FAA TECHNICAL CENTER
LETTER REPORT

THE APPLICATION OF TEST FUNCTIONAL MODULES TO THE REMOTE MAINTENANCE MONITORING SYSTEM

by

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16. Abstract

A major goal in the Remote Maintenance Monitoring System (RMMS) program is standardization of RMMS components, One approach to standardization is the Equipment Monitor/Test Functional Module (EQPM/TFM) concept. The EQM/TFM approach is described at the system level, applications to specific FAA facilities are defined, and the design requirements for a family of TFM's are given. This report can thus be used as a handbook to provide guidance in the design or procurement of RMM equipment.

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FOREWORD

This report is divided into Sections 1 and 2. Section 1 contains the text, which is an overall discussion of the Test Functional Module (TFM) concept, and a number of appendices, each of which defines the TFM application to a specific facility type. Section 2 contains a number of appendices that define the requirements for the various TFM's. By structuring the report in this way, if future needs require the monitoring of additional facilities or additional TFM's, they can be readily included by adding appendices to the report.

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SECTION 1

EXECUTIVE SUMMARY

Under the 80's Maintenance Program, remote monitoring and control of FAA facilities is planned. The Remote Maintenance Monitoring System (RMMS) will thus permit more effective utilization of the Airway Facilities (AF) technical staff by relieving the technician of many routine duties, and thus freeing him for higher level decision-oriented tasks. In addition, by constantly monitoring the facilities, RMMS should provide a higher level of facility availability, and permit the unmanning of many presently manned sites.

A major goal in the RMMS program is the standardization of remote monitoring equipment to the greatest extent possible. One approach to standardization is the Equipment Monitor/Test Functional Module (EQM/TFM) concept. In this concept a family of standard test functional modules would be used as stimulators and/or sensors in RMM applications to existing facilities. The TFM's for a particular facility would be controlled by an EQM. The EQM will be microprocessor-based and will include program memory, data storage, data input/output and standardized interfaces. The EQM/TFM approach should thus minimize logistics and training requirements for RMMS, and result in standard remote monitoring subsystems (Standard RMS) for many facilities.

This report consists of the text and two sets of appendices. The text provides an overall discussion of the Remote Monitoring Subsystem (RMS) based on the EQM/TFM concept. The various factors that must be considered, such as bus structures, environmental requirements, power requirements, and data interchange, are discussed from the systems standpoint, and recommendations are made in these areas.

The first set of appendices defines the application of TFM's to specific FAA facilities. A separate appendix is used for each facility type. These appendices specify the parameters to be monitored, the monitoring approach, and recommend the TFM's that should be used.

The second set of appendices defines the design requirements for each of the TFM's. In this case a separate appendix is used for each TFM. These appendices define the structure of the TFM, the sensors to be used, recommended scaling of the parameter data, and accuracies required.

This report, therefore, can be used as a handbook to provide guidance in the design or procurement of RMM equipment.

INTRODUCTION

PURPOSE.

The purpose of this activity was to define a global family of Test Functional Modules (TFM's) for the Remote Maintenance Monitoring System (RMMS). This work was performed under Task 9 of 9550-AAF-501-78-002.

BACKGROUND.

Under the 80's Maintenance Program, remote monitoring and control of FAA facilities is planned. RMMS will thus permit more effective utilization of the Airway Facilities (AF) technical staff by relieving the technician of many routine duties, and thus freeing him for higher level decision-oriented tasks. In addition, by constantly monitoring the facilities, RMMS should provide a higher level of facility availability, and permit the unmanning of many presently manned sites.

A major goal in the RMMS program is the standardization of remote monitoring equipment to the greatest extent possible. One approach to standardization is the Equipment Monitor/Test Functional Module (EQM/TFM) concept. In this concept a family of standard test functional modules would be used as stimulators and/or sensors in RMM applications. The TFM's for a particular facility would be controlled by an EQM. The EQM will be microprocessor-based and will include program memory, data storage, data input/output and standardized interfaces to the TFM's. The EQM/TFM approach should thus minimize logistics and training requirements for RMMS, and result in standard remote monitoring subsystems (Standard RMS) for many facilities.

During the planning stages of the RMMS program, AF Headquarters personnel generated a list of "Recommended Facilities to be RMM'd". This list was used for guidance in the preparation of this report and is included as Figure 1. Detailed monitoring requirements for the various facilities are given in the appendices to this report. For reference purposes, these monitoring requirements are summarized in Figure 2. Where TFM's can be used for monitoring a facility, the specific TFM's are shown. Where other monitoring approaches are recommended, this is indicated in the notes of Figure 2.

DISCUSSION

ORGANIZATION OF THIS REPORT.

Section 1 of this report consists of the text and a number of appendices. The text of the report is an overall discussion of the remote monitoring subsystem (RMS), based on the EQM/TFM concept. It includes references to the Remote Monitoring Subsystem Processor (RMSP), EQM, and related system requirements. This is necessary because the EQM/TFM structure must be considered in the context of its system implementation and not only as a stand-alone device.

Because of the large number of different facilities to be monitored, details of individual facilities are not included in the text. Instead, a number of appendices are part of this report, with one appendix for each facility type. Thus a reader can readily refer only to those appendices of interest to him. Each appendix contains a description of the facility monitoring approach, parameters to be monitored, and recommended TFM's to be used. Volume 2 of this report defines the functional requirements of the TFM's.

SYSTEM OVERVIEW

A block diagram of the overall system is shown in Figure 3. In a typical EQM/TFM configuration, the EQM and the associated TFM's are physically located in the same card cage, thus the EQM/TFM data interchange is over the common backplane data bus. Each EQM communicates over a serial data link with the RMSP, and the RMSP, in turn, communicates with the Maintenance Processor Subsystem (MPS). Polling of the EQM's is initiated by the RMSP, and the RMSP responds to polls from the MPS. EQM to EQM communication is routed through the RMSP, and does not have to go through the MPS. Since the EQM output is a serial data port it can also communicate directly with an MPS as shown by the EQM in the upper right hand corner of Figure 3.

Figure 3 shows a variety of interfaces for the different system elements, to indicate the options required. In a specific situation, the particular interface combinations used will depend on the physical distance between elements, geography of the area, and the data links available. For these reasons the system element designs should be such as to permit maximum flexibility in interconnecting the various elements.

REMOTE MONITORING SUBSYSTEM PROCESSOR (RMSP).

The RMSP (references 1, 2) provides the interfaces between a number of EQM's and the MPS. The design of the RMSP is flexible enough to interface from 4 to 60 EQM's, thus it can accommodate any mix of remote sites. The RMSP developed at the Technical Center was demonstrated with 35 interfaces: 33 operating at 1200 bits-per-second (bps) and 2 at 300 bps.

The RMSP design uses the Intel Multibus bus structure and is based on the 8086 microprocessor. Polling of the remote sites is controlled by the RMSP. Polling rates and data rates of the channels can be changed by local keyboard messages at the RMSP or by uplink commands from the MPS. In the same way, requests for data from a specific site can be requested at the RMSP local keyboard or by the MPS.

Since the RMSP uses the Multibus structure, it can be tailored to meet a variety of requirements. Memory can be expanded by adding additional memory boards. I/O capacity can be expanded by adding I/O boards. If more processing power is needed, an additional computer board can be added. Since Multibus is an industry standard, many vendors make Multibus-compatible boards, thus a wide variety of boards is available.

EQUIPMENT MONITOR (EQM).

The EQM (reference 3) is the processor that controls the associated TFM's for a particular facility. Figure 4 is a block diagram of a typical EQM/TFM configuration. The EQM and related TFM's will be physically located in the same card cage in most cases. (The exceptions are "Smart" TFM's, which may be remotely located).

The EQM developed at the FAA Technical Center uses the Multibus bus structure and is based on the Z80A microprocessor. Since the TFM's and EQM share the same card cage, the TFM's will also be built on Multibus circuit boards.

The EQM software structure consists of an executive routine and the specific applications program modules for the TFM's in a particular configuration, plus site adaptation data. For example, a radio communications facility, with both a transmitter and receiver, would have a transmitter module, a receiver module, and an environmental module, plus the executive routine and site adaptation data. (Present planning is to store the site adaptation data, constants, and limits in non-volatile RAM.)

TEST FUNCTIONAL MODULES (TFM)

The intent of the Test Functional Module (TFM) concept is to provide a family of standard modules to be used as stimulators, sensors and interfaces to FAA facility equipment. It should be recognized that although standard modules can be used for many monitoring functions, there will be requirements that are unique to certain facilities and these will require either special TFM's or a special monitor.

In considering the system requirements for the EQM/TFM subsystem, various data bus structures and microprocessors were examined. The decision was made to use the Multibus bus structure for the EQM in the system being developed at the Technical Center. (A more detailed discussion of the reasons for this choice is given in Reference 3). Since the TFM's will be physically installed in the same card cage as the EQM (in most cases), they will also be Multibus cards.

For TFM use, the Multibus structure has some definite advantages over other bus structures, which include:

1. Large card size (12 by 6.75 inches) allows many components on a card.

2. The backplane wiring is standard so any card can be plugged into any slot. (I/O is via front edge connectors or D connectors.)

3. Flexible TFM control/service (twenty four address lines and eight vectored interrupts).

4. Standard cards (for certain functions) are available from several vendors.

5. The bus structure is an industry standard, hence components are widely available. It is also an IEEE standard (IEEE-796) hence signal functions and timing are defined.

The disadvantage of Multibus is that the bus structure and bus interfaces are overly complex for facilities that have limited monitoring requirements. To overcome this problem, the use of a "smart" TFM is planned.

1. Smart TFM's

Some facilities will have very limited monitoring requirements (e.g., markers). In these cases the use of a Multibus-based EQM/TFM would be overkill. To provide monitoring of these facilities a "smart" TFM is proposed. A "smart" TFM will consist of a single chip microcomputer and the necessary signal conditioning and conversion components. Presently-available single chip microcomputers (e.g., 8751) can provide:

CPU
4K bytes of EPROM
128 bytes of RAM
Serial I/O port (UART)
Two counter/timers

In addition to the computer chip and signal conditioning/conversion components, a "smart" TFM would require interfaces to the facility equipment, a power supply, and a serial data link. This combination of components can be accomodated on smaller size circuit cards, but, in the interests of standardization, a "bare bones" Multibus card is planned. This card will have the Multibus card form factor but will derive only d.c. power from the back plane, thus there is no need for Multibus interface components. All signal input/output will be via edge connectors on the front of the card. In most cases, a "smart" TFM will be a stand-alone single-card module, remotely located from the host EQM. By using the Multibus-size card, there is enough room to accommodate the serial data line drivers and receivers, in addition to the TFM functions. Another advantage to this approach is that by using a single large card, rather than several small cards, the number of connectors (a source of maintenance problems) is reduced. Finally, by using the Multibus card, the card can also be plugged directly into an EQM card cage, if the "smart" TFM is co-located with other TFM's.

The smart TFM is basically a data acquisition subsystem which is interfaced to a host EQM. The data acquisition functions will be controlled by the microcomputer on the TFM, and the data will be stored for periodic transmission to the EQM. To minimize overhead in the TFM computer, all numeric data will be transmitted as binary data. Limit checking and decision logic will be resident in the EQM software, for the most part.

2. TFM Interfaces

The TFM's will have two interfaces, a digital interface to the EQM and an analog/digital interface to the facility equipment. Since the TFM's will be physically installed in the same cage as the EQM (in most cases), the digital interface to the EQM will be via the backplane wiring in the card cage. The interfaces to the facility equipment will be made external to the facility equipment, as much as possible, to minimize modifications to the facility hardware. However, some signals to be monitored are only available inside the facility equipment. In these cases it is recommended that a modification kit be provided to bring these signals out to a connector and thence to a demarcation strip. Thus all TFM interfaces will be external to the facility equipment. In the case of "smart " TFM's, the interface from the "smart" TFM to the EQM will be via a serial data communications port, which is a standard data interface.

3. EQM/TFM Subsystem Configuration

To establish an EQM/TFM subsystem configuration, a series of steps is required. The following sequence is suggested:

a. Determine the facility requirements:

   1. TFM's
   2. Facility interfaces to TFM's
   3. Data link

b. Select TFM hardware and software modules, and data link hardware

c. Install facility interfaces

d. Assemble and test software:

   1. Executive
   2. TFM software modules
   3. Communications module
   4. Adaptation

e. Program PROM's

f. Configure and test system

g. Install systems at facility

h. Check out system; locally, remotely

ENVIRONMENTAL REQUIREMENTS.

1. Temperature Ranges

In the application of RMMS components for field use, the operating environment of the systems must be considered. There are three classifications of integrated circuits, based (to a large extent) on operating temperature ranges. These are:

Commercial: 0°C to +70°C (+32°F to +158°F)

Industrial: -40°C to +85°C (-40°F to +185°F)

Military: -55°C to +125°C (-67°F to +257°F)

The cost of components in these three classifications increases as the temperature range increases. Typically, industrial grade components are 1.2 to 2 times the cost of commercial grade components, and military grade components are 3 to 5 times the cost of commercial components. Thus in order to keep system costs down, the component environmental requirements should not be overspecified.

In Reference 1, the assumption was made that the RMSP would probably be located in a controlled environment, thus commercial grade components could be used for RMSP's. The EQM and TFM will probably be required to operate under Environment II conditions (-10°C to +50°C, Reference 4) hence components capable of operating over a wider temperature range are required. Based on the temperature ranges given previously, industrial grade components (-40°C to +85°C) should meet the EQM/TFM environmental requirements, rather than using the more costly military grade components. Other options for Environment II conditions are to use CMOS components, or to use commercial grade components with a small resistance element as a heater to keep the component temperature above 0°C. This approach was successfully used in an ILS monitoring System at the FAA Technical Center and operated for more than 1 1/2 years (Reference 5).

Another factor that must be considered in the selection of components for a given temperature range, is the availability of components. Virtually every type of component and board-level assembly is available in commercial grade. However, in the industrial grades, military grades, and CMOS, fewer component types and board-level assemblies are available, because there is less demand for them. Thus, there will not be as large a selection of components in industrial or military temperature ranges, but no major problems should be encountered in providing the required monitoring functions.

2. Power Requirements

The EQM/TFM subsystems, for the most part, will be located at remote facilities. Consideration should be given, therefore, to their power requirements. An EQM/TFM subsystem can require from 100 to 600 watts of input power, depending on the number of circuit boards and their functions. (Most subsystems will be in the 100 to 200 watt region). It should be noted that subsystems using CMOS components would only require about 10% of this power, but only limited types of CMOS components are available at present.

To provide power to RMM equipment, either the AC power line at a facility, or batteries can be used. The choice depends on the criticality of the data from the remote monitor. If the power source is the AC line, failure of prime power (without battery backup) can result in the following:

1. Loss of all stored data. (Present planning for the EOM is to store adaptation data, constants and limits in non-volatile RAM.)

2. Loss of internal time.

3. Inability of the monitor to report the power failure or facility status to the central processor.

Some steps can be taken to minimize the loss of data (e.g., non-volatile or battery backed up RAM), but the processor will not be running. Because of this, and also because the data link requires power, communications with the central processor will be lost. A solution to this is to provide battery backup for both the remote monitor and the data link. If this cannot be justified, because of cost, the alternative is to accept the loss of monitoring capability until power is restored.

In facilities where battery operation already exists (i.e., ILS) it may be feasible to operate the monitor from the existing batteries, if the extra load can be supported. (A 100 watt load will draw about 8 amperes from a 14 volt battery, or 4 amperes from a 28 volt battery.) In the case of a "smart" TFM, the power requirements are estimated at less than 25 watts (about 2 amperes from a 14 volt battery), hence operation of "smart" TFM's from the facility battery is feasible.

3. Lightning Protection

Since the EQM/TFM subsystems will usually be located in a remote shelter, surge protection should be provided on all TELCO lines and power lines. If an RF link is used, lightning protection of the antenna and the transmitter/receiver is necessary, with a good lightning ground.

DATA INTERCHANGE

1. Data Links

The EQM/TFM subsystems will be physically installed in a variety of facility locations, all having different data link capabilities. Data links can be divided into the following categories:

a. Dedicated TELCO circuits

1. Non-shared (data rate: 1200-9600 bps)

2. Shared with other functions, such as voice (data rate: usually 110-300 bps).

3. Frequency division multiplex (FDM), usually a multi-user party line (data rate: 110-600 bps).

b. Dial-up TELCO circuits - single user systems (data rate: usually 300 or 1200 bps).

c. RML circuits

- used the same as dedicated TELCO circuits

- can support broadband transmission

d. RF links

- usually a polled party line type system (data rate: dependent on bandwidth of link)

- potential problems are availability of RF channels, and possible interference to other services

e. Other links

1. Fiber optics

- will support broadband transmission, hence many channels

- immune to electrical interference

- special installation requirements

- installation costs high

2. Coaxial cable

- will support broadband transmission, hence many channels

- installation costs high

3. Infra-red (IR) links

- for short distances (about 3000 feet maximum)

- affected by weather

- high data rate capability

Of the different data links listed, it is expected that TELCO circuits and RML will be used the most (because of availability). Due to the various types of circuits and bandwidths that may be used, maximum data communications flexibility is required. Therefore, it is recommended that asynchronous data transmission be used from the EQM to the RMSP, and also from the "smart" TFM's to the EOM, with the data rate being wire-strap or software selectable.

2. <u>Data Transmission Rates</u>

The data transmission rates to be used for EQM to RMSP communications (and "smart" TFM to EQM communications) are determined by several factors including the following:

a. Data link characteristics

b. Synchronous vs asynchronous data

c. Amount of data to be transmitted

d. User requirements

Each of these will be discussed in turn:

a. Data link characteristics. - The limiting factors in the data link characteristics are the channel bandwidth and the modem design. The channel bandwidth imposes a limit on the baud rate (number of signalling unit changes per second), and the modem design determines the number of bits of information transmitted per signalling unit. Low speed modems usually transmit one bit of information per signalling unit, hence the terms baud and bits-per-second are (wrongly) frequently used interchangeably.

b. Synchronous vs asynchronous data. - FAA Order 1830.2 dated 2/17/78 (Reference 6) states that all data transmitted at 1200 bps and below must be asynchronous, and all data transmitted at 1200 bps and above must be synchronous. At 1200 bps the data can be either synchronous or asynchronous. Since we recommend asynchronous transmission from the EQM to the RMSP, and from "smart" TFM's to the EQM, the data rates recommended are 1200 bps or less.

c. Amount of data to be transmitted. - The amount of data to be transmitted is primarily a function of the number of parameter values to be transmitted. At a data rate of 300 bps, 30 bytes of data per second will be transmitted. At this data rate, a data block of 256 bytes (plus control characters) can be sent in less than 10 seconds. Since a scheduled poll, for data collection purposes, will typically occur once every four hours, data rates of 300 bps (or even less) should present no problem.

A recent project at the FAA Technical Center provides an example of data transmission requirements. In this task, RMMS data was collected from remote MLS sites, via a dial-up TELCO link at 300 bps. Forty parameter values were transmitted as ASCII characters (six characters per parameter). Numerous text characters were transmitted along with the parameter values, for user convenience. However, if we limit the data transmission to only the parameter values plus eight control characters, the total number of characters is:

40 parameters x 6 characters/parameter	=	240
control characters	=	8
total		248

Using asynchronous ASCII code requires 10 bits per character. Thus, at 300 bps, 30 characters per second are transmitted, so transmission of the 248 characters would require about 8.27 seconds. This example used a low data rate system and ASCII characters, and yet, the time to transmit the data is less than 10 seconds.

d. User requirements. - The user requirements affect data rates in two ways, the interface device used, and response time requirements. If the user interface device is a "dumb" hard copy portable terminal (e.g., silent 700), the data rate is usually constrained to 300 bps, since many of these terminals will not print faster than 30 characters per second.

