

COMPACT SLOT-LOADED PATCH ANTENNA FOR 868 MHz WIRELESS BODY AREA NETWORKS

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Abstract:

The development of a compact and highly efficient antenna operating at 868 MHz for communication in ISM-band body area networks is reported. With symmetrical slots and shorting pins on either side of the feed, the antenna exhibited a radiation pattern similar to that of a monopole/dipole antenna with an efficiency of 52.3 % and an impedance bandwidth of 9.3 MHz (1.1 %) when placed in close proximity (1 mm) from a muscle tissue phantom. The maximum dimension of the proposed design is reduced by more than 66 % compared to a conventional $\lambda/2$ microstrip patch antenna. Furthermore, for a simulated on-body path the performance of the new antenna was within 2 dB of a $\lambda/4$ monopole.

1. Introduction

Wearable electronic devices are becoming very popular in personal communications, computer systems and wireless monitoring of vital functions. For example, the preventative monitoring of a patient's health is an application that often requires sensing devices in close proximity to the body. Therefore, there is an increasing demand for effective communication technologies to underpin emerging health care delivery systems such as telemonitoring where physicians can make informed decisions, monitor deterioration in chronic conditions, or assess the response of a patient to a specific treatment plan [1, 2].

Wireless body area networks (WBAN) can be used to interconnect various components in a wearable computer or medical system. In terms of on-body communications, the main design criteria for WBAN modules are weight, physical size and power efficiency, all of which are directly related to antenna performance. Research interest in body mounted (wearable) antennas has rapidly increased in recent years including work on the use of flexible materials (textile antennas), both narrow/wideband antennas: microstrip patch, planar inverted F, dipole, 'button' type, and ultra wide band antennas [3–10]. In this paper, we present a compact, low-profile, slot-loaded planar microstrip patch antenna with radiation characteristics suitable for on-body communications and with relatively high radiation efficiency, taking account of the power absorbed in nearby body tissues.

2. Antenna design and discussion

Fig. 1 shows the geometry of the proposed antenna which is based on a previously reported higher mode microstrip patch antenna (HMMPA) specifically designed for on-body operation [10], with the addition of rectangular slots. The structure consists of a square patch of dimension ' L ' with rectangular slots of width ' w ' and length ' l ', etched on a Taconic TLY-3 substrate material of thickness of ' h ' and dielectric constant ' ϵ_r '. ' W ' denotes the dimension of the square ground plane. The antenna is excited using a probe of diameter 1.2 mm fed at the centre of the patch [10, 11]. Two shorting pins are used on either side of the feed. ' S ' represents the distance between the shorting post from the feeding post. The distance between the shorting post and the slot is denoted by ' U '.

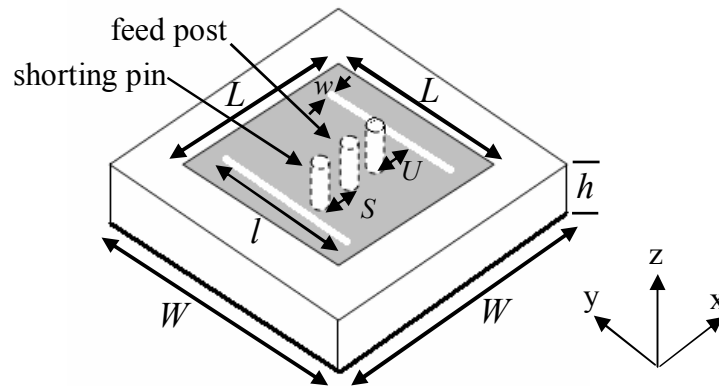


Fig. 1 Schematic of the proposed antenna. For 868 MHz, $W = 60$ mm, $h = 10.5$ mm, $L = 41$ mm, $\epsilon_r = 2.33$, $l = 30$ mm, $w = 2$ mm, $d = 1.2$ mm, $S = 2$ mm, $U = 3$ mm.

Fig. 2 shows the FDTD simulated return loss of the proposed antenna in free space. The 2:1 impedance bandwidth was 4 MHz (0.5 %) with resonance at 868 MHz for the slotted patch. Without the slots, the antenna resonated at 930 MHz with an impedance bandwidth of 3.9 MHz (0.4 %).

