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Maintenance of Broadcast Equipment

PREVENTIVE VERSUS CASUAL MAINTENANCE

The broadcaster may wonder at first why a regular preventive maintenance schedule should be necessary when he has been getting along very well with casual maintenance. The answer lies partly in the far more complex equipment needed for today's broadcast system and partly in the highly competitive aspects of the market place.

In all fairness to those broadcasters who firmly believe casual maintenance is sufficient, it must be pointed out that some highly successful operations have no maintenance engineers as such. An examination of their methods will reveal, however, that transmitter and studio technicians spend a certain amount of their time checking equipment not in use while the station is on the network or in other ways fitting some maintenance into their daily working schedules. Furthermore, these technicians will be found to be highly experienced men who are familiar with the circuitry of the equipment and are excellent "troubleshooters." It will thus be seen that while no formal preventive maintenance schedule is in force in the station, a larger percentage of the working day is being spent in maintenance. It remains a problem requiring a decision to be made by each broadcaster as to whether he will hire maintenance men who can keep the equipment in good operating condition and be able to use less experienced men at the transmitter and studio or he will hire technicians who have the experience, knowledge, and "feel" for maintenance and who can get the station back on the air quickly in the event of equipment failure.

In this part, a suggested preventive maintenance schedule is shown and a few suggestions of a general nature are listed in the hope it may provide the broadcaster with a beginning to which he can add such procedures as are pertinent to his particular type of equipment. Each piece of equipment will have its own individual characteristics, and specific operating procedures for each equipment item are furnished by the manufacturer. It is suggested that a collection of the instruction books for the equipment in the new station be gathered together, and from this collection, specific details can be drawn to supplement the general material which follows.

The object of any maintenance program, whether it be preventive or casual, is to keep the equipment operating at optimum—to satisfy the regulations set forth by the FCC—and to keep operating costs down. Although the most careful and thoughtful maintenance program cannot always prevent occasional equipment failures, the symptoms of impending failure can often be observed during the day's operation, and a well-defined system of reporting should be developed. At the transmitter, the log is the logical place. If it is a chart-recorded log, so much the better. The studio should have a regular place to put notices of equipment troubles. After the maintenance man checks the item noted as being faulty, he makes such adjustments or repairs as are necessary and initials the notice with the notation "adjusted," "tube changed," or whatever work was done. The sheets or logs are kept on file after completion of the work, and over a period of time they provide a good source of study for the idiosyncrasies of each equipment item. From a collection of this nature, conclusions can be drawn as to what type of trouble to expect from each piece of equipment, and in many cases equipment failures can be foreseen and corrected in advance of failure.

In the following pages, a general outline of preventive maintenance is given. Complete details applicable to all kinds and makes of equipment naturally cannot be given, nor is it the purpose of this part to replace the specific instructions given by the manufacturer for the care and maintenance of each equipment item. The purpose of the discussion is rather to supplement these specific instructions by a few notes and suggestions made by station operators as a means of gathering together in one place the beginning of a maintenance manual. The value of such a manual to each station depends entirely on supplementation by recommendations drawn from (1) the manufacturers' instruction manuals and (2) the experience of the chief engineer and his staff as the station develops.

TELEVISION STUDIO PREVENTIVE MAINTENANCE SCHEDULE

Daily

Dust.

Check for signs of overheating on all equipment.

Check pickup equipment for abnormal conditions such as position of control knobs and poor picture quality which may not have been reported.

Check cameras for geometric distortion, alignment, and resolution.

The scanning system of the film photographic sound track must be checked. The alignment of the exciter lamp filament with the optical assembly should be checked. Optical assemblies and any apertures in the light path should be cleaned. Photocells should be examined for oil on the glass.

Projection lenses should be wiped with lens tissue. Coated lenses should be cleaned very carefully in accordance with the manufacturer's instructions.

Check the need for unusual control-knob settings.

Clean film projectors in accordance with manufacturers' instructions, checking especially for accumulations of dust, lint, and emulsion on gate, pressure shoe rollers, teeth, picture aperture, etc.

Visually check the microphone and cables for serious abrasions from pinching, kinks, etc.

Weekly

Thorough internal and external cleaning of cameras, camera controls, monitors, and power supplies. Check insulation on wires.

Check and record equipment voltages.

Run test checks on cameras and projectors using test charts, slides, or films such as those recommended by EIA or SMPTE.

Check the amplitude and pulse widths of the synchronizing generator.

Oil film projectors.

Check and clean fader controls on both audio and video equipment.

Check microphones.

Check the air filter on the power supply.

Lubricate the wheels and moving parts of camera dollies and booms, microphone booms, pulleys for studio lights, and mechanical parts of studio cameras (pan and tilt and optical focusing mechanisms, etc.).

Monthly

Record and compare voltages on all equipment.

Check adjustment of all control knobs, and readjust where necessary.

Check tubes on all equipment.

Check and clean relays and switch contacts in all equipment. Some relays in more recent systems are protected sufficiently from dust and dirt and may not need such frequent inspection.

Low-level audio amplifiers with "plug-in" chassis should be moved in and out a few times to renew the contact between fins and sockets.

FIELD PICKUP (REMOTE) PREVENTIVE MAINTENANCE SCHEDULE (This is also applicable to STL)

Note: These daily, weekly, and monthly schedules will naturally be revised in accordance with usage given equipment.

Daily

Check the switching system for abnormal conditions.

Check cameras for geometric distortion, alignment, and resolution.

Check pickup equipment for abnormal conditions.

Check all equipment for overheating.

Dust.

Weekly

Clean cameras and power supplies internally and externally.

Check and readjust controls.

Inspect and tighten cable connectors and clamps.

Check amplitude and pulse widths of synchronizing generator.

Lubricate moving parts of cameras.

Check and clean fader controls on both audio and video equipment.

Visually check weatherproofing of cables, connectors, and other parts of equipment subjected to weather.

Check batteries if applicable.

Monthly

Check tubes on all equipment (see Studio Preventive-maintenance Schedule).

Record and compare cable voltages.

Check air filters.

Check and clean relays and switch contacts in all equipment.

Transistors

No specific maintenance procedures are included in this Part for translators or solid state devices.

TRANSMITTER PREVENTIVE MAINTENANCE SCHEDULE

Daily

Check the filament line voltages every hour, and adjust if required. FCC Rules governing transmitter logs require that the operating constants of the last radio stage of the aural transmitter (total plate current and plate voltage), transmission-line meter readings for both transmitters, be observed and recorded at three-hour intervals.

Check visual and aural monitoring circuits, observing both voltage and current meters. Changing current or voltage indicates either deteriorating tubes or equipment. If the operator observes any rapid changes, a sufficient note should be left with the log as instructions for the maintenance crew.

Dust and generally inspect for overheating or other signs of abnormal operation.

Weekly

Check all tubes which are not metered in the transmitter.

Clean the internal parts of the transmitter (insulators, etc.). Check of noise, distortion, and frequency characteristics of aural transmitter generally. Check the visual frequency and broadband characteristics of the visual transmitter generally.

(On the last two mentioned checks, spot checks will ordinarily suffice on a weekly basis. However, in this case, a more thorough check should be made monthly.)

Inspect blowers and flow meters. Clean and/or lubricate if required.

Test door interlocks and disconnect switches, being certain that they result in interruption of high voltage when access doors and windows are opened.

Check and operate all relay contacts. Observe closely for hearing.

Check transmission lines for tightness by observing gas or air pressure.

Add distilled water to cooler unit if required.

Correct all meter needles to normal nonenergized readings.

Monthly

Inspect and lubricate small blower motors.

Test spare tubes.

Clean socket contacts if necessary.

Service relay contacts if necessary.

Check air filters, and clean or replace as necessary.

Visually check the condition of the water in the cooling system.

Quarterly

Inspect every unit in transmitter in detail, using tests recommended by the manufacturer.

Service all power contactors if necessary after inspection.

Make a visual inspection of the physical condition of the antenna tower and transmission line.

Inspect and test tower-lighting equipment according to Part 17 of FCC Rules.

Semiannually

Tighten all connections, both electrical and mechanical, in the transmitter and associated equipment.

Lubricate exhaust fans.

Lubricate high-pressure blowers, and check the operation of the air interlocks.

Lubricate the water-cooling system.

Check the outdoor protection to the water-cooler intake before cold weather and for free circulation before summer.

SAFETY

Every possible means of affording maximum protection to personnel working in the station should be considered. Equipment has been designed to operate safely as long as reasonable care and judgment are exercised, but it cannot be too strongly impressed on every person coming into contact with the equipment that the safety rules for handling each item must be observed, since the high voltage of certain components is sufficient to endanger life. Some general safety precautions are given below, and more will probably suggest themselves to the station operator and can be added.

1. Inspect safety interlocks regularly for proper functioning. Check leads and connections to grounding hooks.
2. Check ground connections for tightness.
3. Check insulation on all leads regularly. Never use leads with broken insulation.
4. All high-voltage capacitors should be discharged before they are touched. Although "bleeder" resistors do discharge capacitors after a reasonable time, in consideration of the voltages used, it will still be safer to discharge the capacitor with a shorting bar. Due precaution must be observed in the removal of the shorting bar.
5. Rubber gloves should be worn when working on high-voltage equipment, and a rubber sheet should be placed over the sill of the transmitter compartment or over any place where it is possible to come into contact with live equipment.
6. Before repairs are made on high-voltage equipment, instruction books and schematics should be closely studied. It may also be pointed out here that *high voltage somtimes appears at unexpected points in defective equipment.*

7. Ground leads of test equipment should not be connected to a high-voltage point, since the ground lead of most instruments is connected internally to the case.

8. When high voltages are measured, consideration should be given to both ac and dc voltages present, and peak voltages should be taken into account when selecting voltmeters and multipliers.

9. Rubber gloves and blankets will not afford protection against high radio-frequency voltages. When work is done on circuits carrying high RF voltages, the circuit should be inoperative before work is begun.

10. Extreme care must be used when touching tubes that have been in operation for a considerable length of time, since serious burns can result.

11. Pressure developed on the envelope of large vacuum tubes is extremely high, and when the tube envelope is broken, it must be remembered that the tube will implode—not explode. This means that there is a possibility of the tube base being projected through another portion of the tube. For this reason, tubes should be kept in cartons until time for their actual use. Safety goggles and gloves should be worn when handling large vacuum tubes. Spectators should be kept at a safe distance whenever a tube is outside its carton.

A means of disposition of these tubes must be found, bearing the above hazards in mind, to prevent the scattering of shattered glass and the possibility of the tube elements and base flying free. One suggestion is that the tube should be placed in a shipping container, the container sealed, and a crowbar or similar instrument driven through its top. Another suggestion is that the tube should be placed in a shipping container, leaving the neck or gun end of the tube exposed. A tarpaulin or burlap bag is thrown over the neck to deflect any glass, and the neck is struck sharply with a hammer.

12. It is not generally known that carbon tetrachloride is a strong toxic chemical and that continued breathing of the fumes is cumulative and can become injurious to health. Its use as an open cleaning agent is not recommended. The Navy has discontinued its use for projector cleaning and recommends that alcohol be used wherever possible.

It must be remembered, however, that alcohol and naphtha are both inflammable, and proper precautions must be taken in using either.

GENERAL

In the following pages, some amplification of the preventive-maintenance schedules will be found. In some cases, it may seem that the emphasis has been shifted from "preventive" to "casual" maintenance or from maintenance to operation principles. These are the areas where experience of presently operating stations has indicated a need for calling special attention of the technical staff of the new station.

Certain principles of maintenance are common to all types of equipment. For example, throughout this article, frequent mention is made of the removal of dust from equipment. This is extremely important because, among other things, excessive dust may lead to current leakage or arc-over between high-voltage points. Obviously, dust will do more damage to open equipment than to completely enclosed equipment, but daily efforts must be made to keep the collection of dust at a minimum on all equipment. The problem of dusting requires tools ranging from soft, lint-free cloths and absorbent pads to vacuum cleaners. A small hand-type vacuum which can be reversed and used as a blower may be a wise investment for the station. Various sizes of paint brushes will be helpful in removal of dust and lint from small equipment items. When cloths and brushes are used, they should be absolutely dry or moistened with a volatile liquid such as carbon tet, alcohol, naphtha, etc.—never with oil.

All equipment tests should be made as soon as possible after the close of the day's programming or after the last use of the equipment item during the day. After tests or checks are completed, the equipment should be placed in operating condition to be sure that it is functioning properly. Before any tests are begun, instruction books and schematics should be closely studied and safety precautions observed. Inspection can be made by feel (for overheating), by smell (this often locates an overheated part such as a transformer or reactor), and visual inspection for loose, broken, warping, or cracked connections and broken parts, insulations, or wires.

Before dismantling any part of the equipment, be certain the correct input signals and voltages are being applied. (In other words, there is no use dismantling the engine of a car if it's just out of gas.) The correct input signals and voltages are supplied by the manufacturer as part of the operating instructions.

Be logical—check the obvious first. Also, as mentioned above, instruction books, schematic drawings, and other technical data on the equipment should be readily available to all technical personnel.

TESTS AND TEST EQUIPMENT

Many stations initially going on the air have underestimated the need for appropriate test equipment only to find themselves later on faced with the need for purchasing more such equipment. In addition to the more common test equipment, additional test devices may be required depending upon the complexity of the installation.

Tubes

A record of test readings and hours in use on all critical tubes is considered desirable. In addition to revealing tubes which are likely to fail in the near future, such a record may also reveal types of tubes which are not giving satisfactory service and which should be studied closely to determine the cause of failures. Either a card file or a loose-leaf notebook will be suitable for tube records.

Spare tubes, particularly of the transmitting type, should be operated regularly to prevent them from becoming "gassy."

When transmitter tubes are first received at the station, they should be tested at a time outside the regular hours of operation or into a dummy antenna if this is available. The "tube biography" is then begun with the date of test and condition in which the tube was received being the first entries. Transmitter tubes are guaranteed for a minimum number of hours, and a prorated rebate is made by the manufacturer if failure occurs before the completion of the guarantee. Therefore, a record of the number of hours in operation and other pertinent data is essential for each tube until it is eliminated from service, since hundreds of dollars are involved.

Water-cooled Tubes

The proper care and maintenance of water-cooled tubes is of primary importance in ensuring good service. These suggestions are made as a general outline. They should be checked against the instructions given for different types of water-cooled tubes by the manufacturer, since such instructions will vary.

1. Installation of the water-cooling system and of each new tube placed in service should be in strict accordance with the manufacturer's instructions. Improper operation for only a few minutes can ruin a tube.
2. Always use distilled or water of equal purity in the system. Tap water or even the spring water used for office water coolers often contains impurities which become electrostatically precipitated and form scale, which interferes with the proper operation of the system.
3. Remove the filter strainer regularly, and clean out any sludge that has formed. This should be done quite frequently during the run-in period and periodically thereafter.
4. After the system is cleaned, water should be circulated for a short time and then the entire system refilled with fresh distilled or equally pure water. Never allow chlorinated water to enter the system, as it greatly increases the corrosion rate of the pipes and ducts in the tubes.
5. Regular oiling and greasing of the system motor should be a part of the maintenance routine.
6. Avoid operating the water-cooling system at too high a pressure, since this will cause excessive water turbulence in the tube passages with the possibility of an increase in microphonics.
7. It is highly important to protect the outside intake of the water-cooling system before cold weather begins. (In one station, the intake system was installed in the basement of the transmitter house with no further protection. The first night the temperature dropped below freezing, the intake system froze, causing a great deal of damage and expense before the situation could be corrected.)

Air-cooled Tubes

In general, the maintenance of air-cooling systems is relatively simple. Air filters should be regularly inspected and cleaned or replaced when necessary. Small strips of cloth tied to the blower will give an instant visual check on whether or not the system is working. A suggestion has been made that when the system is first placed in operation, the temperature of the intake and outgo air should be noted and the differential established as an operating standard for the system. (Each system will be found to have its own differential.) The same temperature measurements can be made monthly, and as soon as a wide departure from the standard appears, a check on the system can be made to determine the cause. In making such a check, try the filters first. The cause will usually be found in a clogged filter. Periodically, jackets should be removed from the tubes and fins cleaned with a soft, lint-free cloth. Fins, of course, should be perfectly clean on initial installation. Fan and motor bearings must not be overlooked. Lubrication will depend on whether the bearings are sealed or open. Sealed bearings require attention only every few years.

High-power Radio Tubes

Manufacturing techniques over the past years have greatly increased the reliability and life of high-power transmitting tubes. Experience over the years has indicated that one of the sources of tube failure is the mechanical stress resulting from repeated heating and cooling whenever the tubes are shut down. In certain installations, it is the accepted practice never to turn off the filaments of the tubes completely. Tubes are operated either continuously at rated filament voltage or at reduced voltage during the periods when no plate voltage is applied. During such periods care must be taken that adequate cooling of the seals is accomplished according to the manufacturer's specifications.

Capacitors

Dust must be removed regularly from high-voltage capacitors, since its accumulation tends to cause arc-overs and increases chances of equipment failure. If the method of cleaning with lint-free cloths is used instead of a bellows, extreme caution must be exercised to see that the capacitor is inoperative and *discharged* before handling. Leads and terminal connections must be regularly checked for loose or broken connections, and the insulators checked for cracks.

An excessive rise in the temperature of a high-voltage capacitor can be detected by placing the palm of the hand against it after a long period of operation. Be certain that the capacitor is inoperative and *discharged* and that the case is grounded before touching these capacitors. High-resistance paths to ground have been known to develop, and a normally "grounded" case conductor can become very "hot" electrically. This may be an indication of impending failure from dielectric leakage or improper ventilation. Prompt replacement will avoid loss of air time from overheated capacitors.

Low-voltage capacitors do not require so much care as those of the high-voltage type but should be kept free of dust, oil deposits, and other foreign matter. Since the leads used here are not so rugged as those in the high-voltage type, greater care is necessary in inspection for loose or poorly soldered connections.

Different organizations have found widely differing lengths of service for electrolytic units. Twelve to thirty months seems to be the minimum and maximum periods of service. Dried-out capacitors are one cause of hum bars in the television image. Excessive temperature rises often result in nonlinear scanning, since the capacitance is known to vary with temperature changes.

Resistors

Check load resistors and terminating resistors at least once each year, and replace if there is a critical deviation. Dust should not be permitted to collect on any resistor, especially in high-voltage circuits. Snap-in resistors should have firm, clean contacts to prevent heating at the terminals. If a resistor is removed for cleaning, be certain to follow through, making sure that it is properly replaced; otherwise damage may result to the equipment when it is energized.

Patch Panels and Cables

In both video and audio systems, jacks and plugs should, of course, be maintained in perfectly clean condition. If a faulty cable develops, it should be removed from service and sent to the repair shop immediately. Plugs in audio equipment should be polished regularly. Visual inspection of the connections is very important.

AM AND FM

Preventive maintenance schedule for AM nondirectional and FM stations.

Recommended Maintenance Equipment

The following is a list of items which should be available for handling the regular maintenance procedures.

1. An instruction manual for every piece of technical equipment in the station.
2. A log book set up to indicate the title of each instruction book, its location, and the number of copies available.
3. A file drawer at the transmitter and at the studio where all technical information pertaining to that portion of the plant may be kept.
4. A separate log book for the transmitter and studio, set up with the following headings: Inspection Date; Equipment; Maintenance Performed; Special Remarks.
5. A copy of the NAB Engineering Handbook.
6. A copy of the FCC Rules.
7. The following tools and test equipment:
   a. Small hand tools, consisting of screw drivers, pliers, soldering iron, piece of fine crocus cloth, socket wrenches, pipe cleaners, and contact solvent, etc.
   b. A multimeter having a minimum sensitivity of 20,000 ohms per volt.
   c. A vacuum tube voltmeter.
   d. A mutual conductance tube checker.
   e. A 5 in. cathode ray oscilloscope.
   f. A complete set of audio noise and distortion equipment.
8. Spare parts for each piece of station equipment in accordance with manufacturer's recommendations.
9. An inventory of all station equipment broken down into two categories: "Inside Studio and Transmitter Plant" and "Outside Transmitter Plant."
10. A transmitter tube log, set up to show hours in operation.

Weekly

Check all metered circuits for normal indications in accordance with manufacturer's instruction book.

Inspect all cables and wires and test for loose connections.

Check all pots for noise by rotating with circuit on.

Check all switches for proper operation.

Check all pilot bulbs for proper operation.

Check all turntables in all speeds for correct mechanical and electrical operation.

Check all tape recorders in all speeds for correct mechanical/electrical operation and head alignment.

Check audio console with pots wide open for hum.

Check remote control equipment in accordance with procedure set forth.

Check any miscellaneous equipment in accordance with above.

Check logs for last 7 days for completeness and unusual readings.

Calibrate all remote meters.

Monthly Procedure

Inside Transmitter and Studio Plant

Complete regular weekly preventive maintenance procedure.

Inspect all equipment and parts for charring, heating discoloration, or loose connections.

Clean all equipment during above inspection and remove dust, dirt and foreign particles that may have accumulated.

Inspect all the tube sockets for cracks and dirt. Remove any dirt with contact solvent or crocus cloth.

Test all tubes.

Check voltages with voltmeter against voltage chart.

Check tube log against hours run for transmitter final and modulator tubes.

Check transmitter into dummy load and determine efficiency.

Inspect all switches for normal operation.

Check dehydrator for proper operation.

Outside Transmitter Plant

Inspect antenna coupler for any obvious parts which show charring, heating, discoloration, or loose connections.

Clean entire unit during above inspection to remove all dust, dirt, and foreign particles that may have accumulated.

Inspect remote diode tube socket for cracks and dirt. Remove any dirt with contact solvent or crocus cloth.

Clean antenna meter switch with solvent or crocus cloth.

Check coaxial cable visually for any wear, loose supports, etc.

Visually inspect ground system.

Check tower lights, light control, and flasher.

Check tower visually for any loose guys, broken insulators, etc.

Check and oil lock on tower fence gate.

Quarterly Procedure

Inside Transmitter and Studio Plant

Complete regular monthly preventive maintenance procedure.

Lubricate all motors in transmitter and studio plant for which lubrication is provided.

Check line meter at transmitter and antenna coupling unit for normal readings.

Clean all air filters and if necessary replace.

Make a complete set of noise and distortion measurements on transmitter-studio plant in accordance with FCC Rules. Plot and tabulate data for engineering file.

Outside Transmitter Plant

Complete regular monthly preventive maintenance procedure.

Check tower guys for proper tension by vibration method.

Use field glasses and inspect guy insulators for any breaks or chips.

Check paint on tower for peeling.

Check transmission line support for mechanical rigidity.

Check fence and gate for rigidity.

Check transmitter building on inside and out for any needed repairs.

Check tower lighting system in accordance with Section 17.38 of the rules.

AM DIRECTIONAL ANTENNA PREVENTIVE MAINTENANCE SCHEDULE

Monday

Check all condensers and other equipment in antenna phasing unit immediately after sign-off for overheating.

Clean and check all transmission line end seals.

Clean interior of all sections of antenna phasing units.

Clean contacts and check alignment of antenna transfer relay.

Check and tighten all connections in antenna phasing unit.

Check gas filled condensed pressures.

Tuesday

With array set for directional operation, check drive-point impedance with radio-frequency bridge at operating frequency (first and third Tuesdays in month).

With array set for nondirectional operation, check drive point impedance with radio frequency bridge at operating frequency (first and third Tuesdays in month).

Set up array for normal full-power directional operation. Compare readings of all antenna and remote antenna meters. (Calibrate if necessary.)

Make complete set of field-strength readings at indicated monitor points (second and fourth Tuesdays in month).

Check and record all transmission line gas pressures.

Wednesday-Saturday Antenna Coupling Units

Check all condensers and equipment in coupling house for overheating immediately after sign-off.

Check spacing and clean antenna and transmission-line horn gaps.

Check and clean all antenna lead-in insulators.

Check and clean all transmission-line end-seals.

Clean contacts and check alignment of antenna relay.

Clean contacts and check alignment of antenna ammeter switch.

Check and tighten all connections of inductance coils and condensers.

Clean all meters.

In transmission building, read and record all transmission-line gas pressures.

First Aid and Resuscitation Policy

It should be required that each and every man in technical operations be thoroughly familiar with first aid procedures in the event of an emergency so that his life or the life of one of his coworkers can be saved. *He should be ready to act immediately in any emergency.*

Heads of the technical divisions should *be held responsible* for the carrying out of the program which includes the proper setting up of training classes at regular intervals (preferably every three months), the insistence that each man under his direction duly attends and qualifies, and the maintenance of safety bulletin boards and distribution of pertinent safety information.

The training should include a thorough instruction in resuscitation by a competent instructor, also training in *first aid* with particular emphasis on the type of injuries likely in our operations such as control of bleeding and treatment of burns and general injuries.

General Foreword

Experience, particularly in use of electrical equipment, has shown that all engineers, at times, expose themselves to danger: new engineers because of inexperience, older ones because of overconfidence and habits of work which they have formed. In an endeavor to reduce such exposures, these suggestions have been included.

Although these suggestions cover most of the common accidents, it would be practically impossible to make them cover all, especially those of changing conditions and methods. The purpose is to create the tendency always to *think and act in terms of safety.* In case of electrical shock, it is always important when attempting to free the victim to

1. *Protect yourself* with dry insulating material.
2. *Break the circuit* by opening the power switch or by pulling the victim free of the live conductor. *Be careful and move fast—seconds count. Don't touch the victim with your bare hands until the circuit is broken.*

Procedure to Follow for Prone Pressure Method of Resuscitation

As soon as possible, feel with your fingers in the patient's mouth and throat and remove any foreign body (tobacco, false teeth, etc.). If the mouth is shut tight, pay no more attention to it until later. Do not stop to loosen patient's clothing, but immediately begin actual resuscitation. Every moment of delay is serious. Proceed as follows:

1. Lay the patient on his belly, one arm extending directly overhead, the other arm bent at the elbow and with the face turned outward and resting on hand or forearm so that the nose and mouth are free for breathing.
2. Kneel, straddling the patient's thighs. Place the palms of the hands on the small of the back with fingers resting on the ribs, the little finger just touching the lowest rib, with the thumb and fingers in a natural position, and the tips of the fingers just out of sight (see Fig. 1a).

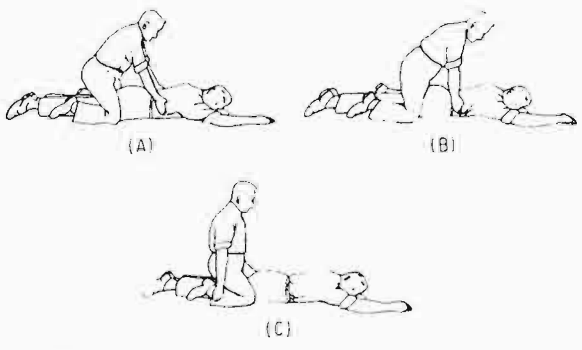

Fig. 1. Prone pressure method of resuscitation.

