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The Technological Pathway to the modern HF Amateur Radio Transceiver.

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Executive Summary

It is a little over 100 years since certain technological discoveries made it possible for individuals to pursue hobby interests in radio communications. The period commenced with an unregulated activity, the necessity of building one's own rudimentary equipment, self experimentation and development through to rigid licensing and controls, commercial manufacture and competition for spectrum space.

The majority of amateur equipment was once home made. This is no longer the case. The availability of specialised components is diminishing. Computer-aided manufacturing has resulted in parts that you can hardly see, let alone hand solder onto a circuit board. Commercially manufactured equipment is far smaller, probably more reliable, and certainly has far more operating conveniences than one could ever hope to emulate at home – if you could find a suitable design and then source the components. You will not be able to construct a full-fledged transceiver with anything like the performance, convenience and size of commercial equipment.

There is still scope for home construction of ancillary support and test equipment.

Anything is available, at a price and it is becoming more and more necessary to ensure that one receives value for money. If you are on a limited budget, like most of us, how should you go about making your spending choice? How much must you spend to ensure that your requirements will be met?

Amateur activities fall into two basic categories. There are those that are very serious and look for the utmost from their equipment and there are those that are far more casual and don't have either the time or the finances to extract the last degree of performance. It is a hobby after all.

The final choice comes down to which of the two categories cover your interests and then, your budget limitations.

If you are casual operator and your decision is not restricted by budget, purchase whatever you can afford and try to get the best-perceived value for the price.

If you are a serious contester, research the important specifications for your particular area of interest. An older transceiver may have superior performance for your budget. If your budget is not a limiting factor, be prepared to pay at least $AUD9,000.00 if you are going to purchase a modern, amateur band only transceiver.

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Introduction

The advance of electronic and communication technologies has had a large impact on amateur radio operators since the inception of their worldwide activity in the early 20th Century. Each time a new technology, or a significant advance on an existing one, occurs, the amateur is faced with a decision. This decision is to either embrace the technological advance and all its perceived benefits, or to ignore or reject it. Eventually, those who have not taken the embracing step fall behind and find it increasingly difficult to maintain their status quo by the inability to source replacement components for their eventually outdated equipment.

The decision to embrace, or otherwise, is often influenced by, on the one hand, a reluctance to venture into the unknown and on the other, an opportunity to learn about and use something new.

Like all technologies and inventions, each has existed in its own space in time by the existence of earlier inventions and technologies. The modern computer, as an example, could not exist without the prior existence of the semi-conductor and digital technologies assisted by the myriad of prior technological discoveries that made them possible.

The modern amateur transceiver with digital signal processing, digital memories, computer interface and surface mount components is a vast departure from the equipment used by early amateur radio pioneers who were inspired by the efforts of Marconi, Tesla, Edison, Faraday, de Forest and many others. Until recently amateurs were known for their resourcefulness and ability to repair their own equipment. They were at the forefront of technology in many aspects. The situation has changed to where technology is advancing at a rate where individual amateurs can no longer keep up with it at the detailed level of the past. Except for those employed in the industry, their knowledge is on a more general level.

This report documents the impacting technologies that have evolved over the last century or so, culminating in the facilities and technology of the modern HF transceiver. It will end with a broad overview of whether modern state-of-the-art transceivers are really any better than their predecessors.

Background

Amateur Radio was a hobby offshoot of radio communications that resulted from a number of earlier inventions and discoveries.

There are many interesting publications and Internet web sites that contain historical accounts of relevant inventions and discoveries over many centuries of very little progress. The last century has turned this right around. Technological advances today are occurring at an astounding rate.

To set the stage for amateur radio and the modern HF transceiver, it is necessary to start somewhere and perhaps, other than starting with the creation of the universe, we should start with a discovery that would eventually play a much more important role than the curiosity it attracted at the time.

600BC The discovery of the ability of amber to produce static electricity and attract thin objects like feathers, leaves or fibres after being rubbed with wool or fur. The famous Greek philosopher Thales of Miletus called this special property "elektron" from which is derived the Latin word "electrocus" meaning "produce from amber by friction" and of course the modern word "electricity". (Lombry, Page 1)

1752 Benjamin Franklin flew a kite at Philadelphia during a thunderstorm to observe sparking from the kite’s wire. (WIA:15).

1782 Count A. Volta began developing the first “Voltaic” battery. (WIA:15).

1789 Dr. Von Sommering applied electrical current as a means of signaling. (WIA:15).

1819 H.C. Oersted and A.M Ampere conducted experiments with electro-magnetism. (WIA:15).

1820 Oersted established the connection between electric current flow and magnetic field. Parallel work by Ampere. (WIA:15).

1826 G.S. Ohm formulated Ohms Law. (WIA:15).

1831 Michael Faraday discovered electro-magnetic induction. Parallel work was done by J. Henry who also continued work on inductance. (WIA:15).

1832 Samuel Morse developed a system of ‘Morse’ code. K.F. Gauss and Professor Weber succeeded in developing two-wire electric telegraph. (WIA:15).

1835 Munk experimented with electro-magnetism. (WIA:15).

1837 ‘Morse’ code was patented. Wheatstone and Cooke patent a system of electrical telegraphy. (WIA:15).

1838 Morse code telegraphy transmitted over a 10 mile path of wire. C.A. Steinheil demonstrated first successful single-wire telegraph (earth return). (WIA:15).

1840 Morse introduced code and patented the ‘key’ to transmit and receive wire telegraphy. Joseph Henry first produced high frequency oscillations. (WIA:16).

1842 Henry magnetised needles from a distance of 200 feet. (WIA:16).

1855 D.E. Hughes patented a type printing telegraph machine. (WIA:16).

1864 J.C. Maxwell mathematically proved the existence of radio waves. (WIA:16).

1865 The International Telegraph Union (ITU) was founded in Paris by 20 nations. (WIA:16).

1866 C and S.A. Varley made observations on the conductivity of metallic powders. (WIA:16).

1867 Ruhmkorff perfected his induction coil. (WIA:16).

1868 Mahlon Loomis demonstrated wireless 'communication' showing that a kite sent aloft affected the flow of current in another kite connected to a galvanometer located 29 km away from the first kite. This discovery triggered the development of wireless telegraphy for long distance communications.

Loomis is also credited with:

The first formulation of the idea that 'waves' travel out from an antenna
The first use of a complete antenna and ground system
The first experimental transmission of wireless telegraph signals
The first use of balloons and kites to raise an antenna wire
The first vertical antenna (a wood tower supporting a steel rod)
The first patent for wireless telegraphy. (Lombry, Page 2)

Loomis had difficulty in getting backing for a lot of his research and development. An unnamed author (The Australasian Radio World, 1948, p11) provides 'an interesting tale of coincidences and circumstances'.

> But this kindly man was without adequate funds to develop fully the secret revealed to him by Nature. Loomis sought to interest people in his invention to acquire financial support. But imagine trying to convince people then that air could be a carrier for electrical impulses when such persons had been only recently converted, with difficulty, to the wired telegraph! People were incredulous and the inventor became the butt of ridicule and coarse humour.
>
> The sceptics had to be convinced. The patient, tireless dentist managed to scrape together enough money to conduct an experiment. In 1868 (or 1866) Loomis, in the presence of scientists and others, communicated between two mountain spurs in the Blue Ridges of West Virginia, eighteen miles apart. The operators of each party were provided with telescopes so that each could sight the others' station. Loomis produced electrical discharges when he touched hi kite wire to the ground, but had no means of detecting them except for the galvanometer at the far point that deflected to indicate a passage of current. He had sent out true waves and it was the first time that such signals had been transmitted over a distance without wires.

1873 J. May observed that sunlight shining on to selenium resistors varied the current flow in a circuit. (WIA:16).

1874 Alexander Graham Bell and T.A. Watson commenced experiments to transmit sounds electrically – succeeded in transmitting speech in 1875. (WIA:16).

1875 Edison claimed the discovery of "etheric force". (WIA:16).

1867 Ruhmkorff perfected his induction coil. (WIA:16).

1877 Edison invented the carbon microphone and the phonograph. (WIA:16).

1878 D.E. Hughes invented the microphonic detector. (WIA:16).

1879 Hughes demonstrated it was possible to transmit signals through space over several hundred yards. (WIA:17).

1883 Edison discovered the electron emission of a conductor filament heated at high temperature in a vacuum. This invention will later be at the root of the function of the electronic valve or tube. (Lombry, Page 2)

1888 Heinrich Hertz demonstrated electromagnetic waves across a room (thought to be about 450MHz) by conduction and a resonator – radiation as opposed to induction. (WIA:17).

1890 Professor Branley conducted observations on conductivity for emf and produced a kind of coherer (name given in 1984). (WIA:17).

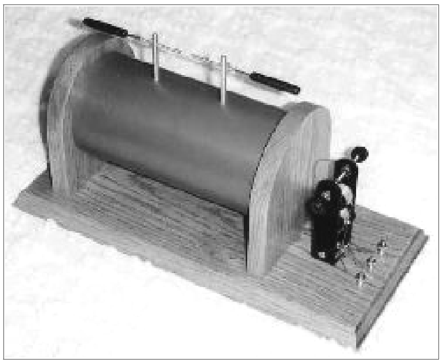
1895 Marconi transmitted Morse over a 1.5 mile radius with his 'Cymoscope'. (WIA:17).

1897 Marconi demonstrated wireless over an 8 mile path on Salisbury Plain, U.K. and over a 12 mile path between 2 Italian warships. (WIA:17).

1898 Marconi made improvements to coherer reception using an air-cored transformer he called a "jigger". (WIA:18).

Meade Dennis, successfully repeated Marconi's experiments and installed what is regarded as the first amateur experimental radio station at Woolwich Arsenal. (Lombry, Page 3).

Leslie Miller published the first description of what he called a simple-to-build transmitter and receiver for an amateur audience in *The Model Engineer and Amateur Electrician.* (Lombry, Page 3).



The simplest spark gap transmitter using a 25 cm (10") coil. The battery and the key are applied on brass contacts at right of the plate. The tuning coil and antenna are connected on top of the right electrode. The system is grounded via the left electrode. (Lombry, Page 3).

1899 US magazine *Scientific American* published a long article discussing Marconi's results and the July 1899 issue of *American Electrician* magazine gave details on the construction of Marconi's antenna and his wireless radio equipment. (Lombry, Page 3).

1901 Marconi's historic reception of a spark transmission of the letter "S" from Poldhu, Cornwall, England to St. John's, Newfoundland - a distance of 3360 km. This demonstration launched the commercial use of radio. (Lombry, Page 3).

1902 Marconi designed and patented the magnetic detector. (WIA:19).

1903 Fessenden recognized that continuous wave transmission was required for speech and continued the work of Nikola Tesla, John Stone, and Elihu Thomson. Fessenden felt he could also transmit and receive Morse code better by the continuous wave method than with a spark-apparatus as Marconi was using and started experimenting with high frequency alternators. (NMAH Archives Centre).

