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External Power Monitoring of the Model DTB DME Transponder

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EXTERNAL POWER MONITORING OF THE MODEL DTB DME TRANSPONDER*

SUMMARY

This report describes a modification of the Model DTB distance-measuring equipment which assures a positive examination of the radiated power output and characteristics of the emitted signal As opposed to the existing monitor wherein the output power is sampled in the radio-frequency transmission line circuit, the new monitor samples radiated power Operational use of the Model DTB equipment has shown that the present monitor system does not adequately detect power-output variations of the reply signal. In this report another modification is outlined which improves the linearity and stability of the monitor power-detector circuitry and provides a less critical adjustment of the monitor power-threshold control

INTRODUCTION

The Model DTB distance-measuring equipment (DME) is a modern aeronautical navigation apparatus which includes a dual transponder installation and automatic control and transfer equipment. Pertinent performance characteristics of the operating transponder are tested continuously by two monitors, one of which performs in effecting transfer action. As long as the controlling monitor is "satisfied" with the performance of the transponder, it will remain on the air. If the transponder performance does not remain within the preset alarm limits of the monitor, however, transfer to the alternate transponder will occur. Should the operation of the second transponder fail to satisfy the monitor, a similar action occurs with the second monitor controlling. Should the second monitor be dissatisfied with both transponders, automatic shutdown of the station occurs.

The design of the original Model DTB monitoring equipment was such that all monitored signals were derived from circuit points within the equipment cabinets. This arrangement was not entirely satisfactory because failure or malfunction of the antenna, its transmission line, the radio-frequency (rf) filter, or the antenna transfer switch resulted in loss of radiated power, or may prevent aircraft interrogation signals from reaching the ground-station receiver. Failures in the transmission line and antenna system have occurred occasionally. Such failures usually are unnoticed until a flight report reveals the condition, except when the failure occurs in the antenna transfer switch. For example, a shorted or open-circuit condition in the transmission line beyond the transfer switch can result in a high impedance point at or near the power-detector coupling probe in the coaxial line due to the high standing wave. In such a case the power monitor may detect a normal or excessively high voltage even though the radiated power may be negligible and no alarm or transfer action results.

The use of an external monitor antenna in the immediate field of the Model DTB antenna will permit direct measurement of relative radiated power from the transponder antenna. Any loss of radiated signal due to failure or malfunction of the transponder, the transmission line, the antenna transfer switch, or the Model DTB antenna then will result in an alarm condition and subsequent transfer to the standby transponder, the standby monitor, or shutdown.

In considering employment of an external monitor antenna, the type of antenna to use and its location are important. Basically, the antenna must have broadband characteristics such that it can operate satisfactorily over the entire reply-frequency range of the transponder.

Several important considerations govern the choice of location of the monitor antenna and associated detector. The existing power-monitor circuitry requires a video-pulse level of less than one volt at the input tube for satisfactory operation. Location of the monitor antenna and detector in close proximity to the Model DTB antenna is essential to obtain this required signal level without adding video-amplifier stages which would contribute to complexity and sources of failure. Further restrictions are imposed when the DME facility is installed at a very-high-frequency omnirange (VOR) site because the placement of monitor antennas on or at

