Some Questions and Answers on the Standard Volume Indicator (“vu meter”)[1]

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Program levels in the USA are usually read with a “Standard Volume Indicator” (SVI)[1], popularly called a “vu meter”. Development of the SVI began in 1938 January, and the final report on the background and development of the SVI, and a summary of the original Bell System specification for its characteristics, is given in a 1940 paper by Chinn, Gannett, and Morris [1]. Chinn [2] also gives a discussion of the problems involved in understanding and using the SVI. The Standard Volume Indicator was soon standardized in an American Standard originally published in 1942 [3], revised in 1952 [4], rewritten as an IEEE/ANSI standard in 1991 [5], and withdrawn in 1999. But the Standard Volume Indicator to is continued to the present day in the 1990 IEC Standard 268-17 [6] .

A number of questions of interpretation that often arise are worth some discussion. Many of the problems come from changes in audio operating practices, such that matters that were originally clear are now ambiguous. Here are some common questions and their answers.

1 *Question*: What does “vu” signify? How does it differ from “dB” and “dBm”?

Answer: The decibel [dB] is a unit of level [7], [8]; it may be used for any kind of level (power level, voltage level, sound pressure level, etc.). The “m”of the “dBm” is a decibel appendage [9], originally intended to designate a power level referred to a power of one milliwatt.[2] The vu[3] is another hybrid “unit” intended to designate “volume”, which is a particular kind of average power level of electrical program signals (that is, complex waves) as measured with a Standard Volume Indicator (Sec. 3.1 of [3], Sec 2.1 of [4], and Sec. 2.2, “volume”, of [5]) with a sine-wave calibration referred to a power of 1 mW (Sec. 4.8 of [3], Sec. 3.8 of [4], and Sec. 2.3.2 of [5]). The vu is thus similar to a “decibel appendage” [9] in that it is a “unit symbol” which is being forced to serve not only as a unit of level, but also as a qualifier for both the quantity itself (electrical power volume) and for the characteristics of the measuring instrument and the measuring technique.

2 *Question*: Does a “volume” measurement with a Standard Volume Indicator relate to system overload prevention, loudness measurement, or balance between different kinds of programs?

Answer: None of these! Overload prevention in a system with restricted overload margin requires a “peak program meter” (Sec. 1 of [5]; [10]). Loudness may be approximated according to a standardized procedure [11], [12] using a “loudness analyzer” [13]. The balance between different kinds of programs — speech, music, etc. — is determined by not only the loudness, but also by the preferences of the listener [14]. (These references are now many years old – there may be newer papers on this subject.) The Standard Volume Indicator is simply an instrument with a *standardized* dynamic response and calibration such that all Standard Volume Indicators give the *same* readings when measuring the same dynamically changing audio program [1].

3 *Question*: Is the Standard Volume Indicator a voltmeter or power meter?

Answer: The Standard Volume Indicator is a voltmeter which the *user* is instructed to calibrate so that it can be used to indicate power level. Thus the user must know and take into account the impedance of the circuit across which the volume indicator is bridged. In the standard, its use is defined in terms of *power only*: its readings are specifically referenced to an electrical power of 1 milliwatt in *any* impedance. Thus, the electrical volume in a circuit is independent of the circuit

[1] This paper was first prepared by the author in 1971, when he was with Ampex Corp; it has been revised many times, most recently in 2006.

[2] Some engineers unacquainted with the original definition of the “dBm” have unwittingly redefined it [8], calling it a voltage level referred to 0.775 volts. Sometimes this voltage level re 0.775 V is also called a “dBV” or a “dBu”. On the other hand, “dBV” is also taken to mean a voltage level re 1 V. Moral: do not add letters to the dB (“decibel appendages”) to qualify the kind of quantity (voltage level, power level, etc.) or the reference quantity (1 V, 1 mW, etc.). Just name the kind of level and the reference quantity that you mean, as for instance in “all levels are voltage levels re 1 V, in decibels”, then you can just say “level = +4 dB”, and the meaning will be clear.

