# Imitative Synthesis Project (Trumpet)

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# Trumpet Analysis

The trumpet is a brass instrument widely used in classical orchestras and jazz ensembles. The group ranges of trumpets from the piccolo trumpet, which has the highest register in the brass family, to the bass trumpet, which is pitched an octave below the standard Bb trumpet. The trumpet type that is commonly used in music is the Bb trumpet. This research paper is based on the investigation of the Bb trumpet. Here is some basic information about the Bb trumpet.

- Note Range: The Bb trumpet has a lower note that s written in F#3, but there is no actual limit on how high it can play. According to "Modern Jazz Voicing", the written range of the Bb trumpet is from F#3 to Eb6, as the sounding range is from E3 to Db6, which is a major second below the written range. (Ted Pease and Ken Pullig, 2001)

- Texture: The Bb trumpet is a monophonic instrument with sustaining time depending on the player's time.

- Physical Construction:

  Brass, an alloy of copper and zinc, constructs the trumpet. It has eight sections: Bell, water key, tuning slide, valves that contain the first valve tube, second valve tube, and the third valve tube, as well as the mouthpiece. The brass tubing of the trumpet bent twice into an oblong shape.

According to Wikipedia, the bore is a complex series of tapers, smaller at the mouthpiece receiver and larger just before the flare of the bell begins; careful design of these tapers is critical to the instrument's intonation. In other words, the structure of the bore is the main character of the brass instrument construction. Cylindrical and conical are two types of bores. The cylindrical bore is a built-in brass instrument with constant diameter tubing predominating. However, a conical bore is constructed in brass instruments with predominately increasing diameter tubing. Like a trombone, the Bb trumpet has a roughly cylindrical bore, resulting in a bright and loud sound. The resonance of a brass instrument resembles a harmonic series, which is often associated with the bore diameters. There are two types of bore diameters-——Whole-tube and Half-tube. The main difference between them is their relationship with bores and tubing length. Whole-tube instruments have larger bores with their tubing length, while half-tube instruments have smaller bores to their tubing length. the Bb trumpet has a half-tube that can't easily play the fundamental tone.

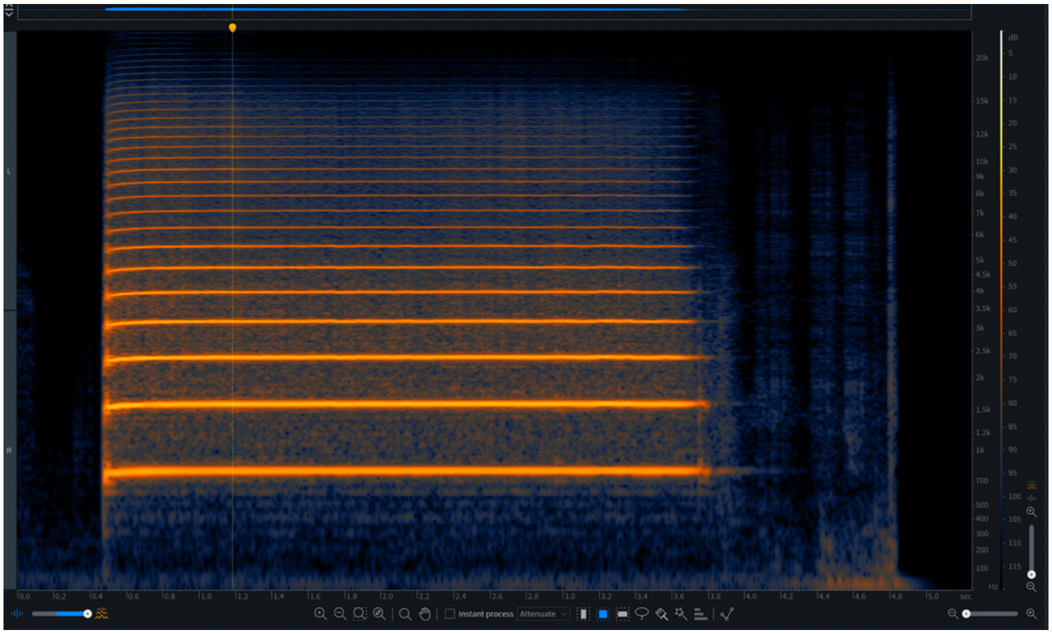
Modern Bb trumpet has three piston valves, each increasing the length of tubing to lower the pitch. The first valve lowers the instrument's pitch by a major second, the second valve by a minor second, and the third valve by one and a half steps which is a minor third. Using solely or in combination, these valves can make the trumpet fully chromatic. Dr Colin Bloch, an Architect in Bristol, UK, states in his article "The Bell-Tuned Trumpet" that the trumpet's pitch is influenced by the usage of the tuning slide, which pulls the slide-out lower while pushing the slide in, raising the pitch. In addition, the trumpet becomes a closed tube when the players press it into the lips.

