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Design of Balanced Slot UWB Antenna with High CM Rejection

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Abstract **– In this paper, a new compact balanced ultra-wideband (UWB) slot antenna is proposed. The antenna consists of a differential feeding line and a non-uniform multi-band radiating slot. The whole antenna structure is deployed symmetrically across the plane of symmetry (POS) to obtain good differential-mode (DM) radiation characteristic and high common-mode (CM) rejection. In this design, the feeding line is placed across the POS so that in DM operation large current distribution around the intersection can be obtained to result in strong coupling with the slot antenna. On the other hand, the transverse (the direction perpendicular to the POS) dimension of the slot antenna is set as small as possible to push the CM resonant frequencies of the parasitic quarter-wavelength slot far away from the UWB passband so that favorable CM suppression can be obtained. The designed balanced slot UWB antenna shows a DM passband ranging from 3.1 to 10.6 GHz and has a maximum CM return loss of 2.5 dB within the DM passband.**

Index Terms **—Balanced slot ultra-wideband antenna, DM radiation pattern, common-mode suppression**

1. Introduction

Ultra-wideband (UWB) RF/microwave devices, including antennas [1], have been widely explored and developed in the past decade due to the increasing application demand in short-range indoor wireless communication systems. However, most of the UWB antennas presented in published papers are of single-ported ones, with the radiating element being multi-mode/multi-band slots or metal patches. The works presented in [2-3] are some examples.

Although the balanced configuration is widely adopted in the design of RF/microwave modules, balanced (or differential) UWB antennas are still scant in the open literature. Up to the present, only a few papers are dealing with balanced UWB antennas. In [4], a band-notched slot UWB antenna is fed by differential microstrip lines. Two symmetric C shaped strips are implemented in the feeding plane of the antenna to increase the high-frequency gain. In [5] and [6], the slot UWB antennas are fed by differential coplanar lines with split-ring resonators or half-wavelength slits etched on the feeding lines to produce the desired notched bands. However, all these works do not show the common-mode (CM) response that is important for the performance of a balanced circuit.

In this paper, a new balanced slot UWB antenna is proposed. The antenna is composed of a non-uniform radiating slot and a differential feeding line which is deployed across the plane of symmetry (POS) to produce strong coupling with the slot antenna. CM suppression is achieved by setting the slot dimension in the direction perpendicular to the POS of the slot antenna small and thus pushing the CM resonant modes to frequencies far away from the DM UWB passband.

2. Balanced Slot UWB Antenna Design

The configuration of the proposed balanced slot UWB antenna is shown in Fig. 1. The antenna is fabricated on a RO4003 substrate with thickness 0.813 mm, dielectric constant 3.55, and loss tangent 0.0027. The antenna consists of a differential microstrip feeding line on one side of the substrate and a radiating slot on the other side. Good differential-mode (DM) UWB radiation performance and high common-mode (CM) rejection are the primary interests of this balanced slot UWB antenna design.

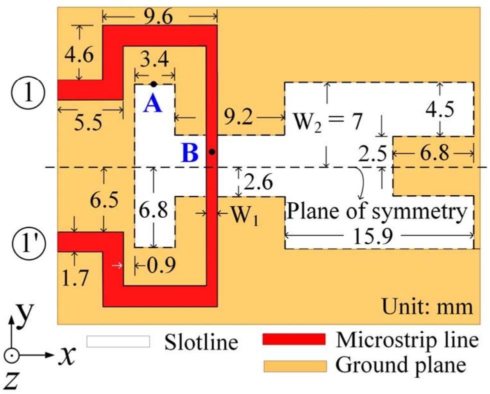


Fig. 1. Geometry of the balanced slot UWB antenna.

To obtain good differential-mode (DM) performance, the antenna structure is deployed symmetrically across the plane of symmetry (POS). Thus when in DM operation, the POS can be replaced with an electric wall. In this case, the half circuit of the slot UWB antenna works as a half-width radiating slot, with the center frequencies of its first three modes, namely, $f_1 = 3.4\,\text{GHz}$, $f_2 = 7.2\,\text{GHz}$, and $f_3 = 9.85\,\text{GHz}$, located in the designated passband to provide the UWB response. It is noted that the radiating slot is purposely designed to be a non-uniform one so that f_1 - f_3 can be properly located. For the design of the feeding configuration in Fig. 1, unlike those using differential open-ended feeding lines in [4-6], the microstrip feeding line for this work is placed across the POS to obtain large current distribution around the center of its vertical section (near point B) when differentially excited. This results in strong surrounding magnetic field over the slot surface and hence strong coupling with the slot antenna. In addition, the vertical section of the feeding line is made narrower to have better impedance matching with the slot antenna and flatter UWB responses.

