A Novel UWB-SP Sensor Based on Notched Microstrip Line*

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***Abstract*—A novel UWB-SP standard sensor is presented in this paper. The sensor is mainly composed of a section of microstrip line with the notched patch. The simulated result shows that the effective time window of the sensor can be expend by adopting a notched patch. Within the effective time window, the sensor can replicate directly the incident electric field without distortion. The upper frequency of the sensor is up to 3 GHz, and the theoretical result and simulated result of the sensitivity have good consistency.**

Keywords*—*notched microstrip line; UWS-SP; time window; sensitivity

I. INTRODUCTION

Technologies in ultrashort electromagnetic pulses (UWB-SP) are finding wider and wider applications each year in radio communications, high-resolution radar, and geology for mineral prospecting, in industry, public health and transport [1-3]. For typical UWB-SP fields, the rise time is from several decuple ps to ns and the duration time is from several hundreds of ps to several ns. The spectrum of the fields is up to 3 GHz or even more. TEM horn and D-dot sensor are used to measure such electric field [4].

For metrology purpose, the monoconical TEM cell [5-6], which can generate standard UWB-SP fields, is always used to calibrate the UWB-SP sensors. Thus, a sensor with ultra-wide bandwidth, high fidelity and compact dimension a needed to monitor the parameters of the field pulses in the working zone of the field-generating system. TEM horn [7] outputs a voltage waveform, which is identical to the incident electric field. But, its sensitivity is incalculable analytically, and its dimension may be too large to ignore the disturbance caused by the receiving antenna. D-dot sensor [8] has a wide bandwidth. But, due to the derivative behavior of D-dot field sensors, an integrator or a numerical integration has to be used to restore the pulse shape of the electric field.

A novel UWB-SP sensor is investigated in this paper. The sensor mainly consists of a section of microstrip line with the notched patch. It has a good fidelity and wide bandwidth. The output signal of the sensor can replicate directly the waveform of the radiated pulsed electric field. Moreover, the sensitivity of the sensor can be calculated accurately. The sensor can be used as the UWB-SP standard sensor for the accurate measurement and metrology of UWB-SP.

II. SENSOR DESIGN

A. The microstrip line coupling to an electromagnetic wave

The transmission line equations (telegrapher's equations) have been derived for the transmission line consisting of two parallel wires separated by a dielectric layer and electromagnetic wave in [9].

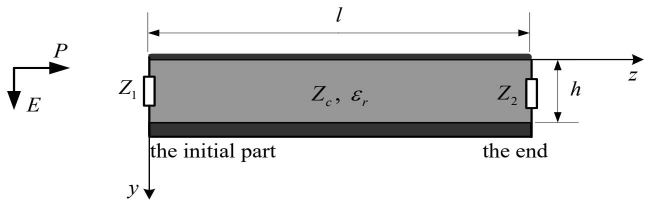

Fig.1 Microstrip line illuminated by a plane wave

Based on the equations, the excitation of the linear nonsymmetric microstrip line by an external electromagnetic field is considered for the loads Z_1 and Z_2. As shown in Fig.1, the vector E is perpendicular to the upper surface of the dielectric substrate, and the poynting's vector P is parallel to the surface.

At the time t=0, the incident wave front reaches the load Z_1. Under the action of external field in the impedance Z_1, there arises an induced voltage

$$U(t) = h_{ef}E(t) = \frac{h(\rho_1+1)}{2}\left[\frac{(1-\frac{1}{\varepsilon_r})}{\sqrt{\varepsilon_{ef}}+1}+\frac{1}{\varepsilon_r}\right]E(t) \tag{1}$$

Where h_{ef} is the sensitivity of the sensor, ε_r is the relative dielectric permittivity, ε_{ef} is the equivalent dielectric permittivity. The sensitivity is mainly determined by the substrate thickness h and the reflection coefficient ρ_1 of the initial part,

$$\rho_1 = \frac{Z_1 - Z_c}{Z_1 + Z_c} \tag{2}$$

The waveform of the induced voltage $U(t)$ is consistent with the waveform of the incident field. At the time t_1=l/c, the incident wave front reaches the load Z_2, then there arise an induced voltage in the load Z_2. The induced voltage signal is transmitted along the microstrip line, and added together with the $U(t)$ at the time

$$t_w = \frac{l\sqrt{\varepsilon_e} + l}{c} \quad (3)$$

So, t_w is the effective time window of the sensor. Within the time window, the output signal $U(t)$ of the sensor can replicate the incident field. A longer length of the microstrip line and a higher equivalent dielectric permittivity mean a longer time window.