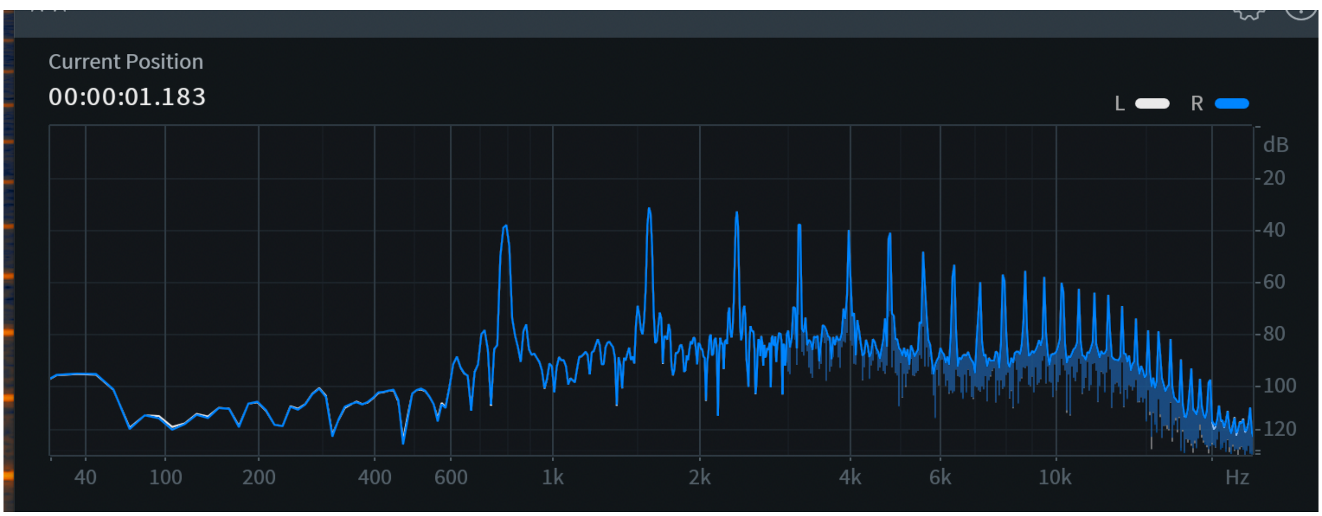
Musicians can use various techniques in trumpet performance. Multiple mutes are used in different music genres, particularly in the jazz ensemble. The common types of mutes are straight mute, cup mute, Harmon mute. Mutes are always made of fiberglass, plastic, cardboard, metal. Besides, many extended techniques are used in modern trumpet performance, such as glissando, vibrato, pedal tones.

## Timbral Analysis

The timbre of the trumpet sound constantly changes in pitch and the volume of the sound that is produced. So, I obtained trumpet samples from my friend, a trumpet player, including one note in the high register and one in the low register. From each note, I also asked my friend to record the sound in two different volumes–one hard and one soft. I used the iZotope RX8 audio editor to see each sample's frequency domain and time domain in waveform opacity mode using a spectrum analyzer.

