IDENTIFICATION OF DME TRANSPONDERS

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IDENTIFICATION OF DME TRANSPONDERS

SUMMARY

This report outlines the development of a suitable means for providing DME ground stations with an identification channel The operation of this channel is such that an indication of the station identity is received by the associated airborne equipment and made available to the pilot The basic problem is discussed, together with a number of proposed solutions each of which is described in detail, and the reasons for selecting the recommended system from among those under consideration are stated The method referred to as a code-bracketing method involves the transmission of a third pulse from the ground transponder at intervals synchronous with the transmission of identification information on the associated VHF omnirange (VOR) or instrument landing system (ILS) channel During transmission of the third pulse, a 400-cycle per second (cps) tone is injected into the pilot's headset Timing is arranged so that the tone is heard just before and just after transmission of the VOR or ILS code identification, if the pilot is tuned to the associated DME transponder

INTRODUCTION

Distance measuring equipment (DME) is the name generally applied to a specific system for providing aircraft pilots with continuous and accurate distance information with respect to preselected ground stations This particular system has been adopted as a standard short range navigation facility in the United States and also will be used abroad System operation is based on the familiar interrogator-transponder principle, with the interrogation originated by the airborne equipment (interrogator) and the reply being transmitted by the ground equipment (transponder) DME is to be used in conjunction with the currently installed VOR to provide a combined azimuth-distance air navigation facility of nationwide coverage It also will be used in conjunction with ILS to provide continuous distance to touchdown during the instrument approach and landing In order to obtain full flexibility, the VOR and ILS facilities are provided with discrete frequency assignments on a grid basis so that no frequencies are repeated without sufficient geographical separation to insure noninterference For similar reasons each of the ILS and VOR frequencies is assigned a different DME channel

Channeling of the DME is accomplished through a combination of different frequency combinations, plus a pulse multiplexing technique, in order to obtain 100 noninterfering channels from a total of 20 assigned frequencies (10 for interrogation and 10 for reply) Crossbanding these 20 frequencies permits the assignment of 100 different frequency combinations, which by themselves would be noninterfering if only a limited number of aircraft were to make use of the system However, widespread use of DME dictates additional means to prevent saturation due to excessively high random-pulse levels on each of these frequencies The added protection is provided by the use of double pulse interrogations and replies. The time interval between each pair of pulses may be any value between 14 and 77 microseconds in steps of 7 microseconds, thereby providing a total of 10 different pulse spacings Each channel of the 100 may be identified by the following parameters (1) an interrogation frequency, (2) a reply frequency, and (3) a mode A mode is defined as a combination of reply and interrogation pulse spacings, and there are ten such modes, the sum of interrogation and reply spacing always being 91 microseconds No two channels of the total of 100 may have more than one of the basic parameters in common Details of the DME system have been amply covered in previous literature[1, 2, 3, 4]

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[1] R. C Borden, C C Trout, and E C. Williams, "UHF Distance Measuring Equipment for Air Navigation," Technical Development Report No. 114, June 1950

[2] H Busignies, "High-Stability Radio Distance-Measuring Equipment for Aerial Navigation," Electrical Communication, Vol. 25, pp. 237-243, September 1948.

[3] Charles J. Hirsch, "Pulse-Multiplex System for Distance-Measuring Equipment (DME)," Proceedings of the IRE, Vol. 37, pp 1236-1242, November 1949

[4] R C. Borden, C C. Trout, and E C. Williams, "Description and Evaluation of 100-Channel Distance-Measuring Equipment," Proceedings of the IRE, Vol. 39, pp 612-618, June 1951.

DME provides the pilots of aircraft equipped with the system with an indication of distance in nautical miles To be of value to the pilot, it is obviously necessary that he know from what point this distance is measured. It is expected that there will be approximately 100 different DME ground stations within a square measuring 400 miles in width and length Each of these ground stations will be assigned a channel of operation which is independent of the remaining 99 ground stations It might appear that an auxiliary means of identification would be unnecessary if the channel assignment of each transponder location is known and properly selected There are, however, a number of reasons that make it necessary to provide a check on the tuning procedure It is possible that the pilot may inadvertently select the wrong ground station either as the result of improper manipulation of the tuning controls or as the result of misreading the assigned channel from his navigation chart In the absence of some substantiating means of identification, it is conceivable that the pilot could unknowingly operate his aircraft while using information originating from some point other than that intended In some extreme cases it may be possible for the aircraft to be within line of sight of two co-channel DME stations Such an occasion could easily arise at extremely high altitudes with long-range DME interrogators

Inasmuch as DME transponders will normally be installed at either VOR or ILS sites and used in conjunction with one or the other of these facilities, it has been argued that improper tuning of the airborne DME would be impossible since the VOR and ILS facilities provide independent voice or code identification If the airborne equipment is designed so that simultaneous channel selection of the DME and associated navigation or landing facility is made through a common electromechanical control box, it would appear that improper selection of the DME transponder would occur only in remote cases. It is conceivable, however, that mechanical or electrical failure in the tuning mechanism could result in selection of some DME transponder other than that associated with the navigation or landing facility being employed In some instances, and particularly abroad, DME transponders will be installed as a complete ground facility with neither associated VOR nor ILS In such cases there would be no means of identifying the ground station. These problems were the subject of much deliberation during the meetings of Special Committee 40 of Radio Technical Commission for Aeronautics (RTCA)[5]

The introduction of DME, a pulse-modulated system, as an airway facility created an identification problem not inherent in previous continuous wave (CW) systems In the case of CW systems, addition of the identification has always been relatively simple and is usually done by modulating the radio-frequency carrier either by voice or by Morse code Unfortunately, the DME ground transmission is inherently unsuited to modulation of this type There is insufficient energy content to convey the necessary intelligence inasmuch as the duty cycle of a DME transponder is only about one-half of one per cent, even when operating under fully loaded conditions The earliest DME models built in this country employed a relatively simple method of transmitting identification information This method was known as gap coding Gap coding, in its crudest form, simply involves a periodic interruption of the transponder reply to form characters of the Morse code If the airborne interrogator is tracking on a ground station and the reply from the ground station is interrupted, a code lamp on the instrument panel can be turned either off or on depending upon the presence or absence of a reply signal The periods during which the reply signal is interrupted are short enough in duration so that DME service itself is not effectively interrupted In the airborne DME this lack of interruption is due to a memory circuit which holds the distance reading constant for a period of approximately 8 to 15 seconds A modification of this particular type of gap coding which has been used in the past involves interruption of the local oscillator of the ground station receiver rather than interruption of the transmitted reply There are certain advantages inherent to this mode of operation However, the basic limitation of insufficient traffic handling capacity is the same In order to provide a more reliable means of identification and to increase the traffic handling capacity, various systems employing an airborne coding gate have been proposed and employed. This airborne gate, which can be made very short in duration, occurs at a specific time interval following the second reply pulse

When using such a coding gate, in addition to the normal two-pulse reply the DME transponder must be made to reply with

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[5] RTCA Paper 121-48/DO-24, Report of Special Committee 40, "DME System Characteristics (Transition Period)," December 15, 1948