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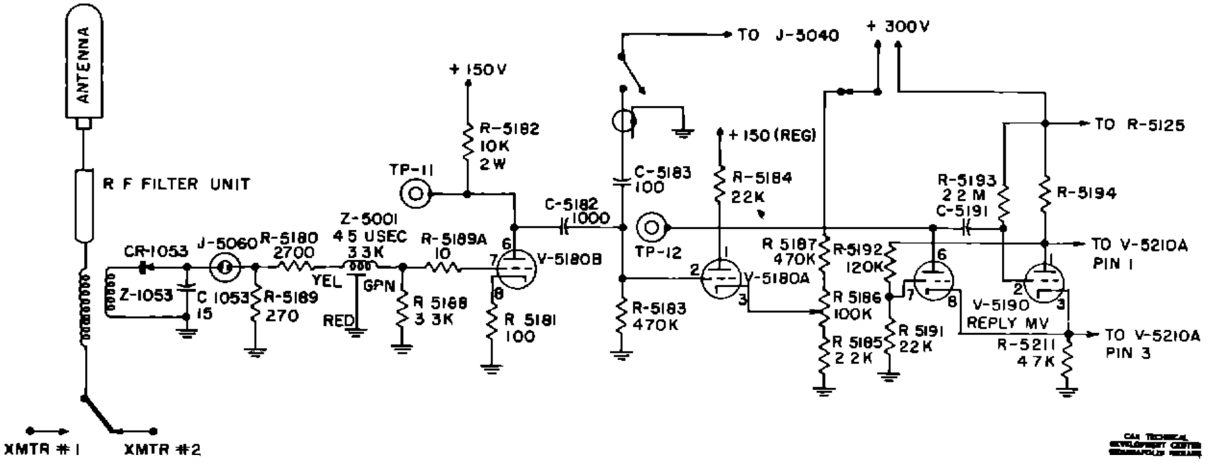


Fig 1 Unmodified DTB Monitor Power-Detector Circuit

the edge of the counterpoise might have an adverse effect on the VOR radiation pattern and which might introduce bearing errors. It is essential also that the external antenna assembly be weatherproofed adequately.

Another deficiency in the existing power-monitoring circuit is the difficulty in adjustment of the power-threshold level for alarm operation. Field experience has indicated that the adjustment of the monitor power-threshold control is extremely critical. This condition is caused in part by instability of the power-detector circuits which results occasionally in needless alarm and transfer action. Investigation of the problem also has revealed that the power-detector system does not always exhibit a linear relationship between detector output and input as it should in order to sense transmitter power-output variations properly. For optimum operation of the power-detector system, the rectified and amplified signal voltage must be proportional to the rf voltage at the detector.

The modifications developed and described in this report adequately eliminated the specified deficiencies and improved the reliability of the Model DTB transponder equipment.

POWER-MONITOR OPERATION

The Monitor-Test Generator produces a pair of pulses which, if accepted by the receiver, trigger the transmitter. A sample of the transmitter rf reply signal is fed to a detector and rectified. The video envelope of the rf pulses is returned to the monitor input circuit at J-5060. See Fig. 1. These signals are fed to the power-detector amplifier tube V-5180, a twin triode. The input triode is simply an amplifier, whereas the second section is an amplifier with variable bias. The bias is adjusted so that a specific input-power level to the detector is necessary to produce the minimum voltage amplitude required to trigger the following multivibrator circuits. Normally the bias is set to that value which results in a discontinuation of triggering of the following multivibrator stages due to insufficient pulse amplitude at TP-12 when the transmitter peak output power is 3.5 kilowatts (kw) or less.

In order to sense transmitter power-output variations properly, it was necessary that the power-monitor system provide a linear response throughout the required power range. In the original circuit, V-5180A was not necessarily linear because of the variable cathode bias and possible variations of other parameters. It was desired that the amplitude of the multivibrator triggering voltage at TP-12 be directly proportional to the peak rf voltage at the power detector. Thus, if the transponder peak-power output (and hence the detector peak-power input) is doubled, the peak voltage at TP-12 will increase by a factor of 1.41. It was imperative that the linear function be closely followed in the range of transponder-power output from 2.5 to 5.0 kw because the operational requirements of the Model DTB equipment specify alarm and transfer action at 3.5 kw.

The established procedure for power-threshold adjustment calls for setting the power-threshold control for an alarm condition when the amplitude of the detected identity pulse drops below a value equivalent to a third pulse-power output of 3.5 kw. This is an extremely critical adjustment, and the stability of the power-detector video-amplifier stages

