

Tech Musings

February, 1998

FM wireless broadcasters
Surplus & auction update
A homopolar traction motor
New power measurement chip
Understanding the Faraday Disk

Let's start off this month with a hot helpline topic that has both a useful new solution and a rather long history of caller interest. In particular, let's talk about developments in...

FM Broadcasters

Lots of folks do want to broadcast over the radio. Perhaps for their own "underground" or "pirate" community radio station; to deliver a commercial "please buy my nice house" realtor message; to free a stage or studio performer from trailing wires; for use in wireless modems or in short haul telemetry; for surveillance, alarms, or baby monitors; or simply to couple a portable CD player into any nearby home or car radio.

It only takes a few milliwatts to go a few feet. A hundred feet will need a hundred milliwatts. Your local town coverage may take ten watts or so. As you might guess, the FCC places very stringent limits on what you are legally allowed to either transmit or broadcast. Anything more than 30 milliwatts or so is probably illegal.

The FM band resides from 88.1 to 107.9 Megahertz. All the FM station channels are precisely spaced every 200 kHz. Thus the channels always end in an "odd" number such as 93.3 MHz or 99.9 MHz. Long ago and far away, the original "FM broadcasters" were a simple oscillator, often based on the superb 2N918 transistor. A varactor or even plain old collector voltage modulation was used to get its mono frequency modulation.

Alas, in those days, most "analog" FM receivers all used powerful AFC *automatic frequency control* circuits. These receivers could easily follow any in-band FM carrier. No matter how far off frequency it was or how much it drifted.

But nearly all of today's better FM receivers are digitally synthesized and work *only* with signals that are both stable *and* precisely on-channel. Thus, *most of the older and simpler low cost FM broadcaster circuits will no longer work!*

The first step in the right direction was a potent chip known as the *Rohm BA1404*. This provided high quality by way of its 38 kHz crystal derived stereo modulation. But the internal RF oscillator was still flakey enough that it drifted unacceptably.

How can you build your own FM oscillator that is both stable and on channel? There are two main routes that you can use.

Any stable FM system is really a contradiction in terms. For you'll want to change your frequency for your musical or voice content. Yet you want its center frequency to be rock stable.

The "correct" and complex way to deal with this is with a variation on a PLL called the *frequency lock loop*. You'll first build an oscillator that is linear frequency modulatable. Then you build a crystal oscillator of the same center frequency. The *average*

frequency of the two get compared and *integrated*, or low pass filtered.

Your resulting *error voltage* from this low pass filtering is a near dc waveform that's used to continuously correct the FM oscillator. Thus long term forcing it to the proper channel frequency.

This frequency lock loop method is how "real" FM broadcasters do it. The big problem is that a lot of parts are needed in a fancy circuit.

Instead, can an ordinary crystal get "pulled" enough in frequency by a capacitive loading? The usual rule of thumb is that you can pull a crystal up to one tenth of a percent. Which does translate to 100 kHz up at 100 MHz. But that tenth of a percent is usually an outside limit. Sadly, the pulling process is usually nonlinear.

Both *Sony* and *Pioneer* found that they could pull special crystals in hard-to-design but simple low cost

