PSK-31 101

Everything you need to know
to understand and use PSK-31

by

George Rothbart, KF6VSG

Presentation to

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October 20th, 2001

Traditional modes of communication

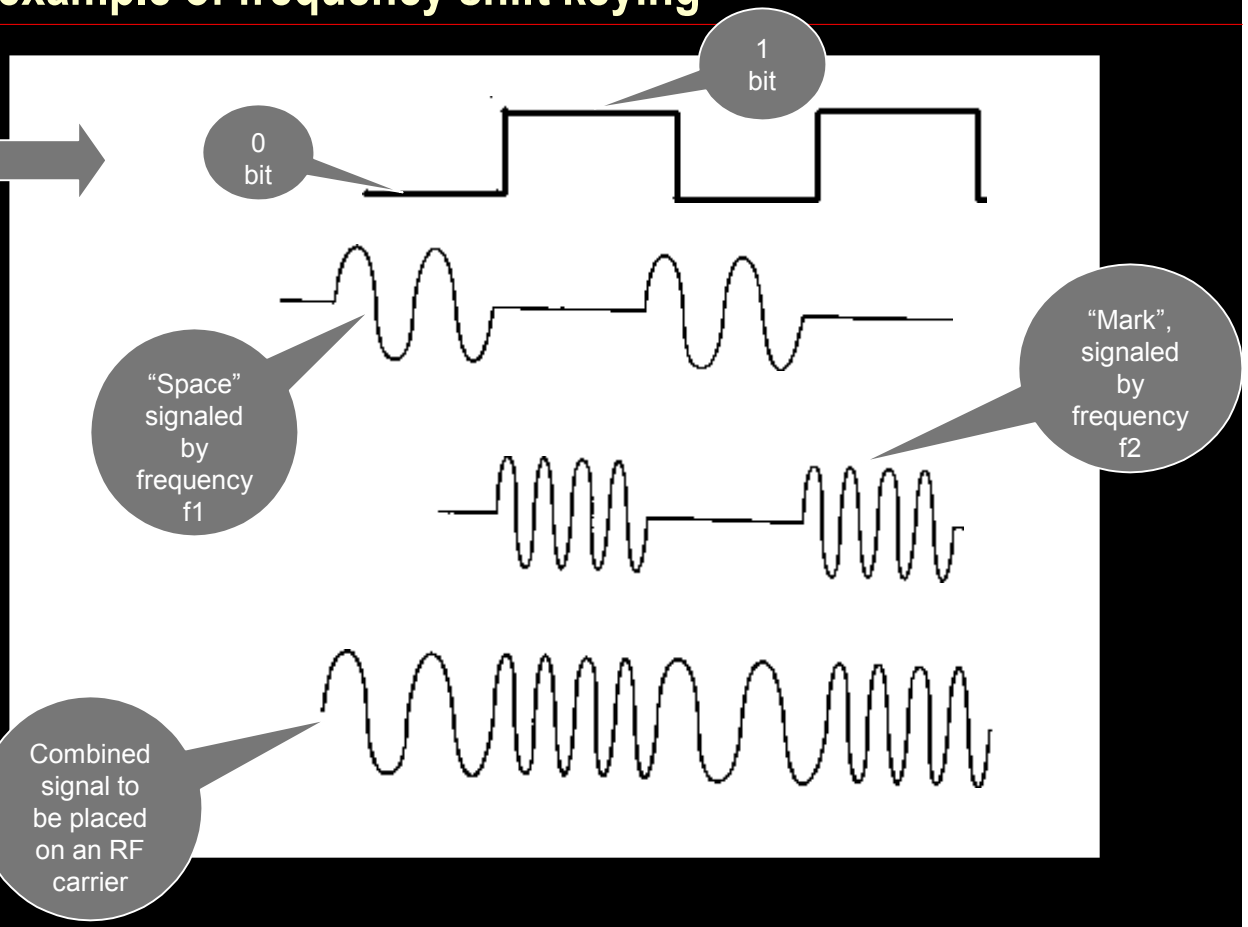
- ✓ Analog modes (voice)
- ✓ Digital Modes (character-based data)

Digital Modes (char- based data):

- ✓CW
- ✓RTTY
- ✓Packet
- ✓APRS
- ✓SSTV
- ✓PSK-31

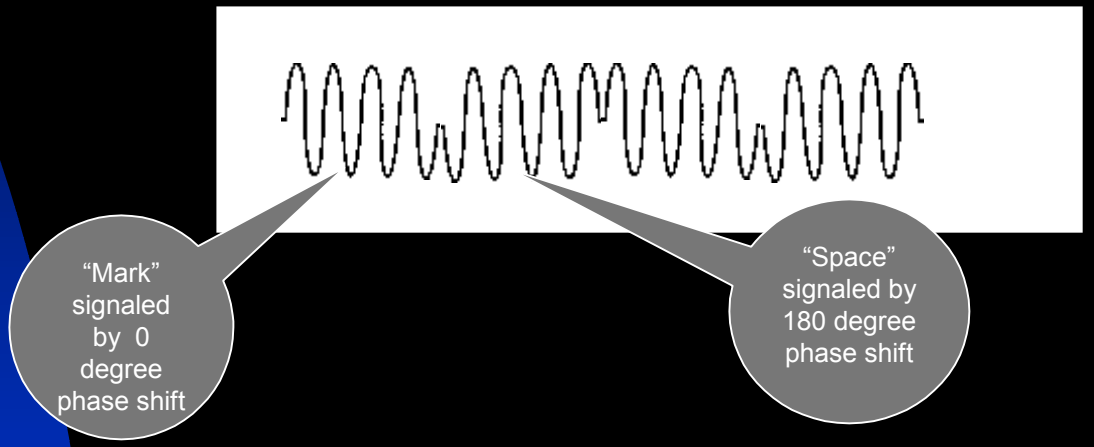
RTTY:
an example of frequency shift keying

Data pattern 0101 to be transmitted



PSK:
Phase shift keying

Let a ‘1’ (mark) be in phase with a reference frequency, and a ‘0’ (space) be 180 degrees out of phase with the reference frequency. Then 1010 would look like this:



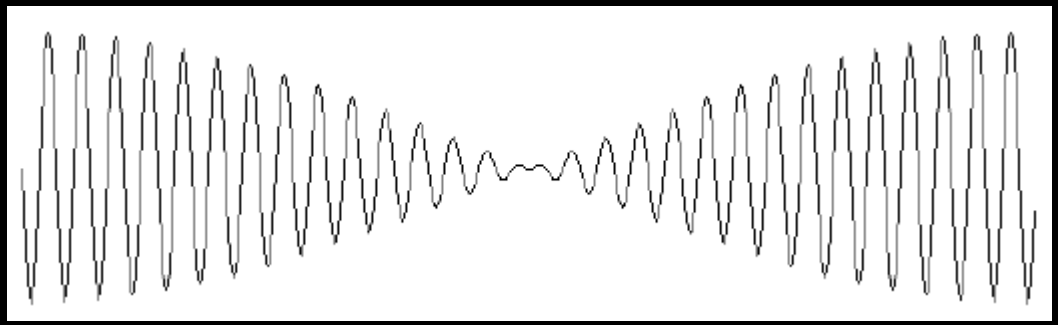
The problem are those nasty sudden reversals in phase—they are going to produce wide bandwidth splatter!

