Spread Spectrum Scene

The PCS, Wireless Network and CDMA Monthly News Magazette

Volume 1, Number 4 July, 1992

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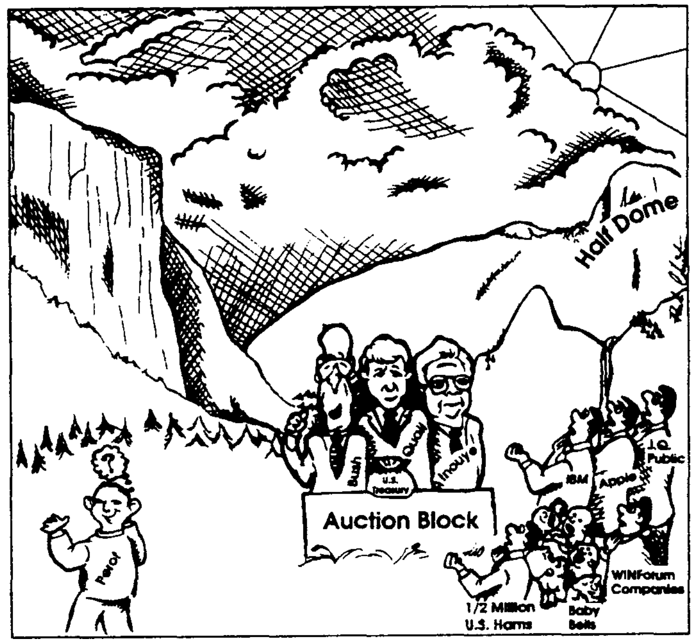
Senator Inouye and his S-218 Have Been Resurrected as the "SPECTRUM AUCTION BILL!"

While Senator Daniel Inouye has not really been resurrected, his Senate Bill 218 *is* gaining new life. Nearly four years in the making, S. B. 218, "The Emerging Telecommunications Act" is rearing it's ugly head once again. The senior Senator from Hawaii, Mr. Inouye, has gained a lot of exposure recently by taking the lead from the White House and the Office of Telecommunications Policy (OTP) and letting an otherwise harmless idea take on a new dimension. Pressures from industry, a tough economic climate, budget cuts and other factors are causing the FCC to increase fees and in effect, generate revenue. If S. B. 218 succeeds in auctioning off the "Spectrum Reserve" it is taking away from previous government allocations, the US Treasury stands to gain at least $250 million.

Last month. Senate Communications Subcommittee Chairman Earnest Hollings and FCC Chairman Alfred Sikes seemed to be at odds. Hollings may introduce legislation because earlier in the year he said "The FCC has not considered fully the needs expressed by the existing users." Hollings subcommittee called on Mr. Sikes to address these concerns.

As always these are complex issues and difficult times -- for more information see the companion story on this page, our editorial, page 3 and Washington Scene, page 16.

What's Inside



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Thank you Ladies & Gentlemen, that completes the auction of Yosemite's "aura". What am I bid for a prime 150 MHz at 1.9GHz?

GOOD NEWS AND BAD NEWS

Spread Spectrum PCS and Wireless LAN Systems Make Headlines

Spread Spectrum signals will soon be making an impact on our daily lives, if the press is to be believed. During research for this month's issue, SSS staff uncovered over 250 pages of recently published significant material in nearly 100 publications, about Spread Spectrum. Not only is SS making headlines -- it is making a dent in our forests!

Rory J. O'Connor, in the June 14, 1992 *San Jose Mercury News*, "Battle for the airwaves", page El, noted: "Silicon Valley companies envision a future where millions of people carry 'around pocket-size computers that link them with their offices by radio waves." Mr. O'Connor and many others think the public needs to know more about our "wireless" communications future. SSS strongly supports this notion_ In

see Good/Bad page 2

SPREAD SPECTRUM SCENE

is dedicated to the Spread Spectrum professional and is committed to being the primary source for the latest news and information about the growth, regulation and opportunities in this emerging science.

SSS provides a forum for publication of technical information, advertising, editorials, opinions and news relating to the emerging fields of our coverage and emphasis.

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Good/Bad from pg. 1

fact, SSS and it's editor/publisher have been using up paper lately too Look for Randy's articles in the following publications.

May and June Satellite Operator, published by R. Myers Communications, Fountain Hills, AZ. (602) X37-6492

July Nuts & Volts, published by T & L Publications, Corona, CA. (7 14) 37 1-8497

· June CCEI NEWSLETTER, published by the California Council of Electronics Instructors, Twentynine Palms, CA.

For more coverage on this topic and related issues see our editorial on page 3 and Washington Scene, page 16.

Reader & Advertiser Services

Welcome back -- this month brings more changes to SSS. First, I hope you have noticed our cleaner layout and two-color front and back covers. We also regret to tell you that due to time conflicts, Kim Robinson's column on SS Networking Software will not appear this month. Is there anyone out there who might be able to take over this column'? We introduce two new features this month: (I) Tom Diskin's, N7TD, new column Technical Trends in Education; and (2) the column Secret Spread Spectrum Signals. Hope you enjoy these changes to SSS. Please write us with your comments and suggestions. Koert Koelman

Bit Errors

Corrections to issue Number 3, June, 1992:

- Page 9: 5 BIT GOLD CODE EPROM CONTENTS Sidebar -- The Minimum Cross-correlation should be -15/31 -- Maximum should be 7/31 and the Worst cross-correlation sidelobe should be -10.4 dB.

- Page 9: The Figure 3 Schematic -- did anyone notice the missing NOT WR signal on U3?

Decipherings

Our present civilization is a gigantic motor car moving at an ever-accelerating speed. Unfortunately, as now constructed the car lacks both steering wheel and brakes, and the only form of control the driver exercises consists in making the car go faster.

- Lewis Mumford -

Don't miss an issue of Spread Spectrum Scene -- subscribe now!

EDITORIAL

As a picture is worth a thousand words, our front page cartoon summarizes SSS' opinions about S. B. 218. We also hope you got a small chuckle from the cartoon. We thank Ms. Paula Christensen, our new Art Director, for her artistic creation.

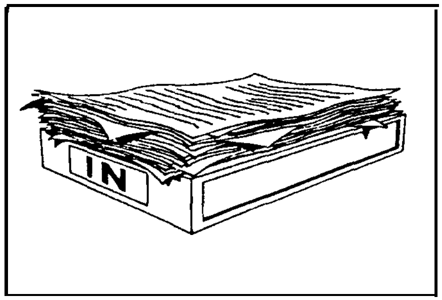
Congress established the FCC in 1934 with the Communications Act of 1934. This enabling legislation provided for the FCC to allocate the frequency spectrum in a fair and equitable manner, balancing the public's good against industry and commercial needs. The government was also provided for in this legislation, because not all of the precious spectrum was given the FCC to manage. The FCC was allowed to license spectrum users, collect application and other fees -- it was also given the job of regulating and policing the frequencies it manages.

Time and events change all things. So the FCC first introduced the "Fairness Doctrine" and "Equal Access" provisions. Then came Cellular Telephone and two-provider monopolies of service areas. Then ahnost ten years ago the FCC and Congress came up with one of the "best" ever: the Communications Secrecy Act. This "super" legislation overturned the basic idea, from 1934, that the airwaves belonged to the public and any signal could be freely received, without charge to the public, provided no commercial use was made of the broadcast.

Now we see the Congressional and FCC greed again at work with the "Spectrum Auction Bill." Don't these people ever think? Our spectrum is a limited and precious natural resource just like our national parks or our freedoms guaranteed by the Constitution. How can they auction off these ethereal things that rightfully belong to the taxpayer, the citizen and the public:'

I guess BIG BUSINESS is more important than we citizens and taxpayers. Is it in the public interest or "fair" or does it provide "equal access" to auction off a "Spectrum Reserve"? Spectrum that was taken from sparsely

See Editorial page 15



Letters & Comments

Sir,

I am interested in your publications "Spread Spectrum Scene," which you advertised in the MAY issue of "NUTS & VOLTS" magazine.

Enclosed is a SASE for your convenience.

Thanks,

Winston Yuen
Woodhaven, NY

To Whom it may concern:

I have read a short description of your newsletter in Don Lancaster's "Resource Bin" in NUTS & VOLTS Magazine. I am interested in reviewing your Spread Spectrum Scene newsletter and request a copy be sent to the above 'address with subscription information.

Thank you for considering my request, I am looking forward to receiving a good communications newsletter.

Sincerely,

James D. Leisring, Jr.
ITT Technical Institute
Indianapolis, IN

Dear Randy,

Congratulations on a very well done and very welcome newsletter. . . .

You may be aware that there is a small but quite intense group worldwide devoted to direct downlinking of digital remote sensing data from meterological satellites. We have been downlinking GOES-VISSR images at 2.11 Mbps since 1985, TIROS-HRPT at 665 kbps since 1989 and recently METEOSAT-PDUS. I will spread the word among this group about your publication since it is of specific interest and aid to our work.

Yours Truly,

John L. DuBois, W IHDX
Boxborough, MA

Randy Roberts,

Please set up a subscription for me for 12 months.

