

A suggested Tone-Frequency set for use with JT4G modulation on Microwave Beacons

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Overview

A number of microwave beacons have adopted the JT4G modulation format to enhance their reception capabilities in weak signal conditions and to permit automatic monitoring with a more accurate measurement of received S/N than the human ear or S-Meter can offer. This suggestion is put forward as a proposal for standardisation of the tones used for JT4G transmissions on microwave beacons.

JT4G consists of a four tone Multi Frequency Shift Keyed (MFSK) waveform transmitted for a duration of about 48 seconds starting on each even minute of a two-minute cycle. The odd minute is taken up with a sequence that contains the callsign and other details sent in either Of-Off or frequency shift keyed CW along with at least one period of plain carrier lasting at least 20 seconds

So far there has been no attempt to standardise the tone frequencies used for the two parts of the transmission, with the result that listeners need to set their SSB tuning dials for various carrier frequency offsets for different beacons.

Tuning Requirements

JT4G consists of four tones spaced by 315Hz. The modulation is such that an SSB receiver set to Upper Sideband is used to deliver audio tones to the software. The demodulator requires that the lowest of the four tones be delivered at nominally 800Hz, although the software will cope with up to a couple of hundred Hz of tuning error. The spread of tones delivered to the receiver therefore covers 800 to 1745Hz. For a precise definition of JT4G frequency setting see the annex.

On a conventional SSB receiver the dialled-up frequency, that of the suppressed carrier, will therefore need to be (about) 800Hz below the lowest frequency of the tone set.

All beacons have a nominated frequency, and their transmission sequence must always include a period of plain carrier, lasting at least 20 seconds on this frequency so listeners can identify and use for frequency calibration checks. The CW ident when on-off keying is used is also sent on the nominated frequency. All this takes place during the odd minute.

With dual frequency FSK keying, current beacon building advice is that a frequency shift of 400Hz is used. The key down state (the 'dah' or 'dit'), is called the mark tone and lies on the nominated carrier frequency. The carrier moves by the 400Hz shift to form the space tone for the key up period; the direction of the shift is not specified. The reason behind a value of 400Hz shift is that stations using a 300Hz wide CW filter can just select the mark tone in its centre, which will now appear as if it were on-off keyed.

There are now TWO completely independent tuning requirements. The need to ensure the JT4G tones come out close enough to 800 – 1975Hz, and the need to place the carrier and CW mark at a convenient and easy to remember point, preferably where the tone 'sounds nice'. For FSK keying, there may also be a requirement to be able to place the key-up space tone somewhere where it won't annoy, or get in the way of trying to read the CW.

Suggested Proposal

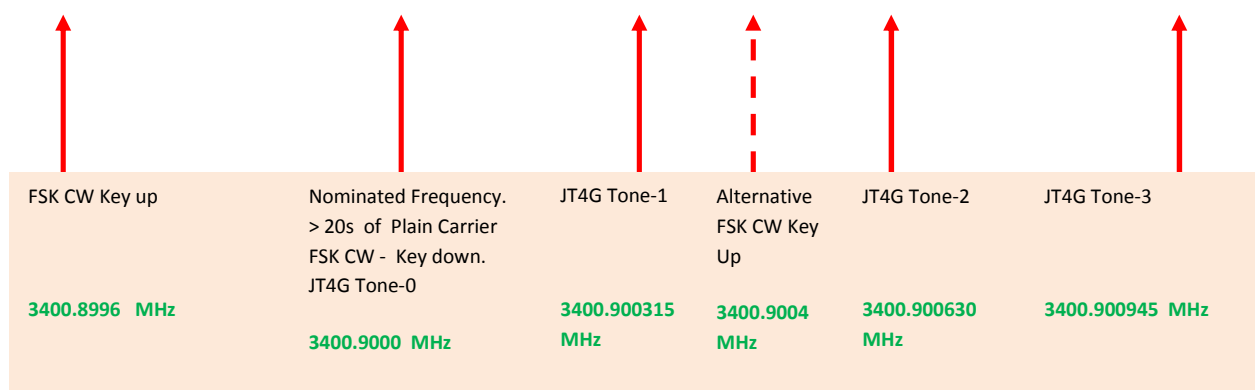
It is suggested that the modulation is chosen so that JT4G Tone zero at 800Hz is sent on the beacon's nominated frequency. Then during the JT4G sequence, the beacon transmission will step up to 945Hz above its nominated frequency. The CW ident when on-off keying is used is also sent using the Tone-0 frequency.

