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FM Transmitter Deviation Adjustment & Calibration

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The purpose of this application note is to explain how to adjust and calibrate the deviation in an FM transmitter. A good place to start for background reading material is the ARRL Handbook, chapter on Modulation and Demodulation [1]. There is also a wealth of material available on the internet, starting with Wikipedia [2]. The math describing FM modulation can be pretty hairy. With FM we don't simply have a single pair of side-bands as in AM or a single side-band as in SSB. Instead we have an infinite number of sidebands which are described by Bessel functions. Fortunately, they decrease in amplitude the farther they get away from the center frequency.

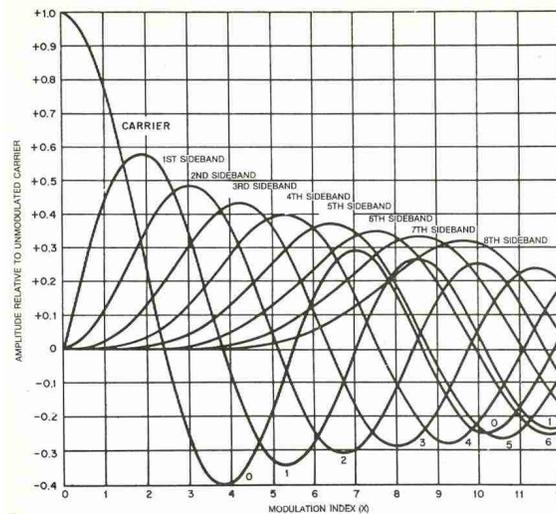


Fig. 1 Bessel functions showing the various sidebands for FM. (from ARRL [1])

The preferred technique for setting FM deviation is called the Bessel Null Technique. From the ARRL handbook, they define the modulation index, χ to be

$$\chi = D / m \quad (1)$$

where D is the peak deviation and m is the modulation frequency. The peak deviation is the maximum frequency excursion away from the center frequency. Fig. 1 above from the ARRL handbook shows the complicated Bessel function relationship of the various sidebands in FM as a function of χ . Of particular importance for our purposes is to look at what happens to the carrier frequency as the modulation index, χ , is increased. Note that it passes through zero several times at χ values of 2.405, 5.52, 8.65, etc.

Now let's take the example of tuning up an FM-TV transmitter. We want the peak deviation, D , to be 4 MHz when we apply a 1 Volt peak-to-peak video signal to the transmitter's video input port. What frequency sine wave should we use to align the transmitter? We want to look for the first null in the carrier at $\chi = 2.405$, so let's rearrange eqn. 1 to solve for m .

$$m = D / \chi = 4 \text{ MHz} / 2.405 = 1.663 \text{ MHz} \quad (2)$$

The easiest way to do this deviation adjustment is with a spectrum analyzer. See Fig. 2. Set the transmitter's video gain pot to zero. Now apply a 1.0 V_{ptp} sine wave of 1.663 MHz to the video input of the transmitter and then start increasing the video gain. As you do this, you will start to notice multiple sidebands appearing. As you continue to increase the video gain you will start to see the center, carrier frequency drop rapidly. Fine tune the video gain pot setting until you have nulled out the carrier frequency. At this point you have properly set the deviation to be exactly 4 MHz. The null can be very deep. The example shown in Fig. 2 (center photo) shows a null in excess of 55 dB. Be sure to stop at the first null. If you keep cranking up the gain pot, you will go through more Bessel nulls. If you stop on the wrong null, you will be over deviating the transmitter.

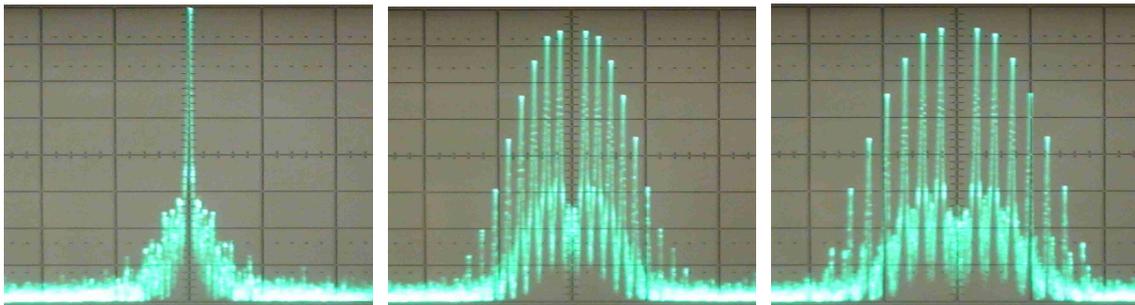


Fig. 2 Spectrum plots of an FM-TV transmitter. 10 dB/div & 10 MHz/div. (left) Transmitter with no modulation (center) Transmitter with flat video response, properly set for 4 MHz deviation with 1.663 MHz tone. (right) Transmitter with pre-emphasis, properly set for 4 MHz deviation with 2.33 MHz tone.

