Simplified Intermodulation Measurement

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The author shows how to use the oscilloscope as a means for portraying intermodulation distortion, with a method especially suitable for amplifier development work.

IT HAS BEEN FAIRLY WELL ESTABLISHED that intermodulation distortion is a serious deterrent to high quality reproduction of speech or music. The measurement of this type of distortion has been discussed frequently in the literature over the past few years, but the principal drawback to its use is the relatively high cost of the equipment necessary for determining the percentage of distortion.

Test Method

To review, momentarily, the principles underlying the measurement of intermodulation, it may be stated simply that two frequencies, widely spaced and not harmonically related, are passed through an amplifier. The output signal is passed through a filter to remove the lower of the two frequencies, and the amount of modulation of the higher frequency by the lower is measured as a function of the amplitude of the higher frequency. In commercial instruments for the measurement of intermodulation distortion, the low frequency usually employed is 60 or 100 cps, while the higher frequency may be 1000, 2000, 4000, 6000, or any other high frequency which is within the pass band of the amplifier. Both of these frequencies are fed into the input of the amplifier, often being combined so that the lower frequency has an amplitude of four times (12 db above) that of the higher. Thus the test signal may be considered to have an appearance similar to that of *Fig. 1*.

Increasing the signal amplitude will cause the grid swings to exceed the linear range of the system, resulting in the "clipping" of the high-frequency fringe of the test signal at the peak swings of the lower frequency, as shown in *Fig. 2* in which the dotted lines represent the maximum signal level that can be passed through the amplifier without distortion by the non-linearity of the tube characteristics above that level. *Figure 2* represents the output of an amplifier stage which is operated at the optimum grid-bias point, with both positive and negative grid swings becoming overloaded at the same signal amplitude.

If the output signal is then passed through a high-pass filter to remove the low-frequency component of the combined signal, the notches placed in the high-frequency carrier still remain as a modulation of that carrier, as shown at (*A*) in *Fig. 3*. This signal

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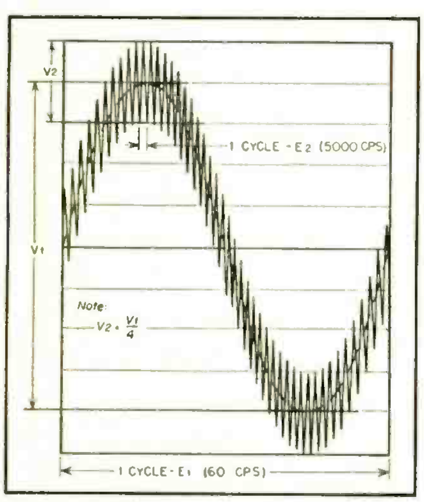

Fig. 1. Oscilloscope pattern of a test signal composed of a low frequency upon which is superimposed a high frequency 12 db lower in amplitude.

Measurement of intermodulation distortion is of considerable importance in evaluating amplifier performance. While this method does not give quantitative results, it does provide a tool whereby the presence of intermodulation can be detected and minimized.

Sound engineering laboratories which are now using this set-up have found it reliable and a great time-saver. Ed.

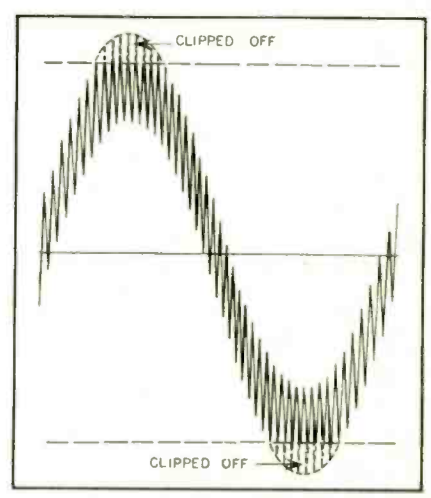

Fig. 2. Test signal after passing through amplifier, with fringe of high frequency signal clipped on peaks of low-frequency wave.

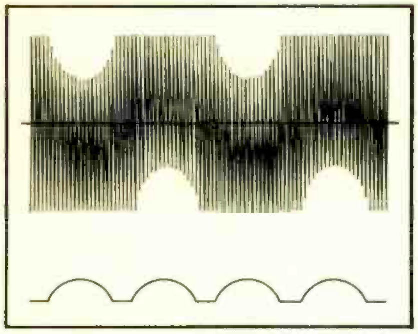

Fig. 3. (A) Output signal after low frequency is filtered out, leaving higher frequency modulated by the lower frequency. (B), below, A-C component of rectified h-f signal.

may now be rectified, and the a-c component, shown at (*B*), measured as a percentage of the amplitude of the carrier. This is a brief statement of the method employed in intermodulation analyzers.

