along-course guidance on approaches to runways equipped with this system.

Lock-on: The condition that exists when the DME receives reply pulses to at least 50 percent of the interrogations. Valid distance information is then available.

Nautical mile (nmi): Equivalent to 6076.1 feet, or approximately 1.15 statute miles.

Paired channels: DME channels are paired with a VORTAC or ILS frequency and are automatically selected when the VORTAC or ILS frequency is selected. Most navigation controls have this feature.

Radar mile: The time interval (approximately 12.359 microseconds) required for radio waves to travel one nautical mile and return (total of 2 nmi).

Search: In this mode, the DME scans from 0 mile to the outer range for a reply pulse pair after transmitting an interrogation pulse pair.

Slant range: The line-of-sight distance from the aircraft to a DME ground station.

Squitter: The random pulse pairs generated by the ground station as a filler signal.

TACAN: Acronym for the tactical air navigation system that provides azimuth and distance information to an aircraft from a fixed ground station (as opposed to DME providing only distance information).

Track: In this mode the DME transmits a reduced pulse pair rate after acquiring lock-on.

Transponder: An avionics equipment that returns an identifying coded signal when interrogated by a ground radar system and used to differentiate between aircraft by ground control approach personnel.

TTS: Acronym for time-to-station, an indication that displays the amount of time for the aircraft to reach a selected ground station while traveling at a constant speed.

Unpaired channel: A DME channel without a corresponding VORTAC or ILS frequency.

VOR: Acronym for vhf omnidirectional range, a system that provides bearing information from a ground station to an aircraft.

VOR/DME: A system in which a VOR and a DME station are collocated.

VORTAC: A system in which a VOR and a TACAN station are collocated.

introduction

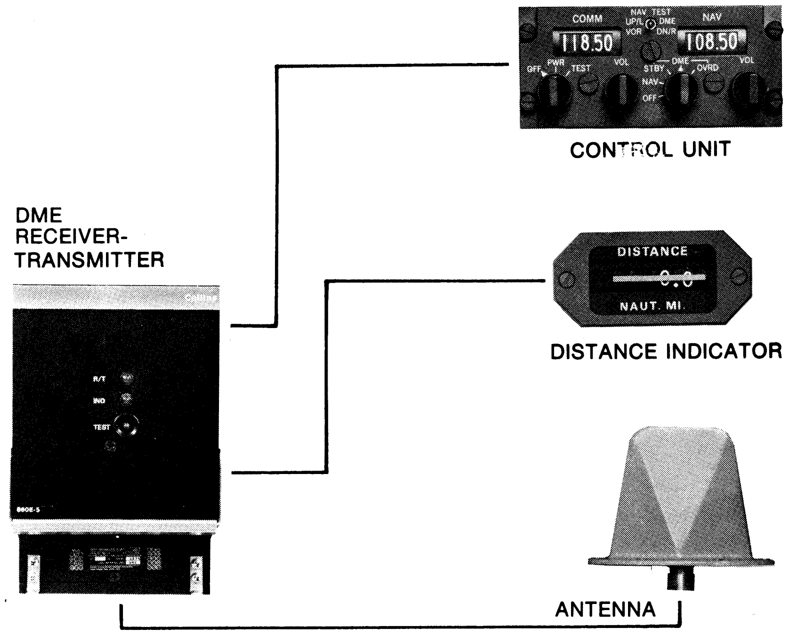
This manual presents the theory and principles of DME operation and answers common questions about DME operation.

What is DME?

DME is a system combining ground-based and airborne equipment to measure the distance of the aircraft from a ground facility.

Why use DME?

DME is used primarily for position fixing, enroute separation, approach to an airport, avoiding protected airspace, holding at a given position, or figuring ground speeds.



Airborne DME
Figure 1

the DME system

The airborne DME consists of a receiver-transmitter (rt), a control unit, a distance indicator, and an antenna. Refer to figure 1. The ground-based DME consists of a receiver-transmitter and an antenna but operates only on a single frequency.

airborne equipment

receiver-transmitter

The transmitter section of the rt unit contains all the necessary circuits to generate, amplify, and transmit the interrogating pulse pairs. The receiver section contains the circuits required to receive, amplify, and decode the received reply pulses.