When in CM operation, the POS can be replaced with a magnetic wall and is virtually open-circuited. The half circuit of the slot antenna is incomplete in structure, resulting in poor radiating performance. However, even with the open boundary along the POS, the half slot circuit can still forms a quarter-wavelength resonator. To push the CM resonant modes to higher frequencies and attain good CM suppression within the UWB passband, the dimension of the slot antenna along y-direction should be as short as possible.

3. Results and Discussion

The proposed balanced slot UWB antenna was designed with the aid of simulation using Ansoft HFSS to obtain the structural parameters shown in Fig. 1. A prototype of the designed balanced slot UWB antenna was fabricated and measured. Fig. 2 shows the frequency responses of the DM and CM return losses for the balanced slot UWB antenna. The measured (simulated) DM 3-dB passband is from 3.1 (3.05) GHz to 10.79 (10.62) GHz, with a minimum return loss of 10.5 (11.44) dB. Furthermore, good CM suppression was observed, with a measured (simulated) maximum return loss of 3.3 (2.7) dB over the displayed frequency range of 1-12 GHz

Fig. 3 plots the peak gain and the radiation efficiency responses. The simulated peak gain is between 3 and 7 dBi and the efficiency is between 90% and 97% within the UWB passband. The simulated radiation patterns in two principal planes, namely, the *x-y* and *x-z* planes, for 4, 7, and 9.5 GHz are normalized and plotted in Fig. 4.

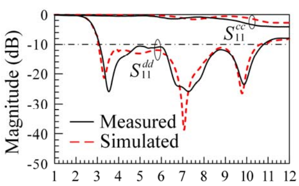


Fig. 2. DM and CM return losses.

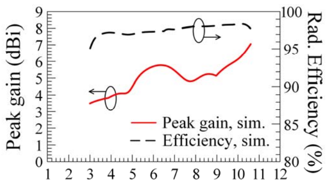
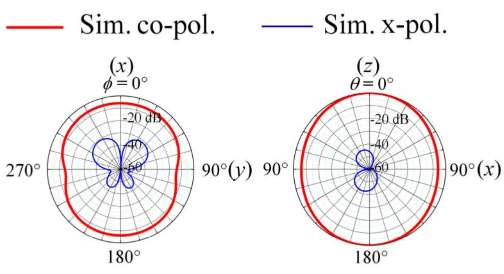
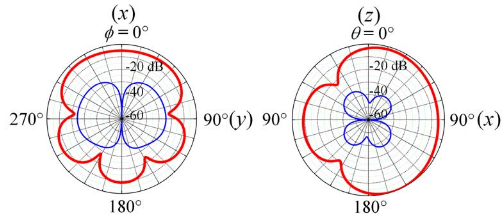


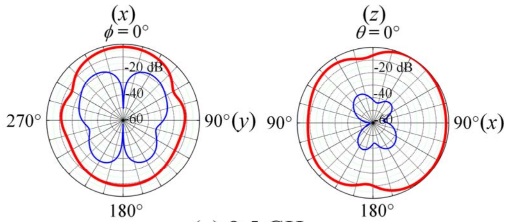
Fig. 3. DM peak gain and efficiency.



(a) 4 GHz



(b) 7 GHz



(c) 9.5 GHz

Fig. 4. DM radiation patterns.

4. CONCLUSION

In this paper, a new differential microstrip-line fed balanced slot UWB antenna has been designed and validated. By locating the first three modes of the non-uniform slot antenna in the UWB passband and placing the differential feeding line across the POS to produce strong coupling with the slot antenna, good DM performance has been attained. In addition, by setting the slot dimension in the direction transverse to the POS of the slot antenna small and thus push the CM resonant modes to frequencies far away from the DM UWB passband, wideband CM suppression has been achieved.

Acknowledgment

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