A solution is to only change the phase when the signal goes through a zero…

PSK—

Keeping the bandwidth narrow

If we gradually take the signal amplitude down to zero when we want to reverse the phase, there will be no sudden signal changes, and nothing splatters outside of the desired bandwidth:



Of course, there is no need to change the amplitude when we don't need to change phase. Thus, we might see a signal amplitude like this:

PSK31 signaling

The signal is sampled at intervals of 31.25 Hz (every 32 msec). Why this rate? Because

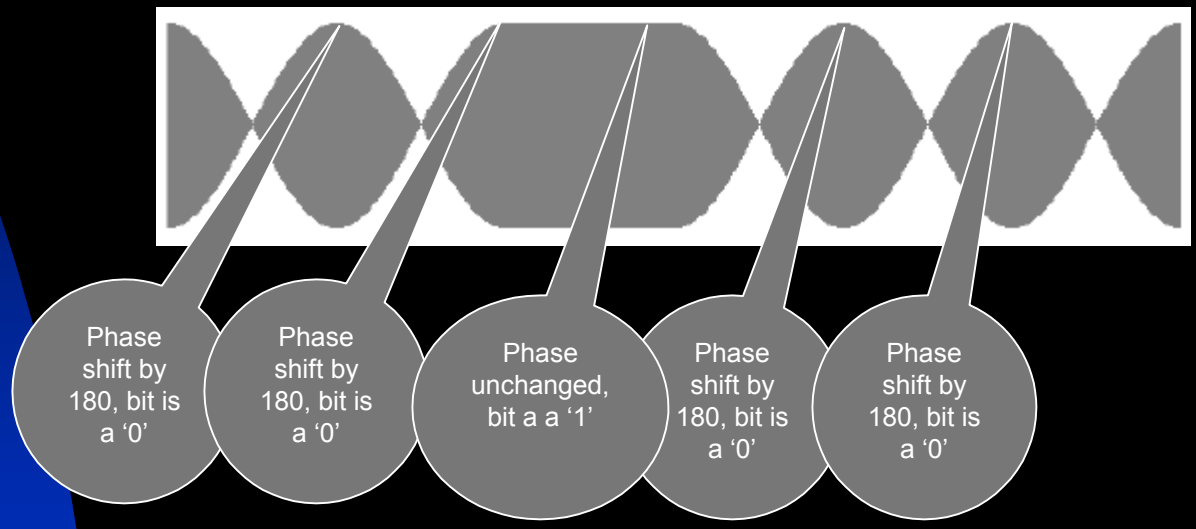
a) It can be easily derived from the 8KHz signal generated by your sound card (8000 Hz divided by 256), and

b) 30 or so bits per second translates to about 50 wpm, the fastest you can type.

A zero (space) is defined as a 180 degree phase reversal from the prior sample,

A one (mark) is defined as no phase change from the prior sample.

PSK31 signaling



Therefore, this signal is detected as 00100, which we will soon see is the representation of the character “SPACE”.

PSK31 signaling

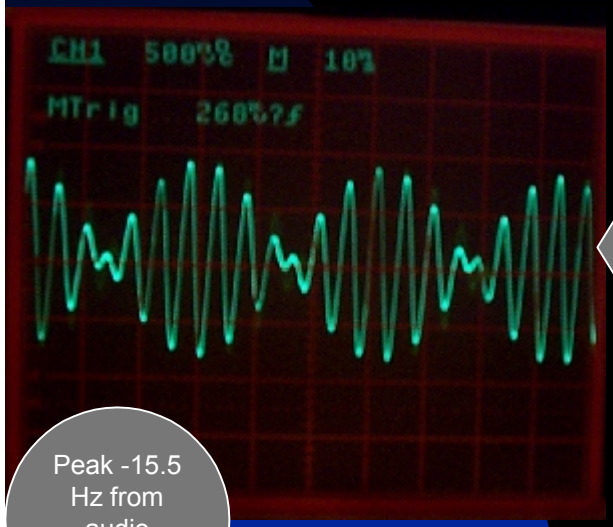
Let's look at PSK31 in the real world on an oscilloscope:

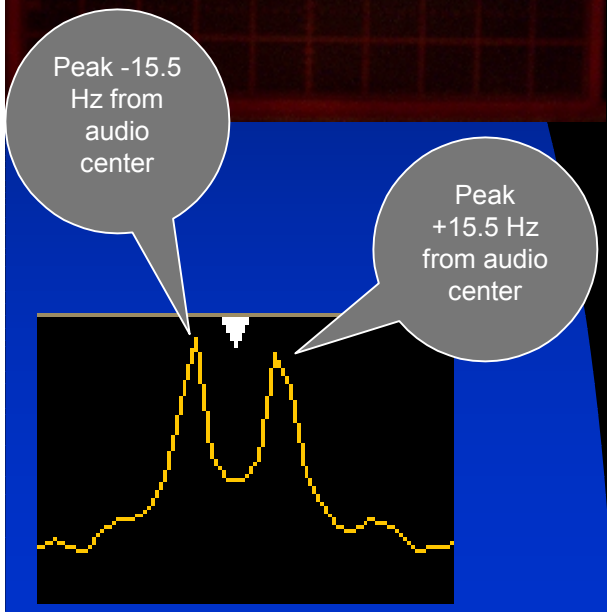
PSK31 sequence of zero bits

Same signal shifted 1 bit (32 msec)

Notice that when we shift the signal one bit width (32 msec), and compare, the phase shift of 180 degrees is clear. This also gives us a clue for how PSK-31 is detected and converted back to the digital world.

PSK—its spectrum





- An idle PSK signal (stream of zero bits) looks almost like a 31 Hz sine wave modulated onto an audio "carrier." Q: How else could this or a similar signal be generated?
  - A: By mixing two tones centered on the "carrier" audio frequency, separated by +- 15.5 Hz.
  - Therefore, a spectrum analyzer would show a two-peak signal.
  - Therefore the bandwidth of PSK-31 is…ta-dah…31 Hz.
  - As characters of data get transmitted, the "valley" gets filled in, so the bandwidth remains 31 Hz.

