Personal Computer Based Wireless Communication System

Introduction

The proliferation of wireless communication technologies has resulted in a vast number of different communication standards over recent years and will continue to do so. As a result, communication users have been continually faced with (i) rapidly changing standards and practices, (ii) the need to purchase new hardware whenever new standards are adopted, (iii) an increasingly steep learning curve for new users, and (iv) a severe problem in integrating multiple add-on peripheral devices with related software for additional features. In addition, the amount of information available to users is growing rapidly with the advent of increased wire, fiber, and satellite communications. Locating desired program material amidst the sea of available channels has become virtually impossible unless the user is an expert and employs additional computer assistance. This difficulty is further complicated by the always changing program schedules which are common with services such as shortwave broadcasters.

Communication standards are rapidly changing in order to accomodate market forces in the wire and wireless marketplaces[1]. Aside from adding additional spectrum resources to the commercial marketplace by the Federal Communications Commission[2] in the U.S. and by other agencies world wide, many services are being mandated to change their systems to be more spectrally efficient (use less frequency bandwidth while transporting the same or more information per unit time) by going to narrower channel spacings and more advanced signaling waveforms. A typical example of this scenario is the APCO-25 standard which is under consideration for all public services such as police and fire in the U.S. This standard would require new communication systems to adopt a standard channel spacing of 5 or 6.25 kHz rather than the present day 12.5 kHz standard with an accompanying use of digitally compressed speech as well as other data compression means. Modulation methods would also be changed from traditional FM to more efficient waveforms such as GMSK and $\pi/4$-DQPSK and the underlying digital information bits would be further processed to

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[1] Wire systems will henceforth refer to wire, cable, fiber, etc. systems which are physically attatched to an information medium. Wireless systems will henceforth refer to wireless, infared, satellite, etc. systems which are not physically attatched to an information medium.

[2] Governing body in the United States of America for wire and wireless standards, requirements, and authorizations.

address such issues as forward error correction (FEC), interleaving, data formatting and protocols, etc. Even standard AM and FM broadcasts will be transmitted by simulcast (overlaying existing broadcast signal with buried digital signals for advanced systems) type means in the foreseeable future in order to allow more advanced hardware to receive a diverse range of material spanning from CD-quality sound to newspapers, stock reports, weather forecasts, etc. This proliferation of communication services and techniques will be unsuccessful in reaching the marketplace if traditional hardware and software means are relied upon stemming from simple economic considerations.

Basic economics dictate that the marketplace can only purchase a limited quantity of communication technology per unit time. Even if new highly advanced cellular telephone technology becomes available every two years for example, businesses and consumers must effectively ammortize previous technology over a reasonable period of time. Therefore, the entry of new technology is largely governed by the near term monetary savings experienced by a would-be new user. It is no longer cost effective or reasonable to necessarily purchase a separate piece of equipment for every communication service a business or consumer desires to interact with. It is also unrealistic to expect the marketplace to purchase new hardware or peripherals every time a new communication service comes on line, or every time existing services need to modify their signaling technique or related data protocols. At the same time, if the flexibility to accomodate change is not present in the marketplace, the insertion of new technology will be dramatically slowed.

The complexity of existing and new communication methods as well as the shear volume of information available over communication channels has come to a point where users are overwhelmed. The airwaves may for example carry 100 different forms of radio teletype signals (RTTY) but virtually no one has the expertise to first identify the signal type being received and then engage the proper peripheral device to effect reception of the actual information. Once the information has been received, porting the data to software such as Microsoft Windows™ is another hurdle which must be addressed. Similarly, increasingly few individuals can decode the Morse code yet the shortwave frequency bands are full of such signals. Due to radiowave propagation changes and program changes, let alone user know-how, most users who may want to receive the RTTY daily newspaper broadcast from Geneva, Switzerland for instance are clueless how to begin. In the cellular telephone frequency bands, the same frequencies are used for standard analog cellular (AMPS), $\pi/4$-DQPSK TDMA digital cellular, SMR, CDPD, Mobitex, pager systems, and a myriad of other services. Although a user may wish to use these services, dealing with the technical and informational learning curves involved for each service is not practical.

Historically, companies have sold add-on devices and peripherals to augment existing communication products, but rarely are these peripherals sold by the original equipment manufacturer. Therefore, the user is often faced with a difficult integration problem with both hardware and software, let alone the encumberance of more and more boxes appended to their basic system. Most of the hardware and software does not operate in a seamless fashion. Simple conflicts for even the communication ports on a personal computer can become a major inconvenience or problem. Most of the hardware and software pertaining to wireless communications aside from cellular phones is targetted to the techology elite or nitche hobby areas such as amateur radio thereby further encumbering individuals who do not have this background from entry into wireless.

The concepts which follow address these problems from a systematic perspective. Just as the standard 1200 baud wireline modem provided access to a virtual universe of computer bulletin boards and services with standard interfaces and protocols from a reasonable skill level, the concepts collected here develop a similar universe of opportunities for wireless communications using the personal computer.

Discussion of Improved Art

One of the primary perspectives which set this embodiment apart from previous approaches is that a top-level systems approach has been adopted. In this respect, a citizen’s band radio and a cellular telephone radio perform the same function; they provide the means for wireless communications. These wireless systems certainly have substantial differences, but at the same time, functionally each system is performing many of the same tasks. Just as a software programmer would write different computer programs to address different computational needs, this embodiment will in principle make it possible for the same type of computer programming to be used to in effect program wireless communication hardware unlike that seen before. Within certain constraints which are discussed momentarily, vastly different communication signals will be receivable using the same piece of hardware with only changes in software. Within these constraints, one piece of hardware will be able to seamlessly deliver a multitude of communications services all capable of being reconfigured with only software.

A second perspective adopted in this embodiment is the highly integrated marriage between the personal computer (PC) and signal processing/radio hardware. Rather than view the radio elements as a separate entity outside the PC, in this embodiment, the radio is an integrated part of the PC which simply provides additional informational resources to the PC much like a simple wireline modem provides resources to existing computers. By making the signal processing and radio hardware virtually stand-alone operational, all of the PC resources are focused upon providing the user with the most sophisticated and complication free interface possible. To this end, reception of vastly different communication signal types such as Morse code (CW), standard AM, weather facsimile or authorized pager signals can be engaged by a simple click of a computer mouse on the appropriate screen icon. This embodiment is hosted using Microsoft Windows® although it could have been cast using any of a number of other software platform.

1.0 System Level

The embodiment provides a fully functioning state-of-the-art radio resource to the user through their personal computer without adding any additional (physical) knobs, switches or other control means to the original computer. Complete control of the resource is achieved through either (i) the computer mouse, (ii) the keyboard, (iii) pre-programmed data files, (iv) external wire or wireless modems, or (v) audible voice commands.

