CATV SYSTEM POWERING CONSIDERATIONS

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ABSTRACT

The input AC Power Factor of a DC power supply has a significant effect on input AC current, and therefore affects system design. Since system efficiency and Power Factor can vary significantly as a function of system configuration, analysis of system powering and overall efficiency requires a realistic system model which accommodates the wide variety of modern system designs, re-designs, and upgrades.

This paper will discuss the effects of system configuration, Power Factor, and AC Line Power Supply performance on overall system efficiency. A unique system simulator which permits accurate modeling of all known system configurations will be described, along with test data obtained. A simplified method of system design and performance analysis which was developed using the system simulator will be presented.

INTRODUCTION

Power supply bench-testing has traditionally been done by connecting the unit under test either directly to an otherwise unloaded AC Line Power Supply (LPS), or through an autotransformer to simulate lower voltages commonly encountered in CATV systems. These testing methods do not place a normal load on the LPS, nor do they account for cable resistance normally encountered in CATV systems. In an attempt to more accurately model conditions encountered in real systems, series resistance was added to the output of the LPS to simulate cable resistance: A significant decrease in AC input current was observed over the entire operating voltage range of the DC power supply.

Actual cable resistance and LPS loading can vary widely depending on the type of cable and amplifier technology, subscriber density, and general system architecture. I realized that the most practical way to establish accurate performance guidelines for system design would be to simulate an entire powered segment of a CATV system, and measure actual performance of a variety of system configurations. Instead of using real cable as in cascade measurements, resistors would be used to simulate cable resistance. By using variable resistors, a wide variety of span lengths and cable characteristics could be easily simulated. Any number of trunk stations and line amplifiers could be used. Provisions would be made for the connection of accurate current and power metering equipment anywhere within the segment. The most useful metering locations would prove to be at the input and output of the LPS and at the input of each trunk station and line extender. Metering the input and output of the LPS would also provide a test of its performance under a variety of realistic conditions. The data gathered using the system simulator could then be applied to a general rule for system power design using switched-mode power supplies.

CHARACTERISTICS OF SWITCHED-MODE POWER SUPPLIES

Compared to the traditional series-regulated DC power supply, the most distinguishing characteristic of a modern switched-mode power supply (SMPS) is its ability to operate at relatively constant efficiency across a wide input voltage range. The efficiency and input characteristics of any AC-input DC power supply are defined by the following equations:

$$\text{Eff} = \frac{V(\text{out}) \times I(\text{out})}{P(\text{in})} \qquad (1)$$

$$P(\text{in}) = V(\text{in}) \times I(\text{in}) \times PF \qquad (2)$$

Where:

Eff	= power supply efficiency (%/100)
V(out)	= DC voltage in Volts
I(out)	= DC current in Amps
P(in)	= AC power in Watts
V(in)	= AC voltage in Volts RMS
I(in)	= AC current in Amps RMS
PF	= input AC Power Factor

Note that unless the AC Power Factor is known, it is not possible to solve for Efficiency unless accurate power measuring equipment is available. Certain "standard" Power Factor values have been used for years in conventional power supply design, but as will be shown, Power Factor can be a significant variable.

Using specialized equipment, it is possible to simultaneously measure AC power, RMS voltage, RMS current, and Power Factor at the input of a power supply. Figure 1 is an example of an equipment set-up which has been used to measure the characteristics of DC power supplies used in CATV applications.

Using the equipment set-up shown in Figure 1, characteristics of the Magnavox model 8PS-60HE are shown in Figures 2, 3, and 4. The 8PS-60HE is a ruggedized high-efficiency transformerless switched-mode power supply.

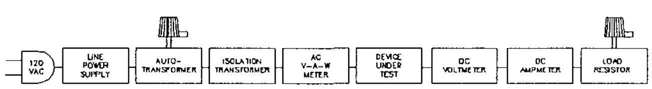


Figure 1. Test Set-Up

As a comparison, the characteristics of the conventional series-regulated ("linear") Magnavox model 7PS-60 are shown in Figures 5, 6, and 7.

Note that compared to the linear power supply, the switched-mode unit maintains excellent efficiency across a wide input voltage and output current range. SMPS Power Factor at 2 Amps output is virtually identical to the linear unit at 1 Amp output.

As shown in equation (2), Power Factor is an important variable which has a considerable effect on AC input current. Equations (1) and (2) can be combined to solve for input current:

$$I(\text{in}) = \frac{V(\text{out}) \times I(\text{out})}{\text{Eff} \times PF \times V(\text{in})} \qquad (3)$$

Since V(out) and Eff are nearly constant for the 8PS-60HE, equation (3) may be further simplified to:

$$I(\text{in}) = \frac{26.7 \times I(\text{out})}{PF \times V(\text{in})} \qquad (4)$$

Use of equation (4) has been suggested for CATV system powering design applications, but its use is difficult for the following reasons:

1. Power Factor varies significantly, not only as a function of V(in), but also as a function of system configuration.

2. AC voltage at a distance from the LPS is a function of current flow in the cable. Since current flow must be estimated until it can be calculated from AC voltage, (and then repeatedly re-calculated based on the new current value) an iterative approach is required for solution.

