SIGNAL LEVEL METER CALIBRATION TECHNIQUES

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1. Introduction

The need to measure signal levels is an ever present one in any CATV system. The need to very accurately measure the absolute value of levels is a necessity in multichannel long cascade systems. In smaller systems it might have been adequate to correlate the readings of the various used meters irrespective of absolute calibration. This approach can no longer be defended.

The Signal Level Meter (SLM) is a basic tool of our trade, like the level and plumb are for a mason. Periodic check of SLM's is an absolute necessity and must be done very carefully and with reliable standards since the performance of the whole CATV system depends on proper level settings.

2. The nature of the TV signal

The output of a TV transmitter (picture information only) is as shown below:

Fig.1

The RF carrier strength varies with the modulation and is greatest during sync peak (interval A). We measure signal strength during sync interval, since the RF level is then steady. This requires a meter responding to the sync peak. A good SLM has therefore a true peak detector.

3. The basic SLM calibration setup

To calibrate a SLM one feeds a RF signal of known value into the meter. Signal generators used for this purpose have a sinusoidal output waveform. It is universally accepted practice to state sinusoidal waveform amplitudes as RMS (root mean square) values. The RMS value is the effective value, the value used when one computes power as the product of AC voltage times AC current. AC meters, unless otherwise stated are always calibrated in RMS value of a sinewave. The peak or crest of a sinusoidal waveform is approximately 40% higher than its RMS value as shown below:

Fig.2

(cont'd)

The SLM responds to the crest of the sinusoidal calibration signal, but it was agreed to calibrate it in RMS value as shown below:

Fig.3

If we, for example, feed a 40 dBmV (100 millivolt) signal from a generator into a SLM and calibrate at this value, a TV waveform with a 141 mV peak value will now read 40 dBmV. This is why we say that SLM's are calibrated in RMS value at sync peak.

4. Available generators/calibrators

SLM manufacturers usually use generators designed for 50 ohm loads. Such generators cost in the neighborhood of $1,500. These generators are suitable for SLM calibration, if properly matched to 75 ohm SLM's, but one must remember that they are not absolute voltage standards either. Laboratory generators also have often a lot of features which are of little use to a CATV operator such as accurately calibrated modulation capabilities; very accurate frequency calibration,etc.

The most important and desirable characteristics of a generator for SLM calibration are:

a) 75 ohm output impedance

b) good sinewave output

c) output level indicator

d) good attenuator

e) stable output over long periods of time

f) moderate output level

g) reasonable frequency accuracy

h) a stable output with temperature change

Several "low cost" generators (SLM calibrators) meeting at least some of the above specifications are available, namely:

1) Delta - model FSM-C4

2) St.Petersburg Communications - model C-524

3) Measurement Corporation - model 950

(cont'd)

One high priced unit featuring 15 separate calibrated oscillators is available from Video Instruments at $1,285.

A new type of calibrator from JFD will be discussed later. We will examine the block diagrams of the 3 above mentioned calibrators.

Delta Model FSM-C4 ($112.50)

Fig.4

This unit is very simple, it has a single transistor oscillator, the output of which is detected and indicated on a meter and its amplitude can be set by adjusting the oscillator voltage. Isolation to the output and 75 ohm back match are provided.

The calibration output voltage for each channel is marked on the front panel and is typically 15 dBmV. To obtain other values one must use an external attenuator. Frequency range is from 54-250 MHz continuous and the dial is fairly well calibrated.

St.Petersburg Comm. Model C-524 ($149.-)

Fig.5

This unit consists of a RF oscillator, a peak to peak detector with associated AGC feedback circuit to keep the output constant, a 15.75 KHz modulation oscillator, a 3 step attenuator and a regulated 117V power supply. The unit is 75 ohm backmatched. Output values from 40 dBmV maximum to -10 dBmV can be obtained in 10 dB steps. Frequency range is from 50-240 MHz in two bands with approximate dial calibration.