PSK brightness

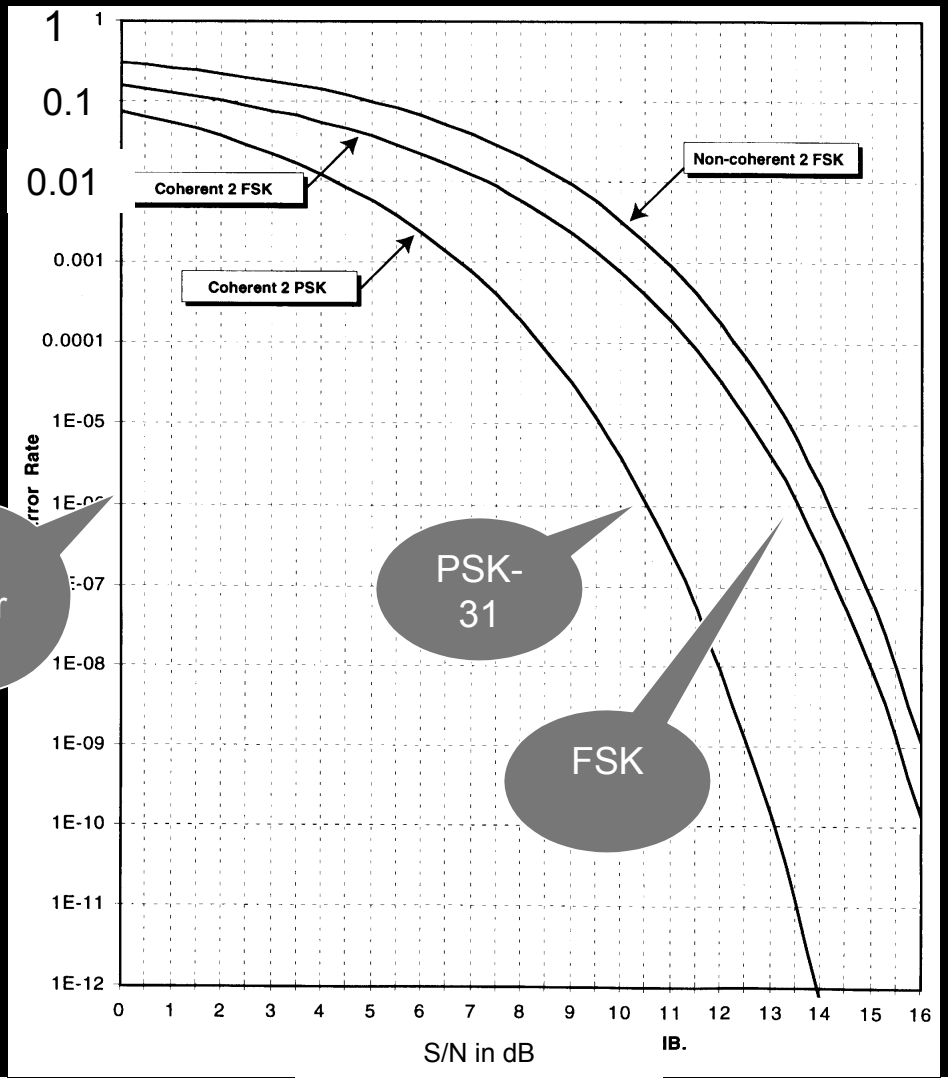
- What' so good about a bandwidth of 31 Hz?
- For SSB voice, imagine putting 100 watts into a voice bandwidth of 3000 Hz. That's 30 mwatts/Hz.
- Putting the same power into PSK-31, however, is packing 100 watts into just 31 Hz. That's 3200 mwatts/Hz. More than 100 brighter (20 dB) than SSB!
- Another way to put it: you need much less power to have the same S/N as voice. Cross-country contacts with 1 watt of power are not uncommon! PSK-31 is ideal for QRP.

PSK vs FSK performance

Example: if S/N is 3db, then the bit error rate for PSK is 0.02 (1 error in 50 bits), but for FSK the bit error rate is almost 1 error in 10 bits!

In fact, the curve for PSK is just the curve for FSK, but shifted to the left exactly 3db.

It means that PSK performs like an FSK signal with 3dB of gain. Or, another way to say it is when FSK is too weak to copy, PSK will still be copiable!



How characters are encoded in PSK31

- You are probably used to the ASCII standard, which encodes every character as 8 bits, with a start and stop bit.
- But PSK-31 does not use ASCII!
- Instead, PSK-31 uses a form of encoding whereby the most common characters are represented by the fewest bits. Does this remind you of any other form of digital communication?

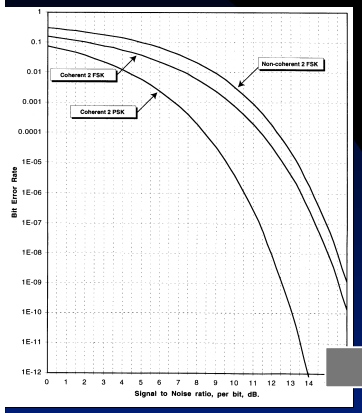
How PSK31 vericode works:

- This variable length code is called “vericode” and works using these two rules:
- 1. All characters are separated from each other by two consecutive 0 bits.
  2. No character contains more than one consecutive 0 bit.
- Next, a list of all bit patterns that obey these rules was generated, and the shortest patterns were assigned to the most commonly occurring characters.

What vericode looks like

- Here are some characters in vericode:
- SPACE: 1
- e: 11
- o: 111
- t: 101
- The average number of bits per character in vericode is *about 6.5*, compared to 10 for ASCII. This improves the data rate by about 50% for the same bandwidth!
- Also: PSK-31 allows both upper and lower case letters, numbers, and all punctuation (including backspace)!

Copy vs. S/N



S/N	Bit Error Rate	Character Copy Rate	Sample Text
0dB	0.1	50%	W1BW DE KF6XSG.Ok, Jjm.!Rh`nks"hoq!thf!calj. L`megfrf!iq George-"QTHis S`n Rafbfl CA, aanut 20 miler-nnruh of Sao"Franciscn. How cmpy? @TW!WOAX DE KF6VSF!K
3dB	0.02	88%	W1AW DE KF6VSG. Pk, Jin. Thaoks for the call. Name jere is George. QTH is Sao Rafbel CA, aaost 20 mileu-north of Tcn Francitco. How copx? BTU"WOAW!DE KF6VSG K
6dB	0.003	98%	W1AW DE KF6VSG. Ok, Jim. Thanks for the call. Name here is George. QTH is San Rafael CA, about 20 miles north of San Francisco. Hob copy? BTU W1AW DE KF6VSG K
10dB	0.000005	99.997%	W1AW DE KF6VSG. Ok, Jim. Thanks for the call. Name here is George. QTH is San Rafael CA, about 20 miles north of San Francisco. How copy? BTU W1AW DE KF6VSG K

Ready to build a PSK-31 station?

- Here is all you need:
  - A computer running Windows 95/98/2000 (or even DOS or Linux)
  - Sound card (SoundBlaster compatible)
  - Stable HF transceiver (1 Hz), Antenna, power supply
  - Rig to computer cables
  - PSK-31 software for your OS
  - PTT hardware (to be described)
  - Free COM port
  - Operating privileges (i.e., your ticket)

To monitor:

To transmit:

How to build it

Antenna

Computer

Speaker Out

a

Sound Card

b*

COM Port

PSK-31 Application

Mic Input*

HF Transceiver

DTR or RTS of, COMn*

a=Line In
b=Line Out

*=not needed to monitor

PPT control & Mic Input

- Both of these signals need conditioning:
- We use a COM port's DTR or RTS lines as a control signal to key the transmitter (I.e., close PTT to ground)
- We use the sound card's "Speaker Out" to provide signal to the transceiver's Mic Input

The details…

Conditioning the Logic signal

- We use a COM port's DTR or RTS lines as a control signal to key the transmitter (I.e., close PTT to ground)
- DTR/RTS are RS-232 levels (+- 12VDC), but PTT needs to be grounded to transmit.
- Solution(s):
  - Use a transistor as a switch
  - Use an optical isolator as a switch
  - Use a relay as a switch