MOUTH-TO-MOUTH AND MOUTH-TO-NOSE RESPIRATION

1. Place the patient on his back. Wipe any foreign matter out of his mouth with your fingers. Lift his neck. Tilt his head back so that his chin points straight upward.

2. You may also position the patient by grasping his lower jaw, as shown here, and lifting upward. But be careful not to press your fingers into soft throat tissue.

3. If his mouth is open, insert your thumb between his teeth to raise his jaw. These steps should open a passage for air, by freeing the tongue from the throat.

4. Pinch his nostrils shut. Open your mouth as wide as possible, place it tightly over his mouth, and blow into him. Remove mouth; wait for rush of exhaled air.

5. Or, especially if his teeth are clenched, you may place your mouth over his nose and breathe into it. For a small child, place your mouth over his mouth *and* his nostrils.

6. If foreign matter blocks patient's throat, roll him onto side and slap him beween the shoulders. Quickly resume blowing—12 times a minute for an adult, 20 for a child.

3. With arms held straight, swing forward slowly so that the weight of your body is gradually brought to bear upon the patient. The shoulder should be directly over the heel of the hand at the end of the forward swing. *Do not bend your elbows!* This operation should take about 2 seconds (see Fig. 1b).

4. Now immediately swing backward so as to remove the pressure completely (see Fig. 1c).

5. After 2 seconds swing forward again. Thus repeat deliberately 12 to 15 times a minute the double movement of compression and release, a complete respiration in 4 or 5 seconds.

6. Continue artificial respiration without interruption until natural breathing is restored, if necessary 4 hours or longer, or until a physician declares that the patient is dead.

7. As soon as artificial respiration has been started and while it is being continued, an assistant should loosen any tight clothing about the patient's neck, chest, or waist. *Keep the patient warm. Send for a doctor.* Do not give any liquids whatever by mouth until the patient is fully conscious.

8. To avoid strain on the heart, when the patient revives, he should be kept lying down and should not be allowed to stand or sit up. If the doctor has not arrived by the time the patient has revived, he should be given some stimulant, such as one teaspoonful of aromatic spirits of ammonia in a small glass of water or a hot drink of tea or coffee. Keep him warm!

9. Resuscitation should be carried on at the nearest possible point to where the patient received his injuries. He should not be moved from this point until he is breathing normally of his own volition and then moved only in a lying position.

10. A brief return of natural respiration is not a certain indication for stopping the resuscitation. Not infrequently the patient, after a temporary recovery of respiration, stops breathing again. Watch, and if breathing stops, resume artificial respiration.

11. In carrying out resuscitation it may be necessary to change the operator. This change must be made without losing the rhythm of respiration. By this procedure no confusion results at the time of change of operator and a regular rhythm is kept up.

It is important that resuscitation effort continue when a patient does not revive. *Sometimes a period of 4 hours may be required.*

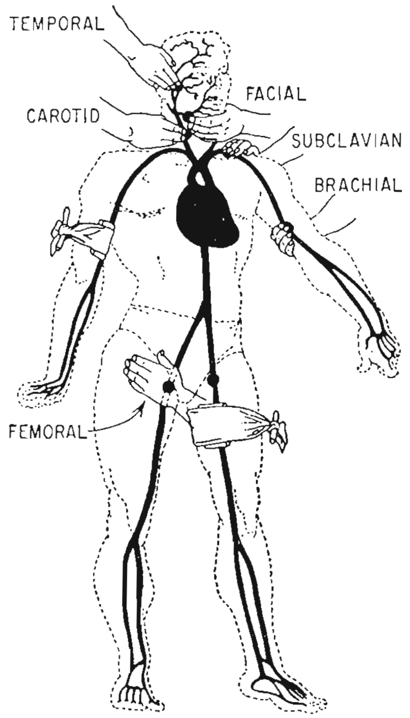

Fig. 2. Pressure points for control of severe bleeding.

Control of Severe Bleeding in the Event of an Emergency

Severe bleeding requires immediate and prompt action, and its control may save a life. All stations should be provided with suitable tourniquets, and all personnel should be ready to act in any emergency. A second person should send immediately for a doctor.

1. *Venous bleeding:* When a vein has been cut, the blood is *dark red* and flows steadily. Pressure, if required, should be applied *below* the wound, or *away* from the heart, to stop bleeding.
2. *Arterial bleeding:* When an artery has been cut, the blood is *bright red* and flows in *spurts.* Pressure should be applied *above* the wound, or *between* the wound and the heart, to stop bleeding. Pressure is best applied by a *tourniquet,* although the fingers and hand can be used temporarily (see Fig. 2).
3. *A tourniquet* is a strip of cloth, bandage, or other material tied above the wound. Place a thick pad, such as a folded handkerchief, on the inside of the arm or leg and under the tourniquet. Loosely tie a simple double knot in the cloth, place a stick or other rigid member between the knots, and tighten the outer knot by pulling the outer ends of cloth. Twist the stick or rigid member until bleeding stops. *Do not* maintain such pressure longer than 15 minutes at a time.
4. *If bleeding continues* after the tourniquet is loosened, allow blood to flow for 30 to 60 seconds and then reapply pressure. Continue this procedure until bleeding has stopped.
5. *Obtain medical services as soon as possible.*

Treatment and Avoidance of Electrical Injuries

Electric shock may be induced either by currents of high voltage or by comparatively low voltage. More people are killed on 110 volts a-c than any other voltage. We are all well aware of cases of shock and burns which result from high voltages, yet the vast majority of serious electrical injuries come from currents of low voltage. The severity of an electrical burn depends upon whether the current is alternating or direct, the voltage and amperage of the current, the character of the ground connection (remember, a concrete floor is *not* an insulator), duration of contact, and the extent of surface involved.

Electrical injuries can be classified as follows:

1. Shock, animation suspended and arrested respirations.
2. Electrical flashes or glare injuries to the eyes.
3. First-degree burns, with red dry skin as in sunburn followed early by blister formation and pain.
4. Second-degree burns, where skin continuity is destroyed.
5. Third-degree burns, where there is destruction en masse of the tissue, perhaps including muscle, nerve, and bone.

In shock due to low voltage, such as used for our domestic household appliances, using 110 to 120 volts, the usual cause of accident is neglect to dry hands or other portions of the body properly.

An accident was reported where a woman answered the telephone and neglected to dry her hands. As she reached up to turn on a light, she received a severe shock and had intense pains in her right shoulder. As she was unable to move her arm, her doctor ordered an X ray. There was no history of a fall or other injury. The picture revealed a dislocation of the shoulder joint and complete avulsion of the greater tubercle. Attempts to reduce the dislocation resulted in fracture of the neck of the humerus. Open reduction through surgery was resorted to, and it was found that the electric current had completely changed the character of the bone, which now was filled with thousands of tiny fissures. Similar effects have been noted in inorganic substances such as glass, porcelain, and metal.

Both *high-* and *low-*tension currents have the same lethal effect, and death is produced, not by amperage or voltage, but by a combination of several physiochemical and physiological phe-

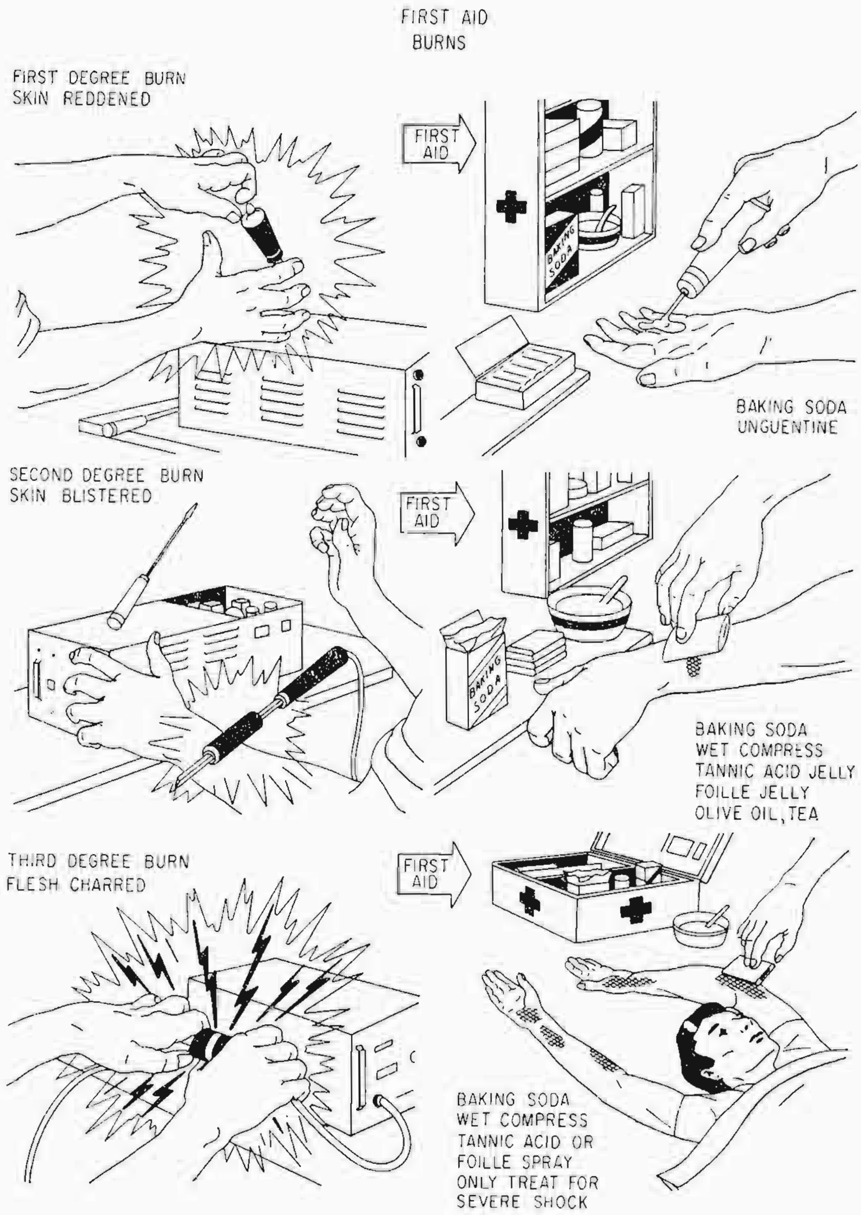

Fig. 3. Treatment for burns.

nomena. *Alternating currents are more dangerous than direct. A good rule to follow when working on or servicing "live" equipment is to keep one hand in your pocket, thus reducing the possibility of a ground return through the upper portion of the body.*

One point which cannot be stressed too often is the importance of dry skin when working around any electrical apparatus. Never touch any electrical fixture when your hands or other parts of your body are wet, especially when there are cuts or abrasions of the skin and particularly where there is a ground current.

These higher voltages usually cause an immediate violent contraction of the muscles, and if the hand has grasped the wire, it cannot be released. Such unfortunates are said to be "frozen" as long as the current continues. Under no circumstances attempt to pull such a victim free or you may share his fate. Rush for the main switch if it is at hand, or otherwise disconnect all current first. Dry wood, dry rope, or a dry coat may help in pulling a victim free, but the location of the switch should be known to everyone in the laboratory. Such an electric shock may and usually does produce severe burns and, if the current is not shut off in time may even char the bones.

In severe cases of electric shock, leaving out burns and their treatment for the moment, we find that the patient has become unconscious. Respiration has stopped completely, but the heart continues to beat until asphyxia intervenes. A certain number of cases develop a ventricular fibrillation; that is, the electrical impulses which regulate the heartbeat are thrown out of order so that the pacemaker is no longer in control, and instead of a normal of 70 to 80 beats per minute, we have 200 to 400. These cases, as a rule, end fatally.

Fortunately, in most cases, there is merely a prolonged apnea—stoppage of breathing. *Artificial respiration by the prone or Schaefer method must be started at once and continued if necessary for* 8 *to* 10 *hours. Cases pronounced dead by all medical tests have suddenly been revived as late as* 8 *hours after the accident.* Injections of cardiac or respiratory stimulants are worthless and a waste of time in electrical shock.

After electric-shock treatment has been started, there is time to treat any burns. However, severe bleeding must be stopped before proceeding with resuscitation.

Treatment for Shock (Not Electrical)

Cots and blankets should be provided for caring for the patient until the doctor arrives. Shock cases require the use of blankets as stated below.

1. Any person severely injured is potentially a patient in shock and should be regarded and treated as such. It is important to conserve body heat, particularly in cold weather; prevent added injury or danger; and get medical services as soon as possible.
2. *Keep the patient lying down* in a comfortable position. Never permit him to stand or walk.
3. *Keep the patient warm.* In many cases the only first aid measure necessary and possible is to wrap the patient underneath, as well as on top, to prevent further loss of heat. Blankets, robes, coats, or any other available woolen material can be used.

General Rules

1. Unconscious persons take cold very easily. Pneumonia is a very frequent complication. Keep the patient warm by use of hot pads or hot-water bottles, but remember that an unconscious man cannot tell you when he is being burned.
2. If necessary to move the patient, keep him lying down and do not permit him to help himself.
3. Never try to give an unconscious person a drink. It will choke him.
4. Never stop artificial respiration in less than 4 hours if the patient has not fully recovered, and if there has been any sign of recovery, continue at least 8 hours.
5. Start artificial respiration at once, and have someone telephone for the emergency squad.

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Audio-Frequency Proof-of-Performance Measurements

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The Commission's rules require each licensee to make audio performance measurements of both the main and alternate main transmitters at least once each calendar year. The dates between successive sets of measurements must not be more than 14 months. One set of measurements must be made during the four month period preceding the filing date of the application for renewal of the station license. Equipment performance measurements for auxiliary transmitters are not required and any qualified individual may make the required measurements. The data, together with a description of the instruments and procedure utilized in making the measurements, must be signed and dated by the person making the measurements. The data may be kept on file at either the transmitter or remote control point and must be retained for a period of two years. The measurements must be made available for inspection to any duly authorized representative of the Federal Communications Commission.

WHAT MEASUREMENTS ARE REQUIRED

For AM Stations

1. Overall audio-frequency response from 50 to 7,500 Hz for approximately 25, 50, 85, and 100 (if obtainable) percent modulation.
2. Audio-frequency harmonic content for 25, 50, 85, and 100 percent modulation for fundamental frequencies of 50, 100, 400, 1,000, 5,000, and 7,500 Hz (either arithmetical or root-sum-square values up to tenth harmonic or root-sum-square values up to tenth harmonic or 16,000 Hz).
3. Percentage carrier shift for 25, 50, 85, and 100 percent modulation with 400 Hz tone.
4. Carrier hum and extraneous noise generated within the equipment.
5. Spurious radiations including radio-frequency harmonics.

For FM Stations (Monophonic)

1. Audio-frequency response from 50 to 15,000 Hz for approximately 25, 50, and 100 percent modulation. Measurements must be made for at least 50, 100, 400, 1,000, 5,000, 10,000, and 15,000 Hz. (Frequency swing of plus and minus 75 kHz is considered 100 percent modulation.)
2. Audio-frequency harmonic distortion for 25, 50, and 100 percent modulation for the fundamental frequencies of 50, 100, 400, 1,000, and 5,000 Hz and audio-frequency harmonic distortion for 100 percent modulation for the fundamental frequencies of 10,000 and 15,000 Hz. Measurements shall include harmonics to 30,000 Hz.
3. Output noise level (frequency modulation) in the band 50 to 15,000 Hz in decibels below the audio-frequency level representing a frequency swing of 75 kHz.
4. Output noise level (amplitude modulation) in the band 50 to 15,000 Hz in decibels below the audio-frequency level representing 100 percent amplitude modulation.
5. Each of the above measurements shall be made employing 75 microsecond de-emphasis.

WHAT EQUIPMENT IS REQUIRED

The Commission does not attempt to set up the procedures or to recommend the equipment to be employed. There are a number of methods of making the required measurements, and numerous makes and models of equipment which are suitable for this purpose are available. In general, however, means must be provided for an audio input signal of known frequency and level and means for measuring the output in the terms desired. The specifications for such equipment must necessarily be considered in connection with the performance standards established by the Commission. It is obvious that the equipment must have such accuracy as to be well within the limits of the operation specifications for the station.

The following equipment is suggested:

1. *Audio oscillator.* This instrument should preferably have a fundamental range of 30 to 17,000 Hz or more. The audio-frequency harmonic content over the entire range should not exceed 1 percent. (Instruments are available

where the distortion does not exceed 0.1 to 0.25 percent.) Accuracy of calibration should be within 3.0 percent, although much greater accuracy will be found in the higher grade instruments. Both high- and low-impedance outputs are desirable.

2. *Attenuator or pad.* To control the signal fed to the microphone terminals from the audio oscillator an accurate attenuator or pad is required. It must be capable of attenuating the signal from at least 50 to 80 dB. (Some audio oscillators have a suitable attenuator built into the unit.)

3. *Level indicator.* The purpose of this item is to measure the input level and/or output level. It is usually available at the station in the form of a VU meter or vacuum-tube voltmeter. It is also included in some audio signal generators.

4. *Isolation and matching transformer.* This is used to isolate the test equipment from the station circuits and to match the impedances of the two. The requirements for this unit depend on the input impedance (normally 600-ohms) and the output impedance of the attenuator.

5. *Distortion and noise meter.* This instrument should have a scale permitting distortion readings as low as 0.5 and as high as 20 to 30 percent. For carrier noise and hum measurements the meter reading should extend to at least 60 dB (preferably lower) below an audio-frequency signal of 0 dbm (the term dbm means the power level expressed in decibels referred to 1 mw). High and low input impedance must be available, and the low impedance is preferably of the bridging type.

6. *Modulation monitor.* This item is required by the FCC in each broadcast station and is, therefore, assumed available.

7. *Field-strength meter or communications-type receiver.* With regard to the observations required on the radio-frequency transmissions of the standard stations, the Commission's Rules state that field-strength measurements are preferred but that observations made with a communications-type receiver will be accepted. To conduct such observations considerable care must be exercised in the selection of the receiver as well as in its actual use. As a general rule this receiver should have at least one stage of RF ahead of the first detector. It should be well shielded, and the frequency range should permit observations to at least the tenth or fifteenth harmonic of the fundamental frequency of the station. A means of making comparative signal-strength checks such as an "S meter" is very desirable and almost essential if suitable and meaningful observations are to be made. Amateur communications receivers will often meet these requirements. Although such observations are not required with respect to FM stations, it is a wise precaution to check spurious and harmonic radiations. Particular attention should be given to the second harmonic to avoid causing interference to television stations.

8. *Oscilloscope.* Although an oscilloscope is not essential, it is often very useful in analyzing and correcting difficulties which prevent compliance with the requirements.

HOW TO MAKE MEASUREMENTS

Detailed instructions for the operation of the particular piece of equipment are normally supplied by the manufacturer and should be followed. Some manufacturers include procedures for making the measurements required by the FCC, but this practice is far from universal. To assist in overcoming this lack and for the benefit of stations assembling the equipment from units purchased from different manufacturers, a step-by-step procedure for making the required measurements is set forth below, together with precautions that should be taken in setting up the equipment and making the measurements.

PRECAUTIONS

1. All measurements shall be made with the equipment adjusted for normal program operation and shall include all circuits between the main studio microphone terminals and the antenna output, including telephone lines, preemphasis circuits, and any equalizers employed except for microphones, and without compression if a compression amplifier is installed unless otherwise noted.

Where an AM station operates DA-2 or DA-N, it is not required to make measurements under both conditions of antenna operation unless there is reason to believe some unusual condition exists. The practice of making two sets of measurements, however, is considered advisable. If the antenna systems are adjusted so that the transmitter is feeding in exactly the same impedances under both conditions, there should be no difference. (Some difficulty may be experienced at the higher audio frequencies when the common-point impedance(s) for sidebands is greatly different from that at the carrier frequency.)

2. Audio systems of most broadcast stations use balanced 600-ohm ungrounded circuits. This, however, is not universal, and before attempting to make measurements, the facts in this regard must be determined. Otherwise, the measurements obviously will be in error and serious damage may result to the station equipment, the measuring equipment, or both.

3. It is very important to guard against stray fields affecting the accuracy of the measurements. This is particularly true with respect to use of the distortion and noise meter and of the VTVM when used in the presence of the transmitter.

Difficulties of this nature are usually evidenced by residual readings. It is suggested that:

a. Use short power cord and bypass it; also reverse plug for lowest residual reading.

b. The chassis of the instrument must be firmly grounded with as short a lead as possible to the station ground bus.

c. Use short voltmeter leads with RF chokes, and bypass. It may also be necessary to shield the terminals and the instrument itself. In some cases shielding the front will be adequate.

d. In some cases, particularly where a high power transmitter is involved, it will be found impossible to reduce the residual reading (R_R) to zero. In such cases a reasonable accurate corrected reading (R_c) may be found by applying the root-mean-square (RMS) principle to the final reading (R_F) i.e., R_c) = $R_F^2 - R_R^2$. Example: If the minimal resident reading is 0.50 and the final reading is 2.50, the corrected value or reading would equal $\sqrt{2.50^2 - 0.50^2} = 2.45$.

PROCEDURE FOR AM STATIONS

Audio-frequency Response

1. Adjust all equipment from microphone preamplifier input terminals to the antenna for normal program operation.
2. Bypass any limiting amplifiers.
3. Connect the audio-signal-generator equipment as shown in Fig. 1. Details of this will depend on the type and impedances of the oscillator, attenuator, and the station audio circuits. (*Do not connect to input terminals yet.*)
4. Adjust the oscillator to1,000 Hz.
5. Adjust the oscillator amplitude control until the VTVM reads zero.
6. Adjust the attenuator to approximately 40 or 50 dB.
7. Connect the signal generator to the microphone preamplifier input circuit.
8. Adjust the amplitude control until the VTVM reads approximately 15 dBm.
9. Adjust the attenuator until the station modulation monitor indicates 25 percent modulation, at the same time making certain that the VTVM still reads the same as Step 8. If it does not, readjust the amplitude control and attenuator until the modulation monitor shows 25 percent at the same time that the VTVM shows the same as in Step 8.
10. Record the attenuator setting in all the upper spaces of the form shown on Form AFP-1 for 25 percent modulation and also in the second space under 1,000 Hz.
11. Adjust the oscillator to 50 Hz.
12. Adjust the amplitude control and attenuator until the modulation monitor reads 25 percent at the same time the VTVM reads the same as in Step 8.
13. Record the attenuator setting in the second space down under 50 Hz in Form AFP-1.
14. Subtract the entry in the second space down from that in the first space, and enter the difference in the third or lower space.
15. Repeat steps 11 to 14 for 100, 400, 5,000, and 7,500 Hz. There should not be more than approximately 0.2 dB difference between any two successive readings. If there is, readings should be taken at intermediate frequencies.
16. Repeat Steps 9 through 15 for 50, 85, and 100 percent modulation. (If 100 percent modulation is not obtainable, use the highest percentage that is obtainable.)
17. Plot all readings in the lower spaces for each percentage of modulation on the graph sheets on Form AFP-2.
18. If the decibel variation between 100 and 5,000 Hz is greater than 2 dB from that at 1,000 Hz, operation is in violation of the Commission's Rules. Appropriate corrective steps should be taken, and the measurements repeated.

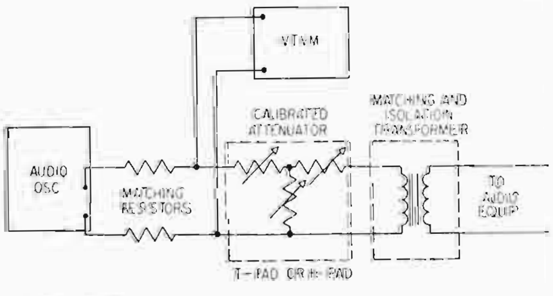


Fig. 1. Basic method of connecting audio-signal-generator equipment.

Audio-frequency Harmonic Distortion

1. Repeat Steps 1 through 9 above.
2. Connect the distortion and noise meter to the output of the transmitter. This connection depends on the instrument employed, and the instructions of the manufacturer should be followed. In general, there are two principal types: one in which the detector circuit is built into the meter and the other where a separate detector must be provided. In the latter case it is normal to use the detector in the modulation monitor.
3. Following the instructions of the manufacturer of the distortion and noise meter determine the harmonic content for 1,000 Hz and record in the space provided on Form AFP-3.
4. Repeat Steps 9 through 12 under Procedure for AM Stations and Step 3 above for 50, 100, 400, 5,000, and 7,500 Hz.
5. Repeat Steps 4 through 12 under Audio-frequency Response and Steps 3 and 4 above for 50, 85, and 100 percent modulation.

6. Plot the data on graphs on Form AFP-3.
7. If the harmonic content is greater than 5 percent from 0 to 84 percent modulation or 7.5 from 85 to 95 percent modulation, operation is in violation of the Commission's rules. Appropriate corrective steps should be taken and the measurements repeated.

Percentage Carrier (Current) Shift

1. Adjust all equipment from the microphone preamplifier input terminals to the antenna for normal program operation.
2. Bypass any limiting amplifiers.
3. Connect the audio signal generator equipment as shown in Fig. 1. Details of this will depend on the type and impedances of the various units and of the station audio circuits. (*Do not connect to the input terminals yet.*)
4. Adjust the oscillator to 400 Hz.
5. Adjust the oscillator amplitude for minimum output.
6. Adjust the attenuator to 40 or 50 dB.
7. Connect to the microphone preamplifier input.
8. Connect a dc voltmeter having a very high input impedance so as to read the dc potential in the detector circuit used in the output of the transmitter as described under Audio Harmonic Distortion.
9. If the detector in the distortion and noise meter is used, adjust the control until maximum dc voltage is obtained.
10. Read and record in the spaces provided on Form AFP-4. (This is the "no-modulation" reading.)
11. Increase the input by adjusting the oscillator amplitude control and the attenuator until the modulation monitor reads 25 percent.
12. Read the dc voltage and record it in the space provided on Form AFP-4. (This is the reading with 25 percent modulation.)
13. Enter the difference between the reading without modulation and the reading with modulation in the space provided.
14. Calculate and enter in the space provided in the percent carrier shift for 25 percent modulation. Percentage of carrier shift is the difference between the readings with and without modulation divided by the reading without modulation and multiplied by 100.
15. Repeat for 50, 85, and 100 percent modulation.
16. If the carrier shift is greater than 5 percent at any percentage of modulation, operation is in violation of the Commission's rules. Appropriate corrective steps should be taken and the measurements repeated.

