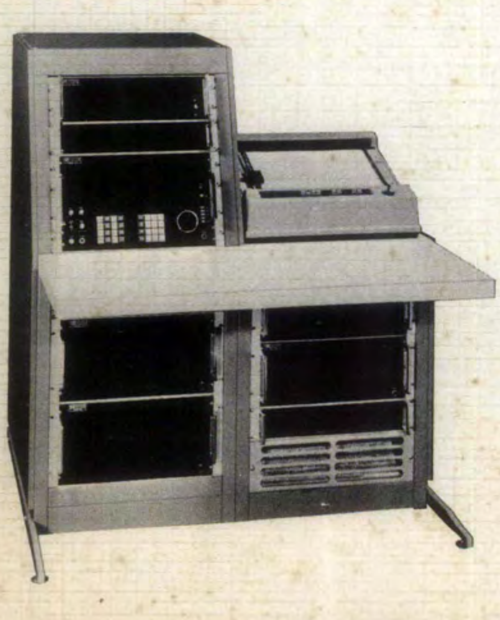
WATKINS-JOHNSON

Application Note

EMC TEST APPLICATIONS OF THE



WJ-8940B RECEIVING SYSTEM

EMC TEST APPLICATIONS OF THE WATKINS-JOHNSON WJ-8940B RECEIVING SYSTEM

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ABSTRACT

This Applications Note describes the Watkins-Johnson WJ-8940B Receiving System characteristics with appropriate technical discussion regarding the utilization of this system for both formal and informal EMI/EMC testing. These characteristics are presented in sufficient detail to allow planning and execution of tests to the most exacting requirements. Other topics addressed include system test performance optimization, software options and system enhancement with associated test equipment.

ACKNOWLEDGMENT

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D. G. Lubar

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1.0 INTRODUCTION

The measurement of potentially interfering signals arising in an electronic equipment is a subtle and demanding technology. Accurate and technologically advanced measurement instrumentation aids considerably in the characterization of emanations arising from such equipments.

The purpose of this applications note is to describe uses of the Watkins-Johnson Model WJ-8940B Receiving System for Electromagnetic Compatibility qualification demonstration testing and other similar measurements.

1.1 CHARACTERIZATION OF ELECTRONIC EQUIPMENT EMISSIONS

Electronic equipment of all types employs electrical power to perform specific functions as decreed by the equipment designer. In efficient designs, most of this power is used to meet the functional requirements of the equipment. As a by-product of these functions, electrical power is also converted to thermal energy. In addition, a considerable fraction of the input electrical power may be an output, such as in the case of an amplifier. A small fraction of the input energy (typically less than 1%) is consumed in producing unwanted or undesired conducted or radiated emissions arising from nonlinear performance of various semi-conductor components or, in some cases, through inadequate design. The detection of Electromagnetic Interference (EMI) generated by such undesired emissions is one of the important objectives in interference testing and measurement.

The functional signals within the equipment, as well as the undesired emissions, will appear distributed throughout the frequency spectrum according to equipment function, and generation mechanism. Although the amplitude versus frequency spectrum characteristics of the functional signals may be developed via analytic techniques, the characteristics of the undesired emissions are difficult to predict. Therefore, to completely characterize the performance of the piece of equipment, it becomes necessary to measure the conducted and radiated emissions from the Equipment Under Test (EUT), over an entire frequency spectrum.

Equipment performance characterization results from following the methods prescribed in commercial and government EMC standards. Standards within the scope of this application note include:

- MIL-STD-461/462
- FCC Part 15
- CISPR Publications 1 - 6

1.2 THE WJ-8940B AS A FREQUENCY SELECTIVE MICROVOLTMETER

The WJ-8940B Receiving System can be thought of as an instrument with the features of a frequency selective, tunable, variable bandwidth microvoltmeter.

This receiving system is used to characterize emissions from electronic equipments over a wide frequency range, as either conducted or radiated emissions measurements. It is frequency selective in that the segment of the frequency spectrum instantaneously undergoing measurement accepts certain frequencies while rejecting others. The broad frequency coverage requirements are met via stepping (or tuning); i.e., translating the "observation" bandwidth (or frequency segment observed) through the frequency spectrum to be measured. A large selection of observation bandwidths are available with the WJ-8940B. Following detection, metering circuits quantitatively determine the signal levels.

All of these factors are interrelated and each will be discussed in turn. A simplified block diagram of a frequency selective microvoltmeter is shown in **Figure 1-1**. The blocks selected for portrayal are those which involve the measurement process and do not represent an entire sophisticated receiver. The first block, at the RF input of the measurement device, is a step attenuator which is a passive signal level adjustment device. The attenuation value selected impacts the calibration output signal level and, unless appropriate adjustments are made in the final measured level (by adding or in some cases subtracting the attenuator position setting), determination errors can occur. The WJ-8940B automatically accomplishes this measured level correction. The RF amplifier adjusts the signal level and is used to drive an RF mixer whose second input is driven by a local oscillator. Since the typical EMI receiver is a superheterodyne, it usually employs double and sometimes triple conversion to achieve recovery of baseband modulation functions. The first local oscillator is actually the tuned frequency determination device, since the intermediate frequencies are independent of the tuned radio frequency.

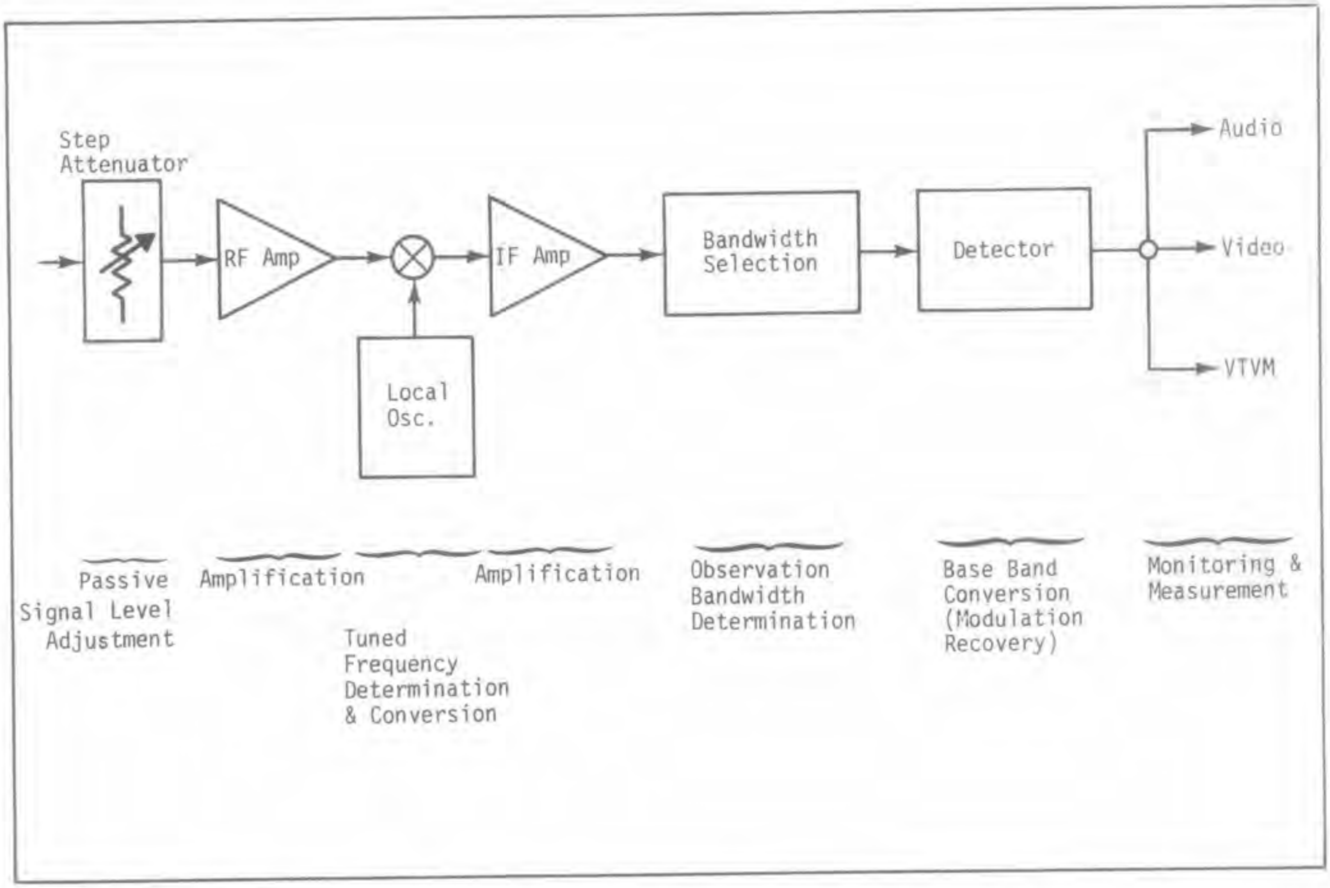

Figure 1-1. Simplified Block Diagram of a Frequency Selective Microvoltmeter

The intermediate frequency (IF) section amplifies the signal information for the set of intermediate frequency filters which determine the observation bandwidth.

The output of the IF bandwidth stage is applied to the modulation detection circuits, which perform baseband conversion, and the recovery of the modulation. The output of the detection circuits is applied to various system outputs providing audio or visual display, and also metering circuits which produce an actual indication of the level of the radio frequency signal observed. The block diagram shown is greatly simplified but the main features are typical of a frequency-selective microvoltmeter.

SECTION 2

2.0 THE WJ-8940B RECEIVING SYSTEM

The WJ-8940B Receiving System is a multipurpose system designed to meet the requirements for EMI/RFI electromagnetic compatibility investigations, wideband RF ambient signal surveys, and visual analysis of narrowband and broadband signals. In its standard configuration, the WJ-8940B tunes from 1 kHz to 999.999999 MHz with 1 Hz resolution. Seventeen IF bandwidths from 200 Hz to 50 MHz, in a 1-2-5 sequence, may be selected as desired to meet specific testing requirements. IF detection modes include AM, AM/AGC, FM, CW, and LOG.

In the LOG detection mode, peak, average, or quasi-peak detectors each provide calibrated signal amplitude which is corrected for measurement variables including RF attenuation, IF bandwidth, narrowband or broadband mode, and system gain variation. This provides amplitude data which may be directly compared to a specification limit.

Corrected data is displayed in five ways:

1. Amplitude data appears on the front panel plasma display.
2. Digital plotter interface generates amplitude versus frequency graphs of the scanned frequency spectrum.
3. Analog X-Y-Z signals can provide external oscilloscope displays during all scanning modes of the WJ-8940B.
4. A serial data output provides an output to a printer for a hard copy table of scanned frequencies and amplitude.
5. In the Remote Control mode data is output via the remote interface to an external controller or processor.

Additional outputs that are available from the WJ-8940B for operator use include: signal monitor outputs designed to interface with IF pan displays, IF output of the selected bandwidth filter, video and audio outputs, and a peak detector output.

Functionally, the WJ-8940B Receiving System has a number of operating modes which aid in performing EMC tests. These modes are described in **Section 2.4.** A thorough discussion of the functional organization of the WJ-8940B may be found in **Section 2.1.** Using features within the WJ-8940B, many EMC tests can be performed by the system without the need for external controllers or computers.

2.1 FUNCTIONAL ORGANIZATION OF THE WJ-8940B

The WJ-8940B Receiving System is a multiple unit electronic equipment configuration that functionally allows very precise amplitude and frequency measurements to be made. Six units, integrated together in a rack enclosure, make up the standard system. These units are as follows:

- Tuner/Synthesizer Unit (TSU)
- Auxiliary Synthesizer Unit (AS)
- IF Demodulator (IFD)
- Digital Control Unit (DCU)
- Power Supply (PS)
- Circuit Breaker Panel (CB)

The units are interconnected as in **Figure 2-1.** Optional peripheral units are shown for the display of system outputs. Some or all of these devices may be needed in a given application.

Six RF sensor inputs are available on the Tuner/Synthesizer Unit (TSU) which accept signals from antennas, current probes, LISN's, signal generators or any other radio frequency source. IF outputs from the TSU, at center frequencies of 160 MHz and 21.4 MHz, are provided for demodulation by the IFD. A frequency reference signal is also sent to the IFD from the TSU.

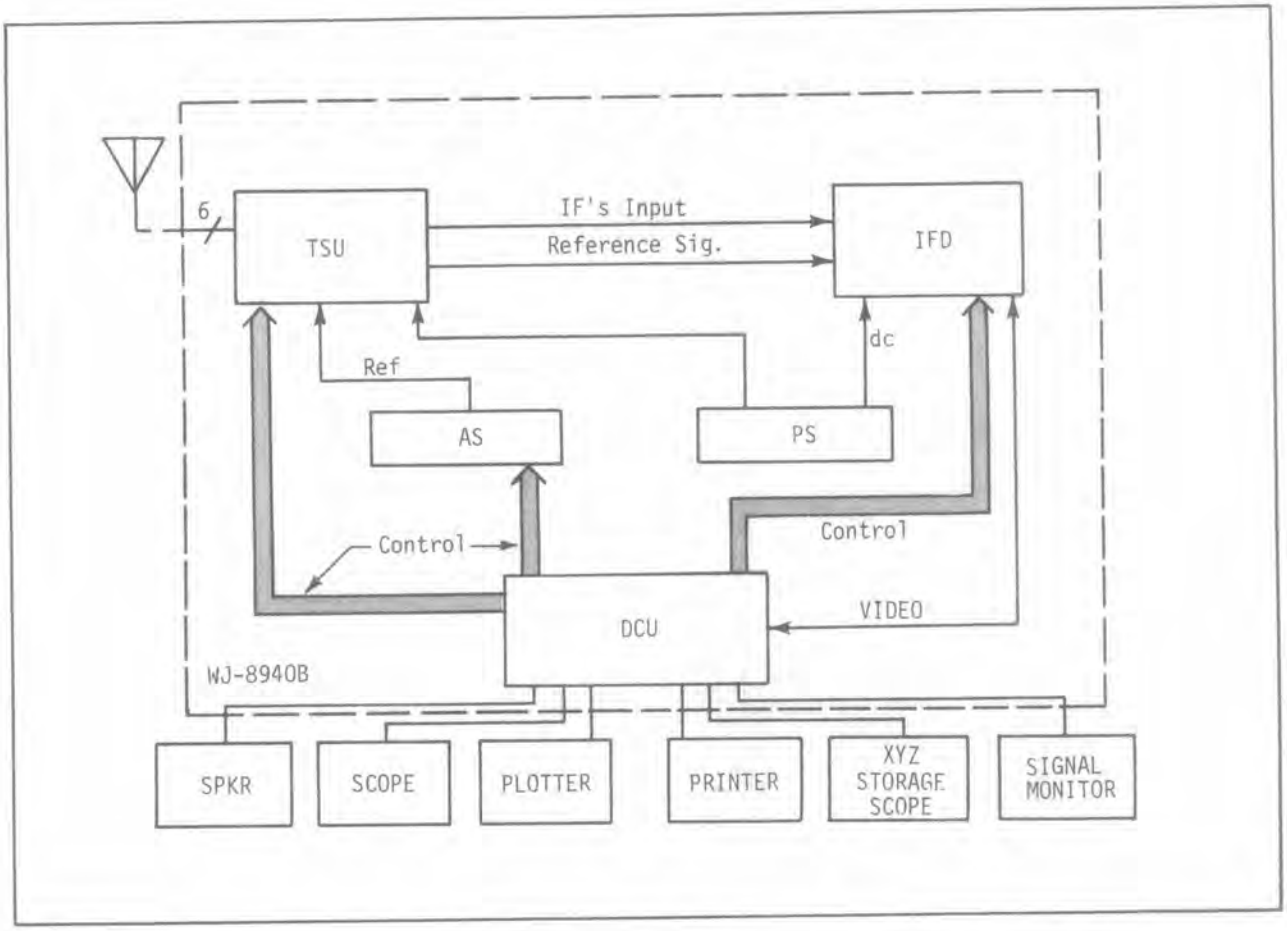

Figure 2-1. Top Level Block Diagram of the WJ-8940B Receiving System

The Auxiliary Synthesizer (AS) provides a stable, accurate frequency reference for the system and is used for precision frequency resolution.

The IF Demodulator (IFD) contains the IF bandpass filters, detectors, and the video processor. Wideband signal monitor outputs from the IFD can be used with standard Watkins-Johnson products for visual observation of signals prior to IF filtering. Buffered IF bandpass filter outputs (at center frequencies of 100 kHz, 21.4 MHz and 160 MHz) and a peak detector output are available for operator use. The baseband demodulation video output is sent to the Digital Control Unit (DCU) for connection to external devices. Input AC power for the system is routed through the Circuit Breaker Panel (CB) to a distribution strip.

DC power for the TSU and IFD is obtained from the Power Supply (PS). The Auxiliary Synthesizer and the Digital Control Unit (DCU) contain their own DC power supplies.

Control of the entire WJ-8940B system is via digital data busses between the DCU and all controllable units. Separate I/O busses from the DCU are routed to the IFD, TSU, and AS. Data and control information for a printer and a plotter are generated by the DCU. The plotter interface is designed for the Tektronix 4662 with options available for the Hewlett-Packard Model 7221A.

2.2 DESCRIPTION OF THE WJ-8940B SIGNAL PATH

As an aid in understanding the measurement capabilities of the WJ-8940B Receiving System, a simplified signal path through the system is described. A simplified version of the RF signal path through the TSU is shown in **Figure 2-2.**

Incoming RF signals are connected to the TSU through one of six sensor inputs. A low-loss RF coaxial switch connects the selected sensor input to the precision programmable RF attenuator. The attenuator, which has a range of 0 to 70 dB attenuation, can be used in an automatic or a manual mode. Following the attenuator stage, an RF limiter section protects the remainder of the TSU front end. This allows an average RF input power burnout level of 2 watts or a peak level of 100 watts for 1 second with a duty ratio of 0.001 (maximum). The 2 watt limitation is determined by the maximum input level of the programmable attenuator stage.

At this point the RF signal path splits into high-band and low-band sections. All signals below 10 MHz are switched into the low-band preselector while all others are directed through the high-band preselector.

The high-band preselector contains varactor-tuned filters that track the tuned frequency of the receiver. These provide a movable "RF window" centered about the receiver-tuned frequency. The width of this RF window is approximately twenty-five percent of the tuned frequency. The high-band preselector can be bypassed if desired.

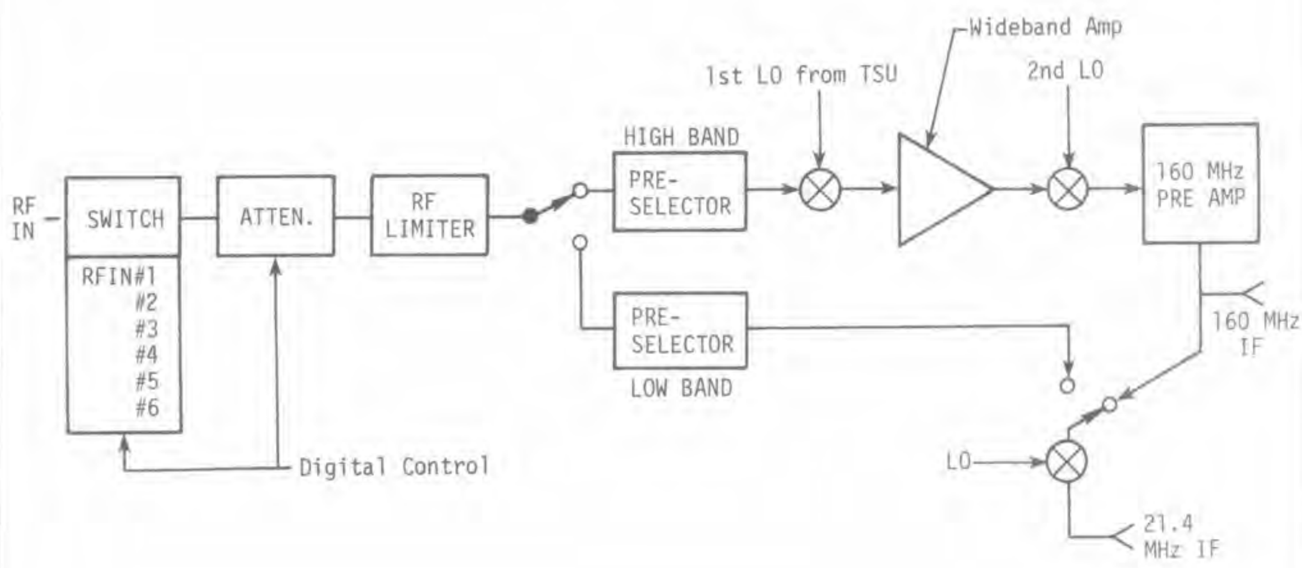

Figure 2-2. RF Signal Path Through the Tuner/Synthesizer Unit (TSU)

The output from the high-band preselector is mixed with the synthesizer first local oscillator output. The resultant signal is input into a wideband amplifier/filter stage and down converted to a center frequency of 160 MHz, using a second synthesized LO. After amplification this output is available from the TSU to drive the IFD. Another down conversion stage provides an additional IF at a center frequency of 21.4 MHz which is also sent to the IFD.

