1

Overview of Wireless Networks – From 2G to 4G

Scanning the existing literature published during the recent two decades and related to the description of the wireless multiple access technologies, we notice that there are a lot of excellent works (see, for example, Refs. [1–22]), in which the multichannel, multiuser, and multicarrier accesses were described in detail for cellular and noncellular networks before and beyond third (3G) generation. However, all these works mostly described the corresponding techniques and technologies via a prism of additive white Gaussian noise (AWGN) and less via a prism of multiplicative noise that depend on fading phenomena, fast and slow, usually occurring in the wireless networks: terrestrial, atmospheric, and ionospheric [21, 22]. In other words, most of the excellent books had ignored the multiplicative noise caused by fading phenomena, which, as was shown in [21, 22], plays the main role in degradation of operational characteristics of any wireless network, such as grade of service (GoS), dealing with service of a lot of subscribers located in areas of service with a dense layout of users and quality of service (QoS), dealing with information data parameters sent and received by individual subscriber, such as the capacity, spectral efficiency, and bit error rate (BER) of data stream passing any wireless and wired communication link.

Thus, in [1–20], the authors dealt mostly with classical AWGN channels or channels with the interuser interference (IUI). As was shown there, the "response" of such channels is not time- or frequency varied, that is, such propagation channels were not time or/and frequency dispersive. In [21, 22] the authors described the main features of the multiplicative noise caused by slow and fast fading that occur in terrestrial, atmospheric, and ionospheric wireless communication links and networks. As was shown in [21, 22], the aspects of fading are very important for predicting the multiplicative noise in various radio channels, terrestrial, atmospheric, and ionospheric, for the purpose of increasing the efficiency of land–land, land–aircraft, and land–satellite communication networks. The proposed approaches were then extended for description of multimedia and optical communications based on stochastic, and other statistical, models [23–27] and on usage of special nonstandard matrices [28, 29].

Advanced Technologies and Wireless Networks Beyond 4G, First Edition.
Nathan Blaunstein and Yehuda Ben-Shimol.

Thus, in land communication channels, due to multiple scattering, diffraction, and scattering or diffuse reflection, the channel becomes frequency selective. If one of the antennas of the subscriber, or of the base station, is moving, the channel becomes both a time- and frequency-dispersive channel. As a result, the radio signals traveling along different paths of varying lengths cause significant deviations in signal strength (in volts) or power (in watts) at the receiver. This interference picture is not changed with time and can be repeated in each phase of a radio communication link between the base station (BS) and the stationary subscriber. As for a dynamic channel, when either the subscriber antenna is in motion or the objects surrounding the stationary antennas move, the spatial variations of the resultant signal at the receiver can be seen as temporal variations, as the receiver moves through the multipath field (i.e. through the interference picture of the field strength). In such a dynamic multipath channel, a signal fading at the mobile receiver occurs in the time domain. This temporal fading relates to a shift in frequency radiated by the stationary transmitter. In fact, the time variations or dynamic changes of the propagation path lengths are related to the Doppler shift, denoted by $f_{d_{\max}}$, which is caused by the relative movements of the stationary BS and/or the moving subscriber (MS). As was defined in [21, 22], the total bandwidth due to Doppler shift is $B_d = 2f_{d_{\max}}$. In the time-varied or dynamic channel, for any real time t there is no repetition of the interference picture during the crossing of different field patterns by the MS at each discrete time of his movements. Thus, in Table 1.1, some characteristic parameters, such as introduced above, Doppler shift, and the delay spread, σ_t, are presented for the ionospheric and terrestrial radio communication links. According to these two main parameters of frequency- and time-dispersive channel "response," additionally two other parameters, B_c and T_c, the coherency bandwidth of channel and the time of coherency, respectively, are usually introduced to define the type of fading occurring in the desired communication channel: frequency-selective or flat (see definitions and relations between the parameters in [21]). As was shown in [21, 22], due to the "time dispersion" and "frequency dispersion" of each specific wireless communication channel, the signal data, as a stream of sequences of symbols (e.g. bits), can be corrupted by fading, and finally, a new phenomenon called intersymbol interference (ISI) is observed at the receiver. Moreover, in multiple accesses servicing, IUI is currently observed.