I have contacted the Canadian D.O.C. in Calgary re: obtaining temporary permission to use SS emissions in Canada. Information you furnished on the US STA has been forwarded to D.O.C. Senior Radio Inspector Mark Hanna, who seems receptive to a similar STA measure here.

If you have any details on other Canadian efforts in this direction, please let me know. I have enlisted several other hams here who will help with the paperwork and want to get on the air with something like the STA- 1. Also, if any other Canadian Hams are interested in joining our effort, please have them contact me.

Best Regards,

Rusty Rushton, VE6TL
Nowsco Pipeline Surveys & Services
Calgary, Alberts, Canada

ATTENTION CANADIAN HAMS!

If you would like to participate in a Canadian D.O.C. STA request and get on Spread Spectrum

Please contact:

Rusty Rushton, VE6TL

Voice: 403-569-8900

Fax: 403-569-8096

Beginner's Box
Learn a Little Japanese

ENGLISH	JAPANESE
Lovely weather, isn't it?	Ii otenki desu ne?
It's hot (cold), isn't it?	Atsui (Samui) desu ne?
Have a good trip!	Yoi goryoko o.
Let's meet again!	Mata aimasho.
Is (are) there _?	_ ga arimasu ka?
I lost ___.	--- o naku-shimahita.
I'm looking for ___.	___ o sagashite imasu.
Whom should I ask?	Dare ni kikeba iinodesu ka?

FLASH: Canadian D. O. C.

In the quickly evolving turn of events, the US's nearest northern neighbor appears to able to move very quickly in Spread Spectrum regulatory matters, as the following letter shows.

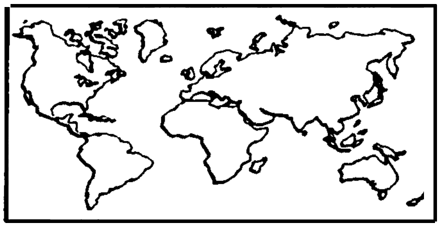
To: Randy Roberts – SSS
From: N. J. Rushton, VE6TL
June 26, 1992 Re: DOC STA

The D.O.C. response (to our inquiries) has been very positive and it would appear that we will probably become active in the 900 MHz band without the need of an S.T.A. The D.O.C. are evaluating the situation at this time.

Later this year we hope to form an experimental group within the Calgary Club and SS will be one of our areas of interest.

As of this week, we have twelve names of local Hams who would be interested in participation with SS. These names are also available for inclusion with a formal application to the D.O.C. should it become necessary. If any other Canadian Hams are interested in joining our effort, please have them contact us.

N. J. Rushton, VE6TL
6131 Longmoor Way S.W.
Calgary, AB T3E 5Z8
403-240-0249 or 403-569-8900



International Scene

STANFORD TELECOM WINS MAJOR CONTRACT for CORDLESS PBX/PCS TELEPHONE SYSTEM

Stanford Telecommunications, Inc. (STel) today announced the award of a Spread Spectrum Cordless Telephone System development program From a consortium of five Taiwan companies. The consortium is building a next-generation digital telephone system for PBX and Personal Communications Service applications. Stanford Telecom will design and develop not only handsets, but also base stations, remote handset cradles, and other key equipment all based on STel's Digital Spread Spectrum and Application Specific Integrated Circuit technologies.

Organized by Taiwan's Industrial Technology Research Institute (ITRI), the consortium consists of manufacturing and communications companies from Taiwan's private sector. The firms seek to use Stanford Telecom's ability to rapidly design communication systems and produce them in ASICs to strengthen the Taiwan telecom industry that is currently dominated by makers of low end conventional telephones.

The award of the development contract comes after a competitive system design and specification phase between Stanford Telecom and another United States based communications company. According to Hatch Graham, Vice President of Stanford Telecom's ASIC & Custom Products Division, Stanford Telecom believes they were selected based on two key points: the high performance and capacity of their Synchronous Orthogonal Waveform™, CDMA technology for communications over multipath channels such as offices, and STel's proven line of ASICs for wireless signal processing, demodulation and decoding.

The Stanford Telecom system is intended to provide mobile telephone capabilities to PBX environments such as offices and factory facilities where users on the move need to link in a wide variety of locations. Using personal codes managed by a single base station, the STel cordless phone system will automatically route calls to the phone of the called person regardless of the individual's position at the time. For a shared phone system, over 60 phones will be supported by a single base station, significantly reducing the *cost* per user compared to existing wireless phone systems. Power efficient and compact handsets will be built for ease of use. The handsets will be set in battery charging desktop cradles when not in transit. To eliminate interference problems common to currently available cordless phones, Stanford Telecom will introduce Synchronous Orthogonal Waveform™ technology designed specifically formobilecommunications within office and other multi-user pedestrian environments.

Stanford Telecom expects to have a working cordless phone system in field testing in the first quarter of 1993. Stanford Telecom's high capacity, Synchronous Orthogonal Waveform™, Code Division Multiple Access (CDMA) technology, enables the telephone systems to be configured into a cellular infrastructure, thereby enabling users to roam from a home base station to other base stations. With this structure, over one thousand wireless users in a cellular configuration may be provided with high voice quality.

Stanford Telecom's proven technology has been used for years in many robust military systems, and with their introduction of standard ASIC building block products, the technology has quickly made its way to numerous industrial and consumer applications where both high performance and low price are mandatory. For example, applying their core competence in navigation and positioning technology, Stanford Telecom is building the wireless signal processing equipment for a nation-wide vehicle location and tracking system backed by Ameritech, a Regional Bell Holding Company.

DSP

for Spread Spectrum

by Matthew Johnson

In my previous column, I gave a preview of the "Basic All-purpose Digital Signal Processor." Before I completely describe it, I should explain that my reason for doing so is NOT that you will often see a device with this architechture, but that this BADSP clearly illustrates the fundamental issues that must be addressed in any DSP application. More importantly, the BADSP shows the <u>fundamental equivalence</u> of the digital signal to the original analog signal (under certain broad conditions I will spell out).

So what is the BADSP'! It consists of the blocks in figure 1. This chain of blocks accept an analog input (usually a voltage varying with time), prepares it for the number cruncher, crunches, and finally produces an analog output.

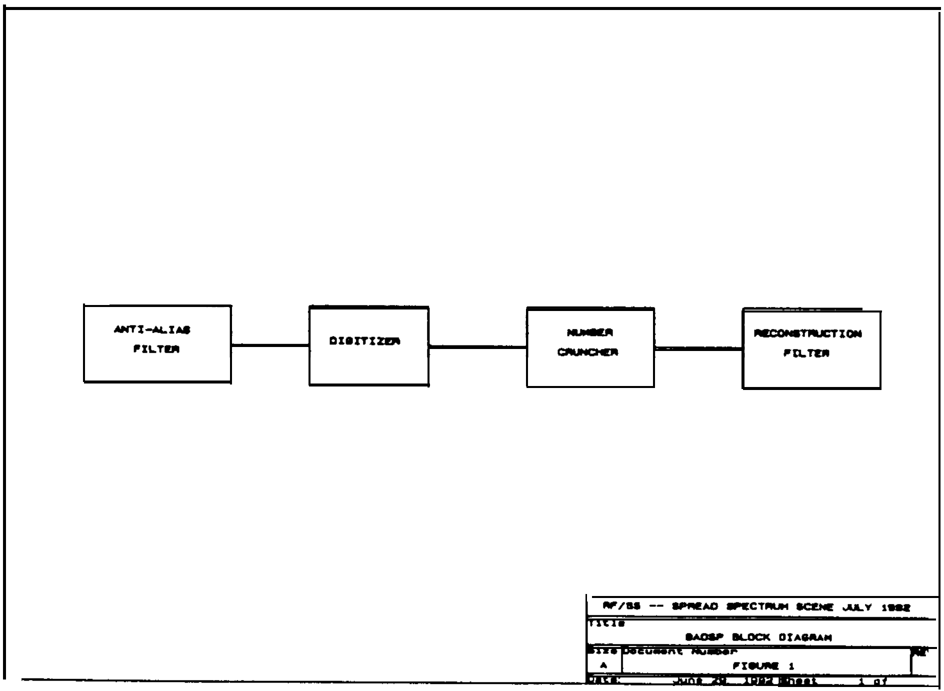
If the number cruncher does nothing but pass through the number received, I have an expensive replacement for a piece of wire or transmission line! But the fact that it <u>can</u> replace the transmission lineis more interesting than actually using it to do so, since it shows that whatever information is in the analog input is still present in the digitized signal. Thus once I choose a digitizer, anti-alias filter and reconstruction filter, that preserves the information, I can focus my attention on the number cruncher, confident that there really is a way to extract the desired information from the stream of numbers flowing from the digitizer.

So what are all these blocks'? The inner two are pretty obvious, but the other two require some background, especially the first, the <u>Anti-Abasing Filter</u>. This prevents "aliaing", a peculiar phenomenon of the DSP world. To explain aliasing I must digress to explain how digitizing is viewed as a convolution, and invoke (without proof) a theorm from functional analysis.