Measurements Corp. Model 950 ($380.-)
(Also available from Vikoa as their model 3913)

Fig.6

This product is a scaled down laboratory signal generator (Measurements Model 80). It consists of a Nuvistor oscillator, a bolometer type RF signal level detector with feedback circuitry to keep the output constant, a balance indicator and a precision 75 ohm backmatched piston attenuator. The power supply is for 117V and supplies regulated DC to all circuits including the

(cont'd)

Nuvistor tube filament. The frequency range is from 54 to 250 MHz in 2 bands with hand calibrated frequency markings within ± 0.5%. The output level can be adjusted continously from +40 dBmV to -70 dBmV with markings every 2dB.

5. Calibration techniques

It makes sense to perform the prime calibration of the SLM's at the most critical signal level to be measured in the CATV plant. The output of the trunk amplifiers is the most critical level. Since levels are measured through test points these must be taken into account. Most trunk amplifiers run at approximately 30 dBmV and use either 20dB or 30dB test points, so calibration at 10dBmV or 0dBmV is indicated.

The calibration setup is simply a length of coax cable connecting the calibrator and the SLM. The cable must be of good quality checked to 26-30 dB return loss and 75 ± 1 ohm. It is also recommended that the same relatively short (approx. 18") cable be used all the time to eliminate a further variable. A good match on the whole setup is important since standing waves can change the calibration considerably.

It is recommended that one uses a separate calibration record sheet for each SLM. A suggested sample form is shown in the figure below:

Fig.7

The calibration procedure consists of several parts:

a) Channel calibration performed at each picture and all pilot carrier frequencies; recording either compensator settings or actual readings for meters without compensators. In either case one can then from the record sheet, prepare a compensator setting table or a correction chart suitable to keep with the SLM (large self-adhesive labels are good for this purpose). The record sheet is kept in the shop it is an inventory and performance record. Deviations from prior calibrations should be noted and if more than a dB or so, close examination of the instrument (or the calibrator) is indicated.

b) One should check the accuracy of the step attenuators against a good standard. This check is recommended at Channel 2 and Channel 13.

(cont'd)

c) Scale calibration check is done against an external variable attenuator. Set SLM for full scale reading at one channel, adjust a 0-10dB attenuator dB by dB and watch for correlation of reading on the meter scale.

d) It is desirable to check the SLM input match occasionally.

e) Most meters are calibrated at a shop temperature of 70-80° F. When setting levels in the field the instrument may be at a much lower or much higher temperature. Good SLM's are temperature compensated, but not every unit is given a temperature test at the factory. The compensation can also become faulty in the field. Check the compensation once a year by placing the SLM in a cold or hot area (after calibrating it in the shop at 70-80° F). Let the SLM stabilize for approx. one hour; readjust voltage and repeak before making the new reading (calibrator must of course stay in the shop at a steady temperature).

There are a few additional guide points on SLM calibration:

a) Calibrate trunk meters at least every 4 weeks.

b) Calibrate installer meters approximately every 8 weeks.

c) Put sticker on SLM showing last calibration date and next calibration date. Meters should be recalled by the office for recalibration, don't rely on the technician to bring back meters.

d) Keep SLM's physically clean.

e) Check SLM's after factory overhaul; the unit may have been damaged in transit.

f) Replace sticky meter movements promptly.

g) Check calibrator every 6 months.

6. Calibration of generators/calibrators

All SLM producers use signal generators to calibrate SLM's and calibrators. The generators in turn, have to be calibrated themselves and for that purpose a variety of instruments are

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used. The most often used device is a bolometer, it measures power. Power can be measured quite accurately and it is a desirable quantity to measure particularly at microwave frequencies, since it is not dependent on match (VSWR) as voltage measurements are.

A bolometer is, in effect, a low power wire resistor, which changes resistance as it is heated by the to be measured RF signal and this resistance change is used in a bridge circuit with a meter, in turn calibrated in power (watts, milliwatts). To calibrate the bolometer itself one can use DC which can be measured very accurately. To measure voltages above approximately 100 mV the bolometer is the preferred method. Commercial units are however built with an impedance of 50 ohms, requiring matching for 75 ohm use.

Another method of calibrating signal generators is the use of a micropotentiometer, which contains a wire resistor heated by the to be measured RF signal flowing through it, the generated heat in turn is transferred to a thermocouple, which generates a voltage suitable to drive a DC millivoltmeter. In series with the RF path is an accurately measured low value resistor. Again, one can calibrate this setup by applying DC to it. The micropotentiometer is the preferred method at the National Bureau of Standards to calibrate Field Strength Meters, since low value RF signals can accurately be produced (see bibliography #6).

