

Telephones

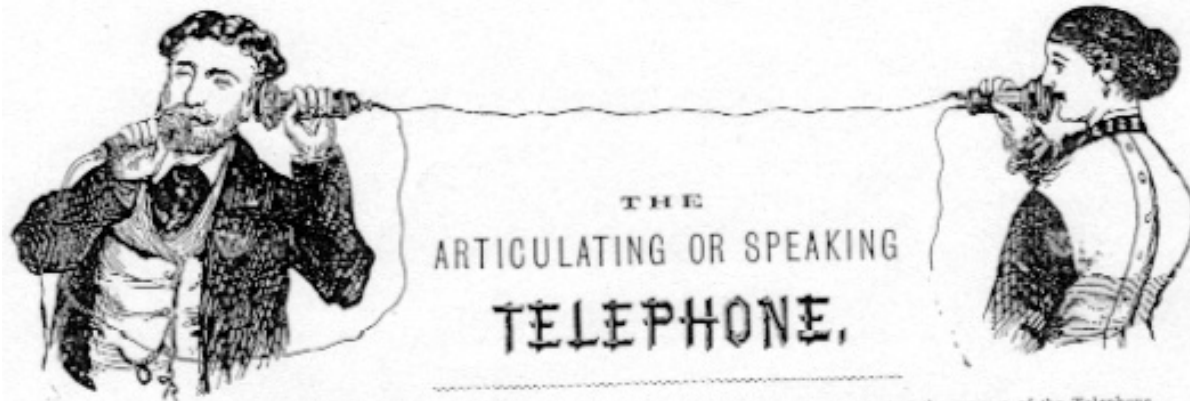
Bob Williamson

Department of Telecommunications Engineering
Research School of Information Sciences and Engineering
Australian National University
Bob.Williamson@anu.edu.au

March 20, 2002

<http://axiom.anu.edu.au/~williams/teaching/engn1211/telephones.pdf>

Telephones: From Old ...



THE ARTICULATING OR SPEAKING TELEPHONE,

During the past few months **MR. J. E. EDWARDS** has made a great variety of experiments to test the powers of the Telephone. It is found possible to speak with facility through a hundred miles of wire, and persons using them on lines of a few miles long can converse with ease in the same manner as though they were in the same room; even the voice of the person speaking can be recognized at the other end of the line.

In the early part of February a pair of these Instruments was fixed on Messrs. **McLEAN BROS. AND RIGG'S** line, which communicates between their Warehouse, 69 Elizabeth street, and their Store, 190 Bowler street west, near Spencer street, about one mile by wire, by which all their business is transmitted, the Telephone having superseded the Wheatstone instruments previously used. The Telephone can be seen in use, and also on sale, there at any time during business hours.

These Instruments are of great practical value. They can be used for any purpose, and in any position, without technical training, wherever communication or conversation is required from a distance, as between the principals and employes in commercial houses—between central and branch banks—in mining operations, between the manager's office and the employes in the mine—in large hotels or mansions—in factories of every description between the manufacturer and his factory, and between the superintendent and his leading men; and, in fact, it may be considered as an ordinary speaking tube, with all the advantages of Telegraphic communication.

The above arrangement sends but a wire between the points of communication, a pair or two pair of Telephones, and two alarm-bells to call attention to either end of the line, though a hundred yards or miles apart.

Further particulars and estimates may be obtained on application to **McLEAN BROS. & RIGG, 69 ELIZABETH ST.;** or

J. E. EDWARDS, the Manufacturer, 37 Erskine st., Hotham Hill, Melbourne.

... to New



The Telecommunications Industry

In 1995 18 companies in the USA paid a total of **\$US 7 740 000 000** for **the right to use** a total of 60MHz of spectrum space (around 1.9GHz)
[1]

Some of them (NextWave) have gone bust because of it. They bid \$US4.7B in 1996, but only paid 10% and filed for bankruptcy. The FCC repossessed them and resold them for a total of \$US17B to Verizon, AT&T and Cingular in 2001. [2]

Telecommunications is big business!

The Choice of the Telephone as Something to Study

In trying to understand the impact of technics or technology on society it is sometimes hard to determine which are the key technologies. For example, rather than the steam engine, Lewis Mumford quite clearly gives the clock the major role in the industrial revolution [15].

Whilst the determination of the key technology of the 20th century is perhaps harder still, most people would have telecommunications, and in particular the telephone, near the top of their list.

Fascinating Telephone Facts

- The worldwide telephone network is the largest integrated system in the world
- Global Information industry **\$1.5 trillion** per year [7]
- AT&T Revenues (1994) **\$US75 094 M**. Income **\$US4710M** [7]
- Telstra Revenues (1999) Basic access **\$2.02B**, Local Calls **\$2.65B**, National long distance **\$2.63B**, International **\$0.987B**, Mobile **\$2.5B** [AAP 30 August 2000]
- US Telephone infrastructure overall **\$US60 000M** in 1970 [4]. **\$US300 000M** now.