Signals below a tuned frequency of 10 MHz are switched to the lowband preselector. The lowband preselector contains a fixed-tuned bandpass filter section for frequencies below 100 kHz. Between 100 kHz and 10 MHz varactor tuned filters provide a bandwidth of approximately 25% of tuned frequency. The preselector may be bypassed if desired. The output of the lowband preselector is switched to the IF converter to provide a 21.4 MHz IF output.

Signals from both IF outputs of the TSU are input to the IFD for further processing as shown in **Figure 2-3.** The signal from the 160 MHz IF input is processed by a distribution amplifier. The pan display output from this section provides a wideband output for a signal monitor (WJ-1622 or other similar device). Signal routing into one of four IF filters (5, 10, 20, 50 MHz) is performed by the distribution amplifier. Outputs from these IF filters are selected by a digitally-controlled switch and are directed to the AM, FM, or LOG detectors and the predetected 160 MHz IF output. All detector outputs are routed through a signal switching matrix in the video processor section.

A similar processing scheme is used for the 21.4 MHz IF output to the IFD. A corresponding distribution amplifier, set of IF filters, (.02, .1, .2, .5, 1, and 2 MHz), switching assembly, and detectors are used at a center frequency of 21.4 MHz. A pan display output from the distribution amplifier provides a wideband output for signal monitors (WJ-SM-9804A or equivalent). Individual detectors are again used for AM, FM, or LOG detection. A predetected 21.4 MHz IF port is available on the rear panel. All detector outputs are routed to the input matrix of the video processor section.

For signals requiring bandwidths less than or equal to 10 kHz, a 20 kHz wide path from the 21.4 MHz IF is down converted to a center frequency of 100 kHz which supports six more IF bandpass filters (200 and 500 Hz, 1, 2, 5, and 10 kHz). Again, as in the other two signal paths, a predetected IF output is available. AM, FM, and LOG detector outputs are routed to the video processor input matrix.

This scheme for IF filtering and detection allows the use of all narrow bandwidths throughout the frequency range of the receiver. Bandwidths equal to or greater than 5 MHz are not available to signals below 10 MHz tuned frequency. No other bandwidth selection restrictions exist.

The signal switching matrix at the input of the video processor selects one of the nine signals from the IF detectors. The selected signal is amplified and routed to the DCU for monitoring and to the video processing circuitry.

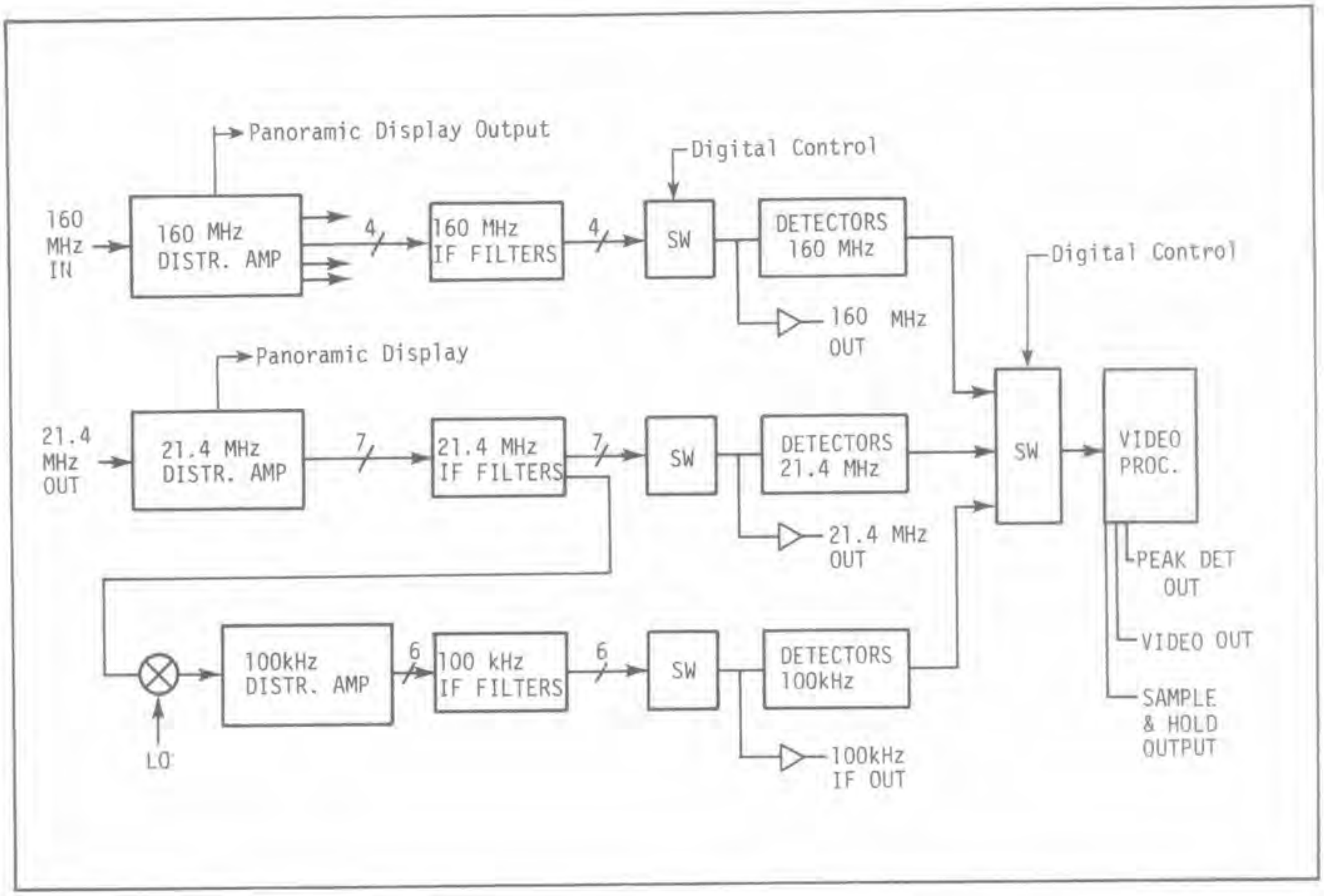

Figure 2-3. IFD Block Diagram

Peak processing is accomplished with a two-stage peak detector. The first stage, a fast peak detector, is optimized for speed and will capture the peak amplitude of a signal with a duration as short as 20 nano-seconds. This stage is cascaded with a second peak detector which is optimized for hold time. An output from the peak detector is available at the rear panel of the IFD.

Averaging is accomplished in an active RC averaging circuit. There are three selectable RC time constants: 15 microseconds, 1.5 and 15 milliseconds.

The Quasi-Peak detector is a fast attack and slow decay peak detector. The attack time is approximately 400 microseconds and the decay time is approximately 75 milliseconds. Other detector times can be provided, under custom configurations, to meet specific requirements.

One of the three video processing modes is selected as the input to a Sample and Hold and A/D converter combination. The 10 bit digital data from the A/D is then transferred to the DCU for correction and display.

2.3 RECEIVER CONTROL PARAMETERS

A unique operational flexibility is derived from the digitally-controlled receiver concept of the WJ-8940B Receiving System. Receiver and signal processing functions are internally controllable down to the module level. This control is utilized during operator or remote control modes of operation. The modes of operation, controlled by the DCU, which allow individual commands to be used for scanning, fixed tuning and various data output formats, are discussed further in **Section 2.4**. This section will summarize the control functions available as an aid in understanding WJ-8904B operation and capability.*

2.3.1 Frequency

Receiver tuned frequency may be changed in 1 hertz steps over the frequency range of the receiver. Frequency may be selected by keyboard entry or adjustment of the tuning knob. Using the tuning knob, the receiver may be tuned in steps of 40%, 20%, 10%, or 5% of the selected IF Bandwidth.* Frequencies may be entered by the keyboard with a resolution of 1 Hz. The tuning range of the standard system is 1 kHz to 999.999999 MHz.*

2.3.2 Step Size

Receiver step size represents the increment of tuning during a scan. With the standard WJ-8940B Receiving System in sector scan mode, the step size may be entered with a resolution of 1 Hz. The step size may also be automatically computed. After the operator enters the start and stop frequencies and a step size of zero Hz, the Digital Control Unit subtracts the start frequency from the stop frequency and divides by 1000 to determine step size. The actual step size, in hertz, is displayed and printed out on the plot of scanned data.

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* A discussion of optionally available features and capabilities may be found in **Section 2.5**.

In order to make manual tuning of the receiver more flexible and better suited to EMI/RFI applications, the manual step size controls are a percentage of IF bandwidth. Their selection causes the internal calculation of a step size that is 40%, 20%, 10%, or 5% of the currently selected IF bandwidth. "Lock" function disables the tuning wheel.

2.3.3 Sensor Selection

The WJ-8940B/TSU has six selectable RF sensor input ports. A programmable coaxial switch with a maximum of 0.5 dB insertion loss over the tuning range of the receiver is used for connection of sensors, substitution signal sources, or terminations to the RF input of the WJ-8940B.

2.3.4 RF Attenuation

RF attenuation may be selected in all receiver operating modes. The attenuator may be programmed to a fixed value from 0 to 70 dB in 10 dB steps or to an automatic mode when using the log detection mode. The automatically selected attenuation value is based upon RF signal saturation levels as measured by the RF detector located in the TSU or by IF saturation levels detected during a measurement sequence. In the event of saturation, the attenuation is automatically increased until the system is no longer saturated. Measurement correction factors are automatically selected for the corresponding values of attenuation.

2.3.5 Preselectors

As discussed in **Section 2.2**, the Tuner/Synthesizer Unit contains two preselector modules. These modules, which provide additional selectivity and out-of-band signal rejection, may be bypassed when desired.

2.3.6 IF Bandwidths

Seventeen different IF bandwidth filters are available for use within the standard WJ-8940B Receiving System IF Demodulator. These bandwidths may be selected in all receiver operating modes. A table of these predetection (6 dB) bandwidths and their center frequencies are listed in **Table 2-1.**

Bandwidths may be selected for all frequency ranges with the exception of bandwidths equal to or greater than 5 megahertz. Bandwidths of 5 MHz or greater are not available to signals below 10 megahertz tuned frequency. The values available are in a logarithmic sequence and are sufficient for most EMI/RFI radiated and conducted testing.*

Predetected IF outputs are available on the rear panel of the WJ-8940B/IFD for subsequent processing with other bandpass filters, or with other measurement equipment.

Table 2-1. Six dB Bandwidths vs. IF Center Frequency

IF BANDWIDTH	IF CENTER FREQUENCY
200 Hz 500 Hz 1 kHz 2 kHz 5 kHz 10 kHz	100 kHz
20 kHz 50 kHz 100 kHz 200 kHz 500 kHz 1 MHz 2 MHz	21.4 MHz
5 MHz 10 MHz 20 MHz 50 MHz	160 MHz

* A discussion of optionally available features and capabilities may be found in **Section 2.5.**

2.3.7 Detection Mode

Five detection modes are available. These five modes are:

- AM (Amplitude Modulation)
- AM/AGC (Amplitude Modulation with Automatic Gain Control)
- FM (Frequency Modulation)
- CW (Continuous Wave Signals)
- LOG (Logarithmic)

The logarithmic or LOG mode is provided for calibrated signal amplitude measurements. The displayed signal amplitude data is referenced to 1 μV or 1 μV/MHz in the LOG mode only.

2.3.8 Video Measurement Modes

Video detectors within the WJ-8940B/IFD provide three types of video measurement characteristics. One of the three modes, "Peak," "Average," and "Quasi-Peak" may be selected as desired for measurements based on test requirements. (Information on peak, average, and quasi-peak measurement modes can be found in **Section 2.2**.)

2.3.9 Gate Time and Detector Time Constants

Measurement gate time is defined as the period of time during which video is applied to the detectors. The five available gate times are as follows:

- 150 μs
- 1.5 ms
- 15 ms
- 75 ms
- 150 ms
- 100 ms

A gate multipler function is also provided to enable the generation of other gate times.

In "Peak" mode the peak detector is held in its reset state until the start of the gate. At the end of the gate time the peak value is sampled by the sample and hold circuit for subsequent A/D conversion, and then returned to the reset state.

In the "Average" mode the selection of a gate time also causes the selection of the averaging time constant. The relationship between the averaging time constant and gate time is as shown below:

- 15 µs - 150 µs and 1.5 ms gates
- 1.5 ms - 15 ms and 75 ms gates
- 15 ms - 150 ms gate

More information on time constants and how they affect the measurement process can be found in **Section 4.**

2.3.10 Video Measurement Bandwidth

The WJ-8940B Receiving System can detect and measure either narrowband (NB) or broadband (BB) signals. The operator can select either the NB or BB mode. Calibration schemes within the system are handled as required for each mode and corrected amplitude data is displayed in either decibels above 1 microvolt (dBµV) for NB or decibels above 1 microvolt per megahertz (dBµV/MHz) for BB.

2.3.11 AM IF Gain

The intermediate stage gains of all three IF signal paths may be controlled from the front panel by using the AM IF gain CONTROL. In remote control mode AM IF Gain may be set INDEPENDENTLY of the manual gain setting. The setting of the AM IF Gain does not affect measurements made in the LOG detection mode.

2.3.12 Data Sampling Interval

Data sampling intervals within the WJ-8940B Receiving System are determined by bandwidth and selected gate time values. In the scan mode or under remote control, the scan time per STEP (T_{STEP}) and total scan time (T_{SCAN}) may be calculated as follows:

$$T_{STEP} = \frac{10}{IFBW(Hz)} + 0.023 + \text{detector gate time}$$

$$\text{SCAN TIME: } T_{SCAN} = (T_{STEP})\ (\text{number of steps})$$

The detector gate time is selectable by the operator as described in paragraph 2.3.9. A built-in overhead time, in the standard system, of 23 milliseconds is used for calculation and transmission of tuning variables and correction of data. $\frac{10}{IFBW(Hz)}$ is the time required to allow the receiving system to settle.

In the Fixed Frequency mode** of operation the data sampling interval, (T_{STEP}), is approximately 36 milliseconds + the detector gate time. Provision is made to control the data sampling rate from an external source. In this mode an external TTL compatible pulse will initiate the measurement sequence; the maximum rate is limited by T_{STEP}.

2.3.13 Signal Threshold and Intercept

In the Repetitive Scan mode** the WJ-8940B Receiving System will allow signal search and stop operation for signal levels equal to or greater than a selected threshold level. When the threshold level has been entered in dBμV or dBμV/MHz and the intercept has been turned on, any signal encountered which is equal to or greater than the threshold will stop the scan and cause the WJ-8940B to revert to Fixed Frequency mode at the signal frequency.

** Modes of operation are discussed in **Section 2.4.**

2.3.14 Data Correction Files

Data Correction Files (DCF) provide for automatic correction of all data for sensor or antenna factors, cable losses, external amplifier gain, external signal or impulse generator calibration curves, or any other predictable external effects. Eight independent data files are provided with up to 36 points of frequency and amplitude per file. Frequency may be entered with a maximum resolution of 1 Hz. Amplitude may be entered within the range of ±199.75 dB with 1/4 dB resolution. A straight line approximation, between the data file points, is internally computed when using files 1 and 2. When using files 3 - 8 logarithmic interpolation is done between points.

Data is entered either with the DCU's keyboard or via the remote control interface. The selection of the DCF to be used is made in the Fixed Tune Setup, each Sector Scan Setup or via remote control. The selection of DCF 0 disables this function.

2.3.15 Interactive Tuning from the Plotter

Using the standard software within the WJ-8940B Receiving System to drive an optional Digital Plotter creates additional tuning capabilities. The Digital Plotter has an interactive control function with the WJ-8940B/DCU (Digital Control Unit) which works as follows:

> After completion of a sector scan,** the WJ-8940B can be instructed to plot data. If it is desired to retune the receiver for another scan within the range of the previous one, verify that the DCU is in Sector Scan mode** and select the start frequency parameter at the DCU front panel. Then, using the joystick on the plotter, adjust the plotter pen over the point on the graph where rescanning will start. Momentarily depressing the call button on the Tektronix model 4662 will program the start frequency for

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** Modes of operation are discussed in **Section 2.4.**

the sector scan. The stop frequency parameter on the DCU will automatically be selected. Repeat for the end point of the scan. Having adjusted the plotter pen accordingly, the WJ-8940B is now ready to rescan the newly selected sector.

The start and stop frequencies for the Data Table mode may be programmed in the same manner as described above, for the Sector Scan mode.

To determine the frequency of a given point (signal) on the graph, and retune the system to that frequency, select Fixed Frequency mode with the cursor at the "FREQ" parameter on the DCU. Position the plotter pen. Momentarily, depress the plotter call button and the WJ-8940B is retuned to the selected signal.

2.3.16 DCU Control Functions

Figures 2-4 and 2-5 are photographs of the entire WJ-8940B system, with plotter and the digital control unit of the WJ-8940B.

Operation of the WJ-8940B using the DCU controls is easy to understand, with all parameters except AM/IF GAIN clearly displayed on the DCU plasma panel. The right hand keypad is used for entering numerical values such as frequency or bandwidth. The left hand keypad is used with any of the three local operating modes. These pushbuttons are used for either pre-operational setup of receiver parameters or selection of a given operating mode. The tuning wheel, located to the right of the keypads, provides a manual means of tuning the receiver in fixed frequency mode. The buttons to the far right are used to select the step size for manual tuning. A remote/local switch and a power switch are also on the far right side of the DCU front panel. The far left side of the DCU front panel contains a BFO Frequency Control, Audio Gain Control, AM IF Gain Control, Audio Pulse Stretcher Switch, and Video and Audio Output Jacks.

Figure 2-4. WJ-8940B System with Plotter

Figure 2-5. WJ-8940B Digital Control Unit

2.4 MODES OF OPERATION

The WJ-8940B Receiving System has four major operating modes which are useful for many aspects of EMC testing:

- Fixed Frequency Mode
- Sector Scan Mode
- Repetitive Sector Scan Mode
- Remote Control Mode

The first three items are the local modes with all necessary controls located on the WJ-8940B/DCU control panel. Remote operation of the unit is via IEEE-488 interface bus using a controller, calculator, or computer. The local operating modes and features are available within the WJ-8940B Receiving System without the need for an external controller and custom software. Details of each operating mode follow in succeeding paragraphs.

2.4.1 Fixed Frequency Mode

The Fixed Frequency mode allows the operator to use the WJ-8940B as a manual receiver to monitor a specific point in the spectrum, or to manually tune or scan the spectrum. When in Fixed Frequency mode, a fixed frequency display on the DCU plasma panel indicates the status of the receiver control functions and the measured signal amplitude.