By using an average value for Power Factor, use of equation (4) may be simplified, but an iterative approach is still necessary for solution.

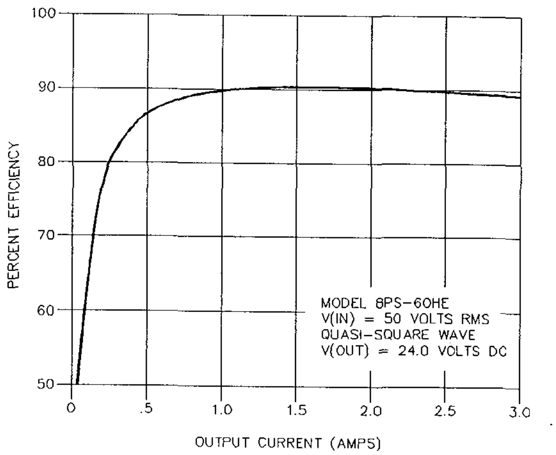


Figure 2.

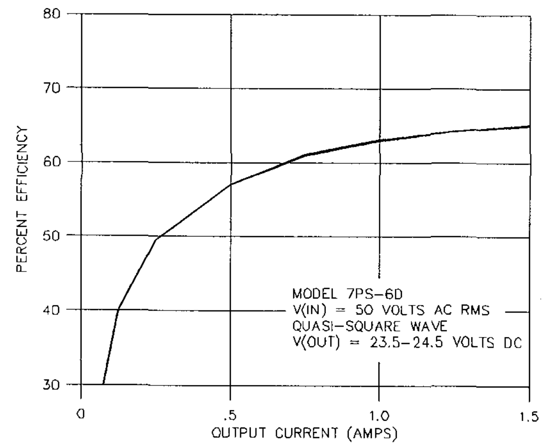


Figure 5.

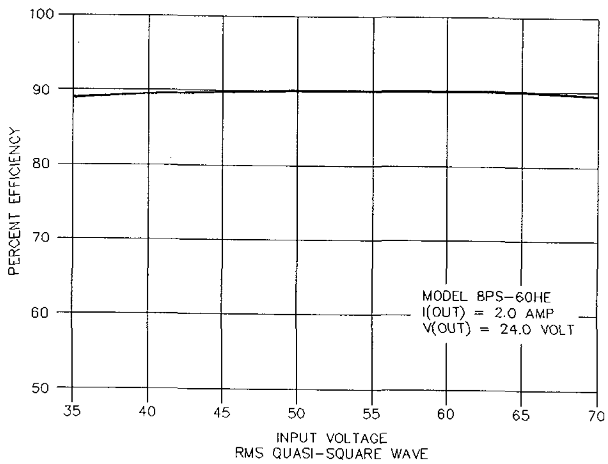


Figure 3.

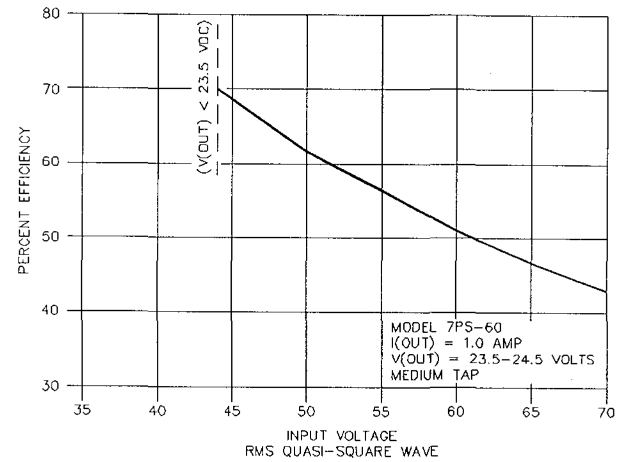


Figure 6.

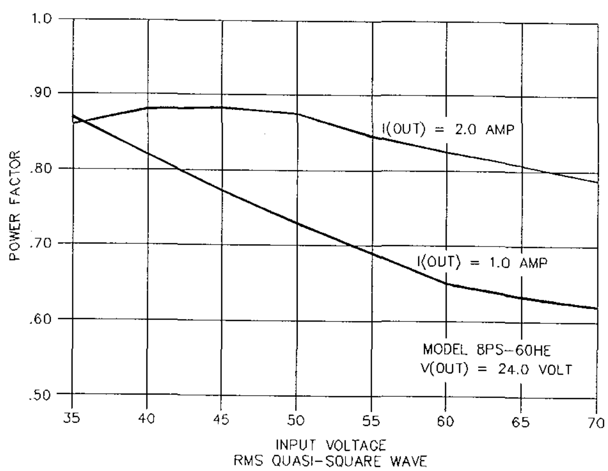


Figure 4.

