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ULTRA WIDEBAND DIPOLE ANTENNA

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This paper considers the antenna-feeder device which helps to realize a new method of antenna excitation. This method enables to transfer dipole antennas into the ultra-wideband category. The paper also demonstrates the experimental characteristics.

One of the existing problems in the modern ultra wideband wirelesses systems is the absence of any ultra wideband antenna radiator like Hertz dipole.

It is known that for all the available type of dipole antennas the wideband matching is a very difficult task as, under the existing methods of excitation, the dipole has a narrow bandwidth of the matching determined by the boundary conditions. For example, for the electric dipole it is the abruption of a regular line, where there is the condition of standing wave currents on the arms of the dipole.

It is necessary to note that it is exactly by standing wave currents is established a reactive nearfield, as, according to the Theorem of equivalence, the field round the dipole is determined by the surface equivalent currents on some surface S inside which is the dipole (Fig. 1).

Dipole antennas appear to be similar to resonance circuits with high quality-factor, therefore they have the frequency band 25-50 %.

All the known ways of reduction of the dependence of the input impedance on frequency by lowering the wave impedance of the vibrator, by smooth variation of its cross-section, by correction of the input impedance of the vibrator or manufacturing the vibrator on the principle of the electromagnetic similarity, lead in a certain extent to increased overall dimensions of the antenna. Besides it is always recognized that the radiation of electric dipole is most efficient when the length of the vibrator arm is about a quarter of the radiated wavelength $l \approx 1/4$; which is equivalent to the process in the oscillator circuit with losses R_l.

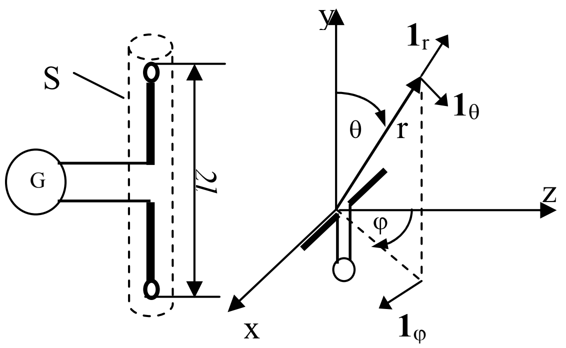

Fig. 1.

The same model, with reactive and active field components, is used as a model of a nearfield of the dipole, the reactive component of which equals zero at resonance. Then all the electromagnetic field power is collected by the active part of the near-field or the circuit $R_l = R_{inp}$. The voltage U_r and current I_r in the circuit oscillate in phase and $U_r / I_r = R_l$.

This is equivalent to that in the near-field of the dipole on surface S (Fig. 1) the electrical and magnetic components also oscillate in phase at any resonance frequency. In this way is satisfied the radiation condition:

$$E_{s,r} / H_{s,r} = W_s ,$$

where W_s – wave impedance of the wave front of a traveling wave near the surface S.

In the far-field region of the dipole the condition of radiation $E_x / H_y = W$ is valid for all frequencies; which evidences that at any frequency the field carries over the real power of that part of the oscillator power which has not returned to the oscillator.

Thus, for the ultra wideband antenna matching it is required to reduce essentially in the given band a quasi-static field near the radiation surface of the antenna. It is possible to reach the validity of the equality $E_x / H_y = W$ in a near-field region. It is difficult to do, and impossible at all for the existing methods of excitation as long as the exciting current on the surface of antenna is defined by the boundary

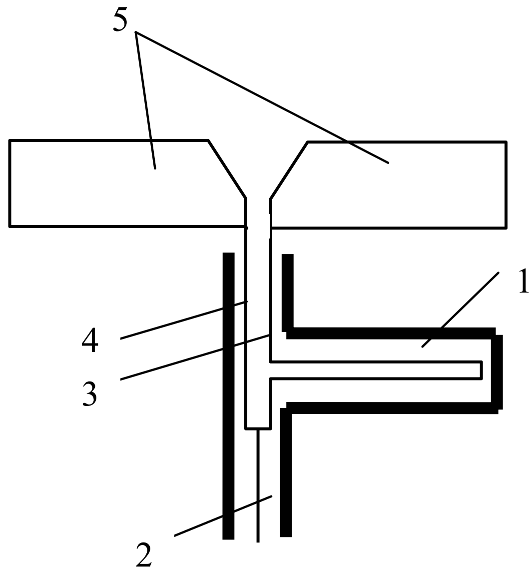

Fig. 2.

conditions: by the abruption or a short-circuit of a regular line.

