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Increasing the Level of the Reflected Signal of a Broadband Pulse Locator by Changing the Pulse Duration of the Shock Excitation of a Broadband Antenna

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ABSTRACT
Is investigated possibility increasing the level of the reflected signal at the set frequency at a choice of optimum duration of an impulse of excitement of locator with shock excitement of the antenna.

Key words: spectral density as a function of pulse's duration, the optimal duration of excitation pulse, trapezium's shaped impulse, spectral density of trapezium's shaped impulse

INTRODUCTION

In locators with shock excitation of ultra-wideband (UWB) antennas, short pulse are used for transmitters. Depending on the purpose of the locator, these pulses can be amplitude from a few volts to hundreds or even thousands of volts and duration from tens of picoseconds to several nanoseconds. The criterion for selecting the marked parameters is the assignment of a locator, whether for subsurface sounding of a medium with large attenuation or for a displacement sensor for small-sized targets in a room. In any case, when the active element [1, 2, 3] is selected, with the help of which impulses are formed, the developers tend to get the maximum return from it. Namely - the maximum amplitude of the signal, reflected from the target. This can be achieved in various ways. For example, careful matching of all nodes of the signal path: the driver of the excitation pulse - the transmission line of the pulse to the antenna - the antenna of the transmitter - the antenna of the receiver - the line - the receiver's input [4]. Or to seek the possibility of increasing the amplitude of the excitation pulse. However, its uncontrolled increase causes additional noise in the reception paths of the locator [5]. Another way is possible, namely, raising the level of the spectrum in the impulse of the antenna excitation at its central frequency by changing the shape of the pulse, in particular by changing the pulse width. As a rule, developers try to reduce the duration of the excitation pulse front, missing the opportunity to vary the pulse duration. The tool for changing the pulse width is the change in the duration of its vertex.

SUBSTANTIATION INCREASING THE LEVEL OF THE REFLECTED SIGNAL

As experiment has shown that in most cases a pulse is used to excite broadband antennas, characterized by parameters such as: amplitude, duration of the front, duration of the flat part (vertex), and duration of the decay. Form such an impulse can be represented as a trapezoid with the corresponding durations. The typical described above real impulse and its analogue - trapezium are presented in Fig.1.

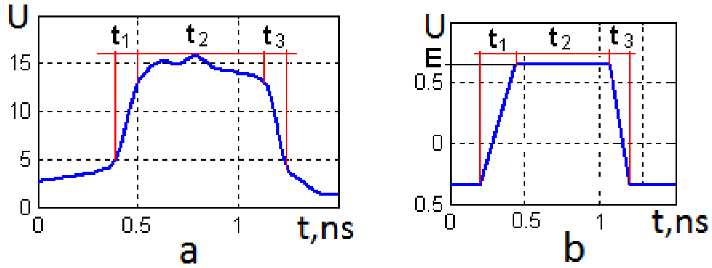

Fig. 1 Typical impulse, used in most cases for shock excitation of broadband antennas (a). Trapezium is the equivalent of the excitation pulse shape (b).

In the spectral representation in the limited frequency range, when the parameters are equal, these pulses are practically equivalent. Studies [6] in which the pulses are represented in the form of a trapezium with smoothed angles approximating the trapezoid to the real pulses gave equivalent results. Therefore, further reasoning and research will be performed with an excitation pulse in the form of a trapezium.
We represent a trapezoidal pulse of unit amplitude in the form of a piecewise function:

$$U_T = \begin{cases} at & 0 \le t \; and \; t < t_1 \\ 1 & t_1 \le t \; and \; t < t_1 + t_2 \\ 1 - b(t - t_1 - t_2) & t_1 + t_2 \le t \; and \; t \le t_1 + t_2 + t_3 \end{cases} \tag{1}$$