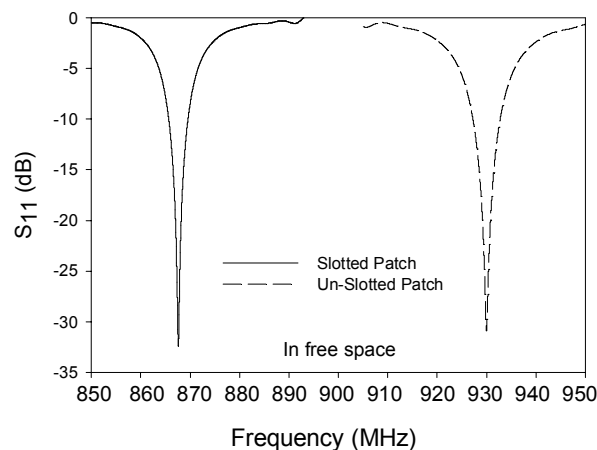


Fig. 2 Comparison of return loss for normal and slotted higher mode patch antenna in free space.

By incorporating rectangular slots on either side of the shorting pin, the surface currents are forced to curve around the slots so as to increase the electrical length thus lowering the resonance frequency down to 868 MHz. The radiation efficiency of the antenna in free space was 88.6 % similar to the value for the un-slotted patch (89.1 %). The feeding point was chosen to be at the centre of the patch to obtain a symmetrical radiation pattern. This is particularly important for on-body wearable antennas since the orientation and placement of WBAN nodes is likely to vary in practice. Shorting pins on either side of the feed are used to match the input impedance of the antenna close to 50Ω . The impedance is matched either by moving the shorting pins or by adjusting the thickness of the feed post. Reducing the thickness of the shorting pins results in a reduction in resonance frequency but the antenna becomes more sensitive to environmental factors such as antenna-body separation distance and it is also more difficult to find the optimum match, so the preferred approach is to vary the distance between the feed and the shortening pins. However, the resonance frequency can also be varied by changing the dimension of the slots. In this case the slots were at a distance of 5 mm from the feed post, which offered the maximum reduction in resonance frequency without affecting the impedance matching. Fig. 3 shows that the antenna radiates with a null in the boresight similar to that of a monopole with a peak directivity of 1.64 dBi. The surface current distribution shown in Fig. 4 confirms that the highest currents are found surrounding the slots and at the feed post and shorting pins. Note that the resonating length of a conventional $\lambda/2$ microstrip patch antenna at 868 MHz should be 113.2 mm on a substrate with $\epsilon_r = 2.33$, whereas the new slotted patch antenna is only 41 mm long at the same frequency (64 % smaller).

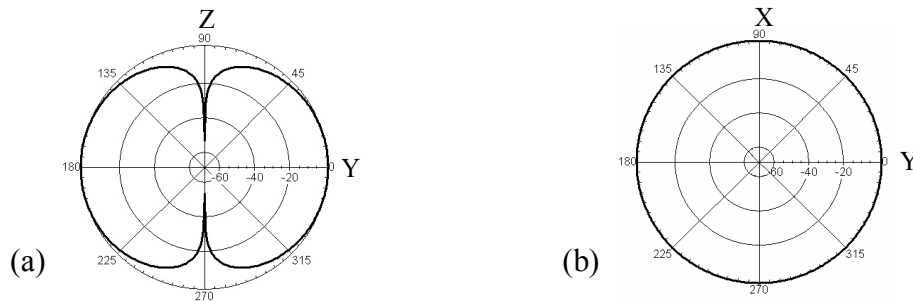


Fig. 3 Normalised co-polar (E_z) antenna directivity in free space a) elevation b) azimuthal.

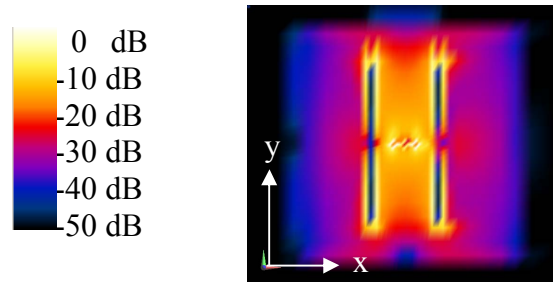


Fig. 4 Surface current distribution.

3. Tissue-Mounted Performance

The effect on the radiation characteristics of the antenna placed in close proximity (1 mm) from a muscle tissue cuboid phantom of dimensions $L_p = 400$ mm, $W_p = 400$ mm and $H_p = 60$ mm was studied. The parameters used for the muscle tissue phantom at 868 MHz were $\epsilon_r = 56.032$, $\sigma = 0.957$ Sm⁻¹. However, since a probe feed is not practical for wearable applications the antenna was also modified so that the centre post was excited using a microstrip line. The microstrip feed was fabricated on a thin substrate of thickness $h_1 = 1$ mm and $\epsilon_r = 2.33$ for better coupling of the energy to the patch. The dimensions of the modified patch antenna were reduced compared to free space since the antenna was detuned when placed over the muscle tissue (by 21 MHz). The modified 38 mm x 36.5 mm patch (Fig. 5) had a substrate thickness $h_2 = 9.5$ mm and $\epsilon_r = 2.33$ with 30 mm x 2 mm ($l \times w$) slots. The diameter of all the three posts was 1.2 mm. The optimum impedance match was achieved by placing the two shorting posts 1.6 mm from the feed post.

