COMPREHENSIVE INVESTIGATION OF BROAD BAND WIRE WEARABLE ANTENNAS

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Abstract— In this paper, non-patch type antennas with broad band operation, light weight, easy integration with garment, low obstruction and impedances are studied. In specific, broad band wire wearable antennas in close proximity of a small ground plane are considered; the designed antennas require no external matching circuitry. This paper presents a comprehensive analysis of three broadband wire wearable antennas to operate over the frequency ranges 2400-2485 MHz that completely encompassing the desired IEEE802.11b/g, Bluetooth frequency band, and 5150-5825 MHz that covers the IEEE802.11a band. The readymade software simulator (NEC-PRO Software Code) is used to investigate the characteristics of the presented antennas.

Index Terms: Wire, Wearable, VSWR, Inverted F- Antenna (IFA).

1-INTRODUCTION

Wire antennas, linear or curved, are some of the oldest, simplest, cheapest, and in many cases the most versatile for many applications. The recent research activity in the field of wearable antennas investigates various different design approaches, including: patches [1], buttons [2], conductive fabrics [3] or combinations of such designs [4]. With the rapid growth of wireless LAN applications, there is a concomitant demand for low cost and small sized antenna designs for commercial markets. The design of communication systems for telemedicine and body worn applications is the subject of much research. These systems are of interest for monitoring the performance of the body during exercise, monitoring functions such as heart rate and blood pressure for medical diagnosis, use by the emergency services and for general network connections. Body worn antennas may be made from textiles [5] and attached on body or into clothing, or may be worn as a button antenna[6]. The radiation properties (pattern, directivity, input impedance, mutual impedance, etc.) of very thin-wire antennas were investigated by assuming that the current distribution, which in most cases is nearly sinusoidal, is known. In practice, infinitely thin (electrically) wires are not realizable but can be approximated. In addition, their radiation characteristics are very sensitive to frequency. The degree to which they change as a function of frequency depends on the antenna bandwidth. For applications that require coverage over a broad range of frequencies, wideband antennas are needed. In this work, a scalable design approach has been chosen to fulfill frequency requirements of different radio and wireless standards such as Bluetooth or Wireless LAN 801.11. This paper presents three types of wire wearable antennas (Rectangular meander, triangular meander, and inverted F antennas). The simulation and analyses of the three proposed antennas are carried out using the readymade soft ware simulator called NEC-PRO software Code [7].

2–RECTANGULAR MEANDERE WEARABLE ANTENNA

Thomas Thalmann [8], presented dual-band meander antenna. The longer meandered dipole was 118 mm long and was designed to be matched to 50 Ohms at 915 MHz, while the orthogonal 72 mm long smaller meandered dipole was matched to 50 Ohms at 1575 MHz.
This paper presents using scalable design approach a rectangular meander antenna to operate over the frequency ranges 2400-2485 MHz that completely encompassing the desired IEEE802.11b/g, Bluetooth frequency band, and 5150-5825 MHz that covers the IEEE802.11a band. The simulation of the rectangular meander antenna using NEC-PRO software Code is done in the proximity of a body. The body is modeled by a finite ground plane (relative permittivity 50.2, conductivity 1.9 S/m) which represents the chest, The simulated antenna is placed parallel to and 2.5 cm above the ground plane as shown in Figure 1; While Figure 2 shows the variation of

the VSWR versus the frequency relative to 50 Ω characteristic impedance. It can be shown from Figure 2, that the antenna has two resonant frequencies at 2.4 GHz, and 5.6 GHz. Their corresponding bandwidths are 385 MHz, 1100 MHz, respectively.

