Bengt Myhrberg
mvh
Christopher

Reprint from

Quatrième colloque
sur l'histoire de l'informatique
Rennes, 14–16 novembre, 1995

Jacques ANDRÉ &
Pierre-E. MOUNIER-KUHN
éditeurs

Irisa / Inria-Rennes
Campus universitaire de Beaulieu
35042 Rennes cedex, France

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Campus universitaire de Beaulieu, F-35042 Rennes cedex, France
tél. +33 99 84 72 51 ; fax: +33 99 84 71 71, email: chir@irisa.fr

Early Electronic Computers and the Swedish Defence

Christopher BENGTSSON

Defence Materiel Administration
SE-115 88 Stockholm, Sweden

Abstract. *The industrial and educational environment in Sweden just after World War II was a good growing ground for computer technology and some of the reasons for the early development of computers as well as the rapid general acceptance of computers in Sweden. The process industry, the advanced administrational organisations and the defence were already in the mid fifties trying to use computers to unload the operational personnel. With the high-frequency-perfomance-transistor came the second computer boom, which alerted the Swedish defence and a most modern computerized early warning and fighter control system was implemented.*
In the light of today those old computers look old-fashioned, of course, but many of the peculiarities they show turn out to be early ideas for solutions of problems also occuring today. As the first one in a planned series of articles on computers in the Swedish defence, this paper describes the use of circulating memories, in particular the technical solution for a magnetostrictive memory, which has been used for thirty years in the Swedish Air Force.
As it has been difficult to find written references, this paper should be regarded as a descriptive essay rather than a scientific paper.

1. Background

When World War II had ended in 1945, the situation in Sweden – not having been exposed to any severe actions of war – was much more favourable than in most other European countries. This is shown by the fact that industry and the productive capacity as well as the general standard of living in Sweden could grow from the level of pre-war, whilst in other European countries great efforts were made to first reach that level, which in most cases took several years to achieve due to the terrible damages to the population, buildings, infrastructure, production machinery and other artefacts. When early ideas regarding how to design electronic computers had matured to more realizable projects in the late forties, it was therefore not astonishing that the Swedish society was better prepared than most other European countries for the first computer wave. In addition to the well functioning society, the industrial and educational environment in Sweden – at that time with a strong emphasis on electrotechnology, electronics, technical physics and telecommunications – was a good growing ground for computer technology and some of the reasons for the early development of computers as well as the rapid general acceptance of computers in Sweden.

The first real computer manufactured in Sweden, an electromechanical machine, made its first calculations late in the forties. Its name was BARK (Binär Algoritmisk ReläKalkylator, which probably could be understood without translation). Next one was BESK (Binär Elektronisk Sekvens Kalkylator), designed 1951–53, for a short time the fastest computer in the world! It was then seriously claimed in the press that BESK could perform all necessary calculations for the whole Swedish society; perhaps there would be room for another one of the same kind! This was probably a sort of reaction from people thinking that too much money already had been spent on research and development regarding computers, or *matematikmaskiner* (machines for mathematics), as they then were called in Sweden. The society of researchers and engineers, however, fortunately had a completely different view of the future for such machines. They were helped by a crowd of potential users, such as the process industry, advanced administrations, the telecommunications administration and industry, the universities and the Swedish defence, in particular the Royal Swedish Air Force, which at that time had a nicely tailored budget for improving the air defence.

The first generation of computers – built up with electronic valves – did not really fit into airborne equipment but they were used very early for logistics and other tasks on ground. When transistors could be used also for higher frequencies and for advanced pulse applications in the late fifties, the second generation of computers appeared, which caused an even stronger computer boom. Now applications to be performed in aircraft or aboard ships as well as many applications for the process industry could be implemented as programs in computers – not to speak about all the telecommunications functions that now could be performed by small pieces of equipment and at low power consumption. This was the main boom for the Swedish defence as well as the telecommunications industry regarding computer utilization. Accordingly, already 1957 a transistorized (special purpose) computer designed by *Standard Radio och Telefon AB*, the Swedish subsidiary of ITT, performed radar target tracking and presentation. At the same time it was planned for airborne computers, after a year the first specification regarding computerized air defence early warning system was presented to the industry resulting in STRIL 59 and a few years later in STRIL 60, in the beginning of the sixties an extremely modern system for early warning and fighter control. The system was based upon digital technology as far as it was possible at that time. The following text tells us about an essential part of the system – today regarded as a peculiarity – a peculiarity that have been working for 30 years and was a forerunner of the real-time data bases of today.

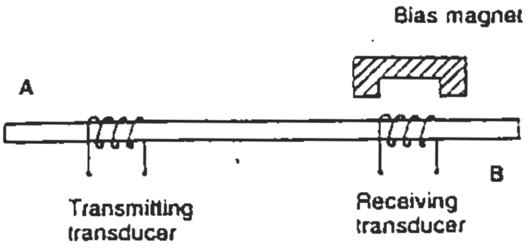

FIGURE 1 –

2. Magnetostrictive Storage Medium

A Nickel Wire with 30 Years of Service in the Swedish Air Defence

Certain metals, for example nickel and some of its alloys, possess the property of changing dimensions when subjected to a magnetic field. Conversely, if a piece of the metal in a magnetic field is subjected to a strain, the flux through the metal changes. These effects are known as *magnetostrictive* effects.