More Fascinating Telephone Facts

Was the driving force for many technological innovations: Vacuum Tube, Negative Feedback, Transmission Lines, Microphones, Transistor, Modulation

Driving force in development of **Systems Engineering**:

Systems engineering - a concept that itself originated at Bell Labs - which is responsible for deciding on a systematic basis what research and development projects are worth undertaking [8, p. 13]

At one time the ability to plan, engineer and operate complex reliable systems was largely confined to telephone companies. [9, p. 180]

Has had a very significant social impact on our society, often not explicitly recognised.

Structure of Lecture

- History: Where did the telephone come from?
- Technicalities: A single example of some technical aspects associated with the development of the telephone system.
- Social aspects of the telephone (in general).
- Gender related aspects of the telephone.
- Brief conclusion.

Bell's Motivation

Improvements in telegraphy.

The problem Bell was originally trying to solve was that of **Multiple Telegraphy**: How can one send multiple telegraph messages over the same wire simultaneously?

Or, how can one **multiplex** several signals?

A telegraph signal just transmits intermittent DC.

Through a difficult and long process [11] Bell managed to show that one could send different signals by switching different tones on and off. At the receiver, he needed a device for filtering out unwanted signals (his 'vibratory analyser' - a bank of resonators tuned to different frequencies.)

Bell's Invention of the Telephone 1

To invent the telephone, Bell had to:

Develop methods for generating undulating currents of different frequencies (with the multiple telegraphy motivation)

This undulating current was Bell's greatest innovation. Telegraphy involved make or break connections well suited to dots and dashes, but poorly suited to speech... But the result of combining undulating currents would be a sinusoidal curve that would be different for every combination of sounds, therefore allowing one to discriminate among different messages [11].

Determine that a human voice was a set of vibrations that could be converted into electrical currents (his phonoautograph)

In doing this he made explicit use of knowledge of the human ear:

Bell sought to duplicate the shape of the membrane of the human ear, the shapes of the bones attached to it, the mode of connection between the two, etc. [11, 13]

Bell's Invention of the Telephone 2

Design and build a microphone (originally liquid, then carbon)

In the design of the transmitting part of the telephone, he refined his phonoautograph. As Bell himself said:

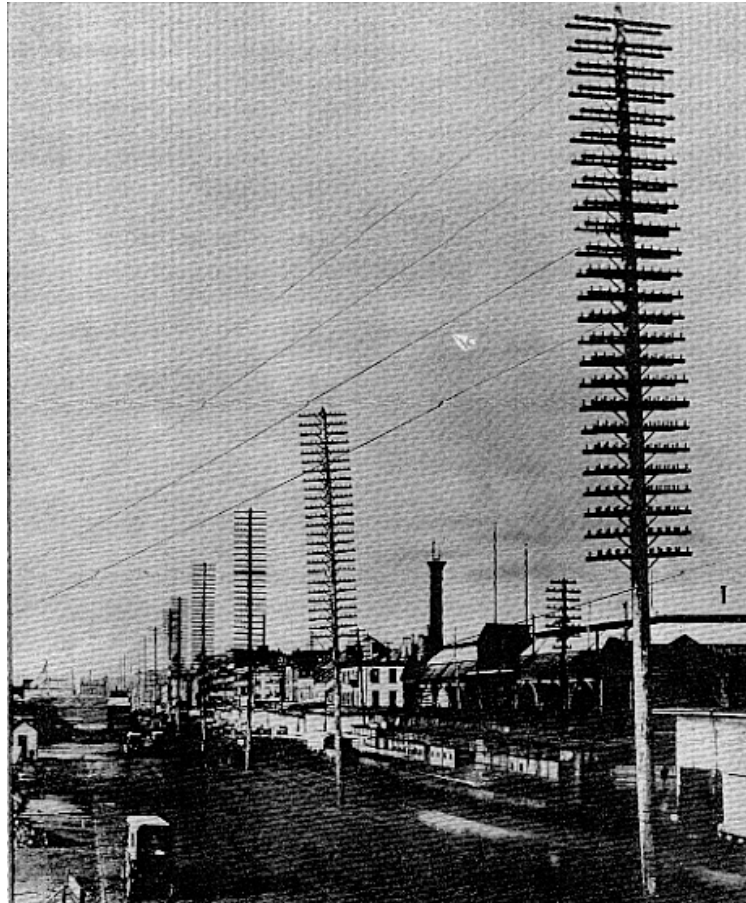
Make the mechanical transmitting instrument after the model of the human ear.
Make armature after the shape of the ossicle. Follow out the analogy of nature.
[12]

Design and build a transducer to convert the currents back to sound.

Originally he thought he would need a whole bank of tuned receivers, and it was a tremendous and serendipitous insight on June 2 1875 when he found that a device he had hoped would pick out just one of two tones applied to it, in fact reproduced the sum of the tones. (Thus it acted as a speaker.)

Wires 1

Originally above ground. With large numbers, there are problems.



Wires 2

Especially in bad weather.

