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Effects observed under modification of semitransparent sporadic *E* layer of the ionosphere by powerful radio emission

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Abstract. The results of the experiments on the impact by a vertical beam of powerful radio waves on the sporadic E layer of the ionosphere of the Earth are presented. The experiments have been conducted at the Sura heating facility (Radiophysical Research Institute, Nizhny Novgorod) from 31 May to 4 June 2001. The main results were obtained on 31 May from 1730 to 2000 Moscow time under rather stable E_s, when the pumping wave frequency fell into the region of its semitransparency. The diagnostics of the ionosphere was performed by the testing waves (TW) of x polarization in the frequency range $f_{TW} = 4.3 - 7.8$ MHz. During the heating of the ionospheric plasma an intensification of the TW signals reflected from E_s (their frequencies being of the same order or slightly higher the critical frequency of the E_s layer) and also an appearance of artificial fluctuations of the reflected signal within the entire frequency region of the sounding were observed. Dynamical properties of the observed phenomena and their dependence on the E_s characteristics and the value of f_{TW} are discussed.

1. Introduction

Though the heating experiments in the ionosphere have a history more than three decades long, the studies carried out mainly dealt with investigations of the properties of artificial ionospheric turbulence (AIT) generated in the ionospheric F region. Many fewer measurements have been conducted to modify the ionospheric E region, and one can indicate only a few measurements concerning the impact on the sporadic E layer.

Sporadic E layers, or E_s, are usually called the horizontally stretched local regions of increased plasma concentration observed sporadically in time at heights of 95–125 km in the ionospheric E region. The E_s layer is characterized by the critical frequency f_oE_s corresponding to the maximal density in the layer and by the blanketing frequency f_bE_s up to which the sporadic layer screens completely the ionospheric regions located above. If $f_oE_s = f_bE_s$ the E_s is called thick. The sporadic layer for which $f_oE_s > f_bE_s$ is called semitransparent. The measurements of *Miller and Smith* [1978] showed that a semitransparent sporadic layer consists of separated ionized clouds.

The limitations of observations of the powerful radio waves impact on the E_s are related mainly to the strong variability of the E_s characteristics on the time intervals as short as tens of minutes during observations in one point. That makes it difficult to carry out in such conditions any full-scale studies because characteristic times of variations of the sporadic layer parameters during its heating and at the stage of relaxation of the artificially created disturbances are often comparable to the time of the natural variations of the layer. Among the conducted experiments we note the following publications. Heating the ionosphere by the powerful radio emission at the frequency close to the gyrofrequency of electrons, *Gurevich and Shluger* [1975] found an increase of the characteristic frequencies of the E_s layer (the limiting reflection frequency f_oE_s and the blanketing frequency f_bE_s by 5–10% and 2–3%, respectively). *Kozlov et al.* [1977a, 1977b] observed a sharp depletion of f_oE_s by ~40% under oblique illumination of the ionosphere by a powerful radio wave. *Erukhimov et al.* [1987] detected in the first minute of the impact an increase of the intensity of

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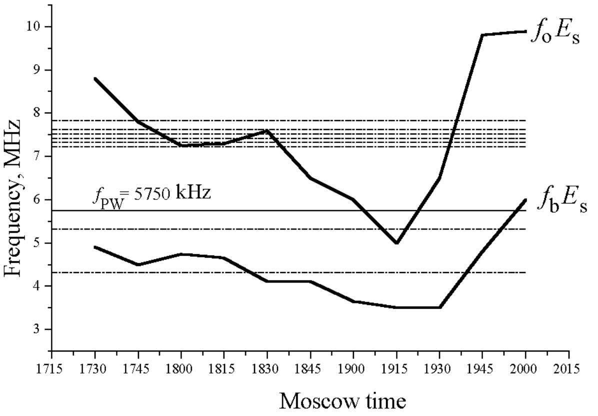

Figure 1. Time dependence of the critical frequency f_oE_s and blanketing frequency f_bE_s of the E_s layer.

the linearly frequency polarized (LFP) signal reflected from E_s with its following decrease in the form of an attenuating oscillation with a period of 2–3 min.

Djuth et al. [1999] and *Kagan et al.* [2000] found an increase of the electron temperature by about a factor of 3 and also an excitation in the region of E_s of the artificial airglow in the atomic oxygen green line ($\lambda = 557.7$ nm) and in the first positive band of molecular nitrogen induced under the impact on the thick and semitransparent layers. According to the *Kagan et al.* [2000] evaluations the green emission was induced by the electrons accelerated in the region of the plasma resonance up to the energies of $\geq 5-6$ eV). In the experiments of *Blagoveshchenskaya et al.* [2001] and *Sergienko et al.* [1997] the heating of E_s led to changes in the character of the ionosphere–magnetosphere interaction that was manifested in an intensification of the auroral activity.