## 1. Trumpet in high note with greater volume



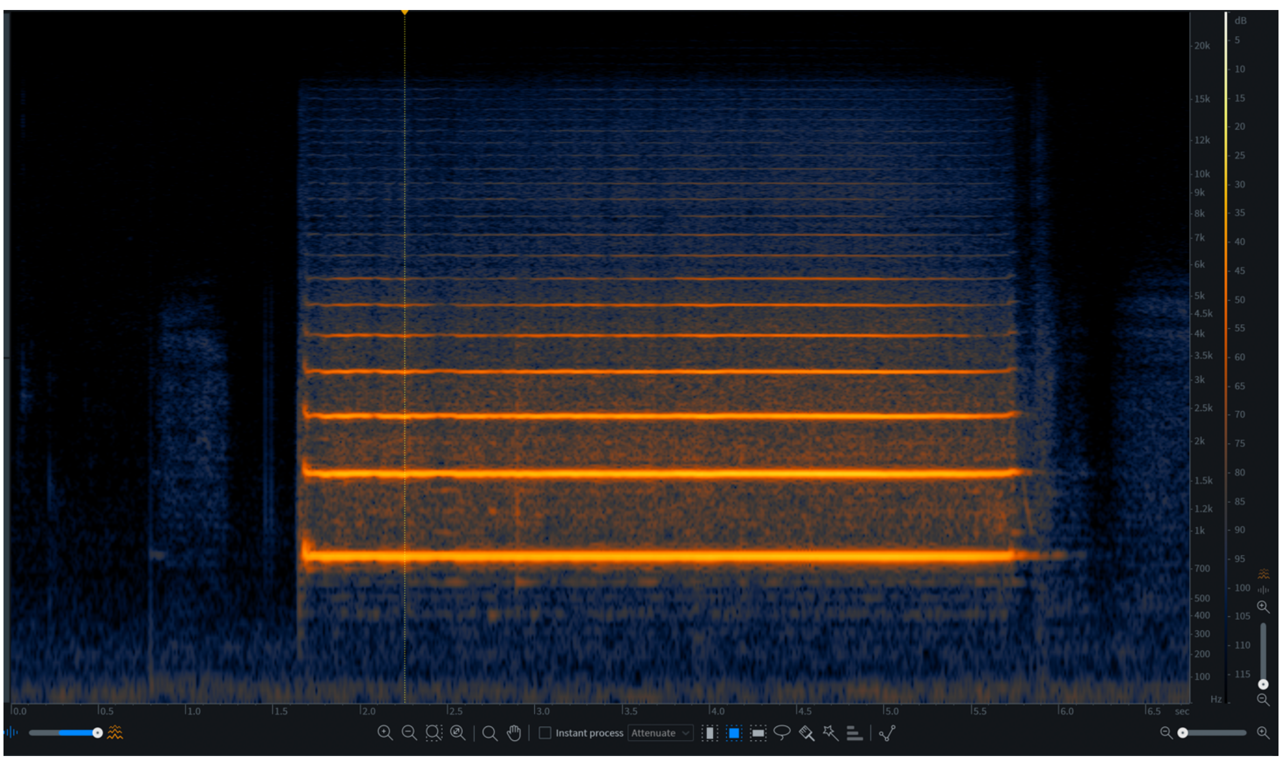


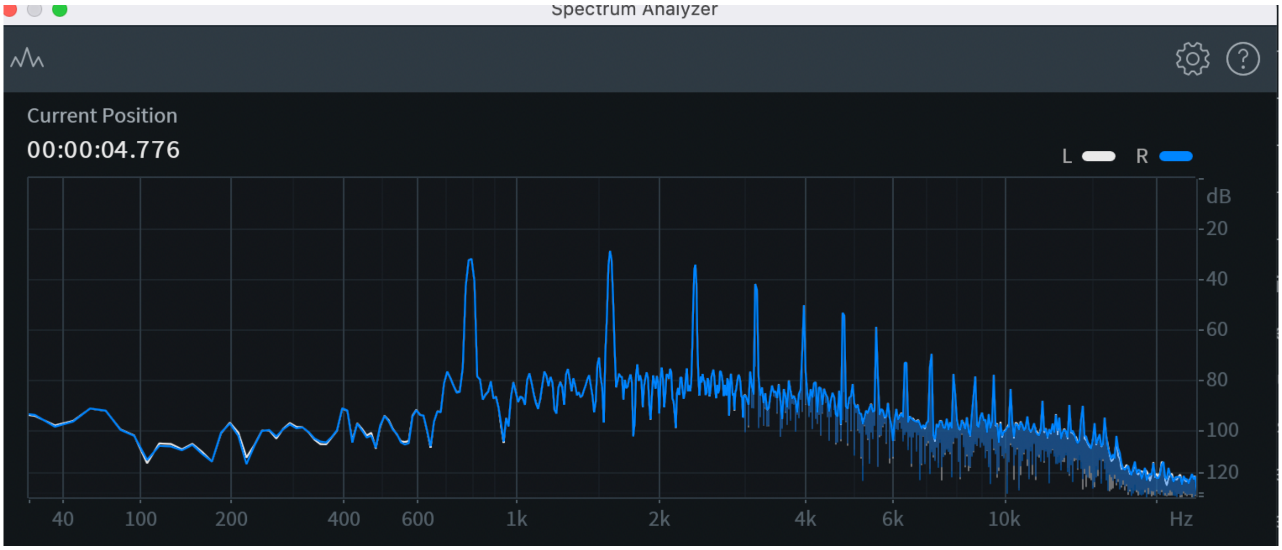
Analysis of Trumpet High Hard

| | Freq(hz) | dB | Normalized(dB) | Lin Amp | Amp(%) |
|---|---|---|---|---|---|
| **1.000** | 792.2 | -27.3 | -5.5 | 0.531 | 53.1 |
| **1.999** | 1584 | -21.8 | 0 | 1 | 100 |
| **2.999** | 2376 | -24.1 | -2.3 | 0.767 | 76.7 |
| **3.998** | 3167 | -28.4 | -6.6 | 0.468 | 46.8 |
| **4.999** | 3960 | -32.4 | -10.6 | 0.295 | 29.5 |
| **5.998** | 4752 | -33.4 | -11.6 | 0.263 | 26.3 |
| **6.997** | 5543 | -39 | -17.2 | 0.138 | 13.8 |
| **7.999** | 6337 | -47.6 | -25.8 | 0.051 | 5.1 |

