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METHODS FOR DETERMINING AMPLITUDE-MODULATION REJECTION PERFORMANCE OF FREQUENCY-MODULATION DETECTORS

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METHODS FOR DETERMINING AMPLITUDE-MODULATION REJECTION PERFORMANCE OF FREQUENCY-MODULATION DETECTORS

Approved

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This bulletin considers the problem of measuring AM rejection performance of FM detector systems. The requirements imposed on signal generating equipment and the methods of measurement used for determination of AM rejection are discussed. Four measuring methods are described: (1) center-frequency method, (2) oscilloscope method, (3) band-elimination filter method and (4) high-pass filter method. The oscilloscope method has been found most useful for design and the high-pass filter method the most useful meter method.

Introduction

One of the important performance characteristics of an FM detector system is its ability to reject amplitude modulation of the incoming signal. This characteristic is normally determined by applying to the input of the detector system a signal which may be amplitude and frequency modulated, and noting the respective detected outputs. The ratio of the amplitudes of detected output produced by each type of modulation is then a measure of the AM rejection of the detector system.

The measurement of AM rejection is most simply made by applying the FM and AM to the input signal separately. When this procedure is used, only the AM rejection at the center frequency of the detector system is obtained. To take into account the AM rejection at each frequency within the frequency deviation range and thus more closely simulate dynamic operating conditions, it is desirable to have the FM and AM applied simultaneously. When simultaneous AM and FM is used, some method must be employed to separate the components in the detected output. Two commonly used methods to achieve this separation are the oscilloscope method and the band-elimination filter method. A third method, using a high-pass filter, has not been widely used. However, by proper choice of modulation frequencies and filter pass-band, this method has been found advantageous when measuring the performance of a detector having high AM rejection.

The discussions in this bulletin assume sine-wave AM and sine-wave FM and are based on experience with detectors used in FM and TV receivers.

Signal-Generating Equipment

The output signals from laboratory r-f signal generators may contain spurious frequency modulation. This spurious FM is of two types, "incidental FM" and "residual FM".

Incidental FM is that spurious FM produced when AM is applied to the signal. Normally, it produces a detected output of the same frequency as the AM but of a difference phase. To enable a signal generator to be used for AM rejection measurements, the incidental FM should produce an audio output from the FM detector system being measured which is small in comparison to the AM audio output at all input levels. This requirement is difficult to satisfy when the amplitude modulation is done in a high-frequency signal generator. An amplitude-modulated high-frequency signal generator with a frequency converter to measure the performance of an FM detector system at its intermediate frequency provides a convenient method to check for the presence of incidental FM. The AM rejection is measured over a range of input levels with the signal generator frequencies both above and below the frequency-converter oscillator frequency. If the AM rejection values obtained with the signal generator below the oscillator frequency are different from those obtained with it above, the presence of incidental FM is indicated. However, incidental FM may still be present and not be indicated by this procedure. In this case, a possible further check for incidental FM may be made by using the signal generator to measure the AM rejection of a special FM detector system which is known to have high AM rejection. The presence of incidental FM would be indicated by the measured AM rejection being lower than normal. If incidental FM is found to prevent reliable AM rejection measurements when the AM is applied in the signal generator, the use of a suitably-designed external AM modulator can usually correct the problem. The characteristics of such an AM modulator should be, (1) isolation from any oscillator circuits, (2) a relatively low operating frequency, and (3) circuit constants of such value that the AM produces essentially no phase modulation.

Residual FM is that spurious FM which remains in the signal when the AM and FM are turned off. It results

from common ground impedances, microphonics, or other spurious couplings in the signal generator. Normally, it produces components of detected output at power line frequency and harmonics. Mechanical disturbances outside the signal generator may also produce spurious FM due to microphonic coupling. Shock-mounting the signal generator will normally remove this source.

