

# CONTENTS

|  |             |
|--|-------------|
| <b>FOREWORD</b>  | <b>xv</b>   |
| <b>PREFACE</b>   | <b>xvii</b> |
| <b>ACKNOWLEDGMENTS</b>                                     | <b>xix</b>  |
| <br>   |             |
| <b>PART I INTRODUCTION AND PERIOD BEFORE 1800</b>          | <b>1</b>    |
| <b>1 Introduction</b>                                      | <b>3</b>    |
| 1.1 Definition of Telecommunications, 3                    |             |
| 1.2 Telecommunications Tree, 7                             |             |
| 1.3 Major Creators of Telecommunications, 11               |             |
| <b>2 Evolution of Telecommunications Up to 1800</b>        | <b>14</b>   |
| 2.1 Evolution of Telecommunications Prior to 1750, 14      |             |
| 2.2 Evolution of Telecommunications from 1750 to 1800, 16  |             |
| <b>3 Optical Telegraphy</b>                                | <b>18</b>   |
| 3.1 Tachygraphe of Claude Chappe, 18                       |             |
| 3.2 Optical Telegraph of Claude Chappe, 20                 |             |
| 3.3 Beginning of Optical Telegraphy, 24                    |             |
| <br>   |             |
| <b>PART II PERIOD FROM 1800 TO 1850</b>                    | <b>27</b>   |
| <b>4 Evolution of Telecommunications from 1800 to 1850</b> | <b>29</b>   |

|                 |   |           |
|-----------------|---|-----------|
| <b>5</b>        | <b>Optical Telegraph Systems Worldwide</b>                      | <b>34</b> |
| 5.1             | Optical Telegraph Systems in France, 34                         |           |
| 5.1.1           | Chappe Systems, 34  |           |
| 5.1.2           | Other Optical Telegraph Systems in France, 37                   |           |
| 5.2             | Optical Telegraphy Outside France, 45                           |           |
| <b>6</b>        | <b>Electrical Telegraphy</b>                                    | <b>48</b> |
| 6.1             | Evolution Leading to Electrical Telegraphy, 48                  |           |
| 6.2             | Electrical Telegraphy in the United States, 55                  |           |
| 6.2.1           | Morse Telegraph, 55   |           |
| 6.2.2           | Washington-Baltimore Electrical Telegraph Line, 59              |           |
| 6.2.3           | Pioneering Telegraph Companies, 61                              |           |
| 6.2.4           | House Direct Printing Telegraph Systems, 65                     |           |
| 6.3             | Electrical Telegraphy in Canada, 66                             |           |
| 6.4             | Electrical Telegraphy in Great Britain, 66                      |           |
| 6.4.1           | Electrical Telegraphs of Cooke and Wheatstone, 66               |           |
| 6.4.2           | Electrochemical Telegraph of Bain, 72                           |           |
| 6.5             | Electrical Telegraphy in France, 72                             |           |
| 6.6             | Electrical Telegraphy in Germany, 74                            |           |
| 6.6.1           | Railway Telegraph Lines in Germany, 74                          |           |
| 6.6.2           | German Electrical Telegraph Equipment for Public Use, 76        |           |
| 6.7             | Electrical Telegraphy in Austria, 83                            |           |
| <b>PART III</b> | <b>PERIOD FROM 1850 TO 1900</b>                                 | <b>85</b> |
| <b>7</b>        | <b>Evolution of Telecommunications from 1850 to 1900</b>        | <b>87</b> |
| <b>8</b>        | <b>Electrical Telegraph Systems Worldwide</b>                   | <b>91</b> |
| 8.1             | Telegraph Transmission Technology, 91                           |           |
| 8.1.1           | Open-Wire Lines, 91   |           |
| 8.1.2           | Underground Cable, 94   |           |
| 8.1.3           | Submarine Cable, 95   |           |
| 8.2             | Electrical Telegraph Lines in the United States, 98             |           |
| 8.2.1           | Western Union, 98   |           |
| 8.2.2           | The Pony Express, 98  |           |
| 8.2.3           | First Transcontinental Telegraph Line, 99                       |           |
| 8.2.4           | Collins Overland Telegraph Line and the Purchase of Alaska, 100 |           |
| 8.2.5           | The Hughes Direct Letter Printing Telegraph, 103                |           |
| 8.3             | Electrical Telegraph Lines in Canada, 104                       |           |
| 8.4             | Electrical Telegraph Lines in Great Britain, 106                |           |
| 8.5             | Summary of National Electrical Telegraph Achievements, 107      |           |
| 8.6             | Major Terrestrial Telegraph Lines, 119                          |           |
| 8.6.1           | Australian Overland Telegraph Line, 119                         |           |
| 8.6.2           | Indo-European Telegraph Line, 124                               |           |