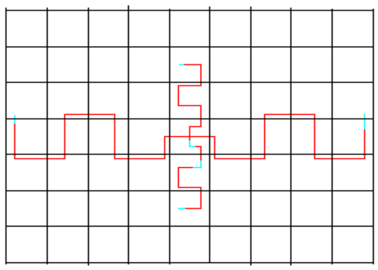

Figure 1 Rectangular meander wearable antenna

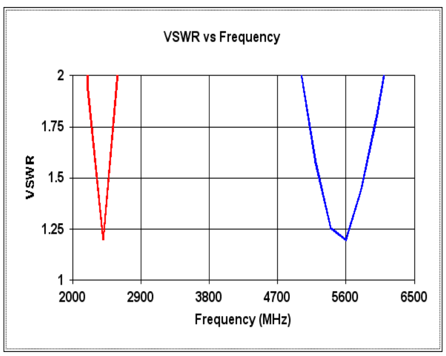

Figure 2 Variation of VSWR versus frequency for rectangular meander wearable antenna

3–TRIANGULAR MEANDERE WEARABLE ANTENNA

This paper presents another scalable design approach that is a triangular meander antenna. The antenna was designed and simulated using NEC-PRO software Code. The simulation of the triangular meander antenna is done in the proximity of a body. The body is modeled by a finite ground plane (relative permittivity 50.2, conductivity 1.9 S/m) which represents the chest. The simulated antenna is placed parallel to and 7.5 mm above the ground plane as shown in Figure 3; While Figure 4 shows the variation of the VSWR versus the frequency relative to 50 Ω characteristic impedance. It can be shown from Figure 4, that the antenna has six resonant frequencies at 1.4, 2, 4, and 4.4, 5.7, and 6.8 GHz. Their corresponding bandwidths are 180,110, 100, 50, and 150, 290 MHz, respectively.

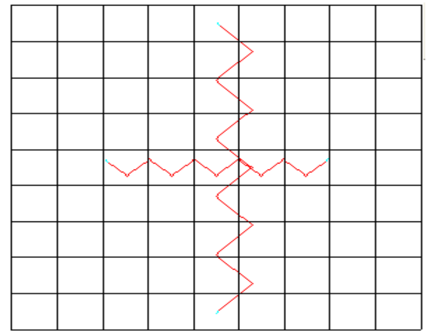

Figure 3 Triangular meander wearable antenna

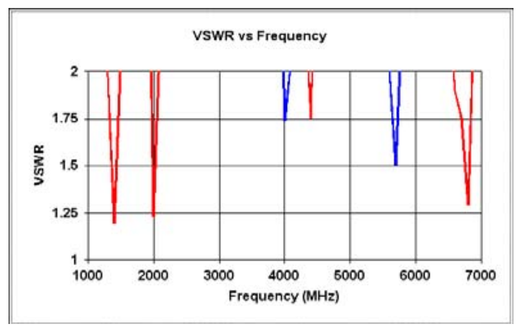

Figure 4 Variation of VSWR versus frequency for triangular meander wearable antenna

4– INVERTED F WEARABLE ANTENNA

Due to its low profile and ability to cover the existing wireless communication frequency bands, the planar inverted F-antenna (PIFA) has been widely adopted in portable units [9]. Due to the limited space available on the printed circuit board of a wireless device, antenna miniaturization is crucial to keep the size of this type of antenna small and appropriate for portable wireless units, without degradation of performance in terms of bandwidth and radiation patterns. Figure 5 shows the geometry of the antenna that proposed by C. H. See [9], where the maximum dimension was about a quarter-wavelength at the center frequency for IEEE 802.11b/g and Bluetooth (2459 MHz).

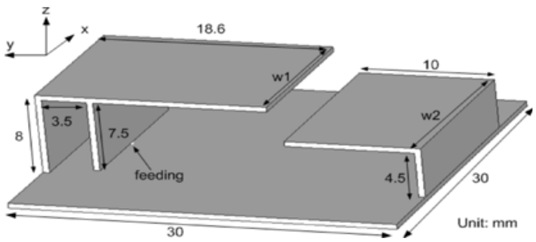

Figure 5 Geometry of the antenna that proposed by C. H. See [9].

