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Bandwidth Enhancement and Radiation Properties of Slotted Antenna

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***Abstract:** The design of low-cost, wideband, printed inverted-F antennas (PIFAs) that are suitable for portable devices operating at the 2–3 GHz band is described. The design specifications were extracted according to the constraints of high data rate wireless sensor devices. Reactive tuning through slot loading was applied to enforce degeneration of a higher resonance, and thus double the bandwidth in the band of interest. Three slotted antenna configurations are reported plus a baseline configuration; a thorough numerical characterisation of performance is provided. Fractional bandwidth (FBW) in the range 22–34% was achieved, which is almost quadruple that of existing implementations. The antennas exhibit total efficiencies around 80% and are elliptically polarised. A suitable figure-of-merit is suggested for performance comparisons; it attempts to capture overall antenna performance in a single quantity. Antenna performance depends heavily on electrical size, which depends on the size of the ground plane, since the RF ground is an integral part of the total radiator. The ground-effect study showed that wrong choice of size can force resonant modes to vanish. Best performance for a slotted PIFA was obtained with a ground plane measuring 0.20l _ 0.28l, significantly smaller than predicted in prior studies. Bandwidth augmentation through slot loading is supported by measurements. Fabricated antennas with sub-optimal ground plane sizes exhibit FBWs in the range 20–23%.*

***Index Terms:** Degeneration, Configuration. Performance, Antenna, Measurement.*

I. INTRODUCTION

Research in wireless sensor networks (WSNs) has focused on scalar networks that convey measured data over lowbandwidth streams. The WSN discipline is shifting towards the delivery of multimedia content. The integration of low-power wireless technologies with inexpensive hardware,suchas complementary metal–oxide semiconductor cameras, is enabling the development of distributed networked systems that are able to transfer video and audio streams. These systems are known as wireless multimedia sensor networks (WMSNs) and video sensor networks (VSNs)[1]. Multimedia data rates exceed those of current sensor nodes by orders of magnitude. Hence, large bandwidth must be added to the de facto constraints of small node size and low cost. The need for bandwidth becomes even more pronounced considering that source encoding requires complex encoders and powerful processing, which lead to high energy consumption: video data will require transmission with inefficient compression. Numerous academic and commercial sensor node implementations ('motes') exist at 2.5 GHz. Motes are severely constrained in terms of battery, memory, processing capability and achievable data rate. Mote designers quickly abandoned bulky discrete antennas and turned to printed radiators. Integrated microstrip antennas coupled directly to RF electronics offer the obvious advantages of low-cost, lowprofile and simplified assembly procedure. Energy consumption is a fundamental issue associated with network lifetime and connectivity. The efficiency of the radiating system is related to the energy efficiency of the whole node, decibel-for-decibel. Antennas designed This paper focuses on the antenna system of a generic sensor node and builds upon the study in [1] to explore bandwidth-enhancement techniques for printed inverted-F antennas (PIFAs). Antennas are immune to size reduction, because the physical laws that determine their behavior because their basic attributes to be self-conflicting: the efficiency-bandwidth product is related to the volume occupied by the antenna[2].The theoretical foundations of small antennas suggest that good performance is obtained when most of the allocated space participates in radiation. Thus, printed antennas seem a priori handicapped. The scope of this work is the challenging task of keeping antenna size reasonably small, while extending bandwidth significantly. Antenna efficiency is equally important: multimedia andvideo sensors will be powered by non-replaceable for WSNsshould exhibit total efficiencies as close to unity as possible.The design approach was augmented by matching the properties of PIFAs to the size of the ground plane (GNDP) of the sensor device, which is an active part of the overall radiating mechanism [3]. The technique adds no cost or complexity, since the ground plane is always there; printed monopoles use the GNDP through current induction to produce an asymmetric image. The GNDP size affects bandwidth, efficiency and gain. The RF ground introduces two degrees of freedom, since both of its sides can contribute to radiation.

Bandwidth Enhancement and Radiation

II. ANTENNA DESIGN

Slot antennas can be used for fixed stations, satellite ground stations and beacons. With proper mounting, a slot antenna can also be used for 'microwave mobile'. With a 16-s ot total, the antenna can have 10-12 dBi gain. Slot antennas can be built from surplus waveguide sections, which will give an omni-directional pattern and horizontal polarization.

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This paper offers a computer aided method to calculate the proper dimensions for the slots and their locations. Because the antenna is of one-piece construction, it is rugged and can be built cheaply, requiring only access to a reasonably precise drill press or milling match.

III. RADIATION PROPERTIES

Efficiency is a crucial attribute of WSN-targeted antennas. Motes are battery-operated and their batteries are considered non-replaceable[4]. Therefore energy efficiency is a fundamental problem determining network lifetime and connectivity. The efficiency of the radiating system is related to the energy efficiency of the whole node, decibelfor-decibel. Therefore mote-oriented antennas should exhibit high efficiency despite their small size.Furthermore, it is well known that small antenna aperture invariably leads to small directivity. Thus, it is anticipated that the far-field pattern of the three slotted antennas will lie somewhere between the theoretical isotropic and the omnidirectional pattern of the half-wavelength dipole (the Hertzian dipole could also be used as the reference antenna at the lower end of directivity, but it is also a linear antenna that exhibits linear current distribution; that is, it shows deep nulls in the far-field). The spatially restricted SCD cannot provide for spatial filtering in the form of lobes and nulls. Most often this hypothesis is correct. Exceptions to the norm are UWB monopoles, which achieve directivity at the upper end of their bandwidth where they become electrically very large (ka _ 2.0 rad). Given the above, the conclusion is easily reached that the far-field pattern is almost irrelevant. The two efficiencies, radiation erad and total etotal, are the relevant radiation properties. The two quantities vary with frequency and are related as in (2) etotal W erad[1 _ jGin(jv)j2] ¼ erad[1 _ jS11(jv)j2] (2) Broadband radiation efficiency in the range 2–3 GHz calculated with a 0.1-GHz step is depicted for all three antennas. A common characteristic, which is more profound in pre-fractal PIFAs, is the greater drop around the frequency of the anti FIGURE1 VCD of the K2-slotted PIFA estimated at the two resonances of 2.41 GHz (upper) and 2.58 GHz (lower).The VCDs show that the situation is far from the worst-case phase difference (Df)WC ¼ 1808, where the lower part of the PIFA becomes a shortened ML antenna, that is, it has near-by traces with opposite currents drop of 0.7 dB, that is, erad drops from 93 to 80%. The fluctuation is less pronounced for the ML-slotted PIFA. Broadband total efficiency is for all three PIFAs. The faster roll-off of the efficiency of the K2 scheme is caused by the faster rate of increase of j Ginj at the band edges. The flat response of the ML-PIFA from 2.3 to 2.8 GHz is a useful property.