[3] The standard (Sec. 3.1 of [3], Sec. 1 of [4], and Sec. 2.1 of [5]) calls “vu” a “term”, not a unit, a unit symbol, nor an abbreviation. Many have assumed that it stands for “volume unit”, but neither [1], [3], [4], [5], nor [6] uses the expression “volume unit”. Chinn, in personal correspondence, says “...there is no such thing as a‘unit‘ of volume and hence the term ‘volume unit‘ is a complete misnomer and will not be found in any knowledgeable discussion of the standard volume indicator.”

Despite this, the term “volume unit” is defined in the following standards: ANSI C42.100/IEEE Std 100 (1977), “IEEE Standard Dictionary of Electrical and Electronics Terms” [and earlier IEEE Std 151 (1965) “Definitions of Terms for Audio and Electroacoustics”, and AIEE/ASA C42.65 (1957) “Definitions of Electrical Terms, Group 65, Communications”]; and finally ANSI S1.1 (1960, Reaffirmed 1976) “American Standard Acoustical Terminology”.

impedance (Sec. 4.8 of [3], Sec. 3.8 of [4], Sec, 2.3.2 of [5]). The original 1942 Standard also referenced power only, although the Bell System [1] and the IEC Standard, Sec 4.2 of [6] specified a 1.228 V reference voltage. Some voltages representing a 1 mW power dissipation in the load of an equal-impedance system are as follows: If the resistance R = 1000 Ω, the voltage U = 1 volt; if R = 600 Ω, U = 0.775 V; if R = 150 Ω, U = 0.387 V; if R = 15 Ω, U = 0.123 V, etc.

4 *Question*: What circuit impedance is the Standard Volume Indicator to be used with?

Answer: The Standard Volume Indicator may be used with *any* circuit impedance (Sec. 3.1 of [4], and Sec. 2.2 of [5]). Preferred circuit impedances are 600 Ω and 150 Ω, and it is good practice to make the input impedance of the Standard Volume Indicator not less than 12.5 times the circuit impedance (Sec. 5.1 of [3], Sec. 4.1 of [4]). This was made a requirement in Sec. 2.3.6 of [5]. Many audio engineers erroneously believe that the "dBm", "vu", and Standard Volume Indicator are all restricted to 600 ohm circuits only. The original 1942 Standard [3] *recommended* a source impedance of 300 Ω (that is, a circuit impedance of 600 Ω terminated by a load of 600 Ω), and the Bell System specification [1] called for a meter system input impedance of 7500 Ω, made up of a 3900 ohm instrument, a 3900 ohm attenuator (if used), and a 3600 ohm series resistor. Commercially-made volume indicators usually have this 7500 ohm input impedance, but the "dBm", "vu" and Standard Volume Indicator are not now (and never were) restricted to 600 ohm circuits by ANSI or IEEE (formerly ASA and IRE, respectively).

5 *Question*: What are the impedance and maximum sensitivity of a Standard Volume Indicator itself?

Answer: No values are given in the original or the present standard (Secs.3.1 and 3.8 of [4]). The 1942 Standard [3] recommended an input impedance of 7500 Ω. The original Bell System specification summarized in [1] specified a sensitivity such that 1.228 V applied to the 7500 ohm system would cause "reference deflection" (deflection to the point marked 0 vu, 100 %, or both). The IEC Standard [6] has returned to these values in [1], and has added a tolerance (Sec 12) to the SVI input resistance: 7500 Ω ± 3 %. These are typical values used in commercial meters to this day. This means that a typical basic system (without an additional meter transformer or amplifier) reads reference deflection (0 vu on the meter face) for a voltage of 1.228 V. In a terminated 600 ohm system, this voltage corresponds to a power of 2.5 mW, and a power level re 1 mW of +4 dB (called "+4 dBm"). In a terminated 150 ohm system, this voltage corresponds to a power of 10 mW, and a power level re 1 mW of +10 dB (called "+10 dBm").