Carrier Hum and Extraneous Noise

1. Adjust all equipment from the microphone amplifier input terminals to the antenna for normal program operation.
2. Bypass any limiting amplifiers.
3. Connect the audio-signal-generator equipment as shown in Fig. 1. Details of this will depend on the type and impedances of the various units and of the station audio circuits. (*Do not connect to the input terminals yet.*)
4. Adjust the oscillator to 400 Hz.
5. Adjust the amplitude control to 15 dB.
6. Adjust the attenuator to approximately 40 dB.
7. Connect to the input of the microphone preamplifier.
8. Adjust the attenuator until the modulation monitor indicates 100 percent modulation.
9. Connect the distortion and noise meter to the output of the transmitter. This connection depends on the instrument employed, and the instructions of the manufacturer should be followed. In the event the instrument does not have a detector circuit built into it, the detector of the modulation monitor can be employed provided it has a low hum and noise level, as this will be added to that of the transmitter in the readings.
10. Follow the instructions of the manufacturer, which will be, in general, to adjust the sensitivity so as to obtain a full-scale reading with the output meter set for maximum reading.
11. Disconnect the radio signal generator, and connect a 600-ohm (wire-wound) resistor across the input terminals of the main studio amplifier. If the input impedance is other than 600 ohms, use the corresponding value of resistor. (The signal generator can be turned off and 20 to 30 dB inserted by the attenuator, but the resistor connected across the input is the preferred method.)
12. Increase the sensitivity of the output meter until a reading is obtained. Read and record.
13. Calculate the combined hum and noise. In percent this is the reading obtained in Step 12 divided by the reading in Step 10 and multiplied by 100. The hum and noise ratio to the 100 percent value can be converted to decibels in the usual manner. Both should be recorded on Form AFP-4.
14. If the hum and noise is less than 50 dB below 100 percent modulation between 150 and 5,000 Hz or less than 40 dB below 100 percent modulation outside that range operation, it is in violation of the Commission's rules. Appropriate corrective steps should be taken and the measurements repeated.

Spurious Radiations

1. All equipment, including any limiting amplifiers, should be in normal adjustment with a program or test tone at as high a percentage of modulation as is ever used.

2. With the communications receiver, make observations at a distance of approximately ½ mile from the antenna or closer if possible for spurious emissions including harmonics. With the gain control turned to a maximum, tune around the frequency of the station and on up to the tenth or fifteenth harmonic of the assigned frequency. By means of the S meter determine and record the approximate signal strength of the spurious emissions that are found.

3. In the event any of consequence are found, steps should be taken to eliminate or reduce them as far as possible. In the event that any disagreement arises with the Commission, it may be necessary to take actual field measurements. It is not acceptable for the radiations on other than the assigned frequency to exceed 60 dB below the fundamental, and they should be 70 or 80 dB down.

PROCEDURE FOR FM STATIONS (MONOPHONIC)

Audio-frequency Response

1. Repeat the procedure outlined under Procedure for AM Stations *except:* Use audio frequencies of 50, 100, 400, 1,000, 5,000, 10,000, and 15,000 Hz at 25, 50, and 100 percent modulation.

(These measurements should be made without deemphasis; however, standard 75-μsec deemphasis can be employed in the measuring circuit or in the system provided the accuracy of the deemphasis circuit is sufficient to ensure that the measured response is within the prescribed limits.)

2. Record in the space provided on Form AFP-5.

3. Plot the data on Form AFP-6.

Audio-frequency Harmonic Distortion

1. Repeat the procedure outlined under Procedure for AM Stations, Audio-frequency Harmonic Distortion, for AM stations *except:* Use audio frequencies of 50, 100, 400, 1,000, and 5,000 Hz for 25 and 50 percent modulation and audio frequencies of 50, 100, 400, 1,000, 5,000, 10,000, and 15,000 Hz for 100 percent modulation. (These measurements should be made with standard 75-μsec deemphasis in the measuring circuit or system and should include harmonics to 30,000 Hz.)

2. Plot the data on Form AFP-7.

3. If this distortion exceeds the following values, operation is in violation of the Commission's rules and the equipment should be readjusted and the measurements repeated: 50 to 100 Hz, 3.5 percent; 100 to 1,500 Hz, 2.5 percent; 7,500 to 15,000 Hz, 3.0 percent.

Output Noise (FM)

1. Repeat the procedure outlined under Carrier Hum and Extraneous Noise for AM stations using FM detection and standard 75-μsec deemphasis and VU meter.

2. Record in spaces provided on Form AFP-8.

3. If the noise is in excess of 60 dB down from the audio level representing a frequency swing of ±75 kHz, operation is in violation of the Commission's rules and appropriate corrective steps should be taken and the measurements repeated.

Output Noise (AM)

1. Shunt the 600-ohm wire wound resistor across microphone preamplifier input.

2. Determine the audio voltage equivalent to 100 percent modulation. This may be considered as equal to the dc voltage across the meter determining the power level in the monitor.

3. By use of the distortion and noise meter with standard 75-μsec deemphasis and VU meter, determine the audio voltage at the same point for the same carrier level.

4. Compute the percent AM modulation by dividing the audio voltage by the carrier level voltage and multiply by 100. Convert to decibels down from 100 percent modulation. Record in spaces provided on Form AFP-8.

5. If the noise is in excess of 50 dB below the audio level representing 100 percent modulation, operation is in violation of the Commission's rules. Appropriate corrective steps should be taken and the measurements repeated.

HOW TO USE THE MEASUREMENTS

Compliance with the Commission's rules in regard to filing the measurements was covered earlier. However, the measurements were required in the first place to determine whether the emissions of the station are satisfactory and in accordance with the rules and good engineering practice. Obviously, if the distortion, hum, noise, RF harmonics, or other spurious emissions are not within the rules, appropriate corrective steps must be taken and new measurements made. Even if the measurements are within the requirements, there are very likely adjustments or changes that can be made with little or no expense which would materially improve the operation or correct a weakness or border-line operation which may otherwise cause off-the-air time later.

In other words, these measurements should not be considered just a necessary nuisance to comply with the Commission's requirements but should be used for station improvement. If the station purchases the equipment, a procedure should be established for making the measurements at regular intervals and the measurements kept on file, together with a record of the adjustments that have been made from time to time to maintain proper operation. This will often indicate potential sources of complete failure at inopportune times, particularly in bad weather, when lines and equipment are more prone to fail and more difficult to repair.

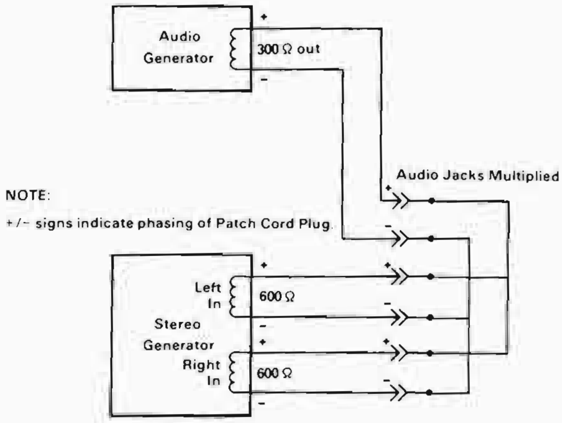


Fig. 2. Simple setup to feed to Left and Right audio channels with monaural signal generator.

As shown, the Stereo Generator is being fed an in-phase (L=+R) signal.

To feed out of phase (L≠−R), reverse the polarity of plug into Right channel.

Since the two 600 ohm input impedances are effectively strapped in parallel, the generator will not see 600 ohms. Therefore, its output should be set as near to 300 ohms as possible, according to the impedances available on the generator.

PROCEDURE FOR FM STATIONS (STEREO)

An FM Station that operates in a Stereo manner, whether on a full time or part time basis, must perform an annual Stereo Proof of Performance. This Stereo Proof is in *addition* to the required annual monaural proof required of all FM Stations. Both modes of operation must meet the requirements of Section 73.254, 73.313, 73.322 of the FCC rules.

Measurements Required

1. Audio frequency response measurements on the left and right audio channels separately at 90 + 10 percent pilot, 40 + 10 percent pilot, 15 + 10 percent pilot percent main channel modulation. As a minimum, these measurements should be made at the fundamental audio frequencies of 50, 100, 400, 1,000, 5,000, 10,000, 15,000 Hz. 1,000 Hz is used as a reference. No deemphasis used during measurements.

More measurements may be made, particularly above 1,000 Hz, which will help in drawing the graph of the response curve and give a more realistic view of the system.

Limits: The system audio response must fit within the FCC Standard Preemphasis curve.

2. Audio Frequency Distortion Measurements on the Left and Right audio channels at 100 percent, 50 percent, 25 percent (includes 10 percent pilot) modulation of the main channel for fundamental audio frequencies of 50, 100, 400, 1,000, 5,000 Hz. At 100 percent modulation, fundamental frequencies of 10,000 and 15,000 Hz. 75 μsec deemphasis used in measurements.

Limits: 50 to 100 Hz, 3.5 percent; 100 to 7,500 Hz, 2.5 percent; 7,500 to 15,000 Hz, 3 percent.

3. Output Noise level (FM) in the band 50 to 15,000 Hz in decibels below the level representing 100 percent main carrier modulation. 75 μsec deemphasis used.

Limits: −60 dB. Each channel.

4. Output Noise level (AM) in the band 50 to 15,000 Hz in decibels below the level representing 100 percent amplitude modulation of the carrier. 75μ sec deemphasis used.

Limits: −60 dB. Each channel.

5. Separation Measurements of the Left and Right audio channels in the band 50 to 15,000 Hz in decibels at a level representing 90 percent (+ 10 percent pilot) main carrier modulation.

Limits: −29.7 dB for each channel.

6. Cross-talk measurements of Main channel into subchannel when main channel is modulated 90 percent (+ 10 percent pilot) with 400 Hz, while subchannel is unmodulated.

Cross-talk measurement of subchannel into the main channel while the subchannel is modulated 100 percent with 400 Hz, modulating the main channel to 90 percent (+ 10 percent pilot) and no audio modulation on main channel.

Limit: −45 dB for both the main and the subchannel.

7. Subcarrier suppression measurements with no audio modulation on the main channel, subchannel modulated by 5,000, 7,500, 10,000, 15,000 Hz, subchannel modulating the main channel to 90 percent (+ 10 percent pilot).

Subcarrier suppression measurement without modulation on the main channel, subchannel or pilot.

Limit: 1 percent main channel modulation (—40 dB).

Equipment Needed

1. The same basic equipment required for the monaural Proof.
2. A Stereo Modulation Monitor. This is required as an operational instrument by the FCC rules. All modern monitors incorporate the required circuits, switches, pads, and metering to make the specialized Stereo measurements.
3. An oscilloscope, although not entirely necessary, is a useful instrument for determining if the system phasing is correct.
4. Some device for feeding the monaural audio signal generator into the left and right audio channels, maintaining correct phasing and impedance matching. This may be built up of various resisters and switches. If the input to the stereo system is on an audio patch panel, a simpler method can be used, provided there are three sets of jacks that are multiplied together. The audio generator is fed to one of the multiple jacks, while two identical length patch cords feed the left and right channels. Each plug should be adequately marked for phasing and which channel.

Precautions

Before making the measurements, certain checks should be made and precautions taken.

1. *Identical* circuit paths and levels are most important. The matrix in the Stereo Generator algebraically adds and subtracts the Left and Right audio channels to provide the main channel modulation and the subchannel modulation. The matrix in the receiver reverses the process to restore the Left and Right audio channels. Should the Left and Right audio channels not be identical in both amplitude response and phase of all passing audio-frequencies, complete addition and subtraction cannot take place. What remains will appear in the opposite channel as reduced separation.
2. System should be checked for 180° phasing. Whenever equipment has been removed for repairs, it is possible that the leads were inadvertently reversed when the equipment was replaced. Such a shift in phase will reverse the Left and Right audio channels.
3. System should be checked for lesser degrees of phase error. Smaller amounts of phase error will cause reduced separation.
4. The demodulator switching action of the monitor should be the same as that used in the Stereo Generator. The monitor should be adjusted or modified as directed in its instruction manual to make the monitor correspond with the generator. Should one unit be square wave switching while the other is sine wave switching, reduced separation measurements will result.
5. Impedance matching of the inputs is most important, as a mismatch will effect both amplitudes and frequency response.
6. Proper terminations are important. This is especially true when only one channel is measured. During such times, the input to the other channel should be terminated with a resister of a value equal to the input impedance. If the channel is left open and unterminated, open circuit hum may be introduced that will affect the measurements taken.

Techniques

There are several types of modulation monitors available. Although none are identical, each performs the required functions in its own way. It is beyond the scope of this section to discuss individual monitors. It is assumed that the engineer making the proof is familiar with operation of the monitor in use. Methods for performing the measurements differ from one type monitor to another.

A check for the correctness of phasing should be done as the first step. Unless the phasing is correct, all the measurements will be in error.

Set up the equipment as shown in Fig. 3. Composite signal from the output of the stereo generator is coupled to the vertical amplifier input of the oscilliscope. At the same time, 19 kHz pilot is fed to horizontal trigger input of the oscilloscope. Using the 19 kHz as a trigger will help stabilize the CRO display. Next, adjust the horizontal sweep controls so that only one cycle is displayed on the CRO.

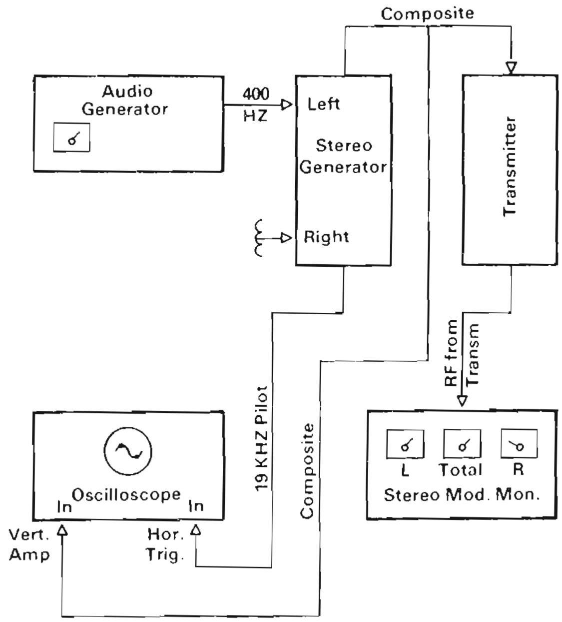
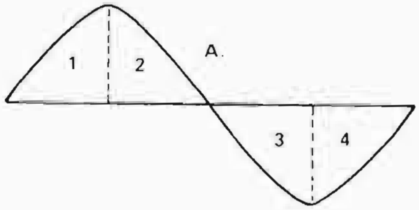
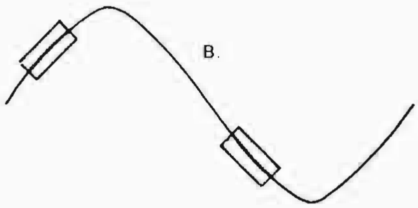


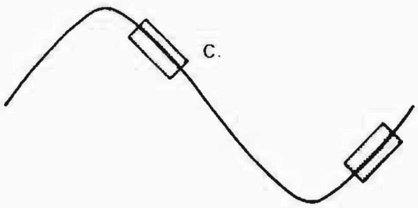
Fig. 3. Equipment set up for checking system phasing. As shown, system is being checked for 180° phasing using Left channel.



A. One full cycle divided in 4 quadrants, a zero base line drawn in.



B. Small amount of 400 Hz fed to Left channel only. Modulation appears in 1st and 3rd quadrants of the cycle.



C. Small amount of 400 Hz fed to Right channel only. Modulation appears in 2nd and 4th quadrants of the cycle.

Fig. 4. One cycle of 19 kHz display on CRO and modulation and correct 180° phasing.

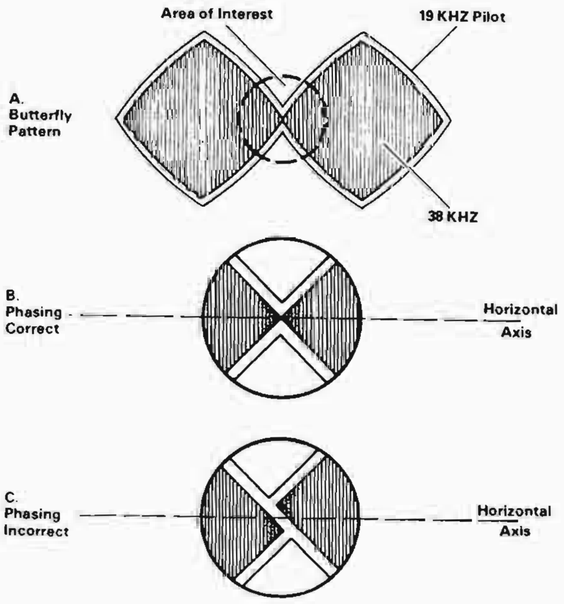


Fig. 5. Butterfly pattern of oscilloscope, used for checking smaller amounts of phase error.

Feed a small amount of 400 Hz audio into the left channel only, the right channel input terminated in 600-ohms. If the phasing is correct, the 400 Hz modulation will appear in the 1st and 3rd quadrants of the cycle displayed on the CRO. At the same time, the left audio meter on the Stereo Monitor will be indicating modulation. This test verifies that both the Stereo Generator and Monitor are correctly phased.

The right channel may now be checked. Simply feed the 400 Hz audio to the right channel, terminate the left channel. The 400 Hz modulation should now appear in the 2nd and 4th quadrants of the cycle displayed on the CRO, and the right meter on the monitor should be indicating. The 180° phasing is now verified.

Lesser degrees of phase error may now be checked. Leave the equipment set up as for the previous test, but with this exception. Feed 400 Hz out of phase ($L = -R$) to both left and right audio channels. Modulate for $90 + 10$ percent pilot total modulation. Adjust the horizontal sweeps on the oscilloscope for the butterfly pattern.

Careful observation of the CRO pattern will show that both wings are filled with fine vertical lines (38 kHz), a dual outer envelope (19 kHz pilot). The central crossover point where the wings join together is the main point of interest. The CRO display should now be expanded so the central area can be observed better. Phasing is correct when the two points of the wings are on the same horizontal axis. Incorrect phasing will be indicated when the two points are on opposite sides of the horizontal axis. How far apart and which side of the line the points are located will depend upon the direction and amount of phase error. If incorrect phasing is indicated, adjust the phasing control on the Stereo Generator so the points are on the same axis.

The audio response, distortion and noise measurements are basically the same as those taken during the monaural proof, with the exception of the dual channels and the stereo section of the monitor.

The stereo proof will require a considerable number of measurements to be taken. Motion economy will make the work proceed faster and require less switching actions. One can combine the response, distortion, and separation measurements on one channel and at the three main carrier modulation percentages. For example, with the audio signal set to feed 1,000 Hz to the left audio channel, the distortion analyzer will be attached to the Left output. Adjust the input to modulate the main channel 100 percent (includes 10 percent pilot). Enter this level onto the appropriate sheet, then measure distortion and enter that reading on the distortion sheet. Next, measure the separation of the Right channel

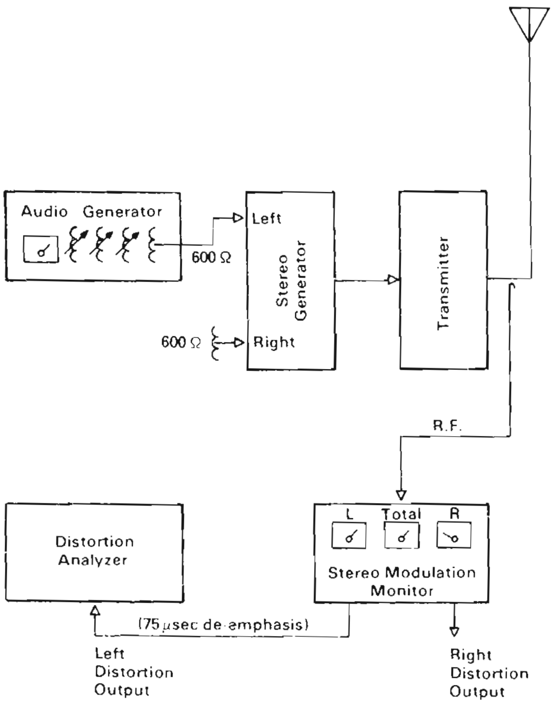


Fig. 6. Equipment setup for measuring audio response and distortion in the system. As shown, equipment is ready to measure the Left channel. To measure the Right channel, the feed is to the Right channel and the distortion meter is moved to the right distortion output of monitor.

(according to monitor in use) and enter that reading on the separation sheet. Next, drop the input level so total modulation is 50 percent, again check distortion and enter on appropriate sheets. Do the same with 25 percent modulation. Separation measurements are made at 100 percent modulation only.

When combining measurements in this way, the work will go faster, but there are possibilities for entering the results in the wrong columns or on the wrong sheets. But if done with care, the work will be performed in a shorter period of time.

Preparing the Results

Whether one uses the charts as given in this manual or those of his own design, here are a few suggestions:

Graphs should be prepared of the audio response and distortion so as to give a quick overall view of the system. The left and right channels should be plotted on the same graph and on the same reference points. Such an overlay will quickly show where the two channels differ. As a further suggestion, each channel can be drawn in with a color different than the opposite channel, or one channel may be drawn in a solid curve while the other is drawn in a dashed curve. In either case, and differences in channels will be very evident.

A graph should also be drawn for the distortion measurements, again plotting both curves on the same sheet and reference points. As a quick aid in viewing the overall system distortion performance, draw in the limits of distortion permitted.

Since a monaural proof must also be made, both the stereo and monaural proofs should be combined in the same folder or other packaging. This will provide a single volume showing the total results of the station overall technical performance. File in the usual manner as done with proofs.

Station ______ KC, City ______ State ______

OVERALL AUDIO FREQUENCY RESPONSE DATA

25% MODULATION

CPS	30	50	100	400	1000	5000	7500
(1)							
(2)							
(3)							

50% MODULATION

CPS	30	50	100	400	1000	5000	7500
(1)							
(2)							
(3)							

85% MODULATION

CPS	30	50	100	400	1000	5000	7500
(1)							
(2)							
(3)							

100%(or %) MODULATION

CPS	30	50	100	400	1000	5000	7500
(1)							
(2)							
(3)							

(1) RECORD THE ATTENUATOR READING FOR THE 1000 CPS REFERENCE SIGNAL IN EACH SPACE IN THIS ROW.

(2) RECORD THE ATTENUATOR READINGS FOR THE SPECIFIED FREQUENCIES IN THIS ROW.

(3) RECORD THE AUDIO FREQUENCY RESPONSE VARIATION IN THIS ROW WHICH IS OBTAINED BY SUBTRACTING ROW (2) FROM ROW (1) THESE FINAL FIGURES ARE TO BE USED IN PLOTTING THE GRAPHS.

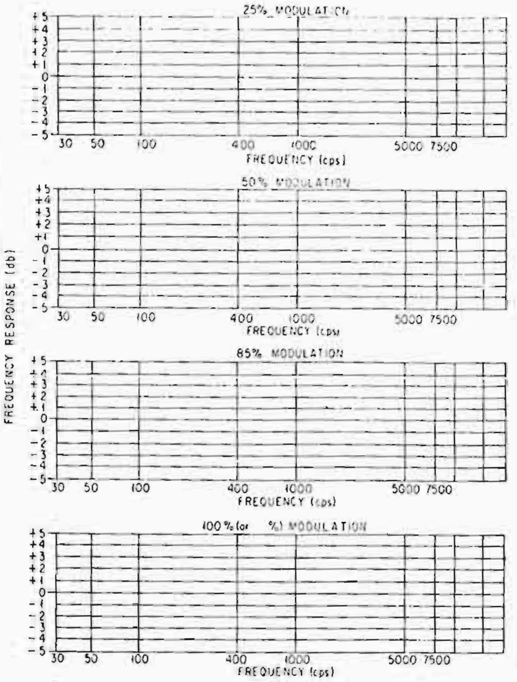
______________ Engineer ______ 19____

Form No. AFP-1

Form AFP-1.

Station KC, City State

OVERALL AUDIO FREQUENCY RESPONSE CURVES



ENGINEER 19

Form No. AFP-2

Form AFP-2.

Station KC, City State

CARRIER SHIFT AND COMBINED NOISE AND HUM DATA

CARRIER SHIFT DATA (at 400 cps)

% MOD	25	50	85	100
(1)				
(2)				
(3)				
(4)				

(1) RECORD DC VOLTMETER READING WITHOUT MODULATION IN EACH SPACE IN THIS ROW.

(2) RECORD DC VOLTMETER READINGS WITH MODULATION IN THIS ROW.

(3) SUBTRACT ROW (2) FROM ROW (1) AND RECORD DIFFERENCE IN THIS ROW.

(4) COMPUTE CARRIER SHIFT BY EQUATION $\frac{\text{ROW (3)}}{\text{ROW (1)}} \times 100$, AND RECORD RESULTS IN THIS ROW.

COMBINED NOISE AND HUM READING

DB	%

Engineer 19

Form No. AFP-4

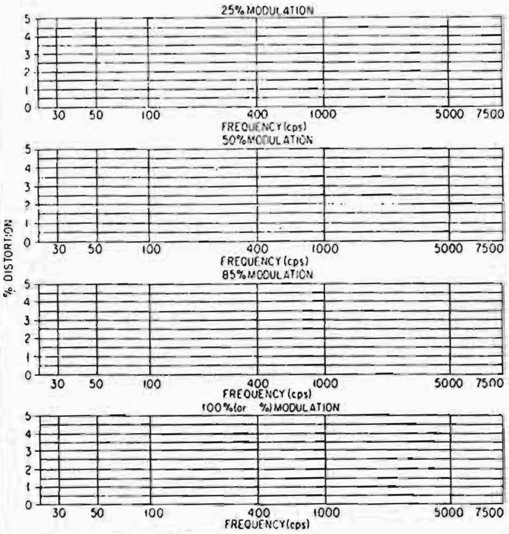
Form AFP-4.

Station KC, City State

AUDIO FREQUENCY HARMONIC CONTENT DATA AND CURVES

HARMONIC DISTORTION

	CPS	30	50	100	400	1000	5000	7500
% MOD.	25							
	50							
	85							
	100							



Engineer 19

Form No. AFP-3

Form AFP-3.