On the whole, all the above mentioned experiments demonstrate that an impact of a powerful wave on the sporadic E layer is able to cause development of various kinds of artificial ionospheric turbulence and its characteristics currently cannot be considered as studied to a sufficient degree. The importance of these studies is determined by the fact that experiments on E_s modification initiate further development of empirical and theoretical models of the layer generation. The latter makes it possible to explain its principal morphological characteristics because their interpretation still meets some difficulties [*Gershman et al.,* 1976; *Kagan*, 2000; *Mathews*, 1998; *Whitehead*, 1989]. It should be noted that (except for the *Kozlov et al.* [1977a, 1977b] study, where the experiments were conducted under oblique propagation of the powerful radio wave) in all the above mentioned experiments the E_s modification was performed under the vertical emission of the pumping wave (PW) when its frequency as a rule was below the blanketing frequency f_bE_s and so there was a complete reflection of PW from E_s.

The results of the experiments on modification of the semitransparent E_s layer of the ionosphere are considered below. The measurements were conducted at the Sura heating facility (Radiophysical Research Institute, Nizhny Novgorod) from 31 May to 4 June 2001.

2. Organization of the Experiment

The main data analyzed below were obtained on 31 May 2001 from 0730 to 1915 Moscow time with stable enough E_s which was semitransparent at the PW frequency (f_{PW} = 5750 kHz). The AIT excitation occurred simultaneously in the E_s and F layers of the ionosphere. In these measurements the o polarization PW was radiated with the effective power $P_{\text{eff}} \simeq 80$ MW except the seance at 1851 Moscow time where the power was reduced down to 20 MW. The time regime of the PW emission was 2 min emission, 8 min a pause till 1831 Moscow time. After that the pause was reduced down to 3 min. For the diagnostics of the disturbed regions (DR) of the ionosphere the x polarization testing wave (TW) emitted in the pulse regime were used. This made it possible using the temporal strobing to separate the signals reflected for the F and E regions of the ionosphere. The testing waves were emitted at eight frequencies: f_{TW} = 4323, 5323, 7223, 7323, 7423, 7523, 7623, and 7823 kHz with the more dense mesh in the upper part of this range. The amplitude and Doppler frequency of the reflected from the ionosphere signals were registered with the help of a quick-operating automatic numeral transformer and computer. The excitation of artificial turbulence in the ionospheric F region was controlled by the TW reflected from it and also with the help of the artificial radio emission of the ionosphere (ARI). Generation of ARI is usually observed at frequencies close to f_{PW} (on the properties of ARI see, for example, *Leyser* [2001] and *Frolov et al.* [2001], and the references therein). It is worth noting that some measurements were conducted at other days but the strong variability of the E_s characteristics made it possible to obtain in these days only rather fragmental data on the properties of the layer observed under its heating. Nevertheless, some results obtained in the above mentioned days are also briefly presented below, since they may be of some importance for the development of our ideas on the nature of the observed phenomena and for selecting the direction of further studies. Concluding the section we note that during all the conducted measurements the ionosphere was controlled using the automatic ionospheric station operated in the 15-min regime.

3. Results of the Measurements

The peculiarity of the cycle of measurements considered below is that initially it was aimed at studying of AIT excited in the F region of the ionosphere. This determined the choice of the TW frequencies. However, conducting the experiment, we found at 1730 Moscow time the presence of fairly intense and stable E_s layer at altitudes of ~115 km, the layer screening the TW signals at the lowest frequencies. We saw at the temporal scan of the oscillograph that every switching on of TW led to a strong change in the amplitude and fluctuation frequency of the reflected E_s signals. In this situation it was decided to reorient the research program to study the effects observed under a perturbation of the ionospheric E_s layer by a powerful radio wave. This program was started at 1801 Moscow time and continued to 1911 Moscow time till the effects of the E_s modification were observed. We note only that from 1801 to 1911 Moscow time the recording of the reflected from E_s signals was performed for all TW. Before 1801 Moscow time and after 1911 Moscow time the sounding was conducted at one frequency of 4323 kHz and 5323 kHz, respectively.

The measurements conducted showed that the properties of the registered effects depend in a significant degree on the characteristics of E_s. Figure 1 shows the values of the critical frequency f_oE_s and the blanketing frequency f_bE_s measured by the automatic ionospheric station (AIS) in two pauses between the impacts. Figure 1 also shows the values of frequencies for PW ($f_{PW} = 5750$ kHz, horizontal thin line) and eight TW (dash-dotted lines). It follows from the data presented in Figure 1 that during the measurements: (1) the blanketing frequency of E_s was always lower than the PW ($f_bE_s < f_{PW}$), (2) the values of f_oE_s and f_bE_s decreased gradually reaching their minimums approximately at 1915 Moscow time when the value of f_oE_s became even lower than f_{PW}, and (3) there was a sharpincrease of the f_oE_s and f_bE_s values after 1915 Moscow time. The latter fact may manifest changes in the conditions of the E_s generation or entering into the over-radar point of a new sporadic layer. The critical frequency of the ionospheric $F2$ layer for the propagation of the o mode varied during the observations only slightly and always was considerably higher than f_{PW}. It was ~7.4 MHz at 1730 Moscow time, decreased smoothly down to ~6.9 MHz at 1900 Moscow time, and then again increased slightly up to ~7.1 MHz at 2000 Moscow time.

