-SPREAD SPECTRUM SCENE

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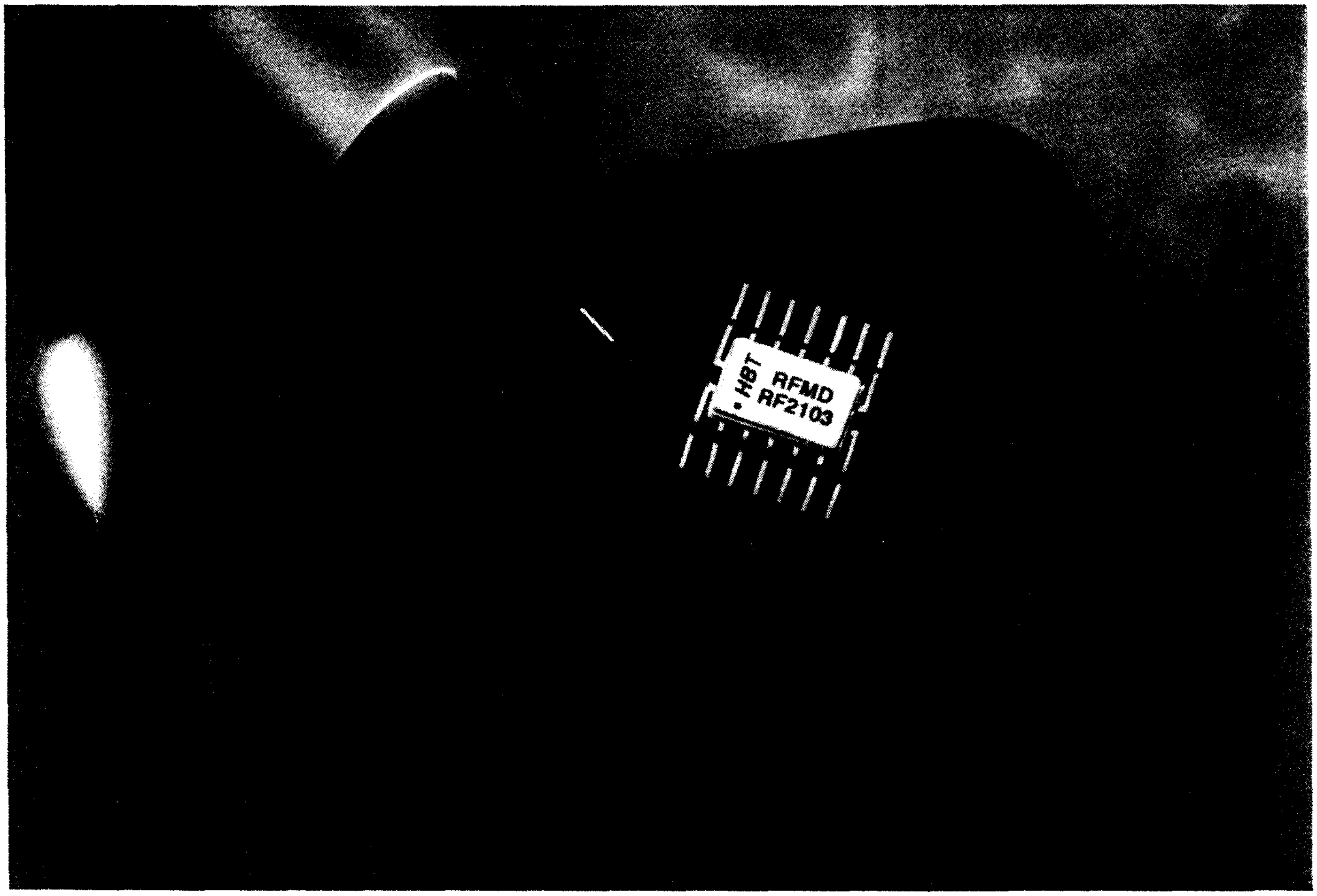
World's First 900 MHz HBT Linear Power Amplifier -- See page 11

SS System Simulation with Mathcad -- See page 15



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Highlights

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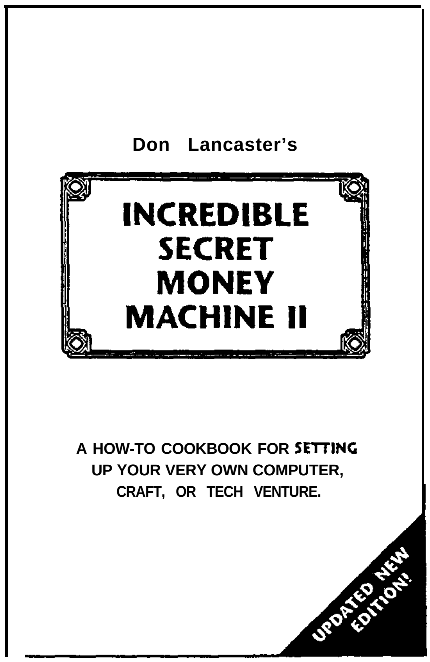
Rumors & Ramblings

- **News and** rumors from the FCC say that the decision on the US selection of an HDTV standard is now a very hot political potato. It turns out that the latest FCC recommendation is for a joint venture of all participants.

- Befitting our first anniversary in April, look for a review of the latest edition of Don Lancaster's. now classic, book:



Decipherings

What lies behind us and what lies before us are tiny matters compared to what lies within us.

- Oliver Wendell Holmes -

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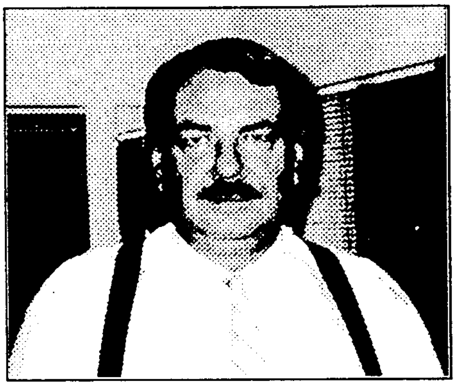
Table of Contents

Think Spread Spectrum!

April Preview

- **Review of RF EXPO West.**
- **GEC-Marconi's new 2.4 GHz GaAs MMIC transceiver chip.**
- **Review of Don Lancaster's book.**
- **Our First Anniversary issue with New Products, columns, features and SS regulatory news.**

EDITORIAL



Trade Shows/Wars

This month brings more trade shows to Silicon Valley. We are enthusiastically anticipating RF EXPO WEST at mid-month (see program on page 2 1) and looking forward to the PLD Design show late in March. Last month we attended Mobile '93 and in January had the Wireless EXPO -- it seems there's another Wireless Expo this month also: this time in Florida. Isn't it getting just a bit much'.' It's bad enough that companies battle it out in advertisements, in the marketplace as a whole and in product performance/features. Now we have to contend with competing trade shows. I don't see how anybody can keep up or attend even half of the interesting trade shows that are being held -- let alone the time or expense!

Our budding industry certainly needs trade shows. We need the training, the company/-product exposure, the personal contacts and all the other niceties that these shows offer -- but, we don't need to do it just about every month! I think the show promoters are overdoing it, lately. Just maybe, they will find that the marketplace weeds out the pool-ly put together and poorly attended shows and things will get back to normal. I hope something like this happens soon -- I can't afford all the time these shows take!