When in fixed frequency mode, the following parameters may be controlled:

- Tuned Frequency to 1 Hz Resolution
- Sensor (1-6)
- IF Bandwidth (200 Hz to 50 MHz)
- Video Measurement Bandwidth (NB, BB)
- Detection Mode (LOG, AM, AM/AGC, FM, CW)
- AM IF Gain
- BFO (CW Mode - IF Bandwidths less than 5 MHz)
- Video Measurement Mode (Peak, Quasi-Peak, or Average)
- Gate Multiplier and Gate Times/Average Detector Time Constants

- Attenuation (0 - 70 dB or Automatic)
- Preselection (Engaged or Bypassed)
- Audio Stretching (On/Off)
- Calibration
- Selection of Data Correction File

The RF signal amplitude is displayed, when in LOG mode, in either dBμV or dBμV/MHz. In other detection modes a number relative to the signal strength is displayed with no descriptive units of measurement.

When operating in the LOG mode a calibration sequence is automatically executed when any operating parameter is changed or when the receiver is tuned beyond preset calibration frequency points. The receiver may be calibrated at any time by depressing the "CAL" button located on the left hand keyboard.

2.4.2 Sector Scan Mode

In Sector Scan mode, the WJ-8940B Receiving System is programmed to scan between two points in the frequency spectrum. All parameters necessary for system operation are pre-programmed by the operator. The standard WJ-8940B system will scan one of eight sectors, when instructed to do so by the operator. Tuning resolution during all scans is 1 Hz. Data is taken when the operator depresses a single button to begin a sector scan.

Calibration of the receiver automatically occurs at the beginning of each scan. Calibration data is acquired using the built-in impulse generators at preset frequencies throughout the selected scan range.

Receiver data taken during a scan is stored in the DCU. This stored data is corrected with internal calibration data, attenuator data and Data Correction File data if selected.

Upon completion of a sector scan, the data can be output to an optional digital-interactive plotter, providing a hard copy of the acquired scan data. Examples of typical Linear and Log plots are illustrated in **Figures 2-6** and **2-7**, respectively. A threshold level will also be plotted if the threshold and intercept -ON- function has been pre-programmed by the operator. Any data correction file may also be plotted. Scan data is also available in a frequency/amplitude format on an optional printer. Frequency/amplitude points which equal or exceed the threshold level are marked with an asterisk if a DCF file was plotted. Video, peak detector, IF and X - Y - Z outputs are also available for use.

Parameters that are controlled or stored in Sector Scan Mode are:

- Sector Number (1-8)
- Sensor (1-6)
- Start Frequency
- Stop Frequency
- Step Size
- Actual Tuned Frequency (to 1 Hz Resolution)
- Threshold (Level from -100 dBµV to 250 dBµV)
- Intercept (ON/OFF)
- IF Bandwidth (200 Hz to 50 MHz)
- Detection Modes (LOG, AM, AM/AGC, FM, CW)
- Video Measurement Modes (Peak, Average, Quais-Peak)
- Gate Multiplier and Gate Times/Average Detector Time Constants
- Video Measurement Bandwidth (NB, BB)
- Attenuation (0-70 dB and Automatic)
- Preselectors (Engaged or Bypassed)
- AM/IF Gain
- Data Correction File Selection

A brief summary of the plot firmware is presented below:

Linear Mode:

- Frequency axis: linear 10-4000 points - Frequency range same as scan.

- Amplitude axis: 12 dB Tics with 10 dB Labels, Origin (-90 dB to 90 dB) and Range (50 dB to 200 dB) operator selectable.

- Data, (1/4 dB resolution).

Log Mode:

- Frequency axis: 1-10 decades logarithmic. Independent of current scan parameters. Multiple scans may be plotted. Up to 400 points/decade plotted. Data compression, if required, peak value plotted.

- Amplitude: 10 dB Labels with 2 dB Tics, Origin (-90 dB to 90 dB) and range (50 dB to 200 dB) operator selectable.

- Data: (1/4 dB resolution).

Plot Options (each may be independently enabled or disabled):

- Scan Data (current sector scan data)
- Threshold (DCF number 1 to 8)
- Axis, tics and labels
- Header

Re-Plot: Current scan data may ba replotted with any desired changes to the plot format.

2.4.3 Repetitive Sector Scan

The Repetitive Sector Scan Mode is used to scan one or more sectors cyclically until halted manually or automatically when the selected threshold level is exceeded. Operational capability is similar to Sector Scan Mode with data output in an analog X-Y-Z format for display on a storage oscilloscope. No data is stored in this mode.

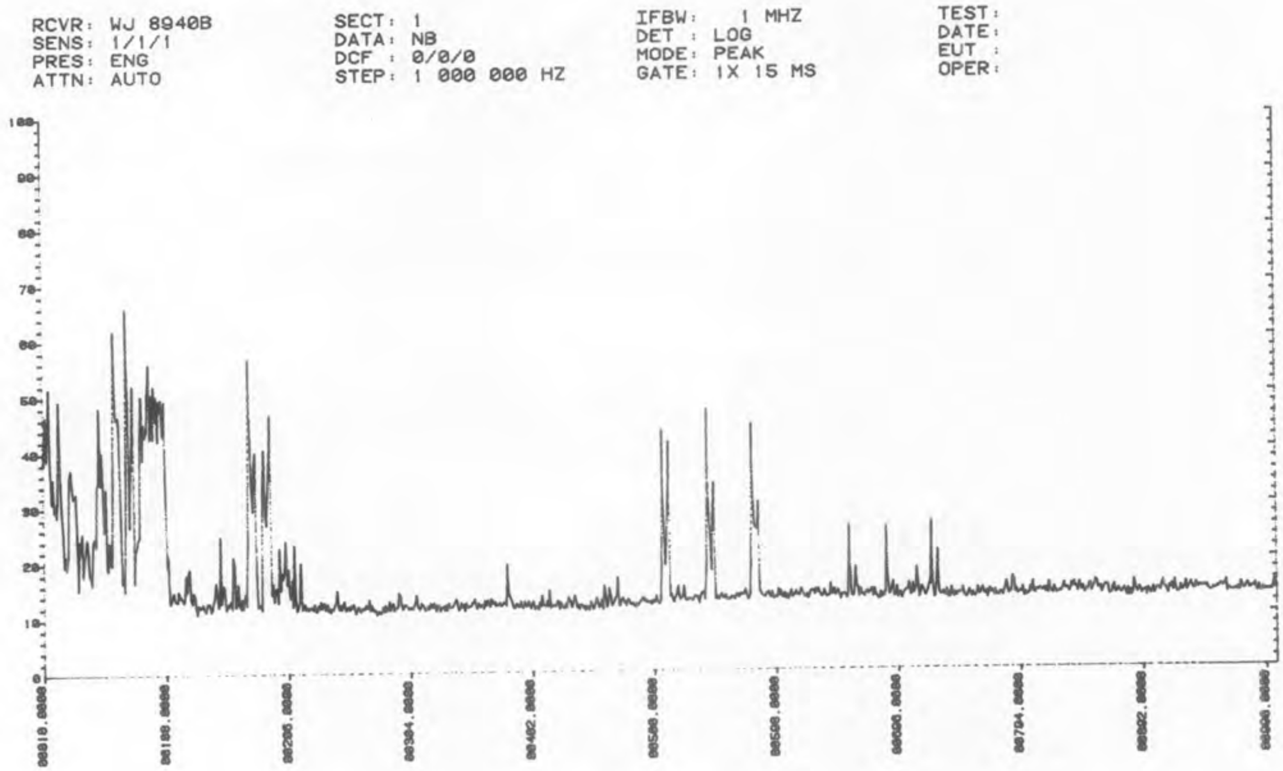

Figure 2-6. Typical Sector Scan Linear Plot

2.4.4 **Remote Control Mode**

Many additional capabilities may be implemented under the remote control mode. Testing scans may be fully automated, using customer furnished equipment and application software. Mass storage of data with custom plots for different commercial specifications may be implemented.

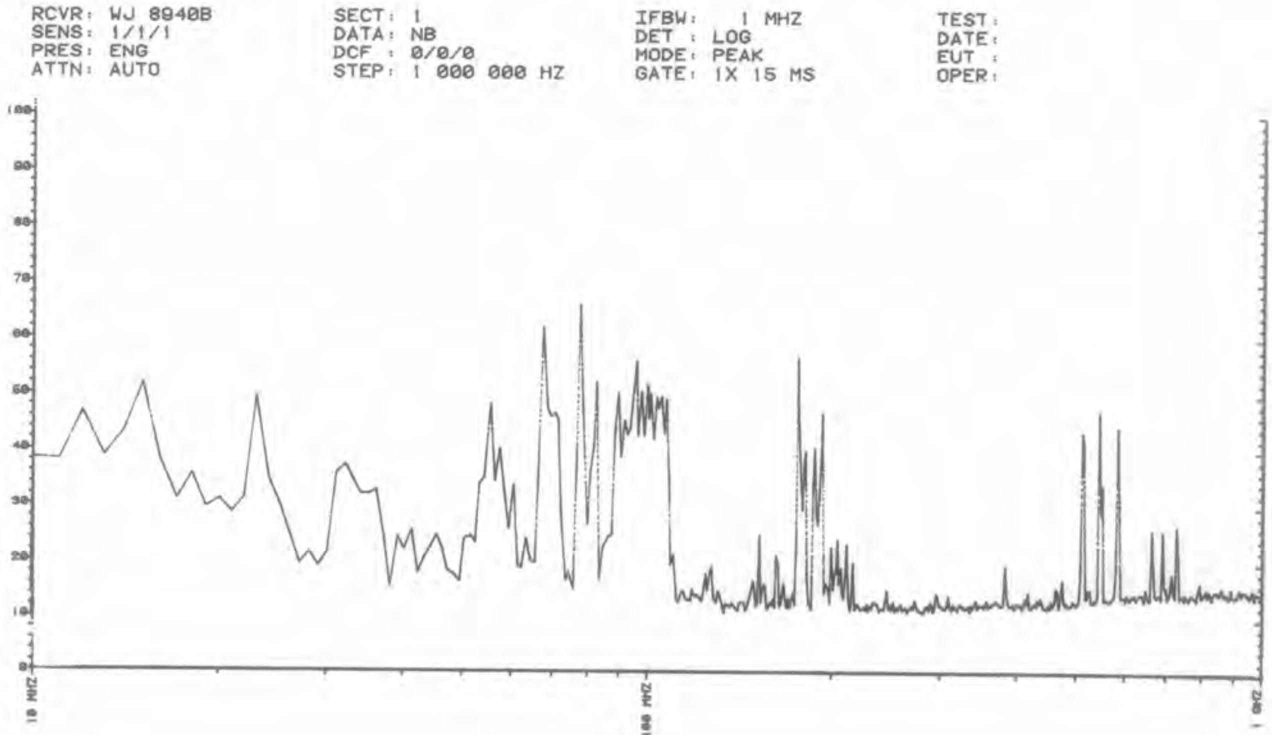

Figure 2-7. Typical Log Plot

Due to the digitally controlled receiver design concept, nearly all receiver parameters that are operator-controlled can be controlled remotely. Four types of commands are used:

- Parameter Setup and Recall Commands
- Operational Commands
- Control Commands

The static setup commands are used to program all of the receiver's operating parameters. These commands include:

- First or Fixed Frequency
- Last Frequency
- Step Size
- Sensor
- Attenuation
- Preselector
- IF Bandwidth
- Detection Mode
- Gate Time/Detector Time Constant
- Gate Multiplier
- Video Measurement Mode
- Video Measurement Bandwidth (NB/BB)
- AM IF Gain
- Data Correction File Selection
- Data Correction File Loading

The parameter recall commands provide the capability to read, from the WJ-8940's buffers, all of the parameters listed above.

The operational commands provide the means for tuning, stepping, scanning calibrating and the acquisition of data. These commands are:

- Tune and Measure - Tunes receiver to new frequency, measures and stores data.

- Step, Tune and Measure - Adds step size to current tuned frequency, tunes, measures, and returns the data.

- Measure - This causes an amplitude measurement to be taken and returns the result to the external device.

- Scan - Executes a scan using the current parameters, returning each data point while the scan is being executed.
- Calibration - Initiates internal impulse calibration and corrects succeeding data measurements.
- Scan Calibration - Initiates an internal calibration sequence between the First and Last Frequencies.
- Enable/Disable Calibration Correction - Allows the transmission of uncalibrated data to the host controller. System calibration may then be done by the host.

2.4.4.1 General Purpose Interface Bus (GPIB) - Remote Control Interface

IEEE standard 488 (1975) compatible remote control interface is provided.

This feature includes the GPIB interface card in the DCU; the operating firmware and an interface cable. The cable is approximately 12 feet in length and is terminated on one end with the connector that mates to the rear panel of the DCU. The other end of the cable is terminated with a molded 24 pin double-ended connector that conforms with the IEEE-488 standard. This double-ended connector, containing both male and female 24 pin connectors, allows both linear and STAR connections to an instrument bus.

The WJ-8940B may be addressed as either a listener to receive commands and data or a talker to send data or status. No controller-in-charge functions are implemented.

2.5 SYSTEM OPTIONS AND ACCESSORIES

Many optional features are available which enhance or extend the operational capabilities and flexibility of the standard WJ-8940B. These features include the following items:

- 16 Bit Parallel Interface
- Expanded Hardware Capabilities
- Custom Configurations

The succeeding paragraphs discuss these items in detail.

2.5.1 Sixteen Bit Parallel Interface

As an optional feature, each WJ-8940B Receiving System may be equipped with a remote interface using a 16 bit parallel format. This interface accommodates data from and to an external control device with 16 input lines and 16 output lines. A full software handshake is used during transmission in either direction.

Four control lines are utilized to implement the handshake. These lines are as follows:

- External Device Data Ready
- DCU Accepts Data
- DCU Data Ready
- External Device Accepts Data

A timing diagram is shown in **Figure 2-8.**

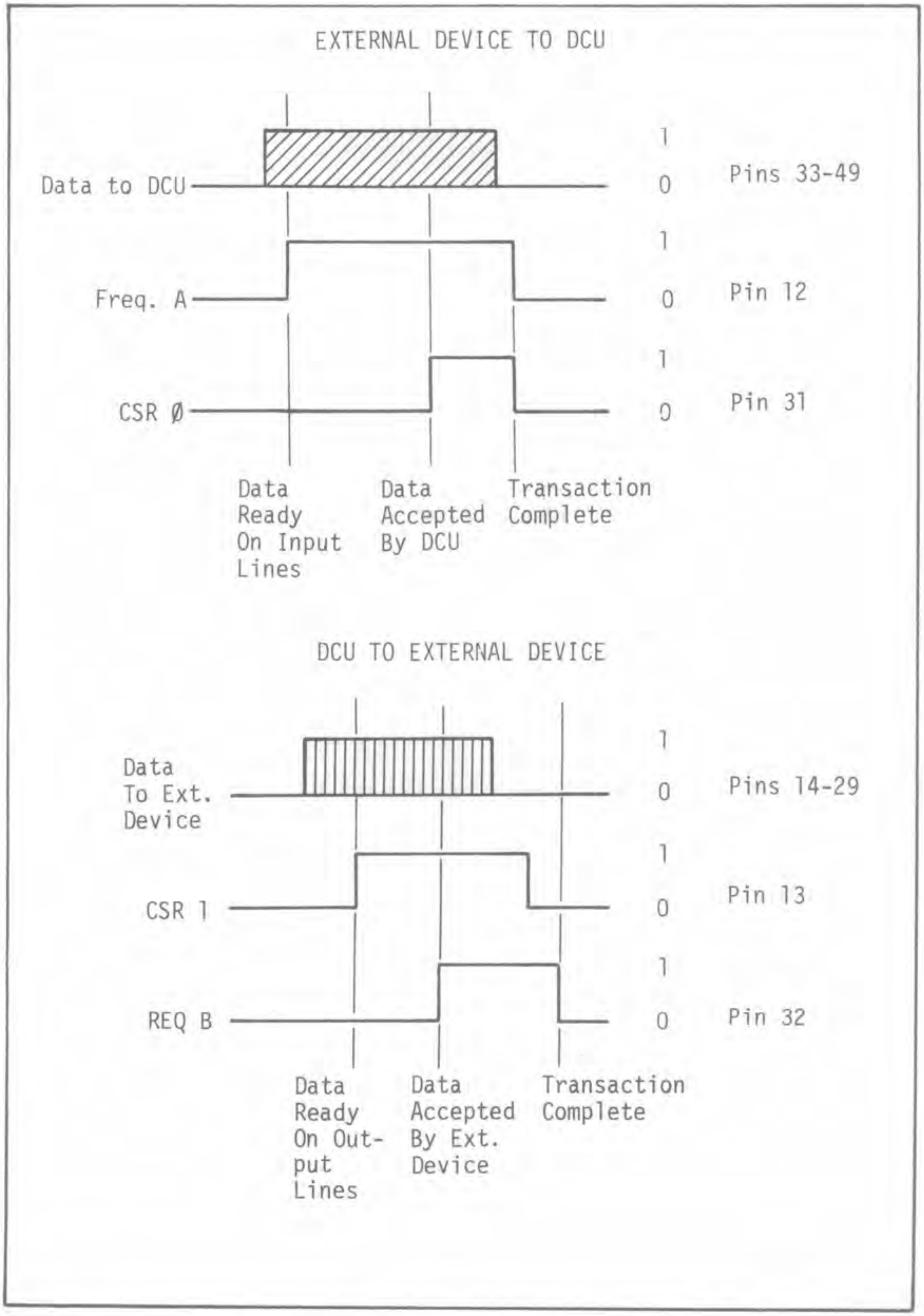

Figure 2-8. Timing Diagram, Handshake

2.5.2 Expanded Hardware Capabilities

In order to more completely support testing to today's specifications and to support the testing of tomorrow's technologically advanced equipments, the tuning range and selection of IF bandwidths may be expanded.

2.5.2.1 Microwave Frequency Extender

The WJ-8940B/MX Microwave Frequency Extender is a fully synthesized microwave tuner designed to complement the WJ-8940B Receiving System, extending its frequency range to 18 GHz. The unit features a minimum RF bandwidth of 500 MHz and synthesized Local Oscillators which are locked to the system reference for maximum accuracy. Operator interface is through the existing WJ-8940B Digitial Control Unit. All band switching is accomplished automatically and is transparent to the operator. The overall size permits installation in the rack of the existing WJ-8940B Receiving System.

Features

- Coverage 1-18 GHz
- RF Bandwidth sufficient to support 500 MHz IF Bandwidth
- Low Phase Noise Synthesized Local Oscillators utilized to permit high quality signal analysis
- Interfaces directly with WJ-8940B Receiving System.

2.5.2.2 Narrowband IF's

The WJ-8940B/NBIF Narrowband IF Unit expands the capabilities of the WJ-8940B Receiving System by providing five additional IF bandwidths and the capability of interfacing the system with the WJ-8940B/LFT Low Frequency Tuner. The added 5, 10, 20, 50 and 100 Hz IF bandwidths are all gain-bandwidth normalized. They are calibrated for 20 Hz to 10 kHz tuned frequencies, but are usable over the entire tuning range of the system. A bypass mode is also provided for bypassing the narrow bandwidths, permitting the Low Frequency Tuner input to be utilized with bandwidths up to 10 kHz.

All control of the WJ-8940B/NBIF is provided by the WJ-8940B Receiving System, via the digital control unit or the remote interface. It also provides a control and signal interface to the WJ-8940B/LFT Low Frequency Tuner, when this unit is used with the receiving system.

Features

- Compatible With the WJ-8940B System*
- Adds 5, 10, 20, 50 and 100 Hz IF Bandwidths
- System Interface For the WJ-8940B/LFT
- Fully Controlled From the WJ-8940B System

* Factory Retrofit Required.