Figure 2 shows the oscillograms of the PW signal amplitudes for the time interval $T = 1756 - 1906$ Moscow time in linear scale (Figure 2, top) and of eight TW which demonstrate an increase of the TW signals at high frequencies ($f_{TW} \geq 7.2$ MHz) during the modification of the ionosphere by a powerful radio wave. We have already mentioned above that a decrease of the TW amplitudes was detected in the period 0801–1911 Moscow time for all TW under their reflection from E_s. Till 1831 Moscow time the 10-min heating cycles with the pause of 8 min were used. After that it became clear that the relaxation of perturbations in the sporadic layer does not exceed 1–2 min and 5-min cycles with the 3-min pause were used. The increase in the amplitude of the TW signals reflected from E_s at high frequencies within the time interval 1820–1833 Moscow time is due to the temporal increase in this period of the E_s critical frequency up to a value of $f_oE_s \simeq 7.6 - 7.8$ MHz. By the way, this shows that the amplitude of the TW signals intensified during the switching on of PW is close by the magnitude to the amplitude of their mirror reflection from E_s. To take this fact into account is very important for a choice of the correct interpretation of the observed phenomena. Figure 3 separately shows the dynamics of the TW signals for the 1836 and 1846 Moscow time seances when the effects of the impact on E_s were the best pronounced. It is also important to note that in the considered measurement cycle no considerable changes in the characteristics of AIT in the vicinity of the TW frequency were detected. This fact may be considered as a manifestation of the fact that a considerable portion of the powerful wave energy (according to estimates, not less than its half) was reaching the $F2$ region of the ionosphere, where plasma instabilities were developed near the TW reflection point and a ARI was generated.

Summarizing the results of the conducted experiments on the impact on the plasma of the semitransparent E_s layer of the ionosphere by powerful o polarization radio wave shown in Figures 2 and 3, one can list the following observed effects.

1. For high-frequency TW with $f_{TW} \geq 7.2$ MHz, when their frequency was slightly higher than the limiting reflecting frequency f_oE_s, an increase of the signal reflected from E_s with a characteristic time of ~10–20 s was observed during the heating. The characteristic relaxation times of this intensified signal (see Figure 3) demonstrate a strong dependence on the TW frequency increasing from 3–5 s to 20–40 s at the decrease of f_{TW} from 7823 to 7223 kHz. In some cases (for example, in the seances at 1811 and 1831 Moscow time, see Figure 2) the signal relaxation has a pronounced step-like character, the second (slower) stage lasting 1–2 min. The effect of the intensity increase of the TW reflected signal disappeared in the seance at 1851 Moscow time when the value of the f_oE_s critical frequency approached the PW frequency. The latter fact may be considered as a proof that the observed effect is related to the direct impact of the powerful radio emission on the sporadic E layer of the ionosphere. If the increase of the signal reflected from E_s is determined by the growth of f_oE_s during the PW emission, than according to the data obtained this growth should be ~20%: from ~6.3 to ~7.8 MHz. Concluding, we note that no similar increase in the intensity of the reflected signals was observed in this cycle of measurements for the low TW $f_{TW} = 4323$ and 5323 kHz, these values being considerably lower than f_oE_s.

2. At all TW frequencies (though in a different degree) there was observed an appearance of artificial fluctuations of the signals reflected from E_s. The frequency of these fluctuations exceeded by several times the frequency of the natural fluctuations. In the strongest way they were manifested at high TW frequencies, having the characteristic times of development and relaxation of the order of a few seconds and tens of seconds, respectively. A broadening of the frequency spectrum of the signal reflected from the ionosphere with separated peaks (indicating to an appearance of the multipath character of the received signal) was also observed. The intensification of the fluctuations was fairly regularly observed also for TW with $f_{TW} = 5323$ kHz, the characteristic times of development and relaxation being ~20–30 s and ~40–60 s, respectively. The occurrence of artificial fluctuations at the lowest sounding frequency $f_{TW} = 4323$ kHz was less pronounced. It was observed approximately in a half of the heating seances, most often after $T = 1836$ Moscow time at lower values of the f_oE_s critical frequency. The characteristic times of TW signal fluctuations at high frequencies were $\tau_{\text{fl}} \simeq 2 - 4$ s. A few seconds after the switching off PW, their period increased by a factor more than 1.5–2. The frequency of the artificial fluctuations was even lower during the slow relaxation stage noted in point 1. It should be noted (see Figure 3) that at low frequencies the characteristic