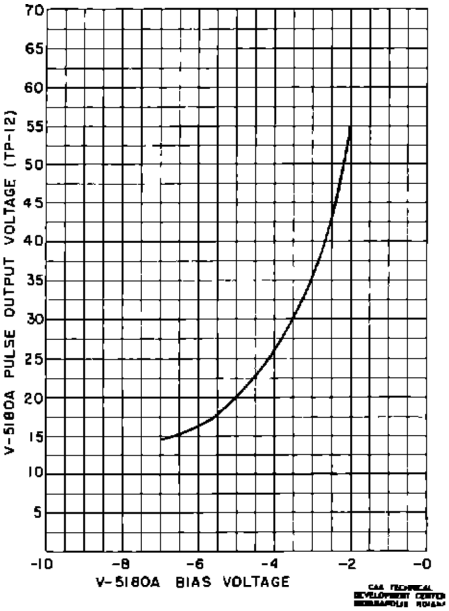
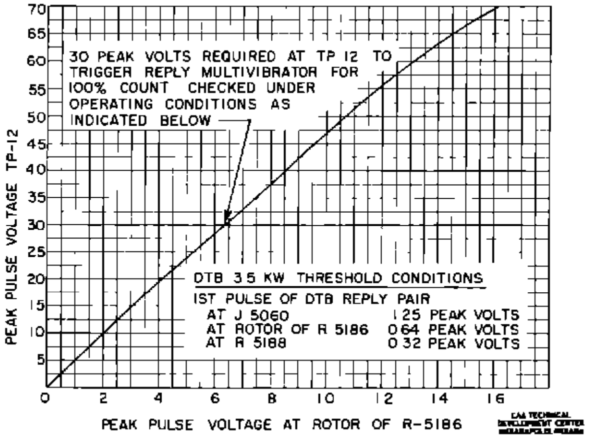


Fig 2 V-5180A Pulse-Output Voltage Versus Grid Bias

t be excellent to avoid voltage-gain changes which, in effect, would provide false indications power-output level For instance, if the gain of one of the video-amplifier stages were to in-se, this variation might result in continued triggering of the reply multivibrator even ough the output power may have dropped below 3 5 kw

Examination of the circuit in Fig. 1 shows that as the power-threshold control R-5186 is ried, the bias and hence the gain and linearity of the power detector V-5180A also are d. Testing revealed that the bias voltage is relatively unstable Figure 2 illustrates the pical effect of variation in output level at TP-12 for small changes in bias voltage Further, rotation of the power-threshold control of approximately one degree was sufficient to change e bias voltage by 0.5 volts It was concluded from field reports and laboratory investigation t the required stability could not be obtained with the existing circuitry

In order to effect optimum linearity of the power-detector circuitry, it was found cessary to fix the bias of V-5180A and to adjust the video-signal level (power-threshold con-ol) at a point in the circuit which does not affect the linearity of the system Figure 3 shows results of tests made to determine the optimum bias voltage for V-5180A. This curve



30 PEAK VOLTS REQUIRED AT TP 12 TO TRIGGER REPLY MULTIVIBRATOR FOR 100% COUNT CHECKED UNDER OPERATING CONDITIONS AS INDICATED BELOW

DTB 3 5 KW THRESHOLD CONDITIONS
1ST PULSE OF DTB REPLY PAIR
AT J 5060 1 25 PEAK VOLTS
AT ROTOR OF R 5186 0 64 PEAK VOLTS
AT R 5188 0 32 PEAK VOLTS

