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MODIFIED BOW-TIE ANTENNA FOR EFFICIENT TRANSMISSION OF UWB PULSES

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1. Introduction

In this paper we describe development of an improved ultra-wideband (UWB) antenna for short-range impulse ground penetrating radar (GPR) applications, carried out in joint research collaboration between IRCTR – Delft University of Technology, The Netherlands, and Bandung Institute of Technology (ITB), Indonesia. The developed antenna has been designed to give improved features in comparison with commonly-used UWB radiators, such as resistively-loaded dipoles (wire or planar) and bow ties. Important improvements have been achieved in the form of higher radiation efficiency with small late-time ringing and reduced antenna dimension. For short-range GPR applications late-time ringing should be as small as possible as it may mask radar returns.

2. Design considerations

The antenna is based on a modified wire bow-tie structure with 120º flare angle and designed for excitation with monocycle pulses having 0.8-ns duration. The 120º-flare angle has been chosen to obtain antenna characteristic impedance of around 100 Ω to match the antenna to the 100-Ω feed system used for measurements. Relatively high radiation efficiency is obtained by creating artificial discontinuities on the wires at a certain distance from the feed point in such a way that radiations from the feed point and the discontinuities combine constructively in the broadside direction of the antenna. Such a technique has been introduced in [1]-[2]. The artificial discontinuities are created by bending the wires, so that part of the wires is parallel to the main axis of the antenna. A great advantage of this approach is that by doing so one considerably reduces the antenna dimension.

Part of the wires that is parallel to the main axis is resistively loaded by lumped resistors in series for suppressing late-time ringing. The resistors start from the bends and extend to the antenna ends. Each wire is loaded with 25 equally-spaced resistors to obtain a smooth profile of the loading. The values of the resistors determine the ability of the antenna to suppress late-time ringing. In this work the challenge is to find the optimal values for the resistors (i.e. to find the loading profile) for maximal ringing suppression. Furthermore, because the resistors start from the wire bends, they also function as additional discontinuities needed to enhance radiations in the broadside direction of the antenna. In addition, by using lumped resistors it is relatively easy to change their values for optimizing the loading profile through an engineering approach.

The antenna length has been determined by simulations using the method of moments (MoM) and the finite-difference time-domain (FDTD) method. To minimize antenna length a series of simulations of the antenna with various loading profiles have been performed and the minimal antenna length which led to acceptable level of ringing was chosen. Moreover, an epoxy substrate has been used in the construction of the antenna to further minimize its dimension. As a result, we obtain a compact antenna with a dimension of 23 cm by 7 cm for excitation with the above-mentioned pulses. In Fig. 1 the geometry of the antenna is shown.

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3. MoM analysis

The Numerical Electromagnetics Code (NEC-2) and a Fourier transform routine are utilized to perform time-domain analyses of the antenna. The 0.8-ns monocycle is used as the excitation model. The antenna is loaded with loading values given in Table 1, in which loading values #2 is 4 times larger than loading values #1. The first value of loading values #1 is intentionally made higher than the rest to enhance discontinuity at the wire bends. The computed transmit waveforms 25 cm in the broadside direction of the antenna is given in Fig. 2. The results are compared with the transmit waveform of a conventional wire bow tie (without loading) with the same flare angle and 25-cm length. It can be seen that the waveform amplitudes of the antenna are much higher that that of the conventional bow tie due to additional radiations from the discontinuities. In the case of the loading values #1, the amplitude is 60% higher. Loading values #2 (which are 4 times larger) even give higher amplitude because the larger loading values near the wire bends introduce stronger discontinuity. However, it can be seen that higher waveform amplitude is followed by a slightly larger ringing.

4. FDTD analysis

To analyze the antenna directly in time domain a series of FDTD simulations have been performed. It has been found that when the antenna is made of a solid plate its time-domain response will not differ much from its wire counterpart, as shown in Fig. 3. This shows that the proposed wire model is a good approximation of the solid plate structure. Its main advantage is that it allows relatively simple implementation of resistive loading, which on the contrary is not easy to implement in the solid plate structure. Both the wire and solid plate models are depicted in Fig. 4.

The computed transmit waveform 10 cm in the broadside direction of the antenna with loading values #1 is presented in Fig. 5. This result shows that this loading profile does not satisfactorily suppress the ringing as a relatively high level of ringing still occurs following the main pulse. This suggests that improved loading profiles should be used to make the tail of the waveform adequately flat. As mentioned above, the main challenge of this work is to find the optimal loading profile, which could be done through an engineering approach as it is relatively easy to play with different values of the loading, in simulations as well as in experiments. In Fig. 5 we also make a comparison with the transmit waveform of the antenna when it is not loaded. It can be observed that the loaded antenna results in higher waveform amplitude as a result of stronger discontinuity caused by the loading near the wire bends. Moreover, it is obvious that the level of the ringing of the unloaded antenna is unacceptably high due to the absence of the resistive loading.

