FM Proof of Performance Manual

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FM Proof of Performance Manual

Includes the test setup and procedures along with the test charts and logs.

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An Easy Guide To The FM E.P.M.

Introduction

The proof of performance is probably the most important piece of engineering that most radio station chief engineers are exposed to, yet the FM proof procedure is still one of the areas where a great deal of confusion abounds. The proof is important for two reasons: first of all, it demonstrates to the FCC that the station is at least able to meet minimum technical standards, or hopefully, exceed them. A satifactory proof also assures the broadcaster that his facility is doing what it is supposed to, at least technically. Conducting the proof is a real responsibility. It must be signed by the engineer or engineers making the measurements and the results are among the factors that determine whether the broadcaster deserves to keep the station license.

This manual was designed to fill the need for a detailed guide to the FM equipment performance measurements based on approved interpretations of the FCC rules that set forth the requirements. Every effort has been made to answer the questions that arise and to present an efficient test format, complete with easy to use forms and graphs. In addition to aiding the engineer with the preparation of the proof, an indepth analysis of each procedure and regulation provides the reader with a genuine understanding of what the FCC expects and how the requirements can best be met.

Ideally, every station would pass every proof without a hitch, but in practice, this is not always the case. It is sometimes more time consuming to get the station to the point where it can pass the proof than to actually make the measurements. For this reason, the manual also covers some of the most common areas of technical difficulty and suggests methods of isolating the problems and correcting them so that the proof may be successfully completed.

While the use of this guide certainly has the effect of reducing the amount of time required to make the equipment performance measurements, its primary intent is to assist the engineer to make a more thorough, accurate and meaningful proof of performance.

Your individual forms for completing the equipment performance tests are located in the back of this manual.

CHAPTER 1. Preparing the test equipment

It is very important that the test equipment be very thoroughly checked out before the proof is begun. The test gear need not be new to be good or expensive to be suitable. While every engineer likes to work with the best possible equipment, some of the simpler, less expensive audio generators and distortion meters are capable of testing down to 0.1% total harmonic distortion. Whatever test equipment is used, the important thing is that its operating condition is known.

The frequency response and distortion tests required by the FCC are all relative measurements which make the job of the test equipment a bit easier. The accuracy of these tests does not depend on the quantative accuracy of the units measured, but rather on the relationship of the quantities to each other. For example, the response variations in decibels is an expression of the ratio between two voltages, so that the exact voltage measured is not important.

Harmonic distortion is expressed as a percentage of the signal voltage; once again a relative value. In either case, if the voltmeter employed calls 1 Volt 1.1 Volts, the accuracy of our relative measurements will not be impaired as long as 0.5 Volts reads out as .55 Volts on our meter. While good engineering practice dictates that we should endeavor to keep all test instruments as accurately calibrated as possible, we need not begin our job at The National Bureau Of Standards.

Let's take a look at what test gear is required and discuss the methods of checking it's operation and connection to the system under test.

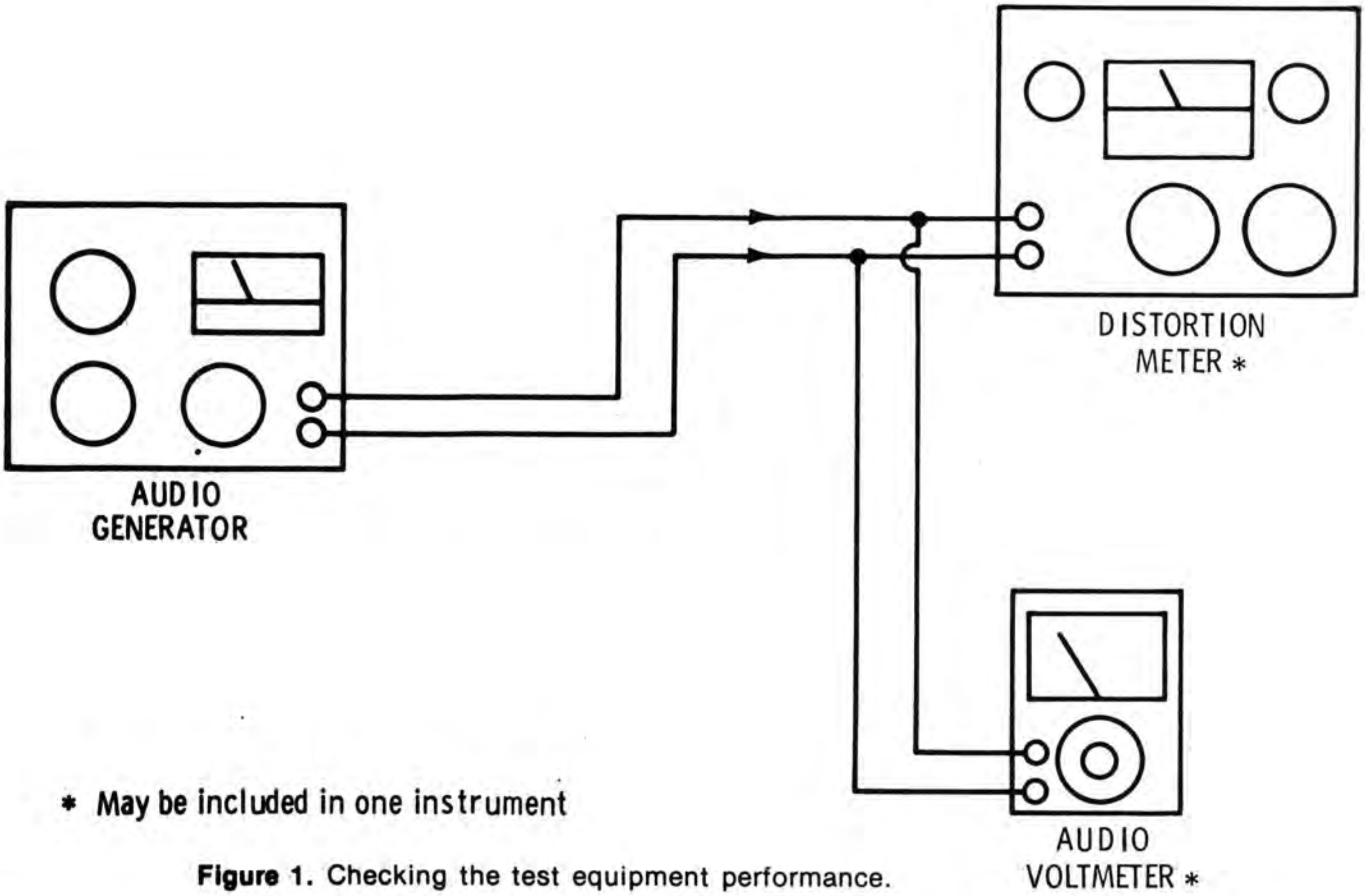


Figure 1. Checking the test equipment performance.

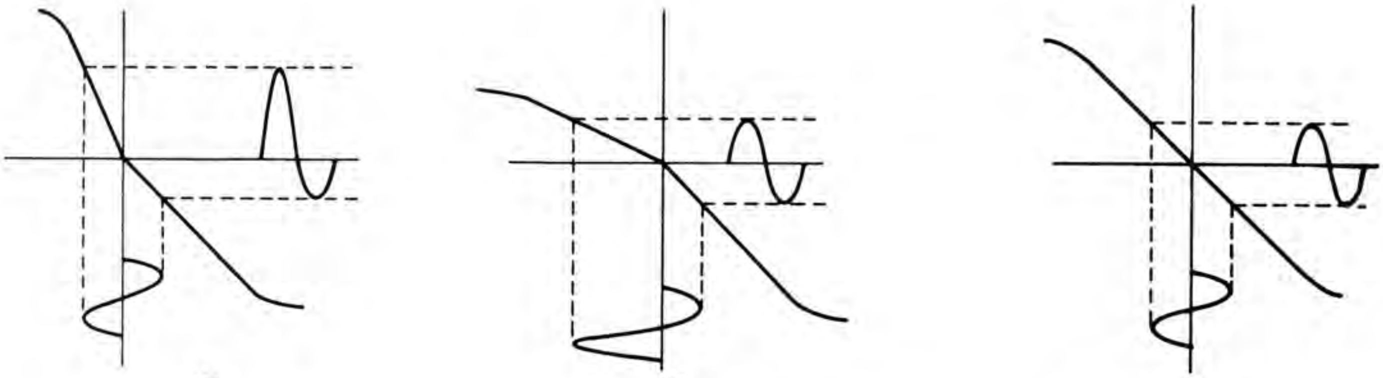


Figure 2. The effect of complimentary transfer characteristics. It is not uncommon for the total system distortion to be less than the total of the distortion of each of the parts of the same system. In the case illustrated above, the nonlinearity is exaggerated for clarity and the resulting distortion is actually less than either half of the system alone! The input signal when applied to transfer A becomes distorted as a result of the base line shift caused by the imbalance. When the output of the first half of the system is applied to transfer B, the amplitude of the positive and negative halves of the waveform is returned to balance and a relatively undistorted output is obtained. If the phase of the input to transfer B had been reversed, the distortion would have been increased rather than decreased however, which is one of the reasons that the audio generator's distortion cannot be subtracted from the distortion readings. Transfer C is the resultant transfer of A to B in phase.

Minimum test equipment required

A. Audio Frequency Sine-wave Generator/Output Attenuator*

B. Harmonic Distortion Meter/Audio Voltmeter*

Useful Additions

A. Cathode Ray Oscilloscope

B. Precision Attenuator ("Gain Set")

C. Spectrum Analyzer with RF head good to 110 MHz minimum; 225 MHz preferred.

Before proceeding, be sure that all test leads are equipped with the proper connectors for making solid, well shielded contact with the console microphone input terminals and the modulation monitor instrument output. Alligator clip connections, sections of unshielded cable and haphazard grounds often cause needless grief and lost time. There is also an understandable psychological advantage to starting out with a "tight ship".

*Most of the commonly available units include both functions in a single instrument.

Checking the test equipment for response variation

. Feed the output of the audio generator into the audio voltmeter input. The generator's output should be held constant while the audio voltmeter indication is observed. Vary the frequency from 50 to 15000 Hz and note any deviation from the 400 Hz value. If there is no change in the indication, then the frequency response over the band that our proof will cover is perfect and no corrections will have to be made to the data that is measured. If the audio voltmeter does show a deviation, record the error in dB at 50, 100, 400, 1k, 5k, 10k and 15kHz.

If the audio generator employed has a built-in voltmeter, you will find that it is quite easy to keep the output perfectly uniform while the frequency is varied so that no calibration chart . is required. If the generator does not have a meter, then obviously we are relying on the accuracy of our audio voltmeter to check it's output uniformity and it would be a good idea to double check by using a second meter and running the same spot checks. Only the worst audio voltmeters would deviate from flat over a 15 kHz band. Most are flat to 100,000 Hz. **If you must use a calibration chart with your generator, remember to subtract the generator errors from the transmitter response deviations measured before entering them on the data sheet when we begin the proof.** If the generator error is 0.2 dB or less, it may be disregarded, as that would allow a test resolution of more than 10 times the tightest response accuracy required of the system, which is about 3.0 dB, as shown in the FCC's diagram of the response limits in Part 73 of the rules.

Measuring the test equipment distortion level

A harmonic distortion meter will read hum, white noise and distortion as distortion, so, we must remember that even if our generator is producing a perfect waveform, it's output noise level must be less than 0.1% or -60 dB for the distortion meter to indicate less than 0.1%, assuming that the distortion meter is perfect. As a practical matter, most generators and harmonic distortion meters exhibit a noise level of around -80 dB or 0.01%, so, this is usually not a problem as long as one is careful to avoid ground loops when making the connections to the equipmeht under test.

If the audio generator is fed directly into the harmonic distortion meter, the total hum, noise and distortion for the combination may be measured. For FM proof measurements, if the reading is 0.25% or less, the instruments may be considered satisfactory since this is 1/10 of the lowest FCC requirement for FM broadcast. Most distortion meter-audio generator combinations yield a residual hum, noise and distortion level of about 0.1%.

CAUTION: The residual test equipment distortion MAY NOT be subtracted from the system distortion figures when doing the proof.

Subtracting the test equipment distortion is not a valid technique because distortions don't necessarily add. As a mater of fact, the only time they would add, would be when all of the harmonics were exactly in phase; a near impossibility when you consider that this would have to be true for every modulating frequency. Non-linearities can also cancel each other if their transfer characteristics are complementary. See Figure 2. This accounts for the fact that a studio with 1% distortion can be connected to a line amplifier with 1% distortion and the line amp connected to a transmitter with 1% distortion. One might expect the system distortion to be 3%, but typically it would test at about 1½ to 2½% because of the factors we've just discussed.

In the FCC rules for FM technical standards (73.317(3)ii), the commission wisely advises that no portion of the system exceed ½ the distortion limit since at some modulating frequency the distortions could add. The same advice applies to our AM systems, of course. So, to summarize, the fact that distortions usually don't add makes our broadcast systems better than the sum of their parts, but it also means that the test gear distortion cannot be subtracted.

The FCC requires that the distortion measurements be made with a test bandwidth of 30 kHz (above the second harmonic of 15 kHz, the highest frequency test input), a requirement that is easily met since most harmonic distortion meters will pass at least 40 kHz. Noise tests must be made with a 50 to 15,000 Hz bandwidth, also easy to meet since most audio voltmeters are flat to 100,000 Hz. **A word of caution here: if your voltmeter has a built-in 1 kHz high pass filter, it must be switched out. The required bandpass STARTS AT 50 Hz. The high pass filter is great for getting hum out of the measurements, but not out of the transmitter! These filters are installed in the test gear as a diagnostic aid to enable the user to determine how much of a noise or distortion reading is hum and how much is white noise or distortion.**

To check the residual noise level of the audio voltmeter, short it's input and switch it to the most sensitive range. It should have a noise level 70 dB or so below the modulation monitor output level corresponding to 100% modulation. Obviously, the noise in the test equipment may not be subtracted from the system noise measured. Since the FCC residual noise limit is -60dB for FM, we should be careful to optimize the noise performance of the system and take care to keep the test set-up noise free as this is not an easy test to pass, especially in stereo.

If all of the test equipment is in good operating order, enter the serial number and manufacturer's model number of each unit in the test equipment and procedures section of the proof. The serial numbers are recorded so that the tests may be exactly duplicated at any time in the future. Proper documentation of any test or experiment in any of the sciences calls for the recording of the serial numbers of the equipment used and a detailed description of the methods employed.

Figure 3 is an outline of a suitable test equipment and procedures section, which you may use as a guide for writing this portion of your proof. As you can see from the outline, there are three main parts to the test equipment and procedures description: a description of the test equipment employed, a description of the test procedures and a diagram showing how the test equipment was connected to the system and the normal audio path through the system. More than one engineer may work on the proof, but one must assume the overall responsibility of the supervisor and the description of the procedure should indicate who was in charge. Only the engineer in charge need sign each page, but it is a good idea to list anyone who assisted.

At this point a very interesting and much debated question arises: Who is qualified to assist with the proof anyway? Section 73.93(b) requires that the proof be supervised by a First Class Radiotelephone Operator or a broadcast consultant regularly engaged in the practice of broadcast station engineering during a period when a First Class Operator is in charge of the transmitter operation, either directly or by remote control. So, a third class operator can assist as long as the chief engineer supervises, but be aware of the fact that the accuracy of the response data depends to a great extent on the careful control of the input signal.

Also remember that stations that broadcast in stereo must complete a full proof of each of the stereo channels with the transmitter in the **Stereo Mode**. The pilot and multiplexing circuitry must be operative when doing a stereo proof! While the Commission does not require that separation, crosstalk, etc., be included in the annual proof unless specifically requested, most stations do include these tests in their proof and we would think that the licensee would want at least a once-a-year check of these parameters.

At this point, if everything is in order we may connect the test gear to the system and take a look at how it shapes up.

