Renovating the Scott 222C, Part 5:

Output Tube Alternatives to the 7189 and Tube Matching Tests

By Charles Hansen

The 7189 is no longer manufactured. It was developed in 1958 for hi-fi use, and produced by Amperex, Mullard, GE, RCA, Sylvania, Telefunken, Tung-Sol, and Westinghouse.[9] The four output tubes that came with my 222C have the Telefunken logo.

You often see eBay tube listings for EL84/6BQ5 tubes as "equivalent" to the 7189. A pair of EL84s in Class AB1 push-pull are only rated for 11W, and require a higher bias current of 31mA per tube. More important, the plate and screen are limited to 250V. While you can probably install the 7189 in an EL84 socket without harm or benefit, installing EL84s in a Scott 222C or 222D is a death sentence for these tubes. You would need to change the power transformer in a 222C or 222D (as well as the 299A or 299B) to use the ubiquitous EL84, which is still readily available thanks to the guitar amplifier manufacturers.

Another tube often portrayed as a 7189 equivalent is the Russian-made "6П14П" (the Cyrillic characters translate to the English *6p14p*). I purchased four "matched" 6П14П tubes on eBay and ran the four 7189 and 6П14П tubes on the Audiomatica Sofia tube curve tracer. Typical plate curves are shown in **Figs. 72** and **73**, respectively. I ran the Sofia matching program, and found two of each tube type to be fairly well matched. I marked them for reference.

For those familiar with the Sofia matching test, the lower the number the better the match, with a match of less than 100 being very close. My matching numbers in order are

7189 matched = 110
6П14П matched = 186
6П14П unmatched = 1276
7189 unmatched = 1439

I don't know how much matching Scott did for their tubes, but the four so-called "matched 6П14П" tubes I purchased had a number "78" that was written in black marker on each tube. These tubes had two different 4-digit numbers etched below the part number, two were 0683 and two were 8910. The matched set had one of each of these codes. Perhaps they were put on a tube tester and sorted by meter readings, but that hardly qualifies them as dynamically matched in the push-pull audio sense. There are plenty of tubes being offered as "matched sets" on eBay. My experience is let the buyer beware!

The 6П14П data sheet has both plate and grid curves, but I have never seen curves for the 7189 or 7189A. Feel free to use the curve in **Fig. 72** for your own use, with the caveat that these 7189 tubes may be 40 years old and I do not know how many hours they have on them. (You can see all four plate curves for each tube type on www.audioXpress.com.)

I measured the Sofia plate curve incremental Gm, μ, and Rp at 22mA plate current and 410V plate voltage (**Table 9**). The 7189 is a higher μ tube, while the 6П14П has a lower Rp. The 7189 is a lower wattage tube, requires a lower grid resistance for self-bias, and has half the rated distortion. The 6П14П is a Soviet military tube with a rated life of 3000 hours.

There are some differences between the 7189 and the 6П14П specifications and measurements. The 6П14П plate and screen

FIGURE 72: 7189 plate curve (typical).

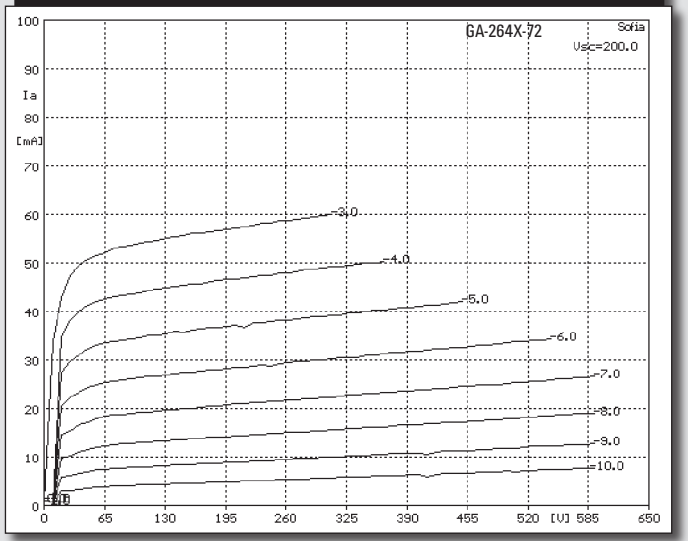


FIGURE 73: 6П14П plate curve (typical).