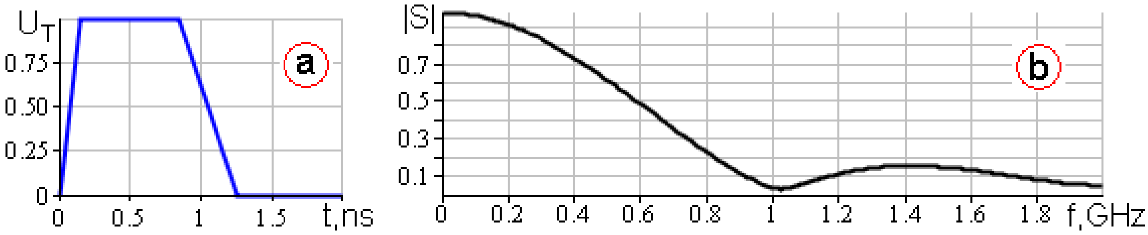

Fig. 2 Trapezoidal impulse (a) and its spectral density module (b) as frequency distribution of amplitudes.

Its spectral density is found by the classical formula: $S = \int_0^{\tau} U_T e^{-j2\pi ft} dt$, where the limit of integration $\tau \ge t_1 + t_2 + t_3$.

For example pulse (Fig. 2a) with parameters $t_1 = 0.15ns; \; t_2 = 0.7ns; \; t_3 = 0.4ns$ the distribution of the modulus of its spectrum is shown in Fig. 2b. Now let us take some fixed frequency f_0 and find the dependence of the amplitude (spectrum S at frequency f_0) on the duration of the flat part of the trapezoidal pulse. To avoid confusion, we denote this dependence (amplitude distribution) as $A(t_2)$. As shown in [6], this dependence can be represented in the form of a periodic function:

$$A(t_2) = \dot{K}_{t_1} - \dot{K}_{t_3} e^{-jwt_2}, \tag{2}$$

where $\dot{K}_{t_1}, \dot{K}_{t_3}$ - constant complex coefficients, determined respectively by the values of t_1 and t_3. The typical dependence of the module $|A(t_2)|$ is shown in Fig.3. The period of the

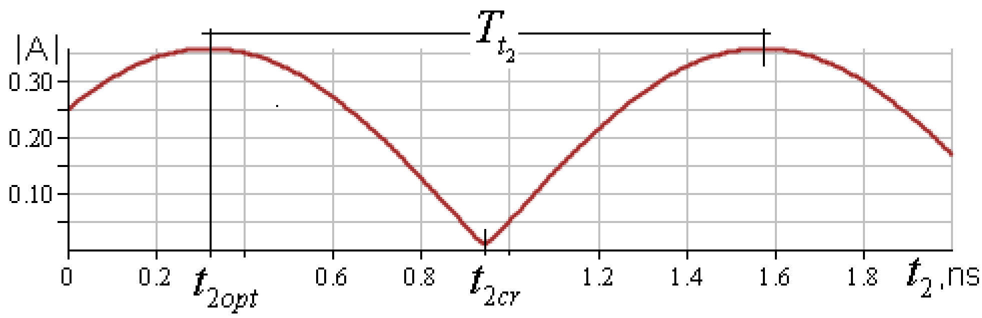

Fig. 3 Typical dependence of the module $|A(t_2)|$ at a fixed frequency on the duration of the flat part of the trapezoidal pulse. (f_0 = 0.8GHz, $t_1 = 0.25ns; \; t_3 = 0.35ns$)

function is $T_{t_2} = 1/f_0$. We will execute our research on the interval of the first period. As follows from the figure and the analysis of the curve $|A(t_2)|$, the latter has extreme values for the duration t_2: the optimal value of the duration t_{2opt} at which the maximum value of the spectrum module is reached, the critical value of the duration t_{2cr} at which the value of the spectrum modulus is minimal. The found expressions for these quantities are:

$$t_{2opt} = 0.5\left(\frac{1}{f_0} - t_1 - t_3\right); \quad t_{2cr} = \frac{1}{f_0} - \frac{t_1 + t_3}{2} \tag{3}$$