Both of the described methods are wideband and measure power. The voltage in turn is computed from the indicated power and the known instrument impedance in case of the bolometer and from the known current and resistance in the micropotentiometer method. Since SLM's measure peak voltage and above methods are based on power we must use a reasonably low distortion sinewave signal source for our calibration or additional errors will result.

The availability of a micropotentiometer together with the necessary accurate DC standards and a good stable Rf source allows one to check calibrators with accuracies tracable to the National Bureau of Standards. Such a setup is costly and it is warned that one cannot merely buy the gear, plug it together and expect NBS accuracy. A good deal of knowhow and care in making the measurements is needed. Micropotentiometers are available from sources like Ballantine (Boonton, N.J.) and Filmohm (L.I.City, N.Y.).

Another means of checking calibrator accuracy is to own two good calibrators and checking them against each other at periodic intervals and returning them both to the factory when they no longer agree with each other within specifications.

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Some commercial instrument calibration laboratories are equipped to check calibrators.

It is also possible to use so called RF milli or micro voltmeters, but these instruments are not very accurate and in turn must be calibrated themselves with better instruments.

7. Suggested equipment packages

	Estimated attainable overall accuracy:
A. Minimum - Delta or St.Petersburg calibrator. \$115.-/\$150.-	± 2 dB
B. Better - Measurements Corporation calibrator. \$380.-	± 1.5 dB
C. Reassurance - Two of the above calibrators, one used as an "in-house" standard, the other used to check SLM's	
D. Best - Above calibrator, plus micro-potentiometer, RF generator voltmeter etc., to facilitate checking of calibrator. Approx. \$2,000.-	± 1 dB

E. Available, but not favored:

Use of standard signal generators such as:

HP 608
Measurements Corp. Model 80 (discont.)
GR model 1021 (discont.)

Reasons:
a) Generators themselves need calibration

b) Units are 50 ohm requiring matching and computations for calibration of 75 ohm SLM's

c) Old used generators may be defective and not accurate.

d) Output voltmeters read voltage into load on some units, behind 50 ohm on others, requiring computations.

F. Not acceptable - Election of one meter as a standard.

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8. Other methods of calibrating SLM's

Precision field strength meters ($3,000.- price range) feature built-in calibrators. These calibrators are of the impulse generating type and require no tuning over very wide frequency bands, they, in essence, provide signals at all frequencies simultaneously. The calibrators are available as separate units from Stoddard and Singer, but are of 50 ohm design.

Similarly noise may be used to calibrate SLM's. A calibrator using this principle is now available from JFD. After initial setup against a built-in single frequency generator no tuning on the generator is needed, the SLM hooked up to the generator can then be tuned through it full range giving a reading all along. The SLM reading depends on its bandwidth since both noise and impulse spectrums contain energy throughout their wide frequency ranges. The figures below illustrate this.

Fig.8 Fig.9

9. Effect of calibrator harmonics

Calibrators may have various degrees of harmonics in their output, this is not desirable since the calibrators are checked with power meters reading energy content of the fundamental and the harmonics. The SLM in turn, is a tuned voltmeter and reads the fundamental component only. Computations indicate that the error is not very large even for relatively large harmonic levels.

	Error on SLM
One harmonic 10 dB below fundamental	0.4dB
" " 15 dB " "	0.1dB
" " 20 dB " "	0.05dB
Two harmonics each 10 dB below fundamental	0.75dB
" " " 15 dB " "	0.25dB
" " " 20dB " "	0.1dB

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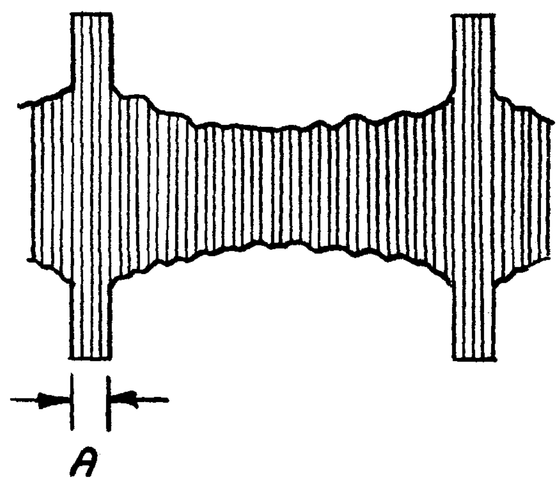