Fig. 3 Pulse Voltage TP-12 Versus Pulse Voltage at Rotor of R-5186

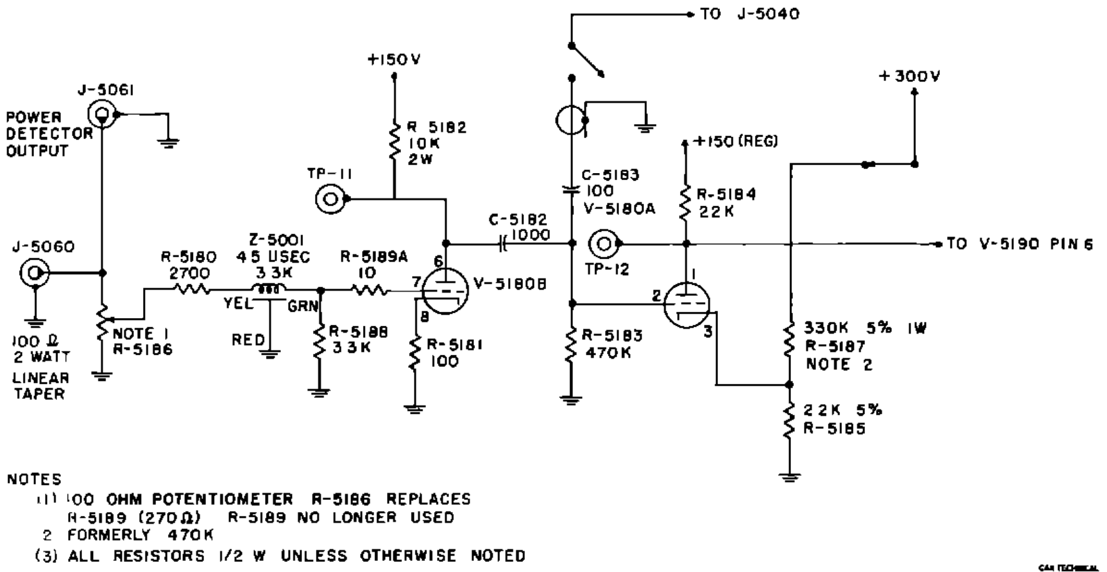


Fig 4 Modified DTB Monitor Power-Detector Circuit

indicates that a bias voltage of 3 5 volts, ±0 5 volts, will provide an adequately linear respon without requiring special selection of replacement tubes

Power-Monitor Circuit Modifications

In order to tie down the bias, the circuit modification required substitution of a single 330K, 5 per cent, 1-watt resistor to replace the 470K resistor R-5187 and the 100K resistor R-5186 See Fig. 4. The 330K resistor was designated R-5187 The cathode of V-5180A, pin was connected to the junction of R-5187 and R-5185 The bias of this stage then assumes an essentially fixed value. The original power-threshold potentiometer R-5186 was removed from the equipment.

Power-Threshold Control

A new power-threshold control designated R-5186 was installed and connected at the mo logical circuit point, that is, at the input to the power detector J-5060 This potentiometer wa mounted at its original location on the small panel door below the signal generator to retain u of the panel designation marking The value of the threshold potentiometer was changed from 100,000 ohms to 100 ohms for reasons to be explained later

With the original internal detector probes connected to the modified circuit at J-5060, adjustment of the monitor power-threshold control may be accomplished in accordance with th existing procedure after proper readjustment of the internal detector-coupling probes

The modification provided stability of the monitor power detector circuits by making the gain and linearity of V-5180A independent of the setting of the power-threshold control Further, the adjustment of the threshold control is not extremely critical. Figure 4 shows that a test jack, J-5061, was provided for checking the amplitude of the detected transmitter pulses and for viewing the shape of the pulse envelope when a suitable coaxial cable from this jack w connected to the external video-input connector of the test unit synchroscope. The test jack was installed just below the power-threshold control for convenience in connection

External Power-Detector Modification

Two important requirements governing the design of the external monitor antenna and associated detector assembly were that the external detector system provide a linear respon and at the same time provide the required amplitude of pulse voltage at J-5060 to operate the modified power-monitor circuit shown in Fig 4 Tests using an oscilloscope indicated that a minimum of about 0.32 peak volts is required at R-5188 to produce about 31 peak volts at TP- for full-count triggering of the reply multivibrator The peak voltage at the rotor of the threshold control R-5186 for this condition is about 0.64 volts

These values are approximate and they will vary because of tolerances in manufacture the external monitor antennas, variations in output level of particular crystals in the external

