The Poor Bugle (No Valves)

A string instrument (piano, violin, etc.) is typically played as a free running oscillator. The string is given an initial impulse (or series of impulses, as in bowing) and then left to freely generate its spectrum, which consists of a fundamental frequency f1 and its harmonics (2f1, 3f1, 4f1...). The fundamental has a wavelength equal to twice the string length. The fundamental frequency is the wave velocity along the string (depends on string tension and mass) divided by this frequency. The relative amplitudes of the harmonic frequencies thus generated depend on the details of the initial impulse, but the fundamental frequency is typically dominant and the resulting sound is heard as having the pitch of the fundamental frequency, with a timbre characteristic of the spectrum of harmonics generated. To change to a different pitch, the player must either choose a different string or adjust the characteristics of a single string (e.g., frets change the active length) to get a new fundamental frequency.

Wind instruments use a tube of air instead of a string. Like the string, this air column can function as a free running oscillator. It can be given an initial pressure impulse to generate a spectrum consisting of a fundamental frequency (wavelength = 2 x length) and its harmonics. The velocity of sound in air (v = 1126 ft/sec) connects each frequency to its wavelength: $f = v/\lambda$. For example, a Xylophone can be made of a series of such "pipes" of various lengths, to generate the desired pitches when struck. Other wind instruments use various mechanisms (e.g., valves, openings) to change the effective length and the fundamental frequency of a single tube.

But a bugle has only a single tube, and has no mechanism for adjusting its length - so its fundamental frequency is fixed and NOT adjustable. How does it generate different pitches (as in "TAPS")?

Unlike the string instruments, the bugle (along with many wind instruments) is NOT played as a free running oscillator (hit or stretched, and then let go to generate its own spectrum) - rather, it is played as a DRIVEN oscillator. At the mouthpiece, vibrating lips continuously try to force the air column into oscillation at a definite frequency of the player's choice. If the applied frequency is one of the frequencies in the tube's harmonic spectrum, it will respond with a resonance and amplify that vibration, generating a sound with the pitch of the driving frequency. The bugle tube here functions more like an amplifier with a spectrum of preferred, resonant frequencies.

In practice, the bugle fundamental (f1) and second harmonic (2xf1) are difficult to produce in this way. So, for example, "TAPS" typically uses only the third, fourth, fifth and sixth harmonics of the bugle’s spectrum. Like the bugle, many other brass instruments (and reed driven woodwinds) operate as DRIVEN oscillators, with pitches determined by the driving mechanism.

Here is the spectrum of a possible bugle. These notes may be transposed to produce bugles of different "keys":

BUGLE SPECTRUM

fundamental C3

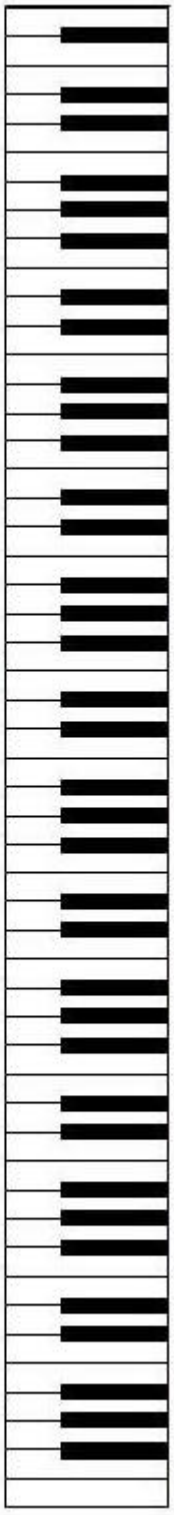
C4

G4

Taps C5

E5

G5



Bugle Length Calculation

Fundamental = 131 Hz.

131 Hz = (1126 ft /sec) / 2L

L = 1126 / (2x131) = 4.3 ft.