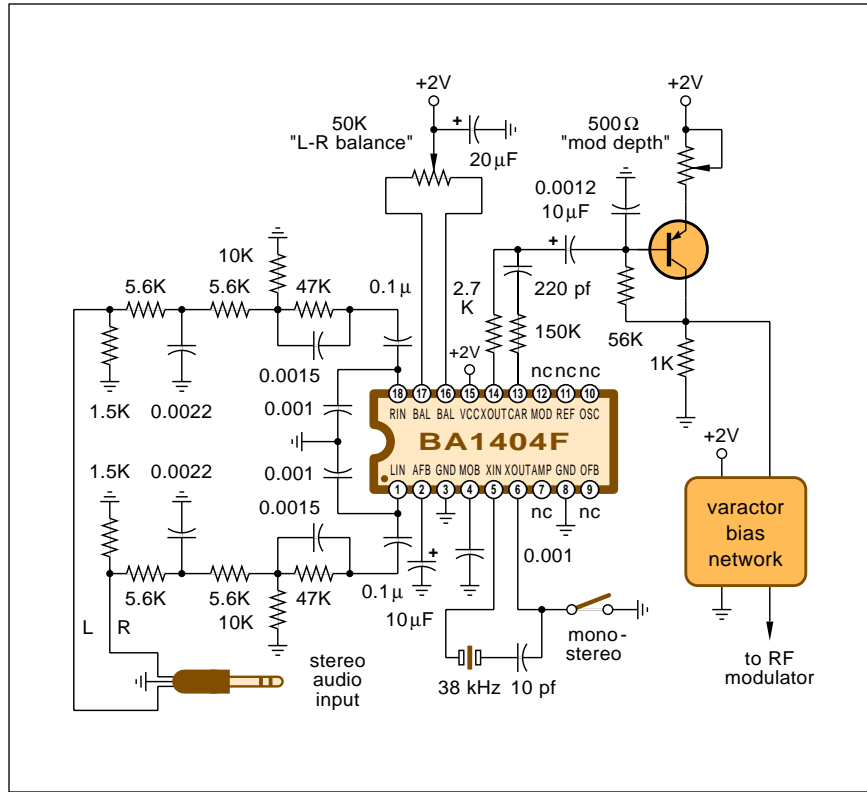


Fig. 1 – THE FM MULTIPLEX PORTION of the new Radio Shack 12-2051 FM Stereo Transmitter. The BA1404 generates a stereo subcarrier.

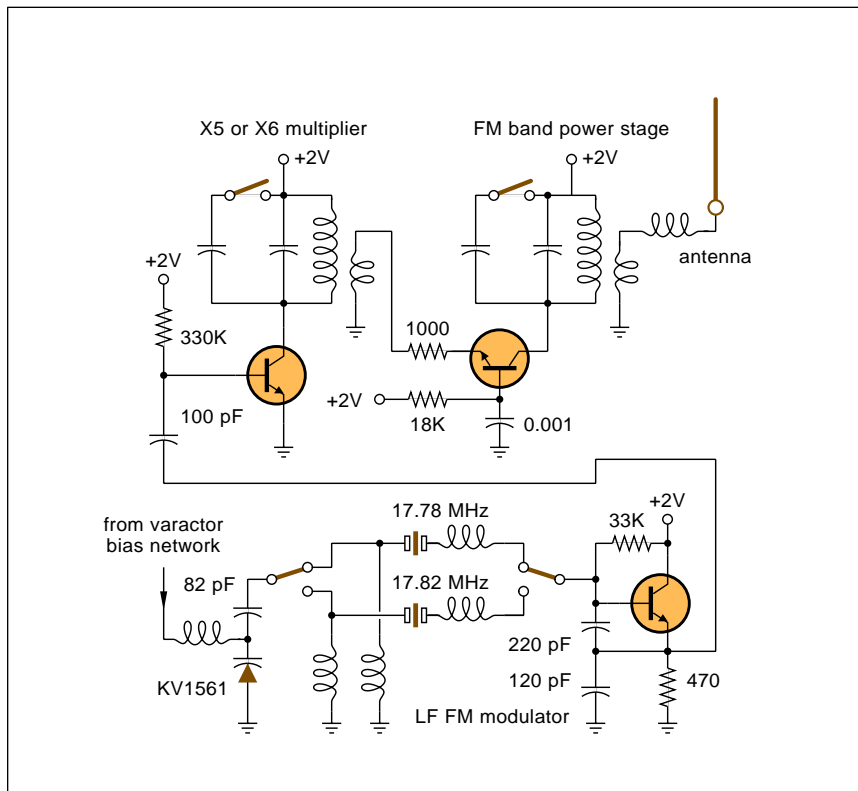


Fig. 2 – THE RF MODULATOR PORTION of the Radio Shack 12-2051 FM Stereo Transmitter. 5X or 6X multiplication linearizes crystal pulling.

circuits. Creating the older Pioneer CD-FM-1 and the Sony XA-7A FM Stereo Modulators.