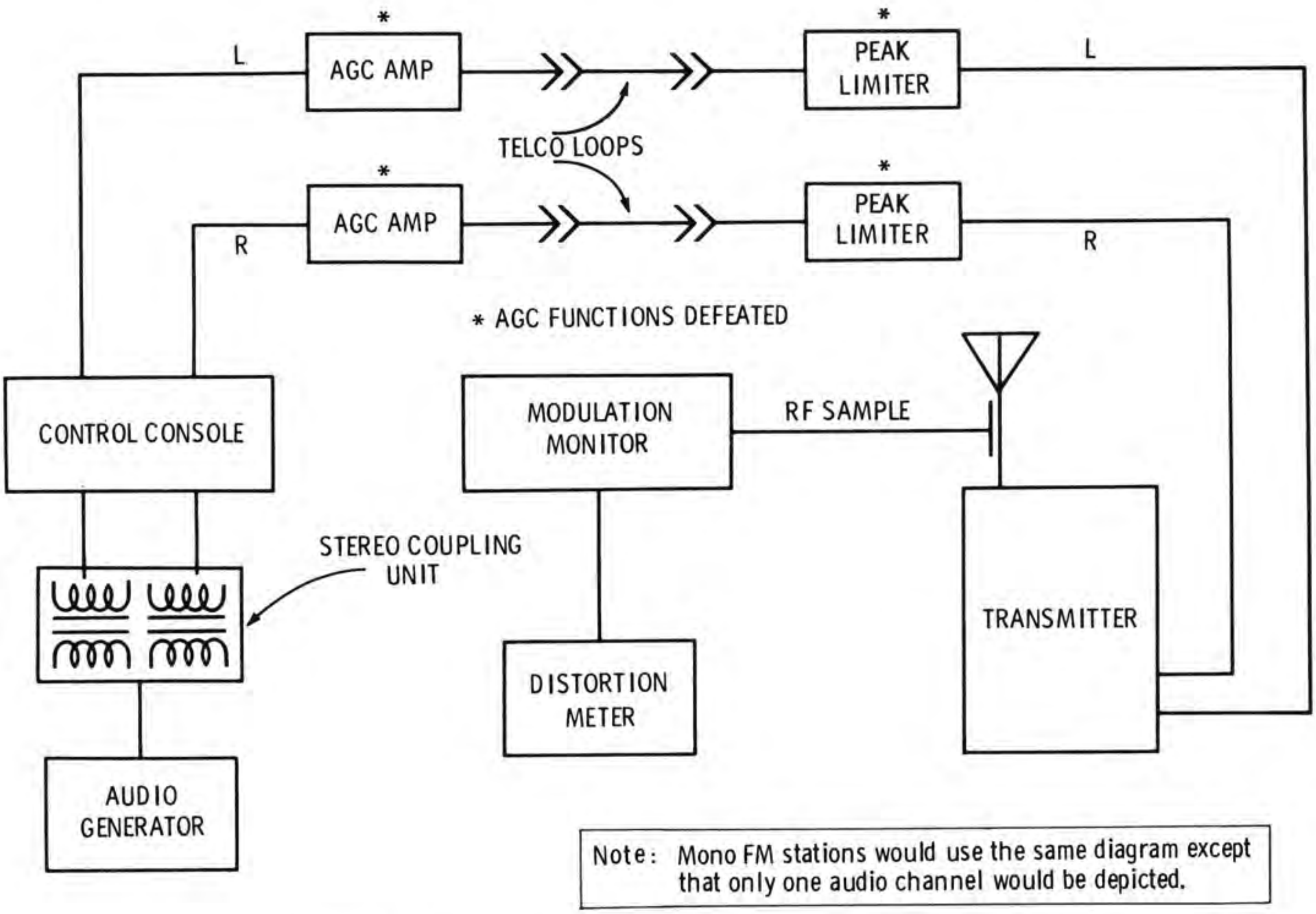


Figure 3A. Sample test equipment connection diagram.

Figure 3 - Test Equipment and procedures outline

I. Equipment List (Give manufacturer, model # and Serial # of each unit)

II. Description of the methods employed and facts relating to the conduct of the tests
- A. Station call letters
- B. Personnel
  1. Who in charge
  2. Assistants
- C. Reference to the equipment list
- D. Reference to the equipment connection diagram
- E. Test resolution
  1. Frequency response accuracy of test equipment
  2. Residual hum, noise and distortion of test equipment
- F. Statement that all station equipment was adjusted for normal operation
- G. Description of how the AGC was defeated
- H. How the actual measurements were made
  1. How the response was measured
  2. Method of checking distortion
  3. How the noise test was made
  4. Description of any spurious emission tests performed
  5. How stereo separation was measured (If included in a stereo proof)
  6. How crosstalk was measured (If included in a stereo proof)
- I. Statement that all of the data is true and accurate to the best knowledge of the supervising engineer

III. Equipment Connection Diagram
- A. Show the path of the audio from the microphone input terminals to the transmitter antenna output circuit
- B. Show the actual points of test equipment connection

Sample Measurement Statement

The following equipment performance measurements for WXYZ-FM were conducted on January 25, 1975. All of the measurements were made by, or directly under the supervision of Henry Ampere, chief engineer, WXYZ-FM. Paul Phon, WXYZ maintenance supervisor, assisted with the tests. The test equipment specified in the attached equipment list was employed for all of the measurements and was connected as shown in the accompanying equipment connection diagram.

Prior to its use, the test equipment frequency response was checked and found to be within 0.1 dB from 50 to 30,000 Hz. The residual hum, noise and distortion of the audio generator and harmonic distortion meter combined was 0.1%.

All station equipment was adjusted for normal operation and all equipment normally used in the system between the microphone input and transmitter antenna output was included in the tests. The AGC functions of the leveling amplifier at the studio and the peak limiter at the transmitter were defeated by switching their function selectors to the "test" position provided by the manufacturer for this purpose. **Measurements were made for each of the stereo channels with the transmitter in the stereo mode.** (Stereo stations only).

The frequency response of the system was measured by adjusting the audio generator to produce the modulation level indicated with a modulating frequency of 400 Hz, then varying the frequency while recording the generator output required to produce the same modulation level at the frequencies indicated.

The harmonic distortion was measured by adjusting the audio generator to produce the modulation levels indicated with the modulating frequencies indicated and measuring the distortion at the modulation monitor instrument output terminals.

The spectrum analyzer listed in the equipment list was employed to ascertain that allowable occupied bandwidth is not exceeded during normal programming. The input signal was removed and the system noise was measured at the modulation monitor instrument output. The noise level given is relative to the voltage at the same point at 100% modulation. The AM noise was measured at the modulation monitor AM noise output jack provided for that purpose.

Optional addition

The stereo separation was measured by modulating each channel (l or r) with modulating frequencies of 50, 100, 400, 1000, 5000, 10,000 & 15,000 Hz while measuring the leakage into the unmodulated channel.

The cross-talk from the main channel to the subchannel was measured by modulating the main channel and measuring the leakage into the subchannel. The cross-talk from the subchannel to the main channel was measured by modulating the subchannel while measuring the leakage into the main channel.

All of the data contained herein is true and accurate to the best of my knowledge.

Engineer ______________________

License # ______________________

Date ______________________

It is recommended that the description of equipment and procedures used in making performance measurements be of sufficient detail that the setup and measurements could be duplicated by another engineer following the given information. The procedures should include settings of gain controls, etc. The exact wording will vary from station to station because of the vast differences between them, so this part of the description has not been included in the more or less standard part of the description given above. Obviously, spurious emission test results should be accompanied by location and antenna data.

CHAPTER 2. Connecting the test equipment

Let's start by taking a look at the console schematic diagram so that we are sure that our connection to the microphone input terminals will effect the proper impedance match. One of the most mis-used terms in communications is the term "balanced" as it refers to transmission lines and input/output circuitry.

Figure 4a shows a truly balanced, transformer-coupled circuit. Note that each transformer is center tapped to ground. This circuit will exhibit a degree of common mode rejection, which depends upon the accuracy of the transformer center tapping or "balancing". The effect is identical to that obtained with balanced push-pull amplifier circuitry.

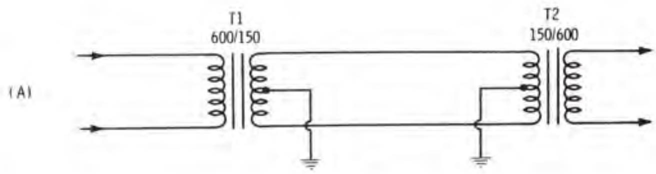
Any hum or noise would have to enter the top and bottom halves of the circuit 180 degrees out of phase to be passed to the output. Any interference affecting the top and bottom halves in common, as a hum field would, causes its own cancellation or rejection, hence the term common mode rejection. (This type of truly balanced circuitry makes long distance wire transmission with surprising noise immunity possible, but is seldom found in studio equipment as the distance of transmission over the connecting lines is usually a matter of feet rather than miles.)

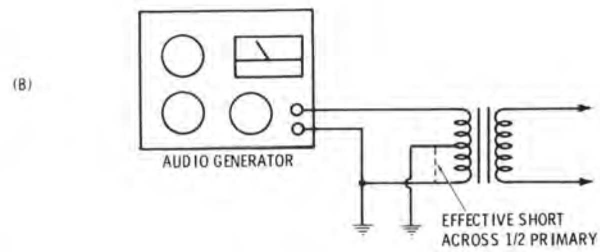
It is very important to know how your console input is wired and unfortunately, the manufacturers usually call any transformer coupled circuit "balanced". Figure 4b shows what would happen if the audio generator's unbalanced, half grounded output were to be connected to a balanced input. As you can see, the impedance mis-match would be 2 to 1. On the other hand, Figure 4c shows what happens when a transformer with a balanced secondary is used to couple to a floating but unbalanced input configuration. Adding a transformer to the audio generator's output is not a cure-all. There is no substitute for knowing the characteristics of the input circuit and making an intelligent decision on the proper coupling technique.

If a matching transformer is required to connect to your console, be sure that it is included in your test equipment response checks so that any effect that it might have is recorded. Load the secondary of the transformer with a resistor equal to the microphone channel input impedance, if it is an unbalanced secondary. If the secondary is balanced, leave the secondary center tap disconnected for coupling to the unbalanced voltmeter input so the transformer may be checked.

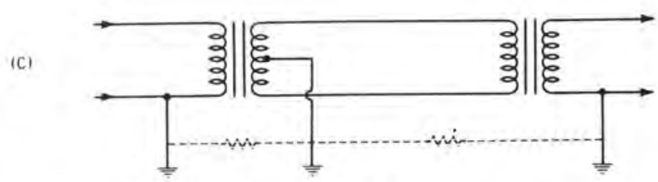
You will find that the larger transformers usually are operated so far below their saturation levels, when used to feed a microphone input, that their low frequency response usually extends almost to DC. At 50 to 600 Ohms impedance, winding capacitance usually isn't a problem, so the high end of most of the coupling transformers is usually flat to well above the audio range, if a quality unit is chosen. Transformer distortion is also generally negligible at microphone levels, but, great care must be taken to avoid hum pickup or RFI.

Don't be too hasty to tack a transformer onto the output of the audio generator, because very often it is not necessary. The purist situation, technically, would be to couple directly to the input circuit and thus eliminate an intervening link that might have some effect on the measurements. As long as the console input does not have a grounded center tapped transformer and the audio generator is located just a couple of feet away, grounding the lower half of the floating input will not cause any additional noise.

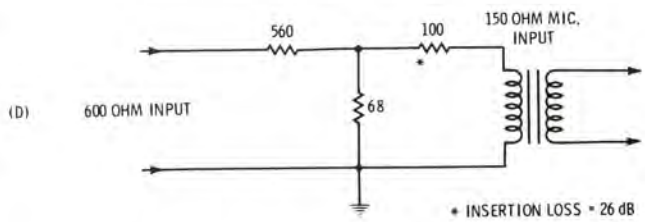




Direct connection across a truly balanced input can result in severe mismatching and test conditions not simulating normal operation of the input circuit.



Multiple ground connections open the door for "ground loops" that could render the measurements invalid.



A simple method of resistive coupling to the mic. input.

Figure 4.

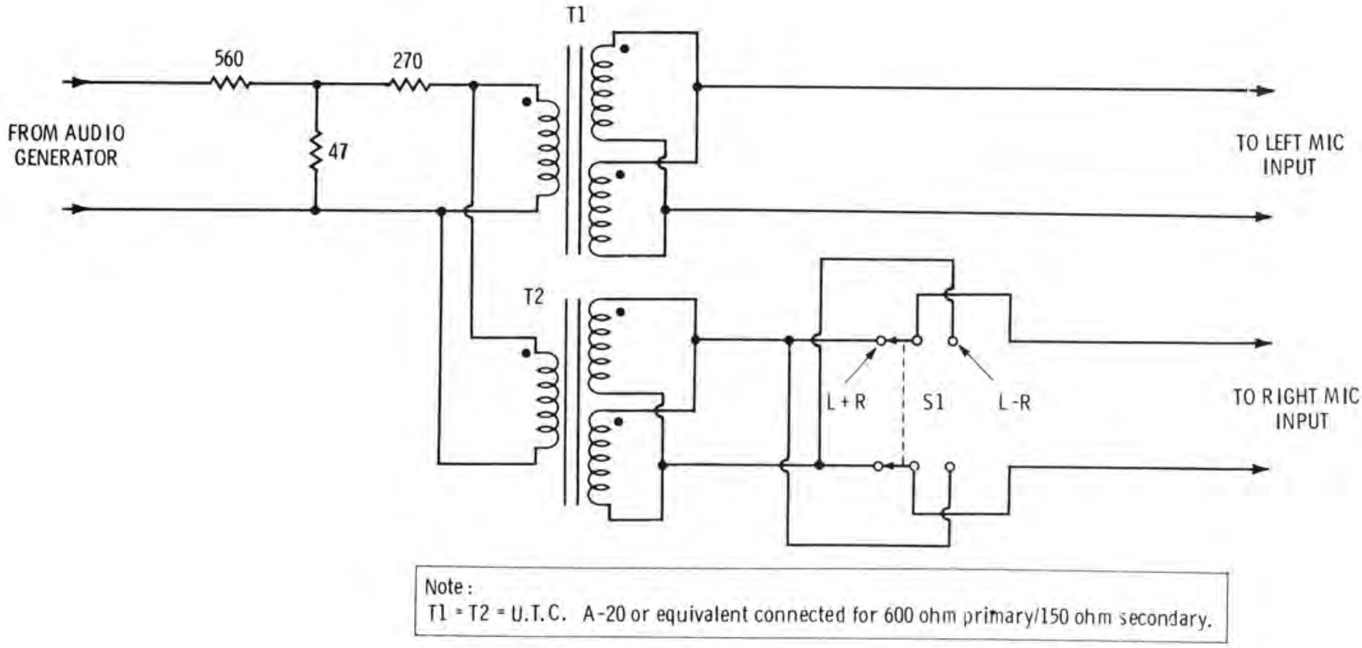


Figure 4E. A coupling unit for stereo tests.

Figure 4d illustrates this coupling technique. Note that a resistive matching pad is used so that the generator sees 600 ohms while the console input is loaded with 150.

If your console microphone input was balanced and you had to add a matching transformer, it is a good idea to use the isolation pad shown in Figure 4d. Although your audio generator may be designed to drive a 600 ohm load, it's internal output impedance may be quite a bit lower, which would mis-match the transformer primary.

The switch selected internal load in some generators is in parallel with the output to insure that the generator is properly loaded when driving a high impedance circuit. It will not increase the internal impedance, but actually lower it. A quick look at the schematic of your audio generator will tell you if it already contains an isolation pad. If you are driving the input through the 150/600 ohm matching pad, the isolation pad is not required. You will note that the pads are both "T" configuration networks. This type was chosen to keep the resistance in the grounded side of the circuit low.

If you are proofing a stereo facility and decide to include the sub-to-main and main-to-subchannel crosstalk tests, you will have to be able to generate a L-R input signal as well as the L+R input. In a pinch, the easiest way to accomplish this is to reverse the output polarity of the console output of either the left or right channel. If the input transformers are easily accessible, the required phase inversion could, of course, be done there as well. While this "quickie" method is O.K. for spot checks, **a real proof test should be performed with the L+R and L-R generation done before the signals enter the system so that the balance and phase linearity of the entire system from the mic input to the transmitter output will be included in the tests.**

Figure 4e shows a very simple circuit that provides all of the necessary impedance matching, isolation and switch selected phasing. The circuit should be very well shielded to prevent hum or RF pickup. Good quality transformers should be used. We recommend + 30 dBm units, although the normal level through the transformers is less than - 30 dBm. This makes the selection of the transformers less critical since they will be operating far below their rated capacity. It is wise to select identical units, however, to minimize the chance of phase shift away from the selected 0 or 180 degrees.