Proposed Method

Since the commercial intermodulation analyzer may not be available to the engineer who desires to make occasional measurements of this type, it is quite possible to substitute an oscilloscope and a high-pass filter for it, and obtain results which will give an indication of the amount of intermodulation, although not an accurate quantitative measurement. The method proposed here is capable of providing certain information, and it requires no equipment which is not generally available. Furthermore, the method goes further than the measurement method in that it indicates to some extent the cause of the intermodulation, thus giving the engineer a clue as to where to look for the trouble. As an advantage over the customary harmonic measurement method which consists of a number of separate observations, the pattern on the oscilloscope may be viewed continuously while making changes in the component values to give improved performance.

Basically, the proposed method consists of the application of a standard intermodulation test signal to the input of an amplifier. The output is terminated with its normal impedance, across which is bridged a high-pass filter and an oscilloscope. The method of obtaining the test signal and of filtering the output will be described later in this article. To aid in making the observations, the screen of the oscilloscope is marked with two limit lines, which are the calibrating points for the carrier, and two additional lines which are one-fourth of the distance from the limit lines to the axis as shown in *Fig. 4*. The use of these latter lines is explained below.

To analyze the results obtained from this method refer to *Figs. 5* and *6*. In *Fig. 5(A)* is shown the test signal applied to the grid of a single-tube amplifier stage operating at an insufficient grid bias. As the amplitude of the test signal is increased, the positive swings of the plate current are flattened out ahead of the negative swings, and the high-frequency fringe of the test signal is clipped at certain points. When the filtered carrier is viewed on the oscilloscope, the effect of the clipping is shown by notches in one side of the pattern. Thus the presence of two notches on one side of the pattern is an indication of an incorrect bias condition in a single-tube stage. Note that the sweep circuit of the oscilloscope is adjusted so that it shows two complete cycles of the low-frequency signal.

In (*B*) of *Fig. 5*, the test signal is shown applied to a tube which is operating at the correct grid bias, but the amplitude of the signal is greater than the linear portion of the E_gI_p curve of the tube can handle. Therefore, the fringe is clipped on both peaks of the low-frequency wave, with a resulting four-notch pattern.

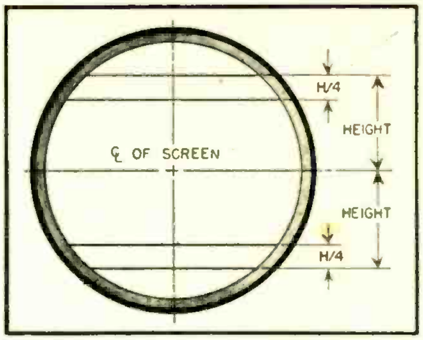

Fig. 4. Screen of C-R oscilloscope tube marked to indicate limits of high-frequency signal and depth of 25 per cent notches.

When making tests of push-pull stages, the patterns obtained from insufficient grid bias conditions are shown in *Fig. 6(A)* which shows the effect of the test signal applied to two push-pull tubes. The positive peak of the wave is clipped by one tube, while the negative peak (which is the positive peak to the opposite tube) is also clipped. The plate-current curves of the two tubes are shown, both having the tops clipped. However, due to the push-pull connection, one of these curves is inverted, so that four notches appear in the pattern, resembling that of *Fig. 5(B)*. When a push-pull stage is operated beyond its maximum permissible grid swing, the pattern will exhibit eight notches, four on each side as in *Fig. 6(B)*.

Pattern Analysis

Analyzing the patterns, then will give a clue to the trouble, as well as to the preferred manner of using the oscilloscope method. Each individual stage should be checked independently, feeding the signal to the grid and observing the output at the plate. By connecting an a-f voltmeter across the output, the operating level of the amplifier is known at all times. As the input is increased gradually, the pattern on the oscilloscope should be maintained at the reference limits, and adjustments of both signal level and oscilloscope gain made simultaneously to maintain the notches at a given percentage (e.g. 25%) of the signal amplitude. The optimum operating point is reached when the output voltage is at its maximum value for the desired type of notching.