Station Ch. City State

OVERALL AUDIO FREQUENCY RESPONSE DATA

25% MODULATION

CPS	50	100	400	1000	5000	10000	15000
(1)							
(2)							
(3)							

50% MODULATION

CPS	50	100	400	1000	5000	10000	15000
(1)							
(2)							
(3)							

100% MODULATION

CPS	50	100	400	1000	5000	10000	15000
(1)							
(2)							
(3)							

—% MODULATION

CPS	50	100	400	1000	5000	10000	15000
(1)							
(2)							
(3)							

(1) RECORD THE ATTENUATOR READING FOR THE 1000 CPS REFERENCE SIGNAL IN EACH SPACE IN THIS ROW.

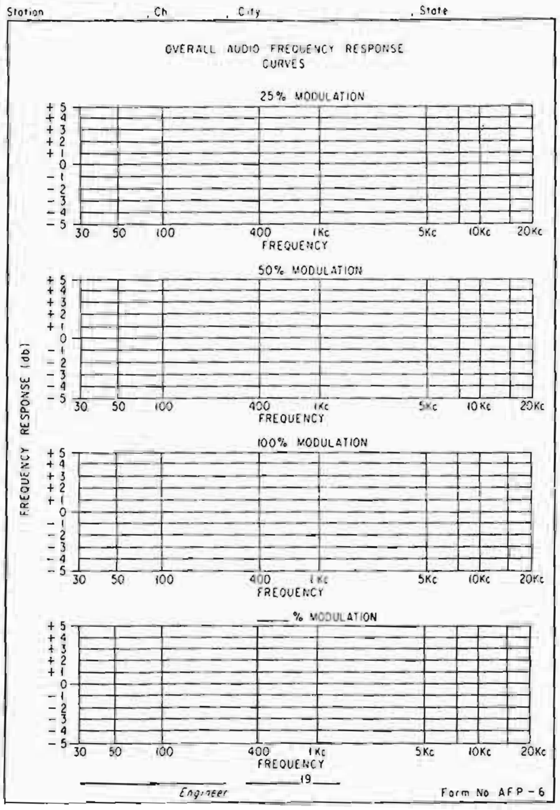
(2) RECORD THE ATTENUATOR READINGS FOR THE SPECIFIED FREQUENCIES IN THIS ROW.

(3) RECORD THE AUDIO FREQUENCY RESPONSE VARIATION IN THIS ROW WHICH IS OBTAINED BY SUBTRACTING ROW (2) FROM ROW (1). THESE FINAL FIGURES ARE TO BE USED IN PLOTTING THE GRAPHS.

Engineer 19

Form No. AFP-5

Form AFP-5.



Station , Ch , City , State

OVERALL AUDIO FREQUENCY RESPONSE CURVES

25% MODULATION

FREQUENCY

50% MODULATION

FREQUENCY

100% MODULATION

FREQUENCY

___% MODULATION

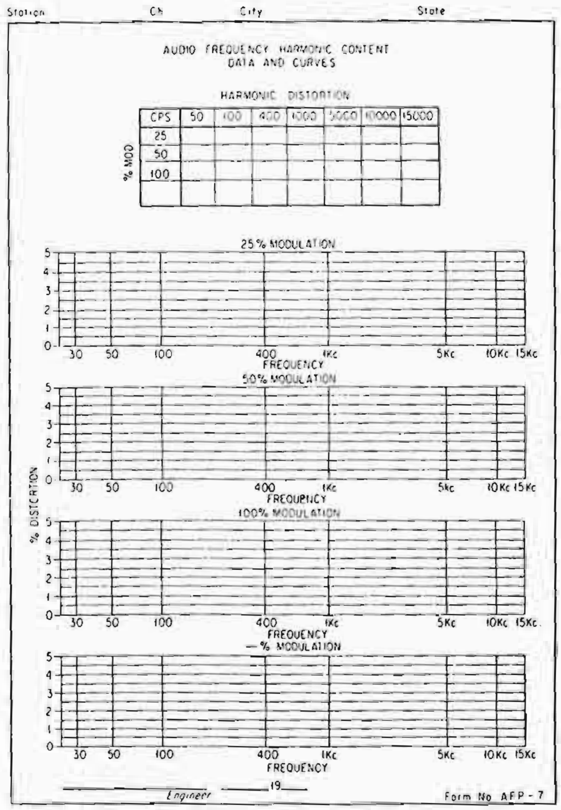
FREQUENCY

FREQUENCY RESPONSE (db)

Engineer 19

Form No AFP - 6

Form AFP-6.



Station Ch City State

AUDIO FREQUENCY HARMONIC CONTENT DATA AND CURVES

HARMONIC DISTORTION

% MOD	CPS	50	100	400	1000	5000	10000	15000
	25							
	50							
	100							

25% MODULATION

FREQUENCY

50% MODULATION

FREQUENCY

100% MODULATION

FREQUENCY

—% MODULATION

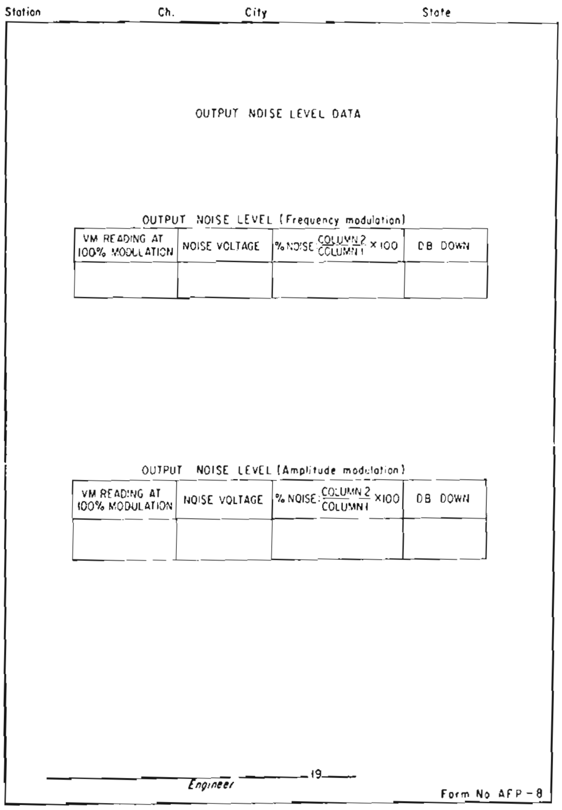
FREQUENCY

% DISTORTION

Engineer 19

Form No AFP - 7

Form AFP-7.



Station Ch. City State

OUTPUT NOISE LEVEL DATA

OUTPUT NOISE LEVEL (Frequency modulation)

VM READING AT 100% MODULATION	NOISE VOLTAGE	% NOISE $\frac{\text{COLUMN 2}}{\text{COLUMN 1}}$ x 100	DB DOWN

OUTPUT NOISE LEVEL (Amplitude modulation)

VM READING AT 100% MODULATION	NOISE VOLTAGE	% NOISE $\frac{\text{COLUMN 2}}{\text{COLUMN 1}}$ x 100	DB DOWN

Engineer 19

Form No AFP - 8

Form AFP-8.

40

Proof-of-Performance for A Television Station

Joseph L. Stern

WHY A PROOF-OF-PERFORMANCE

Proof-of-performance is required by the FCC when an application is filed for a license for a television broadcast station. It assures both the licensee and the Federal Communications Commission that construction and operation have been in accordance with the formal authorizing instruments of the Commission. When modifications are made after the initial licensing, submission of a "proof" is once again required as evidence of continued compliance with the regulations. In addition, and quite importantly, the proof provides an opportunity for the licensee to assess the performance of his plant for his own and his viewers' benefit.

After a "proof" has been accepted by the Commission and the Program Test Authority granted, it is incumbent on the licensee to make periodic proof measurements (1) to have the information available as proof to an FCC inspector that the station is operating within the rules and regulations, (2) to have available as a reference in license renewal applications, and (3) to indicate to the operator that his equipment is operating at peak performance, transmitting pictures and sound of the highest possible quality at all times.

The transmission of a "standard television signal" is a requirement of the rules and the "proof" attests to compliance.

The equipment manufacturer submits Type Acceptance data to the FCC to prove that the transmitter is designed and built to meet the requirements of the Commission's rules and regulations. The TV station submits proof-of-performance data to prove that, as installed, the equipment still meets the rules and regulations.

In making a "proof," the operator establishes a method of operational maintenance which will guide him in a continuous quality assessment. A properly executed "proof," carried out with the full understanding of the operating staff, is a very valuable tool for the station. The measurements carried out for the "proof" can be established as required periodic maintenance measurements within the plant. The formal submission of these data or their inspection by the FCC can be equated to an audit of a carefully kept set of accounting records, confirming the soundness of the operation.

For many operators a "proof" has the onus of something very special and difficult. It is often thought that unusual and obscure measurement techniques are required just to satisfy a special governmental regulation. The following explanation of the performance of a "proof" will show that the measurements are simple to undertake. These measurements not only satisfy the requirements of the FCC, but in addition, assure the licensee that he is getting the maximum return from his equipment and manpower investment.

THE PERFORMANCE OF A PROOF

As an absolute minimum, the "proof" is a series of exhibits detailing information requested in Section II-C of FCC Form 302, License Application Engineering Data Television Broadcast as amended (Fig. 1a and 1b). As a practical minimum, the "proof" is what the name implies, proof (1) that the facility for which license application has been made is, in fact, constructed in accordance with the construction permit and (2) that the facility is capable of operating in conformance with the Commission's Rules and Regulations—that it has transmitted a "standard television signal."

To measure the performance of the television plant, all the normal segments of the system must be included. The main studio, as well as the transmitting plant, should be included in the measurement, for this is the source of the original signals. While program content is not a part of the reported measurements, the handling of program material, both audio and video, is the object of the measurements.

Broadcast Application	FEDERAL COMMUNICATIONS COMMISSION	Section II-C
LICENSE APPLICATION ENGINEERING DATA TELEVISION BROADCAST	Name of applicant	

1. Facilities authorized in construction permit

Call letters	Channel No.	File No. of construction permit

Frequency	Carrier frequency
—— ________ ________ MHz	Visual .... MHz Aural .... MHz

Effective Radiated Power (visual)	Effective Radiated Power (aural)	Antenna height above average terrain
In dbk: In kw:	In dbk: In kw:	feet

2. Station location (principal community)

State	City or town

3. Transmitter location

State	County
City or town	Street Address (or other identification)

4. Main studio location

State	County
City or town	Street address

5. Transmitters Installed

Visual

Make	Type No.	Rated power
		In dbk: In kw:

Aural

Make	Type No.	Rated power
		In dbk: In kw:

Operating constants

Visual transmitter (while transmitting black)

D. C. plate current in last radio stage, in amperes	Applied D. C. plate voltage of last radio stage, in volts

Transmitter power output (after vestigial sideband filter, if used, and after multiplexer, if combined)	Multiplexer loss in db, if separate:	Input to transmission line in dbk:
In dbk: In kw:		

Transmission line power loss in db:	Antenna input power in dbk:	Antenna power gain in db:	Effective radiated power
			In dbk: In kw:

Attach as Exhibit No. complete information concerning the method of power output determination. If power is measured at output of multiplexer, so state.

Reading of power output meter (transmission line voltage, current or power; indicate which) while operating at authorized power:

Aural transmitter

D. C. plate current in last radio stage, in amperes	Applied D. C. plate voltage of last radio stage, in volts
Plate input power to last radio stage in kilowatts	Efficiency factor F of transmitter at operating power, in percent
Transmitter power output In dbk: In kw:	RF transmission line meter reading

6. Antenna and transmission line

Antenna make and Type No.	Number of sections	Power gain in db

Antenna supporting structure

Overall height of antenna system above ground in feet

Geographical coordinates of antenna (to nearest second)
North latitude ° ' " West longitude ° ' "

If directional antenna is used, give full details including horizontal and vertical plane radiation patterns, as Exhibit No.

Is electrical or mechanical beam tilting employed? Yes ☐ No ☐
If so, describe fully in Exhibit No. ,
including horizontal and pertinent vertical radiation patterns.

Has antenna been altered to provide null fill-in? Yes ☐ No ☐
If so, describe fully in Exhibit No.

Transmission line

Make	Type No.	Coaxial or waveguide
Size (nominal inside transverse dimensions) in inches	Length in feet	Power loss in db for this length

Multiplexer

Make	Type No.

If emergency antenna or transmission line measures are provided, describe in Exhibit No.

7. Modulation monitors

(a) Visual monitor or monitoring equipment

Make	Type No. (or describe in Exhibit No.)

(b) Aural monitor

Make	Type No.

8. Frequency monitors

(a) Visual monitor

Make	Normal limits of deviation of carrier frequency shown by monitor
Type No.	high/low cps. to high/low cps.

Fig. 1a.

Broadcast Application | TELEVISION BROADCAST ENGINEERING DATA | Section II-C, Page 2

8. (Continued)

(b) Aural monitor

Make	Normal limits of deviation of carrier frequency shown by monitor
Type No.	high cps. low to high cps. low

If either frequency monitor indicates any carrier deviation in excess of the permissible tolerance, describe in Exhibit No. and state the corrective measures taken.

If the carrier frequencies have been measured by other means, describe in Exhibit No. , giving the date, method used or frequency measuring service employed, the results obtained and the monitor readings (high or low) at the time.

9. Performance data - Visual transmitter

a. Attach as Exhibit No. data showing the following:

1. Overall attenuation versus frequency of the visual transmitter;
2. Field strength or voltage of the lower side-band for a modulating frequency of 1.25 MH_z or greater, and of the upper side-band for a modulating frequency of 4.75 MH_z or greater;
3. A description of the equipment and technique used in making these measurements.

b. Attach as Exhibit No. data demonstrating that the waveform of the transmitted signal conforms to that specified by the standards. Until the form of these measurements may be specified by the Commission, the character of this data is left to the discretion of the applicant.

c. Attach as Exhibit No. a photograph of a test pattern taken from a receiver or monitor connected to the transmitter output.

10. Performance data - Aural transmitter

Attach as Exhibit No. data, diagrams, and appropriate graphs together with description of measurement procedures and instruments with regard to the following: (All measurements shall be made with the equipment adjusted for normal program operation and shall include all circuits between the main studio microphone terminals and the antenna output, including telephone lines, preemphasis circuits and any equalizers employed except for microphones, and without compression if a compression amplifier is installed.)

a. Audio frequency response from 50 to 15,000 Hertz for approximately 25, 50 and 100 percent modulation. Measurements shall be made on at least the following audio frequencies: 50, 100, 400, 1000, 5000, 10,000 and 15,000 Hertz. The frequency response measurements should normally be made without deemphasis; however, standard 75 microsecond deemphasis may be employed in the measuring equipment or system provided the accuracy of the deemphasis circuit is sufficient to insure that the measured response is within the prescribed limits.

b. Audio frequency harmonic distortion for 25, 50 and 100 percent modulation for the fundamental frequencies of 50, 100, 400, 1000 and 5,000 $Hert_z$. Audio frequency harmonics for 100 percent modulation for fundamental frequencies of 10,000 and 15,000 $Hert_z$. Measurements shall normally include harmonics to 30,000 $Hert_z$. The distortion measurements shall be made employing 75 microsecond deemphasis in the measuring equipment or system.

c. Output noise level (frequency modulation) in the band of 50 to 15,000 Hertz in decibels below the audio frequency level representing a frequency swing of 25 kilohertz. The noise measurements shall be made employing 75 microsecond deemphasis in the measuring equipment or system.

d. Output noise level (amplitude modulation) in the band of 50 to 15,000 Hertz in decibels below the level representing 100 percent amplitude modulation. The noise measurements shall be made employing 75 microsecond deemphasis in the measuring equipment or system.

11. In what respect, if any, does the apparatus constructed differ from that described in the application for construction permit or in the permit?

I certify that I represent the applicant in the capacity indicated below and that I have examined the foregoing statement of technical information and that it is true to the best of my knowledge and belief.

Date ____________________ Signature ____________________

(check appropriate box below)

☐ Technical Director ☐ Chief Operator ☐ Registered Professional Engineer ☐ Consulting Engineer

Fig. 1b.

Most of the visual transmitter characteristics described in the rules specify the transmitter as the item being measured but, at the same time, define the transmission standards as applying to the radiated signal. Thus, it is incumbent on the operator to prove the performance of the transmitter where it is specifically requested and also to prove that the entire system can meet the transmission standards. If it is impossible to measure the complete system at one time, an attempt should be made to provide the transmitting plant with operating tolerances more stringent than those in the rules, allowing for some degradation in the studio plant and studio-to-transmitter circuits.

The aural transmitter is defined in two ways: as a transmitter for some measurements and as a transmitting system for others. Transmission measurements for the aural system must be made through this entire system starting with the microphone preamplifier, while the operating characteristics of the aural transmitter alone can naturally be measured on the aural transmitter itself. In all cases, however, for both the aural and visual transmitters, it must be remembered that the "transmitter" input terminals are the *input terminals of the "plant"* and not those physically on the transmitter cabinet. Here the intent of the regulations is quite clear: Those normally used preemphasis and auxiliary components required for proper operation of the transmitter, within the transmitting plant, *are all considered as being a part of the transmitter.*

Examination of FCC Form 302, Section II-C (Fig. 1a and 1b) will aid in demonstrating the performance of a "proof." All information that can be definitively listed is requested in the blank form while information that requires detailing is requested in exhibit form.

Determination of Transmitter Power Output

The first exhibit requested complete information concerning the method of power-output determination (II-C-5). Section 73.689(a)(1) of the rules stipulates that the peak output power of the visual transmitter shall be measured at the output following the vestigial-sideband filter and harmonic filter (if one is used) while operating into a dummy load of substantially zero reactance and a resistance equal to the transmission-line surge impedance while transmitting a standard black picture. The object is simply to provide a means for measuring the output power of the transmitter while operating into a load substantially equal to the load normally seen by the transmitter (which includes the various system filters, traps, transmission line switches, transmission line and antenna system). To accomplish this end, it is necessary to know the impedance characteristics both of the antenna system and of the dummy load being used.[1] This can be ascertained by standard impedance-measuring techniques utilizing bridges, admittance meters, or sweep frequency techniques. Once the similarity of the antenna system and the dummy load wattmeter have been established, a simple power reading can be made. It should be recognized during this measurement, that there are many components between the transmitter output and the antenna system input that can have small losses. The use of lower sideband notch filters, diplexers, and triplexers must be taken into consideration, and their losses attributed to the antenna or transmitter system (as was originally outlined in the equipment description included in the application for construction permit).

When the power measurement is made on the visual transmitter, the peak output power of the transmitter, operating with black picture and standard sync (Fig. 2a and 2b), is determined by reading the average power directly from the dummy load wattmeter and multiplying this value by 1.68.[2] It is advisable to make this measurement at three or more power levels so that it will be possible to plot a graph of peak power output versus the reading of the power-output monitor device of the transmitter. This graph will allow the operating staff to determine readily that they are always operating within the plus 10 minus 20 percent output power variation permitted by Section 73.689(b)(1) of the rules and regulations.

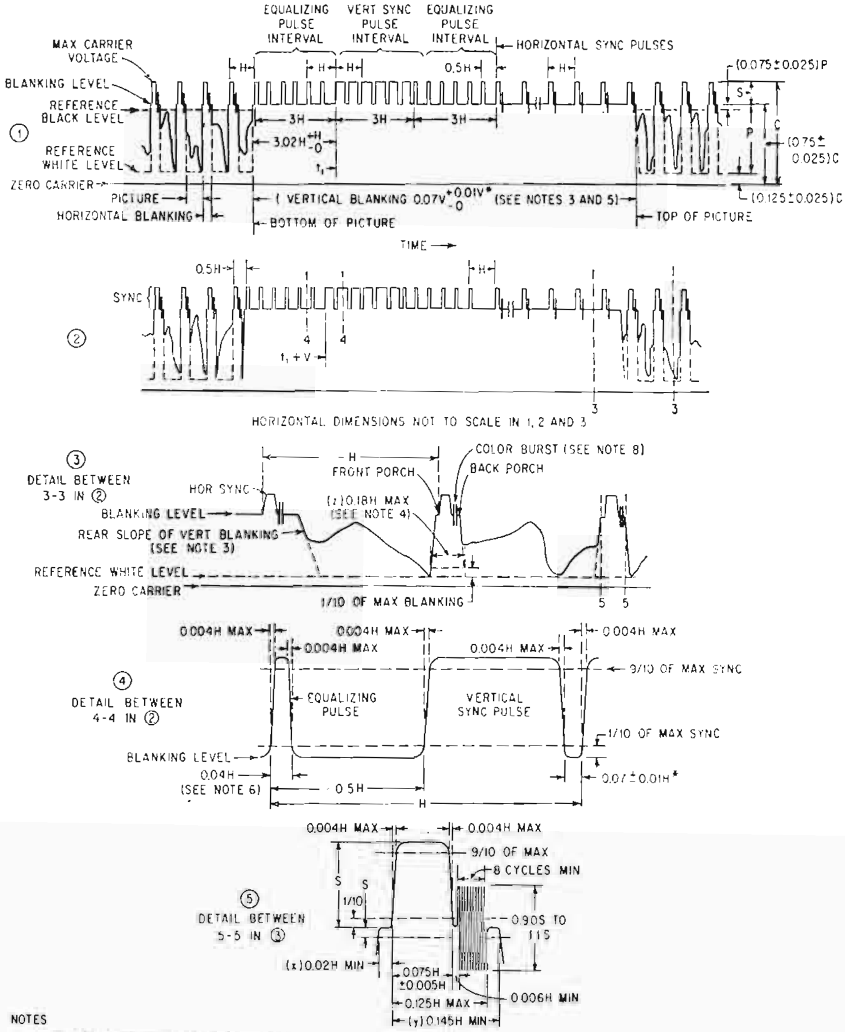
Paragraph II-C-5 of Form 302 requests information to allow determinations of the output power of the aural transmitter by the indirect method as noted in Section 73.689(a)(2). Unfortunately, this method does not take into account possible tube-efficiency variations due to the varying loading conditions possible for the final stage of the transmitter. For the condition of operation for which the transmitter is tuned, the correct stage efficiency can be determined from a power measurement with a dummy load watt-

[1]Section 73.689(a)(1) does suggest, however, that the direct plate voltage and current of the last radio stage and the transmission line meter can be read while making a power measurement into the dummy load and compared with similar readings taken with the dummy load replaced by the antenna system. Substantial argument between these readings should indicate the substantial equality of loads.

[2]The duration of all horizontal, vertical sync and equalizing pulses adds up to 8.9 percent of a TV frame. The average-to-peak power ratio indicated on the meter can be calculated from the value and the relative amplitudes of the black signal (75 percent) and the sync (100 percent). Thus

$$\frac{P_{av}}{P_{pk}} \frac{(0.75 + 0.25 \times 8.9\%)^2}{1}, \frac{P_{av}}{P_{pk}} = 0.596.$$

To determine peak power the meter reading must then be multiplied by 1/0.596 or 1.68. Note that this factor holds only for standard sync height and width.



NOTES

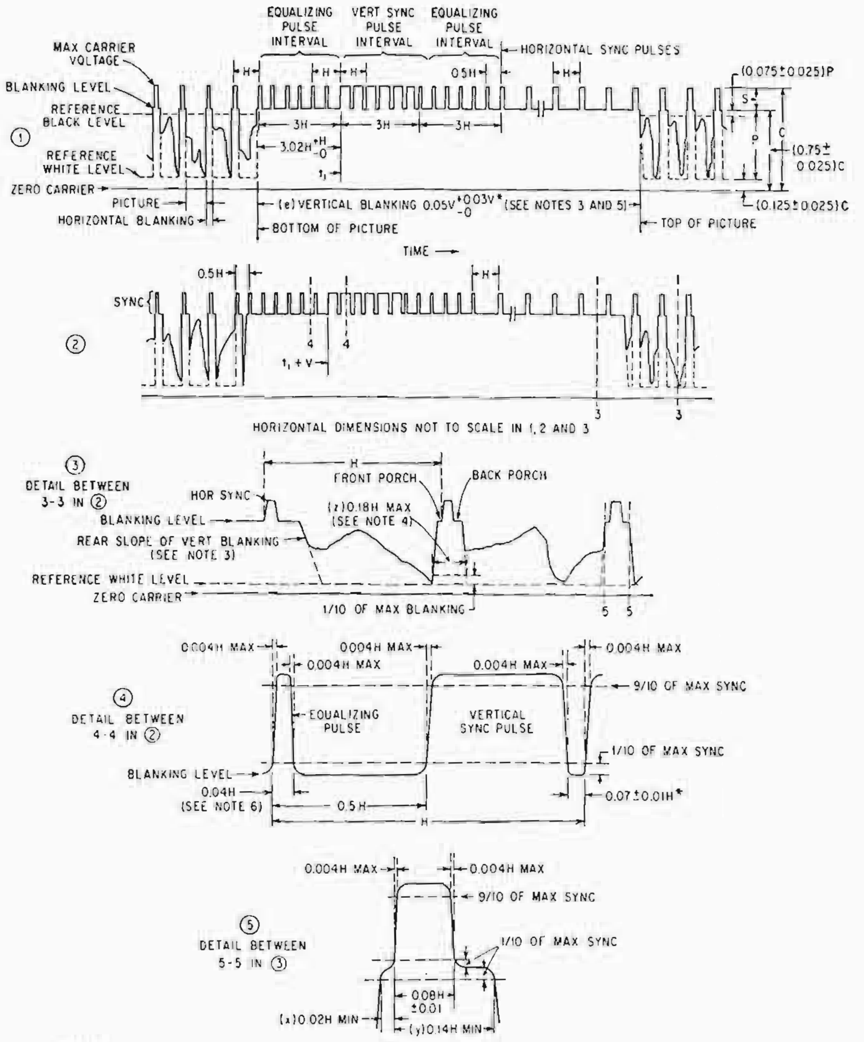
1 H = TIME FROM START OF ONE LINE TO START OF NEXT LINE.
2 V = TIME FROM START OF ONE FIELD TO START OF NEXT FIELD.
3 LEADING AND TRAILING EDGES OF VERTICAL BLANKING SHOULD BE COMPLETE IN LESS THAN 0.1H.
4 LEADING AND TRAILING SLOPES OF HORIZONTAL BLANKING MUST BE STEEP ENOUGH TO PRESERVE MINIMUM AND MAXIMUM VALUES OF (x + y) AND (z) UNDER ALL CONDITIONS OF PICTURE CONTENT.
*5 DIMENSIONS MARKED WITH ASTERISK INDICATE THAT TOLERANCES GIVEN ARE PERMITTED ONLY FOR LONG TIME VARIATIONS AND NOT FOR SUCCESSIVE CYCLES.
6 EQUALIZING PULSE AREA SHALL BE BETWEEN 0.45 AND 0.5 OF AREA OF A HORIZONTAL SYNC PULSE.
7 COLOR BURST FOLLOWS EACH HORIZONTAL PULSE, BUT IS OMITTED FOLLOWING THE EQUALIZING PULSES AND DURING THE BROAD VERTICAL PULSES
8 COLOR BURSTS TO BE OMITTED DURING MONOCHROME TRANSMISSION.
9 THE BURST FREQUENCY SHALL BE 3.579545MC. THE TOLERANCE ON THE FREQUENCY SHALL BE ±10 CYCLES WITH A MAXIMUM RATE OF CHANGE OF FREQUENCY NOT TO EXCEED 1/10 CYCLE PER SECOND PER SECOND.
10 THE HORIZONTAL SCANNING FREQUENCY SHALL BE 2/455 TIMES THE BURST FREQUENCY.
11 THE DIMENSIONS SPECIFIED FOR THE BURST DETERMINE THE TIMES OF STARTING AND STOPPING THE BURST, BUT NOT ITS PHASE. THE COLOR BURST CONSISTS OF AMPLITUDE MODULATION OF A CONTINUOUS SINE WAVE.
12 DIMENSION "P" REPRESENTS THE PEAK EXCURSION OF THE LUMINANCE SIGNAL FROM BLANKING LEVEL, BUT DOES NOT INCLUDE THE CHROMINANCE SIGNAL. DIMENSION "S" IS THE SYNC AMPLITUDE ABOVE BLANKING LEVEL. DIMENSION "C" IS THE PEAK CARRIER AMPLITUDE
13 REFER TO TEXT FOR FURTHER EXPLANATIONS AND TOLERANCES

Fig. 2a. FCC television synchronizing waveform for color transmission.

meter, as above. Section 73.689(a)(2)(i) outlines the direct method of operating power measurement which is similar to the visual transmitter measurement with the exception that the aural transmitter shall be unmodulated during the measurement. This dummy load measurement also allows the power to be measured at varying levels to obtain a plot of output power versus RF transmission-line meter readings to allow for conformance with the plus 10 minus 20 percent power limits allowed as specified in Section 73.689(b)(2). Information developing the output power by the indirect method must be supplied on Form 302, Section II-C-5, and the direct measurement determination may also be supplied.