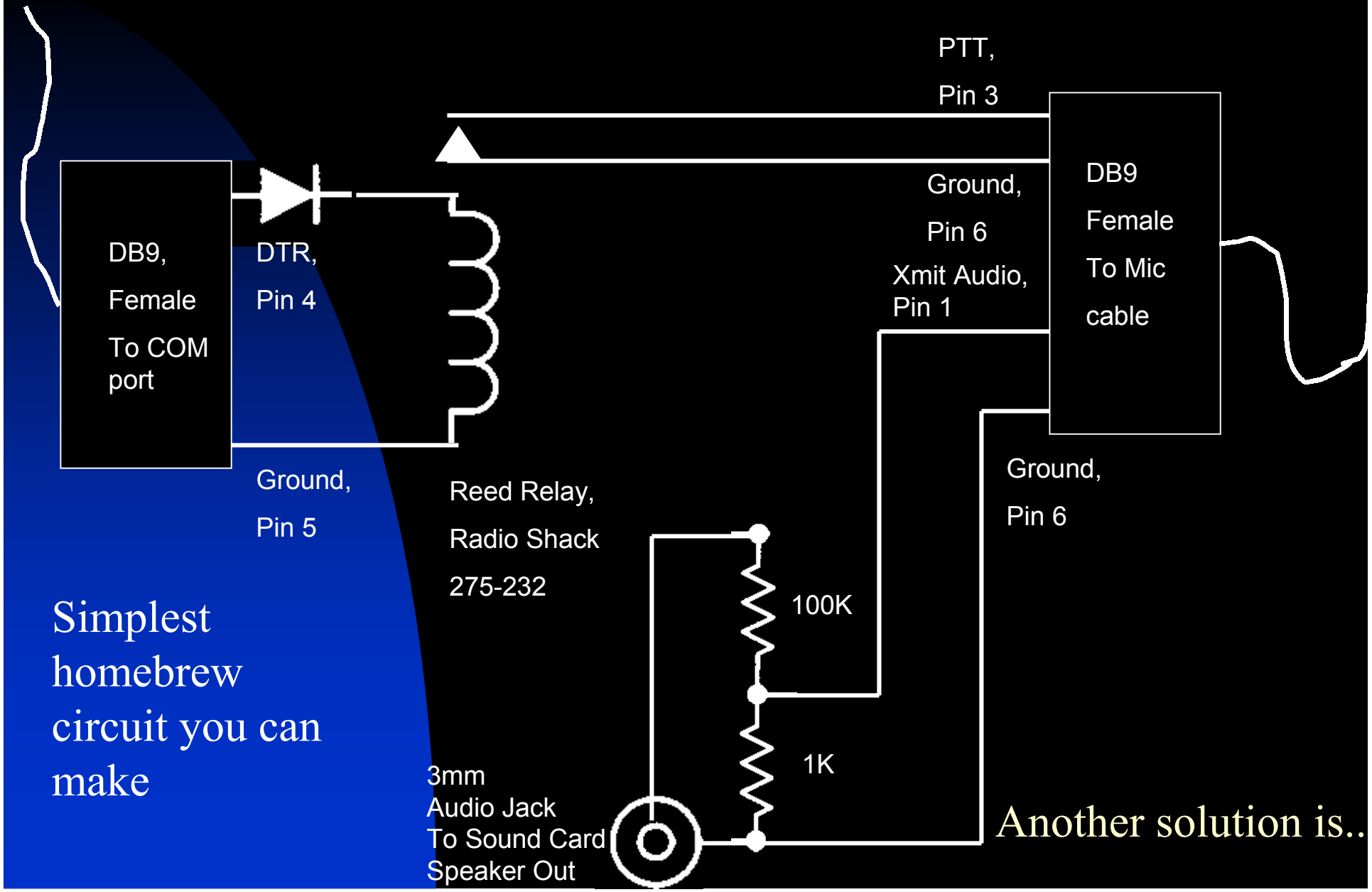
And we also have to think about the analog signal…

Conditioning the analog signal

- We use the sound card's "Speaker Out" to provide signal to the transceiver's Mic Input
- But "Speaker Out" is a low impedance signal, while the transceiver's Mic input is a high impedance signal.
- Solution(s):
  - Audio transformer
  - Resistive divider

Therefore…

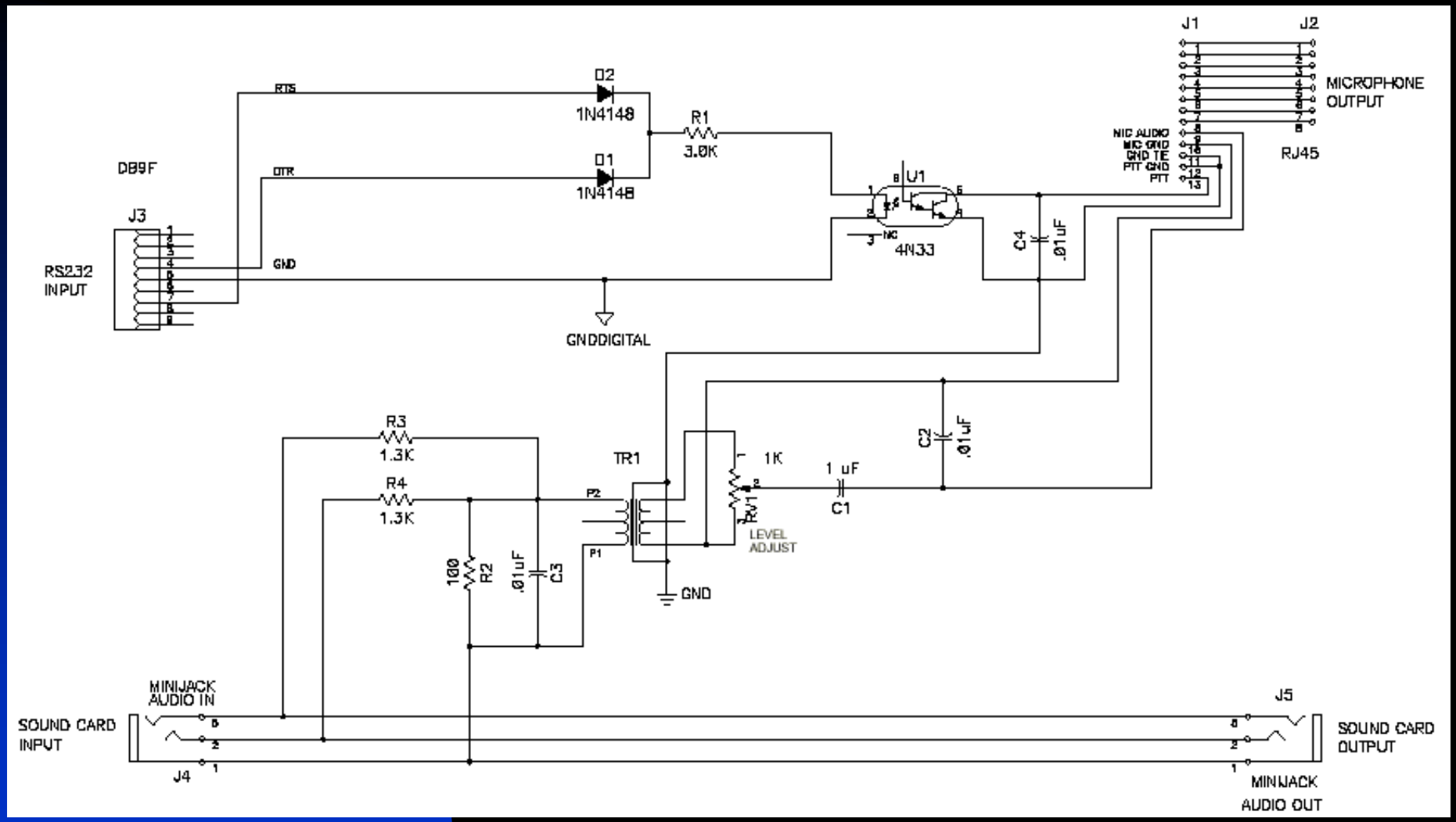
Conditioning Circuit Example



Commercial Interfaces

Product	Manufactureer	MSRP	Web site URL	Front view
RigBlaster	West Mountain Radio	$90	www.westmountainradio.com	
Nomic	West Mountain Radio	$35	www.westmountainradio.com	
SignaLink	Tigertronics	$50	www.tigertronics.com	
MFJ-1275 Soundcard Radio Interface	MFJ Enterprises	$89	www.mfjenterprises.com	

