# FM Tuners: The Continuing Survey

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## Not all tuners are created equal, not even in the same price range. Here is the opportunity for the audiophile to find genuine performance differences. Or are amplifiers that much more interesting?

This is the second part of our tuner survey. We intend to have a third part to bring in a couple more models but we pretty much have all the top-of-the-line production tuners covered between these two installments. That tells you how high-priced tuners are selling these days.

Your Editor has asked me to give some indication of how a high-end tuner should be designed. The question implies that the designers of these tuners know less than I do, which is not the case. Each of the tuners has been designed to emphasize the specifications felt important by the designer, under the constraints of how large the bill of materials would be allowed to get. The ultimate tuner would cost somewhere around $3000 to $5000 these days. Day Sequerra is working on such a design for introduction in the summer of 1997, but no others are on the horizon because manufacturers believe they will never recover the cost to create the tuner, given the falloff of this market.

James Bongiorno has shown me his prototype design and it looks really really good on paper, but as of this writing it is a piece of paper and may remain so. (Bongiorno also has some novel amp and preamp designs that stand a much better chance of seeing the light of day. He also showed me some of his work that predates my involvement with ***The Audio Critic***. I would have praised these designs for their innovation if I had known about them.)

Having hedged sufficiently, I'll tell you what I would do if I were assigned to design a super tuner. My priority would be to design a tuner that minimized adjustments. Almost every tuner we have seen has been out of alignment. I would implement everything past the FM demodulator in a digital signal processor. Keeping the demodulator in analog form makes the requirement on the A/D similar to audio A/D. I should note that work on bringing the demodulator into the digital domain is very much a current research topic, with some promising results, but for this discussion let's keep things simple and digitize after the demodulator.

The passband of a composite FM signal runs out to about 60 kHz, so the sampling rate needs to be higher than for an audio ADC, but the dynamic range is a lot less so we can still use the same front end of the delta-sigma modulator but we need a different decimator. Once we have our signal decimated, we can perform all sorts of mathematical operations that are very difficult in analog land. The neat ideas of the Pioneer Elite F-93 (see below) could be made to work reliably in the digital domain, for example. Properly done, signal-to-noise ratios, distortion levels, and channel separation figures would be much better using the DSP approach. Once the DSP has produced the stereo signals from the composite signal, the data could be sent out of the tuner as an S/PDIF signal or it could be converted to analog by an internal pair of DACs.

So what about all those adjustments in the front end, IF strip, and demodulator? (The latter has adjustments only if we go for the ultimate performance of the PLL demodulator instead of the zero-adjustment pulse-count detector.) Well, once we have DSP on board we can do self-test and alignment. The DSP engine can do level measurements across frequency and it can do distortion and noise measurements. The DSP can be connected to DACs that can generate dc voltages to drive varactors to change the resonant frequency of tuned circuits. The DSP in conjunction with a DAC and an up-conversion mixer would form an RF test generator that could be used for the autoalignment and self-test process. Research papers have been published on the use of these techniques in cellular phones.

OK, time to stop dreaming and look at the reality of what is available today.

(Please note that all stations discussed in the use tests were tuned in and received at Richard Modafferi's test facility near Binghamton, New York, unless otherwise noted. The number of these use tests has been increased this time around. Additional details are in the reviews.)

# Accuphase T-109

*Accuphase Laboratory, Inc., Yokohama, Japan, through Axiss Distribution, Inc., 17800 South Main Street, Suite 109, Gardena, CA 90248. Voice: (310) 329-0187. Fax: (310) 329-0189. Model T-109 quartz-lock synthesizer FM tuner, $2995.00. Tested sample on loan from distributor.*

***(The following is a fly-on-the-wall view of the Accuphase tuner test at Richard Modafferi's lab.)***

Hey, Rich, for three thousand dollars this had better be the world's best tuner. Oh, you tested one already and you think it *is* the world's best. I guess that's proof that there is no free lunch in this world. Yes, Rich, I tried to get schematics but Accuphase would not send them, so let's get directly to the use tests. What do you mean I'm going to have to wait for you to realign the front end? How could a three-thousand-dollar tuner be out of alignment? Wait a minute, you are saying you also have to touch up the stereo separation trim pots? Well, at least you won't have to do anything to the FM detector because pulse-count demodulators require no adjustment.

Finally, you're finished. Let's try that 3/4-wavelength indoor antenna first. Gee, it gets signals 120 miles away. OK, let's connect it up to the antenna tower. Hey, we can get 91.3 MHz with a little splatter even though it is at 100 μV and 91.5 MHz is at 30 mV. Yes, Rich, I know your dear old MR-78 gets this signal cleanly but McIntosh doesn't make that one anymore. Look, we have a very slight cross-modulation caused by the 1 V signal on 92.1 MHz. Remember, the Onkyo and the MR-78 are clean in the local mode but they have some cross-modulation in the DX mode. And note the Accuphase has a $2f_1 \pm f_2$ spurious at 106.3 MHz ($f_1$ and $f_2$ are 105.7 and 105.1). Despite this, you can hear a weak signal at 106.3 MHz on the Accuphase, but no signal is heard on the MR-78 and Onkyo.. Let's try the killer 89.5 MHz test (140 miles away). That's the station surrounded by 89.3 MHz (4 miles away) and 89.7 MHz (2 miles away). Looks like the Accuphase has some splatter. Yes, your MR-78 is better than the Accuphase on this test but not by much.

Hey, Rich, I told you we don't have the schematic but you can reverse-engineer it if you want to. What do you mean it is a very ordinary design? So you found double-tuned RF circuits are used on the RF input and mixer input. What else did you find out? The RF transistor is a JFET 2SK241 and the mixer and oscillator is a 2SC2668. But that's just ordinary semiconductors. Rich, look again, it says right here in the literature on this thing that it has a double-balanced mixer, so you missed a transistor. You're sure it has no double-balanced mixer? But Rich, this front end has excellent noise quieting, very good spurious rejection, and therefore wide dynamic range, so something must be different. Oh, it is just good design with ordinary parts. So that's why RF folks get paid so much because RF design is a black art. While you are in there, what multiplex decoder chip does it use. Sanyo LA3401? Oh, that's the one that McIntosh uses. I wonder why they did not use the better LA3450.

