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MEASURING FM DEVIATION BY THE BESSEL NULL METHOD

Note: This document has been reformatted to provide a hole-punching margin on the left side, to facilitate single-side printing for a ring binder.

SUMMARY

Using equipment available in most two-way radio service shops, servicemen can accurately calibrate (within ±10%) their frequency modulation monitors. The Bessel null method requires only an audio oscillator, an FM receiver (or frequency meter), and an FM transmitter. This method can also be used to check the internal modulation meter of an FM signal generator.

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BY THE
BESSEL NULL METHOD

SOME BACKGROUND INFORMATION

To help understand that peculiar phenomenon referred to as the "Bessel null", let's first review some frequency modulation theory.

CARRIER NULLS

An FM signal, you remember, is composed of a carrier (the center-frequency component of the signal) and one or more pairs of sidebands. The carrier for each of the FM signals shown in Figure 1 is indicated by a heavy vertical line and the sidebands are indicated by light vertical lines. The height of each line indicates its amplitude.

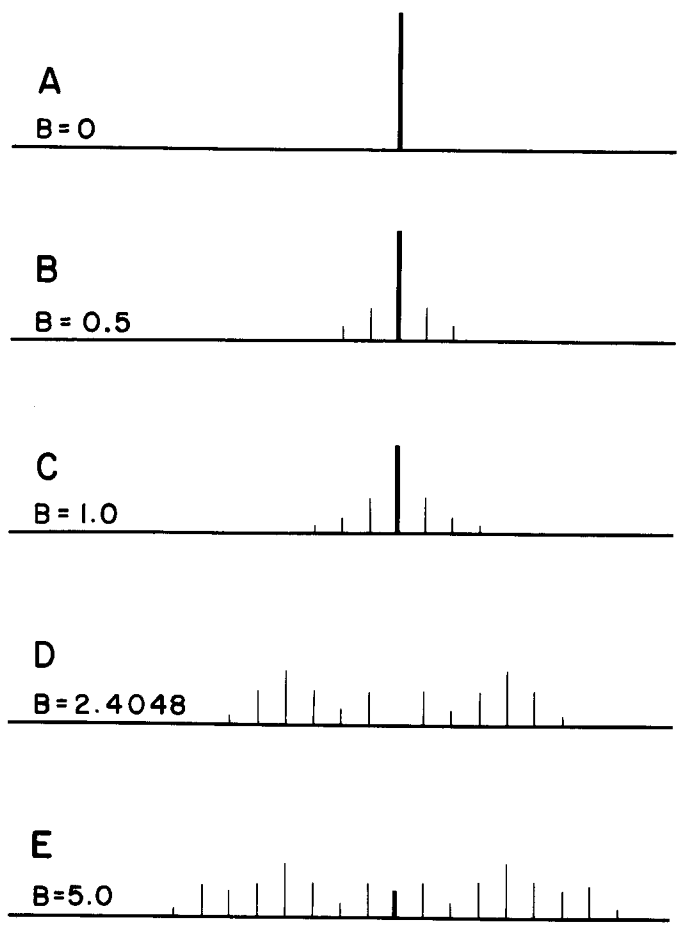

Figure 1 - Frequency spectra of an FM signal with increasing deviation (constant modulating frequency)

Figure 1A is an unmodulated signal and therefore has no sidebands. Figures 1B, 1C, 1D and 1E are each modulated by the same sinewave frequency, but with increasing frequency deviation. The modulation index (B) of each signal is indicated. Modulation index can be found by dividing the maximum frequency deviation (ΔF) by the modulating frequency (f):

$$B = \frac{\Delta F}{f} \qquad (1)$$

The strength of the carrier and sidebands vary as Bessel functions of the modulation index. As the modulation index increases, notice that the number of sidebands increases and the amplitude of the carrier changes. There are several points (nulls) at which the carrier disappears completely (Figure 1D). Figure 2 shows how the carrier amplitude changes as the modulation index increases. (The negative values indicate that the phase of the carrier is opposite to that of the unmodulated