What's inside the Nomic



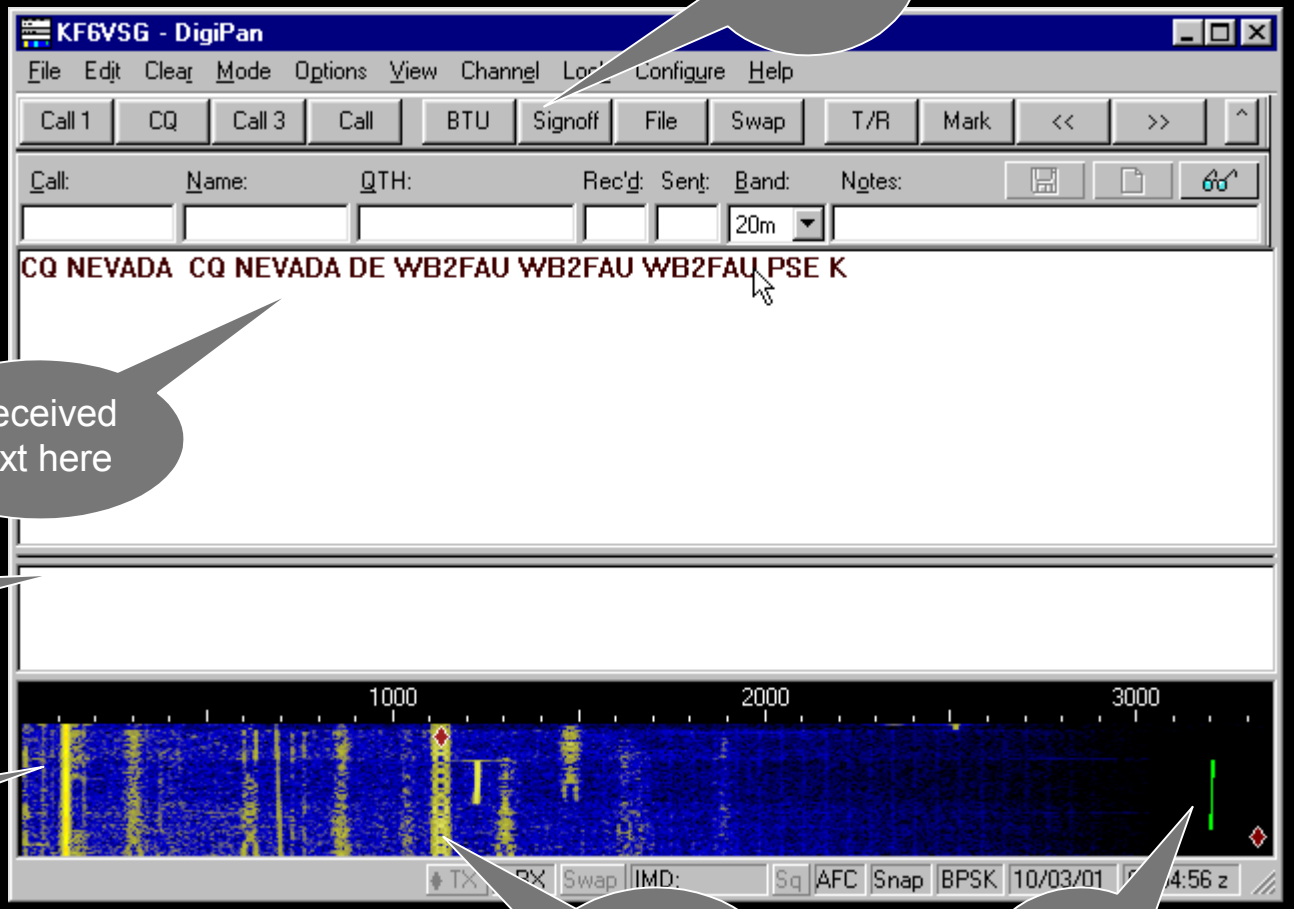
Now for the software…

- You have a large number of freeware and inexpensive shareware programs to choose from. Here are just a few:

WinPSKse	
Intercom	DOS, freeware
MixW	RTTY and PSK31 Terminal for Windows95 (for Sound Blaster). Shareware.
PSK31SBW	The original (updated) program by Peter Martinez, G3PLX. Similar to a portion of Logger (and others), simple to use, currently lacks the spectrum display.
WinPSK	
ZAKANAKA	
DigiPan	This software has really taken hold in the PSK31 crowd, mostly due to its ease of use.
WinSQLPSK	Displays up to 20 PSK signals at the same time.

Digipan

- By far the most popular PSK31 application
- Important features:
  - Waterfall display (time vs. frequency)
  - Macros



W1SQLPSK

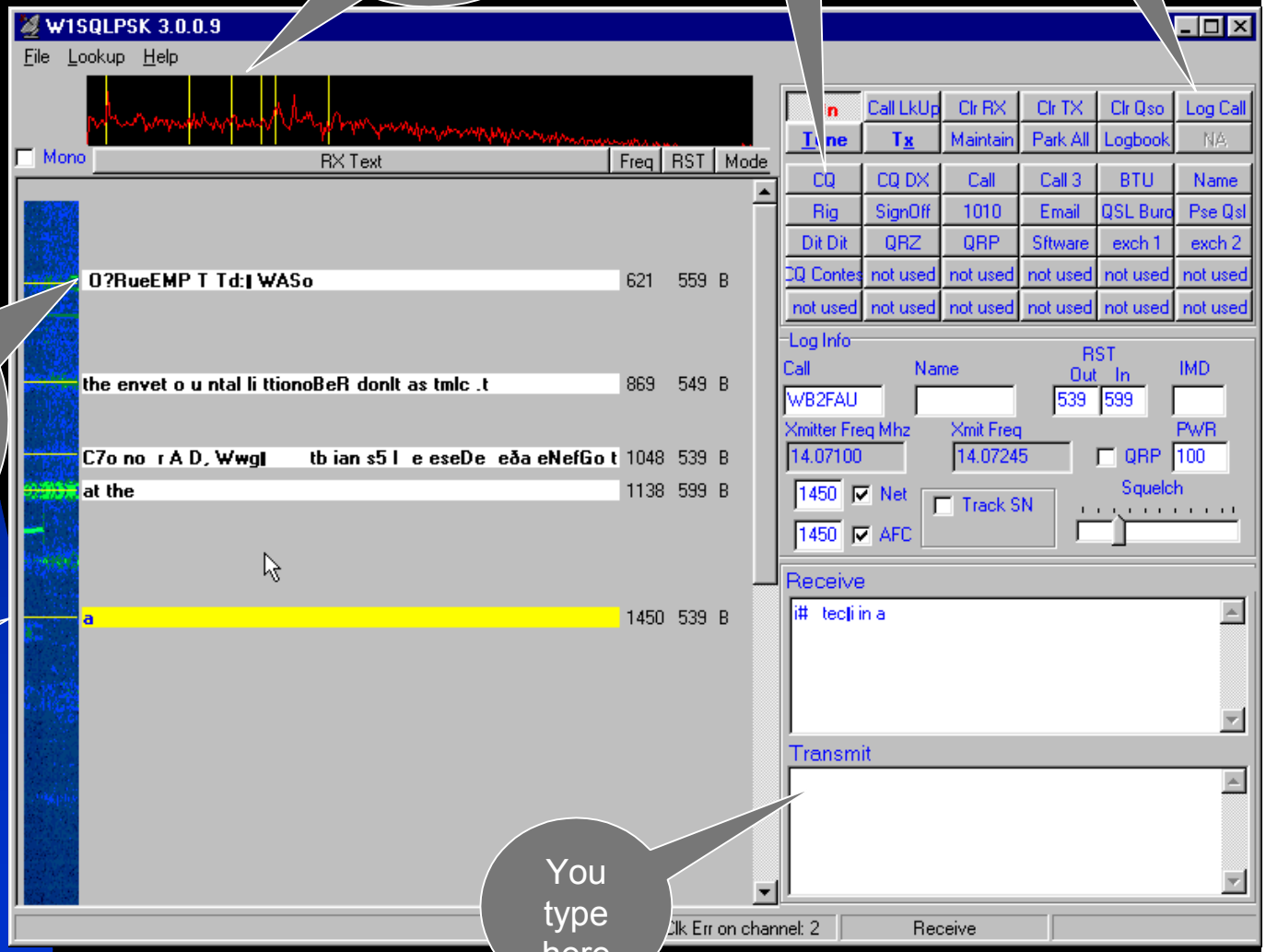
Not as well known, but my personal favorite.