If you have a pair of good 500/125 ohm units on hand, they may be used in place of the 600/150 transformers specified. It is quite easy to come up with a stereo input interface with unmeasurable distortion, response deviation and phase shift using readily available components in the circuit shown.

The connection to the modulation monitor is more straightforward, since the instrument output of these units is usually designed to feed the harmonic distortion meter's high impedance input directly. It is a good idea to keep the connecting cable from the monitor to the distortion meter as short as possible to prevent hum and RF pickup. In some situations it may be very difficult to keep these components out of the distortion meter input even with a short cable run because of the somewhat higher circuit impedance, particularly in the vicinity of high power radio or TV transmitters and antennas. Even AM RFI does not always manifest itself as audible program type audio. RF can infiltrate the system and cause a buzz or other effects that cloud the measurements.

If you have had noise problems in your measurements that don't show up on the air and are obviously in your test set-up, try an isolation circuit between the modulation monitor instrument output circuit and the harmonic distortion meter/voltmeter input. We are assuming that the distortion meter itself is well shielded: if changing the position of the instrument changes the amount of noise, infiltration through the distortion meter case itself should be suspected. The most common problem, however, is the development of an RF potential across a ground loop. Remember that a quarter wave of FM and TV frequencies is only a couple of feet long! Simple 60 Hz hum can invade the test input in much the same way of course.

The high impedance isolation circuit shown in Figure 5 usually takes care of either problem. Isolating the modulation monitor ground from the distortion meter ground eliminates the ground loop and the limited frequency response of the transformer (few will pass 540,000Hz) blocks the RF. The frequency response of the transformer must meet the 30,000 Hz FCC Requirement, however. Small variations in the response (1 or 2 dB) are not important because the actual response data is taken from the modulation meter and the audio generator settings. The transformer distortion is important though, because these measurements must be made through it. The better quality matching transformers will pass the instrument output voltage with less than 0.1% distortion in most cases, so it should not be difficult to find a suitable unit.

This completes the test equipment preparation. Now that we are assured that the response and distortion data that we will measure actually belongs to the radio station and not the test gear, let's see how good our facility really is.

Pre-testing the station

For the engineer to be able to efficiently progress through the equipment performance measurements with a minimum of wasted time, the facility must of course be up to par. You must remember that if you have completed part of the measurements and then find that an adjustment to the transmitter is required, the tests that have been completed are usually invalid. As a practical example, if we begin by making a complete frequency response and distortion series only to find that a defect in the telco loop from the studio has rendered our noise level unusable, we must re-run the same series of tests after the audio line problem has been serviced. Repeating the noise test alone will not suffice because whatever repair or adjustment was made to correct the noise could possibly alter the frequency response or distortion performance.

Obviously, it doesn't take many of these unexpected little setbacks to turn a seemingly simple proof into an all-week affair. The best way to be sure that this won't happen is to pre-test the station. There are many ways to quick-check a facility, but probably the best method is to determine which portions of the measurements will be the most difficult to pass and then prepare a pre-test procedure to be sure that the toughest requirements can be met. The following procedure will serve well for most FM facilities.

PRE-TEST	LIMIT
A. Check system noise relative to 100% modulation (In stereo mode if a stereo facility)	-60 dB
B. Spot check distortion at 50, 1000 & 15,000 Hz, 100% modulation (each channel if stereo)	3½% at 50 Hz 2½% at 1000 Hz 3% at 15,000 Hz
C. Spot check response at 400, 50 & 15,000 Hz, 100% modulation (each channel if stereo)	-4 dB at 50 Hz -5 dB at 15,000 Hz
D. (Optional) spot check separation at 400 & 15,000	30 dB
E. (Optional) spot check cross-talk at 400 Hz	40 dB

If the station can pass this basic series of tests, then the chances are very good that it will breeze through the complete proof, as the above requirements really describe the all-out performance demands placed on the system. It is well worth the few minutes that it takes to go through this little electronic assurance routine. Now the big question arises: What if the station doesn't pass?

Curing the ills

Frequency response defects. - These are among the easiest problems to correct because the errors are usually additive and, therefore, "subtractive". In other words, if the system response is down a total of 4 dB at 15,000 Hz, 1 dB of the loss could be in the console with another two in the line matching transformer and the remaining 1 dB loss in the transmitter.

What makes this kind of deficiency rather easy to correct is the fact that it can be so easily isolated. As a matter of fact, the 2.5 vac range of most VOM's is flat to above 10 kHz and these instruments can be quite convenient for response trouble-shooting as long as the levels are high enough, and audio program levels generally are.

Start "shooting" at the console output and continue through the chain remembering that a dB here and there is going to add up in the end.

Most response problems in the audio equipment can be traced to matching problems. Perhaps something has been added to the chain since the last proof was pulled. RF bypass circuits which have too low a cut-off frequency and slice into the audio range are common offenders. Also bear in mind that what seems to be a response problem can sometimes be a manifestation of a bigger distortion problem. An extreme unbalance in an audio stage will often result in poor low frequency response, in addition to gross distortion.

In any case, once the sections of the system with the most pronounced response drops are isolated, corrective action can be taken, starting with the worst offender. The reverse effect, a response rise or peak can also occur, and because the FM response requirement is in excess of eight octaves, it's easy to get into trouble here when some over-equalization of a response loss occurs.

Distortion. - Non-linearity problems are more difficult to trace and usually require more time to solve because it is usually necessary to disconnect parts of the system so that the individual outputs can be sampled. While it is quite easy to bridge an audio circuit with a VOM to check the response along the way, accurate distortion measurements require that there be no hum loops or matching no-no's inflicted by our diagnostic taps.

It is also important that the test results be accurately interpreted so that they may yield information leading to the defective component or adjustment.

The older tube type equipment can usually benefit from a tube change, while some of the newer solid state audio gear is rather critical to bias balance settings, particularly with respect to low frequency distortion. Be sure to follow the manufacturer's adjustment procedures when adjusting the transmitter and audio gear.

More often than not, the biggest problem with the distortion measurements during an FM proof is really noise, particularly when making distortion tests at the lower modulation levels. This is why we suggested pre-testing for noise first. With a 40 dB s/n ratio, the lowest distortion reading that can be obtained at 25% modulation is about 3%!

Noise. - Before attempting to remedy a signal-to-noise deficiency, it is often helpful to first determine the nature of the noise so that a clue to it's source can be obtained. An oscilloscope is a most useful tool for the task.

Figure 6 illustrates some of the waveforms that are likely to be encountered. A clipped sawtooth configuration usually indicates a power supply filtering problem, while a 60 Hz sinewave can be a sign of hum pollution somewhere along the audio chain. Bear in mind that the common mode rejection of push-pull circuitry depends upon the accuracy of the balance, so be sure that all bias balance adjustments are properly set. Remember also that many line amplifiers and most AGC amps and limiters employ push-pull amplifiers, so don't stop at the transmitter when tweeking the system for optimum performance.

It is usually best to track down the noise by disconnecting the transmitter audio input to determine if the transmitter itself is the noise source, then proceed with the remainder of the system if the residual noise level of the transmitter alone is satisfactory.

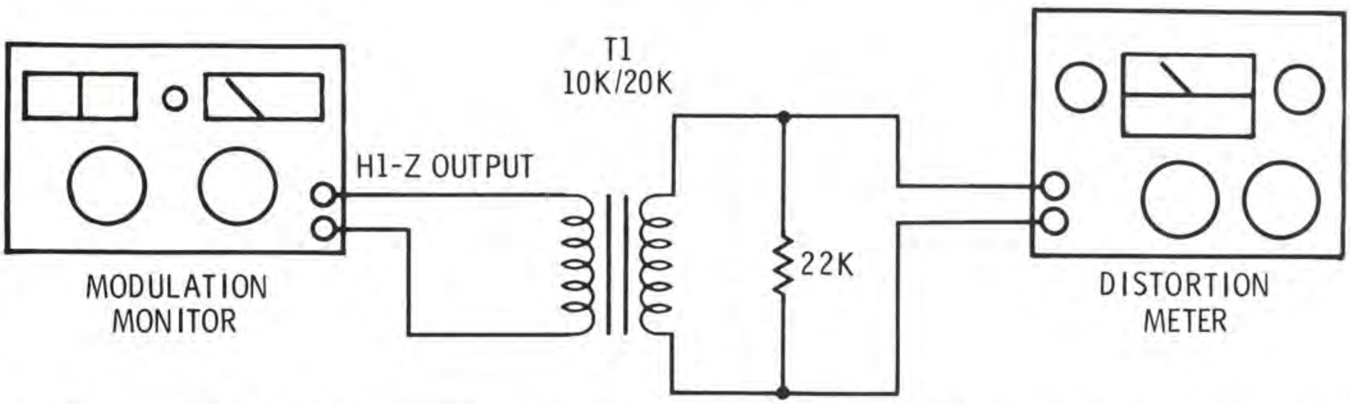
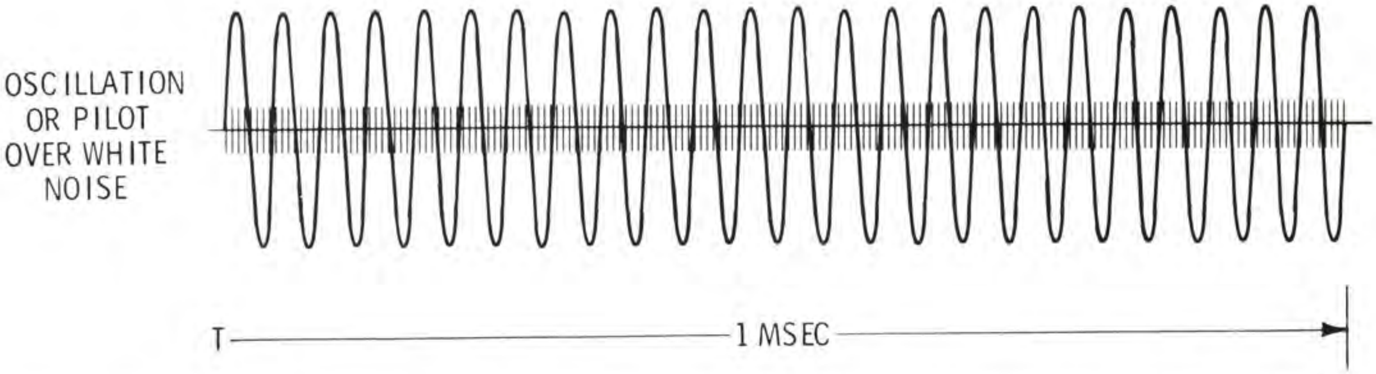
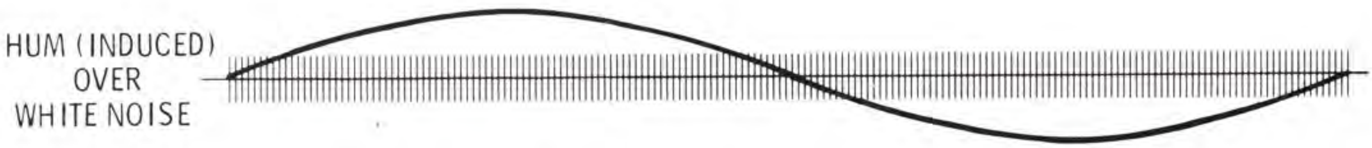


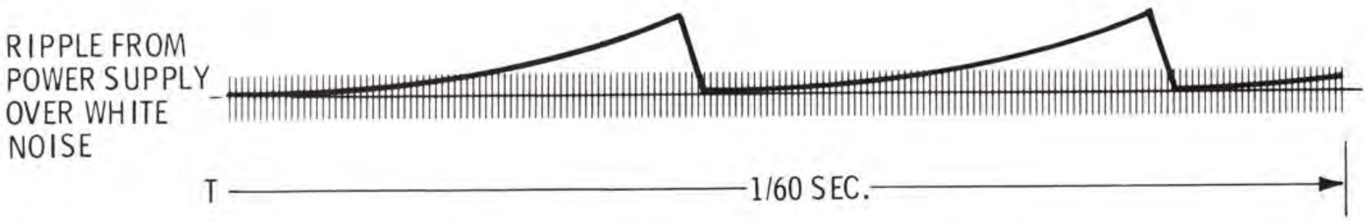
Figure 5. A simple high impedance isolation circuit. Note that the secondary winding of the transformer is loaded with a resistor equal to the secondary impedance. The modulation monitor output impedance will usually be low enough to load the primary, but the 100,000 Ohm input Z that is typical of most distortion meters is too high and unless shunted down can cause a high frequency roll-off. Using a transformer with a very high impedance secondary may invite RF pickup problems.



If the noise is a high frequency oscillation, the scope sweep can be adjusted to lock in on the signal. White noise is random in nature and can not be "synced".



Hum pickup is easy to identify because the pattern will lock when the scope sweep is synchronized to the line voltage.



This type of noise will also sync. to the line but it's frequency will be a multiple of the power line frequency.

Figure 6.

The noise isn't always in the circuitry under test either. The FCC requires that the system be adjusted for normal operation, so, any inputs to the console that are open during normal operation, such as the input fed by the tape cartridge system, should be left in that position while doing the proof. If, however, the residual noise level of the cart system is in excess of -60 dB, it will be passed along to the transmitter. Turning down the fader may reduce the noise level, but if that is not your normal method of operation, it is not honest to do so. The commission intended the equipment performance measurements to indicate the facility's operating condition and not to be an exercise in electronic broken field running.

If the noise problem does turn out to be in the transmitter itself though, remember that transmitters with direct FM exciters (most of the newer ones) are rather critical to power supply ripple in the modulated oscillator section, so be sure to check the ripple at that point against the manufacturer's service data; you may be surprised at how little ripple is tolerable. Also look for microphonic conditions in the exciter, as it is not uncommon to find the blower motor modulating the transmitter at about -55 dB or so. As a matter of fact, you may find yourself rating the end of the blower motor's bearing life in terms of FM signal to noise ratio.

Even the best and most thoroughly maintained stations can develop deficiencies between proofs, so the fact that the pre-test has shown some problems to exist should not be discouraging; it happens to everyone at some time or other. The important thing is that the bugs are worked out in advance of the actual proof and that the results of the proof are the very best that the engineer in charge can do with his facility. The pre-test is especially important when the proof is the very first one on a new installation. At that stage of the game anything can be expected, particularly since the engineer does not have the precedent of any other proof to fall back on.

Remember that repairs made to the system must be written into the maintenance log. This oversight could result in a citation.

CHAPTER 3. An efficient method of measurement and a look at the performance requirements

The equipment performance measurements should not be conducted as a race against the clock, and the engineer-in-charge should start out with a commitment to make the best possible proof no matter how long it may take. If, however, an efficient method of operation can avoid wasting time on redundant test operations, then the engineer is that much ahead of the game.

Eliminating redundancy of operations is very simple and involves simply looking at everything that must be done from end to end to see if there are any duplicated functions and then checking to see if any two tests can share a single test function. Let's begin our analysis of the proof requirements by listing all of the tests to be done with an eye toward spotting duplication of generator frequencies and modulation levels.

Frequency response - at 25, 50 & 100% modulation with modulating frequencies of 50, 100, 400, 1000, 5000, 10,000 & 15,000 Hz.

Distortion - at 25, 50 & 100% modulation with modulating frequencies of 50, 100, 400, 1000, 5000, 10,000 & 15,000 Hz.

Noise level - Below 100%, 400 Hz modulation.

Now let's rearrange the tests listed above in a different way. This time we'll look at what tests are made at each modulation level and frequency rather than at what frequencies and modulation levels each test are made. It may sound like double-talk at this point, but the revised list of tests below should clarify things.

Talk about redundancy of operations! Doing both response and distortion tests at each modulating frequency while the percentage of modulation is held constant enables the engineer to kill two birds with one audio tone and also minimizes the number of distortion meter input level adjustments required. Between 50 and 400 Hz the output of the modulation monitor output will be constant since these frequencies are below the knee of the 75 usec. preemphasis curve. The Commission requires that the standard 75 usec. de-emphasis be employed for the distortion measurements, so the output level will decrease as the modulating frequency increases past 400 Hz.

Stereo stations will have to duplicate the procedure for each channel, of course, and the 100% measurements are made with 45% L + R and 45% L - R modulation with a nominal 10% 19 kHz pilot. Most modulation monitors have a range that is calibrated to read 100% left or right relative modulation, however.