When you can still locate them, the Pioneer unit is single channel but is easily modifiable and worked upon. The Sony version is dual channel but smaller and difficult to adapt. Sony actually manages to linearly pull the special crystal over two adjacent FM channels. Using switched bias.

These small FM modulators were intended to let you add a CD player to your existing car radio. Simply by unplugging and replugging the radio antenna. We did see a circuit and a detailed description of their innards in the [Hardware Hacker IV](#) reprints and in [HACK52.PDF](#)

All of which just may be ancient history now. Thanks to...

Radio Shack's 12-2051

This new FM Stereo Transmitter sells for as little as \$24. It has *four* channels. It is crystal stabilized. The intended use is to route audio from a CD player or any other mono or stereo signal a few feet into a hi fi or a car radio receiver.

The unit can run off an internal battery or from an external 3 volt DC supply. Which powers an internal two volt regulator ic and a special temperature compensation circuit. Current is 9.5 mils on low channels and 7 on the high ones. 100 hours of operation are claimed per pair of AA batteries. 800 millivolts (the usual "line" level of 0 DBM) is needed for full modulation.

Distortion specs are not all that great at one to three percent.

Several sneaky tricks are used to let you pick four stable channels. A switchable *pair* of crystals gets used. Their frequencies get *multiplied* by either *five* or *six*. Which means the crystals now only have to be pulled one-fifth or one-sixth as far. Greatly improving upon their linearity and simplifying the circuit design.

Uh, they did cheat a little as their numbers don't quite work out exact. The 17.78 MHz crystal hits 88.9 right on by using its fifth harmonic. But it slightly misses 106.7 by landing at 106.68 with its sixth. Similarly, the 17.82 MHz crystal hits 89.10 exact, but misses its 106.9 by ending up at

106.92 MegaHertz.

Purty nigh but not plumb. So they fixed it with a little bit of varactor dc bias that is channel dependent.

That FM multiplexing portion of the circuit is shown in figure one. It seems to be a grunt "me to" BA-1404 circuit. But lacking any internal RF oscillator connections.

That box I have labeled *varactor bias circuit* is rather obtuse. What this all passive resistor-diode-switch-capacitor circuit does is combine the multiplexed audio with a temperature compensated master dc level and a custom switchable bias offset for each selected channel. Needed audio preemphasis is also increased a tad on the high two channels.

The net result is a dc varactor bias value appropriate for your selected channel, with properly emphasized audio superimposed. See the RS docs if you really need the gory details.

The discrete RF part is shown in figure two. That varactor diode gets used as an electronically variable capacitor to pull one of two selected crystals. The voltage on the varicap is the sum of the L+R mono audio channel, an L-R signal on a 38 kHz subcarrier, and possibly a dc fine tuning value.

The first stage oscillates in the 18 MHz region. The second stage then multiplies by five for the low two channels or by six for the high two channels. The final circuitry is a grounded base linear amp which operates at FM band frequencies.

Switching can add extra tuning capacitance to the multiplier and output stages. Shifting your tank resonance accomodates either the high or low channels.

I've simplified Figure 2 a tad for clarity. The hi-lo switching is really done with NPN transistors. Further, each of the stages is independently decoupled from +2 VDC by its own RC filter network. See the RS docs if you need additional detail.

Two mechanical switches are used for frequency selection. One picks the crystal; the other peaks for low or high frequency channels.

Note particularly the 1K resistor in the final output stage. Radio Shack apparently added this in their "-A" version to sharply *reduce* the range. This may have been done to meet an