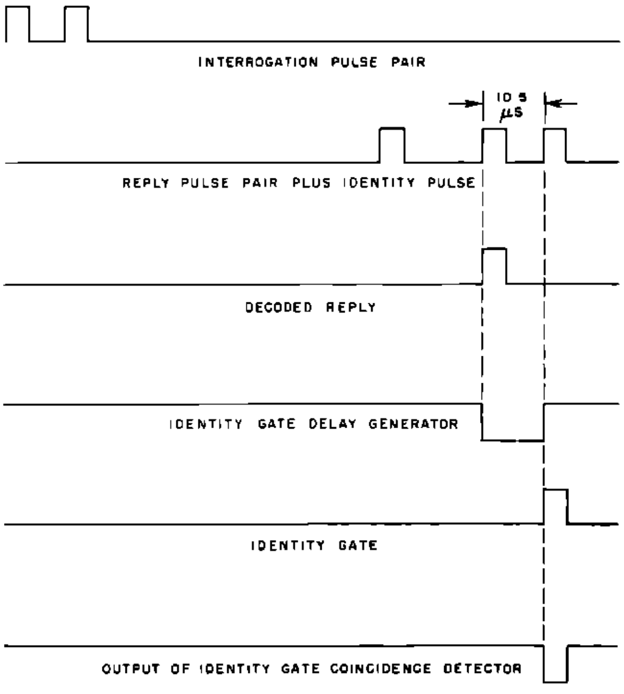

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Fig. 1 Time Relationships of DME Identification Channel

a special pulse arriving simultaneously with the generation of the coding gate in the airborne unit Synchronization is obtained by virtue of the fact that the interrogator may use the second normal pulse reply as a zero time standard from which the coding gate may be delayed by any convenient interval The standard adopted interval is 10 5 microseconds Generation of the third pulse by the transponder is delayed by this same amount following transmission of the second reply pulse Fig 1 illustrates the time relationships involved

EXAMINATION OF IDENTIFICATION CODING SYSTEMS

In order to establish which method from among several of those proposed offered the most practical solution to the DME identification problem, a number of factors had to be weighed Among the requirements for a suitable identification system are the following

1 The system shall be compatible with an early implementation date, inasmuch as the DME procurement program was well underway at the time this investigation was undertaken.
2 The system shall be capable of providing identification for those DME transponders which are installed without companion facilities such as VOR or ILS
3 The system shall operate properly under the heavy traffic loading conditions expected when widespread use of the DME is reached

A proper evaluation of the various proposals dictated that each of them be temporarily implemented, using transponders and interrogators essentially identical to ultimate production type units Facilities available to the Center to perform these tests were

1. Hazeltine Electronics Corporation, Model 1364A DME transponder — two units
2 Hazeltine Model No 1459 DME interrogators — two units
3. CAA VHF omnirange — one unit
4. Federal Telecommunication Laboratories, Inc , Model DIA DME interrogator — one unit
5. CAA audio oscillator-keyer, Type CA-1296 (modified) — one unit

MORSE CODE SYSTEM

The Hazeltine Model 1364A transponders were provided with built-in keyers, the circuitry of which was capable of keying a third transponder reply pulse at intervals determined by the settings of adjustable cams at the periphery of the keyer coding wheel This coder is shown as Fig 2

It had been proposed that use of such a keyer to transmit third-pulse trains in accordance with the Morse code sequence assigned to the DME station would provide an adequate means of DME identification Two problems are involved in such a basic system First, since more than one aircraft (and up to 50) may be receiving service from a single transponder, the airborne coding circuits must be protected from random pulses (such as replies to the other aircraft) entering the coding gate and leading to spurious identification signals. Second, since many aircraft are sharing the service of a single transponder, not all aircraft interrogations will result in a reply Therefore, the coding circuitry must be capable of operation in the presence of count-down, which is the ratio of the number of replies received to the interrogations sent In the DME system, count-down may be as high as 33 1/3 per cent without detriment to system performance

1 Random Pulses

In order to minimize the first of these two problems, it is desirable to require a fairly large number of successive pulses to be received by the coding gate before the

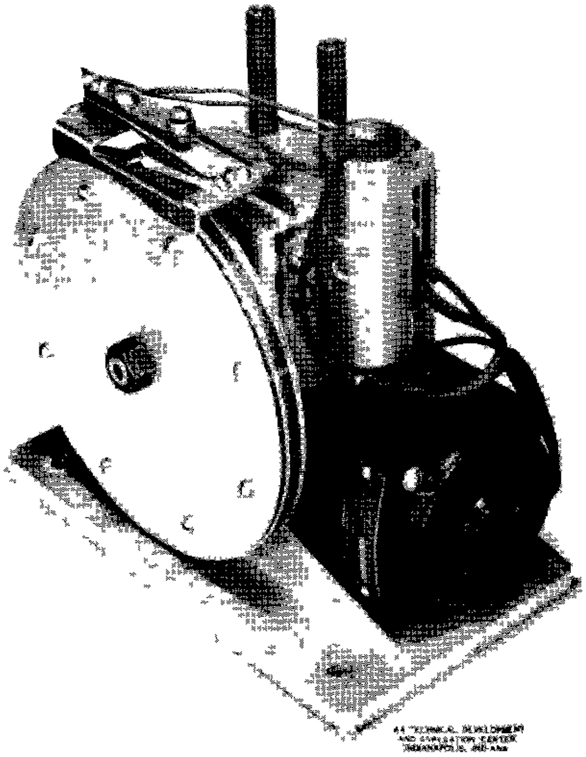

Fig 2 Hazeltine DME Keyer

output circuit becomes activated The number of successive pulses determine the integration time Since the DME airborne transmitter interrogation rate is only 30 per second, unreasonably long dots and dashes would have to be employed if any appreciable number of consecutive pulses (such as ten for a dot) were required to obtain an identification output In order to differentiate between dots and dashes, the dashes would then have to be of approximately 2/3-second duration Such a slow code, when presented aurally, is quite confusing.

2. Count-down

In attempting to minimize this problem, other undesirable factors became evident With such long intervals representing the dots and dashes, the probability that count-down will cause them to be broken up becomes extremely high Garbling in this manner destroys the code as effectively as do the spurious signals received when the airborne integration time is too short Figs 3A and 3B illustrate the two cases Thus, a basic limitation on such a simple coding system is imposed by traffic loading As the traffic load decreases, both of these effects become less pronounced, and when only a single aircraft is operating with the transponder, the duration of the code signals may be any value desired without resulting in code garbling Using existing equipment, the traffic limit at which garbling became excessive was determined experimentally A Hazeltine Model 1364A transponder was used in conjunction with a Hazeltine Model 1459 interrogator

Using the coder shown in Fig 2, the code letters IND were set up with a dash length of 1 1/4 seconds and a dot length of about one-half this value The interrogator was tuned to the transponder channel and permitted to lock on the transponder reply The contacts of the airborne coding relay were used to key the output of a 1020-cps signal generator, the keyed output of which was recorded on tape To simulate traffic loading, the receiver gain of the transponder was increased so that noise pulses successfully passed the decoder at the receiver output and triggered the transponder in random fashion at a rate determined by the gain setting When the normal gain setting was used, the transponder performed as if it were interrogated by a single aircraft Under this condition, the Morse code letters were unbroken and none were omitted, nor were any spurious identification signals introduced This recording was played back to a number of listeners, the majority of whom stated that the code was far too slow The receiver gain of the transponder was then increased to a level equivalent to random interrogation by ten aircraft Under this condition only about 50 per cent of the codes transmitted were uninterrupted, and, as a consequence, operation at this traffic level was considered unsatisfactory At a level of 20 interrogating aircraft, practically all of the codes transmitted were interrupted In an effort to reduce the undesirable effect of count-down, both the integration time of the airborne coding circuit and the duration of dots and dashes were reduced by approximately one-half These tests were repeated, and a very satisfactory and easily readable code signal was received at a traffic level of one aircraft However at traffic levels of ten or more aircraft, spurious signals were created thereby causing serious code garbling Creation of these spurious signals was caused by sufficient numbers of random pulses being received in the identification gate to cause operation of the code relay because of the lower integration time On the basis of these tests, it was concluded that the use of such a basic system would not be feasible even for very low levels of traffic. This had been