In NAS MD-790 (Reference 7) a response time requirement had been given that an alarm should be reported within 5 seconds after it is detected at the facility. The need for a 5-second response time is questionable, since it will take the maintenance technician several minutes to analyze the data and decide on the action required. If a trip to the facility is necessary, it will then take from 15 minutes to several hours to reach the facility (depending on the distance). In comparision to these times, the 5-second response time is negligible, and would require a more expensive high speed data link to support it. If the purpose of the 5-second requirement is to quickly provide facility status information, an alternative approach is suggested. This is the use of an Alarm Status Message. In this message each parameter in the facility is represented by a single bit, with a "1" representing an alarm on the associated parameter.

Thus, using ASCII characters to transmit status information, the four low order bits can be used as status bits. Based on this, if a facility has 40 parameters, their status could be reported in 10 characters. If we add 8 bytes for control characters, the total message length is 18 bytes. Even at 300 bps, 18 bytes could be transmitted in less than one second. The alarm bits in the Alarm Status Message would be decoded, formatted, and displayed by the MPS as status information to alert the maintenance technician. Meanwhile, the facility monitor would follow up by transmitting the actual values of either a subset of, or all of the site parameters for the technician's information and analysis. Thus the alarm condition would be quickly reported, even over low speed data channels.

3. Error Checking

NAS MD-790 defines the interface and protocol requirements to the MPS. In MD-790, the use of a cyclic redundancy check (CRC) character is specified for error checking. While a CRC is a good error check for higher level computers and high data rate systems, a simpler error check should be used in the EQM to RMSP interface (and "smart" TFM to EQM interface), to minimize overhead in these processors. The use of a longitudinal redundancy check (LRC) is recommended for these interfaces. An LRC can be easily implemented in software, requiring a minimum amount of program memory and execution time. A CRC check, on the other hand, requires a special hardware chip (that is not standard on "off-the-shelf" communications circuit boards) or a much larger software subroutine than an LRC. For example, an LRC sub-routine requires two extra instructions, but a CRC subroutine requires about 70 bytes of program code. Additionally when the program execution time is considered, the CRC program consumes substantially more time. To save costs, the use of a LRC is recommended for the EQM to RMSP (and EQM to "smart" TFM) interfaces.

4. Electrical Interfaces

FAA Order 1830.2 states that data interfaces shall use the EIA RS-449 interface. A major problem with RS-449 is that very few commercial devices are available that use RS-449. Most off-the-shelf devices (i.e., terminals, printers, communication devices) use the RS-232C interface. Thus the use of RS-449 devices usually requires that they be made to FAA specification, which increases their cost. For the EQM to RMSP (and EQM to "smart" TFM) interfaces the RS-232C interface is recommended. It should be possible to get a waiver of Order 1830.2 to use RS-232-C for the reasons given.

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10. CT-82-100-56LR

ALS - Approach Light System
MALS - Medium Intensity ALS
MALSR - Medium Intensity ALS with Runway Alignment Indicator Lights
VASI - Visual Approach Slope Indicator (where cable currently exists)
DASI - Digital Altimeter Setting Indicator

ARSR-3 - Air Route Surveillance Radar (FAA and Military)
ATCBI-4,5 - Air Traffic Control Beacon Interrogator
Digital Defruiter
Common Digitizer
Mode S
RMLR -Radar Microwave Link Repeater if current tube type replaced
BUEC - Backup Emergency Communications (all except these at tube type ARSR and ARTCC
ARSR (Tube Type) - Remote control only

ASR-7,8,9 - Airport Surveillance Radar (FAA and Military)
ATCRB - Air Traffic Control Radar Beacon (extent of RMM pending ACE test)

GS Glide Slope Solid State
LOC - Localizer Solid State
Markers - Status only
NDB - Non-Directional Beacon Status only
RVR - Runway Visual Range Solid State
VOT - VHF Omnidirectional Range Test - Part of small airport package
MLS - Microwave Landing System
TACAN - Tactical Air Navigation - Replaced by Second Generation VORTAC
DF - Direction Finder Solid State
DVOR - Doppler VOR
DME - Distance Measuring Equipment if colocated with other RMM'd Equipment
FM - Fan Marker - Status only
LMM, LOM - Compass locators Status only
H, HH - Homing Radio Beacon Solid State status only
IFST - International FS Transmitter Station
IFSR - International FS Receiving Station

RCO - Remote Communications Outlet if located into AWOS
CHI - Cloud Height Indicator when incorporated into AWOS
AWOS - Automated Weather Observation Station
RRH - Remote Reading Hygro thermometers if parent facility is RMM'd
AFSS - Automated Flight Service Station (self-monitor capability)

Battery Backup - If parent facility monitored
Building - Housing equipment that is RMM'd
CTRB - Center Building Maintenance monitored via the CCMS
HVAC - Heat, Ventilation and Air Conditioning at those facilities that are RMM'd
Prime Power Commercial - monitored at those facilities that are RMM'd
Prime Power Agency
PCS - Power Conditioning System if RML is RMM'd, other should be status only
SX E/G - Stand-by Engine Generators when parent facility is RMM'd

FIGURE 1. RECOMMENDED FACILITIES TO BE REMOTELY MONITORED

TFM's (SEE NOTE 15.)

Facility	1	2	3	4	5	6	7	8	9		S1	S2	S3	S4	NOTES
ALS, MALS, MALSR, VASI												X			
ATCBI-4, ATCBI-5, ATCRB, Defruiter				X											
DASI															1
ARSR-3															2
ARSR, CD					X										3
Mode S															4
RMLR															5
BUEC		X	X			X	X								6
ASR-7, 8, 9					X								X		7
GS											X				
LOC											X				
Markers, NDB, VOT FM, LOM, LMM, H, HH											X				
RVR									X						8
MLS															9
TACAN															10
DF						X									
DVOR															11
DME														X	
VOR															10
IFST			X												
IFSR		X													
RCO, RTR, FSS RCO		X	X												
CFW, CHI, LLWAS, AWOS, RRH															12
AFSS															13
Battery Backup, Bldg., HVAC, Prime Power (Comm'l), Prime Power (Agency, PCS, SX E/G	X														14

FIGURE 2. FACILITY/TFM SUMMARY

NOTES:

1. A modification to the DASI will provide a serial data output to the host EQM. (See Appendix D).

2. The ARSR-3 monitoring approach is dependent on the results of ACE ARSR-3 monitor tests. (See Appendix A).

3. ARSR, CD - Uplink control and status only. (See Appendix E).

4. Mode S monitoring will be incorporated in the Mode S system. A task to investigate and evaluate Mode S monitoring is being planned (by APM-320).

5. RMLR. Monitoring should be built in to new RML equipment.

6. BUEC monitoring is not considered cost-effective. (See Appendix F).

7. ASR-7, 8. Present planned approach is to use commercial test equipment by GPIB (IEEE-438 Bus). ASR-9 will have built-in monitoring capability. (See Appendix G).

8. To monitor an RVR, the functions of the Signal Data Converter (SDC) should be duplicated. Thus, it would be more cost-effective to replace the existing SDC's with microcomputer-based SDC's, as described in Report No. FAA-CT-80-43. (See Appendix J.)

9. MLS facilities will have built-in monitoring capabilities. Under a task presently assigned to the FAA Technical Center, parameter data from remotely located MLS sites is being collected and analyzed.

10. TACAN, VOR. The Second Generation VOR will have built-in monitoring capabilities.

11. The TFM approach is not recommended for the DVOR (See Appendix L).

12. Monitoring of these sensors will be accomplished by the AWOS processor.

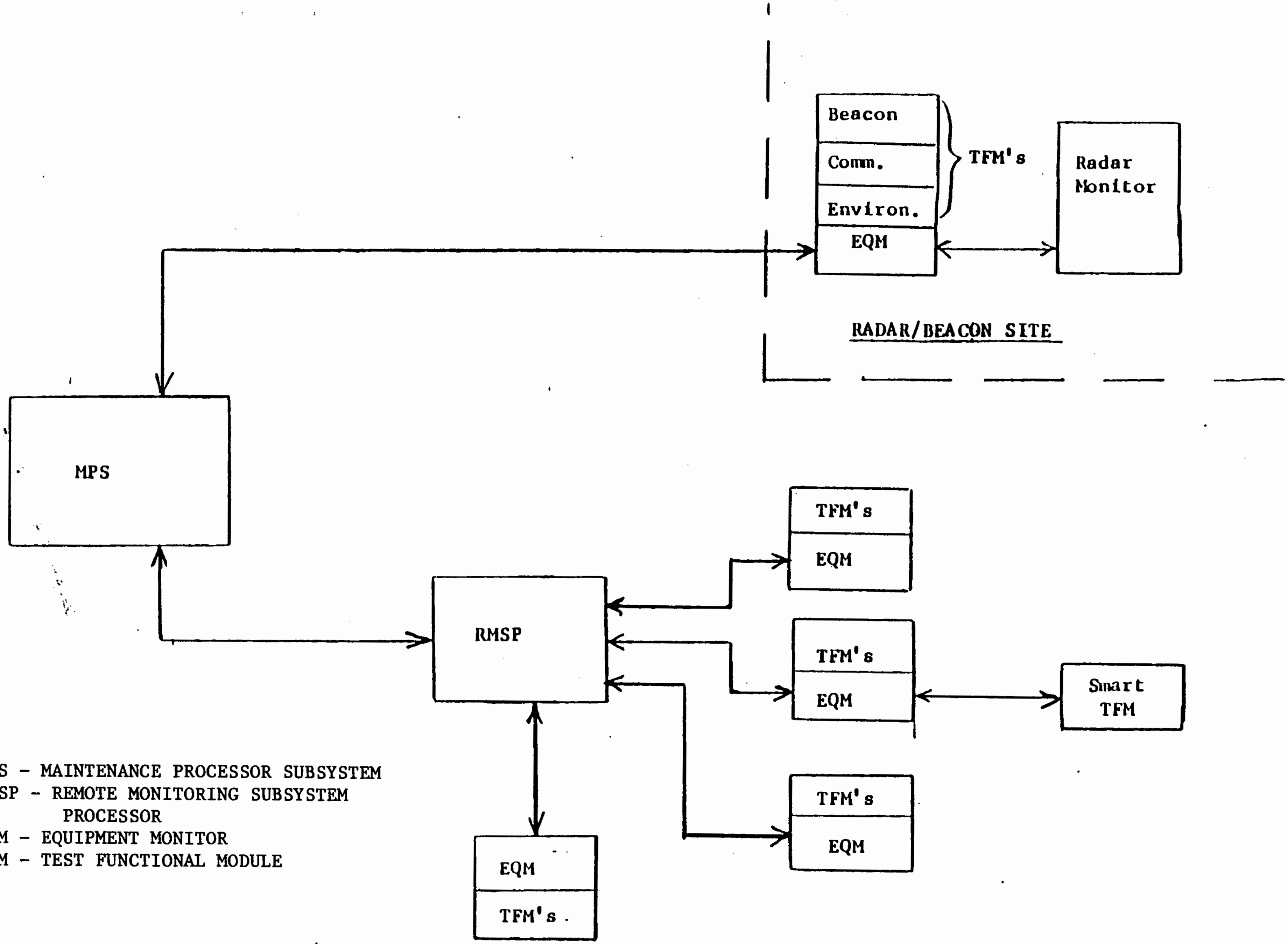
13. The AFSS will have built-in monitoring capabilities.

14. TFM #1, the Environmental TFM will be used at any location where building monitoring is required.

15. List of TFM's

#1 Environmental
#2 Receiver
#3 Transmitter
#4 IEEE-488
#5 Status/Control
#6 Serial Communications
#7 BUEC Controller
#8 BUEC Decoder
#9 RVR

Smart TFM #1. Markers, VOT
Smart TFM #2. Lighting
Smart TFM #3. Radar Interface
Smart TFM #4. DME



MPS - MAINTENANCE PROCESSOR SUBSYSTEM
RMSP - REMOTE MONITORING SUBSYSTEM PROCESSOR
EQM - EQUIPMENT MONITOR
TFM - TEST FUNCTIONAL MODULE

Figure 3. Typical EQM/TFM System Configuration

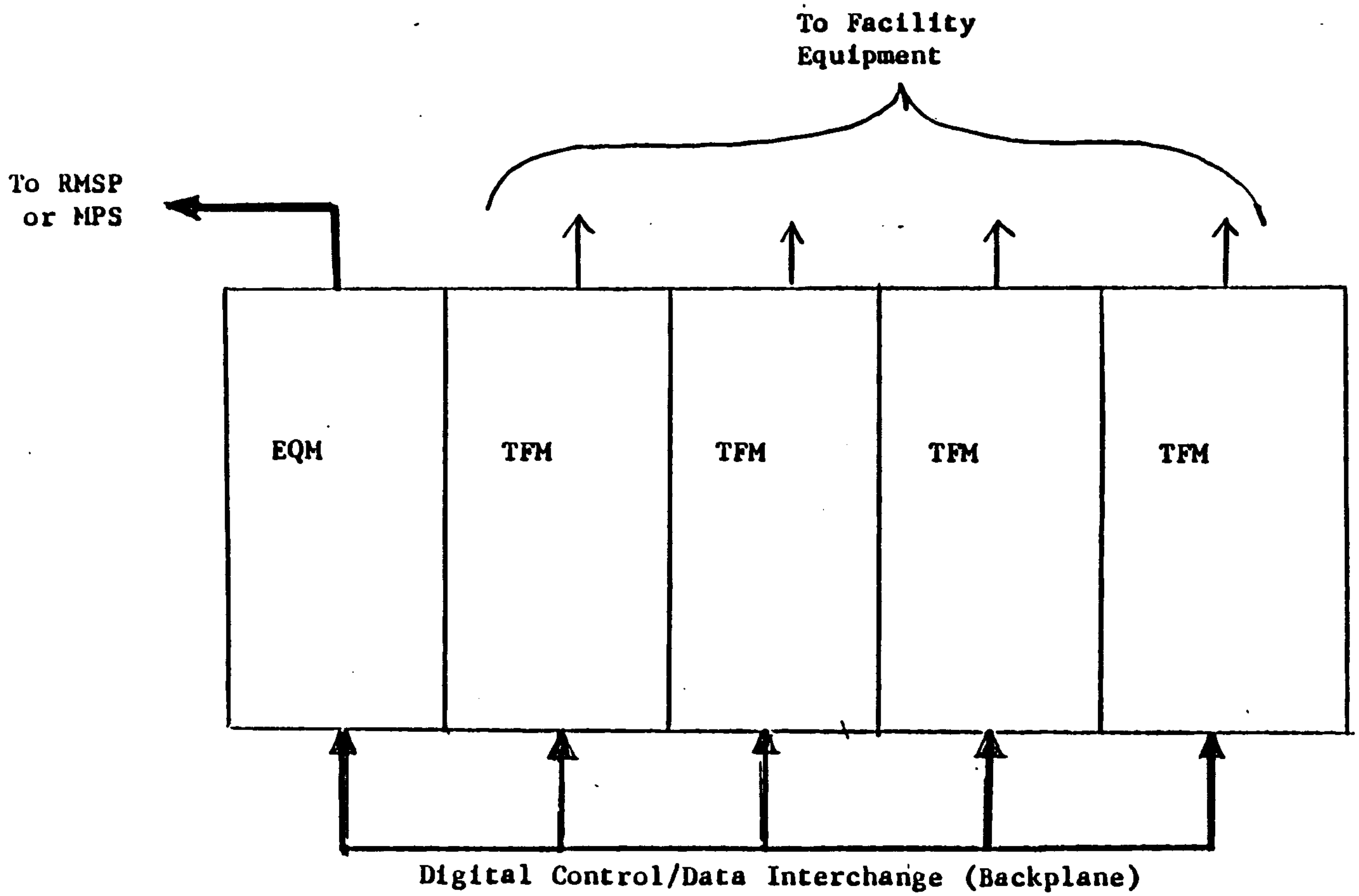


Figure 4. Typical TFM/EQM Interconnection

APPENDIX A

NON-TFM FACILITIES

In the investigation of the use of TFM's for monitoring FAA facilities, it was found that some facilities do not require TFM's, since the facility equipment will have a built-in monitor. The RMMS interfaces to these facility monitors will be either a serial data output (i.e., RS-232C or RS-449) or a parallel data output (i.e., IEEE-488). These interfaces can be accommodated by TFM's #4 or #6. The following paragraphs of this appendix summarize the non-TFM facilities.

1. ARSR - 3

Work is presently on-going in the Central Region to develop a monitor for the ARSR-3 radar. When this activity is completed, the resulting documentation should define the monitor requirements.

2. Mode S

The Mode S equipment will have a built in monitor. Under the Mode S project at the FAA Technical Center the requirements for this monitor will be defined.

3. MLS

The MLS equipment will have a built-in monitor. Under a task at the FAA Technical Center, inputs are being provided to the MLS specification for monitoring requirements.

4. VOR/TACAN

Monitoring of the VOR and TACAN is built in the equipment under the second generation VOR program.

5. AFSS

The Automated Flight Service Station equipment will have a built-in monitoring capability.

6. Weather Sensors

The CFW, CHI, LLWAS, and RRH when interfaced to AWOS, will be monitored by the AWOS processor. Present plans are to incorporate the RMM data into the Weather Mesage that is transmitted from AWOS to user facilities, and strip off the RMM portion for maintenance use.

7. RMLR

New procurement of RML equipment will have built-in monitoring. It is not planned to retrofit existing RML equipment.

APPENDIX B

LIGHTING SYSTEMS MONITOR

PURPOSE

This appendix defines the EQM/TFM application to the Airport Lighting System.

BACKGROUND

Lighting systems at airports cover a full range of configurations from a bare minimum for small unattended airports to multiple runway systems for large airports. To monitor the various combinations and configurations the monitoring system should be a flexible, modular, expandable system. For this reason the lighting systems TFM is a stand-alone module that can monitor the small airport lighting by itself. For larger airports additional modules are used where and as required. This modular approach permits monitoring either centralized or distributed lighting systems. The lighting systems monitor would typically be located in the transformer vault or switchgear room where access to the lighting circuits can be obtained.

The lighting monitor module is a smart TFM (Smart TFM #2) consisting of a single chip microcomputer, a 32-input A/D converter (each with a signal conditioning plug-in) 2 counters, 4 status inputs and 4 control outputs.

MONITORING APPROACH

The 32 inputs to the A/D converter are conditioned by the plug-in units. Depending on the signal to be measured, the appropriate plug-in can be selected to measure a.c. volts, a.c. current, d.c. volts or d.c. current. The plug-in converts the input signal to a scaled DC voltage that is converted to digital data by the A/D converter. The majority of these inputs will be either AC voltage or currents, but the DC option exists in case it is necessary to measure a DC voltage or current.

Because of the different lighting system configurations, this TFM is designed to accommodate all possible variations. The application to a specific lighting system depends on the type of system, and must be configured for the specific airport. For example, in a voltage driven system, the voltage for different intensity levels is known and is stored in the host EQM. Similarly, the current for each lighting circuit is known. Thus if one or more bulbs fail in a curcuit, the change in current can be readily detected and reported.