IV. PROPERTIES OF SLOTTED ANTENNA

The pattern cuts are the f ¼ 0 andu omnidirectional for all antennas and it was omitted. At the lower resonance, the cuts show even shallower nulls; that is, the 3D pattern is closer to isotropic than it is to omnidirectional. The omnidirectional gain pattern in the f ¼ p/2 plane is very desirable for small portable terminals, such as wireless sensor nodes. These terminals often operate in a rich-scattering environment, where incoming waves -resonance where the two subbands join. In the case of K2 and GK2, there is an extra

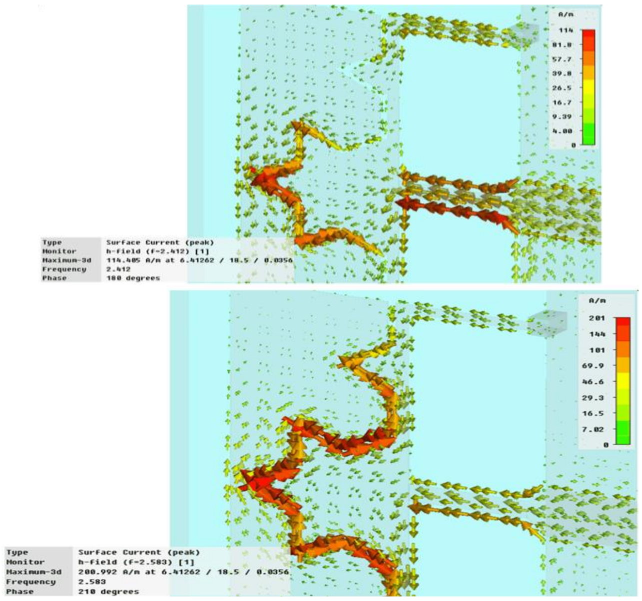

Figure VCD of the K2-slotted PIFA estimated at the two resonances of 2.41 GHz (upper) and 2.58 GHz (lower) The VCDs show that the situation is far from the worst-case phase difference (Df)WC ¼ 1808, where the lower part of the PIFA becomes a shortened ML antenna, that is, it has near-by traces with opposite currents arrive from all directions in space, that is, they have a large angular spread [5]. WSN terminals should be able to receive. efficiently from as many directions as possible. The polarisation at the principal planes is linear, but in general this antenna is elliptically polarised: the two orthogonal polarisations co-exist and have similar magnitudes. Thus, the dominant E-field component changes at every principal plane. The details are tabulated where the dominant E-field component in the far-field is stated along with the cross-polarisation ratio (XPR) in decibels. Note the high cross-polarisation at the f ¼ 0 plane; polarisation is near-elliptical in that principal.

V. CONCLUSION

Given the relatively small number of printed IFA-based antenna designs reported in the recent literature, this work intended to present new design solutions that add to the existing single-band device-integrated antennas.In the evolution of modern antennas, the planar IFA inherited the properties of the microstrip patch antenna,whereas the printedIFA inherited those of the printed monopole[6]. Printed monopoles are well-known wide band radiators, whereas patch antennas are not. A technique thatextends the bandwidth of a wideband family of antennas was described, with the ulterior motive of trading excess bandwidth for size reduction. To this end, reactive tuning of PIFAs was applied in the form of three slotted configurations, plus a baseline antenna.A comprehensive design guide for slotted PIFAs was distilled from the numerical study of the proposed schemes.This guide helps one to design slotted PIFAs in a straightforward manner, without resorting to optimisers, which may take long to converge[7].Electrical performance was characterised through numerous computed results.

Slot loading showed a potential to triple the impedance bandwidth compared to prior implementations (22–34% achievable FBWV). The study of SCDs revealed that most of the area of the element is used for radiation at both resonances. In radiation terms, the antennas provided satisfactory gains and high efficiencies (_80%); polarisation is elliptical, although linear at the principal planes. A simple FOM was used to compare the performance of the three PIFAs headto- head. [8]The final comparison displayed in an emphatic way that modern antenna design is an art of compromise. But the printed antenna element is not the total radiator; focusing only on the elements would be inadequate. For GND planes of the size commonly used in microsensors, inspection of the radiating properties corroborates the GNDP influence on BW and its significant radiation [9]. The study showed clearly that the choice of GNDP size, which is almost equal to the size of the sensor node, can force resonant modes to appear or vanish. GNDP length had a more drastic effect than width[10]. Printed monopoles are well-known wideband radiators, whereas patch antennas are not. A technique that extends the bandwidth of a wideband family of antennas plane, which is hardly a drawback for motes. High crosspolarisation is useful in applications where the antenna is positioned randomly, such as for handheld devices that require linear polarisation response in all directions for good performance.

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