Computation circuits then determine the validity of the reply pulses and calculate the distance.

Also incorporated into the DME rt are self-monitoring circuits that will cause a warning indication to be displayed on the indicator to the pilot if the distance information should become unreliable. After the airborne DME has acquired lock-on, it provides both aural station identification to the cockpit speaker system and distance information to the indicator.

controls

The control unit provides the necessary control and switching circuits for the airborne DME rt. The control unit may also provide the frequency selection for a vhf communications or navigation receiver. Control units that provide frequency selection for more than the DME automatically select the DME operating frequency when the operating frequency for the navigation receiver is selected.

indicators

The distance indicator displays the aircraft distance in nautical miles from the ground station. The indicator will also display, in the form of a flag or dashes (on digital indicators), a warning that the system is either malfunctioning or not locked on to a reply signal.

On some types of indicators, the information displayed also includes a computed ground speed and the time (TTS) to reach the ground station location. The computed ground speed and TTS are accurate only if the aircraft is flying a radial to or from the ground station.

The distance indicator may also be a part of another indicator such as a horizontal situation indicator (HSI).

antenna

The antenna is a single L-band transmit and receive antenna with an omnidirectional radiation pattern.

ground facilities

There are several different types of ground stations. These are VOR/DME, ILS/DME, VORTAC, and TACAN. VOR/DME is a DME station located at the same site as a VOR omnidirectional station. ILS/DME is an ILS station and a DME station at the same site. VORTAC is a VOR omnidirectional station and a TACAN station located at the same site. TACAN is a military navigation system providing azimuth and distance information to an aircraft.

Ground stations are capable of handling approximately 100 aircraft interrogations at one time. If more than 100 aircraft interrogate the ground station, the ground station limits its sensitivity and replies to the strongest 100 interrogations. It is possible that the airborne DME would not receive replies to all of its interrogations, so most airborne DME's operate down to a 50-percent reply efficiency, where the DME is receiving replies to only half of its interrogations.

The ground station continuously transmits a 2700-pp/s squitter signal (filler signal) with a 1350-pp/s identification code signal at 30-second intervals. When interrogated by the airborne DME pulse pair, the ground station transmits a reply pulse pair that replaces a squitter pulse pair 50 microseconds after interrogation.

typical operation

Typical operation of a DME would proceed in the following sequence:

a. The pilot selects an ILS/VOR frequency. The ILS/VOR frequency automatically selects a DME channel that is paired with that frequency.

b. The receiver-transmitter of the airborne DME transmits interrogating pulse pairs.

c. The ground facility receives these pulse pairs, delays 50 microseconds, and then transmits reply pulse pairs back to the airborne DME rt.

d. The airborne receiver-transmitter receives the reply pulse pairs and verifies that the pulse pairs are valid.

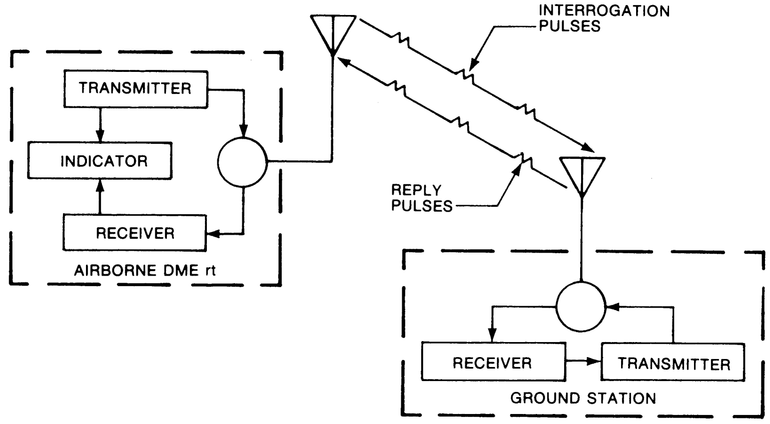
e. The airborne receiver-transmitter calculates the distance.

f. The distance is then sent to an indicator where it is displayed for pilot use.

g. The airborne DME rt continues to interrogate the ground station until another channel is selected or until the aircraft flies out of range.