Fig. 1

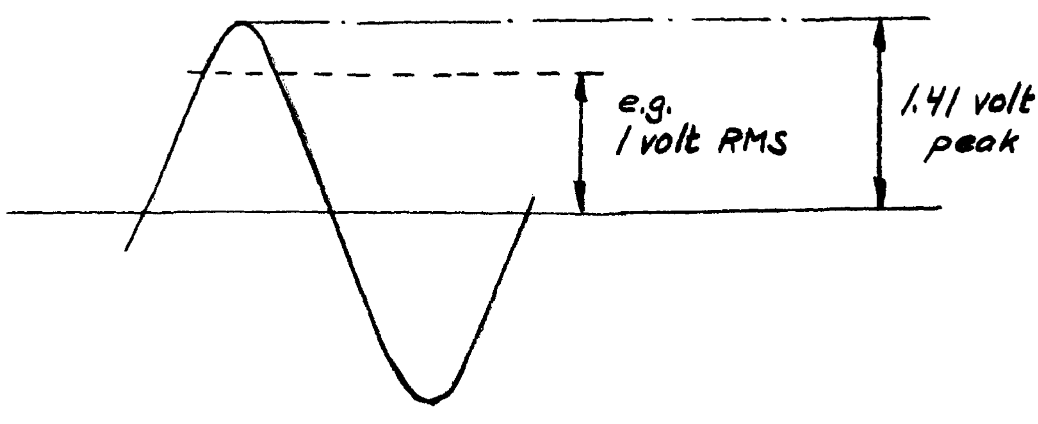


Fig. 2

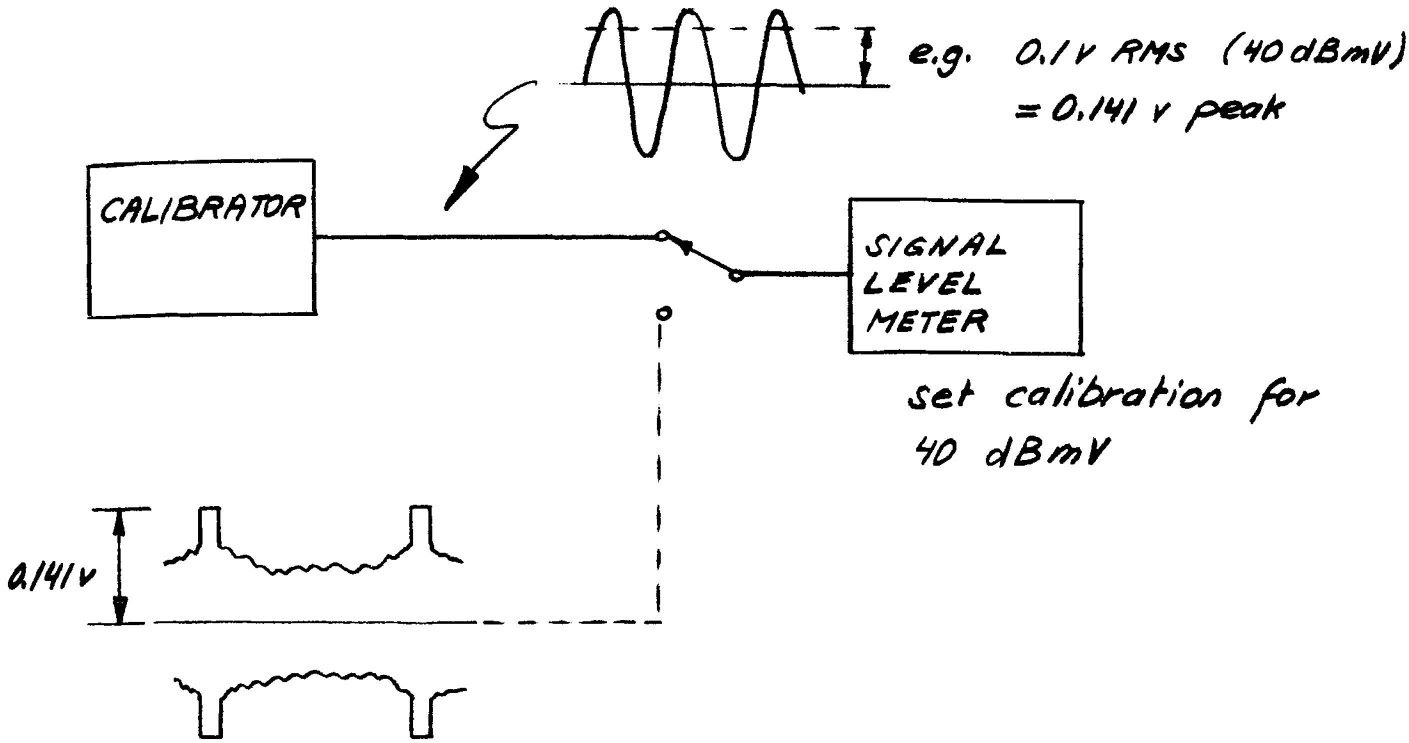

e.g. 0.1 v RMS (40 dBmV)
= 0.141 v peak
CALIBRATOR
SIGNAL
LEVEL
METER
set calibration for
40 dBmV
0.141 v

