VOLTAGE TRANSMISSION FOR AUDIO SYSTEMS

Back to Broadcasting Home Page

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Minor 1999 revisions are [in brackets]

Abstract

The benefits of using a voltage audio transmission system in broadcast facilities is investigated. State of the art microphone preamplifier requirements and an ideal voltage system distribution amplifier are outlined. The application of the Peak Program Meter to the new systems and the modified installation at WABC-TV are covered.

Introduction

Over the years, many audio practices have been followed without anyone asking WHY? or IS THERE A BETTER WAY?

The [then (i.e. 1980)] present [but now deprecated] standard for Broadcast Audio Systems is EIA Standard RS 219 [1]. In light of the fact that the [then] current standard was published in 1959 (and this was merely a reaffirmation of an earlier standard), one might imagine that in relation to today's common audio practices, it is somewhat archaic.

There are several areas to be covered in reviewing this standard and related practices:

1. Microphone inputs - impedance and level.

2. Line input and output impedance.

3. Audio line levels and metering.

4. Multiple load isolation and system reliability.

[The late] Hans Schmid [2] [3], has gone to great lengths to explain levels and metering. His papers serve as an excellent background and point of departure for this paper.

Definitions

dBu - *0dBu is equal to 0.775 Volts rms. This conveniently happens to equal l mW into 600 ohms. dBu is the quantity in which most laboratory instruments are calibrated, despite what they say. (These instruments usually say dBm, but somewhere the manufacturer makes a note that it is referenced to 600 ohms.) dBV is an incorrect usage when applied to audio. 0dBV is defined as one-volt peak to peak, and is used to measure non-sinusoidal and non symmetric signals. [4]*

REFERENCE LEVEL - *This is the steady state line up level of the system. In systems utilizing VU meters, this signal reads 0 or 100%. In systems utilizing Peak Program Meters, this signal reads "straight up" in other words, 4 on the BBC scale, +8 on the CBC scale and -8 on both the European A Scale and the ABC scale.*

STANDARD OUTPUT LEVEL - *This is the level at which distortion is specified, and is the level at which audio peaks are transmitted. Traditionally it is 10dB above Reference Level, however, with the introduction of the PPM, this has been reduced to 8dB. The reason for this is explained later.*

CLIP LEVEL - *This is the minimum level at which severe (greater than 1%) distortion may occur [5]. Typically, it is 6dB above Standard Output Level.*

Microphone Input - Impedance and Level

In the early days ,days, a microphone's frequency-amplitude response was calibrated into a specified load. Since many microphones exhibit a rising low-frequency impedance, connection to a higher than rated load impedance would result in excessive low end.

Most microphones being manufactured today are specified as 150 or 200 ohm devices, but many (especially condenser microphones) are rated to work into a load of no less than about 500 ohms.

The present rule of thumb is to have a microphone preamplifier input impedance of ten times the microphone source impedance. This presents four advantages:

1. Optimal signal to noise ratio, as the preamplifier sees the highest voltage possible. (The voltage drops only 0.8dB from its open circuit value.)

2. Highest headroom in a condenser microphone due to the reduced loading on the microphone's preamplifier.

3. Minimal cable resistive loss.

4. Frequency-amplitude response independent of minor microphone preamplifier input impedance variations.

This is the most widespread use of voltage transmission today, although it is usually not referred to as such. The microphone acts as a voltage source as it is working practically unloaded.

Microphone preamplifier input level sensitivities present a wholly different problem. Typical microphone sensitivities range from -60dBu to -22dBu referenced to 10 dynes/cm2 (94dB SPL). In music recording, 125-130dB SPL is not entirely uncommon and, in broadcasting, 65dB SPL is, unfortunately, not uncommon in talk shows. This gives us a range of about -87dBu to +14dBu, which must be accommodated by the input of the microphone preamplifier. If we use the "in hand" settings of the faders in the console to reach the bottom 17dB (modern broadcast consoles have 30 to 36dB in hand, total, on channel, submaster and master), then the microphone preamplifier need have input Reference Level settings of approximately -70dBu to -20dBu. The overall gain of the preamplifier should be such as to allow for 40dB of overload protection from Reference Level to Clip Level.

In this writer's experience, it is imperative to maintain this amount of overload protection on the microphone preamplifier in a large television production console. (The summing amplifiers need a similar amount of overload protection.) This is due to the sometimes unpredictable nature of the sound sources, limited rehearsal times and the large number of operators (with varying degrees of experience and expertise) who must operate this equipment.