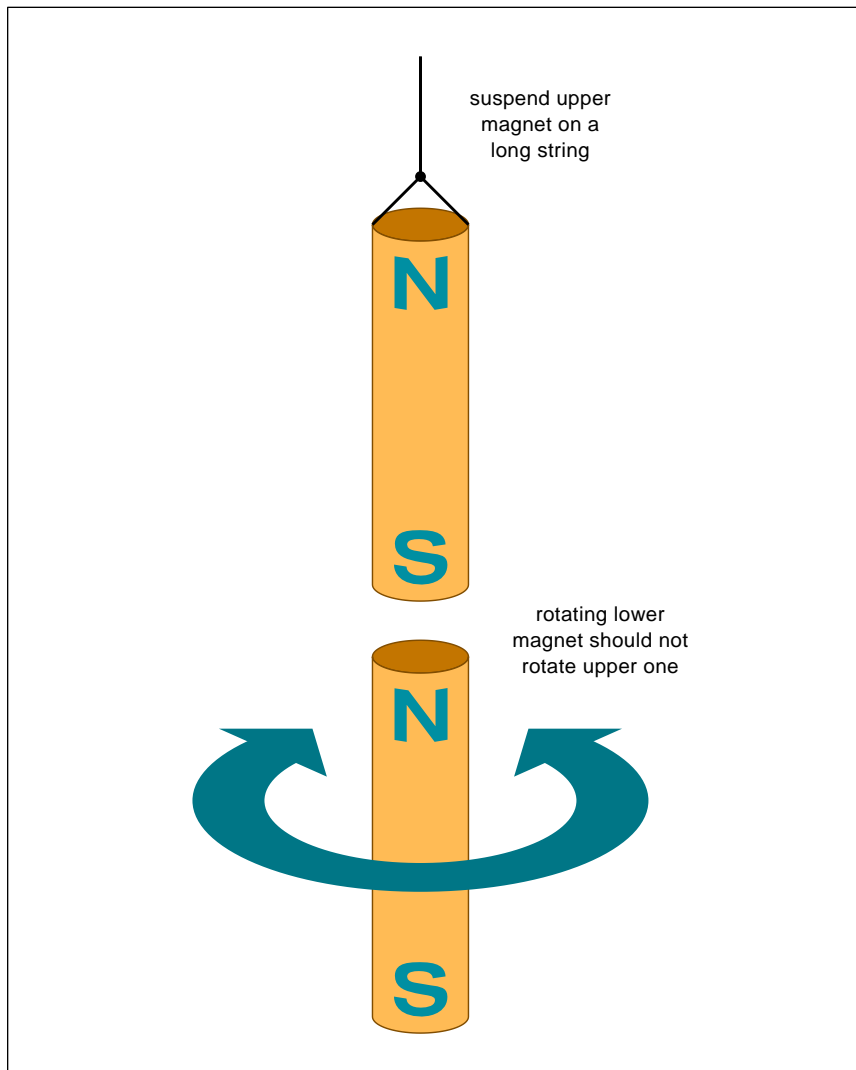


Fig. 3 – THE LAWS OF GENERAL RELATIVITY demand that you cannot tell if a uniform magnetic field is rotating or translating. Rotate the bottom magnet about the string axis and the top magnet should remain stationary.

out of band harmonic spec, to lower distortion, or to discourage adding an illegal external power booster.

There's a small user's manual that comes with the modulator. The more detailed service manual (having full schematics and updates) is available as a special order for \$7 or so. Ask your RS dealer for details.

Some enigmas are more enigmatic than others

It turns out the odd behavior of the Faraday disk is even stranger than I thought it was. In [MUSE117.PDF](#), we looked at homopolar generators. The *Faraday Disk* is one variation on the homopolar generator where the input magnetic field is also rotated.

The key question is this: When you have any perfectly uniform magnetic field, is there any way you can tell that the field is rotating?

Well, a *classicist* would say "Of course you could tell if the field is spinning. The lines of force are busy cutting conductors and are inducing voltage." A *relativist* would instead say "There is no way to tell. There are no such things as magnetic lines; a uniform field is in fact uniform. Further, the laws of general relativity demand field motion independence, especially at high speeds."

Well, as far as we know today, the relativists are correct: *You cannot tell if a perfectly uniform magnetic field is rotating or translating.* One source

for this hard-to-visualize and even harder-to-believe result is in Richard Feynman's *The Feynman Lectures on Physics* volume II, section 13.10. A well documented and peer reviewed experiment you can run yourself is found in the fine *American Journal of Physics*, volume 63 #3 for March of 1995. As Valverde's *The Principal of Relativity as Applied to Motional Electromagnetic Induction*.

All the nasty math involved lies in a Richard Becker's *Electromagnetic Fields and Interactions*. Dover 1982, sections 87 and 88. 87 is background and 88 is on unipolar induction itself.