Strictly speaking, digitizing consists of two seperate operations. <u>ling and quantization</u>. Fortunat if I quantize to enough levels, I can model quantization as additive noise, adding it after sampling. By then the quantizing noise is usually pretty small, so I will come back to it at a later time.

So considering digitizing as sampling with a fixed sample period, consider each sample pulse as an "infintely high" and "infinitesimally wide" curve with an area of 1. Then sampling an input signal S(t) over time becomes the convolution[1] of said signal with a chain of those sample pulses. But by a theorm of functional analysis, this is exactly equivalent to AM modulation of the input spectrum <u>with carriers at all integer multiples of the sampling frequency</u>. -- More next month.

[1] Convolution is the operation that takes as operands the input voltage and the impulse response of a filter and yields as output the voltage at the output of said filter.



AN ANALOG GPS DATA RECEIVER

B Y Dan Doberstein
President, DKD Instruments

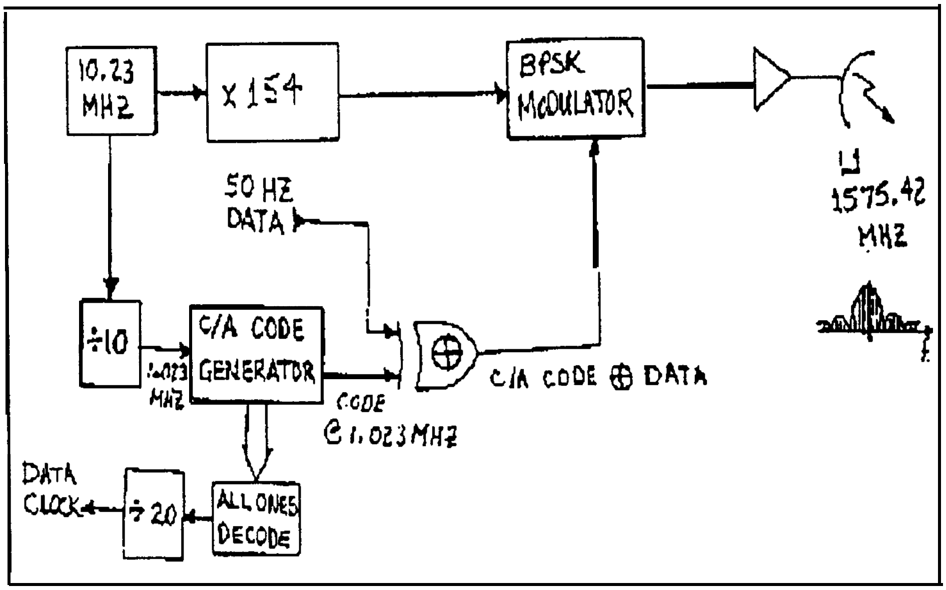


Figure 1: Simplified **L1** Model **(P-code ignored).**

SSS welcomes the opportunity to present Dun Doberstein's analog GPS receiver. This idea article is intended not to show how to build a GPS receiver, but to illustrate concepts Dun used in his design. As most readers know, GPS is nearing full operational status, hus 18 satellites on the air (sometimes) and provides very interesting capabilities. The price of commercial GPS receivers has dropped substantially in recent years. But, Dun's GPS receiver is the simplest and most inexpensive approach we huve seen yet. While not every home workshop may be able to reproduce Dun's GPS receiver. SSS feels that the design presented here is a fresh new look at GPS receiver technology and should be of' interest to all our readers.

INTRODUCTION

This paper describes a Global Positioning System (GPS) single channel data receiver using the L1 carrier. A brief explanation of the GPS system is provided. The needed details of the GPS signal structure are also covered. GPS uses Spread Spectrum techniques. It is one of the first world wide systems to implement this technology. These techniques will play an ever larger part in tomorrow's communication systems.

WHY BUILD AN ANALOG GPS DATA ONLY RECEIVER?

There are right now many commercially made GPS receivers on the market. A benefit of this design is the fact that it is nearly all analog. Many of the commercial receivers digitize the IF and the signal disappears into a black box of digital signal processing. This is great from a cost/performance point of view but not from a intuition and learning point of view. The analog approach lends itself more to seeing the various and different trade offs in the design especially in the code tracking loop. And although the position problem is not 'addressed just getting the data is tough! Many of the insights gained through studying this receiver can be applied to other spread spectrum systems.

THE GPS SYSTEM

GPS is a satellite system that can provide users with time and position information. The satellites transmit satellite position and GPS time information to receivers on the ground or in the air. Orbits are half synchronous. Three satellites must be in view to obtain latitude and longitude (if altitude is known). Four must be in view to obtain latitude, longitude and altitude. These two scenarios assume that the user receiver does not know GPS time. If position is known then GPS time can be obtained. This information will be available globally. twenty four hours a day.

GPS SIGNAL STRUCTURE

The GPS signal uses two carriers L1 and L2. L1 is at 1575.42 mhz. L2 is at 1227.6 mhz. Both carriers have data information on them. This receiver ignores the L2 signal and only the L1 signal is used. Figure 1 is a simplified model of the satellite L1 generator. The carrier is bi-phase modulated with a 1023 bit, 1.023 Mhz pseudo random sequence. The data is also bi-phased modulated onto the carrier at a 50Hz rate. In 'addition the (P-code) EXOR (data) stream is phase modulating the carrier. This modulation can be ignored. All clocks are synchronous.

REQUIREMENTS FOR RECEIVING THE GPS L1 SIGNAL

The combination of the spreading code, high doppler and low received signal power force any GPS receiver to track the code and the doppler SIMULTANEOUSLY. The doppler has a range of about +/- 7 Khz. The low received power level forces a narrow IF bandwidth in addition to a good LNA to achieve tolerable signal to noise ratios which in turn forces the receiver to have some sort of doppler tracker. Doing all these tasks is what makes the GPS receiver a real challenge.

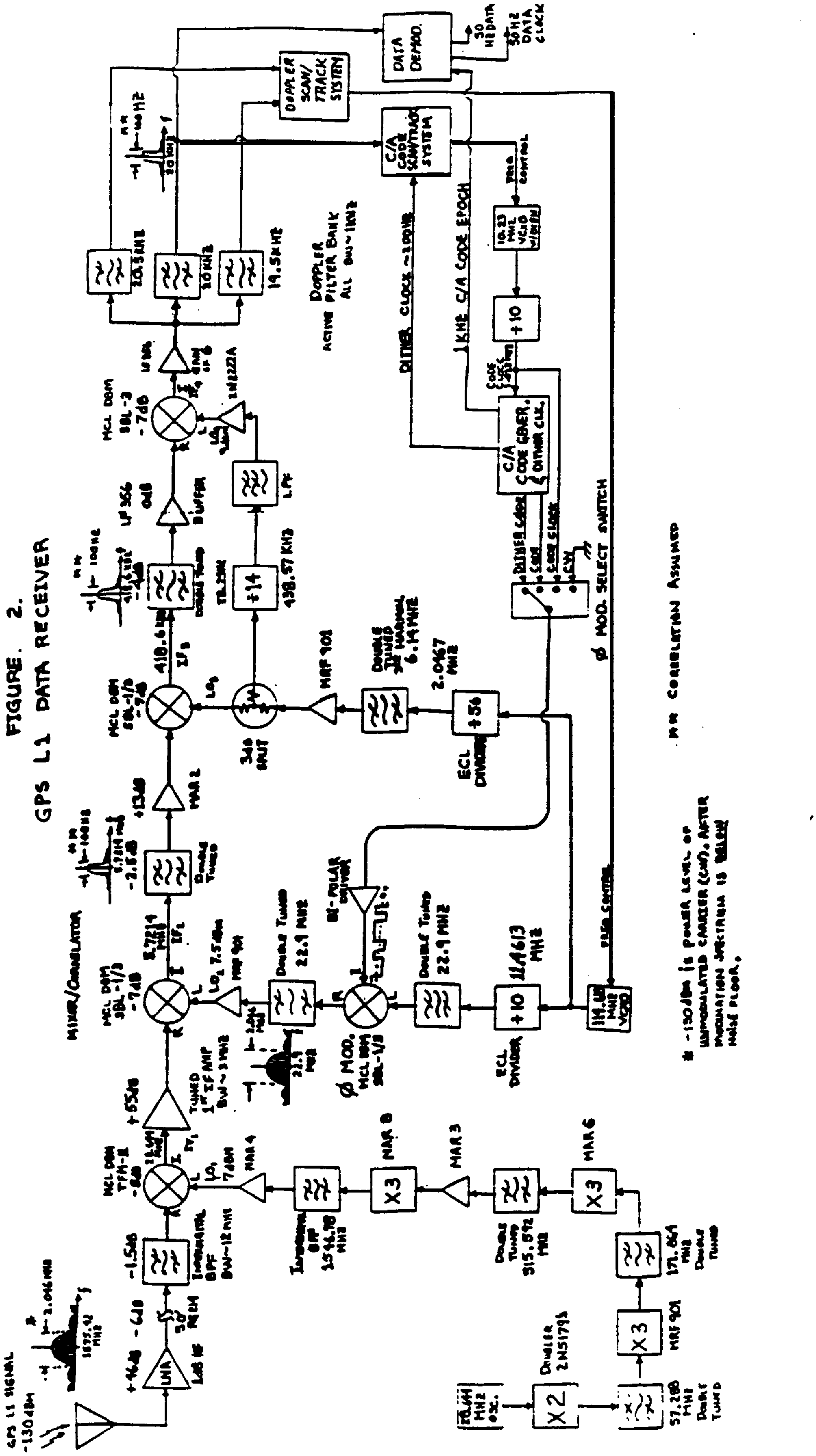


FIGURE. 2.
GPS L1 DATA RECEIVER

The minimum received power at the earths surface is -130dbm for a 0 db gain antenna. The satellite sends this out RH circular polarized. Due to the spreading of the C/A code the L1 signal is BELOW the noise floor of the receiver. It can only be seen if the receiver has a copy of the C/A code to raise it "out of the mud" of the receiver noise. This process is called correlation and is at the heart of GPS receivers.