A.C. Voltage

A.C. voltage is measured by connecting a 6.3 volt transformer and a scaling potentiometer at the source. The scaled a.c. signal is fed to the TFM where it is digitized by the A/D converter.

A.C. Current

A.C. current is measured by using a current transformer to sample the current in the circuit. The secondary voltage from this transformer is fed to the TFM where it is scaled and digitized.

D.C. Voltage

D.C. voltage is scaled by a resistive divider at the source, and fed to the TFM where it is further scaled and digitized.

D.C. Current

D.C. current is measured by a Hall effect transducer, which provides a D.C. output voltage proportional to the current.

Line Frequency

Line frequency is measured by sampling an A.C. input and counting the number of cycles over a 16 second period. This will measure line frequency up to 63.94 Hz and will provide resolution to 0.0625 Hz.

Flash Rate

Flash rate is measured by sampling the flasher control and counting the number of flashes for 15 seconds. The latest four of these 15 second counts are accumulated to provide the one minute count rate. By using a 15-second count interval, changes in flash rate can be detected sooner than by counting for a full minute.

Status Signals

Status inputs are provided to permit monitoring the status of up to four signals. One application for these is to monitor a change in VASI tilt angle. A tilt sensor is mounted on the VASI support and the go/no-go signal from this is fed to the status input to report a change in tilt angle.

Control Outputs

Four relay outputs provide control for switching external devices. One application is to periodically operate a local radio transmitter to check the operation of radio controlled lighting. In this application, the microcomputer in the TFM would control the keying of the transmitter, verify that the lights were turned on, and that they were turned off again after the appropriate time interval.

Microcomputer Operation

The microcomputer in the TFM will control all the data collection/monitoring functions of this TFM. Software for all the subroutines will be resident in the microcomputer, and the required subroutines will be selected by wire-strapping. This TFM is basically a data acquisition subsystem for the host EQM and will be interfaced to the host EQM over a serial data link. Error checking and limit checking will be performed by the host EOM, for the most part.

TFM's REQUIRED

To monitor the lighting systems, Smart TFM #2, Lighting, is required. This TFM is described in Appendix 2BB.

APPENDIX C

ATCBI MONITOR

PURPOSE

This appendix defines the EQM/TFM application to monitoring ATC Beacon systems.

BACKGROUND

Most of the radar beacon systems used by the FAA are ATCBI-4 and ATCBI-5 systems. There are also some ATCBI-3 systems which are vacuum tube devices. To provide a monitor for these systems, the Agency awarded a production contract to Cardion for Radar Beacon Performance Monitors (RBPM). Monitoring a beacon system requires specialized monitoring functions, thus the RBPM was specifically designed to perform this monitoring task. Delivery of the RBPM to the field is scheduled to start early in Calender Year 1983.

MONITORING APPROACH

The Radar Beacon Performance Monitor (RBPM) is composed of two major components, the Remote System Monitor (RSM) and the Integral System Monitor (ISM). The RSM is a dual-channel transponder, with adjustable transmitter power output, receiver sensitivity, range, ID code and altitude code. It is remotely located from the beacon site and serves as a reference target for the beacon system. The ISM is interfaced to the beacon ground station equipment (e.g., ATCBI-5) and monitors the performance of the beacon system.

The ISM is a dual-channel monitor with each channel interfaced to its corresponding channel on the beacon system. A list of the monitored parameters is given in Table C-1.

The output data interface for the ISM is via an IEEE-488 bus. Thus, the TFM for the beacon monitor is TFM #4, IEEE-488, which is controlled by its host EQM. The ISM is designed to output data once per antenna scan for the data acquired during a scan. The TFM/EQM acquires the scan data and double-buffers it in the EQM. Thus while one buffer is receiving the data, the other buffer has the data from the previous scan. When a request for data is received (from an outside source) the filled buffer is locked up until it has transmitted all the requested data to the requesting device. The EQM software will be written so that all the parameters or only specific parameters can be requested. In addition, status and alarm information can be provided.

TFM's REQUIRED

To monitor the beacon system TFM #4, IEEE-488 (Appendix 2D) is required along with the host EQM. In many cases, however, the beacon equipment will be co-located with a radar, possibly a CD and communications equipment. In addition, an environmental TFM is required. The TFM's to support these other functions will thus be included as part of the site monitoring subsystem package.

TABLE C-1

PARAMETERS MONITORED BY RBPM

P1 Directional Power
P3 Directional Power
P1 Omni Power
P2 Omni Power
P1 Directional Pulse Width
P2 Directional Pulse Width
P3 Directional Pulse Width
P1 Omni Pulse Width
P1 - P2 Pulse Spacing
Mode 2 Spacing
Mode 3/A Spacing
Mode C Spacing
STC #1
STC #2
STC #3
Quantization Threshold
Raw Video Level
Quantized Video Level
Defruiter Video Level
VSWR, Directional
VSWR, Omni
RSM Azimuth
RSM Range
RSM Replies
Azimuth Pulse Generator Count
Internal Reference, + 5 Volt
Internal Reference, + 15 Volt
Internal Reference, - 15 Volt
Mode Interlace

APPENDIX D

DASI Monitor

PURPOSE:

This appendix defines the monitoring approach for the Digital Altimeter Setting Indicator (DASI).

BACKGROUND

The DASI is a precision barometric pressure indicator that provides an output in inches of mercury in digital form. The master unit provides a reading to three decimal place (0.001 inch), and the data is transmitted to remote units to display readings to two decimal places (0.01 inch). The remote units are read by air traffic control specialists to give pilots the barometric pressure setting for their altimeters.

MONITORING APPROACH

The master unit of the DASI is a very precise pressure sensor, since 0.001 inch of pressure change corresponds to about a 1 foot altitude change at sea level, thus it is not feasible to provide a monitor reference of equal precision. The monitoring approach, therefore, is to continually monitor the digital pressure values of the master unit and transmit them to the EOM periodically. The EQM software will examine the rate-of-change of pressure, and also compare the pressure to absolute limits. If either the rate-of-change or the absolute pressure values exceed predefined limits, an alarm will be declared. DASI error states will also be reported as an alarm.

The monitor interface to the DASI will not be a TFM. The interface will consist of a small logic assembly (basically a latch and UART) that will be installed in the master DASI unit as a modification. The output from this modification will be a serial data stream that is connected to a serial data port on the associated EQM. The modification will derive its power from the DASI. This modification is installed in the master DASI unit to obtain data that has 0.001 inch resolution.

APPENDIX E

ARSR, CD Monitor

PURPOSE

This appendix addresses the EQM/TFM applications to the ARSR radars and Common Digitizer. It does not address the requirements for the ARSR-3 and CD-2.

BACKGROUND

The monitoring requirements for the older ARSR radars is to be limited to remote control. Similarly, monitoring of the Common Digitizers is to be limited to status monitoring and uplink control. These functions can be implemented with a relatively simple monitor. The FAA presently has a production contract for Remote Control and Interface Units (RCIU) to perform these functions. Under the EQM/TFM concept, these functions can be performed by TFM #5 Status/Control.

Most long-range radar sites also have a co-located beacon system and some communications and environmental monitoring requirements. These additional requirements could be accommodated within the EQM/TFM subsystem package.

MONITORING APPROACH

The Status/Control TFM is an off-the-shelf Multibus board that provides the following capabilities:

24 dedicated status input circuits
16 dedicated output circuits
8 programmable input or output circuits

In use, the status signals to be monitored are brought into the TFM. The output control circuits on the TFM can activate either external logic devices or relays. A modification to the radar and CD must be made to bring the status signals out to an external connector/terminal strip, and also to bring the control signals in.

Status monitoring and control is a trivial task for the EQM since it only requires the computer to examine/command 6 bytes. Thus, the host EQM can readily support beacon monitoring, environmental monitoring, etc. in addition to status and control functions.

TFM's REQUIRED

The Status/Control TFM (TFM #5, Appendix 2E) is required for ARSR, CD monitoring.

APPENDIX F

BUEC MONITOR

PURPOSE.

This appendix defines the EQM/TFM application to the Back-up Emergency Communications (BUEC) equipment.

BACKGROUND.

The BUEC equipment is used for FAA air-ground communications, as back-up to the RCAG facilities. It is usually co-located at a facility with other equipment (e.g., radar, VOR, etc.). Consequently, the BUEC site TFM's can share an EQM card cage with the TFM's for other functions at the site.

Because of the structure of the BUEC system, and the constraints imposed, monitoring is somewhat different than with other communications facilities, hence the BUEC is more costly to monitor.

An investigation of BUEC monitoring requirements was made and it was concluded that full monitoring of BUEC is not cost effective. The most cost effective approach to BUEC maintenance is to extend the site certification interval to that currently used for the RCAG sites (every two months). This would result in a site visitation reduction of 73%, at no cost for monitoring. The results of this investigation are summarized in Figure F-1. Another approach is to have a standby BUEC at the facility with a logic box to detect a faulty BUEC, and switch to the standby unit. If, however, there is a firm requirement to monitor the BUEC equipment, this Appendix gives a recommended method.

Since the BUEC transceiver is powered to an inactive state when not in use, and is turned on by a command from the Center, it is necessary to seize control of the BUEC equipment when performing a site test. Monitoring of the BUEC, therefore, cannot be totally transparent to the user. In discussions with AAF headquarters personnel it was agreed that tests of the BUEC equipment would be manually initiated during low usage periods, to minimize the impact on Air Traffic Operations. (Note that the command to initiate a test can be generated automatically by the MPS during low usage times, if the MPS is programmed this way, rather than by manual request.)

MONITORING APPROACH.

The monitoring approach for the BUEC system is to use an EQM/TFM assembly at each BUEC site, and a BUEC Controller EQM/TFM at the Center. The BUEC Controller TFM at the Center is interfaced to the TELCO lines going to the BUEC sites and also to the Remote Control Group. A request to run a test at a specific BUEC site is initiated by a maintenance technician via his keyboard through the MPS. The MPS will then uplink a command to the BUEC site to alert the BUEC monitor that a test is being initiated. The MPS will also send a command to the BUEC Controller EQM/TFM, to initiate a test on channel XXX. The BUEC Controller EQM/TFM will check all the BUEC channels it is interfaced to, and determine the status of all channels. If the channel activitity is low, the BUEC Controller will initiate the test. If a high degree of channel activity is present (greater than 50%), the Controller will not initiate the test, but will respond that the channel activity is high. The initiating technician then has the option to either defer the proposed test or continue. To initiate the test, the BUEC Controller TFM will send an encoded message to the BUEC (over the normal TELCO line) to turn it on and select the frequency, and will also indicate to the Remote Control Group that the channel being tested is busy. The BUEC Controller will then monitor the return tone signal from the BUEC site to determine that it is correct.

At the site, the BUEC Decoder TFM will decode the signal coming up the TELCO line, verify that it is correct, and store the requested frequency. This frequency is then transferred to the EQM and the EQM initiates the receiver test sequence using TFM #2 and the methods described in Appendix 2B.

For the transmitter tests two options exist. One is to only monitor the transmitter when it is keyed in normal usage. The other is to automatically perform a transmitter test immediately after the receiver test, by having the BUEC Decoder TFM key the transmitter. (This is a wire strap option, and can be used in those locations where the BUEC usage is low). At the completion of the receiver test (and the transmitter test if this option exists) the BUEC equipment will be reset, and the "channel busy" signal to the Remote Control Group will be released.

In addition to the receiver and transmitter tests, the BUEC EQM/TFM at the site will monitor the noise level and tone signalling level and frequencies on the TELCO line. In normal ATC usage, it will passively monitor the transmitter and compare the selected frequency to the actual transmitter frequency. The EQM/TFM at the Center will monitor the noise and tone signal levels on the TELCO lines, and also maintain counts of successful/unsuccessful usage of each channel to indicate potential problems. These counts will be reported to the MPS during scheduled polls.

PARAMETERS.

Table F-1 is a list of parameters to be monitored.

TFM's REQUIRED

To monitor the BUEC system, the following TFM's are required:

TFM #2, Receiver; Appendix 2B
TFM #3, Transmitter; Appendix 2C
TFM #7, BUEC Controller; Appendix 2G
TFM #8, BUEC Decoder; Appendix 2H

	DATA RETURNED	SEIZE CONTROL	MODEM REQUIRED	TRANSMITTER CHECK	RECEIVER CHECK	BI-WEEKLY (MODIFIED)	MONTHLY (MODIFIED)	QUARTERLY (MODIFIED)	SEMI-ANNUAL	ANNUAL	ANNUAL SITE VISIT REDUCTION	ESTIMATED COST/SITE *
FULL SYSTEM	YES	YES	YES	YES	YES	YES	YES	YES	NO	NO	92%	3.7 K
PARTIAL SYSTEM A	YES	NO	YES	YES	NO	YES	NO	NO	NO	NO	50%	1.6 K
PARTIAL SYSTEM B	GO/NO GO TONE	NO	NO	YES	NO	YES	NO	NO	NO	NO	50%	1.3 K

* BASED ON EIGHT PER CENTER

CERTIFICATION INTERVAL CHANGED TO MATCH RCAG	-	-	-	-	-	ONCE EVERY TWO MONTHS		-	-	-	73%

BUEC MONITORING COMPARISONS

Figure F-1. BUEC Monitoring Comparisons

APPENDIX G

ASR MONITOR

PURPOSE

This appendix defines the monitoring requirements for the ASR-7 and ASR-8 radars.

BACKGROUND

The FAA is planning to procure a new terminal radar, the ASR-9, which will have built-in RMM. The older radars (ASR-4,5) will be replaced, but the ASR-7 and ASR-8 will be retained. Since the ASR-7, 8 do not have built in monitoring, this appendix defines monitoring requirements for the ASR-7,8.

Monitoring of a radar system requires sophisticated and highly accurate measuring equipment. For this reason the radar monitor should be a stand-alone subsystem using it's own set of EQM's and TFM's. Although this appendix defines requirements for a radar monitor, it is recommended that a prototype be built to validate the approach prior to the preparation of a production specification.

MONITORING APPROACH

The following parameters are the minimum required to monitor a radar system:

1. Transmitter power (forward and reflected)
2. VSWR (calculated)
3. Receiver sensitivity
    a. Normal
    b. MTI
    c. STC Curve
4. Receiver noise figure
5. Video output level
    a. Normal
    b. MTI
6. Trigger level

7. ACP level/count (4096)

8. ARP level

9. AC line voltage

10. Status indicators

11. Uplink control

Other parameters that can be monitored, but would add to the cost of the monitor are:

12. Receiver recovery time

13. Transmitter pulse width

14. Transmitter frequency

15. Echo box ring time

16. Transmitter pulse width and shape

The ASR monitor discussed in this appendix will monitor only the first set of parameters. (1 through 11). The monitoring subsystem will consist of an EQM, Smart TFM #3, Radar Interface; TFM #4, IEEE-488; and TFM #5, Status/Control, and some commercial test equipment (power meter, signal generator and noise source). In addition to this, interface modifications to the radar will be required consisting of the following:

1. Status/control wiring should be brought out to a connector or terminal board.

2. Video and triggers will be tapped off the coaxial cables.

3. ACP and ARP signals will be picked off at the demarcation strip.

4. R.F. equipment (power meter, signal generator, noise generator) will be interfaced to the directional coupler through coaxial switches as shown in Figure G-1.

Measurement Methods.

1. Transmitter Power - Forward and reflected transmitter power will be measured at the directional coupler using the power meter and coaxial switches as shown in Figure G-1. Average power will be measured.

2. VSWR - The VSWR value is calculated from the forward and reflected power readings.

3. Receiver Sensitivity - Receiver sensitivity is measured by injecting a signal from the Signal Generator into the directional coupler and monitoring the video output. The injected target will be at a range beyond the operationally used processing range, so it will not be displayed on operational displays. The planned approach is to use a tangential sensitivity measurement, rather than an MDS measurement. This area requires some investigation, so a prototype monitor should be built.

4. Receiver Noise Figure - The receiver noise figure is measured by injecting gated noise into the directional coupler beyond the normal processing range. The noise is measured at the video output, using the 3dB method. Again some investigation is necessary to validate this approach.

5. Video Output Level - The video output level is measured by monitoring the video output lines, then using a sample and hold amplifier and an A/D converter to measure the amplitude.

6. Trigger Level - Trigger level is measured the same way as video output level.

7. ACP Level and Count - The ACP level is measured the same way as video output level. The ACP pulses are counted to insure that 4096 pulses occur between ARP's.

8. ARP Level - The ARP level is measured the same way as the video output level.

9. AC Line Voltage - The AC line voltage is measured by the Environmental TFM (TFM #1), as part of the building monitoring function.

10. Status Indicators - The state of the front panel indicators is monitored using TFM #5, Status/Control.

11. Uplink Control - Uplink control channels are provided as an option if wanted. Since the radar has a remote control unit, this option may not be needed. These channels are available on TFM #5, Status/Control.

<u>TFM's REQUIRED</u>.

The following TFM's are required to monitor ASR type radars:

Smart TFM #3, Radar Interface (Appendix 2 CC)
TFM #4, IEEE-488, (Appendix 2 D)
TFM #5, Status/Control (Appendix 2 E)

In addition, commercial test equipment will be required:

Power meter
Signal Generator
Noise Source

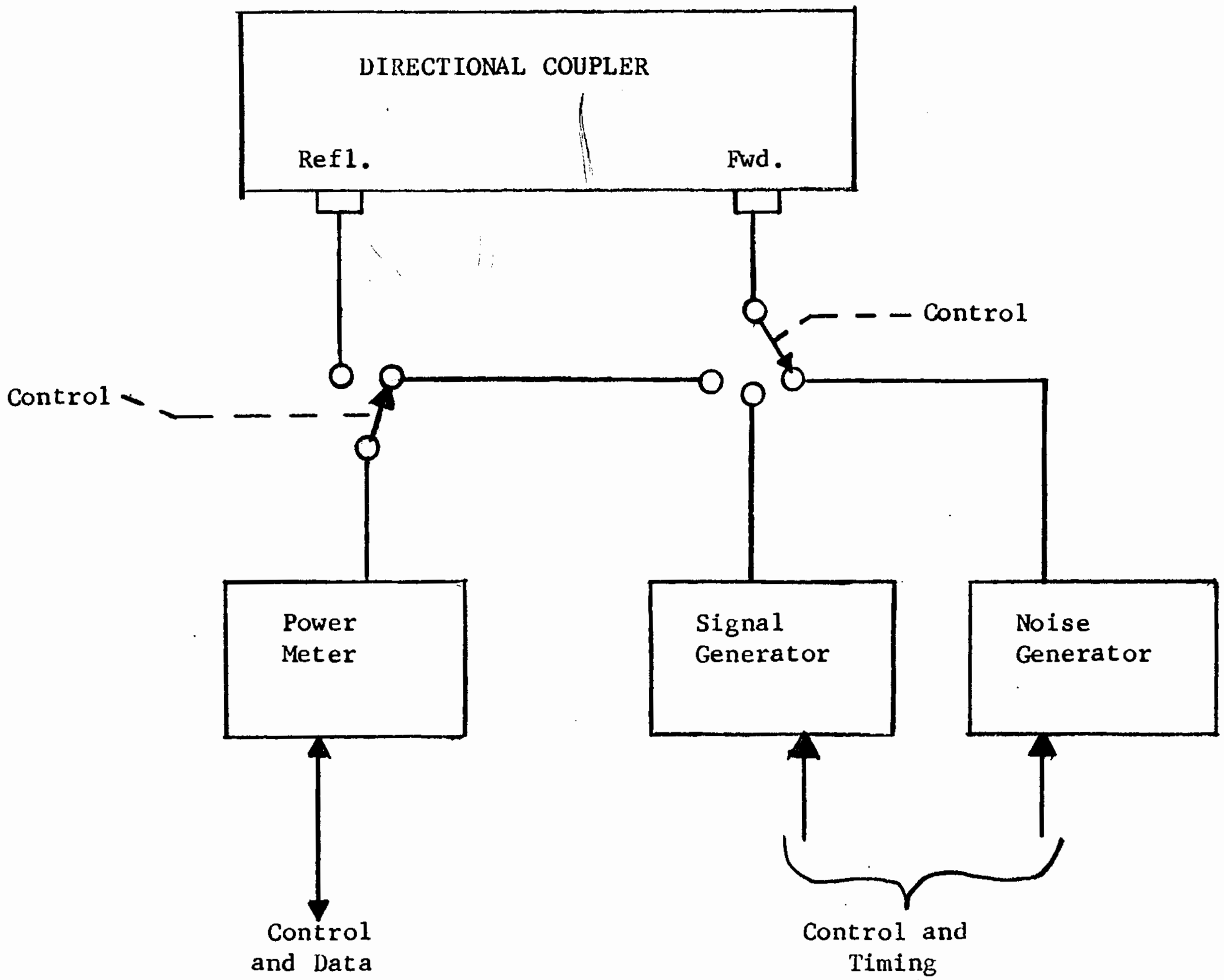


Figure G-1. Directional Coupler Interconnections to Test Equipment.

