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Radio Controlled Wristwatches

Michael A Lombardi discusses watches that are on time, all the time

NEARLY A CENTURY AGO, the renowned horologist Frank Hope-Jones remarked that he favoured collectivism, rather than individualism in clocks. He wrote that the 'root of the evil in timekeeping' was 'the independence of clocks'. For example, a group of self-wound clocks were typically synchronised from different sources and would run at different rates, so that none would agree with the others. By 1910, Hope-Jones had already devoted years to solving this problem; he was then working on the design of an 'ideal synchroniser which both corrects the rate and sets the hands', thus forcing a group of electrically connected clocks to always display the same time.[1]

Even today, however, we still face problems caused by the independence of clocks and watches. One published study checked the accuracy of 152 different timekeepers used to time-stamp events in the emergency department of a large hospital. Many of those tested were watches worn by medical personnel. It was found that 55% were in error by more than one minute and that only 3% were accurate to within one second. The slowest was more than twelve minutes slow, and the fastest some seven minutes fast, so two timepieces could vary by nearly twenty minutes, causing potentially life threatening problems.[2]

The consequences or having the wrong time are less serious in everyday life, but our watches still need to be in reasonable agreement with the other clocks in our household or workplace. The advent of the quartz controlled watch in the late 1960s made the problem of 'correcting the rate' much less serious than it was in the days of Hope-Jones, because a quartz watch typically keeps time accurate to within about three minutes per year after being synchronised, whereas even a good mechanical watch might gain or lose an equivalent amount of time in a single week. And further improvements in watch oscillator technology seem likely. We might one day be able to buy watches containing miniature atomic oscillators that would gain or lose only a small fraction of a second over the course of a century.[3] But no matter how perfect its oscillator, a watch still needs to be synchronised to a reference source before it can display the correct time and lose its 'independence'.

Solving the Independence Problem

As Hope-Jones knew, the best way to solve the problem of the independence of clocks is to have a central distributing clock whose signal is used to synchronise other clocks. The concept is an old one; time signals were sent by telegraph as early as 1852[4], and by wireless telegraphy, later known as radio, as early as 1903[5]. Radio is a nearly perfect medium for controlling clocks, because unlike wired mediums, there is virtually no limit to the number of clocks that can be controlled. The correct time can be delivered almost simultaneously to every clock that resides within the coverage area of the transmitter. Because radio waves travel at the speed of light, the time delay between the transmitter and the receiver is small, too small to be noticed if accuracy to within one second is all that is required.

Despite the advantages of controlling clocks by radio, products for the consumer market did not appear for some 80 years after the first experimental time signal broadcasts. Many things had to fall into place before consumer products became practical, including the widespread availability of time signal stations, the advent of the microprocessor, the miniaturisation of antennas and electronic components, and the sophisticated manufacturing techniques needed to build a low-cost product. The first consumer oriented radio controlled clocks appeared in the mid-1980s with products from German companies such as KUNDO and JUNGHANS,[6] followed by a steady stream of other wall and desk clocks produced by numerous manufacturers.

Due to their obvious size limitations, radio controlled watches (RCWs) are more difficult to manufacture than their wall and desk clock counterparts, and have so far been produced in much smaller numbers. The first RCW, **1**, was probably the JUNGHANS *Mega 1*, whose introduction in 1990 was hailed by one reviewer as 'one of the most momentous horological events ever'.[7] Even so, RCW sales remained modest throughout the 1990s, with the products found only in speciality shops, mail order catalogues, and advertisements in airline magazines. Today, however, the watches are easy to find and sales are rapidly expanding. For example, CASIO, which offers a variety of models through its *Waveceptor* line, reported sales of 2.3 million RCWs in 2005, with an estimated 1.1 million sold in Japan, 700,000 sold in the United States, and 500,000 sold in Europe. Many consumers now realise that RCWs have a clear advantage over conventional watches; because they periodically synchronise to international references, they are on time, all the time. In addition, prices have plummeted to the point where they cost just slightly more than conventional quartz watches of similar quality.

Let's look at how a radio controlled watch works, and at the signals that control them.

1. JUNGHANS MEGA 1, 1990 (courtesy of Reto Castellazzi, www.pmwf.com)

1 F Hope-Jones, 'Modern Electric Time Service,' *Journal of the Institution of Electrical Engineers*, **45**, February 1910, pp. 49-115.

2 W H Cordell, M L Olinger, P A Kozak, and A W Nyhuis, 'Does anybody really know what time it is? Does anybody really care?,' *Annals of Emergency Medicine*, **25** (5), May 1994, pp. 1032-1036.