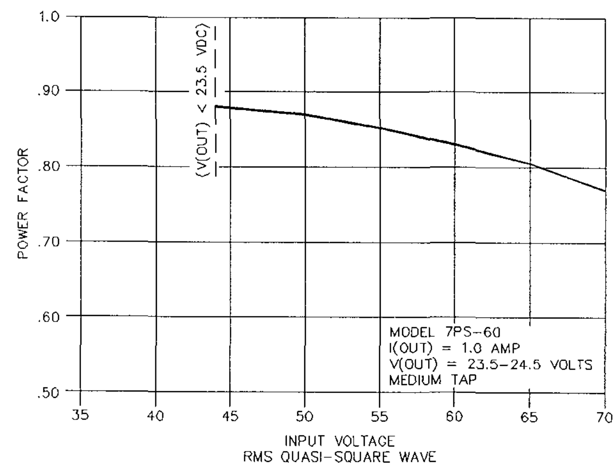


Figure 7.

EFFECT OF SOURCE IMPEDANCE ON SMPS PERFORMANCE

In a CATV system, normal cable resistance would be expected to have an effect on Power Factor. The effect of cable resistance was simulated by adding resistance to the test set-up as shown in Figure 8.

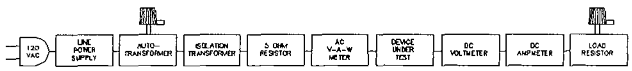


Figure 8. Test Set-Up with 5 Ohms Resistance Added

Using the test set-up in Figure 8 with a simulated cable resistance of 5 ohms, the 8PS-60HE measurements were repeated. A major change in Power Factor was noted, as shown in Figure 9. Small improvements in Efficiency (typically less than .5%) were also noted; these are due to lower AC current.

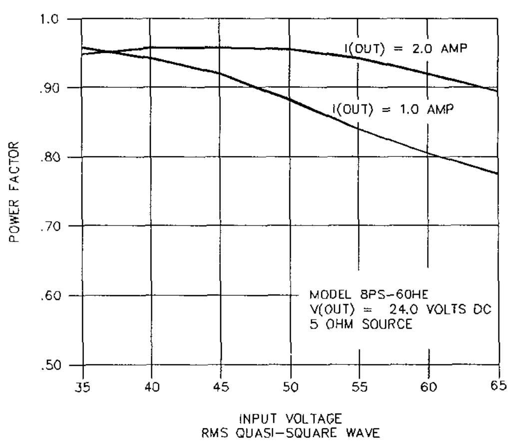


Figure 9.

The selection of a 5 ohm resistor to obtain the data depicted in Figure 9 was based on the typical loop resistance of several spans of cable. The effect of LPS loading was not addressed at all. In a real system configuration, the Line Power Supplies are typically loaded to between 50% and 85% of their current rating, and cable loop resistance is distributed in a network with complex loads applied at many points within the network.

SYSTEM SIMULATOR

To be able to evaluate a variety of system configurations using different types of cable, variable power resistors were used to simulate each cable span loop resistance. An array of 32 line amplifiers was mounted on a wall with the power resistors to permit connection in any configuration. Due to the wide variety of possible trunk amplifier DC load configurations, trunk station loads were simulated using variable load resistors. A standard Magnavox 5-LPS60-14 line power supply delivers up to 14 Amps at 60 VAC to the simulator board. Provisions were made for the insertion of a digital Volt-Amp-Watt meter at the input and output of the LPS, and at the input of each line extender and mainstation DC power supply. The final configuration is shown in Figure 10.

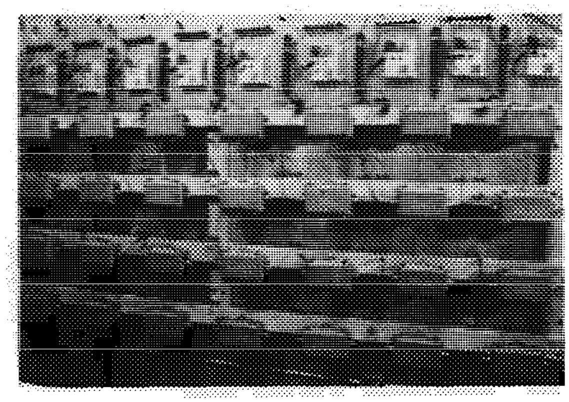
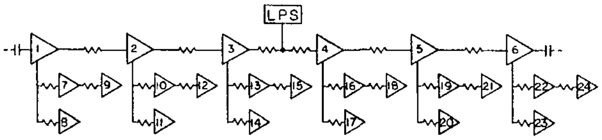


