MEASUREMENT EQUIPMENT

Introduction

The field of interference measurements, including both susceptibility and emanation, employs many of the same methods and equipments used generally in other areas of radio frequency measurement. There is no other area, however, that covers such a wide range of frequencies and signal levels as does interference measurements. Consequently, some of the equipments and techniques are specialized and seldom used otherwise.

Interference measurements, to be useful, must produce usable answers with absolute numbers and definitive units and the susceptibility of an equipment must be proven or disproven. To this extent, the field of interference measurements is an eminently practical one. On the other hand, there are many complex areas in interference measurements which require an understanding and an appreciation of fundamentals, such as a knowledge of conducted and radiated signal measurements in terms of both signal level and frequency, a knowledge of many diverse test equipments and devices, and a knowledge of the equipment under test.

From these requirements has evolved the recognition that interference measurements are definitely engineering measurements. The problems encountered, the range of frequencies and levels used, the equipment used, and the equipment under examination are factors which preclude interference measurements from being considered as routine tests. There are situations, however, where a certain measurement must be performed repetitively on successive units of the same type, i.e., production-line checking, where the measurement can be refined to become routine. It is not likely that this situation will be experienced to any extent in space programs because with the wide variety of programs and equipments and the rapid progress of its various specialties, the majority of programs and equipments and the rapid progress of its various specialties, the majority of interference measurements will be in the one-of-a-kind category.

Interference test equipment may be divided into two broad categories: (1) general test equipment and (2) special test equipment. General test equipment includes signal generators and electronic voltmeters, while special test equipment is intended to indicate instrumentation developed specifically for interference testing. This latter category is primarily made up various frequency-selective voltmeters and their accessories, plus a few special-purpose units. The more common equipment in the general category will be reviewed from the interference measurement standpoint, while the special equipment will receive brief consideration.

The keystone of interference measurements is the frequency-selective voltmeter (FSVM) or calibrated receiver. Traditionally, this device has been designed and produced by specialists such as Singer as shown on the back cover of ITEM. Only in a few instances have successful and widely-used RFI meters, as they are often termed, been marketed by diversified test equipment manufacturers. The pickup devices used in conjunction with these receivers include various types of antennas and probes, some calibrated to provide absolute measurements, and some useful only for relative measurements. There has been significant progress in this area in the last ten years, but there is enormous room for further advances. For example, roughly 15 years after the development of the transistor, only a few of the widely used and approved EMI meters use them to any extent. (However Singer is one of them.) A retarding factor, of course, is the relatively narrow market for such equipment and also the difficulty of obtaining approval of the various users.

A variety of special devices are required for interference tests. These include impulse generators used for calibration and signal substitution measurements, transient generators for susceptibility tests, and several audio equipments for audio susceptibility tests.

As electronic systems become more complex, the interference test planner will find himself devising his own instrumentation, due either to a difficult test specification requirement or to a special test requirement not necessarily associated with a specification. This will be especially true of space systems with their ultrasensitive receivers and high reliability requirements. In instances of this sort, it is generally more expeditious and economical to use modified existing equipment and perhaps provide additional auxiliary units than to develop a completely new instrument. For instance, there are several arrangements suitable for increasing receiver sensitivity if that becomes necessary. In some frequency ranges, preamplifiers with low noise figures are available. In other instances, the bandwidth may be reduced by using a second lower frequency receiver as a tunable IF amplifier.

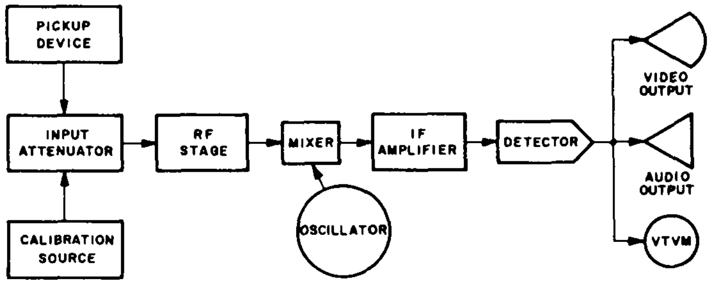

Figure 1. Block Diagram of a Typical Frequency-Selective Voltmeter

Equipment Characteristics

As mentioned previously, the frequency-selective voltmeter is the keystone of the interference measurement field. It is basically a well-shielded sensitive radio receiver with a wide dynamic range and a means of calibration to provide absolute measurements. These instruments are available to cover a frequency range from 30 Hertz to 20 GHz, i.e., from subaudio frequencies to a wavelength of 1-½ centimeters.

From the block diagram in Figure 1, it is evident that the interference receiver is a superheterodyne receiver with some added features. The block diagram depicts only one possible receiver; there are many other configurations. Each of the major blocks on the diagram will be discussed briefly in the following paragraphs.