2.5.2.3 Low Frequency Tuner

The WJ-8940B/LFT Low Frequency Tuner operates within the WJ-8940B Receiving System, extending the system tuning range down to 20 Hz. It is a single conversion tuner that provides five selectable sensor inputs to accommodate a 1 megohm and four 50 ohm sensors. At the input, a 0 to 70 dB attenuator, selectable in 10 dB steps, provides a calibrated attenuation to provide accurate level measurements over a wide range of signal levels. An internal impulse calibrator provides a calibration signal to correct for gain variations within the Low Frequency Tuner and the WJ-8940B Receiving System.

The WJ-8940B/LFT is designed to be mounted remotely, near the input sensors, interfacing with the WJ-8940B Receiving System via the WJ-8940B/NBIF Narrowband IF Unit. Its RFI shielding permits the tuner to be placed in a shielded room with the sensors and the equipment under test, without interfering with the test being performed. Two 50 ohm coaxial cables interface the Low Frequency Tuner with the narrowband IF. The 100 kHz IF output, the tuners local oscillator signal and all control information, coded in a serial format, all utilize these two cables. The interfacing cables are unbalanced coaxial cables which isolate ground, thus, minimizing ground loop problems.

Features

- 20 Hz to 10 kHz Tuning Range
- Compatible With Existing WJ-8940B System*
- Five Sensor Inputs
- RFI Shielded

* A WJ-8940B/NBIF is required to interface the WJ-8904B/LFT with the receiving system.

2.5.2.4 Wideband Demodulator

Features

- IF bandwidths of 100/200 and 500 MHz
- New bandwidths available to all tuning ranges
- AM, AM/AGC, FM and Log detection
- Peak and Average measurement modes

2.5.3 Custom Configurations

The combination of modular design and microcomputer control provides a high degree of flexibility in the operational configuration of the WJ-8940B. Many unique requirements may be satisfied with software/firmware changes alone. Custom firmware configurations could include but are not limited to:

- Special plot formats
- Real time digital plotting
- Multiple plots per page
- Multiple sector scanning and plotting
- Customized remote control commands
- GPIB Interface for printer and/or plotter
- Special handling of frequency vs. data listings
- Unique gate times

Custom hardware/firmware configurations such as special IF bandwidths, averaging time constants, or quasi-peak time constants may also be accommodated. Applications Engineering, SP Division, will be pleased to discuss any special or unique requirements.

SECTION 3

3.0 EMC TESTING

In the previous sections, the features of the WJ-8940B Receiving System have been discussed. The two sections that follow provide an overview of EMC testing and the role of the WJ-8940B Receiving System in these tests.

3.1 OBJECTIVES

EMC testing can be a formal or informal procedure that is followed to characterize the electromagnetic compatibility of equipment with its environment. Testing procedures and methods are governed by written specification documents such as:

MIL-STD	-	461B/462
FCC	-	Rules & Regulations
VDE	-	0871, 0875, 0877
CISPR	-	Publications 1-6

The forward to MIL-STD-461B (1 April 80) explains the objectives of this standard.

"This standard is established to:

(a) Ensure that interference control is considered and incorporated into the design of equipments and subsystems; and

(b) Provide a basis for evaluating the electromagnetic characteristics of equipments and subsystems, as well as for inputs to analyses of the electromagnetic compatibility and effectiveness of systems in a complex electromagnetic environment."*

*MIL-STD-461B (April 1980)

Using this standard as an example, the following paragraphs examine how these objectives are achieved.

3.2 DISCUSSION OF EUT CHARACTERISTICS

Prior to considering testing requirements, the characteristics of the EUT (Equipment Under Test) must be examined. Known operational parameters are the key to conducting a successful test. For example, a receiving device, such as an FM receiver, could contain several oscillators which may be regarded as CW emission sources. In such cases, the emission likely to be encountered during test would be very narrow with respect to the typical bandwidths. Therefore, optimization of the receiving device performance would be based upon finding the best presentation of narrowband* data.

In contrast, a digital device such as a microprossor controller would have a master oscillator (typically a 50% duty cycle multi-vibrator) which could develop an amplitude versus frequency spectrum rich in harmonics. This situation will produce narrowband-type responses so long as the detected emissions were both narrowband and broadband emissions.* In this case, optimization of the receiving device's operating parameters will require an assessment of specific signals and their locations within the frequency spectrum.

These two examples illustrate that many possible signal types within the EUT may cause EMC problems. The first step in developing a test procedure is to examine the characteristics of the EUT in detail. Planning for items at this point is important. Specific receiving system capabilities or options may be required and peripheral equipment may be needed for part or all of the testing.

The amount of data taken to adequately test the EUT must be detemined at this time. The modes of operation of most EUT's are numerous, and must be carefully selected with knowledge of EUT internal functions. Similar modes shold be eliminated if they appear to create redundant test data.

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*MIL-STD-461B (April 1980)

3.3 TESTING REQUIREMENTS

Testing requirements are categorized into two areas:

- EMISSION
- SUSCEPTIBILITY

Emission testing searches for undesired signals radiating from the equipment, subsystem, or system. A receiver and sensor are used to detect the "pollution" from the device to the electromagnetic environment. (This is the primary task for the WJ-8940B.)

Susceptibility testing exposes the equipment, subsystem, or system to a source of RF energy to determine if its operation may be affected by the environment. High power test equipment (such as the WJ model 1235) is used to generate RF energy. Receivers may be used to monitor the RF energy level. (In this application note, susceptibility is discussed in **Section 6**.)

After reviewing the specification requirements, and prior to writing the test plan, the EMC engineer must become familiar with the EUT characteristics.

3.4 TYPES OF TESTING

Many factors are dependent on EUT characteristics. After reviewing the specification requirements and prior to writing the test plan, it is important to become familiar with the EUT characteristics and operation. The end result should efficiently guide an operator through a procedure that will test the emission and susceptibility of the EUT.

Testing procedures used may be either formal or informal. Formal testing requires the adherence to a test plan, which is a written document prepared to direct the test on a specific piece of equipment. This plan will be developed by the testing contractor or group. It identifies and outlines the details necessary for testing. Test equipment setups are discussed. Operating characteristics of the EUT must be selected. Informal testing examines prototype assemblies or units to identify problems, without detailed procedures required for formal specification testing.

3.4.1 Formal Test Requirements

This section describes areas of consideration in the planning and execution of Formal EMC testing. Formal testing includes conducting the test in adherence to the approved test plan, with witnessing if desired by the customer. Data is presented in a graphical format as required by the specification. (The WJ-8940B can prepare graphical outputs that can be directly inserted into a test plan without manual data correction.)

3.4.1.1 Calibration Requirements

The WJ-8940B, as any EMC receiver, must be demonstrated to be within calibration on a periodic basis, typically, six months. Calibration must be demonstrated prior to the start of any new formal test series. This is generally accomplished by use of an independent variable level source whose calibration characteristics and/or calibrating equipment are traceable to the National Bureau of Standards. Calibration amplitude accuracy for MIL-STD-461 would be ±2 dB.

Prior to the initiation of formal data collection, calibration of the instrumentation system will be demonstrated over the entire frequency range to assure quality control witnesses that the system is operating within its measurement parameters. Calibration demonstration is accomplished the day prior to the start of formal testing, or the morning of the start of formal testing. At the conclusion of all formal testing a full calibration demonstration is necessary to assure that none of the electrical parameters of the measurement equipment had changed during testing, thus completely validating the data collected during the performance of all test procedures.

When the EMC test series to be accomplished is lengthy, it is highly desirable, at periodic intervals (once per day), to perform a simplified calibration demonstration. This assures that the equipment used for the development of test data is performing within its design limits and that the data taken is within the calibration accuracy of the system. Such periodic calibration validates data taken since the previous demonstration exercise. Under these conditions a daily calibration of some 5 to 15 minutes is worthwhile since any failure of the test equipment may invalidate all data acquired since any previous checks. This allows for the rapid repair of the system and eliminates repeating what could amount to several days or weeks of test data accumulation.

3.4.2 Informal Testing

During design of units or modules some quick checks for unwanted emissions might eliminate a simple problem that would become a costly engineering change later. An informal test would be ideal to determine if unwanted emissions occur, without going through a full formal test. Performing an informal test on a module might simply consist of doing a radiated emission scan. Evaluation of scan data could be used to improve the design.

During the course of the developmental cycle of most electronic equipments, it is advantageous to perform informal testing at the various stages. Thus, as the development cycle progresses, a simple series of tests performed quickly on an informal basis can provide a great deal of insight into the progress of the EMC design and the overall equipment design. Using these methods during preliminary or intermediate design phases saves the expense of formal testing until it is required.

3.4.2.1 Basic Configuration for Informal Testing

Most functions required for EMC testing are incorporated within the WJ-8940B Receiving System. After the addition of input and output devices, this semi-automatic system is ready to produce useful corrected data measurements.

A recommended configuration for informal testing is shown in **Figure 3-1**. Six sensor ports provide input from antennas, current probes, or line impedance stabilization networks. One input port may be terminated by a fifty ohm (50Ω) resistor for receiver noise floor measurements. Interconnecting cables selected for use between sensors and input ports should be no longer than necessary and follow good grounding and bonding practices. Antenna and cable loss factors should be noted and entered into operator controllable files for automatic data correction.

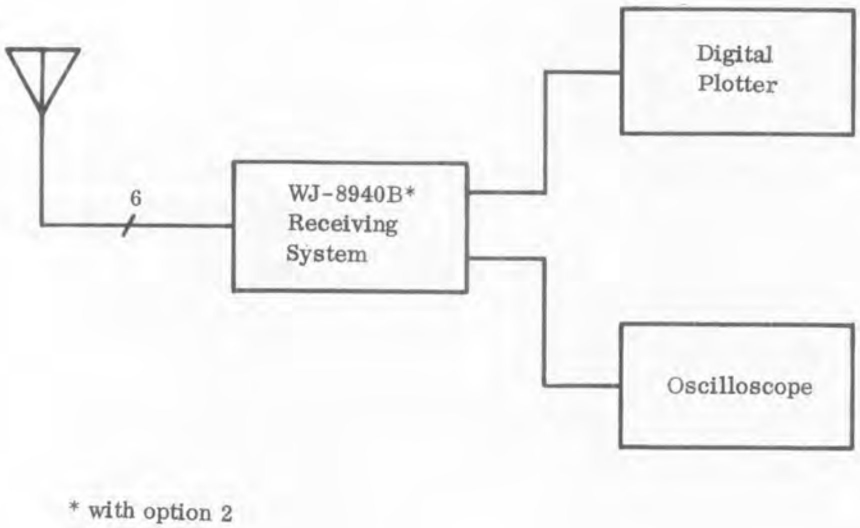

Figure 3-1. Basic Configuration for Testing, 1 kHz to 1 GHz

Since the WJ-8940B will scan the frequency spectrum, a digital plotter may be used to record data. Recommended plotters include the TEKTRONIX Model 4662 which may be driven by the standard WJ-8940B/DCU directly, or using Option 4, a four-color HP-7221 plotter may be connected to the WJ-8940B. These provide a hard copy of the signal scan with data corrected for receiver RF, receiver IF, antenna, and cable losses in a linear or logarithmic frequency format. A completed plot is usually ready to be placed directly into an EMC test report with few or no additions.

Video or analog outputs may be viewed on an oscilloscope. Any good single or dual channel oscilloscope, with time base and sufficient bandwidth, is adequate for visual analysis of signals. The WJ-8940B has video outputs; audio outputs; IF outputs centered at 100 kilohertz, 21.4 megahertz, and 160 megahertz; peak detector outputs; and analog outputs.

These items make up a basic system that can provide automatic or semi-automatic EMC test capability.

3.5 CLASSES OF EMISSION TESTING

Most equipment-level emission testing is performed within a shielded enclosure which reduces ambient signal effects. This laboratory testing may also be performed in open-air test sites but the surrounding RF ambient from broadcast stations, power lines, and equipment often makes measurements difficult.

Emission testing may be divided into two general areas:

1. Radiated
2. Conducted

The following paragraphs discuss both of these areas in detail.

3.5.1 Conducted Emissions Testing

Conducted emissions testing is performed to evaluate the amplitude versus frequency spectra of signals arising in the equipment under test that might cause interference to occur either through the power leads, via interconnection on a common power bus, or in the terminology of MIL-STD-461B, through interconnection by "signal and control leads."

3.5.2 Conducted Emission Test Sensors

Conducted emissions testing is accomplished by coupling a current sensing device (current probe) around a conductor whose spectra is to be evaluated. For power line measurements only, a Line Impedance Stabilization Network is used as a sensor.

3.5.2.2 **Line Impedance Stabilization Networks (LISN)**

LISN devices are used for power line measurements only, and may be regarded as

devices, they tend to exhibit considerably less dynamic range to broadband signals. Dynamic ranges of 20 - 25 dB are not uncommon. This dynamic range, however, is not limited to narrowband signals, where the range may be of the order of 60 dB.

Figure 3-12. Typical Active-Rod Antenna, 14 kHz - 30 MHz

Figure 3-13 shows one exception to the limitations of the active rod antenna. In this device, the 150 kHz to 30 MHz spectrum is divided into 14 approximately one-half octave increments. Thus, intermodulation is reduced and broadband dynamic range increased.

3.5.5.3 **Bi-Conical Antenna, 20 MHz - 200 MHz**

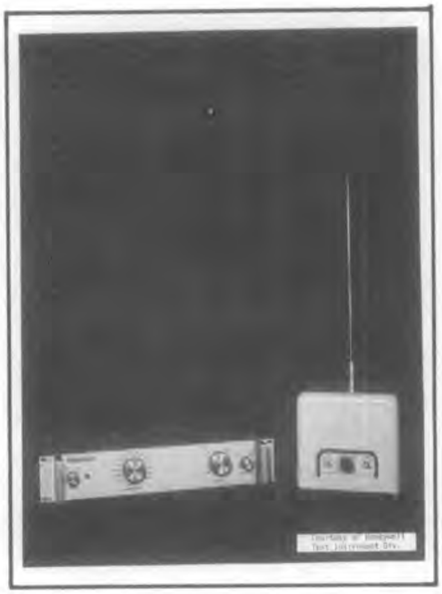

Figure 3-13. Tuned Active-Rod Antenna, 150 kHz - 30 MHz

Set up as shown in **Figure 3-14**, the bi-conical antenna is horizontally polarized and measures the electric-field component of an electromagnetic wave. This orientation is the one called out in MIL-STD-462. The antenna directivity is omni-directional in the H-plane and bidirectional in the E-plane. The antenna elements may be rotated 90° to measure vertical polarization provided the lower elements are at least two feet above the ground. Shorter distances will capacitively load one end sufficiently to change the antenna factors.

Figure 3-15 presents the antenna factors corresponding to the bi-conical antenna as appearing on page 18 of MIL-STD-461A. It develops, however, that this exhibits certain resonant and anti-resonant frequency characteristics at portions of the spectrum below 50 MHz.

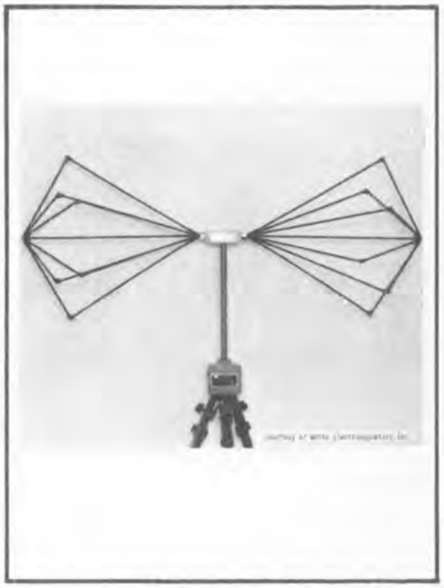

Figure 3-14. Conical Antenna, 20 - 200 MHz

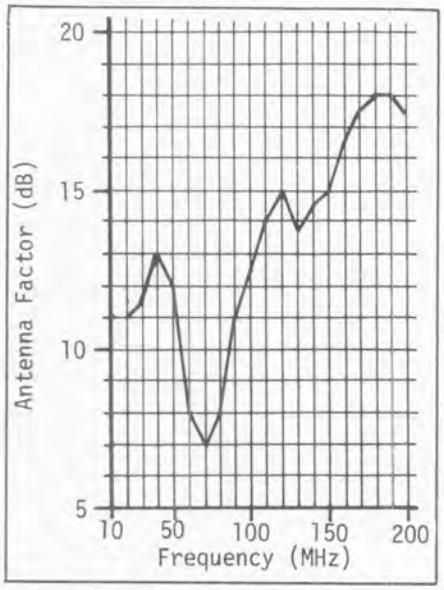

Figure 3-15. Typical Antenna Factors of Bi-Conical Antenna

3.5.5.4 Conical Log Spiral, 200 MHz - 1 GHz

Until recent years, this lower portion of the UHF frequency spectrum was the most difficult to accommodate for radiated emission or susceptibility testing inside shielded enclosures. With the introduction of the Conical Logarithmic Spiral (CLS) antenna during the early 1960's, however, broadband characteristics have been achieved in an efficient manner, resulting in low antenna factors. Since the CLS antenna exhibits circularly-polarized properties in the transmitting or receiving mode, it will also accommodate electric fields that are either circularly or linearly polarized. Thus, for either horizontal or vertical linearly-polarized waves, the circular-polarized antenna factors are increased by 3 dB due to the polarization-coupling loss.

Figure 3-16 is a photograph of a typical CLS antenna covering the frequency spectrum from 200 MHz to 1 GHz. **Figure 3-17** represents typical antenna factors associated with this antenna as presented in page 30 of MIL-STD-461A.

The Conical Log Spiral antenna has proved to be an excellent broadband antenna over the lower UHF spectrum. However, it has been found that the VSWR of this antenna degrades significantly below about 300 MHz and, therefore, its antenna factors are compromised accordingly. Studies are under way to see how this situation may be improved. In the meantime the antenna factors depicted in **Figure 3-17** continue to apply for MIL-STD-461A and other EMI radiated emission specification testing.

Figure 3-16. Log-Spiral Antenna 200 MHz – 1 GHz

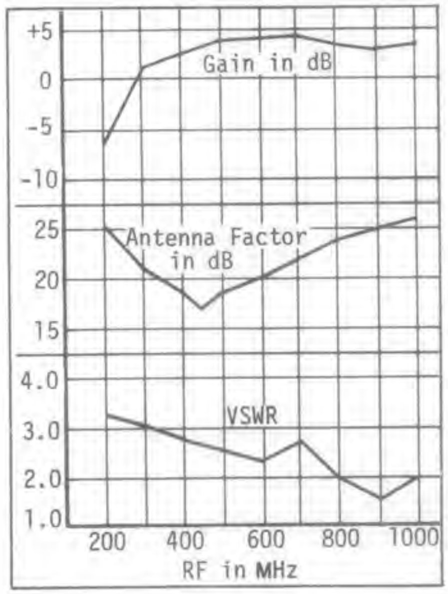

Figure 3-17. Antenna Factors of Conical Log-Spiral Antenna

3.5.6 Typical Radiated Emissions Test Set-up

Radiated emissions testing is accomplished as shown in **Figure 3-18** which shows a simplified block diagram of a typical radiated emissions test setup.

