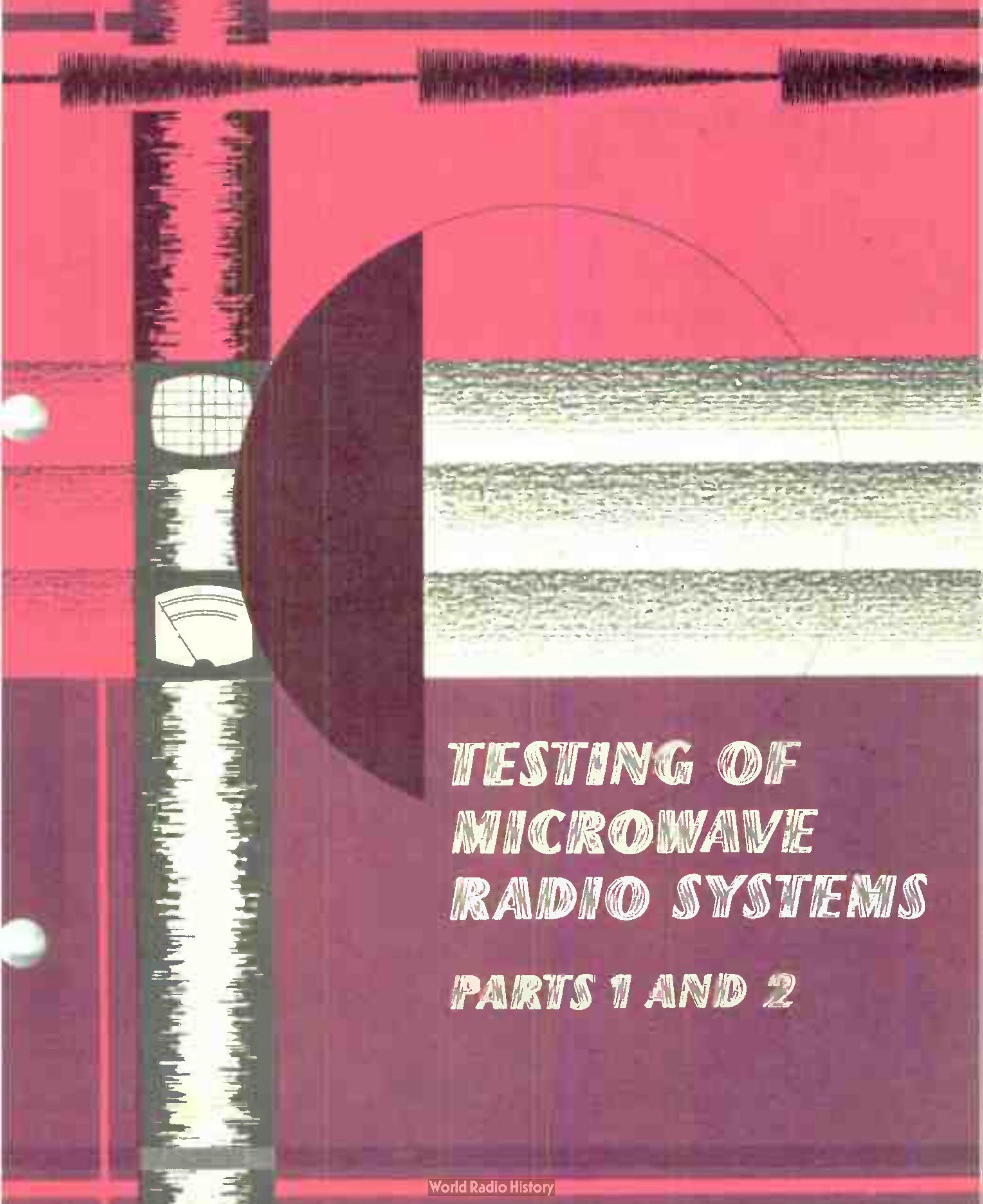
GTE LENKURT

DEMODULATOR

MAY/JUNE 1977



TESTING OF MICROWAVE RADIO SYSTEMS

PARTS 1 AND 2

PART 1

The ultimate goal for any microwave radio system is to provide the best distortion- and error-free service continuity possible within economic restraints. Of paramount importance in achieving this goal is the measurement of performance characteristics.

In order to meet the basic reliability and quality of service requirements of modern telecommunications networks, microwave radio systems must be carefully engineered, installed and maintained. While it would be a relatively simple matter to over-design a system to the point where it would meet these requirements under virtually any condition, economic considerations usually dictate that only the exact level of performance be provided that is necessary to comply with the specifications of a given application. Because of this, it is normally very important that such performance characteristics as transmit and receive power level, deviation, frequency response, nonlinear distortion and noise be controlled. The ability to control, of necessity, implies the ability to make accurate measurements.

The measurements made in microwave radio systems can be divided into two general categories: those that are concerned with equipment operating parameters (levels, deviation, etc.), and those that determine the amplitude and sources of noise.

The traffic carried by a microwave radio system generally consists of a large number of voice frequency (vf) channels, each allocated a nominal 4-kHz portion of the radio baseband. Within any given channel may lie the analog waveform of a telephone conversation, or the pulses representing a digital data transmission. Alternatively, the portion of the frequency spectrum covered by many channels may be occupied by wideband video and program channel signals.

Because the bandwidth of a microwave transmission is considerably greater than 4 kHz, the vf channels that carry voice and data information are most commonly combined using a frequency division multiplex (fdm) process. Equipment to accomplish multiplexing is therefore associated with the radio system terminals (see Figure 1), or with any other site where one or more vf channels are to be separated from the main signal stream.

Baseband equipment is also associated with the radio terminals, and may appear at intermediate locations if a return to the baseband level is required. (A baseband is that range of frequencies within which lie all of the information signals to be used in modulating a carrier to produce the radio signal.) This equipment serves as an interface between the channelizing equipment and the radio transmitter/receiver. It accepts the multi-channel baseband signal and provides level coordination, impedance matching, amplitude and time-delay equalization and, where necessary, pre-emphasis and de-emphasis — an amplitude/frequency shaping process intended to improve signal-to-noise ratios in the