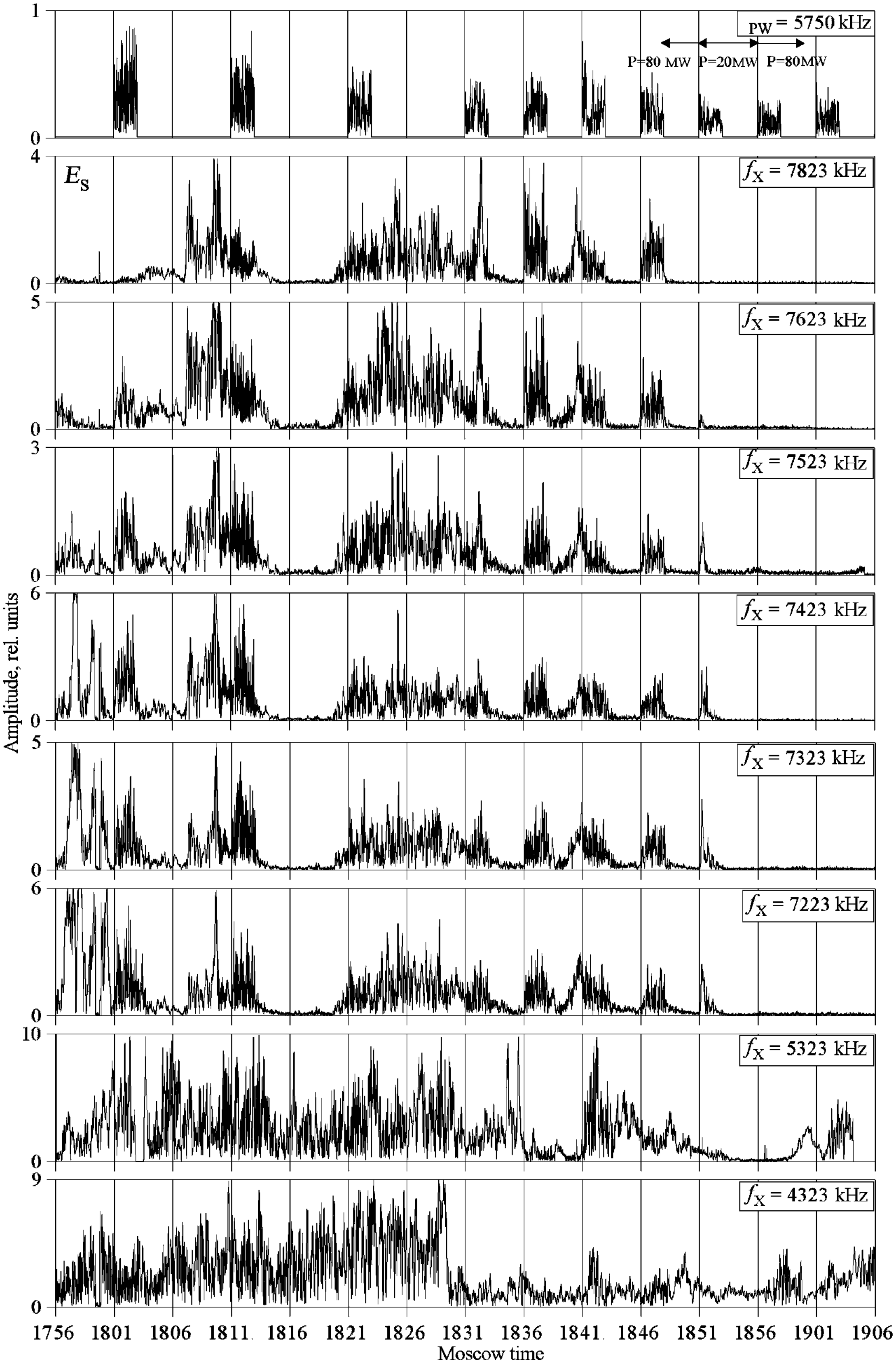

Figure 2. Time dependence of the oscillograms of the PW and 8 TW signal amplitudes.

