Tone and Frequency Placing for Machine Generated Modes (MGM) on Amateur Beacons

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Introduction

As Machine Generated Modes are added to microwave beacons, there has been considerable variation in the way various builders interpret the meaning of the beacon's allocated frequency (*Nominal Frequency*). The majority of these beacons use multi-frequency modes included within the WSJT suite. The resulting spread of frequencies has often been placed somewhat arbitrarily around the beacon's nominal frequency.

The frequency to which a receiver has to be tuned in relation to the nominal frequency, so the demodulated signal is delivered to decoding software with the correct tone frequencies has often been selected unilaterally, with little consultation. This leads to confusion on the part of receiving stations where they need to set their dial to ensure reception of weak signals that may be below the threshold of audibility. Some have made the point that there is a discrepancy between the ideal tuning point for aural reception of the beacon's carrier period and that for correct MGM demodulation

With the increasing number of beacons and the narrow spacing between allocations, particularly at VHF, MGM tone spread needs to be kept as low as possible to ensure staying within a particular channel slot. This paper attempts to define a subset of options and to make recommendations for future beacon builders.

MGM Tuning

Most data modes require demodulation to audio in a receiver set for USB reception, with the resulting audio fed typically to a soundcard. Different data modes need a different span of tone frequencies. The ones most popular for V/UHF and microwave beacons are shown, along with their (exact) audio reference tone and frequency span.

Modulation Type	Reference or lowest tone (Hz)	Frequency Span / signal width (Hz)	Usage
JT65B (65 tones)	1270.48 (sync)	350	VHF / UHF
JT65C (65 tones)	1270.48 (sync)	700	Low Microwave
JT4G (4 tones)	797.96 (Tone 0)	950	Microwave
ISCAT-A (43 tones)	1012.06 (Tone 0)	926	Projected – A/C or Meteor Scatter
ISCAT-B (43 tones)	559.8 (Tone 0)	1852	" "

Note that in all cases the reference tone is not a nice round, easy to remember number. All demodulation software allows some variability in this tone, usually of up to several hundred Hz (the *Tol*. Setting in WSJT, for example) but should ideally be tuned correctly. Demodulation software works most efficiently and speedily when the input is quite close to the desired value

MGM Beacon Frequency definitions

Every beacon has a stated *nominal frequency* which should be the exact value of the RF that is radiated when it is sending plain carrier and CW for aural reception. When CW is sent using FSK, this is the mark, or key-down frequency. An SSB receiver is then tuned to deliver this as a tone to suit the operator's preferences. For most people this is somewhere in the range 400 – 900Hz so the SSB tuning dial is then set by this amount below the beacon's nominal frequency. However, this tuning point will almost-certainly not be the best for demodulation of the MGM tones. For example, if the beacon uses its nominal frequency as the reference tone for JT65, the SSB tuning point will need to be 1270Hz lower. Even if this were defined to the nearest 100Hz step at 1.3kHz, the resulting offset is not obvious or easy to remember, nor the resulting tone ideal for aural reception

JT4G (and only this variant, specifically) is more convenient in that Tone 0 is so close to 800Hz (2.04Hz discrepancy) that for all practical purposes it can be stated as being that frequency. As 800Hz is also a 'nice' frequency for aural reception this solution has been adopted for several microwave beacons. Tone 0 corresponds to the nominal frequency and the MGM tones spread upwards by 950Hz. The asymmetrical span is comfortably accommodated within a 1kHz maximum bandwidth and 5kHz allocation grid for microwave beacons. It is even acceptable if the spacing were to be reduced to a 2.5kHz grid. For most listeners there is no need to change the tuning between aural and MGM decoding and an offset of 800Hz has the advantage that it is also an easy number to remember. Note that this short-cut only applies to the –G variant of JT4. Frequency Shift, or F1B CW keying may make use of Tone 1 for the space, or key-up, with a resulting shift of 315Hz. Alternatively, a fifth tone could be introduced for this purpose at the builder's discretion.

Recommendation:

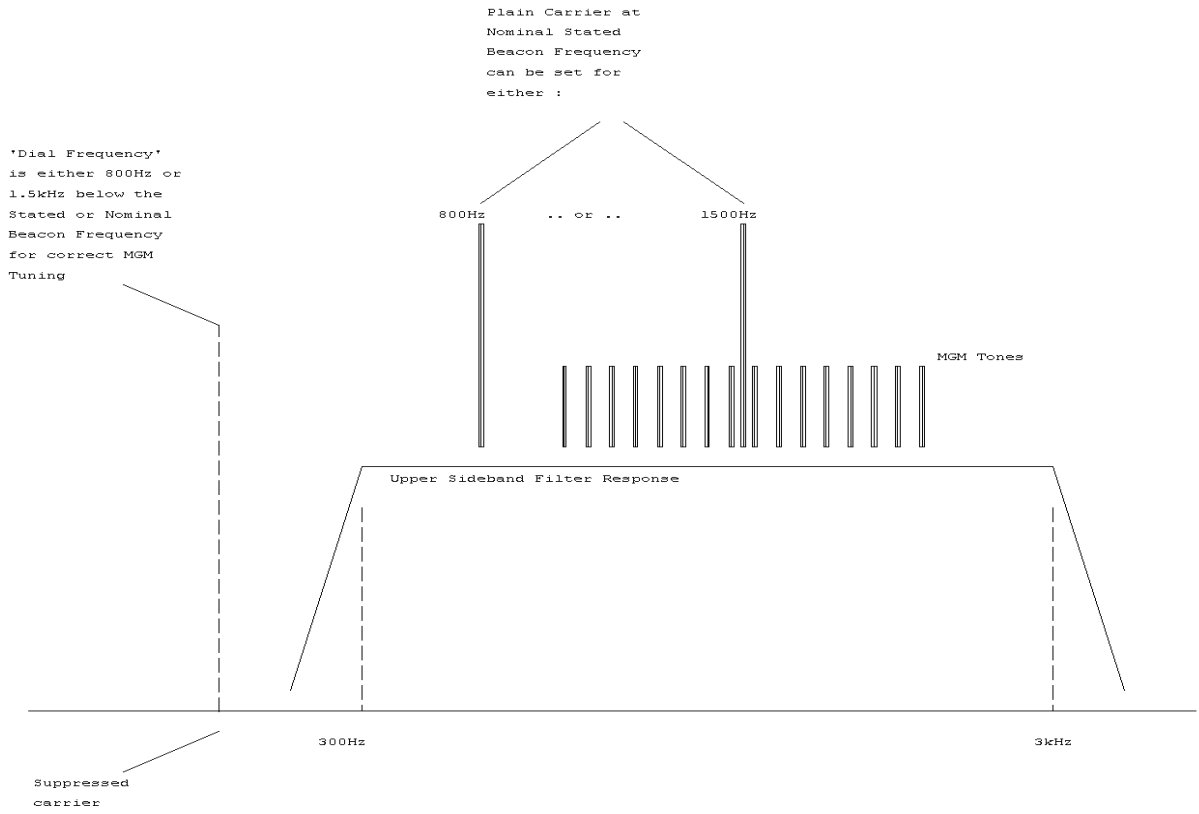
When using JT4G modulation specifically it is proposed that Tone 0 (the lowest of the four) should be made exactly equal to the beacon's allocated frequency as used for the plain carrier period and CW key-down, and that the tuning point is specified as being 800Hz lower than this.

Other modes are not so straightforward. JT65 with its tones spanning from 1270 – 1620Hz or 1970Hz for the –B or –C versions does not accommodate any nice listening frequencies or tuning point! The solution adopted on some beacons in the UK was to define the SSB tuning as being exactly 1.5kHz below the nominal for correct delivery of MGM tones to the decoder. During carrier and CW periods the resulting audio is then delivered at 1500Hz. Anyone wishing to listen to this aurally, has to move their tuning dial to match their individual preferences. A 1500Hz reference tone also has the advantage it is roughly in the middle of the JT65 spread and introduces no extra signal occupancy. This will be referred to as the *1500Hz option*.

Another suggestion defines the SSB tuning point so the MGM tones are placed at a higher RF and are correctly delivered when the carrier gives an 800Hz tone. This has the advantage of the same definition of tuning point as that for JT4G. Now the spread of frequencies is wider. For JT65B it goes from the nominal frequency generating 800Hz up by [1620 – 800] = 820Hz for the top tone of the modulation; a non symmetrical span of 820Hz. For JT65C this span becomes 1170Hz; appreciably wider than the desired 1kHz maximum bandwidth.

This scheme has the advantage of not requiring retuning between aural and MGM receiving periods for many operators. The abrupt jump in tone between 800Hz for carrier / CW and the

sync tone of the MGM may also offer some advantage for listeners in identifying the signal under noisy conditions. This is referred to as the *800Hz Option*.



For both, the space or key-up tone for FSK CW may be placed anywhere convenient, but should avoid extending the span even further. Using the MGM sync tone for key-up when using the 800Hz option may offer a convenient value that keeps the aural listening environment uncluttered.

The wider spacing of the 800Hz option may not be a problem for microwave beacons at 2.3GHz or higher, although the excessive span for JT65C or ISCAT may be deemed unacceptable. At VHF where allocations and spreading is more restricted the 1500Hz option may be all that is acceptable.

Recommendation:

VHF Beacons carrying MGM signals should be arranged so their nominal carrier and CW key-down frequency generates a tone of 1500Hz when correctly tuned for MGM decoding. The 1500Hz Option

Microwave beacons radiating MGM signals should preferably be arranged so the nominal carrier and CW key-down frequency generates a tone of 800Hz when correctly tuned for MGM decoding, provided the resulting tone spread is acceptable in terms of allocation and total signal bandwidth. The 800Hz option.

Where Frequency shift or FSK CW (F1B) is employed, the space, or key-up, tone should lie within the existing tone spread, and must not cause any additional widening of the signal.