Don Lancaster's

Hardware Hacker

March, 1995

The DNA computer language
Some wavelet book resources
Magic digital sinewave codes
Engineering ecomonics review
Hot new fringe FM RBDS tuner

As you might guess, I do get more than my share of high profile nastygrams. Lately, some of them seem to reveal a dismal ignorance of a fundamental engineering topic that nobody talks about too much. So, I guess it's way past time we took a look at…

Efficiency and Engineering Economics

Otherwise know as the bang for the buck. *Efficiency* is simply how much of something you get back compared to what you put in. Physical systems *never* return more than you put in.

But an enterprise or a tech venture sometimes has an *apparent* efficiency well above 100%. This can happen if your rearrangements of the physical inputs and your personal value added causes the *perceived value* of your out-the-door products or services to exceed the cost of the parts, time, and effort that went into them.

Engineering economics is simply finding out exactly what the bang for the buck is. Get more than one buck back, and you'll have a "profit" or a "winner". Less than a buck back, and you probably should have been doing something else.

E&EE tells us why 6% efficient solar cells are useless electric power generators *at any price*. Even if free. Or why thermoelectric coolers simply *do not work* at power levels beyond eight watts or so.

Or why most solar space heating is impractical in much of Arizona. Or why it makes perfectly good sense to pour $20,000 worth of electricity into the Gila River each year.

Or, for that matter, why it is totally insane to try and patent any million dollar idea. Or how I can easily win any one mile race. You in your BMW and me on my *Fuji* bicycle.

Some Details

Say you want to start a technical venture. You first borrow a thousand dollars for your tools and materials. Today, the actual *time value of money* of those dollars will be somewhere around ten percent. Thus, simply to break even, your venture has got to generate more than $100 per year and do so forever.

But your tools and materials won't last forever. If they last for ten years, then your venture must generate more than $270 per year to *amortize* your initial expense and the time value of money over the effective life. With a five year lifetime, your venture must generate more than $329 per year.

Just to break even!

If your *total* cost is less than the returns, then you have an economic loss. The total costs must include all parts, labor, and your time value of money. Plus great heaping bunches of intangibles.

Not to mention taxes and inflation.

Paying cash does not make much difference. Since there's other things you might be doing with the money that gives better returns.

Sadly, any "hacker economy" that substitutes time and energy for cash will only *shift* the viability breakeven points. Often by a lot less than you'd first guess. Even when you factor in entertainment, ego, and enjoyment.

A hacker economy does not in any way eliminate those fundamentals of engineering economics. And there's likely to be subsidies involved. Both subtle and obvious.

Another name for E&EE, of course, is a simple *reality check*.

Let's go back to our examples of really bad engineering economics:

The amount of electricity *per unit area* a six percent efficient solar cell produces cannot *ever* pay for all the installation, structure, interest, land, and operating expenses. The energy recovered is simply too diffuse. The longer you run it, the more it is going to cost you.

Besides their unreliability, this is what makes amorphous solar cells such dismally poor performers. Their