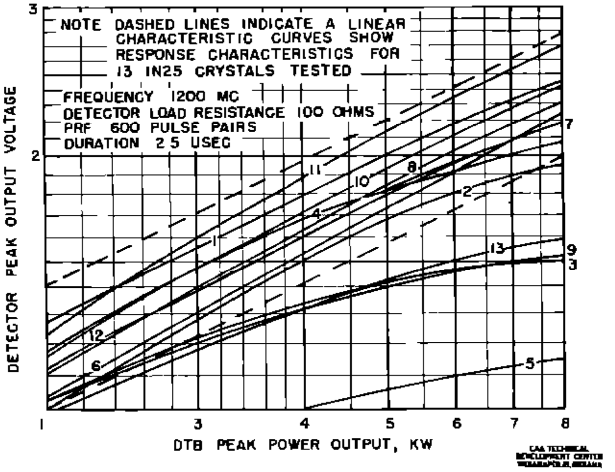


Fig 5 Typical Output Characteristics of 1N25 Crystal in Sierra Model 148 Detector

ector, and tolerances in components and the mutual conductance of V-5180 and V-5190 In r to make allowance for these variables and to provide an adequate range of adjustment ing the threshold control R-5186, it was concluded that the design of the external detector tem should be such as to provide a design center value of approximately 1 7 peak volts at 5060 when the transponder peak-power output is 4 0 kw

The specifications for the Sierra Model 148 crystal detector indicated that these units ight be utilized successfully in the external monitor detector application. It was necessary, wever, to determine if the 1N21B crystal usually employed in the Sierra Model 148 detector uld handle the peak power-input requirements with an ample safety factor Tests indicated at in order to arrive at the design value of 1 7 peak volts across a 100-ohm load at J-5060 r a power output of 4 kw, about 200 milliwatts peak-power input to the detector would be re- ured At 6 kw output, the detector peak-input power would be approximately 300 milliwatts he burnout pulse power of a typical 1N21B crystal is listed as 2.5 watts.[1] Because there is a cided lack of uniformity with regard to the burnout point for crystals of a given type, to reduce e possibility of burnout from external static charges, it was concluded that the lower frequency 125 crystal, with a nominal burnout point of 15 watts peak-pulse power, should be employed

The performance characteristics of the Sierra Model 148 detector with a 1N25 crystal e such that the peak video-output voltage is essentially a linear function of the peak rf input ge, within 10 per cent The response curves of Fig. 5, showing the detector peak-output ge versus transponder peak-power output, illustrate very close adherance to linearity for of 13 1N25 crystals tested in a typical Sierra Model 148 detector

It was recognized that the signal at the detector output should be an accurate reproduction the rf envelope of the transmitted reply pulses and that it would be advantageous to be able examine this signal at the transponder test unit with the oscilloscope. This required that the cted video signal be transmitted over a coaxial cable which is terminated at the monitor wer-detector input circuit in a resistance equal to the nominal impedance of the cable In or- r to match the impedance of the Type RG-62/U cable, a 100-ohm termination resistance in the rm of a potentiometer was substituted for the 270-ohm termination used in the original rcuit Lower values of cable and termination impedance were avoided because a higher ector-input power would have been required to obtain the same output voltage

Some difficulty was experienced in designing a pickup device which would satisfy all of the quirements of the external monitor system. It was demonstrated that Hazeltine Model DID-2 rrogator antennas, mounted in an inverted position at the Model DTB antenna base plate by e brackets, provided sufficient signal for monitoring purposes with no measurable

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[1] Henry C Torrey and Charles A Whitmer, "Crystal Rectifiers," Massachusetts e of Technology, Radiation Laboratory Series, Vol 15, McGraw-Hill Book Company c., New York, 1948, Table 8-3, p 262

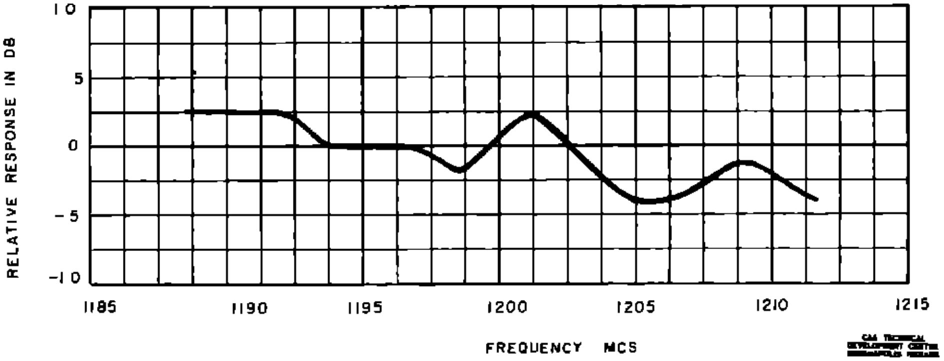

Fig 6 Frequency Response of Typical Pickup Loop and Detector

effect on the VOR course Each of these antennas was connected to its associated Sierra Model 148 detector by a short length of coaxial cable Effective as this arrangement was, the high cost of two such antennas for each of approximately 450 DME facilities precluded utilization of this assembly