Figure 10. The System Simulator

330 MHz: SERIES-REGULATED vs SMPS

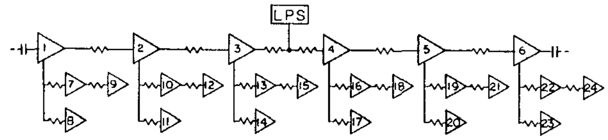
For the first simulation, a typical 330 MHz system segment with conventional power supplies and push-pull amplifiers was built, as shown in Figure 11. This configuration models the use of .750" T4+ trunk cable at 22 dB per span, or 2340 feet; trunk span resistors were set at 1.76 ohms, except for the power insertion location, which was split into two resistors of .88 ohms each. The trunk station 7PS-60 power supplies were loaded at 1.11 Amps DC to simulate the load of a standard trunk amplifier, bridger, and AGC/ASC control module. Standard-gain 5-LEX330-60 line extenders were used. Use of .500" T4+ distribution cable was simulated, assuming a 900 foot span (1.53 ohm) to the first line extender and a 1000 foot span (1.70 ohm) to the second line extender.



LPS Input: 118.0 VAC, 7.11 Amps, 760 Watts, PF = .91
LPS Output: 57.6 VAC, 11.90 Amps, 645 Watts, PF = .94
LPS Efficiency: 85%

Station	VAC(in)	IAC(in)	Power	PF	TAP
1	42.0	1.124	44.0	.93	LO
2	48.5	.970	39.7	.89	MED
3	52.2	.919	40.5	.84	HI
4	52.4	.923	40.7	.84	HI
5	45.5	.963	39.5	.90	MED
6	42.1	1.120	43.6	.92	LO
7	41.1	.350	13.9	.97	2
8	41.7	.338	13.5	.96	2
9	40.5	.331	13.0	.97	2
10	44.9	.295	12.4	.94	3
11	45.2	.300	12.6	.93	3
12	44.4	.304	12.7	.94	3
13	51.3	.337	15.4	.89	3
14	51.8	.328	15.0	.88	3
15	50.7	.334	15.2	.90	3
16	51.5	.350	15.6	.86	3
17	52.0	.340	15.2	.86	3
18	51.0	.335	14.9	.87	3
19	44.8	.304	12.5	.92	3
20	45.2	.298	12.5	.93	3
21	44.3	.294	12.2	.94	3
22	41.0	.345	13.5	.95	2
23	41.5	.350	13.9	.96	2
24	40.6	.347	13.3	.94	2

Figure 11. 330 MHz System with Linear Power Supply



LPS Input: 117.7 VAC, 5.69 Amps, 603 Watts, PF = .90
LPS Output: 58.2 VAC, 9.25 Amps, 498 Watts, PF = .92
LPS Efficiency: 83%

Station	VAC(in)	IAC(in)	Power	PF	TAP
1	46.2	.740	29.8	.87	-----
2	48.9	.782	29.8	.78	-----
3	53.9	.896	29.9	.62	-----
4	54.1	.889	29.6	.61	-----
5	48.8	.780	29.6	.78	-----
6	46.3	.737	29.6	.87	-----
7	45.4	.290	12.8	.97	3
8	45.9	.280	12.5	.97	3
9	45.0	.278	12.1	.97	3
10	48.0	.290	13.3	.95	3
11	48.4	.295	13.5	.94	3
12	47.6	.300	13.6	.95	3
13	53.2	.244	12.3	.95	4
14	53.7	.240	11.9	.92	4
15	53.0	.242	12.2	.95	4
16	53.4	.245	12.4	.95	4
17	53.8	.245	12.0	.91	4
18	53.0	.242	12.0	.94	4
19	48.0	.292	13.5	.96	3
20	48.4	.290	13.5	.96	3
21	47.5	.286	13.1	.96	3
22	45.6	.289	12.4	.94	3
23	45.9	.290	12.8	.96	3
24	45.1	.290	12.3	.94	3

Figure 12. 330 MHz System with Switched-Mode Power Supply

Note that while the output Power Factor of the LPS is .94, its input Power Factor is .91. Power Factors at the DC power supply inputs vary from .84 to .97, with the highest being the farthest from the LPS. Power input to all stations varies considerably due to the nature of the series-regulated power supplies used. The difference between the LPS output power and the total power consumed by all stations (194 Watts) represents power lost in the cable resistance; this total agrees with the total calculated dissipation of the cable resistors. In this case, the total current consumed by the stations agrees exactly with the current output from the LPS. (As will be seen, this is generally not typical.)