This headroom requirement dictates a -10dBu Reference Level at the channel insert points. Experience, however, has shown that this is not a major problem. (We color code jackfields do that all -10 signals are the same color, provide amplifiers to boost the -10 signals to +8, and select and or adjust processing equipment to operate at -10dBu.) [With the advent of digital consoles and signal paths, the trend is towards reducing the headroom to optimize the noise performance. Mix levels are increasing.]

Line Input and Output Impedance

Microphones and their preamplifiers have become a voltage transmission system quite silently, without any fanfare. There is a trend in this direction in line level inputs and outputs. The [then] new NAB Cartridge Tape Standard [now obsolete] calls for input impedances which are 8 times the rated source impedance to which they will be connected, and output impedances which are 0.125 times the rated load to which they will be connected. [5] This is a good start, but it introduces confusion. In voltage transmission systems the source impedances need bear no relationship to "rated" impedances of 150 to 600 ohms. The electric company does not tell you the source impedance of the Hoover Dam, but rather they tell you that you are being supplied with 117 volts.

Audio transmission lines are not transmission lines in the strict sense of the word. The actual cable used is undefined as to characteristic impedance. All discussion in this paper is based on Belden 8451 cable which is a single twisted pair of 22 gage stranded wire, with foil shield, drain wire and an overall jacket of 3.43mm (0.135 inch). A rough calculation of the pair's characteristic impedance based on wire size, dielectric constant, and insulation thickness (pair spacing) without regard to the shield shows it in the neighborhood of 175 ohms. Clearly, this is lower than the common 600-ohm transmission impedance. We must also consider that a quarter wavelength on this cable is approximately 2500 meters (8250 feet) at 20kHz. Most audio circuits in studios never approach the need to be or even if they try, they never become true transmission lines.

Of course, there is no denegration intended of matched transmission lines for long runs. Generally, any run over 500 meters should be treated as a transmission line and normally a 150-ohm +8dBm circuit is acceptable. Equalization of the receive amplifier for both high frequence roll off and group delay should be considered. It is, however, beyond the scope of this paper.

The following table shows the losses to be expected from various means of transmission:

EFFECT OF 300 METERS OF 8451 CABLE ON FREQUENCY-AMPLITUDE RESPONSE
(decibels referenced to unloaded generator output)

Source Impedance	2	40	60	150	600	150	600 ohms
Load Impedance	200K	200K	200K	200K	200K	150	600 ohms
20Hz	0	0	0	0	0	-0.8	-0.3

200HZ	0	0	0	0	0	-0.8	-0.2
2kHz	0	0	0	0	-0.4	-0.8	-0.4
20kHz	+0.4	+0.2	0	-1.2	-8.5	-1.1	-4.2
45kHz (approx. peak)	+2.0	+1.1					

The reduction of the load impedance to 10K ohms did not noticeably effect these results.

In researching this paper, it was discovered that 60 ohms source impedance is the most desirable for several reasons.

1. High frequency resonances are adequately damped.

2. Frequency-amplitude response is flat and relatively independent of cable length, up to 450 meters, as shown in the following table:

EFFECT OF CABLE LENGTH ON FREQUENCY-AMPLITUDE RESPONSE
Source Impedance: 60 ohms
Load Impedance: 200K ohms

Length (meters)	20kHz response	High frequency Roll Off
150	0	-1dB @ 100kHz
300	0	-3dB @ 110kHz
450	-0.1dB	-3dB @ 70kHz
600	-0.4dB	-3dB @ 60kHz

3. This source impedance is as high as practical for maintaining good amplitude stability independent of load.

EFFECT OF VARYING LOAD ON A 60 OHM SOURCE IMPEDANCE CIRCUIT

Load	**Level drop**
20k ohm	-0.03dB
5k ohm	-0.1dB
600 ohm	-0.8dB

The last case, of course, is not a normal operating condition but is a very probable error during the initial introduction of this type of a system.

This impedance provides good output isolation between separate outputs of the same amplifier, to protect from the danger of crosstalk which occurs when on output is connected to a signal source. There is no reason why the split node output impedance can not be 0.1 ohm or less, and the 60 ohm line driving impedance can be supplied by resistive splits (or build outs) (see figure 1B).

In this case, a similar 60 ohm signal from another source would be attenuated 61dB at the split node.

To sum up this section, for many reasons, a 60 ohm source impedance and a 20K ohm or greater input impedance is an ideal combination for audio transmission and distribution. This is a true voltage system in the sense that the load does not match the source nor terminate the line in its characteristic impedance. Modern circuit designs, with their inherently lower output impedance facilitate the adoption of this system.