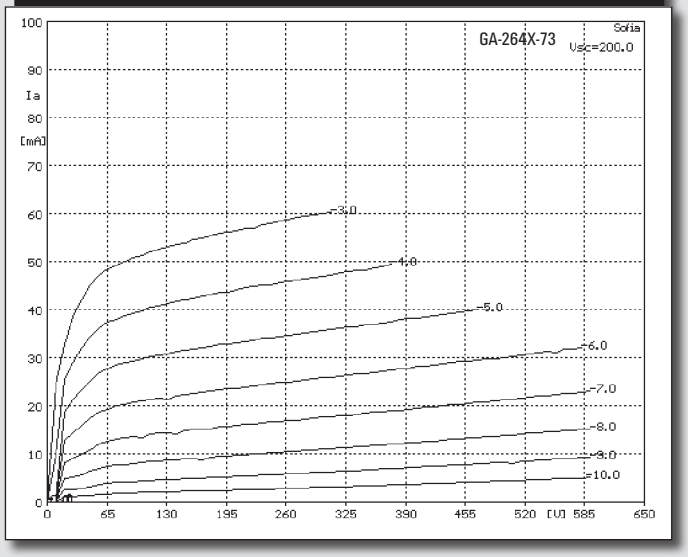


TABLE 9: COMPARISON OF 7189 AND 6П14П MEASUREMENTS AND SPECIFICATION DIFFERENCES.

Tube	7189	6П14П
Gm	7.88	7.63
μ	572	382
Rp	72k6	50k1
Pw	12W	14W
Rg	300k	1 Meg
THD	4%	8%

voltages are called "Limited Operating Values" and are identical to the 7189 ratings. I don't know whether this correlates to the RMA Design-Center Rating or the Design-Maximum Ratings Systems, or perhaps another system devised by the Russian military.

Two other variations of the 6П14П exist. The 6П14П–V has a maximum plate and screen voltage of 500V and a rated life of 1000 hours. The 6П14П–EV has the same higher maximum voltages and a rated life of 5000 hours. Both are designed and specified for high vibration and shock environments.

In order to judge their sonic performance, I installed the 6П14П tubes in place of the 7189s, with the two better matched tubes in channel B again. The initial bias readings were low—about 16mA. I adjusted the bias to 22mA per tube, and then repeated the one-half hour run-in followed by the listening tests. The bias current was still 22mA after one-half hour.

There was no difference between the two tubes in terms of the hum level or its predominance in channel A. The 6П14Пs had much better control over the bass, with good extension and fine acoustic bass accuracy. The treble was a bit more muted but still had nice midrange detail. Again, I preferred the overall sound with the NHT speakers connected to the 8Ω taps.

TABLE 10: COMPARISON OF AMPLIFIER OUTPUT IMPEDANCE, 7189 VS. 6П14П.

Freq	7189 4Ω tap	7189 8Ω tap	6П14П 4Ω tap	6П14П 8Ω tap
20Hz	1.97Ω	3.07Ω	0.47Ω	0.70Ω
1kHz	0.85Ω	1.28Ω	0.50Ω	0.74Ω
20kHz	1.09Ω	1.94Ω	0.71Ω	1.22Ω

With the 6П14Пs still in place, I switched to the Extra input, which brought the steep input filter, the tone controls, and the 12AX7 preamp tubes into play. The bass extension was not as good as with the Direct input, but was improved over the 7189s even using the Direct input with those tubes. When I tried to restore the treble response with the tone controls, the upper midrange and low treble took on a bit of glare and stridency that I did not hear under any condition with the 7189 output tubes in the modified 222C.

Perhaps with more hours on them, the 6П14Пs may lose this treble edginess. I hope so for those who enjoy the classic older audio equipment. Thus far no manufacturer has stepped up to produce the 7189/7189A. Assuming the 6П14Пs remain available, they may eventually be the only recourse for re-tubing the vintage amplifiers that used the 7189 or 7189A.

After my listening session, I performed some limited measurements of the two tube types with just the Direct Input to the power amplifier.

The 6П14П produced a lower output impedance at the 4Ω and 8Ω taps compared with the 7189 (**Table 10**). The output power on the 6П14П plate curve is shown with R_A equal to 5k2,

FIGURE 74: Comparison of THD vs. frequency, 7189 vs. 6П14П tubes.