The Data Summary Sheet is arranged so that if the tests are made in the order they appear on the sheet, maximum advantage will be taken of the duplication of operations that exists. Fill in the generator output settings as each modulation level is reached, but leave the calculation of the actual deviations until the proof is complete. The distortion, carrier shift, noise etc., may be entered as it is measured. Remember that the response will be relative to the 400 Hz sensitivity.

Looking at the requirements

It is important to remember that the frequency response tests for the proof are really modulation

100% MODULATION

400	*100*	*50*	*1000*	*5000*	*10,000*	*15,000*
Response	Response	Response	Response	Response	Response	Response
Distortion	Distortion	Distortion	Distortion	Distortion	Distortion	Distortion
Noise						

50% MODULATION

40	*100*	*50*	*1000*	*5000*	*10,000*	*15,000*
Response	Response	Response	Response	Response	Response	Response
Distortion	Distortion	Distortion	Distortion	Distortion		

25% MODULATION

400	*100*	*50*	*1000*	*5000*	*10,000*	*15,000*
Response	Response	Response	Response	Response	Response	Response
Distortion	Distortion	Distortion	Distortion	Distortion		

sensitivity vs. frequency tests. The FCC rules specify the modulation levels and we measure the relative levels of the input voltage required for each modulating frequency. Part 73.254 requires that the response measurements cover the frequency range of 50 to 15,000 Hz with the results plotted against the 75 usec. standard pre-emphasis curve shown in 73.333. The measured response must fall between the limits shown in the illustration. While a response accuracy of 3 dB is required between 100 and 7500 Hz, the response can be down as much as 4 dB at 50 Hz and 5 dB at 15,000 Hz. The response requirements are set forth in 73.317 which also refers to Figure 2 of 73.333.

At this point a very interesting question arises: What to do with the limiter? Virtually all limiters employed for FM peak control affect an alteration of frequency response which is complimentary to the 75 usec. pre-emphasis curve so that a higher average level of modulation can be obtained without overmodulation. The output of the limiter is normally set so that a 15,000 Hz tone at full level on the console will not cause modulation in excess of 100%. This parameter is controlled by the limiter output level adjustment.

The **input level** determines the amount of high frequency compression and varies quite a bit from station to station, depending upon the format and technical prerogative of the programming and engineering departments. Obviously, stations that employ a high level into the FM peak limiter input will have a higher average modulation level but reduced treble fidelity. Stations with relatively low limiter input level will have less high frequency limiting. The proof rules require that any compression be defeated. But simply switching off the AGC will not do the trick for FM stations using this type of limiter, because response measurements and distortion tests are required at low frequencies and 100% modulation; a level which cannot usually be obtained. Most FM stations operate with a mid and low frequency level of about 60% modulation to leave some room for the treble before compression starts. When the AGC is switched off, the 50, 100 and 400 Hz levels are usually down around 60% while the higher frequencies get boosted by the transmitter pre-emphasis.

There are some rare cases where a station is operated with the 400 Hz level nearly up to 100% modulation (an "all talk" format perhaps) in which case it may be possible to switch off the AGC and increase the level at the console a couple of dB and obtain 100% modulation. In most cases the limiter output level control is after the amplifier output and can be adjusted to produce any maximum modulation level if this difficulty is encountered.

To be able to make the full modulation measurements, the limiter output level should be increased to the point where the threshold of limiting is at 100% modulation with a **400 Hz tone**. The frequency response can then be measured by recording the audio generator output levels required to produce 100% modulation at each of the other modulating frequencies. For example, at 50 and 100 Hz the same voltage would be required because these frequencies are below the pre-emphasis curve, but at 1000 Hz about 0.9 dB less generator output would be required and at 5000 Hz 8.4 dB less would be needed. Similarly, at 10,000 Hz the modulation sensitivity should be 13.8 dB higher resulting in 13.8 dB less generator output for the same 100% modulation level and at 15,000 Hz the generator output should be down to -17 dB. Any deviation from these figures represents a frequency response error.

If, for example, the generator output required to produce 100% modulation at 15,000 Hz is only 14 dB lower than the 400 Hz level, the frequency response is down 3 dB at 15 kHz. If the generator output at 5000 Hz was - 10 dB, then the response at 5000 Hz is +1.6 dB. The 50% and 25% modulation tests are made in the same manner except that the generator output is reduced further to produce 50% modulation at 400 Hz to begin with. The generator outputs for each of the other test frequencies are then compared to the ideal response figures and the system frequency response calculated in the same manner as for the 100% tests. The same procedure is followed for the 25% measurements. Figure 7 illustrates this method of setting the limiter up for the tests and also shows graphically why the limiter output must be increased to obtain full modulation.

Many engineers may be tempted to simply patch the limiter out of the circuit and defeat the AGC that way. While the regulations don't prohibit this kind of electronic surgery in any specific rule, we feel that removing the limiter from the circuit does not follow the "spirit of the regulations".

The distortion measurements are to be made at each of the frequencies the response tests are made at for 100% modulation and only up to 5000 Hz at 50 and 25%. These tests may be made while the response tests are made since the modulation levels will already be set up. At 25% modulation, noise will begin to affect the distortion measurements, particularly at 5000 Hz. The rules specify that 75 usec. de-emphasis should be employed, so expect the 25% 5000 Hz output level to the distortion meter to be quite low; about 20 dB lower than the 100% 400 Hz voltage. The FCC allows 3½% distortion between 50 and 100 Hz, 2½% between 100 and 7500 Hz and 3% from 10 kHz to 15 kHz. The 15 kHz input level is 17 dB lower than the 400 Hz level, so system noise becomes important since the signal is riding 17 dB closer to the noise.

Some modulation monitors do not have sufficient 19 kHz filtering to keep the stereo pilot from affecting the noise and distortion measurements when proofing a stereo station. The pilot is already down to -20 dB as broadcast, so a total of 50 dB of pilot filtering would be required to keep the 19 kHz component down to -70 dB. This may seem like a rather elementary filtering problem at first thought, but if you stop to consider the fact that the same circuit that attenuates the 19 kHz pilot by 50 dB must pass the upper limit of the response range, 15 kHz, without any attenuation.

Check the distortion meter output with a scope and see if you can lock in on any 19 kHz in the output. If the amplitude of the pilot is nearly equal to or greater

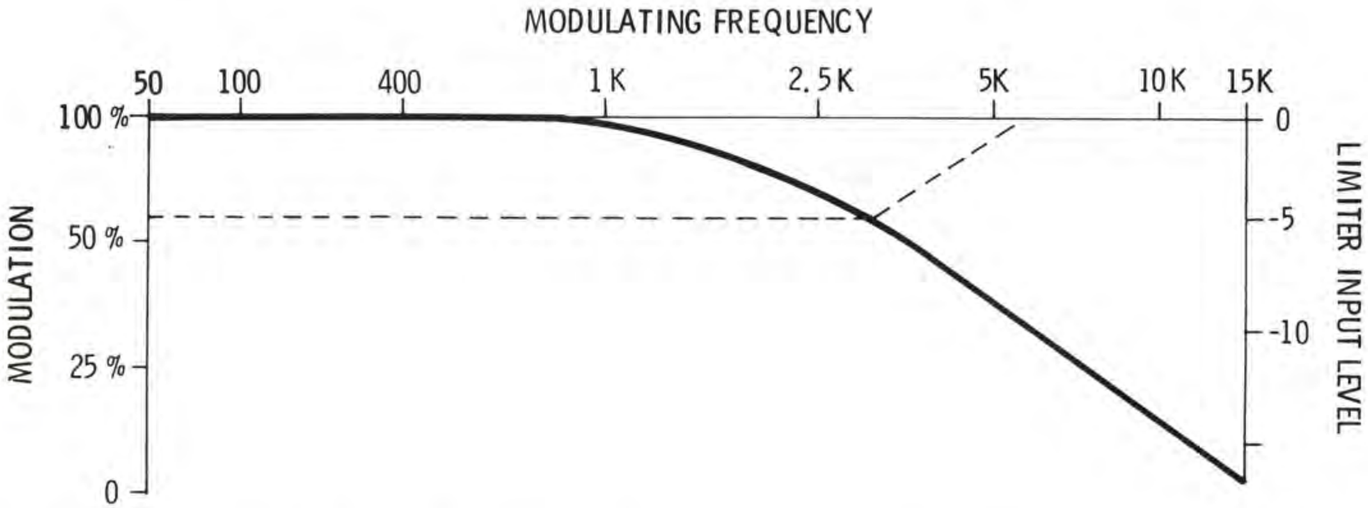


Figure 7. Setting up the limiter. Most FM peak limiters compensate for the effects of the 75 usec. pre-emphasis curve by providing a threshold of limiting that is the exact opposite of the pre-emphasis. A typical FM peak limiter limiting threshold is shown in the diagram above by the solid line. If the limiter was normally operated with the input level set so that any audio frequency would fully modulate the transmitter, the proof could be done by switching off the limiting and simply feeding an audio tone into the system at each frequency and recording the relative level required to modulate the transmitter to 100%. However, most stations do not operate their FM peak limiters at that high an input level because of the treble losses that result. Most stations average about 5dB below the threshold of limiting as shown by the dashed line, although some stations run within a couple of dB of the threshold and others as low as 10 dB below the threshold. The stations running high input levels may find that they can make 100% modulation at the lower frequencies by simply turning the console up a couple of dB but the stations that operate at the lower input levels will need too much drive from the console to get 100% modulation in the low and mid-range. The dashed line also shows the maximum modulation that can be expected at each audio frequency when the level into the limiter is 5 dB below the limiting threshold at 400 Hz. This assumes that the console levels have not been changed. As you can see, an unreasonable amount of increase would have to be obtained from the console; the VU meters would be pinned. The best solution to the problem is to increase the limiter output level controls until the 400 Hz tone @ OdB on the console produces 100% modulation. Adjusting the input controls would also result in satisfactory modulation but the FCC specifies that all equipment should be adjusted for normal operation and increasing the input level does not simulate the normal range of signals through the limiter. The output level controls are generally located after the internal amplifiers and operate as passive adjustable pads and may therefore be considered as modulation level adjustments. All of the program levels through the limiter would be the same as they are during normal programming.

than the peak-to-peak white noise, an external 19 kHz filter may be required. Use the toroid type 15 kHz low pass filter and check its response between 10 and 15 kHz before making the tests so that any roll-off near 15 kHz (1 or 2 dB loss at 15 kHz is not unusual) may be recorded and compensated for. A sharp 19 kHz notch filter could also be used. Most modulation monitors do employ sufficient pilot attenuation however, so you probably won't need any additional filtering to make the -60 dB noise and 3% 15 kHz distortion specs, but you should be aware of what the modulation monitor must do well for your tests to do well, assuming that the station is clean.

When proofing a stereo facility, apply the audio to only one channel at a time when making the distortion tests so that the leakage from the other channel doesn't interfere with the measurements at the higher audio frequencies. Even though the leakage may be down 30 dB, 1% distortion is only -40 dB.

If you are proofing a "Dolby" installation, the noise reduction units should be patched out or otherwise bypassed during the proof, as specified by the FCC public notice of July 10, 1974 clarifying the commissions view of FM Dolby practice.

In an FM system, the noise should be the first proof test made. The Commission requires that the FM noise to be at least 60 dB below 100% modulation and this is a rather difficult test to pass, especially for a stereo facility.

There is no magic solution to passing the noise test; if it's there it must be traced down and reduced to an acceptable level. Sometimes a noise problem can be traced to a basic design concept deficiency. One cannot add equipment to the program chain without regard to optimizing the S/N ratio at each point in the chain without the noise building up. It is quite possible to assemble a radio station in which each individual piece of equipment meets the manufacturer's noise specs and still not be able to pass the noise test because the accumulated noise of all of the equipment together is just too much. In this case, the best solution is usually to simplify the audio chain as much as possible. Careful re-adjustment of the audio chain levels can sometimes yield significant noise reductions, too.

The AM noise test is usually easier to pass with -50 dB being acceptable. Most FM modulation monitors have built in AM noise test facilities that relate the noise to the RF sample voltage. A problem with AM noise generally indicates a power supply filtering problem and should not be difficult to correct. This is one type of noise that you may not notice "on the air" because most FM receivers do not respond to amplitude variation as long as the received signal is strong enough.

Optional stereo tests

We say optional because the FCC rules do not state specifically that these tests should be included in the proof, but we would certainly recommend that they be voluntarily added. At any rate, we cannot imagine that a licensee would want to operate a stereo broadcast station without a check of the stereo performance at least at proof time.

Before beginning, connect a good wide-band scope to the exciter at the composite output sample terminal of the stereo generator and check to see if the baseline is flat and the 19/38 kHz phasing right on. Use the shortest possible test leads with the least possible capacitance. If a low cap probe cannot be obtained, try two short pieces of wire loosely twisted together, just long enough to reach the scope.

Figure 8 illustrates the ideal waveforms to look for. If the base-line is wavy, the L+R gain is either too high or too low (assuming a low capacitance connection). If the points don't match up in the phasing test, the pilot phase should be tweeked. In either case, check the manufacturer's service data for the proper procedure and be sure to check the pilot level after any pilot phase adjustment because the two sometimes interact. It is a waste of time to begin the stereo tests for separation if the composite waveform out of the stereo generator into the exciter is not perfect.

Next, check the length of the cable from the transmitter sample output to the modulation monitor RF input. If the cable is much longer than it has to be to reach the monitor, you may have to shorten it. In some rare cases a VSWR can develop in the sample circuit which will impair the separation measurement accuracy. After you are satisfied that the transmitter is receiving a good input from the stereo generator and the modulation monitor is getting a clean sample signal, the stereo tests can begin.

Adjust the generator for full left modulation and measure the leakage into the right channel at 50, 100, 400, 1000, 5000, 10,000 & 15,000 Hz. The leakage must not exceed 29.7 dB. Remember to decrease the generator output at the higher frequencies so that the pre-emphasis does not boost the signal into overmodulation.

If the channel separation is not up to par, check any phasing adjustment that the modulation monitor may have. The modulation monitor is as much a part of a stereo proof as the transmitter, and it is important to realize that the monitor stereo circuits are also susceptible to drift. If your scope check of the stereo generator phasing showed a perfect waveform but the modulation monitor phase adjustment won't work the way the manual says that it should, suspect the modulation monitor alignment.

If the left to right separation is OK, reverse the audio connections and modulate the right channel while measuring the leakage into the left channel. The separation figures will rarely be equal left to right and right to left, but the 29.7 dB spec should be pretty easy to make across the band. You may have to make some adjustment to the stereo generator to optimize performance, but the scope pre-test should bring you pretty close.

To check the sub to main and main to sub cross-talk, a means of generating a L-R difference signal must be obtained. The circuit shown in Figure 4e was designed for this purpose. The FCC rules specify that the cross-talk may not exceed 40 dB which is quite an easy spec to make if the channel balance is very accurate.

When the L+R signal is applied to the console input, any difference in the relative levels of the left and right channels manifests itself as a L-R component. To avoid generating any L-R that would interfere with the real cross-talk measurement, adjust the channel balance with the master gain controls until a minimum cross-talk indication is obtained. Any high frequency phase shift between the channels will cause a cross-talk indication. The channels **may not be re-balanced** at each frequency. They should be balanced at 400 Hz at the beginning of the test and not changed again.

If you find that the console meters show an imbalance when the master gain controls are adjusted to null out the sub-carrier modulation, this is an indication that there is a channel balance error somewhere down the line in the audio chain. To rectify the situation, adjust the console for equal channel balance and then carefully check the relative levels at each input and output down the line all the way to the transmitter stereo generator input until the source of the balance error is found. The console should be within 1 dB of balance at the point where the L-R nulls out with a L+R signal applied to the input.

Phase shifts are not usually a problem unless there is a Telco loop in the chain. It is important that the Telco loop for each channel be nearly the same length to obtain satisfactory results. Some local telephone installation people may not be aware of the stringent phasing requirement.

The FCC also requires that the 38 kHz sub-carrier be attenuated to 1% or less which is -40 dB. Check the manufacturer's service date for adjusting the sub-carrier null if your transmitter won't pass this test.

Whether the station is a mono or a stereo facility, it is advisable to try to obtain a spectrum analyzer at proof time so that the second harmonic output and occupied bandwidth of the transmitter may be checked. While this instrument usually costs several thousands of dollars to buy, it is often possible to rent one for very little cost. It is impossible to describe one test procedure that would suffice for the spectrum analyzer check because of the vast differences in the units themselves, but the transmitter manufacturer's service department is generally very helpful in suggesting suitable test equipment and procedures.