APPENDIX H

ILS MONITOR (GS/LOC)

PURPOSE

This appendix defines the EQM/TFM application to the ILS Glide Slope and Localizer equipment.

BACKGROUND

The ILS system is the primary landing system in use today. Although it is planned to install MLS equipment as a replacement landing system, the MLS will be phased in over a period of several years. Thus, it will still be necessary to retain ILS equipment to support the many users who have not converted to MLS equipment during this transition period. Therefore, it is estimated that ILS systems will be in use, until at least the year 2000.

The existing ILS equipment does not have a remote monitoring capability that is compatible with RMMS, so it will be necessary to retrofit existing ILS equipment with RMM. Although new ILS procurements will include RMMS capabilities, any new procurements will be very limited.

An ILS system can be a mix of a localizer, glide slope and marker equipments. The marker equipment is monitored by smart TFM #1, and this monitoring is described in Appendix I. The monitoring of Glide Slope and Localizer equipment is described in this appendix (Appendix H).

MONITORING APPROACH

The Glide Slope and Localizer facilities are functionally similar, therefore, the same TFM (Smart TFM #1) can be used for either. (Since ILS sites are stand-alone facilities, the decision was made to use "smart" TFM's at the ILS facilities, controlled by a centrally-located EQM. This approach is considered more cost effective than having an EQM and TFM at each facility). The monitoring method will use some signals from the existing monitor and the alarm panel, and will also sample the transmitter r.f. signals to determine power level, frequency and VSWR. An alternate approach using a microcomputer to independently monitor an ILS was investigated at the FAA Technical Center (Report No. CT-82-100-56LR, Reference 10). Because of time constraints, however, this approach could not be completed. Therefore, the monitoring approach to be used will obtain some signals from the existing monitors.

The Smart TFM #1 will have the capability of monitoring either a Localizer or a Glide Slope, thus some TFM functions may not be used at a specific facility (e.g., identity code is not used at a Glide Slope). The parameters applicable to a specific facility are stored in adaptation tables in the host EQM. (NOTE: Smart TFM #1 is also used to monitor markers, VOT's).

To access the signals in the existing ILS monitors it will be necessary to modify an existing ILS monitor to bring out these signals to a connector (Alternatively, ILS monitors could be built that have the signal pickoff points and connector installed). To sample the r.f. signals it will be necessary to install directional couplers in the r.f. transmission lines. This will require re-phasing of the r.f. feed system, and may require a flight check.

The Localizer and Glide Slope parameters monitored by Smart TFM #1 are listed in Table H-1. The following paragraphs describe the monitoring methods for specific parameters Since this TFM can be used for both Localizers and Glide Slopes, the word "course" is used to represent either the course (Localizer) or path (Glide Slope) parameters.

1. Course Alignment, Course Width, Course DDM, Test DDM. These signals are monitored by accessing the d.c. signals in the ILS monitor and feeding them to the TFM. In the TFM they are fed to the A/D converter and converted to digital format.

2. Course Power Level, Clearance Power Level. A directional power detector (DPD) of the type described in Report FAA-CT-82-100-115LR (Reference 9) should be used. This DPD provides forward and reflected power output signals, each consisting of a d.c. component proportional to r.f. power level, and an audio modulation component. These signals are input to the TFM where the d.c. and audio components are separated. The d.c. components are filtered and fed to the A/D converter to provide the r.f. power values. The audio component of the forward power is filtered to extract the identity modulation signal. From the r.f. power levels, the VSWR is computed.

3. Course Percent Modulation, Clearance Percent Modulation. These signals are monitored by accessing the d.c. signals in the ILS monitor and feeding them to the TFM. In the TFM they are fed to the A/D converter and converted to digital format. Scaling is set up such that the LSB=0.5%. The difference between the 90 Hz and 150 Hz course modulation signals is calculated by the microcomputer and compared to the DDM value obtained directly from the ILS monitor. The SDM can be calculated in a similar way.

4. Identity Percent Modulation, Frequency, and Code. The audio component of the DPD output is fed to a 1020 Hz filter (This is a wire-strap option on Smart TFM #1) to extract the identity tone. The tone is fed to a peak detector and then to the A/D converter to measure percent modulation. The tone is also fed to a zero-crossing detector and code detector. The zero crossing detector is used to gate clock pulses to a counter to measure the period of the 1020 Hz tone (thus the frequency), and the code detector output is decoded by software to verify the site identity code.

5. Course Frequency, Clearance Frequency, and Offset (difference) Frequency. Directional couplers are installed in the r.f. transmission lines to sample the course and clearance frequencies. The outputs of the directional couplers are prescaled by 32 and fed to a 24-bit counter where the prescaler output is counted for one second to count the r.f. frequency.

The offset frequency (difference between the course and clearance transmitter frequencies) has a tighter tolerance than either of the carrier frequencies. This difference frequency is measured directly by feeding the outputs of the two directional couplers to a mixer. The difference frequency (about 8kHz) is taken from the output port of the mixer, fed to a limiter on the TFM (to remove modulation components) and counted for one second to obtain the digital value of the difference frequency.

6. Status/Control. The status indicators on the equipment panel are used to set bits in the status byte. (up to 8 status conditions). In addition, 4 uplink control signals are provided. These can be used to cycle the transmitters, switch the Test DDM relay, etc.

The following parameters are associated with environmental conditions at the facility:

7. Temperature. A Type J thermocouple (TC) is used to sample ambient temperature. The TC voltage is fed to the TFM where it is standardized to 20mv/Degree C and fed to the A/D converter.

8. A.C. Voltage. The a.c. line voltage is measured by connecting a 6.3 volt transformer and a sealing potentiometer at the source. The scaled a.c. signal is fed to the TFM where it is converted to d.c., and fed to the A/D converter.

9. Battery Voltage. The facility battery voltage is measured by feeding it to the TFM where it is scaled and fed to the A/D converter.

10. Battery Current. The battery current is measured by a Hall effect transducer, which provides a d.c. voltage proportional to the d.c. current. This d.c. voltage is fed to the TFM where it is scaled and fed to the A/D converter.

11. A.C. Current. A.C. current is sampled by a current transformer, which provides an a.c. voltage proportional to current. This a.c. voltage is fed to the TFM where it is scaled, converted to d.c. and fed to the A/D converter. A.C. current from two sources can be measured (e.g., prime power and obstruction lights).

12. Intrusion Alarm. Door and window switches will provide a contact break to signify intrusion. The TFM will detect this break and set a bit in the status byte. The maintenance technician has 30 seconds to manually reset the intrusion bit, otherwise an intrusion alarm is sent to the host EOM.

TFM's REQUIRED

Smart TFM #1 (Appendix 2AA) is required to monitor the Glide Slope or Localizer.

TABLE H-1

SMART TFM #1 PARAMETERS (GS/LOC)

PARAMETERS	A/D	STATUS	CONTROL	COUNTER
COURSE ALIGNMENT	1			
COURSE WIDTH	1			
COURSE DDM	1			
TEST DDM	1			
COURSE RF POWER (FWD/REV.)	2			
CLEARANCE RF POWER (FWD/REV)	2			
VSWR (CALCULATED)				
COURSE PERCENT MODULATION	2			
CLEARANCE PERCENT MODULATION	1			
IDENT PERCENT MODULATION	1			
COURSE FREQUENCY				2*
CLEARANCE FREQUENCY				2*
OFFSET FREQUENCY				2*
IDENT FREQUENCY				2*
IDENT CODE (CALCULATED)				
STATUS		8max		
CONTROL			2	
TEMPERATURE	1			
AC VOLTAGE	1			
BATTERY VOLTAGE	1			
BATTERY CURRENT	2			
AC CURRENT	2			
USED	19	8	2	2
SPARES	5	0	2	0
TOTAL	24	8	4	2

* Counters are shared

APPENDIX I

MARKER, VOT MONITOR

PURPOSE

This appendix defines the EQM/TFM application to Markers, NDB, VOT, FM, LOM, LMM, H, and HH.

BACKGROUND

In the development of standard modules for the EQM/TFM system, monitoring of markers was carefully considered. Because of the limited monitoring requirements for markers, it is difficult to justify a full EQM/TFM subsystem as a cost-effective application. However, the requirement exists to provide a family of standard modules(TFM's) for RMMS. The approach taken to resolve this problem is the "smart" TFM. A "smart" TFM consists of a single-chip microcomputer and its associated signal conditioning and conversion components, all mounted on a Multibus circuit card. The "smart" TFM can be used as a stand-alone device, or it can be installed in an EQM card cage when co-located with other facilities. (Note: In ILS systems, where both a Middle Marker and Far Field Monitor are used, they are usually co-located in the same shelter. A single Smart TFM #1 can monitor both these facilities).

MONITORING APPROACH

To monitor the various markers and beacons, Smart TFM #1 will be used (Appendix 2AA of Section 2). The software for all monitoring functions is resident in the single-chip microcomputer. Selection of the monitoring functions required at a specific facility is accomplished by wire strapping. For marker applications Smart TFM #1 will provide the following monitoring functions on a single Multibus card:

Status (8 channels) - To monitor status indicators and intrusion/smoke alarms.

Control (4 channels) - To provide uplink control of the facility.

Temperature (1 channel) - To measure ambient temperature

A.C. Voltage (1 channel) - To monitor primary voltage.

A.C. Current (4 channels) - To monitor AC current in different circuits, including obstruction lights.

D.C. Voltage (1 channel) - To monitor battery voltage.

D.C. Current (2 channels) - To monitor battery charge/discharge current.

R.F. Power (2 channels) - To measure both forward and reflected power (VSWR will be calculated from their ratio).

Percent Modulation (3 channels) - To measure percent modulation of up to 3 frequencies.

R.F. Frequency (1 channel) - To measure carrier frequency.

Modulation Frequency - A single counter is shared to measure modulation frequencies.

ID Decode - The transmitted site ID is decoded and compared to the stored ID for that site.

In addition to the foregoing parameters, one additional parameter is measured at VOT's.

Phase Difference - a digital phase detector measures the difference between the reference and variable phase signals. If this exceeds 1° an alarm is declared.

Application

Since Smart TFM #1 can monitor a number of different facilities, the selection of the parameters to be monitored is an applications requirement to be defined on an individual basis. As defined in Appendix 2AA for Smart TFM #1, arbitrary tolerance limits are established for the various parameters. These limits are in accordance with the "Blue Sheet" tolerances.

APPENDIX J

RUNWAY VISUAL RANGE MONITOR

PURPOSE

This appendix defines the EQM/TFM application to the Runway Visual Range (RVR) system.

BACKGROUND

The RVR system, as presently installed at airports, consists of up to three transmissometers per runway, Signal Data Converters (SDC) and Remote Displays. The RVR value indicates the horizontal distance a pilot can see down the runway. The transmissometers consist of a calibrated light source and a light receiver. The receiver output is a train of pulses, and the pulse rate is proportional to the clarity of the air (i.e., the clearer the air, the more pulses per minute). Transmissometers are usually installed with a baseline between light source and receiver of 250 feet, which will provide RVR values down to 600 feet. For RVR values less than this, a short baseline (40 feet) receiver is installed. When three transmissometers are used along a runway, they are installed at the touchdown, midpoint, and rollout locations.

The pulse train from each transmissometer is fed to a Signal Data Converter (SDC). The SDC counts the pulses received over a one minute period, performs a table look-up and converts the pulse count to an RVR value. (Each SDC can calculate the RVR value for only one transmissometer). The RVR values are then sent to the Remote Displays.

MONITORING APPROACH.

It is not cost effective to install additional transmissometers for monitoring the existing transmissometers. The monitoring approach, therefore, is to count the pulses from the existing transmissometer, compute an RVR value independently and compare this RVR with the RVR value produced by the SDC. In effect the monitor is duplicating the functions of the SDC with some additional capabilities. The monitor will provide the following:

1. Monitor up to 12 SDC's.

2. Provide limit checking on: RVR minimum, transmissometer minimum, transmissometer maximum, background maximum.

3. Self-checking.

4. Detect sudden changes in RVR value indicating potential transmissometer problems (e.g., dirt on lens).

5. Detect changes in signal level from the transmissometer, indicating cable or transmissometer problems.

6. Report alarms when any out-of-tolerance conditions are detected.

Since one RVR monitor is effectively duplicating the functions of up to 12 SDC's, a more cost effective solution for the RVR system would be to replace the existing SDC's with microcomputer-based SDC's. These replacement SDC's would thus have a built-in monitoring capability, and perform the SDC functions at lower cost. A microcomputer-based SDC system to perform these functions was developed at the FAA Technical Center and is described in Report No. FAA-CT-80-43, "A Microcomputer-Based Signal Data Converter for Runway Visual Range Measurements".

TFM's REQUIRED

To monitor an RVR system using a separate monitor, TFM #9, RVR (Appendix 2I) should be used. This TFM consists of 12 counters and 12 SDC decoding channels plus the necessary signal conditioning and logic control functions. The software and RVR tables will be stored in the host EQM. This EQM/TFM subsystem will thus monitor up to 12 RVR channels. If more channels are required, this can be expanded by adding another TFM.

APPENDIX K

DIRECTION FINDER MONITOR

PURPOSE

This appendix defines the EQM/TFM application to the Direction Finder (DF) equipment.

BACKGROUND

The DF is a system to provide unambiguous bearing information of aircraft. There are four types of DF equipments currently in use by the FAA:

FA-9964
FA-5530
CA-3300
FA-7000

The CA-3300, and FA-7000 are older units due to be replaced. The FA-5530 is a tube type DF and is not considered a candidate for RMM. The FA-9964 is a solid state DF intended to replace all existing tube type units, so this appendix addresses the FA-9964. If RMM of the FA-5530 is required, on an interim basis, the FA-9964 monitoring approach can be used.

The DF system has a Built-In-Test-Equipment (BITE) capability, thus any RMM measurements should be performed as part of the BITE test sequence. Since the DF is a single channel system, it must be seized to perform the BITE test, hence monitoring is not transparent to the user.

Most of the DF functions to be monitored are checked during the BITE test and reported over the data link from the local site to the remote site. (The local site is the facility where the DF antenna and receiver/bearing processor are located, and the remote site is where the bearing display/control assembly is located (usually an FSS). The tests that are not performed by the BITE test are receiver sensitivity, selectivity, and squelch tests. The DF manual states that these are to be performed every six months, thus automated checking of these parameters is not recommended. Instead, an alternate check of receiver sensitivity is recommended, as part of the BITE test. This is described under Monitoring Approach.

MONITORING APPROACH

The monitoring approach recommended is to let the DF monitor be a passive subsystem. The monitor will be bridged across the data lines and will collect the data from the BITE test, every time a BITE test is initiated. Since the BITE test seizes control of the DF system it is preferable that the BITE test be manually initiated. However, if automatic BITE test initiation is required, the EQM can be programmed to initiate a BYTE test periodically and collect the data.

The EQM/TFM monitor for the DF will be located at the remote site (FSS). At this location one EQM/TFM monitor can monitor several DF's if the associated bearing display/control asemblies are physically located there. TFM #6, Serial Communications will be used as the interface to the data communications channel. This TFM has 8 serial data ports so it can accommodate up to eight devices. If manual initiation of the BITE test is the means of getting RMM data, this is the only TFM required. If automatic BITE test initiation is wanted, then TFM #5, Status/Control is also required, to control the start/stop of the BITE test.

It is not considered cost effective to install an EQM/TFM subsystem at the local site to perform a receiver sensitivity test, so the following alternative is recommended. At the local site, 4 target antennas are placed around the DF antenna to provide a test signal at known bearings. Perform a modification to one of the target antennas by installing a fixed attenuator in the target antenna cable. The value of the attenuator should be such as to make the received signal from that target antenna 3 dB above the receiver squelch threshold. Thus, during a BITE test, if that target is not detected, it means that the receiver sensitivity has dropped 3 dB or the target transmitter output has dropped 3 dB.

The value of the attenuator to be used is site dependent. For a target transmitter output of 1 milliwatt and a receiver sensitivity of -93 dBm the attenuator should be about 35 dB. The actual value of the attenuator can be determined by inserting a variable attenuator in the target antenna cable and adjusting it to the squelch break point. The fixed attenuator used should then be 3 dB less than the reading of the variable attenuator at squelch break.

Based on this check of receiver sensitivity, the EQM/TFM subsystem at the remote site would interpret the missing target as a loss in receiver sensitivity, and would report it as an alarm condition to the RMSP or MPS.

TFM's REQUIRED.

For DF monitoring TFM #6, Serial Communications (Appendix 2F) is required. If automatic initiation of the BITE test sequence is wanted, TFM #5, Status/Control (Appendix 2E) is also required.

APPENDIX L

DOPPLER VOR MONITOR

PURPOSE:

This appendix defines the monitoring requirements for the Doppler VOR (DVOR) equipment.

BACKGROUND:

The primary world-wide aircraft navigation system is based on the very high frequency omnirange (VOR) equipment. By use of an airborne VOR receiver, the aircraft can determine its bearing relative to a VOR ground station. The VOR system radiates a carrier signal in the 108 to 118 MHz band, and the modulation of this carrier includes two 30 Hz signals (a reference phase signal and a variable phase signal). The phase difference between the reference phase signal and the variable phase signal is the bearing to the VOR station. This phase difference is detected by the airborne receiver and displayed to the pilot as the bearing to the VOR station.