OK, let's put it on the bench and see what it will do. Look, the 1 kHz stereo THD is only –74 dB in the wide mode and your stereo IM test is also at –74 dB. Aren't those the best you ever measured? Separation looks good too, with 50 dB at 1kHz and 36 dB at 10 kHz. And look, the broadband noise is below –80 dB. The narrow mode is not as good, but this is a very narrow filter similar to the one in the Onkyo T-9090II. Oh well, 22 dB channel separation is OK across the band, as is a 1 kHz THD of –46 dB and a stereo IM of –49 dB, but doesn't the Pioneer Elite F-93 do better than that? (OK, I know, the F-93 has a bad RF section, so it doesn't matter how well it does in the narrow mode, and its wide-mode performance was real bad.) Rich, did you know that Accuphase guarantees its specifications? Some of them are a little better than what you measured—maybe you need a better FM generator. OK, please calm down; I will not say anything else about your FM generator, and I know the sample we got did not come anywhere close to specs until you aligned it.

Look, this multipath meter function is really useful. It measures the AM modulation on the signals that are caused by multipath and interfering adjacent signals. I bet my cable FM will make the needle move out of the good zone. Rich, you have any idea why they could not give you a separate meter for signal strength instead of using this pushbutton switch to go between the two functions? It does cost $2995, you know. Yes, I know, it has a separate meter-circuit IF, so strong signals don't just pin the meter, but so do the Onkyo and the Elite, and they cost a lot less. I know, I know, they don't have the look and feel of this unit. It does look a lot more expensive, but I don't see three thousand dollars' worth of parts in there, even if it has higher build quality than Onkyo and Pioneer. Why is it built with single-sided PC boards? Yes, I know, the metalwork on this thing is very expensive, and that big shielded power supply is not something you see every day.

By the way, did you notice that if you tune in a weak signal in the wide IF mode, the stereo/mono indicator goes out? You cannot tell if it's stereo or mono. Looks like a logic error to me. Yes, yes, the problem does not happen in the narrow mode, but this thing is three thousand dollars. And did you notice it has no antenna selector? Oh, and do you know why it beeps every time you move the tuning knob that's connected to the rotary encoder? You say it's for blind people. Very interesting, but I wish they'd give you a defeat switch. I don't like to be beeped at. Did you notice that the tuning knob has such a great feel because they put that big flywheel on it? And at least they give you a remote control and balanced outputs for your $2995.

I wonder how long we can keep it. What's that?

Peter is on the phone and he wants the tuner sent to the home office as quickly as possible? You didn't tell him it was any good, did you? Yes, I know, it *is* the world's best production tuner, and you know it's the world's best, but Peter didn't have to know!

## *Followup (Discontinued Model)*
# Harman Kardon TU9600

*Harman Kardon Incorporated, a Harman International Company, 80 Crossways Park West, Woodbury, NY 11797. Voice: (516) 496-3400. Fax: (516) 496-4868. TU9600 "active tracking" AM/FM stereo tuner with remote control, $449.00. Tested sample on loan from manufacturer.*

This is the followup report on the TU9600 I described and analyzed (qualitatively) in the last issue. Since it is now discontinued, with no tuner of comparable quality in the current Harman Kardon line, you will find out whether you got a bargain if you bought one or missed a bargain if you did not.

The RF section is no bargain, with single-tuned circuits at the input of the RF and IF. This is typical at this price point. An earlier, more expensive, and also discontinued tuner (Citation 23) had double-tuned circuits. It came as no surprise that the external-antenna torture test resulted in the entire dial being filled with spuriae from the 1 V signal at 92.1 MHz and the 250 mV signal at 105.7 MHz. Weaker 100 mV signals were also audible as spuriae. But do not get too depressed; with an indoor or simple outdoor antenna you are not going to get the same signal levels as Richard Modafferi does. What you want is sensitivity and the TU9600 has that in spades. Richard got a mono signal form Canada that was 220 miles away. At my place in Pennsylvania the TU9600 did as well as any other tuner I have had my hands on, as long as it was in the Active Tracking mode. Using the plebeian quadrature detector was a disaster, however. One very minor problem Richard found in the Active Tracking mode was that a very strong AM signal (measuring 5 V/m, from a station 600 feet from his house) could be heard at a dead spot in the FM band. If an FM signal were present, it would override this spurious.

One neat feature of the Active Tracking circuit is the ability to create a static offset at the VCO input. This shifts the PLL lock range. A close interfering signal may thus be ignored by the PLL when the lock range is prevented from extending into the band that the interferer occupies. This feature is called Fine Tuning by Harman Kardon. We did not find this feature helped under our signal conditions but it might help under yours. It is a very clever, low-cost idea.

The IF strip has three ceramic filters. The IF amps are one-transistor discrete circuits. Such a circuit may be less expensive than an integrated-circuit IF amp. No phase adjustments are available in the IF strip. The result of this (and perhaps misadjustments in the quadrature detector) is higher distortion, –54 dB in the normal mode and –48 dB in the Active Tracking mode. Do not feel too bad, though; the $900 Pioneer Elite with the world's most complex detector circuit has only 2 dB better distortion. The Sanyo LA3450 multiplex decoder did strut it stuff. Stereo IM was a state-of-the-art –75 dB in normal mode, dropping to a very good –60 dB in Active Tracking. Channel separation was better than 40 dB across the board. The frequency response of the tuner was up about 1 dB at 15 kHz. AM was typical for tuners of today, which is to say an ancient five-tube table radio would blow it away.

This little tuner even includes A/B antenna switching, as well as high blend. As I said, in the Active Tracking mode it did as well as anything in my system. If it were still around, I would include it under my recommendations. I hope Harman Kardon, makers of a number of great tuners in the past, will replace this unit as well as the more expensive Citation 23.

## *Followup*
# McIntosh MR7084

*McIntosh Laboratory, Inc., 2 Chambers Street, Binghamton, NY 13903-2699. Voice: (607) 723-3512. Fax: (607) 724-0549. MR7084 AM/FM stereo tuner, $1500.00. Tested sample on loan from manufacturer.*

McIntosh's only currently made tuner was introduced and given the once-over by the Editor in the last issue. This is the promised followup after use tests and measurements.