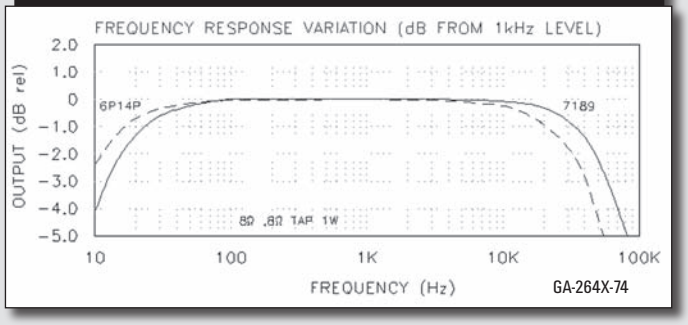


FIGURE 75: Comparison of THD vs. frequency, 7189 vs. 6П14П tubes.

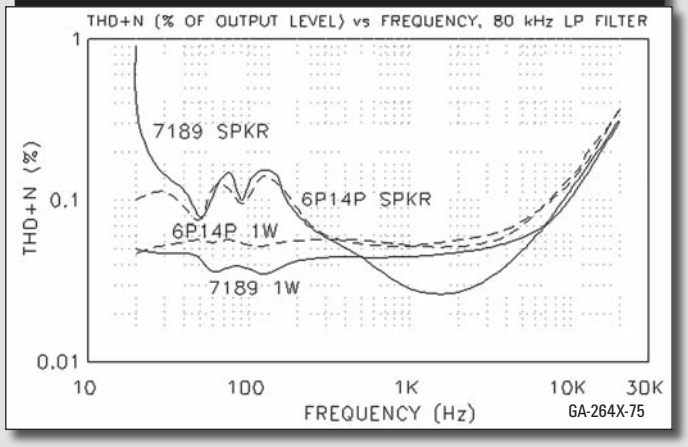


FIGURE 76: Comparison of THD vs. output power, 7189 vs. 6П14П tubes.

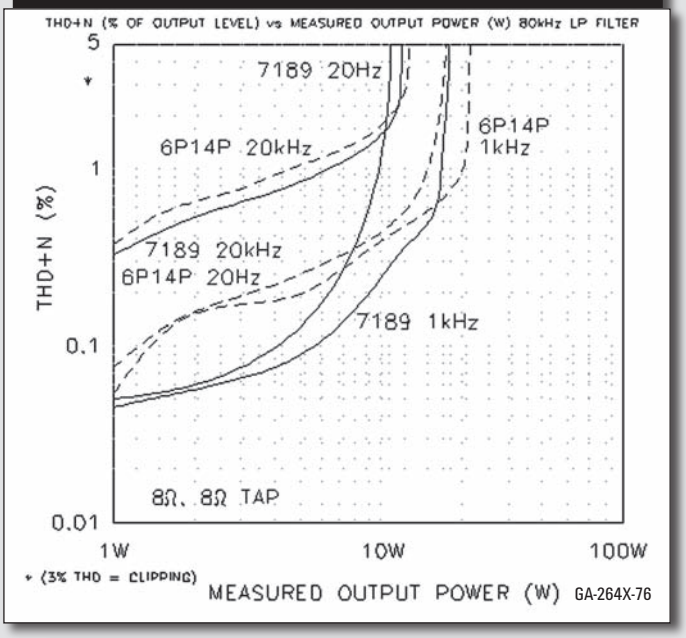
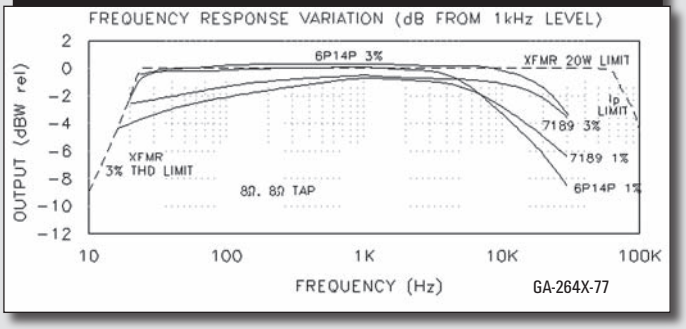


FIGURE 77: Comparison of maximum output power, 7189 vs. 6П14П tubes.



whereas the 7189 uses an 8k total push-pull impedance transformer. This probably makes sense given the lower Rp of the 6П14П.