Another attempt to find a suitable and economical means of external monitoring of the transponder output resulted in the use of small hairpin loops mounted on the Model DTB antenna base plate These pickup loops provide an essentially flat response over the entire reply-frequency band as shown by Fig 6, and they have no detectable effect on either the VOR course or transponder antenna pattern Moreover, the cost of the pickup loop assembly is very nominal compared to that of the Model DID-2 interrogator antenna The final design and mounting details of the pickup loop assembly are shown in Figs 7 and 8 It should be noted that the plane of the loop is parallel to the plane of the Model DTB vertical radiators. This provides a maximum signal with a minimum of loop length When a typical 1N25 crystal is used in the detector, proper operation of the monitor is obtained at about 50 per cent rotation of R-5186

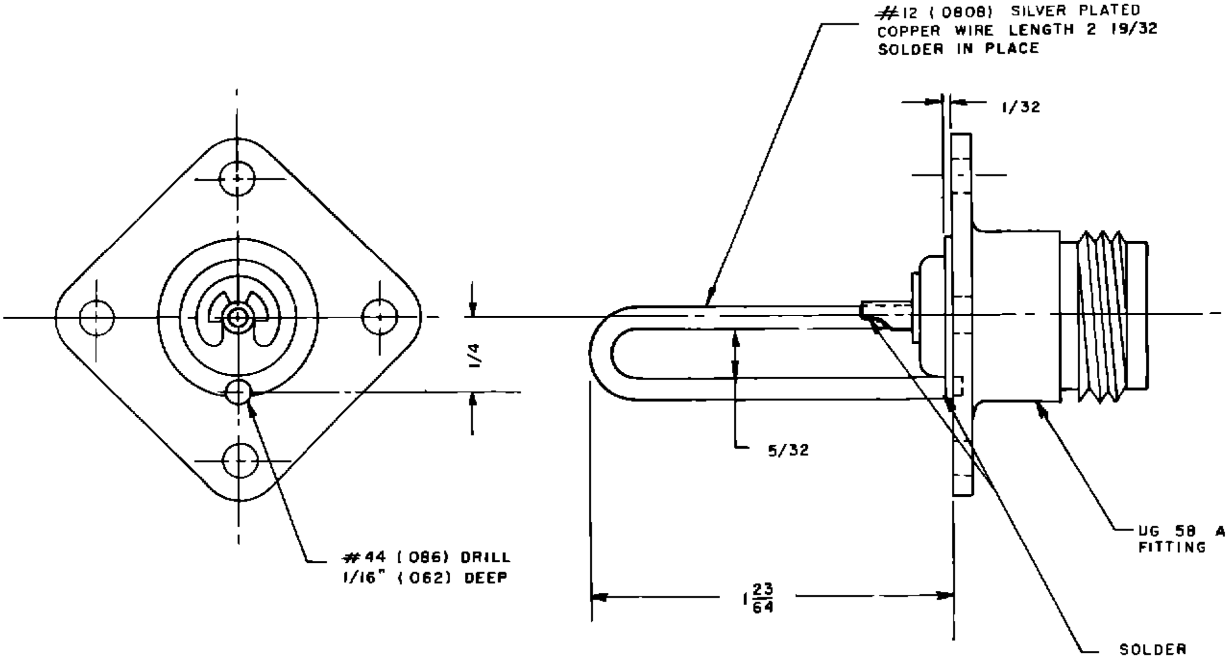

Fig 7 DTB External Monitor-Antenna Installation,
Monitor Pickup Loop Assembly Type 2