Fig. 3

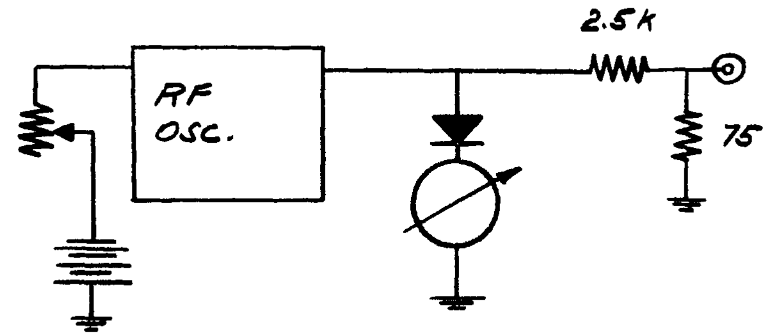

2.5 k
RF OSC.
75

Fig. 4

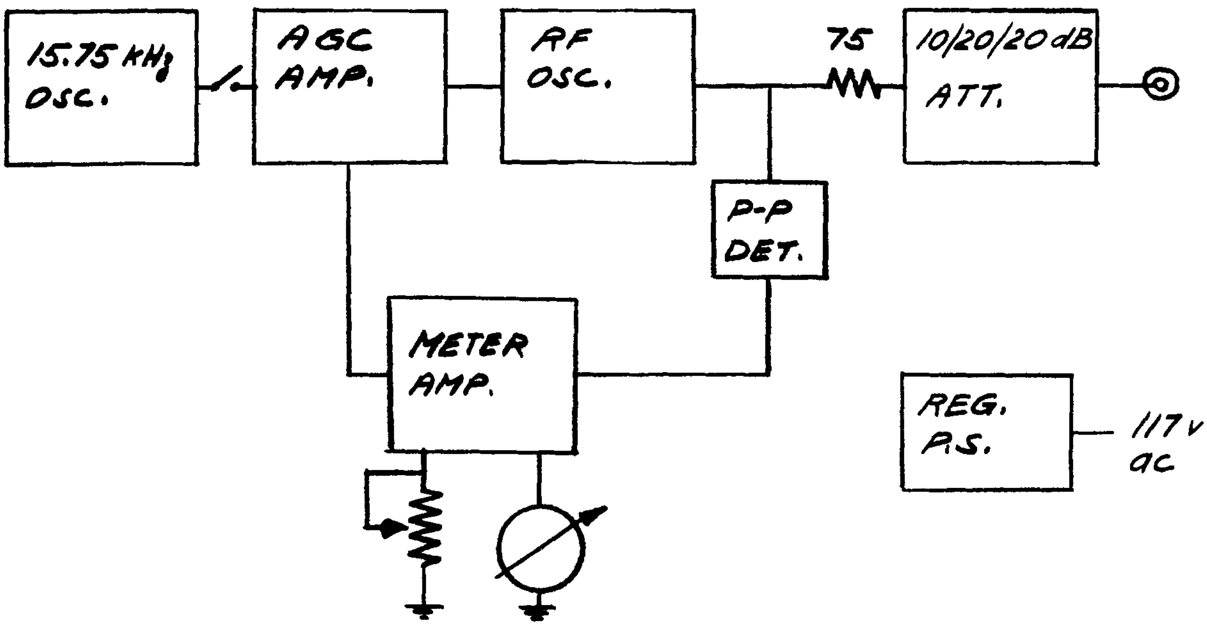

15.75 kHz OSC.
AGC AMP.
RF OSC.
75
10/20/20 dB ATT.
P-P DET.
METER AMP.
REG. P.S.
117 v ac

Fig. 5

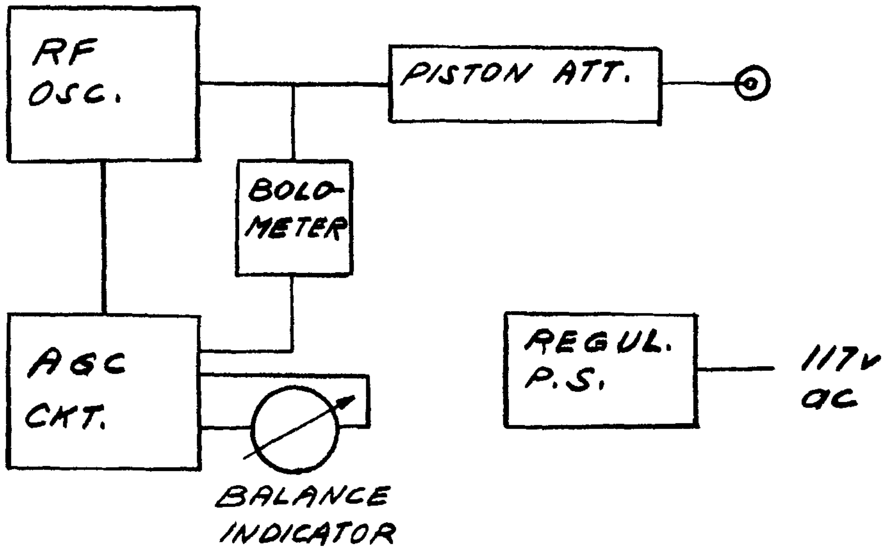
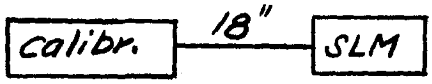

RF
OSC.
PISTON ATT.
BOLO-
METER
AGC
CKT.
BALANCE
INDICATOR
REGUL.
P.S.
117v
ac

Fig. 6

SLM CALIBRATION RECORD

Model: ------ Ser. No. ------