Antenna and Transmission Line

The next portion of Form 302 requesting exhibit information asks for data on the antenna system. Full information recording the special characteristics of the antenna, if any, should be included here. The same holds true for the case where emergency antennas and transmission lines are provided.



NOTES

1. H = TIME FROM START OF ONE LINE TO START OF NEXT LINE
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3. LEADING AND TRAILING EDGES OF VERTICAL BLANKING SHOULD BE COMPLETE IN LESS THAN 0.1H
4. LEADING AND TRAILING SLOPES OF HORIZONTAL BLANKING MUST BE STEEP ENOUGH TO PRESERVE MINIMUM AND MAXIMUM VALUES OF (x + y) AND (z) UNDER ALL CONDITIONS OF PICTURE CONTENT
*5. DIMENSIONS MARKED WITH ASTERISK INDICATE THAT TOLERANCES GIVEN ARE PERMITTED ONLY FOR LONG TIME VARIATIONS AND NOT FOR SUCCESSIVE CYCLES
6. EQUALIZING PULSE ARE SHALL BE BETWEEN 0.45 AND 0.5 OF AREA OF A HORIZONTAL SYNC PULSE
7. REFER TO TEXT FOR FURTHER EXPLANATIONS AND TOLERANCES

Fig. 2b. FCC television synchronizing waveform for monochrome transmission only.

Frequency Monitors

Section II-C-8-b requests an exhibit explaining any difficulties that may have caused the frequency monitor of the station to indicate excessive frequency deviation and the measures that have been taken to correct this deficiency. In addition, information is requested as to "outside" readings of the operating frequencies that may have been taken by means other than the station's own frequency monitor. Even though the station may be using a frequency monitor, it is still necessary to check against an "outside" standard to ensure that the long-time drift of the monitor is periodically corrected. This can be done at the station by comparing the station monitor readings with a signal received from WWV or WWVH or by having the frequency of the station measured by an independent frequency-measuring service. For either of these cases the "outside" measurements should be described in detail and, of course, the station monitor should be corrected if found in error.

The performance of the visual transmitter is the subject of Sec. II-C-9. In essence, the exhibits submitted in response to II-C-9 should show that the visual transmitter meets all the required transmitter and operational characteristics outlined in Part 73, Subpart E, of the rules.

Variation of Output

Variation of output as specified in Section 73.682(a)(16) is the peak-to-peak change in signal amplitude during a period of one frame. Variation of output results from such things as hum, noise, and incorrect low-frequency response. The rules state that the variation of output at sync peak level and at blanking level shall not exceed 5 percent of the average of the peak signal amplitude.

Method of Measurement

A sample of the transmitter output signal shall be detected, and the resulting video signal viewed on an oscilloscope. Means for establishing a zero reference must be provided. The sync peak should be calibrated in terms of peak power. The height of the highest and lowest sync peaks and the highest and lowest blanking levels shall be measured. Their respective differences shall not exceed 4.5 percent of the highest sync peak. This will assure less than 5 percent variation of the average peak signal amplitude. The overall accuracy of the measuring equipment shall be sufficient to allow measurement of variation of amplitude with an accuracy of ±1 percent of the total peak amplitude. The input test signal shall contain a slightly nonsynchronous 60-Hz sine wave whose peak-to-peak amplitude is not less than 75 percent of the excursion from reference black to reference white.

Overall Attenuation

A measure of overall attenuation versus frequency is requested for frequencies from zero to 4.75 MHz. This measurement is detailed in Section 73.687(a)(1) and (2); 73.699 fig. 11 of the rules and regulations and is, in essence, a diode measurement of the transmitter output when the transmitter is fed a video sweep signal. The limits of this measurement are also established in the rules. It is specified that this measurement be made into the antenna system (for color), but if the characteristics of the antenna and the dummy load have been measured to be substantially the same (as in the power measurement), a case can be made for the use of the dummy load in place of the antenna if this makes the measurement more convenient.

Method of Measurement

Section 73.687(a)(4) states that the attenuation characteristics of a visual transmitter shall be measured by application of a modulating signal to the transmitter input terminals in place of the normal composite television video signal. The signal applied shall be a composite signal composed of a synchronizing signal to establish peak output voltage plus a variable frequency sine wave voltage occupying the interval between synchronizing pulses. (The "synchronizing signal" referred to in this section means either a standard synchronizing wave form or any pulse that will properly set the peak.) The axis of the sine wave in the composite signal observed in the output monitor shall be maintained at an amplitude 0.5 of the voltage at synchronizing peaks. The amplitude of the sine wave input shall be held at a constant value. This constant value should be such that at no modulating frequency does the maximum excursion of the sine wave, observed in the composite output signal monitor, exceed the value 0.75 of peak output voltage. The amplitude of the 200 kHz sideband shall be measured and designated 0 dB as a basis for comparison. The modulation signal frequency shall then be varied over the desired range and the field strength or signal voltage of the corresponding sidebands measured. An an alternate method of measuring, in those cases in which the automatic dc insertion can be replaced by manual control, the above characteristic may be taken by

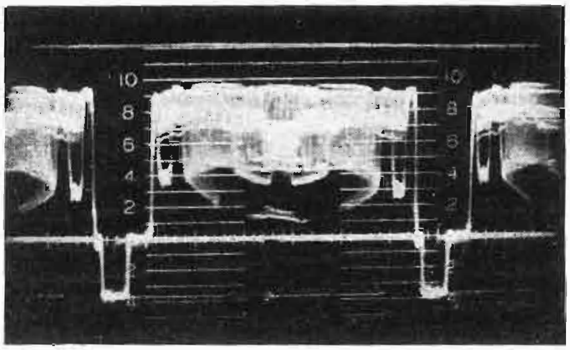


Fig. 3. CRO photograph of H presentation.

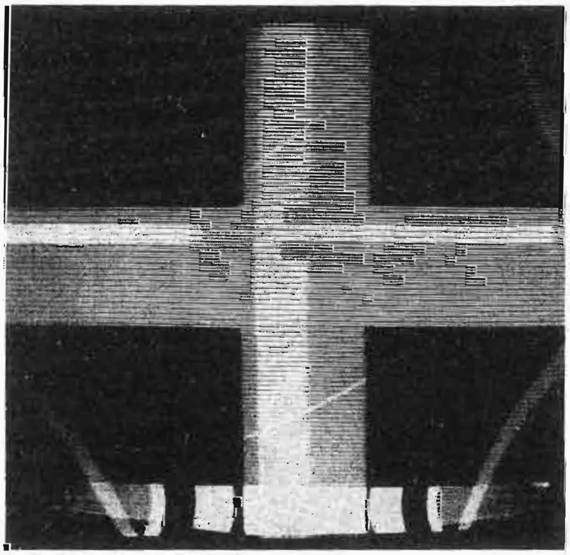


Fig. 4. Photograph of pulse cross display.

the use of a video sweep generator and without the use of pedestal synchronizing pulses. The dc level shall be set for midcharacteristic operation.

The use of a sideband analyzer provides both for this measurement plus considerable additional information helpful in assessing plant performance and preventative maintenance needs. The diode measurement can be checked against the double sideband display and discrepancies due to phase errors and equipment nonlinearities easily discerned.

Field Strength or Voltage of Upper and Lower Sidebands

Section 73.687(a)(3) states that the field strength or voltage of the upper and lower sidebands is to be measured for modulation frequencies from 200 kHz to 5 MHz for the lower sideband and from 200 kHz to 8 MHz for the upper sideband. It should be noted at this time that the rules require measurements of spurious emissions removed in frequency in excess of 3 MHz above or below the respective channel edge as per Section 73.687(a)(1) and these measurements can often be performed at the same time as the upper and lower sideband measurements. In that it may be extremely difficult to make actual field-strength measurements to obtain the above data reliably, it is noted in the rules that measurements made using a probe in the transmission line feeding a dummy load will be accepted. In the measurement of the upper and lower sidebands, it is imperative that the input to the transmitter be held constant throughout the measurement. The detector for this measurement can be an accurately calibrated field-strength meter or a receiver system utilizing a substitution signal generator for calibration. In either case care must be taken to ensure that the field-strength meter or the receiver has a passband characteristic sufficiently narrow to allow only the sideband being measured to register. This is particularly important when the 200 kHz component is being sampled, for this is the reference for the entire measurement. The upper and lower sideband measurement can also be made using a sideband analyzer, but if this is done, great care must be taken to calibrate the device for amplitude linearity. The analyzer is not a perfectly linear device, and if it is used for this measurement, the use of calibrated attenuators is required to obtain the accuracy of measurement desired. The receiver or field-strength meter provides a much more rigorous proof of performance than the analyzer, but the analyzer is most helpful in making a rough check of the system prior to precise measurements.

Throughout the measurement of the upper and lower sidebands the transmitter is adjusted to operate at midcharacteristic and the output is monitored to ensure that 0.75 peak output voltage is never exceeded. Ideally there should be an oscilloscope bridged across the input to the transmitter to monitor the input level at a constant voltage and a demodulator and a modulation monitor on the output to make sure that the modulation limits are not exceeded.

During the setup for this measurement special attention should be paid to the frequencies of minus 1.25, minus 3.58, minus 4.25, plus 4.75, and plus 7.75 MHz. These frequencies are the boundaries of the sideband characteristics (−1.25 and +4.75 MHz down 20 dB), lower sideband of the color subcarrier (−3.58 MHz down 42 dB) as per Sections 73.687(a)(3); 73.699, Fig. 5a, and out-of-band radiation beyond 3 MHz above and below the assigned band edges (−4.25 and

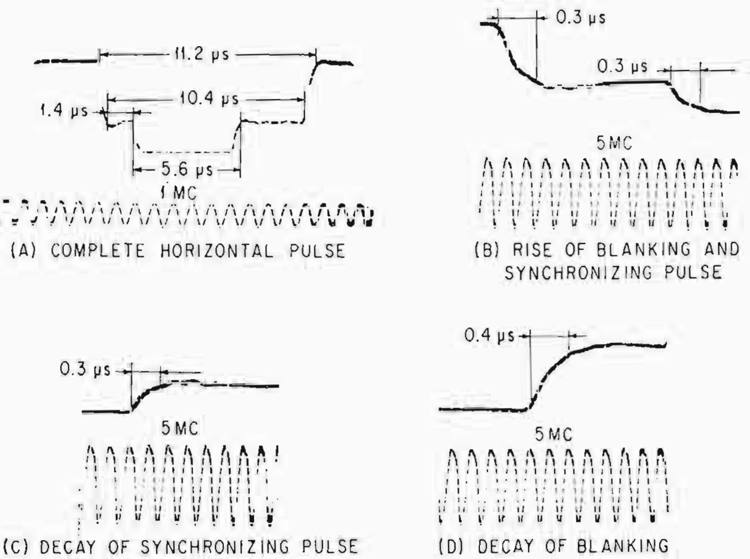


Fig. 5. Waveform showing horizontal synchronizing pulse timing.

+7.75 MHz 60 dB below the peak power) see Section 73.687(i)(1). The region beyond minus 4.25 and plus 7.75 MHz should then be checked to ascertain that there are no spurious signals in these regions. This out-of-band measurement can also be made by applying test-pattern modulation to the transmitter and searching the out-of-band region with the receiver or field-strength meter used above.

Method of Measurement

It is recommended that the sideband characteristic of a visual transmitter be measured by the application of a modulating signal to the input terminals of the transmitter in place of the normal composite television video signal. The signal applied shall be a composite signal consisting of the normal television synchronizing pulses plus a variable-frequency sine wave occupying the intervals between at an amplitude of 0.45 of the voltage of the synchronizing pulse peaks. The amplitude of the applied sine wave shall be maintained at a constant value such that at no modulation frequency does the maximum peak of the sine wave exceed 0.75 of the peak output voltage. The amplitude of the upper 200-kHz sideband when using a 200-kHz modulating frequency shall be measured by means of a field-strength meter or equivalent and used as the reference level. The modulating frequency shall then be varied over the range from 200 kHz to 8 MHz, and the corresponding amplitudes of the upper and lower sidebands measured.

As an alternate method of measuring in those cases in which automatic dc insertion can be replaced by manual control, the above characteristics can be taken by the use of a signal generator and without the use of blanking and synchronizing pulses. The transmitter operating level shall be set for midcharacteristic operation −0.50 of the voltage corresponding to synchronizing peak.

Out-of-band Emissions

Section 73.687(i)(1) states that "all emissions removed in frequency in excess of 3 MHz above or below the respective channel edge shall be attenuated no less than 60 dB below the visual transmitted power." The measurements described above determine the voltage of the upper and lower sidebands and not the relationship of these values to the transmitter peak power. To relate measurements of this type to the transmitter peak power for the purpose of determining compliance with the out-of-band requirements, additional calculations are required. It is necessary to (1) add an additional 6 dB to the measured value to cover the case of one sideband of a 100 percent modulated amplitude-modulation system, (2) add 3.5 dB to compensate for the modulation index of 75-15/90, and (3) add 6.9 dB to correct for the fact that the axis of the modulation is at a point equal to 45 percent of carrier peak and not at carrier peak. Thus, the emission below peak transmitted power is determined by establishing the voltage level below the 200-kHz point (assuming that it is the maximum point) as above and adding to that value a correction of 16.4 dB to relate this figure to emission below the peak transmitted power.

Attenuation of RF Harmonics

The out-of-band emissions requirements also cover radio-frequency harmonics for both aural and visual transmitters. It is specified that these shall be as low as the state-of-the-art permits and in no case attenuated less than 60 dB below the visual peak transmitted power. There are a number of methods that can be used to measure the level of the radio-frequency harmonics, and the simplest is the use of a field-strength meter that has sufficient selectivity and rejection of the fundamental to allow accurate measurements. It is also possible to use a fundamental rejection filter with a field strength meter that does not have sufficient isolation at the fundamental frequency. A second method which can be used is the substitution method wherein a calibrated receiver, fundamental rejection filter and a substitution signal generator are used to simulate a calibrated field-strength meter. A third method utilizes rejection notch filters, heterodyning oscillators, IF amplifier, and a detector. Any of the above systems are acceptable to the FCC provided sufficient data are included with the measurement to attest to the accuracy of the method used.

In all cases the harmonic measurements should be made in the transmission line following the harmonic filters, if used. Measurements are not required beyond 1,000 MHz for transmitters on Channels 2 to 13 or beyond 3,000 MHz for Channels 14 to 83.

TRANSMITTED SIGNAL WAVEFORM

Transmission standards for the transmitted signal waveform are fully detailed in Sections 73.687(a)(7) and (8); 73.682(a)(5) and (6); 73.699 (Figs. 5, 5a, 6 and 7) of the rules as shown in Figs. 2a and 2b. Section II-C-9-b of Form 302 requests an exhibit demonstrating conformance to these standards. It also notes that "Until the form of these measurements may be specified by the Commission, the character of this data is left to the discretion of the applicant."

As in all other data required, the burden of proof is on the applicant. The FCC has accepted many different presentations covering this proof

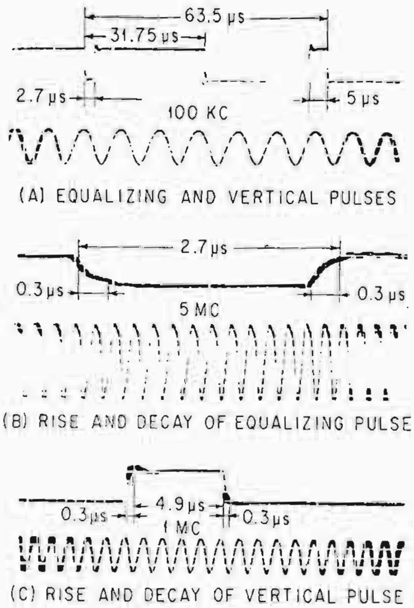


Fig. 6. Waveform showing vertical synchronizing pulse timing.

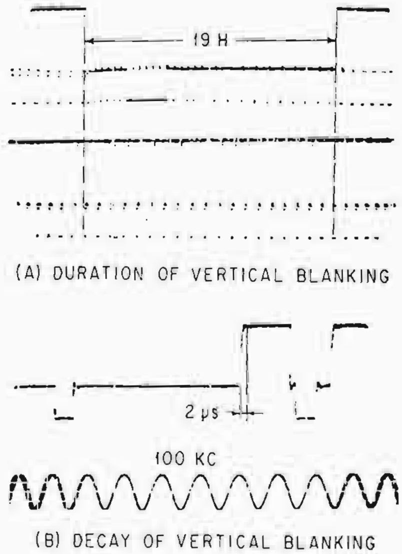


Fig. 7. Waveform showing vertical blanking pulse timing.

of conformity to the rules, but not all of them are of the type that gives definite information. It has been thought by some that the submission of a waveform or pulse-cross photograph (Figs. 3 and 4) taken from the CRO fed by the station demodulator will suffice to show conformity to the transmitted-waveform requirement. A careful check of the resolution possible in such a photograph and an analysis of the technique involved show that the errors possible in interpreting such a display are far greater than the tolerances allowed in the rules.

A simple and straightforward method of preparing such an exhibit is simply to extend the normal maintenance techniques for the sync generator. Measure all the pertinent waveforms accurately on an oscilloscope having the facility for the addition of timing pulses and having sufficient rise time, magnification, and line-selection ability to show individually the section of the signal being studied (Figs. 5 through 7).

Since the source of the synchronizing waveform is the main studio generator, the first part of this test should carefully measure the signals as they arrive at the transmitting plant. This is a normal maintenance procedure of the television plant and checks out not only the alignment of the sync generator but the processing and distribution amplifiers that may be used in the master control location and the studio-to-transmitter circuit. After it has been determined that the sync signal arriving at the transmitter plant is "standard" it is fed to the transmitter. The transmitted characteristics can then be measured using a probe in the output transmission line to the antenna or the dummy load feeding a calibrated demodulator and oscilloscope. An example of this technique and a method of reporting the measurement are shown in the sample "proof" below.

Transmitted Test Pattern

Section II-C-9-c of Form 302 requests that an exhibit be prepared containing a photograph of the transmitted test pattern from a receiver or a monitor connected to the transmitter output. This is a straightforward task easily accomplished. The addition of one other photograph, that of the test pattern signal that is fed to the input of the transmitter, will add a wealth of information to the "proof." A comparison of the "in" and the "out" can then be made to see if any degradation in the "out" test pattern is caused by the transmitter or is present in the incoming signal.

For color transmission there are a number of measurements required that are not listed on Form 302 but are noted in FCC mimeographs and detailed in Sections 73.687(a)(5) and (9); 73.682 (a)(5) of the rules. Conformity to the color-transmission standards requires measurements of transfer characteristic, differential gain, differential phase, and envelope delay as well as all the previously measured transmission characteristics.

Transfer Characteristic

Low-frequency linearity and differential gain is defined in Section 73.687(a)(9) of the rules as the transmitter transfer characteristic and can be measured rather simply. The rules state that the transfer characteristic shall be substantially linear and assigns no values to the degree of linearity. It behooves the color broadcaster to maintain maximum linearity for faithful color transmission. Extreme variations in linearity will also affect the fidelity of the monochrome transmissions. A stairstep generator is the simplest tool for this type of measurement. This unit along with a high-pass filter and an oscilloscope will allow accurate measurements of linearity or transfer characteristics to be made in very short order. Such a measurement is described below in the sample "proof." Once again it is advisable, while making this measurement on the transmitter system, to make a similar measurement on the overall studio-transmitter system for the information of the technical staff. Submission of this extra data is not required, but it allows a check to be made to ensure that there is no predistortion of linearity being used to compensate for the deficiencies of one or more elements of the transmitter plant.

Low-frequency Linearity

Low-frequency linearity is defined as that characteristic which describes the change in RF output signal amplitude resulting from and corresponding to a change in input signal amplitude. No FCC specification is given, but it is advisable as a minimum standard to keep the linearity within 1.5 dB for 10, 50 or 90 percent average picture level when using a stairstep signal having 10 steps of equal amplitude covering the reference-white to blanking-level region.

Method of Measurement

The visual transmitter shall be fed a composite signal consisting of synchronizing pulses and a stairstep signal having at least 10 steps of equal amplitude. The test signal shall be sufficient to modulate the visual transmitter to reference white while maintaining rated blanking level and rated visual transmitter output power. With the use of a linear display monitor of the RF signal or of the RF envelope, the amplitudes of the different steps are compared using the greatest amplitude step as the reference. The linearity will be the ratio, expressed in decibels, of the amplitude of the tallest step to the amplitude of the shortest.

Differential Gain

Differential gain is the difference in gain of the system for a small high-frequency sine-wave signal at two stated levels of a low-frequency signal upon which it is superimposed. With no specific FCC specification, but interpreting the color-signal specification in Sections 73.682 (a)(20), 73.699 (Fig. 8) of the rules. It is advisable that the differential gain be maintained below 1.5 dB for 10, 50, and 90 percent average picture levels.

Method of Measurement

The visual transmitter shall be fed a composite signal consisting of synchronizing pulses and a low-frequency signal with a superimposed 3.58 MHz sine-wave signal whose peak-to-peak amplitude is 20 percent of the low-frequency signal amplitude between blanking and reference white. This composite test signal shall be sufficient to modulate the visual transmitter to reference white while maintaining rated blanking level and rated visual transmitter output power. With the use of a linear demodulator, the visual transmitter output is sampled, detected, and passed through a high-pass filter to an oscilloscope or any other suitable means of observing the 3.58-MHz component of the test signal. Any deviation from a constant amplitude display of the 3.58-MHz signal when viewed at the line-rate frequency is the differential-gain variation. The differential gain at any point is the ratio, expressed in decibels, of the amplitude of the maximum amplitude region referred to the amplitude of the point under consideration.

Differential Phase

Conformity with Section 73.682(a)(20) regarding color-signal specifications can be further assured by a measurement of differential phase. Differential phase is the difference in phase shift through the system for a small high-frequency sine-wave signal at two stated levels of a low-frequency signal on which it is superimposed. When interpreting these color standards, it is advisable to adjust the station equipment so that the differential phase shall be less than 7° at 3.58 MHz when the reference burst region of a 50 percent average picture level signal is used as reference. In addition, the total differential phase between any two levels shall not exceed 10°.

Method of Measurement

The visual transmitter shall be fed a composite signal consisting of synchronizing pulses and a low-frequency signal with a superimposed 3.58-MHz sine-wave signal whose peak-to-peak amplitude is 20 percent of the low-frequency-signal amplitude between blanking and reference white. This composite test signal shall be sufficient to modulate the visual transmitter to reference white while maintaining rated blanking level and rated visual transmitter output power. With the use of a diode demodulator, the visual transmitter output is sampled, detected, and passed to any suitable phase-measuring equipment. The differential phase error is the difference in phase of the 3.58-MHz wave between the burst region of the composite signal and any other level under consideration.

If the station is capable of generating local color signals and has a color-bar generator and Vectorscope, compliance with the color-signal specifications can be proved by a measurement of the phase and amplitude of the transmitted color bar, I and Q signals.

Although color specifications are under Transmission Standards in the rules and not specifically listed as a transmitter characteristic, it is usually satisfactory to make these measurements at the transmitter plant. The same measurements should, however, be made from the studio plant to ensure that the transmission of color signals will be proper under the normal program routing. If it can be done, these measurements should be made from the main studio, checking the entire system for conformity to the transmission standards as the synchronizing waveforms were checked above.

As an added reminder, care must be taken during all the above measurements to assure that the transmitter and all the input equipment in the transmitting plant and in the component links between the studio and the transmitter are operating at their normal settings. The input to the transmitter modulator should be adjusted for the normal program excursions, and the output signal as viewed from the station demodulator should indicate that there is no overloading of the circuits. In brief, normal conditions should prevail.

Envelope-Delay

At this writing, the only practical method of making envelope-delay measurements is through the use of a device known as an envelope-delay measuring set. This measurement is outlined briefly in the sample "proof" below and more fully in the instructions for the use of the instrument. There are instruments presently under development which will provide simpler methods of making this measurement, and industry committees are at work attempting to develop simple coincidence checks to ascertain compliance with the requirements of Section 73.687(a)(5) of the rules. Graphical analysis of square-wave measurements can be used in making this check, but it is an extremely time-consuming effort, requiring a host of accurate measurements and resulting in answers whose possible errors may exceed the tolerances allowed in the rules.