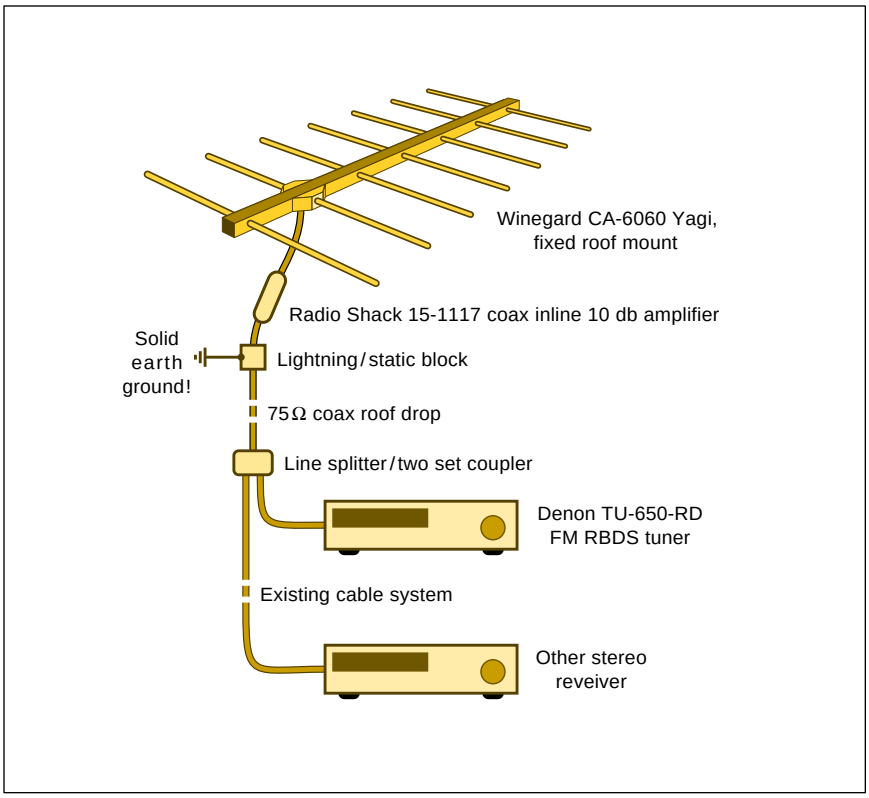
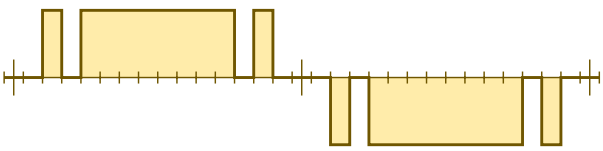


Fig. 1 – MY TEST SETUP for ultra-fringe FM and RBDS.



Code: 0,0,1,0,1,1,1,1,1,1,1,1,0,1,0,0,0,-1,0,-1,-1,-1,-1,-1,-1,-1,-1,0,-1,0

Shorthand Code: 0x2,1x1,0x1,8x1,0x1,1x1,0x3,-1x1,0x1,-1x8,0x1,-1x1,0x1

The fundamental peak amplitude is 1.0545 times the "1" amplitude.

Fundamental:	(1.0000)	11th Harmonic:	0.2230
2nd Harmonic:	0	12th Harmonic:	0
3rd Harmonic:	0	13th Harmonic:	0.2285
4th Harmonic:	0	14th Harmonic:	0
5th Harmonic:	0	15th Harmonic:	0
6th Harmonic:	0	16th Harmonic:	0
7th Harmonic:	0.1184	17th Harmonic:	0.1183
8th Harmonic:	0	18th Harmonic:	0
9th Harmonic:	0	19th Harmonic:	0.1301
10th Harmonic:	0	20th Harmonic:	0

Fig. 2 – A "MAGIC" 30-BIT WAVEFORM for generating power sinewaves.

low efficiency is perilously close to economic breakeven. Which is also why commercial solar electric power plants are being chopped up and sold to hackers at yard sales. There is a lot more profit to be made in selling junk than there is in selling solar power from deteriorating cells.

In the Arizona desert, there are too *few* winter degree days to make solar space heating economical. It's hard to compete with $10 worth of propane or a few sticks of wood.

Because of the gross inefficiency of thermoelectric coolers, your heat sink typically has to deal with *six* or more times your cooling power. At high power, the heat *rise* across your heatsink *exceeds* your cooling *drop* provided by the modules.

Making your "cooler" a heater!

Recovering that $20,000 per year of Gila River electricity from a hot well down my street would demand a low delta-t plant. One whose design time, operating expenses, and time value of money would exceed income.

Especially in a flood plain.

Patenting your million dollar idea makes no sense at all. Why? Because there are not enough profits from a million dollar idea to begin to cover the costs of getting and successfully defending a patent.

Your breakeven is roughly *twelve* million dollars in gross sales. At that 12 mil level, it is still a toss-up as to whether a patent is or is not worth all of the obscenely mind-rotting hassles involved. Much more on this in my WHEN2PAT.PS on *www.tinaja.com*.

Oh yeah. My bicycle race. You do, of course, have to *include* the time you spent *working to pay for the part of the vehicle you used up* during the race. Say you earn $12 per hour after expenses. And it costs one dollar per mile to run your Beemer. Even if the BMW covers the mile at Mach 3, your *minimum* race time will end up five minutes or more.

Are there times when efficiency and engineering economics aren't of crucial importance? Only if *nobody* else can come up with a good answer to "Uh – Compared to What?"