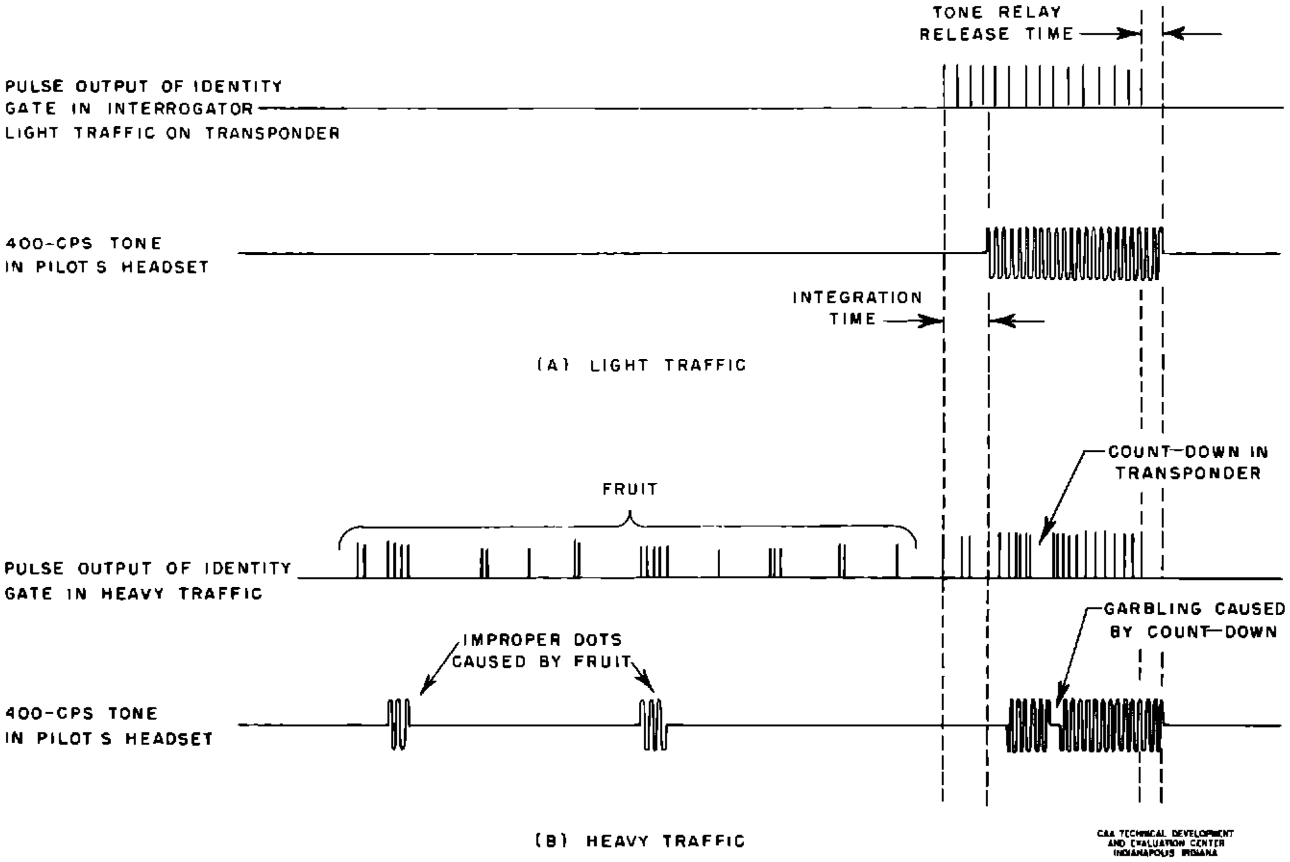

Fig. 3 Improper Coding Effects With Heavy DME Traffic

shown previously in a series of flight tests[6]

It became obvious that the system to be employed could not be expected to convey more than simple OFF-ON information, in which case a fairly large amount of garbling could be tolerated without destroying recognition of this basic type of information Since such a system (when applied to identification in this manner) is inherently capable of identifying only two separate stations, it became necessary to adopt an entirely new philosophy of identifying the DME transponder.

Inasmuch as the VOR transmitter provides the pilot with positive station identification through either a Morse code or voice channel, positive identification of the DME transponder as the particular transponder associated with the identifying VOR could be accomplished through some sort of synchronization between the two equipments at the ground station The problem then would resolve itself into determining in the airplane whether this synchronization existed. With such a system, a simple OFF-ON indication could be employed. The identification information transmitted by the VOR transmitter occurs at regular intervals and is controlled by a keyer This keyer is driven by a nonsynchronous alternating-current (ac) induction motor If keying of the third pulse at the DME transponder bore a definite relationship in time to keying of the Morse code or voice from the VOR, the combined identification signals heard through the pilot's headset would bear this same relationship. The VOR keyer motor is nonsynchronous If the airborne VOR receiver should be tuned to some station other than that to which the airborne DME interrogator is tuned, then the time relationship between receipt of the VOR identification information and receipt of the DME identification information as heard in the pilot's headset would vary, that is, the two identifications would drift with respect to each other

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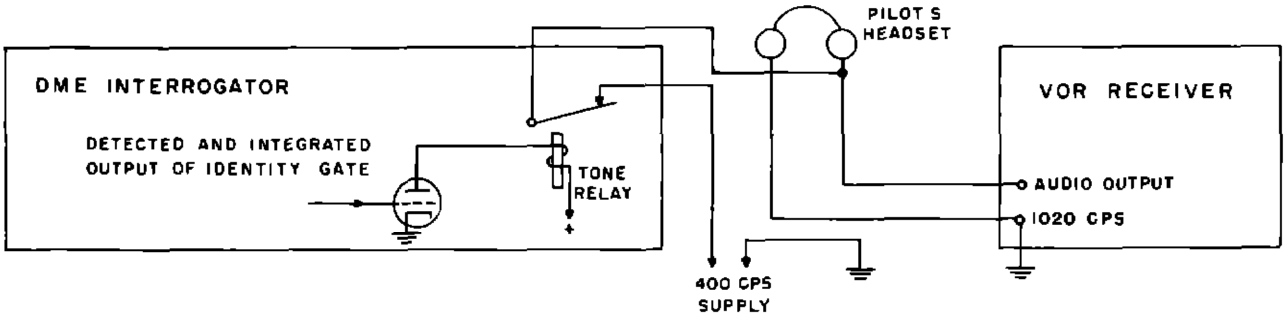
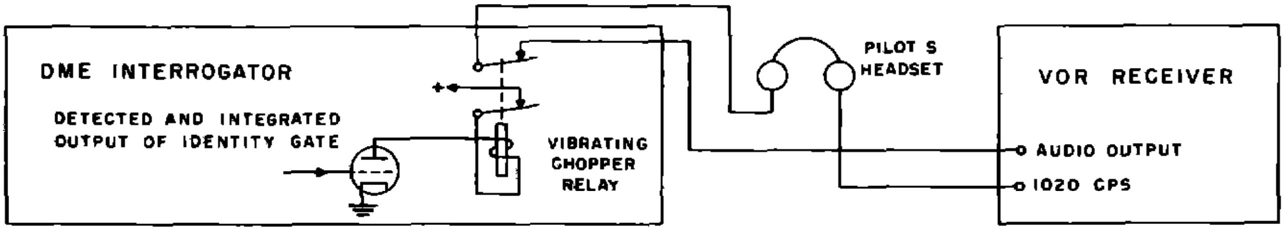
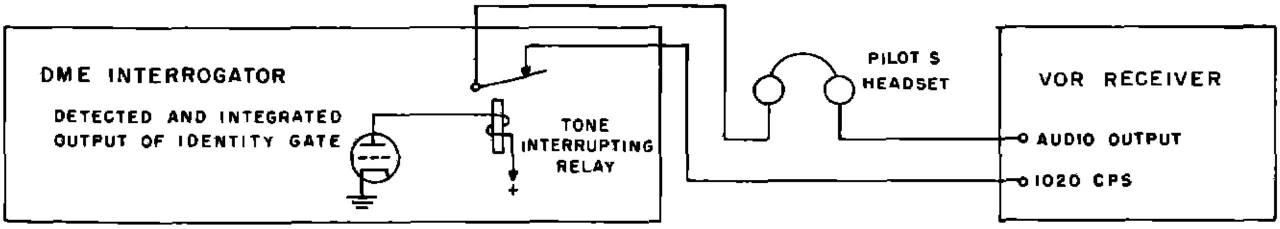
[6] R C Borden, C C Trout, and E C Williams, "Evaluation of 100-Channel Distance Measuring Equipment," Technical Development Report No 119, July 1950



(A) METHODS I, IV AND V



(B) METHOD II



(C) METHOD III

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Fig. 4 Basic Airborne Identification Circuits

SYNCHRONOUS KEYING SYSTEMS

Five methods employing synchronous techniques were proposed Each was implemented, and sample identification signals were recorded and evaluated The five methods are identified as follows

Method I – Beat Tone
Method II – Chopped 1020-cps Tone
Method III – Canceled 1020-cps Tone
Method IV – 400-cps Tone
Method V – Code Bracketing Tone

The means for implementing these five schemes are essentially identical. The basic airborne circuitry is shown in Fig 4. The method of keying the VOR and DME ground stations is shown in Fig. 5, and a view of the combined VOR-DME keyer is shown in Fig 6. Fig 7 is a graphical presentation of the five coding methods

Method I – Beat Tone.