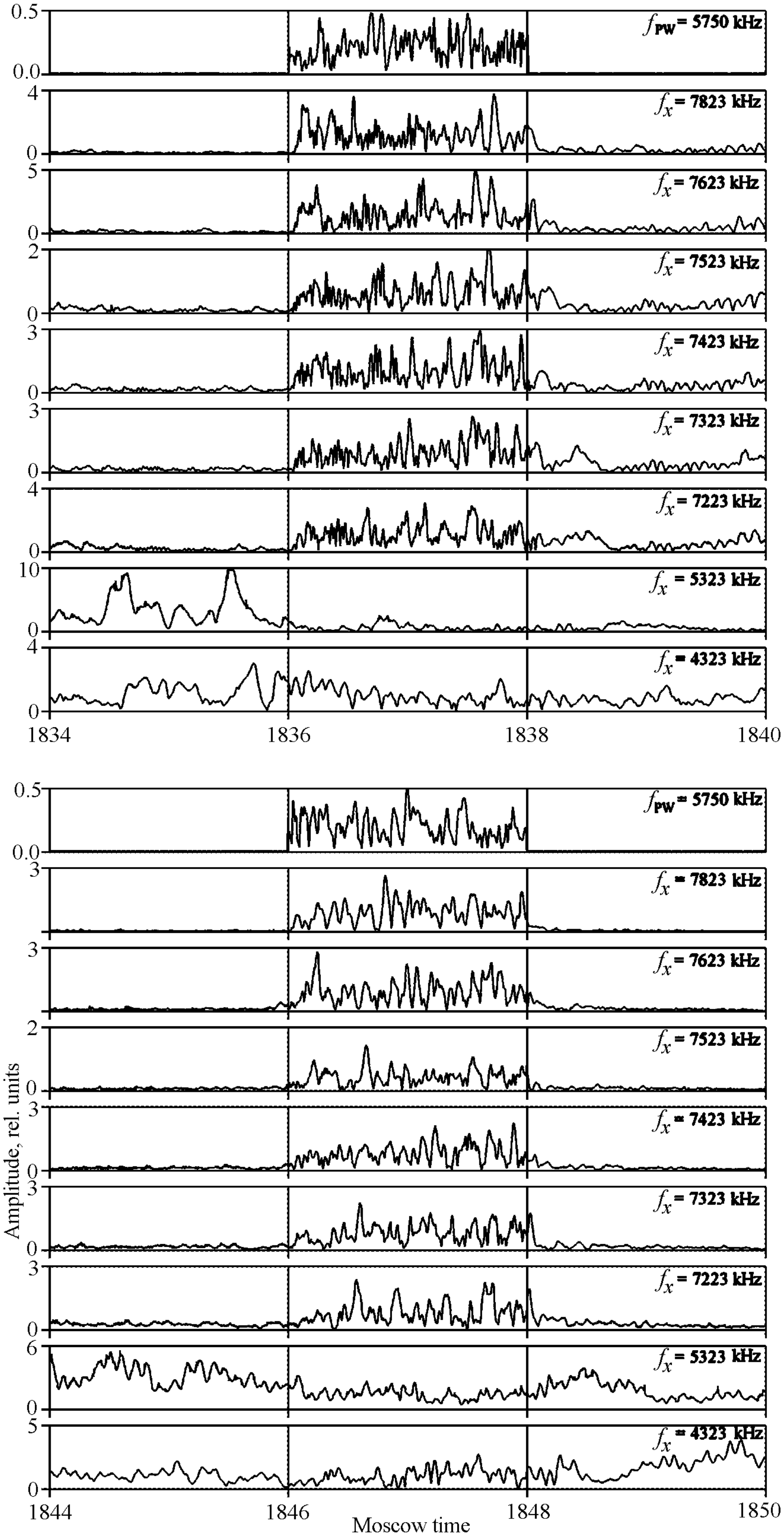

Figure 3. Time dependence of the TW signal amplitudes for the 1836 and 1846 Moscow time seances.

frequency of artificial fluctuations was always considerably lower than for high-frequency TW. If one assumes that such fluctuations appear as a result of the radio wave diffraction at irregularities of the plasma density, their lateral (relative to the geomagnetic field lines) scale may be evaluated as $l_\perp \simeq 2v\tau \simeq 200 - 800$ m (where $v \simeq 50 - 100$ m s^{-1} is a typical, taken for the sake of an evaluation, value of the plasma drift horizontal velocity at the level of the ionospheric E layer). This agrees well with the typical scale of the irregularities observed in the natural E_s [*Gershman et al.*, 1976; *Miller and Smith*, 1978; *Whitehead*, 1989]. One can conclude from this that the heating of E_s leads most probably to intensification of its own irregular structure. In this case the intensity of the E_s irregularities should be considerably depleted already a few seconds after the PW switching off.

3. After the PW switching on, in some cases a gradual (during 1–2 min) increase of the negative Doppler frequency shift of the received signal up to the value of $f_d \simeq -(0.3 - 0.5)$ Hz, is visually seen at high TW frequencies. This may be a consequence of either an increase of the TW reflection point height or a decrease in the integral plasma density on the way of the TW propagation. After the PW switching off, the returning increase of the Doppler frequency may last 1–3 min. At low TW frequencies (especially at the lowest frequency $f_{TW} = 4323$ kHz) the Doppler changes in the reflected signal frequency (if they existed) did not exceed the value of an order of $0.1 - 0.2$ Hz and in a significant degree might have been masked by natural variations. This frequency dependence of $f_d(f_{TW})$ may be a manifestation of the fact that the variation in the plasma vertical profile occurred only within a rather narrow height region ~0.5–1 km. The latter fact indicates to a rather local character of the PW interaction to the E_s-layer plasma. It is worth noting that the effect of the plasma density profile modification in the heating region may be similar to the change in the profile observed under an impact on the ionospheric F region [*Grach et al.,* 1989]. Unfortunately, after the PW switching on, there appears a strong multipathness of the TW signals and it prevents detailed restoration of the plasma density profile variations in the E_s layer.

4. Before the 1851 Moscow time time seance the PW power was decreased down to 20 MW. However, immediately after its switching on (see Figure 2), there continued an increase of the amplitude of the signals reflected from E_s at frequencies $f_{TW} = 7523$, 7423, 7323, and 7223 kHz approximately up the same value as before, though the fluctuation frequency was much lower as compared to the previous seances. The intensification of the signals was much weaker for $f_{TW} = 7623$ kHz and was completely absent for $f_{TW} = 7823$ kHz. About 0.5–2 min after the PW switching off the intensification disappeared for all TW, the disappearance being more rapid at higher frequencies. Though the PW power was again increased up to 80 MW in the next seances no intensification of the TW signals at frequencies of $f_{TW} \simeq 7.2 - 7.8$ MHz was observed. It was noted in section 1 (see also Figure 1) that such changes in the properties of the observed effect was accompanied by a depletion of f_oE_s down to the values of the order of (or even lower) the PW frequency. It should be noted here that though the effects of the E_s heating disappeared at high TW frequencies, the intensity of the artificial fluctuations at $f_{TW} = 5323$ kHz even slightly increased. The latter fact shows that powerful emission is able to cause variations in the E_s characteristics even at $f_{PW} > f_oE_s$, that is, at its heating "throughout" when the energy of PW almost completely passes to the upper ionosphere.