*Chart of spectral character in spreadsheet*

## 2. Trumpet in high note with less volume



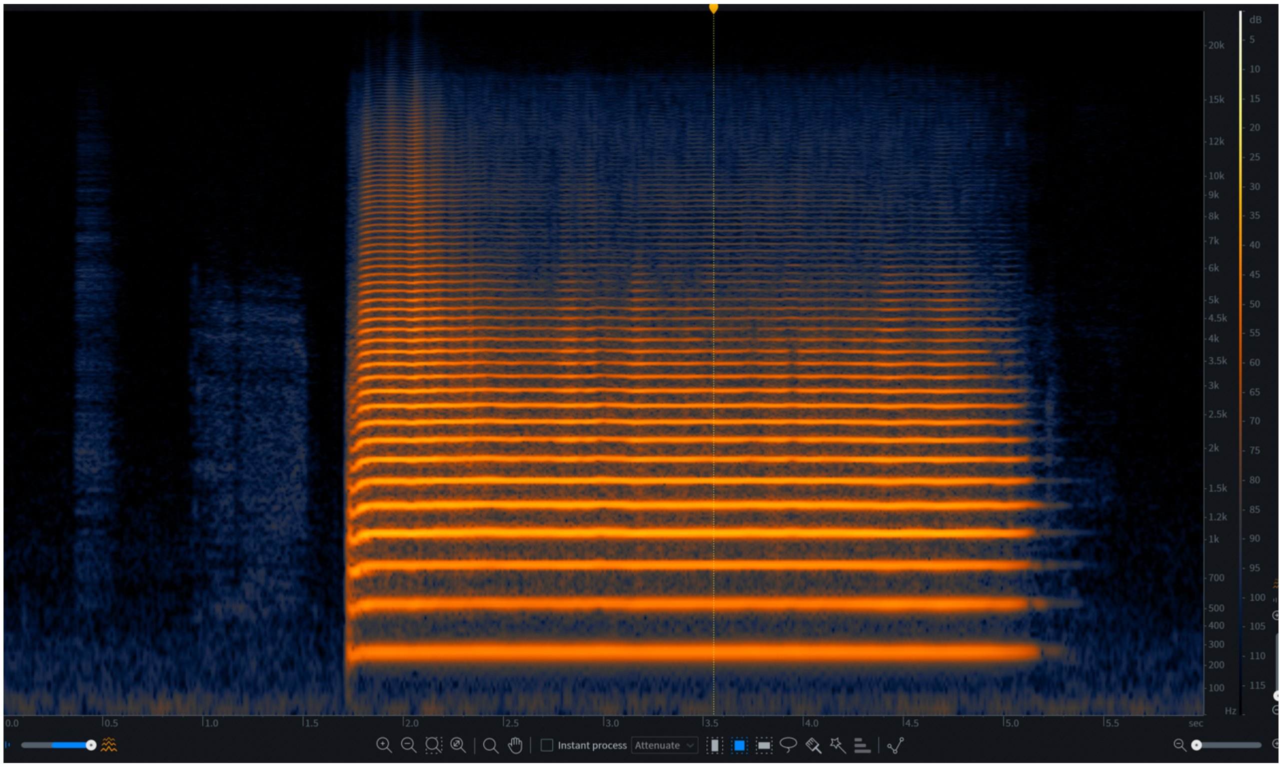


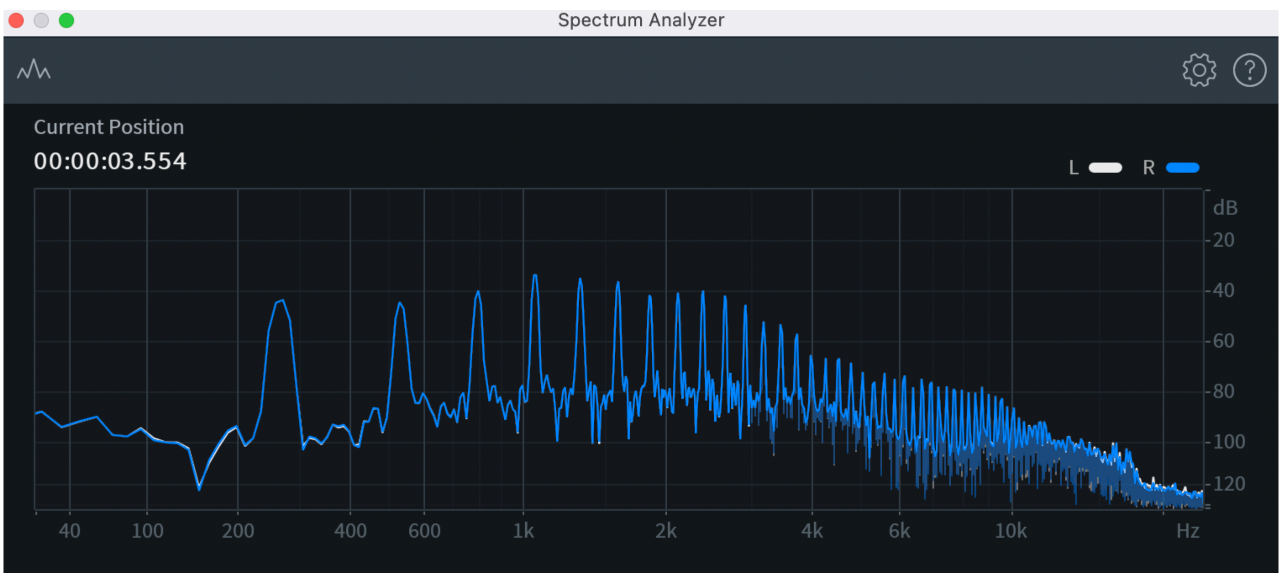

Analysis of Trumpet high soft

| | Freq(hz) | dB | Normalized(dB) | Lin Amp | Amp(%) |
|---|---|---|---|---|---|
| **1.000** | 792.5 | -31.7 | 0 | 1 | 100 |
| **2.000** | 1585 | -32.1 | -0.4 | 0.955 | 95.5 |
| **2.999** | 2377 | -39.4 | -7.7 | 0.412 | 41.2 |
| **4.000** | 3170 | -51.4 | -19.7 | 0.104 | 10.4 |