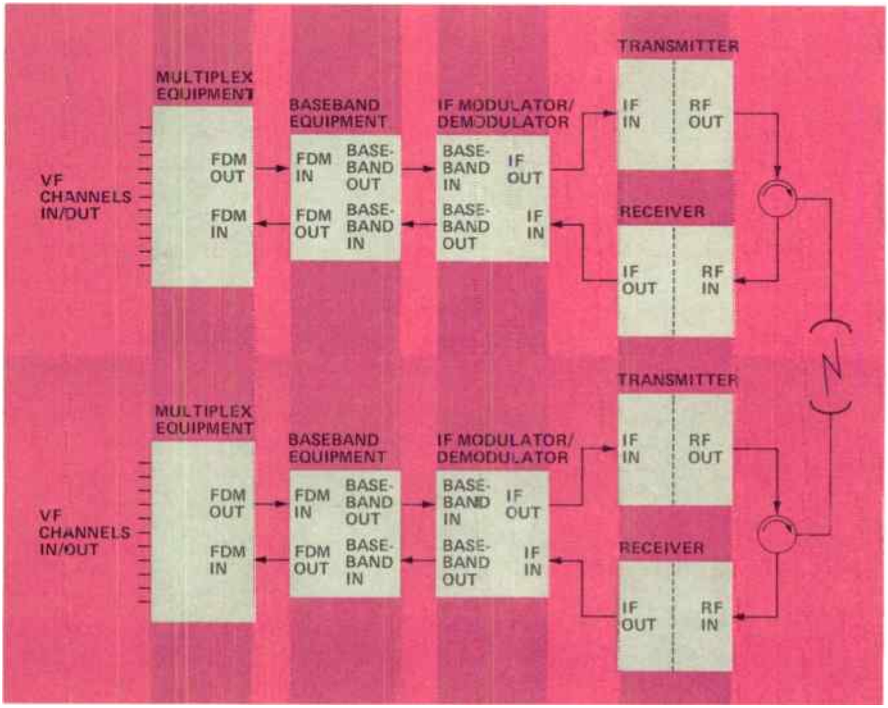


Figure 1. In a microwave radio system such as the simple heterodyne type shown, there are many points at which signal degradation can occur.

upper baseband. It also monitors the radio continuity pilot signal and noise contribution.

Because of the importance of its functions, the performance of the baseband equipment must be satisfactory at all times. Although there is a wide range of options and assembly configurations available throughout the telecommunications industry, there are some basic measurements that can be made to verify operation and allow adjustment to avert system degradation. Of major significance are the transmit, receive, and pilot levels. The pilot signal is of particular interest in hot-standby configurations because its interruption, or an excessive drop in its level, indicates disruption of system continuity and causes a transfer to the standby facility.

Baseband Equipment

The coordination of signal levels in conformity with channelizing and radio equipment interface requirements is performed by baseband pad, filter, and amplifier circuitry in the transmit and receive paths. In order to verify that this circuitry is functioning properly, the baseband equipment must be isolated from the multiplex and radio components, and the signal level must be measured in each direction. The measurement is most readily accomplished by connecting a signal generator to serve as the fdm input of the baseband equipment and, with the pilot disabled, using an ac voltmeter connected through a test transformer to determine signal level at the baseband output. The frequency and amplitude of the generator output, and the desired voltmeter reading, depend upon application, and are stated in the system's design specifications.

When the transmit-path signal level has been ascertained and, if necessary, adjusted, the procedure is repeated in the receive path.

The pilot level is measured in the transmit path only, and again requires that the baseband equipment be isolated. With the pilot-generating circuitry enabled, and with no signal at either the fdm or baseband input, the ac voltmeter is again connected to the baseband output. The desired output level – usually –3 dBm0 for message systems – is given in the design specifications for any particular system.

In remodulating, or baseband, radio systems, there is a direct interface of baseband and transmitter/receiver equipment; that is, the baseband signal directly modulates the radio frequency (rf) carrier, or a submultiple of it. A heterodyne system, however, includes an intermediate frequency (IF) modulator/demodulator (see Figure 2) interface. The purpose of the modulator is to generate an IF carrier – in most instances, 70 MHz – that can be frequency modulated by the transmit-path baseband equipment output. It also provides amplification and IF level coordination. The demodulator provides amplitude limiting, demodulation, level coordination and, when necessary, "mop-up" group delay equalization.

IF Modem

As with baseband equipment, measurements of IF modem performance characteristics are taken with the equipment isolated. Generation of the 70-MHz signal must be among the first measurements taken. The unmodu-

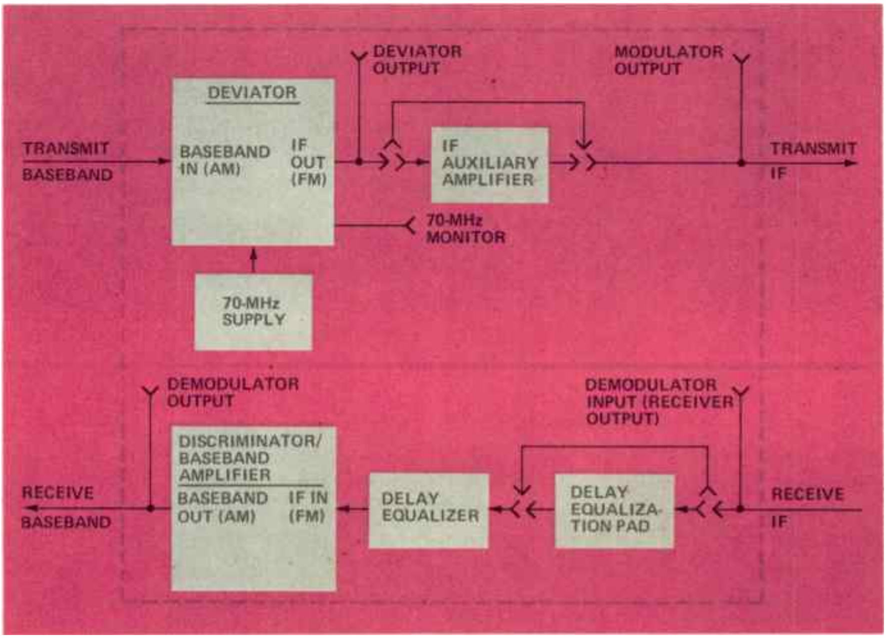


Figure 2. An IF modem interface is included in heterodyne systems. In remodulating systems, deviation and discrimination are performed within the transmitter/receiver equipment.

lated IF carrier frequency itself can be checked by connecting a frequency counter to the 70-MHz IF monitor jack or other test point provided by the manufacturer. The counter reading and the date of the test are generally recorded so that frequency drift can be detected, and corrected, by subsequent measurements. The level of this IF carrier can be determined by connecting an rf power meter to either the deviator or the modulator output test point. The desired reading depends upon system application and configuration, and upon interface considerations, but typical values are −5 or +1 dBm at the deviator (modulator) IF output and +5 dBm at the discriminator (demodulator) IF input.

When the characteristics of the unmodulated 70-MHz carrier have been ascertained, and adjusted if necessary, IF modem performance is tested in the presence of a modulating signal.