The frequency response for the 7189 (solid line in **Fig. 74**) favors the higher end of the band, while the 6П14П (dashed line) is more effective at the low frequencies. Both curves are for 1W output with an 8Ω load on the 8Ω tap.

A comparison of the THD versus frequency at 1W into 8Ω and the loudspeaker load is shown in **Fig. 75**. A comparison of THD versus output power at 20Hz, 1kHz, and 20kHz into 8Ω for each tube type is shown in **Fig. 76**. Again, the 7189 is shown with a solid line and the 6П14П with a dashed line. I was able to squeeze more power from the 6П14П pair than the 7189 pair before reaching 3% THD. At 1kHz into 8Ω the difference is 20.6W versus 17.3W.

Figure 77 compares the frequency response of the power amplifier section of the modified 222C at 3% THD with the two tube types in a manner similar to **Fig. 5** (Part 1). The output load is 8Ω at the 8Ω tap. The 6П14П at 3% THD actually exceeds my transformer 20W limit line between 30Hz and 8kHz. I also added 1% THD curves to this graph to show how close they are in the important midrange frequencies. The THD versus output power curves in **Fig. 76** are nearly vertical lines above 1% THD.

TO MATCH OR NOT TO MATCH

I decided to try to find whether there was any measurable difference in terms of the frequency response, distortion, and the distortion products that are generated between pairs of matched and mismatched tubes. Recall that using the matching program data from the Sofia, the best matched pair of 7189s was better matched than the best pair of 6П14Пs. However, the worst matched pair of 6П14Пs was better matched than the worst matched pair of 7189s. With this caveat in mind, note my findings which follow. I ran each tube pair for 15 minutes before I made my measurements.

First, there is virtually no difference in amplifier frequency response (8Ω load on the 8Ω tap at an output power of 1W, not shown) between matched and unmatched pairs of tubes. This may be because designing around the output transformer limitations swamps out any tube performance limitations.

Figure 78 shows the THD versus frequency for matched and unmatched sets of the Telefunken 7189 and the Russian 6П14П. You can see here that the Audiomatica Sofia software matching program did a good job of predicting the order in which the selected sets of tubes produced their distortion.

The matched 7189s are the best, the mismatched 7189s the worst, with the 6П14Пs lying in between the two 7189

FIGURE 78: Comparison of THD vs. frequency, 7189 vs. 6П14П tubes, matched and mismatched.

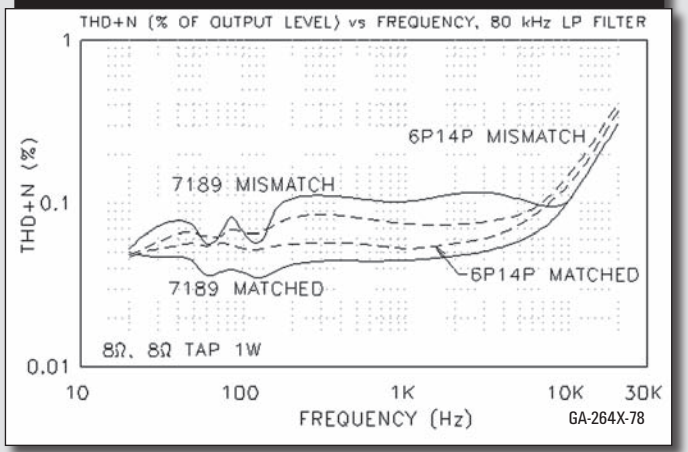


FIGURE 79: Comparison of THD vs. output power, 7189 vs. 6П14П tubes, matched and mismatched.

