A. Appendix A. Operating Notes

The hardware and software design described in this report implements a FSK modem/TNC for HF asynchronous Baudot (ITA-2) and synchronous SITOR/AMTOR (CCIR 476 Mode B) signalling. It operates at speeds to 100 baud, either as a TNC with ASCII input/output via the onboard UART, or as a regenerator with clean AFSK output reconstructed from a possibly noisy input. The algorithms use Butterworth and matched filters, soft-decision detection, maximum a-priory (MAP) estimation and Viterbi decoding. In case of continuous asynchronous signalling, the modem can operate in a synchronous mode using a phase-lock loop (PLL) to flywheel through momentary carrier fades. The predetection design and many of the operator features were inspired by the Dovetron TU of long ago, but implemented in DSP, rather than analog form. The postdetection design, including MAP estimation, Viterbi and matched-filter decoding and synchronous mode was inspired by a LSI-11 program also of long ago. The algorithms implement a theoretically optimum receiver for FSK RTTY and SITOR signals in additive white Gaussian noise with nonfading and Rayleigh fading channels. If this thing can't pull RTTY and SITOR signals from the muck, nothing can.

The modem operates as both a TNC and a regenerator. When operating as a TNC, the modem is connected to a HF transceiver operating in LSB mode, so that the space tone is transmitted at the lower radio frequency. The modem can also be connected to a VHF FM transceiver. In receive mode, received Baudot characters decoded from RTTY and SITOR signals are converted to ASCII and sent to the terminal program at the speed and character format selected by the hardware and program, currently 19,200 baud. In transmit mode, ASCII characters received from the terminal program are converted to Baudot and used to modulate the AFSK output. Since the modem transmitter and receiver are functionally independent and the program can operate with both radio ports, this feature might be useful in a crossband repeater.

The transmit/receive protocol operates as in typical TNCs such as the AEA PK-232. The x command switches to transmit mode and keys the push-to-talk (PTT) line of the transmitter, following which text is transmitted as received from the terminal program. The ASCII ACK (ctrl-F) character switches to receive mode when the transmit buffer is empty; the ASCII EOT (ctrl-D) character purges the buffer and switches to receive mode immediately. The p{1-2} command selects the radio port to use for the transmit, receive and tune functions. Separate first-in first-out (FIFO) buffers are used to save transmitted and received text. Flow control for the transmit buffer is implemented using hardware clear-to-send (CTS) handshaking only.

The frequencies of the mark and space tones are designed to match the AEA PK-232 TNC in either narrow shift (WIDE OFF) or wide shift (WIDE ON) mode. In narrow shift modes, the input and output mark tone is 2125 Hz and the input and output space tone is 2295 Hz. In wide shift modes, the input mark and space tones vary to match the shift, with a center frequency of 1700 Hz. In wide shift modes, the output mark tone is 1275 Hz and the output space tone is 2125 Hz. The o{0-2} command can be used to switch between narrow and wide output shifts, if necessary. The baud rate of the transmit signal is equal to that of the receive signal.

The character translation tables use the US versions of the ITA-2 (Baudot) alphabet and the ITA-5 (ASCII) alphabet. Operating speeds used by both the receiver and transmitter are selectable from the set 100, 75, 50, 45.45, 25 and 10 baud. Speeds below 45.45 baud are useful in marginal conditions where the FSK signal can barely be heard by ear on a SSB voice receiver. The predetection matched

filter at 45.45 baud provides 6dB of processing gain over the typical 100-Hz postdetection lowpass filter used in many TNCs. In addition, the 10-baud rate can provide an additional 6dB gain.

The CCIR 476 SITOR Mode B (FEC) mode is compatible with the AMTOR Mode B (FEC) used by the amateur community. This mode is used for HF broadcasts such as the W1AW and NAVTEX bulletins. This modem supports both receiving and transmitting in this mode at all baud rates and shifts supported by the RTTY mode, but defaults to 100 baud and 170-Hz shift. Only these defaults are permitted under current FCC regulations. Should operation at lower baud rates be permitted by the FCC under a Special Temporary Authorization (STA), for example, the modem performance in this mode at 10 baud would be truly awesome. The same transmitter control functions in RTTY mode are also active in SITOR mode.