1.1 System Architecture

The embodiment consists of (i) an external radio electronics unit, (ii) a digital signal processing card which is plugged into the PC (henceforth referred to as the DSP), and (iii) software. Items (i) and (ii) are connected together using a standard computer cable. The antenna is connected to the external radio unit.

The radio and signal processing elements have been partitioned such that all of the digital signal processing elements (aside from limited serial interface control hardware) reside within the PC on a user-installed standard AT circuit card and all of the sensitive radio electronics are remoted outside the computer in a separate chassis. This partitioning helps to minimize the otherwise invasive electromagnetic interference (EMI) arising from the computer and its monitor. With computer clock speeds climbing quickly toward 100 MHz, EMI is a very serious issue when receiving any signal particularly those employing linear modulation such as AM, single sideband, quadrature amplitude modulation (QAM), etc.

Connection of the installed computer card with the external radio unit is made by one single standard computer cable over which serial control, D.C. power, and radio analog inputs and outputs are conveyed. A 3-wire serial control protocol is used in the present embodiment for cost and EMI issues as well as for later upgrades where multiple radio elements may be jointly involved and cascaded. D.C. power for the external radio unit is provided by the same cable drawing upon the internal voltage supplies of the PC. This approach was adopted to minimize cost and conducted emissions. Most importantly, the filtered and amplified desired received signal is sent through the cable at an intermediate frequency (IF) rather than at low frequency baseband again to minimize EMI problems. This choice also results in no loss of signal information thereby permitting the most advanced signal processing possible to be employed in the DSP when desired.

The DSP electronics were purposely designed not to make use of hardware interrupts to communicate with the PC. This choice was made in order to minimize configuration problems with users' existing PC hardware configurations.

The standalone features of the DSP/radio resources permit the resource to be run in background on the PC under Microsoft Windows® as well as other software.

Narrowband and wideband signals are used for different services. The present radio frequency (RF) hardware shown in Figure 4 is inherently narrowband, being limited to RF bandwidths less than approximately 30 kHz. Many services at 800 MHz and higher utilize spread-spectrum techniques which commonly occupy RF bandwidths of 1 MHz and higher (e.g., CDMA digital cellular, GPS, ISM band). Spread-spectrum is generally employed commercially for mitigating signal multipath, increasing spectrum efficiency (CDMA only), ranging purposes, or signal encryption. Normally, spread-spectrum and narrowband RF hardware is dramatically different due to the disparity in signaling bandwidths used. This embodiment will accomodate limited spread-spectrum capabilities in the future as discussed later.

A high level functional view of the system is shown in Figure 1. Multiple wireless (and wire) *personalities* are shown across the top of the figure ranging from a standard AM radio to wireless services resident in the 800 MHz cellular band. Each personality represents a radio type or communication service which historically users have had to purchase separate hardware in order to have access to.

Each personality shown in Figure 1 has access to the same set of internal processing resources. These resources have been partitioned in this figure as comprising of (i) front panel accessible features such as audio tone controls and squelch which would normally be engaged with a single button or slider, (ii) larger global resources which can be drawn upon to service any personality such as the database or voice prompt features, and (iii) additional global resources which target specific communication types and services such as Morse code, radio teletype, etc. Each of the features shown in Figure 1 are discussed at greater length later.

1.2 High Level User Interface

The user interface is highly visual in nature, deriving directly from the structure shown in Figure 1. The present embodiment user interface is cast using Microsoft Windows®. A fully functional version of this embodiment has also been developed to run under Microsoft DOS but is only used as a development tool.

The user interface is highly organized around the provided wireless personalities. Access to all of the other wireless resources is granted and orchestrated through these personalities. Although only one wireless personality is active at a given time in the present embodiment, it is conceivable that future embodiments will dissolve this limitation. Even so, multiple wireless personalities can be active on the computer screen at any time and switching between the displayed personalities is no more difficult than a click of the mouse. Each wireless personality automatically retains its prior settings including such details as frequency, receive bandwidth, volume and tone settings, AGC time constants, etc. making rapid switches between personality types easy. It is also possible to have multiple copies of the same wireless personality present on the computer screen each with its own set of personality parameters. In this respect, a complete personality is composed of a given radio personality in addition to all the user selectable settings for that given radio personality. Each of these personalities is denoted by a file name under which the associated data is stored on the computer's hard disk. Virtually any number of such personalities may be constructed by a user as desired.

A representative wireless personality (Communications Radio) is shown in Figure 2 as it would appear on the monitor of the PC. All of the buttons, knobs, sliders, etc. are activated by using one of the options mentioned earlier, the most common being the computer's mouse. In Figure 3, the same wireless personality is shown in addition to the automatic Morse Code decoding resource which has been engaged. Regardless of the wireless personality involved, the same Morse Code decoding resource can be used which greatly simplifies matters from the user's perspective.

Wireless Personalities

The embodiment is focused around a core group of radio personalities as shown in Figure 1 which all have access to other functional and computational resources provided by the signal processing hardware and or the PC. The sharing of these resources between different radio personalities reduces the user's learning curve and makes for a homogeneous wireless resource.

The wireless personalities shown in Figure 1 address the most widely encountered signal types appearing in the frequency ranges of 0.5 – 30 MHz and 108 – 174 MHz. Other personalities will of course be added to address other frequency ranges. The wireless personalities being addressed immediately include the following:

- Standard AM Broadcast Radio
- DX (large distance) AM Broadcast Radio
- World Radio
- Amateur Radio
- Communications Radio
- VHF Radio
- 2 Meter FM (amateur)
- Aircraft Radio
- Police & Fire Radio
- Citizen's Band Radio
- Marine Radio
- Pager Radio
- Wideband Spectrum Analyzer
- Time Standard Radio
- Internal Diagnostics

Each of these personalities has a different presentation on the computer's monitor along with different provided features. In all cases, the intention for using multiple personalities is to present users with radio front panels which they are comfortable with if they are an experienced user while at the same time minimizing complexity for the new user.

The user interface for the Communications Radio has already been shown in Figure 2. This wireless personality provides the degree of functionality most high-end users would require in the HF band. Novel to this embodiment is the real-time spectrum analyzer display which is shown in the upper right hand corner of the screen. Beside the spectrum of the incoming signal, the receive channel filtering characteristic along with the programmable notch filter characteristic are overlaid over the spectrum making it dramatically obvious how the user should modify the radio filtering in order to avoid undesirable interference. The spectrum analyzer output is also invaluable for locating weak narrowband signals such as Morse Code. The frequency span of the display can be easily zoomed in and out by the user as desired. The setup file which the user edits during the installation process allows the user to modify the detail level which is shown in the spectrum analyzer. This feature makes it possible to support reasonable screen refresh rates even on much older 80286-based computers with a corresponding loss of spectral resolution. Spectral averaging parameters are also made available to the user for modifying the effective video bandwidth of the display also. The spectrum analyzer also serves as a very useful built-in diagnostic tool as discussed later.