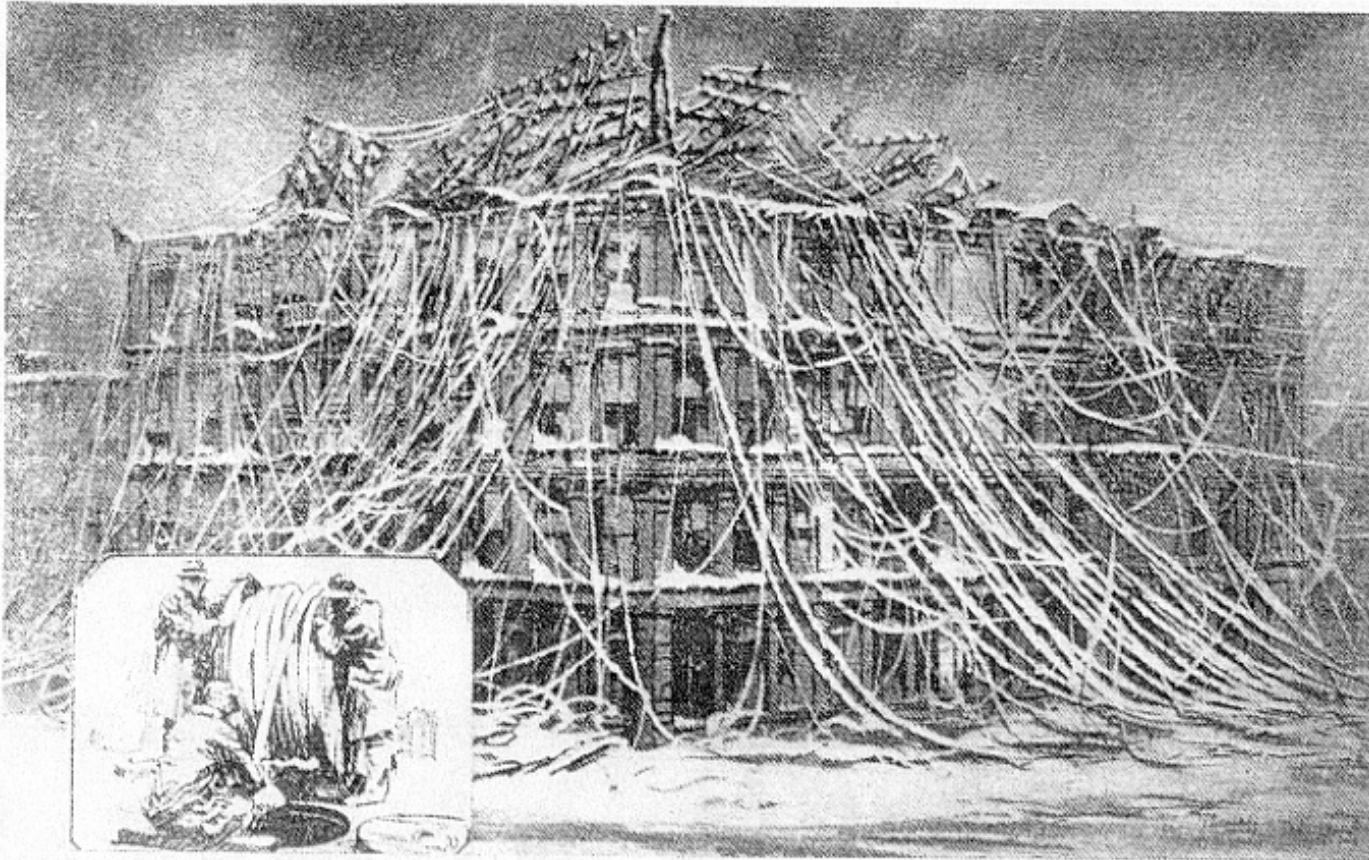


Fig. 4-9. Boston's central station after sleetstorm of 1881. Inset shows installation of underground cables. (From contemporary account in *Telephone Topics*.)

Wires 3

What is the circuit diagram for a piece of wire?

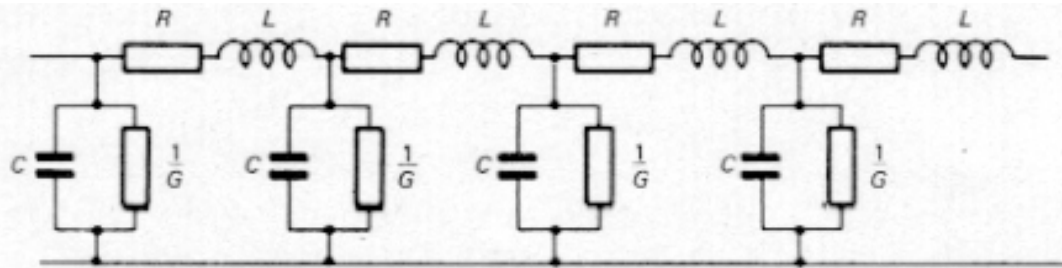


Fig. 6.1 Cascaded network representation of transmission line.