AN L1 DATA RECEIVER

Figure 2 shows a block diagram of the receiver. Some representative spectrums are shown at various points. The L1 signal is received using a quadrafilar circularly polarize antenna. The signal then enters a LNA. From here the signal goes through 60 feet of RG-214 to the crystal down converter. After some amplification the received signal arrives at the Mixer/Correlator. This is just a DBM used in a slightly different way to achieve the 2nd IF of 5.7288 Mhz. The only difference from conventional down conversion here is that the 2nd LO is phase modulated by the receivers own C/A code generator. This is where the C/A code is removed. If the receiver generated code is lined up with the code from the satellite then the 2nd IF will be present otherwise the receiver sees only noise. Assuming the codes are locked the 2nd IF spectrum is as shown. All the LO's for the 2nd, 3rd and 4th IFs are generated by division of the 114.613 Mhz VCXO. The VCXO is needed here to compensate for doppler and is controlled by the Doppler Scan/Track circuitry. From the 2nd IF the signal goes through two more IF's to the final IF of 20 khz. This low IF is chosen so that active BPF's can be used to achieve the narrow 1 Khz bandwidths needed. At this point the signal splits three ways into the blocks Tau-Dither code tracker, Doppler Scan/Track and Data demodulator. The Phase Modulation select switch is used for providing different signals to the phase modulator for the 2nd IF LO. All except the Code w/Dither position are used for testing only.

You might be wondering where the AGC is in this design. There isn't any. The receiver runs wide open. AGC is a problem due to the C/A code spreading. To have AGC it would have to become active AFTER the L1 signal is correlated which means that a switching scheme would be needed. This is not that difficult but its probably better left to a computer todecide on AGC levels. The receiver works without it so why not?

IF SELECTION

The IF's as implemented in this design are less than optimum. The choice of the 28Mhz 1st IF was based primarily on existing designs for the ham band at 1.3 Ghz which used a 28Mhz 1st IF. If any of the 28.644 LO makes it through the multiplier chain ('and some does) it will appear in the 28.644 Mhz IF. This is not as bad as it would first appear. The high gain of the preamp helps here as does the C/A code which will reduce any CW by about 35 db. In many ways the choice the 28.644 Mhz IF was a bad one, but the design still worked and that is what counts!

OPERATION OF THE TAU-DITHER C/A CODE SCAN/TRACK SYSTEM

Figure 3 shows the block diagram of this system. The purpose of this system is to search for C/A code alignment and once found keep it there. Both functions are implemented by controlling the code clock frequency via the 10.23 Mhz VCXO. This code clock VCXO is driven either by a constant voltage for Scan or a varying voltage for Track. An analog switch chooses between the two. When theswitch is in Track position the system is said to be "closed loop". When in the Scan position the system is "open loop". Various waveforms and spectrums are shown accompanying the block diagram of figure 3. Some waveforms are open loop while others are close loop. The open loop waveforms are marked with an 'asterisk.

In order to understand closed loop

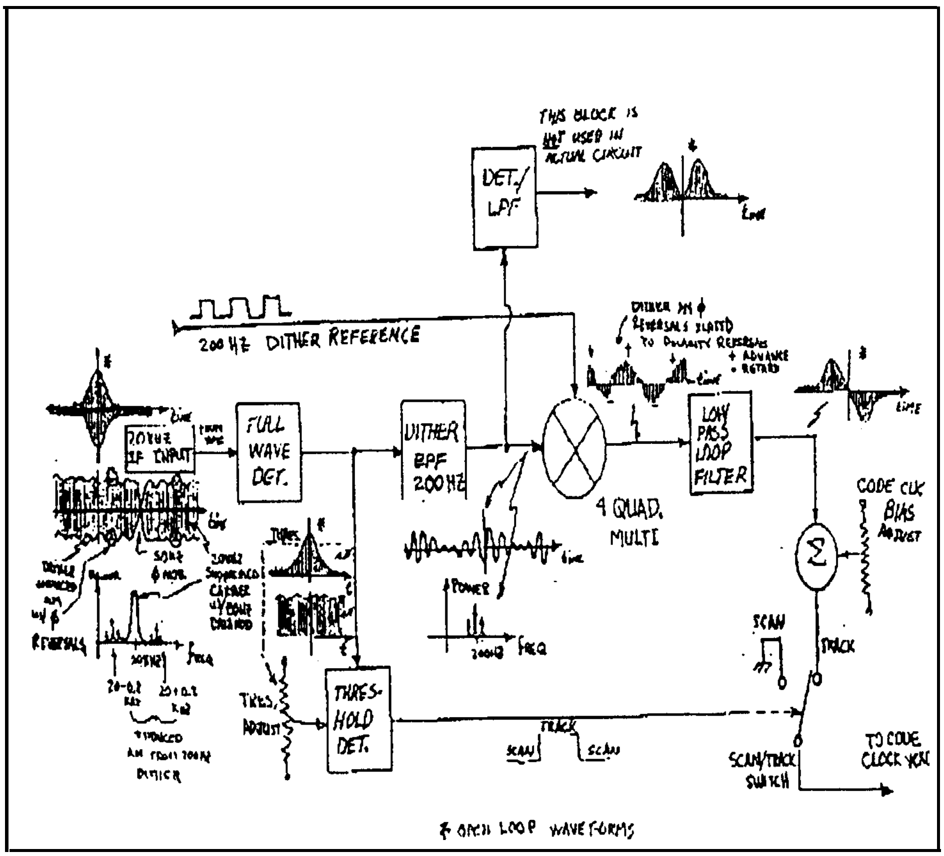


Figure 3: Block Diagram C/A Code Scan/Track System

operation it is first necessary to understand open loop operation. In the open loop mode the code clock VCXO is held at a constant frequency offset from 1.023 Mhz, the zero doppler code rate. This frequency difference, about 10 Hz, causes the receiver generated code to "slip" by the code on the L1 signal. The time it takes for the two 1023 bit codes to make a complete pass is N/DF seconds; where N= 1023 and DF= 1 Ohz the frequency difference between the two code clocks.

Ignoring the effect of the Dither for now lets look at what occurs as the two codes slide by each other. As the two codes slip they will come to point where they "correlate". Correlation is when the two codes are within two chips of alignment. As correlation occurs the 20 Khz IF will start to appear at the output of the BPF. Before correlation the output of the BPF is just noise. The 20 Khz IF doesn't appear all at once, rather it builds in 'amplitude reaching a peak when the two codes are in perfect alignment. As the two codes continue to slip the 20 Khz IF 'amplitude decreases until we are back to our noise output from the BPF. This process gives rise to the characteristic triangular shaped correlation pulse at the output of the Full Wave Detector. The width of this pulse is given by 2/DF, where DF is defined as above.

Now lets look at the effect of the Tau-Dither. Tau dither is used to generate a voltage that can be applied to the code clock VCXO as to keep the codes in "lock". It does this by determining which side of the correlation pulse the receiver generated code is on and how far it is from the peak point. If we know which side of the correlation pulse we are on we can determine if the receiver generated code should be advanced or retarded with respect to the received code. Knowing how far off we are tells us "how much" we need to move the code.

This information is generated by "dithering", or switching, between two versions of the receiver generated code. One version is delayed the other is not. The delay uskd here is about 1/2 microsecond or 1/2 chip. As the two codes slip through correlation the dither switching induces AM on the 20Khz IF. The frequency of the AM is the same as dither clock frequency.The 'amplitude of this AM increases to a maximum and then decreases to zero when the codes are in alignment. As the two codes continue to slip it again grows and diminishes to zero as we pass the correlation point. This "double hump" waveform can be generated by detecting the output of the dither BPE This is shown in the block diagram but it is not used or needed in the actual circuit. At the midpoint of the double hump, at code alignment, the induced AM goes through a 180 degree phase shift. The phase shift contains the advance/retard information while the amplitude of the AM contains the "how far" information. The AM and its 180 degree phase shift at code alignment is caused by the triangular shape of the correlation pulse. In short the dithering of the code induces AM on the received carrier whose phase carriers the advance/retard information and the 'amplitude carriers the "how much" information.