The first proposal prescribed that the DME transponder third pulse be keyed for a period of one second immediately following transmission of the VOR code letters This would be accomplished by a separate cam on the shaft of the VOR keying motor During the time when the DME transponder is transmitting third pulses, the VOR identification channel transmits a 1020-cps continuous tone See Fig 5A In the aircraft, reception of the

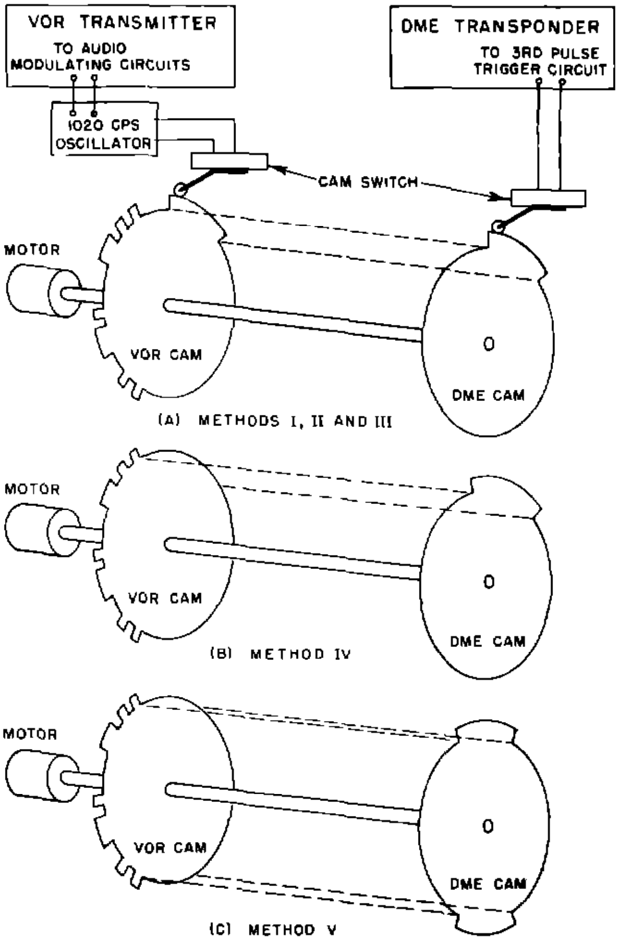

Fig 5 Method of Keying VOR and DME Ground Station

identification pulse causes the operation of the identification relay in such a way as to inject a 400-cps tone into the pilot's headset See Fig 4A This, of course, occurs simultaneously with the 1020-cps tones transmitted on the VOR identification channel Mixing of these two tones results in a beat note Thus when the airborne VOR receiver and DME interrogator are tuned to the same ground station, the full identification signal consists of the station call letters in Morse code at 1020 cps followed by a dash of one second in duration at a beat tone of about 600 cps. If for some reason the VOR receiver and the DME interrogator are tuned to different ground stations, the call letters of the VOR transmitter will be heard and will be followed by a 1020-cps tone of one second duration, however, due to lack of synchronization, the 400-cps tone initiated by reception of the DME identification pulses will not necessarily occur at the proper time but may be heard at any time during the entire code cycle and at a different time during each successive code cycle. See Fig 7, Method I It was felt that such a condition would be immediately apparent to the pilot and would permit him to take steps to check his VOR and DME tuning

It is a well-known fact that tonal perception varies a great deal with the individual As a matter of fact, many persons are almost completely tone deaf This raised the question as to the practicability of depending upon tonal perception to identify the DME ground station In an effort to determine the validity of this problem, a number of recordings of mixed tones were made These recordings were played back to a number of listeners who were asked to distinguish between pure 1020-cps tones, pure 400-cps tones, coincident 1020- and 400-cps tones, and partially coincident 1020- and 400-cps tones Any of these combinations might be created in operation of such an identification system, depending upon proper or improper tuning of the DME and upon the level of the traffic load The ability to recognize whether a particular combination represents the proper code is essential to the satisfactory use of the beat tone system Examples of various code signals and how they might be produced in the pilot's headset are as follows

1 Pure 400-cps tone If the airborne VOR receiver and the DME interrogator are tuned to different stations, there is no constant relationship in time between reception of the one-second, 1020-cps tone transmitted by the VOR and the one-second, 400-cps tone generated in the interrogator The 400-cps tone is generated as a result of reception of the one-second train of DME identification pulses Thus, the 400-cps tone could occur at any time during the code cycle.

2. Pure 1020-cps tone (Same as Item1)

3 Coincident tone Such a tone would be generated when the VOR receiver and DME interrogator are both tuned to the same ground station In actual operation, unless the transmission of the third pulse is initiated somewhat before the start of the one-second, 1020-cps tone, the combined tone heard in the airplane would start with a fraction of a second of pure 1020-cps tone prior to production of the beat tone This would be caused by the integration time of the airborne DME coding circuit In order to eliminate this, the duration of the third pulse DME keying period on the ground should be approximately 1/3 second longer than the duration of the 1020-cps keying of the VOR and should precede the VOR keying by this amount of time