Features:

Spectrum Analyzer

Displays up to 20 PSK signals simultaneously.

Logging



Received text here (and there and there…)

Water-fall display

You type here

Tuning up in PSK-31

- Improperly tuned PSK-31 can result in
  - Undermodulation—your signal will be too weak to be received or copied
  - Overmodulation—your signal will have high Intermodulation Distortion (IMD) and splatter, and possibly will have poor copy also.

Tuning up in PSK-31

- Tuning up involves setting
  - Transceiver RF frequency
  - Sound card line out audio level
  - Transceiver microphone gain
  - Transceiver power setting
  - Turning off the speech processor
  - Turning off AGC

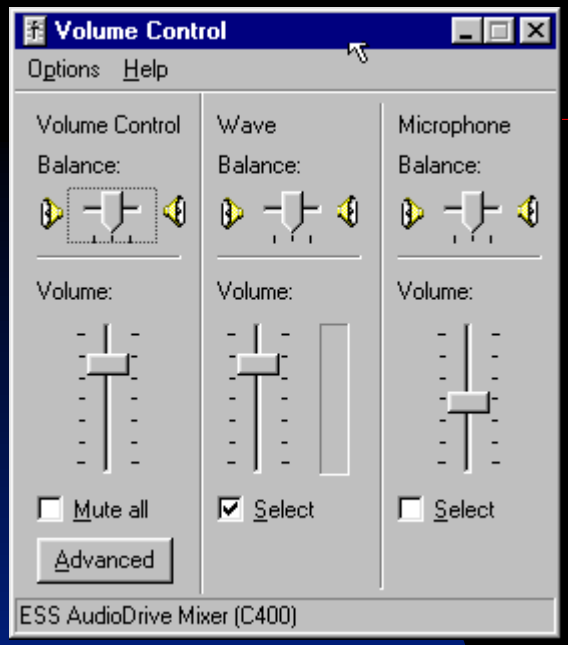
Setting the RF frequency

Band (meters)	Frequency (MHz, USB)
6	50.07,50.29
10	28.120
12	24.920
15	21.080;21.070
17	18.100
20	14.070
30	10.142
40	7.035;7.08
80	3.582 LSB

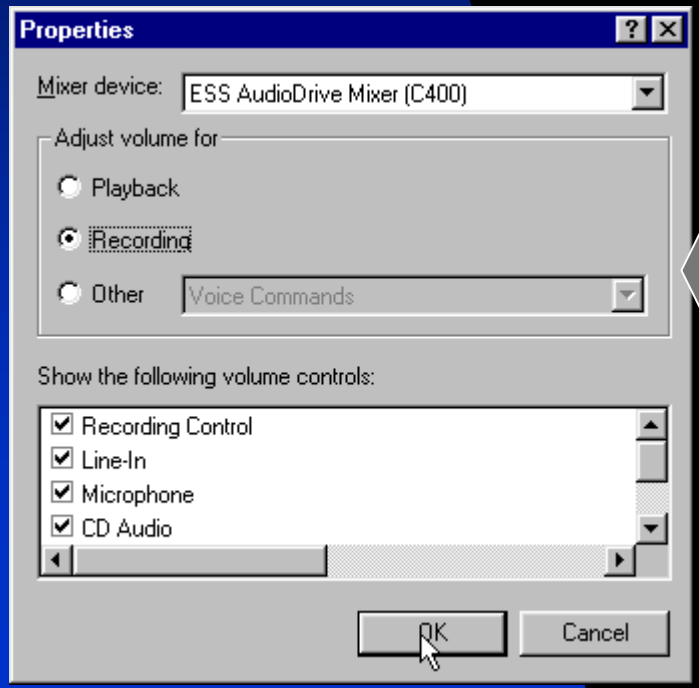
Hottest Band!

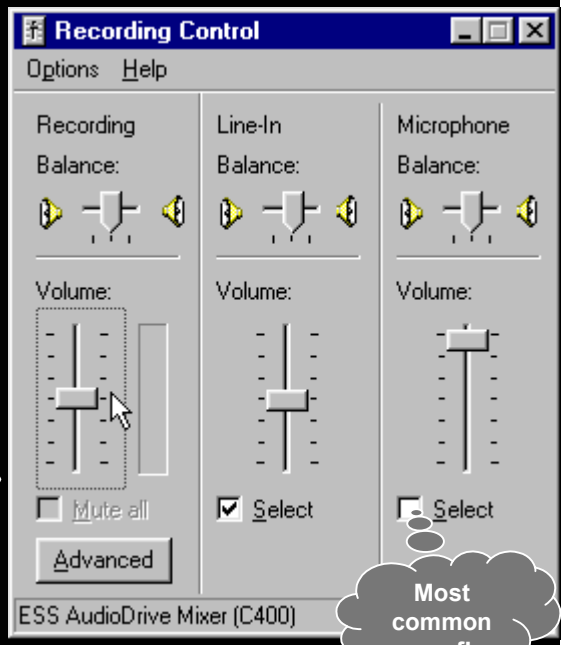
- PSK-31 can be found on the bands shown in the table at the left.
- If you park your transceiver one of these frequencies, you will find PSK signals ranging in audio from 400 Hz to 3500 Hz. Yes, you can pack 100 simultaneous QSO's into "one" RF location!
- You can now pick any audio frequency and start listening or transmitting.
- However, if you get close to the edge, you will find that your transceiver does not have flat audio response, and so your PSK signal will be attenuated and poorly detected.
- If you see a station near the edge of the audio bandwidth that you want to work, first tweak the RF frequency to shift the audio signal to be closer to the center of the transceiver's response—around 1.0-2.5 KHz.