Suggested equipment for radiated emissions testing includes:

- Passive and Active Whips (up to 30 MHz)
- Bi-conical and Log Spiral Antennas (20 MHz - 1000 MHz) or Broadband Spiral Antenna (30 MHz - 1000 MHz)

- Horn Antenna (above 1 GHz)
- EMC Receiver (WJ-8940B)
- Low Frequency Extender (WJ-8940B/LFT)
- MX Extender (WJ-8940B/MX)
- Isolation Transformer
- Oscilloscope
- Digital Plotter

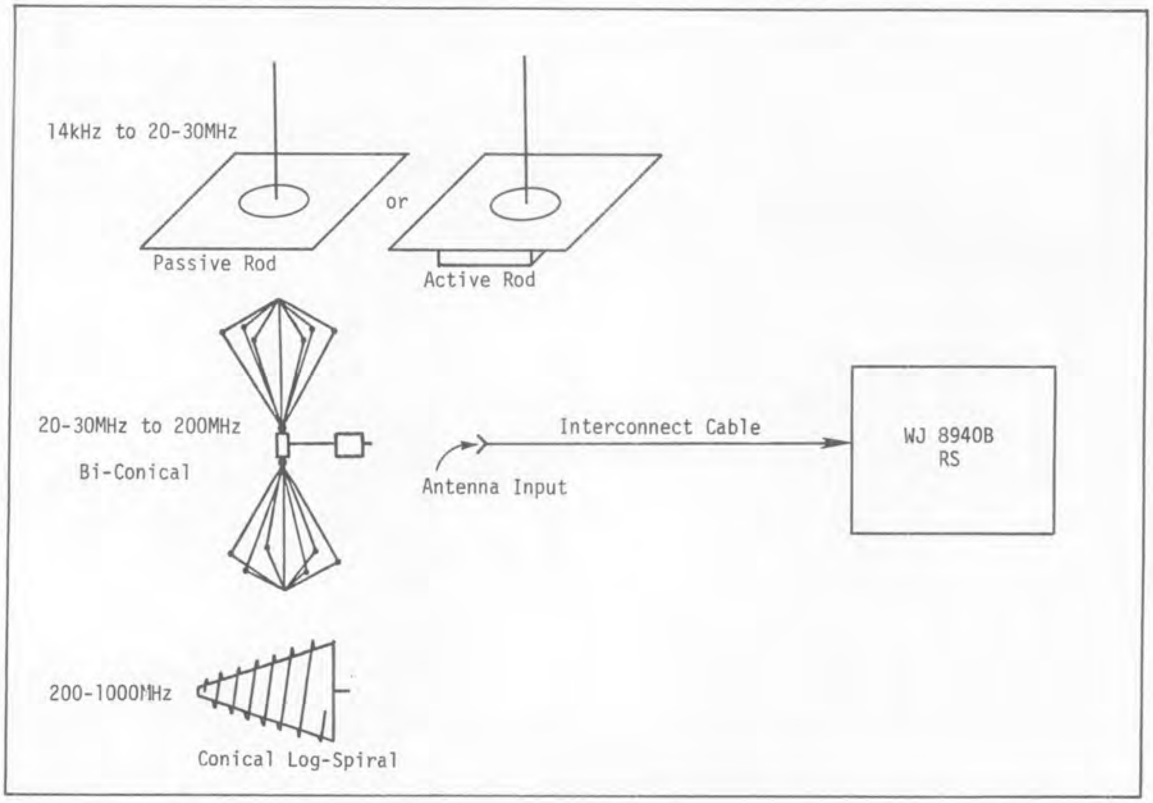

Figure 3-18. Simplified Radiated Emissions Test Setup

Additional recommended accessory equipment for radiated emissions testing includes:

- Printer
- Speaker Panel (Watkins-Johnson S9903E)
- Signal Monitors (WJ-SM-9804A and SM-1622)
- Storage Oscilloscope

Names and addresses of suppliers of equipment accessories may be found in the current annual edition of Interface Technology Engineers Master (ITEM) published by R. & B. Enterprises; Plymouth Meeting, PA 19462, USA.

3.5.7 Radiated Emissions Test Procedures

The radiated emissions test procedure is quite similar to that of the conducted emissions test procedure described previously. Start and stop frequencies for sectors are selected by consideration of the calibrated frequency ranges of the transducers used. Typically, an active or passive vertical rod antenna would be used from 14 kHz to 25 or 35 MHz, depending on the manufacturer of the antenna. The bi-conical antenna would be used for 35 to 200 MHz and the conical log-spiral antenna from 200 MHz to 1,000 MHz. This implies that a minimum of 3 sectors would be employed for the accomplishment of radiated emissions testing. Due to the wide frequency scan or wide frequency range of the vertical rod antennas, two or more sectors may be required to adequately cover the desired spectra, particularly in the case of narrowband testing. In fact, when accomplishing narrowband testing, the bandwidths selected may require the use of as many as three to four sectors. Once such determinations are made, testing will proceed from sector-to-sector as required.

3.5.8 Frequency Coverage for MIL-STD-461B

Emission and susceptibility requirements for MIL-STD-461B are shown in **Table 3-1**. For test requirements above 1 gigahertz or below 5 kilohertz, options are required with the WJ-8940B Receiving System. Also for measurements requiring bandwidths wider than 50 megahertz, additional options are required.

Not all options are required for all categories of emission testing within MIL-STD-461B. **Table 3-2** illustrates tests versus frequency options.

Table 3-1. Emissions and Susceptibility Requirements for MIL-STD-461B

Requirment	Description
CE01	Conducted Emissions, Power and Interconnecting Leads, Low Frequency (up to 15 kHz)
CE03	Conducted Emissions, Power and Interconnecting Leads, 0.015 to 50 MHz
CE06	Conducted Emissions, Antenna Terminals 10 kHz to 26 GHz
CE07	Conducted Emissions, Power Leads, Spikes, Time Domain
CS01	Conducted Susceptibility, Power Leads, 30 Hz to 50 kHz
CS02	Conducted Susceptibility, Power Leads, 0.05 to 400 MHz
CS03	Intermodulation, 15 kHz to 10 GHz
CS04	Rejection of Undesired Signals, 30 Hz to 20 GHz
CS05	Cross-modulation, 30 Hz to 20 GHz
CS06	Conducted Susceptibility, Spikes, Power Leads
CS07	Conducted Susceptibility, Squelch Circuits
CS09	Conducted Susceptibility, Structure (Common Mode) Current, 60 Hz to 100 kHz
RE01	Radiated Emissions, Magnetic Field, 0.03 to 50 kHz
RE02	Radiated Emissions, Electric Field, 14 kHz to 10 GHz
RE03	Radiated Emissions, Spurious and Harmonics, Radiated Technique
RS01	Radiated Susceptibility, Magnetic Field, 0.03 to 50 kHz
RS02	Radiated Susceptibility, Magnetic Induction Field, Spikes and Power Frequencies
RS03	Radiated Susceptibility, Electric Field, 14 kHz to 40 GHz
UM03	Radiated Emissions, Tactical and Special Purpose Vehicles and Engine-Driven Equipment
UM04	Connected Emissions and Radiated Emissions and Susceptibility Engine Generators and Associated Components UPS and MEP Equipment
UM05	Conducted and Radiated Emissions, Commercial Electrical and Electromechanical Equipments

Table 3-2. Frequency Options Required for MIL-STD-461B

MIL-STD-461B Test	WJ-8940B 1 kHz - 11 GHz	LF 20 Hz - 20 kHz	MX 1 GHz - 18 GHz
CE01	X	X	
CE03	X		
CE06	X		X*
RE01	X	X	
RE02	X		X
RE03	X		X
RS01	X	X	
RS02	X		
RS03	X		X*
UM03	X		
UM04	X		X
UM05	X		

*Contact Applications Engineering, SP Division for coverage above 18 GHz.

SECTION 4

4.0 OPTIMIZATION OF WJ-8940B OPERATING PARAMETERS BASED ON EQUIPMENT UNDER TEST CRITERIA

This section describes the selection of the WJ-8940B Receiving System operating parameters to produce the clearest and most accurate data presentation. The following paragraphs examine each of the pertinent parameters and their interrelationships.

4.1 IF BANDWIDTH

The relationships of IF bandwidth to tuned frequency and system sensitivity are important considerations for optimum data acquisition.

4.1.1 IF Bandwidth Versus Tuned Frequency

For freedom from distortion, normal operation should limit the minimum tuned frequency to five times the value of the IF bandwidth, or:

$$f_{min} = 5\ (\text{IF BW})$$

where: f_{min} = minimum tuned frequency of the WJ-8940B

The recommended value of minimum tuned frequency for each of the seventeen IF bandwidths is summarized in **Table 4-1**. It is possible to select starting frequencies lower than the values shown in **Table 4-1**; however, degradation of data accuracy may occur. Local oscillator feed through will occur at a frequency of about two times the bandwidth. The detection circuitry cannot distinguish the local oscillator feed through from a received signal, thus the feed through may obscure the real data.

A second and more subtle form of data degradation can occur at a frequency equal to about four times the bandwidth when operating with the TSU's preselectors engaged. As discussed in **Section 2**, the preselectors are a set of tracking filters whose center frequency is equal to the tuned frequency of the receiver with a bandwidth of approximately 1/4 of the tuned frequency. Since both broadband and narrowband data are corrected based on the IF bandwidth, it is essential that the preselector bandwidth be greater than the IF bandwidth or measurement inaccuracies will result. The maintenance of the IF bandwidth, as the system observation bandwidth, should also be considered when selecting external preamplifiers or filters to meet special requirements.

Table 4-1. IF Bandwidth Selection as Related to Tuned Frequency

Nominal IF BW	Minimum Recommended Tuned Frequency
200.0 Hz	1.0 kHz
500.0 Hz	2.5 kHz
1.0 Hz	5.0 kHz
2.0 kHz	10.0 kHz
5.0 kHz	25.0 kHz
10.0 kHz	50.0 kHz
20.0 kHz	100.0 kHz
50.0 kHz	250.0 kHz
100.0 kHz	500.0 kHz
200.0 kHz	1.0 MHz
500.0 kHz	2.5 MHz
1.0 MHz	5.0 MHz
2.0 MHz	10.0 MHz
5.0 MHz	25.0 MHz
10.0 MHz	50.0 MHz
20.0 MHz	100.0 MHz
50.0 MHz	250.0 MHz

4.1.2 IF Bandwidth Versus System Sensitivity

The ultimate limitation on the sensitivity of a receiver is the noise developed by the internal components of the receiver.

The traditional method of determining a receiver's sensitivity is by direct comparison of the internal noise of the receiver to a received signal. For minimum sensitivity the most widely used comparison is:

$$\frac{\text{Signal + Noise}}{\text{Noise}} = 2 \qquad (4.1)$$

which may be reduced to:

$$\text{SIGNAL} = \text{NOISE} \qquad (4.2)$$

Since it can be shown that at 70° F in a 50 Ω system

$$\text{Noise}_{dB\mu V} = -67 \text{ dBm} + NF_{dB} + 10 \log_{10} (BW_{Hz}) \qquad (4.3)$$

where NF_{dB} = Noise figure (a ratio, usually expressed in dB, that describes receiver performance with respect to an ideal receiver; i.e., one having a noise figure of 1 or 0 dB).

The sensitivity of a receiver with any noise figure and any bandwidth can be determined.

These relationships are shown in **Figure 4-1** with sensitivity described in dBμV (50 Ω system) on the left ordinate and in dBm on the right ordinate ($S_{dBm} = S_{dB\mu V}$ -107 dB). This definition is based on receiver thermal noise which is incoherent. It will hold true for narrow-band signals and broadband incoherent noise.

If the signal used to determine the Signal = Noise relationship is broadband such as a transient or impulse generator, then:

$$N_{dB\mu V/MHz} = +53 \text{ dBm} + NF_{dB} - 10 \text{ Log}_{10} (BW_{Hz}) \qquad (4.4)$$

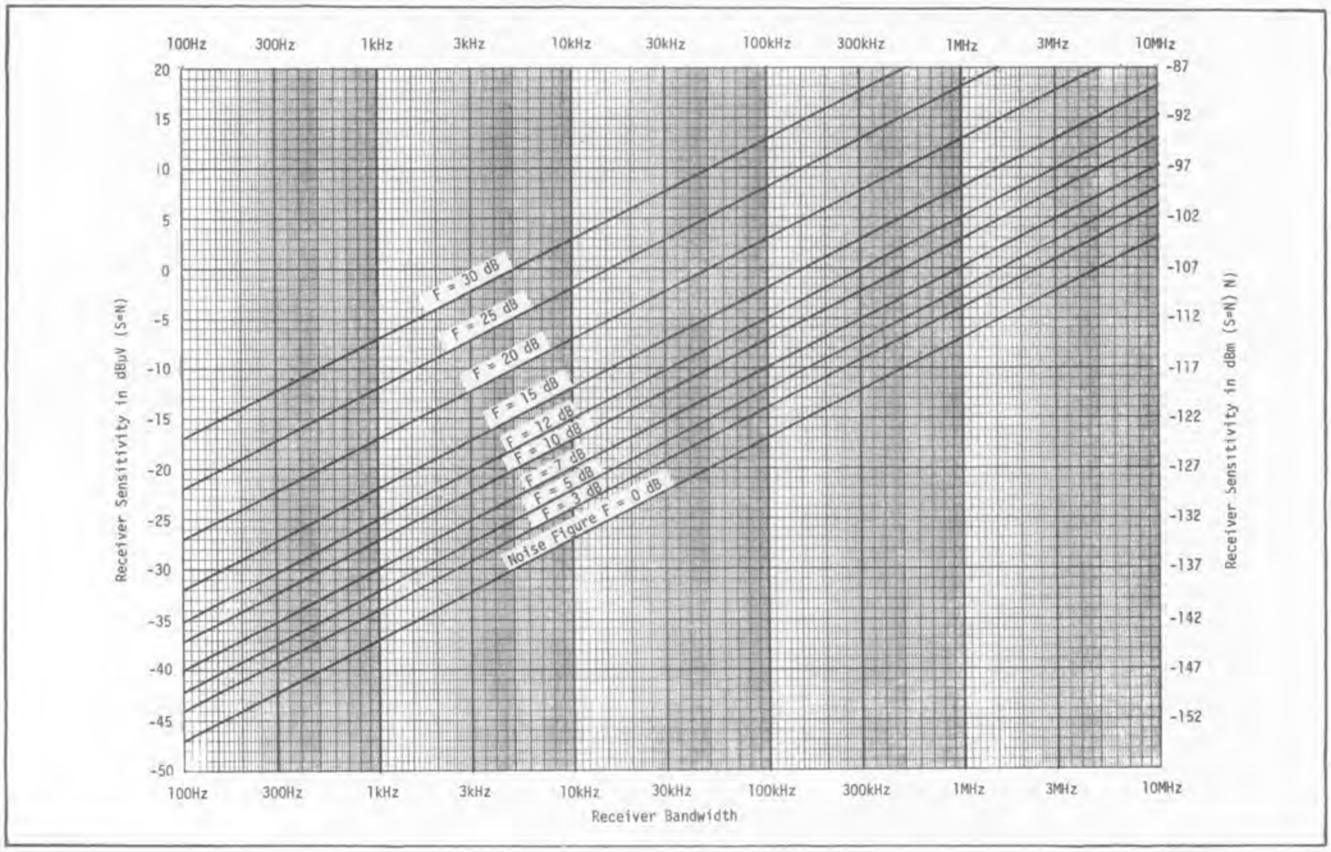

Figure 4-1. Receiver Narrowband Sensitivity vs. Bandwidth and Noise Figure

The relationships between broadband sensitivity, noise figure and bandwidth are shown in **Figure 4-2**.

In comparing **Figures 4-1** and **4-2**, it is noted that:

(1) Narrowband signal sensitivity increases with a decrease in bandwidth at a rate of 10 dB/decade.

(2) Broadband signal sensitivity increases with an increase in bandwidth at a rate of 10 dB/decade.

Thus, it follows that for maximum narrowband sensitivity, the receiver bandwidth should be reduced to just bracket the signal modulation bandwidth. Conversely, for broadband signals such as transients, the receiver bandwidth should be opened as wide as possible to improve sensitivity provided that other interfering signals are not also intercepted. This is one of the advantages the WJ-8940B system has, with its large selection of IF bandwidths, over other EMC instruments. The proper choice of bandwidth and corresponding video measurement parameters enhances capture of the signal of interest.

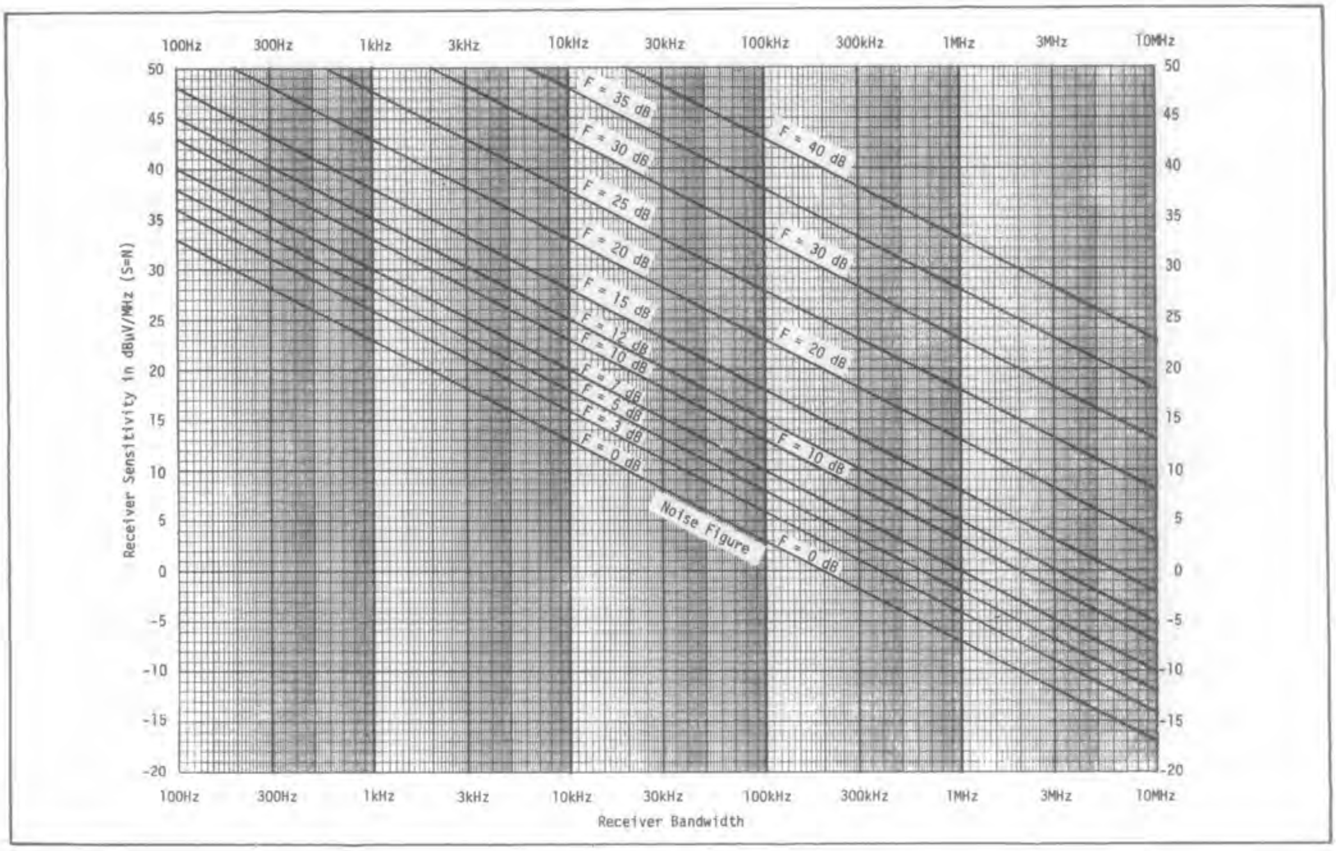

Figure 4-2. Receiver Broadband Sensitivity vs. Bandwidth and Noise Figure

4.1.3 Bandwidth Versus Sensitivity and Plotted Signal Representation

As shown in **Figure 4-3**, a narrowband signal may be observed by a large number of bandwidths, each of which will adequately show the peak amplitude of the signal. Each succeedingly large bandwidth will be somewhat less sensitive as discussed in **paragraph 4.1.2**. However, the larger bandwidths provide a somewhat misleading data presentation. **Figure 4-4** shows data presentations of an unmodulated CW signal in three successive bandwidths. Such a signal theoretically occupies zero spectrum width, though in practice a small but finite portion of the spectrum will be evident. As an RF window is translated through the point of the frequency spectrum occupied by the CW signal, the signal sweeps out the CW selectivity curve of the intermediate frequency bandwidth. If a significantly broader bandwidth is used, the data presentation appears as shown in the broader bandwidth of **Figure 4-4** which, while technically accurate, can be extremely misleading.