The above example was based upon the assumption that the transmitter had a flat video frequency response. According to Mike Collis, WA6SVT [3], if the transmitter has a CCIR 405-1 Pre-Emphasis filter on it's input, then the alignment sine wave frequency should be set instead to 2.33 MHz., . The different frequency accounts for the effects of the pre-emphasis filter. The right photo in Fig. 2 shows the spectrum from such a transmitter.

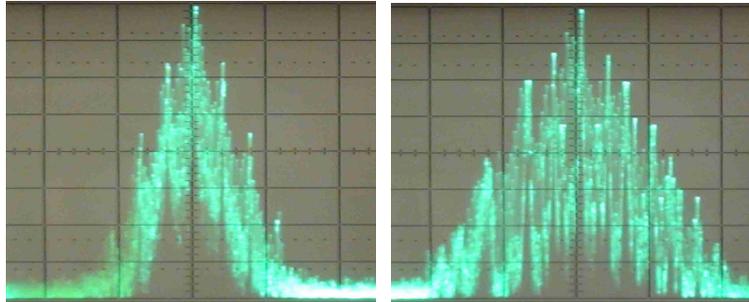


Fig. 3 Spectrum plots of a 4 MHz deviation, FM TV transmitter with pre-emphasis and running with normal, "live", video modulation. 10 dB/div & 10 MHz/div. (left) no sub-carriers (right) with stereo sound sub-carriers at 5.8 & 6.2 MHz

Fig. 3 above shows the spectrums from a normally operating FM TV transmitter running "live" video, both with and without sound sub-carriers. It is obvious that adding the sound sub-carriers broadens appreciably the spectrum. The examples shown here in Figs. 2 & 3 were from a KH6HTV VIDEO, model 23-1, 23 cm, 3 Watt, FM-TV transmitter.

With either analog VUSB-TV or FM-TV, we transmit our audio on sub-carriers using FM. Thus, we need to also consider how to properly set the audio sub-carrier's deviation. Again, we will use the Bessel null technique. The only difference will be the amplitude and frequency of the test alignment sine wave. For detecting the null, a spectrum analyzer is preferred, but it can also be accomplished using a narrow-band radio receiver. In either case, the bandwidth needs to be set to < 1/10 th of the frequency of the test signal. Thus, when testing with audio frequency tones, a good SSB/CW receiver is required.

For conventional, analog TV using either AM or VUSB modulation, the sound sub-carrier is at 4.5 MHz with 25 kHz deviation. For FM-TV, the sub-carrier(s) typically are using a wider deviation of 75 kHz. The FM sub-carriers are usually higher than 4.5 MHz and are most often found between 5 and 6.5 MHz.

The standard audio input to most audio equipment and TV transmitters is called Line Level audio [4]. For consumer audio products, Line Level Audio is defined to be 0 Volume Units (VU) as measured on an audio VU meter.

$$0 \text{ VU} = -10 \text{ dBV} \quad (3)$$

where 0 dBV is 1 V_{rms}. Thus -10 dBV = 316 mV_{rms}. An Average Program Level (APL) is defined to be 0 VU. For a sine wave of 316 mV_{rms}, the peak-to-peak is 894 mV(ptp). The Peak Program Level (PPL) is considered to be 10dB higher than APL, but still registers as 0 VU on an audio VU meter. 10 dB is a 3.16 X factor, thus

$$\text{PPL} = 10\text{dB} \times \text{APL} = 3.16 \times 894 \text{ mV} = 2.83 \text{ V}_{\text{ptp}} \quad (4)$$

This level of 2.8 V_{ptp} seems to be rather consistent with measurements I have made on the typical line level audio coming out of various devices, such as FM tuner, DVD player, Blu-Ray player, camcorder, etc. Frank McClatchie, of FM Systems, has two good application notes discussing this further [5, 6].

The same Bessel Null procedure is used to set audio sub-carrier deviation as was used for video deviation. The alignment test sine waves use an APL of 894 mV_{ptp} amplitude.

25 kHz Deviation: 894 mV(ptp), 3.288 kHz sine wave

75 kHz Deviation: 894 mV(ptp), 9.863 kHz sine wave

Most TV transmitters use 75 μ s pre-emphasis on the modulation audio signal. For the above amplitudes and frequencies to be correct, the Pre-Emphasis must be switched off prior to performing the deviation adjustment. Don't forget to turn it back on after the alignment.

References:

1. ARRL Handbook, Chapter 9, "Modulation and Demodulation", 1991.
2. http://en.wikipedia.org/wiki/Frequency_modulation
3. Mike Collis, WA6SVT, "FM ATV Transmitter Alignment Procedures", Amateur Television Quarterly, Summer, 2008, page 11
4. http://en.wikipedia.org/wiki/Line_level
5. Frank McClatchie, "TV Audio Deviation Measuring and Setting It", FM Systems, <http://www.fmsystems-inc.com/>
6. Frank McClatchie, "Bessel Null FM Deviation Measurement", FM Systems, <http://www.fmsystems-inc.com/>