The original paper [1], in Fig. 18 and the section "Description of Circuits", provided for both the "high impedance arrangement" described above, and a "low impedance arrangement". In the low-impedance arrangement, a 600 Ω-to-3900 Ω transformer would increase the sensitivity by 10 dB, at the expense of decreasing the input impedance to 600 Ω. To the best of my knowledge, the "low-impedance arrangement" was never commonly used.

6 *Question*: Suppose the Standard Volume Indicator reads "0 vu" on the meter face; what is the volume level — isn't it "0 vu"?

Answer: Probably not. The Standards provide that the Standard Volume Indicator shall consist of a meter and an associated attenuator (adjustable loss) or pad (fixed loss), (Sec. 4.1 of [3], Sec. 2.2 of [4], Sec. 2.2 Fig 7 of [5], and Sec. 2.2 of [6]). The method that is given in the standards for reading the volume indicator is to *adjust the attenuator* until the program peaks cause the pointer to deflect just to the "reference deflection" (the point marked 0 vu, 100 %, or both). Then the volume is read *from the attenuator* (Sec. 4.9 of [3], Sec. 3.9 of [4], Sec. 2.4 of [5], and Sec. 2.2 of [6]). Unfortunately no provision is made in the older standards for *displaying* to the user the reference volume when a fixed pad is used instead of an adjustable attenuator. Thus, if one has a mixing console or tape recorder with a Standard Volume Indicator that has an internal pad of value unknown to the operator, he cannot tell without further information what the volume is! A good operating practice which should be added to the standard is a requirement for the manufacturer to affix a label near the vu meter stating the reference; for instance, "Reference deflection corresponds to +4 vu". Better yet would be a statement like "Reference deflection corresponds to an output voltage of 1.23 V". This requirement has been added to [6]: Sec. 20, "Characteristics to be specified", "Data which shall be given by the manufacturer, for complete meter/attenuator units: The reference voltage shall always be marked by the manufacturer on the rating plate".

Chinn comments, "There should be no confusion because the instrument deflects to a scale marking of 0 vu when a level of +4 vu is applied to it." [1], [2]. I believe most users of volume indicators would argue this point: unless the reference kind and quantity (i.e., power level re 2.5 mW) are clearly displayed, there *will* be confusion.

The Standards state (Sec. 5. of [1], Sec. 4.8 of [3], Sec. 3.8 of [4], and Sec. 2.3.2 of [5]) that "A correctly calibrated volume indicator with its attenuator set at 0 vu will give reference deflection when connected to a source of sinusoidal voltage adjusted to develop 1 mW...". This is a correct statement of principle, but must not be interpreted as implying that a Standard Volume Indicator has a sensitivity of 0 vu. In fact, on most commercially made instruments that have an adjustable attenuator, there is *no* "0 vu" step on the attenuator! (This has been deleted from the IEC Standard [6], since it specifies a voltage sensitivity.)

7 *Question*: How does one specify "volumes" in magnetic tape recording, or in disc recording?

Answer: There is no provision in the Standards for use in measuring the fluxivity recorded on a magnetic tape, or recorded velocity in a mechanical disc recording: all of the standards are for volume in *electrical circuits* only . Thus, any specification of level on a tape record in "vu" is completely undefined in the present standard. Electrical input and output signals to and from disc or magnetic recorders may of course be measured by a Standard Volume Indicator.

8 *Question*: How does present-day usage of a volume indicator differ from that assumed in the standard?

Answer: The usage envisioned in the standard was for checking levels in a "long lines" telephone system, where transmitted levels were not always the same — that is, for example, the transmitted level might be +8 vu, or +10 vu, or +16 vu; and the received levels were expected to be different from those transmitted because of transmission-line losses. The engineer wanted to measure what power volume level was transmitted and what was received by a circuit *while it was transmitting a program*. The engineer at the transmitting end would talk to the receiving engineer on a voice line. He would "call the peaks" as the program would run — "plus one, zero, minus three, plus one,..." . Then the standard procedure was perfectly appropriate to this operation — the receiving engineer would adjust the vu meter's attenuator so his meter would match the "called peaks", and read the level from the attenuator.