1904 Fleming developed the first vacuum diode using a cathode and an anode, known as the Fleming Valve and four years later he invented the tungsten filament. Two years later, Lee de Forest took Fleming's valve, added a third element, called the grid, and named the result (a triode), the Audion. It could amplify a signal 5 times. Its use by amateurs did not occur until 1912, following a discovery by Edwin H. Armstrong of the effects of applying feedback. (Lombry, Page 3).

1905 A "state of the art" spark gap transmitter operated on 400 metres (750 kHz) and generated a signal from about 250 metres (1.2 MHz) to 550 metres (545 KHz). The receiver consisted of simple unamplified detectors, generally coherers (small quantity of metal filings lying loosely between metallic electrodes). This later gave way to the famous and more sensitive galena crystal sets. Tuners were primitive or nonexistent. Although these wireless stations were terribly inefficient compared to modern standards, their transmitters were able to reach distances from as little as 180 m with a 12 mm coil to about 160 km using a 38 cm spark coil and a kilowatt station. Professional installations like ships at sea used transmitters up to 5 kW and reached distances up to 800 km, a record for the time. (Lombry, Page 3).

1906 Professors Pierce and Pickard investigated properties of quartz and Rochelle salt crystal detectors. (WIA:20).

General Dunwoody announced success of crystal detectors for radio waves. (WIA:20).

1908 The magazine *Modern Electrics* was the first magazine fully dedicated to wireless communication. Its circulation passed from 2000 to over 30,000 copies in just two years. At about the same time the first experimenters found the first radio handbook titled "Wireless Telegraph Construction for Amateurs" on bookstore shelves. (Lombry, Page 3).

1909 G.A. Taylor demonstrated that pictures could be sent by wireless (done successfully in 1910). (WIA:21).

1910 Formation of the first amateur organization – the Junior Wireless Club Ltd. Of New York (later became Radio Club of America). (WIA:21).

Amateur Radio had now been born and its popularity began to soar as many ordinary citizens and other enthusiasts, inventors and scientists began experimenting with radio communications. The early transmitters were spark generators with coherer detectors for receiving. The transceiver and modulation methods had not yet been invented.

The 20th Century settled in. Over the next 100 years, the developmental pace of new technology, fuelled by mass production, commercial interests and consumer entertainment goods, would see a multitude of inventions and discoveries that would take radio communications in directions that may never have been imagined by those early pioneers who paved the way for it.

Methodology

Research for this report will cover personal experience, amateur radio publications, electronics journals, manufacturer's brochures, user manuals, advertisements and the Internet.

Findings

In 1912, the International Telegraph Union's 2nd World Congress promulgated Radio Telegraph Convention Regulations. As a practical outcome, 'experimenters' (name changed to 'amateurs' after the Second World War) and other services listed, were restricted to '200 metres and down' (WIA:23). It was expected that these frequencies, 1.5MHz and higher, would be pretty safe and the amateurs would not be able to do a great deal with them.

The typical equipment for transmitting and receiving radio communications consisted of a spark transmitter and coherer-based receiver. The transceiver, which permits the dual use of some modules for transmitting and receiving and automatic transmit/receive switching, was not invented until many years later.

John Gazard, (Gazard:14) sums up the amateur technology level of the day as he writes:

> In its simplest form, the spark transmitter consisted of a spark coil with its spark gap in series with the aerial and earth, and the receiver had a crystal detector and headphones in series with the aerial and earth. This simple form depended on the length of the aerial to fix its frequency, but its signals covered a very wide band and had a range measured in yards rather than miles.
>
> An improved form of transmitter was used by most amateurs. It operated as follows. When the primary of the spark coil was interrupted, a current flowed in the secondary and the capacitor was charged up until the voltage was sufficient to cause a discharge across the spark gap. This spark discharge caused a spurt of current which set oscillating currents flowing at the resonant frequency of the circuit. These currents died away (were damped) until the next spark arrived when they recommenced. The resulting waveform was known as a damped wave.
>
> The spark transmitter was not efficient as regards output compared with input and its signals spread over a wide band. The crystal receiver was not sensitive and its selectivity was poor.

The inefficiency and frequency bandwidth of the spark transmitter and the insensitivity of the crystal receiver had to wait for feedback and amplification developments in order to improve them.

America has always had the largest population of amateurs and it is no real surprise to find that America features so prominently in past and ongoing development of this technology.

Impacting Technologies

1913 Lee de Forest, Langmuir, Hogan and Meissner introduced principles of self-oscillation and regenerative oscillation using the triode valve. (WIA:24).

Major Edwin H. Armstrong (also a US amateur) developed the regenerative circuit. (WIA:24).

Armstrong discovered that, when positive feedback was sufficiently increased, the circuit became an oscillator, and was able to transmit its own signal. Thus, in one master-stroke, a sensitive "regenerative" receiver and an effective electronic transmitter had been born. (Columbia University).

1914 Amateur stations closed down for the First World War. (WIA:24).

Langmuir granted a patent for a "hard" valve (used in First World War developments for voice-modulated radio waves. (WIA:24).

There were great improvements and developments during the war due to necessity.

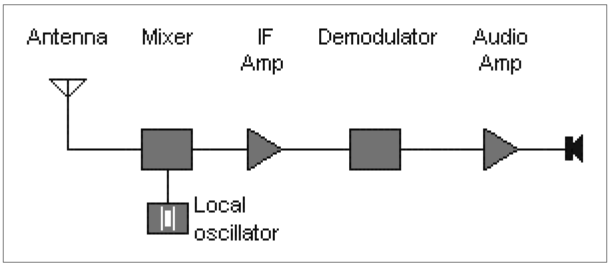
1916 General Electric Co. developed a tetrode valve by inserting a fourth element. (WIA:24).

By 1916, there were 5,000 licensed US amateur licenses, 1000 ARRL relay stations, and 150,000 receivers in use. In the UK there were nearly 2,000 licences and ten times less or even a handful in the other European countries. (Lombry, Page 5).

1918 Major Armstrong developed the superheterodyne receiver circuit. (WIA:24).

The superheterodyne (superhet) receiver incorporated a first local oscillator (VFO or Variable Frequency Oscillator) that enabled the conversion of the incoming frequency to a "more useable" lower or intermediate (IF) frequency where amplification or filtering can be provided. This permitted the receiver to operate over a range or band of frequencies. The technique mixed or beat the incoming frequency and the local oscillator frequency in a non-linear device to produce a third or difference signal that became the intermediate frequency. The superhet, as it is commonly termed, maintains a constant difference between the VFO frequency and the received frequency to provide a constant IF.

The process is still used today but with a few extra modules added. The non-linear device of the day was the vacuum tube but transistor, diode or integrated circuit mixers are used today. In a typical AM receiver, the IF is 455 kHz and 10.7 MHz is used for FM VHF receivers.



Basic superheterodyne block diagram. (Lombry, Page 5).

1920 Radio Corporation of America began producing two types of receiving valves. (WIA:26).

QST magazine included a short note in the Strays column about a simple, low-power oscillating crystal circuit designed by Greenleaf W. Pickard. (Pickard later noted that the basic idea dated back to work done by Dr. W. H. Eccles in 1910). (White, n.d).

1921 First transmitting valves – UV202, UV203 and UV204 – released on to the market but spark transmitters still eminent (made illegal in 1927). (WIA:27).

1922 Dr. W.G. Cady of Wesleyan University, USA, presented papers on the piezo-electric properties of quartz crystals. (WIA:24).

Edwin Armstrong invented the superregenerative receiver. This was a modified superheterodyne that improved the gain while simplifying the adjustment of the receiver. The "regen" as it was called was qualified as a receiver 'unsurpassed in comparable simplicity, weak signal reception, inherent noise limiting and AGC action and, freedom from overloading and spurious responses', nothing less. The "regen" radios made the most of very few components. However, as parts became easier to obtain, the "superhet" replaced it in all radio activities. The superheterodyne receiver is the most common receiver in use today. (Lombry, Page 6).

Hugo Gernsback (White, n.d) announced 'A Sensational Radio Invention' in *Radio News*, proclaiming that Russian O. V. Lossev's work on oscillating crystal circuits meant that "The crystal now actually replaces the vacuum tube". Gernsback predicted that, although development was admittedly still in the experimental stages, within three-to-five years receivers using oscillating crystals in place of tubes would go on sale to the general public.

However, it turned out that for the next few decades radio enthusiasts would have to make do with incremental improvements in vacuum tube design -- tubes that required less current, lasted longer, and could run on household electrical current instead of storage batteries. It was only when a deeper knowledge of solid state physics made it possible to refine oscillating crystals into much more practical and reliable "transfer resistors" (transistors) that, beginning in the mid-1950s, the lightweight radios running on flashlight batteries envisioned by Gernsback finally became available to the general public. (White, n.d).

1926 Quartz crystals were first introduced in USA. By 1935, they had largely replaced self-excited oscillators. (Gazard, 1985:15).

This development enabled greater and more precise control of frequency. Non crystal-based oscillators tend to drift in frequency due to temperature changes.

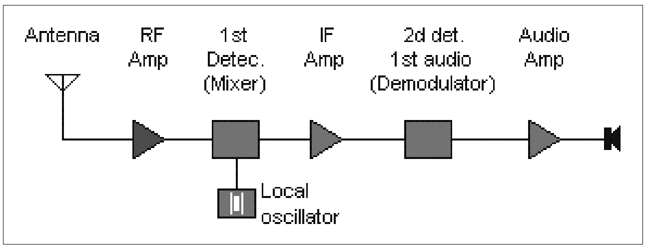
1927 An International Radio Telegraph Conference, the 'first since the value of the higher frequencies were discovered', fixed and considerably narrowed amateur frequency bands. (Gazard, 1985:15).

1933 During the 1930's, the superhet was the most predominant circuit. The spark gap transmitter had been banned due to its wide bandwidth requirement.

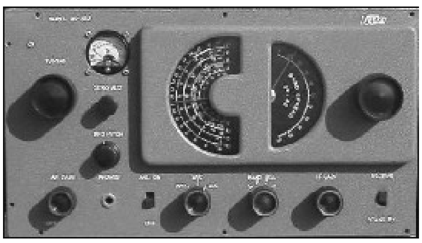
Princeton University commenced experiments with quantum theory and semiconductors. (Lombry, Page 7).

R/9 magazine published a three-part article entitled "S*ingle Sideband Transmission for Amateur Radiophones*" written by Robert M. Moore, W6DEI. It reported an experiment using "single-side-band, suppressing carrier" mode, SSSC. However SSB (single sideband) as it will be called, had to wait until 1947. (Lombry, Page 7).

1935 Edwin Armstrong presents a paper entitled "*A Method of Reducing Disturbances in Radio Signaling by a System of Frequency Modulation*". It was the first description of the future FM radio. It preceeded the discovery made by the New York Institute of Radio Engineers, IRE, who became the IEEE in 1963.



