Jonathan Coopersmith

The changing picture of fax

Introduction

What is a fax machine? Is it a pantelegraph? A wirephoto transmitter? A fax modem? Or is the first machine a failed variation of the telegraph and the last a peripheral device for a computer?

The basic definition of a fax machine – a machine that electrically transmits an image – has not changed since 1843. The three main components were, and remain, the scanner–transmitter, the receiver–recorder and the transmitting medium. What has changed are the enabling technologies, and, equally importantly, the assumptions of the users. As fax technology became less comprehensible and visible to its users, fax machines, somewhat paradoxically, became easier to use and thus far more successful than earlier generations of devices.

Three broad intertwined trends appear in the century-and-a-half of fax history. First, the technical complexity of fax equipment has vastly increased over time. Second, as machines have become more sophisticated, they have become more like 'black boxes', their technical aspects increasingly hidden from view. Third, they have become far easier to use.

These developments have taken place over four generations of technology – mechanical, electromechanical, electronic and one that can be called the computer generation, even though the third generation depended on computer components. The first began with Alexander Bain's patent in 1843 and depended exclusively on the telegraph. The second originated around 1900 with the development of the photoelectric cell and employed the telephone and radio as transmission media. The third phase began in the 1960s and depended on microelectronics to make large-scale commercialisation finally possible in the 1980s. The fourth phase, the integration of faxing with the computer and the Internet, began in the late 1980s and was essentially completed by 2000.

The first use of facsimile was telegraphic, reflecting both the state of technology in the nineteenth century and the idea of sending the exact image – *fac simile* (Latin for 'make similar') – of the original message. The first generations of fax developers, such as Alexander Bain and Frederick Bakewell, conceived of facsimile as part of the regular – and rapidly evolving – world of telegraphy. Notwithstanding the technical challenges, or possibly because of them, many telegraph engineers and inventors tried to improve or perfect facsimile systems. The list is long and honourable – Alexander Bain, Frederick Bakewell, Alexander Graham Bell, Lucy Fossarieu, Gaetano Bonelli, Abbé Caselli, Thomas Edison, Bernard Meyer , Henry Cook, Guyot D'Arlincourt,

William Sawyer, Patrick Delany and Charles Cros to name the main contributors to the art of facsimile.

Facsimile and telegraphy

Early fax machines, like telegraphs, were designed for use in a central telegraph office, which provided the friendly setting often essential for a new technology. The telegraph company or administration could dedicate trained personnel and resources in a controlled environment, and the equipment was designed by engineers for engineers or technicians instead of an office worker, allowing more to be demanded from the operators. So the 'smarts' were in the people, not just the machine. The customer did not send the message directly, but prepared it and then gave it to special telegraph operators for transmission.

A century-long appeal of facsimile for telegraphers was the allure of error-free transmission. In 1848, Bakewell claimed his system offered, as well as speed, 'authentication of telegraphic correspondence by the signatures of the writers, freedom from the errors of transmission, and the maintenance of secrecy'.[1] Almost a hundred years later, promoters of facsimile still promised that replacing ordinary telegrams with an exact reproduction of the sender's original would eliminate errors of transcription and word count while reducing labour costs.[2]

Throughout their history, fax machines have incorporated the latest technology. Consequently, as befits equipment on the cutting edge (or bleeding edge, depending on one's experience), they were expensive, demanded special attention and resources, and proved dependent on the quality of the new technologies they incorporated.

The pre-photocell facsimile systems needed the physical contact of a stylus (or styli) over an electrically insulated or three-dimensional message. This usually meant writing a message in insulating ink on a metallic surface or sprinkling powdered shellac over an adhesive ink and then heating it to melt the shellac. That is, sending a message demanded extensive preparation and special materials. The machine used a revolving cylinder or a curved plate to advance the message past the scanning stylus, which usually moved.

