The Technique of Measuring IM Distortion in Audio Amplifiers

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Although there are as yet no official industry standards for IM measurement, the methods have been used for years in other fields. The author shows the pitfalls to be avoided and gives a specific method for valid measurements.

THE PROBLEM of arriving at a standard for measuring intermodulation distortion in audio amplifiers has, for the most part, been resolved by the high-fidelity industry. There remains, however, the problem of conveying this information and the proper measurement technique to the audio technicians and electronically oriented high-fidelity enthusiasts. Careful investigation has disclosed that a surprising number of audio men are not aware of the discrepancies in the methods they use when making IM distortion measurements. This could prove damaging, for these findings are often conveyed to the public and definite conclusions are opinionated from them. An inaccurate measurement conceivably could condemn a fine high-fidelity instrument even though the intentions of the person taking the measurement were unswervingly honest.

There are two standard forms of IM distortion measurement. The SMPTE (Society of Motion Picture and Television Engineers) and the CCIF (European Standards) are currently used. Since the instrumentation of the CCIF method is far more complex and the findings often misleading, it has become an accepted industry practice to use the SMPTE method for measurement.

With the CCIF method two high-frequency tones of equal amplitude spaced relatively close to each other are introduced into the amplifier. The difference of the two frequencies will appear as a first-order IM product in the output, together with the original frequencies. The ratio of the low-frequency and high-frequency energy is then expressed as a percentage of distortion.

In the SMPTE method a low-frequency signal (anywhere in the range of 30 to 100 cps) is introduced into the amplifier, together with a high-frequency signal of one quarter the amplitude of the low-frequency signal. In the amplifier the high-frequency tone will act as a carrier being amplitude modulated by the low-frequency tone in relation to the intermodulation characteristics of the amplifier. Since every amplitude-modulated signal carries sidebands, these sidebands of the high-frequency signal will be present in the amplifier output. The IM analyzer detects the relative magnitude of the sidebands and expresses them as a ratio to the carrier. This ratio represents per cent IM distortion.

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Power Measurement

Before becoming involved in the actual procedure of measuring intermodulation distortion, we must first discuss certain aspects of the measurement of power output of an amplifier. Although the measurement of power output appears to be relatively simple, it is loaded with pitfalls which may result in very large errors. Here are some of the factors to be considered carefully in making this measurement:

The line voltage must be carefully controlled with a variable voltage transformer and an accurate voltmeter. Variations of as little as 2 or 3 volts in the line voltage will result in major discrepancies in power readings—easily as much as 10 per cent. Example: By controlling the a.c. line voltage at 117 volts, a given amplifier may indicate a clean 20 watts of power output. By raising the a.c. line voltage to a carefully controlled 120 volts, the same amplifier may now deliver 25 watts of clean power output.

The load placed across the amplifier output terminals must correspond accurately to the amplifier impedance markings. Either a precision resistor with a 50-watt rating or a variable resistor adjusted on an accurate bridge is required. Power is then determined by measuring the voltage developed across the resistor—again, this voltage must be carefully monitored. Any error in the voltage measurement will be squared when converted to a power measurement. The standard home-built VTVM for audio measurements, for example, often has an inaccuracy of from 5 to 10 per cent when operating properly. An error of 10 per cent in voltage may reflect itself as a 21 per cent error in the VTVM, which performs entirely within manufacturer's specifications, and come up with a power measurement on a 20-watt amplifier that may fall anywhere between 16 and 24 watts. Granted that a variation from 16 to 24 watts is equivalent to a variation of less than 2 db and is inaudible. However, expressed in watts, it sounds like a great deal.

Summarizing the minimum instrumentation necessary for accurately measuring power output of an amplifier, the following equipment is necessary:

1. A variable voltage transformer to adjust the a.c. line voltage.
2. An accurate voltmeter to monitor the a.c. line throughout the power measurement.
3. A precision 50-watt resistor, or means to measure the accuracy of this resistor.
4. An additional calibrated a.c. voltmeter and an a.c. voltage standard.

If all these requirements can be met, it is possible to take a fairly accurate, repeatable power measurement.