The FCC requires that the second harmonic be attenuated 80 dB, a spec which is easy to check with an analyzer that has a log display calibrated in dB. A linear display is more useful for checking the occupied bandwidth, which should be done with normal program material for a signal source. Most of the better spectrum analyzers have both functions available in the IF strip, switchable from the front panel.

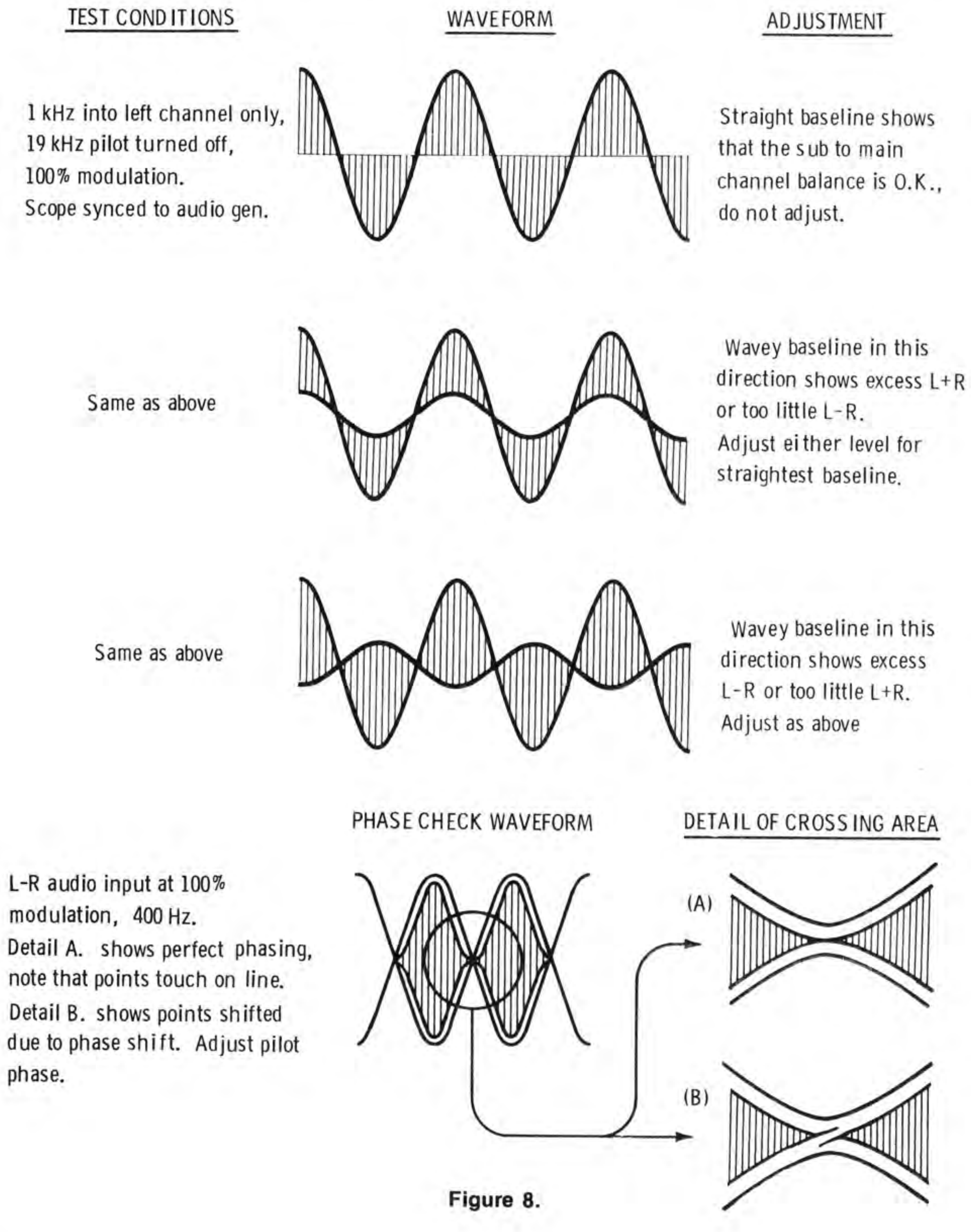


Figure 8.

CHAPTER 4. Using the data summary sheet and evolving the graphs

The purpose of the data summary sheet is to provide an organized plan for recording the test results as they are obtained. The value of this organization will be appreciated later when we must draw from this collection of figures to assemble the graphs required by the FCC.

Before discussing the form itself, let's take a look at how the numerical data should be entered. Most electrical quantities can be recorded as 3-place decimals, although in some cases this is not possible or practical. For example, the response at 50 Hz may be read from the meter face as -2.5 dB but the engineer who can see -2.54 dB has mighty keen vision indeed. A signal-to-noise ratio of 51.5 dB is quite easy to see, however, so there is no way that one can specify the exact number of significant digits that the data should be carried to because the circumstances vary a bit.

Figure 9 illustrates a sample data summary sheet, complete with typical data filled in. From this example you can see that it is possible to enter data directly onto the form as it is measured, and that is the way that it is usually done.

The frequency response section contains two columns; one for the original audio generator output voltage settings and another for the actual response deviation figures. It is important that any possibility for error in transferring the test results from the meter face to the data sheet be eliminated, and that is the reason for recording the audio generator output settings. While it is not difficult to figure out the response deviations mentally as the data is measured, an error in addition or subtraction would never be discovered and erroneous data would be recorded. By recording the generator output, the engineer is free to concentrate on the tests at hand and worry about the math later. There is also a record of the original data that can be double-checked with the deviation figures to insure accuracy.

Filling in the distortion figures is straightforward and can be done at the same time the response data is gathered. When recording distortion figures of less than 1% or response deviations of less than 1 dB, it is customary to place a 0 to the left of the decimal point to preclude any ambiguity about whether the number is whole or fractional. In a group of numbers, -.2 dB doesn't look too different from -2 dB, but -0.2 dB is at once recognizable as a different animal. See Figure 9 for an illustration of how typical values would be recorded on the form.

Much more complex and technically ominous forms for gathering the test data could be evolved, but what the FCC is really looking for is carefully measured and accurately recorded test results without unnecessary garnishment. While good engineering practices should be observed, it is not necessary that each page be a notorized affidavit with all times converted to Greenwich Meridian.

Although the rules for FM performance measurements (73.254) do not specifically require that the data from the tests be graphed as it does in 73.47 for the AM proof, it is customary to do so and really takes very little extra time when pre-printed forms are available. It is recommended that the response deviation and distortion limits be marked on the graphs so that marginal performance in any category will show up more easily.

If your current proof is coming close to the limit in any respect, check past proofs to see if better performance was obtained. If so, a detailed investigation of each segment of the system should be initiated as soon as possible since such drifting performance could indicate degeneration of some part of the system and this may cause the station to fall short of minimum standards before the next regularly scheduled equipment performance measurements are made. This is one of the reasons that the graphic representation of the station's performance is so useful.

Figures 10 & 11 are sample performance graphs illustrating typical performance for FM Stereo stations. You will note that the curves here are really a series of straight lines connecting each measured response or distortion figure. In this case, data was taken only at 50, 100, 400, 1k, 5k, 10k & 15k as required by paragraph 73.254, so these are the only points that are available to connect. It is usually quite satisfactory to limit the measurements to these six modulating frequencies, although if you are interested in determining the exact shape of the roll-off's at either or both ends, more data may be taken between 50 & 400 or 5k & 15k so that a real curve may be traced. If the response is flat within a couple of dB however, it is obvious that the curve will be very close to a straight line.

Any test series may be expanded to include volumnous data, but the FCC is more interested in low distortion figures and flat response than in a multiplicity of measurements.

BROADCAST ENGINEERING®

OFFICIAL PROOF FORM

DATA SUMMARY SHEET

STATION WXYZ FM

NOISE TESTS: AM NOISE -56 dB FM LEFT (or mono) -62 dB FM RIGHT -63 dB

	LEFT (or mono)				RIGHT			
	FREQ.	GEN. OUT.	RESP. DEV.	DIST.	FREQ.	GEN. OUT.	RESP. DEV.	DIST.
100% MOD.	50	-29.0	-1.0	0.7	50	-29.0	-1.0	0.6
	100	-30.0	0	0.6	100	-30.0	0	0.5
	400	-30.0	0	0.5	400	-30.0	0	0.4
	1k	-30.9	0	0.5	1k	-30.9	0	0.4
	5k	-38.0	+0.4	0.5	5k	-38.0	+0.4	0.5
	10k	-43.0	-0.8	0.6	10k	-43.0	-0.8	0.6
	15k	-45.0	-2.0	0.7	15k	-45.0	-2.0	0.7
50% MOD.	50	-34.0	-1.0	0.7	50	-34.0	-1.0	0.6
	100	-35.0	0	0.7	100	-35.0	0	0.6
	400	-35.0	0	0.7	400	-35.0	0	0.6
	1k	-35.9	0	0.7	1k	-35.9	0	0.7
	5k	-43.0	+0.4	0.9	5k	-43.0	+0.4	0.8
	10k	-48.0	-0.8		10k	-48.0	-0.8	
	15k	-50.0	-2.0		15k	-50.0	-2.0	
25% MOD.	50	-40.0	-1.0	0.7	50	-40.0	-1.0	0.7
	100	-41.0	0	0.7	100	-41.0	0	0.7
	400	-41.0	0	0.7	400	-41.0	0	0.7
	1k	-41.9	0	0.9	1k	-41.9	0	0.9
	5k	-49.0	+0.4	1.2	5k	-49.0	+0.4	1.2
	10k	-54.0	-0.8		10k	-54.0	-0.8	
	15k	-56.0	-2.0		15k	-56.0	-2.0	

ALL RESPONSE DATA IN dB
ALL DISTORTION DATA IN%

ALL TESTS PERFORMED BY Henry J. Ampere

DATE 2/15/75

Figure 9.

BROADCAST ENGINEERING
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WXYZ

FM STEREO PERFORMANCE DATA

STEREO SEPARATION

RESIDUAL LEFT IN RIGHT (dB)	FREQ.	RESIDUAL RIGHT IN LEFT (dB)
-39	50	-39
-40	100	-40
-41	400	-42
-40	1k	-41
-37	5k	-38
-36	10k	-37
-35	15k	-36

CROSS-TALK

RESIDUAL MAIN IN SUB CHANNEL (dB)	FREQ.	RESIDUAL SUB IN MAIN CHANNEL (dB)
-47	50	-48
-47	100	-49
-47	400	-50
-48	1k	-50
-48	5k	-50
-47	10k	-50
-47	15k	-49

38 kHz SUPPRESSION = -49 dB (1% = 40dB) PILOT INJECTION = 9.2 %. FREQ. DEV. = +0.4 Hz

ALL TESTS PERFORMED BY: Henry J. Ampere

DATE: 2/15/75

Figure 9A.

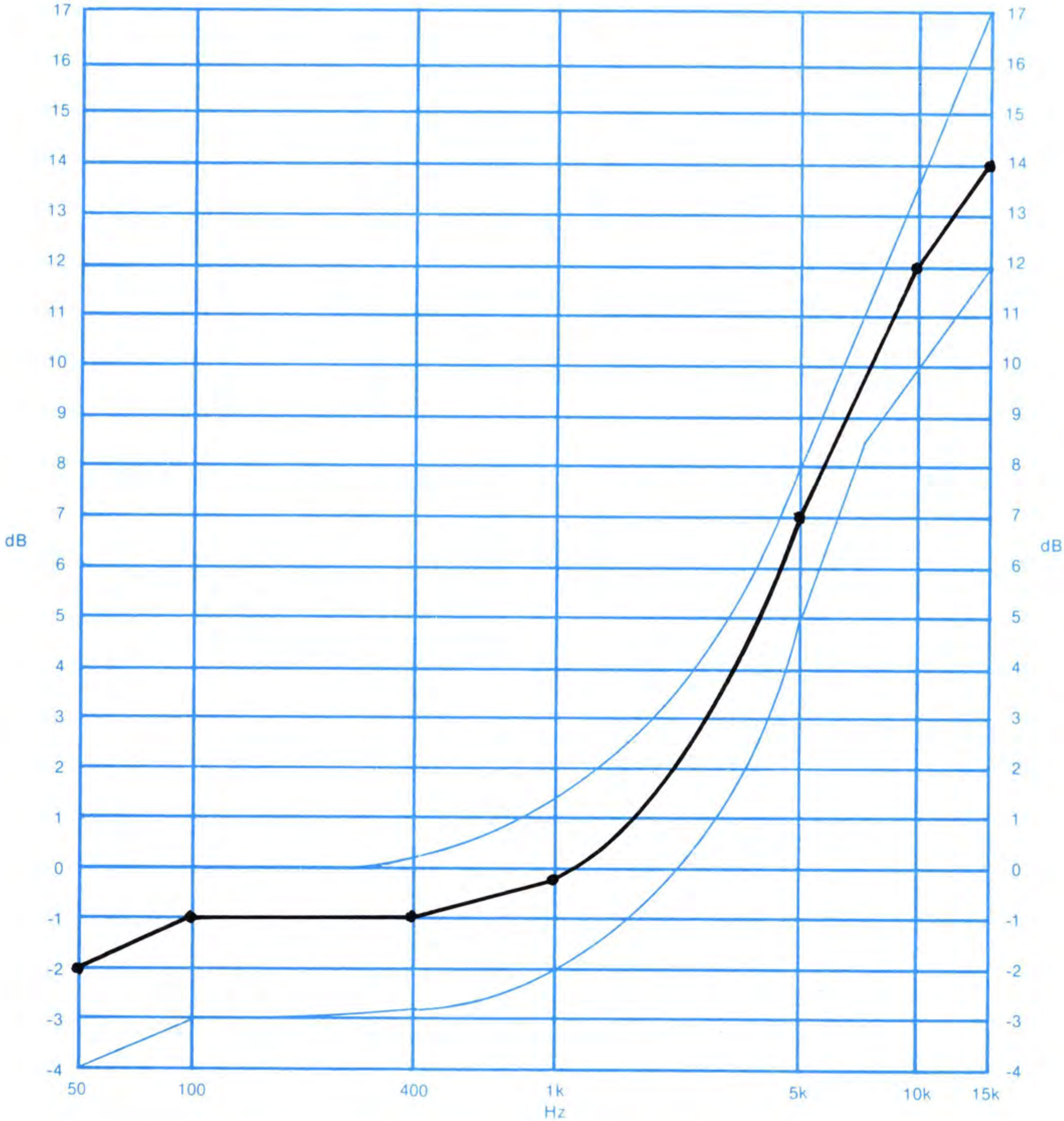
BROADCAST ENGINEERING
OFFICIAL PROOF FORM

WXYZ

FM FREQUENCY RESPONSE

MONO ☐ LEFT ☑ RIGHT ☐

@ 50% MODULATION



ALL TESTS PERFORMED BY: Henry J. Ampere

DATE: 2/15/75

Figure 10.

