Chapter 21
Metamaterial-Based Wearable Microstrip Patch Antennas

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ABSTRACT

This chapter presents metamaterial-based wearable, that is, textile-based, antennas for Wi-Fi, WLAN, ISM, BAN and public safety band applications, which have been designed, fabricated, and tested. Textile substrates like polyester and polypropylene are used to design and fabricate these antennas. The metamaterial inclusions are directly used to load the different microstrip patch antennas on the same substrate, which significantly enhances the gain and bandwidth with considerable size reduction. The microstrip patch antenna generates sub-wavelength resonances under loading condition due to the modifications of its resonant modes. The DNG and SNG metamaterials are used to load the microstrip patch antennas for size reduction by generating the sub-wavelength resonances. The simulated and measured results are found to be in good agreement for all the presented wearable antennas. The bending effect on antenna performance due to human body movements is also presented in this chapter.

1. INTRODUCTION

The handheld communication devices and *body centric communication* (on body and off body) systems are widely used in the day-to-day activities of human being. Some of the devices are used by the military, fire fighters and police personnel for the safety of human life and property, surveillance of sensitive locations like airport, seaport, shopping malls etc. These devices and systems are wearable computers, flexible mobile phones, personal digital assistant (PDA), smart phones, tablet computers, *public safety band* systems, biotelemetry sensors, military and police equipments etc. These devices may be worn under, over, or in clothing, or may be the clothes of the user or wearer (Choi, 2010; Hall, 2006; Hertleer, 2009; Joshi, 2013, 2012, 2012, 2013; Sankaralingam, 2010).

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These systems need compact, high gain, light weight, and hidden antennas which should be an integral part of the wearer clothing. These systems uses different frequency bands under 3G, 4G and 5G technologies such as *Body Area Networks* (BAN), *Industrial, Scientific, and Medical* (ISM) band, WLAN, Wi-Fi, Wi-max, Bluetooth, HYPER LAN, public safety band etc. (Choi, 2010; Hall, 2006; Hertleer, 2009; Joshi, 2013, 2012, 2012, 2013; Sankaralingam, 2010). It is difficult to achieve a better tradeoff between the gain, bandwidth, and more prominently the size of microstrip patch antennas in spite of numerous advantages, hence these antennas are not suitable for wearable applications (Bahl, 1980; Garg, 2001; Joshi, 2011; Joshi, 2010; Joshi, 2011, Joshi 2012; Pozar, 1995). The cloth or textile based antennas which are the integral part of wearer clothing and used for the mentioned applications hence they are called as *wearable antennas*. These antennas can be applied for youngsters, the aged persons, physically challenged persons, sportsmen, monitoring the activities of animals, police and military personnel etc. (Choi, 2010; Hall, 2006; Hertleer, 2009; Joshi, 2013, 2012, 2012, 2013; Sankaralingam, 2010).The textile or cloth based wearable antenna communicates voice, data, or biotelemetry signals at high data rates.

The wearable antenna should have features like light weight, conformal, need to be hidden, and it should not affect the health of user. In practice, synthetic or natural materials are used as substrate to manufacture the textile or cloth based wearable antennas. These materials are cotton, liquid crystal polymer (LCP), fleece fabric, foam, Nomex, nylon, polyester, conducting ribbon, insulated wire, conducting paint, copper coated fabric, geo-textile etc. (Choi, 2010; Hall, 2006; Hertleer, 2009; Joshi, 2013, 2012, 2012, 2013; Sankaralingam, 2010).

Different wearable antennas have been reported in the literature. A study on necessity of wearable antennas for PAN, BAN and ISM band has been presented. (Hall, 2006). A flexible composite right left-handed transmission line flexible antenna fabricated on LCP that resonates at 2.3 GHz (Choi, 2012). This antenna is useful for flexible mounting surface applications because of its insensitiveness to bending. The microstrip patch antenna on conductive fabrics and insulating polyester is experimentally demonstrated by (Sankaralingam, 2010). This antenna is designed for wireless Broadband (WiBro) communication systems operating in the frequency range 2.3 GHz to 2.4 GHz. But, due to size of the patch there is possibility of deposition of electromagnetic signals in the body. A wearable microstrip patch antenna on fabric substrate with a U-slot having reconfigurable beam steering capability at 6 GHz has been reported (Sang-Jun Ha, 2011). An embroidered wearable multi-resonant folded dipole (MRFD) antenna for FM signal reception has been presented (Jung-SimRoh, 2010). A textile endfire antenna for wireless body area networks (BANs) operating at 60 GHzis fabricated on 0.2 mm thick fabric from a cotton shirt (Nacer Chahat, 2012).

The objective of this chapter is to present the metamaterial based wearable microstrip patch antennas for 802.11a WLAN, Wi-Fi, Wi-max and public safety band applications. The polyester cloth and geo-textile that is polypropylene substrates are used to fabricate these antennas. The authors have used different configurations of metamaterial split ring resonators to design and develop the wearable antennas. In this chapter, different metamaterial based wearable microstrip patch antennas designed, fabricated and tested by the authors are presented. The antennas presented in this chapter are simulated by using a method of moment based IE3D electromagnetic simulator.