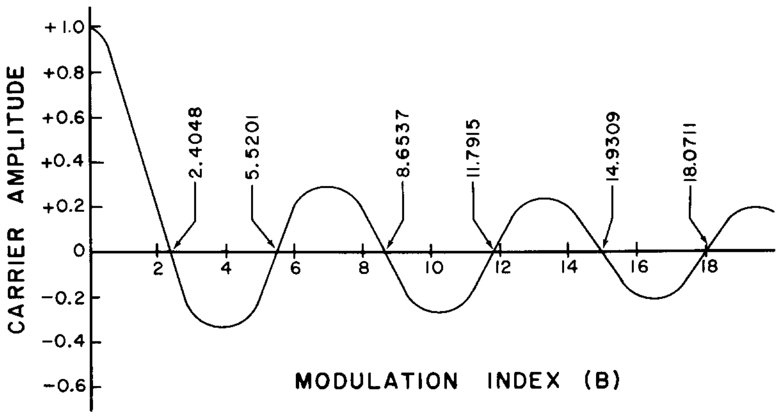

Figure 2 - Variation of carrier amplitude with modulation index

carrier.) The first null occurs when the modulation index reaches 2.4048, the second at 5.5201, etc. Table 1 lists the modulation indexes which produce the first six nulls.

DEVIATION MEASUREMENTS BY MEANS OF CARRIER NULLS

Because the location of the carrier nulls is known very precisely, they can be used for accurately adjusting FM deviation. This will be more obvious if we turn formula (1) around:

$$f = \frac{\Delta F}{B} = \frac{\text{maximum frequency deviation}}{\text{modulation index}} \qquad (2)$$

Knowing the modulation index (B) at which each null occurs, we can use this formula to find what modulating tone (f) will produce a null at the desired deviation (ΔF). If the modulation frequency is accurately adjusted and the modulation is carefully set at the correct null, the deviation will be very accurately set. The null is found by beating the carrier against another RF signal and noting the point at which the beatnote disappears. An example will make the procedure much clearer:

Example 1: Suppose you want to adjust the deviation of a transmitter for ±5 kHz. Formula (2) says, "To find the modulating frequency which will produce a certain deviation, just divide the desired deviation by the modulation index at that point." At the first null, the modulation index is 2.4048. Therefore, if you use a 2079.2-Hz modulating tone ($f = \Delta F \div B$ = 5 kHz ÷ 2.4048 = 2.0792 kHz = 2079.2 Hz) and adjust the deviation for the first null, the transmitter will deviate ±5 kHz.

You can also use a lower modulation frequency and adjust the modulation to a higher null to obtain ±5 kHz deviation. At the second null, the modulation index is 5.5201. Therefore, a 905.78-Hz tone could be used at this null ($f = \Delta F \div B$ = 5 kHz ÷ 5.5201 = 0.90578 kHz = 905.78 Hz) to produce ±5 kHz deviation.

WHICH MODULATION FREQUENCY AND NULL TO USE

Use the highest modulation frequency within the audio passband of the transmitter which will prodice a carrier null at the desired deviation. This will place the sideband beatnotes as far away from

Table 1 - Modulation Frequencies Used to Obtain Common Deviations

Null No.	Modulation Index (B)	Modulation Frequency (f)			
		For 3.0 kHz Deviation	For 5.0 kHz Deviation	For 9.0 kHz Deviation	For 15 kHz Deviation
1	2.4048	1247.50 Hz*	2079.17 Hz*	3742.5 Hz	6237.5 Hz
2	5.5201	543.47 Hz	905.78 Hz	1630.4 Hz*	2717.3 Hz*
3	8.6537	346.67 Hz	577.79 Hz	1040.0 Hz*	1733.4 Hz*
4	11.7915	254.42 Hz	424.03 Hz	763.3 Hz	1272.1 Hz
5	14.9309	200.93 Hz	334.88 Hz	602.8 Hz	1004.6 Hz
6	18.0711	166.01 Hz	276.68 Hz	498.0 Hz	830.1 Hz

* Preferred frequencies.

Table 2 - Deviation Produced by Common Modulation Frequencies

Modulation Frequency	Deviation Produced (ΔF)		
	Using First Null	Using Second Null	Using Third Null
905.8 Hz	±2.18 kHz	± 5.00 kHz	± 7.84 kHz
1000.0 Hz	±2.40 kHz	± 5.52 kHz	± 8.65 kHz
1500.0 Hz	±3.61 kHz	± 8.28 kHz	±12.98 kHz
1811.0 Hz	±4.35 kHz	±10.00 kHz	±15.67 kHz
2000.0 Hz	±4.81 kHz	±11.04 kHz	±17.31 kHz
2079.2 Hz	±5.00 kHz	±11.48 kHz	±17.99 kHz
2805.0 Hz	±6.75 kHz	±15.48 kHz	±24.27 kHz

the carrier beatnote as possible, making this beat easire to follow as you listen for nulls. For two-way radio transmitters, the passband is approximately 300 to 3000 Hz. Tables 1 and 2 will save you some pencil-work determining what modulation frequency to use. Use formula (2) to calculate other frequencies.