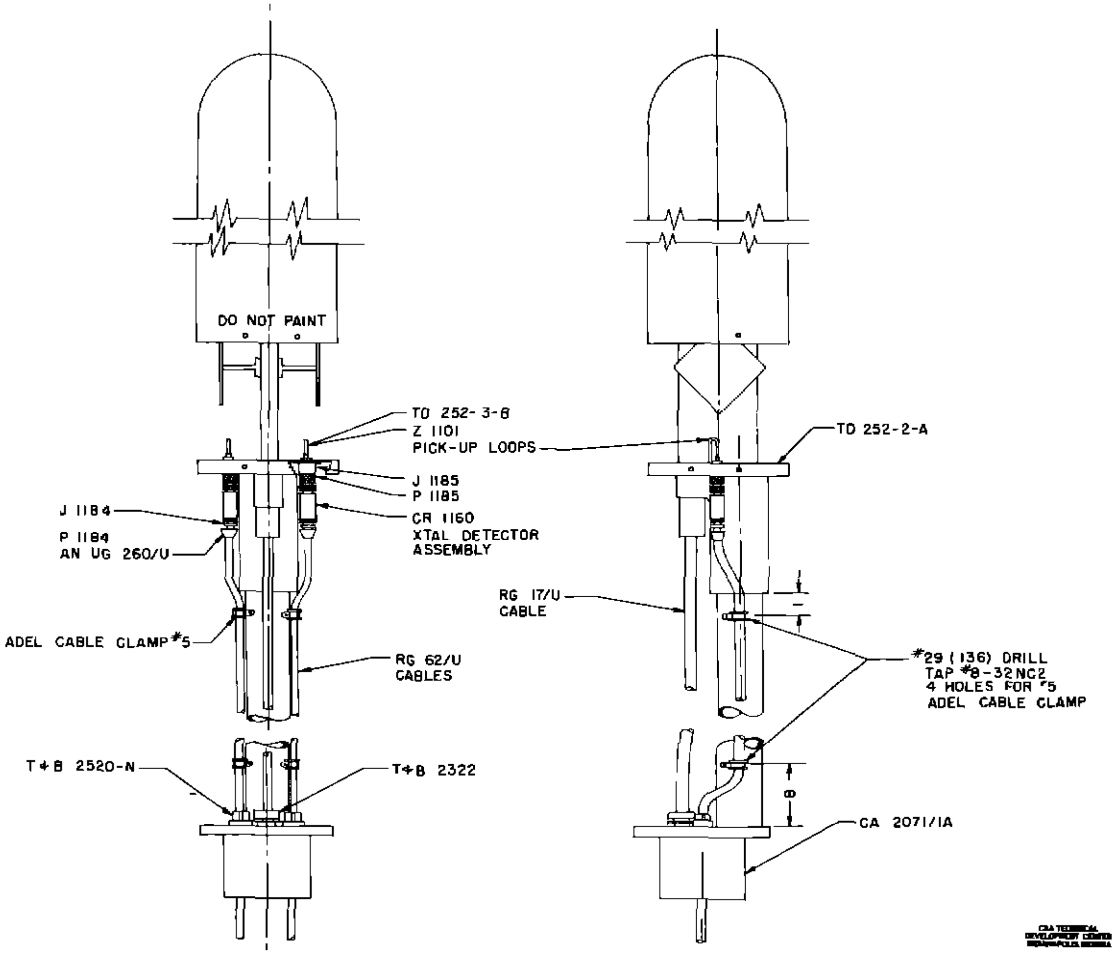

Fig 8 DTB External Monitor Modification Type 2, Monitoring Antenna Assembly

CONCLUSIONS

External monitoring of the Model DTB DME with the modifications described in this port, permits automatic external monitoring of the entire facility for the first time The rcuit modification makes the gain of V-5180A and the linearity of the entire monitor wer-detector system independent of the setting of the transponder power-threshold control e adjustment of the power-threshold control is made considerably less difficult, and the ocedure to be followed in this adjustment is not changed

The efficacy of the modifications has been confirmed by more than six months of operation without failure or malfunctioning of the external detector or the modified rcuitry.