Audio Line Levels and Metering

Most broadcast facilities to date have been designed around power matched distribution systems. The usual Reference Level is +8dB, most often at 600 ohms, but in large facilities, 150 ohms is found. The Standard Output Level is +18dBm, and the Clip Level is +24dBm. Since these are power matched systems, there is a 6dB loss in the output pad (split), and therefore the output amplifier must be capable of delivering at least +30dBm (1 watt) and supplying almost 25Vrms open circuit in the case of the 600 ohm system. [Most major facilities today are +4dBu, unless there is a significant legacy system of +8]

Recording facilities have standardized on a Reference Level of +4dBm, 600 ohms, with a Standard Output Level of +14dBm and a Clip supplying 16Vrms open circuit.

The proposed voltage system would have a reference level of +8dBu, a Standard Output Level of +16dBu and a Clip level of +22dBu. Since there is no voltage drop in the buildout resistors, only a 10Vrms output capability is required.

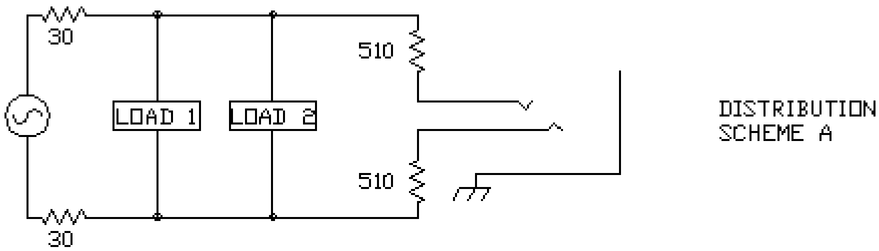
In order to keep the relative program audio levels between PPM and VU facilities as close as possible, it was found independently by both the CBC and ABC that an 8dB difference between Reference Level and Standard Output Level was the best compromise.

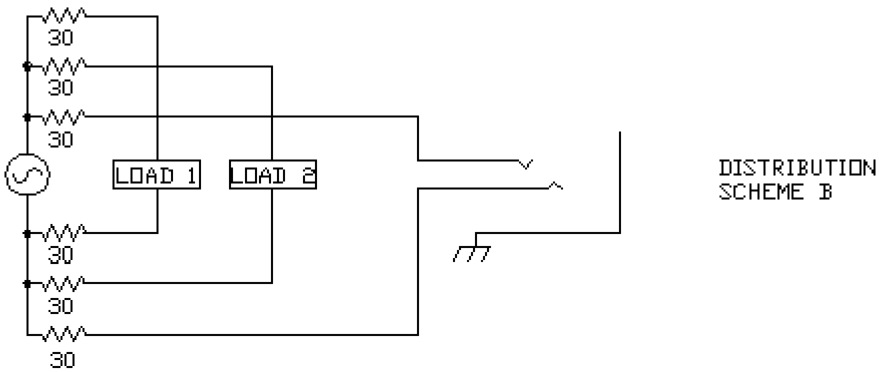
An advantage of the PPM that is not immediately apparent is that in implementing it, it has an electronic input of 40k ohms, rather than a 3.9k ohm resistance isolating the VU meter rectifiers from the audio line. The non-linearities introduced by these diodes show as an increase in harmonic distortion.

Operator acceptance of the PPM at ABC has been better than anticipated. With our scale, program level is still run to "0" and the Reference Level setting is identified by the extended line at the "-8" marking, center scale. [6]

Multiple Load Isolation and System Design For Reliability

There are two schools of thought on how to connect voltage distribution systems, as shown below:





Scheme A is simple to wire, but a short any place on the line will disrupt all feeds, and the isolation against a backfeed from the jack is only about -26dB.

Scheme B, although requiring more wiring, is preferred by this writer from an overall system reliability standpoint. As mentioned before, the isolation against a backfeed in this system is about -60dB. A short on the output will drop the level by about 0.2dB.

In the case of an amplifier equipped with multiple splits, at least 33% of these splits should be permitted to be shorted without adversely affecting the amplifier performance.

Interface Specifications

Ideal interface specifications follow for an amplifier to be used in this proposed voltage system. Performance specifications should be state of the art, but that goes without saying.

INPUT IMPEDANCE 50k ohm, resistive, balanced and
floating (either side may be grounded
without affecting performance)

COMMON MODE REJECTION Greater than 80dB, 20 Hz to 1kHz,
Greater than 60dB to 20kHz.

INPUT CLIP LEVEL Greater than +30dBu (+36dBu at the
-12 gain setting)

INPUT COMMON MODE CAPABILITY + 10v peak to peak

SPLIT NODE OUTPUT IMPEDANCE Less than 0.1 ohm

OUTPUT IMPEDANCE 60 ohms, active balanced, each output
resistively built out.