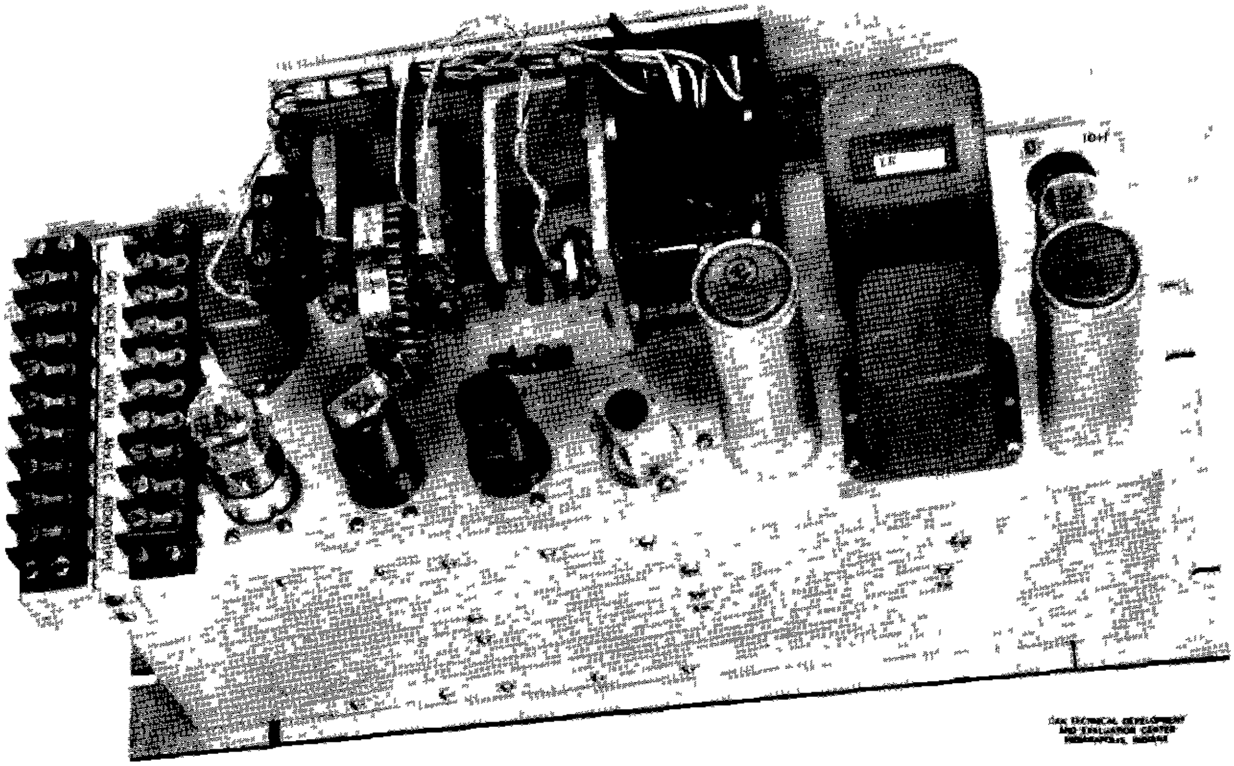

Fig. 6 Combined VOR-DME Keyer

4. Partially coincident 1020- and 400-cps tones If the provision described in Item 3 were made, this type of identification signal would be heard only when the VOR receiver and DME interrogator were tuned to different stations and while the nonsynchronous 400-cps tone is drifting through the 1020-cps VOR tone.

It was found that very few listeners were able to distinghish between pure tones and blended tones or to differentiate between perfectly coincident tones and partially coincident tones when the percentage of coincidence was high (80 per cent or more)

Method II – Chopped Tone

In an effort to create a beat tone more readily distinguishable from a pure 1020- or 400-cps tone, a number of frequencies other than 400 cps were used to represent the DME-generated identification signal After considerable experimentation it was noted that very low beat tones, those created by employing a DME-generated tone very close to 1020 cps, were quite easily recognized Since a tone of such frequency cannot be conveniently supplied by the DME interrogator, an alternative method of achieving the same effect was investigated. In this case operation of the identification circuit (so far as the VOR channel was concerned) remained unchanged, as did operation of the transponder third pulse keyer on the ground The only modification was made in the airborne equipment. Upon reception of identification pulses from the transponder, the identification relay was made to operate as a vibrator at a rate of about 20 cps. See Fig. 4B. When the DME is properly tuned, the 1020-cps dash is interrupted at the vibrator frequency, since the VOR code information (Morse code and one-second dash) is fed to the pilot's headset through the normally closed contacts of this relay during the DME coding period This is illustrated in Fig 7, Method II The large majority of listeners stated a definite preference for this type of identification signal, and an examination of the listeners' ability to differentiate between proper and improper codes, using this method, indicated that it is far superior to that evidenced with the beat tone method The chopped tone method has two primary disadvantages

1. It complicates the airborne identification circuitry
2. It demands that the 1020-cps, one-second dash be transmitted on the VOR channel. It should be noted that this disadvantage is also common to the beat tone method previously described

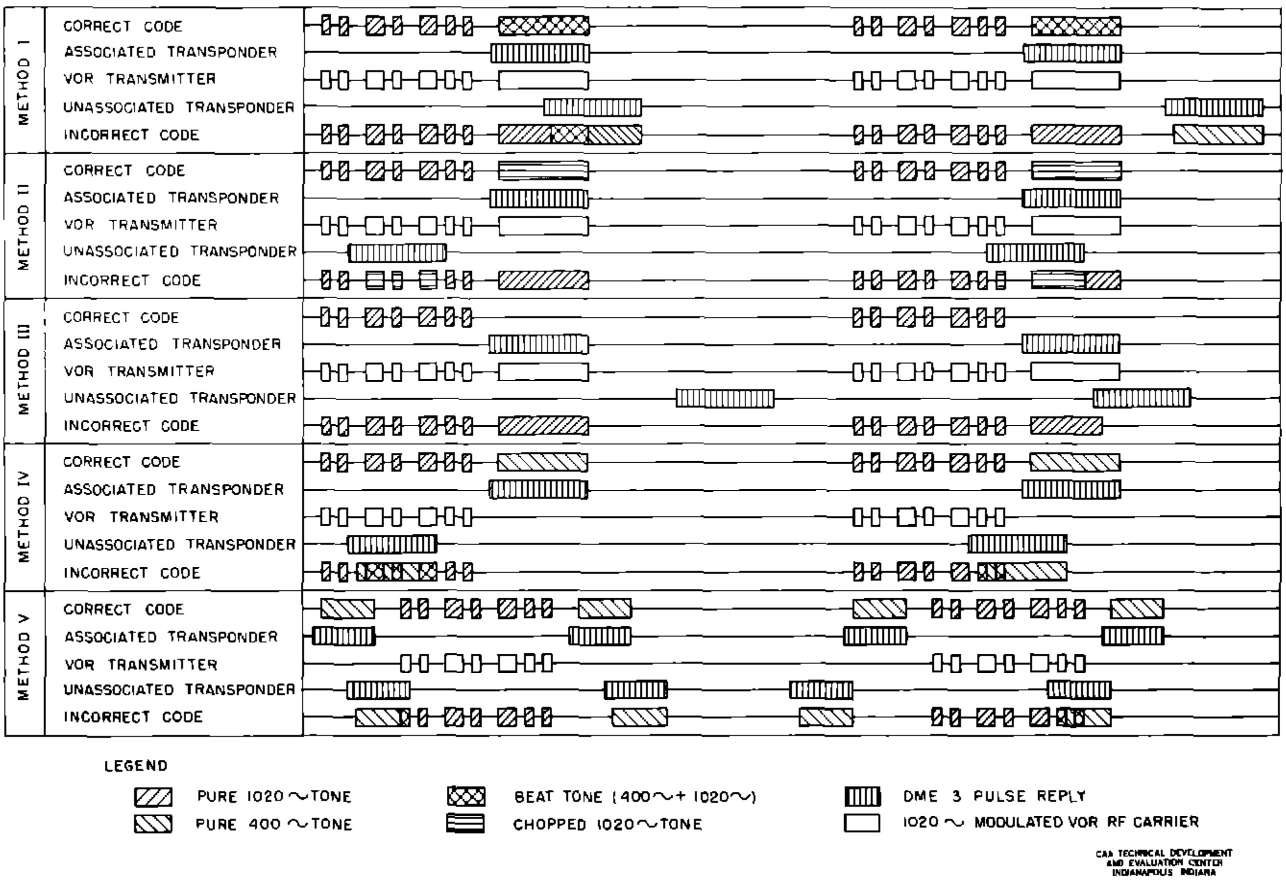

Fig 7 Graphical Presentation of Five 3-Pulse Coding Methods (Two Successive Cycles)

A number of pilots who have flown the VOR system extensively, in the absence of DME, reported that the additional 1020-cps dash following the code letters is extremely annoying and can be confused easily with the letter T.

Method III — Canceled Tone.