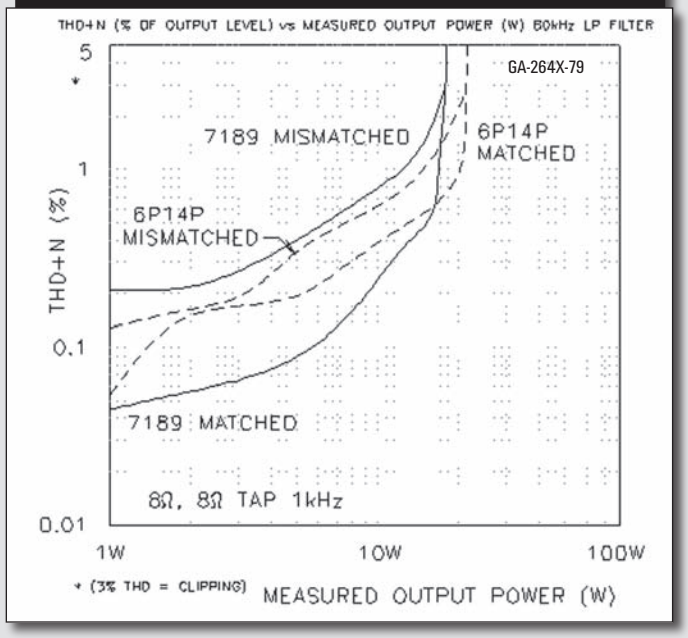


FIGURE 80: Spectrum of 50Hz sine 5W matched 7189 tubes.

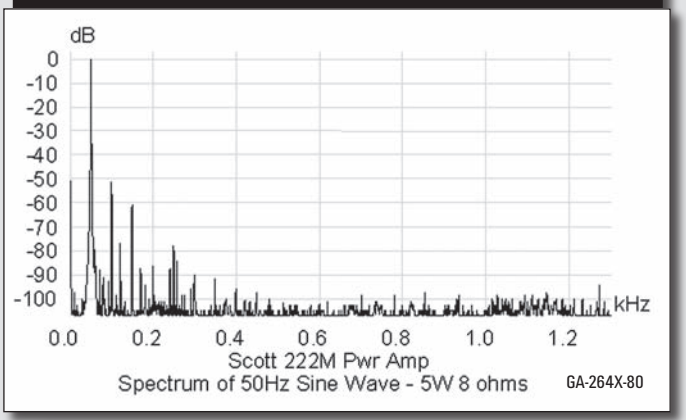
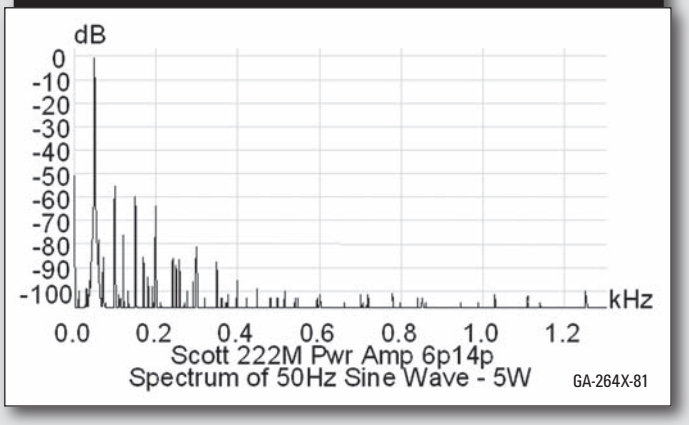


FIGURE 81: Spectrum of 50Hz sine 5W matched 6П14П tubes.



curves. The 7189s also show a greater dip in THD at the 60Hz and 120Hz points on the frequency axis. This may mean that the lower impedance 6П14П does a better job of rejecting power supply hum. Also, above 10kHz the two different sets of 7189 tubes converge to the same distortion level.

Figure 79 shows the effect of tube mismatch on THD versus output power. The software matching program again did a good job of predicting the order in which the selected sets of tubes produced their distortion. The maximum output power for a given tube type above 3% THD seems to be the same, whether the tubes are matched or not.

Figure 80 represents the 7189 matched pair and **Fig. 81** the 6П14П matched pair, where I recorded the spectrum of a 50Hz sine wave at 5W into 8Ω. The second harmonic is higher with the 7189, while the subsequent harmonics are higher with the 6П14П, and it has a lower noise floor. There isn't any noticeable difference in terms of AC line hum. Spectrums of the mismatched tubes (not shown) were similarly close in performance. The harmonics were higher overall but the distribution patterns were the same.

I also performed the multi-tone intermodulation test on the matched set of 7189 and 6П14П tubes. The results for the matched tubes are shown in **Figs. 82** and **83**, respectively. Several of the intermodulation products are higher with the 7189s.

Switching to the poorly matched tube pairs for the MIM test (**Figs. 84** and **85**) show a veritable picket fence of IMD products for the mismatched 7189 tubes, which also includes 60Hz AC line products surrounding each of the even- and odd-order products based on the 9kHz + 10.05kHz + 20kHz test frequencies. The mismatched 6П14Пs had far fewer IMD products and they had lower levels. I calculated the total IMD for the 7189s to be 0.103% while the 6П14Пs were almost half that at 0.057% total.