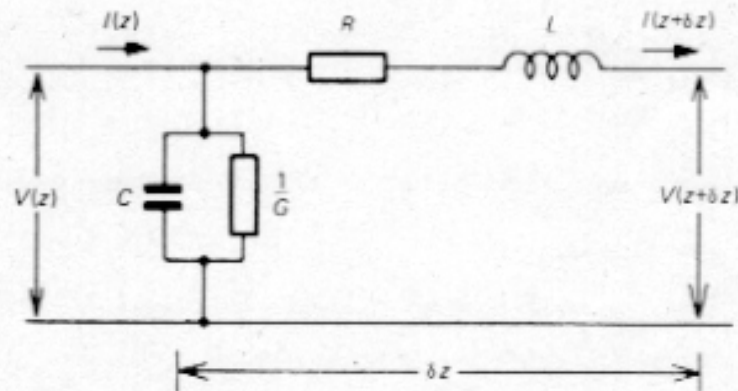


Fig. 6.2 Equivalent circuit for element of length δz .

Wires 4

The advance of **loading coils**: Vaschy **1889** and Heaviside **1893** recognised that artificially increasing inductance could help (either uniformly or by lumped loading).

By **1913** Coil loading extended range of open wire lines to 2000 miles [24]

The **attenuation** α of a line

$$|V(z)| = |V(0)|e^{-\alpha z}$$

where z is distance along line.

$$\alpha \approx \frac{R}{2} \sqrt{\frac{C}{L}} + \frac{G}{2} \sqrt{\frac{L}{C}}$$

Since $G \ll R$, increasing L decreases α .

Wires 5

Understandable in terms of 'characteristic impedance'.

Ground return versus two wire.

Ground return has lower resistance over long distances, but suffers from interference.

Balanced (twisted) two wire line more immune to interference (1880-1900).

Coaxial cable, waveguides, and fibre optic cable.

Radio phone (June 1946, St Louis) [8, p. 215]

Other technical aspects (nontrivial) include microphones, speakers, amplifiers and switches.

Consideration of Social Aspects

Consideration of social effects is all part of good engineering

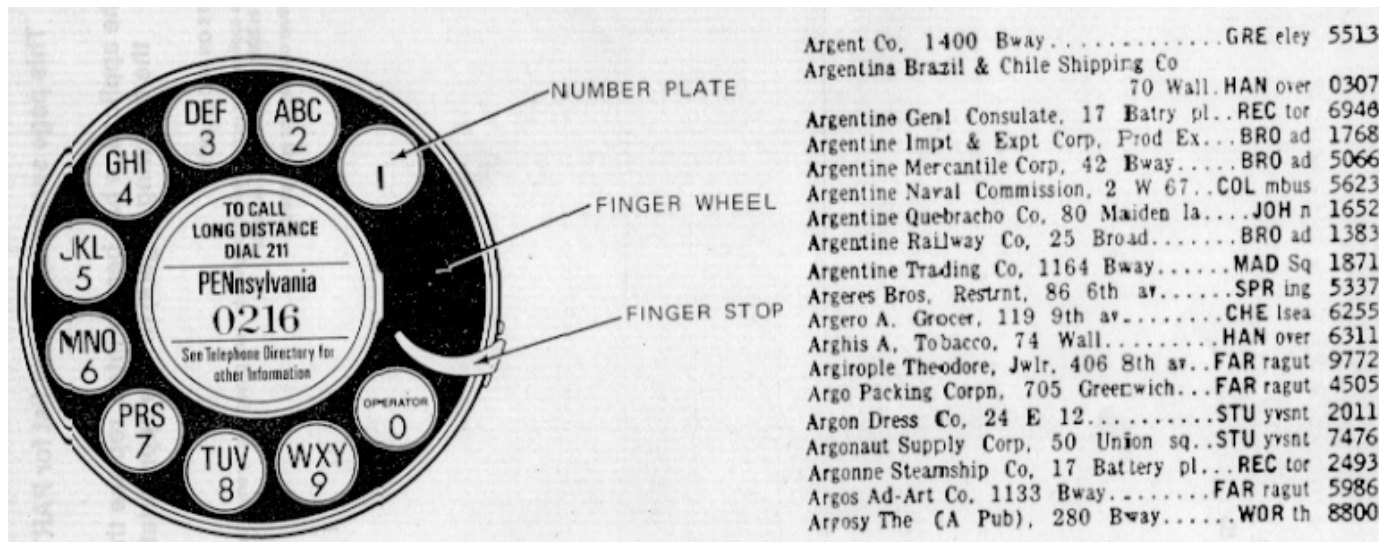
Increasingly, we are finding it necessary to take account of complex social, economic, even political factors which do not figure in the contents of the Engineer's handbook.

Haakon Romnes, President of Western Electric, 1961

Perhaps one of the things he had in mind was the difficulty AT&T had in introducing **All Number Calling** (ANC).