3 J Kitching, 'An Atomic Clock on a Chip,' *HJ*, **147** (2), February 2005, pp. 54-55.

4 D Howse, *Greenwich Time and the Longitude*, PHILIP WILSON, London, 1997.

5 S J Dick, *Sky and Ocean Joined, The U.S. Naval Observatory 1830-2000*, CAMBRIDGE UNIVERSITY PRESS, 2003.

6 D J Boullin, 'Domestic Radio-Controlled Clocks, Parts 1 and 2,' *Horological Journal*, July-August 1988.

7 D J Boullin, 'The Junghans Radio Controlled Watch', *Radio Time*, **1**, (3), 1990, pp. 3-7.

2. Rear view inside of a low-cost RCW, with two crystals and the antenna visible.

3. Radio Station WWVB, near Ft. Collins CD, transmits time signals for RCWs in the US.

LF Time Signal Stations

Some advertisements describe RCWs as 'atomic clocks', but they are nothing of the sort. Like most inexpensive watches, they keep time using a small quartz crystal oscillator that runs at a nominal frequency of 32768 Hz. Near the crystal is a miniature radio receiver that is permanently 'tuned' to the frequency of the incoming time signal using a second quartz crystal that typically produces 40, 60, or 77.5 kHz. The receiver uses a small antenna, typically 15 mm or less in length, that generally consists of a ferrite bar or loop wrapped with a thin coil of wire. Due to the inclusion of the receiver, antenna, and the additional quartz crystal, an RCW tends to be larger than a conventional quartz watch (**2** shows a very low-cost model that is particularly large), but some models are surprisingly compact.

The incoming radio signal delivers a time code, containing the current time and date, that is used to synchronise the watch to within a small fraction of a second. This synchronisation is normally done at night, when the radio signal is strong and easy to receive. The quartz oscillator keeps time between synchronisations, normally to within less than one second per day, so one synchronisation every 24 hours is usually all that it necessary to keep the watch on time. The time code also supplies the information needed to adjust the watch during the transitions between standard and daylight saving time.

Where does the time code come from? Most RCWs get the time from the national laboratory that is responsible for maintaining and distributing the official time for the country. For example, the National Institute of Standards and Technology (NIST) is an official source of time in the United States, and continuously broadcasts time signals from radio station WWVB, located near Fort Collins, Colorado, **3**. As a result, most radio-controlled watches in the United States are synchronised by WWVB through its 50,000 watt signal that reaches all 50 states during the night hours. WWVB continuously transmits a 60 kHz carrier frequency that is locked to a group of caesium oscillators that are steered to agree with the national time standard. A binary time code, consisting of a series of ones and zeros, is sent by simply raising and lowering the power of the carrier. The signal power is dropped by more than 90% at the start of each second and held low for 0.2 seconds to send a 'zero', or for 0.5 seconds to send a 'one'. Because bits are sent at the glacial rate of one per second, it takes a full minute to send a complete time code. In addition to the time and date, the time code contains a flag indicating whether standard time or daylight saving time is in effect, and information about leap seconds.

Like the time stations located outside the United States (MSF in the United Kingdom, DCF77 in Germany, HBG in Switzerland, JJY in Japan, and BPC in China), WWVB is a low frequency or LF station, operating in a part of the spectrum unknown to most radio listeners, well below the AM broadcast band. All of the time stations mentioned above transmit somewhere in the 40 to 80 kHz range. At these 'longwave' frequencies (60 kHz has a wavelength of five kilometres), even a low power signal can travel great distances, and easily pass through non-metallic buildings and walls, making the signal usable indoors. The time stations use different formats for their time codes, but they are similar enough for watch designers to build products that work with multiple stations. The RCW shown in **4** is a truly international product, with the ability to receive signals from MSF, DCF77, JJY, or WWVB, allowing it to stay synchronised in Europe, Asia, and the United States.

The Pros and Cons of RCWs

The benefits of an RCW are obvious, so obvious that they seem almost too good to be true. RCWs always display the right time, accurate to within one second. They never need to be set, even when the time changes by an hour in spring and autumn. The date is always right, no matter how many days are in the month. Some are solar powered and the battery never needs to be changed; you can simply wear them and forget about them. So what's not to like about RCWs? There are a few negatives worthy of discussion, so let's look at them in turn.

One common consumer complaint is that RCWs are too large, and they do tend to be larger than conventional watches, a fact touched on earlier. For many men this is not a problem, but the few RCWs that exist for women are much larger than a typical women's watch, and this has hindered sales in this market. RCWs have gradually become smaller and should continue to do so, but the biggest factor that limits their miniaturisation is probably the antenna. The original models produced by Junghans placed the antenna in the wristband, **1**, and some early RCWs produced by Citizen attached the antenna to the outside of the case, or inside the dial, **5**. Most of the newer models do a

4. An "exploded" view of a multi-region RCW (courtesy of CASIO, Inc.)

5. An early RCW produced by CITIZEN, with the antenna visible inside the dial, now a sought-after collector's item. (courtesy of Reto Castellazzi, www.pmwf.com)

good job of 'hiding' their ferrite bar or loop antennas inside the case, but there are still limitations on how small these antennas can be before they cease to be effective.

The fashion aspect has probably also limited the growth of the RCW market. To many, a watch is a fashion statement, and there are those who refuse to wear a plastic watch. This causes difficulties with RCWs because the antenna must reside behind a non-metallic material in order for the radio signals to pass through. However, watch designers have managed to compensate by using hard plastics or ceramics, or making most of the case metal, except for the antenna enclosure. As a result, some RCWs from manufacturers such as JUNGHANS and CASIO, **6**, are nearly indistinguishable from a conventional dress watch.