| **5.003** | 3965 | -64.7 | -33 | 0.022 | 2.2 |
| **6.001** | 4756 | -65.3 | -33.6 | 0.021 | 2.1 |
| **7.003** | 5550 | -76.3 | -44.6 | 0.006 | 0.6 |
| **8.000** | 6340 | -75.3 | -43.6 | 0.007 | 0.7 |

*Chart of spectral character in spreadsheet*

### 3. Trumpet in low note with greater volume





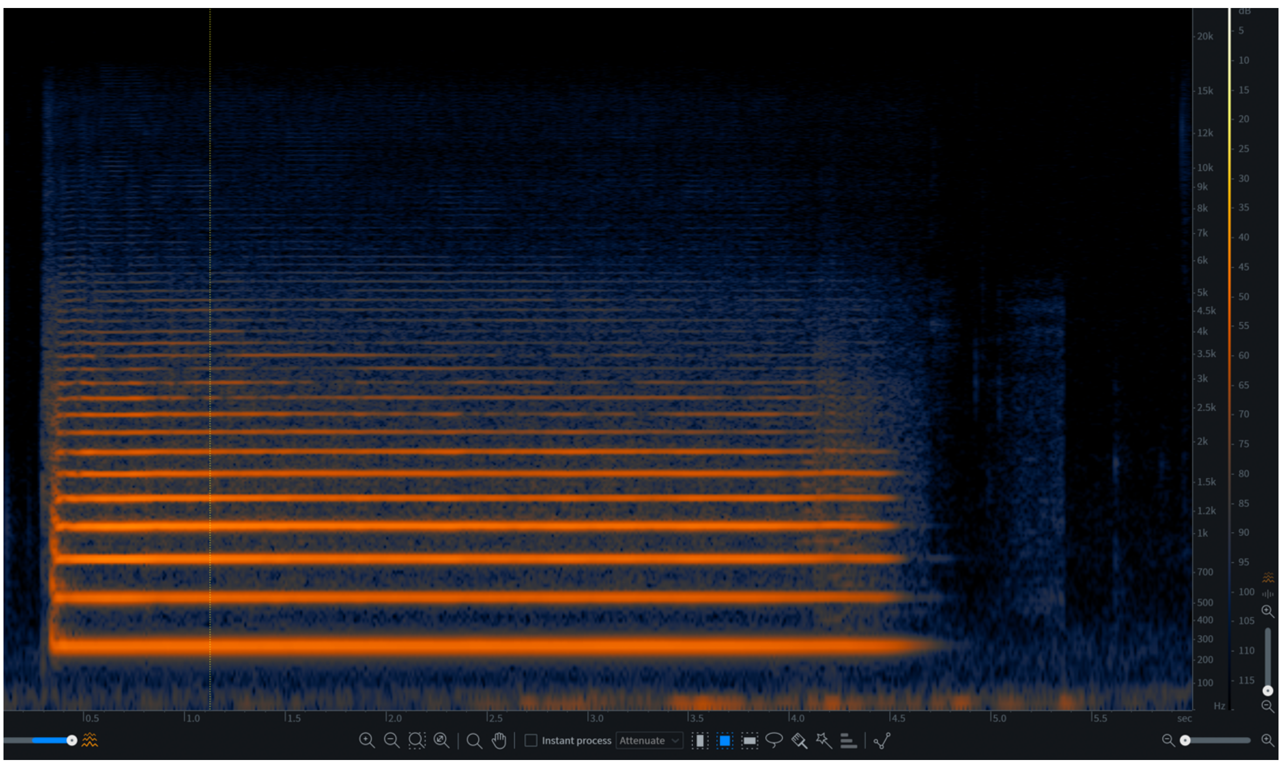
Spectrum Analyzer
Current Position
00:00:03.554
L
R
dB
-20
-40
-60
-80
-100
-120
40
100
200
400
600
1k
2k
4k
6k
10k
Hz

