FM Deviation Calibration

By G8MNY (Updated Jan 16)
(8 Bit ASCII graphics use code page 437 or 850, Terminal Font)

PHASE MODULATION

This is a form of FM where the carrier phase is changed not the frequency. It used to be quite common on Xtal bound PMR rigs as the Xtal Q did not affect modulator gain as varicaping crystal FM designs do. The modulator is slightly different as the varicap is not used directly on the crystal oscillator, but in the following buffer stage.

It is measured differently to FM, in Rad/s, & 1 Rad/s = FM Modulation Index (Dev/ModF) of 1 at ANY Mod Frequency. However it gives much the same results as FM except the modulation is treble lifted at +6dB /Octave. So peak modulation has a different meaning in PM unless there is a clipper set up before a 6dB/ Octave treble cut filter in the modulator (to turn it back to FM), to limit the frequency related deviation!

FM MODULATION STANDARDS

Using Carson's Rule the width of an FM signal is approx..

2x deviation + 2x highest modulation frequency.

This is not all the sidebands as the FM process generates but most of them, to see the rest look into the Bessel functions.

His rule is simply explained by considering what happens at an instant when a low frequency has given almost full deviation. The instant FM frequency is at 1 side of the deviation window, & there is still some treble syllabance mod to carry with its ±3kHz sidebands like an AM signal. This gives the diagrams below for 12.5kHz & 25kHz systems, where the lowest & highest modulations sidebands are added to either side of the FM deviation. So the Rx also has to let in all these wanted sidebands if there is to be no distortion.

12.5kHz CHANNEL FM SYSTEM

```
TX Bandwidth
     Lowest     ____________      Highest        Rx      .--------------. _-3dB
     Lower    /'| deviation |`\  Upper      Bandwidth |              |
    Sideband/'  | +/-2.5kHz |  `\Sideband     (ideal)  |              |
_________,/_____|___________|_____\._______       ____,'_-70dB         `._____
  Next  ||<3kHz><----5kHz---><3kHz>|| Next             |<----11kHz--->|
Channel ||----------11kHz----------|| Channel        |<-----12kHz---->|
        |----------12.5kHz----------|
```

N.B. there is next to no Rx protection "GUARD BAND" between channels on the 12.5KHz system! For this reasion commercially adjacent channels are NEVER used in the same area!

For the 12.5kHz system a MAX of ±2.5kHz Peak deviation is used, giving a modulation index of 0.833 (Dev/ModF), which gives little capture effect over an AM system.

The Tx also needs to have the AF response VERY WELL FILTERED, if the FM sidebands are to be kept out of the adjacent channel.

```
  0dB-|          .----------------------------------.        |-100%  2.5 kHz
 -6dB-|         /                                   >¦       |- 50%  1.25kHz
      |       /   Very tight audio filtering>Ì       |
      |     /                                   > ¦          |
      |   /          for no adjacent ch QRM     > Ì          |
-70dB-|  /                                      >  ¦         |-0.03% 0.75 Hz
      |_______________________________________________________|
      0  150 200 300 400 600 800  1k 1k5  2k  3k  4k  Hz
```

The ideal Rx IF filter can't be made (see Rx bandwidth diagram), so in practice narrower filters give better adjacent channel performance, but with quite high audio distortion (10%), as some of the needed spectrum is lost.

With tight filters, the channel carrier frequency accuracy is important to keep the Tx signal center of the Rx IF. This is not so easy on higher bands without very good Xtal stability (ovens etc), so the 12.5kHz system is NOT for used above VHF!

25kHz CHANNEL FM SYSTEM

```
TX Bandwidth                       |GUARD  |
     Lowest         ____________ Highest  BAND|    Rx      .------------. _-3dB
      Lower     /'|deviation |`\  Upper      Bandwidth |              |
     Sideband /'  |  +/-5kHz |  `\Sideband            |                |
___________,/_____|__________|_____\.________    ____,'_-70dB          `.____
  Next |   |3.5kHz<--10kHz--->3.5kHz|    | Next         |<----17kHz--->|
Channel|   |---------17kHz----------|    |Channel     |<------25kHz----->|
       |-------------25kHz--------------|
```

N.B. Here there is the luxury of an 8kHz GUARD BAND between channels on this system, which is why it can work much better with strong adjacent channel signals than the 12.5kHz system, & with very little distortion!

For 25kHz system a MAX of ±5kHz peak deviation is used, gives a modulation index of 1.4 (1.6 if 3kHz) & has 2x (6dB) more noise rejection & capture effect than the 12.5kHz system.