RCWs may never need to be set, but they do need to be adjusted for the time zone they are in before they can show correct local time. WWVB and other time signal stations broadcast Coordinated Universal Time or UTC, which is equivalent to the time at the Prime Meridian in the United Kingdom. The local time zone has to be manually selected on the RCW so that UTC can be converted to local time. Then, if the RCW is moved to a different time zone, the setting must be changed. Unlike most conventional watches, however, RCWs allow the hour to be changed without stopping or disturbing the minute and second. Thus, after a new time zone has been selected, no accuracy has been lost.

6. Fashionable radio controlled watches (courtesy of JUNGHANS and CASIO, Inc.)

Finally, radio reception problems sometimes occur with RCWs, defeating their primary benefit, which is accuracy to one second or less. A RCW that has not recently synchronised to a time code will be no more accurate than a conventional quartz watch, and will typically be in error by several seconds after a week of non-reception. RCWs can fail to synchronise if they are moved outside of the coverage area of the transmitter, if there is a source of local radio interference, if they are located in a metal or ferroconcrete building and not kept by a window during the night, or if they are always moving (synchronisation is much more reliable when they are motionless). Manufacturer's guidelines recently published by NIST[8] recommend that all radio clocks and watches include a synchronisation indicator that displays in some fashion how long it has been since the last synchronisation. Many RCWs already have this feature, allowing their owners to quickly determine whether they can trust the displayed time.

RCWs for non-LF Signals

The discussion thus far has been limited to watches that receive LF signals, but other types of RCWs are now being sold. Chief among these are Global Positioning System (GPS) watches, which have been available for several years. GPS sends signals from satellites carrying atomic clocks, and can deliver time with unmatched accuracy, since the system corrects for satellite transmission delays. In sharp contrast to LF watches, a GPS watch, **7**, receives a spread spectrum microwave signal at 1.57542 GHz. These watches can display their wearer's location to within about 10 meters, and can also display how fast their wearer is travelling. They also can synchronise anywhere on earth, a distinction that no other type of RCW can claim. However, because the antennas are so large and the electronics so complex, GPS watches tend to be bulky and expensive, and the low-power microwave signals do not usually work indoors. For these reasons, GPS watches are much less common than LF watches, and are likely to remain so.

Most of the other types of RCWs are designed to work with some type of mobile messaging technology. At least two major

7. GPS wristwatch (courtesy Jim Arnfield)

8 WWVB Radio Controlled Clocks: Recommended Practices for Manufacturers and Consumers, NIST Special Publication 960-14, 2005. (available for download from http://tf.nist.gov/general/pdf/1976.pdf)

watch manufacturers, SEIKO and TIMEX, formerly sold watches that synchronised to wireless time codes from paging networks, but these products have been discontinued. Currently, the most promising radio controlled watches in the mobile messaging area are those designed to work with time codes delivered by FM radio stations using a subcarrier, including the popular Radio Data System (RDS), which is often used to set the clocks on car radios, and SPOT (Smart Personal Objects Technology) a system developed by MICROSOFT for use in North America, **8**. These products have advantages and disadvantages when compared to the LF watches. The technology is newer, and time codes are sent much faster, so the watches can synchronise more quickly and more often. Another major advantage is that because the watches were designed for mobile message applications, they can synchronise while moving, and can automatically correct for time zones changes since they receive signals from local transmitters that cover small geographic areas. On the negative side, they tend to be bigger, bulkier, more complex, and often more expensive than an LF watch, because they were designed to do many things in addition to displaying the time, and these additional features usually require paying a monthly service fee to activate. In addition, the time originates from a private network rather than from a national timekeeping laboratory, so it is perhaps more likely to occasionally be in error.

Summary

The radio controlled watch market has developed slowly, but the products are now here to stay. While some will argue that they don't need a radio controlled watch, others derive immense satisfaction from owning a watch that is always right, and have now found that no other type of watch will do. It seems likely that the demand for RCWs will continue to grow, as more and more people expect their watches to be on time, all the time, accurate to within one second or less. Time signal broadcasters and RCW designers are working to meet this demand, and gradually solving the age-old problem of the independence of clocks.

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8. SPOT Wristwatch (courtesy of TISSOT US.)

Notts/Derby Branch Generosity

*Following the Notts and Derby branch's enormously successful auction at the 2005 Show at Upton Hall, the branch has very generously purchased and donated equipment for our teaching workshops. Pictured in the watch workshop are Branch Chairman **Paul Shrouder** and Treasurer **Mike Corby** with some of the equipment, which includes high quality staking sets, jewelling sets and files. Paul discussed requirements with the BHI's other regular tutors before finalising his list of required equipment, which the branch then bought and donated. I'm sure our seminar students will appreciate this generosity, and our very grateful thanks go to the Notts and Derby branch!*

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