The dither induced AM is "picked off" the full wave detected 20 Khz IF with a BPF tuned to the dithering frequency. The dither AM is now multiplied by the dither clock reference. This recovers both the phase and amplitude information simultaneously. The output of the multiplier is lowpass filtered to give the "discriminator" error output. The 180 degree phase change causes a polarity reversal which produces the "S" shape discriminator output. We now have voltage whose polarity tells us whether to advance or retard our code and whose amplitude tells how much.

The low pass filter after the multiplier serves the same purpose as the loop filter in the more familiar phase locked loop. Much of the analysis of the code loop can be done using the tools from phase locked loops with slight modifications.

Closed Loop Operation is initiated when correlation occurs. The carrier detector senses the presence of the 20khz IF and flips the switch from Scan to Track. The code clock VCXO is now being controlled by the error voltage from the discriminator. The discriminator voltage constantly "pushes" the receiver code in the proper direction so as to keep the two codes in lock. When the discriminator output is positive the code should be advanced, or lower the VCXO frequency. Just the opposite for negative voltages. In this manner the code clock VCXO is frequency modulated to keep the codes in alignment.

Getting a feel for the code scan/track process is best done with the aid of a L1 simulator. With the simulator the L1 code and the receiver code can be displayed on a two channel scope. By triggering on either the L1 or receivers code epoch that code can be made to "stand still" on the scope. The other code will move across the screen in the direction determined by the sign of the frequency difference and at the rate determined by the magnitude of the frequency difference. If the loop is held open all the open loop waveforms can be observed as the two codes slide through correlation.

If we allow the scan/track switch to operate we can observe the transient and steady state behavior of the code track process. In steady state the tracking jitter can be seen and measured. Seeing the movement and dynamic properties of the scan/track system on a scope is hard to beat for getting a handle on this tricky problem.

It is easy to get confused with all the bi-phase modulation processes in this receiver. Remember there are three distinct biphase modulation processes; Code, Data and the Dither induced AM is itself bi-phase modulated via the correlation triangle. Each one is independent of the other so there is no interaction between the receiver circuits that operate on these modulations. See page 18 for more information about Dan and DKD's instruments.

Look for the conclusion of this excellent article in the August issue! Dan has made reprints of his original article (over 30 pages) available for only $12.00 postpaid. Contact:
DKD Instruments
(805) 581-5771

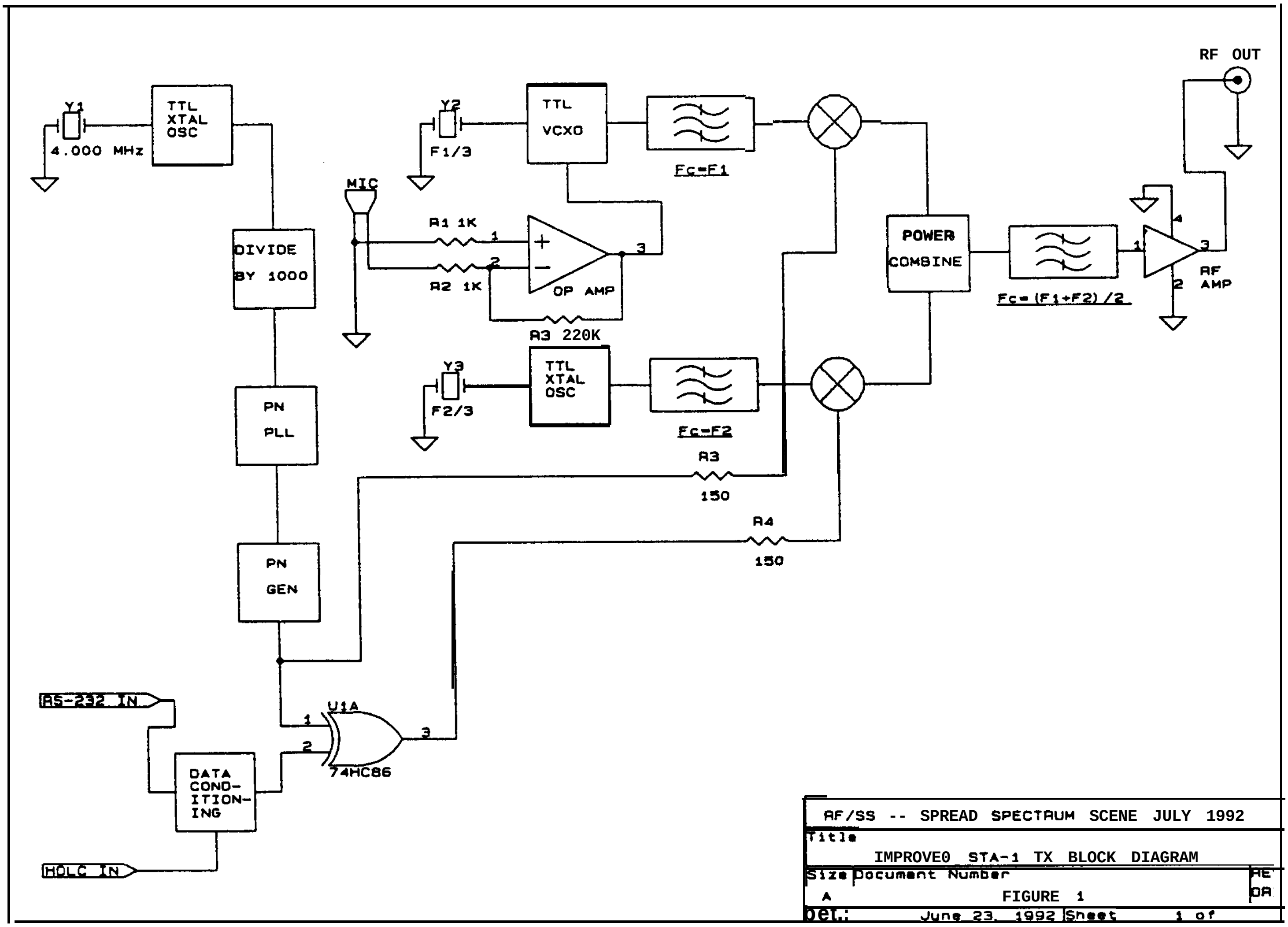
Build The STA-1 Transceiver, Part 2

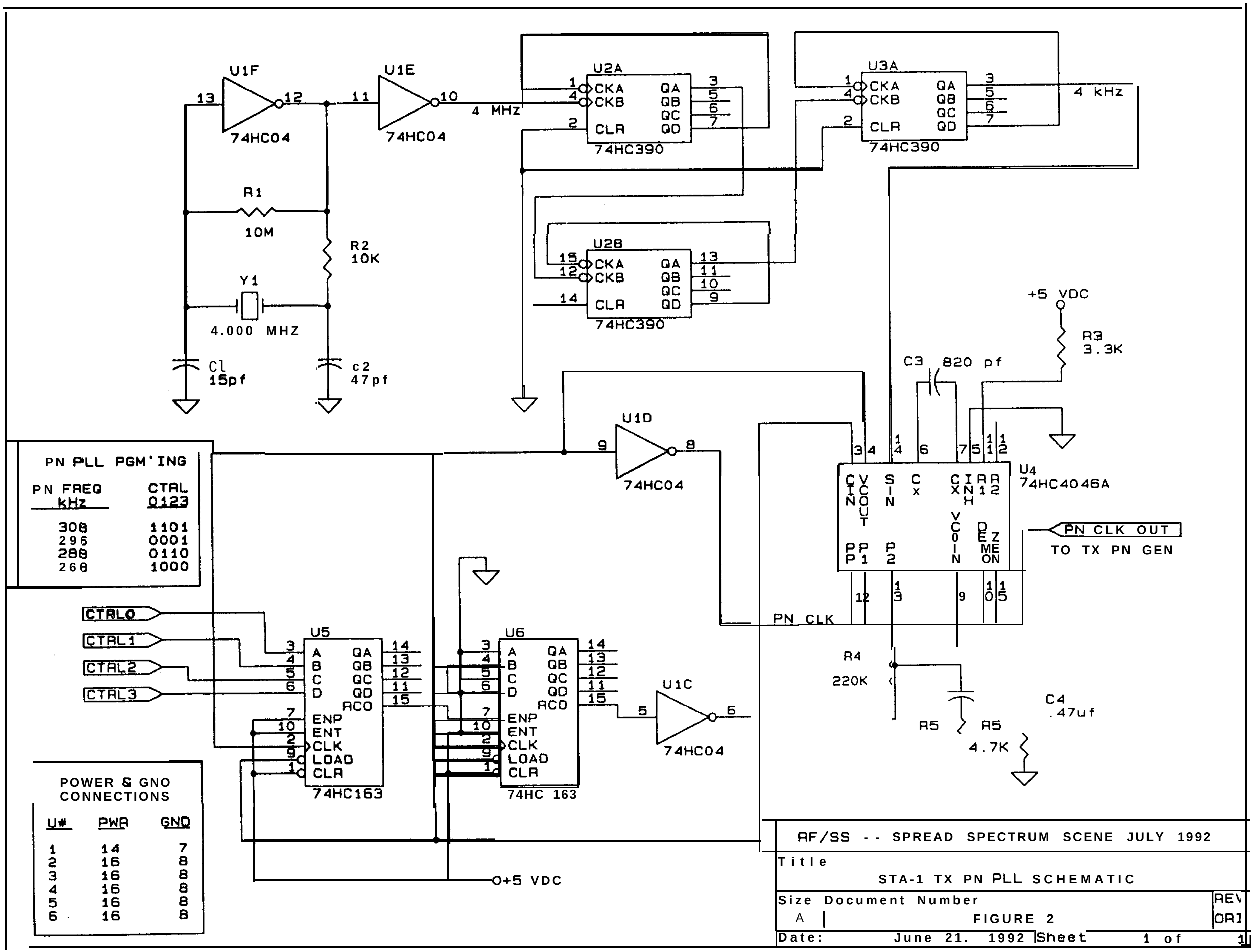
Lust month we begun this series on construction of a simple Spread Spectrum transceiver for use under the new Spread Spectrum STA from the FCC. In the June, 1992 SSS we presented the pros and cons of a basic design using transmitted reference direct sequence spread spectrum (TRDSSS). A block diagram level discussian was presented and the ideu that others may want to duplicate this design wus presented.