Deviation

In frequency modulated (fm) microwave radio systems, changes of baseband signal amplitude cause variations in the carrier frequency, with a higher-level input resulting in a greater frequency shift, or deviation, from a center frequency (see Figure 3). The difference at any given time between the modulated and unmodulated carrier frequencies is the "deviation"; the maximum frequency shift permitted is the "peak deviation." Deviation in a heterodyne system is a function of the IF modem, while it is a function of the transmitter (usually, the frequency modulated oscillator, or fmo) in a remodulating system. In either case, however, a "Bessel Zero" technique is used to determine and adjust the amount of deviation.

Generally, the amplitude of the sidebands created by carrier modulation decreases with distance from the

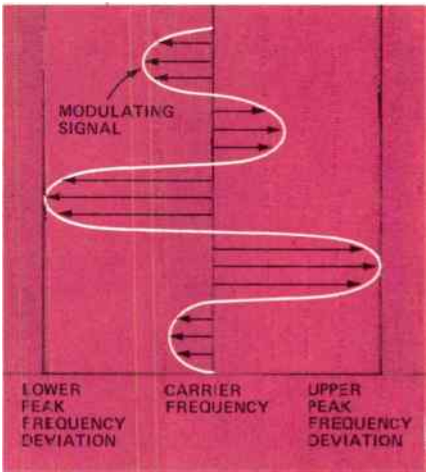


Figure 3. Changes of modulating signal amplitude produce deviation of carrier frequency.

carrier frequency. This decrease can be described by a mathematical series containing all orders of what are called "Bessel functions."

Modulation index (MI) is a measure of the degree of modulation, indicating the extent to which the baseband signal distributes the carrier power to its sidebands. It can be determined by:

$$MI = \frac{f_d}{f_m}$$

where f_d is the peak frequency deviation and f_m is the highest modulating frequency. Bessel Zero is defined as the point at which all of the carrier energy has been distributed among the sidebands; at that point, which is known to exist when MI = 2.405, the amplitude of the carrier is zero.

Since deviation varies in proportion to the modulating frequency level, and the required level-versus-frequency characteristics clearly define the point at which Bessel Zero will occur, a criterion can be established to which deviator sensitivity may be adjusted.

The sensitivity of the deviator, whether it is in an IF modem or an fmo, determines the degree of frequency shift for a given input amplitude and frequency. To set the desired system deviation requires the use of a modulating source and a detector to monitor the carrier frequency component. This equipment is often combined into one "deviation test set." If, for example, a heterodyne-type transmitter operating at 2 GHz is designed for a peak frequency deviation of 283 kHz (200 kHz rms) with a –32-dBm input, the 117-kHz modulating source (283 kHz ÷ 2.405 = 117 kHz) would supply an equivalent input to the deviator. To allow in-service measurement, the monitoring device would be connected to the 70-MHz monitor point: if deviation were correct, the carrier monitor (rf or IF spectrum analyzer, etc.) would indicate a zero level. To ensure that the MI = 2.405 zero point has indeed been reached (there are actually several higher modulation indices that will produce the same effect), the deviation adjustment is normally set to its lowest sensitivity (gain) at the start of the test and the sensitivity increased until the first carrier null appears, at which time the desired peak deviation for the given input will have been attained.

Receive drop level and baseband frequency response are checked after the other levels and the deviation have been properly adjusted.

Receive drop level can be tested using a back-to-back connection of the two modem sections: that is, the modulator IF output can be looped back to serve as the demodulator IF input. In this procedure, a test tone of proper level and frequency is introduced at the deviator baseband input. The level of the discriminator/baseband amplifier output can then be measured and compared to that given in the system's specifications. Alternatively, the output of the modulator can actually be applied to the transmitter; the baseband output of the demodulator at the interfacing receiver site is then measured.

Baseband frequency response is checked from the input of the transmit baseband equipment to the output of the receive baseband equipment at the interfacing receiver. This check is performed by disabling the pilot signal generator and connecting a test oscillator so that it generates an input signal corresponding, initially, to the reference frequency applicable to the baseband under test. An ac voltmeter is placed in the interfacing receiver's baseband output path and arranged to measure the output level. Starting at the appropriate reference frequency – given in the system specifications – a record is made of level variations observed on the meter as the test oscillator is slowly tuned across the baseband frequency spectrum. It is, of course, essential that the output level of the test oscillator at the transmitter be constant at all frequencies, or that the readings be adjusted for pre-determined errors, to make the results valid.

Transmitter

Although the transmitting equipment is checked and factory adjusted before shipment by the manufacturer, the output frequency of the transmitter is also measured and recorded before the equipment is placed in service, and periodically during the life of the system.

Quite often, the measurement can be made simply by eliminating any modulating input, disabling the automatic frequency control (afc) circuitry, and connecting a frequency counter to the rf monitoring jack or terminal (often on a calibrated directional coupler) provided by the manufacturer. The afc circuitry is then enabled and the frequency again measured. If the transmitter cannot be removed from service, its operating frequency can still be measured with a reasonable degree of accuracy by connecting a counter to the monitoring point during a system "quiet" period.

The output power of the transmitter must likewise be measured occasionally. It generally can be measured in very much the same manner as the operating frequency, with an rf power meter being used rather than a frequency counter, and a thermistor (or diode) mount connected to the test point or terminal.

Power output at the antenna flange is generally only measured during the troubleshooting process, but is an excellent way to identify excessive losses in the feeder line between transmitter and antenna. One commonly used procedure is to:

a.) Couple a power meter to a signal source (an rf signal generator or the system transmitter) through a calibrated attenuator (see Figure 4A), making certain not to exceed the power handling capability of the meter.

b.) Make a calibration chart (typically 1-dB steps to a maximum of 5-10 dB) of meter readings versus attenuator settings.

c.) Couple the signal source to the waveguide (or coaxial cable) run (see Figure 4B).

d.) Connect the calibrated attenuator and power meter to the antenna end of the waveguide or coax run and measure the output level, being certain to observe safety precautions, especially those related to possible eye damage due to looking into an energized waveguide.

e.) Compare the loss figures obtained at the antenna end to those acceptable according to the system design specifications.

Receiver AGC Calibration

In most equipment configurations, the receiver has an associated meter that indicates received signal strength derived from the automatic gain control (agc) circuit in the IF amplifier. These agc meter readings are relative indications of received carrier level. An accurate graphic record of agc meter reading versus rf input level must be made to establish when the antenna systems are optimally aligned. This graph is also helpful in determining the condition of the transmission path during subsequent maintenance routines.