principles of DME

how DME measures distance



DME Operation
Figure 2

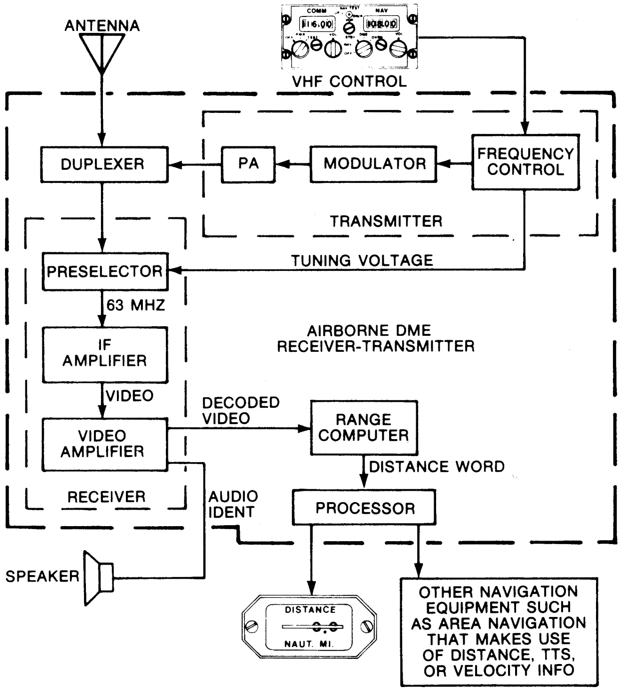
Refer to figure 2. The transmitter circuitry of the airborne DME rt initiates the distance measuring action by transmitting interrogation pulses to the VORTAC or TACAN ground station. The ground station receives these interrogations and, after a fixed delay (50 μs), transmits reply pulses. The 50-μs delay is inserted to standardize the response time to an interrogation and to allow the indicator to read 0 nmi at the touchdown point, at DME-equipped airfields.

The airborne DME rt computes the slant range to the ground station from the amount of time elapsed between transmitting and receiving the pulse pairs.

Since the speed of radio waves is a constant and known factor, the amount of time the signal travels is proportional to the distance. It takes approximately six-millionths of a second for radio waves to travel one nautical mile. The airborne portion of the DME measures the amount of elapsed time and converts this to the distance (slant range) between the aircraft and the station. The difference between slant range and ground distance is negligible if the aircraft is one mile or more from the station for each 1000 feet of altitude.

how DME works

Measurement of the slant range to a ground station begins with the selection of a vhf NAV frequency on the frequency control. The vhf frequency is represented by a 2-out-of-5 coded signal, a bridge-tuned signal, or a serial data word that is applied to the frequency control circuit of the airborne DME equipment. Refer to figure 3. The frequency/channel selected can be any one of 252 channels.



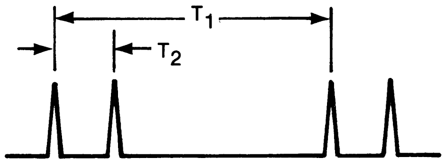
Airborne DME, Block Diagram
Figure 3

Once the frequency is selected, an rf signal is generated to produce a transmitter drive signal. A tuning voltage is also generated to tune the preselector to the proper receive frequency.

The airborne DME interrogation begins with a pair of rf pulses being transmitted. During the remainder of the period, the receiver portion of the DME listens for any ground station replies. The length of the interrogation period is dependent upon the airborne DME mode of operation (search or track). Because of the greater number of pulse pairs per second in search (90 pp/s for 860E-4/5), the interrogation period is shorter than when the airborne DME rt is in the track mode (22.5 pp/s for 860E-4/5).

Whenever a pulse pair is transmitted, another pulse pair (or single pulse, which covers both pulses) is sent, simultaneously, to the internal receiver, the transponder, or to another airborne DME rt if a dual system is used. This other pulse pair is a suppression pulse pair. These pulses protect the receiver portion of the transponder or airborne DME rt from damage and from reception of the pulse transmission.