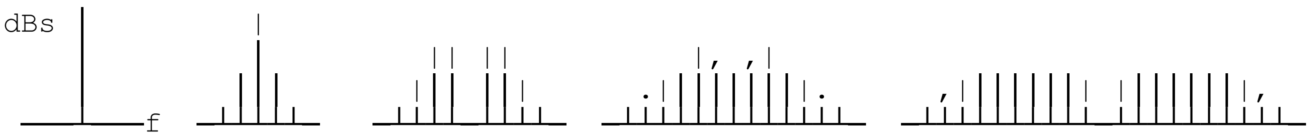
The Tx AF filtering & the Rx filter are far less stringent than for the 12.5kHz system, & the comms sound quality can be quite a bit better. Due to the wider guard band the adjacent channels have less Tx QRM in them & Rx filters can more easily remove the adjacent channel signals.

EMPHASIS
With FM it is usual to apply some Tx treble pre-emphasis & Rx treble de-emphasis, this is to mask the increased treble Rx noise with the FM system. With comms bandwidth the amount of emphasis cannot be very great, but up to +6dB @ 2kHz can be used.

```
FM Rx                Tx Pre-          Rx De-           Overall Audio
Noise Floor          emphasis          Response
 /|\           _.-'              _.-'  ```——..__       ..............
Level__..,,-—'       __..,,-—'               `—._      _ _ _ _ _ _ _ _ _ Noise
     2 3 5 1k 2k 3k  2 3 5 1k 2k 3k   2 3 5 1k 2k 3k   2 3 5 1k 2k 3k  Floor
         Freq ->
```

DEVIATION MEASUREMENT
Here are 2 simple methods for FM deviation calibration. Phase modulators use 6dB/Octave LF lift on the modultion to mimic FM & these need some care when scoping @ the Tx to realise what you are seeing!

1 Bessel carrier null method.
Mr Bessel modulation index graphs show the 1st order carrier null occurs when the Modulation Index (Dev/ModF) = 2.4, then again at 3.142 intervals after that. This means a 1kHz sine wave modulation tone will produce a 1st carrier null at precisely 2.40kHz deviation & a 2nd at 5.54kHz deviation.




```
  No Mod   Some Mod    1st Null       More Mod               2nd Null
MI=  0      <2.4         2.4            >2.4                  2.4+Pi
```

To monitor the modulation spectrum, you will need a SSB Rx with RF gain control, ideally with a very narrow CW filter, or a Spectrum Analyser with a narrow filter. E.g. a sound card from SSB AF output & an AF Spectrum Analyser programme, or just good ears listing to just the carrier whistles nulling while the other sideband ones get stronger.
Also an accurate & pure AF 1kHz sine wave generator is needed to feed the mic circuit via a suitable attenuator (series 100kÛ ?)

Method.
Using a 1kHz sine wave tone, adjust modulation level (mic gain/deviation) to produce no carrier on a SSB/CW Rx.

Now note the modulator drive level (e.g. scope it) @ the modulator, & ensure that the AF FM clipper now hard clips anything at this level by adjusting the deviation pot with the mic gain set at max (shout into the mic etc.)

2 Discriminator DC & Scope method. (can be used on air with a Rx)
Access to monitoring FM Rx's discriminator is needed to display the DC level on a oscilloscope. Make sure the scope is connected to the discriminator point before any de-emphasis components, & that the deviation sidebands being measured will all fit through the IF filter, otherwise the display will lie.

```
SCOPE TRACE    Fc+5kHz _____
                                        _
                                      .'  `.
 Fc ———————                  MOD  |       |      |
               Fc-5kHz _____   ±5kHz           `._,'
```

Send a carrier, & change the Rx/Tx frequency +/-5kHz & adjust the scope gains & position to give a +/- 5 division display.

Now anything you can Rx, will instantly show you the on channel "frequency error" & "deviation" on the scope trace.

Method
For Tx deviation setting, just ensure the clipper hard clips anything @ this level by adjusting the deviation pot with the mic gain at max. (E.g. shout into the mic.) Then set deviation = ±2.4 or ±5.0 divisions peak to peak.

SETTING UP A DEVIATION METER.
At this point with a calibrated reference, it is relatively easy to make a peak reading meter display, & calibrated in peak deviation for your Rx. Once you have a calibrated source, it is easy to put a peak reading meter circuit (not an average VU circuit!) onto any Rx & calibrate it. For accurate work a wide Rx is needed.

HARMONICS
These will deviate more by their hamonic factor. E.g. 2M rig at ±2.5 kHz dev will have a 70cms harmonic deviation at ±7.2 kHz.

With some deviation meters, it is easy to measure a harmonic not the fundimental!

Also see my buls on "FM Stereo Radio Principles", & "RTT Mod Meter (100)"

Why don't U send an interesting bul?

73 de John G8MNY @ GB7CIP