The MIM root-mean-square of the distortion products measured 0.058% on the matched 7189 set and 0.069% on the mismatched 7189 set. The MIM root-mean-square of the distortion products measured 0.044% on the matched 6П14П set and 0.057% on the mismatched 6П14П set.

The differences are characterized by a higher level of even-order products and a broad distribution of multiples of 950-1050Hz with the mismatched set. Even with the bias on both tubes set to 22mA, the differences in gain result in a failure to cancel the even-order harmonics that characterize the ideal push-pull amplifier. This could be corrected by adjusting the plate resistance in the phase inverter triode section of the 6U8, as mentioned earlier.

Some commercial designs provide a shunt variable resistor to make this adjustment whenever tubes are replaced. Other designs provide for a series variable resistor. In either case, the most common failure mode for potentiometers is an open wiper; connect the wiper to one end of the pot so a wiper failure does not leave the plate circuit open. *aX*

References

9. *Tube Lore*; L. Sibley; Sept. 1996, with supplements 1997, 2002; Chernay Printing.

FIGURE 82: MIM spectrum for matched 7189 tubes.

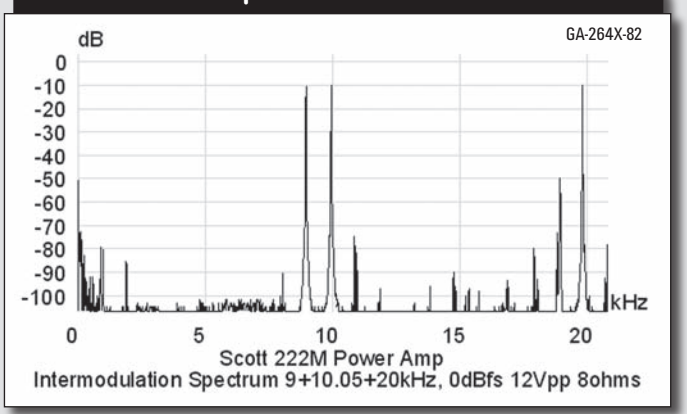


FIGURE 83: MIM spectrum for matched 6П14П tubes.

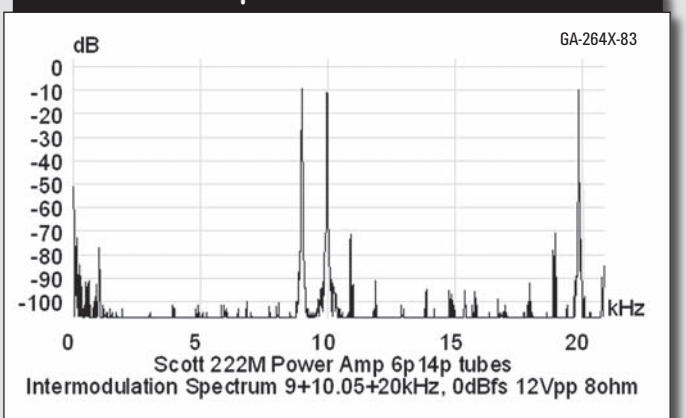


FIGURE 84: MIM spectrum for mismatched 7189 tubes.

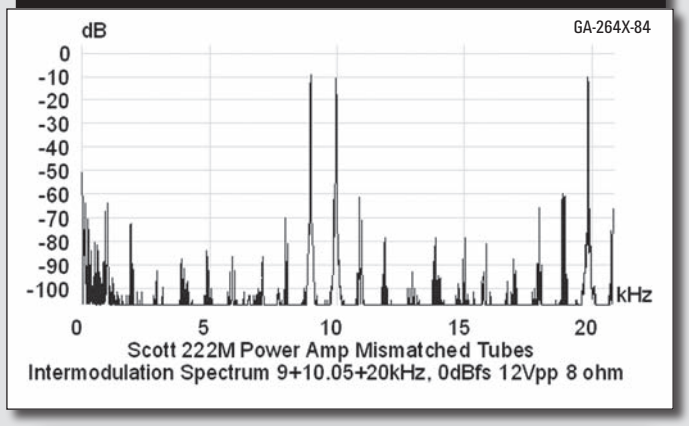


FIGURE 85: MIM spectrum for mismatched 6П14П tubes.