After the interrogation pulse pair has been transmitted, the receiver portion of the airborne DME rt becomes active. The airborne DME rt looks for reply pulses that occur approximately the same time after every transmitted pulse pair. If it finds these pulses, it assumes that these are replies to its interrogations. In order for the transmitted pulse pairs of another aircraft not to be mistaken for reply pulses, the transmitted pulse rate of the airborne DME rt is varied randomly (jittered). Refer to figure 4. In this way, no two airborne DME's are transmitting at the same rate. The airborne DME rt synchronizes itself to its own transmitted pulse pairs so that the pulse pairs transmitted by another airborne DME appear random to it and are ignored.



T_1 = DISTANCE BETWEEN PULSE PAIRS VARIED RANDOMLY

T_2 = PULSE SPACE

Generated Pulse Pairs
Figure 4

When the airborne DME determines that the reply pulses are occurring at regular intervals, it "locks on" and decreases the number of interrogations. This decreased interrogation state of the airborne DME is the track mode previously mentioned.

By decreasing the number of interrogations, the airborne DME relieves the load of the ground station to allow service of more aircraft.

The signal from the ground station is routed to the preselector where it is mixed with an oscillator frequency to produce a 63-MHz if signal. The if signal is mixed, amplified, and detected to produce the video signal. The video signal is then decoded to determine if the pulses have sufficient amplitude and spacing for the channel selected. If so, the decoded video is applied to the range computer.

If the video signal contains the 1350-pp/s identification signal (IDENT), it is converted to a sine wave, amplified, and applied to the aircraft audio system. The IDENT is used by the pilot to confirm, by audio identification, that the airborne DME is tracking the station selected by the pilot.

In the range computer, the decoded video signal is applied to circuits that measure the elapsed time (from interrogation to reception of the ground station reply pulses) and solve the equation:

$$\text{Distance} = \frac{\text{Time} - 50\ \mu s}{12.359\ \mu s/\text{nmi}}$$

where 12.359 μs/nmi is the time required for radio waves to travel one nautical mile and return, and where 50 μs is the delay time before the ground station sends reply pulses.

The computed distance, in different formats, is then applied to external indicators for display.

Another portion of the airborne DME circuitry is devoted to a memory type function. This memory function prevents the distance indication from changing whenever there is a short-time loss of reply signal. If there were no memory, the DME would leave the locked-on condition immediately and enter a search mode, and the indicator would stop displaying the distance.

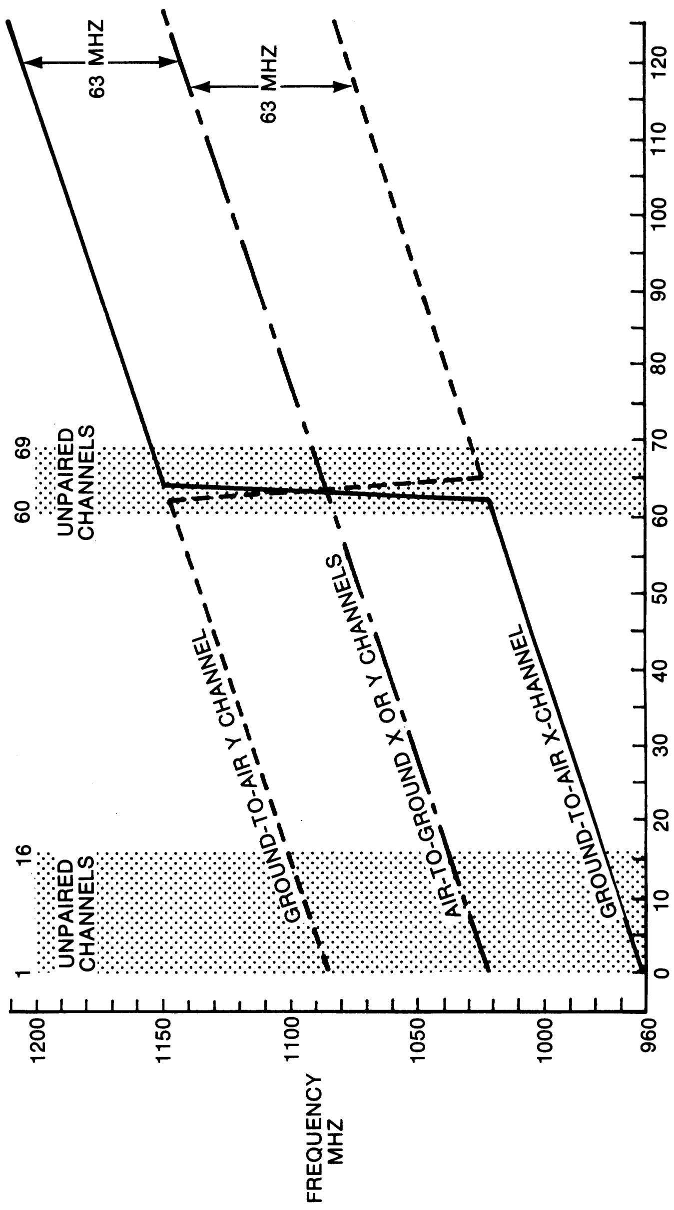
Instead, the airborne DME uses this memory mode to display the distance as if the station were still being tracked. The memory mode of most airborne DME's is approximately 11 seconds. If the airborne DME does not reacquire the signal during this period, the airborne DME enters the search mode.