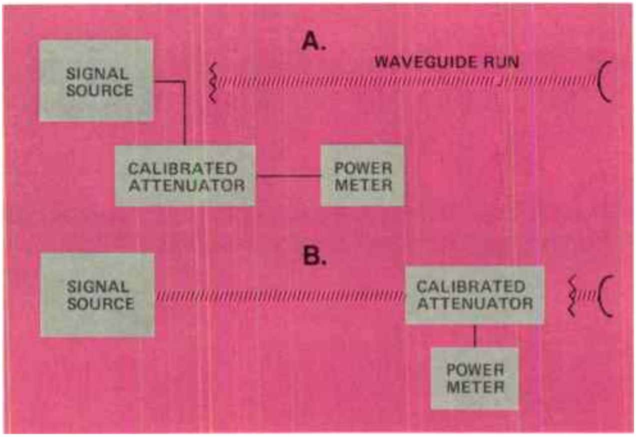


Figure 4. Measurement of output power of the antenna flange serves as a check for excessive loss in the waveguide run.

The procedure for developing an agc curve requires that an rf signal generator be connected to the receiver input — at either the directional coupler or another calibrated rf test input point — to simulate a received signal. With no rf input, the agc meter should indicate near zero. The frequency of the generator output is tuned to the center frequency of the receiver under test, and its level precisely adjusted to the nominal input signal level, with compensation being made for losses in the directional coupler, hybrids and circulators (unless the test point calibration makes allowance for these factors). For example, if the required receive signal level is –30 dBm and the loss through the coupler, etc., is 20.6 dB, the generator output level should be set for –9.4 dBm (–9.4 dBm + [–20.6 dB] = –30 dBm). This simulated rf receive signal is then attenuated (typically, in 5-dB steps to a point below the practical threshold or mute point) and the observed meter readings recorded. A curve of these readings is then plotted on a suitable form (see Figure 5).

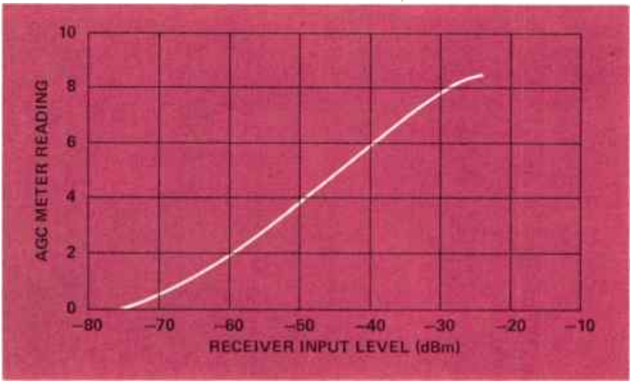
Most microwave radio receivers are equipped with circuitry that indicates an alarm condition when the received signal level drops to a pre-determined level. During the agc measurement procedure, therefore, the appropriate alarm indicator should be observed as the simulated receive signal approaches the minimum level. This constitutes a check of the alarm circuit.

In a remodulating, or baseband, type radio, an off-frequency alarm circuit is also normally provided. When the difference between the received signal and local oscillator frequencies exceeds a predetermined limit, this circuit causes an alarm indication. Operation of such an alarm can be checked during the agc procedure. With the signal generator set for the proper received signal level and frequency, a counter is connected to an appropriate IF monitoring point. With the afc function disabled, the local oscillator is tuned until the off-frequency alarm indication appears. Typically, the counter should read either 69 MHz or 71 MHz, ±200 kHz, at that time. The local oscillator is then re-tuned to produce the proper IF output (in most systems, the requirement is 70 MHz ±10 kHz).

Video Tests

Within a microwave radio system, the carrier and its deviations are transmitted and received with no regard for the type of information being dealt with. It is only at the baseband interface that multi-channel communications and video transmissions are dif-

Figure 5. Typical agc calibration curve.



ferentiated. Because of this, the tests that are unique to video applications need be performed over a heterodyne system only from the video transmit terminal to the video receive terminal. In systems using remodulating repeaters, however, the tests should be made over each modulating section.

Television signals are by nature more waveform-sensitive than most other kinds of transmissions. Because of this, phase characteristics that are relatively unimportant in speech transmission become extremely important in a video system. In general, therefore, video tests are concerned with such parameters as amplitude-versus-frequency and phase-versus-frequency linearity, transient response, differential gain and differential phase. The latter two parameters are specifically oriented to color television and place the most stringent requirements on the radio system.

As the term indicates, differential gain is variation in system gain; in a video system, this variation would be of greatest concern if it were to occur as the brightness, or "luminance," signal varied between the peak values for "black" and "white." Similarly, differential phase, which is variation in phase of a transmitted signal, is most troublesome in a video system when it changes the phase of the color subcarrier as the luminance signal voltage changes.

After all of the initial alignment procedures (operating frequency, power, deviation, etc.) have been accomplished, a simple overall system video response test can be performed by applying a "multiburst" signal to the baseband input of the transmitter under test. At the interfacing receiver, a wideband oscilloscope or waveform monitor is used to display the received signal appearing at the baseband output. A multiburst signal consists of a series of "bursts" of equal-amplitude sine waves, each at a different frequency. As produced by the video test signal generators commonly used, this signal includes a horizontal synchronizing pulse and a "white flag" – a burst whose amplitude represents the maximum whiteness of the television signal – to provide a white reference level. Changes in frequency response will appear as variations in the relative amplitude of the different frequency bursts.

Another quick test makes use of a "stairstep" signal, which resembles a staircase consisting of ten steps extending from black to white level (see Figure 6). In an undistorted signal, these steps are equally spaced; a visual check of the relative heights of the steps at the receiver baseband output

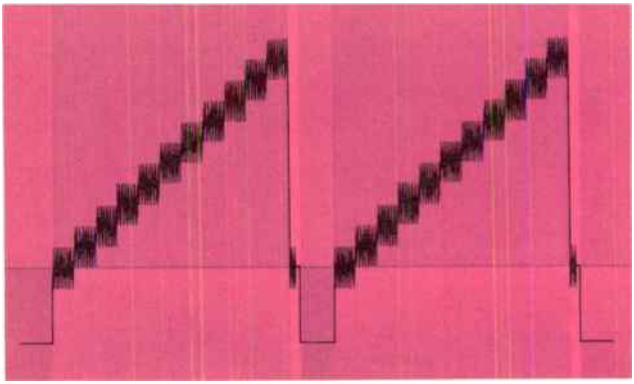


Figure 6. Typical stairstep test signal, with simulated color subcarrier impressed, which can be used to detect nonlinearities, and to measure differential phase and gain, in a video system.

