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An Ultra-wideband Omnidirectional Dipole Antenna for Borehole Radar Application

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Introduction

People's demand for studying underground geological structures and exploring underground resources is increasing :

- **Underground gap measurement;**
- **Water content profile measurement;**
- **Oil well prospecting, etc.**

The pulse signal sent by the common ground penetrating radar antenna will be severely attenuated after passing through the underground medium, so that the detection range is very limited.

Borehole radar antenna can work in the borehole and has the characteristics of high resolution, far detection distance and simple structure.

Antenna Design

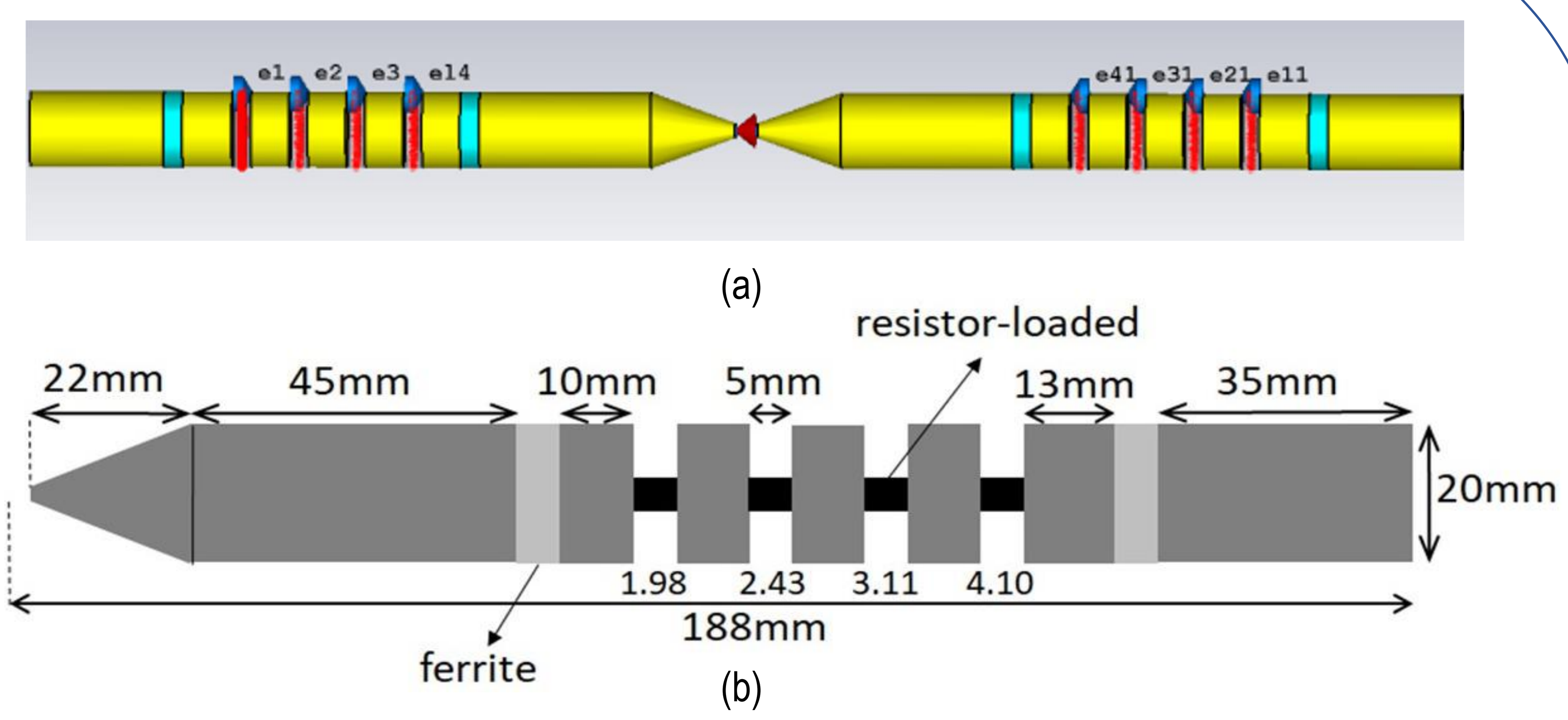


Figure.1 Antenna structure (a) Simulation model. (b) Geometric size of half antenna.