Thus, the DME system will always display the most up-to-date and valid information to the pilot. If there is a failure to the DME system, or valid reply signals are not present, this condition will be detected by the DME system's self-monitoring circuits and will be annunciated.

DME frequencies and channels

The airborne DME transmits and receives on one of 252 channels. Of the 252 channels, there are 126 X- and 126 Y-channels for DME operation. The transmit and receive frequencies of any one channel are separated by 63 MHz. In the first 63 X-channels, the ground-to-air frequency is 63 MHz below the air-to-ground frequency and, in channels 64X through 126X, the ground-to-air frequency is 63 MHz above the air-to-ground frequency. In the first 63 Y-channels, the ground-to-air frequency is 63 MHz above the air-to-ground frequency and, in channels 64Y to 126Y, the ground-to-air frequency is 63 MHz below the air-to-ground frequency. Refer to figure 5. The transmit and receive frequencies of one channel differ by 1 MHz from the transmit and receive frequencies of the preceding or following channel. The air-to-ground transmitted frequencies are from 1025 to 1150 MHz, while the ground-to-air transmitted frequencies are 962 to 1213 MHz.

The pulse pairs transmitted from the airborne DME rt have a characteristic spacing depending on whether it is an X-channel or Y-channel frequency. The pulse spacing on channels with X spacing (X-channels) is 12 microseconds (μs), while the pulse spacing on channels with Y spacing (Y-channels) is 36 μs. Another characteristic difference between X- and Y-channels is that the vhf frequency of X-channels is tuned in 100-kHz increments at the 100-kHz vhf channels (for example, 108.00, 108.10, 108.20), and Y-channels are tuned in 100-kHz increments at the 50-kHz vhf channels (for example, 108.05 MHz, 108.15 MHz, 108.25 MHz). The X-channel reply pulse pairs (from the ground station) are spaced at 12 μs and the Y-channel reply pulse pairs are spaced at 30 μs.



DME Channel Frequencies
Figure 5

Table 1 shows the paired and unpaired vhf NAV channels.

DME CHANNELS	ASSIGNMENT	VHF NAV (MHz)
1 to 16	Unpaired channels	134.4 to 135.9
17 to 56 Even-numbered DME channels paired with ILS. Odd-numbered DME channels paired with VOR.	ILS/VOR	108.0 to 112.0
60 to 69	Unpaired channels	133.3 to 134.2
57, 58, 59, 70 to 126	VOR	112.0 to 117.9

Table 1. Channel Assignments.

troubleshooting

Troubleshooting a DME, with the number of functions it performs, is not as difficult as it sounds. By keeping a few things in mind when a defective unit is discovered, the trouble can be isolated to a section of the total unit.

At the time of the trouble, the more details observed about the DME operation, the more clues there are available to isolate the trouble. Details such as distance from the station, operating frequency, altitude, other equipment operating, and indicated ground speed are all clues that will help pinpoint the trouble.

The indicated ground speed is a good indicator of troubles because the speed is calculated from the changes in distance information. Small fluctuations in distance information may cause the ground speed display to behave erratically.

A problem with the aircraft input power may cause small unnoticed variations in the distance displayed but could cause rapid erratic movements in the indicated ground speed.