When the "new" Swedish air defence early warning system was established in the early sixties, two different types of command centres were introduced. Equipment for one type was contracted to *Marconi Radar Ltd.*, Chelmsford, Great Britain, and equipment for the other type to the Swedish branch of ITT, namely *Standard Radio & Telefon AB*, Stockholm. The Swedish industry groups of *SAAB* and *Ericsson* were also contractors for large information processing and communications equipment.

The computer delivered by Marconi, *TAC*, was claimed to be the first European transistorised computer. It used as a "central memory" a set of magnetostrictive delay lines, in which the stored data circulated. These delay lines were placed two and two together in 72 "trays", which were piled in racks. At that time circulating memories were common; in the United States magnetic drums were frequently used, and in Europe delay lines were used to some extent. The stored data circulated in a loop, and this type of memory had a very essential property: it permitted the stored data to be exchanged during a memory cycle in a very straight-forward way by means of breaking the loop. Whilst you were reading the "old" data from the output of the delay line, you could feed "new" data into it at the input. It was probably one of the first steps towards our real-time data bases of today.

A practical arrangement to illustrate the magnetostrictive effect is shown in figure 1. A rod (or tube) of magnetostrictive material is provided with two coils and one magnet. If a pulse of current flows through the transmitting coil, there will be a magnetic field, which causes a contraction or an expansion of the piece of rod lying within the coil, and a compression wave is transmitted in both directions.

At the receiving end the compression wave, which due to the magnetostrictive effect affects the magnetic flux through the material, will be detected by the coil of the receiving transducer. However, there will be reflections at both ends A and B of the rod. Fortunately, these reflections are easy to suppress by coating the ends with wax or clamping them between damping pads.

The velocity c of sound in the material,

$$c = \sqrt{(E/\rho)}, \qquad [E = Young's(elasticity)modulus, \rho = density]$$

determines the length of the rod for a certain delay time. For example, in our application, a three millisecond delay would be appropriate, which would require a pure nickel rod of about 14 metres. A straight rod of that length would of course – even 30 years ago – be considered most inconvenient! To solve this problem, the longitudinal mode of propagation was abandoned in favour of torsional wave propagation, which allowed the use of a thin wire instead of more rigid rods or tubes. The torsional mode of propagation, also, is much more insensitive to mechanical noise from the environment than the longitudinal mode.

The wire could be coiled up as in the actual delay line. However, such a long wire could be seriously affected by temperature variations. Another improvement was then introduced: Only the short sections of the wire used for transmitting and receiving the pulses had to be magnetostrictive. The propagation between transmitter and receiver could take place in any suitable material, for example in a wire with a very low temperature coefficient. However, the acoustical matching between the two materials had to be good.

Figure 2 is a schematic drawing of the delay line used for the central memory. At both ends are transducers. The transmitting transducer gives for each pulse a compression wave in a short wire, which in turn is transferred as a twist to the long wire, a *torsional pulse*. At the other end the torsional pulse is converted to a longitudinal wave in the short wire, which is detected by the receiving transducer thereby giving a current output.

The data stored in the delay line is always passed to the processing equipment and also fed to the input of the delay line. In order to let the processor get enough time to decide whether the actual data should be exchanged or not, an extra delay of 18 μs is introduced in the circulation.

In the wire 1500 pulses representing binary digits circulate, each pulse has a duration of 1 μs, and the separation between pulse positions is also 1 μs. The circulation or *cycle* time is 3 ms including the 18 μs extra delay.

Although not shown in the figure, there is also a mechanical adjusting device consisting of a screw used to trim the effective length of the delay line by letting the transmitting transducer slide along the coil. When the right effective length had been found, the screw was locked.