Setting audio levels

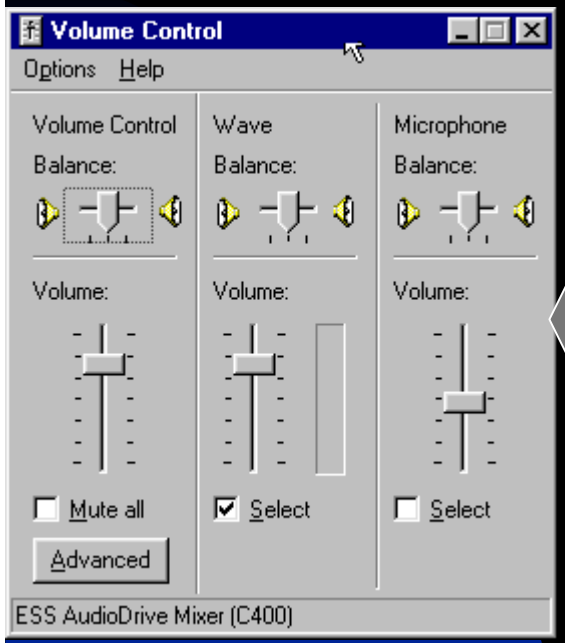


- It's all in the Window's "mixer."
- Double click on the  icon on the system tray. The mixer will pop up, similar to what you see at the left.
- First, let's get the input from the rig to the computer working, so you can monitor PSK-31:
  - Click on Options|Properties. Set the Recording button. Click on Ok.
  - Now select Line-In, and *de-select Microphone*.
  - Set the volume sliders to 50%
  - Adjust the rig volume for best waterfall.





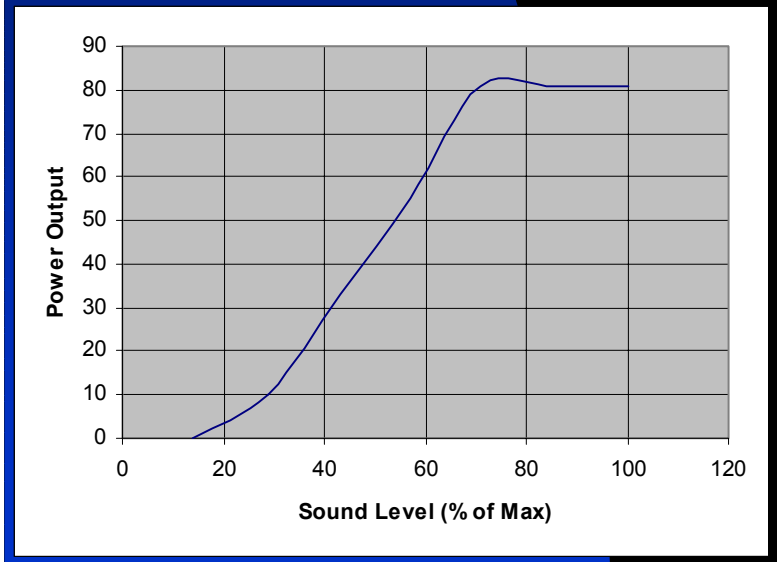
Setting Audio Levels



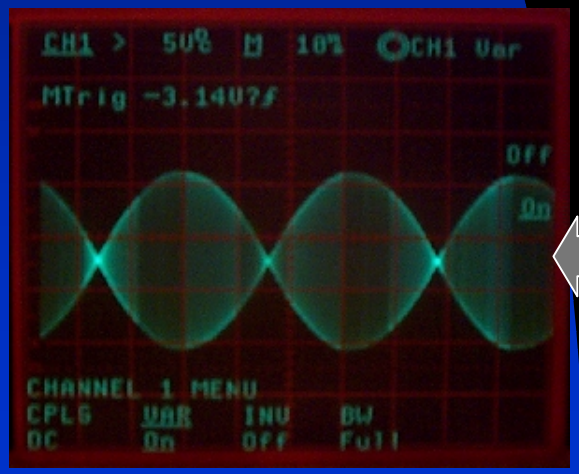
- Now set the audio level from the sound card into your rig's microphone:
- Again, back at the mixer's main display…
- De-select everything but "Wave". That's your line out.
- Set the Wave volume to maximum.
- Now you can adjust the sound level by the Volume Control slider.

Setting the audio level

- Click “TX” button of your PSK-31 software, so that you are sending an idle PSK signal to the transceiver.
- Starting with the maximum sound level, observe the transmitter’s power output and back off the mixer’s audio level until the power level is at about 50%.
- You should observe an S-shaped curve like the one I measured at 1500 Hz.
- The proper audio level in this case would be about 50% of maximum.



Setting the audio level

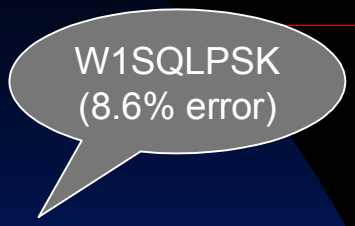


- Avoid the temptation to crank up the audio level to get more power!
- You will only produce horrendous splatter, have very poor IMD, and be less copiable!
- Properly tuned, you will have a low IMD figure (-25 to –30 dB), and a clean spectrum with maximum copy—a signal you can be proud of.

One more clean signal hint:

- If you experience odd computer behavior, or a report of a poorly formed signal, RF is getting into your computer.
- Put a ferrite core toroid on all cables going to your computer (two or three turns):
  - Both audio cables
  - RS-232 cable
  - Keyboard cable
  - Mouse cable
  - Power cable

And a receive signal hint…

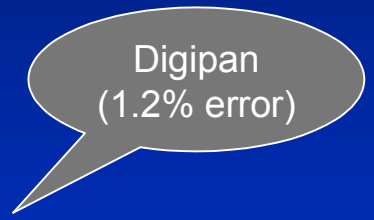


Your siD looks OK to me dDsn't seem to be pverdriven..

I am running 50 watts to 3 el. .p 67 feee h

So how are things in Carson City

BTU JacK AB7NO de W8PSb "



Your sig looks OK to me Doesn't sseem to be pverdriven..

I am running 50 watts to 3 el. beam up 67 feet.

So how are things in Carson City

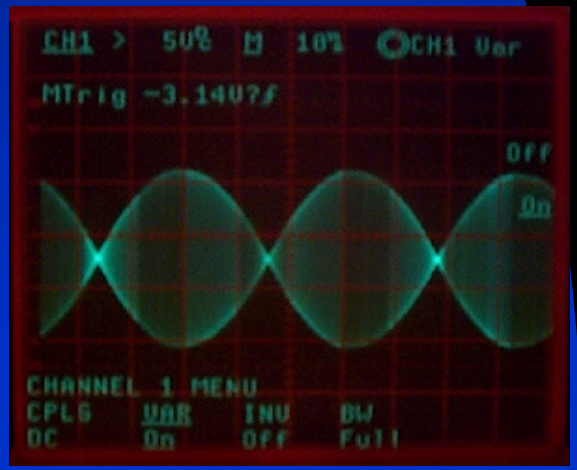
BTU Jack KB7NO de W8PSK K

- Processing incoming audio is CPU intensive! If you see strong waterfall signals, but poor copy, terminate other programs that might be running on your computer and stealing CPU cycles!
- Copy quality depends on your choice of software, too.

Transmitted power in PSK-31

Don’t expect to transmit at the full (peak) power of your rig.