It took well over a hundred years to sort this one out.

Figure three shows you a simple experiment. Hang a magnet vertically on a string. Position another vertical magnet below the first one and rotate it *around the string axis*. Your upper magnet should *not* rotate. It should only get attracted or repelled by the bottom one. But not spun.

Which strongly suggests that any magnetic "lines" do *not* move with a magnet's rotation.

Your easiest access to Faraday's original papers are in the Britannica *Great Books* series, volume 45. One quite readable book about Faraday is a Cantor, Gooding, and James' text titled *Michael Faraday*.

The Faraday disk output seems to depend *only* upon the *strength* of the input magnetic field and the *relative* speeds of the disk rotor and the slip ring and meter stator. *The speed or direction of the magnets do not seem to matter in the least!*

Apparently, the E field and the H field cannot stand alone. They are both an essential part of your result. Thus, any motional energy seemingly missing from the one component gets made up by the other. *You'll have to consider both E and H together any time there is any relative reference motion!* Every time.

I've gathered a bunch of additional key books and papers about Faraday Disks in the sidebar.

Since it apparently does not matter whether the magnetic field rotates, there's probably not any point at all in purposely spinning your magnets. At least in machines of this type.

Rotating magnets would add to the mass, windage, and dynamic braking,

SOME FARADAY DISK RESOURCES

Beatty, Bill, **Untried Homopolar Generator Experiments** Online at <http://www.eskimo.com/~billb/freenrg/n-mach.html>.
Becker, Richard, **Electromagnetic Fields and Interactions**, Dover 1982. Sections 87 & 88
Cantor, Gooding, & James, **Michael Faraday**, Humanities Press, NJ 1996.
Faraday, Michael, **Experimental Reseraches in Electricity**, Britannica Great Books, vol 45, 1952.
Feynman, Richard, **The Feynman Lectures on Physics**, Addison Wesley, 1989.
Hide, **A study of two self-exciting single-disk homopolar dynamos**, Proc R soc London A v452 pp1369-95.
McAllister, **Friction on a rotating disk in a magnetic field** Online <http://www2.hawaii.edu/suremath/jdisk1.html>
Miller, Aurthur I., **Albert Einstein's Special Theory of Relativity**, Addison Wesley 1981.
Moroz, **On self-excited coupled double disk homopolar dynamos driving series motors**, Psysica D, 1997.
Valverde, **Principal of relativity as applied to motional electromagnetic induction**, Am J Phys, v63 #3, p228.
Valone, Thomas, **Homopolar Handbook**, Integretity Institute Press 1994, Washington DC.

and make closing the flux path a lot harder. While not otherwise changing the outcome in any useful way.

Thus, there is no compelling use for a spinning magnet Faraday disk. At least none that I can think of.

Beyond "gee whiz" demos.

No matter whether its mag field rotates or not, *all* of the homopolar generators and *all* Faraday disks *must* obey the same laws of conservation of energy that other generators do.

While counter emfs and counter torque mechanisms are not obvious, they most certainly do exist. More on this in the superb *Untried Homopolar Experiments* shown in the listing.

There is no magic here. Nor any way I see that any "overunity" or any "free energy" or "zero point" energy device can possibly ever result. *All* attempts to do otherwise to date have failed. Ludicrously and miserably. The usual problems are the inability to properly measure true ac power, inept failures to comprehend counter emfs or torques, plus outrageously absurd "not even wrong" theories.

After my much closer look, I now sure can understand how any "free energy" enthusiast could get severely mislead with such a counterintuitive and unobvious way of generating a plain old dc current.

Thanks to Bill Beatty, to Clarence Green, and John Vanco for all their considerable input on this topic. Let me know if you have any more "real science" references for me here. An *Incredible Secret Money Machine II* for your thoughts.

Let's hear from you.

A Homopolar Motor

A new homopolar motor intended for electric vehicles has newly been announced by the *University of Texas Center for Electromechanics*. The motor operates at 5000 amps peak from a 48 volt source. The claimed maximum power efficiency is a very surprisingly high 87 percent.

The appeal of a homopolar traction motor lies in its high current and low voltage. Needing fewer series cells in an electric vehicle.