This month's issue is a slightly special one. We are a little longer than normal -- for two reasons: (1) We wanted a substantial issue (with plenty of "meat") to hand out at RF EXPO; and (2) Our advertising is picking up ever so slowly. If you attend the EXPO stop by, say hello or look us up at one of the technical sessions. We will be hosting/chairing one of the sessions of technical papers at the show and we'll be present most days of the show as well. I think RF EXPO is the premier RF show, nationally, every year -- however, Jack Brown and his Wireless EXPO sure gave RF a run for their money. I hope RF EXPO comes off very successfully for Gary Breed and Cardiff publishing.

While on the issue of shows, I must talk about what 1 thought of Mobile '93. Wow, what a glittery, glitzy, goofy bunch of exhibits and booths. The show sponsors did not provide a conference record or copies of any of the slides presented by the many speakers. All in all, for a new area of technology it was a pretty good, but lightly attended show.

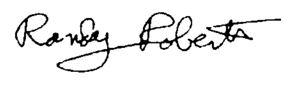
It seems that the world of "Mobile/Portable Computing" or PDAs, or whatever you want to call it, is rapidly evolving. Every booth seemed to have their own "Team Tee Shirts" and a smooth, slick presentation. There was even some working hardware there to see (PacTel provided a mobile cell site in the exhibit hall, to make things work superbly -- is that cheating'!)

In summary, I must say that this mobile/PDA business is so full of hot air, smoke and mirrors concerning the many different ways to use data over cell phone technology that I can't believe it! When are these guys (and Gals) going to wake up and realize that their technology will go NOWHERE until there is a real market need and that need seems to insist on the elimination of per minute charges.

This market will continue to go in the direction of Apple's Newton (exactly nowhere) until something happens with PCN/-PCS technology and the equipment designers put in technical features that belong in 2 1 st century products -- ***like Spread Spectrum digital communications!***

Do you like this month's mug shot of your editor better than last month's'? We'll keep experimenting till we get a photo that makes me look a little less like the a fugitive or a renegade Iraqi leader. I figure somebody out there wants to know what I really look like -- right'?

The US dollar is getting to the point where we can once again compete internationally. Here's a challenge: get some new products out, soon, that are designed for export and use SS technology. I think theres a real market need and a path here for some very successful commercial ventures. Good luck -- go to it -- gentlemen start your engines!



The Aerial

by Peter Onnigian, P.E., W6QEU

In the last column we discussed how electromagnetic energy in the radio frequency spectrum is produced. This month we'll explore the problems associated with radiation from a transmitter and the difficulties it may experience getting into a receiver.

We take so much for granted in life. There is so much radiation, but we don't recognize it. A hot cup of coffee cools with time to room temperature, because it is radiating heat. Heat is radiation at very high frequency, usually higher than humanly detect light waves, which are another form of radiation energy.

The wave incident on the receiving antenna connected to a spread spectrum radio is rarely only the one which has arrived by the most direct path. It is often the resultant of two or more waves which have traveled by different routes and have different distances in doing so.

Alternative paths may arise as a result of reflections ... where a wall intercepts the oncoming waves

If these waves should eventually arrive in phase they would act to reinforce one another. Should they reach the receiving antenna out of phase they would interfere with each other and if they happen to be equal in amplitude, would cancel one another completely.

Alternative paths may arise as a result of reflections in the horizontal plane where a wall intercepts the oncoming waves and deflects them towards the receiver. Reflections may also occur from a point on the ground or the floor. If the reflection surfaces are stationary as in the two cases considered, the phase difference, whatever it maybe, would be constant and a steady signal condition would result.

If the reflecting surface is in motion, as with human bodies in a large office area, the signal strength will vary. This problem plagues many older design wireless LANs.

We have all experienced aircraft flutter in our TV receivers. This occurs when a low flying aircraft flies in the general path between the TV transmitter and your TV receiver. The distance traveled by the reflected wave from the aircraft's wings changes continuously. Some distance cause signal build-ups and some reductions, all caused by variations in amplitude and phase. These signal level changes occur at audible rates, and therefore it "flutters" the audio channel. The video is similarly affected.

GHOST BUSTERS

The Japanese have invented several methods of eliminating TV ghosting. These new circuits are just now appearing in some 1993 and 1994 models, and eliminate both stationary ghosting and aircraft flutter. This feature is especially useful with rabbit eat antennas in urban areas.

Some have lamented the minute power levels allowed by the FCC for the popular SS RF bands. We must remember that reflections are ratios of desired to undesired. Increasing power levels does nothing to this ratio - except perhaps increasing the minimum levels.

Power increase is not possible under present FCC Rules. But radiated power may be increased by using directional antennas. In a large office wireless LAN where a quarter wave antenna is used over a ground plane, the radiation may be increased 1.7 dB, by changing to a half wave antenna.

Reflections within a building occur from hundreds of sources. These include the concrete base floor, walls with conduits, wall studs (steel) filing cabinets, metal desks, florescent light fixtures and its wire hangers, air conditioning ducts, and anything else that is metallic!

MULTI-PATH HARDWARE

Spread spectrum hardware can be used to eliminate the effects of multi-path signals so reliable communications may be carried out on one channel.

One solution is to use CDMA modulation with SS bandwidth up to 26 MHz. CDMA increases the data sequence, increasing the data spread. By synchronizing to one of the multiple reflections, the CDMA receiver can delay the remaining signals more than one chip. All the other multi-path signals, including the direct path signals, are greatly attenuated, increasing reliability. This scheme works very well up to path differences as great as 75 meters.

CONCLUSTONS

VHF and UHF propagation has some problems, mainly multi-path signals. Hardware in the form of CDMA circuitry generally reduces the ill affects of these reflections from mobile and stationary sources.

CONSULTANT'S CORNER

by Gary Mitchell

Finding Customers

One of the first problems facing a consultant is finding customers. It's of no use to just sit there in your kitchen waiting for people to call-some positive action is required here. The first thing you need is name recognition. You can get this through advertising, mailing, cold calling, calling friends os anything else you can think of.

Personally, I think advertising is the way to go. I started advertising in the local IEEE newsletter, then branched out into national magazines (like this one). I started doing this when I still had a job, and it was gratifying when a Vice President at my employer showed me the IEEE newsletter ad and asked me if I knew anything about this company. It was also a little scary, under the circumstances.

Personally, I think advertising is the way to go. I started advertising in the local IEEE newsletter, then branched out into national magazines (like this one).

My goal is to have such a degree of name recognition for my company that whenever someone thinks about RF engineering in the vicinity of my home, they instantly think of my company. I even have a personalized license plate that says "RF ENGNR."

Advertising is very expensive, and it doesn't work instantly, so you need to commit to an extended period of time for your advertising. You get a substantial discount with most magazines for placing ads for a long period of time, as opposed to a one-shot placement. When I say a big discount, I'm talking about typically 50%. You can also get an additional 15% discount by setting up your own in-house advertising agency to place your ads.

I even have a personalized license plate that says "RF ENGNR."

Another benefit of signing up for an extended period of time is that, after you advertise for a few months and the results are not what you expected, you can't get out of the contract without paying a substantial penalty. This helps enormously to keep you going when you get discouraged. One thing I would advise against is a short term or one-shot advertising campaign. It simply doesn't work, and you will be very disappointed. If you can't afford a continuing campaign, get the message out some other way and save your money. If you do advertise for an extended period, you will find that an increasing number of people know the name of your company when you contact them.

Product Review

As promised last month, I will review new RF products every month. This month's product is a quadrature demodulator, the RF270 1, from RF Micro-Devices. The chip, shown below, is a complete quadrature demodulator in one inexpensive monolithic package.