For the simulation shown in Figure 12, the configuration set up for the first trial shown in Figure 11 remained unchanged, except that the 7PS-60 power supplies were replaced by 8PS-60HE units. The series-regulated line extenders remained unchanged, except that their transformer tap selectors were reset to reflect the new operating conditions.

Note that while the Power Factors at the 8PS-60HE inputs of stations 1 through 6 have fallen to between .61 and .87, in each case the current input to these stations has also dropped, and power consumption is uniformly low. As a consequence, cable voltage drop is lower, permitting the selection of the next higher voltage tap in many of the line extenders. Current and power consumption of all the line extenders is significantly lower as a result.

In contrast to the first example, note that the total station current consumption is .5 Amp higher than the output of the LPS. This difference is due to the wide range of Power Factors seen in this example. As will be seen, this difference is typical when switched-mode power supplies are used in CATV systems. (Due to current phase differences which are a consequence of Power Factor, the vector sum of the currents is lower than the arithmetic sum.) Total power dissipation in the cable resistance has dropped to 91 Watts, less than half that of the example in Figure 11.

Although the Power Factors in stations 1 through 6 have fallen significantly, the overall Power Factor at the LPS input and output have changed only a small amount. While the Efficiency of the LPS has fallen from 85% to 83% (due primarily to reduced loading), the overall current and power input to the LPS is 20% lower than the original configuration in Figure 11.

450 MHz: SERIES-REGULATED vs SMPS

In the next two simulations, a 450 MHz transportation trunk application will be evaluated: First with 7PS-60 power supplies, then with 8PS-60HE units. Feed-forward trunk amplifiers will be used at 29 dB operational gain, and 1.00" MC[2] cable will be modeled, resulting in a span of 3920 feet and 1.61 ohms loop resistance per span. AGC/ASC control modules are used, resulting in a total DC load of 1.26 Amps per station.

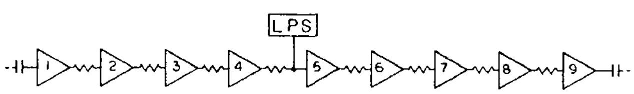
Due to the long spans and lack of distribution, the full output current capability of the LPS unit in Figure 13 cannot be used because of the considerable voltage drop in the cable. This is known as a "Voltage Limited" configuration, and is common in transportation runs and configurations with very low density distribution.

Note that while the Power Factors at the station inputs vary between .84 and .96, the overall Power Factor at the LPS is .95 at the output and .93 at the input. LPS efficiency is excellent at 84%, considering that it is not fully loaded. Total cable dissipation is 141 Watts, and the total station current consumption agrees within 80 mA of the LPS output current.

Figure 14 shows data for 8PS-60HE switched-mode power supplies with the same DC load and physical configuration as Figure 13.

In contrast to the 330 MHz example, Power Factors for Figure 14 station inputs distant from the LPS are equal to those of the conventional power supplies in Figure 13. This is likely due to the considerably higher cable resistance in this configuration. Since the input to station 5 is connected directly to the LPS, its Power Factor is considerably lower. However, the overall .90 Power Factor at the LPS output (and input) is still quite reasonable.

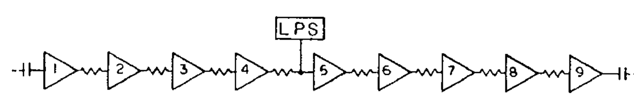
Total power dissipation in the cable has dropped to 63 Watts. Overall LPS power consumption is 30% lower than in Figure 13, and current consumption has dropped 28%. As a result of the low 6.84 Amp loading, LPS efficiency has fallen to 79%; while more savings would be possible if the LPS efficiency was higher, repowering of this configuration for more complete LPS utilization would not be advisable due to considerable cable voltage drop.



LPS Input: 114.8 VAC, 6.19 Amps, 659 Watts, PF = .93
LPS Output: 58.1 VAC, 10.04 Amps, 553 Watts, PF = .95
LPS Efficiency: 84%

Station	VAC(in)	IAC(in)	Power	PF	TAP
1	39.7	1.201	45.6	.96	LO
2	41.8	1.233	48.0	.93	LO
3	45.2	1.047	43.4	.92	MED
4	50.8	.967	43.2	.88	HI
5	57.5	1.066	51.8	.84	HI
6	50.8	.968	43.2	.88	HI
7	45.3	1.056	43.7	.91	MED
8	41.8	1.237	48.2	.93	LO
9	39.8	1.189	45.2	.95	LO

Figure 13. 450 MHz System with Linear Power Supply



LPS Input: 115.9 VAC, 4.43 Amps, 464 Watts, PF = .90
LPS Output: 59.0 VAC, 6.84 Amps, 365 Watts, PF = .90
LPS Efficiency: 79%