The resulting 800Hz tone for carrier and CW is a reasonable compromise frequency, lies in the CW pitch range of most receivers set to CW mode and is an easy number to remember.

The space tone for FSK CW can be sent either above or below the nominated or reference tone, and there are advantages and disadvantages for each. If placed below, the CW appears at 800Hz with the space at 400Hz. When listening with a wide SSB filter, both tones are heard and a consensus seems to be that a low space tone is less annoying than one higher in frequency than the mark tone. (One incidental advantage is that the resulting tones at 400 and 800Hz are an octave apart when perfectly tuned, which 'sounds nice' and may assist in setting the correct tuning point)

The disadvantage is that the total frequency spectrum from the beacon is now extended to 400 – 1745Hz, a width of 1345Hz and greater than the overall 1kHz that has been allowed in some countries. In this event, it will be necessary to make the space tone higher than the carrier, and shift up instead so it sits at 1200Hz.

This all means that four or five tones are needed overall, shown graphically below assuming a beacon on a nominated frequency of 3400.900MHz. Four 315Hz spaced tones for JT4G, with the lowest one forming the reference carrier and CW mark. The fifth tone is used for CW space if Frequency Shift Keying is in use. Here, the SSB dial, or the carrier, needs to be set to **3400.8992MHz**. ie 800Hz below the nominal 3400.900MHz carrier frequency



Exploding a few myths and possible misunderstandings.

The so-called centre frequency of the JT4 waveform (all variants) is not actually an important value. No tone actually sits there (it is where Tone-1.5 would sit, exactly mid way between Tone-1 and Tone-2) As shown in the annex, the frequency of this is obscure and lies at about 1270Hz. There is no reason whatsoever that this should be either on the nominated beacon carrier frequency, or even close to it.

Accurate tuning of the JT4G signal is not essential. The *perfect*-frequency of the lowest Tone-0 is 797.96Hz, but forcing this tone to appear at 800Hz results in only 2.04Hz of tuning error. This is likely to be less than the final frequency setting error when a 32 bit DDS is used for generating the frequencies in the beacon source. It is also less than the 4.375Hz keying rate of the modulation, so will be 'lost in the sidebands'. Even at the lowest 'snap' frequency offset allowed in the WSJT software, 50Hz of tuning error is within the allowed range, with the highest value possible 400Hz.

Early copies of the WSJT documentation erroneously state that JT4G has a total bandwidth of 1260Hz (four tone spacings). It doesn't; four switched tones require a total bandwidth of three times their individual spacing plus the modulation sidebands, ie. $3 * 315\text{Hz} + 4.375 = (\text{approx}) 950\text{Hz}$

Other Modulations

This suggested proposal *only applies to JT4G with its specific tone set*, this being the widest spaced and best suited of all the existing WSJT modulations to the higher microwave bands where frequency spreading of several hundred Hz may occur.

Other narrower JT4 variants (JT4A – JT4F) will not have their Tone-0 at 800Hz so another tone-frequency allocation would have to be decided upon. At the time of writing no other JT4 variants are in use on beacons, and it is arguable that JT4 modulation is not even the best-suited for the UHF to lower frequency bands – there are better ones. For example the 65 tone JT65 has been adopted for several VHF beacons now and offers a dB or so improvement over JT4 (Note that JT65 cannot be implemented with the RDDS module as it stands using a 32 bit DDS)

JT4G Tone Frequencies

For compatibility with other WSJT modes and to assist in some common decoder routines, the centre frequency of all the JT4 sub-modes is defined by :

$$11025\text{Hz (sampling rate)} / 1024 * 118 = \mathbf{1270.46\text{Hz}}$$

$$\text{The JT4 symbol rate} = 11025 / 2520 = \mathbf{4.375\text{Hz}}$$

Tone spacings are at various integer multiples of the symbol rate, with JT4A the narrowest, at $1 * 4.375\text{Hz}$; the intermediate JT4D at eight times the symbol rate and the widest, JT4G, at $72 * 4.375 = \mathbf{315\text{Hz}}$.

The exact tone frequencies are therefore :

$$1270.46 + (1.5 - N) * M * 4.375\text{Hz}$$

Where N is the tone number from 0 to 3, and M the sub-variant multiplier (72 for JT4G)

$$\text{So tone zero ideally lies at } 1270.46 - 1.5 * 315 = \mathbf{797.46\text{Hz}}$$