This paper presents the conventional inverted F wire antenna (CIFA) that uses the advantages of wire antennas of light weight, cheap, small and low profile instead of using PIFA. The proposed conventional inverted F wire antenna that shown in Figure 6, has been designed, simulated, and optimized usin NEC-PRO software Code to operate with center frequency 2.5 GHz. The optimized dimensions are found to be:

Wire Section	a-b	c-d	a-d	b-e
Length of Section [mm]	10.92	10.92	9.75	29.75

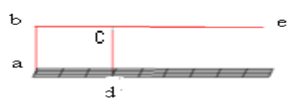

Figure 6 Conventional Inverted F wire antenna

The CIFA was excited by a coaxial line from point d. The section a-b was used for matching the antenna impedance to the feed line impedance 50 Ω. It can be shown from Figure 7, that the simulated antenna has optimum bandwidth of 135 MHz.

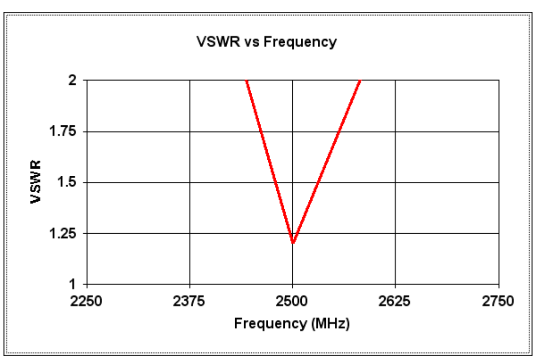

Figure 7 Variation of VSWR versus frequency for conventional inverted F wire antenna

This paper presents a modified inverted F antenna, where the conventional inverted F antenna (CIFA) has been modified to be as shown in Figure 8, by extending the section a-b to f with total length of a-f equals to 11.92 mm, and adding the section f-g with length 20.75 mm.

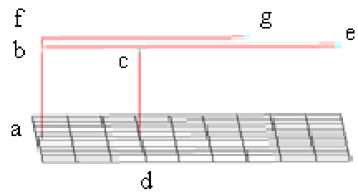

Figure 8 Modified inverted F wire antenna (MIFA1)

Figure 9 shows the variation of the VSWR versus the frequency relative to 50 Ω characteristic impedance of the modified inverted F antenna (MIFA1). It can be shown from Figure 9, that the antenna has a resonant frequency at 2.5 GHz, with frequency bandwidth 200 MHz, which is more than that of CIFA with 65 MHz.

This paper presents another modification to the designed MIFA1 by extending the section b-f to h with total length of a-h equals 16.92 mm in order to widen the bandwidth. The new modified inverted F antenna (MIFA2) is shown in Figure 10.

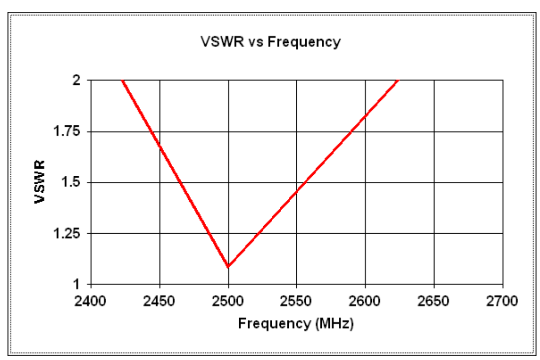

Figure 9 Variation of VSWR versus frequency for modified inverted F wire antenna (MIFA1)

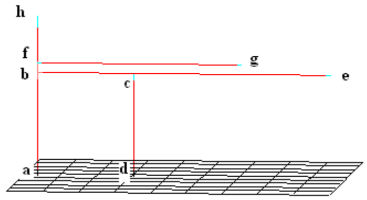

Figure 10 Modified inverted F wire antenna (MIFA2)

The modified inverted F antenna (MIFA2) has a resonant frequency at 2.5 GHz, with frequency bandwidth 250 MHz as shown in Figure 11, which is more than that of CIFA with 115 MHz.