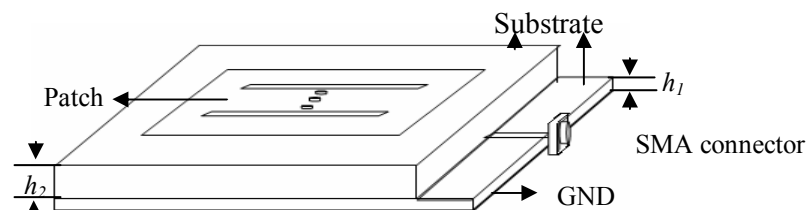


Fig. 5 Geometrical layout of the antenna with modified feed.

Fig. 6 compares the on-phantom coupling performance of the new antenna with a reference $\lambda/4$ monopole on the same size of groundplane. The height of the 1.2 mm diameter monopole was 79.6 mm. The simulation setup consisted of two identical antennas mounted 200 mm apart on the cuboid phantom mentioned above. The radiation efficiency (taking account of both dielectric and tissue losses) of the slotted patch was 52.3 % compared to 65.4 % for the monopole. The return loss results in Fig. 6 demonstrate that the impedance bandwidth of the new antenna (9.3 MHz, 1.1%) is sufficient for ISM-band operation. In terms of on-phantom coupling (an important metric relating to the performance of an antenna for on-body links), the peak $|S_{21}|$ for the slotted patch was only 2 dB less (-17.6 dB c.f. -15.54) than for the monopole. Although the monopole retains a slight performance advantage, because of its height normal to the body surface it is inherently unsuitable for wearable applications.

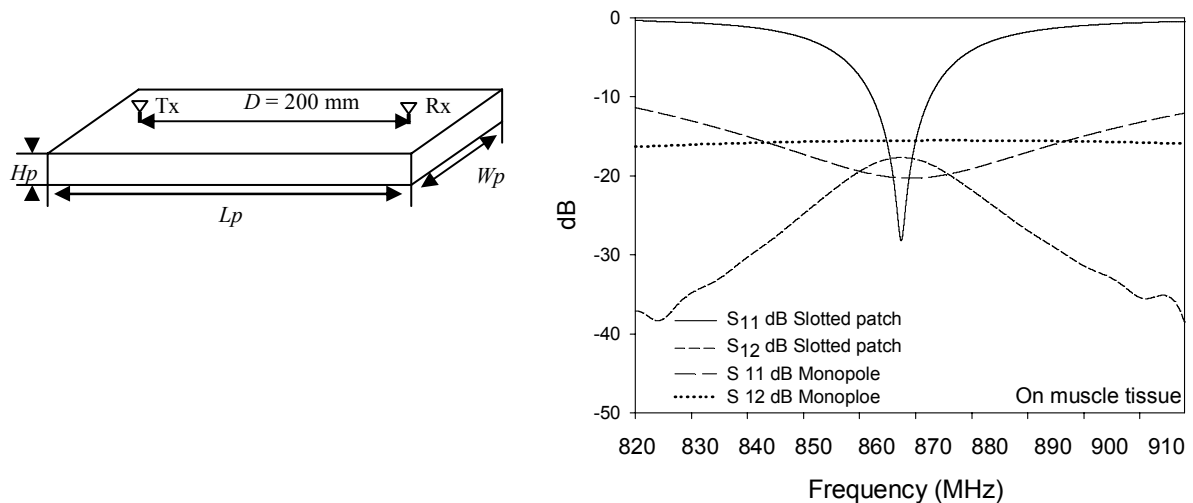


Fig. 6. Simulation setup for antenna coupling on muscle tissue phantom, and comparison of slotted patch antenna and reference monopole return loss and $|S_{21}|$ coupling.

4. Conclusions

A new compact low-profile antenna design for WBAN operation at 868 MHz is presented and studied using FDTD simulation. The antenna offers a significant size reduction with a maximum dimension of only 33.6 % compared to a conventional $\lambda/2$ microstrip patch antenna yet it maintains a relatively high efficiency of 52.3 % when placed in close proximity (1 mm) to a muscle tissue phantom at 868 MHz. Furthermore, the new antenna has an on-body coupling performance close to that of a full size monopole antenna mounted normal to the body surface. Overall, the new antenna had a relatively good performance considering its low profile nature (0.03λ) and small size of the antenna (0.11λ).

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