IM Distortion Characteristics

The IM distortion versus power output curve of an amplifier is a familiar one. The distortion usually rises gradually as the power increases, until it reaches a point close to rated power output. There the curve suddenly changes slope and rises rapidly. Driving an amplifier beyond its rated power output causes the amplifier to become overloaded. This produces very high distortion and causes the curve to assume the shape just described. Unfortunately, we are concerned with measuring the distortion right at the knee of the curve, and that is why it is important to measure the power output of an amplifier with extreme accuracy. To cite an example: An amplifier rated at 20 watts may show 0.5 per cent IM distortion at 19 watts, 1.5 per cent distortion at 20 watts, and 9 per cent distortion at 21 watts. IM measurements at low power can be carried out with less difficulty, but even these measurements are of at least equal importance to those taken at rated output. Since a high-fidelity amplifier reproduces mostly at normal room-listening level, distortion at this level

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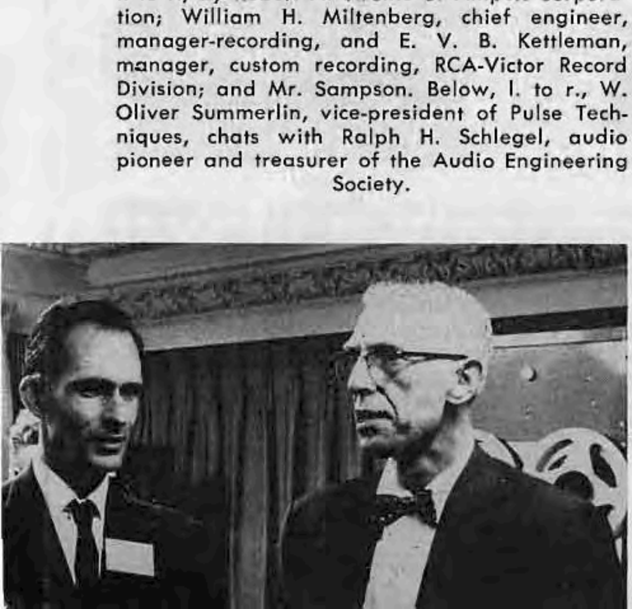
Harvey E. Sampson, Jr., manager of the new display room, at the control center.

Professional Audio Room Opens

Open house marks presentation of first display room devoted solely to professional audio equipment in Harvey Radio Company's well known New York store. Broadcast and recording engineers welcome permanent demonstration facilities.

Above, the lighter side of audio as exemplified, l. to r., by Robert A. Strome of Ampex Corporation; William H. Miltenberg, chief engineer, manager-recording, and E. V. B. Kettleman, manager, custom recording, RCA-Victor Record Division; and Mr. Sampson. Below, l. to r., W. Oliver Summerlin, vice-president of Pulse Techniques, chats with Ralph H. Schlegel, audio pioneer and treasurer of the Audio Engineering Society.



INTENDED PRIMARILY to serve the needs of broadcast and recording engineers, a new operating display of professional audio equipment was opened recently in New York by Harvey Radio Company. Known as the Professional Audio Room, the display is complete in every respect and will be maintained on a permanent basis, with new items being added and obsolete ones replaced in keeping with advances in the audio equipment industry.

On exhibit and in operation are such diverse items as Ampex tape recorders, including the Model 300-3 three-track machine, Ampex tape duplicating equipment, the new Fairchild stereo limiter and cutter, Pultec program equalizers, the Audio Instrument intermodulation meter, microphones, amplifiers, booms, attenuators, and a host of other accessories of interest to the professional audio engineer.

The Professional Audio Room is under the direction of Harvey E. Sampson, Jr., director of the company's industrial sales division. At a dedication ceremony attended by many prominent engineers, Mr. Sampson said, "For a long time we have felt that there has been a need for some kind of operating showroom where audio engineers could not only see current equipment but also put it through its paces. In this room we have established just such a facility."

On this page are pictured but a few of the many engineers who were present at the opening of the Professional Audio Room.

Above, l. to r., Donald R. Plunkett, president of Fairchild Recording Equipment Corporation and of the Audio Engineering Society, discusses diversity of audio interests with Lou Burroughs, vice-president of Electro-Voice, Inc. Below, l. to r., caught in a moment of reflection are C. J. LeBel, president of Audio Instrument Company and AES secretary, and Prof. Vladimir Ussachevsky, widely known audio authority associated with Columbia University.