Pickup devices provide coupling from the signal source to the interference receiver. Two types of coupling are possible: (1) direct or (2) by means of the electromagentic field.

Direct coupling may be accomplished readily since all currently used interference receivers' have some means of providing 50-ohm inputs. Their inputs may be connected directly to 50-ohm source circuits, or through directional couplers, attenuators, or filters where necessary. Coupling to power lines, ac or dc, is usually accomplished with a particular network termed a line impedance stabilization network (LISN) or a current probe.

Electromagnetic field coupling is provided by an antenna. In some cases, a small uncalibrated probe antenna may be used, for example when a leakage source is under investigation, but calibrated antennas must be used to obtain an RF field measurement in absolute units. A wide variety of these antennas is in current use to cover the required frequency range but there has been a somewhat recent trend to provide antennas which do not require adjustments, i.e., broadband antennas.

To provide absolute field strength measurements from the voltage at the antenna terminals, it is satisfactory to use theoretically calculated antenna factors for the half-wave dipoles. This factor will include the correction for the electrical length of the dipole, λ/π, as well as any correction for the mismatch between the antenna impedance (72 ohms) and the interference receiver input impedance (usually 50 ohms). Factors for other antennas must be determined experimentally.

The input attenuator is a device that gives the receiver its usually large dynamic range. The attenuator used on most interference receivers consists of a set of coaxial barrel attenuators, providing attenuation in steps of 20 bd frin 0 to 80 db. The attenuators must have good RF properties over the range of the instrument, and have some power dissipation capability. An added benefit of the attenuators is the stabilization of input impedance over the frequency range.

Due to the variation in gain with frequency, the usual interference receiver must be calibrated at each measurement frequency. This is usually accomplished in one of two ways. Either an internal source is used in conjunction with a gain control to set a reference level (with the input attenuator being depended on for translation to other levels), or the receiver is used simply as a transfer device with each measured signal being matched exactly by a signal from an external source. The methods are similar in that each one requires a known source. In the case of the reference being set only on one setting of the input attenuator, only a single-level signal is required; in contrast, a wide range of levels, as from a standard signal generator, is required for the substitution method.

Calibration sources include CW, random noise, and impulse noise sources. The CW source is analagous to the standard signal generator. The random noise source provides a wideband repeatable signal, which must be initially calibrated against a CW source. The impulse method is also a wideband repeatable source, but has been more highly developed than the random noise source. The impulse generator usually operates by generating an extremely short (5×10^{-10} second, for example) dc pulse, which has a flat frequency spectrum over a wide range of frequencies. This pulse may be generated by charging and discharging a short (a fraction of a centimeter) length of transmission line. The dependability of the spectral output will then be only a function of the dc charging voltage and of the physical condition of the transmission line and its charge-discharge mechanism.

The impulse method of calibration is widespread and is used over all frequency ranges. Many interference receivers have internal impulse generators with widely variable outputs that can be used either for precalibration or for substitution measurements. It should be noted that to use impulse calibration for CW measurements requires either information about the instrument bandwidths or comparison with a CW source at the desired frequency. Normally, sufficient information is furnished with the receiver to allow complete calibration with an impulse generator.

Conventional receiver practice in the past has been to narrow bandwidth to improve receiver sensitivity. While this is a proper approach for CW signals and is only limited by the signal bandwidth and the combined stability of the local oscillator and the signal, it is not the correct approach to improve receiver sensitivity to impulsive signals. With all other parameters constant, the receiver's own random noise voltage, produced in the first one or two stages, will increase as the square root of the bandwidth increases. However, impulsive noise voltage increases directly with an increase in bandwidth, which indicates that to produce maximum receiver sensitivity to impulsive signals requires the widest bandwidth receiver that is possible. There is of course, no benefit if the receiver bandwidth is wider than the bandwidth of the signal. This consideration is particularly important in radar work and has naturally been recognized in the interference receivers designed for this range. They are furnished with two bandwidths, one less than 1 MHz, and the other on the order of 3 to 5 MHz. Future receivers for lower frequency ranges may also be designed with more than one IF bandwidth to take advantage of this method of improving impulsive signal sensitivity.

The detector stage in an interference receiver has the function of separating signals according to modulations, or perhaps more accurately, according to their peak-to-average ratio. This is accomplished by utilizing several different charge and discharge times for the detector. As the charge time is decreased, the detector circuit becomes more responsive to short-duration, fast-rising signals. As the discharge time is lessened, the detector circuit will tend to dump or lose the charge of a signal in a shorter time. Therefore, to provide a detector which responds to CW signals, an "average" function is provided. With the detector operating in this mode, the charge and discharge times are both 600 milliseconds. This is the mode to be used when measuring CW or simply modulated signals. The output meter will indicate in rms volts.