Each of the principle wireless personalities draws upon a pool of standardized front panel controls as mentioned earlier. These features include:

- Narrowband Spectrum Analyzer
- Variable Receive Bandwidth & Offset
- Variable Notch Filter & Offset
- Multi-mode demodulator
- Receive Signal Automatic Frequency Control (AFC)
- Audio Bass & Treble Tone Controls
- Radio Automatic Gain Control (AGC)
- Noise Blanker
- Automatic Line Extraction (ALE)
- Automatic Level Control (ALC)
- Digital Automatic Gain Control (DAGC)
- Squelch
- Personality Save & Restore
- Calibrated Signal Strength Meter

Additional global resources are also available to each wireless personality. These include the following:

- DTMF Decode
- Alarm Clock
- Amateur Band Frequency Chart Reference
- Spectrum Reference Chart
- Voice Prompts
- Radio Audio in Background
- Signal Identification & Classification
- Sample Sound
- Map

Each of these will be discussed briefly next.

Narrowband Spectrum Analyzer

Two spectrum analyzer types are provided in this embodiment, one narrowband and one wideband. The narrowband spectrum analyzer is displayed dynamically on the computer monitor as described earlier and it typically has a frequency span limitation on the order of 20 to 50 kHz. The means used to create this display in the present embodiment relies upon the signal sampling process which is performed at the DSP input.

In the present embodiment, the incoming receiver IF signal (450 kHz in the present case) is synchronously sampled at a rate of approximately 44 kHz. Bandpass sampling techniques are utilized to convert the sample stream into complex in-phase (I) and quadrature-phase (Q) samples. A continuous sequence of N complex samples is accumulated in the DSP and then passed to the PC for subsequent processing. The processing in the PC is composed of (i) a data windowing process followed by (ii) a fast Fourier transform (FFT) operation with (iii) the resulting power spectral density (PSD) being computed in decibels (dB) and subsequently recursively filtered to affect a degree of video filtering.

Variable Receive Bandwidth & Offset

The current embodiment makes it possible to vary the receive bandwidth using 48 geometric steps from 11 kHz to 47 Hz. The geometric nature of this bandwidth progression is an important feature in keeping the DSP program size small, but other progressions could of course be adopted where merited. In addition, the center frequency of the receive channel filtering can be shifted off center in either direction up to a percentage of the underlying Nyquist frequency involved with the DSP processing in 1 Hz steps. Control of these filtering parameters is made available to the user on the wireless personality front panel(s). It should be emphasized that all of this processing is done in the digital domain after quantization by the analog-to-digital converter (ADC) and no analog or RF electronics are involved.

Variable Notch Filter & Offset

A variable notch filter is also provided for eliminating strong selective interference or strong carriers from the desired signal. The notch filter in the present embodiment makes it possible for the user to change the notch (i) offset frequency from center, (ii) 3 dB notch width, and (iii) notch depth in dB. This processing is all done in the digital domain after quantization.

Multi-Mode Demodulator

One of the more powerful features of this embodiment is the provision for many types of signal demodulators. Demodulators which address the more traditional analog waveforms include the following:

- Standard AM envelope detector
- Synchronous AM detector
- Double sideband diversity AM detection with optimal combining
- Single sideband detector, upper and lower
- Standard FM discriminator detector
- Modified FM discriminator detector with improved threshold performance
- Coherent FM detector, PLL
- CW, direct pass thru
- Narrowband CW with programmable audio tone frequency
- Tone-Tag CW

Some of these demodulators are novel to the present embodiment and require additional elaboration. The availability of multiple types of demodulators for the same signal type (e.g., FM) is unprecedented in the same product.

The double sideband diversity AM demodulator makes use of the fact that the AM signal is composed of two separate signal sidebands which are completely redundant. By properly processing the sidebands separately, the effects of severe fading and interference can be reduced.

The Narrowband CW demodulator is novel in that the audible tone frequency for a Morse code signal can be programmed by the user to any frequency f_B from roughly 60 Hz to 1 kHz. If the receive RF bandwidth presently being used is denoted by W, the only tone frequencies which will be heard when tuning past a CW signal will range from roughly $-W/2 + f_B$ to $+W/2 + f_B$.

The Tone-Tag CW detector is actually a prelude to the fully automatic Morse code resource. Similar processing to that done with the Narrowband CW mode is used but additional signal processing is employed. The additional processing performs a number of tasks including (i) automatic frequency tracking, (ii) automatic dynamic optimization of the receiver bandwidth, and (iii) threshold and decisioning of the CW signal presence. Rather than hear the often times weak CW signal buried in noise, the latter feature is used to output a pure noise-free audio tone to the user based upon the optimal signal processing decisions being made in real time. Once again, the frequency of the audio tone can be adjusted by the user as desired.

Additional signal demodulators are buried in other resources and personalities. For instance, precision frequency shift keying (FSK) demodulation is provided in connection with RTTY demodulation. Similarly, QAM demodulation is provided to support TDMA digital cellular and other high capacity services.

Receive Signal Automatic Frequency Control (AFC)

AFC for FM systems is not uncommon in high quality equipment. Beyond this however, this embodiment includes provision for AFC for other signals, notably AM and Morse code. (AFC for digital modulation modes is somewhat necessarily inherent in the demodulation process and will not be separately mentioned.) AFC for RTTY and other FSK type modes is also included.

Audio Bass & Treble Tone Controls

Few if any shortwave or amateur radio receivers include audio tone controls. This embodiment includes provision for bass and treble boost and cut, both being implemented strictly within the DSP using digital techniques.

Radio Automatic Gain Control (AGC)

All radios must include some means of automatic gain control because the received signal strength commonly varies over many orders of magnitude. Normally, this is accomplished by strictly analog or RF circuit means. Since it is necessary for this radio hardware to receive a very wide range of signal types, a different approach was used in this embodiment.

In the present case, the RF gain control elements which are used are PIN diodes because they offer very repeatable low distortion performance. The signal attenuation presented by the PIN diodes in the radio circuitry is set by an analog current which is controlled by a 12 bit serial digital word issued from the DSP. Receive signal power is measured directly by computing the signal strength represented by the I and Q sample values computed in the DSP. The control loop between the measured received signal strength and the PIN diode control currents is then completed through the DSP. This makes it possible to dramatically alter the AGC dynamics as necessary for receiving Morse code, AM, and other signals.

This approach allows many refinements to be made which are simply not possible with other techniques. For instance, fine adjustments to the frequency synthesizer when in AM receive mode normally result in noticeable audio pops due to the frequency settling action of the synthesizer. In the present embodiment, the radio AGC is disengaged and held constant for approximately 5 milliseconds during any frequency synthesizer change to avoid this phenomenon.