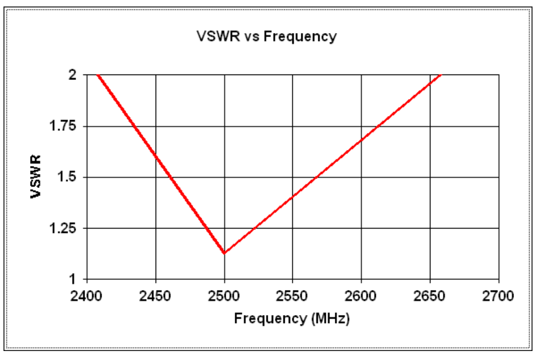

Figure 11 Variation of VSWR versus frequency for modified inverted F wire antenna (MIFA2)

In order to widen the bandwidth of the CIFA, Hisamatsu [10] used a low profile IFA with two parasitic elements (IFA-PE) located on a conducting ground plane of infinite extent. Hisamatsu found that, the frequency bandwidth for a VSWR = 2 criterion of the IFA-PE is approximately two times as wide as that of the CIFA.
This paper presents using scalable design approach a new configuration consisting of two IFA's (2-IFA) to operate over the frequency ranges 2400-2485 MHz that completely encompassing the desired IEEE802.11b/g, Bluetooth frequency band, and 5150-5825 MHz that covers the IEEE802.11a band. The proposed configuration shown in Figure 12 is designed, simulated and optimized using NEC-PRO software Code. The optimized dimensions of the new configuration are found to be:

Wire Section	Length of Section [mm]	Wire Section	Length of Section [mm]
a-b	10.92	b-f	1
c-d	10.92	h-i	10.92
b-c	9.75	j-k	10.92
b-e	29.75	l-k	5.25
f-g	20.75	i-l	27.25
e-l	15	a-h	70

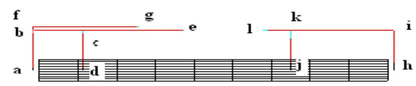

Figure 12 New configuration of two Inverted F wire antenna (2-IFA)

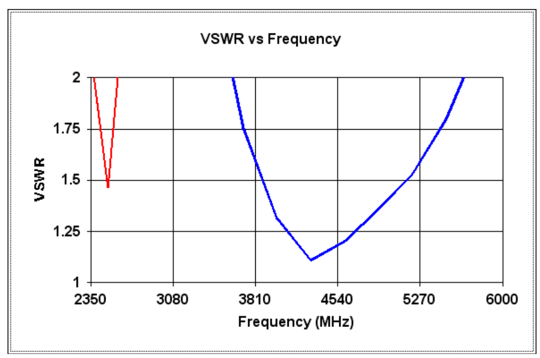

Figure 14 Variation of VSWR versus frequency for the proposed configuration of two inverted F wire antenna (2-IFA))

Figure 14 shows the variation of the VSWR versus the frequency relative to 50 Ω characteristic impedance of the new configuration of two inverted F wire antenna (2IFA). It can be shown from Figure 14, that the proposed antenna has dual resonant frequencies at 2.5, and 4.3 GHz, with frequency bandwidth of 210, and 2355 MHz, respectively, which covers the required bands.

4-CONCLUSION

In this paper, non-patch type antennas with broad band operation, light weight, easy integration with garment, low obstruction and impedances are studied. In specific broad band wire wearable antennas in close proximity of a small ground plane are considered; the designed antennas require no external matching circuitry. Since one of the main objectives in the design of an antenna is to broadband its characteristics, so this paper presents a comprehensive analysis of three broadband wire wearable antennas (Rectangular meander, triangular meander, and inverted F antennas). In this work, a scalable design approach has been chosen to fulfill frequency requirements of different radio and wireless standards such as Bluetooth or Wireless LAN IEEE802.11b/g, the IEEE802.11a band.

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