Station	VAC(in)	IAC(in)	Power	PF
1	46.9	.753	33.6	.95
2	48.1	.750	33.2	.92
3	50.2	.760	33.1	.87
4	53.7	.828	34.1	.77
5	58.0	.986	33.6	.59
6	53.8	.820	33.7	.76
7	50.2	.770	33.5	.87
8	48.1	.760	33.6	.92
9	46.8	.752	33.6	.96

Figure 14. 450 MHz System with Switched-Mode Power Supply

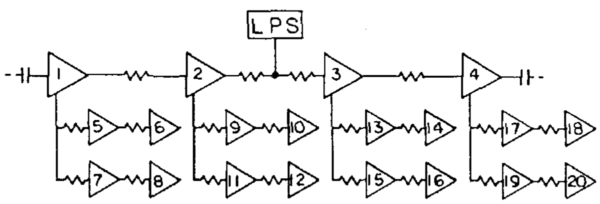
550 MHz APPLICATIONS USING SMPS

The above examples were provided to demonstrate the considerable differences between SMPS and conventional power supplies, and to document the savings possible by upgrading to SMPS units. The remaining examples will show how SMPS use applies to different configurations of 550 MHz systems. All examples will model .750" MC^2 trunk cable and .500" MC^2 distribution cable. A 6-VLE550-SWA Power Doubling SMPS line extender will be used. While the trunk spans and loop resistances will be defined by the type of trunk amplifiers used, for sake of simplicity, all distribution cable will span 600 feet to the first line extender, and 700 feet to the second. Loop resistances of .94 ohm and 1.10 ohm will be used, respectively.

Figure 15 shows a typical system using high-gain Power Doubling trunk amplifiers, for a span length of 2500 feet and loop resistance of 1.83 ohms. Trunk DC load is 1.47 Amps, including trunk, bridger, and AGC/ASC control.

Power Factors range between .68 and .92, and average .84 overall. However, the overall .89 power factor at the output of the LPS is reasonable, and the value of .92 at the LPS input is typical. Note the uniform input power and current for all stations: they appear to be nearly independent of input voltage. Total cable dissipation is 85 Watts, and total station current is .59 Amp higher than the LPS output.

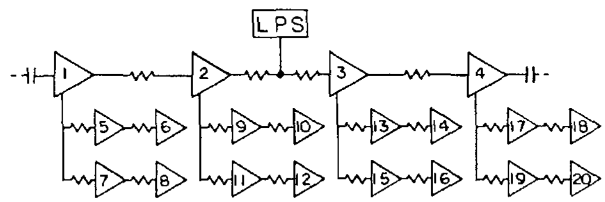
Figure 16 shows another version of the Figure 15 system, except that Feedforward amplifiers are used for maximum span of 2685 feet and loop resistance of 1.96 ohms. Trunk station DC load is increased to 1.96 Amps, and LPS loading is near optimum. Cable dissipation is 126 Watts, and total station current is .4 Amp higher than LPS output. Power Factors are nearly identical to those in Figure 15.



LPS Input: 114.4 VAC, 6.27 Amps, 660 Watts, PF = .92
LPS Output: 58.5 VAC, 10.52 Amps, 548 Watts, PF = .89
LPS Efficiency: 83%

Station	VAC(in)	IAC(in)	Power	PF
1	49.5	.977	38.7	.80
2	53.9	1.093	39.8	.68
3	53.7	1.082	39.5	.68
4	49.5	.987	39.2	.80
5	48.9	.431	18.9	.90
6	48.4	.436	19.3	.92
7	48.8	.435	19.2	.90
8	48.5	.436	19.3	.91
9	53.2	.445	19.3	.82
10	52.8	.437	19.3	.84
11	53.2	.450	19.4	.81
12	52.8	.434	19.2	.84
13	53.2	.433	18.7	.81
14	52.8	.430	19.1	.84
15	53.2	.444	19.1	.81
16	52.8	.429	19.0	.84
17	48.7	.433	19.0	.90
18	48.3	.432	19.2	.92
19	48.6	.430	19.0	.91
20	48.2	.431	19.1	.92

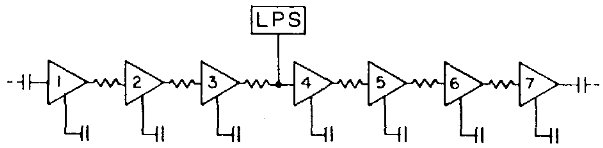
Figure 15. Typical 550 MHz System with Power Doubling Trunk



LPS Input: 114.5 VAC, 7.24 Amps, 763 Watts, PF = .91
LPS Output: 58.2 VAC, 12.4 Amps, 643 Watts, PF = .89
LPS Efficiency: 84%