BROADCAST ENGINEERING®
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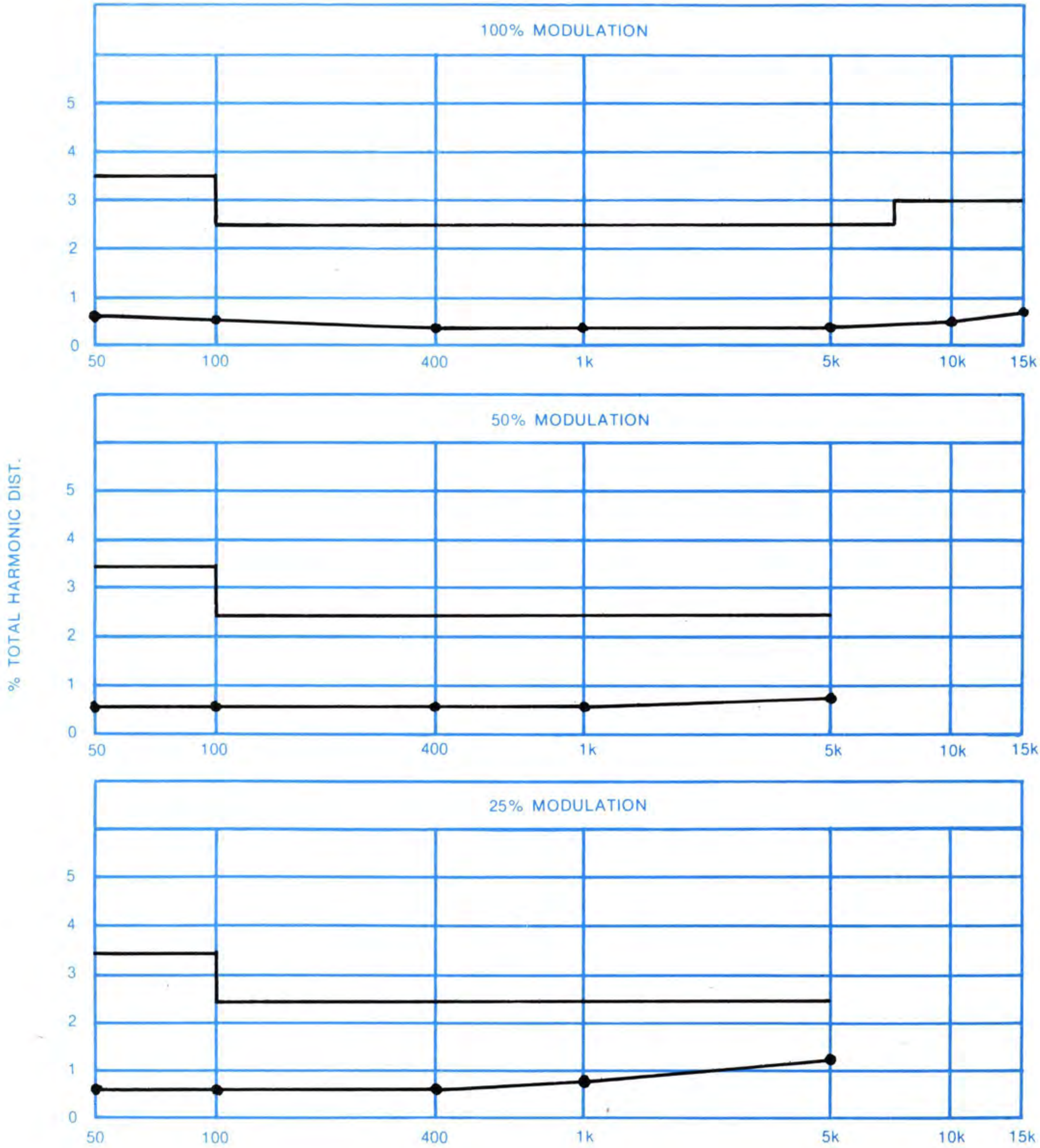
WXYZ FM SYSTEM DISTORTION

MONO ☐ LEFT ☑ RIGHT ☐



ALL TESTS PERFORMED BY: Henry J. Ampere

Figure 11.

DATE: 2/15/75

CHAPTER 5. FCC REFERENCES

§ 73.254 Required transmitter performance.

(a) The construction, installation, operation and performance of the FM broadcast transmitting system shall be in accordance with § 73.317.

(b) The licensee of each FM broadcast station shall make equipment performance measurements at least once each calendar year: *Provided, however,* That the dates of completion of successive sets of measurements shall be no more than 14 months apart. One set of measurements shall be made during the 4 month period preceding the filing date of the application for renewal of station license. Equipment performance measurements for auxiliary transmitters are not required. Equipment performance measurements shall be made with equipment adjusted for normal program operation and shall include all circuits between the main studio microphone terminals and the antenna circuit, including telephone lines, preemphasis circuits and any equalizers employed, except for microphones, and without compression if a compression amplifier is installed. The measurement program shall yield the following information:

(1) Audio frequency response from 50 to 15,000 hertz (Hz) 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 Hz. The frequency response measurements should normally be made without deemphasis; however, standard 75 microseconds 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.

(2) Audio frequency harmonic distortion for 25, 50 and 100 percent modulation for the fundamental frequencies of 50, 100, 400, 1000, and 5000 Hz. Audio frequency harmonics for 100 percent modulation for fundamental frequencies of 10,000 and 15,000 Hz. Measurements shall normally include harmonics to 30,000 Hz. The distortion measurements shall be made employing 75 microsecond deemphasising in the measuring equipment for system.

(3) Output noise level (frequency modulation) in the band of 50 to 15,000 Hz in decibels (dB) below the audio frequency level representing a frequency swing to 75 kHz. The noise measurements shall be made employing 75 microsecond deemphasis in the measuring equipment for system.

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

(c) The data required by paragraph (b) of this section, together with a description of instruments and procedure signed by the engineer making the measurements, shall be kept on file at the transmitter and retained for a period of two years, and shall be made available during that time upon request to any duly authorized representative of the Federal Communications Commission.

§73.317 Transmitters and associated equipment.

(a) *Electrical performance standards.* The general design of the FM broadcast transmitting system (from input terminals of microphone preamplifier, through audio facilities at the studio, through lines or other circuits between studio and transmitter, through audio facilities at the transmitter, and through the transmitter, but excluding equalizers for the correction of deficiencies in microphone response) shall be in accordance with the following principles and specifications:

(1) The transmitter shall operate satisfactorily in the operating power range with a frequency swing of 75 kilohertz (kHz), which is defined as 100 percent modulation.

(2) The transmitting system shall be capable of transmitting a band of frequencies from 50 to 15,000 hertz (Hz). Preemphasis shall be employed in accordance with the impedance-frequency characteristic of a series inductance-resistance network having a time constant of 75 microseconds. (See Fig. 2 of § 73.333.) The deviation of the system response from the standard preemphasis curve shall lie between two limits as shown in Figure 2 of § 73.333. The upper of these limits shall be uniform (no deviation) from 50 to 15,000 Hz. The lower limit shall be uniform from 100 to 7,500 Hz, and 3 dB below the upper limit; from 100 to 50 Hz the lower limit shall fall from the 3 dB limit at a uniform rate of 1 dB per octave (4 dB at 50 Hz); from 7,500 to 15,000 Hz the lower limit shall fall from the 3 dB limit at a uniform rate of 2 dB per octave (5 dB at 15,000 Hz).

(3) At any modulation frequency between 50 and 15,000 Hz and at modulation percentages of 25, 50, and 100 percent, the combined audio frequency harmonics measured in the output of the system shall not exceed the root-mean-square values given in the following table:

Modulating frequency:	*Distortion percent*
50 to 100 Hz	3.5
100 to 7,500 Hz	2.5
7,500 to 15,000 Hz	3.0

(i) Measurements shall be made employing 75 microsecond deemphasis in the measuring equipment and 75 microsecond preemphasis in the transmitting equipment, and without compression if a compression amplifier is employed. Harmonics shall be included to 30 kHz.

(ii) It is recommended that none of the three main divisions of the system (transmitter, studio to transmitter circuit, and audio facilities) contribute over one-half of these percentages since at some frequencies the total distortion may become the arithmetic sum of the distortions of the divisions.

(4) The transmitting system output noise level (frequency modulation) in the band of 50 to 15,000 Hz shall be at least 60 decibels below 100 percent modulation (frequency swing of ±75 kHz). The measurement shall be made using 400 cycle modulation as a reference. The noise-measuring equipment shall be provided with standard 75 microsecond deemphasis; the ballistic characteristics of the instrument shall be similar to those of the standard VU meter.

(5) The transmitting system output noise level (amplitude modulation) in the band of 50 to 15,000 Hz shall be at least 50 decibels below the level representing 100 percent amplitude modulation. The noise-measuring equipment shall be provided with standard 75-microsecond deemphasis; the ballistic characteristics of the instrument shall be similar to those of the standard VU meter.

(6) Automatic means shall be provided in the transmitter to maintain the assigned center frequency within the allowable tolerance (±2,000 Hz).

(7) The transmitter shall be equipped with suitable indicating instruments for the determination of operating power and with other instruments as are necessary for proper adjustment, operation, and maintenance of the equipment (see § 73.320).

(8) Adequate provision shall be made for varying the transmitter output power to compensate for excessive variations in line voltage or for other factors affecting the output power.

(9) Adequate provision shall be provided in all component parts to avoid overheating at the rated maximum output power.

(10) Means should be provided for connection and continuous operation of approved frequency and modulation monitors.

(11) If a limiting or compression amplifier is employed, precaution should be maintained in its connection in the circuit due to the use of preemphasis in the transmitting system.

(12) Any emission appearing on a frequency removed from the carrier by between 120 kHz and 240 kHz, inclusive, shall be attenuated at least 25 decibels below the level of the unmodulated carrier. Compliance with this specification will be deemed to show the occupied bandwidth to be 240 kHz or less.

(13) Any emission appearing on a frequency removed from the carrier by more than 240 kHz and up to and including 600 kHz shall be attenuated at least 35 dB below the level of the unmodulated carrier.

(14) Any emission appearing on a frequency removed from the carrier by more than 600 kHz shall be attenuated at least $43 + 10 \cdot \text{Log}_{10}$ (Power, in Watts) decibels below the level of the unmodulated carrier, or 80 decibels, whichever is the lesser attenuation.

§ 73.322 Stereophonic transmission standards.

(a) The modulating signal for the main channel shall consist of the sum of the left and right signals.

(b) A pilot subcarrier at 19,000 hertz (Hz) plus or minus 2 Hz shall be transmitted that shall frequency modulate the main carrier between the limits of 8 and 10 percent.

(c) The stereophonic subcarrier shall be the second harmonic of the pilot subcarrier and shall cross the time axis with a positive slope simultaneously with each crossing of the time axis by the pilot subcarrier.

(d) Amplitude modulation of the stereophonic subcarrier shall be used.

(e) The stereophonic subcarrier shall be suppressed to a level less than one percent modulation of the main carrier.

(f) The stereophonic subcarrier shall be capable of accepting audio frequencies from 50 to 15,000 Hz.

(g) The modulating signal for the stereophonic subcarrier shall be equal to the difference of the left and right signals.

(h) The pre-emphasis characteristics of the stereophonic subchannel shall be identical with those of the main channel with respect to phase and amplitude at all frequencies.

(i) The sum of the side bands resulting from amplitude modulation of the stereophonic subcarrier shall not cause a peak deviation of the main carrier in excess of 45 percent of total modulation (excluding SCA subcarriers) when only a left (or right) signal exists; simultaneously in the main channel, the deviation when only a left (or right) signal exists shall not exceed 45 percent of total modulation (excluding SCA subcarriers).

(j) Total modulation of the main carrier including pilot subcarrier and SCA subcarriers shall meet the requirements of § 73.268 with maximum modulation of the main carrier by all SCA subcarriers limited to 10 percent.

(k) At the instant when only a positive left signal is applied, the main channel modulation shall cause an upward deviation of the main carrier frequency; and the stereophonic subcarrier and its sidebands signal shall cross the time axis simultaneously and in the same direction.

(l) The ratio of peak main channel deviation to peak stereophonic subchannel deviation when only a steady state left (or right) signal exists shall be within plus or minus 3.5 percent of unity for all levels of this signal and all frequencies from 50 to 15,000 Hz.

(m) The phase difference between the zero points of the main channel signal and the stereophonic subcarrier sidebands envelope, when only a steady state left (or right) signal exists, shall not exceed plus or minus 3 degrees for audio modulating frequencies from 50 to 15,000 Hz.

NOTE: If the stereophonic separation between left and right stereophonic channels is better than 29.7 decibels at audio modulating frequencies between 50 and 15,000 Hz, it will be assumed that paragraphs (l) and (m) of this section have been complied with.

(n) Cross-talk into the main channel caused by a signal in the stereophonic subchannel shall be attenuated at least 40 decibels below 90 percent modulation.

(o) Cross-talk into the stereophonic subchannel caused by a signal in the main channel shall be attenuated at least 40 decibles below 90 percent modulation.

(p) For required transmitter performance, all of the requirements of § 73.254 shall apply with the exception that the maximum modulation to be employed is 90 percent (excluding pilot subcarrier) rather than 100 percent.

(q) For electrical performance standards of the transmitter and associated equipment, the requirements of § 73.317(a) (2), (3), (4), and (5) shall apply to the main channel and stereophonic subchannel alike, except that where 100 percent modulation is referred to, this figure shall include the pilot subcarrier.

CHAPTER 6. Your individual forms

BROADCASTENGINEERING®

OFFICIAL PROOF FORM

DATA SUMMARY SHEET
STATION ____________ FM

NOISE TESTS: AM NOISE _____ dB FM LEFT (or mono) _____ dB FM RIGHT _____ dB

		LEFT (or mono)				RIGHT		
	FREQ.	GEN. OUT.	RESP. DEV.	DIST.	FREQ.	GEN. OUT.	RESP. DEV.	DIST.
100% MOD.	50				50			
	100				100			
	400				400			
	1k				1k			
	5k				5k			
	10k				10k			
	15k				15k			
50% MOD.	50				50			
	100				100			
	400				400			
	1k				1k			
	5k				5k			
	10k				10k			
	15k				15k			
25% MOD.	50				50			
	100				100			
	400				400			
	1k				1k			
	5k				5k			
	10k				10k			
	15k				15k			

ALL RESPONSE DATA IN dB
ALL DISTORTION DATA IN%

ALL TESTS PERFORMED BY: ______________________________

DATE: ______________________ __________

FM STEREO PERFORMANCE DATA

STEREO SEPARATION

	RESIDUAL LEFT IN RIGHT	FREQ.	RESIDUAL RIGHT IN LEFT	
	______	50	______	
	______	100	______	
	______	400	______	
dB	______	1k	______	dB
	______	5k	______	
	______	10k	______	
	______	15k	______	

CROSS-TALK

	RESIDUAL MAIN IN SUB CHANNEL	FREQ.	RESIDUAL SUB IN MAIN CHANNEL	
	______	50	______	
	______	100	______	
	______	400	______	
dB	______	1k	______	dB
	______	5k	______	
	______	10k	______	
	______	15k	______	