This single component replaces a splitter, a quadrature phase splitter, two mixers and some amplifiers with one inexpensive monolithic IC. The device is designed for the standard 70 MHz IF. This device is used to demodulate a complex modulated waveform into its I and Q channel components. The advantages of using this part over a discrete implementation include reduced cost and better matching between channels. By using this chip, you can make a high-performance demodulator by just adding a synthesizer at 140 MHz and baseband filters and comparators on the output. In addition to the components shown on the drawing, the chip also contains an on-chip oscillator and a power-down (standby) circuit.

All of this performance costs you only $8.92 each, in quantities of 500. To find out more about this device, call Chris Fisher at RF Micro-Devices, and be sure to tell him you saw it in Spread Spectrum Scene.

RF Micro Devices can be reached at:

7341-D W. Friendly Ave.
Greensboro, NC 27410
(919) 855-8085

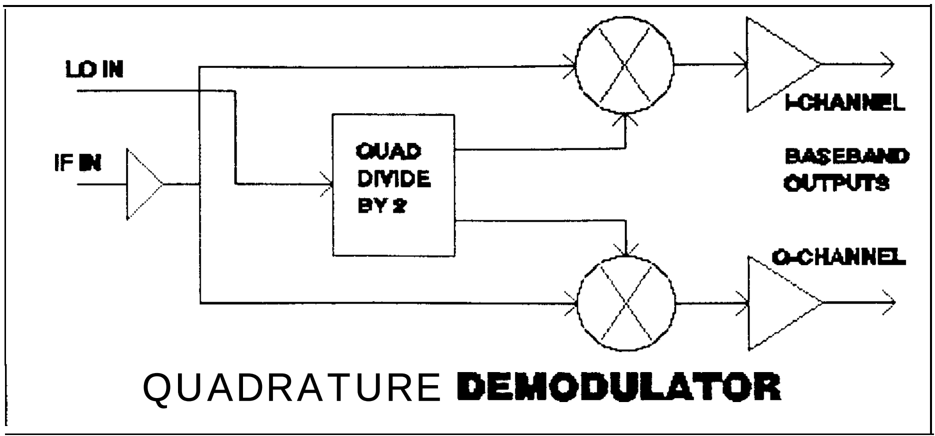


Figure 1: RF Micro-Devices RF2701 Chip Block Diagram

Equipment Corner

by Chris Kilgus

I recently had the opportunity to test a Part 15 transmitter that I had designed at a field test sight, which has been blessed by the FCC. I brought along a competitors device for comparison. Per the rules, the maximum allowable field strength was 10,000 uV/Meter for this type of device. Mine was 7,500 and the competitors, from a large electronics retail chain, was 70,000 uV/M. Was this just an accident, or is the FCC overwhelmed with applications and unhble to follow up? I think we, as an industry, must be self-policing, much like the amateur operators have been fur years. I notified the offending company, and I trust they will take corrective action.

I recently heard that an airline passenger using a portable computing device caused interference to the airplane's navigation system. This is rather disturbing, considering the large number of laptops being used on planes. The first reaction from the airline and FAA was to consider ban on personal electronics. I think the solution is to upgrade the navigation equipment. We are still using technology developed in the 1930's and it is susceptible to all kinds of interference. It is time for a microwave based system using digital techniques. A mandated change would help companies that were military orientated convert to civilian projects, and it would improve safety and efficiency in air transportation. Many of us have upgraded our computer systems in the last couple years. In many instances, an obsolete clone or XT has been left over. One innovative use for such a machine is to use it as a dedicated FAX macchine. There are many good FAX/-modem boards on the market for less than $100. Another good use for the machine is to make it into a dedicated EPROM/PLA programmer. If you don't have an old computer, go buy one surplus rather than stick a programmer in your new 3861486. An XT can program a chip just as fast as a 486DX-66. The Link Computer Graphics, Inc. model CLK-3 100 universal programmer that RF/SS owns is a really "nice," inexpensive unit. It has almost "idiot-proof' software, is rugged and reliable and was installed in an old surplus COMPAQ 286 portable ("lug-able") with a 10 MEG hard drive. See pages 22 and 23 of this issue for more info on Links products. While what makes it "universal" is Link's vast supply of socket adapters for the less common parts, the 3 100 is very "user friendly" and a verv rood buy.

The MC 1317b Chip that was described in the January '93 issue of SSS is really hot. I had the opportunity to use the chip and there are a couple of things I will suggest to help you get it up and running. I found that C4 and C5 needed to be 27 pf, not 47 pf, and a 1000 ohm resistor is needed across the crystal. These changes are necessary to insure that the crystal would oscillate 3rd overtone and not fundamental. The tricky part is getting the tank coil adjusted. The chip has a high frequency oscillator with enough stray C built in, all you need to supply the L. This is where the 3 turn coil comes in between pins 1 and 4. Silver plated #24 buss wire is ideal, but the lead off a 1/4 watt resistor will work. To coil the wire use a small diameter pin such as a drill bit shank. I found that a .086" diameter is good. Put the coil in the circuit without the crystal, and see what its free running frequency is. With a 29.5937 MHz crystal our final frequency will be 915 MHz (X_{freq} x 32). Loosely couple a spectrum

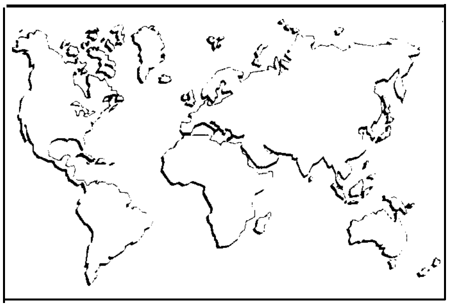
analyzer to the tank and observe the frequency, if it is low, spread the turns slightly. If high, squeeze the turns together. Try to get it to run within 10 MHz of your target frequency. You should then be able to plug in the crystal and get the circuit to lock to 9 15. There is a phase comparator in the chip that varies the internal C to lock with the oscillator. Anyone who doesn't have a spectrum analyzer or is having trouble getting the circuit to work, drop me a line in care of SSS and I will send you a tank coil that I have adJusted to 915 MHz.

I enjoy giving credit to companies that provide excellent service. Readers have responded well to my suggestion to check out Test Lab Co., Mountain View, CA for deals on used test equipment. In all fairness I can not overlook another company, SPECTRA LABS, Santa Clara, CA (408-738-242 1). Although not as big as TLC, they offer personal service and good prices. Give Jon Loll at Spectra a call with your next test equipment or metrology problem. By the way, both TLC and Spectra Labs are welcome advertisers here in SSS.

I have dealt with many PC board fab houses over the years, but CIREXX Corporation, Santa Clara (408-988-3980) specializes in quick turns on tough jobs and has consistently done an outstanding job at a fair price for me. Call Luise Menges for your next quote.

RF Expo West is this month. From the list of exhibitors, it should be an extremely interesting show.

I still have not received my Receiver Design software from Webb Labs. I have called several times, and I merely get a recorded message that says please be patient. Maybe Richard will be at the RF Expo and I can get his explanation for the delay!