This appendix contains information on how to operate the digital modem as a component of a two-way radio station, such as might be used in an amateur radio station or a shipboard radio installation. It includes information on tuning instructions, LED displays, and the various operator commands provided.

A.1. Tuning Instructions

First, make sure LED 2 is on (dimly) to indicate the modem program is running. Set the baud rate, mark/space shift and filter type using the b{1-6} and m{1-8} commands listed below. For ordinary RTTY amateur operation at 45.45 baud, 170-Hz shift, use the b4m8 commands and lower sideband; for most RTTY commercial operation at 75 baud and 850-Hz shift, use the b2m1 commands and upper sideband. When first loaded and after the r (reset) command, the modem is set for RTTY operation at 75 baud and compromise 600-Hz shift, as in the b2m2 commands. The y command switches to SITOR operation; the r command resets the modem and restores the defaults.

Tune in a RTTY or SITOR signal and adjust the receiver output signal level so that LED 1 turns on occasionally, but is not solidly lit. If a speaker or headphones is connected to the speaker jack, use the d1 command to monitor the modem input signal. Adjust the receiver frequency to maximize the intensity of LED 3 (carrier detect) or the midpoint of the tuning range where LED 3 turns on from off. It may be useful to temporarily reduce the receiver gain to the point that LED 3 just turns on at the center of the range. Use the g{0-7} command to reduce the analog gain of the DSP-93 or the l{0-5} command to reduce the limiter gain, if necessary. The t{+ −} command can be used to tune the receiver, if the receiver and cable support the DSP-93 signals; however, note that the tuning resolution of some radios is not fine enough when the predetection matched filters are in use (m{5-8} command).

If the FSK signal is not being modulated, you may observe two peaks in LED 3 intensity, one where LED 5 (mark) turns on, the other where LED 6 (space) turns on. The correct peak is where LED 5 turns on, which can then be used as a fine-tune indicator. If the FSK signal is being modulated, LED 5 and LED 6 should be flashing alternately. In this case, the receiver frequency should be adjusted to equalize the intensity of LED 5 and LED 6. Use the m{+ −} command to fine-tune the space frequency and maximize the intensity of LED 6. Usually, this is necessary only if the transmitter is using a nonstandard shift. A word of caution, however; this thing is really very selective, especially when the predetection matched filter is in use, where it needs to be tuned to within 10 Hz for optimum results.

LED 7 shows the space signal of the regenerated signal. It flashes to indicate a valid character is being received. When transmitting in RTTY operation, it flashes as each character is transmitted;

in SITOR operation, it flashes continuously. When the transmit buffer nears capacity, the modem will drop the CLEAR-TO-SEND (CTS) line, which normally stops transmission from the terminal program. In this condition, indicated when LED 7 flashes regularly at a 2-Hz rate, it is not possible to enter commands until the buffer partially empties, the CLEAR-TO-SEND (CTS) line is raised again, and LED 7 stops flashing. If the terminal program ignores the state of the CLEAR-TO-SEND (CTS) line and the buffer overflows, LED 2 flashes at a 2-Hz rate and continues flashing until the modem switches from transmit to receive.

If a speaker or headphones is connected to the speaker jack, use the d5 command to monitor the modem baseband signal. A properly tuned in RTTY signal will produce a distinct "tick-rumble" signal sounding vaguely like a Teletype Model 12 (which is not completely accidental). The tick is produced when a valid start bit has been found; the rumble is produced as each bit of the signal is processed. With practice, signals can be tuned in accurately by watching the LEDs and listening with the d1 and d5 commands on the speaker. For instance, an improperly tuned in or malformed signal may produce no tick, an irregular tick, or a weak or nonexistent rumble.

In RTTY operation, an autostart function can be used to avoid messy garbles when a RTTY signal of sufficiently good quality is not being received. (In SITOR mode, these functions are intrinsic in the signal and protocol design.) The a{0-1} command is used to select the autostart mode. In the a0 mode, which is the default, output is blocked, unless the signal level of either the mark or space channel is above the carrier threshold (c{+ −} command) and the character quality estimate (distance) is above the erasure threshold (v{+ −} command). In the a1 mode, output is blocked until a continuous spurt of about ten correctly framed RTTY characters is received with a quality estimate above the autostart threshold (a{+ −} command). Once a spurt is received, a 30-s timer is started and begins counting down. Any character received while the timer is running resets it to 30 s. If no characters are received before it runs out, output is again blocked and LED 4 flashes at a 1-Hz rate.