Noise Blanker

This embodiment includes provision for a noise blanker which is helpful in reducing strong random impulse noise. The striclty digital implementation permits nearly optimal noncausal blanking to be performed which is unprecedented.

Automatic Line Extraction (ALE)

The digital signal processing approach used in this embodiment makes computation of signal correlation features straight forward. Simple correlation processing is in fact what is used in standard digital FM demodulation. The ALE feature exploits the digital signal processing capabilities to identify interference which is long lasting and predictable (e.g., sinusoidal). Using a number of well known methods found in the open literature, the ALE feature adaptively eliminates multi-tone sinusoidal interference which may be present.

Automatic Level Control (ALC)

Once the narrowband receive filtering and demodulation have been performed, the derived audio signal often has significant level variations over time due to severe multipath fading, particularly over shortwave frequencies. This is minimized within this embodiment with the inclusion of digital ALC following these two processes. The digital ALC must respond fast enough to prevent computational overflows in later processing elements but be slow enough in the case of other signals such as Morse code that severe level overshoots are not introduced.

Digital Automatic Gain Control (DAGC)

The maximum receive RF bandwidth in this embodiment under normal operating conditions is approximately 15 kHz. Smaller receive bandwidths are implemented by the DSP. Since the radio AGC must maintain the total signal power ideally constant at the ADC input of the DSP in order to avoid saturation or loss of computational dynamic range, the radio AGC is ineffective when realizing smaller receive bandwidths. This problem is solved here by the use of digital AGC within the DSP filtering algorithms. The same type of attack and decay considerations pertaining to the radio AGC must be considered here as well.

Squelch

The squelch function for FM reception is again implemented with the DSP. Squelch threshold, attack and release times are all programmable by the user.

Personality Save & Restore

It may become obvious to a user during reception of a particular signal type or station that saving all of the present radio settings would be advantageous for later use. A total save of the wireless personality and all supporting parameters may be accomplished using this feature. This setting may then be retrieved at a later date by simply invoking this function once again while supplying the name under which the original setup was saved. List boxes and editing features are provided for maintenance of personality records.

Calibrated Signal Strength Meter

A calibrated signal strength meter is provided in this embodiment. This feature is possible due to the precision gain control possible using the PIN diode gain control elements. Since the radio AGC loop is closed through the DSP, accessibility to the needed signal strength information is readily available.

DTMF Decode

Many analog VHF services utilize dual tone multi frequency (DTMF) techniques in order to communicate numerical data such as telephone numbers or access codes. Such transmissions can be decoding using this resource.

Alarm Clock

The alarm clock mode is accessible from the wireless personality front panels. The user can engage a number of features including:

- alarm at a given time
- total length of present session
- awake and sleep times for audio output

Amateur & Spectrum Allocation Charts

In order to enhance user accessibility to wireless communications, built-in graphical displays of the amateur frequency band assignments and general spectrum allocation assignments can be engaged from any of the wireless personalities. In the case of the amateur band assignments, clear demarkation of Technician, General, Advanced, etc. operating priveledges are clearly shown. In the case of general spectrum allocation, FCC mandated usage for all frequencies receivable by the present embodiment are clearly delineated graphically. This on-line reference helps in identifying and finding stations quickly.

Voice Prompts

The present embodiment includes hardware capabilities for line and microphone inputs. Using trained voice recognition signal processing, future embodiments will make it possible to direct many of the wireless resources verbally. Similarly, directions to the user will be given over the external speaker to facillitate on-line instruction, questions, or assistance.

The baseband audio features which have been included within this embodiment make it possible for the DSP to perform the processing needed to support the wireless resource as well as additional sound card like capabilities. Future embodiments will expand upon this role and make it possible for the DSP board to completely support sound card and wireless resource functionality.

Radio Audio in Background

The architecture adopted for this embodiment makes it possible for the received signal audio to be output even though the user has left the wireless resource window application. The alarm clock feature can be used to automatically disengage or engage this audio output at any future time. This is possible because minimal support is required from the PC when the user is not interactively involved with the wireless application.

Signal Identification & Classification

With so many signals receivable by even modest equipment, aside from traditional AM, SSB, etc. type signals which are analog in nature, identification of unknown digital-type signals is normally very difficult. The present embodiment addresses the signal identification task in two ways.

First, the integrated database can be consulted for stations which appear at the same observed time and frequency as the subject signal. This is only most effective if the database is kept current.

Signal classification and potential identification can also be done in the present embodiment using a number of digital signal processing means which are provided. As supported throughout most of the present embodiment, these reports are provided to the user in a heavily visual manner. Computational options include the following graphically presented results:

- instantaneous signal frequency versus time, linear & cyclical
- instantaneous signal amplitude versus time, linear & cyclical
- instantaneous signal phase versus time, linear & cyclical
- instantaneous signal amplitude versus instantaneous frequency
- power spectral density
- histogram of instantaneous signal frequency
- histogram of instantaneous signal amplitude
- histogram of instantaneous signal phase

Additional features for specific identification of modulation type, baud rate, etc. will be either be kept as internal trade secrets, or will be disclosed as additional related patents at a later date.

Sample Sound

Many different kinds of signals can be heard over the air waves. Although the Signal Identification and Classification methods can be used to help sort out signal types, a properly trained human ear can often times identify many signals which are present particularly over shortwave frequencies. The Sample Sound resource is dedicated to this purpose.

Most people have an idea what Morse Code sounds like but would probably be completely unable to differentiate certain forms of RTTY from say WEAFAX. By clicking on appropriate signal icons, this mode computes representative signal samples for a specified signal just as if the samples were to be transmitted and sends them out over the external speaker for listening. With a little practice, a user can train themselves to reliably recognize many signals which are receivable.

At least one existing shortwave product provides a floppy disk of pre-recorded signal sounds for this purpose. The present embodiment expands this training to more signal types, and rather than consume disk space for signal samples, computes them in real time mathematically. This step is in part a prelude to including complete transmit capabilities within an extension of the present embodiment.

Map

The world and regional mapping functions available in this embodiment are perhaps the some of the most attractive features of this entire invention. Aside from being linked to the exhaustive information database, the map modes allow a user to dynamically tune the radio to a desired signal at a glance.

Take for instance a user who wants to tune in a shortwave station near Bosnia at 4:00 pm on a Tuesday afternoon but has no idea what frequency to tune to or whether propagation conditions are even desirable. By engaging the world map resource, the user first identifies their listening preference in terms such as language (e.g., English), program type (e.g., news), and geographical area. This information is used to prescreen the complete station and frequency database for stations which meet the user's search specifications. Stations meeting the search requirements are segregated into a separate list box area and each potential signal is examined by the DSP and radio electronics for signal presence and strength. Signal polling is done very rapidly on the order of 100 stations per second. Once the polling operation has been completed, icons representing each station meeting the user's requirements are overlaid over the world map at their appropriate geographical locations using colors corresponding to the measured signal strength observed. The user can then engage any particular station with a simple click of the computer mouse. This operation is termed "tuning at a glance."