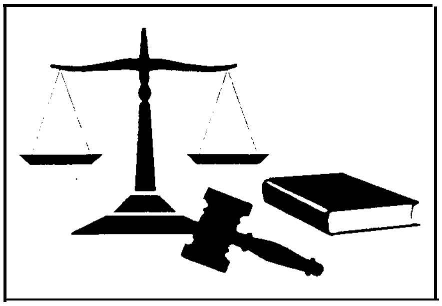
International Scene

- The European Community has decided to abandon the independent development of its own new generation of HDTV televisions, acknowledging that more advanced systems under consideration in the United States almost certainly will become the worldwide standard.

By recommending that the community drop its plan to impose an EC-developed high-definition system on broadcasters and program producers, Industry and Technology Commissioner noted that there was no point in supporting a technology that already has been overtaken in the race to provide super-sharp television pictures. European officials have said they were not conceding to the United States the right to dictate a worldwide standard. But they said they believed that some US standard would become the global norm. The systems being studied by the FCC are all based on digital technology.

In developing HDTV, Europe and Japan both initially concentrated on conventional analog broadcasting systems, believing that digital systems were years if not decades away.

But rapid advances in digital technology have led broadcasters and electronics companies in Europe to oppose an analog standard.



Washington Scene

- The California Public Utilities Commission recently said it will launch an official review of Pacific Telesis Group's proposal to split itself in half, giving the phone company's critics a platform to lobby for consumer protections on the deal.

In December, San Francisco based PacTel announced plans to divide its business in two: Pacific Bell, the regulated provider of local phone service, and a new unregulated company for PacTel's cellular phone and paging business.

Stockholders would get shares in both companies. PacTel has sought to portray the spin-off as simply rearranging the corporation's financial structure -- a maneuver that would not require PUC approval.

- General Magic grabbed worldwide headlines recently when it announced its futuristic vision: Someday we'll all have little wireless gadgets that combine the technologies found in cellular phones, fax machines, electronic mail and modems.

As General Magic and its partners figure it, anyone with one of these things will be able to call or send text, graphics or video to anyone else. They predict that these so-called "Personal Intelligent Communicators" will be our all-in one connection with the rest of the world. PICs will help us better connect with each other, with banks, libraries and brokerage houses maybe even with government bureaucracy.

But when? At Mobile 93 last month, officials at the tiny Apple spinoff said they will be the only be creating the necessary software, and that big partners like AT&T, Motorola, Sony and Panasonic will build the various PIC devices and services needed to support that software. This long-term vision from General Magic is intriguing. But it's only seizing the near-term opportunities -- and for entrepreneurs, that's best.

- Here's the dream: a world where millions of people carry miniature "personal communicators" that keep them constantly in touch over the airwaves, spewing everything from faxes to phone calls to news reports all using an electronic pen.

It's a vision revealed recently by a host of companies from industrial giants such as AT&T, Motorola and Apple to little Silicon Valley start-ups like EO Inc. and General Magic. Reflecting the work of the companies' PR machines, there has been a lot of press about it. Investors are ringing the companies' phones off the hook, wondering how they can get in on what sounds like a gold mine.

But there's only one problem, according to many in the business. Such a world is years away, perhaps even decades. And the first few generations of personal communicators will not only be very expensive, they won't be nearly the wonder machines consumers envision.

RF Micro-Devices Announces World's First HBT Linear Amp for 915 MHz Spread Spectrum

RF Micro Devices, Inc. has announced the availability of the first commercial linear power amplifier (RF2 IO3) fabricated using TRW's Heterojunction Bipolar Transistor (HBT) technology The RF2103 performs at high efficiencies which were previously unattainable with existing technologies. These enhanced performance characteristics will enable designers of battery powered wireless equipment to extend battery life. Applications include digital communications systems. spread spectrum communications. and consumer battery powered wireless applications.

"The use of HBT technology for low-cost linear amplifiers is an industry first." states Jerry D. Neal. Vice President of Sales and Marketing, RF Micro Devices, Inc. "Previously this technology was primarily used in aerospace and government systems applications. Existing power amplifiers are either discrete or hybrid GaAs designs which are relatively large and require both positive and negative power supplies." The use of HBT eliminates the negative supply and the monolithic approach reduces the size to approximately 25% of existing designs. TRW's process uses Molecular Beam Epitaxy (MBE) for consistent doping profiles which results in a highly reliable and high yielding HBT device. The RF2 IO3 is a medium power linear amplifier capable of operating from 800 MHz to 1 GHz.

The device will efficiently operate from a single power supply from 3.0 to 6.3 VDC. Maximum output power at 6.3 V is 800 mW. The RF2103 is the first of a complete line of HBT amplifiers with power outputs from 100 mW to 2.5 W. RF Micro Devices, Inc. has completed the design of these products and will announce their availability during 1993.

The RF2103 is now available in a ceramic SO- 14 package and will be available in a low cost plastic package later this year. Pricing for the RF2 IO3 in the ceramic SO-14 package in quantities of 1 OOK is $15. Projected prices for the plastic version are less than $ IO.

Technical Tricks

More About Sliding Correlators

by Randy Roberts. Director. RF/SS

Last month we talked about DS (Direct Sequence) correlators in general. We covered an introduction to most of the different types of correlators used today. This month we will concentrate a little on the so called Serial Sliding correlator. This type of analog or digital or analog digital hybrid implementation is the most commonly used correlator today. It is easy to get working. It is easy to design. It is simple to get working and align. Finally, it is a sure-fire, almost idiot-proof way of correlating a locally generated code against the incoming coded signals.

Key to making this correlator work is that it must be embedded into a multi-channel PN correlation/detection scheme. One way of doing this is shown below in figure 1. In this design a three channel, "Delay Lock" or "Early - Late" correlator design is used. Three time staggered samples of the PN code are required to make this design work. The time staggered code samples are easily generated by driving a two or three bit shift register with your locally generated PN code. The actual time stagger used depends on the priorities of your design. It can be any rational fraction of a "chip" -- up to one full chip. Don't make it more than one full chip, however -- it will rapidly loose correlation gain beyond one full chip because of the triangular nature of the PN autocorrelation function.

The actual data demodulation is done in the "center" channel. The DC outputs of the "Early" and "Late" channels are subtracted from each other in an Op Amp. The difference between the Early and Late channel correlations forms a straight line, triangular looking, discriminator "S-curve" of the time difference between the local and incoming codes. This DC signal can be fil-