The FM has an audible 500 Hz beat note on signals from 87.9 to 90.0 MHz. It is about 50 to 60 dB down. It may be a PLL loop-filter problem in the electronic tuning system. FM selectivity was good enough to get a station 140 miles away at 91.5 MHz between a station 75 miles away at 91.3 MHz and a station 50 miles away at 91.7 MHz. This test was done at night, when the station that is 4 miles away at 91.5 MHz is off the air. We run the test with that station *on* the air when testing the super tuners. With the MR7084, forget it; its selectivity is not good enough. The tuner could get a station 220 miles away, showing it has good sensitivity if not selectivity. No spurious problems occurred with a 250 mV signal at 105.7 MHz. A weak signal at 105.3 MHz could not be tuned in because of the lack of selectivity (recall the tuner has no narrow IF mode) but not because of a spurious problem that affects so many other tuners here. With a 1 V signal at 92.1 MHz cross-modulation at 91.7 MHz is audible, but it looks like that may be a problem with the tuner's sensitivity, not the RF section. We look for a $2f_1 \pm f_2$ spurious signal ($f_1$ and $f_2$ are 105.7 and 105.1 MHz) that can cover a weak station at 106.3 MHz. The weak spurious signal at 106.3 MHz could not be heard but 106.1 MHz came in noisily at that location. Insufficient selectivity prevented us from seeing if the spurious signal was present. The 106.1 MHz station was clean when we tuned to it because of the good spurious response rejection of this tuner. Other tuners might not get this station. Given the ordinary components in the RF section, performance is remarkably good. Only the Onkyo T9090II, Accuphase T-109, Yamaha TX-950, and Rotel RHT-10 are in the same class. This again shows that superior RF design is achieved by good engineering and black magic. Overall, our use test of the MR7084 showed that the RF spirit is willing but the IF flesh is weak.

On the bench, the THD performance was good, with 1 kHz stereo distortion at –63 dB and 10 kHz IM at –67 dB. What's more, channel separation was state-of-the-art, measuring better than 50 dB across the audio band. Maybe those IF filters do have superior phase characteristics, just as McIntosh claims.

The AM section was badly misaligned. Once aligned, AM performance was very good. A 1560 kHz station 220 miles away came in with no spuriae, even with a 1430 kHz station broadcasting just 600 feet from the test site.

In the area of ergonomics, the preset pushbuttons have a 1 to 2-second delay, which is a pain. Features such as A/B antenna switching, rotary knob tuning, and a serious signal-strength meter are absent here. It is hard to recommend a tuner that has a low whistle on stations below 90 MHz and lacks a narrowband IF mode. If you listen to well-spaced stations above 90 MHz and have always wanted a McIntosh tuner, this might be the one for you, but I would consider a used MR-78 instead. In most cases it will cost less and is so much better than the MR7084.

# Pioneer Elite F-93

*Pioneer Electronics (USA), Inc., 2265 East 220th Street, Long Beach, CA 90810. Voice: (213) 746-6337 [PIONEER]. Fax: (310) 952-2260. Elite F-93 AM/FM stereo tuner, $900.00. Tested sample owned by reviewer.*

Pioneer has an interesting philosophy in the design of top-of-the-line tuners. With each generation they make a major advance—but they remove the advance they made in the last tuner. Take the Pioneer Elite F-99X (and the similar Pioneer F-90) introduced in 1985. It had a highly innovative baseband signal processor using two Pioneer ICs (PA5006 and PA5007). A pulse-count demodulator controlled a switch that chopped a 38 kHz sine-wave carrier signal. This system was discussed in Issue No. 23. *Audio* magazine (November 1985) measured this tuner's stereo THD to be –76 dB at 1 kHz and –60 dB at 10 kHz. Stereo separation was 53 dB at 10 kHz. In 1988, the F-91 was introduced. This had the active-tracking IF strip that offered sharp transition bands and good phase characteristics (again, see Issue No. 23). In addition, it allowed the station to be slightly detuned without incurring a distortion penalty. But for some unknown reason Pioneer had removed the stereo decoder they had had in the F-99X. Instead, they used a PLL demodulator and what appeared to be an analog multiplier for generating the L–R signal. By doing this they retained the approach they had used in the F-99X, demodulating R+L and R–L, and then forming the sum and difference to get L and R. As explained in Issue No. 23, a switching MPX decoder gets L and R directly from the composite FM signal. The sinusoidal 38 kHz carrier tone required when an analog mixer is used to generate L–R came from the same chip as used in the F-99X (the PA5006). The result of the change in MPX decoder technology was THD which measured twice to five times that of the F-99X, as reported in the August 1988 issue of *Audio*. Strangely, no mention of this backward progress was made in the review.

Now we have the F-93 with a novel stereo noise-reduction filter and stereo decoder, but the active tracking IF is gone. Also gone is the PLL, replaced by a (oh no!) quadrature detector. Actually, three quadrature detectors. Two Pioneer PA5008 FM demodulator chips are run parallel to reduce noise by 3 dB. (The Sanyo LA1235 appears to be a lower-noise device, and one LA1235 does the job about as well as any quadrature detector can be expected to.) The analog multiplier block for the generation of the L–R signal is also in the Pioneer chip (PA5008), as are the final stage of the IF strip, the mixer for the quadrature detector (for L+R generation), the signal meter circuit, and the mute circuit (these last items are also part of the LA1235 and similar chips).

In the PA5008 the analog multiplier actually has three inputs: one for the output of the IF strip, one for the delayed signal from the LC filter that is part of the quadrature detector, and one for the 38 kHz sine-wave tone. This suggests that this block demodulates the L–R signal directly from the IF signal by combining the mixer function of the quadrature detector with the analog multiplier function required to decode L–R (I think this is what Pioneer means by direct decode), but I do not have the circuit details of the PA5008 to say exactly what is going on inside the chip. The other mixer in the PA5008 produces the L+R signals from the output of the IF strip and the delayed signal from the LC filter. This is the standard approach for a quadrature detector.