By the late 1930s, Armstrong's superheterodyne receiver invented in 1918 was soon equipped with an RF stage. It was a major improvement. The goal of the first stage is to provide front-end amplification in the signal path to the audio. The RF stage tunes the signal picked up by the antenna, amplifies it, and passes it on to the converter stage (mixer). (Lombry, Page 7).



The Hallicrafters S-38 receiver manufactured in 1946. It was priced at only $US47.50, an affordable entry-level product for the listeners. (Lombry, Page 9).

1945 Amateur radio was closed down again for World War 2. The end of the war saw its return and there were new frequency band allocations, including VHF and UHF, and new modes of operation. War surplus equipment became readily available and this was scooped up for modification and spare parts by the amateurs of the day.

1947 Oswald Villard, W6QYT, and a group of student hams at Stanford University start experiments with SSB, the famous challenging technology that was a big flop in 1933-34. The Technical editor of *QST*, George Grammer, W1DF, wrote about SSB, '*It may not be too much of an exaggeration to say that our present-day phone methods will be just as obsolete, a few years from now, as spark was a few years after c.w. got its start. Old-fashioned phone will eventually be something that can be tolerated only where there is plenty of room for it'*. (Lombry, Page 9). This time the market was ready as there were plenty of valves around to support the new technology.

1948 *QST* magazine reviewed the development of the transistor by Bell Laboratories, which included the construction of a simple superheterodyne receiver, noting that 'These clever little devices are well worth keeping an eye on.' (White, d.d).

An article in The Australasian Radio World, February 1948, raises concern at the crowding of radio frequency bands as broadcasting services, commercial, government and amateur interests compete for spectrum space. Intensive competition existed between narrow bandwidth telegraphy (code) and wider bandwidth telephony (voice). This also existed in the maritime mobile service.

It was suggested that '*if the communication services do not watch out, some fine day the broadcasters will possess the spectrum, and the art born of Marconi and Popoff and nurtured by generations of communicators everywhere will disappear from the earth and turn over its frequencies to syrupy voices selling coffee, purgatives and national ideologies'*.

This problem, *'the problem of finding more and more frequencies for more stations, has been growing for at least 20 years'*.

1950 Bell Labs develop the first transistor. (Lombry, Page 10).

1951 The junction transistor is invented. (Lombry, Page 10).

A significant development in frequency stability took place in the 1950's – see **Appendix** 1. Chris Arthur (The Wadley Loop Receivers, n.d.) outlines the development:

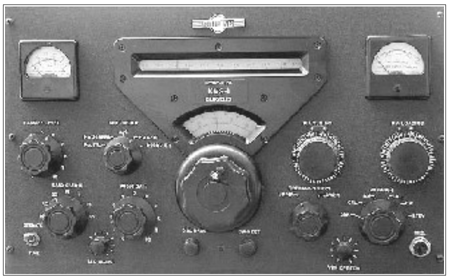
> A problem that was faced by the designers and constructors of early communications receivers was that of maintaining frequency stability. Prior to WW2 achieving this aim required precision tuned circuits contained in large metal enclosures, this helped in minimising drift effects but it was difficult to maintain over several octaves. The advent of crystal controlled oscillators provided constructors with a far better frequency stable source and when used with a heterodyne oscillator could maintain high stability over a small tuning range of not more than 500 to 1000 KHz. Obviously one would need 27 crystals to cover the entire HF band (3 - 30 MHz), so we see how the need for frequency synthesis using only one or two crystals arose.
>
> The Phase Locked loop is by no means a recent addition to Radio Receivers and Transceivers. Such a system has been in use for over 30 years now but during the 60's and early 70's the cost of implementing such complexity into a receiver or transceiver would only see specialist use such as military or high end commercial applications. Since the advent of Large Scale Integration (LSI) Integrated Circuits in the later part of the 1970's, both cost and complexity has reduced to the point were PLL controlled receivers are now common place. A system that put high performance frequency control into the reach of the Amateur and SWL'er before LSI was the Wadley Loop.

During WW2, while working on a wavemeter project a "Dr Trevor Wadley" developed a unique circuit for cancelling frequency drift, a circuit later to be known as the Wadley Loop. The first well known implementation of Wadley's Loop was during the 1950's in the development of the Racal RA-17, as shown above. The RA-17 and later RA-117 where quite unique receivers, gaining extensive use by the British military from the late 1950's and through the 60's, in fact the 117 made it into the early 70's.

The RACAL RA-17 based on the Wadley Loop, drift cancelling circuit developed by Dr. Trevor Wadley.

The future development of the Phase-Locked Loop and other digital techniques eventually surpassed the effectiveness of the Wadley Loop.

1954 First transistor radio sold by Texas Instruments. (Lombry, Page 10).



One of the first SSB transceivers (Collins KWS-1) released in 1955. (Lombry, Page 10).

The first transistor based computer emerges (Lombry, Page 10):

Engineers at Bell Labs built the first computer using no vacuum tubes (valves), the TRADIC (standing for TRAnsistorized DIgital Computer). For the public this electronic machine looked like a magic box of about a cubic meter (three cubic feet), more than 300 times smaller than the famous vacuum tube computer ENIAC!

TRADIC contained approximately 800 point-contact transistors and 10,000 germanium crystal rectifiers where ENIAC used 18000 vacuum tubes! TRADIC could perform a million operations per second, quasi as fast as the vacuum tube computer to date, and last but not least it operated on less than 100 watts of power. Only drawback a transistor was 20 times more expensive than a tube, $20 vs. $1. But in respect to the Moore Law saying that the price of electronic components decreases by half each 2 years, if not faster, it was expected that the price of the next computer should decrease. It was only a question of time. In any case, micro-computing was in sight.

1958 First integrated circuit made by R.Noyce from Fairchild Semiconductor. (Lombry, Page 10).

During the "transistor" years, most amateurs continued to work with vacuum tubes, oscillating detectors, and AM transceivers. SSB and the first transistorised transceivers (1952) were rising at the horizon but were not yet in fashion. (Lombry, Page 10).

1960 SSB becomes the predominant HF operating mode. Transistors were finally being designed into most HF and V/UHF ham equipment. Among the first SSB transceivers were the Heathkit SB-100 and the Collins S-line. Within two years, if you still worked with an AM receiver, you would have noticed that amateurs were gradually becoming ‘invisible’ on shortwaves. You heard some unreadable noises on the bands but nothing intelligible. In fact most amateurs moved to either LSB or USB mode. (Lombry, 11).

Hugh (Hughs Ominous Valve Works (n.d)) creates a snapshot of the state-of-the-art as it existed in the 1960's:

> After World War II, HF voice radio started out pretty much with pre-war AM technology, but soon began the slow conversion to the far more efficient SSB. It's true that hams invented sideband, but not that they perfected it. The phone company was using it in the 1930s. The ARRL pushed hard for its adoption after the war, but the real impetus for conversion came when General Curtis "Iron Ass" LeMay got the U.S. Air Force to adopt sideband for all of its HF communications. After this, it was only a matter of time for hams, and just about everyone else on HF. AM didn't die out completely, and it remains a fine ragchewing mode and a viable hobby within a hobby, but for most hams the quack-quack sound became far more prevalent.
>
> SSB required some circuit changes in receivers, but nothing fundamental. The BFO had to be refined, filter passbands had to be adjusted, AVC had to be tweaked, and ultimately product detectors replaced simple diodes. Stability, both mechanical and electrical, needed a magnitude of improvement. The common solution was a multiple conversion/ fixed HFO/ narrow-range PTO/ high first IF/ low last IF design, as pioneered by Collins. The signal flow of the receiver remained essentially unchanged from the 1930s, as it still does in today's superheterodynes.
>
> Transmitters, however, needed a complete rethinking. For most hams, transmitters had always been more fun than receivers. They were simpler, and way easier to work on. Also, they tended to look like serious equipment, which they were. They could even kill you. Most transmitters were relatively simple oscillator/ multiplier/ driver/ PA chains, with class B modulators.
>
> However, SSB required considerably more complex designs, with filters or phase-shift networks to get rid of the carrier and unwanted sideband. Modulation took place at low level, early in the signal chain, and this modulated signal was heterodyned to the working frequency. PA's were set linear, instead of the more efficient class C. This design approach involved severe compromises to AM operation, and to a lesser extent CW, both of which are still way more fun on the 'boat anchors.' The ham radio became a complex mass of critically aligned circuits, best adjusted by trained techs. The average ham, even the technically aware one, couldn't just tweak a tx by ear anymore.
>
> Even so, the 60s began the gradual acceptance of small, self-contained transceivers, which could share a lot of the same mixer and filter circuits. Within a decade, these had replaced the roomfuls of equipment once associated with short wave radio. By the mid-70s, vacuum tubes remained a viable design approach only in the largest, external, linears, where they were a cheap, rugged alternative to high current, solid-state devices. Boat anchor linears, using heavy-duty components and commercial-grade output tubes, are very much with us today.

The E.F. Johnson Viking Ranger transmitter manufactured between 1954 and 1961. It operates between 160 and 10m, including the 11-meter band, with 75 W in CW and 65 W in AM. (Lombry, Page 11).

The Rhododendron Swamp VHF Society in Massachusetts succeeded in working Moonbounce (reflecting radio signals from the moon) on 1296 MHz. (Lombry, Page 11).

1961 A group of American amateurs built and launched the very first Amateur Radio satellite OSCAR 1, standing for Orbiting Satellite Carrying Amateur Radio, a term that is still used today to identify most Amateur Radio satellites. It was launched on December 12, barely four years after the launch of Russia's first Sputnik. A 140 mW, 144.983 MHz transmitter that discharged its non-rechargeable batteries after only three weeks of operation. It re-entered the earth's atmosphere on January 31, 1962 after 312 revolutions. It was followed six months later by the launch of OSCAR 2, using a design almost similar (Lombry, Page 11). More than 70 amateur satellites would be launched within the next four decades.

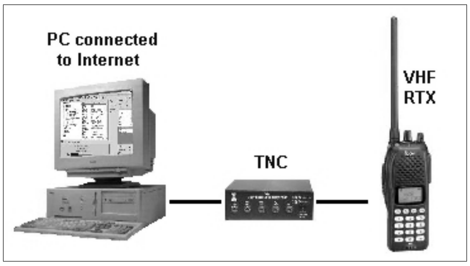
1968 SSTV (Slow Scan TV) was authorized by the FCC. This new digital mode permitted the amateur to transmit and receive still black and white or colour pictures. SSTV uses a bandwidth of 3 kHz on dedicated frequencies and quite specialized equipment (camera, modem, software, etc). Standard vidicons were developed the same year by WB8DQT and K7YZZ. (Lombry, Page 12).

1970 The first FM repeaters emerge. The 10m band is the only HF band in which FM is permitted and even so, the bandwidth is less than that permitted on VHF and UHF.

Japanese equipment continues penetration of the market. While Kenwood introduced its JR-500SE receiver and prepared the blue prints of its first transmitter (TS-120S in 1979), in less than 6 months Yaesu released two transceivers, the FTDX-560 and FT-101. In America, Drake released its Drake TR-4, Henry Radio introduced its Tempo-One transceiver and Heath announced the HW-100 and soon after the HW-101, two traditional tube-type SSB transceivers. (Lombry, Page 13).