|           |   |            |
|-----------|---|------------|
| 8.6.3     | Great Northern Telegraph Line, 128                          |            |
| 8.6.4     | Central American Telegraph Line, 128                        |            |
| 8.7       | Submarine Telegraph Cables, 129                             |            |
| 8.7.1     | European Submarine Cables, 129                              |            |
| 8.7.2     | Transatlantic Telegraph Cables, 130                         |            |
| 8.7.3     | Submarine Telegraph Cables Connecting Europe Worldwide, 135 |            |
| 8.7.4     | Inter-American Submarine Telegraph Cables, 138              |            |
| 8.8       | Worldwide Electrical Telegraph Network, 139                 |            |
| 8.9       | Morse, the Father of Electrical Telegraphy, 141             |            |
| 8.10      | Morse Codes, 143  |            |
| 8.11      | Morse Telegraphers, 145                                     |            |
| <b>9</b>  | <b>Image Telegraphy</b>                                     | <b>147</b> |
| 9.1       | Facsimile Device of Bain, 147                               |            |
| 9.2       | Image Telegraph of Bakewell, 148                            |            |
| 9.3       | Pantelegraph of Caselli, 149                                |            |
| 9.4       | Autographic Telegraph of Bernhard Meyer, 151                |            |
| 9.5       | Telaugograph of Elisha Gray, 151                            |            |
| <b>10</b> | <b>Telephony</b>  | <b>153</b> |
| 10.1      | Evolution Leading to Telephony, 153                         |            |
| 10.2      | The Telephone of Alexander Graham Bell, 156                 |            |
| 10.2.1    | Alexander Graham Bell, the Father of Telephony, 156         |            |
| 10.2.2    | Early Days of Bell in Great Britain, 159                    |            |
| 10.2.3    | Bell's Telephone Experiments in the United States, 159      |            |
| 10.2.4    | Bell's Telephone: "It DOES Speak", 163                      |            |
| 10.2.5    | Bell Telephone Company, 165                                 |            |
| 10.2.6    | Bell's Honeymoon Trip to Europe, 167                        |            |
| 10.2.7    | Telephone Developments in Sweden, 174                       |            |
| 10.2.8    | Biggest Patent Battle on Telecommunications, 176            |            |
| 10.2.9    | Battle of David Against Goliath, 178                        |            |
| 10.2.10   | Pioneers Leave the Telephone Business, 179                  |            |
| 10.3      | Companies with Common Bell Roots, 180                       |            |
| 10.4      | Worldwide Introduction of Telephony, 181                    |            |
| 10.5      | International Telephony, 181                                |            |
| 10.6      | The Art of Telephone Sets, 185                              |            |
| <b>11</b> | <b>Telephone Switching</b>                                  | <b>188</b> |
| 11.1      | Manual Switching, 188                                       |            |
| 11.2      | Evolution Leading to Automatic Switching, 192               |            |
| 11.3      | Strowger System, 194  |            |
| 11.3.1    | Strowger's First Operating Exchange, 194                    |            |
| 11.3.2    | Strowger's Up-and-Around Switch, 195                        |            |