All Number Calling 1

Early 1920's, have numbers like **BRoad 5066**, and dials had letters on them.



Since 1930s in large cities a phone number was two letters (the exchange name), followed by 5 numerals such as **PL 59097** (Plaza 59097).

All Number Calling 2

Engineers foresaw a shortage of numbers, and difficulties when international networks were set up (different alphabets).

Early 1950s directory entries simply had letters (e.g. CR 1-2345) rather than CRestview 1-2345.

Mid 1950s, letter pairs bearing no relationship to name of exchange.

By 1960, introduction of all number calling in a few exchanges.

Mid 1962 half of Pacific Bell's phones on ANC.

Formation of Anti Digit Dialling League in opposition to the 'cult of technology' (San Francisco Bay area)

All Number Calling 3

Over 80% of users polled by the *San Francisco Chronicle* preferred the old system.

1963 California Public Utilities Commission ruled in favour of AT&T (response to petition for restraining order).

But thereafter AT&T moved more cautiously. Even in mid **1970s**, there were letter prefixes in Manhattan telephone directory.

Nowadays (in US) **1-800-IBM-3333**

In this small but illuminating matter, however, AT&T's failure to grasp the symbolic meaning of what it did for unassailable technical reasons was more than a public relations failure. It was a measure perhaps of the extent to which management in its necessary and miraculously productive obsession with technology had lost the larger vision so prized by Theodore Vail [an early president of AT&T]. [8, p. 273]

The Social Impact of the Telephone

Caution: Want to study something that is enormously taken for granted. Brooks, in his history of the telephone said:

Use of the telephone involves exposure; for some, to be 'hung-up on' is amongst the worst of fears; others dream of a ringing telephone and wake up with a pounding heart. The telephone's actual ring - more perhaps than any sound in our daily lives - evokes hope, relief, fear, anxiety, joy, according to our expectations. The telephone is our nerve end to society. [8, pp. 8-9]

Ingrained Habits

Consider how often you have had someone answer a phone when you have been in face-to-face conversation with them. This illustrates how imbued we are with the primacy of the telephone.

A remarkable example is related by Carpenter [34]:

Some years ago in New Jersey, a mad sniper killed thirteen people then barricaded himself in a house while he shot it out with the police. An enterprising reporter found out the phone number of the house and called. The killer put down his rifle and answered the phone. 'What is it?' he asked. 'I'm very busy.'

Dual Aspects

- Saves physicians from making house calls, but originally physicians thought it would increase the number;
- Invades our privacy with its ring, but enhances it by allowing us to transact affairs from within our homes;
- Allows dispersion of authority, but also tight supervision of distant subordinates;
- Makes information available, but reduces written records.

Pool [14] argues that these dual effects are

One reason for the relative paucity of literature on its social impact ... Rather than constraining action in one direction, the telephone is an agent of effective action in many directions.

Effects 1

Effect on Securities Trading: Before the telephone, if you wanted to trade in securities, you had to be down-town in a large city. With the introduction of the telephone:

A foreshortening of time and space, amounting to a new dimension came into stock and bond trading; Wall street went national. The economic effect was to increase the liquidity of securities and to increase vastly the fund-raising capability of business paving the way for economic expansion. [8, p. 115]

Effect on the Structure of Cities: The effect here is contradictory: Allowed the construction of skyscrapers [17, p. 140], as well as the development of suburbs [18].

Effects 2

Different countries: Effects are different in different countries. France has had a rather poor telephone system for much of this century. One can speculate that this was caused in part by the very strong controls the government wanted on all forms of communications.

In **1837**, a law was passed which imposed 'jail sentences from one month to one year, and fines of from 1000 to 10000 Francs on anyone transmitting unauthorised signals from one place to another by means of the telegraph machine and other means.' [8, p. 99] (!)

Gossip: Of course a more homely effect of the telephone is to provide much greater opportunities for gossip. In a remarkable piece of foresight, Bell in **1877** suggested

The time would come, when Mrs Smith would spend an hour with Mrs Brown 'very enjoyably cutting up Mrs Robinson' over the telephone; connection between the two women would be made possible by means of a central switching office. [19, p. 120]

Gender Issues Relating to the Telephone

First question is: can some **object** or **artefact** such as a telephone have an implicit gender?

One's first reaction is "of course not."

Because of its very concreteness, people tend to confront technology as an irreducible brute fact, a given, a first cause, rather than as hardened history, frozen fragments of human and social endeavour. [27, page 22]

But popular culture abounds with stories, usually at the expense of women, concerning Women's supposed confusion with new technologies.

A More General Question

A more general question is : “*Can Artifacts have Politics?*” In a nicely argued essay of that title, Landon Winner claims yes.

A very nice example is that of **Bridges**.

Robert Moses’ parkway designs, especially that to Jones Beach on Long Island.

Construct the bridges low enough, and buses can’t use the road; that keeps the poor people out...

Have to distinguish between an artifact “in itself” and how it is used. (Can use bridges in many ways).