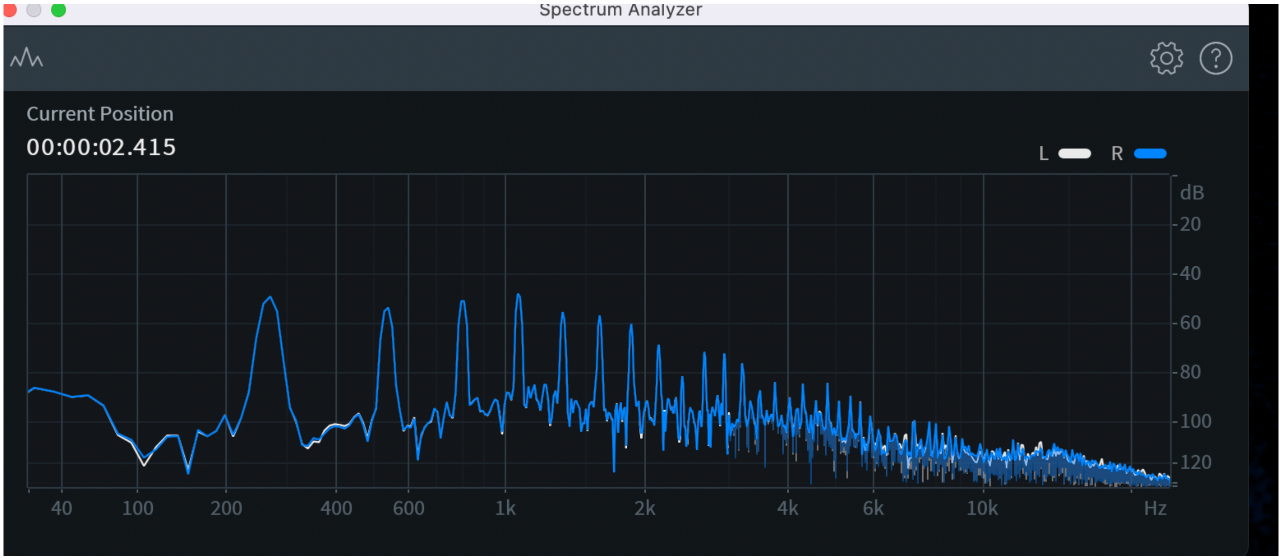
Analysis of Trumpet Low Hard

| | Freq(hz) | dB | Normalized(dB) | Lin Amp | Amp(%) |
|---|---|---|---|---|---|
| 1.000 | 265.2 | -40.7 | -10.5 | 0.299 | 29.9 |
| 2.000 | 530.6 | -40.9 | -10.7 | 0.292 | 29.2 |
| 3.000 | 795.6 | -37.5 | -7.3 | 0.432 | 43.6 |
| 4.000 | 1061 | -30.2 | 0 | 1 | 100 |
| 5.000 | 1326 | -33.3 | -3.1 | 0.700 | 70 |
| 5.999 | 1591 | -33.7 | -3.5 | 0.668 | 66.8 |
| 6.998 | 1856 | -36.2 | -6 | 0.501 | 50.1 |
| 7.998 | 2121 | -37.6 | -7.4 | 0.427 | 42.7 |