If the user clicks on a station icon which has a particularly weak signal strength, the maximum usable frequency (MUF) and lowest usable frequency (LUF) for that station are computed for the next 24 hours and displayed graphically for the user. These graphics permit the user to determine what time of day is better for reception of this specific station.

In frequency scanning mode like that commonly done at VHF, a different map mode can be employed if the corresponding regional map data is available. Icons representing each station to be scanned can be entered into a local regional map and the corresponding icon highlighted whenever a signal presence is detected. In the same manner as with shortwave listening, the user knows by way of a simple glance of the computer monitor which scanning channel has captured the scanning receiver.

1.3 Reprogrammable Wireless Resource

Aside from basic receive (or transmit) signal filtering, amplification, and frequency translation, almost all of the traditional radio functions such as demodulation, highly selective filtering, audio tone control, etc. are performed within the DSP as described in part above. As such, virtually every aspect of the radio resource is reconfigurable within certain constraints. This makes it possible for one piece of hardware to cover a myriad of communication services.

When viewed as a programmable wireless resource, the present embodiment can be easily expanded and modified to provide a very wide range of communication services including local area networking, etc. to the PC user.

The processing limitations primarily pertain to (i) the range of receive carrier frequencies delivered, (ii) the RF bandwidth of the signal involved, and (iii) the degree of post demodulation signal processing required. In the present embodiment, the range of carrier frequencies supported span 0.5 to 30 MHz and 108 to 174 MHz with additional ranges planned for inclusion in the future. As discussed later in the hardware discussion, the present embodiment includes cascadable features to support an add-on receiver unit within the same radio chassis as well as an external IF input (at 45 MHz). The RF bandwidth of the received signal is important in that it dictates the minimum signal processing quantization rate necessary per the Nyquist sampling theorem. As the sampling frequency is increased, DSP computing resources eventually become exhausted. Finally, without dedicated post demodulation hardware present, DSP resources can become constrained with more advanced multi-layer communication waveforms and protocols. As digital signal processing hardware increases in speed and density, the limitation in principle should become less and less. It is also possible to foresee situations where the information is burst to a would be user and the received signal samples are processed in a nonreal time sense given the limited computational resources available.

In simple spread-spectrum applications, the primary quantity of interest is the bandwidth of the de-spread information bearing signal. In situations where the de-spread signal bandwidth can still be accomodated within the radio and DSP electronics, these same concepts can apply.

1.4 Frequency Accuracy

Frequency accuracy for the radio resource is accomplished by two means. First of all, the unit contains an oven-controlled crystal oscillator (OCXO) in order to make the performance largely independent of ambient temperature. Over time and circumstances however, the accuracy of this standard will degrade. In order to circumvent this problem, this embodiment provides a venier adjustment of the OCXO frequency by the DSP. Using this venier adjustment and appropriate automatic frequency control (AFC) signal processing, the DSP is able to keep the worst case frequency error of the resource to less than 1 part per million (ppm) even years later. This frequency calibration can be done with any known station which is precisely known and resident in the system database.

1.5 Time Keeping Accuracy

The embodiment also allows precise local time keeping by using shortwave stations such as WWV in Fort Collins, CO. When directed by the user, the PC internal clock can be automatically set to within an accuracy of approximately 50 milliseconds[3] by the DSP as well. In principle, the time accuracy achievable by this means could be extended further to calibrate additional computer peripherals such as networks or other ancillary equipment.

1.6 Self-Test and Built-in Diagnostics

The embodiment also contains built-in self-test diagnostics in order to streamline trouble shooting independently by a user or to assist in identifying a problem with additional factory support. These diagnostics can be engaged by the user with proper computer mouse entries and entry point key codes provided by the manufacturer. Later versions may well include additional software features which would permit factory personel to remotely assess hardware and software problems using standard wireline telephone modems.

With the proper key codes, additional diagnostics can be engaged as well. In order to bar subsequent unauthorized access by the user at a later date, the key code, DSP hardware key, and internal computer calendar date are all used to determine whether access is granted. These additional diagnostics include the following:

- All of the internal DSP operational parameters can be viewed and modified.

[3] Precision only limited by the minimum time increment allowed by Microsoft Windows®. Later software will no doubt allow this precision to be improved.

- Intermediate DSP processing results from all of the key algorithm areas can be viewed much like an oscilloscope on the user's monitor.
- Known receiver birdies (false receive signals) can be measured and reported for further insight.

1.7 Database

One of the primary reasons for hosting a wireless resource on the PC is to make use of the extensive data storage and manipulation features of the PC. This embodiment is unique in that the PC computational resources are primarily reserved for supporting the user both from an interface perspective as well as an information perspective. Traditional radio type functions such as demodulation or automatic gain control (AGC) are strictly performed by the DSP only. One of the cornerstone elements of this embodiment is the multi-dimensional database which is shown conceptually in Figure 4.

The fully integrated database engine used in this embodiment is a resource which is available from any radio personality as shown in Figure 1. The database engine used in this present configuration is ___________________. The database engine is only a portion of the actual database computational resources available through the PC to each radio personality as shown in Figure 4.

Multiple data bases and resources are linked as shown in Figure 4 in order to tie program material information, user queries, user preference lists, ongoing update support, and additional computational elements together. Key to shortwave listening in the HF band and to a lesser extent other frequencies, world and regional maps are used to easily orchestrate the interplay between database information, computations, and the user thereby providing truly visual (map oriented) tuning.

Database materials for the program schedule materials, user profile and preference materials, and map materials are all dynamic in nature. Each may be updated on a continual basis by a number of means. First of all, the manufacturer may offer a paid subscription arrangement where periodically the user is sent a floppy disk with all updates to all database materials. Validation of a subscription is done by using an embedded hardware key resident on the DSP board. For more immediate updates, the user may choose to subscribe to an on-line bulletin board service where updates could be received over a standard wireline modem, the subscription again validated using the embedded hardware key. Finally, all database materials including pertinent map features can be modified manually by the user at any time. The user’s previous database updates are done in such a way that they are preserved if so directed.

One of the resources available in the embodiment is the signal classification and identification resource shown in Figure 1. This resource can be used to automatically scan specified frequency bands for signal activity, and when encountered, log each observance in terms of key signal parameters such as modulation type, signal strength, baud rate (for digital communication types only), transmission duration, occuppied bandwidth, etc. in a computer file. This material can then be further post-processed to provide additional database information as directed by the user.