To properly radiate these VOR signals, with minimum station error (in degrees) as seen by the aircraft, requires accurate adjustment of the VOR transmitter, and careful attention to the siting of the VOR. The siting criteria are quite stringent and require flat ground near the VOR (up to 200 feet) and no cables, structures, or trees within 750 feet. For these reasons, VOR sites are located in isolated areas and on hilltops or mountain tops, where possible. In some cases, however, it was necessary to install VOR stations at less-than-ideal site locations. To improve VOR performance at these locations the Doppler VOR (DVOR) was developed. The DVOR generates two r.f. signals, a carrier signal and the sideband signals (offset from the carrier by 9960 Hz). The carrier signal is fed to the carrier antenna, and the sideband signals are fed (through the distributor) to the Doppler antennas. The two signals combine in space, and, to the VOR receiver in the aircraft, they appear the same as a conventional VOR signal. The DVOR provides better performance (less scalloping) in problem siting locations where reflecting objects exist. As a result, DVOR's have been installed at a limited number of problem VOR locations.

The FAA is presently replacing all the VOR's in the U.S. with the Second Generation VOR's (SGV). The DVOR's are composed of two transmitters, the carrier transmitter and the sideband transmitter. The DVOR's will have the carrier transmitters replaced by the SGV, but the sideband transmitters will be retained. Since the SGV's have RMM built into them, monitoring of the DVOR should consider transmission of the DVOR monitor data over the same data link as the SGV monitor.

MONITORING APPROACH

The number of DVOR's in use is relatively small (about 60). In addition, the types of signals to be monitored, taken as a group, do not readily lend themselves to the TFM approach. For these reasons it is recommended that a DVOR monitor be built as a stand-alone module. This module will monitor those parameters associated with the DVOR function, since it is assumed that the carrier transmitter will be part of the SGV program and it will have built-in RMM.

The DVOR monitoring approach will use at least one pick up antenna/detector located in the far field. The received signal from this field detector will be fed to the monitor module where the following parameters will be extracted:

1. Received r.f. level
2. Percent Modulation - 30 Hz
3. Percent Modulation - 9960 Hz
4. Percent Modulation - 1020 Hz
5. Levels of 30 Hz reference and variable signals
6. Bearing angle
7. Identity code and frequency

In addition to these parameters, directional couplers will be installed in the carrier feed line and sideband feed lines (to the distributor) to obtain the following parameters:

8. Carrier frequency
9. Difference - Upper sideband/carrier frequency
10. Difference - Lower sideband/carrier frequency
11. Upper SB power (forward/reflected)
12. Lower SB power (forward/reflected)
13. VSWR

Note that carrier power can also be measured, but this will be done by the SGV monitor.

These parameters are summarized in Table L-1.

The monitor will be microcomputer-based, and should provide a data communications capability to interface with the SGV data link and/or a remote processor. The methods of monitoring specific parameters are discussed in the following paragraphs:

1. Pickup Antenna/Field Detector. Because of the design of the DVOR, far field monitoring of the radiated signal is required. The pickup antenna/field detector is installed at a defined azimuth about 400 feet from the VOR antenna. The radiated signal is picked up by the antenna and detected. The detected signal (d.c. plus audio) is fed to the monitor module via buried cable for processing. The question arises as to the number of pickup antennas required to adequately define the station error curve. VOR's have used an 8-point monitor, and the SGV uses a 16-point monitor. These antennas are located close to the VOR antenna and the installation cost is relatively low. DVOR's have used three pickup antennas spaced 120° apart. Thus, for this application to a DVOR, one pickup antenna should work (three would be better) particularly if a periodic check is made with a portable antenna and test set. There is another test in this monitor to perform a check on the individual Doppler antennas which will provide additional monitoring of antenna performance. (This is discussed under 9. Upper/Lower Sideband Power and VSWR).

2. Received RF Level. The d.c. component of the signal from the detector is measured by an A/D converter in the monitor. The digital value of this level is compared to tolerance limits stored in the microcomputer. Out-of-tolerance values indicate either a malfunction in the detector or reduction in radiated signal from the VOR.

3. Percent Modulation, 30 Hz, 9960 Hz and 1020 Hz. The three modulation signals are separated by filters and fed to peak detectors to provide d.c. values corresponding to their amplitudes. These d.c. values are fed to the A/D converter and the digital values are compared to stored limit values by the microcomputer. The 9960 Hz signal is also fed to an FM detector to extract the 30 Hz reference signal for use in the phase detector.

4. Levels of 30 Hz Reference and Variable Signals. The amplitudes of the 30 hz variable and reference signals are measured and compared to stored limit values by the microcomputer. Out-of-tolerance conditions implies incorrect modulation level for one or both of these signals. The two 30 Hz signals are also fed to the phase detector to determine the bearing angle.

5. Bearing Angle. The two 30 Hz signals (reference and variable) are fed to a digital phase detector in the monitor. The resulting phase angle is the bearing angle to the VOR site. This angle is compared with stored limit values by the microcomputer.

6. Identity Code and Frequency. The 1020 Hz code signal is fed to two places. The tone is fed to a zero crossing detector to generate a gate corresponding to the period of the 1020 Hz tone. This period is measured by a time-base counter, and the values of several periods are averaged to obtain the frequency of the 1020 Hz signal. The keyed 1020 Hz tone is also fed to a code detector. The output of the code detector is a series of dots and dashes corresponding to the station identity. A subroutine in the microcomputer converts the dots and dashes to the characters representing the station identity. These are compared to the stored station identity.

7. Carrier Frequency. A directional coupler is installed in the carrier transmission line to sample the carrier signal. This coupler should have a directivity of 15db and coupling of -20 to -25 dB. A prescaler is mounted near the coupler and divides the carrier frequency by 16. This provides a TTL level output pulse train (at about a 7 Megabits/second rate) to the monitor. A 24-bit counter (counts to 16,777,215) counts these pulses for one second to provide a digital value of the carrier frequency. This is compared to the stored value by the microcomputer. (Note: Standard counter chips are available in either 4-bit or 8-bit modules, and a 24-bit counter was chosen, since it is used in other applications of TFM's).

8. Difference Between Upper and Lower Sidebands/Carrier Frequency. The 9960 Hz difference between the sideband frequencies and the carrier frequency has a tight tolerance ($\pm$ 10 Hz), thus counting the r.f. frequencies and subtracting them is not feasible. The approach recommended is to sample the carrier, and upper sideband signals, using directional couplers, and feed the two signals to a mixer. The same thing is done for the lower sideband. The mixer output will contain the two input signals and their sum and difference. The difference signal (9960 Hz) is an audio frequency so it can be readily separated from the r.f. signals. The difference frequency can then be counted for one or more seconds. Since the 9960 Hz signal is frequency modulated by the 30Hz reference signal, the period of individual cycles will vary. However, if the FM deviation is symmetrical, long term integration (i.e., one second or more) should give the average frequency (or resting frequency) of 9960 Hz.

9. Upper/Lower Sideband Power and VSWR. To measure the sideband power (forward and reflected) directional power detectors (DPD) of the type described in Reference 9 are installed in the upper and lower sideband transmission lines ahead of the distributor. The DPD's provide d.c. output voltages proportional to forward and reflected power. The commutating pulses for the distributor are used to derive a sample gate for the DPD. The sample gate will sample the forward and reflected power in the feed line at the center of the dwell time for each Doppler antenna. These power measurements are digitized by an A/D converter and stored in the microcomputer memory. The computer program examines all these samples and if there is a marked change in any one or more (particularly reflected power) the computer tags the associated Doppler antenna as faulty and generates an alarm message. The forward and reflected power levels are also compared to stored limit values for out-of-tolerance conditions. The power measurements are also used to calculate the VSWR.

Other Considerations

The DVOR monitor should use the same data link as the co-located SGV components. The data link for the SGV uses the speech-plus-data technique with a 150-baud data channel, and the data and voice channel filters are part of the SGV. One way of getting the DVOR data over the data link is to modify the SGV to accept DVOR data and transmit it over the link. This is not too desirable since it would require non-standard modified SGV components. Another approach would be to make the DVOR a stand-alone communications link and bridge it across the TELCO line along with the SGV. The DVOR would then require its own data/voice filters and would have to be uniquely addressed by the centrally located processor. Before a decision is made on this, some investigation is required.

TABLE L-1

MONITORED DVOR PARAMETERS

Field Detector Derived

1. Received r.f. level
2. Percent Modulation - 30 Hz
3. Percent Modulation - 9960 Hz
4. Percent Modulation - 1020 Hz
5. 30 Hz reference and variable signal levels
6. Bearing angle
7. Identity code and frequency

Site Derived

8. Carrier frequency
9. Difference-upper sideband/carrier frequency
10. Difference-lower sideband/carrier frequency
11. Upper sideband power (forward/reflected)
12. Lower sideband power (forward/reflected)
13. VSWR

APPENDIX M

DME MONITOR

PURPOSE

This appendix defines the EQM/TFM application to the Distance Measuring Equipment (DME).

BACKGROUND

The implementation of the Second Generation VOR program will replace the existing VOR's and most of the co-located DME's (or TACAN's). For these new systems, monitoring will be built into the equipment. The DME's that are not replaced, however, will require an RMMS monitor.

The existing DME systems have a local monitor that provides the capability of:

a. Front panel status indicators

b. Automatic transfer from on-line channel to standby, if a fault occurs.

c. Remote indication of status.

d. Local indications of transmitter power, site ID etc.

They do not however, provide the capability of remoting the parameter values to a centralized location. The DME monitor described in this appendix provides this capability.

MONITORING APPROACH

The monitoring approach for the DME system is to use a "smart" TFM (Smart TFM #4). By using this approach, the TFM can be operated as a stand-alone monitor if the DME is not co-located with another facility, or the TFM can be installed in the EQM card cage if it is co-located with another facility. Most of the existing status indicators on the front panel of the DME will not be reported. These indicate fault conditions of the measured parameters. Since these fault conditions will also be detected by the RMMS monitor, there is no need to report status type fault indications. If, however, there is a requirement to report the status of the front panel indicators at specific DME facilities, this requirement can be accommodated by adding a TFM #5 (Status/Control) to the RMMS monitor.

Limited environmental monitoring is also provided by smart TFM #4, for use when the TFM is installed as a stand-alone monitor. If full environmental monitoring is required, TFM #1 (Environmental) can be added to the RMMS monitor.

Parameters

The following parameters are monitored in the DME system by this TFM:

1. RF power (forward)
2. RF power (reflected)
3. VSWR (calculated)
4. Pulse width
5. Pulse spacing
6. Reply rate
7. Reply delay
8. Reply efficiency
9. ID tone frequency (1350 Hz)
10. ID occurance rate (30 seconds)
11. Site ID
12. Status
    - DME Alarm
    - Shutdown
    - On-line (Tx 1 or Tx 2)
13. Environmental
    - Line Voltage
    - Line currents (2)
    - Battery Voltage (if required)
    - Battery Current (if required)
    - Temperature (2)
    - Smoke detector (status)
    - Intrusion Alarm (status)
14. Uplink control (2)

Measurement Methods

1. RF Power (forward and reflected), VSWR - A directional coupler is installed in the antenna transmission line. The coupler should have sufficient isolation to limit peak power at the output ports to about 0.1 watt. (An external attenuator can be used at the forward port to reduce the power to this level). Diode detectors are connected to the coupler ports and the detected video pulses are fed to the TFM where they are scaled and fed to peak detectors. The outputs of the peak detectors are digitized by an A/D converter. Since the transfer function of the diode detectors is not linear, the diode characteristics will be stored in PROM as a look-up table. The forward and reverse power can thus be calculated using the peak voltage and the values stored in the table. Once the forward and reflected power are known the VSWR can be calculated.

2. Pulse Width, Pulse Spacing. For pulse width and pulse spacing measurements, a 20 MHz (0.050 microsecond) clock will be used as the reference clock. The forward power detected video pulse will be fed to a voltage comparator. The other input to the comparator will be 50% of the voltage out of the peak detector, thus the comparator will change state at

the 50% point on the leading edge of the pulse. The comparator output will gate the 20 MHz clock pulses into the counter. At the 50% point on the trailing edge of the pulse, the comparator will again change state gating off the clock pulses. The accumulated count in the counter (nominal 70 counts) thus represents the pulse width in 50 nanosecond increments.

The pulse spacing is measured by using successive pulse pairs to toggle a flip-flop. The flip-flop is toggled on by the first pulse and off by the second pulse. When the flip-flop is on, it gates the 20 MHz clock pulses into the counter and when toggled off it gates off the clock pulses. The accumulated pulse count (nominal 240) represents the pulse spacing in 50 nanosecond increments. To insure that the flip-flop is ready to receive the next pulse pair, the flip-flop is reset 20 microseconds after the first pulse, if it has not been reset by the second pulse.

3. Reply Rate. The reply rate is measured by counting the number of forward power detected video pulses for a period of one second. The one-second reference is provided by the microcomputer and gates the detected pulses into the counter for a one second period. The accumulated count in the counter (nominal 2700) is the number of pulses per second.

4. Reply Delay, Reply Efficiency. The reply delay is measured by using the reply enable pulse to gate the counter on (to accept 20 MHz clocks) and gating it off by the detected forward power pulse that occurs 50 microseconds later. The accumulated count in the counter (nominal 1000) represents the reply delay in 50 nanosecond increments. Note that it is necessary to develop a "window" that opens about 49.5 microseconds after the reply enable pulse, so that only the correct transmitted pulse will gate off the counter.

The reply efficiency is measured by counting the number of reply enable pulses and also the number of resulting delayed transmitted pulses for a defined period of time (i.e., 1,2 or 4 seconds). By dividing the number of transmitted pulses by the number of reply enable pulses, and multiplying this by 100, the reply efficiency in percent is obtained.

5. ID Tone Frequency, ID Occurrence Rate and Site ID. The detected forward power pulses are fed to a 1350 Hz detector (a pulse stretcher followed by a resonant circuit). The period of the output frequency is measured and averaged for several periods to measure the ID tone frequency.

The 1350 Hz ID tone is fed to an ID detector (a diode with a filter to remove 1350 Hz components) to obtain the dots and dashes for Site ID. When the ID is transmitted, the ID is decoded by a microcomputer subroutine. The ID obtained is compared to the stored site ID for validation. In addition, the time between transmissions of the ID is measured by the microcomputer (typically 30 seconds). This provides a measure of the ID occurrence rate. If the period between ID transmissions exceeds 70 seconds, a fault is reported.

6. Status Signals. Four DME status signals are reported, DME alarm, shutdown, and channel 1 or 2 on line. These signals are obtained from the DME status light circuits and fed to the TFM. These signals are coupled to the TFM logic by on-board opto-isolators.

7. Environmental. The environmental parameters monitored by this TFM are:

- Line Voltage
- Line Current (2)
- Battery Voltage (if required)
- Battery Current (if required)
- Temperature (2)
- Smoke Detector (status)
- Intrusion alarm (status)
- Intrusion reset (status)

These signals are monitored in the same way as described in Appendix 2A (TFM #1, Environmental) so the monitoring will not be described here.

8. Uplink Control. Two channels of uplink control are provided that can be used as required. These provide a relay contact closure that can be used to control heavier duty external relays.

TFM's Required.

To monitor the DME, the following TFM is required:

Smart TFM #4, DME

APPENDIX N

R.F. COMMUNICATIONS

PURPOSE

This appendix defines the EQM/TFM application to monitoring radio frequency (RF) communications equipment including RCO, RTR, FSS RCO, IFST, IFSR. It does not include BUEC equipment.

BACKGROUND

The FAA has a variety of radio communications equipment at various locations. At some locations the transmitter and receiver are co-located (e.g., RCO), and at others the transmitters are physically separated from the receiver (e.g., RTR). To allow flexibility in configuration, the TFM's for transmitters and receivers are separate modules, thus allowing monitoring of either co-located or separated equipments.

Many FAA communications facilities use the AN/GRT-21 and AN/GRT-22 transmitters. Under contract, the FAA procured modification kits for these transmitters, to provide a sensor interface from the transmitter to an external RMM system. This modification consists of a printed circuit card that plugs into the A-3 card slot in the transmitter, and some wiring changes. This sensor interface will not be used in the EQM/TFM application to transmitters for the following reasons:

1. The A-3 modification is only used in the AN/GRT-21 and AN/GRT-22 transmitters. Since the TFM's can be applied to other transmitters, the TFM's and sensor should be independent of the transmitter type.

2. The A-3 modification has some shortcomings which can result in parameter errors. (See Reference 8, pages 16, 17).

MONITORING APPROACH

The monitoring approach for VHF/UHF communications is to use transmitter TFM's and receiver TFM's with the EQM where the transmitters and receivers are co-located. Where the transmitters are not co-located with the receiver, the transmitter TFM's and EQM will be used at the transmitter site, and the receiver TFM's and their EQM at the receiver site. If the transmitters and/or receivers are co-located with other facilities, the TFM's for the other facilities will also be supported by the EQM. In most cases an Environmental TFM (TFM #1) will also be included at a transmitter/receiver facility.

Transmitter Monitoring

Transmitters will be monitored using TFM #3, Transmitter. This TFM can monitor two transmitters, that may or may not be keyed at the same time. Only the on-line transmitter is monitored (every time it is keyed) and the parameter values are stored in the EQM. The EQM performs limit checking on the parameter values and reports out-of-tolerance conditions as alarms. The EQM stores the most recent data from the transmitter and provides this data to the RMPS (or MPS) upon request. Note that for a transmitter that is keyed infrequently this data could be several hours old.

The parameters that are monitored by the transmitter TFM are the following:

1. Forward power
2. Reflected power (used in VSWR calculations)
3. Percent modulation (peak and average)
4. R.F frequency
5. TELCO signal level
6. Modulation frequency (for tone modulated transmitters)
7. Status signals (PTT and channel selected)
8. VSWR (calculated from forward and reflected power)
9. Modem tone level (provide an indication of TELCO line quality)

Detailed explanations of the transmitter measurement methods are given in Appendix 2C of Section 2, "TFM #3, Transmitter". Since the transmitter measurements are only made when the transmitter is keyed, the EQM software for transmitter measurements is activated by the PTT signal.

Receiver Monitoring

Receivers will be monitored using TFM #2, Receiver. This TFM can monitor two receivers on different frequencies. Receiver monitoring will be performed on off-line receivers only. This is a constraint imposed by the operating services, although the feasibility of monitoring on-line receivers has been demonstrated. (See Report FAA-RD-79-125).

In receiver monitoring, a controlled test r.f. signal is injected into the receiver under test, and several outputs from the receiver are measured. The test signal is injected into a directional coupler at the input to the receiver. Since the signal source for testing the off-line receiver is on the same frequency as the on-line receiver, the TFM design should provide sufficient isolation to prevent interference to the on-line receiver.

The parameters that are monitored by the Receiver TFM are:

1. RF Sensitivity
2. Squelch threshold
3. AGC threshold and control
4. Channel status (on-line/off-line)
5. Audio output level

Detailed explanations of receiver measurement methods are given in Appendix 2B of Section 2, "TFM #2, Receiver" and in Reference 8. Since the receiver measurements are made on the off-line receiver, they are not usually time-critical. There are, however, some precautions associated with receiver testing, specifically:

1. The on-line/off-line status of the receiver should be monitored. If the receiver under test becomes selected and goes on-line, the test must be immediately aborted, to avoid interference with ATC operations.

2. The PTT function of transmitters on the same frequency as the receiver must be monitored, and, if detected, the receiver test must be aborted, since the test data would be invalid. If the transmitter is not co-located with the receiver, a sudden rise in AGC voltage can indicate keying of a transmitter on the same frequency, or an interfering signal. In either case, the test should be aborted.