But on the other hand, the higher currents raise the controller costs and increase wiring losses. And ultra high current brushes or slip rings do not sound like all that great a thing to purposely design into a car.

While certainly a real interesting development, I'd bet upon switched reluctance ac as the "best" solution to hybrid electric vehicles. I also do feel that the optimum number of motors per car might end up something like 4000 to 40,000 millimotors instead of just using four humongous ones. The

same *distributed* way a dollar power FET is really half a million devices working together in parallel.

Surplus Update

The Feds have recently cleaned up their surplus website. Find this one at www.drms.dla.gov It's nicer arranged and far easier to use than before.

But military surplus doesn't seem all that great these days. You'll find much better bargains at downsizing research labs and commercial firms. And one often overlooked source for incredible test instrument buys are outlying community colleges. Many of whom seem to be sharply cutting back on electronics programs.

Two auction houses I have found interesting are *Bentley Auctioneers* in Albuquerque (mostly Los Alamos stuff) and *B & B Auctions* in Phoenix (mostly Intel). One guide to general surplus and distress merchandise is *Closeout News*. Another trade journal with lots of mechanical and electrical items: *Industrial Marketplace*.

I've got a new surplus and auction story up as [RESBN73.PDF](#) For some surplus bargains of my own, check into www.tinaja.com/barg01.html.

New Tech Lit

A new MAX126 chip from *Maxim*. This ic is a switchable four channel, 14 bit A/D converter that is able to *simultaneously* sample all its inputs. Which ends up super important for real power measurement. Especially when strange waveforms or nonlinear loads are involved. The device appears able to handle exceptionally

NEED HELP?

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high crest or pulse factors with ease.

Up to now, accurate measurement of real power has usually been both outrageously expensive and painfully difficult. Thankfully, their MAX126 just might be able to singlehandedly blow away much of the "free energy" hogwash currently polluting the web. Besides opening up all sorts of great new motor control and home energy conservation apps.

More details and free samples are at www.maxim-ic.com I'll try to work up a PIC wattmeter on this.

From Cypress a new CD ROM on that *Universal Serial Bus* and their related low cost microcontrollers. Or from Inframetrics, free demo disks on their new *ThermaCAM* infrared imaging instruments.

Additional info on those nitrogen

powered cars appears at www.aa.washington.edu/AERP/CryoCar.htm and also at www.mtsc.unt.edu/CooLN2Car.html Among a few other compelling advantages (such as a potential 20X cost reduction over comparable pure EV's), this new idea sure simplifies summer air conditioning!

The pricey *International Journal of Refrigeration* does seem to be the definitive scientific pub on cooling topics. Their Volume 20 has a tutorial on *thermoacoustic refrigerators* in it. This is an apparently valid scheme to employ high pressure standing sound waves to move thermal energy. The second trade journal this month is *Tech Capital* on venture funding.

Peavey's *Fuel from Water* is this month's misnamed but highly useful home and auto Hydrogen book from

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Tech Musings

Lindsay Publications. More details on their keynet.net/~lindsay web site. From *Newnes*, the new *Audio Power Amplifier Design Handbook*. By one Douglas Self. By the way, I am now an *Amazon Books* associate. More info: www.tinaja.com/amlink01.html

For most individuals and smaller scale startups nearly all of the time, patents are virtually certain to end up as a net loss of time, energy, money,

and sanity. Find out why along with my tested and proven alternatives that do work in the real world. All in my *Case Against Patents* package. Per my nearby *Synergetics* ad. Or view www.tinaja.com/patnt01.html

I have recently added new *Santa Claus Machines* and *Golly Gee Mr. Science* library pages to my *Guru's Lair* at www.tinaja.com. You'll also find my freshly updated *Synergetics*

catalog along with some new, free, and linked *Hardware Insider Secrets*. Be certain to check out *meowwrrr's* new *SureGrip* magnetic paws.

As usual, most of our mentioned items should appear in the *Names & Numbers* or *Faraday Disk Resources* sidebars. Always be sure to look here before you phone our US technical helpline shown in that *Need Help?* box you'll find nearby. ♦

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