Resistive and Inductive Loading Techniques on Microstrip Antenna for Wideband Application

Sangbong Jeon* and Chang-Hoi Ahn[†]

Abstract – In this work, an exponentially tapered microstrip antenna was implemented using a resistive loading technique in order to suppress the internal reflections. The inductive loading was realized by introducing slits on the antenna to improve radiation efficiency. Compared with a resistive-loaded antenna, the proposed antenna had an average improvement of about 6.2% in radiation efficiency within the range of 2–10.5 GHz. In addition, the highest peak of the radiated short pulse from the proposed antenna became 45% greater than that of an antenna with resistive loading only.

Keywords: Multiple reflections, Resistive and inductive loading, Short transient pulse

1. Introduction

A ground penetrating radar (GPR) that operates in the time domain may produce "late-time ringing" because of its ability to transmit in the ultra-wide bandwidth. The term "late-time ringing" refers to the oscillations that follow the transmitted pulse after the radiated pulse. Resistive loading [1] is a useful technique that suppresses late-time ringing. However, this technique decreases radiation efficiency because of dissipating currents. Capacitive loading [2] that is realized on a planar structure, such as a bow-tie antenna with a slot perpendicular to the current direction, has been proposed to improve radiation efficiency. However, in the case of a microstrip antenna with a narrow strip, capacitive loading is not appropriate because the slot has low capacitance. To apply non-dissipative reactance loading, we implemented inductive loading using slits that are parallel to the currents' directions. Furthermore, we gained control of the resistive loading effect by changing the size of the slits. In other words, resistive loading increases toward the end of the antenna as the equivalent width of the strip decreases. The present paper proposes a resistive technique to suppress late-time ringing using graphite strips as well as an inductive loading technique to improve radiation efficiency by introducing slits on the strips.

2. The design of the wideband microstrip antenna

GPRs are commonly used in two types of antennas, namely, the V antenna and the Vivaldi antenna. These antennas have tiny gaps serving as feed lines; thus, the feeding point is difficult to fabricate accurately. To overcome the drawback, a double-sided antenna has been proposed [3, 4], which has multiple reflections between the feed and open ends of the antenna. This proposed technique [3] to reduce reflections is not easy to implement. To reduce internal reflections, the present work is concerned with improving the impedance match of antennas over a wide range of frequencies. This can be achieved using a resistive and inductive loading antenna, with a loading profile that increases from the feeding point to the open ends of antenna. The geometry of the antenna under consideration is depicted in Fig. 1. The feed has a width of 3.99 mm and length of 102.43 mm. At the end of the feed line, the exponentially-tapered antenna begins to achieve broad frequency bandwidths. The feed line is copper-printed. Each tapered line is graphite-printed for resistive loading, and has a slit for inductive loading on a 1.59 mm-thick epoxy glass. Furthermore, the surface resistance can be controlled along the lines by changing the gap of the slits.
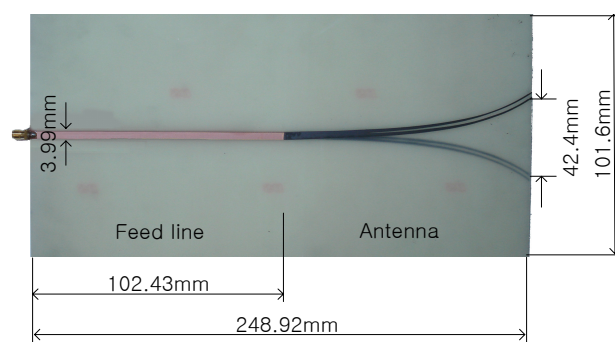

Fig. 1. Geometry of the proposed double-sided microstrip antenna

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3. Numerical and experimental results

A dipole model with lumped resistive and inductive elements in series was used to analyze the loading effects in the frequency and time domain. Accurate resistance and inductance were extracted using commercial software (Q3D Extractor) for the three-dimensional structures shown in Fig. 1. The antenna part was discretized to 15 sections. The extracted resistances and inductances of each section are listed in Table 1.

Table 1. Parameters of the resistive and inductive loading for the antenna.

n	$R_n(\Omega)$	$L_n(nH)$	n	$R_n(\Omega)$	$L_n(nH)$
1	10	17.742	9	90	18.482
2	20	17.725	10	100	18.726
3	30	17.734	11	110	19.015
4	40	17.787	12	120	19.351
5	50	17.866	13	130	19.764
6	60	17.98	14	140	20.236
7	70	18.118	15	150	20.815
8	80	18.283			

Fig. 2 shows the normalized current distributions on the strip with no loading, resistive loading, and resistive and inductive loading. The current distributions of the non-loaded antenna oscillated because of the standing wave created by reflection in the open ends of antenna. In comparison, the R-loaded antenna sufficiently suppressed the currents near the ends. The RL-loaded antenna suppressed the current in a lesser degree compared with the R-loaded antenna; however, the current, which was less frequency-dependent along the antenna, appeared as a smooth distribution.