While no quantitative measurement is offered by this method, it may be stated that for a signal composed of 60 and 5,000 cps, with a 12-db difference between the two, many laboratory measurements of various amplifier types have shown that the recommended notch of 25% of the carrier amplitude corre-

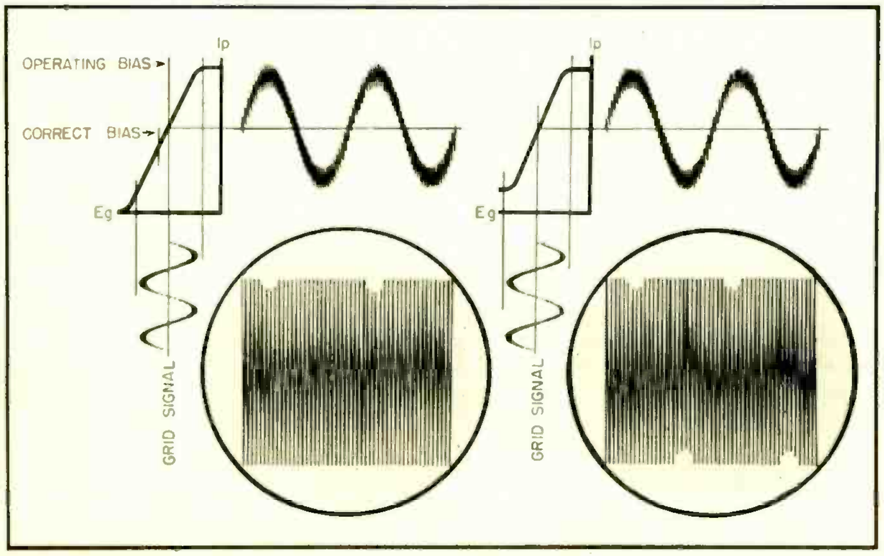

Fig. 5. IpEg curves, and type of indications resulting from single-tube amplifier stage with (A) insufficient bias, and (B), right, excessive input signal.

sponds roughly to the point at which 1% harmonic distortion is obtained. This would seem to indicate a relationship between harmonic distortion and intermodulation distortion, but since many other quantitative measurements have shown that no such relationship necessarily exists, it should not be inferred that this is so. The 25-per-cent point is selected as a purely arbitrary reference which is sufficiently observable even on a 2-inch oscilloscope tube to be readily usable.

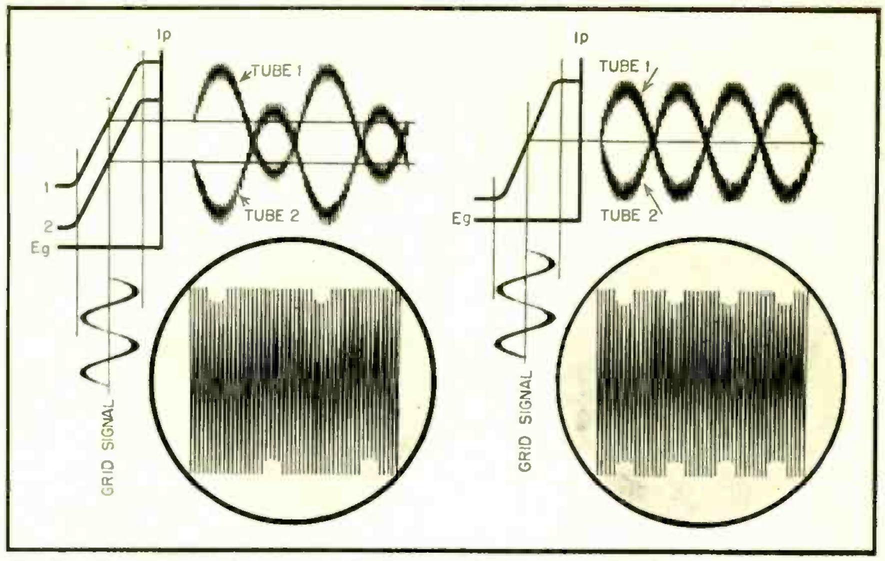

Fig. 6. IpEg curves, and type of indications resulting from push-pull amplifier stage with (A) insufficient bias, and (B), right, excessive input signal.