The third quadrature detector employs a strange distortion-canceling system. This third quadrature detector uses a much simpler phase-shift circuit that results in more distortion. The output of this quadrature detector is subtracted from the main quadrature detector output (coming from the two paralleled PA5008 chips) to yield the distortion. This distortion is then summed into the left- and right-channel audio signals at the output of the tuner (after L+R and L–R have been combined to make L and R). A pot adjusts the level and polarity of the distortion being introduced. The object appears to be to cancel some of the distortion in the main signal path. Separate pots are included for narrow and wide mode. But wait, there is more kludge to come! Another set of distortion-reduction pots forms a feedback loop from the output of the analog multiplier in the PA5008 back into the input port along with the 38 kHz carrier signal that is normally connected to this port. The pots are adjusted for best distortion. The exact function of the feedback is unclear, since I do not have a schematic of the analog multiplier inside the PA5008 chip. Different pots are used for the narrow and wide mode.

You would think this complex mess would not work over time and temperature, and you would be correct. *High Performance Review* (Winter 1991–92) measured between –60 dB and –54 dB stereo THD out to 3 kHz. At 10 kHz the number was –40 dB (1%). Once again, a two to five times doubling of the THD over the F-91, or four to ten times over the original F-99X. Now, I thought it was possible that the *High Performance Review* unit had been out of alignment, so I asked Pioneer to align our test sample before shipping it out. It did not help. Our sample measured –56 dB at 1kHz in stereo and our 10 kHz stereo IM test was at –54 dB. These were just about the poorest numbers we got in this survey. Stereo separation was 49 dB at 1kHz and only 36 dB at 10 kHz. That is better than *High Performance Review*'s 32 dB and 28 dB, respectively, so it looks like our sample was better aligned, but even the aligned numbers are much worse than those obtained with the old F-99X.

Let's summarize. In 1985 Pioneer produced a tuner with state-of-the-art FM demodulator and MPX demodulator performance, even by today's standards (only the Accuphase matches it—see above). It had 5 adjustments. The current product has performance that would have been average in 1980. It requires 14 adjustments and uses twice the number of components. Is something wrong with this picture? Pioneer must have thought so because they use a Sanyo chip in their new receivers (see my SX-203 review elsewhere in this issue) instead of their own parts. That Sanyo chip has a higher-speed, adjustment-free VCO that is missing on the F-93 MPX decoder chip (the original PA5006 from the F-99X). It is interesting to see that this low-end Sanyo chip can take on the complex F-93 setup. For example, I had a station with a low-level 19 kHz pilot tone that would not go into stereo on the F-93 but did so with the Sanyo-based tuners we were testing.

One nice thing on the F-93 is the use of individual pots to adjust separation in wide and narrow mode. Another nice thing is that the MPX filters in the audio chain are a GIC-based 5th-order elliptical ladder design using 4 op-amps. That kills the 19 kHz pilot and subcarrier very well. *Audio* reported problems with the F-91, which had a simpler 2nd-order circuit with one op-amp. *Audio*, however, in the typical fashion of the commercial press, reported that they suspected the problem "was peculiar to [their] sample." The circuit used in the F-91 provided only a theoretical 6 dB of rejection at 20 kHz. Even if the pilot-tone canceler was misadjusted, it would have taken divine intervention to make any sample of the F-91 have good subcarrier product rejection.

The RF front-end design of the F-93 looks more promising than the demodulator and decoder, with double-tuned filters for both the RF stage and the mixer. The mixer is double-balanced, with two TV-tuner front-end chips used in the mixer section. Unfortunately, the power supply voltage for the RF stage is 8.5 V, which is lower than in most tuners (usually 12 to 15 V). Perhaps that was why the tuner's performance on our outdoor antenna torture tests was so poor. Another reason may have been that the F-93 does not modify the RF circuits in the local mode as Rotel and Onkyo do but instead has just a 4-position signal attenuator at its input.

Our 1 V signal received at 92.1 MHz caused serious cross-modulation at ±0.5 MHz from the signal frequency. A signal at 91.7 MHz could not be heard clearly. The 91.3 MHz signal that is only 100 μV and adjacent-channel to the 30 mV local signal at 91.5 MHz was receivable but of only fair quality. The 250 mV local signal at 105.7 MHz caused cross-modulation from 105.1 MHz to 106.9 MHz. Activating the RF attenuator eliminates this, but a weak desired signal will also be attenuated. With the attenuator on, we were still able to receive a 10 μV signal at 105.3 MHz. A serious $2f_1 \pm f_2$ spurious occurred at 106.3 MHz (105.7 MHz interacting with 105.1 MHz, which could not be received). We did not find $2f_1 \pm f_2$ spuriae resulting from the even stronger 92.1 MHz, however.

The front-end problems made it impossible to see how well the very complex IF filter worked because the worst-case desired signals were covered with cross-modulation and spurious signals. The IF strip has 8 (count them, eight) filters and amplifiers in the signal path. The first 3 filters are swapped in narrowband mode. I strongly suspect that the last 5 filters are used as bandpass limiters, accounting for this tuner's very high AM rejection of 80 dB. (This is the manufacturer's spec. We did not measure AM rejection.) That specification just would not happen if the tuner had a simpler IF and quadrature detector. Somebody at Pioneer is clearly familiar with the work of Baghdady, since the concepts of narrowband limiters and tracking filters in FM both originate with him. I still cannot understand why Pioneer punted on the tracking bandpass-filter-based IF in the F-91. They claim part of the problem was the number of adjustments required to make it work, but the F-93 IF strip also requires lots of adjustments. It has 6 phase-tweaking adjustments, 3 for wide and 3 for narrow, to correct the phase response of the strip. The F-91 did not need to be phase-tweaked.

On our indoor antenna tests in Pennsylvania the tuner did as well as the other super tuners in this survey because the smaller signals did not overload the front end. The IF strip in the narrow mode brought in weak adjacent-channel signals as well as, but not any better than, the rest of the pack.