The database, radio, and DSP resources are linked together in a number of ways. This is particularly true of the visual tuning mode of the embodiment. While in this visual tuning mode, the user may enter or select a previous user preference profile which when used in conjunction with the database materials, pre-screens database entries for the user. Only database entries which pass this pre-screening are qualified for further processing. The DSP and radio resources then working together automatically measure the signal strength of all candidate stations at a rate on the order of 100 channels per second. Signal quality is visually reported to the user by using multi-colored station icons on the world or regional maps. This same information is channeled to text-based list boxes for more in depth examination also. A very strong signal would be indicated by perhaps a choice of hot red whereas an unreceivable signal would be indicated by leaving the icon gray. Any specific station could then be selected by the user by clicking the computer mouse on a specific station icon. The color-coded icon approach allows a user to quickly assess worldwide radio propagation conditions at a single glance. If the user clicks the mouse on a very weak station icon, the utilities for calculation of the maximum usable frequency (MUF) and lowest usable frequency (LUF) are called upon automatically in order to predict what time the station will be most ledgible over the next 24 hour period.

For scanning operations, particularly at VHF frequencies, the database capabilities are used to store far more than just simple frequency information. Rather, the entire signal profile for each scanned station is stored and dynamically updated. Profile information includes the last signal strength measurement, demodulation parameters and bandwidths, scan priority, dwell time, station frequency, simplex/duplex operations and frequency split, time since last squelch break, and other parameters. In cases where regional or metropolitan map information is available for the database, the real-time channel dwell activity can again be displayed in the map mode with the active scanner channel being denoted by an appropriately colored icon. Manual tuning by visual means through the map interface is again possible when desired.

1.8 Overview of Other Personalities

The wireless personalities represented in this present embodiment are shown across the top portion of Figure 1. Since it is fully anticipated that future embodiments will include additional personalities, only a subset of those presently identified will be discussed further. In general, all of the personalities draw upon the DSP and PC resources as described earlier.

Standard AM

The Standard AM wireless personality is an extremely simple standard broadcast personality which is void of all but the most basic of features. This personality would normally be employed for casual local reception. The database includes listings for every FCC licensed AM broadcaster in the United States. Station frequency, city location, and transmit power level are standard entries in the database.

DX AM Broadcast

On occasion, it is may be desirable to listen to standard broadcast systems which are not local and therefore have weak signal strengths. This personality addresses this mode of operation.

Audio tone controls, receive bandwidth, and demodulator choices to name but a few resources are available for the user in this personality. Expanding beyond the Standard AM personality, a regional map of the United States can be engaged as well. This feature can be very helpful in identifying weak stations particularly in the evening when combined with other database information.

World Radio

The World Radio personality is equivalent to the Standard AM personality except that its use is targeted toward international shortwave listening. Once again, advanced processing features are abandoned in favor of tuning the radio frequency using a map of the world. The front panel view of the wireless personality is shown here in Figure 5.

Amateur Radio

The Amateur Radio wireless personality includes most of the signal processing features included in the Communications Radio personality, but frequency tuning is restricted to the U.S. amateur radio bands. Other customization is automatically invoked particularly in the database area using this personality.

Communications Radio

The top-level control panel for this wireless personality is shown in Figure 6. As described earlier, extensive control over many radio resource functions is available. Station database information is readily available by selecting the 'Select Station' option and extensive database manipulation features are available as shown in Figure 7.

Using this personality, it is possible for instance to tune in a Morse code station. The automatic Morse Code Translator service resource may be engaged by using the pulldown menu under the 'Decode' option as shown in Figure 8. Additional resources can be selected by using other pulldown menus as shown in Figure 9 such as the world map shown in Figure 10.

VHF Radio

The VHF Radio personality emulates the performance of a state-of-the-art VHF scanning receiver but with additional processing features. The basic front panel for this wireless personality is shown in Figure 11 and with the Morse Code Translator resource engaged in Figure 12. Powerful scanning functions which make use of multiple databases can be engaged from this personality.

Time Standard

The Time Standard wireless personality is novel to this embodiment because it allows precision time and frequency to be imparted directly to the host PC. Using the digital coding present on the WWV time standard from Fort Collins, CO, the PC's internal clock can be set automatically to within an accuracy of approximately 50 milliseconds (which is only limited by Microsoft Windows). At the same time, the carrier signal from WWV is processed in order to precisely adjust the internal OCXO 10.1 MHz frequency standard to within less than ±1 part per million accuracy.

Wideband Spectrum Analyzer

The Wideband Spectrum Analyzer personality is actually a subset of the Signal Identification and Classification resource mentioned earlier. This personality permits a specified frequency range to be repetitively swept with the observed signal activity displayed graphically much as done with a laboratory spectrum analyzer. Variable sweep rates, maximum hold, and other commonly encountered features are provided.

2.0 Hardware Design

The hardware design of the present embodiment utilizes a number of important novel features. Each of these is identified in some detail below. A block diagram overview of the RF electronics portion for the present embodiment is shown in Figure 13 with a similar high-level perspective of the DSP resource shown in Figure 14.

All power for the external radio unit is derived directly from the internal voltage sources within the PC. This results in a cost savings in that no additional power supply is required.

The means by which the received signal is transported to the DSP is particularly important. Rather than send a baseband I and a baseband Q signal to the DSP and incure signal contamination problems as well as requiring two analog to digital converters (ADC), the present embodiment transports a signal at IF (450 kHz here). Bandpass sampling techniques are then used which only require a single ADC rather than two, and gain imbalances between I and Q and D.C. offset problems are completely avoided. The same single ADC which is shown in Figure 14 can be used for digitization of baseband audio signals as mentioned earlier thereby resulting in additional cost savings.

Due to the hardware independence of the radio and DSP, once an audio wireless personality has been engaged, the wireless resource can be run in the background with Microsoft Windows without requiring any further attention from the PC.

The DSP was purposely designed not to have on-board PROM for program storage. Rather, RAM is used to hold the DSP signal processing executable code which is downloaded to the DSP from the PC. Multiple versions of DSP executable code can then be downloaded as required to support arbitrary wireless personalities.

An additional cost savings is realized in the boot PROM area of the DSP. Rather than have a dedicated boot PROM or RAM area, the present embodiment uses the boot RAM area of the DSP to perform a dual function. The first function is to serve as a boot memory area for the DSP. The second function is to provide an dual-port RAM capability for communication of large amounts of data between the PC and DSP. This dual-port RAM area makes it possible for the PC and DSP to exchange large amounts of data without dropping signal samples during real time signal processing activities. This hardware is labled Boot RAM in Figure 14.