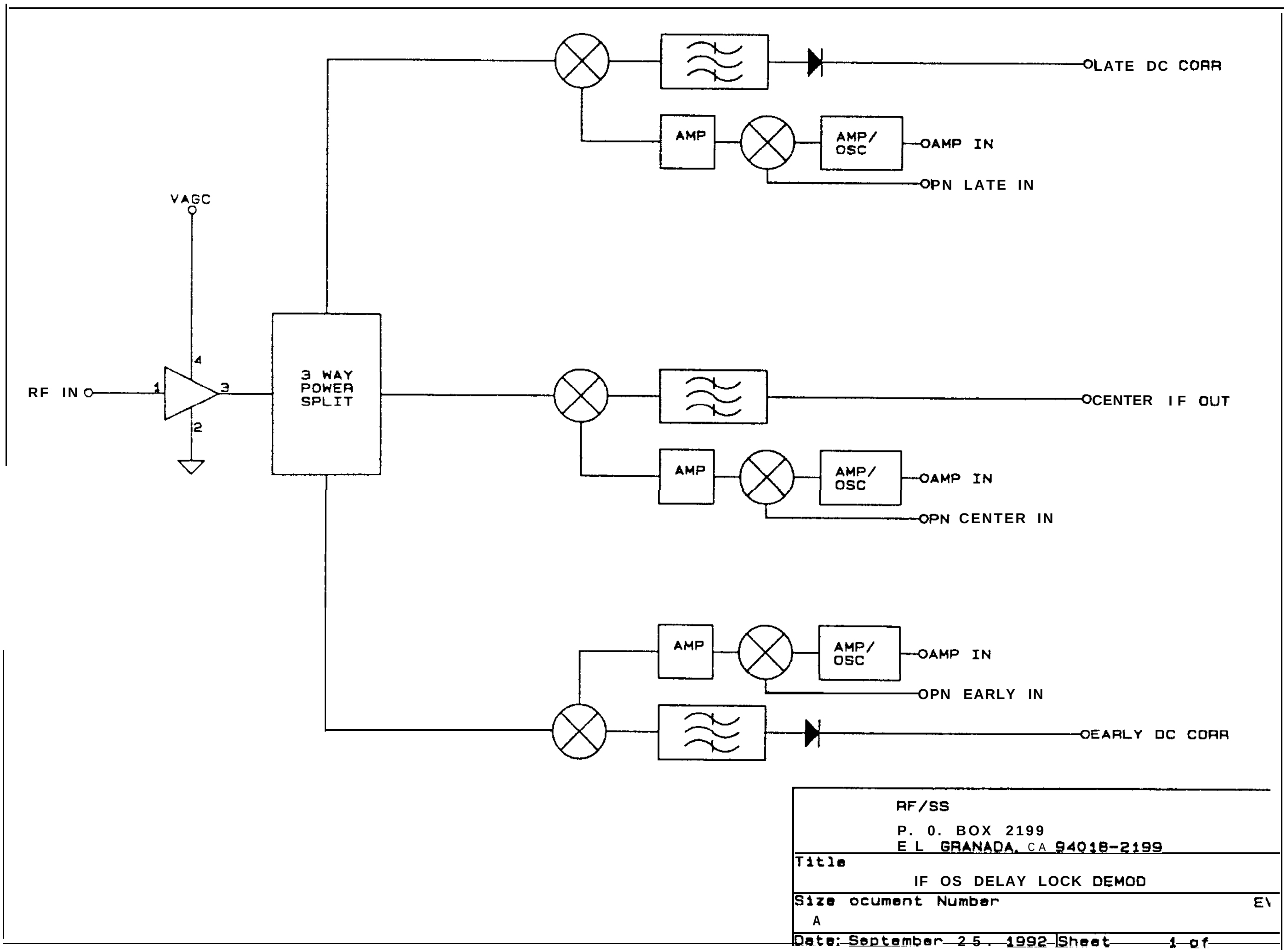


Figure 1: IF DS Delay Lock Loop Block Diagram

tered and used to close an AFC type tracking loop around the local PN clock source (VCXO or VCO). Thus this correlator architecture is capable of demodulating the data (the de-spreading correlation operation) and generating a time tracking reference signal for the receiver it's used with.

You need more than just the circuitry shown, however! First the initial frequency of the receive PN clock must be offset, by some small amount, from the transmitting PN clock. This frequency offset causes a beat note between the two signals that actually slowly sweeps the received PN timing across the transmitted signal's PN timing. Thus the name "Sliding Correlator."

Normally this frequency offset is easy to achieve, because only by a very fortunate accident would the TX and RX PN clocks be on exactly the "right" frequency -- they probably would not stay on the exact same frequency for long anyway.

Next month we'll show you how to control the actual TX and RX frequency offsets precisely, in a fully digital manner. For now, suffice it to say that it is desirable to control the frequency offset between TX and RX PN clock generators! This controlled time offset allows the sliding correlator to precisely sweep through the unknown time delay repetitively so that sync-up time can be controlled.

Figure 2, below, shows an alternative implementation of the Delay Lock DS loop. This scheme is useful for a DSP based or more digital demodulation correlation implementation. The performance of the two block diagrams is identical if the baseband low pass filters of figure 2 match the equivalent bandpass characteristics of the filters in figure 1.

Let me give a little hint about a faster scheme using the "Hybrid Sliding" correlator approach: If you use 5 or 7 channels instead of 3 you can acquire sync much quicker! More details on this scheme and other "neat stuff' next month.