Methods of Measurement

Center-Frequency Method

In this method, the AM rejection is measured only at the center frequency of the detector. The FM and the AM, normally of the same frequency and below 1000 cps so that the de-emphasis network will not affect their amplitudes, are applied independently and the respective outputs are observed. The AM rejection is expressed as the ratio of the two outputs. A voltmeter responding to the average value of the applied waveform is used as an output indicator. A test set-up is shown in Fig. 1.

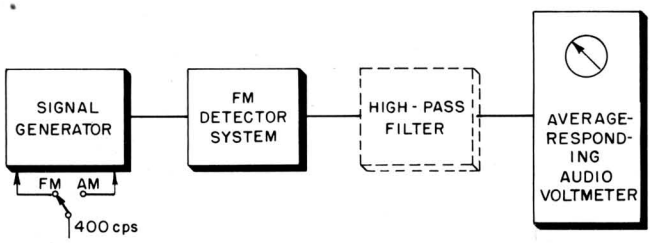

Fig. 1 – Center-frequency method.

The center-frequency AM rejection is a measure of the rejection capability of an FM detector only during quiet portions of broadcasts. The rejection figures obtained are also difficult to duplicate on remeasurement since a slight change in the frequency of the input signal can cause a relatively large change in AM output. The method, however, is otherwise easy to apply since no filter or oscilloscope is required.

With an input signal that is essentially free of incidental FM, the limit to the maximum measurable center-frequency rejection is normally determined by the level of residual FM occurring in the signal generator. If a high-pass filter is used, the residual FM will normally be reduced to such a low value that the sensitivity of the audio voltmeter becomes the limiting factor.

Oscilloscope Method

With the oscilloscope method, the relative amounts of audio output caused by FM and AM are obtained from

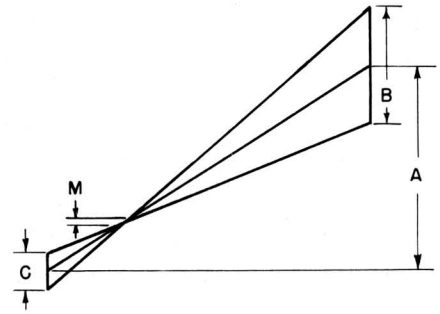

Fig. 2 – Typical FM detector output characteristic obtained in the oscilloscope method.

an oscilloscope display of the output characteristic of the FM detector. An input signal which is simultaneously amplitude and frequency modulated is used. The audio signal which is used for producing the FM of the input signal is applied to the horizontal input of the oscilloscope and the audio output from the detector is applied to the vertical input. The two audio-modulating frequencies are chosen below 1000 cps. They are non-synchronous and sufficiently different in frequency so that a solid bow-tie-shaped pattern similar to Fig. 2 is produced on the oscilloscope. A test set-up is shown in Fig. 3.

On the pattern, the distance A is the peak-to-peak output voltage due to the FM while the distances B, C, and M are the peak-to-peak output voltages due to AM. Balanced, unbalanced, composite and maximum AM rejection ratios may be expressed:

$$\text{Balanced rejection ratio} = \frac{B + C}{2A}$$

$$\text{Unbalanced rejection ratio} = \frac{|B - C|}{2A}$$

$$\text{Composite rejection ratio} = \frac{0.707}{A}\sqrt{B^2 + C^2}$$

$$\text{Maximum rejection ratio} = \frac{M}{A} .$$

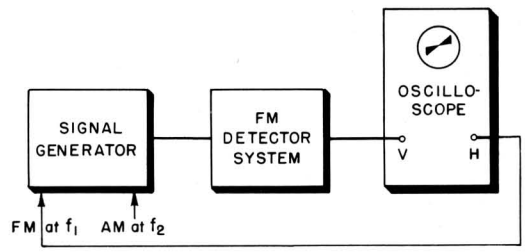

Fig. 3 – Oscilloscope method.

When the crossover (point of minimum AM) is outside the pattern, the numerator for the balanced rejection ratio be-

comes $|B - C|$ and the numerator for the unbalanced rejection ratio becomes $(B + C)$.