When in idle, the output power is the peak power times the RMS of a sine wave (0.707). If you are running 100 watts



Operating in PSK—
Use of macros

You can personalize your macros for:

CQ

CQ DX

BTU

Answer CQ

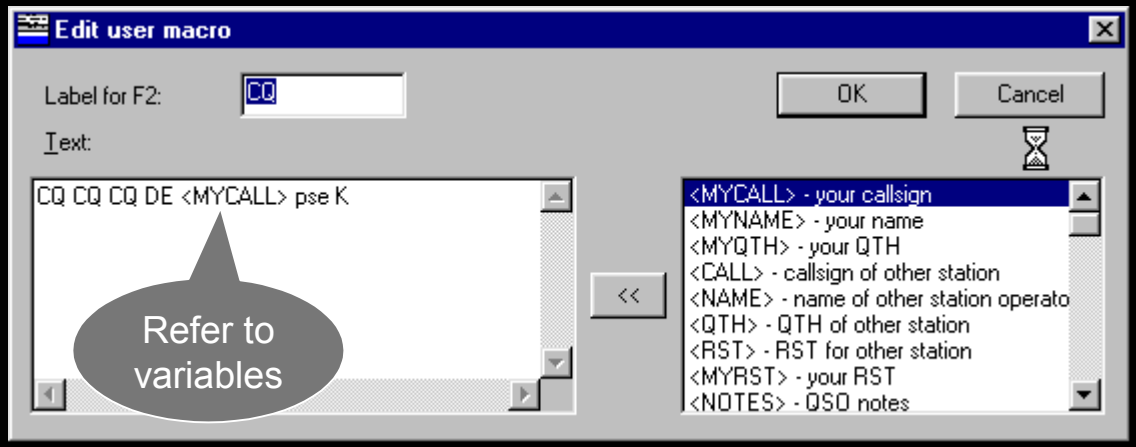
Name and QTH

Station Description (brag files)

QSL address info

…use your imagination!

- Macros allow you to “pre-record” text that gets transmitted when you click a button.
- Example: CQ macro as it appears in the macro editor:



So when you click on the CQ button, this gets transmitted as:

```
CQ CQ CQ DE KF6VSG pse K
```

Operating in PSK-31
QSO conventions

- No split operation—RX and TX on same frequency
- Abbreviations
  - Not so important as with CW. You are communicating at about 50 wpm, using a keyboard, and using macros, so “tnx fr call” might as well be “Thanks for the call.”
- Case
  - Use mixed case! PSK-31 supports upper and lower case and all punctuation, so you can type as if in a word processor.

Operating in PSK-31
QSO conventions continued

- Repeat important info.
  - PSK is *not error correcting*! Each character you type is immediately sent and received. A certain fraction of characters will be corrupted. Therefore, repeat vital info, like this:
    - Name here is George George. QTH is San Rafael CA San Rafael CA.
- RST reporting
  - You'll have to guess at the signal strength based on the waterfall or spectrum analyzer display. Your rig's S-meter won't help you here. 'R' and 'T' are always 5 and 9.

Operating in PSK-31
QSO conventions continued

- IMD reporting
  - Most PSK-31 software reports the received signals Intermodulation Distortion.
  - More negative is better. A clean signal will have IMD < -25dB, and the best is around –29dB. When IMD is greater than –10dB, the sender is overdriving his rig (and generating splatter). Be sure to advise him to reduce his line out audio level!
  - Likewise, if you get a report of a poor IMD, you are not properly tuned up. Take a moment to reduce your audio level.

Where to go for more info

Issue	Page	Title	Author
Apr 2001 QST	83	Revisiting "Clean Up Your PSK31 Signal" (Technical Correspondence)	Kruis, Richard J., K8CAV
Mar 2001 QST	105	DX4WIN/32 (Short Takes)	Ford, Steve, WB8IMY
Mar 2001 QST	41	The Considerate Operator's Guide to 3580 kHz (sidebar to The Warbler--A Simple PSK31 Transceiver for 80 Meters)	Benson, Dave, NN1G
Mar 2001 QST	37	The Warbler--A Simple PSK31 Transceiver for 80 Meters	Heron, George, N2APB
Mar 2001 QST	37	The Warbler--A Simple PSK31 Transceiver for 80 Meters	Benson, Dave, NN1G
Feb 2001 QST	88	Clean Up Your PSK31 Signals (Technical Correspondence)	Kruis, Richard J., K8CAV
Jan 2001 QST	50	The HF Digital "Tower of Babel"	Ford, Steve, WB8IMY
Oct 2000 QST	81	PSK31 on FM (Technical Correspondence)	Mason, Butch, W6KAG
Jun 2000 QST	31	A Panoramic Transceiving System for PSK31	Teller, Howard, KH6TY
May 2000 QST	45	"My PSK31 Doesn't Work!" (sidebar to PSK31 2000)	Ford, Steve, WB8IMY

Where to go for more info

Issue	Page	Title	Author
May 2000 QST	42	PSK31 2000	Ford, Steve, WB8IMY
Dec 1999 QST	35	A PSK31 Tuning Aid	Urbytes, Don, W8LGV
Nov 1999 QEX	59	PSK31: A New Radio-Teletype Mode (Jul/Aug 1999 QEX) (Replies) (Letters to the Editor)	Martinez, Peter, G3PLX
Nov 1999 QEX	59	PSK31: A New Radio-Teletype Mode (Jul/Aug 1999 QEX) (Comments) (Letters to the Editor)	Sabin, William E., W0IYH
Jul 1999 QEX	9	The convolutional Code (sidebar to: PSK31: A New Radio-Teletype Mode (reprint from RadCom))	
Jul 1999 QEX	9	Is PSK31 Legal? (sidebar to: PSK31: A New Radio-Teletype Mode (reprint from RadCom))	Sumner, Dave, K1ZZ
Jul 1999 QEX	3	PSK31: A New Radio-Teletype Mode (reprint from RadCom)	Martinez, Peter, G3PLX
Jul 1999 QEX	2	PSK31 (Empirically Speaking)	Smith, Doug, KF6DX
May 1999 QST	41	PSK31 - Has RTTY's Replacement Arrived	Ford, Steve, WB8IMY

Where to go for more info

Wireless Digital Communications: Design and Theory, Tom McDermott, N5EG

www.arrl.org (members only, search for PSK31)

www.ssiserver.com\info\psk31 (copy of this presentation as an Adobe PDF document)

www.psk31.com ("official home page")

www.aintel.bi.ehu.es/psk31.html ("official home page")

www.arrl.org/tis/info/HTML/psk31 (Steve Ford's original QST article)

Email reflector: send email to psk31-request@aintel.bi.ehu.es. Put "subscribe" in the subject line.

Demonstration Time!

Conclusions

- PSK31 is just great if you…
- Want to try a new mode without a big investment
- Enjoy digital modes
- Enjoy ragchewing
- Enjoy DX
- Enjoy software and computers
- Enjoy QRP
- Enjoy kit building
- Have a poor antenna, low power or poor location
- Want to stay on the cutting edge

Acknowledgements

See you on 14.070 PSK-31!

You've been a great audience!

73's from
George, KF6VSG

Failure modes--Hardware

- Transceiver problems
  - volume level changed
- Audio cables/connector problems
  - Mono vs stereo audio cables
- Sound card failure/Driver failure
- COM port failure (RTS or DTR stuck either high or low)
- Signal conditioning circuit failure (stuck relay, jack failure)
- Antenna is too close to computer (hum and audio distortion)

And of course…

Failure modes--software

- Sound mixer
  - Improper audio levels
  - Audio sources disabled or muted

But, after you have it working, get ready for some fun…