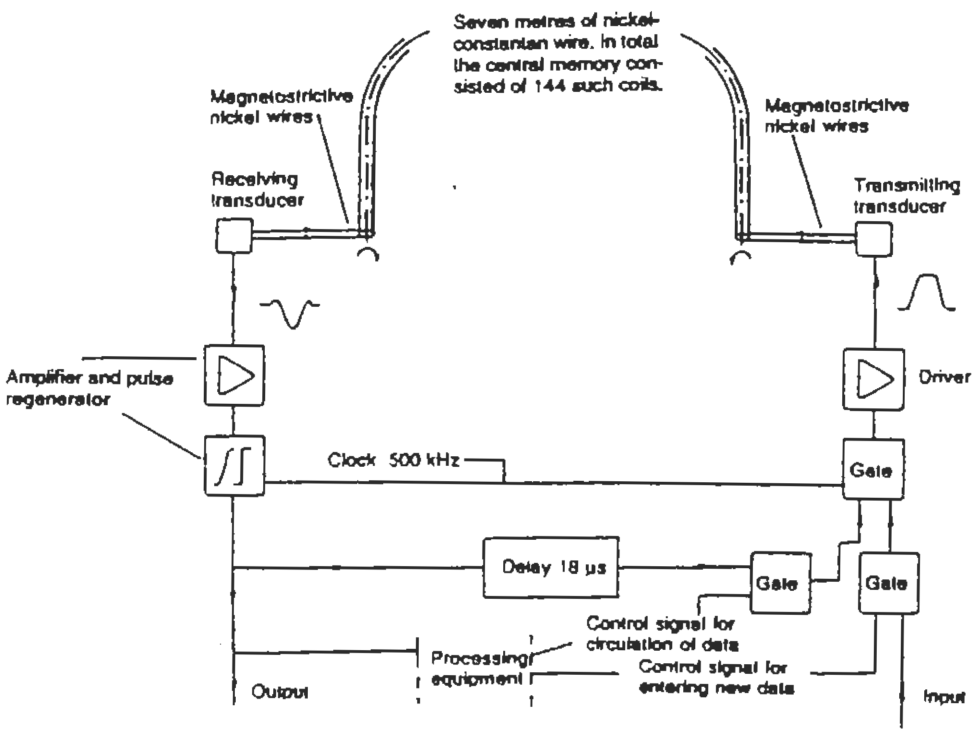

FIGURE 2 –

In contrary to the other circulating memory mentioned above, the magnetic drum, this magnetostrictive memory had to be refreshed. When travelling along the wire, the acoustic pulses were attenuated and distorted, so every third millisecond the pulse train was regenerated. This is in fact a process one has to apply upon more modern memories, the DRAMs (dynamic random access memory), which in general have to be refreshed every 64th millisecond.

Applications

The central memory was primarily used for storing data on tracked targets – both friendly and hostile. Each target was assigned a certain delay line, a "memory location". The processing equipment calculated coordinates and speed for each target based upon data from remote radar stations. It also calculated the estimated position for the next up-date, and performed intercept calculations. The results of all different kinds of calculations were stored for every target in the central memory, where different processes could fetch data for further use in other calculations and for presentation.

Some of the types of data within the memory were

- basic data: x- and y-coordinates, altitude

- calculated data: speed, heading, prediction of next position (six to ten seconds ahead);
- manually loaded·data: identification result, e.g. hostile, bomber, escorting interceptor, missile etc., friendly, interceptor, attack, reconnaissance, transport, civil etc., unknown, unidentified (not yet identified);
- engagement information: for own interceptor what (hostile) target it was supposed to fight down; for hostile target by what interceptor (of ours) it was engaged;
- some additional information regarding jamming etc.

All the calculations were based upon basic data which changed almost continuously. With an up-date rate of 6–10 times per minute for a radar station and, say, 100 targets to track and three–four different data updates to perform for each target, there would be 40–50 calculations per second. For some of these targets the processor was even more utilized, for example for intercept calculations. But the memory had a cycle time of just 3 ms, which roughly means that the mean access time for any data in the memory was 1.5 ms. Therefore the memory seldom wast he bottle-neck of the process.

The real-time features of the memory are obvious if we consider the fact that when new radar data for a target was available, within 3–6 ms all the data for that target was updated and predictions performed.

3. Concluding words

The central memory, or *store* as the British manufacturer preferred to name it, thus had the capacity of 1500 times 144 bits or *216 k bits*. However, at that time it was thought that hardware was unreliable, so the memory was doubled, which means that the effective capacity was only 108 k bits. But this magnetostrictive memory turned out to have a very high degree of reliance! The surrounding electronics, however, worked more in accordance with the prejudgement, so now and then we were happy to have the high redundance of two memories with exactly the same contents. 1963–1992, if one includes part of 1962 after installation and during all kind of tests, this makes 30 years of excellent service, which is about five to six times the commercial lifetime of memories today!

Acknowledgement

For having read the manuscript regarding the magnetostrictive delay line and given me valuable suggestions for the final version I am very much obliged to Mr. John M. Williamson, who in fact is the engineer that thirty-four years ago designed the delay line for the central memory.

Literature

This paper is to a certain extent based upon information given in the textbook by Charles V.L. Smith, *Electronic Digital Computers*, McGraw-Hill, 1959.

A good theoretical treatment of magnetostriction can be found in "W.P. Mason, *Electromechanical Transducers and Wave Filters*, Van Nostrand, 1942". (More than half a century ago!)

The following paper describes the type of delay line discussed here. J.W. Fairclough, A Sonic Delay-line Storage Unit for a Digital Computer, *Proc. of the Convention on Digital Computer Techniques*, I.E.E., London, Apr. 9-13, 1956.

Further references could be found in the textbook by C.V.L. Smith.