The EQM stores the values from the most recent test sequence and performs limit-checking on the data. Out-of-tolerance conditions are reported as alarms. The parameter data is stored and transmitted to the MPS (or Sector MPS) upon request. Note that on a busy communications channel the latest receiver data could be some minutes old, due to the receiver test sequences being aborted by frequent transmitter keying.

TFM's Required.

The following TFMS's are required for monitoring receivers, transmitters, and the environment:

TFM #2; Receiver (Appendix 2B)
TFM #3; Transmitter (Appendix 2C)
TFM #1; Environmental (Appendix 2A)

SECTION 2

DISCUSSION

Section 2 of this report consists of Appendices 2A through 2I, and 2AA through 2DD. These appendices define the requirements for Test Functional Modules (TFM's). The Appendices with the single letter identifiers (e.g., 2A) define regular TFM's. The appendices with the double letter identifiers (e.g., 2AA) define "smart" TFM's. By arranging the appendices in this manner, additional appendices can be added if additional TFM's are needed because of future expansion.

APPENDIX 2A
TFM #1, ENVIRONMENTAL

PURPOSE

The purpose of the Environmental TFM is to interface sensors that monitor the facility environment, and convert the sensor signals to digital format for processing by the EQM. Table 2A-1 provides a summary of the parameters to be monitored and the monitoring method.

DESCRIPTION OF TFM

The Environmental TFM will basically monitor three types of signals; analog voltages, contact closures (or status bits), and line frequency, and will also provide uplink control. The analog signals will be digitized by an on-board 8-bit A/D converter. The contact/status signals will use opto-isolators to isolate the external voltages from the TFM. In the case of external contact closures, the voltage for the opto-isolators will be provided by the TFM board. Line frequency will be measured by a 10-bit counter. Signal conditioning and scaling will be accomplished on the TFM board.

The signals listed in Table 2A-1 include all anticipated signals. (As noted below, some spare channels are available. In addition, if some channels are not used for the function listed in the table, they can be used for other functions.) In some facilities some of the signals will not exist, thus they will not be measured. The designation of the signals to be monitored at specific sites is part of site adaptation, and will be defined during the initial set-up of the facility.

In digital modules, many devices are packaged as 2, 4, 6, or 8 functions in a module (depending on the function type). When the total number of required signals were determined, they were rounded upward to the next module size, so some spare channels are available. Thus the channels on this TFM are:

	Total	Used	Spares
A/D	24	24	0
Contact/Status	16	15	1
Control	8	7	1
Counter	1	1	0

To reduce the processing load on the associated EQM, all the signals for A/D conversion are scaled to provide binary output numbers (e.g., 1/2/, 1/4, 1/8). The least significant bit (LSB) can thus be defined as a binary fraction where required.

MEASUREMENT METHODS

1. A.C. voltage

Each A.C. voltage will have a low-voltage (6.3 volts secondary) transformer and a scaling potentiometer connected at the source. The scaled AC voltage will be input to the TFM board where it will be converted to a d.c. voltage it will be converted to a d.c. voltage, and fed to the A/D converter. Three A.C. inputs for both prime power and backup power allow measurements of three-phase or single phase systems. Recommended scaling is LSB = 0.5 volts for 120 volt systems and LSB = 1.0 volts for 240 systems.

2. A.C. Current

AC current will be sampled by a current transformer. The resulting secondary voltage will be converted to D.C. and scaled on the TFM board. Six A.C. current inputs are available to allow monitoring of current in various circuits (e.g. obstruction lights, prime power, etc.) Scaling depends on the sensor and current levels.

3. Temperature

The GFE temperature sensor will probably be a temperature-sensitive resistance element. (A recommended alternative temperature sensor would be a Type J thermocouple with a solid state converter. A typical device of this type (provides an output of 20 mv/degree C.) This will provide a D.C. voltage as an input to the A/D converter. Recommended scaling is LSB = 1° C; range -40°C to 125°C.

4. Humidity

The humidity sensor will be a resistance type element. With appropriate excitation and scaling this will provide a d.c. voltage as an input to the A/D converter. Range is 0 to 100%, scaling: LSB = 1%

5. Battery Voltages

The battery voltage at a facility can be either 12, 24, or 36 volts depending on the type of facility. (Actual fully-charged voltages are slightly higher.) The D.C. voltage from the battery will be input to the TFM board, where it will be scaled and fed to the A/D converter. Recommended scaling is:

LSB = 0.25 V (for 36 volt battery)
LSB = 0.125 V (for 24 volt battery)
LSB = 0.0625 V (for 12 volt battery)

Similarly the voltage of the starting battery for the backup generator should have the same scaling.

6. Battery Current

The sensor for the battery charge current and discharge current are Hall effect transducers. These transducers will provide a D.C. output voltage proportional to the D.C. current, and can be obtained in a variety of ranges. The output voltage of the transducer will be input to the TFM board, where it is scaled and fed to the A/D converter. Scaling depends on the sensor used and the current levels.

7. Fuel Level, Oil Level, Coolant Level

The fuel, oil, and coolant levels will be a D.C. voltage proportional to the level of fuel, oil, or coolant for the backup generator. This will be input to the TFM board, scaled, and fed to the A/D converter. Scaling is dependent on the sensor and can be relatively crude. (An alternative approach is to use two-level status bits, indicating normal or low for the oil and coolant.)

8. Line Frequency

The line frequency signal will be picked off the A.C. voltage inputs on the TFM. This signal will be squared and will drive the 10-bit counter for a time interval of 16 seconds. Frequencies up to 63.94 Hz can thus be measured with the LSB=0.0625 Hz.

9. Contact Closures/Status Bits

A number of signals to be monitored are either contact closures or voltages indicating an off-on condition. These signals include:

(a) Intrusion alarm
(b) Smoke detector
(c) HVAC status
(d) Engine generator oil pressure (2) *
(e) Engine generator off/run status
(f) Heater, air conditioner, and exhaust fan off/run status
(g) Heater and A/C air flow

* NOTE: If actual oil pressure values are required, rather than go/no-go indications, a pressure transducer can be used and fed to the A/D converter. These type transducers are more expensive than contact pressure switches.

These inputs will all use opto-osolators on the TFM board. Where external voltages provide the status signals, the input resistors for the opto-isolators will be sized to the voltages. Where contact closures are provided, the voltage for the opto-isolators will be obtained from the TFM board.

10. Uplink Control

Eight channels of uplink control are provided. These will actuate relays on the TFM board that can control external heavy duty relays, for functions such as Heater, Air Conditioner, etc.

TABLE 2A-1

ENVIRONMENTAL TFM SIGNALS

SIGNALS	A/D	STATUS	CONTROL	COUNTER
EQUIPMENT ROOM:				
AC VOLTS, PRIME	3			
AC VOLTS, STANDY GEN.	3			
AC CURRENT	6			
TEMPERATURE	2			
HUMIDITY	1			
SITE BATTERY VOLTAGE	1			
SITE BATTERY CURRENT	2			
LINE FREQUENCY				1
SMOKE DETECTOR		1		
INTRUSION/RESET		2		
STANDBY GENERATOR:				
FUEL LEVEL	1			
OIL LEVEL	1			
COOLANT LEVEL	1			
TEMPERATURE	2			
BATTERY VOLTAGE	1			
OIL PRESSURE		1		
RUN/OFF		1		
SMOKE DETECTOR		1		
UPLINK CONTROL			2	
OTHER STATUS/CONTROL:				
HEATER 1 AND 2		2	2	
A/C 1 AND 2		2	2	
EXHAUST FAN		1	1	
AIR FLOW (HEATERS)		2		
AIR FLOW (A/C)		2		
TOTAL SIGNALS	24	15	7	
SPARES	0	1	1	
TOTAL CHANNELS	24	16	8	

APPENDIX 2B
TFM #2, RECEIVER

PURPOSE.

The purpose of the Receiver TFM is to generate the necessary signals to test a radio receiver, and measure and digitize the resulting outputs. The Receiver TFM is controlled by the associated software module in the EQM. Table 2B-1 provides a summary of the parameters to be monitored and the monitoring method.

DESCRIPTION OF TFM.

The Receiver TFM consists of a dual-channel crystal controlled r.f. signal generator; and the necessary detectors and filters to feed the receiver output signals to an on-board 8-bit A/D converter. The signal generator frequencies (one VHF frequency and one UHF frequency or two VHF frequencies) are determined by plug-in crystals. (Consideration was given to the use of a synthesizer as a signal source, but it is not cost effective for most locations). The r.f. output level is controlled digitally by a variable attenuator. The modulation signal is switched on or off as required.

It should be noted that only off-line receivers are monitored. This is a constraint imposed by the operating services, although the feasibility of monitoring on-line receivers has been demonstrated. (See Report No. FAA-RD-79-125).

MEASUREMENT METHODS.

In receiver testing it is necessary to inject a controlled r.f. signal into the receiver, and to measure several outputs from the receiver. (Table 2B-1 is a summary of receiver TFM signals). To inject the r.f. signal, a directional coupler should be installed in the antenna transmission line that feeds the receiver (as close to the receiver as possible). The recommended coupling is 20 dB, coupling flatness 0.5 dB, and directivity 15 dB. The coupling value and the attenuation of the cable from the TFM to the receiver must be accurately known, as these must be added to the attenuation inserted by the TFM, to determine the input signal level actually fed to the receiver. In some locations, the r.f. interference picked up by the antenna transmission line may cause problems. In these cases, instead of a directional coupler, a coaxial relay should be installed (as close to the receiver as possible). This will effectively disconnect the antenna transmission line from the receiver during testing. The TFM will provide a control signal to activate this relay, to be used if needed.

The signals required by the TFM to monitor the receivers are:

1. Audio output

2. Detected I.F. output (ahead of the squelch circuit)

3. AGC voltage

4. On-line/standby status

5. PTT

6. Squelch break

7. Although not required for receiver testing, d.c. supply voltages in the receiver can be monitored.

These signals should be made available external to the receiver, via a connector and/or a demarcation strip.

During receiver testing it is necessary that the on line/standby receiver status be monitored. If the receiver under test becomes selected and goes on-line, the test must be immediately aborted, to avoid interference with ATC operations. Similarly, the PTT function of transmitters on the same frequency must be monitored, and, if detected, the receiver test must be aborted, since the test data would be invalid. If the associated transmitter is located in the same facility as the receiver, PTT can be sensed at the transmitter. If the transmitter is not located in the same building, a sudden rise in AGC voltage can indicate keying of a transmitter on the same frequency or an interfering signal. In either case, the receiver test should be aborted.

Current maintenance procedures in testing receivers require that the maximum undistorted audio output level be determined. This level is higher than the level fed to TELCO lines in normal operation, so (with current manintenance procedures) the audio gain must be readjusted to the required TELCO level after this test is completed. For automated testing, however, it is recommended that the audio be checked at the normal TELCO line level, since checking the maximum level would add substantially to the cost and complexity of the TFM and the receiver interface.

1. <u>R.F. Sensitivity and Squelch Threshold</u>

The r.f. sensitivity is measured by feeding an r.f. signal (30% modulated at 1000 Hz) into the receiver at a level 15 dB below the specified sensitivity for the receiver. The audio output and squelch break are monitored. The r.f. signal is increased in 1 dB increments until the audio output reaches the level used for certification. (The signal level at which squelch breaks should be stored also). When the certification audio level is reached, the modulation is turned off and the noise level measured. The signal plus noise/noise ratio should be 10 dB or greater. The r.f. signal level at this point is used as the certification sensitivity of the receiver. Note: Whenever the r.f. signal input is changed (e.g., 1 dB steps, modulation on/off, etc.), a 150 millisecond receiver settling time should elapse before measuring the output signal.

To measure the squelch threshold, use the squelch break point previously obtained as a reference, and inject an unmodulated signal 3 dB below this reference value into the receiver. Then increase the r.f. signal in 1 dB increments until squelch breaks, and store this r.f. level as the squelch threshold.

In some locations, the squelch threshold may be set higher than the receiver sensitivity level because of a local interference problem. In this case two options are available: (1) disable the squelch during testing, or (2) measure the audio signal ahead of the squelch circuit (i.e., detected I.F. output). Disabling the squelch circuit is not recommended, since this approach reduces the "transparency" of the RMMS. Instead it is recommended that the 10 dB signal + noise/noise ratio be determined at the detected I.F. output, by switching the modulation on and off after each 1 dB increase in r.f. signal level. Although the sensitivity can be determined in this manner, it is still necessary to assure that the audio output of the receiver meets certification values when squelch is broken, and the r.f. input level at which this occurs is also stored. The option of performing sensitivity tests at the detected I.F. output is site dependent and is set by a wire strap on the TFM.

2. AGC Threshold and Control

The performance of the receiver AGC is determined by injecting an R.F. signal into the receiver, stepping it in increments and monitoring the resulting AGC voltage. For AGC threshold determination, this test may be performed concurrently with the sensitivity test. For testing AGC control, the r.f. signal level is stepped in larger increments while monitoring the AGC voltage and the audio output of the receiver. Reference 8 provides a detailed description of this method of AGC testing. Recommended AGC measurement range is 0 to 18.0 volts; LSB = 0.1 volt.

3. Status Signals

The receiver status signals required are channel select signals (ie., channel A or B indicating on-line or standby). These signals are obtained from the channel-select relays, and are input to the TFM through on-board opto-isolators. Each channel status is reported to the EQM, and the EQM (in conjunction with on-board TFM logic) uses it to select the receiver to be tested. If the transmitter is co-located with the receiver, the PTT signal from the transmitter should also be input as a status signal.

4. Control Signal

An uplink command capability should be provided to disable the r.f. signal generator in the TFM. This provides a manual override capability of the r.f. being generated by the TFM, if required.

TABLE 2B-1

RECEIVER TFM SIGNALS

SIGNALS	A/D	STATUS	CONTROL
RECEIVER INPUT:			
R.F. SIGNAL GENERATOR			
RECEIVER OUTPUT:			
AUDIO OUTPUT	2		
DETECTED I.F. OUTPUT	4		
AGC VOLTAGE	4		
CHANNEL SELECTED		2	
PTT		2	
SQUELCH BREAK		4	
RELAY CONTROL			4
SIGNAL GENERATOR DISABLE (INTERNAL CONTROL)			
TOTAL SIGNALS	8	8	4
SPARES	8	4	0
TOTAL CHANNELS	16	12	4

APPENDIX 2C
TFM #3, TRANSMITTER

PURPOSE

The purpose of the Transmitter TFM is to interface sensors that monitor radio transmitter parameters, and convert these sensor signals to digital format for processing by the EQM. The Transmitter TFM is controlled by the associated software module in the EQM. Table 2C-1 provides a summary of the parameters to be monitored and the monitoring method.

DESCRIPTION OF TFM

The Transmitter TFM will measure the parameters listed in Table 2C-1 for two transmitters that may or may not be on at the same time. These can be a VHF and a UHF transmitter that are keyed simultaneously, an exciter and LPA that are connected together, two separate VHF transmitters, etc. Some consideration was given to the use of a single shared TFM for several transmitters with a relay module to connect the keyed transmitter to the TFM. However, in a multiple transmitter environment, it is possible for several transmitters to be keyed simultaneously. Thus, it was decided that the TFM approach chosen, with two transmitters per TFM (that could be "paired") would provide the most flexible configuration.

It should be noted that transmitter measurements are made only to the on-line transmitter, and only when the transmitter is keyed, thus PTT is sensed as a control signal. In addition, some signals are sampled for discrete time intervals during a transmission. For example, the percent modulation is sampled for one second, the digital value is stored, then another sample is taken, etc. If PTT is dropped during a sample period, that sample is not retained.

The Transmitter TFM consists of the necessary input detectors and filters to interface the two transmitters. A 16-input 8-bit A/D converter is shared by both channels, and the frequency measurements are made by shared counters. Status information is stored for the PTT and channel select functions. A high-stability crystal oscillator provides the time base for frequency measurements. (Table 2C-1 is a summary of transmitter TFM signals).

MEASUREMENT METHODS

1. Forwarded and Reflected Power

To measure forward and reflected power, a directional power detector (DPD) is installed in the antenna transmission line external to the transmitter, (on the antenna side of the antenna transfer relay). A DPD of the type described in Report FAA-CT-82-100-115LR (reference 9) is recommended. This DPD provides forward and reflected output signals, each consisting of a d.c. component proportional to r.f. power level and an audio modulation component. (NOTE: The manufacturer of this DPD (Coaxial Devices, Inc.) believes he can also add the prescaler for R.F. frequency measurements to this DPD, as required in section 4 of this appendix). These signals are fed to forward and reflected signal inputs on the TFM where the d.c. and audio components are separated. The d.c. components of the forward and reflected power signals are filtered and fed to the A/D converter, and the resulting digital values are then fed to the EQM. The audio component of the forward power is detected, filtered, and fed to the A/D converter to provide a percent modulation value. Recommended scaling for r.f. power depends on the transmitter power level. As an example, however, for a 10 watt transmitter, the recommended scaling for forward power is LSB = 0.0625 watts, for reflected power LSB = 0.005 watts.

2. Percent Modulation

As stated previously, the audio component of the DPD forward power signal is detected and filtered to provide percent modulation signals. The audio signal is fed to two different detectors, one to provide a d.c. output proportional to the peak audio signal level, and the other a d.c. output proportional to the average audio signal level. In reference 8 it is noted that the peak audio signal in conjunction with average is a better indication of modulation percentage, for speech information, then the average audio signal alone. Thus both peak and average signals are fed to the A/D converter and the digital output values are then fed to the EQM. Recommended scaling is LSB = 0.5%.

3. TELCO Signal Level

The TELCO signal level is input to the TFM and the peak and average signal levels are measured in the same way as the percent modulation signals, whenever the transmitter is keyed. In addition, when the transmitter is not keyed, the noise on the TELCO line is measured. A history of line noise can provide an indication of potential TELCO line degradation.

Note that if the TELCO line is shared (speech-plus-data) the audio signal should be picked off after the filters that separate voice and data. Because of the wide dynamic range to be covered (signal levels are typically -9 to -16dBm but can be higher, and noise is typically in the range of -45 to -60dBm), dual scaling of the TELCO signal to the A/D converter is recommended with a ratio of 8:1 (or 16:1) between high and low scales.

4. R.F. Frequency

To measure R.F. frequency (if required) a directional coupler is installed in the transmission line, connected to a prescaler, and the prescaler output is fed to the TFM. (The coupler should have an isolation of a least 20 dB, with a directivity of at least 15 dB.) The prescaler is mounted adjacent to the coupler to minimize the length of the r.f. signal path. (See note under Section 1 of this Appendix). For VHF monitoring, a divide by 16 prescaler is used, providing a TTL output of 8.5 MHz (when the R.F. frequency is 136 MHz). For UHF monitoring, an extra stage on the prescaler provides a divide by 32 capability, thus, at 400 MHz, a 12.5 MHz TTL output is generated. (The prescaler should also have a low-level input with an amplifier and detector to measure the signals discussed in 4a.) TTL signals in the frequency range indicated can readily drive a cable to the TFM. In the TFM, the TTL prescaled signal is fed (via the carrier frequency input pin) to a 24-bit counter (counts up to 16,777,215), which counts the prescaled frequency. With a gate time base of 1 second for the counter, the resolution of the counted r.f. will be 16 Hz for VHF and 32 Hz for UHF. With a time base accuracy of 10^{-7}, frequency measurement accuracy of 200 Hz at VHF and 400 Hz at UHF can be readily attained.