5. It should be noted that in this series of experiments no impact effects (similar to the above-considered effects registered at the modification of the sporadic E layer nontransparent at the PW frequency) were registered.

In addition to the above, we present here two results of the measurements conducted on 4 June 2001, when the impact on the ionosphere was performed by a powerful x polarization wave at the frequency $f_x = 6480$ kHz with $P_{\text{eff}} \simeq 200$ MW. During the measurements the critical frequency f_oE_s did not exceed 5 MHz and the impact of the powerful radio emission was performed in the throughout regime. As before, in this series of experiments the diagnostics of AIT was performed using x polarization TW with parallel registration of reflections from the $F2$ and E_s ionospheric layers. Since E_s was not stable enough in this cycle, there was no possibility to carry out some completed program of studies so the data obtained are of a rather fragmental character. Nevertheless, they make it possible to conclude that in some cases here also artificial fluctuations were observed at the TW signal reflected from E_s, the latter fact manifesting intensification of its irregular structure. The second point we would like to draw here attention to concerns possible influence of E_s on the properties of AIT generated in the ionospheric F region. Figure 4 shows the oscillogram of the TW signals reflected from the F region at a frequency of $f_{TW} = 5323$ kHz for three seances of 2-min heating: at 2001 and at 2021 Moscow time, when the sporadic layer was fairly weak ($f_bE_s \simeq 2.6 - 3.0$ MHz and $f_oE_s \simeq 3.5 - 3.8$ MHz) and at 2011 Moscow time, when there occurred its temporal intensification up to $f_bE_s \simeq 4.1$ MHz and $f_oE_s \simeq 4.8$ MHz. The presented data visually show that the character of the turbulence generated in the F region of the ionosphere is significantly different for all three seances of the PW switching on: the absence of the appearance of artificial fluctuations in the first seance, strong and rapid fluctuations in the second seance, and strong but much slower fluctuations in the third seance. The appearance of strong fluctuations of the reflected TW signal during the intensification of E_s may be interpreted as an intensification of the generation in the upper ionosphere of rather small-scale irregularities with $l_\perp \simeq 100 - 500$ m.

Since no generation of such intense irregularities has been observed earlier while modifying the ionospheric F region by x polarization waves in the absence of E_s, one can assume that their occurrence is a consequence of the influence on the AIT properties of the electrodynamic interaction of the F and E regions of the ionosphere. The details of this interaction were considered, for example, by *Kelley* [1989], *Lyatsky* [1978], and *Whitehead* [1989]. It is worth noting that earlier such interaction was experimentally detected, for example, by *Mathews* [1998] and *Swartz et al.* [2002]. In the future we plan to conduct new experiments aimed at more detailed studies of the characteristics of this kind of effects and a search for their diagnostic features.

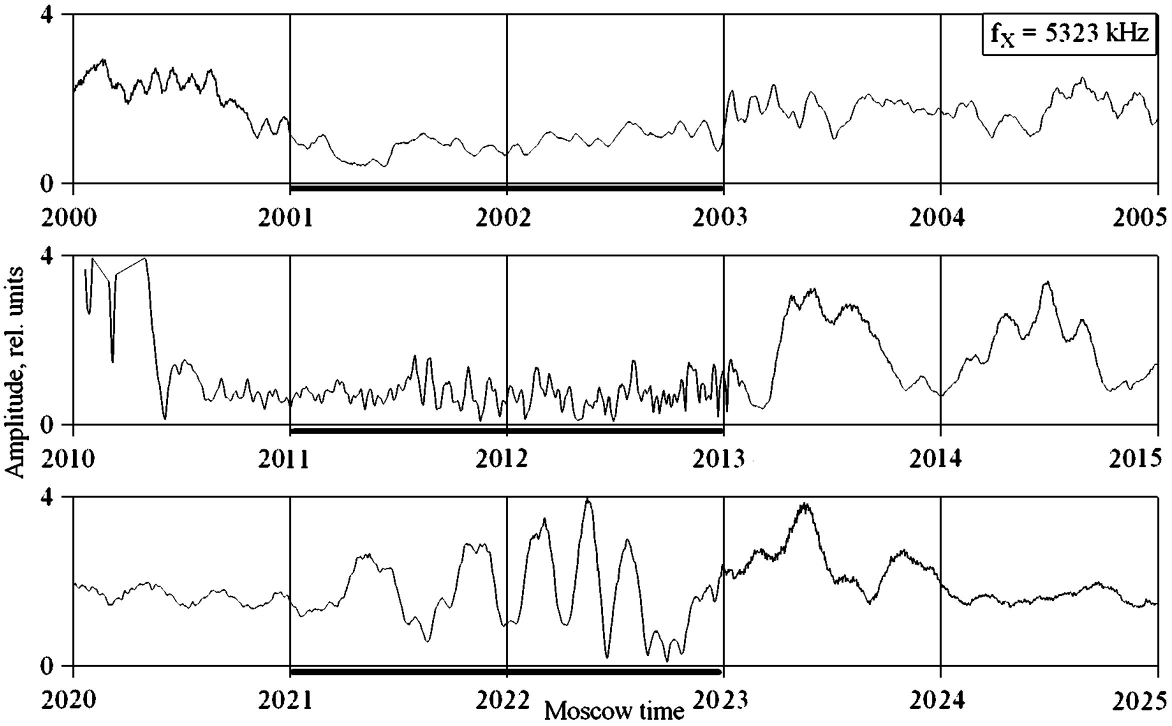

Figure 4. Oscillograms of the TW signals reflected from the F region.