Ferinstance, inefficient solar cells seem wonderful for calculators but useless for power generation. Peltier thermoelectrics are great for cooling a microscope slide, dewpoints, or an infrared detector. But worthless for making ice.

Solar hot water works really fine in the Arizona desert, but solar space heat does not.

Wavelets Update

There's sure been a lot of interest in *wavelets* recently. These can be a super performing replacement for the older Fourier analysis techniques that relate time and frequency. Important usage areas include everything from video compression schemes to human vision to seismography.

Advanced math is required.

The field is maturing and there are now dozens of books available. I've listed several of the more popular of them in our resource sidebar.

The best tutorial paper is probably by Rioul and Vetterli in *IEEE Signal Processing Magazine*, vol 8, #4, Oct 1991 pp 14-38. Also check that Dec 1993 issue of their *IEEE Transactions on Signal Processing*. Note that these are two different pubs.

Yes, we have wavelet shareware up on *www.tinaja.com*

Hot New FM Tuner

In past issues and in the *Hardware Hacker* reprints, we've been looking at ultra-fringe FM reception as well as those new FM RBDS data services. The folks at *Denon* were kind enough to loan me one of their superb new TU-650-RD premium FM tuners. At $375 list, $299 or so street.

RBDS is a 1200 BPS data subcarrier service. An early intro shows up as HACK73.PS on my *www/.tinaja.com*. Along with do-it-yourself circuits. The most common RBDS use is to show the call letters and station format. Other uses are for song, singer, traffic, weather, emergency alerts, GPS corrections, and coupon radio promotions.

Sadly, most FM stations have yet to pick up on this great new suite of services, all cheaply provided. The latest *Radio World* listing shows only 220 or so stations on line.

Besides showing the station call letters, this *Denon* receiver lets you search on format. Like asking it to scan only for classic rock.

There are now only a few Arizona stations offering RBDS. But several came in just fine. Even though most of them only provided the format and call letters so far. It seems the usual chicken-and-egg problem. Nobody wants RBDS if only a few stations have it; the stations do not want to

spend money on a service nobody is yet using very much.

But all the benefits are definitely there. Especially for car radios.

Scottsdale KSLX (100.7), Kingman KZZZ (94.7), and Cottonwood KZGL (95.9), broadcast the GPS corrections. Which upgrades position accuracy down to several feet.

The theory in *differential* GPS is that you have one known and *fixed* location at the radio station. Over several dozen miles, the errors at the radio station will be pretty much the same as the error in your instrument. You just subtract the two to pick up a lot more accuracy.

More on these techniques in *GPS World*. Two major RBDS resources include *Differential Corrections* and *Coupon Radio*.

The Denon receiver would have to be slightly modified to receive GPS. This is a custom and encrypted fee based commercial service.

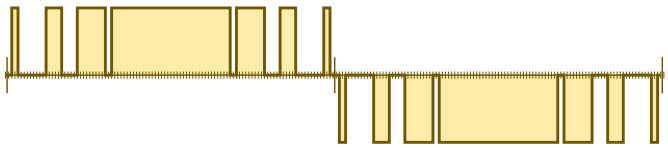
There are several unique features that make their TU-650-RD a good ultra-fringe receiver. A fully shielded super hot front end design. And an optional narrow band if filter that blocks most co-channel interference. Yes, you can still receive stereo and RBDS in the narrow mode.

Figure one shows my current test setup. A high fixed mount *Winegard* CA-6060 ten element Yagi on the roof pointed due west. A lightning block and ten decibel *Radio Shack* 15-1117 amplifier on the antenna. A two-set coupler in the living room driving the TU-650-RD. And on back through the previous cable system going to the second and lower quality receiver in the computer room.

Performance? First and foremost, KDKB comes in like a champ. You can arc weld with their signal. Which is all that really matters to me. There are some 40 FM stations of listenable quality. At an *average* distance of over 105 miles!

Their if filter is incredible. Weak Tucson alternate radio KXCI at 91.3 gets easily separated from the much stronger Phoenix KJZZ at 91.5.

The rule on a bandpass filter is to try it and see. If the station *changes*, or the noise goes *up*, you have got co-channel problems. But any weak signal by itself might come in better with or without the filter. In general, the filter only makes a difference on a few stations.