To look through the pages of *Mechanic's Magazine* or electrical journals is to realise the beauty and art of the early fax machines. As the Caselli machine, which enabled the French government to introduce the world's first regular fax service in the 1860s, illustrates, these machines revealed their workings to the world (Figures 1 and 2). These electromechanical devices exhibited a very high level of craftsmanship and precision, but, in the words of Dr Lardner:

> This form of telegraph has proved too slow in operation, and too uncertain and difficult in management, to allow of practical application; besides which, it requires the apparatus to move onward at exactly the same speed at each end, a result almost impossible to attain.[5]

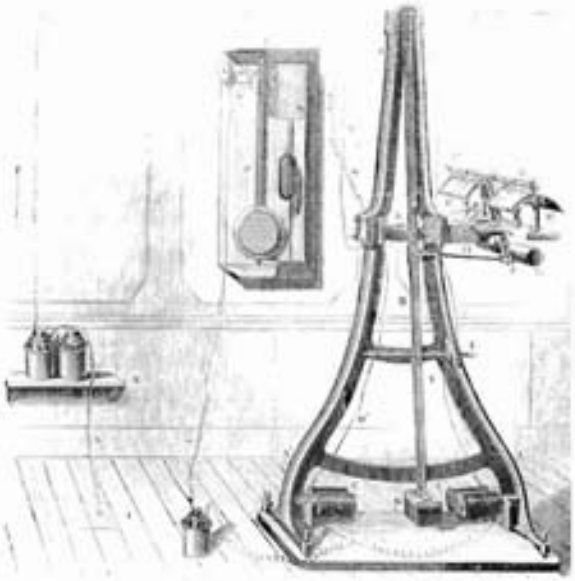

Figure 1 Caselli pantelegraph, 1865.[3]

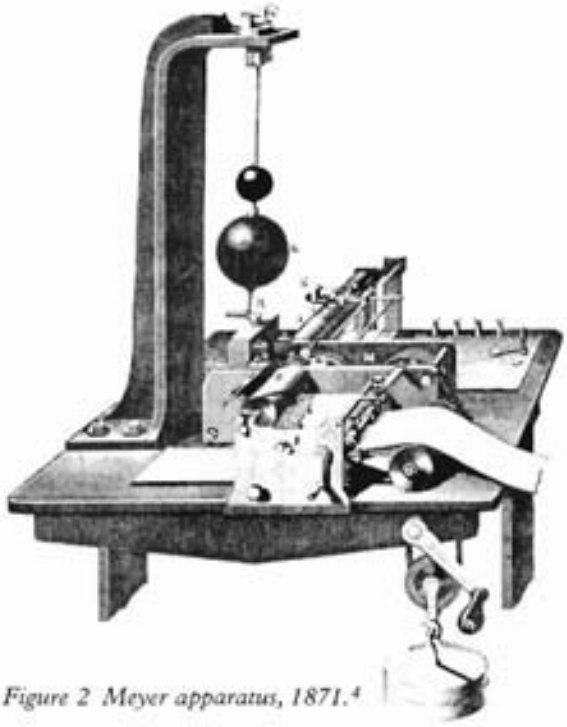

Figure 2 Meyer apparatus, 1871.[4]

As Thomas Edison noted in 1868, these early fax systems suffered from their reliance on complicated clockwork pendulum systems for synchronisation.[6] Mechanical gearing, no matter how precise or accurate, simply could not provide the precision necessary for fully synchronised transmission. Not until the 1960s and the advent of all-electronic fax machines with error-correcting algorithms was the challenge of synchronisation easily met for images.

The photocell and photography

The 1881 invention of the selenium photocell by Shelford Bidwell and its subsequent development eliminated the need for physical contact while scanning. The photocell also introduced the possibility of transmitting gradations of grey instead of just black and white. This led to the first major application of facsimile, transmitting photographs for newspapers.

The photocell inaugurated the 'blackboxing' of facsimile. Many models still kept the major components exposed – the cylinder revolving as the photocell traversed the guide screw, but much of the equipment now disappeared into metal boxes. Looking at the boxes provided no clue about how they operated or what they did.[7] This disappearance reflected changes in technology as much as the prevalent style of industrial presentation. To power the machines, electric motors replaced clockwork with unwinding weights. The photocell and its light source replaced the stylus and

its haptic imaging. Instead of impressive swinging of pendulums, environmentally isolated tuning forks attempted to provide synchronisation.

Although Germany's Arthur Korn introduced a pre-First World War system for transmitting newspaper photographs on the Continent, major growth and acceptance of picture telegraphy (PT) did not occur until the late 1920s, benefiting from wartime advances in photoelectric cells, vacuum electronics, telephone and radio transmission and other technologies. In the space of a few years, all major European postal, telegraph and telephone administrations (PTTs), as well as AT&T and RCA in the United States, introduced PT services (Figures 3 and 4).

Through the 1930s, the operational concept remained unchanged: PTTs and telecommunication firms provided the actual service. Customers came to them. The first generations of photocell-based scanning and drum cylinders were placed at a central PTT/telecommunications office. Material, however, did not need special preparations by the customer, greatly easing the effort needed to send a facsimile. The operators, however, often had to prepare the image, which increased the overall transmission time.