|   |  |            |
|---|--|------------|
| <b>12</b>                               | <b>Radio Transmission</b>                                | <b>199</b> |
| 12.1                                    | Evolution Leading to Radio Transmission, 199             |            |
| 12.2                                    | Experiments of Heinrich Hertz, 201                       |            |
| 12.3                                    | Radio Transmission from Theory to Practice, 204          |            |
| 12.4                                    | The Radio Invented by Marconi, 207                       |            |
| 12.5                                    | Radios of Marconi's Competitors, 212                     |            |
| <b>13</b>                               | <b>International Cooperation</b>                         | <b>217</b> |
| <b>PART IV PERIOD FROM 1900 TO 1950</b> |  | <b>223</b> |
| <b>14</b>                               | <b>Evolution of Telecommunications from 1900 to 1950</b> | <b>225</b> |
| <b>15</b>                               | <b>Worldwide Telephone Penetration</b>                   | <b>229</b> |
| 15.1                                    | Worldwide Telephone Statistics, 229                      |            |
| 15.2                                    | Telephone Penetration in the United States, 231          |            |
| 15.3                                    | Telephone Penetration Outside the United States, 234     |            |
| <b>16</b>                               | <b>Electromechanical Telephone Switching</b>             | <b>237</b> |
| 16.1                                    | Worldwide Introduction of the Strowger System, 237       |            |
| 16.1.1                                  | Strowger System in the United States, 237                |            |
| 16.1.2                                  | Strowger System in Canada, 238                           |            |
| 16.1.3                                  | Strowger System in Japan, 240                            |            |
| 16.1.4                                  | Strowger System in Germany, 241                          |            |
| 16.1.5                                  | Strowger System in Great Britain, 244                    |            |
| 16.1.6                                  | Strowger System in Austria, 246                          |            |
| 16.1.7                                  | Strowger System in Sweden, 246                           |            |
| 16.2                                    | Automatic or Semiautomatic Switching?, 247               |            |
| 16.3                                    | Electromechanical Indirect-Control Systems, 250          |            |
| 16.3.1                                  | Automanual and All-Relay Systems, 251                    |            |
| 16.3.2                                  | Lorimer System, 252                                      |            |
| 16.3.3                                  | Panel System, 255  |            |
| 16.3.4                                  | Rotary System, 258                                       |            |
| 16.3.5                                  | Uniselecter System in France, 260                        |            |
| 16.3.6                                  | LME 500-Point System, 261                                |            |
| 16.3.7                                  | Hasler Hs 31 System, 262                                 |            |
| 16.3.8                                  | Automatic Switching Systems in the USSR, 264             |            |
| 16.4                                    | Crossbar Switching, 264                                  |            |
| 16.5                                    | Private Switching, 266                                   |            |
| <b>17</b>                               | <b>High-Frequency Radio Transmission</b>                 | <b>269</b> |
| 17.1                                    | Evolution of Radio Technology, 269                       |            |
| 17.1.1                                  | Spark Radio Transmitters, 269                            |            |
| 17.1.2                                  | Squenched Spark Radio Transmitter, 271                   |            |
| 17.1.3                                  | Poulsen Convertor Arc Radio Transmitter, 274             |            |