Shorthand Code: 0x2,1x2,0x9,1x5,0x5,1x9,0x2,1x38,0x2,1x9,0x5,1x5,0x9,1x2, 0x3,-1x2,0x9,-1x5,0x5,-1x9,0x2,-1x38,0x2,-1x9,0x5,-1x5,0x9,-1x2,0x1.

The fundamental peak amplitude is 1.0281 times the "1" amplitude.

Fundamental:	(1.0000)	11th Harmonic:	0.0108 (!)
2nd Harmonic:	0	12th Harmonic:	0
3rd Harmonic:	0	13th Harmonic:	0.0891
4th Harmonic:	0	14th Harmonic:	0
5th Harmonic:	0	15th Harmonic:	0
6th Harmonic:	0	16th Harmonic:	0
7th Harmonic:	0	17th Harmonic:	0.2892
8th Harmonic:	0	18th Harmonic:	0
9th Harmonic:	0	19th Harmonic:	0.2613
10th Harmonic:	0	20th Harmonic:	0

Fig. 3 – AN "EVEN MORE MAGIC" power sinewave waveform of 210 bits.

But what a difference.

Does it make sense to add a lower quality booster at the antenna ahead of an ultra hot receiver? A modest 10 db boost at your antenna gives your antenna a fixed impedance to work into and makes up for both line and distribution losses.

The slightly higher signal level is enough to override the "no stereo on weak signal" feature. Which lets you switch by yourself rather than using the factory preset. Naturally, mono is cleaner for marginal signals.

But any preamp also adds to your cross mod and can cause overloading. Which was only observable at half a channel away from a nearby station. If you use a preamp, be sure to use an inline coax version which is totally shielded. Providing you with only the bare minimum gain needed.

Does a fixed antenna make sense? Fixed is cheaper and more rugged. And there's not too much east of me because of this slight rise that some folks call the Continental Divide.

But Bee does not get her classic Tucson KUAT very well. Despite its strong reception on the car radio in the driveway. Some sniffing around with an unboosted cheap fringe-but-not-ultra *Radio Shack* 15-1636 FM antenna led to a big surprise.

A large number of FM stations appear to now use *vertical* or *circular* polarizations. Their apparent aim is to improve nearby auto reception at the cost of distant coverage.

For KUAT, flipping the antenna to the vertical dramatically improved the reception in Thatcher.

The ultimate solution is antenna height. Which conquers all. At the top of the two mile high mountain in my front yard, I can take a $4 pocket FM receiver and tune it to 93.3. By pointing the whip antenna in one of three directions, I can get KDKB in Phoenix, KKOB in Alburquerque or a

NEED HELP?

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US email: *don@tinaja.com*
Web page: *www.tinaja.com*

WAVELET BOOK RESOURCES

C.K. Chui, *An Introduction to Wavelets*, Academic Press, 1992.

C.K. Chui, *Wavelets*, World Scientific Pub, 1992.

C.K. Chui, *Wavelets: A Tutorial in Theory & Applications*, Academic Press, 1992.

C.K. Chui, L. Montefusco & L. Puccio, *Wavelets, Theory, Algorithms, & Applications*, Academic Press, 1994.

J.M. Combes, *Wavelets*, Spr-Verlag, 1989.

I. Daubechies, *Ten Lectures on Wavelets*, Soc Indus-Appl Math, 1992.

G. David, *Wavelets & Singular Integrals on Curves & Surfaces*, Spr-Verlag, 1992.

M. Farge, *Wavelets, Fractals & Fourier Transforms*, 1993.

E. Foufoula-Georgiou, P. Kumar, *Wavelets in Geophysics*, Academic Press, 1994.

Frazier, *Wavelets, Mathematics & Applications*, CRC Press, 1993.

Jawerth, *Practical Guide to Wavelets*, CRC Press, 1994.

G. Kaiser, *A Friendly Guide to Wavelets*, Birkhauser, 1993.

T.H. Koornwinder, *Wavelets: An Elementary Treatment of Theory & Application*, World Scientific Pub, 1993.