Station	VAC(in)	IAC(in)	Power	PF
1	46.7	1.307	51.7	.85
2	52.4	1.465	53.2	.69
3	52.3	1.450	52.6	.69
4	46.6	1.313	52.1	.85
5	46.0	.450	18.9	.91
6	45.6	.460	19.4	.93
7	46.0	.462	19.3	.91
8	45.6	.460	19.3	.92
9	51.6	.462	19.3	.81
10	51.3	.454	19.3	.83
11	51.6	.466	19.5	.81
12	51.3	.450	19.2	.83
13	51.6	.448	18.7	.81
14	51.2	.447	19.1	.84
15	51.6	.455	19.2	.82
16	51.2	.444	19.1	.84
17	46.0	.451	19.1	.92
18	46.6	.454	19.2	.91
19	45.8	.451	19.1	.93
20	45.4	.455	19.2	.93

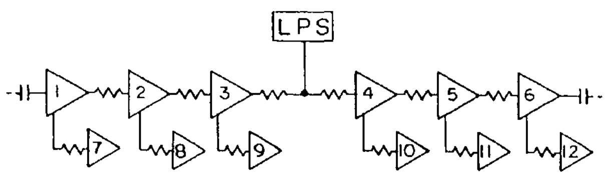
Figure 16. Typical 550 MHz System with Feedforward Trunk



LPS Input: 116.1 VAC, 5.36 Amps, 565 Watts, PF = .91
LPS Output: 58.8 VAC, 8.63 Amps, 460 Watts, PF = .91
LPS Efficiency: 81%

Station	VAC(in)	IAC(in)	Power	PF
1	44.8	1.200	51.3	.95
2	47.3	1.207	51.6	.90
3	51.5	1.262	52.9	.81
4	58.3	1.485	52.0	.60
5	51.5	1.252	52.3	.81
6	47.2	1.221	52.0	.90
7	44.8	1.224	52.0	.95

Figure 17. Rural 550 MHz System with Feedforward Trunk

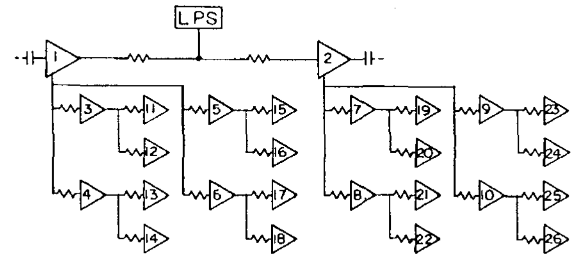


LPS Input: 114.8 VAC, 6.25 Amps, 660 Watts, PF = .92
LPS Output: 58.4 VAC, 10.37 Amps, 551 Watts, PF = .91
LPS Efficiency: 83%

Station	VAC(in)	IAC(in)	Power	PF
1	44.3	1.276	51.2	.91
2	47.0	1.272	51.5	.86
3	53.5	1.423	51.3	.70
4	53.2	1.409	52.6	.70
5	47.1	1.291	52.0	.86
6	43.7	1.296	52.0	.92
7	43.6	.490	19.0	.89
8	46.8	.467	19.4	.89
9	53.1	.466	19.6	.79
10	53.0	.446	18.7	.79
11	46.7	.465	19.1	.88
12	43.4	.488	19.1	.90

Figure 18. Low Density 550 MHz System with Feedforward Trunk

Figure 17 shows a Feedforward system with the very low distribution loading typical of a rural area. This system configuration is similar to a transportation trunk, except that trunk station power consumption is higher. Trunk span and DC load are the same as in Figure 16, but the LPS is not fully loaded due to the lack of line extenders. Station Power Factors cover a wide range from .60 to .95, but LPS input/output Power Factors remain typical. Cable dissipation is 96 Watts, and total station current is .22 Amp higher than LPS output current.



LPS Input: 116.7 VAC, 7.03 Amps, 743 Watts, PF = .91
LPS Output: 58.2 VAC, 12.21 Amps, 619 Watts, PF = .87
LPS Efficiency: 83%

Station	VAC(in)	IAC(in)	Power	PF
1	53.1	1.052	39.0	.70
2	53.4	1.051	39.0	.69
3	52.1	.430	19.5	.87
4	52.2	.437	19.6	.86
5	52.2	.431	19.3	.86
6	52.3	.432	19.5	.86
7	52.3	.432	19.4	.86
8	52.4	.430	19.3	.86
9	52.3	.427	19.2	.86
10	52.4	.427	19.4	.85
11	51.8	.422	19.1	.87
12	51.9	.414	18.9	.88
13	51.9	.424	19.3	.88
14	51.8	.424	19.4	.88
15	51.9	.421	19.1	.87
16	52.0	.419	19.0	.87
17	51.8	.420	19.2	.88
18	51.8	.431	19.7	.88
19	51.8	.430	19.8	.89
20	52.0	.425	19.3	.87
21	51.9	.419	19.0	.87
22	52.0	.426	19.4	.88
23	52.0	.424	19.3	.87
24	52.0	.422	19.2	.87
25	51.9	.419	19.1	.88
26	51.9	.421	19.2	.88