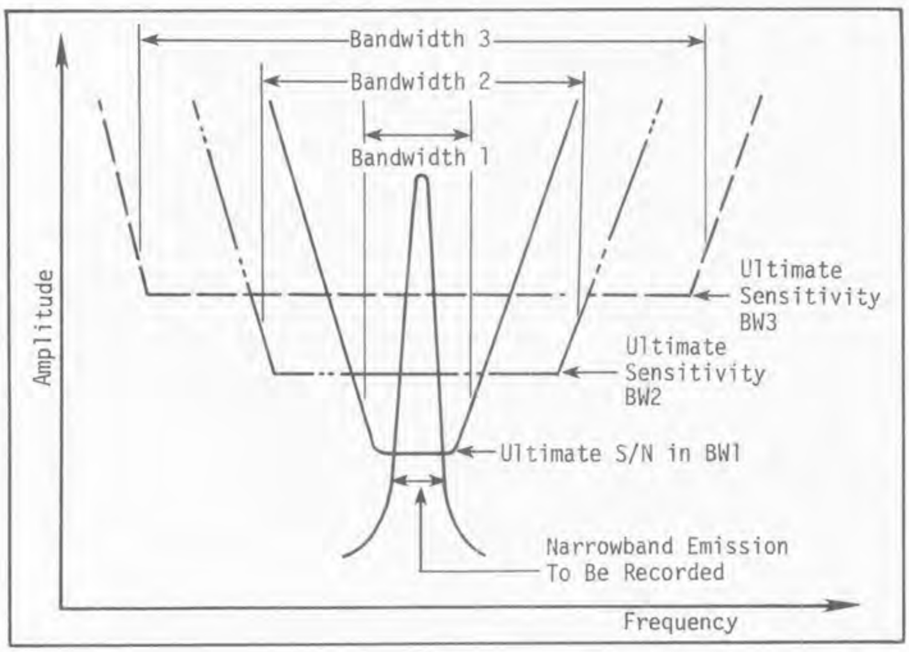

Figure 4-3. RF Window Size and Selectivity for a CW Signal

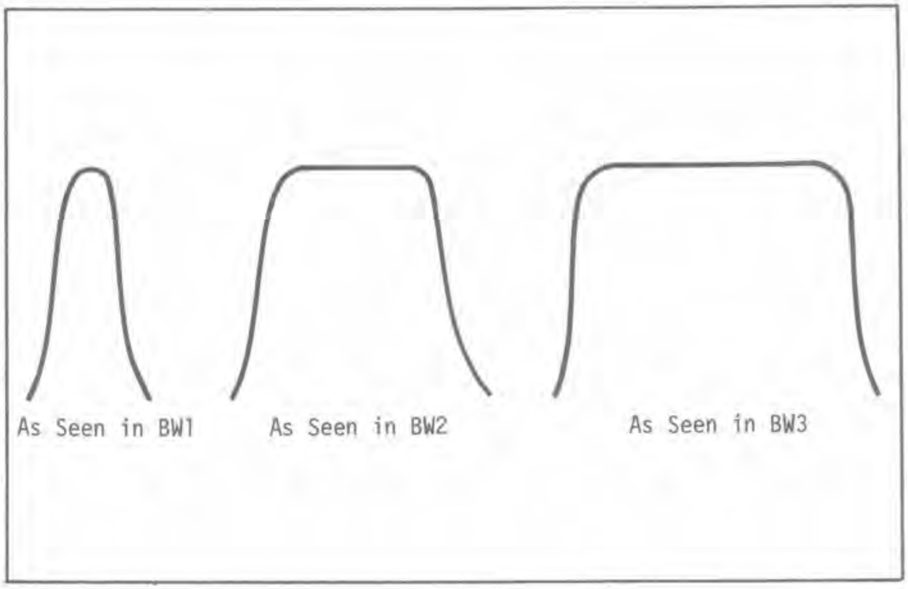

Figure 4-4. Plotted Displays of CW Signal in Three Observation Bandwidths

4.2 STEP SIZE

The WJ-8940B is an incrementally tuned receiver. The size of each increment (step size) should be selected such that every portion of the frequency specturm is observed.

Figure 4-5 shows the step size set to slightly less than the IF bandwidth, assuring that there is complete coverage. A step size smaller than this will not degrade data, but will increase the time to complete the data acquisition. If the step size is set somewhat in excess of the IF bandwidth, as shown in **Figure 4-6**, there is the possibility of lower level CW signals remaining undetected.

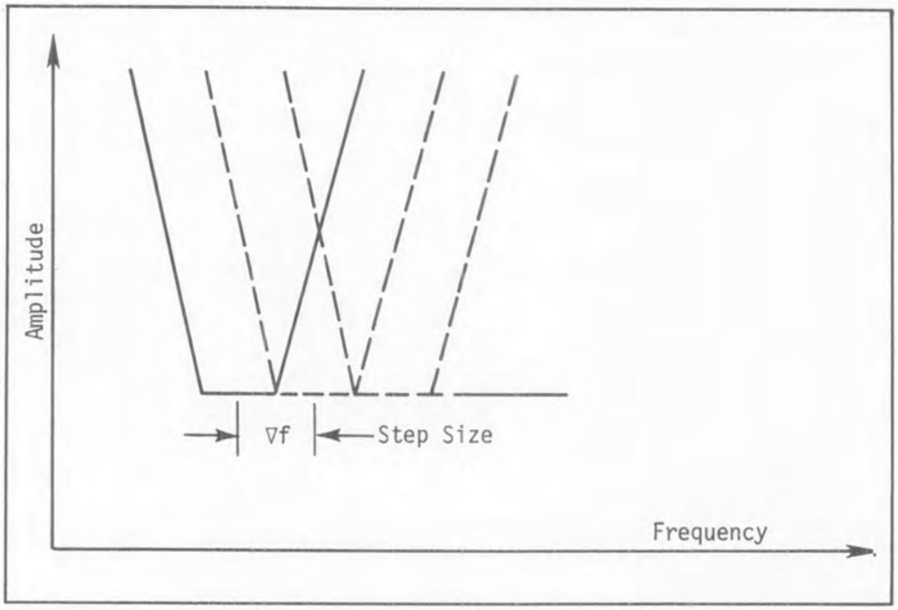

Figure 4-5. Step Size Adequate

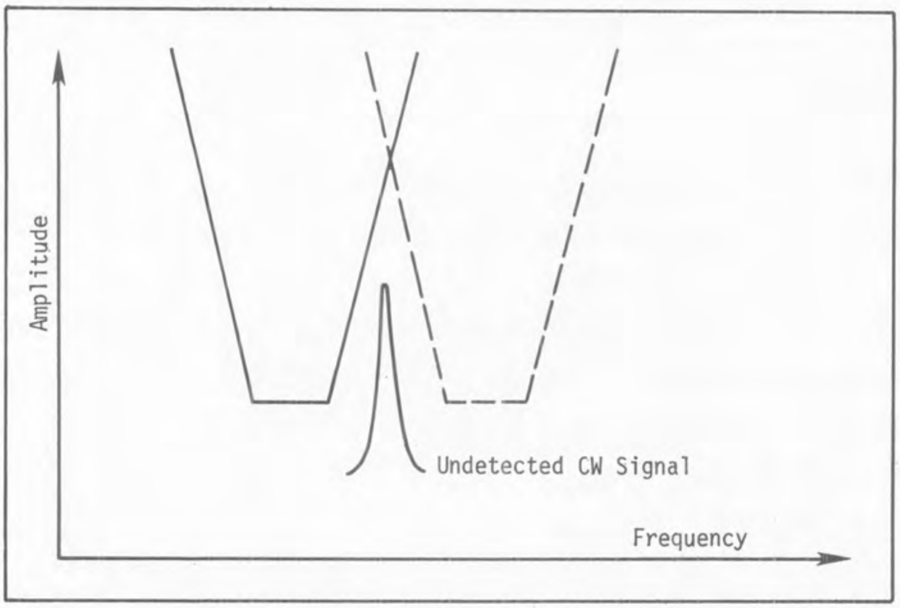

Figure 4-6. Step Size Too Large

4.3 DETERMINING NUMBER OF STEPS

A WJ-8940B provides for the entry of an operator selectable step size. When selecting the values for start frequency, stop frequency and step size it is necessary to determine the number of steps, or data points in a scan. The number of steps, due to internal limitations, must be constrained to values between 10 and 4000.

$$\text{Number of Steps} = \frac{\text{STOP FREQ} - \text{START FREQ}}{\text{STEP SIZE}} \qquad (4.6)$$

where

$$10 \leq (\text{number of steps}) \leq 4000$$

If the required start frequency and step size are known, the scan stop frequency may be determined as follows:

$$\begin{aligned} \text{STOP FREQ} &= \text{START FREQ} + (\text{STEP SIZE} \times 4000) \quad (4.7) \\ &= 5\text{ kHz} + (1\text{ kHz} \times 4000) \\ &= 5\text{ kHz} + (4000\text{ kHz}) \\ &= 4.005\text{ MHz} \end{aligned}$$

Note that any stop frequency between 15 kHz and 4.005 MHz could have been chosen based on other test considerations.

The step size maybe internally generated by entering a zero Hz step size according to the formula:

$$\text{Step Size} = \frac{\text{STOP FREQ} - \text{START FREQ}}{1000}$$

It is necessary for the operator to verify that the internally generated step size is equal to or less than the IF bandwidth as previously determined in order to ensure that no data is lost.

4.4 RF ATTENUATION

Front end attenuation, which adjusts the amplitude of the signal applied to the receiving system, is accomplished internally by a programmable step attenuator. It has a range of 0 - 70 dB in 10 dB steps. This level adjustment is used to preclude saturation effects. If desired, the attenuator can further be used to reduce (or alternatively, increase) signal levels to any convenient level for presentation. The WJ-8940B, using the auto attenuator mode, selects near optimum presentation of data. When the auto attenuator mode is not used, in preference to the fixed attenuation, the attenuation selection is made by the operator. In either case, the WJ-8940B automatically corrects data levels for any setting.

When using the attenuator in manual mode, it should be noted that the WJ-8940B does not discriminate between large signals and small signals, or receiver noise. It will treat all data points uniformly, assuming that a signal has been attenuated, adding a correction factor equal to the amount of attenuation. The results, while accurate, can create an unnecessarily high minimum detection level.

In the automatic attenuation mode this problem is circumvented because the decision to insert or remove attenuation is made prior to making the measurement for each data point so that a fixed value of attenuation need not be applied to all data points.

WJ-8940B provides data correction files which can be programmed by the operator to automatically correct the measured data to account for gains or losses external to the receiving system.

4.5 DETECTION MODE

The log detection mode provides calibrated data which is presented in decibels above or below 1μvolt (dBμv) in narrowband mode or in decibels above or below 1μvolt/MHz (dBμV/MHz).

Other detection modes (AM, AM/AGC, FM, CW) are provided primarily for signal analysis functions. When using these modes there are variable receiver gain parameters which preclude internal determination of absolute signal level referenced to the sensor port.

Accurate measurements of signals using these detection modes may be made by signal substitution techniques.

The operator is not prevented from running scans in any mode. However, except in LOG mode, the prevention of RF, IF or detector saturation, and the selection of an appropriate gain setting rests with the operator.

4.6 MEASUREMENT MODES

Various potential victims of EMI may either be more sensitive to impulsive interference or more sensitive to average levels of interference. The selection of the measurement mode, peak, average or quasi-peak, is therefore made based on the evaluation of the potential emissions of the EUT and sensitivities of possible receptors. The selection may also be dictated by the test specification.

4.6.1 Peak Detection Mode

The peak detector in the WJ-8940B will capture the peak amplitude of any signal occurring while video is gated to it. This gating function, GATE TIME, is discussed in **paragraph 4.7**. At the end of the gate the level from the peak detector is sampled and held for subsequent digitizing. Prior to the initiation of the next gate the peak detector is dumped. This ensures that the peak detection function is not affected by signals or noise except during the gate time and that each measurement is independent.

4.6.2 Average Detection Mode

When the average mode is selected, an averaging time constant must also be selected. The WJ-8940B provides three time constants in an active RC averaging network. These time constants, 15 µs, 1.5 ms and 15 ms, should be chosen such that the time constant is long compared to the period of the modulation, data bit rate or clock period of the signals that are being examined.

Since the averaging must be done over a period of time, the selection of the RC network is made as a function of the gate time. The relationship of the RC time constant and gate time selection is shown below:

RC Time Constant		Gate Time
15 µsec	–	150 µsec
15 µsec	–	1.5 msec
1.5 msec	–	15 msec
1.5 msec	–	75 msec
15 msec	–	150 msec

4.6.3 **Peak Versus Average Detection**

If it is assumed that the time constant of the average detector is long relative to the modulation rate of the emission source to be measured, then the average detector will read the average level of the modulation envelope. Thus, to a CW signal having no modulation, the peak and average detectors will read the same as shown in **Figure 4-7.** For a 100% tone amplitude modulation, the peak detector will read 6-dB higher than the average as also shown in **Figure 4-7.** In general, for an AM signal, the difference between the peak and average detector outputs will be:

$$\begin{aligned} dB &= 20 \log_{10} (1 + \%\ \text{Modulation}/100) \qquad (4.8) \\ &= 0 \text{ for CW emissions} \\ &= 2.3 \text{ dB for 30\% amplitude modulation} \\ &= 3.5 \text{ dB for 50\% amplitude modulation} \\ &= 6.0 \text{ dB for 100\% amplitude modulation} \end{aligned}$$

The difference between the peak and average detector readings is also useful in identifying other emissions. For example, a computer clock having a 50% duty cycle will have a difference of 6 dB corresponding to the 50% duty cycle as shown in **Figure 4-8.** The clock rate, however, must be less than about one-half of the receiver impulse bandwidth for this relationship to hold.

For digital data, where the duty cycle is about 0.25, the difference will be about 12 dB as shown in **Figure 4-8**. In general, then, the difference between the peak and average, will approximate:

$$\Delta_{dB} = 20 \log_{10} \delta$$

where,

$$\delta = \text{duty cycle} = \tau \times f_r \quad (4.9)$$

τ = pulse width

f_r = average pulse repetition rate

4.6.4 Quasi-Peak Detection

At one time, most of the potential EMI victims were AM broadcast receivers. In order to correlate the impact of EMI noise to the AM receiver/human ear combination, it was determined that a modified peak detector could be used. This device, the quasi-peak detector, has a charge time that is slow compared to a normal peak detector and a discharge time that is relatively rapid. With the advent of modern technology the use of the quasi-peak detector finds limited application.

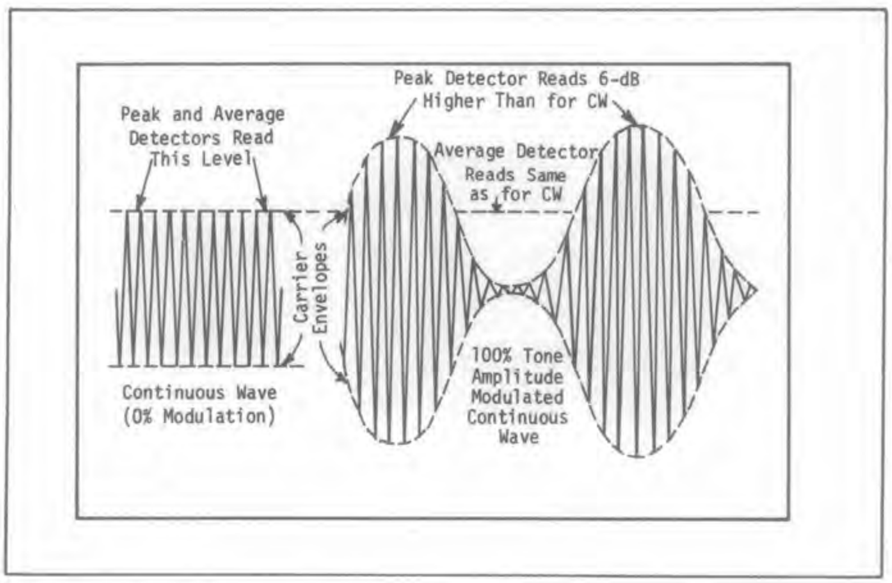

Figure 4-7. Peak and Average Detector Readings for Amplitude Modulation

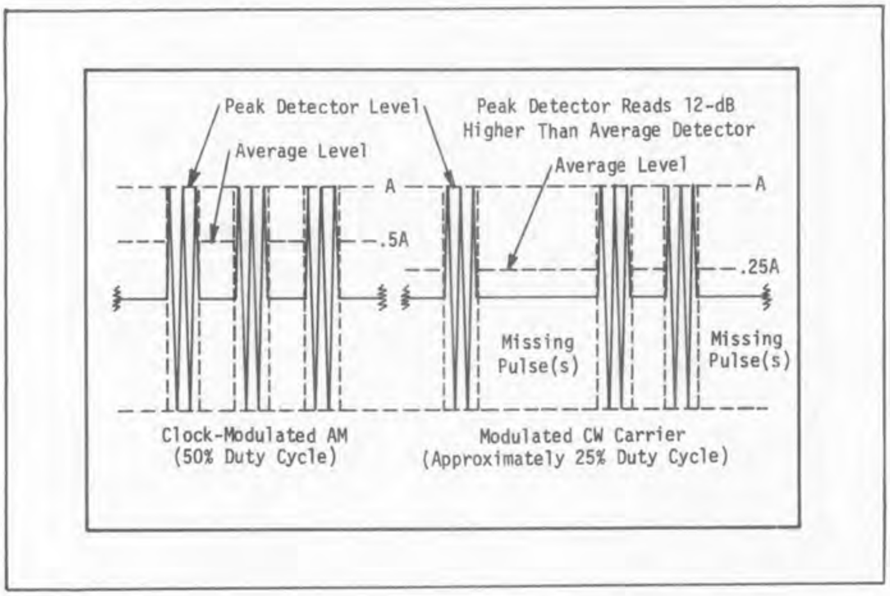

Figure 4-8. Peak and Average Detector Readings for Clock and Modulated C-W Carriers

4.7 SELECTING THE GATE TIME

The WJ-8940B parameter called "GATE" is a time windowing function. It is the time during which video is applied to the peak, average, and quasi-peak detectors for each individual measurement. When using the average detector the selection of the gate time is based on the averaging time constant required as discussed in **paragraph 4.6.2**. When using the peak detector, the gate needs to be long enough to ensure one or more occurrences of the potential EMI source during the gate time. For example, if the potential noise source is likely to be related to the AC line, then a gate time longer than the period of the line frequency (16.6 ms for 60 Hz or 20 ms for 50 Hz) should be chosen (i.e., 75 ms or 150 ms). In the case where a digital signal is the potential source of EMI the gate time needs to be long enough to ensure that the effects of both positive and negative transitions are captured.

Potential EMI sources that occur in short bursts with moderate to long repetition intervals (**Figure 4-9**) need special consideration. There are several approaches that should be evaluated. First the gate time can be selected such that it is equal to or greater than the repetition interval.