4a. Additional R.F. Frequency/Level Measurement

Experience has shown that if the drive level out of the oscillator is low it can cause transmitter problems. Also, in some cases the oscillator frequency may have shifted, resulting in a change in output frequency. To help the maintenance technician to localize these conditions a proposed additional capability of this TFM, is to measure the oscillator output frequency and level (or synthesizer output for BUEC). This can be accomplished by installing a miniature directional coupler in the oscillator (or synthesizer) output coaxial cable. This coupler should have an isolation of 25 dB and directivityof 15 dB. The sampled signal at this point should be fed to the amplifier input of the prescaler. (Amplification is necessary since the r.f. signal level out of the coupler is about 40 millivolts). After being amplified, the r.f. signal is fed to the counter in the prescaler. The amplified r.f. is also fed to a detector and filter to provide a d.c. level proportional to the r.f. signal level. Thus there are two outputs from the amplified signal: A prescaled oscillator (synthesizer) frequency, and a d.c. level proportional to the r.f. level. The prescaled frequency is fed to the oscillator frequency input on the TFM. (A logic gate under program control selects either the transmitter carrier frequency or oscillator frequency to be counted). The d.c. input is fed to the A/D converter and reported as the oscillator level. (Note that the oscillator level measurement can be relatively crude, since it is used as a go/no-go indication, not as an absolute power level. The detector characteristics, therefore, are not as critical as the detectors used for transmitter output measurement).

5. Modulation Frequency

For transmitters that are modulated by fixed frequency tones the modulation audio signal is fed to a zero crossing detector and the period measured, using the time-base oscillator as the reference clock.

6. Status Signals

Two status signals are reported for each transmitter: PTT and channel selected. The PTT signal is used to initiate data collection on keyed transmitters by the TFM. In addition, each PTT is reported to the EQM where they are accumulated and the total count reported to the RMSP (or MPS) on the next scheduled poll. The channel select bits identify whether channel A or B (VHF and UHF) is on-line or standby. This signal is obtained from the channel select relays. All status signals are input to the EQM through opto-isolators.

7. VSWR

The Voltage Standing Wave Ratio (VSWR) is not measured directly, but is calculated by the EQM from the forward and reflected power measurements. RANGE: 1.00 to 2.10, INCREMENT: 0.05

8. Modem Tone Level

While not required as a transmitter parameter, monitoring of the RMMS modem tone level on the TELCO line is provided. Monitoring this signal can give an indication of potential TELCO line degradation. Where a separate circuit is provided for modem use, this signal is taken from the TELCO line. If the TELCO line is shared (speech-plus-data) this signal should be picked off after the filters that separate the voice and data. The modem audio tone is fed to the TFM, detected and filtered and then fed to the A/D converter.

9. Transmitter Power Supply Voltage

While not required for certification, the d.c. voltage for the power amplifier or modulator can provide a useful indication of potential problems. This voltage must be brought out of the transmitter via a connector or terminal strip, and then scaled and fed to a spare channel on the A/D converter.

TABLE 2C-1

TRANSMITTER TFM SIGNALS

SIGNALS	A/D	STATUS	COUNTER
FORWARD POWER	2		
REFLECTED POWER	2		
OSCILLATOR OUTPUT LEVEL	4		
PERCENT MODULATION	4		
TELCO SIGNAL LEVEL (ALSO NOISE)	2		
CHANNEL SELECTED		2	
PTT		2	
CARRIER FREQUENCY (OR OSCILLATOR FREQUENCY)			1
MODULATION FREQUENCY			1
MODEM TONE LEVEL	1		
TOTAL SIGNALS	15	4	2
SPARES	1	4	0
TOTAL CHANNELS	16	8	2

APPENDIX 2D

TFM #4, IEEE-488

PURPOSE

The purpose of the IEEE-488 TFM is to interface facility equipment, monitors, and test equipment that have a General Purpose Interface Bus (GPIB) capability. This TFM is controlled by the associated software modules in the EQM.

DESCRIPTION OF TFM

The IEEE-488 TFM is an off-the-shelf Multibus IEEE-488 board that is available from several vendors (e.g., Intel, National, etc.)

A typical board (ZIATECH CORP. ZT 85/38) has the following features:

1. On-board intelligence to implement GPIB functions.
2. Programmable interrupt controller.
3. Access to 1 Megabyte of Multibus system memory
4. I/O control block for programming GPIB functions.
5. 8K bytes of dual-port RAM, that can be mapped anywhere in the 1 Megabyte Multibus system memory.

MEASUREMENT METHODS

In use, this TFM is connected to the device or devices being controlled via the IEEE-488 bus. The TFM is the GPIB controller and receives commands from the associated EQM. The TFM contains all the handshaking and protocol for the GPIB command and data interchange. The program for a specific interface configuration is stored in RAM on the TFM. (This program is loaded from the EQM). Upon command from the EQM, the TFM executes the appropriate portions of this program, and stores the collected data in its dual-port RAM, or at any defined memory location. Since the dual-port RAM can be mapped to any location in the Multibus system memory, (up to 1 megabyte) it can be accessed by the Multibus system and appears as a slave RAM board. (NOTE: The original multibus structure provided 20 address lines (up to 1 Megabyte). The adopted IEEE-796 standard for Multibus provides 24 address lines (up to 16 Megabytes).

The functions that are performed by this TFM (control and or data collection are dependent upon the specific facility that is being monitored, and are defined by the EQM software for that facility.

APPENDIX 2E

TFM #5 STATUS/CONTROL

PURPOSE

The purpose of the Status/Control TFM is to interface facility equipment that provides status information and/or requires control signals. The TFM is controlled by the associated software modules in the EQM.

DESCRIPTION OF TFM

The Status/Control TFM is an off-the-shelf Multibus board that is available from several vendors (e.g., National, Intel). A typical board (National Semiconductor BLC-556) provides the following:

24 dedicated input circuits
16 dedicated output circuits
8 programmable input/output circuits

All inputs and outputs are optically isolated with user-installed plug-in optical isolators. Sockets are also provided for user-installed I/O terminators, input resistor packs and output drivers.

MEASUREMENT METHODS

In use, this TFM is connected to the device providing the status signals and/or requiring control signals. All input signals and output signals are connected to the TFM (each as a separate pair of lines) via two 50-pin edge connectors. Selection of the desired input or output signal is accomplished by addressing the lines as 8-bit ports (or 4 bit/8 bit ports for the programmable lines). Each bit within this group of 8 or 4 then defines a specific status or control line.

The functions that are performed by this TFM (status reporting and control) are dependent upon the specific facility it is being used with, and are defined by the EQM software for that facility.

APPENDIX 2F

TFM #6 SERIAL COMMUNICATIONS

PURPOSE

The purpose of the Serial Communications TFM is to provide eight additional serial data communications ports to interface with "smart" TFM's or other RMMS subsystems that require a serial data interface. This board is used where an EQM requires more I/O channels than are on the EQM CPU board.

DESCRIPTION OF TFM

The Serial Communications TFM is a commercially available intelligent off-the-shelf Multibus board (e.g., Central Data Corporation). It is composed of eight RS-232C serial output ports, USARTS, and the associated addressing, control, and interrupt logic. An on-board CPU and memory controls the Data I/O transmission, thus relieving the EQM of much of the overhead in servicing these data channels. For standardization purposes, this is the same Multibus board that will be used in the Remote Monitoring Subsystem Processor (RMSP).

MEASUREMENT METHODS

This TFM is not used as a measurement device. It is used as a transparent asynchronous serial data communications I/O interface between the EQM and "smart" TFM's or other RMMS subsystems.

In use, the interrupt structure is set up by wirestrapping. The baud rate for each channel is selected under program control by the associated EQM. Since the interface to the EQM is interrupt driven, interrupt handling subroutines for this TFM must be incorporated in the EQM software.

Since this TFM is a transparent I/O interface, all message formatting and protocol are performed by the EQM. The on-board processor, in this TFM, can be programmed to perform error checking and priority detection/handling if required.

APPENDIX 2G

TFM #7, BUEC CONTROLLER

PURPOSE

The purpose of TFM #7 is to provide control of the Back Up Emergency Communications (BUEC) test sequence at the ARTCC end. It is used in conjunction with the TFM's at the BUEC site.

DESCRIPTION OF TFM

The BUEC Controller is fabricated on a Multibus circuit card which includes Multibus interface components. All software to operate the controller is resident in the host EQM. The controller consists of ten (4-wire) interfaces to TELCO lines, ten interfaces to the BUEC Remote Control Group, a 20-channel 8-bit A/D converter, and the necessary logic and tone generators to perform its functions. The ten interfaces to the TELCO lines are bridging inputs that allow the TFM to be bridged across the lines without appreciable loading (about 20 dB isolation). The interfaces to the Remote Control Group (RCG) perform two functions. They sample the status of each of the ten circuits to determine if the channel is busy, and they provide "channel busy" status to the Remote Control Group on the channel that is selected for RMMS test.

MEASUREMENT METHODS

This TFM performs the following functions under control of the EQM software:

1. Examines the status of the TELCO channels in the RCG.

2. When a channel is selected for a test, it sends the "channel busy" signal to the RCG.

3. Initiates the test sequence by sending the appropriate code to the remote BUEC (via the TELCO lines).

4. Verifies that the remote BUEC responds correctly to the transmitted command sequence.

5. When not conducting a test, the TFM is a passive "listener" that monitors the TELCO lines to assess system performance.

When a BUEC test is requested (by the maintenance technician via the MPS) the MPS uplinks a message to both the BUEC site and the BUEC Controller EQM. This EQM causes the BUEC Controller TFM to check the status of all TELCO channels in the RCG. If more than 50% are busy, the EQM notifies the Technician (via the MPS) and does not continue the test unless a command is received from the MPS to continue.

The EQM/TFM selects the requested BUEC channel, sets the channel status (in the RCG) to "busy", and selects the associated TELCO line. Under EQM control, the TFM generates the tone sequence to turn on the BUEC, and select the test frequency. (The test frequency is a standard frequency for each BUEC site.) The EQM/TFM then should receive the down-linked tone indicating that the BUEC is operating and locked on frequency. At this point, the TFM does nothing further until the completion of the test.

At the completion of the test sequence at the BUEC site, the site EQM will down-link a message to the MPS containing the BUEC parameter data. Upon receipt of this message, the MPS will notify the BUEC Controller EQM/TFM that the test is complete. Under EQM control, the TFM will release the TELCO line and set the status line (in the RCG) for that channel to "not busy".

When not conducting a test sequence, the EQM/TFM passively monitors all channels to collect data on channel activity, and maintains counts of successful/unsuccessful usage of each channel, to pinpoint potential problems. It also monitors the noise level and tone level on the TELCO lines via the A/D converter to pinpoint TELCO line problems.

APPENDIX 2H

TFM #8, BUEC DECODER

PURPOSE

The purpose of TFM #8 is to decode the BUEC signals on the TELCO line, and monitor tone levels and noise levels on the TELCO line.

DESCRIPTION OF TFM

The BUEC Decoder is fabricated on a Multibus circuit card which includes Multibus interface components. All software to operate the Decoder is resident in the host EQM. The controller consists of four (4-wire) interfaces to TELCO lines, a 16-channel 8-bit A/D converter, tone decoders, modulation tone generator, and the necessary logic to perform its functions. Four TELCO channels are provided to allow for various options and expansion (e.g., a UHF and a VHF BUEC, multiple BUEC's, etc.) The interfaces to the TELCO lines are bridging inputs that allow the TFM to be bridged across the lines without appreciable loading (about 20 dB isolation).

MEASUREMENT METHODS

The function of TFM #8, during a test sequence, is primarily to decode the signals coming over the TELCO lines. It is used in conjunction with TFM #2 (Receiver) and TFM #3 (Transmitter) to perform the test sequence at the BUEC site.

When a BUEC test sequence is initiated at the ARTCC, the MPS uplinks a command to the BUEC site EQM that a test is being started. The BUEC Controller TFM (at the ARTCC) sends a standard tone sequence up the TELCO line to the BUEC site that turns on the BUEC and selects the test frequency. The BUEC Decoder TFM decodes the tones, stores the decoded frequency, and transfers this frequency to the EQM. The EQM then initiates the receiver test sequence using TFM #2, and the methods described in Appendix 2B. After the receiver tests are completed, two options exist: the EQM can perform the transmitter test or not. (This is a wire-strap option on the BUEC Decoder TFM.) If the transmitter test option has been selected, the EQM keys and modulates the transmitter (via the BUEC Decoder TFM and TELCO line). The EQM then initiates the transmitter test sequence using TFM #3 and the methods described in Appendix 2C. At the completion of the test sequence, the EQM will transmit the parameter data to the MPS. If the transmitter test option has not been selected, monitoring of the transmitter is performed in the passive mode as described in the next paragraph.

As a passive transmitter monitor, the TFM monitors the TELCO lines. When the tone sequence to turn on a BUEC and the selected frequency is detected and stored, the TFM generates an interrupt to the EQM. The EQM services the interrupt and gets the frequency from the TFM. The EQM then performs the transmitter test sequence using TFM #3 and the methods described in Appendix 2C.

When the BUEC site monitor is not performing transmitter or receiver tests, it passively monitors the TELCO lines (via TFM #8) to measure the noise levels on the lines. These are compared against stored limit levels in the EQM, and, if out of tolerance, are reported as alarms.

ADDITIONAL FUNCTIONS

The 16-channel A/D converter used on this TFM is a standard plug-in IC used on other TFM's. Since only four of the channels are used for monitoring TELCO lines, twelve spare channels are available to monitor other signals if required.

APPENDIX 2I

TFM #9, RVR

PURPOSE

The purpose of the RVR TFM is to provide the interfaces to monitor the performance of the Runway Visual Range (RVR) system.

DESCRIPTION OF TFM

The RVR TFM will accept input pulses from up to 12 transmissometers and the outputs of the 12 associated Signal Data Converters (SDC). It also accepts inputs defining the ambient light level, the runway edge lighting levels, and background count commands from the SDC. The RVR TFM consists of the following:

a. 12 input pulse signal conditioners - to accept transmissometer pulses and standardize them.

b. 12 16-bit counters (three on a chip) - to count the transmissometer pulses.

c. 12 serial data decoders/registers - to receive the RVR values from the SCD's.

d. Status sensing;

    12 bits to sense "background count" commands
    24 bits to sense edge light levels (up to six runways)
    4 bits to sense ambient light levels

MEASUREMENT METHODS

The pulses from up to 12 transmissometers are input to the TFM and standardized by the signal conditioners. These pulses are sent to a set of 12 counters. Every 15 seconds the EQM acquires the counter values and resets the counters. A running 60-second total count is kept for each transmissometer. For each transmissometer, the EQM selects a particular table based on the light sensor information (runway edge lighting and ambient light level). From that table an RVR value is selected that corresponds to the last 60-second count for that transmissometer. (The tables used in the EQM are the same as those used in the RVR-500 SDC). These values are saved for comparison with the SDC computer values.

The data outputs of the SDC's (RVR values) are input to the TFM where they are decoded and transferred to the EQM. The EQM compares these values with the values stored from its own independent computation. The values should agree (plus or minus one table entry value).

During a background count, the TFM/EQM counts the background pulses (Background count is started upon sensing the "background count" command from the SDC).

In addition to performing these counts the TFM/EQM will perform limit checking on: RVR minimum, transmissometer minimum, transmissometer maximum, background maximum. It will also detect sudden changes in RVR value indicating potential transmissometer problems (e.g., dirt on lens).

APPENDIX 2AA

SMART TFM #1, MARKERS, VOT

PURPOSE

The purpose of the Smart TFM #1 is to provide monitoring functions of facilities that have limited monitoring requirements (e.g., marker, NDB, compass locator, etc.). In addition this TFM will monitor the ILS localizer and Glide Slope Facilities. It will operate as a stand-alone TFM and, in most cases, will be physically separated from its host EQM. Table 2AA-1 provides a summary of the monitoring capabilities of the TFM.

DESCRIPTION OF TFM

The Smart TFM #1 is fabricated on a single "bare-bones" Multibus circuit card. This card will have the Multibus form factor but will derive only its d.c. power from the back plane, thus no Multibus interface components are required on the card. All signal input/output will be via edge connectors on the front of the card. This TFM is designed as a flexible stand-alone universal monitoring subsystem. It consists of a single chip microcomputer, a 24-channel 8-bit A/D converter, counter, eight status inputs, two control outputs, a UART, and serial data output. Power input to the card is ± 12 volts d.c. and + 5 volts d.c. Software for all the monitoring functions is resident in the single chip computer. Selection of the monitoring subroutines required for a specific facility is accomplished by wire strapping.

To keep this TFM as flexible and simple as possible, arbitrary limits will be used for alarm detection based on the following:

Status:	Any bad status condition will be reported as an alarm.
A.C. Voltage:	Nominal a.c. voltage is 120 volts. A change of 15% or more is an alarm.
A.C. Current:	The nominal current in a circuit is considered 100%. A change of 20% or more is an alarm.
D.C. Volts:	A 10% change from nominal (13.8 volts or 27.6 volts) is an alarm.
D.C. Current:	This is site dependent, based on the facility type.
R. F. Power:	R.F. power will be scaled per site requirements. A change of 2.0 dB is an alarm.
Percent Modulation:	A change of 2% is an alarm.
R.F. Frequency:	The actual frequency is site dependent. A change of 0.002% is an alarm.
Modulation Frequency:	A change of 1% or 2% (wire strap option) Is an alarm.
ID Decode:	Must agree with site ID. Non-agreement is an alarm.

MEASUREMENT METHODS

1. Status/Control

Status reporting and uplink control are common requirements for markers and non-directional beacons. The facility status signals (or contact closures) are fed to the TFM and optically-coupled to the TFM processor. Uplink (or locally generated) control signals are decoded by the microcomputer and drive the selected control relay on the TFM.

2. A.C. Voltage

The a.c. voltage will have a low voltage (6.3 volts secondary) transformer and a scaling potentiometer connected at the source. The scaled AC voltage will be input to the TFM board where it will be converted to a d.c. voltage, and fed to the A/D converter. Scaling is LSB = 1 volt. If the voltage changes by 15% or more an alarm will be reported.

3. A.C. Current

A.C. current will be sampled by a current transformer. The resulting secondary voltage will be input to the TFM, converted to d.c., scaled, and fed to the A/D converter. Four a.c. current inputs are available to allow monitoring of current in various circuits (e.g. obstruction lights, prime power, etc). Since the currents in the different circuits are site dependent, scaling will be set on a percentage basis with the normal current in a circuit equal to 100%. If the current in any circuit changes by more than 20% an alarm will be reported.

4. D.C. Volts

The d.c. battery voltage will be fed to the TFM, scaled, and fed to the A/D converter. If the battery voltage changes by 10% or more from nominal (13.8 volts for a 12 volt battery, 27.6 volts for a 24 volt battery) an alarm will be reported. Scaling is LSB = 1/8 volt.

5. D.C. Current (Battery Charge/Discharge)

The sensor for the battery charge and discharge currents will be Hall effect transducers. These transducers will provide a d.c. voltage proportional to the d.c. current. The output voltage of the transducer will be input to the TFM board where it is scaled and fed to the A/D converter.

6. R.F. Power

To measure forward and reflected r.f. power, a directional power detector (DPD) is installed in the antenna transmission line. A DPD of the type described in Report FAA-CT-82-100-115R (Reference 9) is recommended. This DPD provides forward and reflected output signals each consisting of a d.c. component proportional to r.f. power level, and an audio modulation component. These signals are input to the TFM where the d.c. and audio components are separated. The d.c. components are filtered and fed to the

A/D converter to provide the r.f. power values. The audio component of the forward power is peak detected, filtered, and fed to the A/D converter to provide a percent modulation value. Scaling of the r.f. signals is dependent on the transmitter power level. From the r.f. power levels the VSWR is computed.