OK, is anything really good about this tuner? Well, yes, it has a proprietary MPX noise reduction system that is the only serious attempt, other than Carver's, to deal with noisy FM signals. In the Pioneer, as explained in the last issue, the L–R signal is split into 8 bands. A voltage-controlled amplifier (VGA) block determines how much L–R signal in each band will be subtracted from the L+R signal when the final L and R signals are formed. The VGA is controlled by a noise detector. The more noise in the band, the less L–R signal is allowed out. Two LSI ICs and 18 op-amps are needed in this circuit. Those LSI circuits each have another 22 op-amps plus the 8 VGAs. The good news is that it works. Noise is reduced much more than with a high-blend circuit, and the stereo effect appears to remain intact. The bad news is that even though noise is dramatically reduced, the signal is still more distorted than it is in mono, and you can hear the signal clean up if you switch to mono. How important this feature is to you depends on how important stereo on weak signals is to you. This is the only super tuner that has this kind of function now that the Carver TX-11 is discontinued.

Another neat trick on the F-93 was also explained in Issue No. 23. The L–R signal can be generated using only the lower sideband of the subcarrier in the F-93. This is done using a single-sideband demodulator. Pioneer calls this the S-MPX mode. In a normal double-sideband demodulator you multiply the carrier (for FM stereo the 38 kHz sine wave generated from the 19 kHz pilot tone) with the signal to be demodulated (the composite FM signal). In a single-sideband demodulator you do that and then add in a 90° phase-shifted version from a second multiplier. The input to this multiplier is the composite signal and a 90° phase-shifted version of the carrier. It is very difficult to phase-shift the broadband multiplier output (it is easy for the single-frequency 38 kHz signal), and a circuit that requires 12 op-amps and 38 passives is used in the F-93. The two PA5008 chips are used for the two multipliers. Instead of being paralleled together as they are in normal operation, one PA5008 gets the inphase 38 kHz signal and the other gets the phase-shifted version. A simple one-op-amp circuit generates the 90° phase shift of the 38 kHz signal in the S-MPX mode. In the normal mode the circuit is reconfigured so that no phase shift occurs, allowing the second PA5008 to be paralleled with the first (when in the S-MPX mode, the L+R of this second PA5008 goes unused). True nerds who get the service manual will note errors in the schematic around the 38 kHz phase shifter. You have to trace the board to figure out how it works.

Now we get a clue to what this tuner is about. It looks like the S-MPX circuit was designed first and then they backfilled to get the normal circuit. The normal circuit does not work so well, but the S-MPX is excellent when considering its job of bringing in weak signals with nearby interference. With the S-MPX and narrow filter enabled, we obtained 1 kHz THD of –44 dB, and the 10 kHz IM was –50 dB. Stereo separation was also very good, running about 44 dB at 1 kHz and 36 dB at 10 kHz. These are very impressive results considering that the upper sideband of the multiplex signal is not being used. In practice we did not find the S-MPX mode made much difference under our signal conditions, but it may be just the thing in your signal environment. One is left to wonder how well the circuit would work in a digital implementation, where the nonideal effects in the phase shifters and mixers of this analog implementation would not exist.

The ergonomics of this tuner are very good. Included are all the super-tuner goodies, such as a tuning knob with rotary shaft encoding and a signal indicator that gives signal levels in dBV. There is a separate IF strip, a detector circuit (another PA5008), plus an A/D converter to make this work. The LED display that gives the signal level also shows the preset station number. Why for $900 you cannot have separate LEDs for each function is beyond me. Other goodies include 10 kHz fine tuning (which can sometimes help under bad signal conditions by allowing the tuner to move away from a strong signal), variable and fixed line outputs, A/B antenna selection, and a tuning mode that allows direct entry of a station's frequency. The autoselect operation mode does not appear to do as well as that of the Onkyo T-9090II. It never went into MPX noise reduction or mono mode even when the signal clearly needed it. It also will not update automatically if signal conditions change, the way the Onkyo does. Oh, and I forgot to mention the F-93 does not have a remote control, although you can control it with other Pioneer equipment.

The F-93 has AM, which Richard Modafferi tested. He notes it has variable selectivity, and the noise figure is good. From his upstate New York site he could get Toronto and New York City. Richard has a station broadcasting at 1430 kHz 600 feet away. That wiped out everything above 1100 kHz. He notes that any 1950s vacuum-tube table radio would have no spuriae.

When you open up the F-93, you see one of the most complex tuners ever made. Construction is typical of mass-market Japanese equipment, but you can see $900's worth of stuff. Now, engineers have a principle called KISS (Keep It Simple, Stupid!) and the Pioneer F-93 violates KISS with a vengeance. The result is performance that is mediocre at best in normal operation or with strong signals. On the other hand, it can under some weak signal conditions deliver better reception than any other tuner currently available, and it does that for me. I actually bought this thing. But purchaser beware! Get a home trial before you use your credit card. The F-93 could do great things for you or it could make things worse. If you are using an outdoor antenna, or trying to receive a strong clean signal, then worse is more likely than better. Also note that this tuner has more adjustments than any other. At least 50—count them, fifty. Many of the adjustments interact, so it takes a long time to adjust this set, and adjustments will drift with time and temperature. What you get out of the box may not be properly adjusted. I asked Richard (a true believer in KISS) to tweak up my unit, but he declined. I was not surprised by his answer.

# Rotel RT-990BX

*Rotel of America, Equity International, Inc., 54 Concord Street, North Reading, MA 01864-2699. Voice: (508) 664-3820. Fax: (508) 664-4109. RT-990BX stereo FM tuner, $749.90. Tested sample on loan from manufacturer.*

This is the lower-cost "stripped" version of the Rotel RHT-10. The folks at Rotel decided to send us one after they calmed down about the review we had given one of their power amps. The tuner is almost identical to the RHT-10. The high-blend function is gone. The signal-strength display is a set of 5 bars instead of the numerical readout of the RHT-10 (the separate meter amp is still included, only the display has changed). Board construction and layout are almost identical, with most parts on the board identical between the two units, including the critical stuff like the IF filters. Resistors remain metal film. Pioneer, Sony, Onkyo, and Yamaha use carbon resistors. The RHT-10 does have a better enclosure and a toroidal transformer, but nothing I saw would lead me to expect a difference in performance between the two tuners.