From (1), the transfer function of the sensor can be computed. Considering the change of the equivalent dielectric constant is small in the range of frequency that we care about, we neglect the change. Thus the ideal distortionless conditions

$$|H(w)| = \frac{h[\rho_1(w)+1]}{2}\left[\frac{(1-\frac{1}{\varepsilon_r})}{\sqrt{\varepsilon_{ef}}+1} + \frac{1}{\varepsilon_r}\right] \quad (4)$$

$$\varphi(\omega) = wt_0$$

can be got. Formula 4 signifies that the bandwidth of the sensor is related to $\rho_1(w)$.

B. The geometry of the sensor

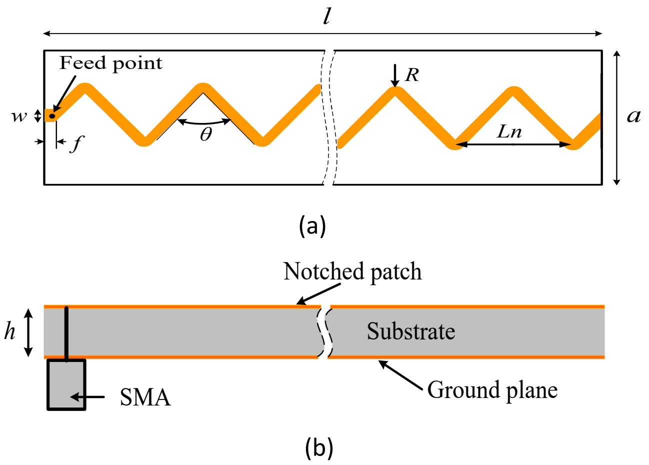

Fig.2 Geometry of the proposed sensor (a) Top view, (b) Feed structure

The geometry of the proposed sensor is shown in Fig. 2. The sensor consists of a layer of substrate, a notched patch located at the top layer of the upper substrate, a large square ground plane and a 50 Ω SMA connector. The output signal acquisition is realized from the initial part of the microstrip line by the SMA connector connected to a coaxial line, and it means that unwanted interference from the end of the microstrip line comes to the recorder after the wanted measuring signal. The notched patch is use to lengthen the transmission time of the interference signal from the end along the microstrip line, thus to extend the time window. The high-frequency losses in the substrate can lead to an increase in the rise time of the output signal. In addition, the bandwidth of the sensor is also limited due to the construction of the junction for removing its output signal, which has a parasitic capacitive-inductive impedance together with the load Z_l. So, a dielectric substrate with low relative dielectric permittivity and thin thickness h and a narrow patch should be adopted to broaden the bandwidth.

In consideration of the sensitivity, the time window and the bandwidth, an appropriate standard sensor is designed with parameters shown in Table 1.

Table1 DIMENSIONS (IN MILLMETERS) OF THE SENSOR

Parameter	*l*	*w*	*a*	*f*	*Ln*	*h*
Value	332	2	50	2	4	2.54

III. Simulation Results And Discussion

The substrate used in the design is PTFE with ε_r=4.1. The angle θ of the notched patch is 45º. The proposed sensor is simulated by a commercial software CST. Linear polarization plane wave is set as the excitation source in the simulation. Instead of oscilloscope, matched loads are connected to the ends of the transmission line. The output field waveform from the sensor are calculated under the condition of the Gaussian pulse of which the pulse width is about 270 ps and the spectrum covers from DC to 3 GHz as the excitation signal. It can be seen from Fig. 3, the time window of the sensor is about 3.3 ns. The result is longer than the 3 ns of the sensor with a straight patch. Within the effective time window, the recovered waveform by the sensor coincides with the incident waveform very well. In addition, the sensitivity of the sensor can be got by dividing the peak value of the recovered signal and the peak value of the excitation signal, and the simulated result is 0.51 mm.