Test Signal Generator

For most rapid and convenient operation, it is suggested that a small oscillator unit be provided with sufficient flexibility to permit the mixing of the two frequencies. For preliminary testing of the method, however, it should be sufficient to place a series resistor in the output circuit of an oscillator, applying a 60-cps voltage across this resistor. Any method used for mixing the test frequencies should be checked carefully to ensure that no intermodulation takes place in the generator circuits. *Figure 7* shows a suitable method for combining the two frequencies, with the meter switching being arranged for indication of relative levels. When the switch is set at "CAL HIGH," the output of the oscillator is adjusted to a reference indication on the meter. The switch is then thrown to the "CAL LOW" position which also introduces a resistor in series with the meter so that 0 db on the scale indicates a +12 db level, and the low-frequency level is then adjusted to the same setting. The instrument is ready to use when the switch is thrown to the "USE" position.

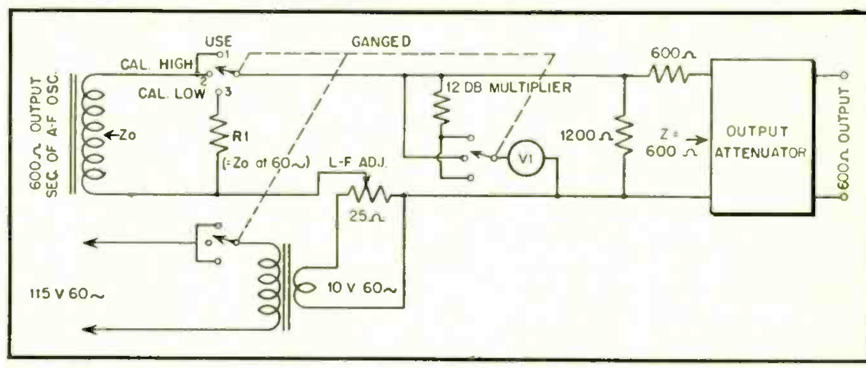

Fig. 7. Diagram of connections in mixer unit to supply intermodulation test signal for amplifier testing. Adjustment of high-frequency output is made with oscillator output control.

The block schematic for this method of measurement is shown in *Fig. 8*. The high-pass filter may be any standard filter capable of removing the low frequency, or, since the input of the 'scope is high, a parallel-T null circuit may be employed with excellent results, since the frequency to be measured is well removed from the low-frequency carrier. With a 60-cps low-frequency signal, the oscilloscope may be synchronized easily at a sweep frequency of 30 per second, giving the desired pattern which will include two full cycles of the carrier frequency. A refinement in the generator would include a dual potentiometer so arranged that the output of the amplifier being measured is passed through the second unit before being applied to the oscilloscope — thus as the input to the amplifier is increased, the output fed to the 'scope is decreased by the same amount, making it unnecessary to vary the vertical amplitude control when making a series of measurements. If a dual potentiometer is so used, care must be taken to ensure that the two circuits are sufficiently isolated to avoid feedback. However, this entire method is submitted because it is simple to use with existing equipment, and such refinements are not necessary.

In the development of amplifiers and other equipment, this system has proven to be a convenient aid in determining the exact values of components for optimum performance. For example, if a number of variable resistors are placed in a circuit, adjustments can be made to the values while observing the pattern on the screen, and after obtaining the desired results, the variable elements can be replaced by fixed values. In this manner, a complete amplifier may be assembled with the assurance that each stage is working under the best possible conditions, yet without the necessity of making a large number of laborious harmonic distortion measurements.

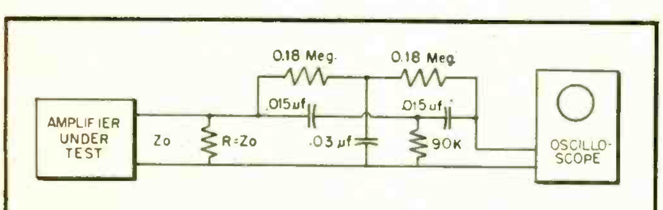

Fig. 8. Block diagram of connections of intermodulation test signal generator, amplifier, high-pass filter, and oscilloscope for testing by proposed method.

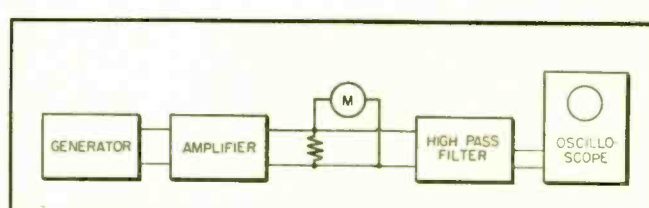

Fig. 9. Parallel-T network suitable for filtering out low-frequency (60-cps) signal before applying output of amplifier to vertical input of oscilloscope.