W. Light, *Advances in Numerical Analysis*, V2, OUP, 1992.

Y. Meyer, *Wavelets: Algorithms & Applications*, Soc Indus-Appl Math, 1993.

Y. Meyer, *Wavelets*, Cambridge University Press, 1993.

Y. Meyer, *Wavelets & Applications*, Spr-Verlag, 1992.

R.L. Motard & B Joseph, *Wavelet Applications in Chemical Engineering*, Kluwer Ac, 94.

D.E. Newland, *An Introduction to Random Vibrations, Spectral & Wavelet Analysis*, Halsted Press, 1993.

Ruskai, *Wavelets & Their Applications*, Jones & Bartlett, 1992.

L.L. Schumaker & G. Webb, *Recent Advances in Wavelet Analysis*, Acad. Pr., 1993.

G.G. Walter, *Wavelets & Other Orthogonal Systems with Applications*, CRC Press, 94.

G. Wornell, *Wavelet-Based Signal Processing with Fractals*, P-H, 1994.

R.K. Young, *Wavelet Theory & Its Applications*, Kluwer Ac, 1992.

Mexican station from the south.

Tuning on the TU650RD is every 100 kiloHertz, giving you one stop *between* channels. This could reduce co-channel interference or might be useful for some homebrew wireless broadcaster that is off frequency. It also helps the channel six tv sound near 87.8 MegaHertz.

One strange restriction: This tuner is so hot you'll have to activate the internal rf attenuator to prevent any overload on cable systems. For some reason, you can only do this from the remote. I suspect this may have been an afterthought when the design was nearly completed.

Because there is a microcontroller inside, you'll find all sorts of unusual features. You can manually teach any *non*-RBDS stations their call letters and formats. Or store other messages of 13 or fewer characters.

You can scan for all of the classic rock stations, all the news stations, or any of 20 other formats. Since there is no keyboard as such, you use the *up/down* button to select any of the 66 characters. Which is not quite as bad as it sounds.

There are 30 station presets. These are bright enough to remember the RBDS or manually entered data, AM versus FM, the rf attenuator setting, and the filter bandwidth.

There is a panel light dimmer. All presets get saved during power down.

The power consumption is only 12 watts. Being a component tuner, an external stereo amplifier is needed.

I'd sure like to see a "raw" RBDS output jack on this product.

The next step here is obvious. A monthly updated plug in card, chip, or modem line that stores *all* of the stations in North America with all of their formats and the operating hours. Which would be most useful for long auto trips.

More "magic" Waveforms

High power sinewaves are quickly becoming one hot hardware hacker topic. For such uses as car battery power inverters, UPS computer power supplies, telephone ringers, electric autos, line conditioning, and variable speed induction motor drives.

Most of these apps *demand* fairly decent sinewave outputs. Square or other sloppy waveforms could cause inefficiencies, heating, resonances, cogging, or severe audio whine.

Analog solutions which use power amplifiers will not hack it because of their lousy efficiency.

A microcontroller oriented digital solution is the *only* route to use these days. Especially when stability, wide range, easily adjusted voltage, or a constant speed is involved.

You'll also want to minimize how many power switches you use. And you'll want your switch currents to be reasonably efficient.

So, the trick is to find a "magic" single train of fixed amplitude ones and zeros that could fake a decent variable voltage sinewave. Often, you will pick a RZ or *ternary*, or PWM pulse width modulation scheme that has states of +1, 0 and -1.

Figure two shows a wonderfully "magic" 30 bit waveform for power sinewaves. When you go through *all* possible binary sequences for 36 or less bits per word, there is *no* other code that even comes close.

The "top" half of your waveform is 001011111111010. The "bottom" half gets repeated with -1 values. Note that you mirror top-to-bottom but *not* right-to-left! Giving you the 30 bit word. Or a 1800 Hertz clock for 60 Hertz line power. The 30 bit length nicely taps out by tens if you need three phase power.