7. Percent Modulation

The audio component from the DPD is peak detected, filtered, and fed to the A/D converter. Scaling is adjusted such that the LSB = 0.5%. A change of 2% is an alarm.

8. R. F. Frequency

To measure R.F. frequency a directional coupler is installed in the transmission line, connected to a prescaler and the prescaler output fed to the TFM. (The coupler should have an isolation of 20 dB and a directivity of at least 15 dB). The prescaler should be a dual modulus (2 and 16) unit. For a 75 MHz marker and ILS Localizer prescaling by 16 is performed. For ILS Glideslopes, prescaling is 32. This output is fed to a 24-bit counter in the TFM where 1 second samples are obtained to get the equivalent frequency. For low frequency beacons, prescaling by 2 is performed. If the frequency changes by 0.002% an alarm is declared.

9. Modulation Frequency

Since the modulation can be keyed on and off by the ID code keyer, the modulation frequency is determined by measuring the period of several modulation cycles and averaging the measurements to derive a smoothed period time, which is then converted to frequency. A change of 1% or 2% (wire strap option) in modulation frequency is an alarm.

10. ID Decode

The transmitted ID is decoded by detecting the modulation envelope and then using the microcomputer to translate the resulting code structure into the site ID. The transmitted ID must agree exactly with the stored site ID or an alarm is declared.

11. Phase Detector

One other function is a digital phase detector. This function will allow this TFM to also be used as a VOT monitor. Some consideration was given as to whether it is more cost effective to include this, or to have it on a separate card, considering the limited number of VOT facilities. It was decided to include it, since it would only add some logic and comparators, to the cost of the TFM.

Additional Software.

In addition to the subroutines used for monitoring the various functions, routines common to all facilities are part of the resident software. These include: initialization routine, main routine (executive), and formatting and communications routine.

TABLE 2AA-1

SMART TFM #1 SIGNALS (FOR MARKERS, VOT)

SIGNALS	A/D	STATUS	COUNTER	CONTROL
STATUS		8		
CONTROL				4
TEMPERATURE	1			
AC VOLTS	1			
AC CURRENT	4			
DC VOLTS	1			
DC CURRENT	2			
RF POWER	2			
PERCENT MODULATION	3			
RF FREQUENCY			2*	
MODULATION FREQUENCY			2*	
ID DECODE				
PHASE DETECTOR			2*	
TOTAL SIGNALS	14	8	2	4
SPARES	10	0		0
TOTAL CHANNELS	24	8	2	4

* COUNTERS ARE TIME-SHARED

TABLE 2AA-2

SMART TFM #1 SIGNALS (FOR GS/LOC

SIGNALS	A/D	STATUS	CONTROL	COUNTER
COURSE ALIGNMENT	1			
COURSE WIDTH	1			
COURSE DDM	1			
TEST DDM	1			
COURSE RF POWER (FWD/REV.)	2			
CLEARANCE RF POWER (FWD/REV)	2			
VSWR (CALCULATED)				
COURSE PERCENT MODULATION	2			
CLEARANCE PERCENT MODULATION	1			
IDENT PERCENT MODULATION	1			
COURSE FREQUENCY				2*
CLEARANCE FREQUENCY				2*
OFFSET FREQUENCY				2*
IDENT FREQUENCY				2*
IDENT CODE (CALCULATED)				
STATUS		8max		
CONTROL			2	
TEMPERATURE	1			
AC VOLTAGE	1			
BATTERY VOLTAGE	1			
BATTERY CURRENT	2			
AC CURRENT	2			
USED	19	8	2	2
SPARES	5	0	2	0
TOTAL	24	8	4	2

* Counters are shared

APPENDIX 2BB

SMART TFM #2, LIGHTING

PURPOSE

The purpose of the smart TFM #2 is to provide monitoring of lighting systems at airports. It will operate as a stand-alone TFM, thus it can be either co-located or physically separated from its host EQM. Table 2BB-1 provides a summary of the monitoring capabilities of the TFM.

DESCRIPTION OF TFM

The Smart TFM #2 is fabricated on a single "bare-bones" Multibus circuit card. This card will have the Multibus form factor but will derive only its D.C. power from the back plane, thus no Multibus interface components are required on the card. All signal input/output will be via edge connectors on the front of the card. This TFM is designed as an intelligent stand-alone monitoring subsystem. It consists of a single-chip microcomputer, a 32-channel 8-bit A/D converter, counter, four status inputs, four control outputs, a UART, and serial data output. Power input to the card is ±12 volts d.c. and +5 volts d.c. Software for all monitoring functions is resident in the single chip computer. Selection of the subroutines required for a specific application is accomplished by wire-strapping. Since some applications of this TFM may require more than 32 a.c. inputs, additional boards can be "daisy-chained" at a given location and be polled by the EQM as a party line.

MEASUREMENT METHODS

1. AC Voltage

Each a.c. voltage will have a low voltage (6.3 volts secondary) transformer connected at the source, with a scaling resistor/potentiometer network connected across the 6.3 volt winding. The scaled voltage will be input to the TFM board where it will be fed to the a.c. voltage input module. The a.c. is converted to d.c., and fed to the A/D converter. The scaling used is a function of the voltage being measured, since the A/D converter can provide a full scale digital output of 255. Recommended scaling is LSB = 0.5 volts for 120 volt systems and LSB = 1.0 volt for 240 volt systems. For higher voltage systems the scaling should be adjusted proportionately.

2. AC Current

A.C. current will be sampled by a current transformer. The resulting secondary voltage will be converted to d.c., scaled, and fed to the A/D converter in the same manner as a.c. voltages. The scaling depends on the sensor used and the current levels.

3. DC Voltage

The option of measuring d.c. voltage and current is also provided. To measure d.c. voltage, a resistive voltage divider is connected at the source to reduce the voltage that is fed to the TFM to approximately 5 volts. The reduced voltage is input to the TFM board where it will be fed to the d.c. input module. The d.c. input module scales the voltage and it is then fed to the A/D converter. Since the A/D converter can provide a full scale digital output of 255, scaling should be such as to make full use of this range.

4. DC Current

D.C. current is measured by using a Hall effect transducer, which produces a d.c. output voltage proportional to the d.c. current. The d.c. output voltage is input to the TFM, where it is fed to the d.c. input module. The d.c. input module scales the voltage and it is then fed to the A/D converter. Scaling is dependent on the current level and the sensor being used.

It should be noted that a.c. and d.c. current and voltage are measured in the same way (with appropriate scaling). Thus the 32 inputs measured by the A/D converter can be any mix of currents and voltages.

5. Flash Rate

The flash rate of approach lighting systems is measured by sampling the flash pulses and feeding these pulses to a counter on the TFM, where they are counted for 15 seconds. The latest four of these 15 second counts are accumulated to provide the one minute count rate.

6. Line Frequency

Line frequency is measured by sampling an a.c. voltage signal on the TFM and feeding it to a 10-bit counter for a time period of 16 seconds. This will measure frequency up to 63.94 Hz with the LSB = 0.0625 Hz.

7. Status Signals

Four optically-isolated status inputs are provided. These can be used for a number of functions including:

a. Change in VASI angle
b. Intrusion alarm
c. Smoke detector

8. Uplink Control

Four channels of uplink control are provided. These will actuate four relays on the TFM board that can control external relays for any required functions.

9. Address Decoding/Party Line

This TFM board will have an address decoding capability so that up to eight TFM's can be connected in a "daisy chain" type party line configuration. In this mode of operation, communications between a single output port on the host EQM and any one of the TFM's at a time can be supported. A wire strap jumper will enable the party line mode or convert to single board operation. In single board operation, each Lighting TFM must be connected to a separate I/O port on the EQM.

TABLE 2BB-1

SMART TFM #2 SIGNALS

SIGNALS	A/D	STATUS	COUNTER	CONTROL
AC VOLTS	16*			
AC CURRENT	16*			
FLASH RATE			1**	
LINE FREQUENCY			1**	
STATUS		4		
CONTROL				4
TOTAL SIGNALS	32	4	1	4

* TOTAL OF 32 CAN BE DIVIDED BETWEEN A.C. VOLTS AND A.C. CURRENT (OR D.C. VOLTS AND CURRENT) AS REQUIRED.

** SHARED COUNTER

APPENDIX 2CC

SMART TFM #3, RADAR INTERFACE

PURPOSE

The purpose of the Radar Interface TFM is to generate the necessary control signals for radar testing, and measure and digitize the resulting outputs. This TFM is controlled by the associated software modules in the EQM. Its application to ASR radars is described in Appendix G.

DESCRIPTION OF TFM

The Radar Interface TFM is fabricated on a single "bare-bones" Multibus circuit card. This card will have the Multibus form factor but will derive only its D.C. power from the back plane, thus no Multibus interface components are required on the card. All signal input/output will be via edge connectors on the front of the card. This TFM is designed as a data acquisition subsystem for radar data. It will operate in conjunction with an IEEE-488 TFM (TFM #4) to coordinate control of radar measurements, and with Status/Control TFM (TFM #5).

The TFM consists of a single chip microcomputer, an 8-bit A/D converter, a 12-bit azimuth counter, a 12-bit range counter, and the necessary logic and control circuits to perform test signal source selection, attenuation, gating, and signal channel selection.

MEASUREMENT METHODS.

1. Transmitter Power

Forward and reflected transmitter power will be measured at the directional coupler using a power meter controlled by the IEEE-488 TFM. The selection of the forward or reflected power port will be performed by coaxial switches controlled by the Radar Interface TFM.

2. Receiver Sensitivity

Receiver sensitivity will be measured by injecting a test signal from a commercial UHF signal generator into the directional coupler. If the signal generator has a GPIB capability it will be controlled by the IEEE-488 TFM. If a conventional signal generator is used, the attenuation will be controlled by the Radar Interface TFM. Range and azimuth gating of the test target will be performed by the range and azimuth counters on the TFM.

The video output of the receiver will be fed to the TFM, where a gated sample-and-hold amplifier will store the peak video level, which will then be digitized by the A/D converter. The planned approach is to measure the tangential sensitivity of the receiver rather than the MDS, hence samples of the baseline noise level and the signal plus noise level will be required. Depending on the target video level, the attenuator on the signal generator will be stepped until the sensitivity is determined.

3. Receiver Noise Figure

The signal from a noise generator will be injected into the directional coupler through a programmable attenuator. The noise source will be range and azimuth gated, and the selection of the noise generator as the signal source will be controlled by the TFM.

The video output will be sampled and digitized for noise input, in the same way as for the receiver sensitivity test. The attenuator on the noise generator will be stepped until the receiver noise output power increases 3 dB. The attenuator value and the noise source reference level will then be used to determine the receiver noise figure.

4. Video Output Level

The receiver output level is measured by using targets of opportunity at short ranges. The receiver video is fed to the TFM where it is routed to a track-and-hold amplifier, digitized by the A/D converter and stored.

5. Trigger Level

Trigger level is measured in the same way as the video output level. Since the trigger timing is known, however, the sample time can be defined.

6. ACP Level/ARP Level

The ACP and ARP levels are measured in the same manner as the trigger pules (e.g. sample-and-hold and then to an A/D converter).

7. ACP Count

The ACP count is accumulated in the ACP counter. When the ARP is received, the ACP count is compared to a stored reference. If the ACP count does not agree with the stored reference, an alarm is declared.

GENERAL

Since range and azimuth gating are included in the TFM, signals can be generated over a defined azimuth interval. Therefore, the approach is to take a number of samples and average them to minimize the effects of perturbations. This can be readily accomplished by the microcomputer.

It should be noted that all of the measurements described in this appendix do not have to be made simultaneously (In fact, they cannot, since the directional coupler ports are shared). Thus the tests can be performed in sequence with no critical time requirements. The only interrupt driven functions of the microcomputer program are the ARP count (which is predictable since it occurs once per antenna scan), communications with the EQM, and time updates.

APPENDIX 2DD

SMART TFM #4, DME

PURPOSE

The purpose of Smart TFM #4 is to provide a monitor for Distance Measuring Equipment (DME) facilities. Table 2DD-1 provides a summary of the monitoring capabilities of the TFM, and the measurement method.

DESCRIPTION OF TFM

The Smart TFM #4 is fabricated on a single "bare-bones" Multibus circuit card. This card will have the Multibus form factor but will derive only its d.c. power from the back plane, thus no Multibus interface components are required on the card. All signal input/output will be via edge connectors on the front of the card. This TFM is designed as an intelligent stand-alone monitoring subsystem. It consists of the following components:

1. single chip microcomputer
2. 16-channel 8-bit A/D converter
3. 12-bit counter
4. detector characteristics PROM
5. ID detector
6. eight status inputs
7. two control outputs
8. UART and serial data output
9. various logic elements

A 20 MHz crystal-controlled oscillator is the basic clock generator. This is gated into the counter for measuring pulse width, pulse spacing, and reply delay. The 20 MHz clock is divided by 4 to provide a 5 MHz clock for the microcomputer.

Power input to the card is ± 12 volts d.c. and +5 volts d.c. Software for all the monitoring functions is resident in the single chip computer.

MEASUREMENT METHODS

1. R.F. Power (forward and reflected), VSWR.

The forward and reflected power is measured by installing a directional coupler in the antenna transmission line. The coupler should have sufficient isolation to limit the peak power at the output ports to 0.1 watt (an external attenuator can be used at the forward power port if necessary). Diode detectors are connected to the coupler ports and the detected video pulses are fed to the TFM where they are scaled and fed to peak detectors, and then digitized by the A/D converter. The characteristics of the diode detectors are stored in a look-up table in a removeable PROM on the TFM.

(Present thinking is that if the detectors are field replaced, a PROM with the new diodes characteristics will replace the old one). The forward and reflected power can thus be calculated using the peak voltages and the values stored in the table. The VSWR is calculated from the forward and reflected power levels.

2. Pulse Width, Pulse Spacing.

For pulse width and pulse spacing measurements, the 20 MHz clock on the TFM is used as the reference time base clock. The pulse width (3.5 microseconds) is measured at the 50% points. The detected forward power pulse is fed to a low hysteresis voltage comparator. The other input to the comparator will be a d.c. voltage equal to 50% of the voltage out of the peak detector. At the 50% point of the leading edge of the pulse, the comparator will change state and gate the 20 MHz clocks into the counter. At the trailing edge of the pulse, the comparator again changes state, gating off the clock pulses. The count in the counter (nominal 70 counts) thus represents the pulse width in 50 nanosecond increments.

The pulse spacing (12 microseconds) is measured by using successive pulse pairs to toggle a flip-flop. The flip-flop is tuggled ON by the first pulse and OFF by the second. When the flip-flop is ON it gates the 20 MHz clocks into the counter and when it is OFF it gates them off. The accumulated pulse count (nominal 240 counts) represents the pulse spacing in 50 nanosecond increments. To insure that the flip-flop is ready to receive the next pulse pair, the flip-flop is reset by a one-shot 20 microseconds after the first pulse, if it has not been reset by the second pulse.

3. Reply Rate.

The reply rate is measured by counting the number of forward power detected video pulses for a period of one second. The one-second reference is provided by the microcomputer and gates the detected pulses into the counter for a one-second period. The accumulated count in the counter (nominal 2700) is the number of pulses per second.

4. Reply Delay, Reply Efficiency.

The reply delay is measured by using the reply enable pulse to gate the counter on (to count 20 MHz clocks). The detected forward power pulse, that occurs 50 microseconds later, gates the counter off. The accumulated count in the counter (nominal 1000) represents the delay in 50 nanosecond increments. The counter and a decoding gate are used to develop a "window" that opens about 49.5 microseconds after the reply enable pulse, to insure that only the correct transmitter pulse will gate the counter off.

The reply efficiency is measured by counting the number of reply enable pulses and also the number of resulting delayed transmitter pulses for a defined period of time (1, 2 or 4 seconds). These pulses can be counted by the microcomputer. (An alternate approach would add an 8-bit counter to the TFM and use the two counters to do this). By dividing the number of transmitted pulses by the number of reply enable pulses, and multiplying this by 100, the reply efficiency in percent is obtained.

5. <u>ID Tone Frequency, ID Occurrence Rate and Site ID</u>.

The detected forward power pulses are fed to a 1350 Hz detector. This consists of a one-shot (period about 70 microseconds), followed by an LC resonant circuit tuned to 1350 Hz. The period of the output frequency is measured (using the 20 MHz clock as the reference time base) and averaged for several cycles to measure the ID tone frequency.

The 1350 Hz tone is fed to an ID detector (a diode with a filter to remove 1350 Hz components) to obtain the dots and dashes for Site ID. When the ID is transmitted, the dots and dashes that comprise the Site ID are decoded by a microcomputer subroutine. The ID obtained is compared to the stored Site ID for validation. (The site ID could be stored in the same PROM that stores the diode detector characteristics). In addition, the time between successive ID transmissions is measured by the microcomputer (typically 30 seconds). If the time between ID transmissions exceeds 70 seconds, a fault is reported.

6. <u>Status Signals</u>.

Four DME status signals are reported, DME alarm, shutdown, and channel 1 or 2 on line. These signals are obtained from the DME status indicator circuits and fed to the TFM. These signals are fed through opto-isolators to the TFM logic.

7. <u>Environmental</u>.

The environmental parameters monitored by this TFM are:

- Line Voltage
- Line Current (2)
- Battery Voltage (if required)
- Battery Current (if required)
- Temperature (2)
- Smoke Detector (status)
- Intrusion alarm (status)
- Intrusion reset (status)

These signals are monitored in the same way as described in Appendix 2A (TFM #1, Environmental) so the monitoring methods will not be described here.

8. <u>Uplink Control</u>.

Two channels of uplink control are provided that can be used as required. These provide a relay contact closure that can be used to control heavier duty external relays.

The various parameters listed for the DME will be measured sequentially. This is necessary because some of the components on the TFM are shared. A typical sequence would probably be:

1. Status Check
2. Forward Power
3. Reflected Power
4. Pulse Width
5. Pulse Spacing

While 7 and 8 are occurring the environmental signals would be measured, and VSWR calculated. The site ID occurs about every 30 seconds, so the foregoing parameters could be checked at least 5 times between site ID's. The communications to/from the EQM is interrupt driven and it would be serviced as required.

TABLE 2DD-1

SMART TFM #4 SIGNALS

PARAMETER	A/D	Status	CONTROL	COUNTER
FORWARD POWER	1			
REFLECTED POWER	1			
VSWR (CALCULATED)				
PULSE WIDTH				1**
PULSE SPACING				1**
REPLY RATE				1**
REPLY DELAY				1**
REPLY EFFICIENCY				1**
ID FREQUENCY				1**
ID OCCURRENCE RATE (COMPUTER)				
SITE ID (COMPUTER)				
STATUS		4		
ENVIRONMENTAL				
LINE VOLTAGE	1			
LINE CURRENT	2			
BATTERY VOLTAGE	1			
BATTERY CURRENT	2			
TEMPERATURE	2			
SMOKE DETECTOR		1		
INTRUSION		2		
UPLINK CONTROL			2	
TOTAL USED	10	7	2	1
SPARES	6	1	0	0
TOTAL	16	8	2	1

** SHARED COUNTER