*Chart of spectral character in spreadsheet*

## 4. Trumpet in low note with less volume






Analysis of Trumpet Low Soft

| | Freq(hz) | dB | Normalized(dB) | Lin Amp | Amp(%) |
|---|---|---|---|---|---|
| **1.000** | 267.6 | -46 | -2.6 | 0.741 | 74.1 |
| **2.000** | 535.2 | -49.4 | -6 | 0.501 | 50.1 |
| **3.000** | 802.8 | -46.2 | -2.8 | 0.724 | 72.4 |
| **3.999** | 1070 | -43.4 | 0 | 1 | 100 |
| **5.000** | 1338 | -50.2 | -6.8 | 0.457 | 45.7 |
| **6.001** | 1606 | -52.7 | -9.3 | 0.343 | 34.3 |
| **7.003** | 1874 | -58.5 | -15.1 | 0.176 | 17.6 |
| **8.004** | 2142 | -59.1 | -15.7 | 0.164 | 16.4 |

*Chart of spectral character in spreadsheet*

As the timbral analysis of trumpet in the pictures that are shown above, the ADSR amplitude archetype parameters can be described. A short delay will occur before the attack happens because the wave of air that the trumpet blows need to travel the full length of the tubing to be reflected by the bell. The attack level is less than the instant (about 12 million seconds), but the decay level should be longer, and the sustain level should be medium. The release time is relatively fast (about 15 million seconds).

## Pitch Analysis

As the pictures shown above, we can know that when a player plays very quietly, the fundamental harmonic will play louder than the second harmonic. When the player plays louder, the overtones of the second harmonic will begin to dominate. There are also more frequencies in the frequency domain when the trumpet plays harder than when it plays softer. In the first few milliseconds of the sample, no standing wave exists. Instead, the vibrating air will cause some inharmonic overtones when trumpet plays low note with greater volume, the dB is increases as the frequency increases. However, in other scenarios, the dB decreases as the frequency increases.

## Implementations

Now, we can have a vision of the implementations in subtractive synth, which is Massive and addictive synth which are Max Beap and modular, as well as the FM 8 by using frequency modulation technique.

The trumpet produces very bright and brassy sounds for subtractive synth, so I will start with sawtooth wave, since it has the richest harmonic content. In Massive, I set the two oscillators to a sawtooth wave and tune them in unison. I also use cross-modulation to induce a slight inharmonic in the sound. Low-pass filter will also be needed, and the cut-off should be set less than half. Meanwhile, I use another band-pass filter to cut the unwanted frequencies. At the same time, adding some resonance. The parameters of the envelope generator will be set as same as the previous ADSR analysis, which are short attack, long decay, medium sustain, and short release. Noise should be also added as well. For my Massive patch, I think the LFO is optional for the vibrato effects because I compare two patches and find the one without LFO sounds better. I use same concept in the modular implementation.

In Max Beap, which is used as an addictive synth, I use eight oscillators which adding the sine waves together with attenuators. I set the number of the parameters in oscillators and attenuators by referencing the frequency and linear amplitude from the spreadsheets. I also tune it with keyboard by divided the frequency of the C4. I put a LFO with sine wave around 5Hz with small amount of an attenuator into the CV2 of each oscillator. I use a high-pass filter since the trumpet produces bright sound. White noise device also be introduced to the patch. I use two ADSRs which triggered by the gate of the keyboard, one is for the VCA, one is for the noise source. oscillators in the modular, so I pick three significant frequencies in order to implement the trumpet sound. For the FM 8, the concept is basically same except it’s using the frequency modulation.

## Reference:

Pease, Ted, et al. *Modern Jazz Voicings: Arranging for Small and Medium Ensembles*. Berklee, 2001.

Massey, Howard, et al. *A Synthesist's Guide to Acoustic Instruments*. Amsco, 1987.

Synthesizing brass instruments. (n.d.). Sound on Sound. https://www.soundonsound.com/techniques/synthesizing-brass-instruments