By appropriately altering the charge and discharge times, a peak detector may be obtained. This arrangement will have a very short charge time, on the order of tens of microseconds, with a long discharge time, on the order of hundreds of milliseconds. This results in a metering circuit which will respond quickly to the highest signal and "remember" it over a short interval.

There is another widely used peak detecting method, commonly referred to as the "slideback" method. The detector constants are about the same as for the average mode, but there is now a dc bias which is adjusted by the operator until the audio just disappears or is at the threshold of audibility. The operator, in effect, matches the peak of the signal level with a dc level. The dc level is read on the metering circuit. This aural slideback method offers the possibility of measuring one signal in the presence of another when the desired signal may be somewhat lower in level. Otherwise, the visual peak methods referred to as direct peak reading are to be preferred. They reduce the time required for measurement and also reduce the subjectivity experienced in the aural method.

In the past, another detector function was widely used. It was the quasipeak (QP) mode, with a charge time of one millisecond and a discharge time of 600 milliseconds. The idea was to have a detector mode which would measure the effective interference in a communications system or to express it in another way, a measure of the "nuisance value" of the interference. This mode may also be useful for scanning in frequency where it will "stretch" short pulses to the point where they are long enough to be audible.

The detector function must be considered if X-Y recordings are to be made automatically. It is obvious that if the receiver is tuned through a CW signal fast enough, the signal will not fully charge the detector in the average detector mode. The scan rate must be selected so that the largest signal to be measured will be accurately detected. The response of the recorder is also a factor in this problem. It must be fast enough to record the detector output within the required accuracy.

The detector stage is the point where AGC voltage is normally derived in the conventional receiver. In the interference receiver this is also true except that some receivers do not use AGC. In the normal receiver, the dynamic range expected without adjustment may exceed 60 db, while in the receiver this figure is either 40 db or 20 db. Additional range for the receiver is provided by the input attentuator.

The final stages in the interference receiver provide the readout or indication of a signal. Normally, a panel meter is the indication used, but a number of other methods are available. Headphones are usually used in an axuiliary manner to aid in the selection or identification of a particular signal. They may also be used in the aural slideback method for measuring one signal in the presence of another.

The panel meter is usually the indicator for a vacuum-tube voltmeter circuit or its transistorized equivalent. It is a conventional circuit, requiring only a balance control or "zero adjust." In conjunction with this circuit, a recorder output is often provided suitable for strip-chart recording or for the Y axis of X-Y recorders.

A video amplifier is sometimes provided separate from other output circuits for analysis of the detected modulation, either by recorder or oscilloscope.

There are several areas of design which require special consideration to provide necessary characteristics for interference receivers. For example, the receiver must be carefully shielded to prevent any signal leakage through the case. The leakage paths may be either actual physical openings, such as cracks or holes, or may be leads which penetrate the case, such as power leads. In extremely high-level fields, or in strong magnetic fields, it is possible that leakage may occur through the case itself, but it is more likely that leakage will be apparent through other paths at lower levels.

Calibration and Certification

It is apparent, after considering some of the instrumentation used for interference tests, that any laboratory or group engaged in interference measurements must have available for use a considerable inventory of equipment, both standard and special. To efficiently manage and maintain the equipment, a formal maintenance, calibration, and certification program is a necessity. In this context, maintenance refers to the overall repair work on equipment, while calibration refers specifically to verifying that an instrument performs to its specification. Certification is the formal declaration, in one form or another, that an instrument has been examined and found to meet its specifications. The certification may well be indicated by a small tag on the instrument with the date of certification and the certifier's name.

The operation or use of a calibration facility is well known to any laboratory or group using electronic instrumentation. Whether the group performs its own calibrations, uses the facilities of commercial calibration laboratories, or the calibration service of an instrument manufacturer, most users recognize and appreciate the need for periodic calibration of electronic instrumentation.

To discuss all phases of a cliabration facility would require several volumes, so the material here will be limited to mentioning the necessities for calibrating interference receivers which comprise the majority of the instruments used in interference work.

The interference receiver can usually be checked adequately with a standard signal generator. The absolute levels cover the same range, and the accuracy of the generator frequency and level are usually sufficient to verify proper operation of the receiver. The attenuator in the receiver should be checked at several frequencies, and the over-all absolute accuracy should be checked at several frequencies in each band. Calibration of the various accessory items used with the interference receiver is usually not necessary, since they are fairly straightforward antennas and related equipment. Verification of good physical condition and a visual inspection of cables and connectors will usually suffice for these devices.

In some situations, an actual calibration may not be possible or necessary, but still an indication of proper operation is desired. In these cases, the unit can be compared to a similar unit, if available, or a spot check or two may be made using a signal generator or other known source.

Adequate and capable maintenance and calibration of the equipment used for interference tests is necessary for obtaining good data, and will also serve to improve the attitude and morale of the persons using the equipment.

SEE

SINGER INSTRUMENTATION

ON

BACK COVER