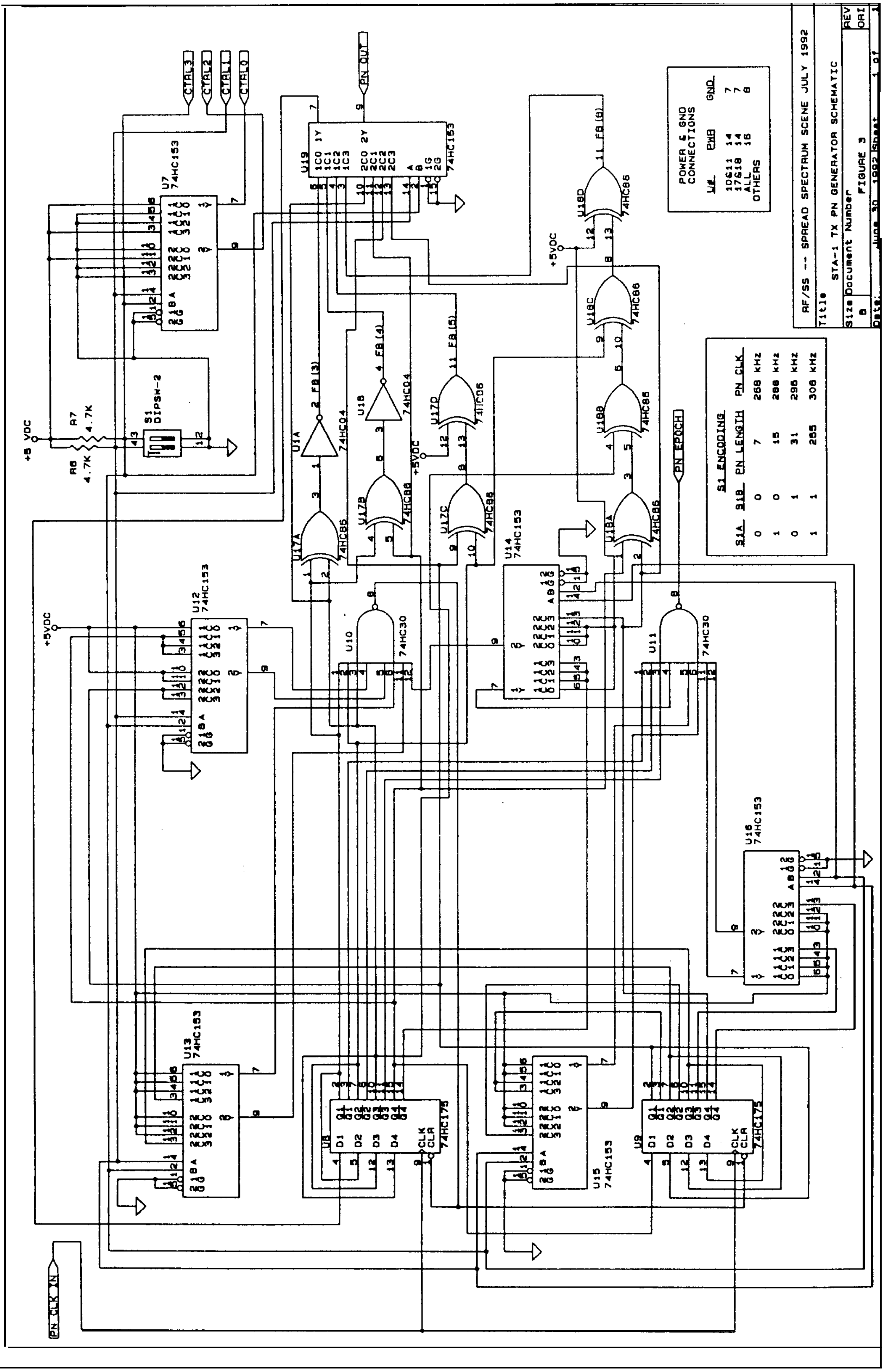
This month we cover the TRDSSS transmitter circuitry. Complete schematics ure given for the transmitter as is a new and improved transmitter block diagram.

During breadboarding of the STA-1 transmitter (Tx) circuitry it became apparent that the initial Tx block diagram was a little more expensive to produce than we had hoped. The original Tx block diagram shown in June's SSS, used separate PLL frequency synthesizers to generate the transmit carriers for each TRDSSS channel. This approach results in a single crystal, coherent design which has some very interesting features -- but it is not the simplest design approach that provides useful results. Some readers may still want to pursue the original design because the carrier spacing and actual carrier frequencies are fully programmable, providing enhanced flexibility.

Figure 1, below is the revised block diagram of the simplified STA-1 Tx circuitry. The two PLL synthesizers are replaced by two crystal oscillators. One oscillator is voltage tunable over +/- 1 to 2 kHz to provide analog FM capability for voice ID'ing. The other oscillator is a straight fixed frequency crystal oscillator. Both oscillators run at 1/3 of the output frequency and are based on an HC speed '04, TTL hex inverter design. Thus, each crystal oscillator's output is rich in odd frequency harmonics in their outputs. A simple two pole bandpass filter on each output can be used to select the third harmonic (the Tx carrier output) frequency for later processing. Most of the rest of this new design is identical to that shown in June.




U1F
74HC04
U1E
74HC04
4 MHz
U2A
CKA
CKB
CLR
QA
QB
QC
QD
74HC390
U3A
74HC390
4 kHz
U2B
74HC390
R1
10M
R2
10K
Y1
4.000 MHZ
C1
15pf
c2
47pf
+5 VDC
R3
3.3K
C3
820 pf
U1D
74HC04
U4
74HC4046A
PN CLK OUT
TO TX PN GEN
PN CLK
R4
220K
C4
.47uf
R5
R5
4.7K
PN PLL PGM'ING
PN FREQ kHz | CTRL 0123
308 | 1101
296 | 0001
288 | 0110
268 | 1000
CTRL0
CTRL1
CTRL2
CTRL3
U5
74HC163
U6
74HC 163
A
B
C
D
ENP
ENT
CLK
LOAD
CLR
RCO
U1C
74HC04
+5 VDC
POWER & GND CONNECTIONS
U# | PWR | GND
1 | 14 | 7
2 | 16 | 8
3 | 16 | 8
4 | 16 | 8
5 | 16 | 8
6 | 16 | 8
RF/SS -- SPREAD SPECTRUM SCENE JULY 1992
Title
STA-1 TX PN PLL SCHEMATIC
Size Document Number
A
FIGURE 2
REV
ORI
Date: June 21. 1992
Sheet 1 of 1


RF/SS -- SPREAD SPECTRUM SCENE JULY 1992
STA-1 TX PN GENERATOR SCHEMATIC
FIGURE 3
POWER & GND CONNECTIONS
U# PWR GND
10&11 14 7
17&18 14 7
ALL OTHERS 16 8
S1 ENCODING
S1A S1B PN LENGTH PN CLK
0 0 7 268 kHz
1 0 15 288 kHz
0 1 31 296 kHz
1 1 255 308 kHz
CTRL3
CTRL2
CTRL1
CTRL0
PN OUT
PN EPOCH
PN CLK IN
+5 VDC
S1 DIPSW-2
R7 4.7K
R6 4.7K
U7 74HC153
U19 74HC153
U12 74HC153
U13 74HC153
U14 74HC153
U15 74HC153
U16 74HC153
U8 74HC175
U9 74HC175
U10 74HC30
U11 74HC30
U1A 74HC04
U1B 74HC04
U17A 74HC86
U17B 74HC86
U17C 74HC86
U17D 74HC86
U18A 74HC86
U18B 74HC86
U18C 74HC86
U18D 74HC86