Noise pickup from other equipment or connecting cables would also result in an erratic ground speed indication.

Another clue is the reception of the DME identification tone. If the identification is received, it indicates that the receiver and antenna portions of the DME are working properly.

A DME which performs poorly in terms of range and distance information might be an indication of a poor antenna installation or location.

While these troubleshooting hints do not cover all possible problems, they do indicate the information and troubleshooting clues a person should look for. More specific troubleshooting aids are discussed in the overhaul manuals of each particular piece of equipment.

questions and answers

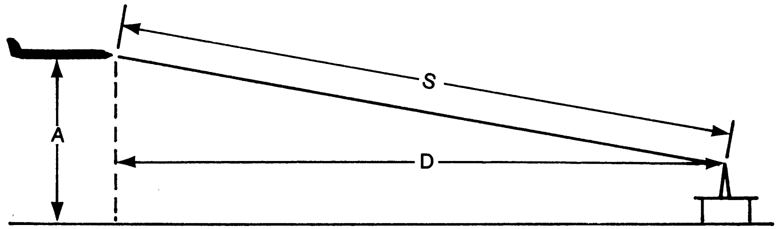
This section is intended to answer commonly asked questions about DME operation and DME principles.

Q: Can you obtain ground distance by knowing the slant range?

A: Yes, the ground distance may be computed by knowing the slant range and altitude of the aircraft.

Q: How is ground distance calculated?

A: The ground distance, D, equals $\sqrt{S^2 - A^2}$ where S is the slant range in nautical miles and A is the altitude in nautical miles (figure 6).



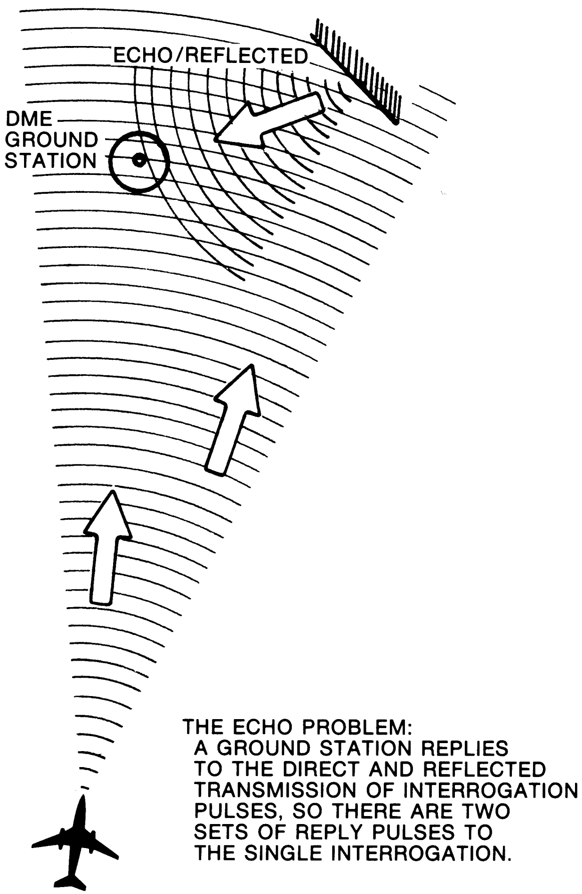
Ground Distance Calculations
Figure 6

Q: How fast is the search speed?

A: The DME searches from zero mile out to its longest range, so the search time depends on the distance the aircraft is from the station. At 390 miles, it may take approximately one second before the DME locks on (for Collins 860E-4/5).

Q: Is it possible for the DME to lock on to an echo of its interrogation pulses?

A: A properly working DME will not lock on to echo pulses. The DME always searches from zero mile out, so it will always lock on at the shortest distance. Refer to figure 7. The reflection of the radio waves will travel a much longer distance than the line-of-sight interrogation pulses. If the DME does lock on to an echo pulse, it is an indication of a problem in the ranging computer. The 860E-4/5 contains an echo monitor circuit which would correct an echo lock-on, should one occur due to a reply efficiency problem.



Reception of Echo Pulses
Figure 7

Q: Is indicated ground speed the true ground speed?