The value of loaded resistance is calculated by the following formula :

$$R_i(z_i) = \frac{R_0}{(1-|z_i/h|)+(1-|z_i/h|)^2}$$

Where R_0 is expressed as :

$$R_0 = \frac{\Psi_0 \zeta_0}{2\pi h}$$

Where ζ_0 is 120πΩ, and Ψ_0 is expressed as :

$$\Psi_0 = 2\left[\ln\left(\frac{2h}{b}\right) - 1\right]$$

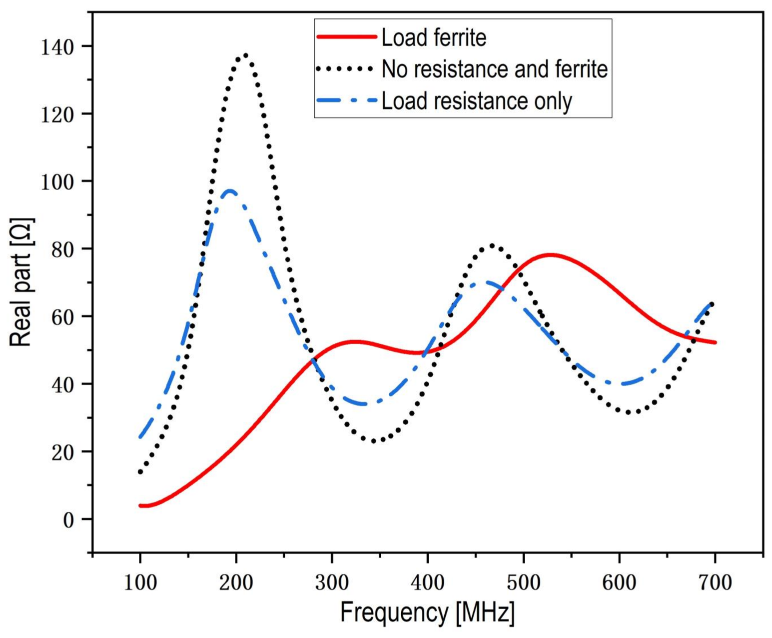
In the above formula, z_i is the distance from the ith resistor to the feed point along the antenna arm; h is the length of the single arm of the antenna, and b is the radius of the dipole antenna.

Simulation Results

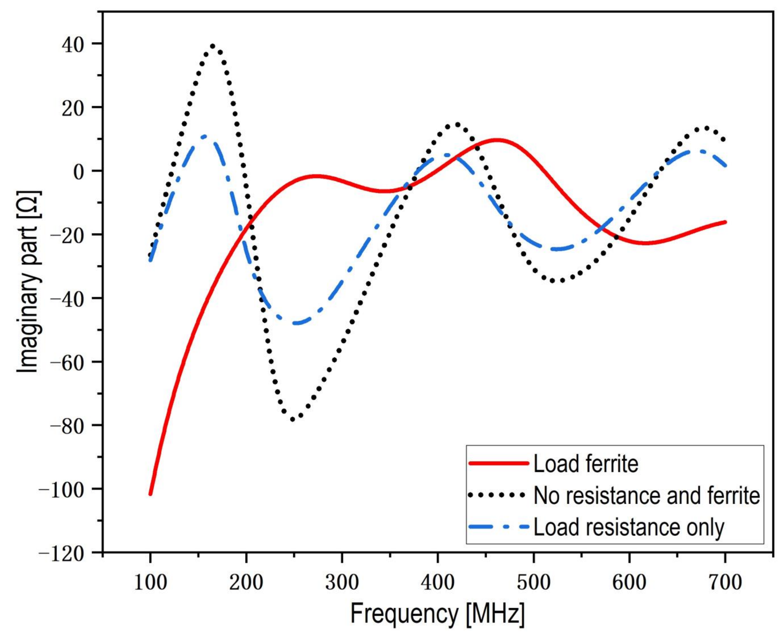
The simulation results are offered by the CST MWS. In order to simulate the working environment of the borehole radar antenna, set the relative permittivity of the simulation background to 8.