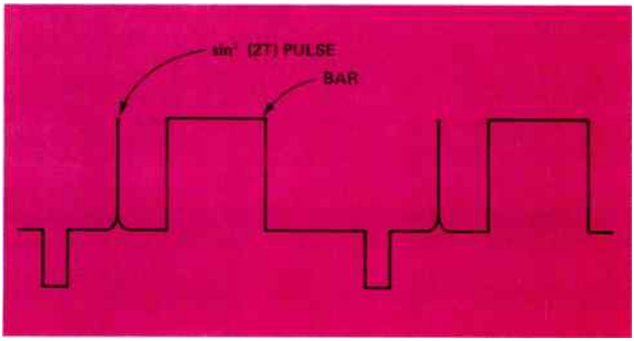


Figure 7. A pulse-and-bar test signal permits sensitive performance evaluation across the entire frequency band of a video system.

can thus reveal the presence of distortion in the system.

A sine wave of 3.58 MHz (the nominal color subcarrier frequency) can be impressed on the stairstep signal to allow measurement of differential phase and gain. Differential phase can be measured by using a phase detector to compare the phase of the 3.58-MHz, stairstep-carried sine wave with the phase of a reference signal of the same frequency. Passing the composite signal (stairstep plus simulated color subcarrier) through a highpass filter at the receiver will remove the step components and permit the sine wave to be displayed on the waveform monitor by itself. Differential gain will then appear as amplitude variations in the horizontal presentation.

Although these steady-state tests may give a general indication of system conditions, their waveforms are not necessarily typical of the signals that may have to be transmitted: they do not, therefore, allow full evaluation of system performance. Additionally,

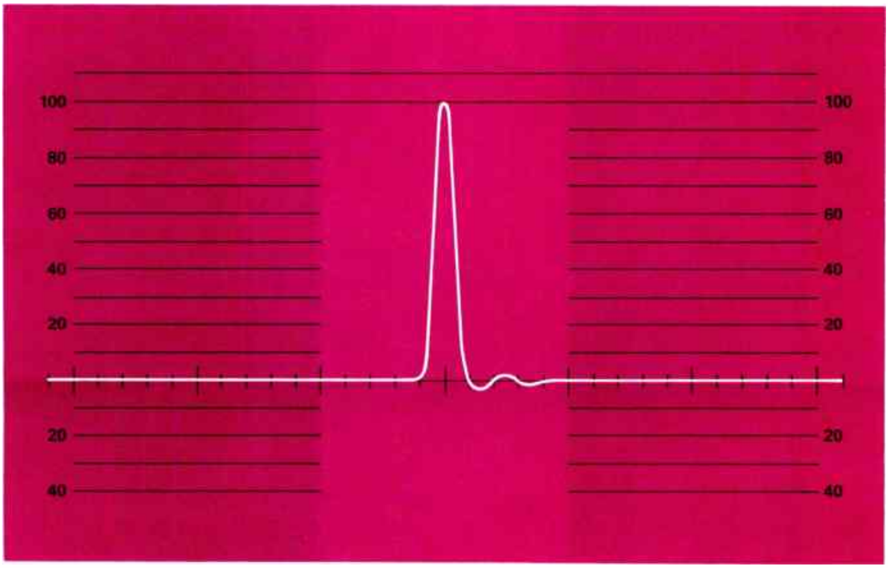


Figure 8. Ringing due to bandwidth constriction will appear as a series of peaks following the sin² (2T) pulse.

the low-frequency components of the steady-state test waveforms may mask or modify the response of the system to transients. To overcome these disadvantages, a transient response test is widely used; the waveform generated for this test is a combination of a "sine-squared," or "$\sin^2$ (2T)," pulse and a modified square wave which together constitute a "pulse and bar" test signal (see Figure 7).

For routine testing, a video test signal generator introduces a pulse and bar signal into the transmitter. At the interfacing receiver, a display using a special "IRE graticule" allows determination of distortion. Essentially, the test amounts to a visual inspection to see whether the received signal fits into the limits indicated on the graticule. When, for example, a ringing, or "overshoot," test is performed, the horizontal sweep of the waveform monitor is expanded to display only the $\sin^2$ (2T) pulse. If ringing – which is caused by bandwidth restriction – is present, the pulse will resemble that shown in Figure 8. The amplitude of the first negative peak is measured from the base line to the peak. The amount of overshoot varies depending upon the particular filters used in the system, but it should not exceed two IRE units on the first negative lobe.

There are, of course, tests of equipment operating parameters that have not been covered. It may, for example, be necessary to measure group and supergroup pilots in multi-channel systems, to perform waveguide sweeping procedures, or to insert a test tone into a single vf channel and observe the effects of the equipment on it at various stages of the transmission process. Such additional testing techniques – and the specifics of those that have just been described in general terms – can normally be found in the installation and maintenance instructions provided by the equipment manufacturer.

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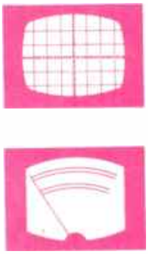

PART 2

Noise in a microwave radio system is the result of several contributing factors. To achieve optimum quality and reliability of service, the effect of each factor must be determined and minimized.

With such equipment-dependent characteristics as operating frequency, power and deviation measured and adjusted, system noise performance must be determined. The goal is to establish the lowest practical noise level in every baseband-derived communication channel.

Within any given vf channel, the total, or "loaded," noise level results from the interaction of many contributors. All of the individual contributors, however, can be placed in one of two general categories: those noise sources and types that are present at all times in the system, and those that exist only when a modulating signal is present. Thermal noise, for example, is the result of random currents in every electrical conductor and in the propagating medium; it exists whether or not a modulating signal is applied to the system and may thus be grouped with what can, for the sake of convenience, be called the "idle" noise contributors.

Idle noise, as the term indicates, is that residual noise measured in a baseband-derived vf channel with no modulation present (with the baseband input terminated, for example). In an interference-free environment, idle noise is composed of thermal and "intrinsic" elements. (The intrinsic, or basic, component is noise in the transmission path generated within the baseband, transmitter, and late receiver stages.) Under most conditions, however, the effects of interfering signals must also be considered.

Idle noise may be considered to be excessive if it does not conform to the recommendations given in the system design specifications. In a remodulating-type radio, idle noise could be excessive if it were within 3 dB of the loaded noise requirement; for example, to meet a loaded noise requirement of 20 dBrnc0, idle noise should not exceed 17 dBrnc0, and would preferably be much less. The remainder of the loaded noise would be due to contributors whose effects are apparent only when the system is being modulated. These contributors all fall within the general category of "intermodulation distortion" producers. Echo distortion, for example, is a type of intermodulation noise that is created when delayed echo signals – frequently the result of discontinuities or moding within the waveguide run or, less frequently, caused by path reflections – appear in the fm portion of the system.