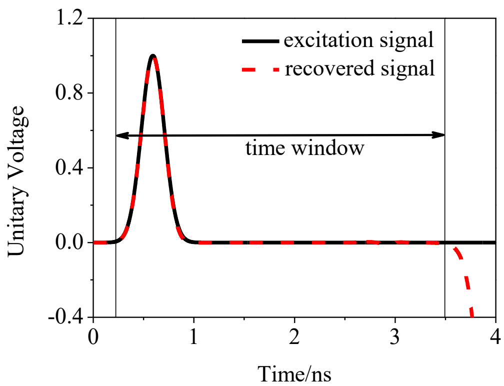

Fig.3 excitation signal and recovered signal

If we lengthen the length l of the sensor further, the sensor can measure the Gaussian pulses with longer pulse duration and lower spectrum.

Adopting a short Gaussian pulse of which the spectrum covers from DC to 4 GHz as the excitation signal, we convert the incident electric field and the output voltage to the frequency domain, then the amplitude response and the phase response of the transfer function can be calculated respectively in Fig.4 (a) and (b).

It can be seen from Fig.4 that for frequencies less than 3 GHz the amplitude response is approximately flat and the phase response are straight lines, satisfy the distortionless conditions (as shown in formula 4) approximately. It signifies that the sensor has a wide bandwidth from DC to 3 GHz, when the effective time window is long enough.

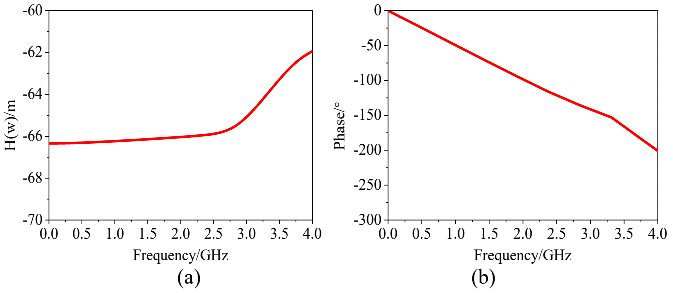

Fig.4 Transfer function (a) Amplitude response, (b) Phase response

Fig. 5 show the simulated TDR impedance of the sensor. The simulated result show that the impedance of the coaxial cable is about 50 Ω, and the characteristic impedance of the notched microstrip line is 75.5 Ω. From formula (2), the reflection coefficient of the initial part ρ_1 of the sensor can be calculated. Thus, the sensitivity h_{ef} of the sensor can be gained from the formula (1), and the result is 0.52 mm, which is almost in agreement with the simulated result of the preceding context. It means that the theoretical calculation and numeral simulation have good consistency, and the sensitivity of the sensor fabricated can be calibrated accurately by a vector network analyzer in the actual application.

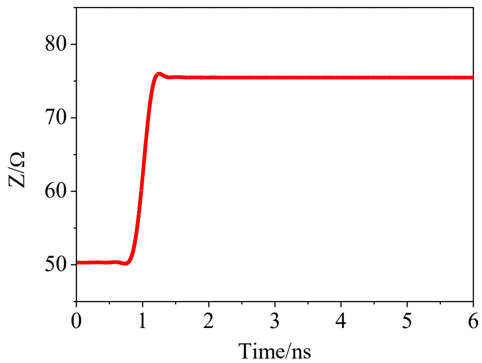

Fig.5 TDR impedance

IV. Conclusion

Based on notched microstrip line, a novel UWB-SP Sensor has been described in this paper. The sensor consists of a section of notched microstrip line and a SMA connector. The simulated effective time window is 3.3ns. Within the effective time window, the sensor can capture directly the incident field without distortion. The upper frequency of the sensor is up to 3 GHz, and the sensitivity can be calculated accurately. The good performance and easily fabricated method make it attractive for the field measurement of UWB-SP. More detailed study on the sensor performances is left for a future work.

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