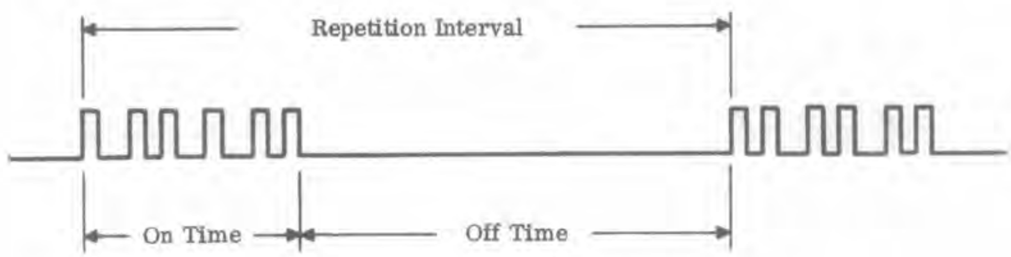

Figure 4-9. Example Long Interval EMI Digital Burst

Using a standard WJ-8940B this is the easiest way to run a scan. There are however some alternatives. An external sync input is available in all of the operating modes. This makes it possible to synchronize the gate anywhere within the repetition interval of the potential EMI source. Since the peak detector is only turned on during the gate time the peak detector output from the IFD may be used as a monitor point to ensure synchronization.

4.8 NARROWBAND AND BROADBAND DEFINTIONS

The term "broadband" is used in several different electronic disciplines. A microwave antenna engineer may refer to a conical log-spiral antenna as broadband since it is designed to be used over 3.32 octaves, while a non-ridged waveguide horn is considered narrowband since it is used over about a 70% bandwidth 0.7 octaves. Thus, to this engineer, three octaves is considered broadband, while less than one octave is regarded narrowband.

An audio engineer, discussing a hi-fi power amplifier which has a bandwidth from 10 Hz to 100 kHz, considers this to be broadband since it covers 13.3 octaves. He would probably consider a less elaborate amplifier with a bandwidth of 30 Hz to 30 kHz (10 octaves) narrowband.

In the above situations note that a 3-octave bandwidth to the microwave antennna engineer is considered broadband while a 10-octave bandwidth to the audio engineer is regarded as narrowband (or at least not broadband).

The above use of broadband and narrowband is not what is meant in EMI measurements.

4.8.1 Narrowband Emissions and Identification

The term "narrowband emission" means that the emission bandwidth is less than some reference bandwidth. The reference bandwidth may be that associated with a potentially-susceptible victim receptor which should also be the bandwidth of the measurement receiver. Thus, an emission source is narrowband when its 3-dB bandwidth is smaller than that of the measurement receiver 3-dB bandwidth.

4.8.2 Narrowband Tuning and Bandwidth Tests

If the receiver, in narrowband mode, is tuned up or down in frequency by an amount equal to its own 3-dB bandwidth, and if the output level changes by more than 3 dB, then the emission source is narrowband. If there is a very large change (say, greater than 20 dB), then the emission source is very narrowband with respect to the receiver bandwidth.

A second test for narrowband emission identification involves changing the bandwidth of the EMI receiver. If the bandwidth in the receiver is increased by a factor of at least 2, and if the output level changes by less than 3 dB, then the emission source is narrowband. A further increase in bandwidth would result in little or no perceptible change in output.

4.8.3 Broadband Emissions and Identification

The term "broadband emission" means that the emission bandwidth is broad or greater than the reference bandwidth that is associated with a potentially-susceptible victim receptor. Specifically, as discussed earlier, the reference bandwidth is that of the measurement receiver. An emission source is broadband when its 3-dB bandwidth exceeds that of the 3-dB receiver bandwidth.

4.8.4 Broadband Tuning and Bandwidth Test

If the receiver in narrowband mode is tuned up or down in frequency by an amount equal to its own 3-dB bandwidth and if the output level changes by less than 3 dB, the emission source is broadband. If there is no perceptible change at all, the emission source is extremely broadband relative to the receiver bandwidth.

The second test available for broadband emission identification involves changing the bandwidth of the receiver. If the bandwidth of the receiver is decreased by a factor of at least 2, and the output level changes by an amount greater than 3 dB, then the emission source is broadband.

Special situations may develop when the change in test receiver output is approximately 3 dB, viz: (1) transitional situations or (2) broadband incoherent. There is not much that can be done for transitional situations although its impact in terms of identifying the emission type of EMI specification limit compliance can be significant. For example, if an emission is identified as either narrowband or broadband (i.e., transitional situation), it may be within specification for one situation and out of specification for the other.

The second special situation mentioned above involves identifying that an emission may be, or indeed is, broadband but that the receiver output level in the bandwidth change test changed by approximately 3 dB. A broadband signal, depending on whether or not it is coherent, will exhibit different characteristics. An emission is said to be coherent when neighboring frequency increments are related or well defined in both amplitude and phase. For the broadband case neighboring frequency increments are equal in both amplitude and phase. The change in receiver output level (ΔV) when performing the bandwidth change test will be:

$$\Delta V_{dB} = 20 \, \mathrm{Log}_{10} \frac{(B_{new})}{B_{old}} \qquad (4.10)$$

If the bandwidth is decreased by a factor of 2, it can be seen that a 6 dB change will occur which qualifies it as broadband. Examples of coherent broadband emissions may include transients, pulsed sources such as computer clocks, radar and PCM telemetry.

However, incoherent broadband emissions, those whose neighboring frequency increments are random or pseudo-random in either phase or in amplitude and phase, will exhibit a change in receiver output (ΔV) according to:

$$\Delta V_{dB} = 10 \, \mathrm{Log}_{10} \frac{(B_{new})}{B_{old}} \qquad (4.11)$$

If the bandwidth change test is done as before, decreasing the bandwidth by a factor of 2, the change will be 3 dB which could be interpreted as a transitional case. Decreasing the bandwidth by a factor of 10 will cause a 10 dB change if it is an incoherent broadband emission. Examples of incoherent broadband sources are noise diodes, black bodies including internal receiver noise, DC energized gas lamps and high voltage corona discharges.

SECTION 5

5.0 HARDWARE ENHANCEMENT TECHNIQUES FOR EMI/EMC TESTING

Extension of WJ-8940B capabilities may be accomplished through the use of additional hardware. This section describes several possible extensions through the use of such hardware to enhance system performance.

5.1 SELECTION OF DISPLAY DEVICES

In general it is desirable to utilize a plotter, along with a variable persistence oscilloscope, for diagnostic or developmental testing with a WJ-8940B. Typically, developmental testing requires the utilization of large amounts of plotter paper due to the many unforeseen variables and hardware changes which may be required on the equipment under test. The use of the oscilloscope will greatly reduce the large amounts of plotter paper normally required. However, for formal testing, the plotter is the appropriate choice since a permanent printed record of acquired data is required for insertion into the test report.

5.1.1 Using the WJ-8940B with Interactive Plotter

The WJ-8940B has been designed for use with a Tektronix Model 4662 digital interactive plotter (optional). It provides considerable plotting flexibility, allowing operator selection of the Y-axis origin and the Y-axis range, plotting of a variable threshold, choice of linear or logarithmic X (frequency) axis, and the choice of omitting the axis and labels, the threshold, the header information or the scan data. Special versions of firmware also allow the use of the Hewlett-Packard 7221A four pen plotter to generate multi-color plots.

5.1.2 Using the WJ-8040B with a Storage Oscilloscope

The WJ-8940 may be used with a standard or variable persistence storage oscilloscope to observe the amplitude versus frequency characteristics of various signals. The

WJ-8040B provides scaled detected video, a sweep signal proportional to the tuned frequency within a sector, and a blanking gate for direct connection to an oscilloscope that can be configured in an X-Y format.

A standard or variable persistence oscilloscope may also be used to observe the amplitude versus time characteristics of various signals. This is accomplished by providing a coaxial cable interconnection between the video or the appropriate IF output of the WJ-8940B and the vertical amplifier of an oscilloscope. Adjustment of the time base of the oscilloscope can be made to provide a conveniently observable display on the screen. The video output may also be connected to an oscilloscope's DC coupled Z-axis to provide swept Z or falling raster displays.

5.1.3 Using the WJ-8940B with Signal Monitors

Watkins-Johnson signal monitors provide the WJ-8940B with a visual tuning aid and spectral display capabilities. Suggested units include a WJ SM-9804A for the 21.4 MHz IF output port and a WJ SM-1622 for the 160 MHz IF output port (**Figure 5-1**). Both are mounted side by side in 3.5 inches of vertical rack space using an EF-201D Equipment Frame.

5.2 USE OF THE WJ-8940B WITH A SPECTRUM ANALYZER

Recently, equipment manufacturers have placed on the market sophisticated digitally controlled spectrum analyzers, many of which can enhance measurement capabilities of the WJ-8940B. Direct use of spectrum analyzers for testing can be accomplished but spectrum analyzers are limited in comparison with the WJ-8940B in specific areas:

- The overall sensitivity is limited. The design of broadband spectrum analyzers produces input noise figures of 10-30 dB higher than the WJ-8940B.

Figure 5-1. Signal Monitor WJ SM-9804A

- The selection of bandwidths available with a spectrum analyzer does not match those available with the WJ-8940B, particularly for bandwidths above 1 MHz.

- The broadband front ends of spectrum analyzers are subject to the development of intermodulation products.

However, the signal processing and analysis capabilities of the WJ-8940B may be considerably expanded with the addition of a sophisticated spectrum analyzer to the receiving system.

5.2.1 The Hewlett-Packard Model 8568A Spectrum Analyzer

The 8568A Digital Spectrum Analyzer offers several features. One of the most useful of these is trace manipulation. The 8568A and other similar spectrum analyzers have built-in trace manipulation capabilities which are capable of being exercised from the front panel or external control, thus providing a rather unique amplitude versus frequency spectrum analysis capability. These trace manipulation characteristics can be used to add and subtract spectra and produce information not currently available or not easily available through the WJ-8940B operating by itself.

For example trace manipulation allows trace subtractions for comparison of data describing two modes of EUT operation or an ambient level versus an emission measurement all using the advanced technology, low noise figures of the WJ-8940B.

With the 8568A used to observe the broadband intermediate frequency outputs of the WJ-8940B, particularly in bandwidths above 1 MHz, it is possible to extract data from the backgrounds of successive scans via trace manipulation and, when used with the external computational capability, historical records of these traces may be stored and later recovered for more detailed analysis.

5.2.2 The Tektronix 7L12 or 7L13 Spectrum Analyzer Plug-Ins and the 7704A Digital Processing Oscilloscope Main Frame

The Tektronix Digitizing Oscilloscope consisting of a D7704A display unit, a P7001 Digitizer and standard plug-ins, provides the capability of digitizing and storing up to 4 waveforms for comparison. These may be frequency domain waveforms from a 7L12 or 7L13 spectrum analyzer plug-in or time domain waveforms from any of the 7000 series plug-ins. When the Digitizing Oscilloscope is coupled with an external computer these stored traces can be manipulated by the computer to provide additional features such as averaging of either time domain or frequency domain traces, trace subtractions and statistical analysis.

5.3 TEST CAPABILITY ENHANCEMENT VIA EXTERNAL CONTROL

As a stand-alone item, the WJ-8940B Receiving System provides many features that simplify EMI/RFI test measurements and reporting. The printed data plot of the frequency spectrum, which is generated in sector scan mode, is one example. Many other features are discussed throughout this application note. Some testing specifications and procedures have requirements that are simple to achieve with further software enhancements to the WJ-8940B system or with user-defined software tasks. Many of these tasks are best accomplished via a controller, desk top calculator, or computer with the WJ-8940B under remote control.

For example, with an external control device such as a mini-computer with associated mass storage and software, unattended recording of data of many points is possible. A great deal of off-line computation may also be accomplished.

5.3.1 Suggested System Configuration

The selection of external control devices for the WJ-8940B is widely variable and is dependent on the existing digital control hardware available for a particular installation. It is recommended that the system configuration consist of a mini-computer, and sufficient mass storage, such as a disc or diskette to allow storage of multiple amplitude versus frequency scans. There are many additional configurations and options which are possible but the consideration of all alternatives is beyond the scope of this document.

It should be noted, however, that the choice of an external computer should be based on the entire scope of tasks to be performed. The control of the WJ-8040B may well be the most menial task the computer will be required to perform.

5.3.2 Advantages of an External Computer

The use of an external computer with adequate storage provides the user with a wide variety of signal processing options such as:

- Multiple frequency versus amplitude scan averaging for signal to noise ratio enhancement.
- Multiple scan storage for time of day versus spectral occupancy analysis.
- Differences between scans to aid in the identification of problem areas.
- Determination of harmonic relationships in spectral data to help identify problem areas.
- Statistical analysis of the stored scans taken from a number of EUT's to aid in evaluation of recurring problems.

The addition of an adequate digitizer would allow additional processing in the amplitude versus time domain. The possibility of signal to noise improvement, pattern recognition and signature analysis could speed up the process of evaluating, isolating and correcting problems in a production environment.

5.3.3 Calibration via Remote Control Techniques

Under external control it is possible to utilize one of the input ports of the WJ-8940B as a calibrated signal generator input. A signal of known amplitude and frequency can be injected at this port, which can be automatically switched between a signal of unknown characteristics on another port. This function allows for automated CW substitution measurements not previously available. Many specifications, among them MIL-STD-461, call for substitution measurements as a proof of overall calibration. The signal generators may be independently calibrated, therefore the application of this technique is quite interesting in terms of overall calibration determination, because it can be applied as a check technique or as an independent calibration method.

Substitution measurements are possible with the WJ-1250 series microwave frequency synthesizers. The use of the WJ-1250 and the WJ-8940B under external control constitutes a powerful automated system. The WJ-1250 series synthesizer is ideally suited for test applications requiring stability, spectral purity, and computer programmability. Twelve plug-ins covering the frequency range from 100 MHz to 40 GHz are available. Both Fluke and Hewlett-Packard manufacture a wide range of remotely controllable signal generators which could also be used.

SECTION 6

6.0 SUSCEPTIBILITY TESTING

Susceptibility testing is performed on equipment to determine its vulnerability to externally applied energy. This energy simulates electromagnetic sources which may be present in the environment where equipment must be used. The term "susceptibility" refers to the undesirable response of the equipment to the external energy source. The WJ-8940B can be used in conjunction with an EMC Test System, such as the WJ-1235 (refer to **Figure 6-1**) to perform susceptibility testing. This section describes some of the disadvantages of traditional susceptibility testing, talks about the WJ-1235, and discusses how the WJ-8940B may be used to simplify testing.

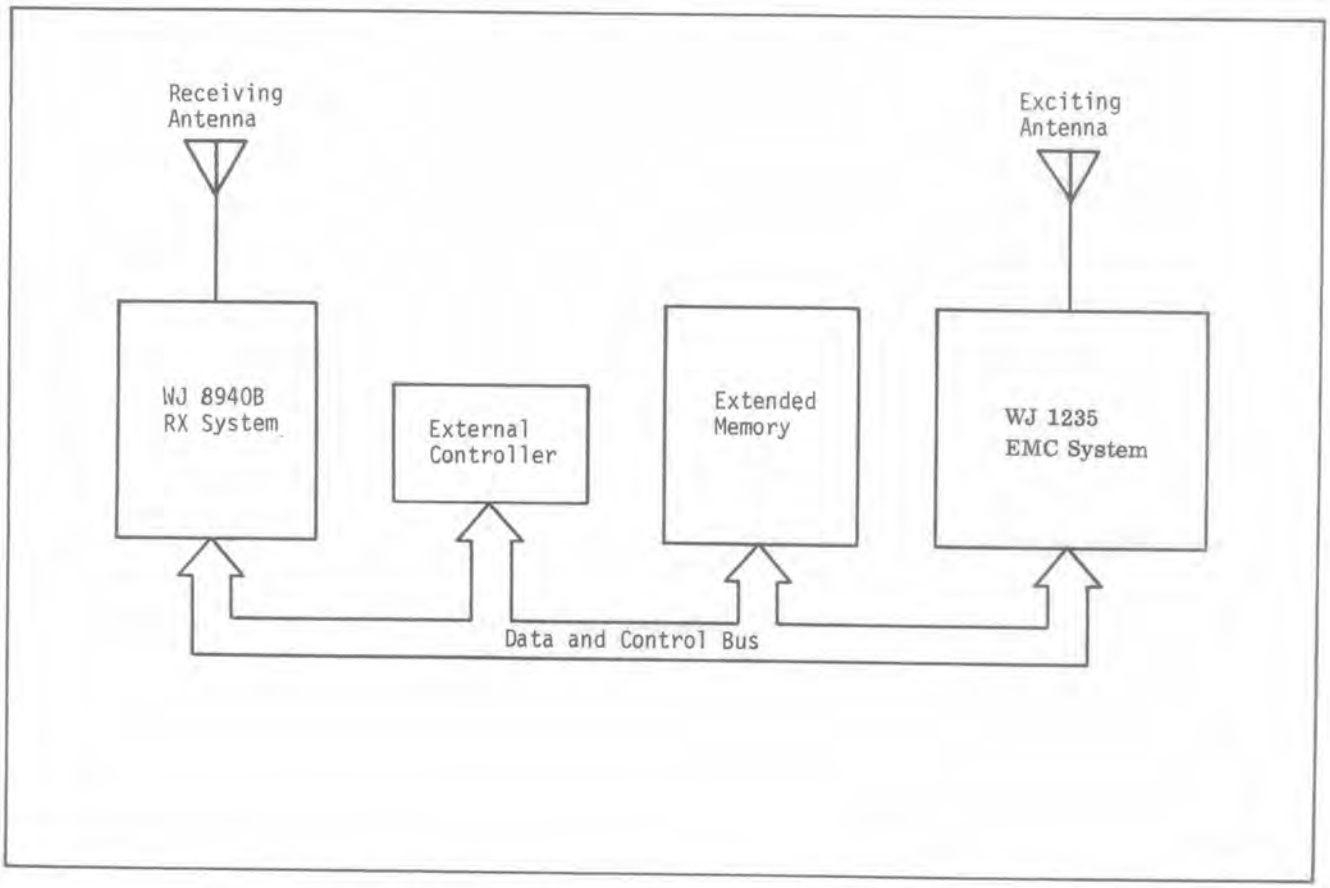

Figure 6-1. WJ-8940B Configured for Susceptibility Testing

6.1 TRADITIONAL EMC SUSCEPTIBILITY TESTING

Radiated susceptibility tests are usually performed semi-automatically with level correction done manually. A typical procedure would require that an amplified RF signal source feed a transmitting antenna within an anechoic chamber. Receiving antennas would be positioned within the "quiet zone" of the chamber in place of the equipment under test (EUT). The quiet zone within the chamber is an area where reflections create minimal disruptions to the uniform electromagnetic field. An EMC receiver would sample the field in this zone. Since the object is to provide a uniform electromagnetic field at a specified level throughout the quiet zone of the chamber, the measured levels indicated by the receiver may be used to provide corrected field intensities.

Reflections created by enclosure effects are minimized by absorbing material in the chamber. Further reflections may be created by the EUT, but these may also be corrected using EMI receiver measurements. These corrections are now done manually in a time consuming process.

6.2 THE WJ-1235 EMC TEST SYSTEM

Key in Watkins-Johnson's susceptibility product line is the WJ-1235 which provides a flexible capability for versatile EMC work. A simplified block diagram of the WJ-1235 is shown in **Figure 6-2**.

6.2.1 General Description

The WJ-1235 Electromagnetic Compatibility Test System is a multipurpose test system designed to generate a high power radiated environment for EMC far field testing of medium to large scale objects. The basic system covers the frequency range 10 kHz to 1.0 GHz with provisions for frequency expansion to 18 GHz and drives the radiating antennas with RF power at kW CW levels.

Key features of the WJ-1235 are:

- 10 kHz to 18 GHz frequency range
- AM, FM, Pulse, EW modulation
- Computer or manual control (IEEE-488 bus)
- Remote data collection subsystem with fiber optic control
- Modular construction
- Sensitive protection circuitry
- Fiber optic interface
- Complete, fully integrated system.