38 kHz SUPPRESSION = ______ dB (1% = 40dB) PILOT INJECTION = ______ %, FREQ. DEV. = ______ Hz

ALL TESTS PERFORMED BY: ______________________

DATE: ______________________

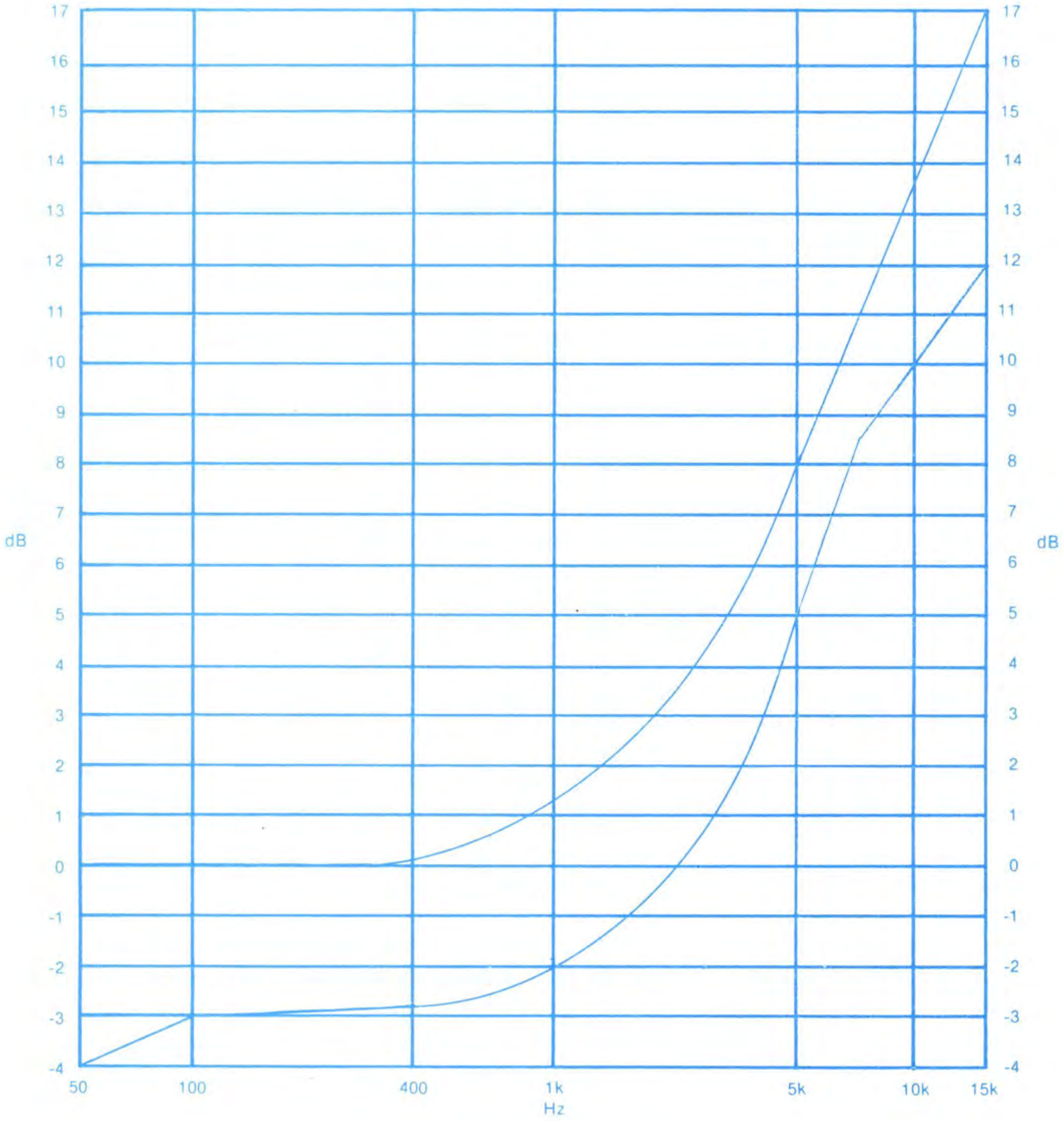
BROADCAST ENGINEERING

OFFICIAL PROOF FORM

FM FREQUENCY RESPONSE

MONO ☐ LEFT ☐ RIGHT ☐

@ ____________ MODULATION



ALL TESTS PERFORMED BY: ____________________

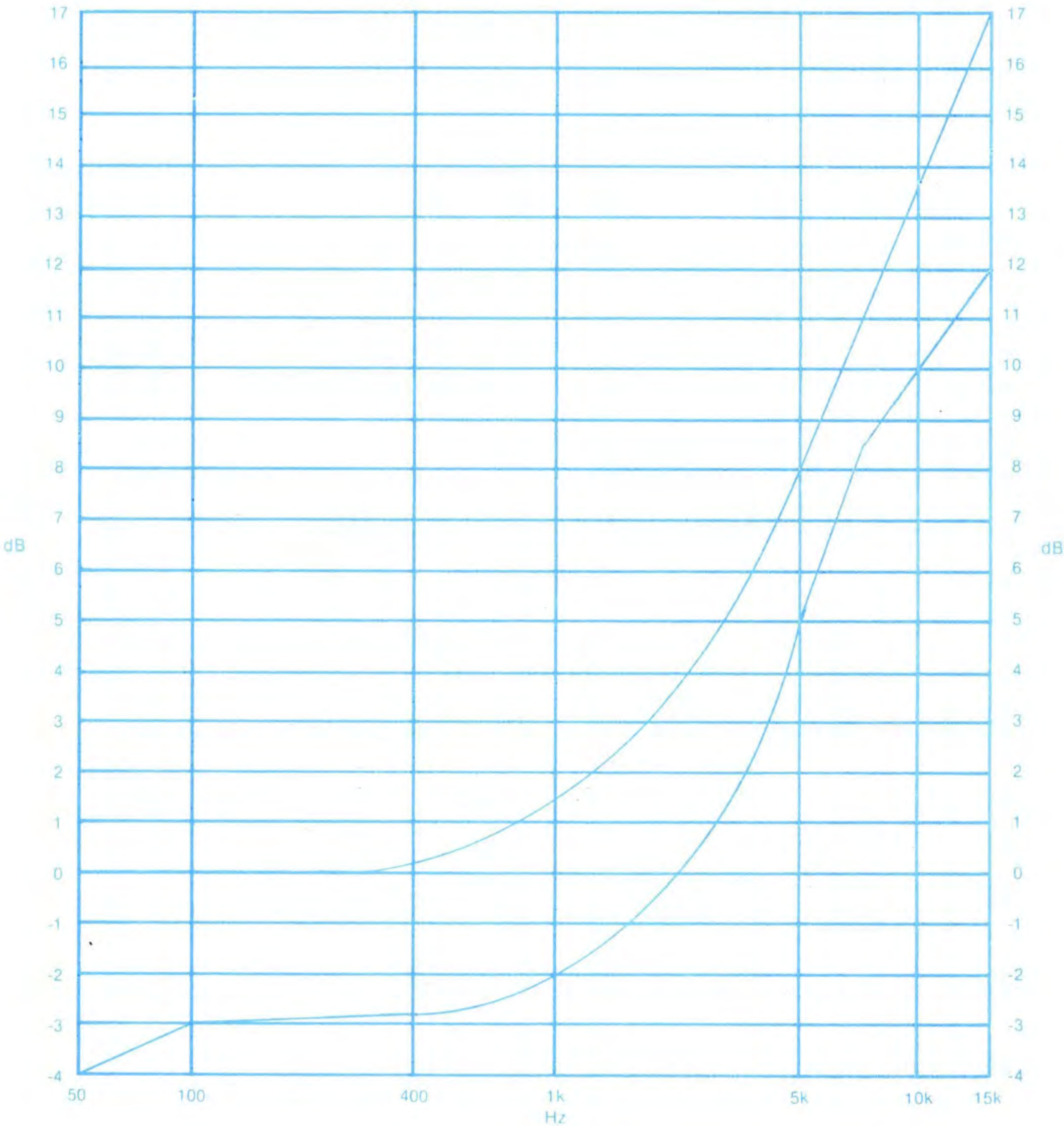
DATE: ____________________

____

FM FREQUENCY RESPONSE

MONO ☐ LEFT ☐ RIGHT ☐

@ ________ MODULATION



ALL TESTS PERFORMED BY: ______________________

DATE: ______________________

BROADCAST ENGINEERING®

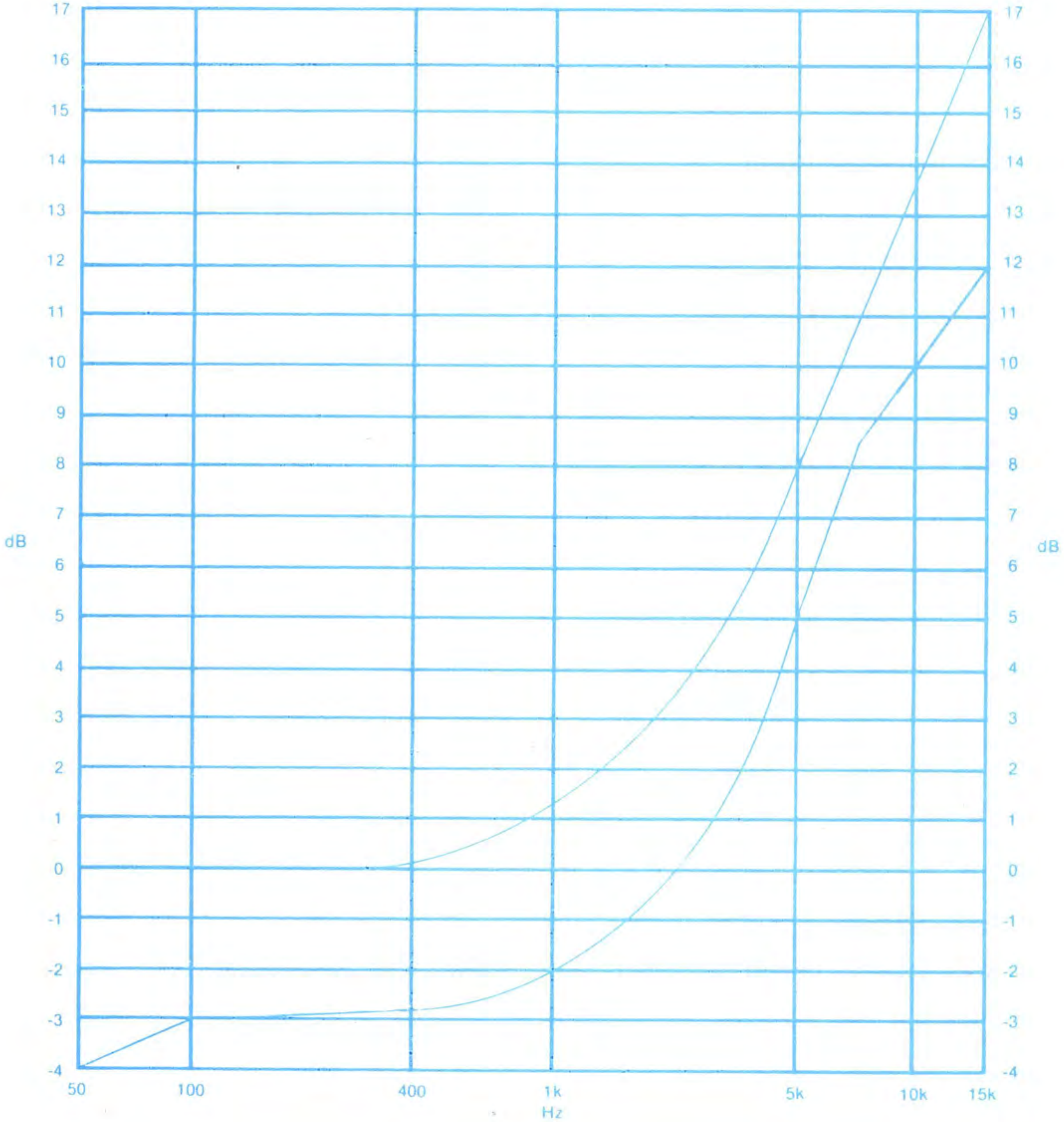
OFFICIAL PROOF FORM

____

FM FREQUENCY RESPONSE

MONO ☐ LEFT ☐ RIGHT ☐

@ __________ MODULATION



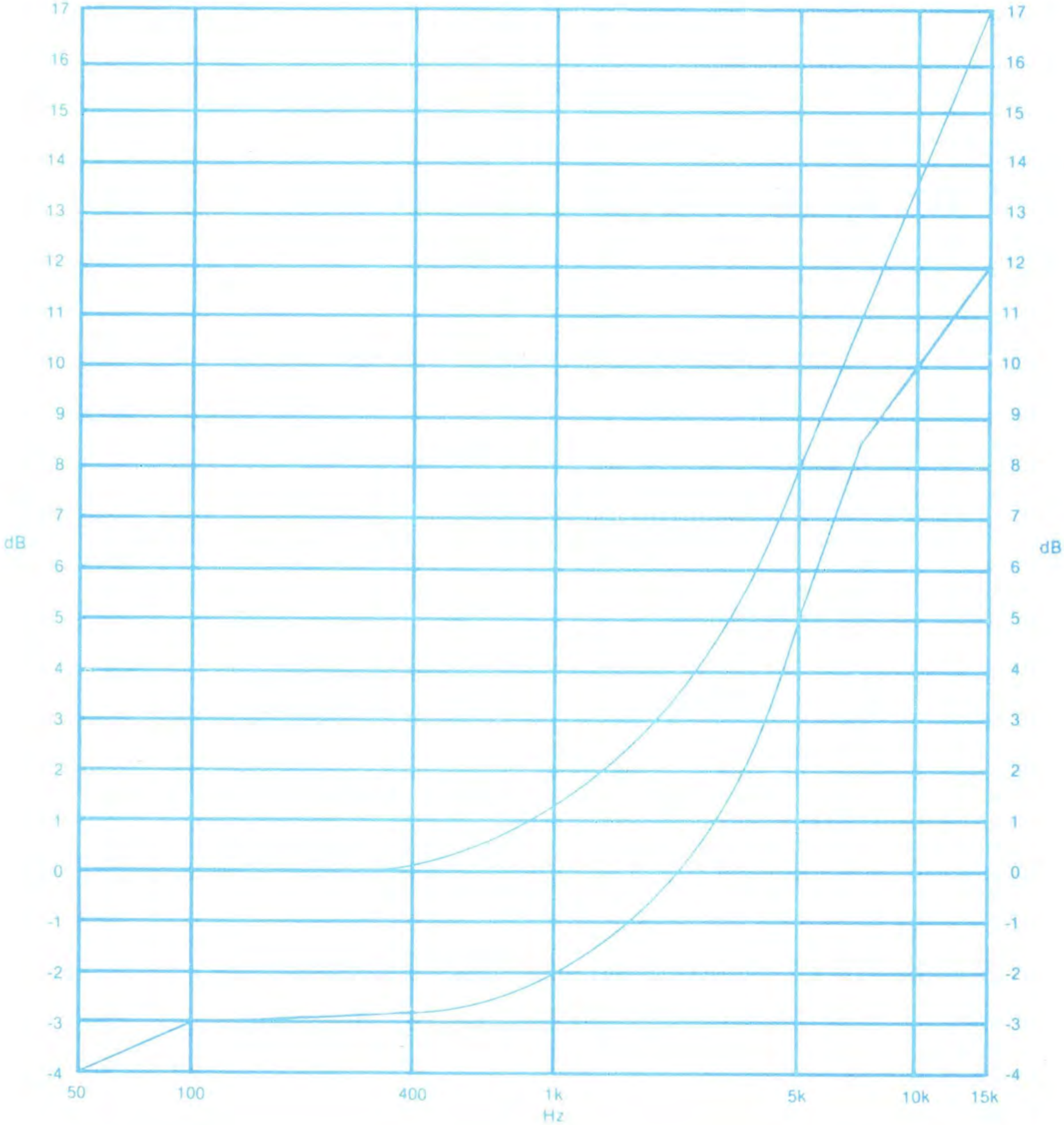
ALL TESTS PERFORMED BY ______________________________