Transmitting a 3 × 5-inch photograph took only 20 minutes; however, the total time from acceptance to delivery averaged 2 hours. The difference included preparation, waiting for an open line and ensuring a good connection. Because higher-quality circuits provided more accurate transmission, pictures often had to wait until a suitable trunk circuit became available. Even over the best AT&T lines, 30 per cent of all transmissions had to be re-sent.[8]

Despite expectations of wide use, the PTTs soon discovered that only newspapers, fiercely competing among themselves to publish the latest news first, were willing to pay the handsome prices for the benefits of rapid transmission. A phototelegram from London to Germany cost between £1 and £4, a large sum of money in the 1930s.[9] Air mail to Paris cost fourpence for the first ounce and

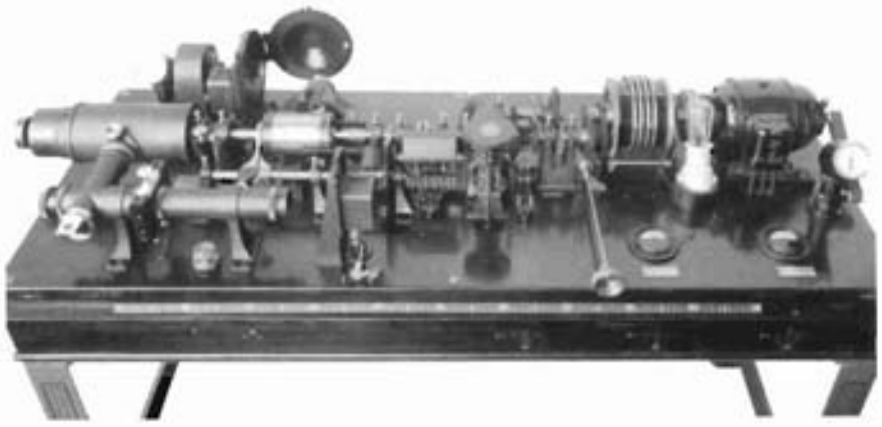

Figure 3 Telefunken equipment of 1930. (Deutsches Museum)

Figure 4 Siemens–Karolus–Telefunken system of 1929 with supporting equipment. (Deutsches Museum)

threepence for each additional ounce, so an air-mail package could weigh 3 pounds before reaching the cost of one phototelegram.[10] An RCA Photogram from New York to Berlin cost $57 compared with 6 cents for a 2-ounce letter.[11]

The failure of facsimile

The European PTTs, concerned less about profit than providing services, kept offering phototelegrams through the Second World War. In the United States, even though ATT reduced the cost of sending a picture from New York to Chicago from $50 in 1925 to $20 by 1927, its Picture Telegraphy business proved a solid money-loser so the corporation dropped it in 1933. The technology survived in the form of wirephoto for the Associated Press in 1934.[12] For the first time, actual users – trained newspaper photographers and darkroom technicians – directly operated the facsimile equipment. This was the first real commercial success of facsimile. Unsurprisingly, it occurred in a niche market of users who had specific needs that faxing could serve better than other approaches and who were willing to invest human, material and financial resources.

A 1928 AT&T survey found 18 different systems under development in Europe, Japan and the United States.[13] Like their telegraphic predecessors of the nineteenth century and electronic successors, these machines explored a variety of technical approaches, demonstrating the wide range of perceived technological options and market possibilities. Not until the 1970s would so many players again enter the facsimile market.

The technology rarely matched proposed applications, as RCA demonstrated in the 1930s. RCA promoted radio-based facsimile

(Figure 5) as a substitute for domestic telegraphy, for transatlantic picture transmission, for weather maps to ships, for duplication and, most interestingly, as a way to broadcast newspapers to homes and offices. Despite significant investments and technical developments, all these efforts failed. The cost was too great, the transmission too slow, the equipment too fragile or unreliable and alternatives too compelling.

Broadcast facsimile involved the most fundamental rethinking of a fax machine yet and the most serious effort to create a large base of consumers. The concept was simple: a newspaper would broadcast its latest edition to fax recorders attached to radios. The initial faxpapers would be 'flash news', intended to provide readers with breaking news. Ultimately, faxpapers might replace the entire process of printing and distributing a newspaper.