Table 1.1 Characteristics of fading parameters in different channels

Channel	σ_τ (s)	$f_{d_{\max}}$ (Hz)
Ionospheric (HF)	$\sim 10^{-3}$	50–150
Atmospheric (HF/VHF)	$\sim 10^{-2}$	5–40
Land (VHF/UHF)	$\sim 10^{-6}$–10^{-5}	10–100

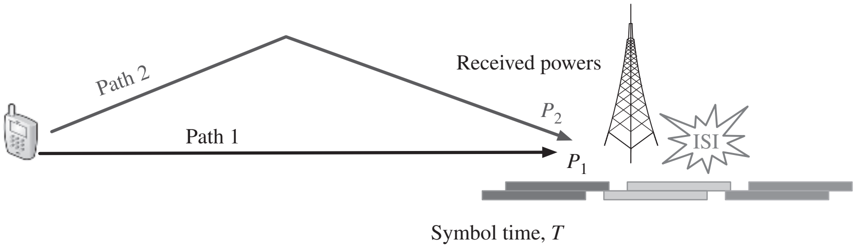

Figure 1.1 ISI caused by multipath fading phenomena

In Table 1.1, in this situation, a new “artificial noise” takes place, which causes the so-called IUI or interchannel interference (ICI). An example of how multipath fading causes ISI is shown in Figure 1.1. To overcome such kinds of effects caused by multiplicative noise, some canonical techniques were introduced in modulation schemes of current networks, defined and briefly described in [22], such as the spread spectrum modulation techniques direct sequence spread sectrum (DS-SS), frequency hopping spread spectrum (FH-SS), and time hopping spread spectrum (TH-SS)).

The work in [22] briefly explains how the IUI in the classical multiple access technologies can be overcome: CDMA (code-division multiple access) on the basis of DS-SS modulation, FDMA (frequency-division multiple access) on the basis of FH-SS modulation technique, and TDMA (time-division multiple access) on the basis of TH-SS modulation. Reference [22] also briefly introduced these techniques based on space, time, frequency, and polarization diversities for multibeam adaptive antenna applications. In this section, we introduce the orthogonal frequency-division multiplexing (OFDM) techniques and the corresponding orthogonal frequency-division multiple accesses (OFDMA), occurring in the frequency domain, as well as the orthogonal time-division multiple access (OTDMA), occurring in the time domain.

In Chapter 2, we briefly introduce the existing canonical and modern recently performed networks via their historical perspective, such as the Global System for Mobile Communications (GSM), the wireless personal area network (WPAN), also called Bluetooth, the wireless local area network (WLAN), related to the wireless fidelity (Wi-Fi) system, the wireless metropolitan area network (WirelessMAN or WiMAX), and the long-term evolution (LTE) standards. All these systems and technologies cover the time period of the past four decades in wireless generation’s developments – from the past second generation to the new fourth generation. It is important to notice that all modulation techniques, the conventional CDMA/TDMA/FDMA and advanced OFDM/OFDMA/OTDMA, related to the above networks, fully depend on the fading phenomena that occur in such networks.

We do not focus in the description of the respective current and advanced protocols, such as 802.15, 802.11, and 802.16, for LTE releases, which are usually used in the above networks, as well as on the architecture of these networks, because these aspects are beyond the scope of this book and are fully described in other Refs. [1–9, 11–20]. At the same time, based on the fading parameters introduced above, we show the advantages and disadvantages of the corresponding techniques and propose for practical applications more attractive and advanced technologies.

In other words, Chapter 2 illuminates the current wireless networks and the corresponding technologies before 4G and 5G in their brief overview. In Chapter 3, we introduce some advanced diversity techniques adapted for the multicarrier accessing networks. Chapter 4 describes the advanced multiple-input-multiple-output (MIMO) spatial-time diversity and spatial multiplexing techniques, focusing the special attention on how fading phenomena affect the capacity and spectral efficiency of MIMO channels. Fading propagation effects are described in terms of the unified stochastic approach introduced in [21, 22] for land communication networks. In Chapter 5, we introduce the femtocell–microcell and femtocell–macrocell (indoor/outdoor) configurations for different types of femtocell advanced deployment strategies. Chapter 6 shows advances of the combined femtocell–microcell layout with modern concept of MIMO/LTE for future performance in 4G and 5G technologies. In previous books [22, 23], based on a general stochastic model, we describe in detail the present operative parameters of the multibeam adaptive antennas in the angle-of-arrival (AOA), time-of-arrival (TOA) or time-delay, and frequency (Doppler) domains. Finally, in Chapter 7, based on the general stochastic multiparametric approach, briefly described in Chapter 4, the main technique – how to localize, from the signal's distribution in the time-delay and Doppler spread domains, the exact position of any subscriber located in multiuser land-atmospheric communication link – is presented.