The ultra wideband matching of the dipole shown in Fig. 2 is achieved with the aid of the matching and phase-shifting antenna-feeder device 1 executed on a coupled line. At that in the feeder line of antenna 2, with the electromagnetically coupled separate conductors 3 and 4, there are the wave oscillations inherent to a coupled line: the even and odd modes. On the surface of the radiating arms of the dipole 5 these modes produce the electromagnetic field in which the vector of electric field E on one arm's surface and the vector of magnetic field H on the other arm's surface oscillate in phase concerning the oscillator.

As the even and odd oscillations on the surface of the dipole are independent oscillations with wave impedances Z_{oe} and Z_{oo}, they can be presented as separate links loaded with the wave impedance of free space W.

As in coupled lines the wave impedance W obeys inequality

$$Z_{oo} > W > Z_{oe},$$

in this case the waves reflected from loads have the opposite signs and are cancelled at the input of the oscillator G because $W / Z_{oo} < 1$ and $W / Z_{oe} > 1$; and when $Z_{oo} Z_{oe} = W^2$, the waves have equal amplitudes also. Therefore the broadband matching is achieved in the dipole (Fig. 2). In Fig. 3 and Fig. 4 there are the electric and magnetic (as a current loop) dipoles in which the double-mode way of excitation of the currents in the radiator is used. Their experimental frequency characteristics SWR in Fig. 5 confirm that the dipoles are ultra wideband.

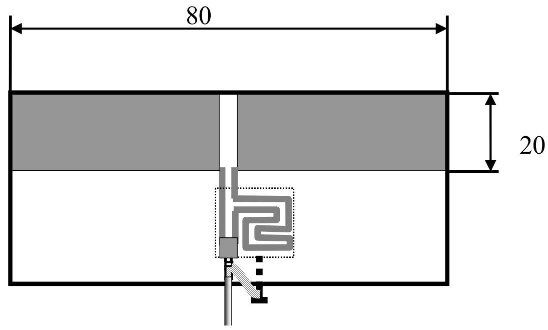

Fig. 3.

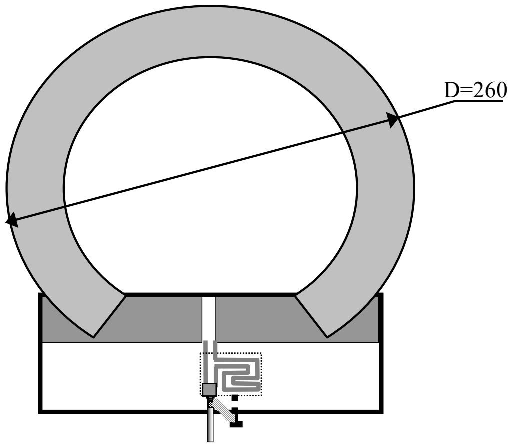

Fig. 4.

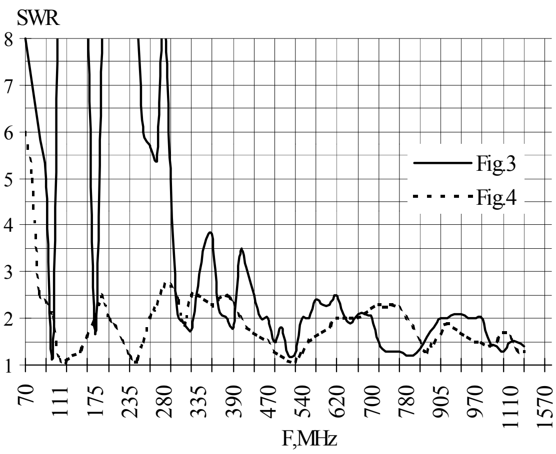

Fig. 5.