If equipment to measure the envelope-delay characteristics of the transmitter is not available, reference can be made to the fact that the envelope-delay correction filters installed for the particular transmitter have been designed and adjusted by the manufacturer to provide the proper overall envelope-delay characteristic. The approximate accuracy of this adjustment can be checked by observing the fidelity of a color-bar test signal and also by checking a square-wave signal for equality of "ringing" before and following a transition when the signal is observed through an ideal demodulator. Even though the envelope-delay-correction filters are passive, an attempt should be made at the earliest opportunity to make an actual measurement of the overall system to ensure that the proper predistortion and correction are being made. It is hoped that new devices for this measurement will be available shortly.

Envelope-delay is the first derivative of the phase vs. angular velocity characteristic at a particular frequency. In essence it is a measure of the coincidence of arrival of chrominance and luminance information and, per the FCC specifications, the predistortion introduced to produce this coincidence in a color receiver.

Method of Measurement

Envelope-delay measurements shall be made with commercial envelope-delay-measuring equipment under the same operating conditions as described above for overall attenuation measurements. The RF diode can be used for measurements above 1.25 MHz. (Further information is given in the sample "proof" below.)

It must be kept in mind here, as above, that even though the specifications in the rules are for the transmitter, the envelope delay in the entire studio and link system should be kept within the FCC tolerances in order to provide the highest fidelity of color transmission within the specifications of the NTSC system. For the benefit of the station the envelope delay of this entire system should be measured periodically as both a maintenance tool and a proof of performance.

Section II-C-10 of Form 302 requests exhibits describing fully measurements of performance of the aural system including "all circuits between the main studio microphone terminals and the antenna output, including telephone lines pre-emphasis circuits and any equalizers employed except for microphones, and without compression if a compression amplifier is installed." Sections 73.687(b)(1), (2), (3), (4), (5), (6), (7) list the operational characteristics required of the system and further recommend that none of the three main divisions of the system (transmitter, studio-to-transmitter circuit, and audio facilities) shall and further recommend that none of the three main divisions of the system (transmitter, studio-to-transmitter circuit, and audio facilities) shall

contribute more than half of the allowable total degradation for the entire system. This requires that not only the system as a whole be measured but that measurements be made separately on each of the three main divisions.

Audio-frequency Response

The measurement of the audio-frequency response of the aural system is a straightforward type of measurement but requires modifications of the usual "amplifier" testing techniques to truly measure the performance of the aural transmission system. Since there is a difference in peak voltages reached by pure sine-wave and normal program signals for equivalent volume-indicator readings, adjustments of the input level of the test signals should be made to compensate for this difference. One method is to use an "elevated" level 10 dB above normal (-50 dBm at microphone input) to simulate 100 percent modulation. This technique will measure the frequency response for normal program transmission and not simply the response of the system to sine waves. The detailed procedure for this measurement is described in the sample "proof" below.

Distortion

System distortion should be measured with the same setup used for the frequency-response measurement above to save time and minimize setup errors.

FM and AM Noise

Frequency-modulation noise on the carrier is the residual frequency modulation resulting from disturbances produced in the transmitter itself within the band of 50 to 15,000 Hz. The level is expressed as the ratio of the residual frequency swing in the absence of modulation to the full-frequency swing with modulation as weighted by the effect of a standard 75-μ sec deemphasis circuit. FM-noise-level measurements can be made with the distortion-measurement equipment used for the above measurement.

Method of Measurement

The frequency-modulation noise level can be obtained by demodulating a sample of RF output of the transmitter and comparing the rms voltage developed by the demodulator in the absence of modulation voltage to the rms voltage obtained with 100 percent, 400 Hz modulation. The audio input terminals of the transmitter shall be shunted by a resistance equal to the transmitter input impedance. The frequency-response characteristic of the demodulator shall be within ± 1 dB of the standard 75-μ sec deemphasis curve from 50 to 15,000 Hz.

The amplitude-modulation noise level on an aural transmitter carrier is the ratio of the rms value of the amplitude-modulation components (50 to 15,000 Hz) of the carrier envelope to the rms carrier value in the absence of applied modulating voltage.

Measurement of the carrier amplitude-modulation noise level can be accomplished by the use of a linear peak-carrier-responsive AM detector with 75-μ sec deemphasis coupled to the output of a transmitter. Readings are made of the dc voltage and the rms value of the ac component across the detector load resistor. The dc voltage must be multiplied by 0.707. These measurements shall be made in the absence of modulating voltage. The audio input terminals of the transmitter shall be shunted by a resistance equal to the transmitter input impedance. Equipment for this measurement is commercially available or can be assembled by the station.

In all cases, the equipment used for any of the measurements should be identified by manufacturer, type, and serial number, and if composite, a general description of the device should be included in the "proof."

THE PROOF-OF-PERFORMANCE

Herein follows a composite sample "proof" made up from six "proofs." A composite of these "proofs" was chosen rather than a sample of one "proof" in order to illustrate as comprehensively as possible the method of proving performance.

(SAMPLE PROOF-OF-PERFORMANCE)

STATION CALL, CITY

AURAL AND VISUAL
PERFORMANCE MEASUREMENTS

REPORT (NUMBER)

(DATE)

(EXAMPLE)

STATE OF — — —
SS:
COUNTY OF — — —

(include here qualifications of
engineer making measurements)

Subscribed and sworn to before
me this — — — day of — — — (Notary)

(Note: Affidavit not required if engineer performing or directing measurements signs Form 302, Section II, page 2, attesting to validity of measurements.)

SUMMARY

This report details aural and visual performance measurements made at television station (call), (city), (state), following the installation of ______ in accordance with Television Broadcast Station Constructing Permit ______________ , dated___________. The measurements reported herein are submitted as engineering exhibits associated with application for television broadcast station license for station (call), and establish that the (call) transmitter and studio equipments are operating in full conformity with the Rules and Regulations as established by the Federal Communications Commission and in effect as of this date.

INTRODUCTION

In association with Section II of subject application for license this exhibit answers fully all questions pertaining to the operation and technical performance of (call). All of the measurements reported herein were made on the complete transmitting plant and reflect the true and normal operation of television Station (call) for the effective radiated power specified in Construction Permit ______, dated ___________. Construction authorized by this permit was begun on ____________ and was completed on ___________. In addition to the measurements specified in Form 302 additional measurements have been made to ensure that the entire plant meets the more rigid requirements for color transmission and they are described herein.

TRANSMITTER POWER-OUTPUT DETERMINATION (SECTION C-5)—(EXAMPLE)

The power output of both the visual and aural transmitters was measured by the use of a calibrated dummy-load wattmeter, the impedance of which was measured and found to be substantially equivalent to the transmitting-antenna system impedance. Impedance measurements of the dummy-load wattmeter and the antenna system were made with a General Radio Type 1602-A admittance meter to establish that the impedance of the antenna system was equivalent to that of the dummy load wattmeter for power-determination purposes. The VSWR of the dummy load was found to be less than 1.05 in a 51.5-ohm line over the 54-to 60-MHz band, and the antenna system VSWR was 1.11 or less over the 54- to 60-MHz band as shown in Fig. P-1. The wattmeter

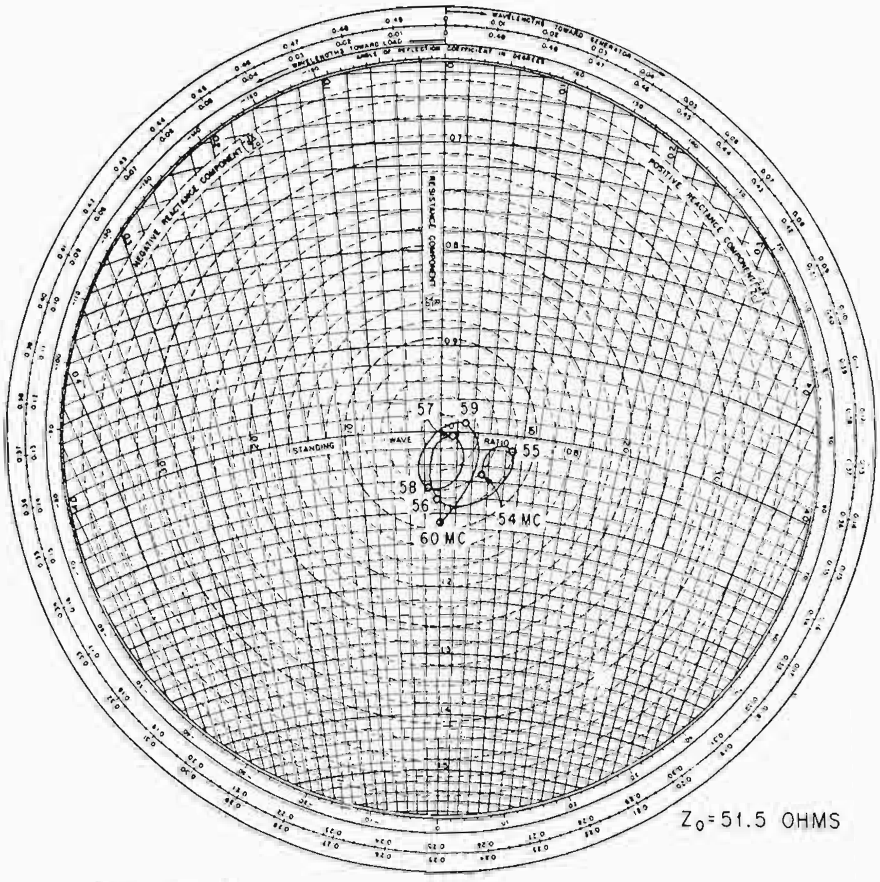


Fig. P-1. Measured impedance of antenna at diplexer input.

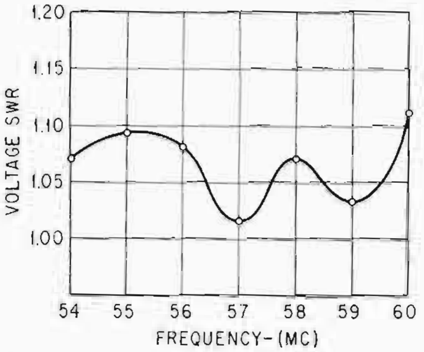


Fig. P-2. Voltage standing-wave ratio of antenna and transmission line.

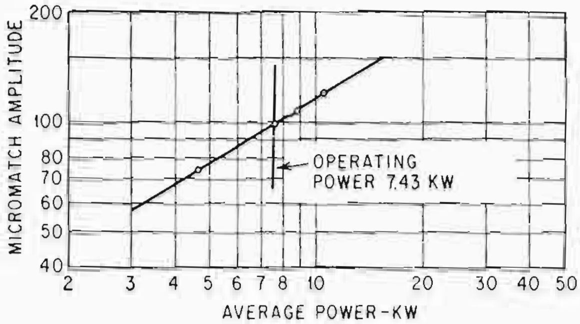


Fig. P-4. Reflectometer calibration in aural transmitter.

(General Electric Co. Model 19193) contains a calibrated voltmeter which reads average power directly. The visual transmitter is equipped with a peak-reading voltmeter coupled to the output transmission line as well as a reflectometer which indicates the forward and reverse voltage in the transmission line. The aural transmitter also contains a reflectometer unit for the measurements of forward and reverse voltage in the output transmission line. Fig. P-2 shows the voltage standing-wave ratio of the antenna system and transmission lines. This figure was obtained from the data plotted in Fig. P-1.

In measuring the power output of the visual transmitter, the output of the transmitter vestigial sideband filter was connected directly to the dummy-load wattmeter. The transmitter was then modulated with an all-black picture and the standard 25 percent sync. The average power was read on the wattmeter indicator, and the peak power (power during sync pulse) was obtained by multiplying the average power by a factor of 1.68. Reflectometer readings were noted for several adjustments of transmitter power output, and a graph of the relationship was prepared. This graph is presented in Fig. P-3 and serves as a calibration of transmitter peak power output during normal operation.

The power output of the aural transmitter was measured by connecting the transmitter output directly to the dummy-load wattmeter, described above. The efficiency factor F was determined from this measurement and used in completing paragraph II-C-5 of FCC Form 302. The transmitter was adjusted for a number of different operating levels, and the average power was read directly from the indicating meter of the dummy-load wattmeter. A plot of the transmitter output vs. aural reflectometer reading is presented as Fig. P-4. Thus calibrated, the reflectometer reading serves as an indication of transmitter output power during normal operation.

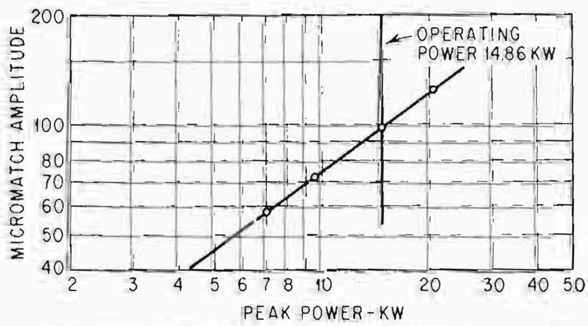


Fig. P-3. Reflectometer calibration in visual transmitter.

The (call) antenna system has a VSWR of 1.11 or less over the 54- to 60-MHz band. This means that the reflection coefficient is less than 0.052 and that the power reflected from the antenna system is less than $(0.052)^2$, or 0.27 percent of the power reaching the antenna. Therefore, the reflectometer and peak-reading voltmeter give a true measure of the power entering the antenna system.

After the measurements described above had been made, the visual transmitter was adjusted to give a peak output power of 11.7 dBk (14.8 kw) at the output of the diplexer. The power gain of the antenna system is 5.65 dB at visual frequency, and the transmission-line efficiency is 86 percent, representing a loss of 0.67 dB. The diplexer being a hybrid device has a negligible loss and, accordingly, this combination results in an effective radiated power of 16.7 dBk (46.8 kw) as specified in the construction permit.

The aural transmitter was adjusted for an output of 8.7 dBk (7.4 kw) average power with an antenna gain of 5.65 dB and a transmission-line efficiency of 86 percent, representing a loss of 0.67 dB, thus giving an effective radiated power of 13.7 dBk (23.4 kw).

ANTENNA AND TRANSMISSION LINE (SECTION II-C-6) — (EXAMPLE)

There are complete regular and auxiliary transmitting facilities at the (call) plant as well as complete regular and auxiliary antenna and transmission lines. Either transmitter can be fed

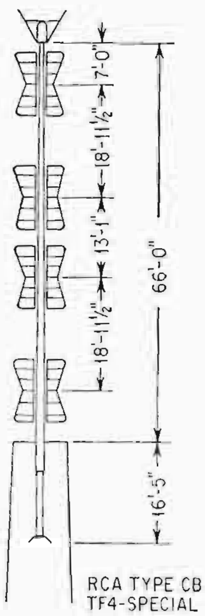


Fig. P-5. Transmitting antenna (designed for null fill-in).

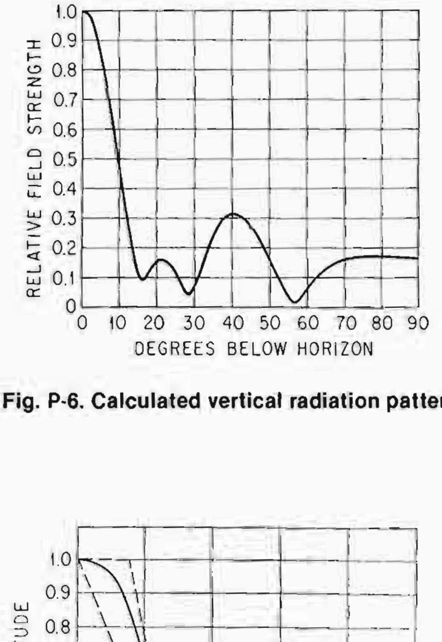


Fig. P-6. Calculated vertical radiation pattern.

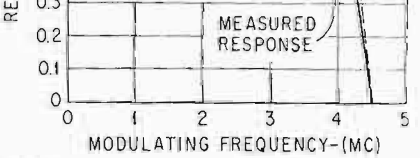


Fig. P-7. Over-all attenuation vs. frequency of visual transmitter (as measured with a diode on the RF transmission line).

to either antenna by means of a patch panel. The auxiliary antenna and transmission line are described in the application for construction permit (File No. and date)

The regular transmitting antenna is an RCA Type CB-TF4-special. The essential mechanical details of this antenna are shown in Fig. P-5. This antenna is designed for null fill-in, and the calculated vertical-radiation pattern is shown in Fig. P-6.

FREQUENCY MONITORS (SECTION II-C-8) — (EXAMPLE)

In addition to regular readings of the station visual and aural frequencies made on the station monitors, measurements have been made by (Name) Measurements Company, (Address), (City), (State), for the purpose of adjusting the station monitors, with the following results:

Transmitter	T & T Radio Measurements Company, measurement cycles	Station monitor measurement cycles
Visual	55,250,040	55,250,100
Aural	59,750,060	59,750,100
Visual	55,250,030	55,250,000
Aural	55,750,050	59,750,050

The assigned frequency is 55,250,000 Hz for the visual transmitter and 59,750,000 cycles for the aural transmitter.

PERFORMANCE DATA-VISUAL TRANSMITTER (SECTION II-C-9) VARIATION OF OUTPUT—(EXAMPLE)

The peak-to-peak variation of transmitter output within one frame of the video signal was measured while the transmitter was being fed with a 60-Hz sine wave and standard synchronizing signals and was found to be 4 percent of the average sync peak amplitude.

OVERALL ATTENUATION VERSUS FREQUENCY (SECTION II-C-9-a-1) — (EXAMPLE)

Fig. P-7 is a plot of the measured overall attenuation versus modulation frequencies from 0 to 5 MHz. These data were obtained by feeding the transmitter input system (containing all corrective equipment required to meet the FCC rules and regulations) with a video sweep signal with the transmitter operating at midcharacteristic, and observing the output of a diode coupled to the RF transmission line feeding the antenna system. This plot was prepared by taking data from the CRT of a Tektronix Type 524-D oscilloscope using inserted single-frequency marker signals for

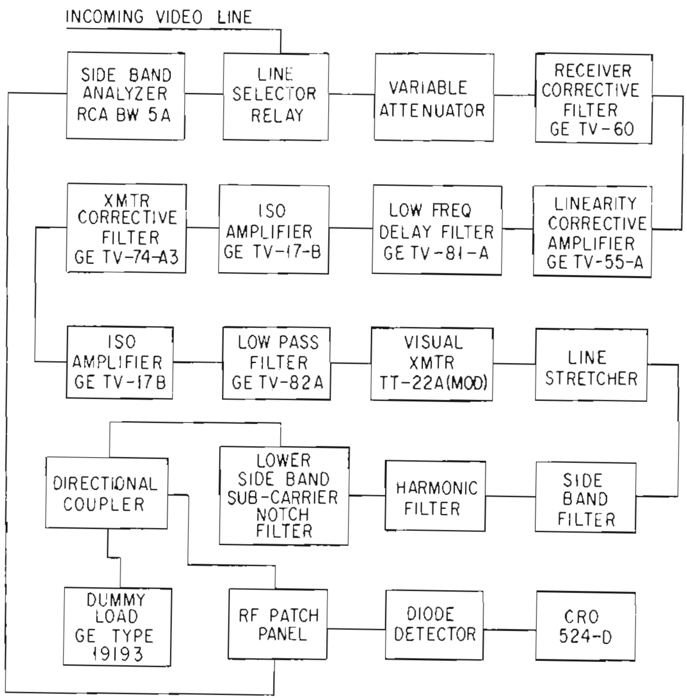


Fig. P-8. Block diagram for over-all attenuation measurements.

frequency determinations. Fig. P-8 is a block diagram of the equipment setup used in making these measurements.

FIELD STRENGTH OR VOLTAGE OF UPPER AND LOWER SIDEBANDS (SECTION II-C-9-a-2) — (EXAMPLE)

Fig. P-9 is a plot of the relative voltage amplitude of the (call) transmitter upper and lower sidebands from 5 MHz below carrier to 8 MHz.

These measurements were all made at the output of the transmitter which was connected to the dummy load. The measuring equipment was set up as shown in Fig. P-10. The field-strength meter was tuned successively to the upper and lower sideband for each modulating frequency used, the input being held constant at all frequencies, and the amplitude was recorded. As shown by Fig. P-9 the attenuation of the upper and lower sidebands of the (call) transmitter fully meets the Commission's Rules concerning the relative levels of upper and lower sidebands also shown on Fig. P-9.

OUT-OF-BAND EMISSIONS—(EXAMPLE)

Section 73.687(i) of the rules states that "all emissions removed in frequency in excess of 3 MHz above or below the respective channel edge shall be attenuated no less than 60 dB below the visual transmitter power." As shown in Fig. P-9 the voltage amplitude for a frequency 4.25 MHz below carrier, relative to a 200 kHz reference, is 57.8 dB down. To relate this measured value to the actual emission, relative to visual transmitted peak power, it is necessary to (1) add an additional 6 dB for the case of one sideband of a 100 percent modulated amplitude-modulation system, (2) add 3.5 dB to compensate for the modulation index of 75-15/90, and (3) add 6.9 dB to correct for the fact that the axis of the modulation is at a point equal to 45 percent of carrier peak and not at carrier peak. Thus, the emission

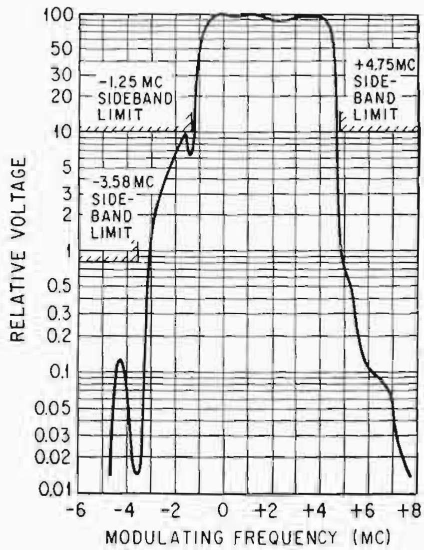


Fig. P-9. Measured voltage amplitude of upper and lower sidebands.

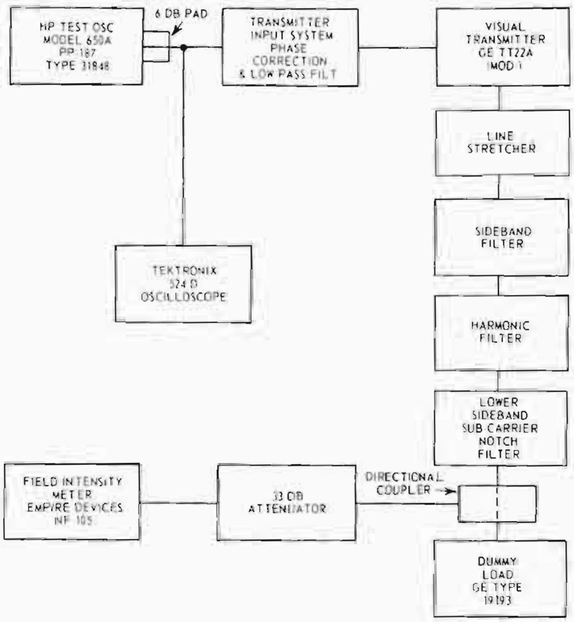


Fig. P-10. Block diagram of equipment used for measuring voltage of upper and lower sidebands.

at −4.25 MHz is at least 57.8 dB + 6 dB + 3.5 dB + 6.9 dB = 74.2 dB below visual transmitted peak power.

In the case of the upper-band-edge requirement, Fig. P-9 shows a measured value of −77.2 dB for a frequency 7.75 MHz above visual carrier. Adding the correction factors, as above, the emission is 77.2 dB + 6 dB + 3.5 dB + 6.9 dB = 93.6 dB below transmitted peak power.

ATTENUATION OF RF HARMONICS — (EXAMPLE)

Fig. P-11 shows the equipment setup that was used for the measurement of the attenuation of RF harmonics in the output of the aural and visual transmitters.

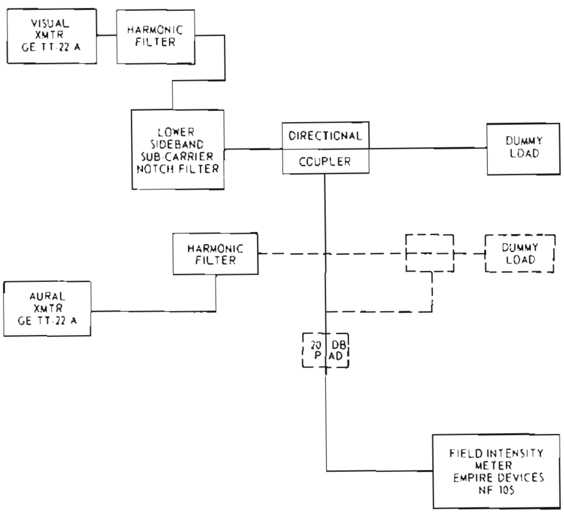


Fig. P-11. Block diagram of equipment used to measure attenuation of RF harmonics.

Using the equipment shown in Fig. P-11, measurements were made of the attenuation of the aural and visual harmonics with the transmitters feeding a General Electric Type 19193 dummy load. A directional coupler was used to probe the transmission line in these measurements. The variations of output voltage versus frequency of this coupler were compensated for during these measurements. The results of these measurements are shown in Figs. P-12 and P-13 and prove that the harmonic attenuation of the (call) transmitters are well within the Commission's requirements.

TRANSMITTED SIGNAL WAVEFORMS (SECTION II-C-9-b) — (EXAMPLE)

The FCC Rules and Regulations specify that the transmitted waveforms shall conform to Sections 73.682(a)(5), 6; 73.687(a)(7), 8; 73.699 Fig. 2, 5, 5a, 6, and 7, as modified by vestigial sideband operation. Synchronizing and blanking pulse durations and slopes are specified, not taking into account the effects of vestigial sideband operation.

A studio camera was set up in typical fashion, but with the pedestal control adjusted to give a maximum white picture and the gain reduced to eliminate noise. This signal with sync was fed to the transmitter through the normal master control routing, and the transmitter was modulated in the normal fashion. The signal was so adjusted that blanking was 75 percent of sync and white was 10 percent of sync. An RF diode probe in the antenna transmission line was used to feed a Tektronix 524-D oscilloscope, and photographs

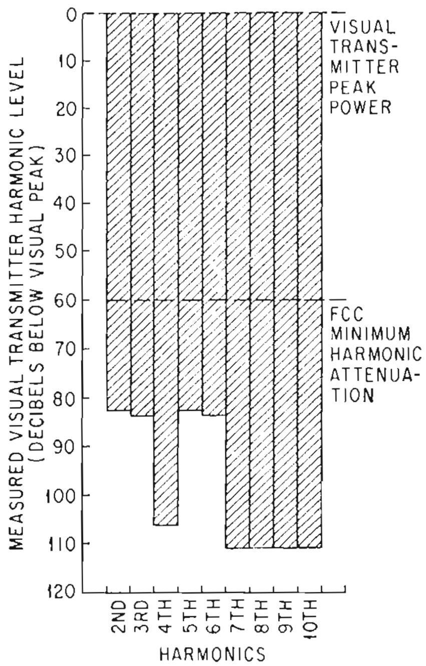


Fig. P-12. Measured visual transmission-line harmonic content.