In any radio system, tuned or active components have the capacity to degrade signal quality because they are all inherently nonlinear; that is, either their amplitude response or rate of phase shift is not uniform over a band of frequencies. When a single frequency passes through such a nonlinearity, it emerges as a fundamental frequency (f) and harmonics of that fundamental (2f, 3f, 4f . . . nf). Energy that would normally be contained in the fundamental is divided among the harmonics. When more than one frequency passes through the nonlinearity, harmonics of all the fundamentals are produced.

Besides this harmonic-type intermodulation distortion, a nonlinearity causes the various fundamentals in a complex signal to modulate one another and generate intermodulation (IM) products. These products represent not only the sum and difference of the original fundamentals, but also the sum and difference of every harmonic and of the IM products themselves.

Under busy-hour traffic conditions in a microwave radio communications system, the number of individual frequencies in a given vf channel is very large, and many vf channels are simultaneously transmitted over the same facilities. The modulating spectrum is thus so uniform over the baseband as to have characteristics similar to random, or "white," noise. A white noise signal is therefore a convenient tool for conducting tests.

White Noise Testing

White noise testing of microwave radio systems is based on the fact that a band of random noise having a uniform frequency distribution and a suitable power level very closely resembles the condition of a fully loaded telecommunications system. The testing procedure essentially involves introducing such a band of noise (a "noise load") into a system, filtering one or more narrow bands to produce "quiet" channels, or "slots," and then measuring the amount of noise introduced into these slots by the transmission medium.

This technique has several advantages over other noise-measuring methods. Among these are the direct measurement of total noise contributed by all components at once, and the ability to measure noise at any point in the spectrum. The latter is especially significant, in that it allows the accurate determination of noise distribution, from which the source of the impairment can be identified.

A white noise test set, consisting of a noise generator and receiver, is typically used to simplify the measurement procedure. The generator, capable of simulating full-traffic conditions in a large number of channels, is supplied with high- and low-pass filters to limit the noise bandwidth, and with band-stop filters to produce the slot or slots. Corresponding band-pass filters are provided in the receiver, which is also usually equipped with attenuation and metering facilities. A dc-millivolt output is often supplied for the connection of an external recorder to make a permanent record of the readings obtained on the meter, or for making the information available at another location.

The band-stop filters are most commonly selected to produce slots that correspond to several widely separated channels within the baseband spectrum of the system under test. For example, in a 300-channel system, the noise band, in order to cover the limits of the band occupied by the vf channels, would extend from 60 kHz to 1300 kHz; the slots might be chosen to correspond to vf channels having center frequencies of 70 kHz, 534 kHz, and 1248 kHz. Similarly, the noise introduced into an 1800-channel system would have to cover the band from 316 kHz to 8204 kHz, and the slots might center upon 534 kHz, 3886 kHz, 5340 kHz, and 7600 kHz.

To perform a white noise test, the noise generator is connected to the baseband equipment input of the transmitter (the equipment involved in the test must, of course, be taken out of service). The noise receiver is likewise connected to the baseband equipment output of the interfacing receiver. The output of the generator is limited by filters to the bandwidth required by the equipment under test and its level is set according to system considerations. In most instances, the amplitude of the white noise used to simulate a busy-hour spectrum with reference to a zero dBm test tone level (0TTL) is based on an assumed 25-percent activity factor (one-fourth of the spectrum in use) for system densities exceeding 239 vf channels, and a larger activity factor (approaching 50 percent) for a smaller number of channels. In any case this white noise approximates busy-hour traffic in a telecommunications system.

At the noise receiver, the noise level at one of the slot center frequencies is measured; this represents the received signal level in the selected channel. A filter is then inserted at the transmitter to create a slot in which no signal is being transmitted. The noise measured in the slot at the receiver (see Figure 1) is thus the product only of intermodulation from the surrounding channels, and of idle contributions (the ratio of the unfiltered measurement to the filtered measurement is the "noise power ratio," or "NPR," from which is developed the bucket curve whose use is described in the March/April 1976 *GTE Lenkurt Demodulator*). The idle contribution is determined by simply disabling the generator and measuring the noise remaining in the slot.

When the test has been performed at one of the chosen slot frequencies, it is repeated at each of the others across the spectrum.

Out-Of-Band Testing

While white noise testing across the entire baseband spectrum provides an accurate description of conditions within the system, the procedure requires that only the test signal be transmitted. Quite often, it is not possible to remove an entire system from service to test it; when this is the case, out-of-band techniques can be used.

Out-of-band testing involves the measurement of noise in narrow bands centered very closely – typically, within 10 percent – of the lower and upper frequency limits of the baseband under actual traffic conditions. The procedure simply requires that the level of noise present in the out-of-band "slots" be monitored while the system is operating under its peak busy-hour conditions.

The test is usually conducted in bands at both extremes of the transmitted spectrum because of the contributors that characteristically have the greatest influence. At the upper end of the band, for example, the effects of thermal and delay distortion contributors in the IF and rf portions of the system are greatest. Noise contributions attributable to equipment intrinsic noise, and to any poor linearity match of the modulators and demodulators, are most readily detectable in the lower band.

Idle Noise Considerations

High levels of idle noise may be produced by high thermal contributions from a low rf received signal level or improper deviation, high intrinsic noise contributions from noisy radio or baseband equipment components,

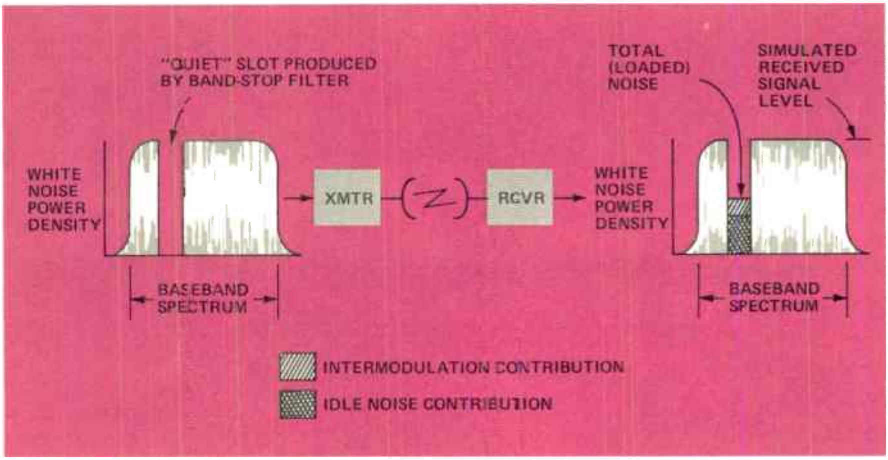

Figure 1. The loaded noise measured in a test slot is the product of both intermodulation and idle noise contributors. Depending upon the location of the slot in the spectrum and the characteristics of the contributors, the source of an impairment can be identified.

baseband-level interference from central office relays, and/or by interference at or near the rf, IF, or image frequencies of the receiver.