This method of AM rejection measurement is probably the most useful in the initial design phase of FM detectors since it shows the magnitude and type of AM output (balanced and/or unbalanced). However, if the FM/AM output ratio is much greater than 20, the ratio becomes difficult to measure.

*Band-Elimination Filter Method**

In this method, the components of audio output due to AM and FM are separated by a band-elimination filter. The input signal is simultaneously frequency modulated at 1000 cps and amplitude modulated at 400 cps. The fundamental component of the audio output due to FM is removed by a 1000-cps band-elimination filter; the remaining audio output is considered to be due to the AM. The AM rejection is then expressed as the ratio of the FM output to the output with the FM fundamental component filtered out. An audio voltmeter which responds to the average value of the applied waveform is used as an output indicator. A test set-up is shown in Fig. 4.

The maximum measurable rejection will normally be limited by the audio output caused by harmonics of the FM audio frequency and by residual and incidental FM occurring in the signal generator.

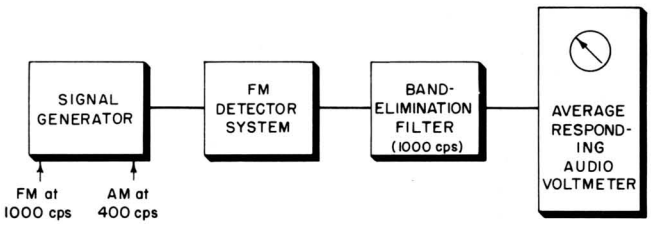

Fig. 4 – Band-elimination filter (1000 cps) test setup.

High-Pass Filter Method

This method utilizes a high-pass filter to separate the FM output, hum, and their low order harmonics from the AM output. A signal which is simultaneously amplitude and frequency modulated is applied to the input of the FM detector system. The frequency modulation is done at a low audio frequency, 50 or 60 cps being convenient. The amplitude modulation is done at a frequency which is many times that of the FM, yet not so high that the de-emphasis network will appreciably affect the magnitude of its low order harmonics. A convenient choice for the AM frequency is 400 cps. The cutoff of the high-pass filter is chosen to pass the lowest intermodulation component of the AM output unattenuated, 350 or 340 cps respectively for the FM frequencies mentioned. (A stock UTC type HMI-200 filter has been used for this purpose). The reference level of FM output is obtained by turning the AM off and momentarily changing the FM modulating frequency to 400 cps. The AM rejection is expressed as the ratio of the FM to AM output. A test set-up is shown in Fig. 5.

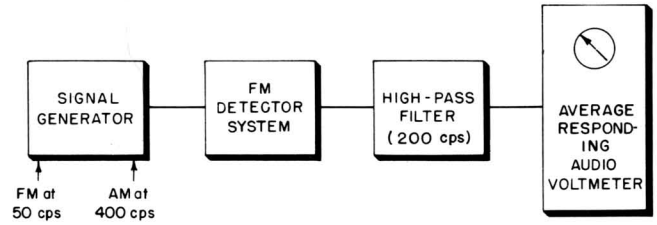

Fig. 5 – High-pass filter test setup.

Since suitable commercially-available filters have a relatively low characteristic impedance, it may be necessary to connect the filter to the circuit through a series resistor. If the sensitivity is too low when this arrangement is used, the filter may be followed by an amplifier or connected to a point of higher audio level. An audio voltmeter which responds to the average value of the applied waveform is used.

With the modulating frequencies and high-pass filter cutoff frequencies mentioned previously, this method is insensitive to the audio output caused by distortion components of the FM and by low-frequency residual FM in the signal generator.

With an input signal essentially free of incidental FM, the limit to the maximum measurable rejection is normally set by the sensitivity of the audio voltmeter.

Conclusions

When designing an FM detector, the oscilloscope method provides more information than any meter method can, since it shows both amplitude and character of the detector response to AM. After the detector design has been refined, the high-pass filter method offers a more sensitive measure of AM rejection which can be expressed as a simple number.

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*IRE 17.S1 Standards on Radio Receivers: Method of Testing Frequency-Modulation Broadcast Receivers, 1947.