DATE: ______________________________

FM FREQUENCY RESPONSE

MONO ☐ LEFT ☐ RIGHT ☐

@ ______ MODULATION



ALL TESTS PERFORMED BY: ______

DATE: ______

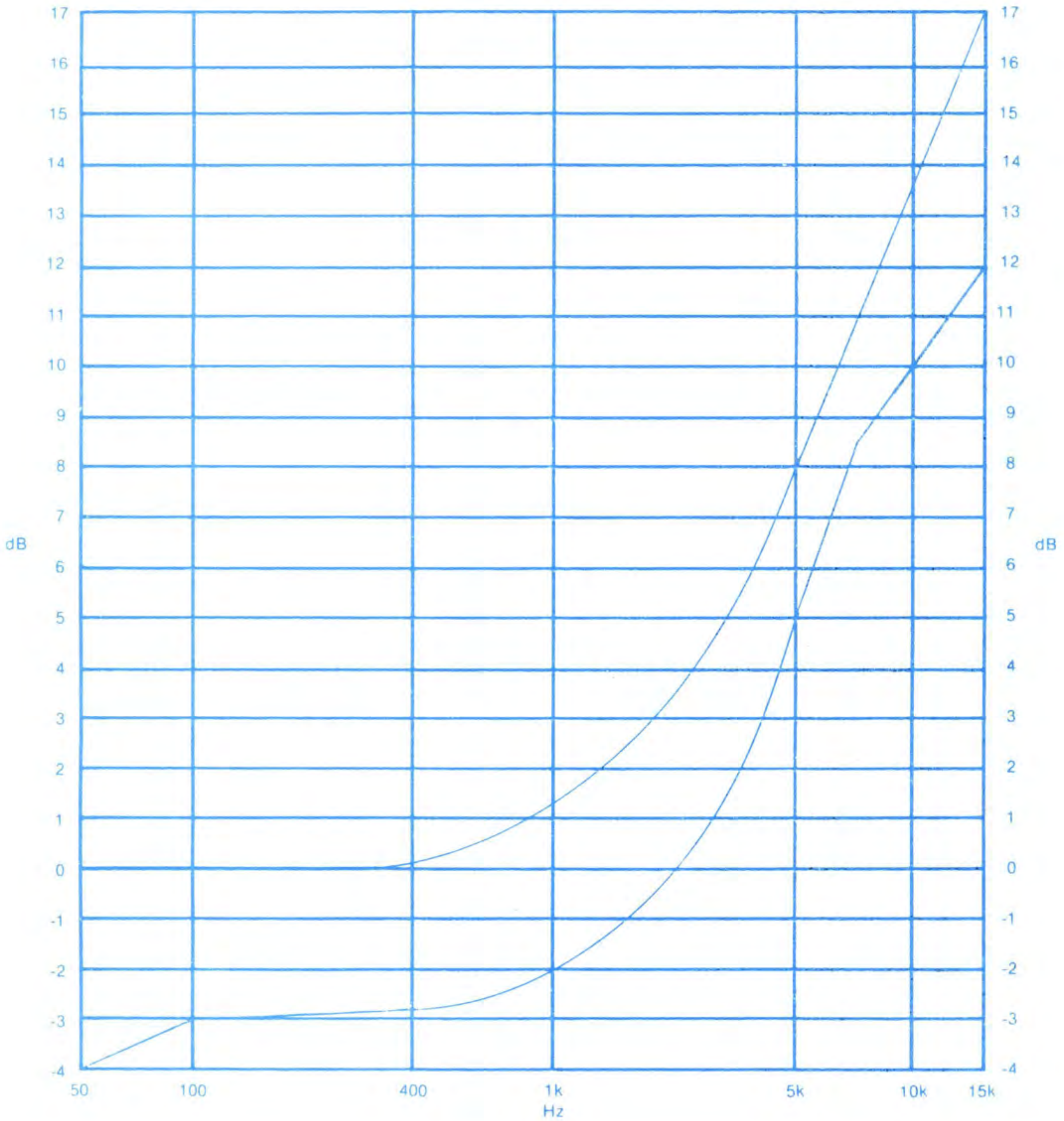
BROADCAST ENGINEERING

OFFICIAL PROOF FORM

FM FREQUENCY RESPONSE

MONO ☐ LEFT ☐ RIGHT ☐

@ ________ MODULATION



ALL TESTS PERFORMED BY: ____________________

DATE: ____________________

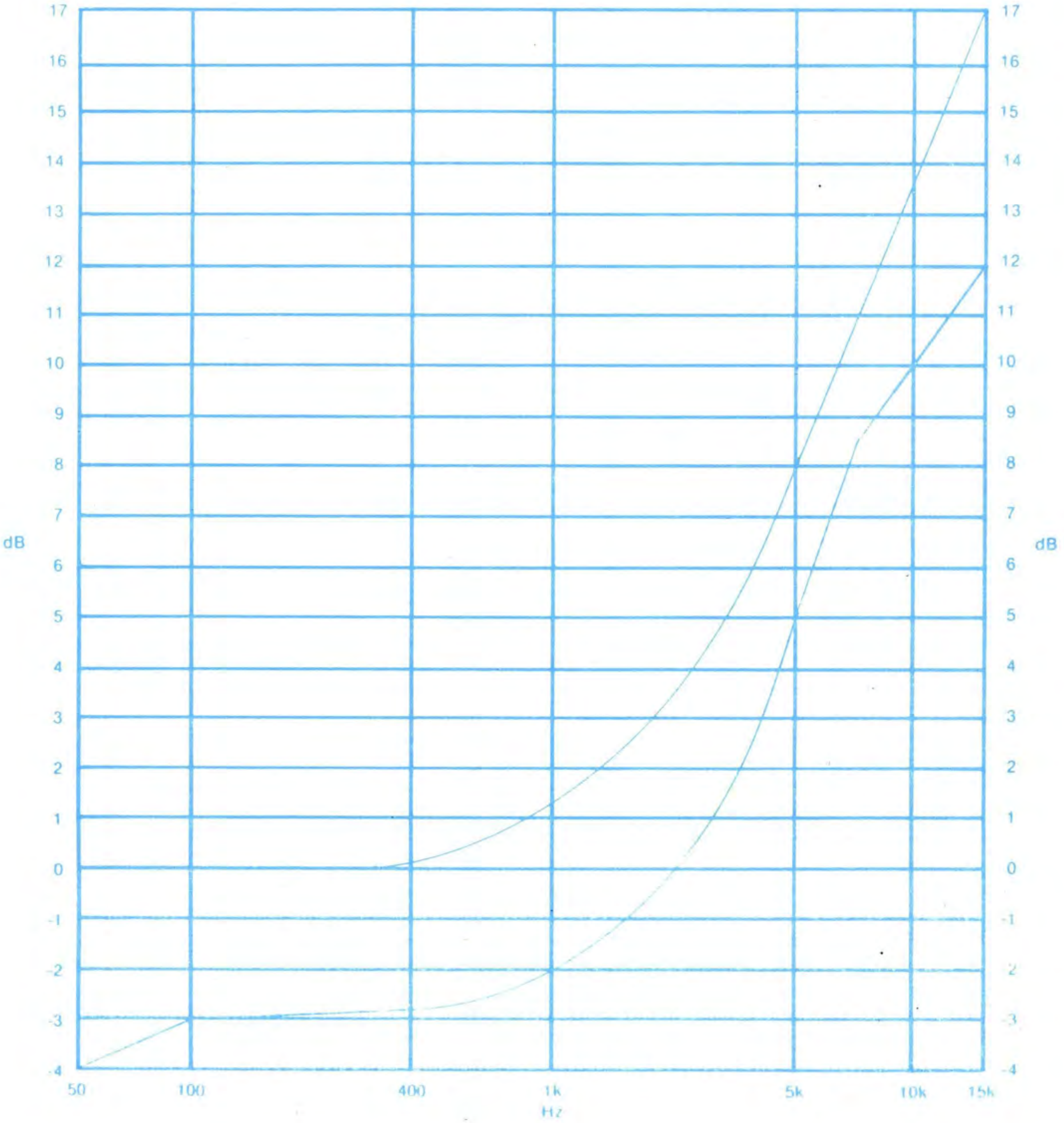
BROADCAST ENGINEERING®
OFFICIAL PROOF FORM

____

FM FREQUENCY RESPONSE

MONO ☐ LEFT ☐ RIGHT ☐

@ __________ MODULATION



ALL TESTS PERFORMED BY ______________________

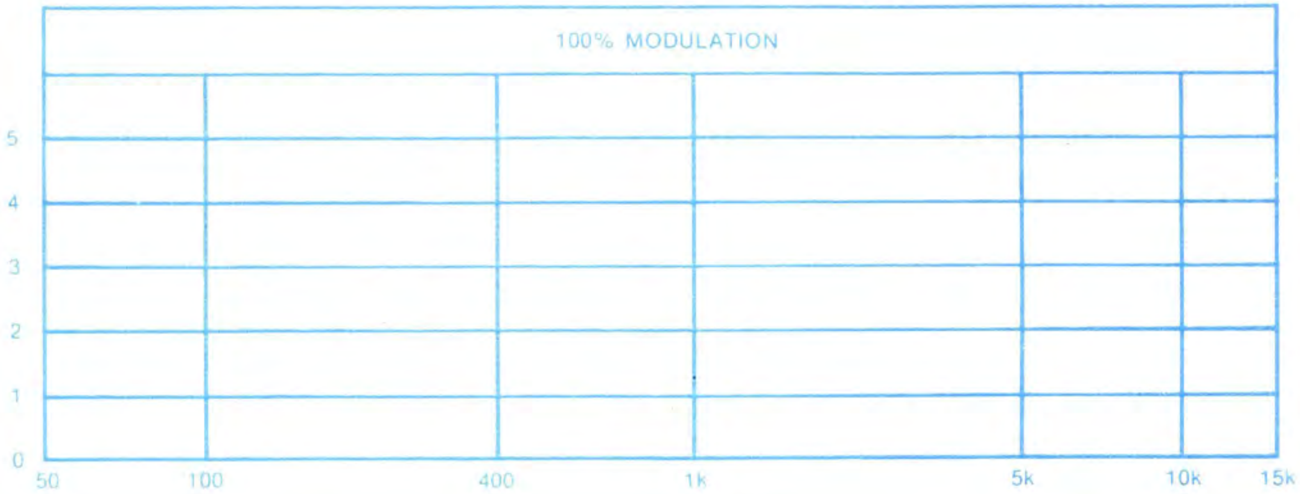
DATE ______________________

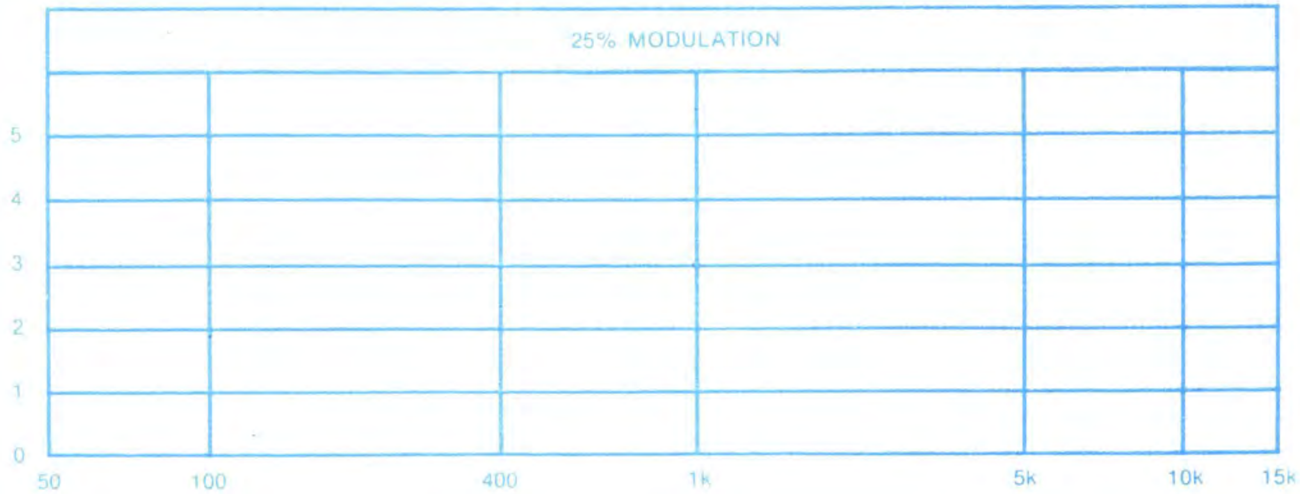
BROADCAST ENGINEERING®

OFFICIAL PROOF FORM

____________FM SYSTEM DISTORTION

MONO ☐ LEFT ☐ RIGHT ☐





ALL TESTS PERFORMED BY: ______________________

DATE: ______________________

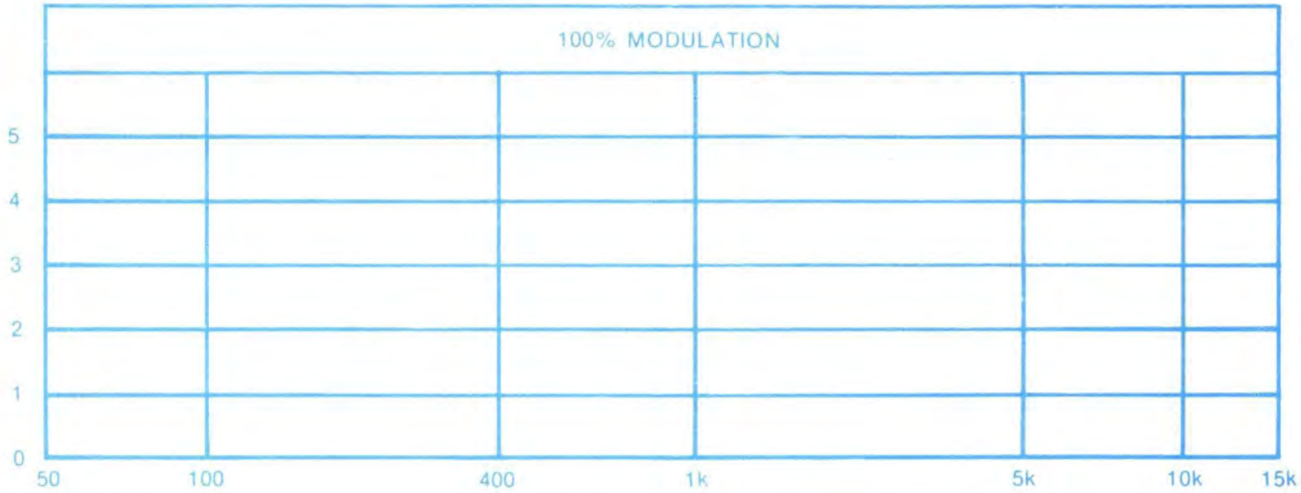
BROADCAST ENGINEERING®

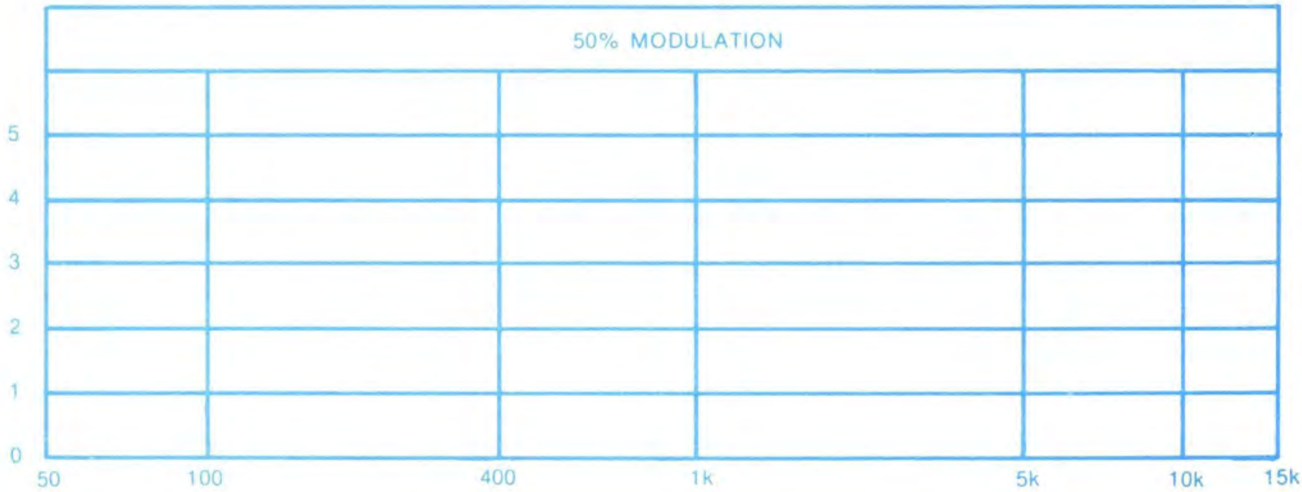
OFFICIAL PROOF FORM

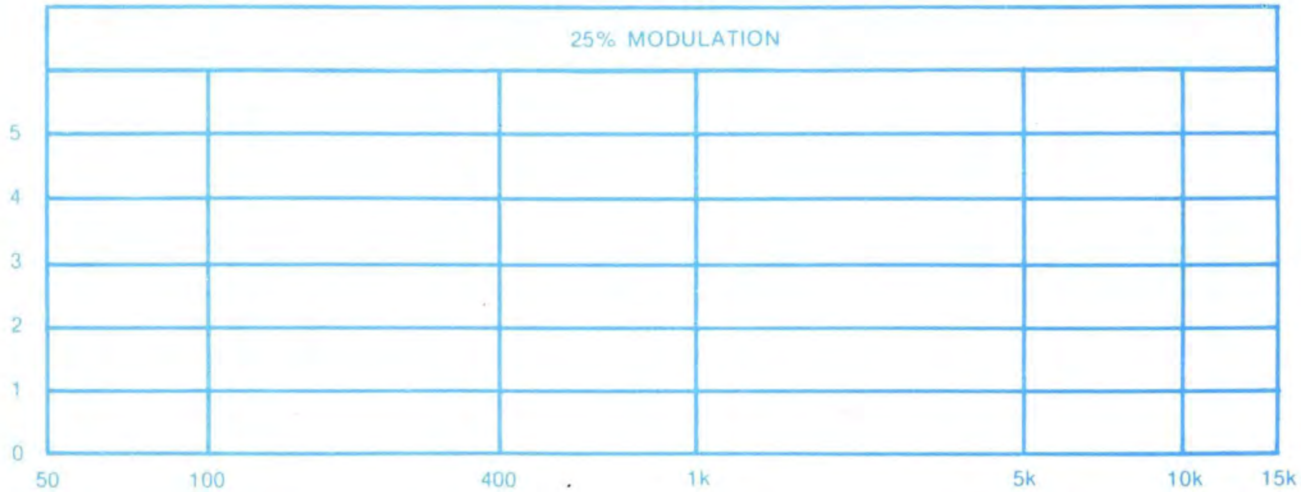
____________ FM SYSTEM DISTORTION

MONO ☐ LEFT ☐ RIGHT ☐

% TOTAL HARMONIC DIST.







ALL TESTS PERFORMED BY: ______________________

DATE: ______________________