If the test procedure indicates a high idle noise condition, a flow chart (see Figure 2) can provide a logical progression of steps for isolating the cause or causes. Depending upon where in the spectrum the excess idle noise appears, one or more contributing mechanisms may be found.

For example, thermal noise generated in the front end of a receiver will increase in direct proportion to the received signal level in the higher slots, but will be negligible in the low slot. With an adequate receiver rf input signal level and negligible interference, low-slot idle noise may be isolated by substituting such components as modulation amplifiers, frequency modulated oscillators, IF amplifiers, discriminators, and power supplies.

Radio frequency interference (rfi) may result from interaction with systems external to that under test (intersystem rfi), from sources within the system itself (intrasystem rfi), and/or from within one particular facility (intrastation rfi). When the interfering signal's frequency lies near one of the in-band test slots, it will add to the idle noise contribution. If the interference frequency appears in the IF but is outside the baseband spectrum of the radio, it will interact with the transmitted baseband traffic and produce not idle noise but excessive intermodulation distortion. This distortion will appear as a high IM noise level, usually in the high, but sometimes in the low, slot.

Intersystem rfi can be detected by disabling the transmitter of the system under test and noting any idle noise swings that would indicate the presence of a foreign signal. It may also be suspected when other transmitters are operating nearby, particularly if they are operating at a submultiple of the system's receive frequency (a 3-GHz radar transmitter interfering with a 6-GHz receiver, for example), and can

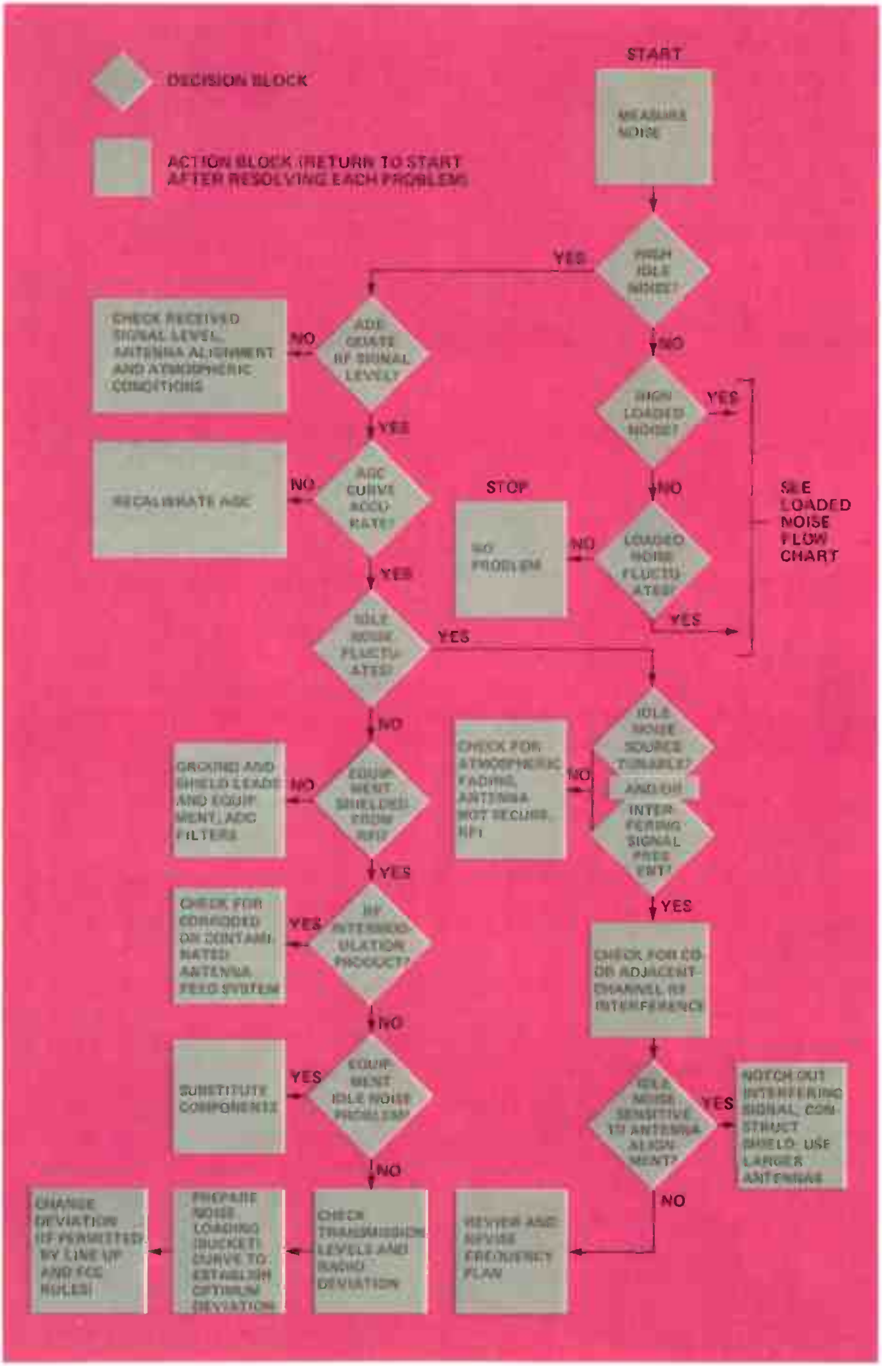

Figure 2. An idle noise flow chart can be of considerable value when attempting to isolate the source of a high idle noise measurement.

be readily identified through bucket curve analysis. Intersystem rfi can be reduced in many cases by careful antenna orientation (including polarization), and by shielding or using shrouded antennas.

Intrastation rfi sources can be identified by disabling suspected transmitters within the building or area. If the interfering signal is still present with the receiver waveguide terminated to eliminate external signals, interrack interference that can usually be corrected by grounding and shielding is indicated. If intrastation rfi is not found, yet the interference contribution to idle noise continues, such intrasystem conditions as antenna coupling may exist.

Intermodulation Noise Considerations

If idle noise is acceptable but the measured loaded noise level still exceeds the system's loaded noise requirement, excessive intermodulation distortion is the problem. Again, a flow chart (see Figure 3) is a useful tool in isolating contributors.