In the time domain, an electric field that radiated at a 150 mm distance in the broadside direction of the antenna was simulated, as shown in Fig. 3. The non-loaded antenna re-radiated periodically in the time domain through the reflection at the ends of antenna but with a high peak signal. The R- and RL-loaded antennas showed reduced late-time ringing. For the R-loaded antenna, the highest peak of the radiated electric field dropped to 44% compared with that of the non-loaded antenna. However, with the RL-loaded antenna, the highest peak was 61% that of the non-loaded antenna. The reflected signals were measured from a large perfect electric conducting plane, which was placed 100 mm in front of the antenna using a network analyzer (0.5–10.5 GHz). The non-loaded antenna had the biggest reflection, but had large multiple reflections as well (Fig. 4). Meanwhile, the R-loaded antenna had the smallest peak reflection, denoting radiation inefficiency. The peak reflection in the RL-loaded antenna was higher than that of the R-loaded antenna; the RL-loaded antenna maintained the ripples at a similar level with the R-loaded antenna. The RL-loaded antenna also showed improved peak amplitude, which was 45% higher than that of the R-loaded
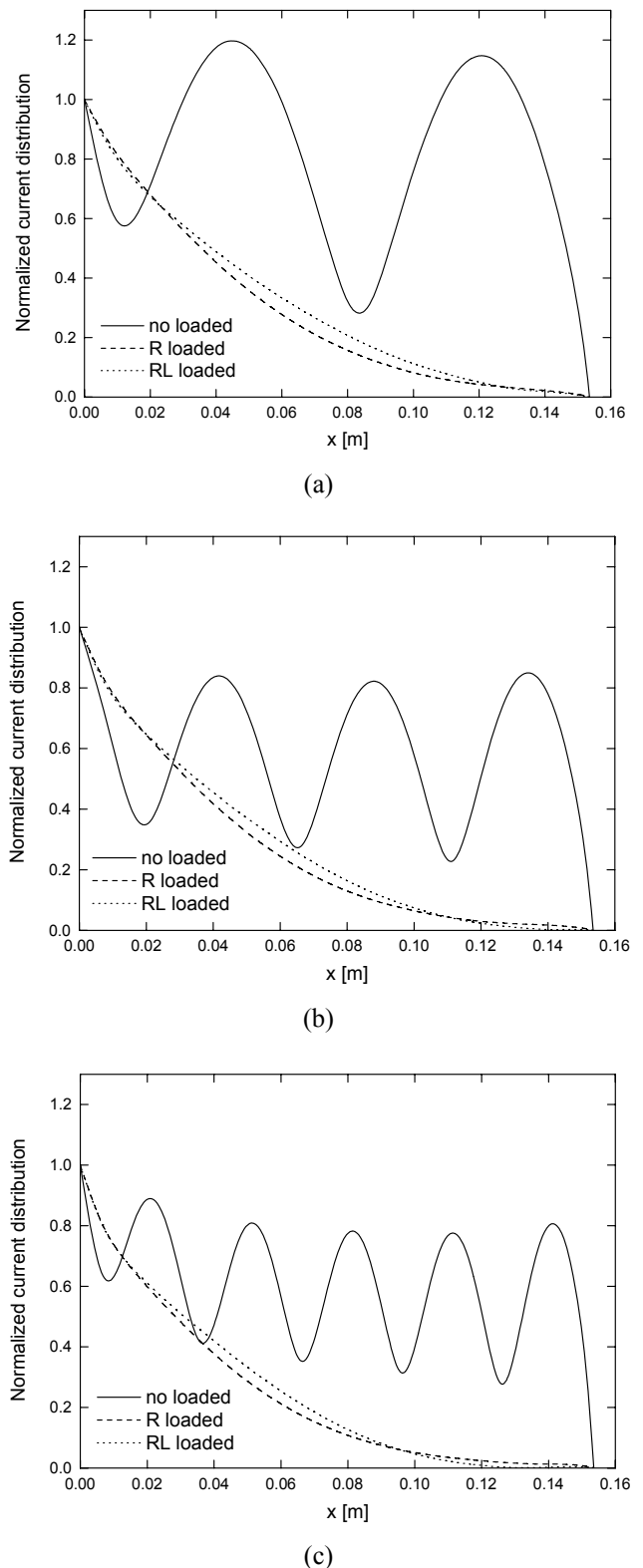

(a)

(b)

(c)

Fig. 2. The normalized current distributions of the antenna at (a) f = 2 GHz; (b) f= 3.25 GHz; (c) f=5 GHz.