The values of the optimum and critical durations of the flat part of the excitation pulse of an antenna, calculated from these formulas, allow in practice to achieve a gain in the reflected signal or to explain the reason for the low level of the reflected signal in the presence of excitation pulses at the transmitting antenna. An example is the oscillograms, obtained on the layout of the locator and shown in Fig. These signals correspond to reflections from a metal sheet located at a distance of 1.5 m from the antennas. For the excitation pulse $t_1 = t_3$=0.1ns.

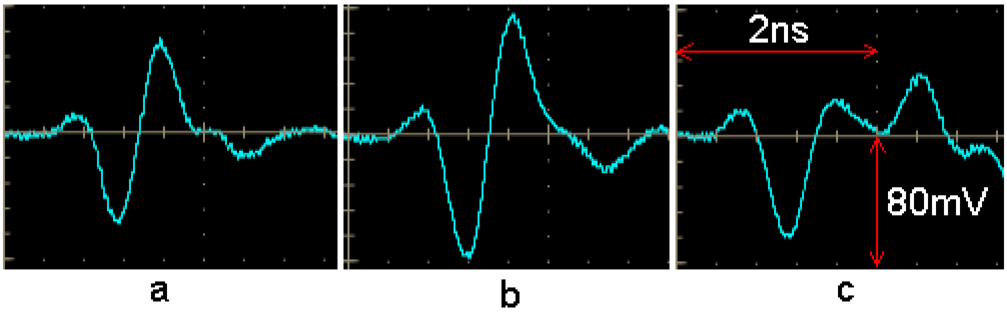

Fig. 4 Oscillogram, corresponding to reflections from a metal sheet when the antenna is excited by pulses with the flat part duration equal to: a) - zero; b) - t_{2opt}; c) - t_{2cr}.

The center frequency in the spectrum of the reflected signal is f_0=1.1GHz. With an error not exceeding 10%, the values of the calculated and critical durations coincided (t_{2opt} = 0.35ns, t_{2cr} = 0.8ns).

In the complex shape of the trapezoidal excitation pulse (see Fig. 1a), it is necessary to have the experience of correctly assigning values t_1, t_2, t_3 and selecting the center frequency f_0 in the spectrum of the reflected broadband signal. At small values of the excitation pulse duration (t_1, t_3<0.3ns), one should keep in mind that most of the common cables (for example RG-58, RG-316, RG-405) used to transfer the pulse from the generator to the antenna " stretches" the front and the decay of pulses. Therefore, when calculating, one must take those values of the durations that are measured for the cable used.

PRACTICAL USE OF RESEARCH RESULTS

In addition to the ability to adjust the transmitter by adjusting the duration of the flat part of the excitation pulse, for example, by the methods proposed in [7, 8, 9], at which the maximum amplitude in the received signal is reached, it is necessary to note the following possibilities, resulting from formulas (3).

For practical use, a family of graphs is useful (Fig. 5), for which you can quickly determine t_{2opt} for given f_0 and $(t_1 + t_3)$.