Excessive IM results from poor baseband linearity or from delay distortion (including waveguide echo distortion). Poor linearity affects the loaded noise level in all of the test slots, but is particularly noticeable in the lower slot. Delay distortion influences only the higher slots, unless an extremely long echo path – exceeding, perhaps, several thousand feet of delay – is involved.

Poor linearity, as reflected in high low-slot loaded noise, is generally related to the amplitude-versus-frequency characteristics of the deviator-discriminator pair. A nonlinear deviator paired with a mirror-image nonlinear discriminator may result in excellent linearity and good low-slot loaded noise performance. However, such dedicated pairing is frequently not possible, so most manufacturers linearize each component against a factory standard or a linearity test set.

Excessive low-slot loaded noise may also be caused by baseband amplifier input or output levels that are too high, or by unbalanced baseband amplifiers, so balance adjustments and maximum levels are normally specified by manufacturers for these active devices.

Distortion due to unequal transit delay time across the passband of the IF signal results in excessive loaded noise in the high test slot. If such group delay distortion is present, it can be corrected by an equalization technique. Delay equalization is best accomplished with a distortion measuring test set that displays the delay characteristic on an oscilloscope. These test sets normally have the capability of measuring from baseband to IF (for deviator adjustments), IF to IF (for heterodyne repeater adjustments), IF to baseband (for limiter/discriminator adjustments), and baseband to baseband (for remodulating equipment and section/system mop-up adjustments). When such a test set is not available, delay adjustments can be made to achieve the best noise in the higher baseband slots as indicated by the noise receiver.

Another IM contributor that produces excessive high-slot loaded noise is waveguide echoes. These are commonly the result of impedance and aperture discontinuities, waveguide moding, and interference between the desired transmission path and a secondary advanced or delayed path. Echo distortion causes delay ripples that, in modern, high-performance microwave links, are often the major noise contributors. Path IM – generated by secondary reflections from buildings or other terrain features –

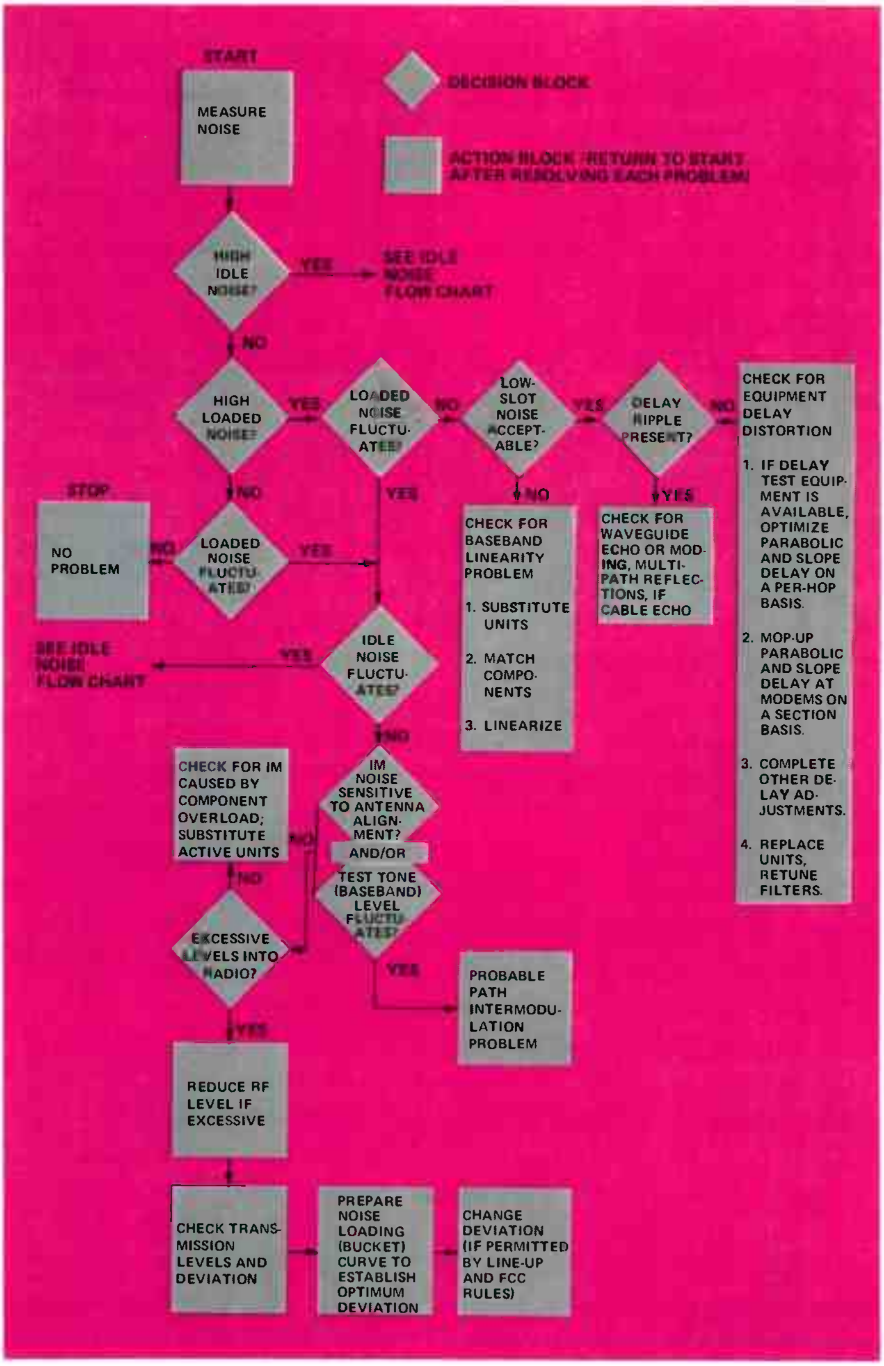

Figure 3. A loaded noise flow chart is a logical progression of steps taken to isolate the cause of a high loaded noise measurement.

may be suspected if the high-slot idle noise is stable but the loaded noise fluctuates rapidly and is sensitive to slight adjustments in antenna orientation.

In the testing of microwave radio systems, it is often advantageous to view the system as a "series circuit" from the transmitter baseband input to the receiver baseband output. Application of orderly thought processes through the asking of pertinent questions then can simplify the testing process. For example, at the input it would be worthwhile to ask whether the levels are correct and whether deviation is properly set. The next questions might concern the transmitter: Is it operating on the right frequency? Is its output power adequate?

Tracing of the "signal flow" through the "circuit" would proceed in this manner, with each item being carefully checked in turn, corrected as necessary, and noted to prevent duplication of effort, until the entire radio system had been tested and its ability to transmit information faithfully and reliably verified.

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