The Drake TR-4C transceiver (Lombry, Page 13).

1978 Doug MacDonald Lockhart, VE7APU, adapted the concept of the packet mode of transmission to ham activities. Until then it had been used in computing networks. (Lombry, Page 13).



As displayed at left, you need a computer, a digital interface (Pakratt, Rigblaster, etc) and any HF or VHF transceiver. (Lombry, Page 13).

1980 The 1980's allowed amateurs to use digital modes on all frequencies. The Internet and home computers were gathering popularity and, with some amateurs at least, began to merge with amateur radio.

Peter Martinez, G3PLX, developed AMTOR (Amateur Teleprinting Over Radio). (Lombry, Page 14).

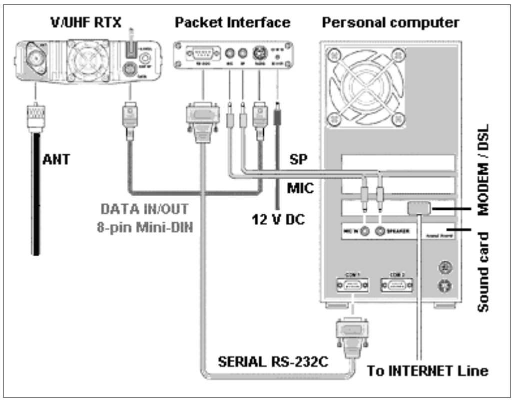
Amateur Radio research and Development Corporation (AMRAD), in collaboration with AMSAT (amateur satellite organization) organized the first amateur radio computer networking conference. At the same time the Tucson Amateur Packet Radio (TAPR) prepared the first terminal node controllers. It was followed by the development by the Vancouver Amateur Digital Communication Group (VADCG), of the first Terminal Node Controller (TNC), also known as the VADCG board. (Lombry, Page 14).

Packet radio provides a lot of different operating opportunities. In the '80s it was limited to a TNC linking a computer to a VHF transceiver, base or hand-held. Then it was interfaced to Bulletin Board Systems (BBS) so that amateurs could send and receive personal messages to and from their colleagues. (Lombry, Page 14).

1981 Not less than 8 amateur satellites were launched successfully. (Lombry, Page 14).

1990 Lombry (Lombry, Page 15) outlines DSP developments:

> In a time of computers, modems and digital transceivers, amateurs looked for a conversational communications means like RTTY, but somewhat upgraded and taking advantage of the latest digital technologies like DSP and FFT. The 1960 teleprinter for example could be replaced by the screen of a computer and the teletype interface with a modem or similar interface - and a HF transceiver. As transceivers were now more stable in frequency, the bandwidth could be much narrower. (Lombry, Page 15).
>
> In the beginning of '90s, the Polish amateur, Pawel Jalocha, SP9VRC, had already developed various DSP systems (noise suppressor, Q15X25, FSK interface for Fax, etc) and Peter Martinez, G3PLX who developed AMTOR, used these concepts to create PSK31, standing for "Phase Shift Keying, 31 bauds", a new digital mode more suited to the "computer assisted amateur". PSK31 kept some concepts of its ancestor, like the shifted keying of RTTY, now phase shifted instead of frequency shifted, the low speed, a very short transmission delay (400-800 ms), the lack of error-checking, and the mandatory keyboard interface. Its bandwidth dropped from approximately 120 kHz for RTTY to as narrow as 31.25 kHz in PSK31.



A typical packet installation - a dedicated 2m transceiver, the interface and a computer. (Lombry, Page 15).

> In addition to RTTY, AMTOR, PSK31 and Packet there is a plethora of other digital modes developed. OH2AQ, and his team, provide on their website what we call "spots information" displaying in real-time a summary of contacts established on various bands and modes.
>
> A cluster or node is a computer system connected to the Internet on one side and to radio receivers on the other side using VHF (2m) or UHF (70 cm) packet connections. In the field, these computers are connected to one or more dedicated transceivers, themselves connected to a TNC (e.g. Pakratt or Rigblaster), a sort of multimode modem able to process high tones if its bandwidth is large enough. The information is transmitted in small packets, hence its name (see '80s).
>
> Licensed hams that have heard or worked a station and who want to publish the information for the information of the ham community have first to contact a near cluster using the TNC connected to their 2m or 70cm transceiver or using their Internet connection to a dedicated website like OH2AQ.

1996 Digital Radio Mondiale, (DRM – digital transmission/reception over long wave, medium wave and shortwave bands) emerged from an informal meeting in Paris, France, between some of the large international broadcasters and broadcasting equipment manufacturers. This new mode did not become a reality until 2003. (Lombry, Page 16). RFI, noises and fading problems were expected to disappear with this development.

WinRADIO, an Australian company, released the first digital radio receiver, WR-G-303i. An HF interface card is installed in a PCI slot of your computer and includes a dual-conversion superheterodyne receiver with software-defined last IF stage and demodulator.

The WinRADIO digital radio interface as it appears on a computer monitor. (Lombry, Page 16).

Most if not all radio cards are now capable of receiving LW, MW and SW in most modes (AM, FM, USB, LSB, CW) and soon in DRM (Digital Radio Mondiale) mode, while the more sophisticated cards cover SHF frequencies up to 4 GHz. (Lombry, Page 16)

2002 Echolink, a computer program using the Voice-over-Internet Protocol, VoIP for short, to establish long-distance communications is developed by Jonathan Taylor, K1RFD. (Lombry, Page 18). This digital method uses the Internet as a means of conveying the radio signal around the world.

There has been a myriad of radio technology developments since it was discovered some 2,600 years ago that static electricity could be generated by rubbing amber with cloth. Initially, progress was slow and developments were few and far between. The last 100 years has seen technology advance at an ever-increasing rate to the point where it is now almost impossible to keep up with it.

Amateur radio commenced about 100 years ago as an unregulated hobby activity with a single equipment choice - a spark transmitter and a coherer. The development of the vacuum tube or valve and modulation techniques, as well as the regulation of the hobby, saw the spark transmitter and coherer consigned to the museum shelves in only a few years. This was the first case of the amateur having to update or retire from the hobby.

As the years passed, radio frequency bands became crowded with broadcasters, commercial, government and amateur stations as they all searched for a clear spot for their transmissions. Convenience and necessity drove the development of supporting technologies for modulation methods and equipment.

Valves started to give way to semiconductors in the 1950’s except for high power requirements. Semiconductor integrated circuits began to combine many transistors in miniature encapsulated, multiple pin building blocks and amateurs launched the first of many of their own satellites in the 1960’s. Digital electronics realised the digital frequency synthesiser, digital frequency displays, memories and scanning. Digital communication modes gathered popularity in the 1980’s and, with the advent of the personal computer and merging technologies, a computer or at least a microprocessor, has now become an integral part of all commercially manufactured amateur transceivers. Modern transceivers have in-built personal computer interfaces for digital mode support and DSP modules.

The connection between each end of a communication link has gone through many developments in just over a century. It started with a necessary piece of wire, then to radio waves and along the way branched off into intermediate links such as the moon (EME or earth-moon-earth), aircraft reflection, repeaters, satellites, and the Internet.

Amateur radio has gone from a period where most of the equipment had to be home made. Many amateurs were at the forefront of technology and some of them have even been credited with some of the documented discoveries. New technologies in the latter half of the 1900's, such as miniaturisation and microprocessor control made it more and more difficult for progressive amateurs to make their own equipment. Many became alienated by the amount of circuitry that was hidden from their sight encapsulated in blobs of plastic. Up to then they were able to see and handle every individual component within their equipment. It was foreign to them to consider new components simply as building blocks.

Specialised components required for the repair of older equipment or the building of replacement equipment based on tried and proven, well known older designs, are becoming scarce as it becomes more and more uneconomical to manufacture them.

Amateurs have long been known for their ability to troubleshoot and repair their equipment. Current circuit complexity and component miniaturisation has forced most owners to return to the dealer except for the most basic of repairs and/or modification.

The modern HF transceiver (nominally bands within the frequency range of 0 to 30MHz) is a very complex product that contains numerous digital signal processing modules – usually in the last IF stage. The transmitter section must be able to handle 100% duty cycle digital modes. The receiver section must be able to handle a wide range of signal frequencies, modes and signal strengths virtually undreamed of 100 years ago. Sensitivity and selectivity are prime features. Like almost everything else in this mass production, commerce driven age, facilities and conveniences can sell and the discerning amateur will be comparing specifications and user conveniences.

Although the amateur radio market is not the bread and butter of the major manufacturers, if they wish to cater for the market they must provide a wide range of models. Today's amateur indulges in one or more fixed station, mobile, portable, high power, low power, single band, multiband, single mode and multimode activities. They can be further categorised into two groups – casual or serious DX (long distance) award chasing.

The majority of amateurs, when looking at upgrading their equipment, almost universally purchase new and there is considerable brand loyalty.

The first Swan transceiver model SW-120 covering 14.2MHz to 14.35MHz only manufactured in 1962.

There are many major players from years past that are almost never heard of these days except in nostalgic discussions. The most predominant manufacturers of the 1950's and 1960's were American such as Barker & Williamson, Central Electronics, Collins Radio Company, E.F. Johnson

Company, Gonset Company, Hallicrafters, Hammarlund, The Heath Company, National Radio Company and R.L. Drake. According to Hugh (Hughs Ominous Valve Works (n.d)) all except Drake gradually folded, were taken over or moved into other fields.

The mainstream manufacturers today, at least as far as brands commonly available in Australia, are concerned, are Yaesu (Vertek), Icom, Kenwood (all Japanese) and Ten-Tec (American). There are also many smaller manufacturers such as MFJ and AOR making a variety of wide-range scanners, receivers and amateur accessories.

The modern amateur HF transceiver.

What, exactly, is it? The just released ICOM IC-7800 is an example of a top-level, modern, state-of-the-art transceiver. ICOM claims that the IC-7800 is the most advanced amateur radio ever. (It may very well be the most expensive ever produced as it is priced in excess of $AUD18,000.00). It has four 32-bit floating point DSP chips, two completely independent receivers, 7-inch wide TFT display, RTTY/PSK31 encoder and decoder and compact flash technology. See **Appendix** 2 for more pre-release details.

Of course, it is not necessary to purchase the most expensive transceiver to enjoy the hobby. Vertek, who now manufacture the Yaesu brand, have a model FT-847 “Earth Station” with a special satellite mode and many other facilities and conveniences. This model is currently available for $AUD2,500.00 or around one eighth of the IC-7800 price. It is claimed by the manufacturers to be the first HF/VHF/UHF all-mode transceiver with the versatility of covering every modern operating mode. See **Appendix** 3 for details.