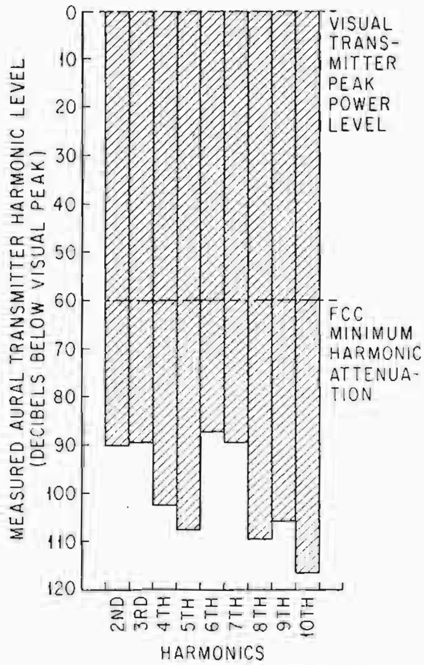


Fig. P-13. Measured aural transmission-line harmonic content.

TABLE 1
Analysis of Synchronizing Waveforms

Portion of synchronizing signal	Measured[a] times	FCC rules & regulations specifications
Duration of horizontal blanking (10% black)	11.0μsec	11.44μsec max
Duration of horizontal blanking (90% black)	10.9μsec	10.48μsec min
Duration of horizontal pulse	5.8μsec	5.08 / 4.45 μsec
Rise of horizontal pulse	0.183μsec	0.254μsec max
Decay of horizontal pulse	0.196μsec	0.254μsec max
Rise plus decay of horizontal blanking	0.62μsec	0.957μsec max
Duration of front proch	1.42μsec	1.27μsec min
Duration of equalizing pulse	2.6μsec[b]	2.54μsec
Rise of equalizing pulse	0.195μsec	0.254μsec max
Decay of equalizing pulse	0.152μsec	0.254μsec max
Rise of vertical pulse	0.21μsec	0.254μsec max
Decay of vertical pulse	0.21μsec	0.254μsec max
Duration of serration in vertical pulse	4.7μsec	3.81 / 5.08
Duration of vertical blanking	20 H	17.8 H / 20.4 H
Decay of vertical blanking	2.5μsec	6.355μsec max
Back porch from horizontal pulse to start of color burst	0.6μsec	0.381μsec min
Number of cycles in color burst	8½ Hz	8 Hz min
Rise of vertical blanking not listed but observed to be same as decay.		

[a] The measured times are for waveforms at the output of the transmitter and, therefore, include the effects of the vestigial sideband system.

[b] The area of the equalizing pulse should be 45 to 50 percent of the horizontal pulse. It was measured from the photograph to be 49 percent of the horizontal pulse.

were taken of pertinent waveforms. Timing signals were also inserted in the oscilloscope. These photographs were enlarged to a convenient size, and graphical measurements made of the pertinent durations and slopes. These data are presented in Table 1 along with the requirements of the rules. Some of the rise and decay times do not conform exactly with those specified in the rules, and these discrepancies are attributable to the vestigial-sideband operation which is known to lengthen the rise and decay times of pulses of this type. These rise and decay times of the signals fed into the transmitter system were measured and found to be within the specifications of the rules and regulations. Table 1 listed the output-waveform characteristics only.

PHOTOGRAPH OF TRANSMITTED TEXT PATTERN (SECTION II-C-9-c) — (EXAMPLE)

Fig. P-14 is a photograph of a (call) test pattern, taken from a monitor connected to the input of the visual transmitter. Fig. P-15 is a photograph

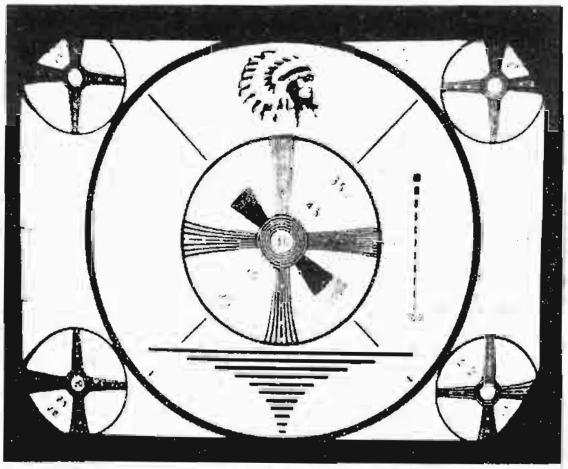


Fig. P-14. Photograph of test pattern—transmitter input.

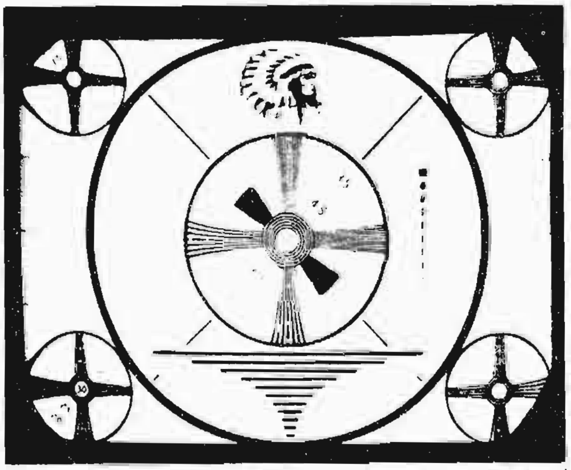


Fig. P-15. Photograph of test pattern—transmitter output.

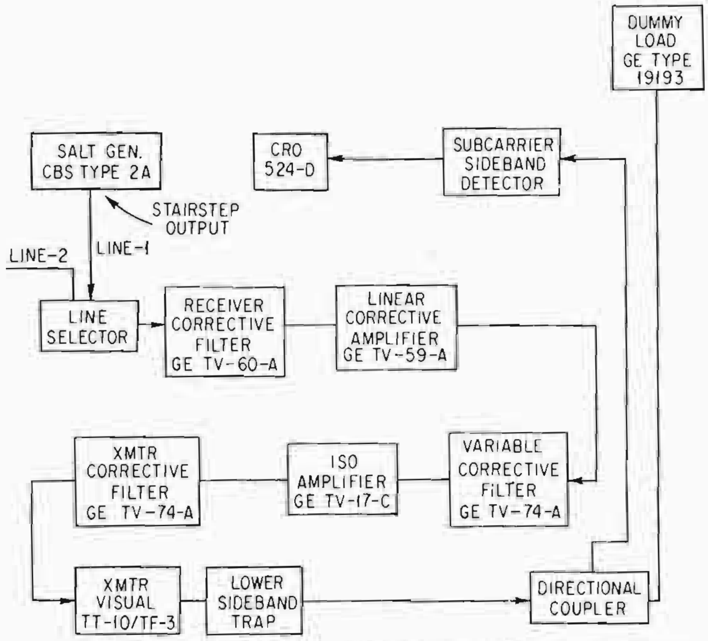


Fig. P-16. Block diagram for transfer-characteristic measurements.

of a (call) test pattern, taken from a monitor fed by the station demodulator coupled to the output transmission line feeding the dummy load.

TRANSFER CHARACTERISTICS — (EXAMPLE)

The transmitter transfer characteristic was measured using a stairstep generator and associated equipment as shown in Fig. 16. During this test, a 50 percent duty cycle was maintained, as preliminary checks showed no significant differences in transmitter transfer characteristic for the 10, 50, or 90 percent duty cycle. The results shown in Fig. P-17 indicate that the relationship between the RF output and the video signal input is substantially linear between reference-black and reference-white levels.

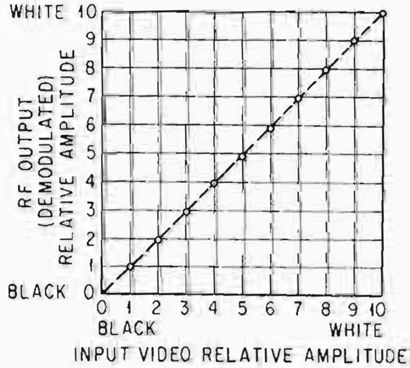


Fig. P-17. Measured transfer characteristic.

DIFFERENTIAL PHASE—(EXAMPLE)

The differential phase or phase-versus-amplitude characteristic of the transmitter was measured using a CBS-2A SALT sweep-amplitude-linearity-test generator feeding the video system input as shown on Fig. P-16. Using a stairstep signal (sync with 10 steps, each step containing a superimposed 3.58 MHz sine wave with a peak-to-peak amplitude of 20 percent of the total amplitude of the 10 steps) feeding the input system, the output of the dummy-load dirational coupler is fed into the sideband phase detector, where the "stripped" 3.58 MHz signal is "bucked out" by an external 3.58 MHz signal from the SALT generator through the use of a calibrated phase shifter. The balancing of these signals is observed on the cathode-ray tube of a Tektronix Type 524-D oscilloscope. Measurements were made at three different duty cycles, 10, 50, and 90 percent, and the maximum phase shift between the black step and the white step was measured and is as follows.

Duty cycle, %	Phase shift between steps 1 and 10 Modulator output, deg	Transmitter-output, deg
10	1.0	6.5
50	2.0	9.0
90	2.0	4.5

COLOR SIGNAL CHARACTERISTICS — (EXAMPLE)

Color-bar amplitudes and phase angles were measured at the input to the transmitter and compared with signals taken from the station demodulator connected to the output transmission line. The results, listed below, indicate that amplitudes and phase angles fall within the limit specified in the Commission's rules and regulations.

Color bars	Transmitter input Amplitude	Angle	Demodulator output Amplitude	Angle
Burst	0.40	0	0.40	0
Yellow	0.65	+1	0.62	+1
Red........	1.0	+3	1.0	+4
Magenta ...	0.98	0	0.96	+2
Q..........	0.40	−2	0.45	−2
Blue.......	0.65	−3	0.65	−1
I...........	0.40	0	0.45	+1
Cyan.......	1.0	+3	0.96	+4
Green......	0.98	−1	0.90	0

ENVELOPE-DELAY MEASUREMENTS — (EXAMPLE)

Fig. P-18 is a block diagram of the equipment setup used for measuring the phase envelope delay of the visual transmitter. Fig. P-19 shows the measured envelope delay and the FCC limits for color transmission.

AURAL TRANSMITTER PERFORMANCE (SECTION II-C-10) — (EXAMPLE)

Performance measurements of aural transmitters are to include a typical chain of equipment from a microphone input to transmitter output. Fig. P-20 contains a block diagram of the equipment setup and pertinent data concerning the conditions under which these performance measurements were made.

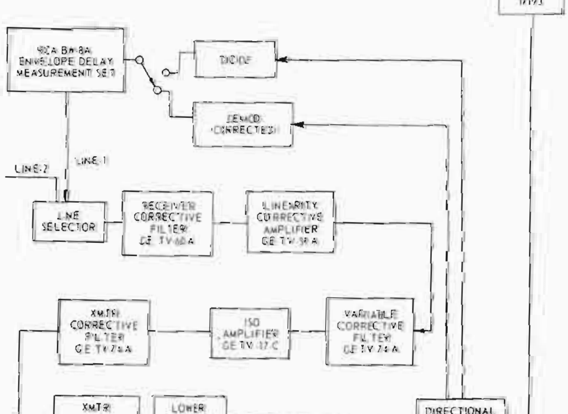


Fig. P-18. Block diagram for phase envelope-delay measurements.

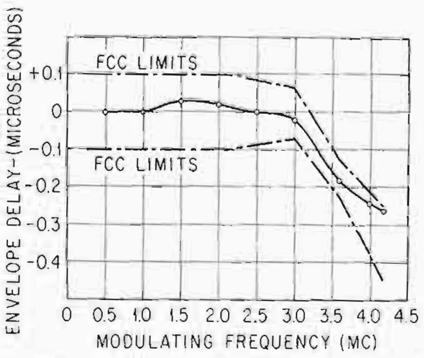


Fig. P-19. Envelope delay of radiated signal.

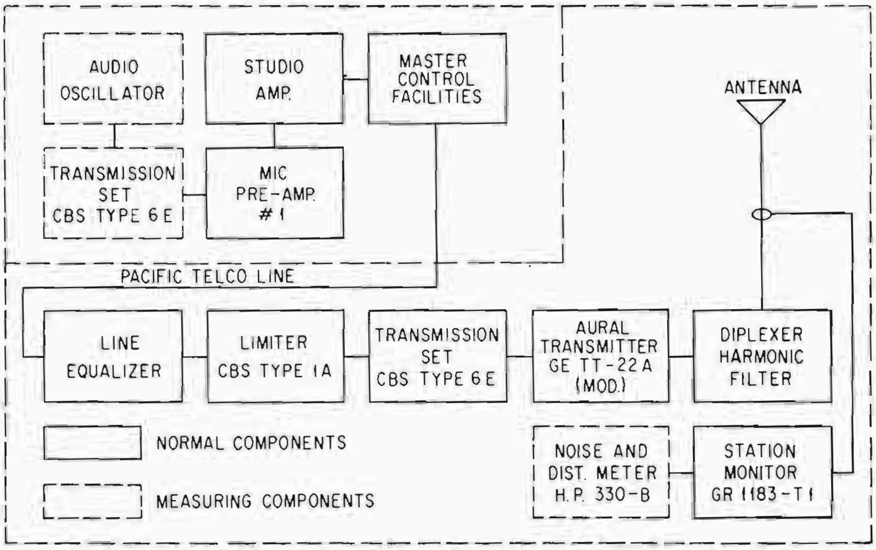
FREQUENCY RESPONSE, DISTORTION, AM AND FM NOISE (SECTION II-C-7-a, b, c, d) — (EXAMPLE)

Since there is a difference in peak voltages reached by pure sine-wave and normal program signals for equivalent volume indicator readings, an "elevated" level of 10 dB above normal (−50 dBm at microphone input) was used throughout the system shown in Fig. 20 to simulate 100 percent modulation. With sine-wave input the normal settings of all controls produced 100 percent modulation. The limiting circuit of the limiting amplifier was completely disabled during all of these measurements.

A constant level of —50 dBm (for the condition of 100 percent modulation) was fed to the microphone preamplifier at all frequencies involved, and the transmission set attenuator at the transmitter input was adjusted so that the modulation as indicated on the modulation monitor was always 100 percent. The attenuator settings were recorded at each measurement frequency, and the distortion was measured for each frequency. This procedure was repeated with microphone input levels reduced so as to produce transmitter modulation levels of 50 and 25 percent, respectively. Fig. P-21, P-22, and P-23 are plots of the system frequency response, and Fig. P-24 shows the system distortion for the three modulation levels used.

AM and FM noise levels were measured with a reference frequency of 400 Hz, with the following results: AM Noise Level = −52 dB below 100% modulation; FM Noise Level = −58 dB below 100% modulation.

It is recommended in the rules and regulations that none of the three parts of the system, studio, studio-transmitter link, and transmitter, contribute more than half of the total degradation allowed for the entire system. Each part of the system was measured, and it was determined that no one part of it does contribute more than half of the allowable degradation.



BLOCK DIAGRAM OF MEASURING SET-UP

CONDITIONS FOR MEASUREMENT

STUDIO	TRANSMITTER	ANTENNA
NO. D	TYPE GE TT-22 A	TRANSMISSION LINE
INPUT TO PREAMP. NO. 1	POWER 7.43 KW	OUTPUT POWER 7.43 KW
GAIN SETTING (MIXER) 11	PLATE VOLTAGE 7300 VLTS	TYPE RCA CB-TF-4 SPEC.
GAIN SETTING (MASTER) 11	PLATE CURRENT 2.6 AMPS	POWER GAIN 3.66
PROGRAM LINE REGULAR (REGULAR OR SPARE)	FIL. VOLTAGE 12.0 VLTS	

MEASURING EQUIPMENT

	MANUFACTURER	TYPE	SERIAL NO.
AUDIO OSCILLATOR	HEWLETT-PACKARD	201-B	815
DISTORTION AND NOISE METER	HEWLETT-PACKARD	330-B	
TRANSMISSION MEASURING SET	DAVEN	6-E	E-75092
DECADE ATTENUATOR			
AM DEMODULATOR	GENERAL RADIO	1932 P-1	149

Fig. P-20. Measurement data, TV aural data sheet 1.

25% MODULATION

	30 CPS	50 CPS	100 CPS	400 CPS	1000 CPS	5000 CPS	10000 CPS	15000 CPS
ATTENUATOR READING-DB	*	2.8	3.0	4.3	5.0	11.6	19.2	21.4
CONSTANT **	*	5.5	5.5	5.5	5.5	5.5	5.5	5.5
FREQUENCY RESPONSE	*	-2.3	-2.5	-1.2	-0.5	6.1	13.7	15.9

50% MODULATION

	30 CPS	50 CPS	100 CPS	400 CPS	1000 CPS	5000 CPS	10000 CPS	15000 CPS
ATTENUATOR READING-DB	*	2.5	3.0	4.3	5.1	11.5	19.1	21.2
CONSTANT **	*	5.6	5.6	5.6	5.6	5.6	5.6	5.6
FREQUENCY RESPONSE	*	-3.1	-2.6	-1.3	-0.5	5.9	13.5	15.6

100% MODULATION

	30 CPS	50 CPS	100 CPS	400 CPS	1000 CPS	5000 CPS	10000 CPS	15000 CPS
ATTENUATOR READING-DB	*	2.7	3.6	4.2	5.1	11.5	19.1	21.3
CONSTANT **	*	5.6	5.6	5.6	5.6	5.6	5.6	5.6
FREQUENCY RESPONSE	*	-2.9	-2.0	-1.4	-0.5	+5.9	+13.5	15.7

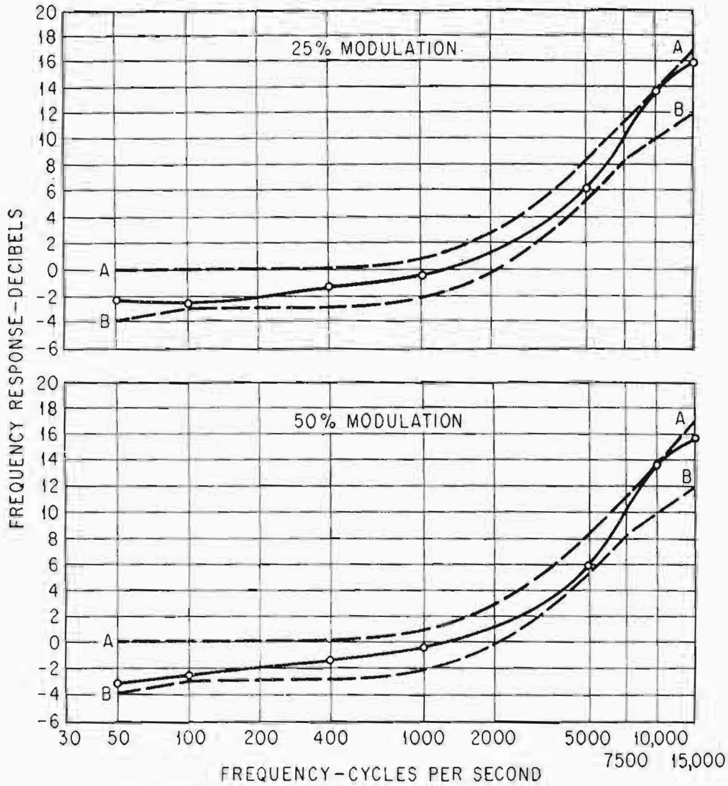
* NOT REQUIRED BY FCC

** ADD OR SUBTRACT AN ARBITRARY CONSTANT TO BRING THE RESPONSE CURVE WITHIN THE REQUIRED TOLERANCE SHOWN ON FM DATA SHEET-3

OUTPUT NOISE LEVEL (FM) 58 db BELOW 100% MODULATION (±25 kc FM at 400 cps)

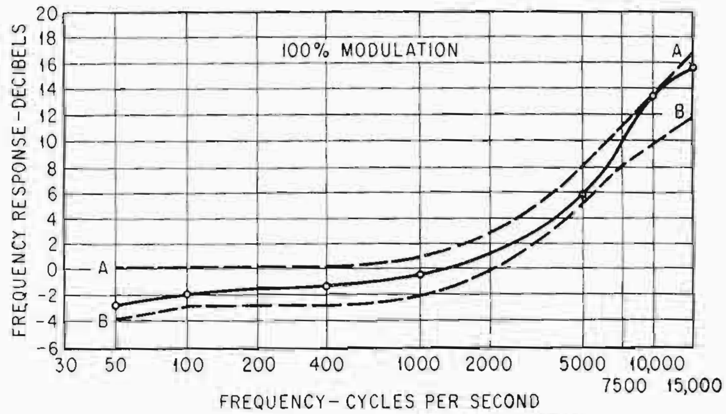
OUTPUT NOISE LEVEL (AM) 55 db BELOW 100% MODULATION (AM at 400 cps)

Fig. P-21. Over-all audio-frequency-response data and output-noise-level data, TV aural data sheet 2.



A, B – FCC STANDARD OVERALL SYSTEM RESPONSE LIMITS

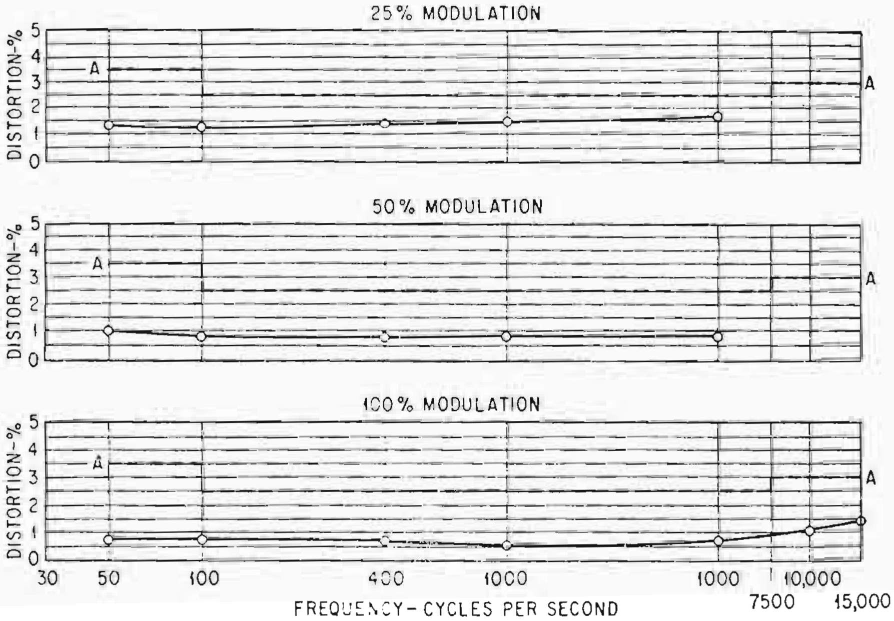
Fig. P-22. Over-all audio-frequency-response graphs, TV aural data sheet 3A.



A, B – FCC STANDARD OVERALL SYSTEM RESPONSE LIMITS

Fig. P-23. Over-all audio-frequency-response graph, TV aural data sheet 3B.

	50 CPS	100 CPS	400 CPS	1000 CPS	5000 CPS	10,000 CPS	15,000 CPS
25% MODULATION	1.4	1.3	1.4	1.5	1.7	*	*
50% MODULATION	1.0	0.8	0.8	0.9	0.9	*	*
100% MODULATION	0.8	0.8	0.7	0.6	0.7	1.0	1.4



*-NOT REQUIRED BY FCC
A-FCC STANDARD OVERALL SYSTEM TOTAL HARMONIC DISTORTION LIMITS

Fig. P-24. Audio-frequency harmonic distortion, TV aural data sheet 4.

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The Control of Audio Levels

On July 9, 1965, the Federal Communications Commission adopted a Report and Order (Docket No. 14904) and a "Statement of Policy Concerning Loud Commercials." To assist broadcast stations in making every reasonable effort to comply with these new requirements, the NAB Engineering Advisory Committee and its Subcommittee on Loudness have considered methods of implementing this FCC policy.

In view of the complex and subjective nature of loudness as applied to broadcast program material, the FCC Policy Statement recommends that licensees take appropriate steps prior to broadcast to review (pre-screen) recorded commercials as the best means of avoiding excessive "loudness" in broadcast commercials.

The National Association of Broadcasters, working with the NAB Engineering Advisory Committee and its Loudness Subcommittee, has prepared a Standard Loudness Reference Recording which is being made available to the broadcasting industry. The objective of this Recording is to provide an industry standard which may be used as a common denominator against which loudness of any program element can be judged.

Such a standard, when properly used, can provide individual broadcast station operators (AM, FM and/or TV) with a convenient means of pre-screening program material prior to broadcast to ascertain that all program elements have a reasonably uniform maximum loudness. Extension of acceptance of the NAB Standard Loudness Reference Recording through allied industries (i.e., program producers and recording companies) will contribute materially toward assuring that all recorded material furnished the broadcasting industry is prepared in its original form with reasonably uniform maximum loudness.

The NAB Standard Loudness Reference Recording consists of (a) 60 seconds of noise one octave side centered on one kHz and (b) three minutes of a male speaking voice, with both noise and voice adjusted to peak at reference level on the VU meter. The noise record is intended for gain and level adjustment of the reproducing equipment. The Standard Loudness Reference is the record of the male voice.

Four documents have been prepared or included to assist the user in deriving optimum benefits from the NAB Standard Loudness Reference Recording—"NAB Guidelines for Loudness Review," Loudness vs. Volume," "Automatic Audio Level Control" and the FCC Statement of Policy Concerning Loud Commercials. The Guidelines include a recommended practice for applying the NAB Standard Loudness Reference Recording as an aid in evaluating the loudness of broadcast program material. Other procedures leading toward the same objective will undoubtedly suggest themselves to the user. The significance of the difference between the terms "loudness" and "volume" as applied to broadcast program material is described in the paper "Loudness vs. Volume." The application and use of various devices for control of audio level in broadcast systems is described in the paper entitled "Automatic Audio Level Control." The Commission's policy statement is self-explanatory.