SOURCES OF AUDIO MODULATION

The accuracy of deviation adjustment by the Bessel null method is proportional to the accuracy of the audio tone used. Service shops fortunate enough to have a frequency counter can use it to set almost any audio oscillator to the desired frequency. The oscillator used must have a sinewave output with low harmonic content to obtain an accurate adjustment.

Figure 3 - The 1811-Hz output of Oscillator EX-6-A is very useful in making Bessel null calibrations.

Audio Oscillator Type EX-6-A is designed for use in Bessel null measurements. Both of its output frequencies (1000 Hz and 1811 Hz) are accurate within ±5%. The 1811-Hz signal is particularly useful, because it can be used for setting narrow-band modulation (±4.35 kHz) at the first null and wide-band modulation (±10.0 kHz) at the second null.

Type 90 or 99 tone encoders and the tone generators used in tone dialing equipment also make ideal tone sources for Bessel null calibrations, because their output frequencies are very precisely known.

TO CHECK THE CALIBRATION OF AN FM MONITOR

The calibration of an FM monitor can be checked against a transmitter whose deviation has been accurately adjusted by the Bessel null method. The monitor can usually be checked at several points. If the 1811-Hz output of Audio Oscillator EX-6-A is used, the monitor can be checked at ±4.35 kHz (first null), at ±10.00 kHz (second null), and at ±15.67 kHz (third null).

EQUIPMENT REQUIRED

- Audio Oscillator (such as GE Type EX-6-A)
- AC Voltmeter
- FM Receiver (wide-band, if available)
- I-F Generator (such as GE Type EX-7-A)
- RF Attenuator (such as GE Part No. 19B201404-P1)

It may be difficult to hear nulls beyond ±5-kHz deviation with a narrow-band receiver, because of the distortion produced by signals exceeding the receiver's bandwidth. Nulls at deviations up to ±15 kHz should be detectible with a wide-band receiver.

A frequency meter of the heterodyne type (such as the Gertsch FM-3) can be used in place of the FM receiver and the I-F generator. If a frequency meter is used, follow the standard procedure for measuring frequency (omitting calibration) and adjust the meter for a beat note from the internal speaker.