OUTPUT CLIP LEVEL +24dBu, +22dBu with 15 ohms on the split node.

OUTPUT BALANCE Less than +0.1dB difference, ref. to ground.

OUTPUT DC Less than +/- 50mV

NUMBER OF OUTPUTS 12 in the amplifier plus split node.

GAIN RANGE ADJUSTMENT Front panel screwdriver adjust: -12, -6,0, +12, +18, +24, +30, +/- 0.1dB.

VERNIER ATTENUATOR Front panel screwdriver select: DISABLED ENABLE 0 to -6, 0 to infinity.

VERNIER ATTENUATOR Front panel screwdriver adjust.

FRONT PANEL INDICATORS Power, audio present, clip.

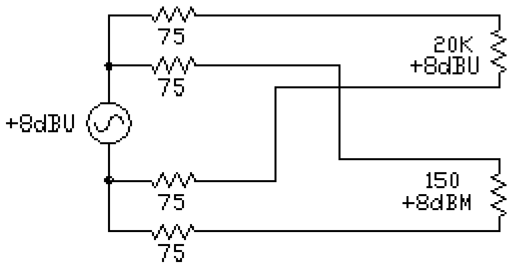
POWER Self powered from mains.

PACKAGING Plug in module

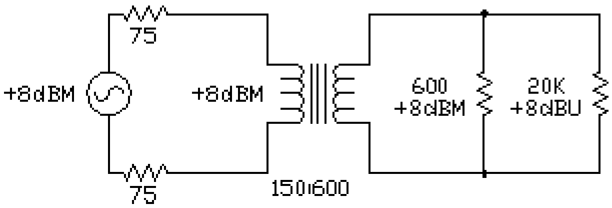
The WABC-TV Application

It was desired to use voltage type audio transmission in the new television facility for WABC-TV at 7 Lincoln Square. Within the facility, this philosophy has been maintained. This facility, however, needed to interface with the existing network facility, 450 meters away, which is a 150 ohm +8dBm power matched system. We decided that this level and impedance would be ideal for the long run between facilities. Two alternatives were considered for the interface between the two systems. The most obvious choice was to provide a separate amplifier in the WABC-TV facility for each line. This, due to the number of lines involved (in excess of 100) became costly, and introduced a decrease in overall system reliability.

An alternative passive interface system was considered preferable and was designed as shown below:



WABC-TV
OUTPUT CIRCUIT



WABC-TV
INPUT CIRCUIT

The WABC-TV output circuits were designed with buildout resistors providing a 150 ohm source impedance. In order to send a signal to the network facility, the +8dBu signal is simply patched into the 150 ohm150-ohm circuit. The 150 ohm load causes a 6dB drop in level to +2dBu, which is the voltage equivalent of +8dBm at 150 ohms. The only caveat that remains is that if an output split is used to feed a signal to a 150 ohm circuit, its level will, of course, be 6dB too low to "mult" to any other voltage system input.

The receive circuits were handled by using a 150 to 600 ohm step up transformer with its secondary terminated in 600 ohms. The voltage inputs then see a +8dBu source, but the source impedance was higher than desirable. the solution to that problem was to keep these source runs short and all within one room.

Conclusions

This writer is looking forward to refining the voltage transmission concept in future projects. It is a system which offers greater reliability from an electrical standpoint due to the lower power levels involved and from an operations stand point due to the fact it is almost fool proof. It is a fact of life that audio signals will be "multed". Let us at least provide a system that permits, without performance degradation, this "multing".." It seems that we have nothing to lose and everything to gain if we make the switch.

References

1. EIA STANDARD 219, "Audio Facilities for Radio Broadcasting Systems",," New York, Electronic Industries Association, 1959.

2. Schmid, Hans, "Audio, The Stepchild of Television Broadcasting", J. SMPTE, Volume 85, page 6-9 (1976 Jan.).

3. Schmid, Hans, "Audio Program Level, The VU Meter, and The Peak Program Meter", IEEE Transactions on Broadcasting, Volume BC-23, No. 1, page 22-26 (1977 Mar.).

4. Jay, Frank (ed.), IEEE Standard Dictionary of Electrical and Electronic Terms, Second Edition, Institute of Electrical and Electronics Engineers, Inc., New York, 1977, page 771.

5. NAB STANDARD: "Cartridge Tape Recording and Reproducing", National Association of Broadcasters, Washington, 1976, pages 9-10.

6. Schmid, Hans, "Audio Program Level, The VU Meter, and the Peak Program Meter", op cit.

Return to home page

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