One nice feature of the RF section of both the RT-990BX and the RHT-10 was not explained correctly in my RHT-10 review in the last issue. I wrote that the RF section can be bypassed as in the Onkyo. In fact, it is not like the Onkyo. In the local mode the RF section remains active but another LC circuit is connected at the RF input. This triple-tuned filter improves selectivity at the RF input but at the cost of some insertion loss and hence reduced sensitivity.

In actual use, the RT-990BX turned out to be as good as, or better than, the RHT-10 in some respect but not others. On our killer 91.3 MHz test only slight splatter was heard from the 200 times larger signal at 91.5 MHz, provided the RF attenuation was engaged. Similar results occurred with the RHT-10. The RT-990BX cross-modulated badly on the 1 V signal in our 92.1 MHz killer test, and 91.7 MHz could not be received even with the attenuator on. The RHT-10 had no problems with the 1 V signal at 92.1 MHz and 91.7 MHz could be received. We also found serious $2f_1 \pm f_2$ spurious signals ($f_1$ and $f_2$ are 105.7 MHz and 105.1 MHz) at 106.3 MHz. The station at 105.7 MHz produces a 250 mV signal. Obviously the very weak 106.3 MHz could not be received, but in addition the signal at 106.1 MHz could not be received either. The attenuator again made no difference. Notes on the 106.1 MHz signal are not in the evaluation of the RHT-10, which probably indicates the RHT-10 received it. The signal at 105.3MHz (10 μV) was received on the RT-990BX. So cross-modulation from 105.7 MHz was not a problem. The tuner did get a 3 μV (75 miles away) signal at 88.3 MHz that was surrounded by adjacent-channel local signals, but crosstalk from the signal at 88.5 MHz was heard. These results were good, but why the RHT-10 did much better is a mystery. Perhaps the board layout changes (which would have to be very small, since the layout looks the same to me) caused some coupling that does not occur on the RHT-10. Perhaps an alignment problem in the RT-990BX caused the differences, although the tuner did not appear to be out of alignment. It could also be due to variations in the RF components between the two samples.

On audio performance things were reversed. Measured performance showed a 1 kHz THD of –72 dB, but recall that the Rotel RHT-10 did only –60 dB. Variability of the quadrature detector coil is responsible for these very different results. With age, drift will occur and that low distortion may not last. Even changes in temperature could change the results. The 10 kHz IM was also very good at –71dB. In the narrow mode the 1 kHz distortion was –45 dB and the IM distortion was –58 dB. Channel separation was 44 dB at 100 Hz, 55 dB at 1kHz, and 38 dB at 10 kHz. Narrow-mode numbers were only 3 dB worse, a very good result. The RHT-10 was less good in all these tests. The RT-990BX has the same very sophisticated MPX decoder as the RHT-10 except for a change of output op-amp. They went from an AD847 to an NE5534. No big deal, since the change, if anything, helped the performance of the RT-990BX. The high pilot tone of the RHT-10 was not present in this tuner. The canceler circuit must have been better adjusted. The output filter is still 2nd-order with no finite zeros. That will let a lot of subproduct out the end of the tuner.

The quadrature decoder in this sample of the RT-990BX is about the best we have seen but it is the luck of the draw, since our RHT-10 sample had worse performance. Contrast this to two samples of the Accuphase T-109. Both had near identical performance because a pulse-count demodulator was used. It requires no adjustment. It is impossible to tell whether the less good RF performance of the RT-990BX is due to component variations and alignment, or a systematic change from the RHT-10 in the RF stages' performance. Despite this, as only very large input signals give the RT-990BX problems, it still is a lot of tuner for the money provided you do not need some of the features found on other tuners (multiplex noise reduction, A/B antenna selection, tuning with a knob, AM, or a signal-strength meter calibrated in volts), and it is therefore highly recommended.

# Sony ST-SA5ES

*Sony Electronics, Inc., 1 Sony Drive, Park Ridge, NJ 07656. Voice: (201) 930-1000. Fax: (201) 930-4748. ST-SA5ES AM/FM stereo tuner, $800.00. Tested sample on loan from manufacturer.*

Often readers will ask which companies produce the best products. Unfortunately it does not work that way. While some companies, such as Sony, produce more than their share of winners, and most high-end tweako companies can almost be guaranteed to produce products that are losers (at least from the engineering point of view), you still cannot tell what an individual component will do until you test it. So we had to test this top-of-the-line Sony tuner to see if it is a winner or not.

The ST-SA5ES tuner is similar to the 10-year old ST-S700ES. New features such as A/B antenna switching and rotary knob tuning have been added. Retained is the IF stage, which uses two ceramic filters in the wide mode with two more added in the narrow mode. Two of the IF amps are μPC1163 ICs. The remaining stages are discrete circuits. Separate phase-tweaking coils are provided for mono and stereo operation.

Retained is the PLL FM demodulator. The loop bandwidth is changed in the narrow mode, trading distortion performance for better capture of weaker signals. The VCO is a surprisingly simple one-MOSFET affair that uses a single varactor. It is surprising that this VCO can have good linearity when it is not balanced. In addition to the VCO, a standard diode bridge mixer is used as the phase detector. An M5220P op-amp is used in the loop filter and PLL output buffer. The PLL mixer is driven by a μPC1163H IF amp that in turn is driven by the IF amp/limiter in the Sanyo LA1135. This chip also forms the meter drive circuit. No separate meter-amp path is included. This is a surprise for such an expensive tuner.

The Sony CXD1064S multiplex decoder is retained form the earlier design. This chip looks identical to the state-of-the-art Sanyo LA3450. I strongly suspect it was a codesign between the two companies. Sony had the CXD1064S out first. Often, in these IC development arrangements, the chip cannot be sold in the open market until after some period in which the developers have exclusive rights to it. In the ST-SA5ES, a new hybrid lowpass filter module is added for improved subcarrier rejection.

What has been removed from the ST-SA5ES is the tracking bandpass filters in the RF section. In the older tuner these filters were being shifted to correspond to the instantaneous frequency of the incoming signal. It is unclear why this feature was removed. It may have been a manufacturability problem or an attempt to reduce cost. In any case, it left only four tuned elements. In front of the RF stage there is only a single tuned circuit. A double-tuned circuit precedes the mixer that is not balanced.