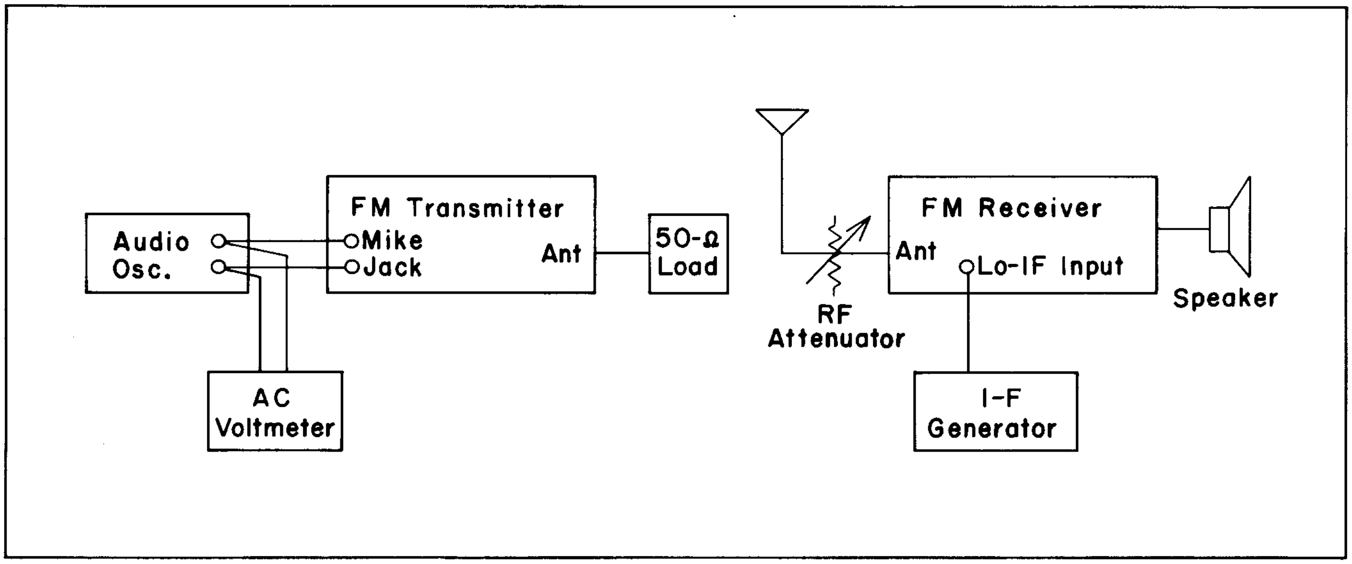

Figure 4 - Test Setup for Adjusting FM Transmitter Deivation

PROCEDURE

1. Test Setup: Connect the test equipment as shown in Figure 4. Set the output frequency of the I-F generator at the Lo-IF frequency of the receiver (455 kHz for MASTR or Porta-Mobil, 290 kHz for Progress Line to TPL). If I-F Generator EX-7-A is used, set the LEVEL control to mid-position. Set the modulation adjustment and the audio oscillator output to zero.

2. Receiver Adjustment: While transmitting an unmodulated carrier, adjust the RF attenuator for a signal level of 1 to 5 microvolts into the receiver. This can be done by adjusting the attenuator so that the limiter reading (below limiting) is the same as the produced by a 1 to 5-microvolt signal from a signal generator. Then adjust the receiver's first oscillator so that a beat frequency of approximately 200 to 400 Hz is heard from the speaker. (This is not recommended for 450—470 MHz receivers which use ICOM oscillators, due to the accuracy required to reset the receivers on frequency.) If preferred, the transmitter can be set off frequency, rather than the receiver. The beat note must be high enough to be clearly audible, but low enough to avoid confusion with audible beats from the sideband frequencies. Adjust the RF attenuator and the I-F generator LEVEL control for the clearest tone.

3. Audio Oscillator Adjustment: Accurately adjust the audio oscillator for the desired frequency, determined from Table 1 or 2 or from formula (2). Adjust the signal level so that it does not produce limiting in the transmitter (10 to 100 millivolts RMS for GE transmitters which use variable reluctance microphones).

4. Modulation Adjustment: Increase the transmitter modulation adjustment very slowly until a null is heard in the 400-Hz beat frequency from the speaker. This is the first null. If the 1811-Hz

modulating tone from Oscillator EX-6-A is being used, the transmitter is now modulating ±4.35 kHz. If a null other than the first is to be used, continue increasing the modulation, counting the nulls, until the correct one is found. Set the modulation exactly at the null.

NOTE

> It is necessary to concentract on the 400-Hz beat frequency to avoid error, because other tones are also present in the speaker output, each having its own nulls.

5. Calibrating the Monitor: Use the signal from the transmitter to calibrate your FM monitor. If possible, check the monitor at several points. Don't forget to readjust the receiver or transmitter to its proper operating frequency after you finish.

TO CHECK THE DEVIATION OF AN FM SIGNAL GENERATOR

The Bessel null method can be used to check the internal deviation meter in an FM signal generator (1) if the generator's center frequency does not shift significantly as modulation is applied and (2) if the generator does not drift more than approximately ±200 Hz. This can be observed by listening to the beat note with no modulation applied to see if it changes frequency, due to generator drift. If the beat note remains relatively stable, the following procedure can be used to check the deviation. Otherwise -- particularly for the 400—470 MHz range -- it will be much easier to calibrate your FM monitor as described above and then check your signal generator against the monitor.

EQUIPMENT REQUIRED

Audio Oscillator (such as GE Type EX-6-A)
FM Receiver (wide-band, if available)
I-F Generator (such as GE Type EX-7-A)

If Audio Oscillator EX-6-A is used, a transformer is required between the oscillator and the signal generator to step up the voltage and for impedance matching. Connections for the transformer are shown in the maintenance manual for the oscillator.

PROCEDURE

This procedure can be used to check the deviation of the Measurements Model 560 signal generator or equivalent.

