The Nanosecond Pulse Generator-Radiator for Subsurface Radar Videopulse Systems

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Subsurface radar videopulse systems (SRVS) intended for remote non-destructive control and diagnostics of semiconducting dielectric media and also for detection and identification of embedded small-sized low-contrast artificial and natural objects are characterized by the growing use in various branches of economy.

The transmitting channel, which determines the main characteristics (parameters) of SRVS, is one of the underlying elements of such systems. These parameters are the following: amplitude, duration and repetition frequency of radiated video-pulses. In present SRVS, the radiated video-pulse amplitude can be varied from tens Volts up to several kV, depending on the systems purpose, when the pulse duration equals 0.1-5 ns and pulse repetition frequency equals to 10-500 kHz. In general, the transmitting channel consists of a videopulse generator [1], which effectively works on low-resistance load (from units to several tens Ohm), a broad band antenna with high-resistance impedance (from 160 up to 240 Ohm in operation frequency band), and broad band matching device realized with the use of coaxial or long lines like impedance transformer with transformation factor 1:4. When the signal is directed from generator to antenna, an additional energy losses and signal distortions take place, since the real efficiency of such matching transformers equals to 40-70% in operation frequency band (from 500 MHz to 1.5 GHz).

The accomplishment of necessary efficiency for the given parameters (amplitude, duration, form and frequency) of signals is the main problem that appears in designing the SRVS transmitting channel. It is reasonable to find possible solution of the problem in development of the generator-radiator which is functionally and constructively combined with the radiating antenna. Such solution is possible with using the videopulse generator miniaturization and low-impedance antennas.

The horn, biconical, dipole, flat and cone helix antennas used at present in subsurface radar applications have input impedance equals to 140-240 Ohm in operation frequency band that hinders these antennas matching with the generator.

In the paper, a generator-radiator of nanosecond videopulse developed on the basis of videopulse generator [1] and such dipole antenna as degenerate symmetrical microstrip line, is presented. To match the antenna with the generator, an impedance transformer in the form of symmetrical microstrip section having the exponential profile of wave resistance along its length (Fig.1) was developed. The section length is determined by the antenna dimensions and required matching. If there are not limitations on the junction length, it is possible to obtain arbitrarily small dismatching for a quite large band. However, in practice it is desirable the section length to be as less as possible for the given wave resistance jump, frequency band and acceptable dismatching. The investigations have shown that the use of the exponential transformer allows to obtain the better results in matching than with using the transformer which has linear changing of the wave resistance along its length. The exponential law of the wave resistance changing is implemented by the changing the distance between strips or the strips width, and correspondingly by the changing the linear inductance and capacitance along its length [2]:

$$Z_B(l) = \sqrt{Z_{B1} \cdot Z_{B2}} \cdot \exp\left[\frac{2l - L}{2L} \cdot \ln\frac{Z_{B1}}{Z_{B2}}\right] \quad (1)$$

where Z $_{B1}$ – input resistance of the section, Z $_{B2}$ – output resistance of the section, L - the impedance transformer length.

The impedance transformer section has the amplitude-frequency dependence which is equivalent to a high pass filter dependence. In such a case, good matching is achieved at all frequencies higher than a certain boundary frequency.

In practice, the exponential transformer length is determined by the following expression:

$$L = \frac{1}{b} \cdot \ln\frac{Z_{B2}}{Z_{B1}} \quad , \quad (2)$$

where the transformer length L must be increased with the rise of Z_{B2}/Z_{B1} ratio, called as the transformation factor, and with decrease of the parameter b (changing degree of the linear parameters along the line length). If b value is small, then reflections at the matching transformer do not exceed admissible values, thus the mode similar to the running wave mode can be attained. The b and $K_{св}$ parameters are connected by the relation:

$$|b| = \frac{8\pi}{\lambda_{max}} \cdot K_{CB} \quad , \quad (3)$$

where λ_{max} – maximum wavelength, which allows to attain the matching.

Both transmitting and receiving antennas for SRVS are two Hertz dipoles orthogonally placed. Such antenna design is explained by the using the vector properties of radiated and received signals.

The matching device is placed in the antenna center where the dipoles are crossed. This explains the design of the matching device in the form of the opening equilateral four-petal where the each petal is a microstrip with varying width. In the center of the radiator, a rod, which has a square base and made from dielectric with ε=3.6 in order to obtain small input resistance of the radiator, is placed. The input wave resistance of this radiator equals to 25 Ohm. The output resistance equals to 180 Ohm. The wave resistance behaviour along the matching device length is shown in Fig.1. The matching device length is equal to 70 mm. At acceptable standing wave ratio 1.3, the minimum operation frequency equals to 280 MHz as following from (3). The measured dependence SWR versus frequency for the given matching device is presented in Fig.2.

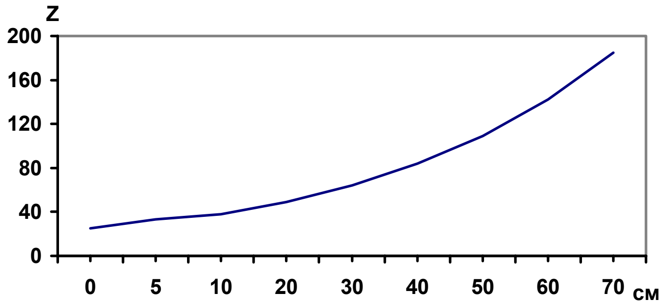

Fig.1. Wave resistance versus the matching device length.

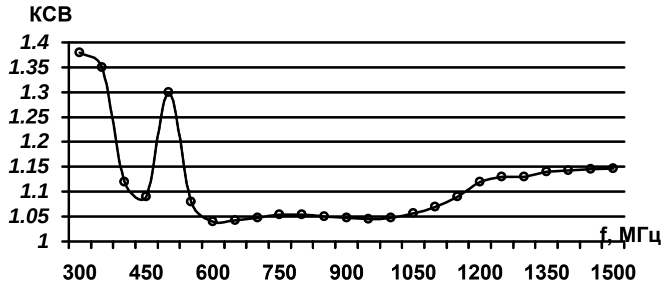

Fig.2. SWR versus frequency measured dependence for the matching device.

Conclusion

The presented engineering and design solution for the generator-radiator has allowed to increase the energy radiation efficiency, broaden the frequency band and improve the radiated signal form.

References

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[2] Sazonov D.M. et al. Microwave devices. Editor : Sazonov D.M. Moscow, “Higher School” Publ., 1981 (in Russian)