The major challenge was the recorder. To attract customers, designers expected the user to have minimum technical knowledge and no significant contact with the machine save for refilling the paper rolls. This goal, minimising user involvement with the recorder, posed a major technological challenge. RCA considered unattended operations and high reliability essential for success. Yet a fully automated receiver necessitated putting the 'smarts' in the machine, thus creating a more complex and costly electromechanical device. RCA hoped for a recorder that would sell for under $50; actual costs were an order of magnitude higher. Although the transmission time for four pages shrank from one hour in 1938 to 15 minutes in 1948, the concept still proved too slow and too costly, especially compared with simply turning on a radio or spending a few cents to buy a newspaper.[14]

Fax broadcasting attracted substantial press attention, partly because its implied potential to transform the news media was so great. Far less heralded but far more successful was the attempt to turn the fax machine into an extension of the telegraph. The technological dynamic was to increase the efficiency and lower the costs of telegraphy. No company developed this further than Western Union, starting in the mid-1930s. Until the 1970s, this proved the most successful application of fax, if measured by the number of machines in use.

Western Union: facsimile as telegraphy

For Western Union, facsimile promised to provide the exact reproduction of a telegraphic message, thus avoiding transmission errors, which were the cause of the company's expensive 'Accuracy First' programme. Other advantages were lower labour costs, by eliminating operators because of more automated operations, and faster message handling. Western Union began serious development of facsimile technology in 1935 and developed two major lines of automatic

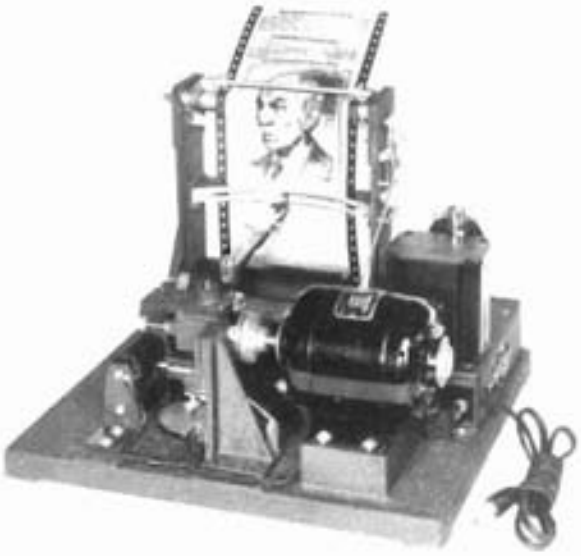

Figure 5 Finch radio facsimile newspaper receiver of 1938 with cover removed. (Smithsonian Institution)

Figure 6 The ultimate black box: RCA Ultrafax system of 1950. (David Sarnoff Laboratories)

equipment. One was for long-distance trunk circuits, where the equipment transmitted telegrams between large Western Union offices.[15] More visibly, the firm also developed fax machines for its patrons to use in their offices or in public spaces.

In the same way that ATT reshaped its picture telegraphy service from a public service to a private network for the Associated Press, Western Union found a successful market by redefining the customer. Instead of individuals, Western Union focused on businesses. In the late 1930s the firm introduced Telefax equipment as an 'excellent opportunity' to improve service for businesses too small to justify installing a teleprinter but sufficiently large to demand the daily services of messengers.[16] By December 1941, Western Union had 200 Telefax circuits in operation in New York, Chicago, Atlanta and San Francisco.[17] 'Concentrators' at branch offices transmitted and received telegrams from customers' offices. The technology evolved, always in the direction of more automated, faster operations.

After the Second World War, Western Union introduced Deskfax, a smaller version of Telefax that extended the ability to send and receive telegrams directly to and from an office desk. Messages sent from a Deskfax or public machine arrived at a central office for transcription into telegraphic code.[18] Compared with RCA's efforts (Figure 6),

Deskfax technologically was a step backward from photocells to a stylus that physically touched electrically-sensitive paper. But the small machine was inexpensive and very easy to use – the sender just put a message form into a slot and pushed a button. This simplicity was one reason for its success. The other reason was that Western Union integrated Deskfax into an existing system of communications. Designed for minimum maintenance and adjustment, the 45,000 Deskfax machines became the most widespread application of facsimile technology until the mid-1970s, when they were eclipsed by telephone-based fax machines.[19]

From the 1950s until the early 1960s, Western Union created variations of Deskfax for a wide variety of niche markets where closed systems could complement fax's advantages of exact reproduction of a message and low labour costs. The development of automatic switchboards allowed Western Union to offer private fax networks for subscribers to transmit directly to other patrons or via the central operator to non-subscribers.[20] Intrafax, for example, was a leased private facsimile system for internal correspondence using Deskfax-type transceivers linked to a central company message centre. LetterFax sent letter-size documents instead of the smaller telegram-size messages. These profitable services accounted for $42 million of Western Union's $255 million in revenues in 1958.[21]