Believe it or not, this elegantly simple "magic" word has a *zero* dc term. It has *zero* second, third, fourth, fifth, sixth, eighth, ninth, and tenth harmonics! The peak fundamental is around five percent *above* the "1" value, for nicely behaved switching currents. The seventh harmonic ends

NAMES AND NUMBERS

Coupon Radio
10 Rockefeller Plaza
New York NY 10020
(212) 595-1313

Crystal Semiconductor
PO Box 17847
Austin TX 78744
(800) 888-5016

Dallas Semiconductor
4401 South Beltwood Pkwy
Dallas TX 75244
(214) 450-0400

Denon
222 New Road
Parsippany NJ 07054
(201) 575-7810

Differential Corrections
10121 Miller Avenue #201
Cupertino CA 95014
(800) 446-0015

GEnie
401 North Washington Street
Rockville MD 20850
(800) 638-9636

GPS World
859 Willamette Street
Eugene OR 97440
(503) 343-1200

IEEE/Signal Processing
445 Hoes Lane
Piscataway NJ 08855
(908) 981-0060

National Semiconductor
2900 Semiconductor Drive
Santa Clara CA 95052
(800) 272-9959

Radio World
5827 Columbia Pk #310
Falls Church VA 22041
(703) 998-7600

Science/AAAS
1333 H Street NW
Washington DC 20005
(202) 326-6400

Synergetics
Box 809
Thatcher AZ 85552
(520) 428-4073

Whole Earth Catalog
27 Gate Five Road
Sausalito CA 94965
(415) 332-1716

Winegard
3000 Kirkwood Street
Burlington IA 52601
(319) 754-0600

up around 11.8% amplitude, which will translate to 1.39% power.

Uh, there are a few minor points over this one, though. There's flat out no way you are going to get all those fancy square corners with nothing but a fundamental sinewave and a weak seventh harmonic.

So, all the 11, 13, 17, and 19 teen harmonics are sorta gruesome. But no worse than the third in any plain old square wave. They end up mid-audio with 60 Hertz power. But these are usually easy to filter out. Even the winding inductance of a motor acts as a low pass filter.

Still, you will definitely need some low pass filtering and you will have to watch for system resonances.

Note that the "-1" state can simply be a reversed current. With a bridge driver, only a single supply is needed for both current directions. Another option is to use a *pair* of oppositely phased windings.

Details vary with the use and your intended application..

Naturally, the fine general purpose PostScript computer language is *the* quick and fun way to interactively analyze waveforms. I've written a new FOURIER.PS tutorial exploration utility and my ZEROHARM.PS code finder to *www.tinaja.com*

I'm currently checking out 210 bit words using PostScript. One highly interesting 210 bitter is shown in figure three. Whose very first nasty harmonic is the *seventeenth*.

A library of low harmonic codes with listings of different fundamental amplitudes can be used to provide variable output voltage from a fixed supply. Call me for details.

At longer bit lengths, you do have to think smarter rather than harder to quickly get any useful answers. But PostScript does explore any high bit count words with aplomb. The key secret is to represent your words by ones and zeros *in a string*. And then manipulate the strings.

Many thanks to mathematician Jim Fitzsimons for his help on this.

New Tech Lit

From *Crystal Semiconductor* a new *Audio Databook*. On digital audio products, particularly low distortion delta-sigma A/D converters.

From *Dallas Semiconductor*, a *System Extension Data Book*. This book includes digital potentiometers and electronic thermostats.

From *National Semiconductor*, a *Power IC's Databook*. Full of linear and switching regulators, motion controls, and power drivers.

That November 24, 1994 issue of *Science* proves something that has been completely obvious to me for some time. That 97% of so-called "junk" DNA is really a sophisticated computer language! Or, at the very least, passes all the exact tests in the same ways that *all* current human and computer languages do.

Details on page 1320.

If you want to make a real quick buck on this, just publish the pocket reference card for the DNA language. And maybe show us how to access a utility subroutine or two.

At long last, the *Millenium Whole Earth Catalog* is shipping. A "must have" essential resource on access to tools. Don't miss this one.

I've just newly reissued my classic *Active Filter Cookbook* and do have bunches of autographed copies on hand. And I do still have scads of classic Apple computers, monitors, cards, and drives on hand. Cheap enough for use as a programmable controller. Even rare and collectible Apple III's. Write, call, or email me for more details.

A reminder that unique downloads, freebie insider secrets, catalogs, and technical help are available on my *www.tinaja.com*. More info per the *Need Help?* box.

Please note that my area code has just changed to 520. Be sure to update any earlier catalogs or whatever I may have sent you.

As usual, most of these resources I've mentioned appear in the *Names & Numbers* or *Wavelets* sidebars. Be sure to check here first before you call our no-charge tech helpline. ✦