antenna. Moreover, its radiation efficiency, simulated by using CST software, showed an improved efficiency of 6.2% on average in the range of 2–10.5 GHz.
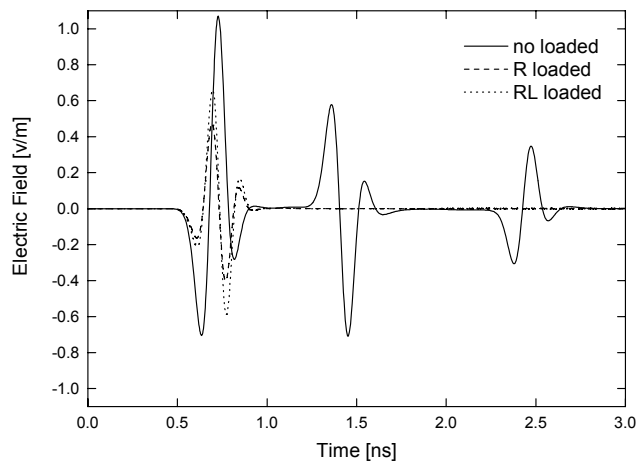
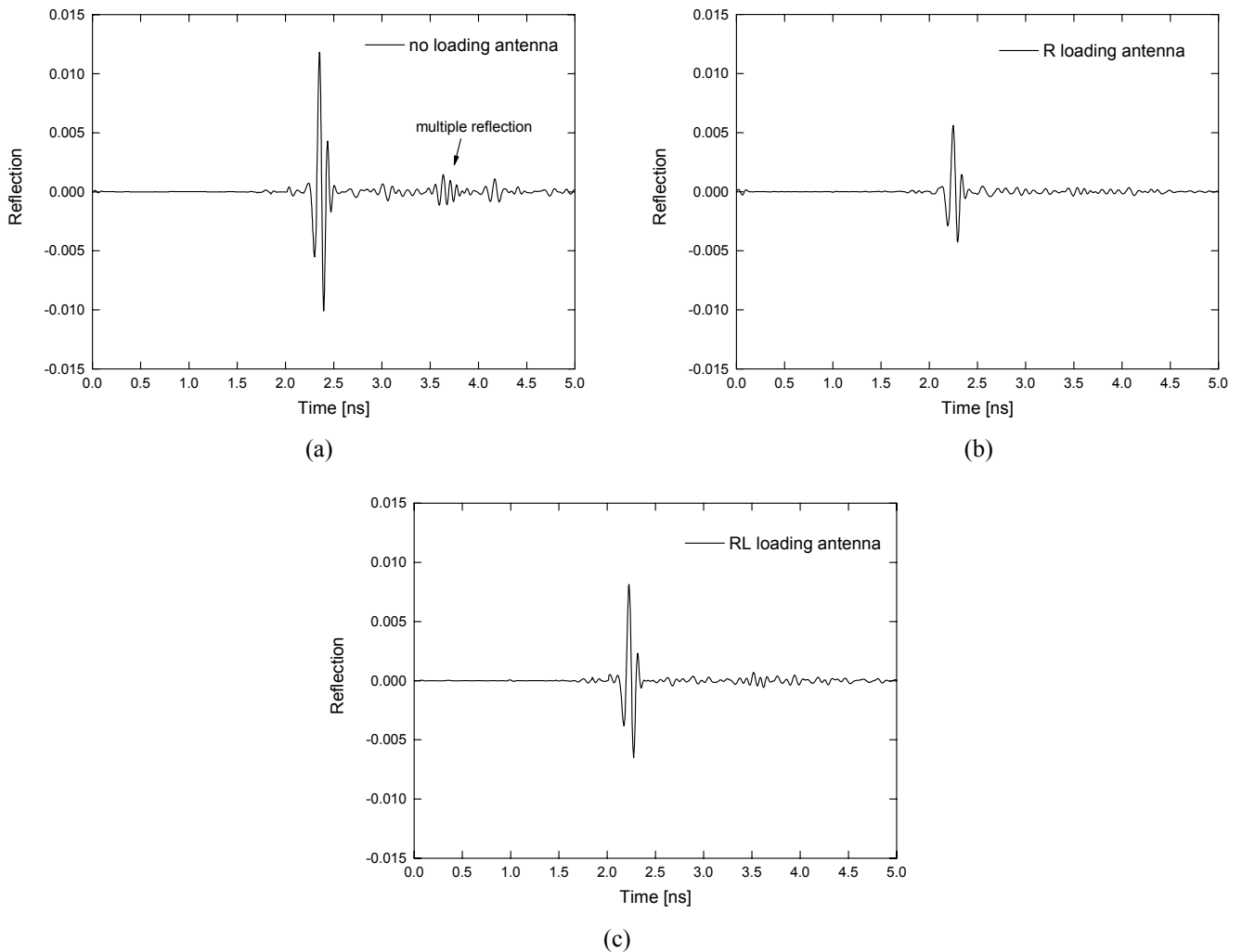**Fig. 3.** The simulated radiated electric field of the antenna in the time domain

(a)

(b)

(c)

Fig. 4. The reflection signals from a PEC plane: (a) no loading antenna; (b) R-loading antenna; (c) RL-loading antenna

5. Conclusion

The present study designed a broadband antenna using a resistive loading technique for short transient pulses in order to reduce internal reflections within the antenna. Inductive loading was achieved by introducing slits on the strips. The internal reflections of the antenna were reduced by adapting the resistive loading; the radiation efficiency

was improved by inductive loading. Therefore, the proposed antenna can be used to prevent the masking of the target signal efficiently.

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