4. Discussion

The interest in experiments using artificial impact on the sporadic E layer of the ionosphere (using powerful short-wave emission, in particular) is determined by the need for further development of the theory of its formation and turbulization. The opening new possibilities to study the electrodynamic interaction of the F and E regions of the ionosphere also present an important aspect of these experiments. Results of such experiments may influence the development of ideas on the AIT generation in the upper ionosphere. Though the data on the modification of a semitransparent E_s layer obtained are far from being exhaustive and prevent from drawing definite conclusions on the physics of the observed phenomena, we nevertheless are able to state the following.

1. Modification by powerful o polarization wave of the sporadic E layer, when the PW falls into the region of its semitransparency, leads to an intensification of its irregular structure.

2. The increase in the irregularity of the plasma density in E_s is observed also during its "throughout" heating when $f_{PW} > f_oE_s$, as well as under an impact on it by a powerful x polarization wave.

According to various experimental data obtained at middle latitudes [see, e.g., *Alpers et al.*, 1994; *Brunelly and Namgaladze*, 1988; *Cornelius and Essex*, 1979; *Gershman et al.*, 1976; *Kagan*, 2000; *Kagan et al.*, 2000; *Mathews*, 1998; *Miller and Smith*, 1978; *Sherstyukov and Stenin*, 2002; *Whitehead*, 1989], the formation of the signal reflected from E_s at the sounding frequencies exceeding its blanketing frequency f_bE_s occurs either due to the backscatter of radio waves at sharp gradients of the concentration, or at the irregularities (presented within the layer) of the plasma density with $l_\perp \simeq 100-500$ m, or due to the clouds of increased plasma density with the dimensions from one km or more reflecting the radio waves up to the f_oE_s frequencies. *Newman et al.* [1998] showed that in the latter case the main plasma heating by the o polarization waves occurs in the narrow (a few hundreds meters) altitude region due to the development of a striction parametric in stability in the vicinity of the PW reflection.

Interpreting the obtained results in the scope of models of partial reflection of radio waves from sharp concentration gradients or of radio wave scattering at plasma density irregularities, one can not explain the strong dependence of the relaxation time of the intensified TW signals on their frequency (see Figure 3). If one accepts the patch structure of E_s, the experimental data considered above may be interpreted as an increase in the density in these clouds (to explain the increase of the f_oE_s value) together with intensification of their irregular structure (to explain the increase of the fluctuation frequency of the reflected TW signals). Then the disappearance of the intensified TW signals after the PW switching off should be determined by the plasma density decrease in the clouds down to below the critical frequency for each of the f_{TW} frequencies. The analysis of the obtained experimental data showed that in this case the change in the plasma concentration after the PW switching off follows the exponential law: $\delta N(t) = \delta N(0) \times \exp(-\gamma t)$ with $\gamma \simeq (4-5) \times 10^{-3}$ s^{-1}.

Variations of the electron concentration in the ionospheric E region may occur due to either dissociative recombination or diffusion [*Sherstyukov and Stenin,* 2002]. In the former case the recombination coefficient may be calculated as $\alpha_r \simeq 0.5\gamma N^{-1} \simeq 5 \times 10^{-9}$ cm^3 s^{-1}. The obtained value of α_r is by an order of magnitude and more lower the dissociative recombination coefficient for the molecular ions ($\alpha_{dr} \simeq 10^{-7}$ cm^3 s^{-1} [*Gershman et al.*, 1976]). Assuming a diffusion character of the spreading of the plasma concentration disturbances by the law $\delta N(t) = \delta N(0) \times \exp(-Dk^2 t)$ and taking the E_s-layer thickness of the order of $\simeq 0.5 - 3$ km ($k \sim 2/a \simeq (0.7-4) \times 10^{-5}$ cm^{-1}) one can obtain an evaluation of the diffusion coefficient value: $D \simeq (0.25-10) \times 10^7$ cm^2 s^{-1}. It follows from *Gershman* [1974], *Gershman et al.* [1976], *Ignat'ev* [1978], *Ignat'ev et al.* [1972], *Mathews* [1998], and *Whitehead* [1989] that the intensity of sporadic layers and their properties at middle latitudes are determined mainly by the presence within the layers of metal ions for which dominating is the process of ambipolar diffusion with the coefficient $D_a \simeq 2 \times 10^6$ cm^2 s^{-1}. The latter value may be agreed with the measurement results for $a \simeq 0.5$ km. However, because of the increase of the diffusion coefficient the plasma heating should have led to a decrease of the partial electron concentration in the E_s layer and so to a depletion of the reflected signals for the high-frequency TW signals with the characteristic times not less that 15 min (in the scope of this model, for example, the results of the measurements considered by *Kozlov et al.* [1977a, 1977b] were explained). However, our experimental data show that the impact on the sporadic E layer led to, vice versa, a rapid (for the time ~10–20 s) increase of the level of the TW signals reflected from E_s. Thus, in the scope of the patch structure of the metal E_s layer, one also can not explain the effect of an increase in the amplitude of the TW signals reflected from the layer. The characteristics of this increase do not correspond neither to the sign of the expected change in the concentration in the ionization clouds nor to the characteristic times of the plasma redistribution.