1. Test Setup: Connect the test equipment as shown in Figure 5. Set the output frequency of the I-F generator for the Lo-IF frequency of the receiver (455 kHz for MASTR or Porta-Mobil, 290 kHz for Progress Line or TPL). If I-F Generator EX-7-A is used, set the LEVEL control

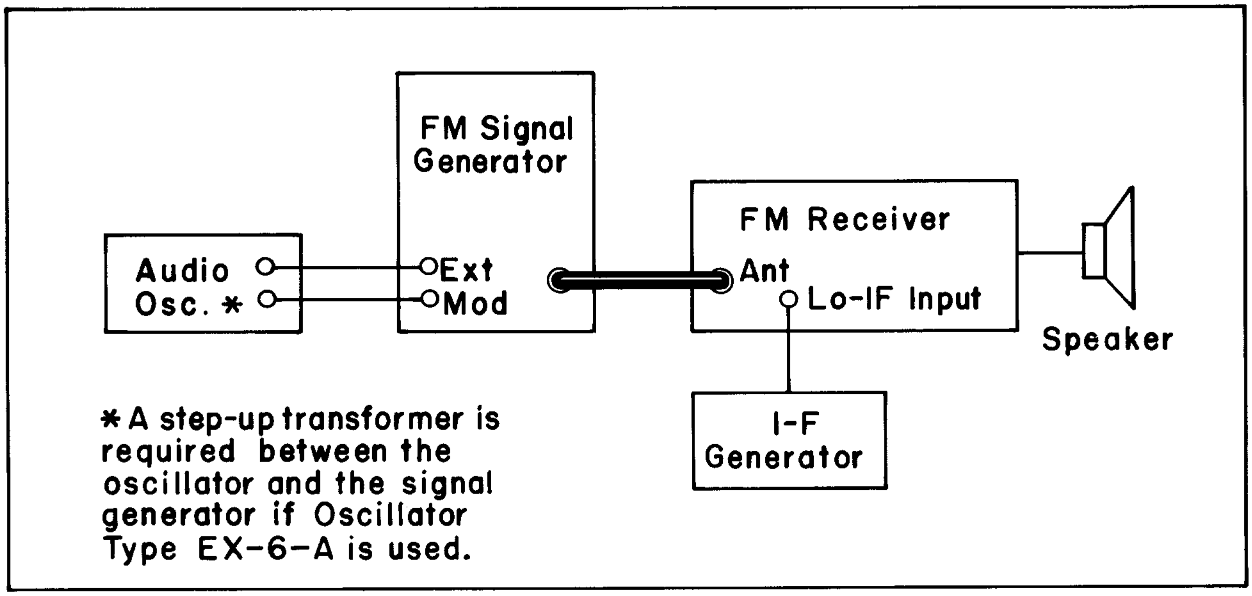

Figure 5 - Test Setup for Checking Deviation of FM Signal Generator

to mid-position. Set the generator modulation control and the audio oscillator output to zero.

2. Generator Adjustment: Apply a 1 to 5-microvolt unmodulated signal on the receiver frequency and then adjust the generator frequency slightly so that a beat frequency of approximately 200 to 400 Hz is heard from the speaker. The beat note must be high enough to be clearly audible, but low enough to avoid confusion with audible beats from the sideband frequencies. Adjust the signal level and the I-F generator LEVEL control for the clearest tone.

3. Audio Oscillator Adjustment: Accurately adjust the audio oscillator for the desired frequency, determined from Table 1 or 2 or from Formula (2). If Audio Oscillator EX-6-A is used, set the LEVEL control for maximum.

4. Modulation Adjustment: Increase the generator modulation very slowly until a null is heard in the 400-Hz beat frequency from the speaker. This is the first null. If the 1811-Hz modulation tone from Test Set EX-6-A is being used, the generator is now modulating ±4.35 kHz. If a null other than the first is to be used, continue increasing the modulation, counting the nulls, until the correct one is found. Set the modulation exactly at the null.

NOTE

> It is necessary to concentrate on the 400-Hz beat frequency to avoid error (1) because other beat notes are also present in the speaker output, (2) because these tones have their own nulls, and (3) because some generators shift center frequency when modulation is applied.

Note the reading of the generator's internal deviation meter at the null points for use in future test procedures.

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