References

1 Jakes, W.C. (1974). *Microwave Mobile Communications*. New York: Wiley.
2 Lee, S.C.Y. (1989). *Mobile Cellular Telecommunication Systems*. Hoboken, NJ: McGraw-Hill.
3 Steele, R. (1992). *Mobile Radio Communication*. IEEE Press.
4 Proakis, J.G. (1995). *Digital Communications*, 3e. New York: McGraw-Hill.
5 Stuber, G.L. (1996). *Principles of Mobile Communications*. Boston, MA: Kluwer Academic Publishers.
6 Peterson, R.L., Ziemer, R.E., and Borth, D.E. (1995). *Introduction to Spread Spectrum Communications*. Hoboken, NJ: Prentice Hall PTR.
7 Rappaport, T.S. (1996). *Wireless Communications: Principles and Practice*, 2e in 2001. Hoboken, NJ: Prentice Hall PTR.

8 Steele, R. and Hanzo, L. (1999). *Mobile Communications*, 2e. Chichester: Wiley.

9 Li, J.S. and Miller, L.E. (1998). *CDMA Systems Engineering Handbook*. Boston, MA and London: Artech House.

10 Saunders, S.R. (2001). *Antennas and Propagation for Wireless Communication Systems*. Chichester: Wiley.

11 Burr, A. (2001). *Modulation and Coding for Wireless Communications*. Hoboken, NJ: Prentice Hall PTR.

12 Molisch, A.F. (ed.) (2000). *Wideband Wireless Digital Communications*. Chichester, England: Prentice Hall PTR.

13 Paetzold, M. (2002). *Mobile Fading Channels: Modeling, Analysis, and Simulation*. Chichester: Wiley.

14 Simon, M.K., Omura, J.K., Scholtz, R.A., and Levitt, B.K. (1994). *Spread Spectrum Communications Handbook*. New York: McGraw-Hill.

15 Glisic, S. and Vucetic, B. (1997). *Spread Spectrum CDMA Systems for Wireless Communications*. Boston, MA and London: Artech House.

16 Dixon, R.C. (1994). *Spread Spectrum Systems with Commercial Applications*. Chichester: Wiley.

17 Viterbi, A.J. (1995). *CDMA: Principles of Spread Spectrum Communication, Addison-Wesley Wireless Communications Series*. Reading, MA: Addison-Wesley.

18 Goodman, D.J. (1997). *Wireless Personal Communication Systems*. Reading, MA: Addison-Wesley.

19 Schiller, J. (2003). *Mobile Communications, Addison-Wesley Wireless Communications Series*, 2e. Reading, MA: Addison-Wesley.

20 Molisch, A.F. (2007). *Wireless Communications*. Chichester: Wiley.

21 Blaunstein, N. and Christodoulou, C. (2007). *Radio Propagation and Adaptive Antennas for Wireless Communication Links*, 1e. Hoboken, NJ: Wiley.

22 Blaunstein, N. and Christodoulou, C. (2014). *Radio Propagation and Adaptive Antennas for Wireless Communication Networks – Terrestrial, Atmospheric and Ionospheric*, 2e. Hoboken, NJ: Wiley.

23 Hadar, O., Bronfman, I., and Blaunstein, N. (2017). Optimization of error concealment based on analysis of fading types, Part 1: Statistical description and error concealment of video signals. *J. Inf. Control Syst.* 86 (1): 72–82.

24 Hadar, O., Bronfman, I., and Blaunstein, N. (2017). Optimization of error concealment based on analysis of fading types, Part 2: Modified and new models of video signal error concealment. Practical simulations and their results. *J. Inf. Control Syst.* 86 (2): 67–76.

25 Sun, M.T. and Reibman, A.R. (2001). *Compressed Video over Networks*. New York: Marcel Dekker.

26 Doshkov, D., Ndjiki-Nya, P., Lakshman, H. et al. (2010). Towards efficient intra prediction based on image inpainting methods. *28th Picture Coding Symposium*, PCS2010, Nagoya, Japan (8–10 December 2001), p. 6.

27 Chen, B.N. and Lin, Y. (2006). Selective motion field interpolation for temporal error concealment. *International Conferencde on Computer and Communication Engineering 2006* (ICCCE 2006), Kuala Lumpur, Malaysia (9–11 May 2006).

28 Hadar, O., Huber, M., Huber, R., and Greenberg, S. (2005). New hybrid error concealment for digital compressed video. *EURASIP J. Appl. Signal Process.* 12: 1821–1833.

29 Blaunstein, N., Arnon, S., Zilberman, A., and Kopeika, N. (2010). *Applied Aspects of Optical Communication and LIDAR*. Taylor and Francis Group.