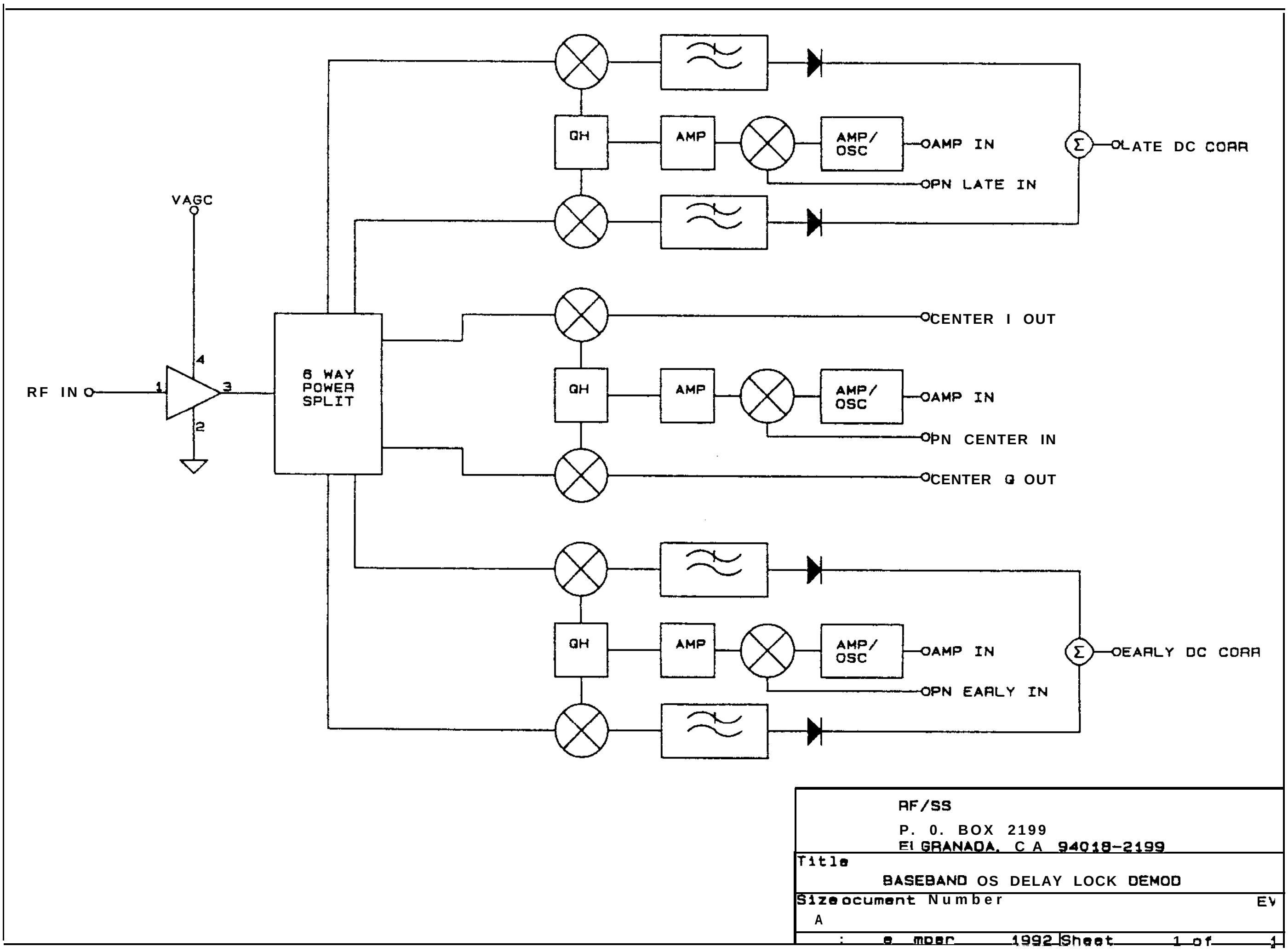


Figure 2: Baseband DS Delay Lock Block Diagram

A 16 kBps Full Duplex Spread Spectrum RF Data Link -- Part 4

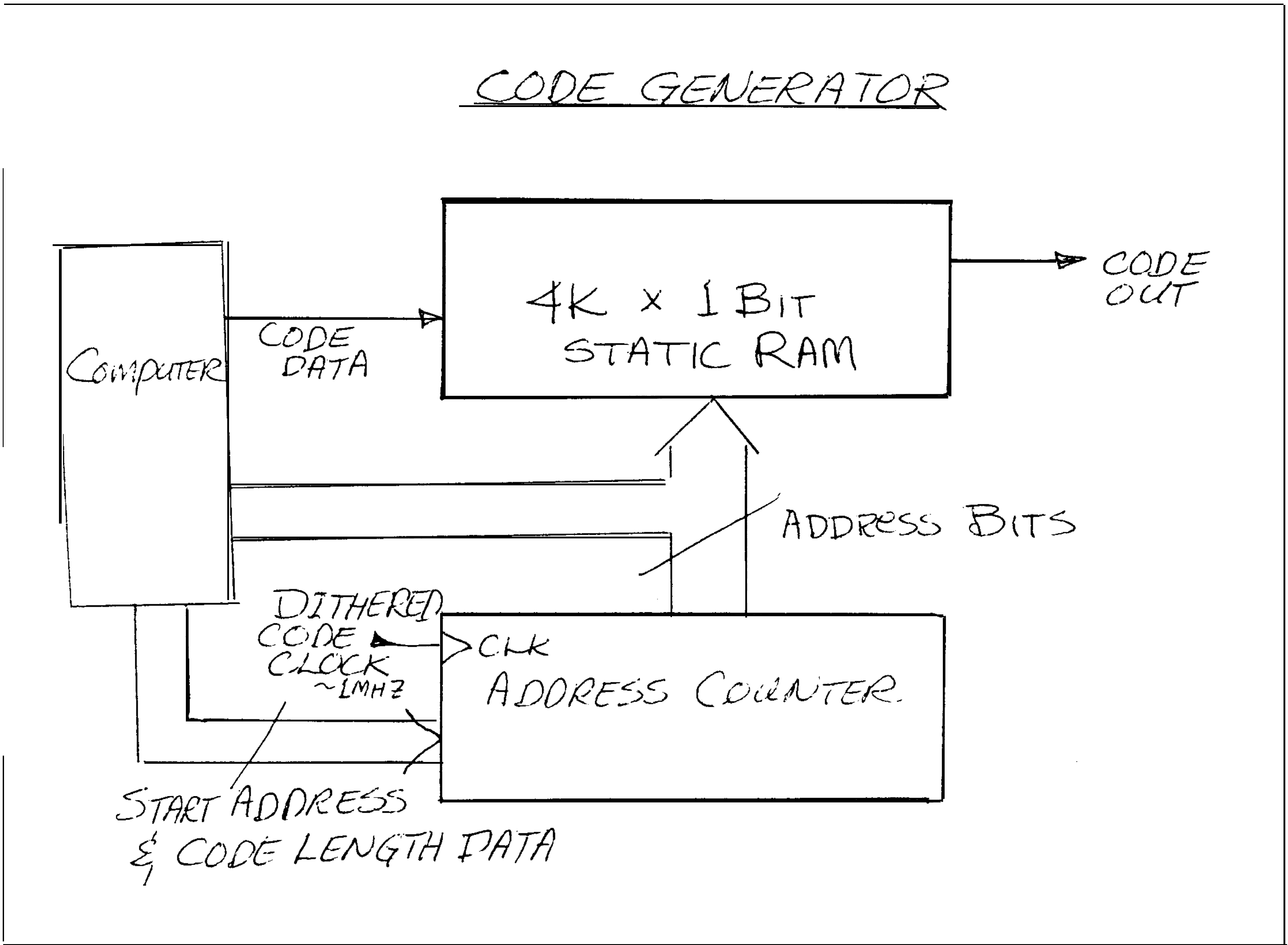
by Dan Doberstein, President
DKD Instruments

In January we covered the CVSD and Costas loop subsystems. This being the last part of this article we will talk about a possible solution for code generation. alternative PLL and CVSD solutions.

Figure 1 shows the code generator block diagram Instead of the tried and true shift register approach a 4K x 1 bit piece of static RAM is used. A counter/address generator is driven by the dithered code clock which in turn generates sequential addresses which clock the code out of the RAM. This architecture allows complete code flexibility since codes can be generated by the controlling computer and downloaded to the RAM. A start address and code length word are also sent. This allows storing multiple codes in the RAM and accessing them on the fly.

This architecture allows complete code flexibility since codes can be generated by the controlling computer and downloaded to the RAM.

Switching codes on the fly could be used to implement a two code system where acquisition is done using a short code of say 15 bits and after code lock switch to a much longer code. Longer codes increase the number of users (within limits) per channel and decrease the probability that another user will be "on" your code. The down side of longer codes is increased acquisition time especially with the sliding correlation method used here, hence the short/long code solution. It is the synchronizing of the switch between the codes that is tough! One method would be to deliberately put a small offset (in code bits) in the receiver long code w.r.t. the transmitted code at the moment



when the codes are switched. This will temporally break lock but by forcing the receiver to search in one direction only, towards lock, you will quickly achieve lock again on the long code.

A neat replacement for the MC3417 CVSD is the Hall-is CVSD chip set. The HC55536 does the demodulation operation while the HC55564 does the modulation operation. Operation from 9 kBps to over 64 kBps is claimed. The design replaces the analog filters used in the Motorola design with internal digital ones. This results in fewer components for a complete solution.

I hope you are inspired to try some of this out and at the least found it interesting reading.

Another more flexible choice for the PLL is the Fujitsu MB 15 19. This dual PLL goes to 600 Mhz and has a user programmable divider using swallow A counter l/N counter technique. A three wire serial interface is used so minimum hardware connection to computer is needed. The reference divider has only two values, 5 12 and 1024. This forces channel spacing of 20 khz or 10 khz with a 10.24 MHZ reference. By adding a divide by 2 prescaler, NEC584, we can double our VCO max frequency to 1200 MHz. Of course at these higher frequencies we are losing image rejection with that 1st IF of 10.7 Mhz, so another IF in the receives chain may need to be added.

Well that's it for this article, I hope you are inspired to try some of this out and at the least found it interesting reading.

Write or FAX Dan with your comments, questions or suggestions for improvement c/o sss.