There is now a lot of evidence of gender-specific usage patterns of the telephone, and it is in fact not unreasonable to talk of the technology itself (broadly construed) as being gender-specific [35].

Women's Use of the Telephone

Whilst there has been anecdotal evidence of different patterns of use of communication technologies such as telephones for a century now, there has been very little in the way of **systematic** study of the differences. [31, page 16].

Ann Moyal [31, 30] carried out an in depth study of 200 women drawn from a cross-section of Australian society.

Her results indicate a very distinctive pattern of use by women (on average).

- 2–6 instrumental calls per week (usually just a few minutes, unless they get stuck in a queueing system)
- 14–42 personal communication calls per week (typically 10–20 minutes, but often longer: “Grandma I want to tell you something!”).

Intimacy

The phone is a very intimate means of communication:

Women talk more freely and intimately on the phone with close friends than they do face-to-face.

As one of her respondents reportedly said:

You can convey “I know you’re worried” even if you don’t say it.

This mainly personal use of the telephone explains the very strong opposition to timed local calls (proposed towards the end of the 1980s). Moyal reports 92% of her respondents were against the idea.

Telecommuting

Another apparent gender difference relating to the telephone occurs in the idea of telecommuting.

The idea here is that people can work at home with the benefit of modern communications technologies.

Wajcman [27, pages 40–42] reports that whilst men viewed telecommuting as a way of working *from* home rather than *at* home, and ended up working longer hours than before; women tended to value the idea of telecommuting because it allows them to concurrently look after children.

The Social use of the Telephone

The clear distinction between the reported usage of the phone by women, and the received view of its use by men has a long history.

It is worth noting that to start with, the need to use a telephone had to be created. Theodore Vail said (1909) that the “public had to be educated to the necessity and advantage of the telephone.”

Claude Fischer [33] has documented how the telephone companies slowly and very begrudgingly accepted that a valuable use of the phone was simple sociability.

In 1909 a Seattle telephone manager wrote

The telephone is going beyond its original design, and it is a positive fact that a large percentage of telephones in use today on a full rental basis are used more for entertainment, diversion, social intercourse and accommodation to others, than in actual cases of business or household necessity.

(He listened to a sample of calls at his exchange.) [33, page 48]

How the Telephone was Marketed

From 1900 to World War 1, the telephone was marketed as

- Useful for businessmen as it impressed customers and saved time
- Useful for household management (calling the florist), or for husbands letting their wives know they would be late home;
- But sociability themes were rare: typical suggested use was to inform of safe arrival at the end of a journey.

By the 1930s, this had changed and advertisements for the telephone would say [33, page 40]:

1932 “Friends who are linked by the telephone have good times.”

1937 “ ... friendship’s path often follows the trail of the telephone line.”

Reasons for the Change

Fischer [33] in analyzing why the change in attitude occurred draws no very firm conclusions. We saw before how the telephone originally developed technically from the telegraph, and indeed it was operated by the same groups of people. Fischer's most firm conclusion shows this:

The key change was the loosening, under the influence of public practice with the telephone, of telegraph tradition's hold on the telephone industry.

The Differences Are Not Completely Accepted

It is remarkable, and probably quite significant, that given this acceptance within the general community, the different uses of the telephone (across gender, as we have been considering now) are still not given strong credence at the policy level.

Ann Moyal relates [30, page 68] the following about the presentation of her commissioned report into women and the telephone:

When Telecom Australia's senior management were presented with the Women's study, they expressed the view: "That is my wife, mother, and daughter." But they have, it would seem, failed to accommodate the findings as a basis for policy assessment.

Perhaps there is still a significant element of what the "right" use of the telephone is!

Conclusions 1

The story is interesting, and Fischer concludes his study of how the telephone industry (partially!) discovered sociability in the use of the telephone with a more general conclusion, which is worth presenting:

The story of how and why the telephone industry discovered sociability provides a few lessons for understanding the nature of technological diffusion. It suggests promoters of a technology do not necessarily know or determine its final uses; that they seek problems or “needs” for which their technology is the answer (cf. the home computer business); but that consumers may ultimately determine those uses for the promoters. And the story suggests that, in promoting a technology, vendors are constrained not only by its technical and economic attributes but also by an interpretation of its uses shaped by its and their own histories, a cultural constraint that can be enduring and powerful.

Conclusions 2

Rakow [35] concludes her study with:

The story of the history of the telephone cannot be told without accounting for the gender relations within which a telephone system developed. The telephone, in turn, was used to construct and maintain gender differences and hierarchies. The story of the telephone teaches us the lesson that communications technologies in a gendered society are not gender-neutral.

Engineers would do well to treat the literature on the topic as a good warning of the difficulty of predicting or controlling a technology; of the difficulty of predicting the social utility of a technology; and of the importance of listening to all sides of debates about technologies, and not just those couched in hard-headed technical terms.

The value of the telephone system today resides not so much in its technical infrastructure, which is readily replaced (for a mere trillion dollars world-wide), but in its deep cultural acceptance and use, which has taken a century to develop.