In the external radio electronics area, cost and internal EMI considerations made the frequency synthesizer area in Figure 13 critical in this embodiment. The approach adopted makes use of a single loop fractional-N synthesizer architecture which utilizes a reference frequency no less than 100 kHz while realizing fractional parts as small as 1/256. The remaining frequency precision is obtained algorithmically through the DSP. By virtue of the fractional-N peculiarities as well as the need for gain compensation within the phase-locked loop, choice of synthesizer synthesis parameters is not always straight forward. In the present embodiment, each signal frequency which is to be tuned is passed to a subordinate PC program subroutine which computes preferred values for all of the synthesis parameters. This preferential approach purposely avoids parameter choices which would result in less than ideal phase noise performance or undesirably high fractional-N spurious outputs.

An external control signal is provided from the DSP card for controlling external tape recording functions. Under user direction, or delay taping directives programmed by the user, an external tape recorder can be turned on and off as desired to record user specified programs. These functions can be performed without requiring intervention from the Windows platform.

An external IF input is provided as shown in Figure 13 to support subsequent expansion of the present embodiment to extended frequency ranges. As mentioned earlier, the serial control interface from the DSP is similarly configured to allow daisy chaining of multiple external radio units for expanded support.

Although the present embodiment is specifically designed for narrowband signals, limited extension of the present architecture to certain forms of spread-spectrum is possible by the inclusion of a despreading code function on the first local oscillator signal as shown in Figure 15. In this manner, the wideband signal spectrum is collapsed prior to the very selective narrowband filtering functions of the otherwise narrowband radio. Location of the despreading mixer in the local oscillator chain is particularly advantageous because any losses incurred here to not degrade the overall noise figure of the receiver. As shown here, a dedicated digital device supplies the despreading code under the supervision of the DSP resource. This technique will permit limited forms of spread-spectrum signals and narrowband signals to be accomodated within the same RF hardware. Although this will permit only single channel spread-spectrum signals to be received at a given time, the cost savings outweigh the degradation in performance for nonmobile applications.

2.0 Signal Processing

The extreme signal processing flexibility of the present embodiment makes it possible to receive many different signal types as alluded to earlier. Different DSP executable code files can be used as required to service different processing needs. A representative block diagram of this type of processing is shown in Figure 16 where the input signal sample stream is first converted to a parallel stream of I and Q samples for subsequent processing. Following some de-rotation of any residual frequency error by the complex rotator (Rotate 1), notch filtering and selective channel filtering can be performed. Completely arbitrary lineup of processing functions can of course be accomodated by this flexible approach.

3.0 Support for Multiple Communication Services

As introduced by way of Figure 1, multiple communication services will be supported in this embodiment with new services routinely added. As these services are brought on line, patent issues will be addressed at that time as necessary. At the present time, only the Morse Code Translator service will be identified for its novel features.

Automatic Morse Code Translator

Computerized decoding or Morse code (CW) is not new, but particularly features of the approach adopted in this embodiment are new. The new features include the following:

- dynamically updated graphical output of dot and dash length probability density functions, and spacing probability functions
- dynamically updated indication of decoder confidence
- user-adjustable output tone frequency independent of the received signal frequency
- slide-bar activated zoom-in on a given CW signal with automatic signal centering
- automatic frequency tracking of the CW signal
- Word Guess^{TM} mode which uses maximum likelihood probability computations to guess received characters which are known to be questionable
- automatic Q-signal abbreviation insertion into decoded text
- automatic abbreviation decoding into decoded text

Each of these will be discussed briefly following.

Graphical Output

In order to track the changing Morse code style of a human operator, statistics of the senders signal are continually gathered and updated. This alone is not new. In the present embodiment however, graphical outputs of these quantities are available to the user. If for instance the length of a signal's dots and dashes are always uniform, the plotted results would show heavy emphasis of the distribution near specific durations on the plot.

Decoder Confidence

Using the computed probability distribution functions in addition to other metrics such as signal strength, a measure of decoder confidence is displayed and continually updated. This display is particularly helpful with new users who are not familiar with Morse code in that it decreases the likelihood of trusting received non-CW signals.

Zoom-in Feature & Signal Tracking

Normally during the reception of CW signals, a user recognizes their presence using a fairly wide receive bandwidth, on the order of several kHz. In order to engage the automatic Morse Code Translator (for any known product or approach), it is necessary to reduce the receive bandwidth substantially. Normally, since the CW signal is not precisely centered in the receiver's bandwidth, the user must iterate between reducing the bandwidth and centering the signal which is a nuisance.

The zoom-in feature automatically centers a CW signal within the receive bandwidth such that no tuning adjustment is required by the user as they narrow the receiver's bandwidth.

Closely related to this zoom-in feature is automatic frequency tracking during actual Morse Code Translation. When using effective receive bandwidths as small as 10 Hz or less, precise frequency tracking is obviously mandatory.

Word Guess™

Word Guess is a novel extension to the automatic decoding process beyond the actual signal reception process. Once the dots and dashes have been received and identified, maximum a posteriori processing is used to further improve message accuracy. Since this processing is not directly observable by a user, the details will be kept as a trade secret.

The Word Guess mode is based upon maximizing the probability of each decoded message character given (i) statistics of the dots and dashes, (ii) signal strength, (iii) decoder confidence, and (iv) the hypothesized letter along with the letter(s) sent immediately previously. We will only focus on the last of these items in that these quantities are not involved except with Word Guess mode.

In the english language, the probability of a 't' being followed by an 'h' is fairly high whereas the probability of it being followed by a 'z' is very low. These kind of probabilities are called transition probabilities. Similarly, taking all the letters in this brief, the probability that any random character is an ’e’ is much higher than it being an ’x’. Finally, the probability that certain letters are the first or the last in english words is also quantifiable. These statements apply to any language as well as to different types of transmissions where perhaps many abbreviations are used for instance. Large english text files were used to compute the probability tables shown in Figures 17 and 18. In general, many such probability tables can be resident and used as directed by the user for different situations, languages, etc. The same type of feature can be used with any digital transmissions where forward error correction (FEC) is not employed.

Q–Signal and Abbreviation Decoding

Many abbreviations are used with Morse code in order to increase effective message throughput. A number of these abbreviations have been standardized, the Q–signals given in Figure 19 and the international CW abbreviations in Figure 20. The user can engage decoding features for these abbreviations by clicking on the appropriate button on the Morse Code Translater resource front panel. When engaged, the definition of an abbreviation or Q–signal will immediately follow the received text and will be shown in parenthesis and or color.

Other Services

Many services will be supported in this embodiment such as weather FAX (WEAFAX), radio teletype (RTTY) and its numerous forms, slow–scan television (SSTV), and many more. The details for support of these different services will be claimed as appropriate at a future date.

Identifiable Claim Items

The following is a fast run down of the areas where I see potential claims for this immediate patent application. The citations are brief here given that all of these areas have been discussed earlier in the text.