Simulating with Mathematical Software

by Ed Stoneham

General purpose mathematical software occasionally proves handy for various system simulation tasks. Mathsoft's Mathcad®, Wolfram Research's Mathmatica®, and The MathWorks MATLAB® are a few of the better known general purpose, multi-platform mathematical tools. With the capability of handling large arrays and matrices, performing Fourier transforms, solving simultaneous nonlinear equations, integrating and differentiating, and iterating over time, these software packages can be used to handle virtually any simulation task with great flexibility. The main drawback, with respect to dedicated system simulation software, is that the user must supply the appropriate equations and that calculations may proceed rather slowly. Nevertheless, the author has found math software useful for doing radio link range calculations, filter response calculations, passive circuit transfer function calculations, discriminator simulation, and full wireless system simulations showing digital out versus digital in with white noise and phase noise taken into account.

As an example this article demonstrates an application of Mathcad to simulate phase noise on a carrier. Figure 1, on the next page, shows a measured phase noise spectrum the author was attempting to duplicate. Figure 2, on page 17, is a printout of the Mathcad file used to simulate the signal. Version 2.0 of Mathcad was used on a Macintosh IIsi with a built-in math coprocessor.

Referring to Figure 2, the initial portion of the phase noise simulation application sets up the time and frequency steps. To enable the use of fast Fourier transforms, the number of time steps n_t is set by the user to an integral power of two. An index i, is defined as a "range variable" which takes integral values from zero to n_t. The time t_i, corresponding to each value of the index i, is defined as i_t times the user-specified time interval Δt. Similarly, a set of $n/2 + 1$ frequencies is defined representing the domain of fast Fourier transform taken over the time set t_i.

These software packages can be used to handle virtually any simulation task with great flexibility.

Phase noise is simulated though a series of steps each of which is grouped under a heading in the printout of Figure 2. The synthesis starts with the generation of white noise (with a power per unit bandwidth that is constant over all frequencies). The white noise is filtered to produce pink noise (noise with power per unit bandwidth inversely proportional to frequency). The pink noise modulates the frequency of a carrier to produce the phase noise. The resulting phase noise spectrum shows skirts lower than those observed in Figure 1. The discrepancy is eliminated when the frequency modulated carrier is run through an appropriate limiter.

These steps closely reflect what is happening physically in a typical oscillator. Energetic charge carriers replete with shot noise (white noise) stimulate various phenomena such as the charging and discharging of interface states and traps in the amplifying device. With a distribution of time constants weighted toward the lower frequencies, the phenomena responsible for fluctuations in the amplifying device acts as a natural *1/f* filter producing pink noise. The fluctuations perturb the oscillator in such a way as to produce frequency modulation. The signal undergoes limiting by the nonlinearities of the oscillator itself and, possibly, by saturation in subsequent stages of amplification.

The pink noise modulates the frequency of a carrier to produce the phase noise.

The method chosen for generating white noise, as can be seen in Figure 2, is to set up the discrete frequency spectrum so that every frequency component has the same amplitude but each component is random in phase. This is accomplished by setting each complex frequency component equal to $e^{i\theta}$, where θ is a random phase angle between zero and 2Π radians. Mathcad's ***rnd*** function is used to produce the random numbers. The inverse fast Fourier transform function ***ifft*** operating on this complex frequency spectrum yields the desired white noise amplitude versus time, as seen in the graph at the end of the "White Noise Simulation" section in Figure 2.

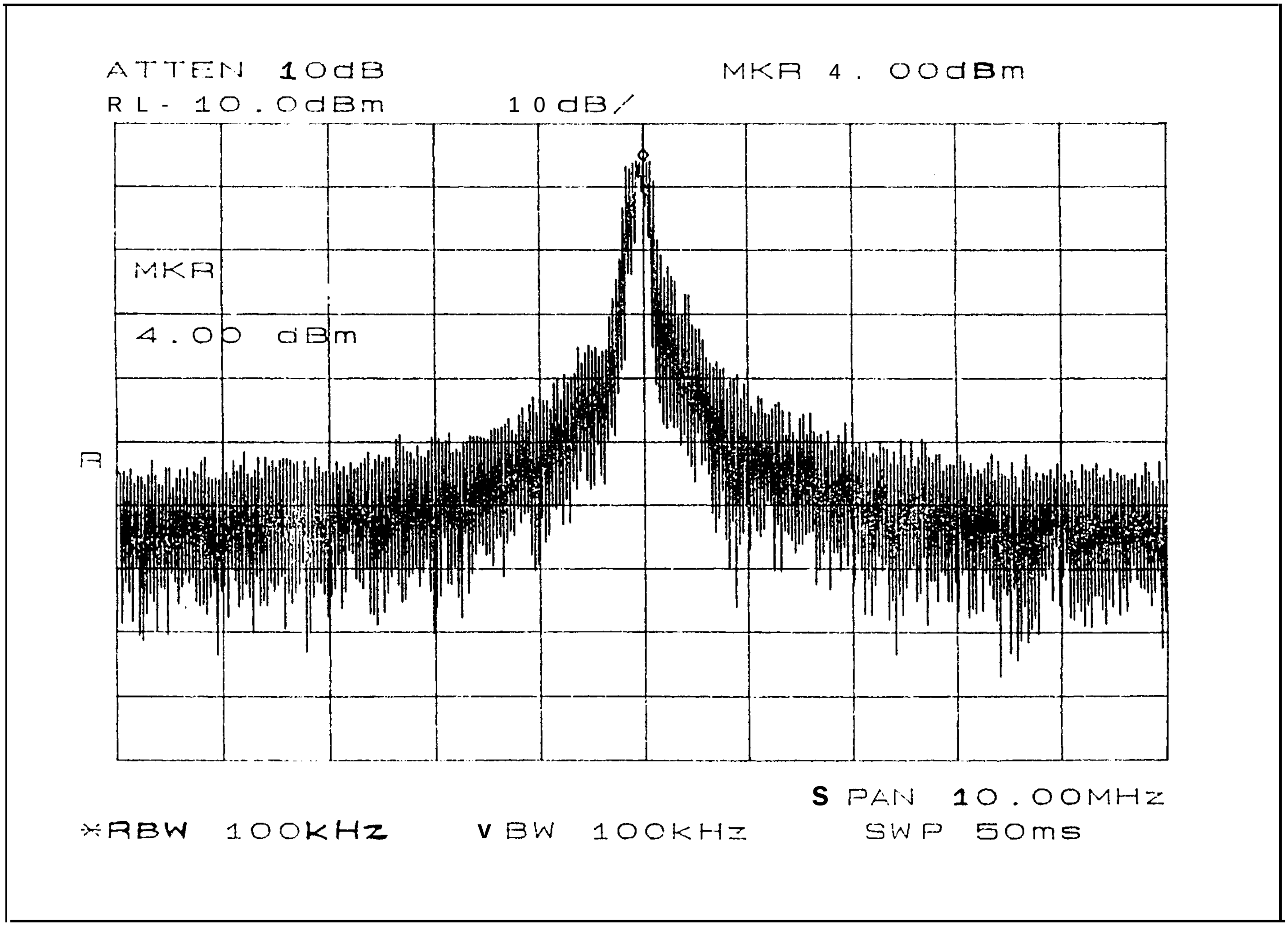


Figure 1: Measured Oscillator Phase Noise

To simulate the pink noise, the fi-equency components of the white noise are tailored to achieve a $1/\sqrt{f}$ amplitude dependence up to a noise corner frequency f_o beyond which the amplitudes are held constant. In addition, the zeroth fi-equency component (direct current) is set to zero. The resulting waveform is displayed on two different time scales at the end of the "*1/f* noise simulation" section in Figure 2.