In SITOR operation, the modem sensitivity is such that good copy can be made with signals that cannot be reliably detected by ear with a SSB voice receiver. This includes signals buried in noise or interference, where the LEDs and speaker are generally useless as tuning indicators. Even a scope connected to the detector output (d5 command) may not help much. Therefore, tuning in such signals requires some ingenuity. The most useful technique may be using the d8 command and a DVM or DC-coupled scope connected to the analog interface DAC output. The output is about 2V with no input signal and decreases with increasing input signal and signal quality. When the output decreases below zero, the modem should be synchronized and delivering copy. The output is particularly sensitive to the CCIR retrain sequence (see below for more information on this sequence). This sequence, which normally is sent at the end of each line or when no traffic is available, produces a strong negative voltage excursion when received.

A.2. Command Interpretation

The command interpreter is driven by a hierarchical set of tables, together with short code sequences which implement the various functions. The interpreter also performs transmit/receive functions and translates received CR characters received from the terminal program to the transmitted sequence CR-LF when translated to Baudot.

Tables A1 and A2 show a summary of the modem commands and their associated options and defaults. Commands consist of a single letter in either upper or lower case and followed by an optional modifier digit, plus sign "+" or minus sign "–". For those commands with numeric or {+

Command	Default	Function
a{0-1}	a0	select autostart mode
		a0 disable autostart
		a1 enable autostart
a{+ –}	midrange	adjust autostart gate threshold
b{1-6}	b2	select baud rate
		b1 100 Baud
		b2 75 Baud
		b3 50 Baud
		b4 45.45 Baud
		b5 25 Baud
		b6 10 Baud
b{+ –}	midrange	adjust baud interval up/down 1 μs
c{0-2}	c0	select mark/space channel
		c0 mark/space
		c1 mark only
		c2 space only
c{+ –}	midrange	adjust carrier gate threshold
d{0-9}	d0	select display/output
		d0 audio output signal (AFSK)
		d1 audio input signal
		d2 filtered/limited input signal
		d3 mark channel output signal
		d4 space channel output signal
		d5 detector output signal
		d6 carrier gate signal
		d7 erasure gate signal
		d8 autostart gate signal
		d9 VCO phase signal
e{1-3	e1	select analog/digital loopback echo
		e1 analog loopback echo
		e2 digital loopback echo
		e3 full duplex
g{0-7}	g2	select analog gain 0-36dB in 6-dB steps
		plus comparator (g7)
g{+ -}	midrange	adjust digital gain
i	normal	select upright/inverted shift (toggle)
l{0-5}	l5	select limiter gain 0-30dB in 6-dB steps

Table A1. Command Summary

–} suffixes, the suffixes can be used repeatedly for the same function. The function is redetermined at the next command letter.

Command	Default	Function
m{1-8)	m2	select mode, filter and shift m1 IIR filter, 850-Hz shift m2 IIR filter, 600-Hz shift m3 IIR filter, 400-Hz shift m4 IIR filter, 170-Hz shift m5 matched filter, 850-Hz shift m6 matched filter, 600-Hz shift m7 matched filter, 400-Hz shift m8 matched filter, 170-Hz shift
m{+ –}	midrange	adjust space frequncy up/down 10 Hz
o{0-2}	o0	select output shift o0 follow input shift (170 Hz/850 Hz) o1 170-Hz shift o2 850-Hz shift
p{1-2}	p1	select radio port p1 radio port 1 p2 radio port 2
r		master reset
s	disable	enable/disable RTTY sync mode (toggle)
t{+ –}		adjust radio frequency up/down one step
u{0-3}	u0	select unshift-on-space u0 disable transmit and receive u1 enable receive u2 enable transmit u3 enable transmit and receive
v{0-1}	v0	enable/disable erasures v0 enable erasures v1 disable erasures
x	receive	transmit
y	RTTY	select SITOR mode

Table A2. Command Summary (Continued)

Commands take place immediately; there is no line-end character or provision for backspace or line-delete functions. Command characters are echoed as received with a line-feed (LF) character echoed following a received carriage-return (CR) character.