The antenna without resistance and ferrite loaded (referred to as no resistance in the figure), the antenna with discrete loaded (referred to as load resistance only in the figure) and the antenna with ferrite and resistance jointly loaded which is the antenna proposed in this paper (referred to as load ferrite in the figure) are compared respectively.

Real part of the input impedance



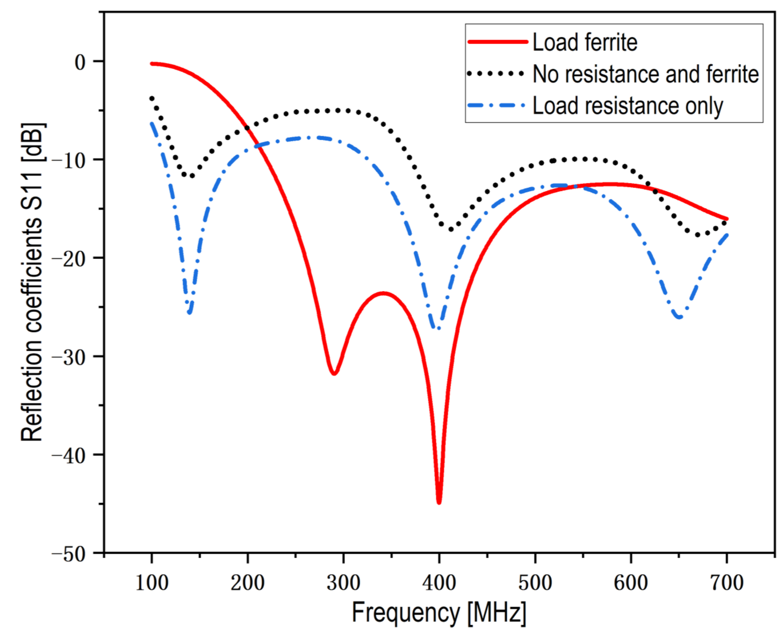
Imaginary part of the input impedance



Simulation Results

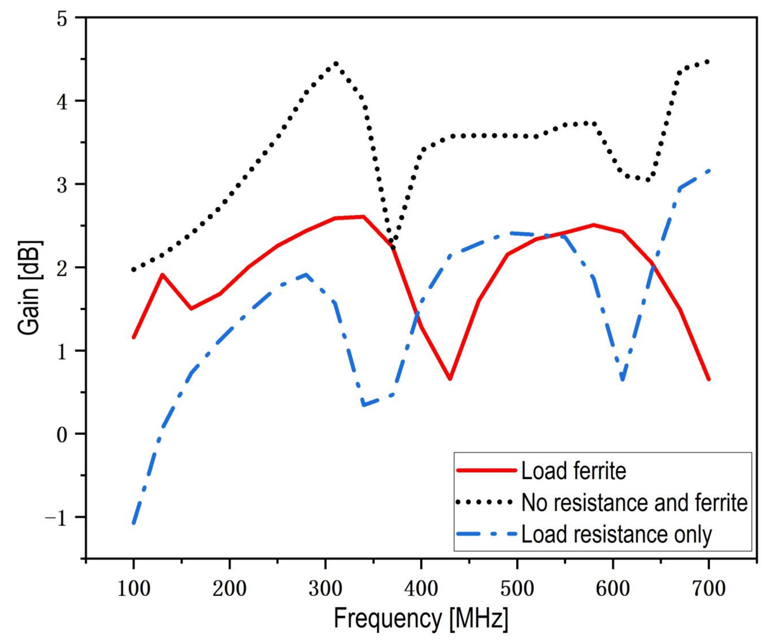
The antenna proposed in this paper has flatter input impedance than the other two antennas, and its real part fluctuates around 50Ω while its imaginary part fluctuates around 0Ω which facilitates the connection with the coaxial cable.