The presence of two stages of the increased signal amplitude depletion may indicate to the action of two relaxation mechanisms, where the more rapid stage may be generally speaking determined by the influence of the eddy diffusion with the coefficient $D_T \simeq 10^7 - 10^8$ cm^2 s^{-1} on the relaxation of the disturbances created by the powerful radio wave [*Chimonas*, 1974; *Gershman*, 1974; *Gershman et al.*, 1976]. In this case it is easy to explain the characteristic times of the observed effect. However, the intensification of the turbulence as a result of the powerful radio wave impact should have led in this case too to a depletion of the mean plasma density in the E_s layer but not to its increase as it is observed in the experiment.

Among the other possible explanations of the experimental data similar to the data described in this paper we note the paper by *Erukhimov et al.* [1987], who assumed that the increase of the amplitude of the TW signals may be related to the formation of an artificial plasma "mirror" (a plasma reflector) due to the spatially irregular pressing though of the E_s-layer plasma under the action of the powerful radio wave because of the variations of the PW power over the directivity diagram of the installation antenna. The above mentioned effect should lead to a distortion (pressing through) of the plasma profile and so explain the observed negative Doppler shift of the reflected signal frequency and create a focusing of the radio waves reflected from it. However, again the plasma redistribution in the metal E_s after the PW switching off should occur during considerably longer time than the characteristic times of variations of the TW signals level observed after the switching off, even if we do not consider here the change in the dependence of the relaxation time of the increased signal on f_{PW}.

Finally, *Gurevich and Shluger* [1975] related the increase in the characteristic frequencies E_s to the increase of the electron concentration due to the decrease (under the plasma heating) in the recombination coefficient. However, it is possible only for the E_s layers of a non metal origin. The characteristic times in this case would have been of a few minutes. This also considerably exceeds the characteristic times of the considered effects and corresponds more to the second (slow) stage of the relaxation of the intensified TW signals.

Summarizing all the above we state that the presented analysis of the experimental data makes it possible to conclude that (in the scope of the available ideas on the formation of sporadic E layer of the ionosphere) one can not provide a satisfactory self-consistent interpretation of the phenomena observed during the modification of the semitransparent E_s layer.

Unfortunately, short time of the measurements due to the high nonstationarity of E_s and in some cases their singularity made it impossible to study in detail the characteristics of the observed phenomena and, first of all, their dependence on the frequency and power of PW. This information would be of importance for the development of more complete empirical model. Nevertheless, some found facts and raised questions make it possible today to come with better understanding to planning and choice of methods of conducting further measurements. Here the experiments aimed at detailed study of the dependence of the observed effects properties on the type of the layer and its intensity seems interesting. Also interesting is the change in the properties while transferring from the conditions of the E_s throughout heating to the conditions of the influence on a semitransparent layer and, further, to the conditions of the complete reflection of PW. The heating of the sporadic E layer in the regime of pulse PW emission (when one often gets an additional important information on the dynamical characteristics of the turbulence induced by the powerful wave) still stays absolutely blank region of studies. One should also carry out full-scale studies of the effects observed at the E_s modification by powerful x polarization waves. Possibly, it may provide a new understanding of the influence of the ionospheric plasma heating by x waves on AIT generation in the upper ionosphere (such studies were presented by *Frolov et al.* [1999]).

Performing all these programs it is important to determine the type and shape of the E_s layer since the measurements [*Bakhmet'eva et al.*, 2001; *Kagan*, 2000; *Kagan et al.*, 2000; *Mathews*, 1998; *Miller and Smith*, 1978; *Whitehead*, 1989] show that the layer may have a complicated internal structure. The optic-dynamical method changes in the structure and dynamics of sporadic E layers was suggested by *Kagan et al.* [2002]. In our experiments it is possible using the scattering of radio waves at artificial periodical irregularities [*Bakhmet'eva et al.*, 2001; *Kagan et al.*, 2002] or the Doppler measurements of the reflected TW signals. To study the electrodynamic interaction of the F and E regions of the ionosphere, it is important in the future to conduct detailed comparative measurements of the properties of the AIT generated in the upper ionosphere in the presence and absence of the E_s layer.

Concluding we note that the results considered in this paper unambiguously show a strong change in the properties of the sporadic E layer in the conditions of an influence on it by a powerful radio wave when the PW frequency falls into the range of the layer semitransparency. The latter fact should be taken into account interpreting the data obtained by the method of visualization of the E_s horizontal structure (in this method suggested by *Kagan et al.* [2000] an illumination of the sporadic layer by powerful SW radio emission is performed) and conducting the experiments using artificial periodical irregularities for diagnostics of the E_s layer [*Bakhmet'eva et al.*, 2001; *Kagan et al.*, 2002].

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