In order to reduce the complexity of the airborne identification circuit, a third method of operating the identification channel was investigated. Again, insofar as operation of the identification channel on the ground (both VOR transmitter and DME transponder) is concerned, this method is identical with the beat tone method However, upon reception of the third pulse in the interrogator the contacts of the identification relay which carry the VOR identification information to the pilot's headset are opened See Fig 4C Therefore, when the DME and VOR are both tuned to the same ground station, the pilot hears only the station call letters in Morse code and nothing else If any portion of a 1020-cps tone other than that contained in the station call letters is heard, the implication is clear that the DME and VOR receiver are tuned to different ground stations This is shown in Fig 7, Method III The listeners' ability to differentiate between proper and improper codes by this method was shown to be superior to that demonstrated with either the beat tone or chopped tone methods. Again there were two primary objections

1 Many persons felt that this system violated a basic principle of safety by providing no signal in cases of normal operation
2 Again, a 1020-cps, one-second tone is required on the VOR channel, which is considered an imposition on those flyers using VOR only

Method IV — 400-cps Tone

In order to eliminate the objection raised by pilots using VOR only, a system was set up identical both on the ground and in the air to the beat tone system except that the one-second, 1020-cps tone on the VOR channel was omitted See Figs 4A and 5B. In this case the proper identification signal consisted of the VOR Morse code call letters at 1020 cps which call letters were immediately followed by a pure 400-cps tone of one second duration, as presented in Fig 7, Method IV If the VOR receiver and DME interrogator are tuned to different stations the 400-cps tone will not necessarily follow immediately after the station call letters, thereby providing an indication of improper tuning A serious objection which can be raised in connection with this method is that, in the event of improper tuning, several complete code cycles may pass before the pilot can be sure whether the tuning is proper or improper. Variation in the starting time of the 400-cps dash as heard in the airplane and a relatively slow drift of the keying motors at the various VOR stations aggravate this situation This objection is not valid in the case of any of the three previously described methods, since the 1020-cps dash generated by the VOR serves as an unvarying time base for ready comparison and detection of drift

Method V – Code-Bracketing Tone

To overcome the objection to Method IV, transmission of the third-pulse train was split into two separate transmissions, each approximately 0.7 seconds in duration See Fig. 5C As a result, two 400-cps dashes are heard in the pilot's headset The first of these dashes is heard just prior to reception of the station call letters, and the second is heard just following reception of the station call letters. See Fig 7, Method V An alternate method of achieving the same effect would be to employ a single 400-cps dash of sufficient duration to fill completely the gap between the end of one code and the start of the next In either case it is obvious that any small drift of the 400-cps tones with respect to the station call letters will result in garbling of the code letters regardless of the direction of drift. The large majority of listeners considered this method superior to any of those previously described. As a result, a code-bracketing method was recommended for adoption both domestically and abroad. Before final recommendation as a standard system for DME identification, Method V was thoroughly examined both in the laboratory and in flight tests

At the request of the International Civil Aviation Organization (ICAO), a number of laboratory tests were conducted to determine the ultimate traffic handling capacity of this method Specific information requested by the United States ICAO representative was as follows

1 Output dash length – duration of dash as heard in the pilot's headset
2. Integration time – time between initiation of the third-pulse transmission on the ground and initiation of the 400-cps tone in the pilot's headset
3 Effective width of the identification gate in the airborne equipment

This information was to be obtained with a 0.7-second dash transmitted from the ground transponder as proposed in the split tone method. The conditions under which these tests were to be performed were to simulate, as nearly as possible, full traffic loading on the DME system with the aircraft in reception range of several ground transponders For this reason the "fruit" (random pulse) levels were to be held as high as possible, with a count-down of the desired replies to 50 per cent It was not possible with the equipment available to achieve these conditions fully, however, the maximum fruit levels and minimum transponder efficiency of 70 per cent which was used approximates rather severe environmental conditions, when considered on the basis of practical DME usage in the foreseeable future

Since the time of release of the airborne identification relay adds to the length of the dash as actually heard by the pilot, this time was measured and should be considered in the over-all operation of the system. By the time these tests were performed, a second model of a 100-channel interrogator was available This unit was developed by the Federal Telecommunication Laboratories, Inc , and is identified as Model DIA Measurements were made on both the DIA interrogator and the earlier Hazeltine Model 1459 interrogator

In order to measure the characteristics of the identification circuits of these two types of existing DME interrogators, each was set up in the laboratory under conditions simulating actual operation It was necessary to deviate in certain instances because of equipment limitations which will be described later. The measurements were made on both kinds of equipment in a similar manner, and the arrangement differed only in the method of furnishing the proper signal to the identification circuits It will be noted in Figs 8 and 9 that the high-speed chronoscope with its start-stop adapter was arranged so that several different time intervals could be measured by connecting it to relays or contacts in the equipment under test The points of connection and the actual time interval measured in each test for both interrogators are described below

Output Dash Length

The chronoscope was connected to the normally open contacts of the code relay in the interrogator and was adjusted to measure

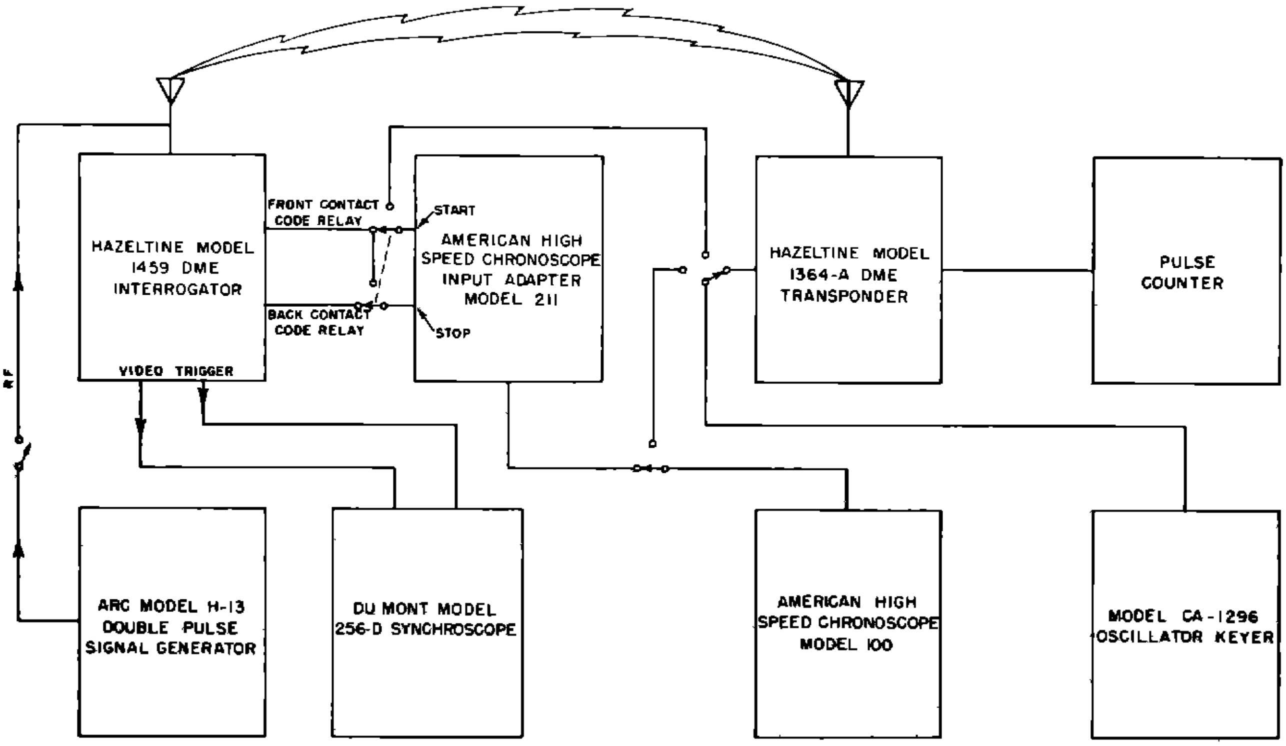

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Fig. 8 Identification Test Setup, Hazeltine Interrogator

the interval during which these contacts were closed. This measurement is the length of the 400-cps tone heard in the pilot's headset

Duration of Closed Keyer Switch

The chronoscope was connected to the normally open contacts of the cam-actuated switch in the Type CA-1296 oscillator-keyer, and the time that it remained closed was measured This time should equal the length of time of transmission of the third (or identification) pulse from the transponder, with a tolerance of plus zero and minus a maximum of 0.066 second

Integration Time

The start-stop adapter was used in this test, and the actual elapsed time from the closing of the normally open contacts in the cam-actuated switch in the oscillator-keyer to the closing of the normally open contacts of the code relay was measured This time should equal the time from the beginning of the third pulse transmission to the beginning of the tone in the pilot's headset, with a tolerance of plus zero and minus a maximum of 0 033 second.