Reflection coefficients S11



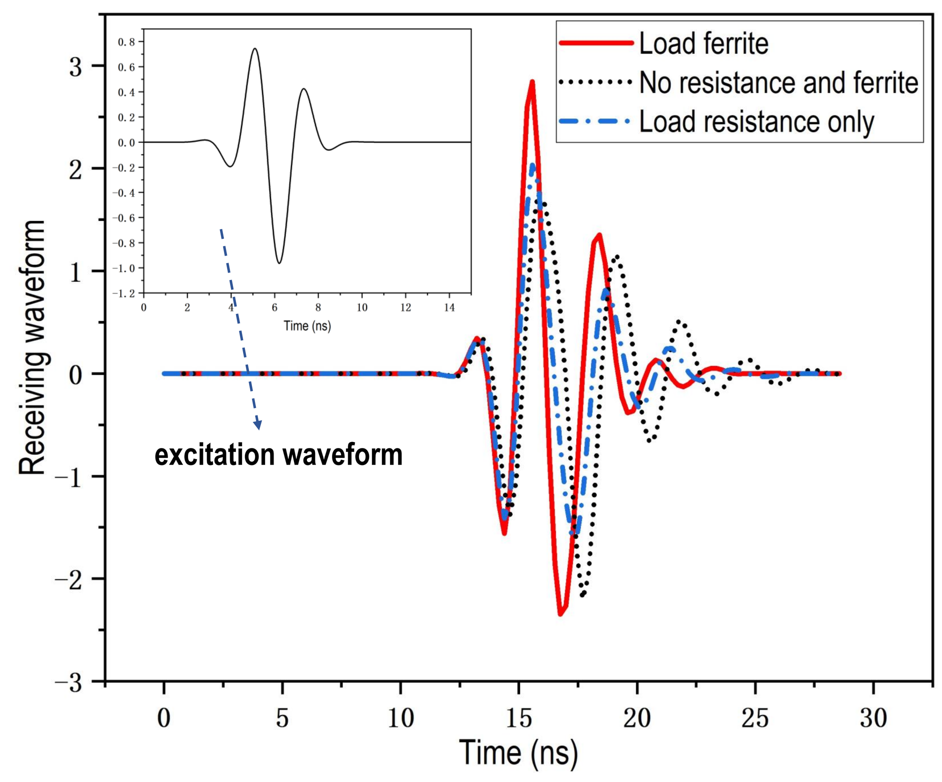
- Bandwidth is 221MHz-700MHz;
- Relative bandwidth is 104%;
- The bandwidth of the proposed antenna is increased by nearly 115MHz compared with the dipole loaded with resistors only.

Gain of the antenna



- The antenna gain decreases after loading.
- The gain in the other frequency bands has been improved except that the gain is slightly smaller in the range of 409MHz-550MHz.

Radiation waveform observed at 1m from antenna



An electric field probe is placed 1m directly in front of the feed port. Compared with the other two antennas, the time domain waveform of the proposed antenna is improved :

- Peak-to-peak value has been improved;
- Amplitude of the tail is reduced;
- Duration of the tail is shorter;
- Distortion degree of the waveform is reduced.