References

- [1] Trudy E. Bell, 'Main Event: Spectrum Auctions,' *IEEE Spectrum*, January 1996, page 28. Bell points out that 'The successful bidders spent \$13.60 to \$31.90 per person in the prospective service areas *for the licences alone.*' The frequencies will be used for broadband personal communication services.
- [2] Elisa Batista, "Next for Nextwave: Sink or Swim," *Wired News*, 31 January 2002. <http://www.wired.com/news/wireless/0,1382,50075,00.html>
- [3] M.D. Fagen (Ed.) *A History of Engineering and Science in the Bell System: The Early Years (1875-1925)*, Bell Telephone Laboratories, Incorporated, 1975
- [4] *Historical Statistics of the United States*, pp.139, 481-482; *Statistical Abstracts of the United States*, 1974, p. 364; *Statistics of Common Communication Carriers* 1972, p. 19. Quoted on page 336 of Ronald Abler, 'The Telephone and the Evolution of the American Metropolitan System', pp. 318-341 of [5].
- [5] Ithiel de Sola Pool (ed.) *The Social Impact of the Telephone*, MIT Press, Cambridge Massachusetts, 1977. (ANU Library G HE8735.S65 1977). This is a fascinating collection of articles covering all aspects of the social impact of the telephone.

Some other books, perhaps not as consistently interesting, but useful nonetheless are: Jerry L. Salvaggio (Ed.), *Telecommunications: Issues and Choices for Society*, Longman, New York, 1983 (ANU Library G HE7631.T43 1983) (chapter 3 and 9 are the most useful); Sven B. Lundstedt (Ed.) *Telecommunications, Value and the Public Interest*, Ablex Publishing Corporation, Norwood, New Jersey, 1990 (ANU Library G HE7604.T458 1990). The effect of telecommunications on cities, discussed in [18] is the focus of the large book by Stephen Graham and Simon Marvin, *telecommunications and the City: Electronic Spaces, Urban Places*, Routledge, London, 1996.

You may have heard telecommunications leaders recently talk of the "convergence" of telephones, television, and computers. The prospect of this occurring, with some predictions as to its effects was detailed in a report by a senior French Civil Servant (inspecteur-général of the Ministry of Finance) two decades ago: Simon Nora and Alain Minc, *The Computerization of Society: A Report to the President of France*, (1978); English translation: The MIT Press, Cambridge, 1980 (ANU Library LS QA76.9.C66.N6713). A worthwhile collection of essays on (*inter alia*) the impact of the computer on society is Michael L. Dertouzos and Joel Moses (Eds), *The Computer Age: A Twenty Year View*, The MIT Press, Cambridge, 1979. (ANU Library LS QA76.9.C66.C64)

The prediction of the effects of *new* communications technologies is a risky business. The warning implicit in the following passage by Mumford should be heeded:

By turns the steamboat, the railroad, the postal system, the electric telegraph, the airplane, have been described as instruments that would transcend local weaknesses, redress inequalities of natural and cultural resources, and lead to worldwide political unity - 'the parliament of man, the federation of the world.' Once technical unification was established, human solidarity, 'progressive' minds believed, would follow. In the course of two centuries, these hopes have been discredited. As the technical gains have been consolidated, moral disruptions, antagonisms, and collective massacres have become more flagrant, not in local conflicts alone but on a global scale. There is no reason whatever to think that radio and television will enable us to fare better, until they themselves become the instruments of wiser human decisions, and embrace every aspect of life, not limiting themselves to those that conform to the [requirements of "megatechnics"] [16, p. 296]

- [6] *Telstra 1995 Annual Report*, Key Financial Statistics,
<http://www.telstra.com.au/overview/annrep/1995/keyfin.html>
- [7] *AT&T Annual Report*, 1994,
http://www.att.com/factbook/fb_04_financial.html
- [8] John Brooks, *Telephone: The First Hundred Years*, Harper and Row, New York, 1976. (ANU Library G HE8815.B76 1976)
- [9] John R. Pierce, 'The Telephone and Society in the Past 100 Years,' pages 159-195 in [5].
- [10] John R. Pierce and A. Michael Noll, *Signals: the Science of Telecommunications*, Scientific American Library, New York, 1990. (ANU Library LS TK5101.P54 1990). This is an excellent introduction to telecommunications written at a level that would allow first year engineering students to read it very easily. It is nicely illustrated, and I recommend you have a look at it.
- [11] Michael E. Gorman, *Alexander Graham Bell's Path to the Telephone*, Hierarchical WWW site beginning at <http://jefferson.village.virginia.edu/albell/albell.html>. See the textual introduction at <http://jefferson.village.virginia.edu/albell/introduction.html>. (This site is a wonderful illustration of the non-linear process of invention. Sometimes historical studies tend to rationally reconstruct the sequence of events so that they appear more organised and goal directed than they really were. This site avoids that error admirably.)
- [12] A.G. Bell, *Experimental Notebook*, Entry dated February 21, 1876. Quoted in [11].
- [13] A.G. Bell 'Improvement in Telegraphy', Patent No. 174,465, witnessed 20 January 1876, submitted 14 February 1876, granted 7 March 1876. By the time of his 20th January, 1876 patent application, Bell could state:

Electrical undulations, induced by the vibration of a body capable of inductive action, can be represented graphically, without error, by the same sinusoidal curve which expresses the vibration of the inducing body itself, and the effect of its vibrations upon the air; for, as above stated, the rate of oscillation in the electrical current corresponds to the rate of vibration of the inducing body - that is, to the pitch of the sound produced. The intensity of the current varies with the amplitude of the vibration - that is, with the loudness of the sound; and the polarity of the current corresponds to the direction of the vibrating body - that is, to the condensations and rarefactions of air produced by the vibration.

- [14] Ithiel de Sola Pool, 'Introduction', pages 1-9 in [5]. Pool's point was made more generally, some 60 years ago by Lewis Mumford with regard to the benefits of all communication technologies, which are effectively 'instruments of multiplication':

As with all instruments of multiplication the critical question is as to the function and quality of the object one is multiplying. There is no satisfactory answer to this on the basis of technics alone: certainly nothing to indicate, as the earlier exponents of instantaneous communication seem pretty uniformly to have thought, that the results will be automatically favourable to the community [15, page 241].

- [15] Lewis Mumford, *Technics and Civilization*, George Routledge and Sons, London, 1946. (Originally published in 1934). Although now over 60 years old, this remains one of the best history of technics (the arts of technology as opposed to the artefacts) in existence. Some of the same ground is covered more recently in [21].

Regarding the clock, the following is from page 14.

The clock, not the steam engine, is the key machine of the modern industrial age. For every phase of its development the clock is both the outstanding fact and typical symbol of the machine: even today no machine is so ubiquitous. Here, at the very beginning of modern technics, appeared prophetically the accurate automatic machine which, only after centuries of further effort, was able to prove the final consummation of technics in every department of industrial activity.

And page 17-18:

The modern industrial regime could do without coal and iron and steam easier than it could do without the clock.

- [16] Lewis Mumford, *The Pentagon of Power*, Volume 2 of *The Myth of the Machine*, Harcourt Brace Jovanovich, New York, 1970.
- [17] Ithiel de Sola Pool, Craig Decker, Stephen Dizard, Kay Israel, Pamela Rubin, and Barry Weinstein, 'Foresight and Hindsight: The Case of the Telephone', pages 127-157 in [5]. They make the point (page 140) that without

the telephone there would be such a great number of messengers going in and out of large skyscrapers as to necessitate an enormous increase in lift capacity, so much so to make them unviable.

- [18] Jean Gottmann, 'Megalopolis and Antipolis: The Telephone and the Structure of the City,' pages 303-317 in [5]. Her assessment is captured on page 311:

[T]he experience of the last 100 years indicates that the telephone has been used in the evolution of settlement in diverse ways but mainly as a help in the development of large metropolitan systems with a more diversified and complex structure. Excellence of communications has made possible the more variegated, multiply partitioned structure of modern cities. The telephone has not made space fungible; it has not modified human nature much; however, it has permitted a spatial and political restructuring of cities of considerable portent.

- [19] Rosario J. Tosillo *The Birth and Early Years of the Bell telephone System, 1876-1880*, Doctoral Dissertation, Boston University, 1971. Cited and quoted on page 31 of [20].
- [20] Sidney H. Aronson, 'Bell's Electrical Toy: What's the Use? The Sociology of Early Telephone Usage', pages 15-39 of [5].
- [21] Lewis Mumford, *Technics and Human Development*, Volume 1 of *The Myth of the Machine*, Harcourt Brace Jovanovich, New York, 1966. A deep investigation into the nature of the machine. Mumford goes back thousands of years in a magnificent reinterpretation of the machine, and its role in human development. This book contains a detailed argument for the primacy of language over tools in the making of man. Although over-reaching sometimes in his conclusions, it is the most thought provoking books I have read on the subject.
- [22] J. Dunlop and D.G. Smith *Telecommunications Engineering*, third edition, Chapman and Hall, London, 1994.
- [23] W.C. Johnson, *Transmission Lines and Networks*, McGraw-Hill Kogakusha, Tokyo, 1963.
- [24] See [25]. Technical discussion in [23, pages 50-52], [22, page 183ff] and [3, pages 207-208] Loading coil patent awarded to Michael Pupin in June 1900.
- [25] *Encyclopaedia Britannica*, vol 21, page 780, 1970 edition.
- [26] Langdon Winner, "Do Artifacts Have Politics?", *Daedalus*, **109**, 121–136, 1980.
- [27] Judy Wajcman, *Feminism Confronts Technology*, Allen and Unwin, Sydney 1991.
- [28] David Noble, *Forces of Production: A Social History of Industrial Automation*, Knopf, New York, 1984.
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