5. Experimental antenna

For experimental verifications the antenna has been constructed on an epoxy substrate and loaded with loading values #1. The transmit waveform 50 cm in the broadside direction of the antenna is measured and plotted in Fig. 6. As the FDTD result in Fig. 5 suggests, late-time ringing still occurs in the waveform indicating an improved loading profile should be used. Nevertheless, we can see that the antenna behaves as expected, i.e. the level of ringing is already much reduced and the waveform has a triplet shape as a result of superposition of radiations from the feed point and the wire discontinuities, which should significantly increase the amplitude of the waveform. The experimental antenna is shown in Fig. 7.

6. Conclusions

A design of a compact UWB antenna is presented. The antenna shows potential improvements in comparison with commonly-used resistively-loaded dipoles or bow ties. The improvements have been shown in the form of significantly higher radiation efficiency, suppressed late-time ringing and reduced dimension. Further improvement of the antenna is confined in finding the optimal loading profile, which can be done through an engineering approach and will be the subject of a future paper.

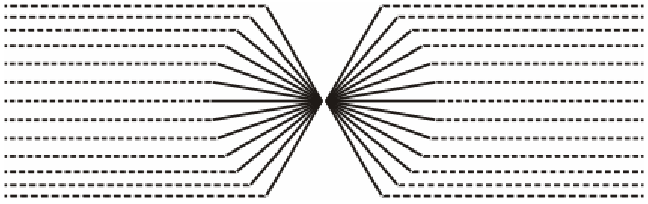

Fig. 1. Geometry of the antenna. The antenna length and width are 23 cm and 7 cm, respectively. The gaps in the horizontal wires are locations for the lumped resistors.

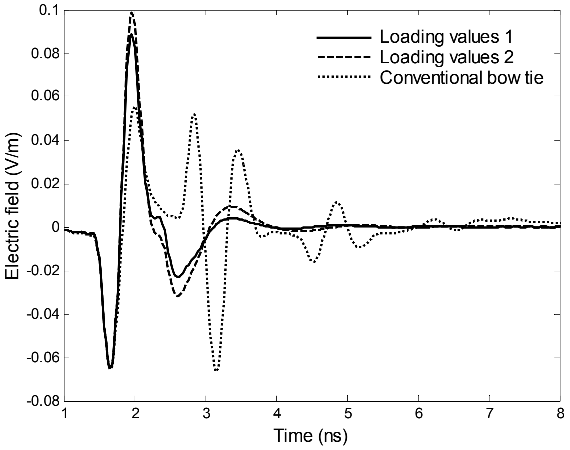

Fig. 2. Computed transmit waveforms (MoM) of the antenna with loading profiles in Table 1 and a conventional bow-tie antenna with 120° flare angle. The observation point is 25 cm in the broadside direction of the antenna.

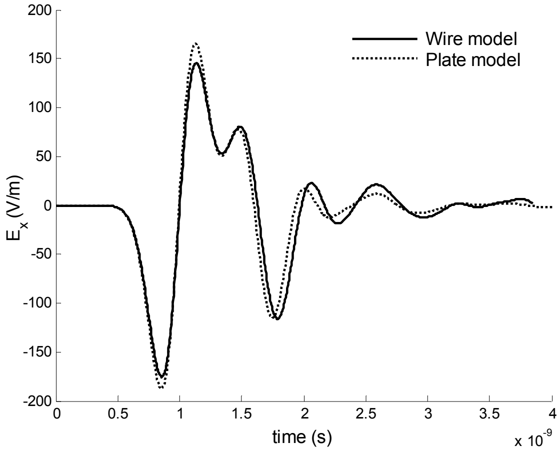

Fig. 3. Computed transmit waveforms (FDTD) of the antenna with wire and solid plate models (without loading). The observation point is 10 cm in the broadside direction of the antenna.

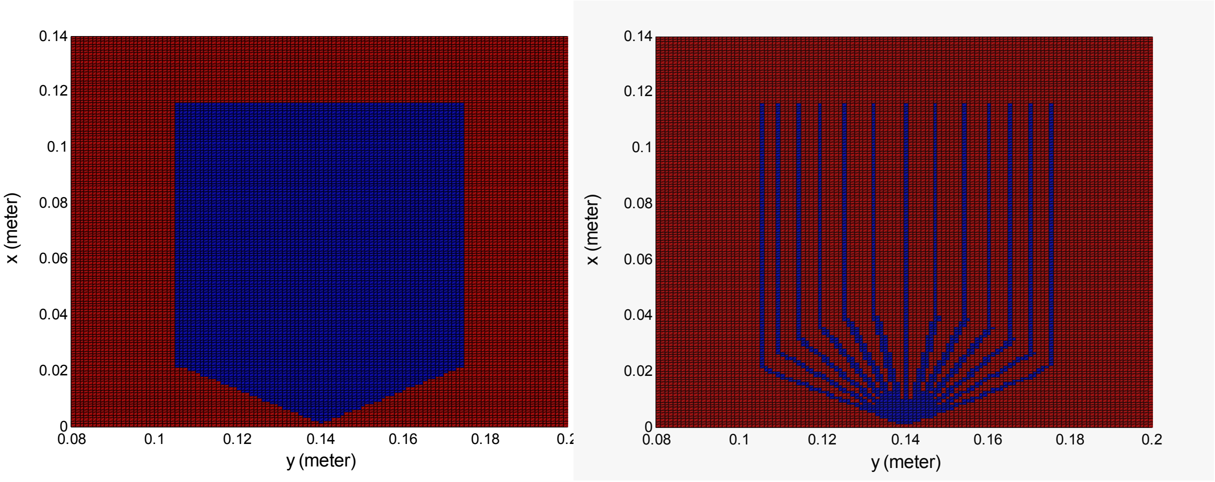

Fig. 4. FDTD models of the antenna: solid plate model (left) and wire model (right).