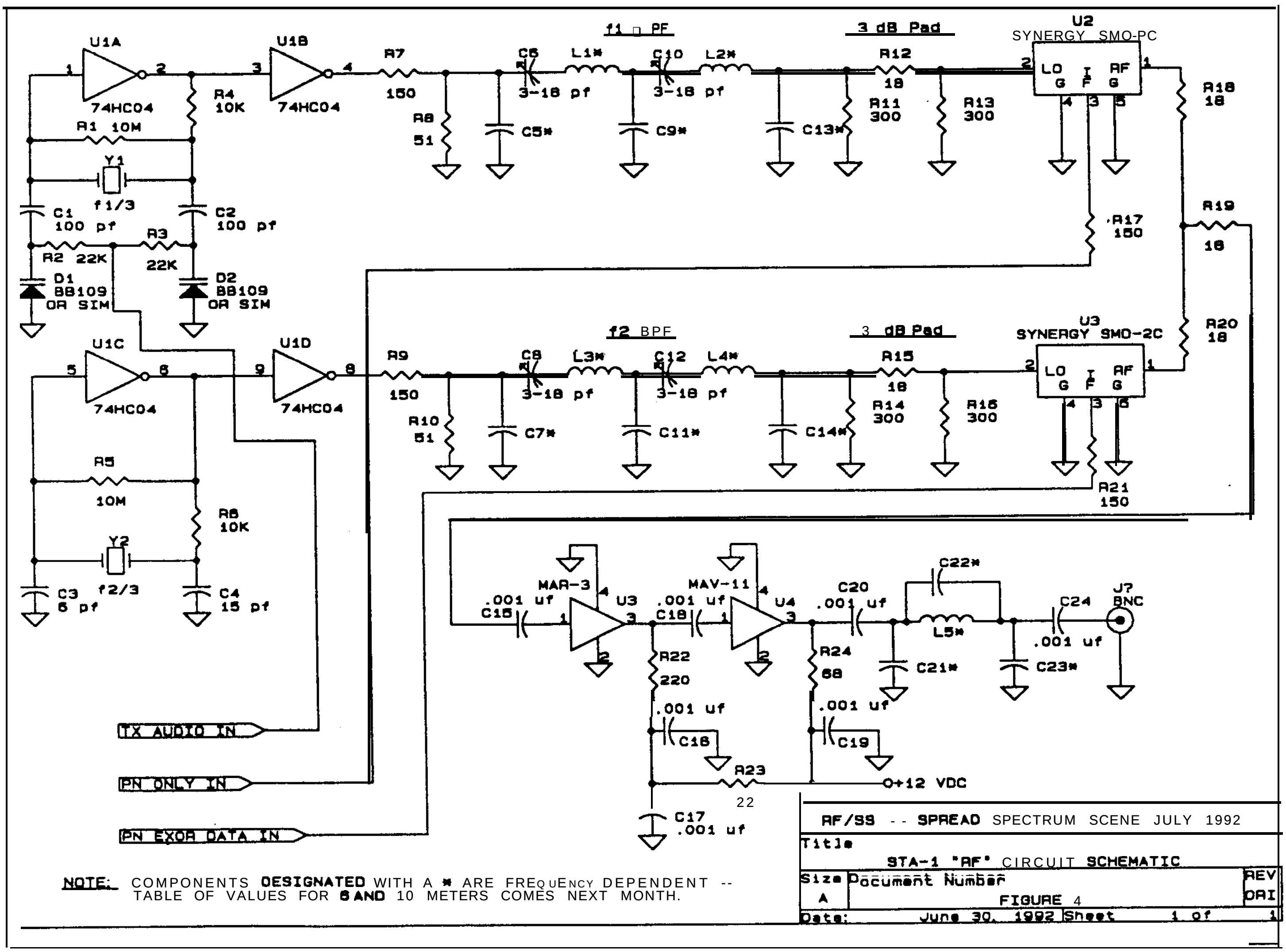
The only other difference is that the reference frequency divider chain for the logic uses a 4.000 MHz AT cut quartz crystal oscillator, instead of the 24 MHz design shown in June. By the way, how many of you noticed the error that showed a 1/8 divider instead of the required 1/6 divider in last month's block diagram? Sorry, about that -- but it's only academic now, isn't it?

The complete schematic for the Tx PN PLL clock generator and digital frequency divider chain is shown on page 11, in figure 2. The Tx PN generator circuit schematic is shown on page 12, opposite, in figure 3. This B sized schematic was reduced for publication -- I hope it is still readable.

Figure 4, below, shows the schematic of most of the remaining Tx circuitry. Some of the Transmit / Receive switching circuitry, common power supply regulators and miscellaneous common circuits will appear in future installments of this series.

The new Tx design sacrifices some of the flexibility of fully programmable frequencies in each TRDSSS carrier for simpler, more inexpensive circuitry. The basic function and theory of operation of both the old and new designs are very similar, however. The essential double tone set of carriers are generated at the Tx output frequencies, then one tone is BPSK modulated with PN only. The other tone is BPSK modulated with the product (PN EXOR DATA). The two modulated signals are linearly summed in a resistive power combiner and then bandpass filtered and amplified to the proper level for subsequent transmission. Bear in mind that after the two modulated signals are combined and filtered, all amplification must be done by linear, class A or AB, amplifiers. If you try to use class C type amplification, any bandpass filtering benefit (like keeping the signal in the assigned Ham band) is wiped out. Further, non-linear amplification creates Intermodulation and other two-tone distortion products that just waste precious transmit power.

Please write if you need more detailed information on the TX section. Next month we will present the complete receive (Rx) circuitry. The final installment in this series, in the SSS September issue will tie all the loose ends together, show the circuit board layouts and announce price and availability of the STA-I kits. In the meantime, some of you may want to breadboard or test some of the circuit concepts and the circuits presented so far -- go to it! Please let us know how you progress and inform us of any changes you'd like to see. We want this to be a group effort -- we need your feedback! Enjoy and don't forget to send off those forms, published in June SSS, to Bob Buaas, K6KGS.



Introduction to Spread Spectrum
Part 3

by Randy Roberts

Chapter 2 - Why Spread Spectrum?

The previous chapter presented highlights of the most commonly used forms of spread spectrum. The first chapter also gave some brief reasons for using spread spectrum in several different communications and navigation applications. This chapter will concentrate on why spread spectrum is used, it's benefits and it's advantages. We will also discuss drawbacks and disadvantages of spread spectrum other than the complexity and cost issues involved in providing spread spectrum.

Spread spectrum signals, by their very nature are more expensive to generate than marrow band signals. Spread spectrum receivers are also more expensive than their narrowband counterparts -- because of the special synchronization requirements of SS signals. These are "inherent" to the use of spread spectrum and are part of the trade off required to decide if SS is even needed in a particular application.

The focus of this chapter is the "technical" strengths and weaknessesof spread spectrum, in genera!. More specifically, we will present several application case studies and examine their relative technical merits. This approach to 'answering why spread spectrum, will thus provide the reader with an introduction to some of the existing SS systems.

SPREAD SPECTRUM SYSTEMS UTILIZE DIGITAL SIGNAL PROCESSING EFFICIENTLY

Most, but not a!!, spread spectrum systems utilize digital signal processing techniques. While not a seemingly strong advantage, the ability to replace temperature dependent. aging prone. and tight tolerance analog signal processing components with inexpensive mass producible digital circuitry like custom ASICs (Application Specific Integrated Circuits) or custom LSI (Large Scale Integration) chips is a strong economic factor today.

SPREAD SPECTRUM SYSTEMS PROVIDE INHERENT MESSAGE PRIVACY

Spread spectrum waveforms can be designed with any degree of privacy or security desired. In fact, spread spectrum signals can be made cryptographically secure, if you work for the right government agency. Commercial and industrial applications make use of this feature of spread spectrum systems because business communications often has a monetary, time value to it. In other words, a user of an in-building spread spectrum wireless LAN (Local Area Network) may not want his competitor next door overhearing or eavesdropping on his next year's business plans. Even the simplest commercial spread spectrum systems can deny access to casual listeners with "Radio Shack" scanners.

SPREAD SPECTRUM SYSTEMS ALLOW USERS TO OPERATE UNDER FCC PART 15.247 RULES WITHOUT LICENSES

This non-technical reason seems to be the most important reason to use spread spectrum commercially today. The FCC, who regulates the frequency spectrum in the United States, has chosen to allow low power un-licensed operation of spread spectrum equipment in several of the so called Industrial, Scientific and Medical frequency bands. The 1992 assignments include 9 15, 2450 and 5500 MHz frequency ranges. Several legislative and FCC rule making moves are in process at the time this book was in preparation that may allow spread spectrum to be used for wireless LAN and PCN/PCS (Persona! Communication Network / Persona! Communication System) systems near I.9 GHz. Next month we present more of chapter 2.

Editorial from page 3

used government frequency allocations, sould be auctioned off to Apple, IBM, the Baby Bells, the WINForum companies, or whoever? This auction could give them new spectrum monopolies so they can gouge us with expensive charges for access to our airwaves (like they do in Cellular Telephone).