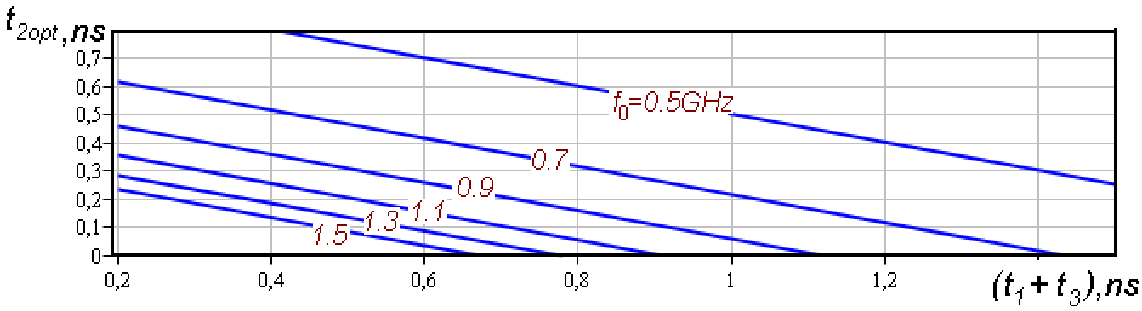

Fig. 5 A family of graphs for the practical determination of the pulse duration t_{2opt} from given f_0 and $(t_1 + t_3)$.

It should not be forgotten that research was conducted to optimize the duration of the flat part of the excitation pulse for any fixed frequency in the signal spectrum. If we are dealing with an ultra-wideband signal, for example, one that is taken for the layout of a pulsed locator, then it is necessary to choose for ourselves what frequency to calculate. In general, it is recommended to take the center frequency of the reflected signal spectrum. Earlier in the practical example of finding the relationship $A(t_2)$, we set the fixed values of the durations t_1 and t_3 of excitation pulse. However, their value affects the optimum duration of the flat part (3). As follows from the analysis of the maximum modulus $|A|_{\max}$ for t_{2opt}, both of them have the greatest value with the minimum duration of the front (decay) and decrease with its growth (Fig. 6). From which it follows that for a gently sloping front (for example, $t_1 > 0.8$ ns), the maximum of the function $A(t_2)$ approaches to the zero mark of duration t_{2opt}. In this case, for excite the antenna, there is no need to optimize the duration of the pulse flat part because of the small gain obtained in this case.

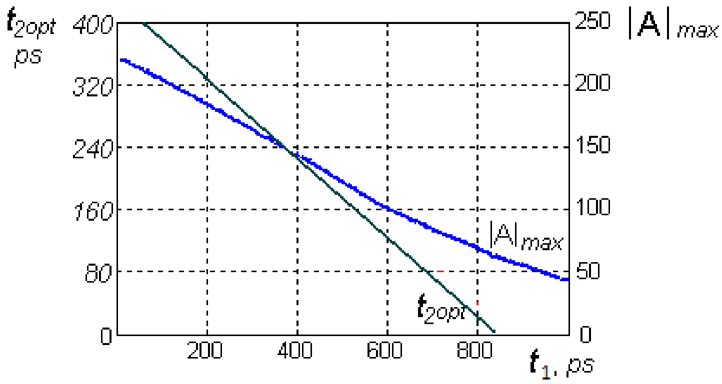

Fig. 6 Influence of the pulse front duration on the value of the optimum flat part duration for the frequency f_0 = 0.8GHz and f_0 = 400 ps.

CONCLUSIONS

- As shown by theoretical and practical studies, in most cases, when the broadband antenna is excited by trapezoidal pulses, it is possible to raise the level of the reflected signal by adjusting the duration of the flat part of the pulse with the approach of the latter to the optimum value. For example, when the excitation pulse is rebuilt, having a front t_1 and a decay t_3 of 0.25 ns from zero vertex duration t_2 to 0.35 ns at a frequency of f_0 = 0.8 GHz, the amplitude is increased by 50 percent at this frequency.
- The periodic character of the behavior of the dependence of the level of the spectrum on the duration of the vertex of the exciting pulse makes it possible to choose the duration of the vertex of the pulse not only equal to the optimum value, but also, if the technical realization of this variant is impossible, a multiple of the period of the above dependence. The period is inversely proportional to the frequency f_0 under study.
- If the trapezoidal excitation pulse has a gently sloping a front or a decay, the gain to be achieved when choosing the optimal pulse vertex duration is negligible. This indicates that it is not advisable to adjust the duration of the vertex for the above-mentioned front or decay. For example, for a variant of the first conclusion with decay duration of 3.5ns, the gain is only 5 percent.

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