|           |   |            |
|-----------|---|------------|
| 17.1.4    | Frequency Alternator Radio Transmitter, 277                 |            |
| 17.1.5    | Electronic Radio Equipment, 279                             |            |
| 17.1.6    | Shortwave Transmission, 280                                 |            |
| 17.2      | Maritime Radio, 281   |            |
| 17.3      | Mobile Radio, 285   |            |
| 17.4      | Intercontinental Radiotelephony, 287                        |            |
| 17.5      | RCA and C&W Created to Beat Marconi, 289                    |            |
| 17.5.1    | Radio Corporation of America, 289                           |            |
| 17.5.2    | Cable & Wireless, 290                                       |            |
| <b>18</b> | <b>Phototelegraphy</b>                                      | <b>294</b> |
| 18.1      | Kopiertelegraph of Gustav Grzanna, 294                      |            |
| 18.2      | Telautograph of Arthur Korn, 294                            |            |
| 18.3      | Telegraphoscope of Edouard Belin, 295                       |            |
| 18.4      | Siemens-Karolus-Telefunken Picture Transmission System, 296 |            |
| 18.5      | Facsimile Machines of AT&T and Western Union, 297           |            |
| 18.6      | Photograph Transmission Equipment in Japan, 298             |            |
| <b>19</b> | <b>Teleprinters</b>   | <b>300</b> |
| 19.1      | Teleprinter Development in the United States, 300           |            |
| 19.2      | Teleprinter Development in Great Britain, 303               |            |
| 19.3      | Teleprinter Development in Germany, 306                     |            |
| 19.4      | Teleprinter Development in Japan, 307                       |            |
| <b>20</b> | <b>Copper-Line Transmission</b>                             | <b>308</b> |
| 20.1      | Telegraphy Transmission on Copper Lines, 308                |            |
| 20.2      | Telephony Transmission on Copper Lines, 314                 |            |
| 20.3      | Phantom Circuits, 316                                       |            |
| 20.4      | Pupin Coils, 317  |            |
| 20.5      | Krarup Cable, 321   |            |
| 20.6      | Telephone Amplifiers, 322                                   |            |
| 20.7      | Analog Multiplexing, 324                                    |            |
| 20.8      | Digital Multiplexing, 327                                   |            |
| 20.9      | Coaxial Cable, 331  |            |
| <b>21</b> | <b>Radio-Relay Transmission</b>                             | <b>337</b> |
| 21.1      | Evolution Leading to Radio-Relay Transmission, 337          |            |
| 21.2      | World's First Radio-Relay Link, 342                         |            |
| 21.3      | Initial Radio-Relay Systems, 343                            |            |
| <b>22</b> | <b>Cryptography</b>   | <b>350</b> |
| 22.1      | Manual Coding, 351  |            |
| 22.2      | Automatic Coding, 352                                       |            |
| <b>23</b> | <b>International Cooperation</b>                            | <b>357</b> |

|   |            |
|---|------------|
| <b>PART V PERIOD FROM 1950 TO 2000</b>                                | <b>361</b> |
| <b>24 Evolution of Telecommunications from 1950 to 2000</b>           | <b>363</b> |
| 24.1 The Semiconductor Era, 364                                       |            |
| 24.2 Digitalization, 366  |            |
| 24.3 New Telecommunications Networks, 367                             |            |
| <b>25 Radio-Relay Networks</b>  | <b>369</b> |
| 25.1 Technological Development of Radio-Relay Systems, 369            |            |
| 25.1.1 All-Solid-State Radio-Relay Systems, 370                       |            |
| 25.1.2 Digital Radio-Relay Systems, 371                               |            |
| 25.1.3 Radio-Relay Systems for the Synchronous Digital Hierarchy, 374 |            |
| 25.1.4 Transhorizon Radio-Relay Systems, 375                          |            |
| 25.2 Radio-Relay Systems Worldwide, 376                               |            |
| 25.2.1 Radio-Relay Systems in North America, 376                      |            |
| 25.2.2 Radio-Relay Systems in Latin America, 376                      |            |
| 25.2.3 Radio-Relay Systems in Europe, 379                             |            |
| 25.2.4 Radio-Relay Systems in Asia, 381                               |            |
| 25.2.5 Radio-Relay Systems in Australia, 382                          |            |
| 25.2.6 Radio-Relay Systems in Africa, 383                             |            |
| 25.3 Wireless Access Systems, 386                                     |            |
| 25.4 Radio-Relay Towers and Aesthetics, 391                           |            |
| <b>26 Coaxial Cable Transmission</b>                                  | <b>397</b> |
| 26.1 Terrestrial Coaxial Cable, 397                                   |            |
| 26.2 Submarine Coaxial Cable, 399                                     |            |
| 26.2.1 Transatlantic Coaxial Telephone Cables, 399                    |            |
| 26.2.2 Worldwide Submarine Coaxial Telephone Cables, 404              |            |
| <b>27 Satellite Transmission</b>                                      | <b>407</b> |
| 27.1 Evolution Leading to Satellite Transmission, 407                 |            |
| 27.1.1 Rocketry Pioneers, 408   |            |
| 27.1.2 Passive Satellites, 410  |            |
| 27.1.3 Postwar Rocket Development in the United States, 410           |            |
| 27.1.4 Postwar Rocket Development in the USSR, 411                    |            |
| 27.1.5 Sputnik, the First Satellite, 412                              |            |
| 27.1.6 First Communication Satellites, 413                            |            |
| 27.2 First Synchronous Communication Satellites, 419                  |            |
| 27.3 Satellite Launching, 421   |            |
| 27.4 Satellite Transmission Systems, 426                              |            |
| 27.4.1 Global Satellite Systems, 427                                  |            |
| 27.4.2 Regional Satellite Systems, 428                                |            |
| 27.4.3 Domestic Satellite Systems, 431                                |            |
| 27.4.4 Mobile Satellite Systems, 433                                  |            |