This magazine is, after all, devoted to the advancement of the Art and Science of Spread Spectrum. We do need industry to move out, develop new products, new services and make a few bucks. All of these things we encourage. All of these things are good for the country and if done competively are good for our economy.

What we are against is the blind seeming direction that S. B. 218 is now taking. We join with the ARRL, who represents 500,000 amateur radio operators in this country, in opposition to S. B. 218 as it now stands. We join with FCC Spectrum Reserve NRPM cornmentors, the Utilities Telecommunications Council (UTC); the Association of American Railroads (AAR); the Public Power Council; the American Public Power Association (APPA); the National Rural Electric Cooperative Association; and the US Energy Department in opposition to S. B. 2 18 until it is better thought out and has had full public hearings, a reasonable comment period on pending FCC rulemakings and until our elected representatives and paid civil servants wake up and see who pays them.

To be completely fair, I guess I should offer some constructive answer or alternative to the government's latest goodie: S. B. 2 18. In this spirit let me first admit that some very tough choices are necessary in this arena -- there are no clear, clean "optimum" alternatives available that can please everyone. Until this country is fully cabled with a wide band fiber optic network, we probably need more and better use of the RF spectrum.

I think a slower going approach, where more short term experimental licenses are granted by the FCC is in order -- not wholesale,

See More Editorial page 16

Technical Trends in Education

by Tom Diskin

In this issue of *Spread Spectrum Scene* we will embark on a new area of technical applications, "Technical Trends in Education". In this column, I will report to you on new developments in the education arena, and particularly those which involve the use of high technology and spread spectrum communications techniques. This is a broad and rapidly changing field, so please feel free to contact me if you are aware of developments in the field for which you would like more information.

Technical education is a field which is important to all of us in the electronics industry, because it is an endeavor which allows us to keep abreast of new developments in our areas of expertise, as well as keep us informed of new changes in peripheral fields. We may consider education first as a way of preparing ourselves for our profession; however, its overall benefit is probably more in terms of how we use it to "update" our skills and knowledge to encompass new emerging technologies in our segment of the profession. This kind of education, sometimes called "lifelong learning" will probably have a much greater effect on our performance as a professional in a particular field than any amount of "formal" or "preparatory" learning we completed before entering the profession .

An area of debate which exists within the field of technical education is the difference between "education" and "training". In the most simplistic way, "training" may be defined as learning which relates to a specific procedure or methodology which may be directly applied to a specific piece of equipment or technique. An example of training might be a session on how to set up and use a specific manufacturer's radio equipment in a spread spectrum installation. "Education", on the other hand, is a much more generalistic approach to learning, in that it describes a more generic understanding of concepts and techniques that may then be applied to any number of specific situations. Implied in this definition is the concept of "critical thinking", meaning the ability to apply knowledge to a wide variety of somewhat related scenarios, and judge the best approach to solve a particular problem. An example of education might be a generalistic procedure for installation and operation of any spread spectrum system.

In this column, we will look both at how education is affected by new emerging technologies, as well as how education can help speed public acceptance and understanding of these technologies, For example, we will look at a proposal for a new college course in Spread Spectrum, advantageous both to benefit current students who want to gain some experience in this new field, as well as a retraining course for those currently working in the field who want to update their skills and knowledge to newer technologies. We will also explore how spread spectrum can be introduced in high school (maybe even middle school) programs to introduce young people to the concepts of networking and how RF can be used to greater advantage as a transmission medium.

About the Author: Tom Diskin is a Professor of Electronics at College of San Mateo in San Mateo, California. He holds a BS in Industrial Technology from California Polytechnic State University and an MS in Trade and Industrial Education from Oregon State University. Tom has worked both as an educator on the high school and community college levels, and has also taught for various electronic companies as a trainer, course developer and technical writer.

Write Tom, c/o SSS with any ....comments or ideas you'd like to share.

More Editorial from page 15

permanent auction or sale of the "reserve" frequencies. Let industry and the government (the FCC in it's policing role) try out new ideas, new concepts and new services. Let the FCC charge dearly for the right to experiment in the subject frequency bands -- but do it slowly, and only temporarily until all the bugs are worked out in this new commercial technology.

The ARRL's Pacific Division Director, Charles McConnell, W6DPD had the following to say about this subject in his July, 1992 **Pacific Division Update: "Another problem** in the Congress is S. 218. This bill could cause the government to give back 200 MHz of spectrum for private sector use. The catch is that between 420 MHz and 5 GHz the Government and Amateurs share frequencies. In order to get funds for replacement circuits, S. 2 18 proposes to auction the frequencies. This could be detrimental to Amateur Radio. Keep your word processors ready and be prepared to write letters to your Senators if you are asked to do so."

ARRL Exec. V. P. and QST magazine's Publisher David Sumner. K1ZZ, told SSS. on the telephone last week, that "The Amateur Radio Service should be exempt from the auction of it's frequencies, which are shared with the government between 420 MHz and 5 GHz. While the ARRL is not on record as opposing S. B. 218, itself. we continue to believe in the FCC's philosophy of grouping Amateur Radio with Public Safety Communications. Since Amateur Radio was established, it has provided **valuable public service** in emergencies and has served as an adjunct to Public Safety Communications whenever required. Re-allocation of Amateur radio shared frequency allocationsmust not be permitted -- we must maintain our amateur allocations. as H. R. 73 and S. 1372 will guarantee, if passed." SSS supports Mr. Sumner's and the ARRL viewpoint and **strongly supports** related bills: H. R. 73 & S. 1372 -- please write your Congressman!

Washington Scene

As our Good News and Bad News cover story said, there is a lot going on in the press about Spread Spectrum these days. To save our readers some time, the sidebar below lists some of the more important publications touching on Spread Spectrum.

SS Resources & References

The Economist, "The fruitful, tangled trees of knowledge," on telephone companies and the growth of Information networks, June 20, 1992, pp. 85-88.

The Economist, "A way of life," on the fast growing mobile telephone market (PCN/PCS), May 30, 1992, pp 19-22.

The Economist, "Vehicle valhalla," on GPS and navigation systems in new cars, May 23, 1992, pp 70-72.

Microtimes, Connecting "Without A Wire," Robert Moskowitz, about LAN's, June 8, 1992, pp. 58 & 222.

The San Francisco Examiner, "Cable TV braces for competition," Michelle Vranizan. about cable TV / DB Sats and wireless alternatives, June 14, 1992, pp. E-14.

San Francisco Examiner, "TV : You ain't seen nothin' yet," Michelle Vranizan, about soon to be wireless TV adjuncts and services, June 14, 1992, pp. E-14.

The Spectrum Report, "NTIA Eyes 2 GHz Band as First Spectrum Reserve Comments Arrive," most of this Issue Is of great interest, June 24, 1992, pp. I-12.

S ec Report., "Hollings Moves to Develop 'record' on Spectrum Reserve Proposal," also most of this Issue Is of Interest, June 10, 1992, pp. 1-12.

PCS NEWS., "Senate Hearing Gives Utilities their dry la Court," most of the rest of this Issue Is at the heart of SS, June II, 1992, pp. 1-10.

TR Wireless News, "ET Docket 92-9 PCS-Microwave Battle Continues In Hollings' Hearing on FCC's," entire issue and June 4 issue provide good background, June 18, 1992, pp. i-12.

SECRET SPREAD SPECTRUM SIGNALS

Several readers including Bill Hemmings and Ron Runswick have pointed out that some very "interesting" signals exist on satellite downlinks these days. Several "underground" publications have sprung up in the last few years to provide information about how to decode, de-crypt, decipher or otherwise utilize these "secret" signals. Remember that actually succeeding in cracking any of these signals and you have broken the law! Our good ol' "Secrecy of Communications Act" prohibits you from successfully using any encoded transmission in any way. But it seems there is a challenge there -- and like the mountain, some people must try to break any code in common use. SSS understands that some 8,000 to 10,000 people subscribe to "underground" publications that purport to give technical information about these "secret" signals.

Since the interest seems to be there, SSS will provide space and a reader based forum for the exchange of technical information in this subject area. Many of these signals do indeed use various forms of Spread Spectrum and are of interest in the purely academic and tutorial arenas as commercial examples of existing SS systems.

SSS seeks short technical notes, schematics, documentation of any kind and tutorial information in this subject. Keep the stuff legal and academically oriented, if possible, and we will publish it. SSS would also like to find someone who might take on co-ordinating this monthly column. Please call if you would like to volunteer -- you'll get a free subscription to SSS and have a lot of fun, you may also learn a thing or two.

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August SSS Preview

Special: Fourth installment of *Introduction to Spread Spectrum*.

Build-it: Build the Spread Spectrum STA-1 Receiver Section - part 3 of this series.

Unique: Conclusion of Dan Doberstein's Analog GPS Receiver Idea Article.

Interesting: More on DSP, "Secret" Signals and Technical Education in our columns.

NEWS: Latest news on S. 218, H. R. 73 and other legislative developments.

Ham Radio: More on Canadian D.O.C. SS developments & Buaas STA.

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