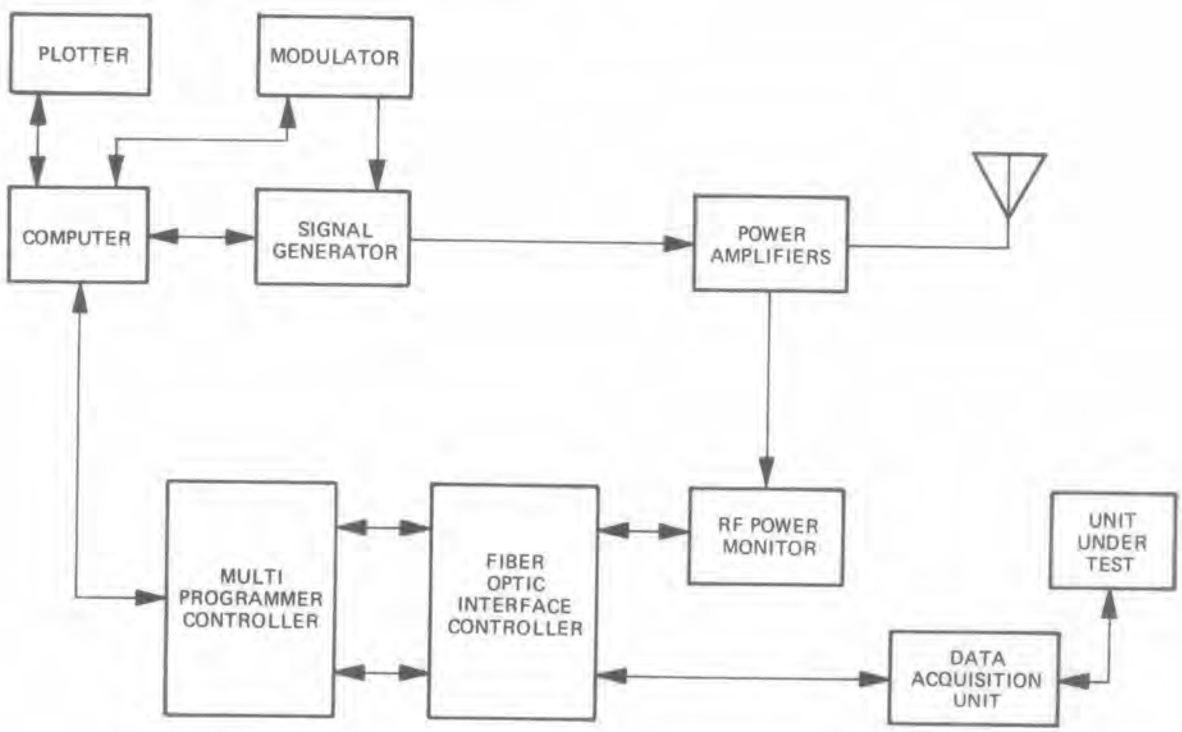

Figure 6-2. Simplified Block Diagram of WJ-1235 EMC Test System

A complete system consists of a computer control complex, signal generators, RF modulation and control, RF amplifiers, antennas, and a data acquisition unit. **Figure 6-3** presents a detailed block diagram of the WJ-1235. The modular design of the WJ-1235 permits

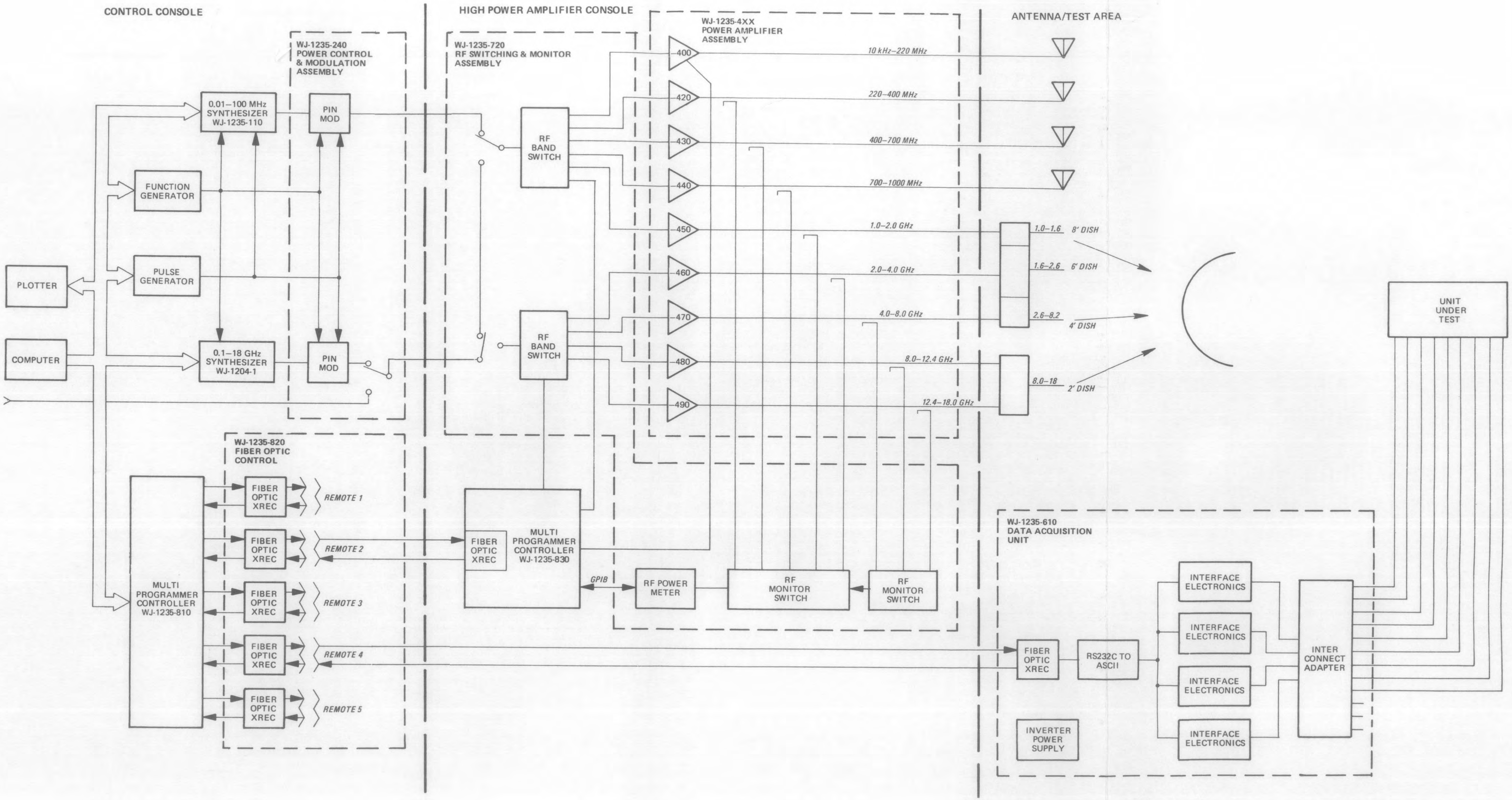

Figure 6-3. System Block Diagram of WJ-1235 EMC Test System.

a system to be configured as a single frequency band for a specialized requirement or as many as nine frequency bands to cover the full 10 kHz to 18 GHz band. The frequency bands are primarily a function of the high power amplifier bandwidths. Normal system control is through the system computer. In addition, there are provisions on the front panel of the various generators, modulators and amplifiers to allow manual control. The system is housed in two consoles. The control console contains the computer and peripheral equipment, signal generators, modulators and system monitoring equipment such as video monitor, fault indicators, and system fail-safe equipment. The high power console consists of the preamplifiers, high power amplifiers, high power monitor, system cooling and power amplifier controls.

Control between the computer complex and instrumentation within the control console is provided across the General Purpose Interface Bus (GPIB IEEE-488). Control of the high power amplifier console and the remote data acquisition unit is provided through a multiprogrammer and fiber-optic serial data links.

The combination of state-of-the-art broadband high power amplifiers and special high gain antennas provides this system with the unique capability of producing a minimum 200 volts/meter from a distance of 5 meters. This capability is shown across the frequency band in **Figure 6-4**.

6.2.2 RF Generation

Broadband RF generation for the WJ-1235 is accomplished through the use of two synthesized signal generators. The WJ-1235-110 Synthesized Signal Generator, used to cover the frequency range of 10 kHz to 100 MHz, is programmable in 1 Hz increments with 1 part in 10^{-9}/day accuracy and stability. A ten-digit numerical display provides a front panel readout of the programmed frequency. A built-in programmable attenuator permits power output attentuation in 1 dB steps over a 159 dB range.

The WJ-1204-1 Synthesized Signal Generator covering 100 MHz to 18 GHz is programmable in 100 kHz increments over the frequency range of 100 MHz to 1.9999 GHz and in 1 MHz increments over the frequency range of 2.0 to 18 GHz. Frequency accuracy and stability is 5×10^{-6}/year as read on the five-digit LED front panel readout. A front panel attenuator provides attenuation control over a 100 dB range.

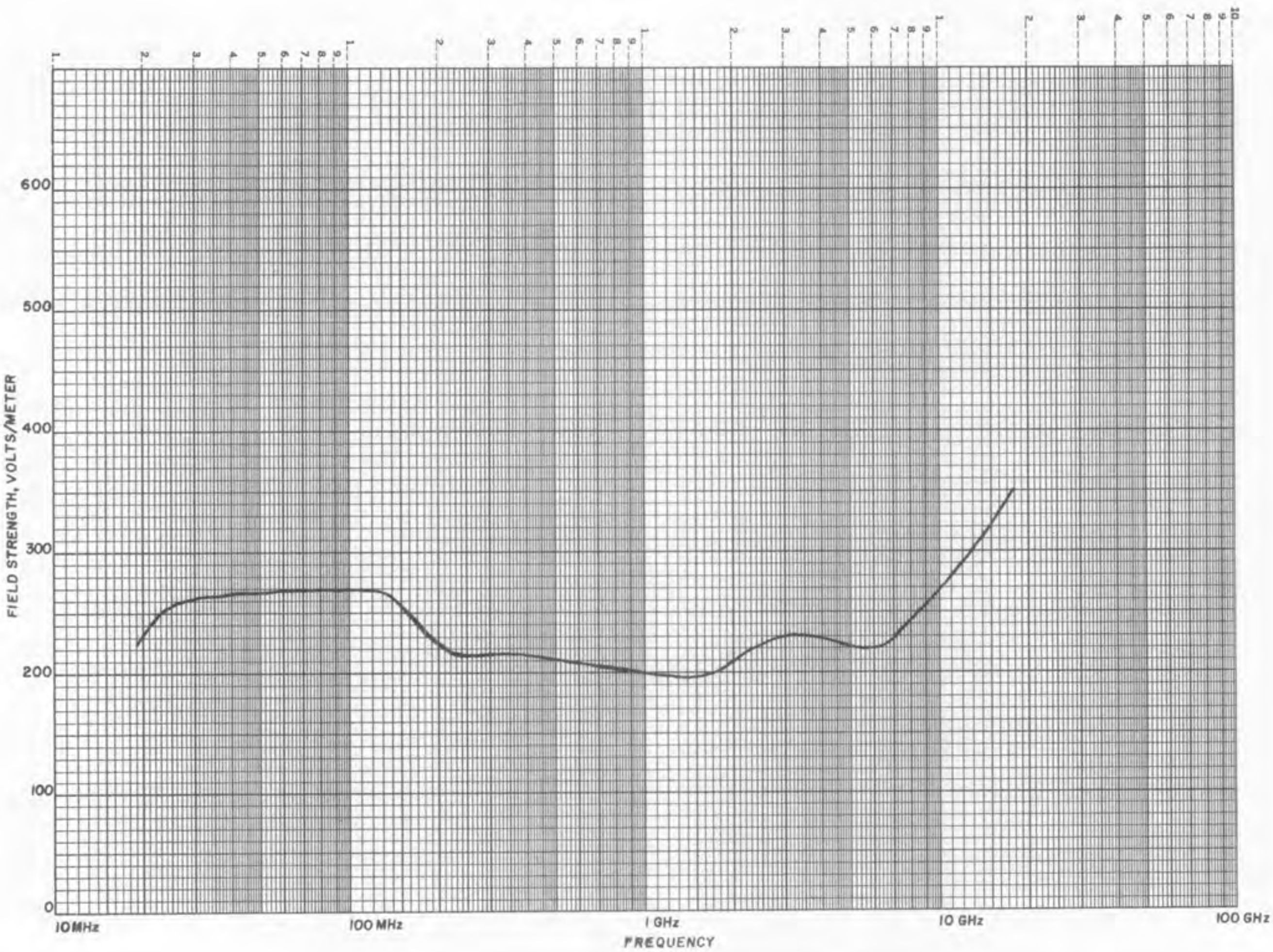

Figure 6-4. Calculated Field Strength in Anechoic Chamber with Watkins-Johnson Designed and Built (or Specified) Antennas

Both synthesizers can be controlled from the instrument front panel or from an external computer via the General Purpose Interface Bus. A unique combination of frequency accuracy, spectral purity, and single sideband phase noise is attained through the combined use of these two synthesizers wherein the WJ-1204-1 is used as a range extender for the WJ-1235-110. In addition to the standard synthesized signal generators, several special purpose generators are available from Watkins-Johnson Company. A significant number of complex EW modulated waveforms can be obtained with the inclusion of WJ-4700 series generators. These generators can be routed through the WJ-1235 external RF input port to the power amplifiers for the simulation of EW signals. Field strengths of about 5000 V/m for the simulation of 60-Hz high power tension lines and for pulsed lightning simulated signals can be provided by the WJ-1235-150 EMR generator.

6.2.3 Power Control and Modulation

Power control and modulation are provided by the WJ-1235-240. This unit routes the signal generator outputs to the various power amplifiers and modulates the RF carrier with AM and pulse modulated signals. Because separate PIN modulators are used, pulse and AM modulation can be accomplished simultaneously. The RF switching matrix permits signals from any one of the two synthesized signal generators or external generators to be routed to any one of the nine high power amplifiers.

An external pulse generator and function generator are used to drive the pulse-forming networks of the modulation assembly. The function generator is also used to drive the two synthesizers for FM modulation. EW modulation is included in the WJ-4700 series EW generators when they are selected in place of the synthesized signal generators.

6.2.4 Power Amplifier Assemblies

A complete WJ-1235 system includes nine amplifier drivers and final power amplifiers to cover the various bands from 10 kHz to 18 GHz. The power amplifier bands are 10 kHz to 220 MHz, 220 to 400 MHz, 400 to 700 MHz, 700 to 1000 MHz, 1.0 to 2.0 GHz, 2.0 to 4.0 GHz, 4.0 to 8.0 GHz, 8.0 to 12.4 GHz, and 12.4 to 18.0 GHz. The required 200 V/m of radiated field strength is obtained through the combination of amplifier output power and antenna gain. The antenna gain at low frequencies is usually very small, typically less than 5 dB. To offset this low gain, very high output power amplifiers must be used. As the frequency increases, so does the gain of the antennas. Thus, less power is needed at high frequencies to produce the same 200 V/m radiated energy.

Cooling of the power amplifiers depends on the rated power output. For frequencies below 400 MHz, where very high power amplifiers are used, a combination of water cooling and air cooling is used. Power amplifiers operating above 400 MHz are cooled by convection air. Each amplifier has built-in provisions for self protection. Excessive heating, arcing, or reflected power will cause the protection circuit to shut down the amplifier. A power sampler or directional coupler is provided at the output of each amplifier to monitor the RF output power. This RF sample is routed to the RF switch and monitor assembly for power sampling and monitoring.

6.2.5 RF Switching and Monitor Assembly

Two types of power monitors are used in the WJ-1235-720 RF Switching and Monitor Assembly. For Band 1 (10 kHz to 220 MHz), a built-in RF sampler/detector samples RF power output and provides an analog voltage. Bands 2 through 9 use high power directional couplers following the power amplifiers. A sample of this coupled output power is switched to a programmable digital RF power meter. The analog and digital readouts are routed through the system multiprogrammer to the computer.

6.2.6 System Antennas

The WJ-1235-54X system antenna is an important element of any transmitter. Special consideration is given to the antennas of the WJ-1235 system to provide the 200 V/m field strength for far field radiation. Available technology establishes the amount of power available from broadband high power amplifiers. Watkins-Johnson Company provides high gain, low frequency antennas which, in conjunction with the high power broadband amplifiers, produce 200 V/m at a distance of at least five meters from the radiating antenna. A combination of corner reflectors or array antennas is used below 1.0 GHz and various sizes of paraboloid antennas are used from 1.0 to 18.0 GHz. Development of the WJ-1235 required the effective handling of difficult design tradeoffs of antenna gain, effective aperture, beamwidth, phase and physical size to obtain a suitable combination of amplifiers and antennas.

6.2.7 Unit Under Test (UUT) Data Acquisition Unit (DAU)

A WJ-1235-610 data acquisition unit located at the UUT site monitors critical UUT parameters during radiation. Twenty input lines can be monitored by the DAU scanner. UUT status information is routed through a special interconnect adaptor to the DAU test electronics where it is converted to serial data. This data is routed to the system multiprogrammer via fiber optic cable. A separate dc to ac power inverter unit is used to power the DAU.

6.2.8 System Control

The system can be operated manually by front panel controls on the various generators, modulators, switching assemblies and amplifiers, or under automatic control by programming commands to the system computer. Communication between the computer and the system is across the IEEE-488 interface bus. The computer communicates with the plotter (used for alphanumerical printing of data and recording and plotting of charts and graphics), both synthesized signal generators and the multiprogrammer control unit.

The multiprogrammer control unit (WJ-1235-810) interfaces to equipment within the control console not on the GPIB bus. An example of this interface is the fiber optic transceivers. In the multiprogrammer, the computer GPIB information is first converted to ASCII, then to RS-232C serial data. The serial data is then processed to the WJ-1235-820 fiber optic unit. In the fiber optic unit, the serial data is converted to serial light data for transmission on up to 16 fiber optic cables. A typical WJ-1235 system uses only five fiber optic cables; four to drive the UUT data acquisition unit at four different locations and a fifth to drive a remote multiprogrammer in the high power amplifier console.

The remote multiprogrammer located in the high power amplifier console is used to control and monitor the operation of the amplifiers. Each amplifier has a fault output which is monitored by the multiprogrammer. The multiprogrammer controls ac primary power to the amplifiers, RF input power to the amplifiers, and RF output power to the power meter. The RF power meter reading and fault output information are processed through the multiprogrammer to the system computer through the fiber optic cable.

6.2.9 System Operation

Typical operation of the WJ-1235 is through the keyboard entry of the system computer. A program is created establishing the frequency ranges and field strengths to be radiated for a given UUT. (The data necessary to establish frequency ranges and field strengths could be partly derived from level measurements made by the WJ-8940B Receiving System sampling high power levels.) The incremental frequency steps and modulation parameters are then selected. The program also establishes data parameters and limits from the data acquisition unit. A sense monitor from the UUT is connected to the data acquisition unit and the data acquisition unit connected to the system fiber optic cable.

Radiation testing is begun by an "execute" command from the operator. Should a failure occur in the power generation system or the safety status of the chamber, a message informs the operator of the failed condition. Assuming all safety controls are functioning correctly, the program steps through the pre-programmed frequency and power levels.

Data from the data acquisition unit is constantly being monitored by the computer and can be recorded on the alphanumerical printer, stored on the magnetic tape storage media, displayed on the computer CRT display or plotted in various forms on the multi-colored plotter.

Special tests or other requirements may be accomplished in the manual mode by front panel control of the various generators, modulators, switching assemblies and amplifiers.

NOTE

The initial printing of EMC Test Applications of the Watkins-Johnson WJ-8940B Receiving System is subject to revision in subsequent printings. Any suggestions or corrections should be directed to Applications Engineering in Gaithersburg, Maryland, U.S.A. Watkins-Johnson Company wishes to acknowledge selected illustrations and graphs from the EMC Handbook series published by DWCI in Gainesville, Virginia, U.S.A.

Test setups and test limits should follow applicable test specifications. Watkins-Johnson Company assumes no liability for use of data contained herein.

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