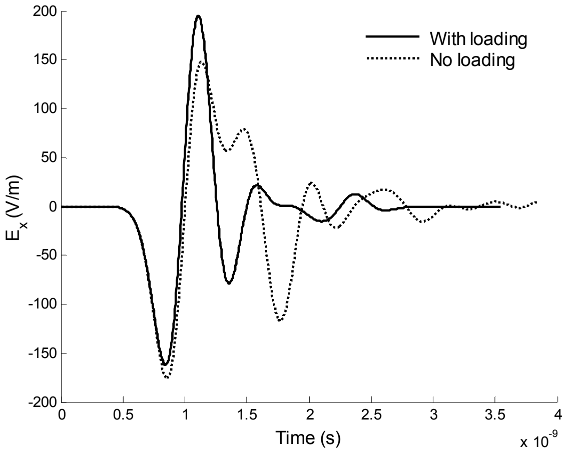

Fig. 5. Computed transmit waveform (FDTD) of the antenna with and without loading. Loading values #1 are used. The observation point is 10 cm in the broadside direction of the antenna.

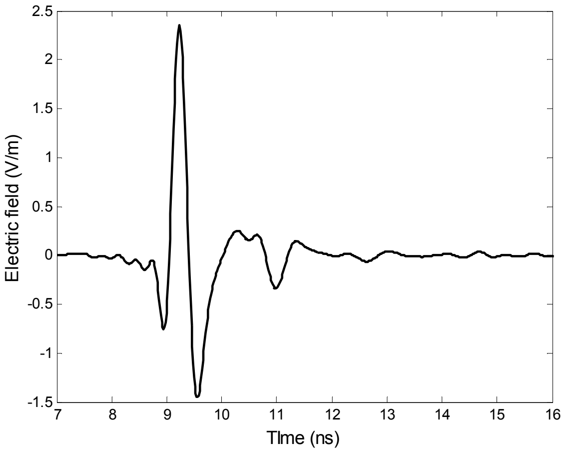

Fig. 6. Measured transmit waveform of the antenna with loading values #1. The observation point is 50 cm in the broadside direction of the antenna.

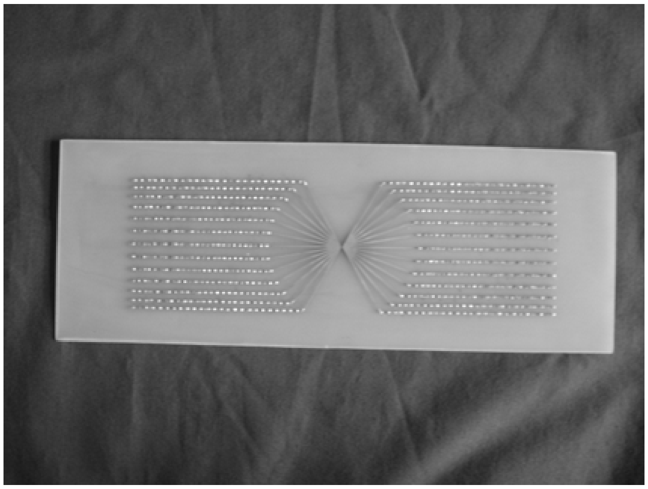

Fig. 7. The experimental antenna.

Table 1

LOAD	VALUES 1	VALUES 2
R_1	1000 Ω	1000 Ω
R_2	20 Ω	80 Ω
R_3	30 Ω	120 Ω
R_4	40 Ω	160 Ω
R_5	50 Ω	200 Ω
R_6	60 Ω	240 Ω
R_7	70 Ω	280 Ω
R_8	80 Ω	320 Ω
R_9	90 Ω	360 Ω
R_{10}	100 Ω	400 Ω
R_{11}	110 Ω	440 Ω
R_{12}	120 Ω	480 Ω
R_{13}	130 Ω	520 Ω
R_{14}	140 Ω	560 Ω
R_{15}	150 Ω	600 Ω
R_{16}	160 Ω	640 Ω
R_{17}	170 Ω	680 Ω
R_{18}	180 Ω	720 Ω
R_{19}	190 Ω	760 Ω
R_{20}	200 Ω	800 Ω
R_{21}	210 Ω	840 Ω
R_{22}	220 Ω	880 Ω
R_{23}	230 Ω	920 Ω
R_{24}	240 Ω	960 Ω
R_{25}	250 Ω	1000 Ω

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