A: The indicated ground speed is calculated from the change in the distance measured. Since the distance measured is the slant range, there will be some error the closer the aircraft is to the station. When the aircraft is directly over the station, the slant range is not changing, so the indicated ground speed would be zero.

The indicated ground speed will also be in error if the aircraft is not heading directly to or away from the ground station. For example, if the aircraft is circling a ground station, there would be no change in distance and therefore a zero indicated ground speed.

Q: Are there minimum specifications for DME operation?

A: The desired characteristics and specifications for DME equipment are presented in ARINC Characteristic No 568-5 and No 521 D.

Q: What is the operating output power of a DME?

A: The average airborne DME operates with a peak power output of 316 to 2000 watts (25 to 33 dB W).

Q: Does the aircraft speed affect the operation of the DME?

A: No, the airborne DME is capable of tracking accurately up to an aircraft velocity of 2000 knots.

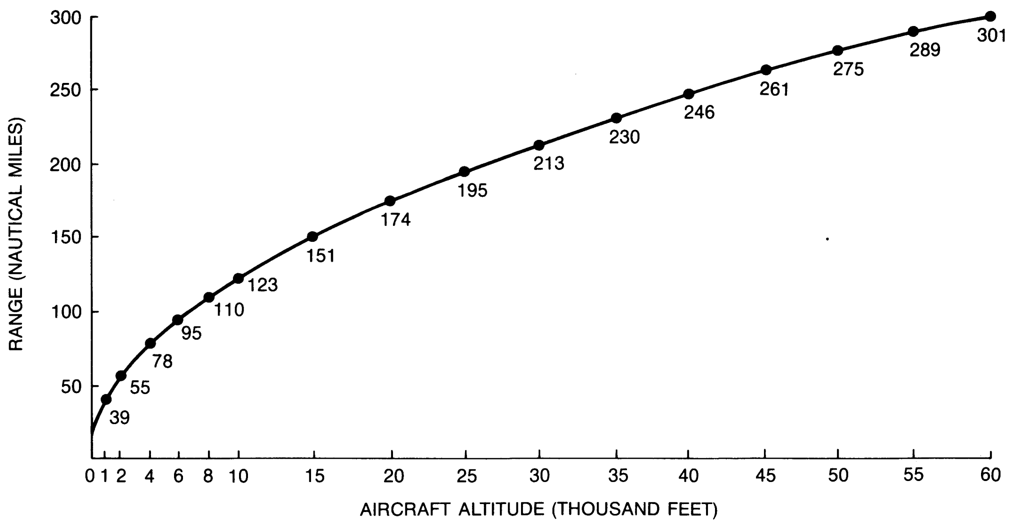
Q: What are the operating range limitations of the DME?

A: The airborne DME's range is limited by its peak-power output, receiver sensitivity, the terrain, and altitude of the aircraft.

Because the distance measured by DME is the line-of-sight (LOS) or slant-range distance, there is a limit to the distance measured, due to the curvature of the earth. The distance that a DME can measure is limited by the altitude of the aircraft and the height of the ground station antenna. Figure 8 graphically displays this relationship. The curved line in figure 8 represents the maximum distance the DME can measure with respect to the aircraft altitude.

The range in some airborne DME's may also be limited by the pilot. Older models, such as Collins 860E-2, have short-range channels with a search limit of 50 miles unless overridden. Later models (Collins 860E-4/5) have search limits up to 200 miles on all channels, except when overridden.

When the range is overridden, the search limit is extended to 390 miles.



NOTES:

1. DISTANCE CALCULATED AS FOLLOWS:
   DISTANCE (NMI) = 1.23 $\sqrt{\text{AIRCRAFT ALTITUDE (FT)}}$.
2. GRAPH REPRESENTS FLIGHT OVER LEVEL TERRAIN WITH GROUND STATION AT SEA LEVEL.
3. GRAPH PROVIDES OPTIMUM DISTANCES WHICH ARE NOT ALWAYS ATTAINABLE DUE TO TERRAIN AND INSTALLATION VARIABLES.

Operating Range Versus Altitude
Figure 8

Avionics Group/Rockwell International
Cedar Rapids, Iowa 52498

523-0769886-10111R 3-15-84 Printed in USA

Rockwell International