The defaults assumed at initial start and after a software reset (r command) are presently set at 600-Hz shift (m2), 75 baud (b2), 30dB limiter gain (l5), autostart gate off (a0), sync enable off (s), display AFSK generator (d0), analog loopback echo (e1), and 850-Hz output shift (o). Some commands may affect the settings for others; in particular, the m{1-8} command resets the c{0-2}, e{1-3}, i, o{0-2}, p{1-2}, q, s, and u commands to their defaults. This is probably more a bug than a feature.

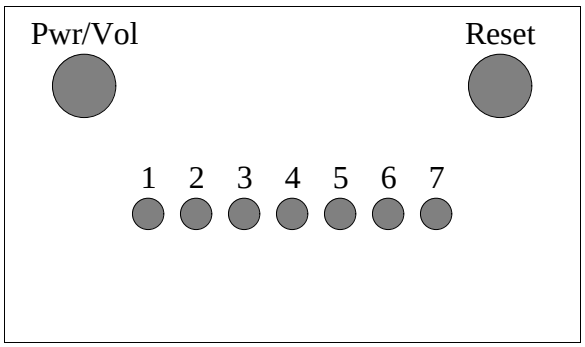

Figure A1. DSP93 Front Panel

A.3. LED Indicators

The arrangement of the LEDs on the front panel of the DSP-93 is shown in Figure A1. The various indications are interpreted as follows:

LED 1 spike limiter. This LED indicates that the signal input is above the clipper threshold. Under ordinary conditions, it should flash occasionally, but not be on all the time.

LED 2 program running. The brightness of this LED represents the fraction of CPU cycles available for other than signal processing. It flashes at a 2-Hz rate to indicate an error (output buffer overflow) condition.

LED 3 carrier gate indicator. This LED on when the carrier gate is unblocked, which indicates a valid carrier signal is being received.

LED 4 autostart gate indicator. This LED indicates the status of the character decoders. In SITOR mode and RTTY asynchronous mode, it flashes with received characters when unblocked by the erasure gate. In RTTY synchronous mode, it is on continuously, but blinks with received characters when blocked by the erasure gate. If the a1 command has been given, it also flashes with received characters as long as the autostart gate is unblocked. If no input data have occurred in the last 30 s or so, it will flash at a 1-Hz rate.

LED 5 mark channel output. This LED is on when the carrier gate is unblocked and the mark channel signal is above the carrier threshold.

LED 6 space channel output. This LED is on when the carrier gate is unblocked and the space channel signal is above the carrier threshold.

LED 7 output space indicator. This LED is on when the encoder output is at space. It flashes at a 2-Hz rate when the CLEAR-TO-SEND (CTS) signal at the UART connector is down, indicating the output buffer is nearly full and the terminal program should cease sending data.

LED 8 power indicator. This LED should always be on.

A.4. Oscilloscope Signals

In transmit mode, the analog interface DAC output is always connected to the AFSK generator. In receive mode, the DAC output can be connected to a DC-coupled Oscilloscope to view various internal signals of interest, including the AFSK generator. The d command is used to switch among

the signals listed under the d command. Even when a scope is not available, a speaker can be used as a fairly accurate tuning indicator and operating aid. The d1 monitor point is the analog interface ADC input signal supplied from the receiver. The signal amplitude should be adjusted so that LED 1 flickers occasionally, but is not on all the time. If the amplitude is too high, the signals will be distorted, which is readily apparent to the ear. The d2 monitor point is the input signal after the FIR filter and limiter. If the limiter gain is reduced to unity (l0 command), the signal can be centered in the filter passband by ear and checked with LEDs 3 and 4. The d5 monitor point can be used as an aural activity monitor. When no channel activity is present, the speaker will be silent. If a carrier is present and characters are being received, the sounds produced mimic a clunky old Teletype Model 12 printer. That wasn't intentional, but it is satisfying.

A.5. Bugs

The transmit mode needs a watchdog timer.

An autobaud function should be added to the UART code to handle terminal programs operating at other than 19,200 baud.

The transmitter needs a right margin check and auto-CR/LF, especially when using analog loopback echo.

Automatic speed select and upright/invert detect function could be relatively easy to implement. Automatic narrow/wide-shift selection and AFC would also be a valuable features, but harder to implement.