What real advances have occurred with recent technological developments? It is obvious that almost any improvement on the spark transmitters of old would be welcomed. Indeed, it eventually became necessary due to legislation. How much more desirable is a modern transceiver over one produced around 25 years ago? The prices have slowly increased but dollar for equivalent dollar there are probably more facilities available today with the economical advantages of computer design and manufacture.

The table in **Appendix** 4 provides a comparison of specifications of two modern transceivers and one that is almost 25 years old. It is necessary to view the specifications with an understanding of the fundamental differences between the three transceivers shown. The ICOM IC-7800 is a very expensive state-of-the-art 2004 design. The YAESU FT-847 is around one eighth of the price and is designed with satellite operating convenience in mind. The YAESU FT-107M would be approximately similar to the FT-847 as far as technology allowed in the pre-DSP 1980’s and it operates on amateur band frequencies only.

A casual amateur might be forgiven for assuming that modern technology should automatically mean better. After all, his requirements are considerably less stringent than for the serious operator who is looking for and attempting to extract the utmost in performance from his station. On this basis, it is assumed that almost any model, providing it has sufficient facilities for his area of interest, will suffice for the casual operator. After all, he is not looking for that competitive edge in operation.

The serious amateur will not be so easily satisfied. He will be looking for optimum performance and will be considering those design elements that will give him an edge in a competition environment. Assuming that the chosen transceiver has the appropriate mode capability and power output, this edge relates to ease of operation, automation, weak signal handling capabilities and freedom from the adverse affects of close by, unwanted transmissions.

Are current transceivers an automatic better choice for the serious amateur?

Lombry (Lombry Hardware Review n.d.) poses a number of questions in developing an appropriate conclusion.

> What features make the difference between a mid-range and a high-end model?
>
> Is the price a good indicator?
>
> Are DSP functions useful?
>
> Is it better to install mechanical filters or DSP filtering?
>
> Is the selectivity and 3rd-order IMD important?

Sensitivity and Selectivity

The most important module in a transceiver, after the transmitter, is the receiver. It is quite easy to transmit a signal but you will never know if you have been heard unless you are able to at least hear the reception report from the recipient. The receiver's sensitivity is a measure of its ability to detect a useable weak signal. Four things can combine to make this a difficult task. These are atmospheric noises picked up by the antenna along with the wanted signal, random noise contributed by the electronic components of the receiver, the strength (or weakness) of the signal itself and degradation of that signal by the effects of close-in, stronger signals. The noise contributed by the receiver components is called the noise floor, below which a signal is not discernible.

The closer a signal's strength to the noise floor, the more difficult it is for the receiver to reproduce it. Therefore, the lower the noise floor, the more sensitive the receiver.

Selectivity is a measure of the receiver's ability to discriminate between wanted and unwanted transmissions or its ability to reject those signals that are not of current interest to the listener.

Tadeusz Raczek (Raczek: Sept/Oct 2002) considers ARRL laboratory comparison test results from a number of modern receivers and casts doubt on the credibility of manufacturers' sensitivity and blocking testing procedures. Manufacturers are catering for a wide clientele but the avid DX-er is looking for real performance on weak signals The manufacturers' testing regime provides more optimistic results than the procedures applied by amateurs in the ARRL laboratory. The amateurs' regime more realistically approximates real world situations.

In his comparison between a number of modern transceivers, Raczek (Razcek: Sept/Oct 2002) makes some pertinent comments about sensitivity, BDR (Blocking Dynamic Range) and IMD DR (Intermodulation Dynamic Range):

> We can presume that almost any modern HF receiver has enough sensitivity and selectivity to copy the weak DX station with no other signals present. Nevertheless, for real, on-the-air situations when plenty of strong signals are present near DX-station frequencies, some receivers will do better than the others. That will depend on how great is their BDR, how great is their IMD DR and how much phase noise accompanies the LO for any particular HF transceiver.
>
> If the receiver has only average BDR, even a single adjacent signal … if it is strong enough will desensitise the that receiver and the weak DX station will not be heard in the presence of strong interference.

Raczek (Raczek: Sept/Oct 2002) provides the following table of receiver front-end dynamic-range measurements performed by the ARRL laboratory at various signal spacings:

Table 1—IC-765 Receiver Front-End Dynamic-Range Measurements

Signal Spacing (kHz)	***Blocking DR (dB)*** *IF Shift Off*	*IF Shift On*	***IMD DR (dB)*** *IF Shift Off*	*IF Shift On*
5	120	91	85	73
10	130.5	105	90	88
20	151.5	139.5	97	95
50	152	152	99	99

The measurements show a considerable difference between the 5kHz and 50kHz signal spacings.

It is interesting to note that the top receivers chosen by Raczek from the ARRL laboratory testing results were the Elecraft Model K2, Ten-Tec Model Omni-V1+ and a heavily modified Drake R-4C. These appear in bold print in Table 2 and Table 3 from Raczek's detailed article.

Table 2—20 and 5-kHz-Spacing BDR and IMD DR for some HF receivers tested by the ARRL

Manufacturer	*Model*	*BDR (dB)*	*BDR Decrease*	*IMD DR (dB)*	*IMD DR Decrease*
Elecraft	**K2**	**133 and *126***	**only 7 dB**	**97 and *88***	**only 9 dB**
ICOM	IC-706MkIIG	120nl and *86*	34 dB!	86 and *74*	12 dB
ICOM	IC-746	113 and *88*	25 dB!	92 and *78*	14 dB
ICOM	IC-756PRO	120 and *104*	16 dB	88 and ***80***	**only 8 dB**
ICOM	IC-775DSP	132 and *104*	28 dB!	103 and *77*	26 dB!
Kenwood	TS-570S(G)	119 and *87*	32 dB!	97nl and *72*	25 dB!
Kenwood	TS-570D	"	"	"	"
Kenwood	TS-2000	121nl and *99*	22 dB!	92 and *67*	25 dB!
Ten-Tec	**OMNI-VI**	128nl and ***119***	**only 9 dB**	100 and ***86***	14 dB
Ten-Tec	**OMNI-VI+**	"	"	"	"
Yaesu	FT-847	109nl and *82*	27 dB!	89 and *73*	16 dB
Yaesu	Mark-V FT-1000MP	126 and ***106***	20 dB!	98 and *78*	20 dB!

Raczek says Elecraft and Ten-Tec have '… abandoned ideas commonly exploited during the last 20 years by most other makers of HF transceivers and returned to proven designs used previously but with modern implementations.'

Table 3—10 and 2-kHz-Spacing BDR and IMD DR for some HF transceivers tested by W8JI

Manufacturer	*Model*	*BDR (dB)*	*BDR Decrease*	*IMD DR (dB)*	*IMD DR Decrease*
ICOM	IC-751A	98 and 83.5	14.5 dB	91 and 79	12 dB
Drake	R-4C (stock 1)*	109 and 57	52 dB!	82 and 48	34 dB!
Drake	R-4C (stock 2)†	116 and 80	36 dB!	86 and 68	18 dB
Drake	**R-4C (heavy mod)††**	**131 and 127**	**only 4 dB**	**119 and 118**	**only 1 dB**

*Stock 1 has MOSFET second mixer.
†Stock 2 has vacuum-tube second mixer.
††Heavy mod is rebuilt with solid-state doubly balanced high-level mixers and Sherwood 600-Hz roofing filter.

The Drake R-4C was discontinued some 20 years ago. Although the unmodified receiver is not impressive compared to current transceivers, the modifications mentioned in Table 3 turn it into a good receiver for DX purposes.

The Elecraft Model K2 and Ten-Tec Model Omni-V1+ cover the amateur bands only and both avoid the now common up conversion to 50-90 MHz. Unlike the majority of current transceivers, no general coverage is provided. Despite the tried and proven design philosophy from 20 years ago, the receivers include a variety of modern microprocessor controlled operator conveniences including keypad frequency entry, memories, variable tuning rates and RS-232 interface.

Raczek also comments on selectivity filter placement in the Ten-Tec Omni VI+:

> Such a mixing concept allows installation of narrow crystal filters in both IF chains right at the beginning of first and second IF receiver amplifiers. Therefore, the receiver main selectivity filters are

close to the mixers, where they should be according to Dxers – and where they are not in most ham radio HF transceivers made in the last 20 years.

Conclusion

Having considered the preceding comparisons, it is obvious that the suitability, or otherwise, of a modern transceiver will depend on the requirements of the potential purchaser. The size of the purchase budget would also be a moderating factor.

A serious DX-er has conflicting requirements. Is sensitivity and selectivity more important than operator convenience – especially when modern transceivers have so much automated logging and contest participation facilities? Automation might enable a high turnover rate of contacts and therefore enhance contest scoring. A lack of sensitivity and selectivity might also permit weak signals to pass by undetected.

The casual operator has possibly the best of both worlds. Operator convenience and facilities will be more attractive. After all, if contesting ability is not paramount, what does it matter if the transceiver is a little light on in this area?

What does a limited budget do to the decision? Here is a balancing act between affordability and satisfying requirements. It will probably be seen that wide frequency coverage, convenience and facilities are more important than the nth degree of performance. If the budget is limiting, wouldn't you want to ensure that you could do as much with the purchase as possible?

In making the final purchase decision, it is necessary to consider an increasingly wide range of products with varying performance specifications and, perhaps, a bewildering array of what is termed 'bells and whistles'. Be aware that manufacturers are trying to cater for a mass market and need to recover research and development costs. They will be trying to attract you to their particular product with glossy brochures and other marketing ploys.

The process can be simplified a little by:

Identifying your budget constraints.

Identifying the critical performance criteria.

Researching those products that are within your budget and that satisfy the critical performance criteria.

Comparing secondary facilities and conveniences from your research.

Ultimately, an understanding of the meaning of the many specifications, and their importance, may be necessary to ensure the best decision.

If you are casual operator and your decision is not restricted by budget, purchase whatever you can afford and try to get the best-perceived value for the price.

If you are a serious contester, research the important specifications for your particular area of interest. An older transceiver may have superior performance for your budget. If your budget is not a limiting factor, be prepared to pay at least $AUD9,000.00 if you are going to purchase a modern, amateur band only transceiver.

Research for this report has uncovered an emerging technology that may well bring about an increase in amateur construction activity, although part of the construction will require some expertise that many simply will not have. This emerging technology is Software Defined Radio or SDR and has been brought about by the convergence of computers, digital electronics and the increasing need for radio communication and bandwidth economies.

The International Amateur Radio Union, IARU, (IARU – International Amateur Radio Union (20 February 2002)) indicates that once again, amateurs are at the forefront of the development of radio communication technologies.