Western Union also developed telegram transmitters for public use. Installed in lobbies and other public places, these machines enabled anyone to write a message and dispatch it immediately to the local Western Union office. The coin-operated machines replaced special telephones where customers called in their telegrams. First displayed at the 1939 New York World's Fair and expanded as late as 1957, Autofax suffered from physical vandalism and hooligans 'sending sketches and poetry of the type found on public washroom walls'.[22]

From back room to front office

Partly because of wartime experience, demand grew in the 1950s for specialised fax equipment to transmit weather maps as well as photographs. By the 1950s, some small markets used specialised equipment that did not demand extensive training. Often these machines could only perform limited tasks and were linked in a dedicated network. Banks, for example, employed facsimile machines to verify signatures on cheques with signatures on file in a central office. Such dedicated markets also provided initial markets for the new generation of general-purpose machines in the 1960s. Some railway companies, which had a specific need for transmitting waybills, adopted fax, replacing telephone calls and telegraphy.

Fax manufacturers and telephone companies also experimented with general-purpose equipment and services for broader audiences in the 1950s. Despite the commercial failure of these trials, the fax

community assumed that the next evolutionary step was to shift machines from the central post office and specialised uses to the business office.

Moving from a niche to the much larger general market demanded very different assumptions about the equipment and its marketing. Among the technical assumptions were higher machine reliability, less operator expertise and better quality telephone lines. Equipment had to be more robust and operate in less controlled environments, which demanded major technological and packaging developments. Fax machines became more hidden in their external appearance, enclosing components to minimise the possibility of unskilled users, such as secretaries and executives, damaging the machine. Another incentive was the desire to offer an attractive machine that would look appropriate in an office instead of a back room, and that would confer prestige and status to its users.

Spearheaded by Western Union's Deskfax, faxing began moving physically closer to the originator of the document. Instead of travelling downtown or mailing a photograph to the Central Post Office in the 1930s, users could remain at their desks with Deskfax in the 1950s or just walk down the hall to the Xerox Telecopier in the late 1960s. Sending faxes was done by the same division of labour involved in sending a letter or making a photocopy. The sender now usually was a staffer, often a secretary, not a technician.

The mid-1960s marked the birth of a new era in facsimile, the era of the general-purpose machine. It culminated two decades later with the integration of facsimile into regular office operations. Pulling facsimile into this new era were liberalised access to telephone networks, the growing cost of alternative forms of communication, the increasing globalisation of business and the rising demand for rapid communications. Of particular importance was faxing across time zones, especially internationally. Facsimile enabled companies and individuals to send letters worldwide, regardless of the time. Unseen but essential technological changes in the public telephone network produced a vastly improved medium for fast, error-free transmission. Without these changes, invisible to users, facsimile would have required special high-quality circuits which would have restricted faxing to point-to-point transmission instead of universal access to other fax machines.

The black box arrives

Pushing facsimile were technological improvements in components that created a smaller, faster fax machine that could operate on regular telephone lines. The first generation of machines in the mid-1960s took 6 minutes to transmit a page and the second generation of the mid-1970s needed only 3 minutes. The third generation, in the 1980s, took less than a minute.

The introduction by Xerox of the Telecopier in 1966 provided the first general-purpose equipment designed for standard office operations over a regular telephone line instead of costlier special circuits. Customers could both send and receive faxes with minimal training and standard office skills (e.g. making telephone calls and operating a photocopier). As in previous equipment, the message had to be clipped onto a cylinder. To use this new generation, the sender called the receiving party, then both placed their telephone handsets in acoustic couplers to initiate transmission.

By the mid-1970s, operation was even easier. The switch from a cylinder to a flat-bed scanner eliminated the need to clip the message onto the cylinder and simplified transmission of multiple pages. As a result of the liberalisation of the telephone market, telephone wall jacks replaced hard-wired telephone lines. Microprocessors removed the need for human-to-human contact by enabling automating sending and receiving.