Therefore, it is fairly easy to expand the band of the matching and shift it towards the long waves. At this the radiation occurs from the arms of the dipole 2 whose length is much less than half a wavelength $2l \ll \lambda / 2$ The conditions imposed on the stretch 2 of the transmission line and on the radiation elements of the antenna, Fig. 2, allow to establish in the near-field the wave environment where the tangential components E_s and H_s in a mixed mode, tending in the limit to standing waves, form such vector field regarding the oscillator that the radiation condition is valid as

$$E_x / H_y = W .$$

But this matching condition here, in the absence of losses, determines the radiation condition of the dipole determined by relationship [1]:

$$\left(\dot{E}_{\mathbf{s1}} / \dot{H}_{s2}\right)\left(\dot{E}_{s2} / \dot{H}_{s1}\right) = Z_{oe}Z_{oo} = W^2 = Z_G^2 , \quad (1)$$

Thus, the in-phase oscillations of tangential components E_{s1}, H_{s1} and E_{s2}, H_{s2} near the surface S of the dipole occur under the condition of the matching of the equivalent bridge circuit – $Z_{oe}Z_{oo} = W^2$ on S. Then, according to the Uniqueness theorem, one can tell that at any point of the field the in-phase oscillation of two independent modes occurs; and the coupling between their wave impedances – $Z_1 Z_2 = W^2$ – is invariant to the matching condition. And in any band and any point of the field there is a traveling wave and there are no backward waves concerning the oscillator (Z_G) or viewpoint in front of the antenna (W). Consequently, the relationship (1) provides the radiation condition of the antenna.

By the circuit theory, if the input characteristics of the dipole impedances Z_1 and Z_2 are related as $Z_1 Z_2 = K^2$, where K is a real number having the dimension of resistance, such dipoles are dual or backward.

In electromagnetics such dipoles are known as the electrical and magnetic ones. The processes in these dipoles, though different, have similar in shape quantitative features. Therefore the offered dipole, in distinction, e.g., from the ordinary electric dipole, radiates not only the usual electric vector E but also the electric vector E which corresponds to the magnetic dipole radiation.

Thus, on the surface of the dipole are to be excited the electric and "magnetic" currents which excite the orthogonal electromagnetic fields generating a traveling wave.

This orthogonality of the fields is represented in the directivity diagrams of the electric dipole, Fig. 3, for two polarizations of the electric vector E: $E_\omega(\omega)$, Fig. 6, that is directed along the dipole axis (i.e. along axis Ox) and $E_\varphi(v)$, Fig. 7, that is perpendicular to the dipole axis (i.e. along axis Oy). And also for the magnetic dipole, Fig. 4, the directivity diagrams are with two polarizations of vector E: $E_\omega(\omega)$, Fig. 8, and $E_\varphi(v)$, Fig. 9. The initial direction 0° is that of axis Oz.

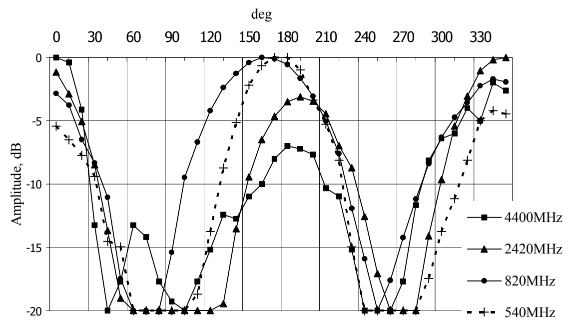

Fig. 6.

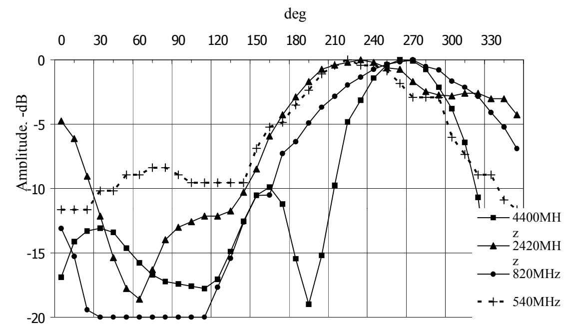

Fig. 7.