Tone Relay Release Time

The start-stop adapter was used, and the elapsed time from the opening of the normally open contacts of the cam-operated switch in the oscillator-keyer to the opening of the normally open contacts of the code or identification relay in the interrogator was measured This time measurement equals the time from the end of transmission of identification pulses from the transponder to the end of the tone in the pilot's headset, with a tolerance of plus zero and minus a maximum of 0 033 second

The Hazeltine Model 1459 interrogator was operated in a normal manner against a Hazeltine Model 1364A transponder in the laboratory, and the Type CA-1296 oscillator-keyer was connected to the transponder in a normal manner in order to key the third pulse transmission Fig 8 shows the arrangement of the equipment used The additional traffic load on the transponder was simulated by adjustment of the gain stabilization and intermediate-frequency gain controls in the transponder receiver in such a manner that sufficient noise triggering of the transponder was produced to create the

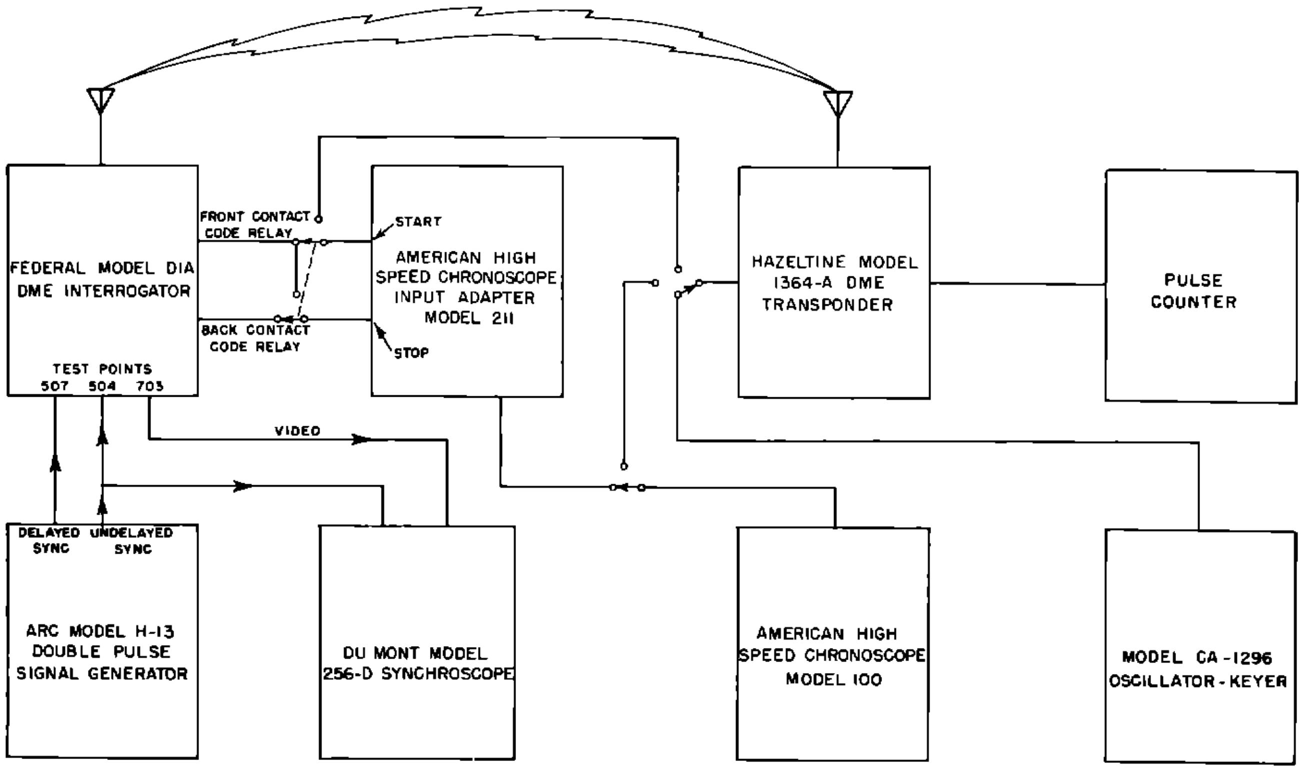

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Fig. 9 Identification Test Setup, Federal Interrogator

desired number of transponder replies. The number of replies was counted by connecting the pulse counter to the proper transmitter video circuits. Additional nonsynchronous replies of improper spacing were provided by insertion of a T-fitting in the interrogator antenna transmission line and by connecting the double pulse signal generator at this point. The double pulse signal generator was then adjusted to the proper rate by means of the pulse counter.

Due to the fact that a model of the Federal DIA interrogator was loaned for these tests before complete testing and adjustment of the radio-frequency components had been completed at the factory, it was necessary to modify the method of signal injection during the tests on this unit. The arrangement is shown in Fig. 9. The signals supplied to the interrogator under test were at video frequencies, since the equipment would not function with the transponder available. The transponder video circuits were used to produce fruit pulses of the proper spacing, with the output of the transponder removed before modulation of the radio-frequency circuits. The properly synchronized reply signal was furnished as a single pulse by the double pulse signal generator and was fed into the interrogator video circuits beyond the point of decoding. In the injection of the signals care was exercised to prevent effects which would disturb the normal operation of the interrogator, in order to provide data which would simulate that obtained in normal operation against a transponder.

The effective width of the third pulse gate was measured in both types of equipment by displacing the third pulse from its proper spacing and by measuring the displacement limits. This method actually provided a measurement of the spacing tolerance of the interrogator. The arrangement of equipment between the two interrogators differed because of the different methods of signal injection.

In the case of the Hazeltine Model 1461 interrogator, the identification pulse coil in the moder delay line in the transponder was displaced mechanically to the limits of operation of the identification relay, and the distance was carefully measured between these two points. Relaying upon the velocity of transmission of signals in the line as 0.186 inch per microsecond

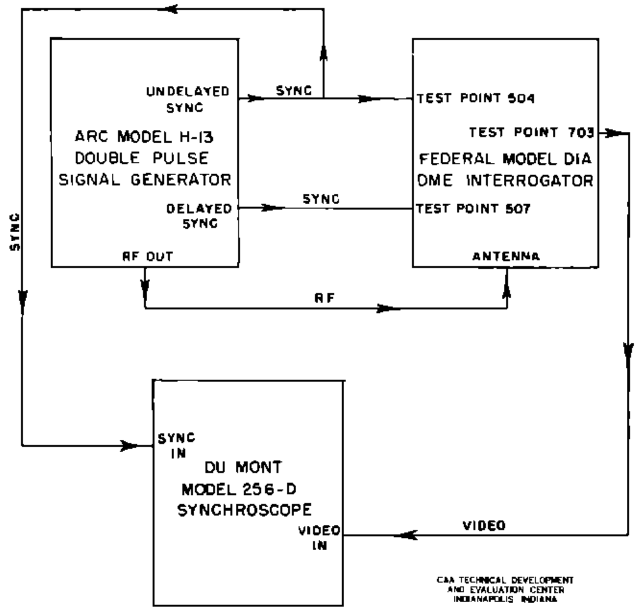

Fig. 10 Test Setup for Determining Coding Gate Width, Federal Interrogator

(5.38 microseconds per inch), the actual time delay was calculated.

For the effective gate width measurement on the Federal Type DIA interrogator, it was necessary to use the arrangement shown in Fig. 10. The strobe (or gate) circuits were disabled to prevent search or track so that the third pulse gate remained stationary, and signals were introduced from a signal generator to cause operation of the identification relay when within the gate. The pulse so introduced then was displaced by manipulation of the proper delay control, and the limits of operation were measured with the calibrated strobe in a Du Mont Type 256-D synchroscope.

Since effects produced by the fruit pulses and especially the count-down were of a random nature, a number of readings were taken in each case, and an average for all readings was calculated. The high and low limit readings also are furnished in the following data compiled on the two types of equipment.