Frequency modulation of the carrier is achieved, as shown in Figure 2, by adding an increment proportional to the pink noise amplitude to the carrier center frequency f_{cc} to produce the instantaneous frequency f_{cp} for each time step. The modulated carrier waveform is generated as the cosine of a phase angle Θ_{it}, which is derived iteratively through addition of an increment proportional to instantaneous frequency at each time step.

Finally, amplitude limiting is achieved with the help of user-defined function $r(A, A_{lim}, \Delta)$ which produces symmetrical limiting of waveform A at a level A_{lim}, and with a softness set by Δ. A graph of the limiter transfer function appears in the "Amplitude Limiting of Carrier" section in Figure 2.

The resulting waveform is displayed on two different time scales at the end of the "1/f noise simulation."

The last section in Figure 2 shows graphs of the spectral power distribution of the noise-modulated carrier after limiting as calculated with the fast Fourier transform function *fft*. The first graph reveals the spectral distribution of the fundamental and of the third harmonic created by the symmetrical limiter. The second graph, plotted with the same scale limits as the graph in Figure 1. demonstrates a reasonable simulation of the measured phase noise spectrum.

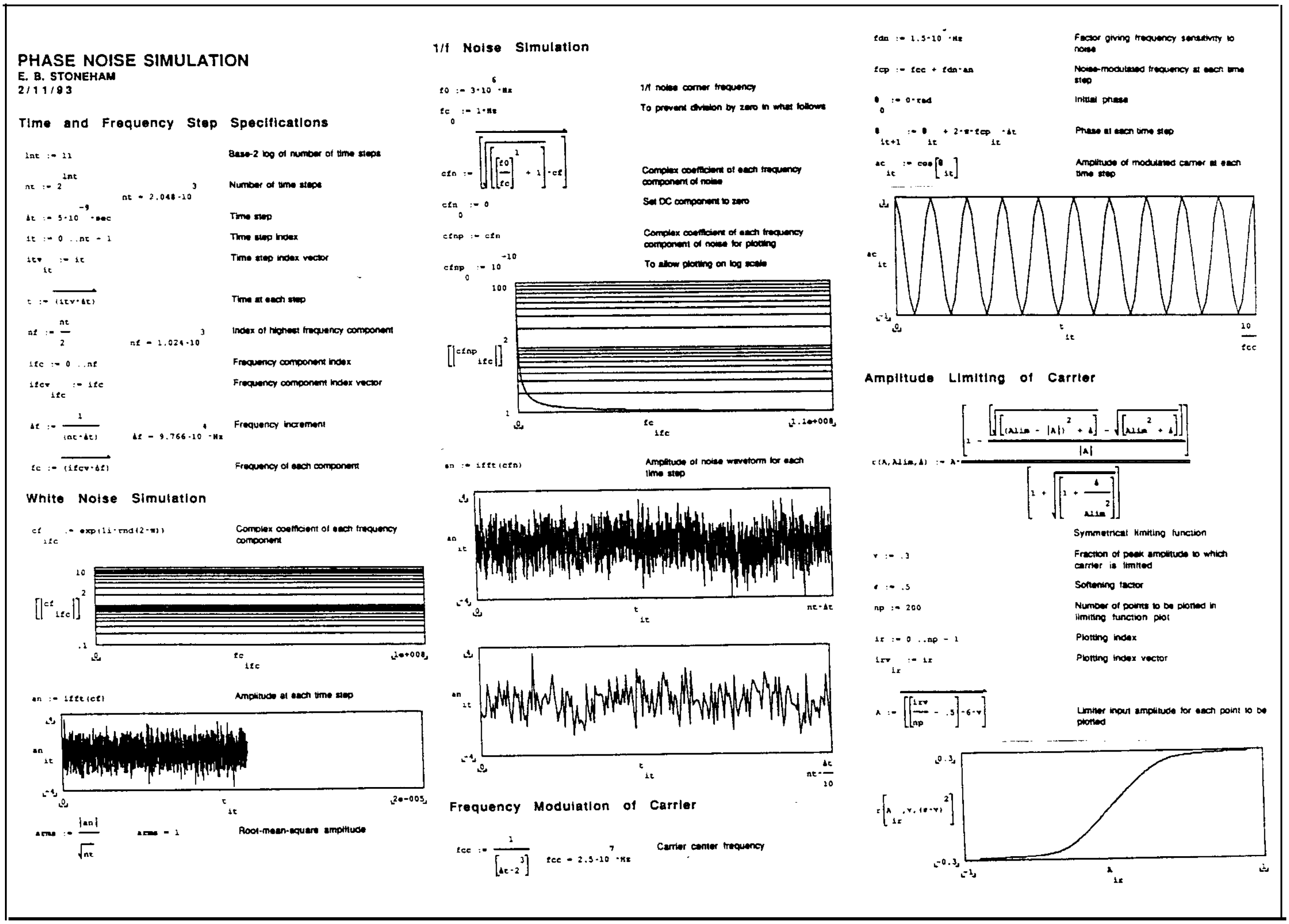


Figure 2: Mathcad Simulation Printout.

This application, with 2,048 time steps, required 4 minutes on a Macintosh IIsi with coprocessor. After it's development. the results were checked and the bulk of the application was merged with a system simulator created in Mathcad and was used to check the effects of phase noise on the receiver's digital output waveform. Generating the phase noise application required about two or three days, somewhat longer than the time required to set it up on dedicated system simulator software. However, the extra time yielded helpful insights into the nature of phase noise. Happily, the application can now be modified and put to use quickly whenever needed in a system simulation.

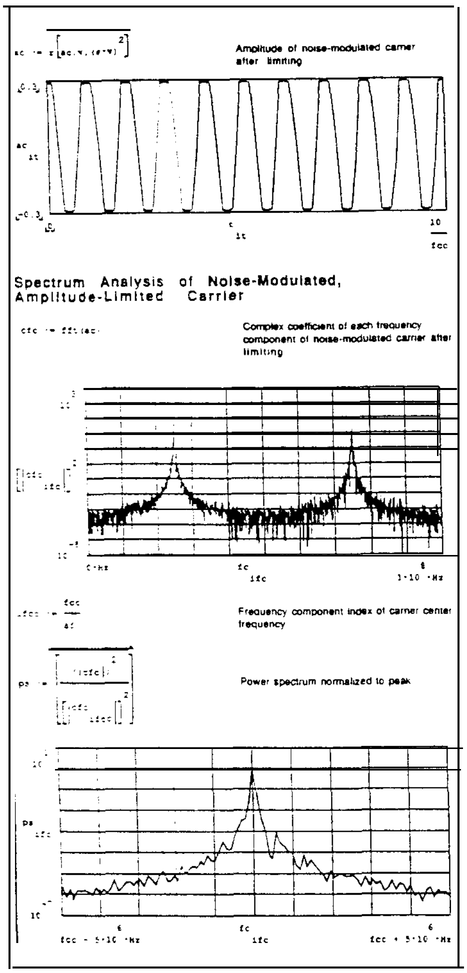


Figure 2 Continued

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Nibbles & Bits

● Qualcomm Incorporated, late in January, promoted Steve Morley to vice president, VSLI Products. Qualcomm's VLSI products include Viterbit and trellis decoders, vocoders, direct digital synthesizers (DDS), phase locked loop (PLL) and voltage controlled oscillators.

● GEC-Marconi announced the availability of it's P35-4701 2.4 GHz GaAs MMIC for wireless and PCS applications. This is a complete RF transceiver on a chip.