New in the ST-SA5ES is an RF attenuator. That is something required for a front end that has poor dynamic range. It did not help. The tuner failed all our difficult outdoor reception tests. Bad spuriae were observed. The signals at 91.7 MHz, 106.1 MHz, and 106.3 MHz discussed in the reviews above could not be received. The stations in our tough selectivity tests were also not receivable. Included in the selectivity tests were stations at 88.3 MHz, 89.5 MHz, and 91.3 MHz that have been discussed above. As already explained in this survey, poor RF performance prevents accurate assessment of a tuner's real-world selectivity since, by definition, a selectivity problem also involves signals with large dynamic-range differences.

Indoors things were better, but not much better. We could still not receive 91.3 MHz because 91.5 MHz was still too strong. Furthermore, 96.3 MHz, 106.9 MHz, and 107.1 MHz were noisy. Since 96.3 MHz is the 9th harmonic of the IF and 107.1 MHz is the 10th harmonic, this noise is an indication that the tuner tailbites. Tailbiting happens when harmonics generated in the IF (which has lots of harmonics because of all the limiting action) get back into the RF stage.

It is unlikely that the tuner was defective or missaligned, since our instrument-based tuner tests came out OK. In the wide mode, 1 kHz distortion was –67 dB and in the narrow mode –47 dB. The 10 kHz IM results were –71 dB and –54 dB for the wide and narrow modes, respectively. Channel separation is 40 dB or better in the wide mode and 34 dB or better in the narrow mode.

AM use test results showed good selectivity and quieting, but like the FM section the AM had poor performance with respect to spurious responses and cross-modulation. The tuner was able to receive 770 kHz (WABC, New York City) at a distance of 195 miles in Binghamton, NY, but above 1200 kHz everything was wiped out by the very strong local signal at 1430 kHz. The tuner did receive the strong signal well, however, indicating good AGC action. The AM selectivity switch also proved useful.

Obviously, Sony needs to reengineer the front end of their top-of-the-line tuner to improve dynamic range and eliminate the tailbiting before we can recommend it.

# Yamaha TX-950

*Yamaha Electronics Corporation, USA, 6660 Orangethorpe Avenue, Buena Park, CA 90620. Voice: (714) 522-9105. Fax: (714) 670-0108. TX-950 AM/FM stereo tuner, $429.00. Tested sample on loan from manufacturer.*

It was not our intention to save the clear bargain in this survey until the end, but it so happens that this Yamaha tuner is it, and we do things alphabetically around here. At a mere $429 we have here a tuner that is clearly inferior only to the $2995 Accuphase T-109 and no other. The FM front end has a very wide dynamic range. Perhaps it should be no surprise that the topology of the front end is similar to that of the Accuphase. Double-tuned circuits are used before and after the RF stage. The mixer is not balanced. An RF attenuator can be engaged at the input, and with that function activated we had no cross-modulation or spuriae to interfere with reception of stations that could be received by this tuner.

The IF stage consists of discrete IF amplifiers whose complexity varies from one to six transistors. Two ceramic filters are used in wide mode, with another added into the IF section in narrow mode. Selectivity of the IF strip was good enough to receive 91.3 MHz with some audible splatter. The Accuphase and Onkyo have more selective filters and less splatter. The old McIntosh MR-78 has still more selectivity and no splatter. The very weak signal at 106.3 MHz that is normally covered up with spuriae was still not receivable because the local signal at 106.5 MHz interfered as a result of inadequate selectivity. For the same reason the difficult stations at 88.3 MHz and 89.5 MHz also could not be received. Moving indoors produced closer to excellent results. All Pennsylvania torture tests were passed. In Binghamton, NY, performance was also good indoors, although lower adjacent-channel selectivity did prevent the tuner from receiving at least one station that those with greater selectivity could get.

The demodulator and stereo decoder also show excellent performance. In the wide mode the 1kHz distortion in stereo was –71 dB. That is a hairsbreadth away from the Accuphase. In the narrow mode the 1 kHz distortion rose to –61 dB. Recall that the unit's narrow mode is not as narrow as that of the best super tuners; thus these distortion numbers are better than in the narrow mode of those tuners. This is the reason why Onkyo has three IF modes. Stereo IM test results were also excellent (2 dB better than on the Accuphase!), with –76 dB in the wide mode and –68 dB in the narrow mode. Channel separation over the full band was 46 dB or better in the wide mode and 40 dB or better in the narrow mode, also very good results.

The excellent performance of this tuner is no doubt due in part to the Sanyo LA3450 multiplex decoder used in the design. The 4th-order passive filter that follows also helps by doing a good job suppressing subcarrier products. But the low distortion numbers also result because the FM demodulator is doing its job well. At this tuner's price you would think you could only get a quadrature detector, but it turns out that an even older technology, the ratio detector, is used!

Those old enough to run for president may recall all the ink that was spilled in discussing the advantages and disadvantages of the Foster-Seeley "discriminator" and the ratio detector. These two detectors, along with the quadrature detector, use similar methods to demodulate FM. A time-delay circuit approximates a differentiator that converts the frequency-modulated signal to one that is both frequency- and amplitude-modulated. An AM demodulator then recovers the signal. In the quadrature detector, the AM demodulator is a balanced synchronous detector. In the Foster-Seeley, it is a balanced envelope detector that uses a lot more passive components. The transition from detectors like the Foster-Seeley to the quadrature detector occurred because the latter detector requires fewer passive components, but it needs a mixer circuit that became easy to manufacture only with the onset of IC technology.

The ratio detector looks very similar to the Foster-Seeley detector—one diode is reversed and a large capacitor added. But those changes make a big difference. The ratio detector performs the function not only of an FM demodulator but also of a dynamic limiter. It has internal AM rejection unlike other circuits in the time-delay-differentiator/AM-demodulator category. The downside of the ratio detector is that it is not balanced. That should translate into more distortion but it does not in the case of the TX-950. Careful selection of the passives, a time-delay differentiator design that is accurate over wide frequency deviations, and a modified topology that uses an op-amp (NJM2068S) as differencing amp in the demodulator account for such an amazing performance in this classic circuit. Please note that the circuit works well only if it is precisely adjusted. It turned out that the Yamaha was one of the few tuners that did not need any tweaking to get it to perform well.