Signal received from the receiving antenna

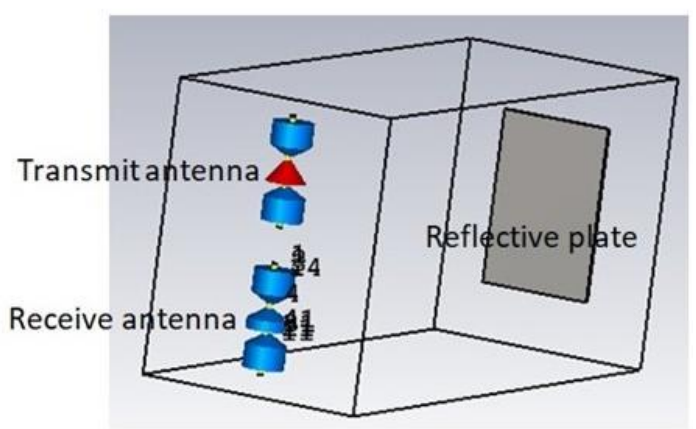
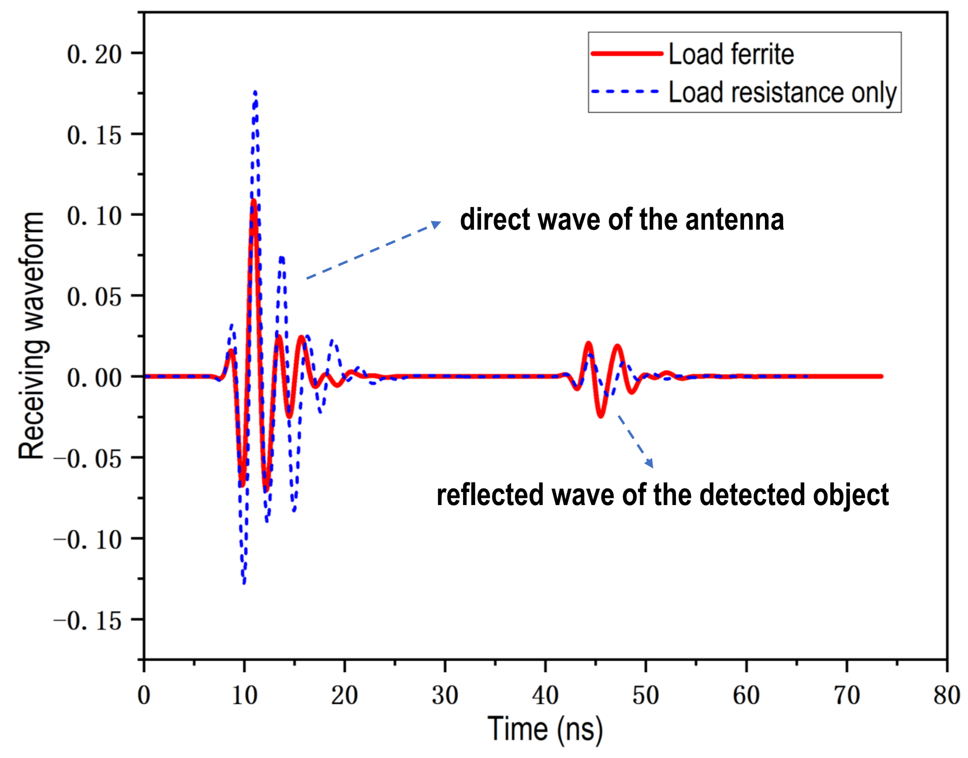


Figure.2 Schematic diagram of antenna transmitting and receiving model.



The distance between the centers of the transmitting and receiving antennas is 50cm. A metal reflector with a size of 40cm*60cm*1cm is placed 2m away from the antenna.

By observing the reflected waves of the two antennas, we can see that the reflected wave amplitude of the ferrite-loaded antenna is larger, the waveform distortion is smaller, and the fidelity is significantly better, which verifies its superior working performance.

Conclusion

A dipole omni-directional antenna for borehole radar system is designed by using the combined loading of ferrite and resistor. The simulation results show that the proposed antenna has the characteristics of ultra-wideband and low ringing, and has good performance, which can be used in borehole radar systems.