- 27.4.5 Global Mobile Personal Communication by Satellite, 435
- 27.4.6 Multimedia Satellite Systems, 439

## **28 Optical Fiber Transmission 445**

- 28.1 Evolution Leading to Optical Fiber Transmission, 445
- 28.2 Terrestrial Optical Fiber Cable Systems, 456
- 28.3 Submarine Optical Fiber Cable Systems, 459
  - 28.3.1 Transatlantic Optical Fiber Cables, 460
  - 28.3.2 SEA-ME-WE Cable System, 461
  - 28.3.3 Caribbean ARCOS Network, 463
  - 28.3.4 Global Submarine Optical Fiber Cable Systems, 463
  - 28.3.5 African Cable Network Africa ONE, 466
  - 28.3.6 Various Submarine Cable Systems, 467
  - 28.3.7 Repeaterless Submarine Cable Systems, 467
- 28.4 Fiber-in-the-Loop Systems, 471
  - 28.4.1 Worldwide Testing of FITL Solutions, 472
  - 28.4.2 Delay of FITL Deployment, 475

## **29 Electronic Switching 480**

- 29.1 Continuation of Deployment of the Prewar Switching Systems, 480
  - 29.1.1 Crossbar Switching, 480
  - 29.1.2 Siemens Rotary Switch, 480
  - 29.1.3 End of the Strowger Switch, 482
- 29.2 Implementation of Automatic Telephone Switching, 483
  - 29.2.1 National Automatic Switching, 483
  - 29.2.2 International Automatic Switching, 484
- 29.3 Electronic Switching Systems, 485
  - 29.3.1 Evolution toward Electronic Switching, 485
  - 29.3.2 Preliminary Electronic Switching Systems, 489
  - 29.3.3 Commercial Electronic Switching Systems, 494
- 29.4 Digital Switching Systems, 495
- 29.5 Data Switching, 500
- 29.6 Integrated Services Digital Network, 505
- 29.7 Broadband Switching, 506
- 29.8 Private Switching, 507

## **30 Telex 510**

- 30.1 Continuation of Teleprinter Deployment, 510
- 30.2 Telex Service, 510
- 30.3 Teletex, 512
- 30.4 Termination of Telex Services, 512

## **31 Telefax 515**

- 31.1 Technological Development of Telefax, 515
- 31.2 Worldwide Telefax Penetration, 517