HAZELTINE MODEL 1459 INTERROGATOR

Output Dash Length

Transponder load 1 aircraft
Improperly spaced fruit 0
Transponder efficiency 100 per cent
Duration keyer switch closed 0.68 second
Number of readings 10
Dash length 0.52 second, average
0.54 second, high limit
0.50 second, low limit

Transponder load 41 aircraft
Improperly spaced fruit 0
Transponder efficiency 70 per cent, approximately
Duration keyer switch closed 0.68 second
Number of readings 20
Dash length 0.34 second, average
0.46 second, high limit
0.26 second, low limit

Transponder load 41 aircraft
Improperly spaced fruit 1500 pulse pairs per second
Transponder efficiency 70 per cent, approximately
Duration keyer switch closed 0.68 second
Number of readings 20
Dash length 0.36 second, average
0.50 second, high limit
0.25 second, low limit

Note: The apparent inconsistency of the data is due to the random nature of the readings. The 0.02 second increase in average dash length upon the addition of 1500 additional pulse pairs has been assumed to indicate no change. Due to the rather extreme dash shortening at high traffic levels, it would appear that a larger initial dash length should be employed and that the two dashes be permitted to overlap in the case of short coding cycles.

Integration Time

Transponder load 1 aircraft
Improperly spaced fruit 0
Transponder efficiency 100 per cent
Number of readings 10
Integration time 0.31 second, average
0.32 second, high limit
0.30 second, low limit

Transponder load 41 aircraft
Improperly spaced fruit 0
Transponder efficiency 70 per cent, approximately
Number of readings 20
Integration time 0.43 second, average
0.60 second, high limit
0.32 second, low limit

Transponder load 41 aircraft
Improperly spaced fruit 1500 pulse pairs per second
Transponder efficiency 70 per cent, approximately

Number of readings 20
Integration time 0.43 second, average
0.59 second, high limit
0.32 second, low limit

Tone Relay Release Time

Number of readings 10
Release time 0.16 second, average
0.17 second, high limit
0.15 second, low limit

Effective Identification Gate Width

Gate width 4.5 microseconds

Note Under the conditions of a load of 41 aircraft on the transponder and 1500 pulse pairs per second of improperly spaced fruit, no variation of the effective gate width could be observed

FEDERAL MODEL DIA INTERROGATOR

Output Dash Length

Transponder load 1 aircraft
Improperly spaced fruit 0
Transponder efficiency 100 per cent
Duration keyer switch closed 0.68 second
Number of readings 11
Dash length 0.618 second, average
0.670 second, high limit
0.550 second, low limit

Transponder load 41 aircraft
Improperly spaced fruit 0
Transponder efficiency 70 per cent, approximately
Duration keyer switch closed 0.68 second
Number of readings 21
Dash length 0.480 second, average
0.610 second, high limit
0.190 second, low limit

Transponder load 41 aircraft
Improperly spaced fruit 1500 pulse pairs per second
Transponder efficiency 70 per cent, approximately
Duration keyer switch closed 0.68 second
Number of readings 21
Dash length 0.479 second, average
0.630 second, high limit
0.330 second, low limit

Note The output dash exhibited some erratic operation under all conditions of a 41-aircraft load on the transponder. Again it appears that a longer initial dash length is desirable. This is attributed to both the integration time and the tone relay release time being too short

Integration Time

Transponder load 1 aircraft
Improperly spaced fruit 0
Transponder efficiency 100 per cent
Number of readings 10
Integration time 0.124 second, average
0.170 second, high limit
0.100 second, low limit
Transponder load 41 aircraft
Improperly spaced fruit 0
Transponder efficiency 70 per cent, approximately
Number of readings 20
Integration time 0.147 second, average
0.270 second, high limit
0.080 second, low limit

Transponder load 41 aircraft
Improperly spaced fruit 1500 pulse pairs per second
Transponder efficiency 70 per cent, approximately
Number of readings 33
Integration time 0.200 second, average
0.540 second, high limit
0.080 second, low limit

Tone Relay Release Time

Number of readings 10
Release time 0.112 second, average
0.120 second, high limit
0.100 second, low limit

Effective Identification Gate Width

Gate width 3.0 microseconds

Note Under the conditions of a load on the transponder of 41 aircraft and 1500 pulse pairs per second of improperly spaced fruit, no variation of the effective gate width could be measured

It might be noted that the erratic operation mentioned above in the test on output dash length for the Federal Model DIA interrogator consisted of two distinct types of undesirable operation. The first was the momentary closing of the tone relay at times other than during the dash transmission from the transponder The closing of the tone relay at an improper time produced in the headset a tone of approximately 0.1 second or less duration. This improper timing of the tone would confuse a pilot The second was the momentary opening of the tone relay during the dash transmission caused by momentary loss of sufficient replies from the transponder This condition caused the dash to be broken up and was judged to be unsuitable for proper identification use Further tests to determine the maximum amount of traffic, which such an arrangement would tolerate, revealed that the output dashes were completely solid at a load of approximately 20 aircraft on the transponder and that they were judged usable at a load of approximately 27 aircraft The output dashes were considered usable if 90 per cent were perfect

IDENTIFICATION OF UNASSOCIATED TRANSPONDERS

The code-bracketing method of DME identification has been recommended as standard in all cases where the DME transponder is associated with either a VOR or ILS installation Where DME transponders are installed as single facilities, as will be the case in many localities abroad, a special independent identification code is to be employed[7] The characteristics of the independent identification signal shall be as follows

1 The identity signal shall compose two groups of mark signals, each group having one to five marks
2 Mark signals and the intervals between marks forming a group shall be 0 75 ± 0 1 second in duration The variation in the duration of marks and the intervals within any complete identity group shall not exceed 0 1 second The interval between the end of the last mark of the first group and the start of the first mark of the second group shall be 2 5 ± 0 4 seconds
3 A mark will be created by transmission of three pulse replies for the stated period

Implementation of either the independent or associated identification code at any given DME transponder shall be guided by the following factors

1. The independent identification code shall be employed wherever a transponder is not specifically associated with a VHF navigational facility
2 Wherever a transponder is specifically associated with a VHF navigational facility, identification shall be provided by the independent code, by the associated code, or by both
3. The independent identification code shall be employed wherever a transponder is required to provide service for aircraft not fitted with VHF airborne navigational equipment which could provide the associated identification code

PROPOSED ULTIMATE IDENTIFICATION SYSTEM

During the deliberations of RTCA Special Committee 40, an extremely flexible and entirely independent means of DME identification was proposed[8] This method is intended for implementation with transponders operating unassociated with VHF facilities, as well as with those installed in conjunction with either a VOR or ILS. In the aircraft, this system is to provide a special identification indicator which will automatically display the station call letters through decoding of data transmitted on the DME channel only It is proposed that the third pulse reply from the transponder during identification periods be spaced either 10 5 or 24 5 microseconds following the second reply pulse, one of these spacings denoting a mark and the other a space By providing a sequence of 15 such marks or spaces, each of one second duration, a complete code cycle can be transmitted every 15 seconds. Using a binary type of decoder, the particular combination of marks and spaces can be converted to any combination of three letters, depending upon the particular sequence transmitter. Such a system will require two identification gates in the aircraft in addition to the binary decoder and either circuits or mechanisms for operating the final display It is believed that the additional requirements imposed on the airborne equipment and the added duty cycle imposed on the transponder do not warrant the implementation of such a system in the near future

CONCLUSIONS

It is concluded that a code-bracketing method of DME identification will serve as a suitable means for identifying DME transponders for the foreseeable future. It is believed that by the time this method becomes obsolete due to traffic handling limitations, newer DME designs and techniques will also

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[7] Report of the Fourth Session, Communications Division, ICAO, Doc 7171-COM/544, Montreal, 1951, pp. 99-101.

[8] RTCA Paper 121-48/DO-24, op cit

have made obsolete the present-day airborne interrogators, and it is also believed that an improved and more flexible, yet compatible identification system will be introduced

The results of these tests were furnished to the United States representatives, at the Fourth Session, Communications Division, ICAO, and a code-bracketing method has been recommended for use by the member states of that organization at locations equipped with both DME transponders and with either VOR or ILS

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