> As we enter radio's second century, amateurs continue to lead the way in numerous areas.
>
> **Digital HF Radio:** Radio amateurs are the leading developers of new digital techniques for high-frequency (HF) data and text communication. For example, PacTOR combines the strengths of packet radio and the mode known commercially as SITOR to offer reliable and essentially error-free data communication. Disaster relief agencies have adopted it for use from remote locations where no telecommunications infrastructure is available. PSK31 is a user-friendly mode that provides live keyboard communication at low transmitter power levels when error correction is not required. An implementation of PSK31 using computer sound cards has made this the most popular digital mode for radio amateurs in less than two years. Other developers, building on the success of PSK31, are using sound cards to explore a wide range of other digital modes tailored for the challenging HF environment.
>
> **Software Defined Radios:** Perhaps the outstanding example of a DSP radio designed for experimental use is the DSP-10, a transceiver for the 144-MHz amateur band designed by Bob Larkin, W7PUA, of Corvallis, Oregon, USA. Working with Mr. Larkin, a team of amateur software developers is refining a family of programs tailored to explore a wide range of VHF, UHF, and microwave propagation media, including moonbounce (Earth-Moon-Earth) and extended-range tropospheric scatter. These are but examples of what is happening in the 21st Century Amateur Radio Service.

A personal computer is basically a machine whose output is entirely dependent on the software program that drives it. A change or upgrade of software can result in an entirely different output without changing any of the physical components of the computer. The same computer can be a spreadsheet, a database or a CD player – it all depends on the software.

SDR is basically similar. A black box contains a limited amount of electronics to capture and digitise a received signal. The digitised signal is then fed to a personal computer whose software and sound card determine what is done with the signal. This allows virtually unlimited application of digital signal processing technology. Once the black box is constructed, it is only necessary to modify or upgrade the software to bring about different transmitter or receiver functions.

The black box is not a transceiver. It is simply a black box that could just as easily be configured to be a digital telephone, a signal generator or anything else the software could bring about.

The ultimate goal is to position the digitising technology as close to the antenna connection as possible.

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All the creators of technical web sites and the Internet itself for providing such a vast, readily accessible, research facility.

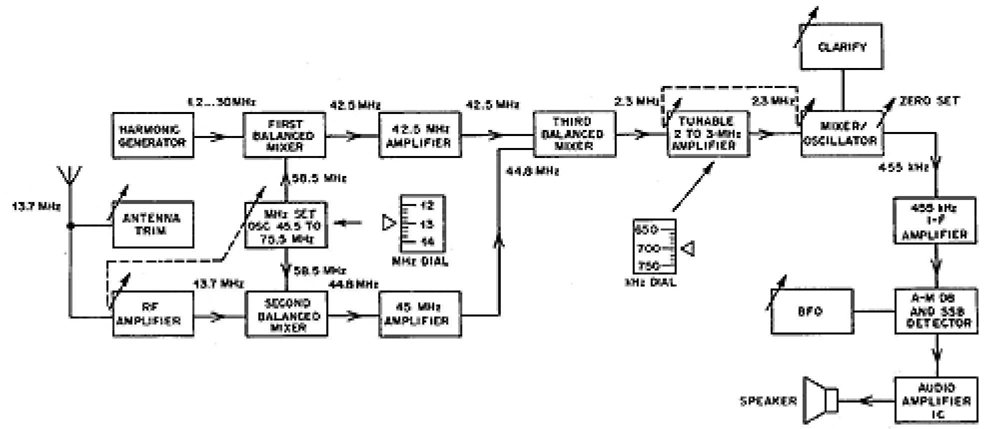
Scientists and experimenters who either discovered or created the foundations of radio communications.

Amateur radio operators throughout the world for providing the enjoyment and the reason for the hobby.

Appendix 1 - The Wadley Loop Drift Cancelling System

There were several different frequency schemes used by manufacturers who employed the Wadley Loop but the basic principle of operation is applicable to all. A further comment worth making is that the Wadley loop should not be confused with a phase locked loop, both systems are quite different in operation. The following operational description is for the Barlow Wadley XCR-30.

The Loop system uses a single 1 MHz crystal to generate harmonics at 1 Meg intervals, a double mixing process with a tuneable 45.5 to 75.5 MHz oscillator provides 30 tuneable ranges from 500 KHz to 30 MHz. The outputs of the first mixer (42.5 MHz) and second mixer (45 MHz) are amplified and then fed to a third mixer. With the 45 MHz Amp having a flat band-pass range of 1 MHz the output of our 3rd mixer is 2.5 MHz +- 500 kHz. This 2 to 3 MHz signal is then amplified and tuned with a 2.455 to 3.455 MHz mixer/oscillator, passing through a 455 kHz IF to the AM and SSB detectors.



Barlow Wadley XCR-30

Who used the Wadley Loop?

During the mid 1970's, Wadley's loop system was employed by several manufacturers, such as Yaesu (FRG-7), Drake (SSR-1) and Realistic (DX-300) but little is known of the actual Barlow Wadley Receivers and for that matter the Barlows Television Company (The Wadley Loop HF Receivers n.d.).

Ian Pogson, VK2AZN, used the Wadley Loop system in his well known valve and solid-state Deltahet communications receiver projects described in Australian magazine Electronics Australia in the 1960’s and 1970’s. Phase-Locked Loop and other digital technologies eventually rendered the Wadley Loop obsolete.

Appendix 2 – ICOM IC-7800 Brochure Details

The just released ICOM IC-7800 is an example of a modern, top-level, state-of-the-art transceiver and these details are taken from the pre-release brochure.

In the brochure, Icom claims to be the first manufacturer to bring transistor technology, digital PLL technology and the latest DSP technology to name a few achievements. The IC-7800 amateur transceiver is claimed to be the most advanced amateur radio ever. (It may very well be the most expensive ever produced as it is priced in excess of $AUD18,000.00). It has four 32-bit floating point DSP chips, two completely independent receivers, 7-inch wide TFT display, RTTY/PSK31 encoder and decoder and compact flash technology.

Four 32-bit floating point DSP units

Four independent DSP units are used. One for the transmitter, one for each receiver, and the final one for the spectrum scope. The DSP units are combined with a 24-bit AD/DA converter to support many of the DSP features exclusive to the IC-7800.

+40dBm ultra high intercept point

Icom has developed an amateur rig that challenges the performance of any "Military Grade" transceiver. A +40dBm* 3^{rd} order intercept point and ultra wide dynamic range that is amateur radio's highest. Mechanical relays instead of traditional semi-conductors and high performance DMOS mixers with a high-drive Local Oscillator. Two IF stages and Icom's new image rejection technology, enables the IC-7800 to clearly reproduce very weak signals as well as very strong signals without distortion.

Automatic tracking pre-selector

The 7800's pre-selector automatically tracks the intended signal, keeping the pre-selector's bandwidth centered on the operating frequency.

Two completely independent receiver circuits

Dual receivers are completely independent all the way from the 4 antenna jacks, through the pre-selectors, DSP, signal detectors, front panel control, right into the stereo headphone jack In addition to the separate receivers, the audio amplifiers and control circuits are duplicated for either headphones or external speakers

200W output power at full duty

Newly designed push-pull MOS-FET amplifiers work with 48V DC, providing 200W of output power at full duty cycle with low IMD in all bands. A low-noise switching power supply is built-in.

Ultra high frequency stability

A standard stability of ±0.05ppm. Even on 6m band (52 to 54MHz), that is less than 3Hz error from the Oven Controlled Crystal Oscillator. A 10MHz reference frequency can be input/output for external equipment.

7-inch wide color TFT LCD

A large 7-inch wide (800×480 pixels) color display. High linearity needle S-meters, multi-function spectrum scope and RTTY/PSK31 messages are displayed in vivid color. There is also a VGA connector allowing connection to an external monitor.

Multi function spectrum scope

With the dedicated DSP unit, the spectrum scope offers linearity, accuracy and resolution. By adjusting the scope selectivity (resolution band width), the spectrum scope allows selection of weak signals right next to strong ones. Monitoring the distortion or width of the received signals is also possible. The scope range can be set independently from the receiving frequency. You can monitor the band condition between the selected sweep edges, as well as sweep a selected bandwidth centered on the receiving frequency in the scope screen.

RTTY /PSK31 operation without PC connection

The IC-7800 has a modulator and demodulator for the 2 major HF Amateur digital modes. It is possible to encode and decode PSK31 as well as baudot RTTY signals by simply connecting a USB keyboard to the transceiver. It is no longer necessary to connect a PC for RTTY/PSK31 operation. In addition, transmitted and received messages can be stored to the CF card memory and transferred to a PC.

IF notch filter with adjustable notch filter characteristics

The DSP controlled manual notch filter shape can be set in 3-steps for the various receiving conditions. Use a soft filter shape for tuning an interfered tone, then switch to the sharp one to cut 70dB off the tone.

Professional 6m receiver

Most HF/50MHz transceivers share the preamp between the HF bands and 50MHz band. The IC-7800 uses an exclusive preamp and mixer especially for 50MHz. The preamp and mixer are both tuned to the 50MHz band and improve cross modulation characteristics, particularly important when picking up a very weak signal near a strong one.

Digital Voice Recorder

The Digital Voice Recorder (DVR) is a convenient function for contests, DX peditions, field days and even normal operation. It will record callsign, CQ, or other station information into a memory. Independent Record and Play buttons are on the front panel.

CF (Compact Flash) memory card

The IC-7800 has a CF card slot and a CF card will be supplied for storing various settings such as filter, display, mic equalizer, etc. When sharing the IC-7800 with multi-users such as on a DX pedition, in a contest or as a club rig, the CF card allows instant restoration of personal settings.

And more....

- Soft and sharp IF filter shapes for receiver
- Synchronous AM detection
- Reverse power protection circuit built-in
- RS-232C port for PC connection
- BNC type RF accessory connectors
- Audio Peak filter for CW
- Multi-function noise blanker
- Advanced noise reduction and auto notch
- Twin peak audio filter and tuning indicator for RTTY
- High speed automatic antenna tuner
- Built-in Voice synthesizer
- Main/Sub receiver connectors
- Optional IC-PW1 1kW Linear Amplifier available

Appendix 3 - Yaesu Musen FT-847 Earth Station

The 2004 version of the Vertek manufactured Yaesu FT-847 "Earth Station" with a special satellite mode and many other facilities and conveniences is an example of a general purpose, modern multi-band and mode transceiver. This model is currently available for $AUD2,600.00.

Yaesu claims to be the first manufacturer to produce a self-contained amateur HF transceiver, the first to produce an FM transceiver with memory and the first to produce a full-duplex satellite transceiver. With the FT-847, they also claim to be the first to produce an HF/VHF/UHF all-mode transceiver with the versatility of covering every modern operating mode.

Optional Automatic Antenna Tuner

Analyses the impedance present at the radio end of the coax. Stepper motors adjust variable capacitors to match 50 ohms. Includes 100 memories for tuning data.

Optional Active-Tuning Antenna System

The FT-847 can be expanded for mobile use on the 7/14/21/28/50/144/430 MHz bands. Controlled by a DC voltage from the transmitter to adjust the single antenna to resonance in seconds.

Separate Antenna Connectors

Separate antenna connectors for HF, 50, 144 and 430 MHz to permit full-duplex operation. The 50MHz connector can also be electronically switched to the HF section to permit the use of two antennas on the HF bands.