One more reason for the low distortion of the TX-950 is that it uses a high-tech form of automatic frequency control. The PLL frequency synthesis brings the station in. Then, once the station is acquired, control of the varactors in the front end of the tuner is switched over to the AFC system. Even if the incoming signal is slightly mistuned, the AFC system will still ensure that the IF signal is centered around 10.7 MHz, where minimum distortion occurs. The AFC system also has the potential to create a local oscillator signal with less phase noise because the control voltage to the varactor can be more heavily filtered. This could improve signal-to-noise ratios and reduce spurious interference.

The AFC system is not the same as found in your old '60s tuner. It is built with a totally separate IF strip and FM discriminator. Yamaha uses the Sanyo LA1266 AM/FM receiver chip to do this (they also use this for the AM section). Yamaha's AFC used to have the problem of switching between the two tuning systems on weak signals—at least my 10-year old Yamaha T-70 liked to do this. The TX-950 has a more advanced design that does not have this problem. The meter circuit of the TX-950 also uses the LA1266 to provide a wide range of signal-strength indications, just like the state-of-the-art tuners.

Despite its low price, all the high-end features are on the Yamaha. They include A/B antenna selection, a tuning knob that drives a shaft encoder, call-letter display option, 40 presets, etc. (One small omission is the absence of threads on the 75Ω antenna jacks; they accept only push-on connectors.) Even the AM tuner is good. No spuriae or overload occurred from the local 1430 kHz signal, and the weak signal from WQEW in New York City could be tuned in. Richard notes that the AM tuner section works as well as 1950s vintage six-tube radios. How comforting that modern electronics has made no progress in 40 years.

### Recommendations:

The best production tuner is the **Accuphase T-109**, and at its price it had better be. The **Yamaha TX-950** comes quite close to the Accuphase at a much lower price. Lacking only the ultimate in selectivity (but achieving better audio performance in the narrow mode as a result), the Yamaha is clearly a best buy. Obviously, the build quality and appearance of the TX-950 are those of a typical Japanese audio component. The only tuner in this survey, other than the Accuphase, that uses higher-quality parts and can be recommended is the **Rotel RT-990BX**. That tuner also puts the emphasis on high-end audio-circuit design, if you care about such things. To achieve the low $750 price point and still use quality parts, Rotel had to leave something out, and what they left out were features. The **Onkyo T-9090II** is still the DX champ at a price under a thousand dollars, but this is an old design and the multiplex decoder does not perform as well as those of the other recommended units. The Onkyo's build quality is similar to the Yamaha's. The **Magnum Dynalab 205** 'Signal Sleuth' RF front end is also recommended for potentially improving weak signal reception when using good indoor antennas. ◊

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## David Rich on Yamaha AX-570 *(continued from page 54)*

this one application too expensive. Electrolytic capacitors are in the input, output, but not the more capacitor-sensitive feedback loop, of the line stage.

In between the line-stage output and the power-amp input lies the Pure Direct switch. With it engaged, we have completely described the signal path. The signal at the input plugs flows through the input selector to the volume control to the line amp and then into the power amp. If Direct is not engaged, the signal ends up going through a cheap balance control (with detent) and then on to the tone control stage (more cheap controls). If you want to put an active crossover between the preamp and the power amp, you will need to keep the Direct switch disengaged because the loop is not in the direct path. The Pre Out is active all the time to allow connection of a subwoofer in a system that does not need a highpass filter in the main signal path. All low-power circuits are powered from taps on the main transformer. A separate bridge rectifier drives 3300 μF of filtering capacitor. The regulator is in the high-end style, with a simple pass transistor driven from a zener diode reference.

Our measurements yielded the following results:

In the power amplifier section, THD + N reaches a minimum of –94 to –96 dB from 20 Hz to 20 kHz (meaning virtually no dynamic distortion) with a load of 8.15Ω. Clipping occurs at 115 watts. Into 4.17Ω, the 20 Hz to 20 kHz minima are in the –90 to –94 dB range, and clipping occurs at 200 watts. Channel separation, measured at 1 watt output, is 100 dB at the lowest frequencies, decreasing to 70 dB at 20 kHz. Most remarkably, the above figures barely change, certainly no more than a dB or two, when the preamp line stage is included in the loop—with the Direct switch engaged, of course. When the Direct switch is disengaged and all the controls are in the signal path, at least 12 dB of deterioration is observable.

The phono preamp uses a discrete differential pair driving a UPC4570 op-amp. Distortion and frequency response are respectable but would be better if two-gain-stage topologies and better passive components were used. Our measurements in the MM mode showed THD + N minima of –85 to –87 dB at maximum output (approximately 7 V at Tape Out) in the entire audio band from 20 Hz to 20 kHz. In the very high-gain MC mode, on the other hand, the minima were only in the –60 to –64 dB range. RIAA equalization accuracy was ±0.15 dB up to 10 kHz, but at 20 kHz there were inexplicable errors of –0.6 dB (left) and –0.3 dB (right).

Separate wafers on the function selector are used for each tape-monitor output. This prevents self-oscillations. The tape monitors are not buffered, but by setting the tape selector to a position other than the main selected program, you can ensure that the selected input will not be loaded.

The AX-570 comes with a remote control that also controls the CD player, tuner, and two tape decks, provided they are also by Yamaha. One remote instead of five. What a novel idea. The volume control and selector switch are motor-driven for remote operation. A semiconductor switch approach (B&K) offers more reliability but may cause distortion. Engineering involves a lot of tradeoffs, with no single "right" answer. In this case, the Yamaha engineers went for the low distortion figures.

Measured results and use tests of the AX-570 show that $499 will purchase as much electronics as most of us will ever need. That does not mean that spending more is not a rational decision, but it does mean that you are on the steep part of the curve of diminishing returns. Perhaps the only real design flaw is that the ventillation slits in the cover are large enough to allow a child to drop change inside the unit.

As for those of you who want to know "how it sounds"—well, we must not be getting our point across.◊