|   |            |
|---|------------|
| <b>32 Cellular Radio</b>  | <b>519</b> |
| 32.1 Evolution of Cellular Radio, 519                           |            |
| 32.2 Analog Cellular Radio, 521                                 |            |
| 32.2.1 Analog Cellular Radio in Japan, 522                      |            |
| 32.2.2 Analog Cellular Radio in Scandinavia, 523                |            |
| 32.2.3 Analog Cellular Radio in North America, 523              |            |
| 32.2.4 Analog Cellular Radio in West Europe, 524                |            |
| 32.3 Digital Cellular Radio, 524                                |            |
| 32.3.1 Global System for Mobile Communication, 528              |            |
| 32.3.2 D-AMPS System, 532                                       |            |
| 32.3.3 Personal Digital Cellular System, 534                    |            |
| 32.4 Personal Communications Network, 535                       |            |
| 32.4.1 CT1-CT3 Systems, 536                                     |            |
| 32.4.2 Japanese Personal Handyphone System, 537                 |            |
| 32.4.3 Digital European Cordless Telecommunications, 537        |            |
| 32.4.4 Personal Access Communications System, 539               |            |
| 32.5 International Mobile Telecommunication System, 540         |            |
| <b>33 Telephony and Deregulation</b>                            | <b>546</b> |
| 33.1 Telecommunications Deregulation and Liberalization, 546    |            |
| 33.2 Telephony and Deregulation in the Americas, 551            |            |
| 33.2.1 Telephony and Deregulation in the United States, 551     |            |
| 33.2.2 Telephony and Deregulation in Canada, 555                |            |
| 33.2.3 Telephony and Deregulation in Mexico, 556                |            |
| 33.2.4 Telephony and Deregulation in Central America, 557       |            |
| 33.2.5 Telephony and Deregulation in the Caribbean, 558         |            |
| 33.2.6 Telephony and Deregulation in Brazil, 558                |            |
| 33.2.7 Telephony and Deregulation in Chile, 559                 |            |
| 33.2.8 Telephony and Deregulation in Argentina, 561             |            |
| 33.2.9 Telephony and Deregulation in Peru, 561                  |            |
| 33.2.10 Telephony and Deregulation in Venezuela, 561            |            |
| 33.2.11 Telephony and Deregulation in Colombia, 561             |            |
| 33.2.12 Telephony and Deregulation in Ecuador, 562              |            |
| 33.2.13 Telephony and Deregulation in Bolivia, 563              |            |
| 33.2.14 Telephony and Deregulation in Uruguay, 563              |            |
| 33.2.15 Telephony and Deregulation in Paraguay, 563             |            |
| 33.3 Telephony and Deregulation in Africa, 563                  |            |
| 33.3.1 Telephony and Deregulation in North Africa, 565          |            |
| 33.3.2 Telephony and Deregulation in South Africa, 566          |            |
| 33.3.3 Telephony and Deregulation in Sub-Saharan Africa, 566    |            |
| 33.4 Telephony and Deregulation in Asia, 567                    |            |
| 33.4.1 Telephony and Deregulation in India, 568                 |            |
| 33.4.2 Telephony and Deregulation in China, 569                 |            |
| 33.4.3 Telephony and Deregulation in Japan, 571                 |            |
| 33.4.4 Telephony and Deregulation in Other Asian Countries, 573 |            |
| 33.5 Telephony and Deregulation in Europe, 574                  |            |



|                       |   |                |
|-----------------------|---|----------------|
| 33.5.1                | Telephony and Deregulation in the European Union, 575   |                |
| 33.5.2                | Telephony and Deregulation in Eastern Europe, 575   |                |
| 33.6                  | Telephony and Deregulation in Oceania, 577  |                |
| <b>34</b>             | <b>Multimedia</b>   | <b>580</b>     |
| 34.1                  | Evolution Leading to Multimedia, 580  |                |
| 34.2                  | Computers and Communications, 581   |                |
| 34.3                  | Global Information Infrastructure, 581  |                |
| 34.4                  | Internet, 583   |                |
| 34.5                  | Global Village, 589   |                |
| 34.6                  | Multimedia Services, 590  |                |
| <b>35</b>             | <b>International Cooperation</b>  | <b>597</b>     |
| <br><b>APPENDICES</b> |   |                |
| <b>A</b>              | <b>Chronology of the Major Events in the Two Centuries of Telecommunications</b>                | <b>601</b>     |
| <b>B</b>              | <b>Worldwide Statistics of Population, Internet Users, Cellular Phones, and Main Telephones</b> | <b>607</b>     |
| <b>C</b>              | <b>Glossary</b>   | <b>613</b>     |
| <br><b>INDEX</b>      |   | <br><b>621</b> |