Figure 19. High Density 550 MHz System with Power Doubling Trunk

Figure 18 shows a low density Feedforward system with one line amplifier per trunk station. While station Power Factors are significantly different than in Figure 17, Power Factors at the LPS input/output are typical. Cable dissipation is 124 Watts, and total station current is .42 Amp higher than LPS output current.

Figure 19 shows a high-density system with Power Doubling trunk amplifiers, Power Doubling bridgers, and AGC/ASC control. Trunk span is 2222 feet, loop resistance is 1.62 ohms per span, and trunk station DC load is 1.47 Amps. Overall, line extender Power Factors are very consistent; since input voltages are similar, this is expected. LPS output Power Factor is a bit on the low side of typical, but does not appear to affect LPS input Power Factor significantly. Cable dissipation is 78 Watts, and total station current is .10 Amp higher than LPS output current.

A NEW APPROACH TO SYSTEM POWERING

Initially, it was expected that since the input current of a SMPS unit (at constant load and efficiency) is a function of input voltage and Power Factor as predicted by equation (4), accurate calculation of input current for system powering design could become a complex task. However, since input power is nearly constant for SMPS units with equal loads, equation (2) may be restated to:

$$I(in) = \frac{P(in)}{V(in) \times PF} \tag{5}$$

Where:

$$P(in) = \frac{24 \text{ VDC} \times I(out)}{Eff} \tag{6}$$

For trunk stations, P(in) is calculated from known DC load current and SMPS efficiency specifications; for line extenders, P(in) is specified for each model. For SMPS units, most variation in P(in) is actually due to variations in I(out).

System powering design using equation (5) still requires knowledge of actual Power Factor and an iterative approach. However, system simulator data shows that station AC current is nearly independent of AC voltage. If AC input current is truly constant, system powering design would be greatly simplified.

Referring back to the system simulator data, notice that in each case, Power Factor increases at nearly the same rate as AC input voltage decreases. The increase in Power Factor due to the effects of cable resistance demonstrated by the test configuration in Figure 8 is complemented by a decrease in voltage due to the same cable resistance. It follows that equation (5) may therefore be further simplified to:

$$I(in) \approx \frac{P(in)}{K} \tag{7}$$

Where K = SMPS system power constant

While a value for "K" could be derived using equation (7) and measured data for I(in) and P(in) for each station, errors due to Power Factor related current phase errors can be resolved by using measured data for LPS output current and total station power consumption (excluding cable loss) according to the following:

$$K = \frac{P(in)\ total}{I(out)\ LPS} \tag{8}$$

Using equation (8) and data from SMPS trial runs shown in Figures 12 through 19, the following "K" values have been calculated:

FIGURE	CONFIGURATION	"K"
12	330 MHz upgrade to SMPS (trunk-only)	44
14	450 MHz transport upgrade to SMPS	44
15	550 MHz typical Power Doubling	44
16	550 MHz typical Feedforward	42
17	550 MHz ultra-low-density Feedforward	42
18	550 MHz low-density Feedforward	41
19	550 MHz high-density Power Doubling	44

Notice that most "K" values are within a few percent of each other. If an average "K" value of 43 is used for 60 VAC system powering design using equation (7), for typical cases calculated LPS output current agrees within 3% of measurements.

SUMMARY

The "system simulator" addresses two issues which affect all systems using switched-mode power supplies: the magnitude and effect of Power Factor on system performance, and the simplification of system powering design.

System Power Factor as measured in the cable and at the LPS output is only slightly lower than that for a conventional system, even though SMPS Power Factor differs significantly from that of a conventional series-regulated unit. Furthermore, there is no significant difference in Power Factor at the 120 VAC LPS input.

The existence of significant Power Factors in CATV systems using switched-mode power supplies complicates the already complex task of system design using these devices. The system powering approach proposed in this paper takes advantage of the "constant input power" characteristic of the switched-mode power supply, and avoids dealing directly with Power Factor. The new design approach is simpler and more accurate than previous methods.

In a simple upgrade from linear to SMPS units, savings in overall power consumption are substantially higher than the improvement in power supply efficiency alone, due to the sizable reduction in cable losses. Overall, SMPS units are far better suited to CATV use than linear types due to their high efficiency, constant input power characteristic, and their capability for operation across a wide input voltage range.

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