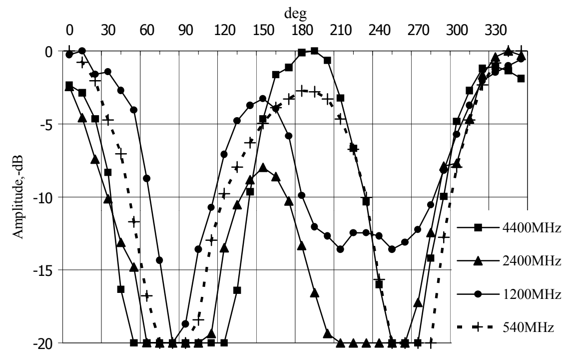

Fig. 8.

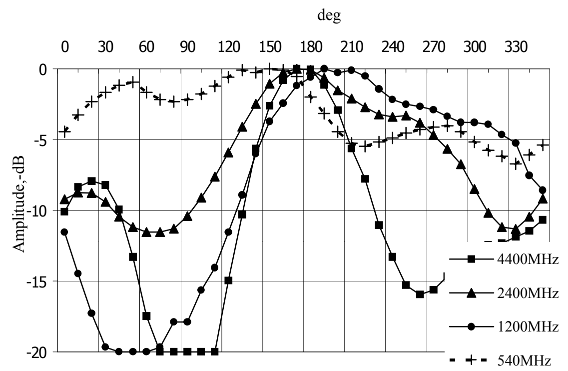

Fig. 9.

Thus, there are simultaneously the electric and magnetic currents as regards the oscillator in the dipole; which is confirmed by the calculation and experiment.

From the above said the following conclusions are to be drawn up:

1. The offered small-sized vibrator has a very wide band of the matching by the input characteristic SWR, and the directivity diagrams have the steady shape and amplitude in the band with the overlapping 10:1.
2. The antenna-feeder device of the dipole establishes two independent oscillations of the electromagnetic field in the power line and on the radiation surface of the dipole.
3. There are the flowing currents in the dipole which, as regards the properties of the directivity diagram for vector E, can be referred to as electrical and "magnetic" currents. Therefore the dipole radiates two polarizations – the horizontal and vertical ones.
4. The separate independent wave modes on the dipole surface are in the condition of a standing wave whereas the condition of the abruption of a line is valid.
5. The appearance in the antenna near-field of a traveling wave under the condition a standing wave of currents on the surface of its radiator is determined by the presence on the surface of the even and uneven modes of oscillations which are coupled by the matching condition.
6. The electric vector $\mathbf{E}$ of one mode and the magnetic vector $\mathbf{H}$ of the other oscillate in phase on the different arms of the dipole. Therefore, the conditions of proportionality of the fields $\mathbf{E}$ and $\mathbf{H}$ in the near-field region of the dipole are valid, and the Poynting vector is real.
7. The construction of the antenna-feeder device for the excitation of a traveling wave in dipole antenna is provided, with the ultra wideband of the matching [8,9].
8. The dipole antenna has the new qualities which allow to include it into the class of ultra wideband antennas.

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СВЕРХШИРОКОПОЛОСНАЯ ДИПОЛЬНАЯ АНТЕННА

Л.Д. Бахрах, В.Ф. Лось, А.Н. Шаманов

В этой статье рассматривается антенно-фидерное устройство, в котором реализован новый метод возбуждения антенны. Это позволяет использовать дипольную антенну в качестве сверхширокополосной.

НАДШИРОКОСМУГОВА ДИПОЛЬНА АНТЕНА

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У цій статті розглянуто антенно-фідерний пристрій, у якому реалізовано новий метод збудження антени. Це дозволяє використовувати дипольну антену у якості надширокосмугової.