IM MEASURMENT TECHNIQUE

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contributes heavily to the characteristic tone quality of the amplifier.

When we measure power output we are primarily concerned with the amount of energy the amplifier is capable of feeding into the speaker. With a single-tone input to the amplifier, this is a relatively simple concept. Most voltmeters, although they respond to the "average" voltage, are calibrated in rms and will give an accurate indication only with a pure sine wave. However, the complex wave form required for IM measurement (a mixture of a low frequency with a high frequency) will result in grossly incorrect meter indications, due to the discrepancy between "average" and "rms" values.

No direct power measurement, therefore, can be obtained in this way with a two-tone IM signal.

Since the asymptote of distortion-free reproduction in an amplifier is determined by the "peak" of the possible grid swing, it has become an industry practice to establish reference levels for output power based on "peak" value. This method affords suitable correlation of the measurements of various amplifier characteristics, such as harmonic distortion, square-wave response, and intermodulation distortion.

It is, therefore, not possible to feed the composite signal from an IM analyzer into the amplifier and monitor the output with a simple power meter, yet how many audio fans and technicians measure IM in this manner? The figure is astounding.

As a last note, before describing a specific method of measuring IM distortion, it is necessary to impress the importance of the proper use of the oscilloscope. At all times and for all measurements, an oscilloscope should be connected across the amplifier load. Without the scope you are literally working blind and can never be quite sure what is being measured. With an oscilloscope you may observe faulty hookup, excessive hum, or distortion in output measurement; and make the proper corrections.

Measurement Method

Use the following as a basis of the proper method of measuring intermodulation distortion in a 20-watt amplifier feeding into a 16-ohm load.

1. Adjust the line voltage to the specified value and monitor with a voltmeter throughout the measurement.
2. Feed a single-tone oscillator into one of the high-level inputs and monitor the output of the amplifier on the oscilloscope.
3. Adjust the tone controls so that the amplifier is flat beyond the range of the IM analyzer (such as 60 to 6000 cps).
4. Turn the loudness control to maximum and turn off all auxiliary controls as contour, rumble, scratch, and so on.
5. Use the formula $P = E^2/R$ to arrive at the proper voltage reading for a specific power level. For a 20-watt output into a 16-ohm resistor, the voltmeter across the resistor should measure 17.9 volts.
6. Adjust the oscillator level at 1000 cps so that the output voltmeter indicates the computed value. In this case, it will be 17.9 volts.
7. Adjust the vertical gain of the oscilloscope, connected across the load, until the peaks of the output sine wave touch two well-defined gradation lines on the oscilloscope face mask. The pattern should cover a major portion of the scope screen. This establishes the "peak" reference for the actual IM measurement. At this point, also make sure that the sine wave is undistorted and is not flattened at the end. IMPORTANT: Do not alter the vertical gain of scope thereafter. This method applies for power levels below amplifier clipping. IM distortion measurements should not be made above the clipping point because most available instrumentation, although calibrated for rms, reads average voltage values. Great errors will be introduced unless the output signal contains fairly clean sine waves.
8. Replace the oscillator with an IM analyzer signal. Adjust the 4-to-1 relationship of the low- and high-frequency signal in accordance with the operation manual of the analyzer. The proper relationship of the two signal amplitudes should be checked on the oscilloscope again.
9. Adjust the level of the IM input signal to the "peak" reference on the oscilloscope. The pattern should again fall precisely between the same two gradation lines on the mask.
10. Follow the remainder of the instructions of the IM analyzer and complete your measurement.
11. Repeat this procedure several times over an extended period of time. If you come up with a group of corresponding measurements, you have in all probability produced an accurate IM measurement.
12. NOTE: if your amplifier has an output-tube balance control, adjust this control for minimum IM indication.

It is almost impossible to make a proper IM measurement without an oscilloscope unless you have a tremendous amount of experience with your particular amplifier and your test equipment. It may be theoretically possible to make an IM measurement without an oscilloscope, but you would need a very carefully computed conversion chart to convert the indications on a power meter to the true peak value of a complex wave, and you will have to leave a great deal to chance. Æ