The next two decades saw a slow flowering of facsimile as more firms, both established, such as Xerox, and new, such as Graphic Sciences and Rapifax, entered the market. Between 1970 and 1980 the number of installed machines in the United States grew from 25,000 to 250,000. While impressive, this was hardly the awakening of the 'sleeping giant' proponents had imagined.[23] The three main reasons for the slow growth were high costs, slow speed and incompatible machines. The incompatibility was deliberate, as manufacturers gambled that their equipment would dominate the market and establish the communications standards their competitors would have to follow. The gamble failed, impeding overall adoption of faxing because users had no assurance their fax machines could communicate with other users' equipment. Not until after 1980 and the acceptance of the Group 3 standards did a universal standard exist, a standard which led to the successful acceptance of faxing.

The initial international standards for the 6-minute and 3-minute machines (called Group 1 and 2 respectively) were ex post ante, reifying the existing order. In 1980, the International Telegraph and Telephone Consultative Committee (CCITT) of the International Telecommunication Union adopted recommendations for Group 3 digital fax machines. The Group 3 standard marked the first CCITT facsimile standard approved before any significant investment in equipment had occurred. The significance of the Group 3 standard is hard to underestimate.

How can you visually portray the significance of communication algorithms in particular and of software in general? Or the fact that, under recent CCITT procedures, these standards can be easily and quickly updated? The Group 3 standard of 2004 has evolved greatly since 1980, enabling companies to offer new, competitive features while still maintaining compatibility with earlier, less capable Group 3

machines. This major institutional development explains why Group 3 faxing proved far more durable than expected and is still around, despite numerous predictions of its demise.

Smaller, better, cheaper

Compatibility was not the only virtue of the Group 3 machines. Improved technology, such as light-emitting diodes (LEDs), decreased transmission time to under one page a minute and reduced machine size. Inexpensive thermal printing replaced the expensive and smelly wet electrolytic and dry electrographic papers that were dominant until the 1980s. Computer chips made possible automated operations, such as the initial contact between fax machines and broadcasting to multiple receivers.

Just as important was good design, which packaged these complex technologies into a form so easy to use that anybody could operate a fax machine. The enabling technologies, now truly inscrutable, were more sophisticated than ever, but faxing was never more accessible. The post-1980 Group 3 machines were truly black boxes, with the processing completely hidden from simple observation. Paper entered and left the machines without any indication of how the machine worked. Moreover, the box kept shrinking, from a free-standing machine to a stand-alone to even portable faxes. A large range of equipment developed to meet a wide range of users.

The introduction of the Group 3 equipment in the 1980s and the later diffusion of computer-based fax comprised part of a larger transformation of the office. Based on computers, office automation allowed – or demanded, due to reduced staffing – the actual creators of a document to transmit it without going through a secretary or central mail room.

The 'blackboxing' of faxing has accelerated even further in the world of computers and the Internet. From a digital perspective, facsimile, with its combination of digital scanning and analogue transmission, was an anachronism destined for the dustbin of history.[24] Yet the introduction of the fax modem in 1985 and Internet-based faxing a decade later kept facsimile alive while integrating it into the computer-based office.[25] Facsimile has evolved considerably beyond a stand-alone machine into individual computers, local- and wide-area networks, fax-on-demand, broadcast fax, and Internet-based fax. Documents may never appear in solid form, being composed and stored in computers. The modern black box of facsimile does not even have a corporeal form.

The sleeping giant did finally awaken, thanks to a combination of communication standards, improved technologies, a more communications-hungry environment and good packaging. Over time, facsimile operations shifted from the tight control of telecommunications firms and PTTs to niche markets and then a

general business market. As the pool of potential users grew, so did the number of uses they found for fax, uses unimaginable and unimagined decades or even years earlier. The trend has been towards increased ease and greater flexibility, a democratisation of technology.

Conclusion

The distinction between the operators and customers of facsimile changed with the technology. Initially, the telegraph operators controlled the entire process. As the technology evolved and improved, facsimile's consumers increasingly became the actual operators, and the technology itself became more and more hidden from the view of the user. As the capabilities of the systems increased so did the ease of use, increasing faxing's attraction to a wider range of audiences. This easier use was not automatic, but depended on building the increasingly complex technology into packages deliberately designed for operation by less-skilled operators.

As faxing has moved from being an easily understood system to a mysterious machine, its customers have grown from the few to the many and markets from the specific to the general. With the computer and Internet, faxing has entered the ultimate black box and essentially disappeared as a discrete entity. We still fax, but more and more documents never exist in physical form.

The beauty of fax technology is no longer in the actual machines, but in the elegance and efficiency of computer codes. This beauty, however, can be appreciated only by the cognoscenti, the programmers themselves. What the public can appreciate is the benefit of easy, inexpensive and reliable faxing.

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