1. Channel calibration

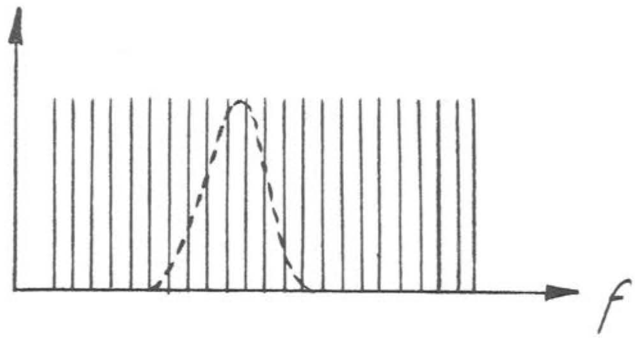


set meter and calibrator for ------ dBmV

channel	CALIBRATION DATE AND COMPENSATOR SETTING				
	ORIG.				
	-/-/--	-/-/-	-/-/--	-/-/- -	-/-/--
2 PIX					
3 PIX					
4 PIX					
⋮					

2. Attenuator check

10dB 2P					
10 dB 13P					
20dB 2P					
20 dB 13P					
20dB 2P					
20dB 13P					



IMPULSE GENERATOR SPECTRUM

Fig. 8

NOISE GENERATOR SPECTRUM

Fig. 9