In most present-day applications (e.g., mixing consoles and tape recorders in sound recording studios), the transmitted level is constant throughout the studio (once it leaves the mixer) and the received level always equals the transmitted level. Neither the operating personnel running programs, nor the maintenance personnel running test tones usually want to know the actual power level relative to 1 milliwatt being transmitted (or received); rather, they want to know the level relative to *whatever* the reference quantity may be. Thus, suppose that a recording system is set up so that the reference deflection (0 dB) the volume indicator corresponds to the reference voltage of 1.23 V in the electrical system, which in turn corresponds to 250 nWb/m in the tape recorder; the operator will want to know what the level is relative to these reference quantities.

Thus, the original usage envisioned measuring the absolute power volume level re 1 mW, while the present usage often requires measuring the relative volume level of various kinds relative to whatever may be the reference quantities.

9 *Question*: How could the Standard Volume Indicator terminology be changed to provide for the present-day usages?

Answer: By using the principles of [7], [8], and [9]: Separate the designations for the measured quantity, the reference quantity, and the unit; the culprit — the "vu" — could then be completely eliminated. For example, designate a level by writing "the power volume level (re 1 mW) is +4 dB". "Volume level" tells us that the measurement is made with a Standard Volume Indicator; "power" tells us the kind of volume level — it could alternately be voltage, flux, etc.; "(re 1 mW)" tells us the reference quantity — it could have been 2.5 mW, or for a voltage level, 1 V or 1.23 V; for a tape flux level, 250 nWb/m; or some other appropriate quantity. The example given — "the power volume level (re 1 mW) is +4 dB" — could also be expressed more simply and more clearly as "the power volume level (re 2.5 mW) is 0 dB", since a power level 4 dB above 1 mW corresponds to a power of 2.5 mW.

If this suggestion were followed, the scale of the Standard Volume Indicator would *not* be marked in "vu", but rather in "dB"; the meter face could, in general, be labeled "volume level". If the instrument were to measure absolute level, a designation on the adjacent attenuator would read "power volume level (re 1 mW)", and be marked +4 dB, +6 dB, +8 dB, etc. If the instrument were to measure level relative to a fixed reference quantity (say of 2.5 mW), the meter face could be printed "power volume level (re 2.5 mW)".This example corresponds to the awkward old designation which has a double reference quantity, such as writing, for instance, "the level [re a level(re 1 mW) of +4 dB] is X dB".

10 *Question*: Present dynamic specifications are for a rise to 99 % of final deflection in 300 ms ±10 %, with 1.0 to 1.5 % overshoot (Sec. 4.2 of [3], Sec. 3.2 of [4], Sec. 2.3.4 of [5], and Secs. 8.1, 9, and 10 of [6]). Direct measurement implies using a high-speed motion picture camera to photograph the needle position as a function of time. This isn't common "electronic test equipment". Is there a specification and a measurement method which uses equipment available in an electronics lab?

Answer: Yes. The original Standard Volume Indicator was a rectifier and a galvanometer. The galvanometer is a mechanical 2-pole low-pass filter. Its dynamics may be alternately specified as follows: The resonance frequency of the meter movement shall be 2.1 Hz ±10 %, and the overshoot shall be 1.0 to 1.5 %. The measurement of the resonance frequency requires only an oscillator which covers this frequency range, a small dc power supply (to provide current to turn on the rectifiers, and give an upscale reading of the meter), an oscilloscope with equal phase-shift on both X and Y axes down to about 2 Hz, and two resistors. A Lissajous voltage figure is made from the voltage across the meter and the oscillator voltage, which is in phase with the current through the meter. The oscillator frequency is adjusted until the voltage and current are in phase — that is, the Lissajous figure closes from a circle to a straight line. This frequency is the desired resonance frequency. The overshoot of the meter system (that is, the galvonometer when driven from a 3900 Ω source resistance) can be measured visually. This technique is described in more detail in [15].

The IEC Standard [6], in Sec. 8.2 and Fig. 2, gives a method using a tone burst generator, a start pulse generator, a stop pulse generator, a light source and reflected light detector, a clock pulse generator, and a counter. This would seem to be a much more complicated method than that suggested in [15].

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