NAB GUIDELINES FOR LOUDNESS REVIEW

In that loudness is a relative matter, it is desirable in evaluating loudness to have a reference of loudness against which a judgment can be made. Accordingly, the NAB has established a "Standard Loudness Reference Recording," made at normal level. This recording will serve as a uniform reference against which "recorded commercials and other material" may be compared for subjective loudness.[1] The methods of using this reference and conditions recommended for review of commercials and other materials are contained in the following Recommended Practice.

A. Recommended Practice for Use of NAB Standard Loudness Reference Recording

1. *Scope*

This recommended practice specifies the method and conditions under which the NAB Standard Loudness Reference Recording is to be applied as an aid in evaluating loudness of broadcast audio material.

[1]A station's practice in the origination of live program material should be compatible with recorded material.

2. *Application*

Under the same or exactly equivalent conditions of equipment and environment, a presentation in sequence shall be made of:

(a) a fifteen-second, or longer, portion of the NAB Standard Loudness Reference Recording;

(b) the audio material whose loudness is to be evaluated; and

(c) a ten-second, or longer, portion of the NAB Standard Loudness Reference Recording.[2]

An observer, or observers, whose judgment has been found from experience to be objective shall make a determination as to the loudness of audio material in question as compared to the NAB Standard Loudness Reference Recording. If the loudness of the audio material being reviewed is considered excessive under the terms of the FCC Policy Statement, the audio material should not be broadcast without modifications.

3. *Environmental Conditions*

In monitoring critically for relative loudness of announcements vs. the NAB Standard Loudness Reference Recording, it is important that listening conditions be as similar as possible to those existing for the average audience during broadcast. The reviewer should also have the proper mental attitude and avoid pre-occupation with other matters, if an objective appraisal of so subjective a matter as relative loudness is to be accomplished. The space in which the reviewing operation is carried on should provide conditions comparable to the home. It should be neither excessively noisy nor abnormally quiet.[3] An average room with carpeting or an acoustic ceiling should be adequate.[4] The judgment should be made at a normal home listening level, (approximately 65 to 75 dB above acoustic reference level with "A" weighting as measured on a Standard Sound Level Meter).

4. *Reproducing Equipment*

The reproducing system should be of good quality but not necessarily broadcast standard. It should duplicate the performance of a good quality TV or radio receiver to provide listening conditions found in the home.

[2]It is recognized that in practice, there may be other methods of achieving results equivalent to those obtained by the foregoing.

[3]That is, a room whose noise level is approximately 35 to 45 dB above the acoustic reference level with "A" weighting, as measured on a Standard Sound Level Meter.

[4]Provided, of course, that a film projector or other source of noise does not increase the room noise level.

LOUDNESS VERSUS VOLUME

The American Standard Volume Indicator[5] has been in use in this country for some thirty years. Perhaps because of this long devotion to a particular measuring technique, broadcasters sometimes tend to confuse "loudness" with "volume". While somewhat related, loudness and volume are really two quite different things.

With the adoption of the FCC Report and Order (Docket No. 14904) and a "Statement of Policy Concerning Loud Commercials," a clear understanding of the difference between loudness and volume is essential. A review of the significance of these two terms should help to clarify their relationship.

Volume

Volume is a purely empirical term evolved to meet a practical need. It cannot be defined in precise mathematical terms involving the familiar units of current, voltage, and power. The electrical amplitude of audio program material does not lend itself to measurement with the usual root-mean-square, average or peak reading voltmeters used for the measurement of periodic waves. In the communications field this fact led to the concept of a value known as "volume." American Standard S1.1-1960, Sec. 2.17, defines the term as follows: "The volume level in an electric circuit is the level, as measured on a standard volume indicator, of a complex wave such as produced by speech or music."

Volume is simply the reading of an instrument, known as a Volume Indicator (colloquially; "VI" or "VU meter") which has specific *dynamic* and electrical characteristics, a specified means of calibration, and a prescribed method of reading.[6] Readings made with a standard volume indicator are commonly called volume levels. Volume indicators are not intended to measure loudness, although there is a rough relationship between relative volume level and relative loudness.

Loudness

American Standard S1.1-1960 states that "Loudness is the intensive attribute of an auditory sensation, in terms of which sounds may be ordered on a scale extending from soft to loud."

[5]Chinn, Gannett, and Morris, "The New Standard Volume Indicator and Reference Level," Proc. IRE, 28:1:1 (Jan., 1940).

[6]Howard A. Chinn, "The Measurement of Audio Volume," *Audio Engineering*, 35:9:26 and 35:10:24 (Sept. and Oct., 1951, respectively).

In other words, loudness is a subjective experience which has no equivalent in physical terms. It is the magnitude of the auditory sensation produced by a sound. In the past, it has sometimes been assumed that the sensation is proportional to the number and strength of the nerve pulses reaching the brain from the inner ear in a unit of time. Except for certain kinds of sounds (e.g., continuous tones), it is now generally recognized that the sensation of loudness also involves the psychological reaction of the listener to the nature of the sound.

The judgment of the loudness of program material (as distinguished from the loudness of tones) is a two-dimensional function. The two attributes are (a) sensory or physiological loudness and (b) perceptual or psychological loudness.

Sensory loudness is related to the nerve pulses which, upon reaching the brain, cause a sensation of loudness. The loudness of most tones and noises is largely determined by this phenomenon. Perceptual loudness, on the other hand, is related to the previous emotional conditioning of the listener to the sound being produced.

Sensory vs. Perceptual Loudness

A few examples will help to distinguish between sensory and perceptual loudness. For example, a person interested in a particular radio or television program may adjust the sound reproduction level for comfortable listening. Another person in the same room who is trying to concentrate upon a difficult passage in a textbook would probably object to the program material as being too loud. Thus, the same sound is judged to be normal by one listener and loud by another, although both are subjected to the same variations in sound pressure. This is a case where, although the sensory loudness is the same, the perceived loudness is quite different depending upon the viewpoint of the listener.

Another example is the apparent loudness of a person who is shouting compared to one talking in a normal conversational manner. Even though the sound pressures produced by both voices may be adjusted until they are essentially alike, the shouting voice will generally be perceived as louder than the conversational one.

Other examples are well known to broadcasters. For instance, there are a number of processing techniques that make the apparent or perceptual loudness of speech seem louder than would otherwise be the case. These include the use of rapidly paced, shouting, or strident voice delivery, the addition of reverberation, amplitude compression, restricted bandwidth, and other forms of response-frequency equalization. Exactly why this kind of processing produces sounds that seem louder than unprocessed material is not exactly known. It is evident, however, that psychological conditioning plays an important role in a person's assessment of the loudness of certain sounds.

In recent years considerable work has been undertaken to determine the characteristics of the auditory ear-brain system. At this point, sensory or physiological loudness is a reasonably well understood phenomenon which can be measured with good statistical accuracy. Further, electronic instruments have been both devised and proposed for the measurement of physiological loudness.

On the other hand, since an instrument can be provided with only rudimentary psychological insights, it is not reasonable to expect a meter to measure accurately perceptual or psychological loudness.

The Measurement of Loudness

From the foregoing, it should be clear that the measurement of loudness is not a simple matter even at this point in history. Further, the standard volume indicator was never intended to be a loudness meter as reference to the original paper describing the instrument will verify. (See Footnote 1.) Basically, the standard Volume Indicator measures amplitudes in a special way that is determined by the electrical and dynamic characteristics of the Volume Indicator (or VU meter). Depending upon the nature of the sound and the previous psychological conditioning of the listener, volume measurements and perceived loudness are probably related with some to-be-determined degree of accuracy. Very preliminary indications are that, in some cases, the order of the correlation is probably no better than perhaps 10 dB which, as far as broadcast operations are concerned, is really no correlation at all. Thus, in the absence of a loudness meter reliance must be placed upon the judgment of skilled observers when it is desired to equate the loudness of two or more program elements, particularly where they are quite different in nature. It is with this thought in mind that the NAB Standard Loudness Reference Recording is being made available. It provides a common denominator against which the loudness of any program element can be judged. Thus, if the loudness of all program elements is made to sound equal to the NAB Standard Loudness Reference Recording, then, when reproduced serially in any combination, these elements should sound about equally loud.

AUTOMATIC AUDIO LEVEL CONTROL

The automatic control of audio level is a widely used and accepted practice in broadcasting today. When properly used it is capable of controlling peak levels (or peak modulation) in a manner that is substantially superior to manual methods. When improperly used it can cause objectionable distortion of waveform, amplitude range, and even dynamic range.[3] Further, automatic methods are not a substitute for good judgment, such as is required when determining a pleasing balance between multiple sources of sound.

There are three basic types of automatic audio level controls. One type senses waveforms in excess of a given amplitude and, by means of a signal derived from this sensing, causes a modification in gain of the device in accordance with some pre-established relationship. These devices are often known as automatic gain control[3] amplifiers. Below the threshold amplitude the gain of the device is fixed and, hence, the input-output relationship is linear. Above the threshold the output increases at a materially slower rate than does the input because of a progressive reduction in gain. In addition, since the gain of the device is a function of the loudest signal, weak signals that are closely associated in time with a loud signal are also reduced in level. Thus, although the original balance is maintained, weak signals may be reduced below the level originally intended. This would be an indication of excessive dynamic range in the program material with respect to the limitations of the aural broadcast system. It should be noted that the amplitude range requirements and limitations are quite different for AM, for TV, and for FM broadcasting.

A second type of automatic level control device is the limiter[7] which, by nonlinear action or by essentially instantaneous changes in impedance, limits or modifies waveforms above some predetermined threshold value. This type of device has the fundamental disadvantage of producing both harmonic distortion and cross-modulation of the audio frequency waveform to which it is applied. A low-pass filter can reduce the effect of higher order distortion, but it cannot affect the cross-modulation of the lower frequency components.

A third type of device is the compressor amplifier. Compression is defined as the "process in which the effective gain applied to a signal is varied as a function of the instantaneous signal magnitude, the effective gain being greater for small than for large signals."[8] This device is akin to an automatic gain control amplifier except that in the latter, as noted above, the gain modification in the form of reduction only takes place after the signal exceeds a given amplitude and the gain does not restore to normal maximum immediately with a reduction of signal amplitude.

True compressor amplifiers usually find application in certain communications and some recording applications. They are usually associated with an "expander" amplifier having conjugate gain characteristics with signal amplitude. They are not normally used in broadcasting plants. Accordingly, they are not discussed further herein.

Automatic gain control amplifiers, however, are used in a variety of forms. These and limiters are discussed further in the following paragraphs.

Limiters

Limiters are widely used in voice communication services for increasing average voice modulation levels. It has also been offered to and used by broadcasters for providing a sharp limit on modulation, especially in connection with preemphasized programs on TV aural and FM transmitters.

Limiters are sometimes used with, or as a part of, an automatic gain control amplifier. When employed in this manner, objectionable distortion may be avoided when the device is adjusted to clip not more than a very few decibels from excessive audio peaks. If, however, the unit is permitted to clip normally encountered peaks by more than 3 or 4 dB, serious distortion can be caused in an otherwise high-fidelity system. The use of a limiter in place of the modulation limiting form of automatic gain control amplifier should not be permitted in a broadcast transmitting system.

Automatic Gain Control Amplifiers

There are a great variety of automatic gain control amplifiers in general use. Their differences reside primarily in their attack and release times, their compression ratios, their operating logic and the purpose they are designed to serve. The attack times of typical units normally range from microseconds to milliseconds. The release times, on the other hand, range from hundreds of milliseconds to seconds. Compression ratios range from less than 2 to 1 up to as much as 20 to 1.

In a continuing effort to devise a wholly satisfactory automatic device, many kinds and many combinations of circuit logic have been incorporated in commercially available devices. These

[7]For definition, see "IRE Dictionary of Electronics Terms and Symbols." (Pertinent extracts included in Appendix.)

[8]IRE Standard No. 53 IRE 11.S1.

include signal delay, amplitude discrimination, memory, and frequency-spectrum modification. Because of this proliferation, and the complexity of some of the operating logic, it is not possible to present a meaningful summary of the many subtypes of automatic gain control amplifiers currently available. A common application for this kind of device is the automatic modulation "limiter" often used at broadcasting transmitters to prevent aural overmodulation.

Automatic Gain Control Amplifier Application

Fully as important as the selection of the proper automatic level control device for a given application is the manner in which a given unit is operated. If not properly adjusted, an automatic device can completely negate the best efforts of the most skilled sound technician. The following examples will serve to illustrate the point.

Frequently, in dramatic acts and in comedy sketches, there are passages where the action takes place with the sound consisting only of relatively low level background noises or music. If such audio material is routed through a badly overcontrolled automatic level control device or system, the desired effect can be lost due to the increase of level under these circumstances.

A somewhat less extreme but more frequent case is also encountered both in dramatic and musical programs. Here medium level passages may be increased in level by an automatic device to the point that, when a crescendo, a fortissimo, or a loud sound effect is encountered, there is no headroom left for further increase in volume. The effect upon the discerning listener is likely to be one of disappointment with the performance.

The reverse condition, however, in which insufficient average program level or modulation is maintained because of a lack of sufficiently uniform level is one which can also cause dissatisfaction with the aural broadcast heard under unfavorable or noisy conditions. Thus, automatic level control should be arranged and so adjusted as to maintain satisfactorily uniform levels to overcome noise but should also avoid excess modulation and reduction of desired amplitude range or aural contrast.

Problems such as those just enumerated may be largely avoided by judicious use of automatic level adjusting devices. For example, in transmitter applications the automatic device should be used primarily as a means to avoid overmodulation. A properly designed automatic modulation limiter operated so as to effect a gain reduction of say 6 dB on program peaks should effectively control maximum modulation levels on most transmitters. Gain reduction in excess of 6 dB is unnecessary to the modulation control function and tends to reduce the amplitude range of the program.

An automatic modulation limiter should be operated so as to have a gain reduction of about 6 dB on maximum program peaks for two reasons. One is that most such limiters have a ratio of compression in the operating range of approximately 10 to 1, which means that an increase in level of 6 dB in the control range is converted to an increase of only 0.6 dB. This will permit the FCC specification of 85 to 100 per cent modulation on maximum peaks to be complied with readily. The other is the fact that the gain reduction indications of most meters are usually greater by 2 or 3 dB than the actual dB reduction in gain of the amplifier. Thus, it usually requires at least a few dB indications on the meter for control to be effective.

Another form of automatic control quite similar to the modulation limiter is the automatic level control or automatic gain control. This device, while fundamentally similar, is used for a different purpose and in a different manner than the automatic modulation limiter. There are two differences in design or operating characteristics. First, the automatic level control has a much slower gain restoration time than the modulation limiter. It may be as much as 10 to 20 secs. as compared to something less than 1 sec. for the modulation limiter. Second, the ratio of compression in the operating range is much less severe, being in the order of 3 or 4 to 1.

The automatic level control has been used with gain reductions of as much as 20 dB (i.e., for a compression ratio of 3 to 1, an input level increase of 30 dB results in an output level increase of only 10 dB). The use of excessive automatic gain reduction or control range does create the possibility of raising noise level during pauses in programming. Correctly used and adjusted, the automatic level control will maintain program level from a studio in much the same manner as would a skilled studio technician except that it usually does it better. It should be emphasized, however, that uniform program or modulation level is not necessarily synonymous with uniform loudness which is a highly complex and subjective function of the reproduced program.

APPENDIX

Extracts from "IRE Dictionary of Electronics Terms and Symbols," published by the Institute of Radio Engineers, Inc., 1 East 79th Street, New York 21, New York, 1961:[9]

Amplitude Range. The ratio, usually expressed in decibels, between the upper and lower limits of program amplitudes which contain all significant energy contributions.. (58 IRE 3.S1)

Dynamic Range. The ratio of the specified maximum signal level capability of a system or component to its noise level, usually expressed in decibels. (58 IRE 3.S1)

Automatic Gain Control (AGC). A process by which gain is automatically adjusted as a function of input or other specified parameter. (58 IRE 3.S1)

Limiter. A transducer whose output is constant for all inputs above a critical value. (48 IRE 2, 11, 15.S1; 52 IRE 17.S1)

FEDERAL COMMUNICATIONS COMMISSION STATEMENT OF POLICY CONCERNING LOUD COMMERCIALS

1. During the past two years, the Commission has studied intensively the problem of loud commercials in television and radio. We are told by industry engineers, broadcasters and others that subjective loudness of commercials cannot be electronically measured, and therefore the Commission cannot act to prevent them. However, in hundreds of complaints from the public we are also told that some commercials are objectionably loud, often louder than adjacent programming—and often so objectionably loud that listeners are compelled to turn the volume down.

2. We conclude today in our Report and Order in the inquiry proceeding (Docket No. 14904) that objectionably loud commercials are a substantial problem, are contrary to the public interest, and that their presentation is to be avoided.[10]

3. The purpose of this policy statement is threefold—to set forth our policy and the policy we expect licensees to follow in this respect, to detail some of the practices which are common causes of loud commercials, and to advise licensees not knowingly to broadcast commercials involving such practices. All licensees are expected to take appropriate measures to assure strict adherence to this policy. The Commission, through its complaint procedure or by spot checks at renewal time, will determine whether licensees are carrying out their obligations in this respect, and will take whatever action is appropriate on the basis of such review.

4. Among the practices which the Commission has identified as often causing loud commercials, and which licensees shall avoid, are the following:

(a) *Excessive modulation* on commercials as, for example, through inadequate control-room procedures. We are today amending our modulation rules to make it clear that minimum modulation on peaks of frequent recurrence need not be as much as 85 percent if a lesser level is required to avoid objectionable loudness.

(b) *Excessive volume compression* resulting from the use of automatic gain control, or similar devices—particularly in the broadcast of pre-recorded commercial material which may have been prepared with extensive compression and other electrical processing. Extensive compression permits material to be broadcast at a higher than normal average level of modulation. At lease on pre-recorded commercial material, a maximum of 6 dB compression in broadcasting is recommended.

(c) *Excessive use of other electrical processing devices,* such as filters, attenuators and reverberation units—again, particularly where prerecorded material is being presented.

(d) *The use of prerecorded commercials* which have been subjected to excessive compression, filtering, attenuation, "equalization" or reverberation (echo).

(e) *Voice commercials presented in a rapid-fire, loud and strident manner;* and

(f) *The presentation of commercial matter at modulation levels substantially higher than the immediately adjacent programs.* A maximum of 4 dB increase (40 percent to 60 percent to 100 percent modulation) is recommended.

To make sure that such practices are avoided, licensees are to adopt adequate control-room procedures to prevent them, and to take appropriate steps to provide for prescreening recorded commercials for loudness.

5. Much of the loud commercial problem arises in connection with the broadcast of prerecorded commercials. In fulfilling their obligations in this area, braodcasters are expected to take reasonable steps to get the cooperation of the recording industry so as to prevent the presentation of loud commercials.

6. We now turn to a brief discussion of the matters referred to above.

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[9]The Dictionary is out-of-print; the Institute of Radio Engineers (IRE) has been superseded by the Institute of Electrical and Electronics Engineers (IEEE), whose address is 345 East 47th Street, New York, N.Y.

[10]As industry parties point out, there is not no acoustic or electrical tool for determining precisely whether or not a given sound is objectionably loud. Nevertheless, it has been repeatedly held that objectionable or excessive loudness is both a proper subject for preventive governmental action, and a condition sufficiently definable for its existence to be established for legal purposes. See, for example, Kovacs v. Cooper, 336 U.S. 77 (1949); Ex parte Trafton, 271 S.W. 2d 814, 160 Tex. Cr. 407 (1954), and Thompson v. Anderson, 153 P. 2d 665, 107 Utah 331 (1944).

Minimum Modulation Requirement

7. One argument advanced by some broadcasters is that they are prevented by our rules from avoiding loud commercials, because the rules require modulation on peaks of frequent recurrence to be at least 85 percent thus prohibiting the operator from reducing the transmitter gain even if necessary to eliminate loudness. We do not so construe the rules. However, in order to make this matter completely clear, we are today amending the modulation rules (Sections 73.55, 73.268 and 73.687(b)) to provide that, while in general modulation should not be less than 85 percent on peaks of frequent recurrence, it may be reduced to whatever level is necessary to avoid objectionable loudness in commercial and other material, even if this is substantially less than 85 percent on peaks. We expect television and radio broadcasters to observe this practice where necessary to avoid loud commercials.

Control Room Procedures

8. Presentation of loud commercials is due partly to inadequate or lax control-room procedures. One cause is inaccurate reading of or inattention to the modulation monitor (required by our rules) or the widely-used volume unit (VU) meter. Another aspect is excessive reliance on automatic gain control (AGC) or peak-limiting devices, which, unless properly regulated, are likely to result in loud commercials. Broadcasters are to adopt control-room procedures adequate to prevent the presentation of loud commercials which result from these deficiencies or practices. Attention is invited to a description of accepted procedures in the IRE (now IEEE) Standards on American Practice for Volume Measurement of Electrical Speech and Program Waves, 1953 (53 IRE 3.S2).

Compression and Other Processing

9. One contributing cause to the problem of loud commercials is the use of moderate amounts of volume compression, which permits material to be broadcast at a higher than the normal average level of modulation without having peaks exceed 100 percent on the modulation meter. Compression in broadcasting, when used in moderation, appears to be desirable; but excessive use thereof, particularly in the broadcast of commercial material, is unquestionably undesirable and a major factor in causing objectionable loudness. Broadcasters are to exercise care in using devices causing compression. It is recommended that an appropriate maximum amount of compression is 6 dB, at least in broadcasting prerecorded commercials. Certainly, as a general rule, no more compression should be used in broadcasting a commercial than in presenting preceding material. Similar care should be used in connection with employment of other processing devices, such as attenuators, filters, or reverberation units. *Particular care is to be exercised when the commercial material has been prerecorded,* where substantial amounts of compression and other processing may have been used in the recording. The combination of such processing in recording and in broadcasting—e.g., what might be called "compression on compression"—may, when carelessly used, produce what one broadcaster has termed "a rather overwhelming effect" in terms of loudness. Therefore, the use of further compression or other electrical processing in broadcasting such commercials is to be avoided to the extent necessary to prevent objectionable loudness, and the amount thereof which may properly be used may well be substantially less (e.g., 6 dB of compression less) than that which is appropriate for other types of material.

Use of Recorded Commercial Material; Prescreening

10. Compression, filtering, "equalization," reverberation, and other processing are extensively used in recording commercial material, along with a generally high-volume level of recording. Again, these techniques when used in moderation serve desirable purposes, such as protecting equipment, producing a recording of good technical quality, and producing distinctive effects other than loudness. But it appears that sometimes they are used extensively for no other purpose than to produce loud commercials. *Broadcasters are to exercise care in the presentation of recorded material in which such processing has been used resulting in an effect of excessive loudness.* Under the revised modulation rules, where a commercial has been prescreened and found too loud, a licensee should reduce modulation below 85 percent where necessary to avoid objectionable loudness. Also as mentioned above, care is to be exercised in use of any further electrical processing in broadcasting recorded commercial material.

11. We note in "A Guide for Advertising Agencies and Television Stations in handling Materials for SPOT TELEVISION COMMERCIALS," a joint recommendation of the Station Representatives Association and the American Association of Advertising Agencies, that film, tape and slides should be in the hands of licensees 48 hours in advance of use. The Guide further suggests that materials should be

examined by the station on receipt for "damage, defects and completeness." Clearly this contemplates delivery in adequate time to permit prescreening.

12. We are aware that in actual practice these guidelines are not always observed. However, we expect broadcasters to adopt appropriate practices and procedures to provide time for prescreening, not only for damage, defects and completeness, but for loudness.

13. We recognize that to require each station, large or small, to prescreen all commercials for loudness may impose some burden. The small radio licensee can engage in extensive spot prescreening, and, if a loud commercial escapes prior detection through this process, he can be alert to the need for prescreening further commercials from the same source. Further, we suggest that the organizations, state or national, which represent advertisers, station representatives, agencies and licensees, should consider the establishment of a group to prescreen and label commercial material as to loudness for the industry.

Strident Delivery

14. One common source of complaint is commercials which are delivered in a loud, rapid and strident manner, with the maximum number of words crammed into the time period and all delivered at or close to maximum peak modulation. Presentation of such material is to be avoided.

Contrast with Preceding Program Material

15. Aside from differences resulting from varying degrees of electrical processing used in different types of material, another common source of complaint is the contrast between loudness of commercials as compared to the volume of preceding program material—e.g., soft music or dialogue immediately followed by a rapid-fire, strident commercial. Such contrasts are to be avoided. For guidance, it is recommended that a maximum of 4 dB increase over the immediately preceding program segment (40 percent to 60 percent to 100 percent modulation) is appropriate for general observance.

Conclusion

16. We conclude that the presentation of objectionably loud commercials is contrary to the public interest. Therefore, to the extent it is within their control, broadcasters have an affirmative obligation to see that such material is not presented. In today's Report and Order we recognize that loudness—the impression created in the listener—is to a degree the result of factors beyond the broadcaster's control and varies as between individual listeners (for example, a reaction to a particular product or a particular sound effect other than volume). But we conclude that objectionably loud commercials result in large measure from factors of a technical or partly technical nature which are within the broadcaster's control, and which are not adequately controlled simply by adherence to our rules in the various broadcast services limiting modulation to 100 percent on peaks of frequent recurrence. While there is no evidence that broadcasters in substantial numbers deliberately "boost the power" in presenting commercials, neither is there indication of any concerted, industrywide effort to deal with the problem. While most complaints of loud commercials are directed to television rather than radio (particularly at prerecorded commercials), the problem is by no means confined to television.

17. We have set forth above the broadcaster's general affirmative obligation, and specific practices and policies to which we expect strict adherence. The list of specifics is not intended to be all-inclusive, and there may well be other steps that can be taken. What is called for is a good faith effort on the part of licensees to prevent the presentation of commercials which are too loud. In setting forth this policy statement, we recognize the underlying importance of advertising to the American system of broadcasting, and the legitimate interest of the advertiser in presenting his message attractively and understandably, and in drawing attention to what he has to say. But these are not irreconcilable alternatives.

18. We note with pleasure a recent suggestion by the American Association of Advertising Agencies that its Subcommittee on Commercial Production might assist in dealing with this problem, by screening commercials referred to it by the Commission about which loudness complaints have been received. We appreciate this offer of assistance, and if the circumstances appear appropriate we will take advantage of the suggested procedure.

19. We also appreciate the consideration and attention being given this problem by the N.A.B. Engineering Advisory Committee. It is understood that investigations and studies are to be made by this committee, regarding the technical considerations that may be involved in the matter of "loudness" and also as to the possibility of developing a new volume measuring meter. The technical staff of the Commission is, of course, ready to cooperate in this endeavor as may be requested.