1. single A/D converter for audio as well as bandpass sampling of the 450 kHz IF signal from the radio

2. integrated software spectrum analyzer on the computer monitor; overlay of receiver filter and notch filter over display for easy manipulation of filters by user; use of spectrum analyzer for built-in diagnostics

3. organization around personalities with pooled common resources available to all

4. signal sound feature to allow users to familiarize themself with sound of WEAFAX, CW, and other signals

5. tuning at a glance with the map features

6. automatic signal centering during zoom-in with CW

7. adjustable Morse code audible frequency output

8. integrated, updatable, database purposely organized to warrant user subscription fees and services

9. software reconfigurable wireless resource(s)

10. icon signal strength indicator on maps

11. no physical knobs, buttons, etc. multimode radio

12. features to allow voice activated radio control

13. PC powered external radio hardware

14. ability to run radio hardware & software in background while performing other Windows tasks & programs

15. ability to add more personalities

16. geometric progression of receiver bandwidths available

17. multi-mode demodulator with multiple types of demodulators for the same signal type
18. double sideband AM with diversity demodulator mode

19. tone-tag Morse Code mode

20. automatic frequency control for AM and other signals having a carrier present

21. shortwave/VHF radio with DSP implemented audio tone controls

22. AGC radio loop closed through the DSP

23. digital DSP implementation of audio noise blanker

24. calibrated S-meter

25. ability to emulate sound-card functions with DSP as well as perform needed tasks as a wireless resource

26. integrated world and regional maps with database and radio resources; click on icon, signal strength with icon, MUF & LUF predictions, VHF scanning icons or highlighted entries in list box

27. external IF input and cascadable serial interface for expansion

28. accurate adjustment of OCXO frequency via database frequencies and received signals + processing

29. setting of internal PC clock via radio resource

30. diagnostics access by user using key code, hardware key, and calendar date

31. means for subscription update for users

(outline)

System

- use as a generalized communications node,flexible, multi-mode, etc.
- computer operated radio under Windows, visually oriented
- integrated DSP with radio/computer
- integrated station data base radio, dsp, computer query of data base info, post-processing of data base info, auto sniff of stations, visual map icon with signal quality
- preload of all radio settings for each station of a group of stations to be scanned by the DSP for VHF...more than just freq; ALC level, demod mode & bandwidth, squelch threshold, simplex/duplex freq pairing etc.
- freq calibration using WWV & others
- time calibration with WWV & setting computer time automatically
- partitioning to do all demods & radio functions in DSP for extreme flexibility...anticipatingmore and more powerful DSPs
- database maintenanace: by user, over modem, by floppy ; without loosing their changes; subscription, auto search & classification
- built-in diagnostics for radio using dsp (filter alignment, listening to birdies, etc.
- database with integrated MUF/LUF calculation
- use of key database stations to auto assess prop conditions
- remote radio portion to alleviate EMI issues; edge control on all digital signals; bursting of radio parameters over serial bus to minimize spectral content issues by spreading energy
- grounding philosophy of cable, box, antenna

- integrated world & regional maps with database, radio tuning, etc.

- availability of multiple resources to different personalities regardless of frequency...minimize user learning curve

- no physical knobs or switches

- download of complete DSP program; no code resident on dsp board, use of hardware key also (individualized)

- avoidance of interrupt-driven approach to avoid interoperability issues with interrupts as well as real-time processing issues in a windows environment

- **User Interface**
- Windows

- multi-personality

- potential voice activated,prompted

- visual display of signal classificaiton & identification patterns; extend to neural network/associative memory/wavelet techniques for signal classification

- spectrum with overlay of filter, notch, & real-time spectrum; size of FFT programmable by user to accomodate different pc computing power

- oscilloscope option, numeric display of filter bws & details

- user scenarios: use of map, use of database, use of spectrum analyzer, mixture, other ?

- permit user to select different screen background colors easily to prevent CRT EMI

Hardware Design
- power from PC

- final IF over cable for EMI, quadrature issues

- ability to run radio & other in background

- single A/D for IF and baseband processing

- dual-port ram for PC with multiple DSP, double as boot prom

- fractional-N with derotation in DSP

- use of computed synthesizer parameters along with DSP for best spurious performance of synthesizer (frac-N spurs & noise peaking)

- use of stereo plugs to support more I/Os from dsp card

- tone control via DSP to save cost of tone control chip
- auto engage of external tape recorder per timer, signal nature, or other criteria; also in background

- ability to switch out final IF filter to accomodate larger signal bws

- multi-use IF strip to accomodate add-on freq bands

- completely digital AGC with programmable parameters, coupled with ALC also and digital AGC;

Signal Processing
- use of multi-rate dsp techniques for filters, etc.

- multi-rate processing for morse code, rtty, sstv, fax, etc.

- signal identification and classification including baud rate, mark/space frequ, signal constellations, spectrum, correllogram, phase trajectories, transmit signal signatures, rms occupied bw, etc.

- use of IF samples rather than baseband or I/Q; pros & cons

- AM demod with recursive equation for square root business

- Tuning meter for AM to get exact center tuning; same for FM & morse code

- synchronous AM with AFC pull-in

- multiple FM demods cross-product, traditional discrim, curve-fit FM discrm, modified discrm, PLL,

- approach for USB/LSB without resorting to BPFs (use of rotators)

- use of rotators for notch filtering and shifting filters off center
- BFO implementation & baseband filter implementation for NB CW
- multi-bws using multi-rate processing with reusable FIRs; use of decimation approach, use of 0.4 rather than 0.5 on decimation routines
- blanking implementation
- dsp controlled AGC
- in depth discussion of dsp block diagram
- disabling digital AGC during freq synthesizer hop
- priority channel sniffing for VHF & other; priority level
- double sideband diversity for AM
- support for GMSK, other waveforms
- cascaded decimation and interpolation stages using same FIR coeffs
- cascaded rotators & filters approach; avoidance of cross complex filter terms..only need I and Q paths
- philosophy of digital AGC maintaining same signal power through decimation
- internal signal probe points within DSP algorithm architecture
- calibrated S-meter
- background check for radio frequency accuracy for exactly known stations (in database) by looking algorithmically at center frequency for AM, FM, and suppressed carrier modulations

Services

- FCC frequency chart on line for easy referal, also amateur band chart
- WWV and other stations for freq accuracy, computer time; use of computer to set other clocks, even wrist watches & networks

- MUF/LUF info
- ability to produce sounds of CW & other waveforms in real time for user (don’t use stored copies); prelude to transmitter mode
- Morse code: zoom-in with CW-TT & auto decode, auto variation of rx bw for CW, word quesser, abbreviaiton decode & insertion, etc.
- tone-tag CW; adjustment of tone-tag frequency for user
- automatic morse code reception: error rate, baud rate, center freq AFC, auto bw variation, pdfs for quality & visual display, decoder integrity, sender quality
- spectrum analyzer (wideband): binary search, under dsp control for blocks of freq.
- RTTY
- WWV
- WEAFAX
- FAX
- SSTV