Cross-band full duplex operation

Effortless satellite operation whereby you can monitor the downlink signal from the satellite while simultaneously transmitting – only available if transmitting on one band while listening on another. Independent display of uplink and downlink frequencies is possible.

Uplink/Downlink Normal and Inverted Tracking

Slaves the two VFO's according to the requirements of the satellite's transponder.

Satellite Convenience Features

Alphanumeric tags for labelling the 19 special satellite memories.

The satellite meter will indicate, power out, discriminator or ALC by selection.

Rear panel DATA IN/OUT and PKT jacks can accommodate 9600 GMSK, 1200bps PSK or 1200 bps AX.25 AFSK modes.

All Mode Operation

All mode (SSB, CW, HSCW, AM, FM, Packet, SSTV and RTTY) operation on HF (100W), 50MHz (100W), 144MHz (50W) and 430MHz (50W).

Advanced Digital Signal Processing

Independently adjustable audio high-pass and low-pass DSP filters.

A total of 16 DSP noise reduction parameters.

DSP Auto Notch Filter with instantaneous sensing and notching of multiple interfering signals.

DDS Synthesiser

A new generation ultra-low-noise Direct Digital Synthesiser local oscillator with tuning steps down to 0.1Hz for careful tuning of EME signals, seamless Doppler shift during satellite work and effortless digital mode tuning.

Low-noise Receiving Pre-amplifiers

Receive pre-amplifiers for all bands. The 430MHz band pre-amplifier is a 10db HEMT (High Electron Mobility Transistor) design

Push-Pull Cooling

Twin cooling fans. The front panel fan sucks cooling air in and directs it around the internal cooling ducts and the rear fan forces it out the rear.

Additional Features

Expanded receive frequency range – 0 to 36MHz, 37MHz to 76MHz, 108 to 174MHz and 420 to 512MHz.

IF Shift for shifting the IF passband to avoid interference.

IF Noise Blanker for reduction of automotive ignition noise.

Input RF Attenuator – 20db reduction of signal.

Fixed level AF output jack for tape recorder or weather fax decoder.

Optional Collins mechanical filters

Built in RF type speech compressor.

10 key direct frequency entry keypad.

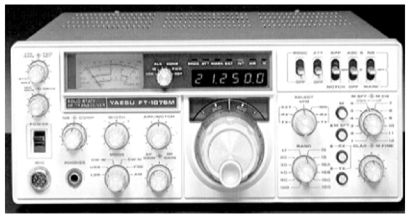
Built in RS-232C level converter for data transfer at 4800, 9600 or 57,600bps.

Optional voice frequency announcement module.

78 regular memories, upper/lower band/scanning limit memories, a Call channel, a Home channel on each band, a single channel Quick Memory bank, 12 special Satellite memory channels.

Appendix 4 – Transceiver Specification Comparison





IC-7800 $AUD18,000.00 (2004) **FT-847 $AUD2,750.00 (2004)** **FT-107M $AUD999.00 (1983)**

Category	ICOM IC-7800	YAESU FT-847	YAESU FT-107M
General			
Frequency Coverage – Receive	0.030 – 60MHz	100kHz – 30 MHz 36MHz – 76MHz 108MHz – 174MHz 420MHz – 512MHz	160m, 80m, 40m, 20m, 15m, 10m, amateur bands
Frequency Coverage - Transmit	160m, 80m, 40m, 30m, 20m, 17m, 15m, 12m, 10m and 6m amateur bands	160m, 80m, 40m, 30m, 20m, 17m, 15m, 12m, 10m, 6m, 2m and 70cm amateur bands	160m, 80m, 40m, 20m, 15m, 10m, amateur bands
Emission Modes	USB, LSB, CW, RTTY, AM, FM, PSK31	USB, LSB, CW, AM, FM, F1 (9600bps packet), F2 (1200bps packet), AFSK	USB, LSB, CW, FSK, AM
Number of memory channels	101 (99 regular and 2 scan edges)	78 regular memory channels 4 special Home channels 20 Smart Search channels Single Quick Memory channel 12 Satellite memory registers	12 memory channels plus Digital Memory Shift (Memory unit optional)
Antenna Impedance	50Ω unbalanced	50Ω unbalanced	50Ω unbalanced
Antenna Connector	SO-239 x 4	SO-239 x 3, N x 1	SO-239 x 1
Temperature Range	0° – 50° C	-10° – 50° C	No spec.
Frequency Stability	Less than ±0.05ppm	Less than ±2ppm	With 10 minute warmup, 300 Hz over 30 minutes, less than 100 Hz after 30 minutes.
Frequency Resolution	1Hz	1Hz	Analog tuning with 6 digit readout.
Power Supply Requirement	85-265V AC	13.8V DC ±10%	13.5V DC
Power Consumption	Tx Max. power 800VA Rx Standby 200VA typ. Max Audio 210VA	Tx 22A Rx 2A	Tx 20A Rx 1.5A
Dimensions	424 x 150 x 420mm	280 x 86 x 270mm	334 x 129 x 400mm
Weight	23kg	7kg	12.5kg
Transmitter			

Output Power **SSB, CW, FM, RTTY, PSK31** **AM**	5-200W 5–50W	160-6m – 100W (AM –25W) 2m/70cm – 50W (12.5W AM)	LSB, USB, CW – 240W input AM, FSK – 80W input All HF bands 100W output
Modulation System	SSB - DSPN AM - Low power FM - Phase	SSB - Balanced AM – Low level FM – Variable reactance	SSB – Balanced AM – low level
Spurious Emission	Less than –60dB	At least 40dB down HF At least 60dB down (V/UHF)	Better than 50dB below rated output.
Carrier Suppression	More than 60dB	More than 40dB	Better than 40dB
Unwanted sideband Suppression	More than 80dB	More than 40dB	Better than 50dB
Microphone	8 pin (600Ω)	200-10kΩ (600Ω supplied)	No spec
Receiver **Receive System**	Double conversion superhet	Double conversion superhet	No spec
Intermediate frequencies	1st IF – 64.455MHz 2nd IF – 36kHz	No spec	No spec
Sensitivity (typical) **Preamp on where provided**	**SSB, CW, RTTY** 0.1-1.79MHz – 0.5μV 1.8-29.99MHz – 0.16μV 50.0-54.0MHz – 0.13μV **AM** 0.1-29.99MHz - 2μV 50.0-54.0 - 1μV **FM** 28.0-29.99MHz – 0.5μV 50.0-54.0MHz - 0.32μV	**SSB, CW, RTTY** 0.5-1.8MHz – No spec 1.8-30MHz – 0.25μV 50.0-54.0MHz – 0.2μV 144/430MHz – 0.125μV **AM** 1.8-30MHz - 1μV 50.0-54.0 - 0.5μV 28.0-29.99MHz – 0.5μV **FM** 28-30MHz – 0.5μV 50.0-54.0MHz – 0.25μV 144/430MHz – 0.16μV	**SSB, CW, FSK** 0.2525μV **AM** 1μV
Selectivity	**SSB, RTTY** (BW: 2.4kHz) More than 2.4kHz/-3dB Less than 3.6kHz/-60dB **CW** (BW: 500Hz) More than 500Hz/-3dB Less than 700Hz/-60dB **AM** (BW: 6kHz) More than 6.0kHz/-3dB Less than 15.0kHz/-60dB **FM** (BW: 15kHz) More than 12.0kHz/-6dB Less than 20.0kHz/-60dB	**SSB, CW** 2.2kHz/-6dB 4.5kHz/60dB **CW-N** (optional filter) 0.5kHz/-6dB 2.0kHz/-60dB **AM** 9kHz/-6dB 20kHz/-60dB **FM** 15kHz/-6dB 30kHz/-60dB **FM-N** 9kHz/-6dB 20kHz/-60dB	**SSB** 2.4kHz/-6dB 4.0kHz/-60dB **CW** Optional filter 600Hz/-6dB 1.2kHz/-60dB **AM** Optional filter 6.0kHz/-6dB 12.0kHz/-60dB

The above comparison specifications have been extracted from publicity brochures and/or operator manuals.

Appendix 5 - Amateur Digital Communication Modes

Amateur digital (computer generated) communication modes have blossomed due to the generosity of amateurs with programming knowledge providing their software essentially free over the Internet and wide spread use of the Personal Computer with a digital sound card for the required Digital Signal Processing required. HF digital operation today is distinguished by the use of lower power and operating bandwidth.

The following explanation of digital modes is provided by (The Digital Ham Radio Revolution n.d.)

> PSK31 mode led the way starting in 1997, and since then experimentation has shown that incremental improvements can be made. The popularity of a single mode, like PSK31, over other new modes seems to be driven at this time by how many freeware programs are available for the mode. It is possible that a more advanced mode like MFSK16 will emerge as a standard for HF band operation in the future. We can all participate in the revolution by trying out the other modes and judging their performance on all of the HF bands. Fortunately, the interface needed to operate these new PC sound card programs is the same for all the modes. The next challenge for the ham programmers out there is to create a single program that will incorporate modules for all the new sound card modes.
>
> Confusion over band space is the obvious downside as new and old modes compete for band space. Crowding on a single band like 20 meters is partly to blame for this issue. Fortunately, the new modes, like MFSK16, are designed to improve performance inside a wide range of operating conditions. This should allow for increased ham band usage to relieve crowding and extend contact opportunities as propagation changes to favor different bands. I don't know what is going on with the phone portion of the ham bands, but these are exciting times for us digital operators!
>
> **TOR** is an acronym for Teleprinting Over Radio. It is traditionally used to describe the three popular "error free" operating modes, AMTOR, PACTOR and G-TOR. The main method for error correction is from a technique called ARQ (automatic repeat request) which is sent by the receiving station to verify any missed data. Since they share the same method of transmission (FSK), they can be economically provided together in one TNC modem and easily operated with any modern radio transceiver. TOR methods that do not use the ARQ handshake can be easily operated with readily available software programs for personal computers. For these less complex modes, the TNC (terminal node controller) is replaced by an on-board sound card or out-board audio device. These modes may use redundancy or "human processing" to achieve a level of error correction.
>
> **AMTOR** is an FSK mode that has been fading into history. While a robust mode, it only has 5 bits (as did its predecessor RTTY) and cannot transfer extended ASCII or any binary data. With a set operating rate of 100 baud, it does not effectively compete with the speed and error correction of more modern ARQ modes. The non-ARQ version of this mode is known as FEC, and known as SITOR-B by the Marine Information services.
>
> **PACTOR** is an FSK mode and is a standard on modern TNCs. It is designed with a combination of packet and Amtor Techniques. It is the most popular ARQ digital mode on amateur HF today. This mode is a major advancement over AMTOR, with its 200 baud operating rate, Huffman compression technique and true binary data transfer capability.
>
> **PACTOR-II** is a robust and powerful PSK mode which operates well under varying conditions. It uses strong logic, automatic frequency tracking; it is DSP based and as much as 8 times faster then Pactor. Both PACTOR and PACTOR-2 use the same protocol handshake, making the modes compatible.
>
> **PACTOR-III** is a proprietary mode used for message and traffic handling over an HF radio circuit. Use of Pactor-III protocol is limited for US hams and some other countries due to the very wide bandwidth of the Pactor-III signal. Presently digital signals that occupy the bandwidth of PCT-III are restricted to a few sub bands: 28.120-28.189 MHz, 24.925-24.930 MHz, 21.090-21.100 MHz, 18.105-18.110 MHz, 14.0950-14.0995 MHz, 14.1005-14.112 MHz, 10.140-10.150 MHz, 7.100-7.105 MHz, or 3.620-3.635 MHz. Only the embedded hardware (modem) from the German company that owns the rights to this mode, is capable of operating Pactor-III.
>
> **G-TOR** (Golay -TOR) is an FSK mode that offers a fast transfer rate compared to Pactor. It incorporates a data inter-leaving system that assists in minimizing the effects of atmospheric noise and has the ability to fix garbled data. G-tor tries to perform all transmissions at 300 baud but drops to 200 baud if difficulties are encountered and

finally to 100 baud. (The protocol that brought back those good photos of Saturn and Jupiter from the Voyager space shots was devised by M.Golay and now adapted for ham radio use.) G-tor is found in only one manufacture's TNC and is rarely used today.

CLOVER is a PSK mode which provides a full duplex simulation. It is well suited for HF operation (especially under good conditions), however, there are differences between CLOVER modems. The original modem was named CLOVER-I, the latest DSP based modem is named CLOVER-II. Clovers key characteristics are band-width efficiency with high error-corrected data rates. Clover adapts to conditions by constantly monitoring the received signal. Based on this monitoring, Clover determines the best modulation scheme to use.

RTTY or "Radio Teletype" is an FSK mode that has been in use longer than any other digital mode (except for Morse code). RTTY is a very simple technique which uses a five-bit code to represent all the letters of the alphabet, the numbers, some punctuation and some control characters. At 45 baud (typically) each bit is 1/45.45 seconds long, or 22 ms and corresponds to a typing speed of 60 WPM. There is no error correction provided in RTTY; noise and interference can have a seriously detrimental effect. Despite it's relative disadvantages, RTTY is still popular with die-hard operators.

PSK31 is the first new digital mode to find popularity on HF bands in many years. It combines the advantages of a simple variable length text code with a narrow bandwidth phase-shift keying (PSK) signal using DSP techniques. This mode is designed for "real time" keyboard operation and at a 31 baud rate is only fast enough to keep up with the typical amateur typist. PSK31 enjoys great popularity on the HF bands today and is presently the standard for live keyboard communications. Most of the ASCII characters are supported. A second version having four (quad) phase shifts (QPSK) is available that provides Forward Error Correction (FEC) at the cost of reduced Signal to Noise ratio.

HF PACKET radio is a FSK mode that is an adaptation of the very popular Packet radio used on VHF FM ham radio. Although the HF version of Packet Radio has a much reduced bandwidth due to the noise levels associated with HF operation, it maintains the same protocols and ability to "node" many stations on one frequency. Even with the reduced bandwidth (300 baud rate), this mode is unreliable for general HF ham communications and is mainly used to pass routine traffic and data between areas where VHF repeaters may be lacking.

HELLSCHREIBER is a method of sending and receiving text using facsimile technology. This mode has been around a long time; the recent use of PC sound cards as DSP units has increased the interest in Hellschreiber. The single-tone version (Feld-Hell) is the method of choice for HF operation. It is an on-off keyed system with 122.5 dots/second, or about a 35 WPM text rate, with a narrow bandwidth (about 75 Hz). Text characters are "painted" on the screen, as apposed to being decoded and printed. A new "designer" flavour of this mode called FM HELL has some advantage for providing better quality print, at the expense of a greater duty cycle. As with other "fuzzy modes" it has the advantage of using the "human processor" for error correction.

MT63 is a new DSP based mode for sending keyboard text over paths that experience fading and interference from other signals. It is accomplished by a complex scheme to encode text in a matrix of 64 tones over time and frequency. This overkill method provides a "cushion" of error correction at the receiving end while still providing a 100 WPM rate. The wide bandwidth (1Khz for the standard method) makes this mode less desirable on crowded ham bands such as 20 meters. A fast PC (166 Mhz or faster) is needed to use all functions of this mode.

THROB is yet another new DSP sound card mode that attempts to use Fast Fourier Transform technology (as used by waterfall displays) to decode a 5 tone signal. The THROB program is an attempt to push DSP into the area where other methods fail because of sensitivity or propagation difficulties and at the same time work at a reasonable speed. The text speed is slower than other modes but the author (G3PPT) has been improving his MFSK (Multiple Frequency Shift Keying) program. Check his web site for the latest developments.

MFSK16 is an advancement to the THROB mode and encodes 16 tones. The PC sound card for DSP uses Fast Fourier Transform technology to decode the ASCII characters, and Constant Phase Frequency Shift Keying to send the coded signal. Continuous Forward Error Correction (FEC) sends all data twice with an interleaving technique to reduce errors from impulse noise and static crashes. A new improved Varicode is used to increase the efficiency of sending extended ASCII characters, making it possible to transfer short data files between stations under fair to good conditions. The relatively wide bandwidth (316 Hz) for this mode allows faster baud rates (typing is about 42 WPM) and greater immunity to multi path phase shift. This mode is becoming a standard for reliable keyboard to keyboard operation and is available in several popular programs.

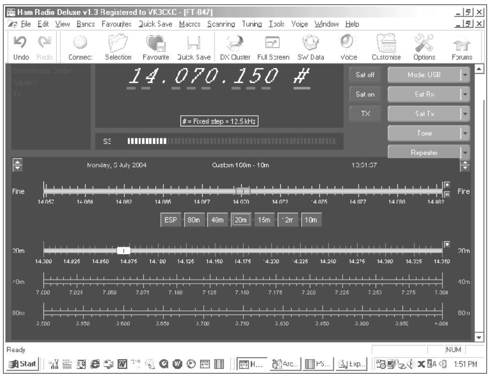
NOTES:

Frequency-shift keying (FSK) shifts between two known states. Phase-shift keying (PSK) changes PHASE of a signal against some reference. FSK is sent by either shifting a carrier frequency (F1B) or modulating SSB with two shifting audio tones (AFSK). When sending PSK, a complex audio waveform is transmitted by SSB. Tracking is much more critical for PSK, thus requiring more frequency stability. DSP (Digital Signal Processing) techniques use high speed processing to convert audio into digital coding, so that a program can manipulate the coded audio in ways not possible with traditional hardware filters. The 16 and 32 bit sound cards found in modern PCs provide this capability. FUZZY MODES are those modes that allow the human eye/ear/brain to be used to its maximum potential. In order to do this, a number of rules are required, to ensure that any electronics or logic circuitry is not allowed to make decisions which may be less inspired than human decisions. Examples of potentially Fuzzy modes are Morse Code, HFFAX, SSTV and Hellschreiber.

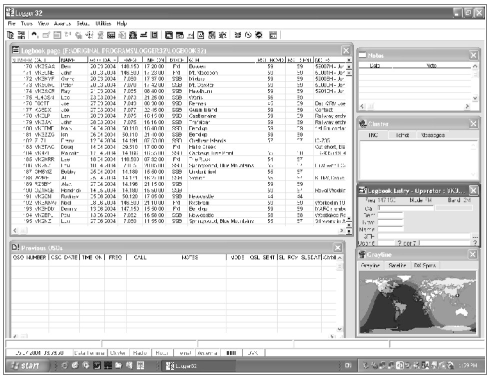
The rules are:

The transmissions must be uncoded. (The signal is sent as a real-time language.)
The receiver must not decide when data is present. (Untouched by any prior decisions.)
The receiver must not decide what data is present. (It must be presented as received.)

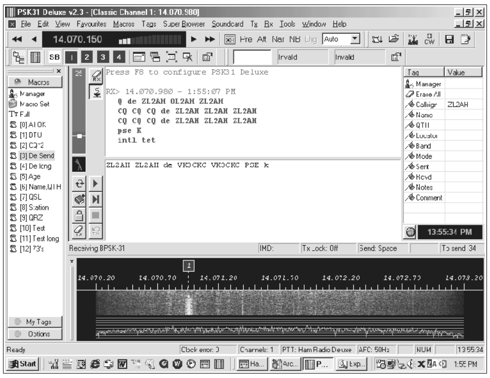
Appendix 6 – Digital Software Screenshots



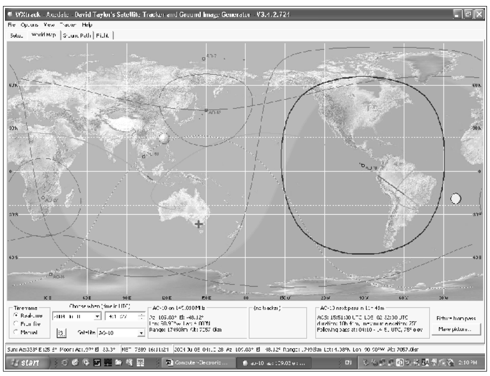
Ham Radio Deluxe: Transceiver control interface showing current tuned frequency and various band and mode controls. Software available from available from http://www.hb9drv.ch.



Logger32: Contact logging software program. Software available from http://www.qsl.net/kc4elo.



PSK31 Deluxe: PSK31 digital mode transceiver interface showing a received signal as decoded text and the signal's position on the waterfall spectrum display. Software available from http://www.hb9drv.ch.



WXtrack: Satellite tracking software showing a number of amateur satellites with AO40 highlighted and a day/night grayline. Software available from .http://www.satsignal.net.

Appendix 7 - Websites of Interest

The Spark Museum - John Jenkins' collection of Vintage Radio and Scientific Apparatus. http://www.sparkmuseum.com

Marconi Calling - A fascinating exploration of Guglielmo Marconi's life, his scientific discoveries, the impact of wireless and the development of modern communications. http://www.marconicalling.com

Hammond Museum of Radio – A collection of Hammond and other radio related items. http://www.hammondmuseumofradio.org/

RigPix - Source of information and pictures of radios, accessories and more. http://www.rigpix.com/

Western Historic Radio Museum - Vintage Radio Equipment and Memorabilia from 1910 through the 1950s. http://www.radioblvd.com/

Gerard's Radio Corner – Images and details of vintage radios. http://www.cs.uu.nl/people/gerard/RadioCorner/

American Museum of Radio & Electricity
http://www.americanradiomuseum.org/

W1TP Telegraph & Scientific Instrument Museums
http://www.chss.montclair.edu/~pererat/telegraph.html

USA Amateur Radio History and licensing, by AC6V
http://ac6v.com/history.htm

Amateur Radio 1965, N4MW
http://www.n4mw.com/g1965.htm

History of JARL, JARL
http://www.jarl.or.jp/English/1_Amateur/A-1-a.htm

AMSAT
http://www.amsat.org/

PV Scientific Instruments (replicas of classical electric apparatus for sale)
http://www.arcsandsparks.com/